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Troubleshooting for Printed Board Manufacture and Assembly

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Developed by

THE INSTITUTE FOR
INTERCONNECTING
AND PACKAGING
ELECTRONIC CIRCUITS

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The Institute for Interconnecting and Packaging Electronic Circuits

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Users of this standard are encouraged to participate in the development of future revisions.

Contact:

IPC
2215 Sanders Road
Northbrook, Illinois
60062-6135
Tel 847 509.9700
Fax 847 509.9798

Acknowledgment

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Patricia J. Goldman
PPG Industries, Inc.

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Andrea Long, Lucent Technologies Inc.
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Leland McCrory, Delsen Testing Labs
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R. Bruce Officer, Sanders, A Lockheed Martin Co.
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James Paulus, AlliedSignal Laminate Systems
Charles Payne, Merix Corporation
Paul Quinn, Lockheed Martin Missiles & Space
Gary Roper, HR Industries Inc.
Paul Rose, Lockheed Martin Electronics & Missiles
Roddy Scherff, Printed Circuit Resources
Friedrich Schlitter, Ruwel & Schoeller GmbH
Robert Seyfert, E. I. du Pont de Nemours and Company
Linda Sheldon, Neltec Inc.
Robert Shook, Lockheed Martin Vought Systems
Jeff Shubrooks, Raytheon Company
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James (Tom) Turner, isolaUSA
Kim Van Landingham, E. I. du Pont de Nemours and Company
Nick Virmani, NASA/Goddard Space Flight Center
Eric Vollmar, Methode Electronics Inc.
Debra Weaver, E. I. du Pont de Nemours and Company
Gerry Wing, Lehighton Electronics Inc.
Wally Younger, Nelco Technology Inc.
Michael Yuen, Plexus Corp.

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Section 1
General Introduction

1.0 GENERAL INTRODUCTION

The Process Effects Committee of the IPC has developed this Process Control Handbook for Printed Board Manufacture and Assembly, which is a documentation of problems, and the corrective action that may be taken. The inputs were voluntarily established by technical representatives of IPC member companies, and have been reviewed in open discussion at the Process Effects Handbook meetings prior to publication.

New inputs are encouraged to help assure that the future Process Control Handbooks are complete and match the latest state-of-the-art in a particular subject. All new or revised information will go through an approval cycle, so that the material contained in the Handbook represents the best consensus of the industry at large.

1.1 PURPOSE AND FORMAT The purpose of this Handbook is to provide guidance in the form of troubleshooting examples, process cause and effect information and statistical methods for correcting problems in all areas relating to the design, manufacture, assembly, and test of printed wiring products. A comprehensive Table of Contents deals with all of the various aspects of the design through delivery cycle. At times there may be duplication in the material presented, however, in many instances the material is cross referenced.

The Guide has been segmented into 21 major sections:

1.0 General Introduction
2.0 Design and Documentation
3.0 Phototooling
4.0 Base Materials
5.0 Mechanical Operations
6.0 Hole Preparation
7.0 Electroless Processes
8.0 Cleaning of Printed Boards
9.0 Imaging Processes
10.0 Electroplating
11.0 Etching
12.0 Innerlayer Fabrication
13.0 Lamination
14.0 Metallic Protective Coatings
15.0 Non-metallic Protective Coatings
16.0 Component Mounting
17.0 Soldering Processes
18.0 Cleaning of Printed Board Assemblies
19.0 Post Solder Process
20.0 Inspection and Test
21.0 Rework, Repair and Modification

The Handbook also contains an index which helps to provide the user with the relationship between the various sections. The Process Control Handbook follows a format:

1. Problem Identification (as specifically as possible)
2. Possible Causes
3. Methods to select which causes apply (when available)
4. Suggested corrective actions/control methods

Where available, an illustration is included to aid in clearly identifying the problem. Examples or tutorials (in bold outline) are provided in many areas. These may take several forms (e.g., SPC tools, recommended procedures, designed experiments, case histories, etc.) and should not be considered all-inclusive. All processes are, to some degree, unique and there is no substitute for thoughtful local input.

General instruction may at times be provided. Text will be printed across the page, dealing with the subject in general, and not highlighting a problem, cause, or corrective action.

1.2 GUIDELINES FOR EFFECTIVE TROUBLESHOOTING AND PROCESS CONTROL One of the keys to effective problem solving is a structured routine that addresses key points each time a problem is encountered. This section suggests steps to be taken in order to effectively find the cause of a problem and to solve it permanently. Refer to IPC-PC-90 for greater detail to suggested methodology for practical troubleshooting.

1.2.1 Problem Identification and Statement Before beginning a detailed troubleshooting project, use common sense in defining the problem. Verify that there is a problem. Observe the defective product and compare to the standard. Identify the standard process and product, then determine any present deviation from the standard, or any change in the product.

Establish whether operating procedures were followed and whether an assignable cause can be quickly identified as the reason behind the problem. Only continue into more detailed analysis if the initial questions do not lead to an obvious answer. Even if the answer appears to be obvious, confirm the answer by operation of the process before closing the project.

Develop a clear, concise problem statement that quantifies the problem whenever possible and reduces the scope of the investigation to a manageable size.

Gather all pertinent data and facts. Use SQC, historical data, records, logs, etc. This includes temperature charts, analysis records, maintenance logs and the like.

Existing process data can be used to identify the most important subsets of the problem and better focus troubleshooting efforts. If the requirement is qualitative, establish a clear, common and understood definition of acceptance criteria.

1.2.2 Immediate Action Plans Every problem experienced should be addressed, using an appropriate action plan, by someone designated as the individual responsible. The solution to each problem varies in urgency and intensity, however a documented procedure or plan should exist that describes the decision making processes, such as:

1. Emergency problems (fire, chemical spills, etc.) require immediate action.
2. Producing out-of-specification parts require immediate action (i.e., shut down the process).
3. Out-of-control processes require determination as to whether the process can continue to operate.
4. Severe process variation requires evaluation of the severity and effect of the problem on the final product.

The action plan should include the procedures for addressing products produced during out-of-specification or out-of-control conditions. The plan should also indicate who should make those decisions. These issues include but are not limited to:

A. Disposition of the defective material (repair, scrap, replace, etc.)

B. Checking the effect on scheduled delivery.

C. Informing the effect on scheduled delivery.

D. Request for non-conformance authority or Material Review Board (MRB) action.

Once the immediate problem is under control, the decision must be made to determine a failure analysis plan, responsibility and schedule in order to reduce or eliminate the likelihood of recurrence.

1.2.3 Measurement System Evaluation ''Measurement System'' in this context refers to the means used to detect and identify the problem. This includes not only the measuring apparatus, but also the sampling method, the measuring personnel (and their instructions), accuracy and calibration of equipment, and environmental factors (i.e., lighting, temperature, and relative humidity). The measurement system must adequately measure the variation in the parameter or attribute which is considered critical. Imprecision (inability to reliably measure changes large enough to have a process effect) and poor reproducibility of measurements undermine process control, much less troubleshooting efforts. Example: innerlayer line width requirements of 0.005 mm cannot reliably be measured with a 30 power shop scope with a reticle scaled in 2 mil increments.

Decisions based on poorly understood measurement systems can be a major cause of misapplied manpower and missed opportunities. Before any statistical decisions can be made, the variation in the measurement must be understood. Occasionally correction of a problem in measurement can be a solution.

The variation inherent in the measurement of attribute data and responses that are subjective in nature can be addressed. The evaluation is more complex in nature, but it is still an essential part of the analysis of the problem. Section 6.0 of IPC-PC-90 discusses this subject in greater detail.

1.2.4 Parameter Diagnostics The purpose of Parameter Analysis, as detailed in Section 9 of IPC-PC-90, is to identify, isolate and rank major sources of variation. Further evaluation of the problem can be better focused if the nature of the variation is understood. Common sources are Positional Variation (within a piece), Cyclical Variation (piece to piece) and Temporal Variation (over time). Information gathered in this effort can be used to modify the Problem Statement if appropriate.

1.2.5 Parameter Analysis The purpose of Parameter Analysis, as detailed in Section 9 of IPC-PC-90, is to identify cause-effect relationships. This step of the troubleshooting process can be handled in various ways, but a common and effective routine is given here as reference.

1.2.5.1 Brainstorming The development of a cause-and-effect diagram by a cross-functional problem solving team is critical to the identification of variables to be studied. Care should be taken to include representatives of the disciplines that are part of the process being studied, such as engineering, quality, manufacturing operators, analysis laboratory, etc.

Identify all possible causes of the problem, including process steps, raw materials, materials handling, inspection and personnel. The ranking of these factors by the problem solving team should be used to establish those factors that will be studied experimentally. While engineers are normally responsible for troubleshooting, they should take care to openly consider new ideas on the problem. The insight of manufacturing personnel that are intimate with a process can be invaluable.

Situations may occur where the formation of a team for brainstorming is inappropriate. Only someone with experience at troubleshooting should make the decision to approach a problem alone. Considerable time and effort can be wasted by failure to get input from all knowledgeable sources.

1.2.5.2 "Divide and Conquer" Approach List all process steps in sequence. Examine product halfway through process for defects or its possible cause (is the problem there yet?). Keep on dividing until the exact process step causing the problem is located. Also, make use of other information sources, such as suppliers and available literature (i.e., IPC-PE-740).

1.2.5.3 Process Audit Conduct a process audit by reviewing the entire operation (e.g., documentation, transfer, handling, processing, etc.). Identify current conditions and compare to the standard. Define process windows. An audit is best conducted by someone not directly involved in the day-to-day operation of the process.

1.2.5.4 Initial Capability Assessment Process Capability Studies ideally are done before the process is accepted for production. This means creating a match between the process and the product, and results in a Process Control Window that is capable of producing the product.

One approach to troubleshooting that quantifies improvement for reporting to management involves the use of Capability Assessment. Section 7 of IPC-PC-90 discusses the generation of capability indices in greater detail. This step promotes the clear understanding of the process matrices but does require time and resources.

1.2.5.5 Optimization This step includes the variety of techniques used to isolate factors that affect the response being studied. Full and fractional factorial matrices are the most common tools used for this purpose. While some simple problems may not seem to require rigorous experimentation, proper technique must still be used when making one-factor-at-a-time changes. Comparison of the output at both settings is mandatory to establish the real effect of the process change. Outside factors that are not controlled when a new factor setting is evaluated can cause incorrect conclusions to be drawn. Always run a control!

1.2.5.6 Confirmation and Final Capability Assessment After determination of preferred settings for those factors studied, a confirmation run must be performed to establish the performance of the modified process. This step often consists of a Short-Term Capability Analysis for comparison with the initial capability assessment. A quantitative comparison of indices can be easily understood by uninvolved parties such as management. Only after confirmation of the test results should process changes be made.

1.2.5.7 Parameter Control At this point, the factors that significantly impact the identified problem are understood and must be controlled. Section 10 of IPC-PC-90 discusses Parameter Control in detail. If the Tolerance band for these parameters is not clearly understood, more advanced experimental techniques can be used to establish specification limits.

A common misapplication of Control chart techniques occurs when variables that are easily measured are charted. Unless the relationship between a variable and the output of a process is understood, this data has little use. The main purpose of Parameter Control is the maintenance of the improvements achieved during earlier efforts. The knowledge gained in the Parameter diagnostics step must be used when establishing subgroups for control charting. Failure to capture the important sources of variation can lead to misleading control charts.

1.2.6 Corrective Action Plan When a problem is located, recommend required course of action, then follow it up to assure that it is understood and implemented.

Determine what measures must be taken to prevent recurrence. Document the problem and solution. Redefine the process control window. Set up permanent controls to keep the variables within the set limits. These may include:

a. Process audits at specified intervals

b. Process control or parameter measurement reporting (control charts, etc.).

c. Preventative maintenance to keep equipment functioning at established levels.

Report the problem and the corrective action to the appropriate people.

1.3 APPLICABLE DOCUMENTS The following documents of the issue currently in effect, form a part of this Guide to the extent specified herein.

1.3.1 IPC

IPC-T-50 Terms and Definitions

IPC-PC-90 General Requirements for Implementation of Statistical Process Control

IPC-D-310 Guidelines for Artwork Generation and Measurement Techniques

IPC-D-325 Documentation Requirements for Printed Boards

IPC-A-600 Acceptability of Printed Boards

IPC-A-610 Acceptability of Printed Board Assemblies

IPC-TM-650 IPC Test Methods Manual

IPC-2221 Generic Standard on PWB Design

IPC-2222 Sectional Standard on Rigid PWB Design

IPC-6011 Generic Performance Specification for Printed Boards

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-7711 Rework of Electronic Assemblies

IPC-7721 Repair and Modification of Printed Boards and Electronic Assemblies

Other IPC documents are referenced in the text at the point of interest.

1.3.2 Government

1.3.2.1 Federal Specifications

PPP-B-566 Box, Folding, Paperboard

PPP-B-676 Boxes, Setup

1.4 HANDLING Handling of printed wiring products in all phases is often a major cause of problems and defects that are noted later in the end products. A general lack of concern for handling tools, raw materials, equipment, or end products can easily result in the production of a product that is substandard.

Many companies have adopted policies that strive to let the employees know the care and attention that must be placed on all aspects of the manufacturing and assembly cycles. This starts with the basis for handling and storage of incoming raw materials and continues into the attitude of personnel working in phototooling (handling of artwork area, humidity, and temperature control).

On the production line, discrepancies in procedures are many times noted where no rigid process controls are used to control layer placement procedures, drill speeds and feed rates, sharpening and replacing of drill bits, proper smear removal, insufficient baking and rinsing cycles, incorrect ratio of plating constituents, incorrect orientation of panels and plating tanks, contaminated plating baths, lack of plating bath analysis, and poor microsectioning - or no program at all.

The above list, although not exclusively dealing with handling procedures, provides an overview of the conditions that many times lead into the problems detailed in this Guide.

Appropriate employee attitude, coupled with concrete and well defined company procedures will help, not only to control the areas of problems, but to provide a trace back and identification of the failure mechanisms which caused a particular problem.

Unique handling requirements are detailed in the applicable sections, however, some general discussion of major handling defects is given here.

1.4.1 Scratches Copper-clad panels are surprisingly easily scratched—usually by another copper-clad panel. Scratches and gouges in the copper surface can affect the imaging and etching processes, creating opens or shorts. Panels should not be dragged across each other or across any abrasive surface.

Resist-coated panels (ready for etching or plating) are extremely vulnerable to scratches. While the resists are able to withstand corrosive plating solutions, they are fragile when it comes to mechanical damage. Be aware of sharp edges on racks or tanks or other panels. A scratch through the resist will create an open (in etching) or a short (in plating). Scratches on phototools can lead to similar defects.

1.4.2 Bending or Flexing Panels Thin material is somewhat more susceptible but the results can be the same. Excessive bending or flexing of panels can damage the resin-to-glass bond in the laminate. This can appear as crazing or measling and can affect the material dielectric and resistance to chemical baths. If a multilayer board is flexed, internal delamination can occur and the entire board integrity destroyed.

1.4.3 Fingerprints Fingerprints can be the scourge of a printed board shop, from the phototool area through final inspection, and all process steps in between. Fingerprints can affect light transmission and therefore the quality of the printing operation in the phototool area and in the imaging area. Fingerprints can affect adhesion—in the resist lamination area, in the plating areas, in the multilayer lamination area. Some fingerprints do not clean easily in electroless or electroplating cleaners. The copper does not microetch well and subsequent plating adhesion may suffer. Some people's fingerprints can actually etch the copper surface. In some cases heavy fingerprints may affect the electrical test operation by acting as an insulator. At final inspection, fingerprints could affect board cleanliness and ionic contamination levels.

Fingerprints, as with all handling defects, are preventable through proper operator training and constant concern and vigilance. The basic prevention method is to take all steps necessary to keep hands off panels. Everyone should be trained to handle panels by their outer edges only. When this is not possible, gloves can be worn, but operators (and all others) must be trained in proper glove usage. Gloves can be easily contaminated and end up creating as many problems as fingerprints. They should not come in contact with the face (make-up, body oils) or dirty areas (dust, chemicals, etc.). Some shops will not permit the use of gloves because they can create a false sense of cleanliness and the users become careless in their handling.

1.4.4 Storage Printed board manufacturing areas can be hostile environments to the very boards processed in those

areas. High temperature and humidity can oxidize clean copper surfaces, as can chemical fumes from the plating area. Strong lighting may adversely affect resist-coated panels even after development. Boards in-process should be stored in clean, dry areas of the shop if at all possible, or processed as soon as possible. Other critical storage points are: oxide-coated innerlayers prior to lamination; prepreg which is temperature and humidity sensitive; all phototools and screens and their associated processing areas (imaging and screen-printing); panels prior to resist lamination through coat, image and develop; after electroless copper (the somewhat porous surface can absorb other airborne contaminants).

1.5 BAKING Laminate materials are baked several times during the manufacture of a printed wiring board. There are four major reasons for baking:

1. To insure proper cure of the laminate resin.
2. To relieve stresses that may impact the dimensional stability of the laminate.
3. To remove volatiles, e.g., moisture.
4. To cure any organic coatings that may be applied to the laminate (e.g., thermal cure solder mask).

1.5.1 General Problems Associated With Baking

1.5.1.1 Cross Contamination Certain baking operations volatize (drive off) materials which may contaminate subsequent work process through the oven. Consider separate ovens for these functions, improved venting, or more frequent cleaning.

1.5.1.2 Excessive Baking (Over-Temperature Or Over-Time) In addition to excessive oxidation of metallic cladding, excessive baking can change mechanical and/or chemical properties of some laminates. Verification of actual oven temperatures (vs. set points) and a mechanism for enforcing removal at the specified time are required.

1.5.1.3 Improper Loading Stacking can result in uneven time/temperature profiles with variation in results. Stacking also has the potential for trapping contaminants between laminates at high temperatures, possibly degrading the metallic cladding's surface. Racks or frames improperly designed or maintained can lead to surface damage.

1.5.1.4 Hold Time After Bake Uncontrolled dwell times after bake can defeat the original purpose of the bake, especially moisture removal.

1.5.2 Resin Curing Fully curing the laminate resin is important to increase the laminate resistance to moisture absorption, to reduce drilling smear, and possibly to help reduce the incidence of copper cracking by increasing the dimensional stability of the finished laminate. Generally, full cure of the initial core laminate is done by the supplier prior to shipment to printed board fabricators. Full cure of composite multilayer PWBs is done by the fabricator based on laminate suppliers recommendations for correct lamination and cure parameters.

A common measurement for completeness of cure is glass transition temperature (T_g) of the laminate resin. The T_g is an indicator of the laminate thermal performance capability and will vary accordingly to the resin system used. To achieve the T_g specified by the laminate supplier, the resin must be fully cured. Full cure is accomplished by heating the resin above the T_g and holding it here for a sufficient time to achieve maximum cross linking of the resin system. It is recommended that the PWB manufacturer check with his laminate supplier for the recommended time and temperature (to avoid thermally damaging the laminate or excessive cure). Any bake above the resin T_g should be done under pressure/weight.

Two IPC test methods are available to check laminate for its state of cure (evaluating its T_g). One is Thermal Mechanical Analysis of TMA method, IPC-TM-650 Method 2.4.23, the second is the Differential Scanning Calorimetry or DSC Method IPC-TM-650 Method 2.4.25. Because the two methods typically yield different values, the method used should be consistent with that used by the supplier. It is also wise to specify the test method to the supplier.

In order to determine if additional cure is needed, a single sample can be tested two successive times. During the first test, the sample's cure is advanced by the test which essentially acts as a bake (if undercured). If the second test differs significantly, baking is advised. If the two test values are nearly identical, further baking should not be required.

1.5.3 Stress Relief Stresses are inherent in the lamination process and are the result of the naturally occurring mismatch between the various constituents of the laminate coupled with the material manufacturing process. An example of this is the different coefficients of thermal expansion of the copper and resin system. Another example is the remaining stress from the original yarn fabrication where glass strands are twisted and plied.

Stress relief assists in improving dimensional stability of the laminate by relaxing the stresses prior to further processing. This is especially important for MLB core material. As with increasing cure of the resin, stress relieving requires that the laminate be elevated to a temperature above the glass transition temperature of the resin. Stress relief may well be accomplished at the same time as increased cure is being effected, as long as a slow cool

down is used. In order to prevent bow and twist, the bake and cool down should be done under low pressure or under a uniform weight.

Typical bake times and temperatures for the various laminate resins are shown below:

Table 1–1 Bake Times and Temperatures

Resin Type	T_g*	Bake Temperature	Time
Difunctional Epoxy	130°C	160°C (320°C)	2-4 hours
Multifunctional Epoxy	140-150°C	175°C (350°C)	2-4 hours
Tetrafunctional Epoxy	150-160°C	150°C (350°C)	2-4 hours
BT Epoxy	180°C	190°C (375°C)	2-4 hours
Cyanate Ester	245°C	220°C (425°C)	4 hours
Polyimide	260°C	220°C (425°C)	4 hours

*T_g data obtained using DSC Method (IPC-TM-650 method 2.4.25)

Bake times are ''at temperature,'' that is, after the material has reached the bake temperature.

1.5.4 Moisture Removal Resin systems used for PWB laminates vary in their tendency to absorb moisture. Some resin systems (such as PTFE) are virtually impervious, others can be rather hygroscopic. Residual moisture in the laminate has been shown to cause a variety of deleterious effects from measles to blow holes to excessive resin flow during lamination. Because of this, moisture removal baking is advantageous and may be employed at the following stages:

- After oxide coating of innerlayers
- After hole preparation
- Before fusing
- Before solder coating/solder leveling
- Before any soldering operation, including wave solder and rework

The bake for moisture and volatile removal is typically done at 100—125°C for 2–4 hours. Panels should be separated to permit air circulation: stacks of panels will not heat properly and the moisture will not be able to escape. The user must note that the most practical temperature and time conditions must be determined for each facility and each printed board assembly.

When assemblies must be set aside (e.g., secondary component mounting of soldering operations), the assembly should be stored in a desiccator cabinet at room temperature and 40% maximum relative humidity (Desiccants may be baked out and reused.)

1.5.5 Organic Coating Cure Follow supplier's recommendations for each curing or drying process.

1.6 RINSING Water rinsing plays a very important role in the manufacture of printed wiring boards and assemblies. Rinsing is employed at nearly every process step beginning with phototool development. Proper rinsing is especially important in the wet processing cycles such as imaging, etching and plating. Generally, after each exposure to a chemical solution, the printed boards are rinsed by either immersion or spray techniques. This applies to both manually and automatically operated processes.

The quality of the rinsing operation can and does have direct influence on the quality of subsequent processing. Poor rinsing can result in both board and process tank contamination, as well as directly contribute to poor quality product and rejects. Improper rinsing can also cause frequent bath changes due to contamination, increase waste treatment costs, and create very elusive processing problems.

Improved rinsing techniques often do not require additional water use. Many techniques are both inexpensive and easily implemented, once understood. Some of these techniques include air agitation, sprays (continuous, time or pulsed), counterflows, tempering, longer drip times and new rack designs. The sections below discuss the many ways to improve board quality through improved rinsing.

In some areas, an understanding of the incoming water source (i.e., well vs. reservoir, pH, mineral quantity, filtration), as well as any changes in the source can help prevent problems before they occur - or at least provide a place to start pinpointing the problem. Water districts often change water sources at set times during the year. Well water may contain higher quantities of minerals, while reservoirs sometimes have a high content of organic matter, especially when their level is low. It may be necessary to filter or soften incoming water. Some heavily mineralized water can leave deposits on boards or cause precipitation in certain rinse tanks. Carbon filtration could prevent the introduction of organics into a critical process.

1.6.1 Rinse Time Longer rinse times generally result in a better rinsed board. Very small holes take longer due to the fluid dynamics involved. Alkaline or caustic solutions typically take longer to rinse than acids. Warm solutions rinse faster than cold. More concentrated solutions require a longer rinse time (and contaminate the rinse tank faster). Closely spaced panels (in a rack) are more difficult to rinse than those spaced far apart or singly.

Occasionally there are reasons to keep rinse times fairly short. Clean copper surfaces tend to oxidize readily which can inhibit the next operations.

1.6.2 Rinse Water Temperature Warm water will rinse a surface faster than cold water. The general rule for chemical reactions states that for every 10°C increase in temperature, the reaction rate doubles. Rinsing (dissolving a material off a surface) can be thought of as a type of reaction. An ideal cold water rinse temperature is 15–24°C. Hot water is usually recommended after alkaline cleaners to speed up the rinsing process. Extremely cold water rinses can be tempered by adding warm water through a commercially available mixing valve. Warm or hot water will oxidize clean copper surfaces faster than cold water.

1.6.3 Agitation to Improve Rinsing The most commonly employed method is air agitation. It is both inexpensive and extremely effective. Air agitation improves rinsing in two ways: by keeping the rinse water mixed so that concentrated pockets do not occur; and by continuously moving fresh water to the board surface. Air agitation should not be used in rinses immediately after cleaners that foam.

Mechanical agitation of the boards or rack of boards in the rinse tank also aids in rinsing—again by bringing fresh water to the board surface. When the motion is perpendicular to the board, this method also helps to rinse the through-holes by forcing water through them.

A third method of agitation, that is somewhat less effective, is the introduction of rinse water through a sparging system. Generally the water flow rate is not sufficient to make this as effective as air agitation, unless a pump is used.

1.6.4 Spray Rinsing Sprays can be a very effective way to rinse. Pressurized water quickly removes contaminants and supplies fresh water to the board surface. A single spray rinse tank can serve several processes. There are a few drawbacks to spray rinsing that should be taken into consideration when planning a spray rinse system:

a. When in operation, sprays consume a tremendous amount of water. Therefore, they should be on only when boards are ready to be rinsed. Generally, the sprays are activated automatically by action of a hoist, or are timed. Often intermittent sprays are used.

b. If spray nozzles become clogged, areas of the board may not be properly rinsed.

c. Holes in the board to not rinse as well as the surface. Very small holes must rely on capillary action as the primary rinse mechanism. Since this is a slower process, more spray time may be necessary than would be expected for a surface. Consider a combination immersion rinse plus sprays.

d. Sprays are only effective when both sides of the board can be sprayed. When boards are side-by-side in a basket-type rack (such as those used on an electroless line), sprays cannot adequately rinse the inside boards, since they are shielded by other boards.

1.6.5 Counterflow Rinsing The diagram below (Figure 1–1) illustrates the principle of counterflow rinsing. Basically, a single water source flows through multiple rinses in a direction opposite or counter to the flow of the work being processed. Counterflow rinses provide the benefit of multiple rinse stations but use the water flow of a single rinse. Therefore, rinsing can be greatly improved without using additional water. Kushner (see references) gives an excellent technical discussion on the benefits of counterflow rinsing, including calculations to determine required water flow for a given number of rinses.

Both immersion rinse tanks and spray rinse systems can be counterflowed. In an immersion system, the water should be introduced at a spot as far as possible from the outlet. Generally counterflow rinse tanks are joined by a common wall that is an overflow weir, as shown in Figure 1–1. If a process tank separates two rinses, it is possible to externally counterflow the water by piping the outlet of the first to the inlet of the second. Remember that the water flow is by gravity, so the second rinse water height must be slightly lower than the first.

Sometimes the rinse water from one process step can be counterflowed and used at another process step. An example would be a sulfuric acid dip that follows a micro etch step. The rinse water from the acid can be used as rinse water for the micro etch step. It is best to consult the appropriate supplier(s) to insure process compatibility. Some incompatibilities could create precipitates or mix waste streams incorrectly or create later process problems.

In order to counterflow a spray system it is necessary to collect the water from the initial spray into a sump, them pump it to provide the necessary spray can also be reduced by use of a sump and pump system. Counterflowed spray rinses are very common in conveyorized equipment.

1.6.6 Drip Times A major contributing factor to the rinse process is the amount of material carried over on the board into the rinse. Obviously, the less process solution left on the board surface, the less to be rinsed off. There are several ways to reduce the amount of material carried over, including increased bath temperature and reduced bath concentration. However, these are limited by the process. A more practical way is to control the drip time of the board(s) over the process solution.

Kushner gives some examples that show the amount of material saved by increased drip times. The material savings and improved rinsing occur in several ways:

a. Less material is dragged out of the process tank resulting in a chemistry savings.

b. Less material enters the rinse tank resulting in cleaner, more efficient rinses.

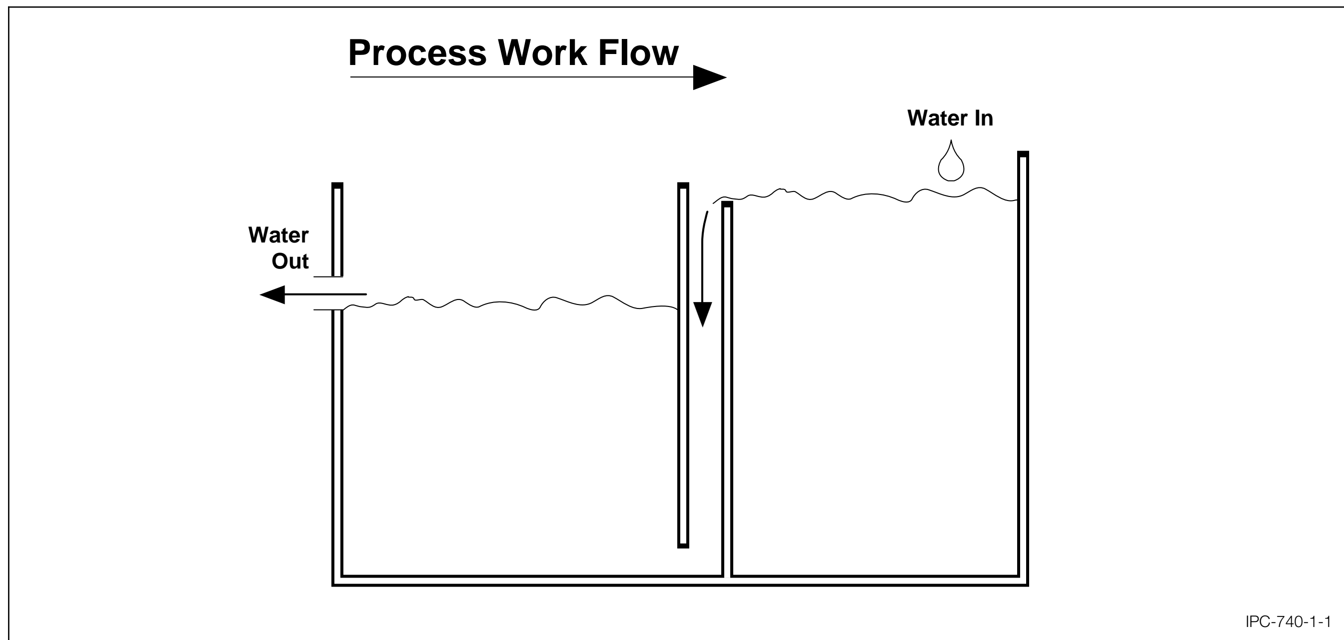

Figure 1–1 Example of counterflow rinsing

c. Less material is on the board surface so there is less to rinse off, therefore the rinse operation is more efficient.

d. Less material needs to be waste treated resulting in a cost savings.

The trade-offs on drip times are time and oxidation of the panel surface. On some large automated lines, drip times can add up and increase the total cycle time. On some processes, a long drip time may affect the board surface. This generally occurs more easily with heated baths. Process solutions should never be allowed to dry on the board surface. Dried-on salts often will not redissolve in the rinse station.

Recommended drip times over process tanks are 10 to 30 seconds. Some drip times over rinse tanks (especially the one immediately following a process tank) are also beneficial. Generally 3 to 10 seconds are used. Angling the boards in their racks, so that a corner is the lowest point, also improves dripping.

In the case of conveyorized systems, whether vertical or horizontal, drip times must be re-thought in terms of the pinch rollers that tend to wipe the board surfaces of process chemistry. The tighter and more compliant these rollers are to the board surface, the better the surface is wiped and the less amount of material carried over. Also, the slower the conveyor speed, the less material carried over.

1.6.7 Special Rinse Techniques There are several specialized techniques that have been developed with the twin goals of improved rinsing and reduced water consumption. These include:

a. Conductivity meters and/or flow restrictors. A conductivity meter will activate the water flow when contamination levels in the rinse tank exceed a certain limit. Restrictors simply limit the flow volume. Timers are also placed on rinses so that water is not wasted when no parts are being rinsed. These methods are fine, provided they have been properly set-up and are monitored.

   Changes in incoming water pressure or quality, increased product flow through the rinses, or changes in the processes could all adversely affect the rinse quality. In addition, conductivity meters must be calibrated regularly. Flow restrictors tend to age and deteriorate (some actually shrink, further restricting flow). Actual rinse flow rates should be routinely measured as part of a preventive maintenance item.

b. Pulse Sprays. Beyer discusses these in IPC Technical Paper IPC-TP-376. Basically, water sprays are on for several seconds, then off to allow contaminated water to drip off. This cycle is repeated until the board is sufficiently rinsed.

c. Air Blow-off. Also discussed by Beyer, this procedure involves air knives near the solution surface. Care must be taken to not allow the board to dry or to create excess foam.

d. Sweeping Sprays. Sometimes foam forms on rinse tanks that is then carried down the line. It can be a frustrating source of contamination and is often difficult to keep off the rinse water surface. Installation of a bank of sprays angled across the surface can serve to ‘‘sweep’’ the foam into the overflow weir. The sprays can be timed or hoist activated as necessary.

e. Fog Sprays. Fog sprays use very little water and are designed to be used over a process tank. Their purpose is to aid in dripping, to keep process solution in the process tank.

f. Top Sprays. To gain an extra rinse without additional space or tank, sprays can be installed at the top of an immersion rinse tank. As the boards exit the rinse tank, the top sprays are activated as a final clean rinse. The top spray water can also serve as the water input to the tank.

g. Hoist Spray Systems. A design out of Europe encloses a spray rinse system in the hoist. This permits rinsing immediately after the boards have been drawn out of the solution and into the hoist chamber. Rinsing can be done while the hoist is traveling to its next position. There is a space savings in that no rinse tanks are needed on the process line.

1.6.8 References

Water and Waste Control for the Plating Shop, 2nd ed. Kushner and Kushner, Gardner Press

IPC-TP-376, Water Saving Concepts in Automatic Preplate/Electroplate Lines for Printed Circuits, Gustav H. Beyer

1.7 PACKAGING The packaging of printed wiring boards and/or raw materials at incoming is very important. Containers should be of material and form agreed upon by user and supplier, and related to the particular product being packaged or shipped.

The containers or material used for shipping should not introduce gases or chemicals that could be detrimental to the product itself or to the solderability of the board and later assembly steps. Bags or containers made of silicones, sulfur compounds, or polysulfides or processed with these compounds, should not be used.

All parts that are packaged should be clean, dry and packaged in a manner that will afford adequate protection against corrosion, deterioration and physical damage from supply source to the first receiving activity.

Where plastic bags are used for packaging printed wiring boards, they should be clean and free from ionic contaminants. Heat sealing of plastic bags may release volatiles that may contaminate board surfaces.

1.8 MAINTENANCE Maintenance concerns itself with maintaining the process as it was designed. This is needed to assure a consistent product and to prevent accidents.

It should cover everything from the equipment and instrumentation through process procedures and process controls to housekeeping and environmental controls.

1.8.1 Process Maintenance Process maintenance deals with replenishing process consumables with decontamination and wear of tooling inherent to the process. e.g., concentration of plating solutions, carbon treatment, drill bit wear, etc.

1.8.2 Preventative Maintenance Preventative maintenance is scheduled and designed to replace or repair before catastrophic failure occurs. By instituting a good preventative maintenance program, unscheduled breakdown can be essentially eliminated.

1.8.3 Corrective Maintenance Corrective maintenance is repair following breakdown.

1.8.4 Calibration Program A calibration program is a maintenance program for instruments, gauges and test sets. Periodic comparison with standards are checked and adjusted based on statistical evidence of an out-of-control condition. If the instrument is in control but out-of-spec, work needs to be done to reduce the inherent variation of the instrument to less than or equal to the specification at a 99.73% confidence interval (±3 sigma). After this adjustment has been made the instrument should be recalibrated. Failure to do so may cause the process to go out of control while the controls appear to be within specification.

1.8.5 Housekeeping Housekeeping looks after removal of all unnecessary items from the work area. Clutter causes accidents, mistakes and delays. Also, good housekeeping reports any cleaning problems caused by equipment breakdown or poor maintenance. Getting a small crack repaired may prevent catastrophic failure later when the crack propagates. Good housekeeping shows regard for the equipment, the investment and the product.

Excessive variations in the environment may affect the process or the health or effectiveness of the workers. For example, photoprocesses are sensitive to dust, temperature and humidity. Workers are sensitive to chemicals, heat and RH.

1.8.6 Process Documentation and Procedures Process documentation and procedures must be maintained, because sloppy notes and unrecorded changes invariably lead to errors. Transfer of information between shifts should be clear and preferably in writing. Engineering changes always should be in writing, and be subjected to a time limit, leading to incorporation of the procedures.

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Section 2
Design and Documentation

2.0 DESIGN AND DOCUMENTATION

Design of printed boards and printed board assemblies requires a complete understanding of the board manufacturing process and the assembly and joining processes. Designers must consider manufacturing allowances for conductor definition and plated-through hole to land relationships in order to ensure adequate annular ring definition. In addition, proper clearances for automatic component insertion or placement equipment heads must be accommodated.

Choice of materials for board construction is important relative to the performance of the electronics assembly in its usage environment. High temperature laminate is used in products that must dissipate extreme heat or are subjected to the temperature gradients in the location where the assembly is used (i.e., automotive product that must operate under the hood).

The requirements of the design must be properly documented to ensure proper board fabrication and assembly conditions. Proper documentation requires the definition of all features and tolerances, plus references to any performance specifications to which the product must adhere. Customer dissatisfaction can result when product performance expectations are not properly documented and the manufacturer uses his best judgement in order to meet the assumed requirements. Refer to IPC-D-325, Documentation Requirements for Printed Boards.

Section 2 details some of the major problems that occur in the design and documentation processes.

2.1 DESIGN

Design disciplines use manual or automated techniques in order to describe the characteristic of the printed board or printed board assembly. The design principles may be applied to single-sided, double-sided, or multilayer structures. Materials may be organic in nature, either rigid or flexible, or non-organic, such as ceramic or porcelainized steel printed boards.

At times, combinations of different materials are chosen in order to satisfy the design objectives. An example of this would be a rigid-flex multilayer product with a metal core to dissipate the heat from several components. Choosing the proper materials requires an understanding of the end product usage environment and the manufacturing process in order to be able to build the final board at acceptable yield and cost.

There are many computer-aided (CAD) stations available to assist in the design process. Cost of hardware and software has dropped significantly, so most designers can take advantage of these automation tools. Unfortunately not all CAD systems provide the most manufacturable designs. Success or failure of a CAD system's performance may be measured in terms of design completion or number of electrical nets connected. Benchmarking may consist of the time it took the machine or man/machine combination to place all components and to interconnect all component leads on terminations. The measurement made did not include the requirements for manufacturability or testability of the board or assembly. In this case many designs are ''thrown over the wall'' to the manufacturer and many non-manufacturable designs are produced. This situation has lead to coining of the phrases Design for Manufacturability (DFM) and Concurrent Engineering (CE) to reflect the needs of designs to be manufacturable. An understanding of appropriate design principles that address pertinent manufacturability, testing and quality issues must be applied during the design process. Refer to IPC publications for guidance, such as IPC-2221 & 2222 and IPC-D-330. Several others are available for specific applications (refer to IPC publication catalog).

A final concern is an industry characteristic that assumes the designer understands the manufacturing and assembly processes. After spending large sums for CAD hardware and software, CAD operators are expected to perform the design functions, as opposed to Printed Board Designers who have computer skills. Thus many designs produced are a product of the computer algorithms and the manner in which the operator was permitted to change or modify the system design rules to complete the component placement and interconnection functions. These conditions have resulted in many of the problems identified in this section.

2.2 LAYOUT PROBLEMS

A PROBLEM	CAUSE	ACTION
Components and plated-through holes are not referenced to datum or grid outline.	Improper establishment of datum reference frame.	Re-evaluate board layout and identify a minimum of two features to establish the mutually perpendicular datum reference frame. Identify location of 0/0 datum feature so that all or most of the board characteristics are in a positive Cartesian coordinate zone.
	Intermixing of metric and inch based parts.	Establish majority of parts dimensional characteristics and choose that concept as the master grid. Identify all parts that do not fit that description as off-grid and code as such in the CAD library definition.
	Design completion technique. Establish an alternate or secondary grid system.	Re-layout board starting with a positioning approach and single grid system that comes closest to meeting initial objectives. As redesign proceeds, adjust room to accommodate problems forcing alternate grid systems.
	Density of layout prevented the datum reference from being on the board.	Establish off board tooling hole relationship to a conductor or land pattern cluster in order to be able to evaluate the end product board. Use automatic optical inspection techniques to evaluate artwork or conductive pattern.

B PROBLEM	CAUSE	ACTION
Layout does not match schematic or logic diagram or CAE file.	Changes made to design were not incorporated in schematic/logic diagram.	Evaluate engineering change control procedures. Incorporate routine checks/check lists to insure that changes are appropriately made to the entire document set. Document policies and procedures, and enforce.
	Back Annotation never completed.	
	Handbook for equipment maintenance required reassignment of reference designators.	

C PROBLEM	CAUSE	ACTION
Tooling holes not established or wrong size.	Design has not been coordinated with fabrication and assembly engineering.	Establish Design for Manufacturability (DfM) Standards which consider tooling hole location requirements for both fabrication and assembly. If board size and/or density prohibits internal tooling holes; panelize boards as part of design, with external tooling holes. Boards can be excized following fabrication and assembly processes.
	Board is very small and there is no room for tooling holes.	
	Board is very dense and there is no room for tooling holes.	

2.3 ELECTRICAL

A PROBLEM	CAUSE	ACTION
Electrical arcing between adjacent conductors.	Improper conductor spacing.	Recalculate conductor spacing per IPC-2221 & 2222.

B PROBLEM	CAUSE	ACTION
Unable to achieve functionality/ reliability using high speed/high frequency devices.	HS/HF printed board design principles not followed for controlled impedance HS/HF applications.	Refer to IPC-D-316: High Frequency Design Guide and IPC-D-317: Design Guidelines for Electronic Packaging Utilizing High-Speed Techniques.

C PROBLEM	CAUSE	ACTION
Conductor crosstalk and board radiation (RF).	Power distribution layout, causing high inductance and few adjacent signal return paths.	Redesign voltage and ground distribution layout, using design principles of IPC-2221 & 2222, see Figures 2-1, 2-2, 2-3.

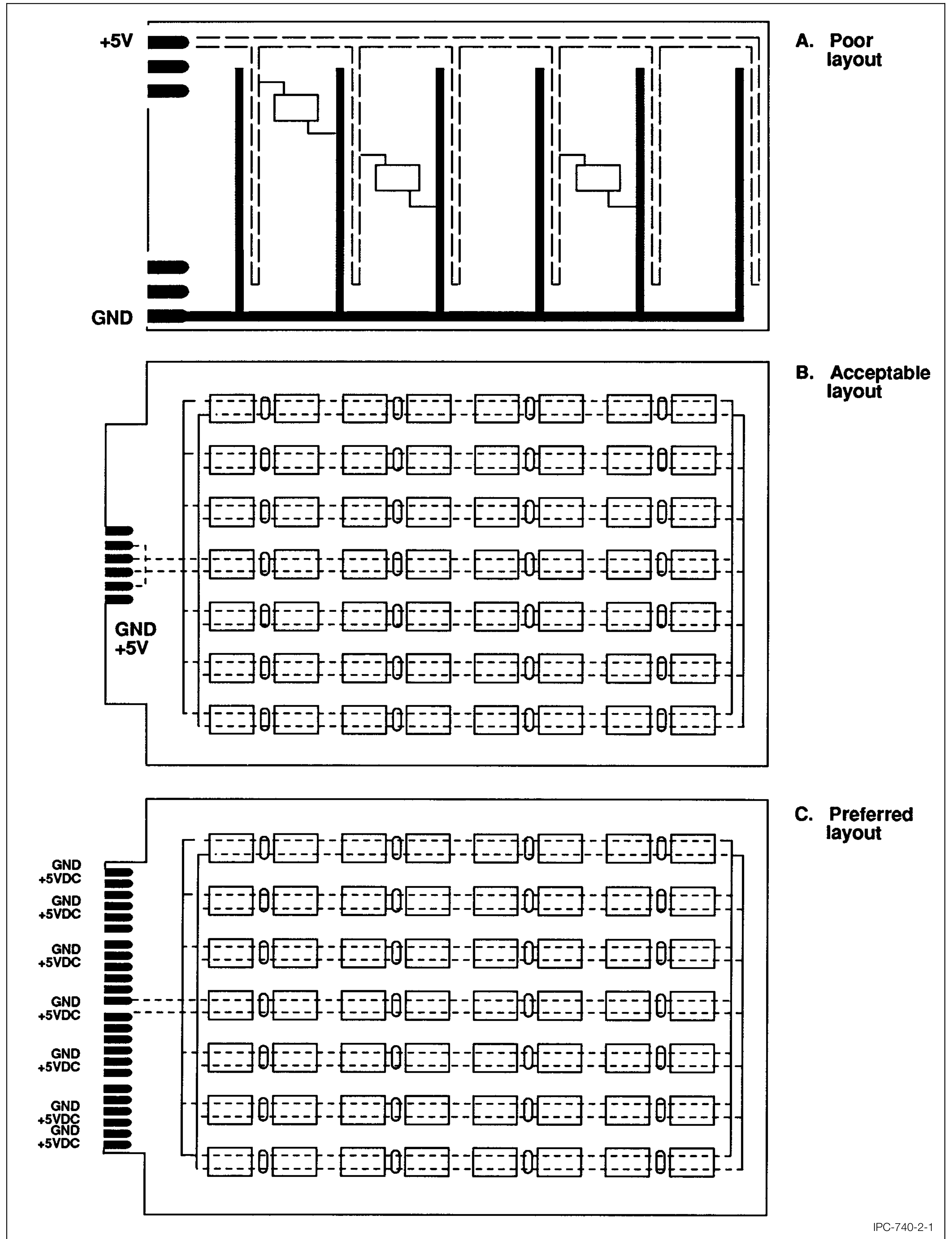

Figure 2–1 Voltage/Ground Distribution

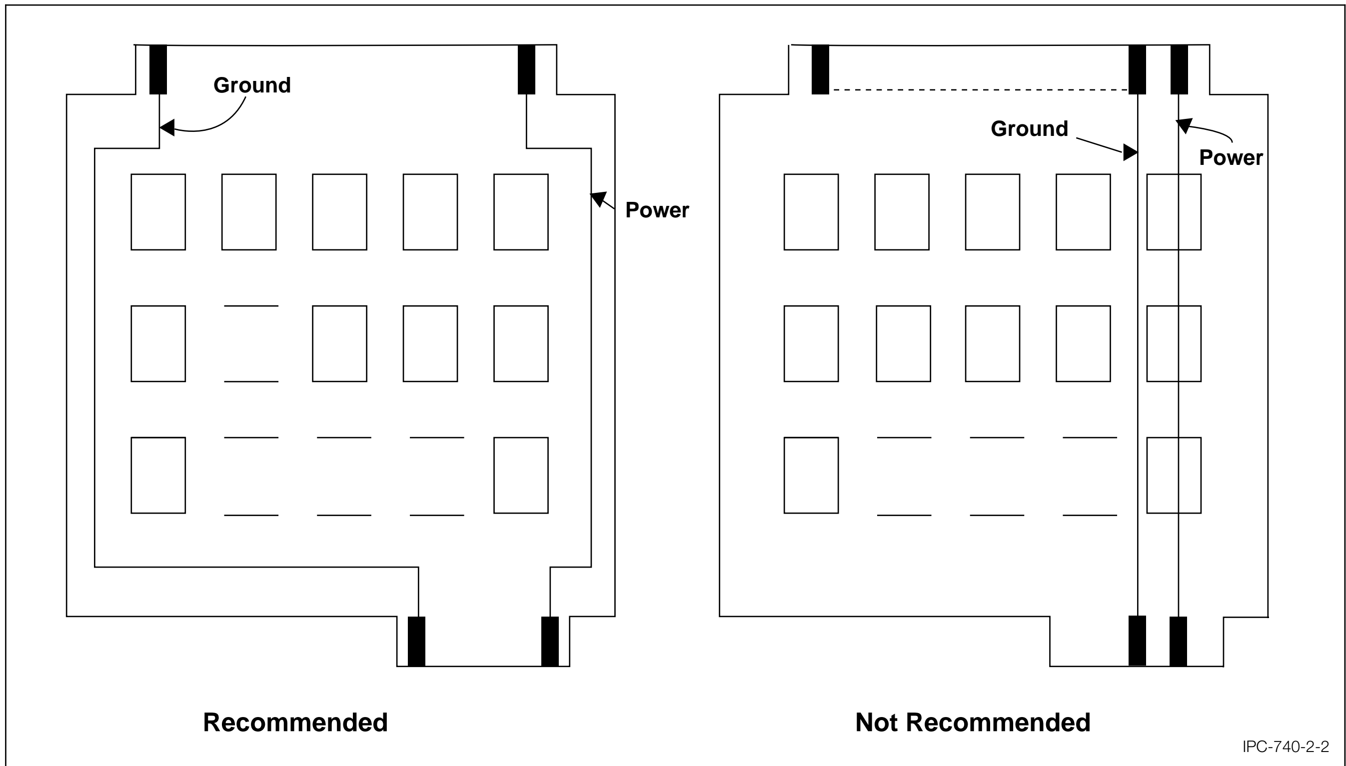

Figure 2–2 Single Reference Edge Routing

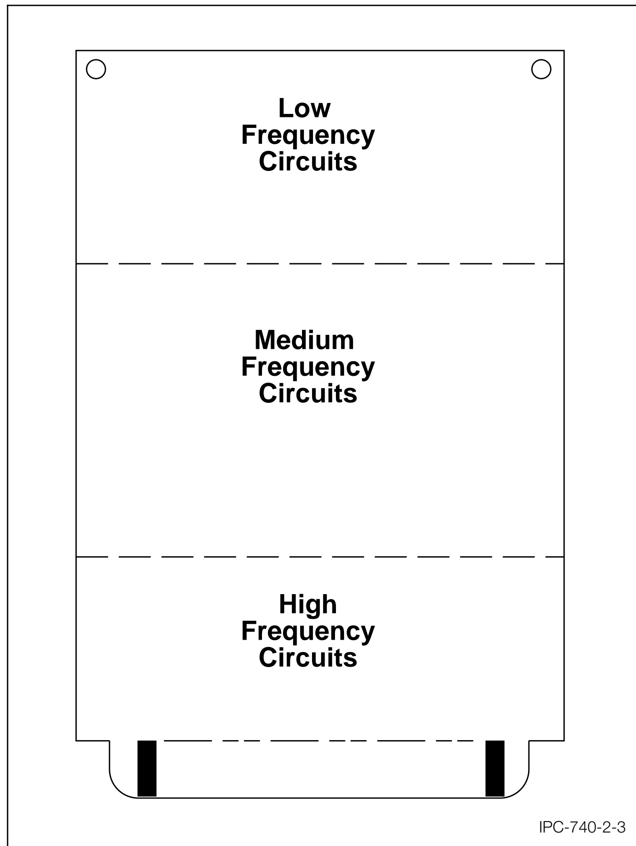

Figure 2–3 Circuit Frequency Distribution

2.4 MATERIAL

A PROBLEM	CAUSE	ACTION
Unable to optimize printed board construction because material specification is either incomplete or too restrictive.	Material specification is either incomplete or too restrictive. For example: If no material is specified, and no functional or performance requirements are given, manufacturer cannot produce boards; or, if construction requirements are too specific, manufacturer is prevented from choosing a more efficient, or more functional construction.	Consult with manufacturers to keep current with material technology. Document note call-out to give manufacturer maximum option to fabricate the printed boards to end product performance requirements, without the restriction of starting materials. (Define only requirements for dielectric separation, end product copper, impedance, solderability, protective coatings, etc.)

B PROBLEM	CAUSE	ACTION
Unable to optimize solder resist requirements because specification is either incomplete or too restrictive.	Incomplete notes; performance requirements for resist are not defined, or specification is restrictive in the use of a single type of resist.	Contact originator/customer for clarification; request update to documentation and purchase order/shop order. Also, run tests to evaluate solder resist compatibility with end product assembly and use requirements. (Detail the "class" of solder resist needed per IPC-SM-840, or describe required properties, such as abrasion resistance, resistance to solvents, adhesion, insulation, reversion, etc.)

2.5 COMPONENTS

A PROBLEM	CAUSE	ACTION
High degree of solder shorts for 1.27 mm lead pitch connectors at wave solder.	Printed board design based on 2.54 mm lead pitch. (Factors that affect yield are lead length, land geometry and pattern, and resist aperture.)	Elongate alternate lands on printed board design (Land pattern). This increases the separation points during wave soldering.

B PROBLEM	CAUSE	ACTION
Component package melts during soldering operations.	Package specification not thoroughly evaluated, related to assembly process conditions, when defining component/procurement specifications.	Understand and/or develop applicable assembly process standards, then limit approved supplier selection to packages which can withstand peak temperatures in production and rework.

C PROBLEM	CAUSE	ACTION
Excessive solder shorts at SOIC device locations.	Designed land width too wide.	Reduce land width to a width which will reduce solder shorts, while maintaining joint strength. (Refer to IPC-SM-782, and IPC-EM-782 electronic format which allows adjustments to solder requirements and resulting land patterns.)

2.6. ASSEMBLY

2.6.1 Component Positioning

A PROBLEM	CAUSE	ACTION
SMT chip components twist off lands during reflow.	Improper land pattern design.	Redesign land pattern per IPC-SM-782.

B PROBLEM	CAUSE	ACTION
Insufficient toe and heel fillets.	Improper land design.	Redesign land pattern per IPC-SM-782.
	Over-etched board.	Refer problem to PWB supplier.

C PROBLEM	CAUSE	ACTION
Through hole components do not consistently go into mounting holes during automatic assembly.	Component mounting holes too small.	Increase mounting hole size in accordance with IPC-2221 & 2222.
	Hole patterns not located to datum planes.	Locate hole pattern to datum planes.
	Assembly equipment not properly maintained.	Maintain assembly equipment within operational specifications

D PROBLEM	CAUSE	ACTION
Cannot access component for repair.	Incorrect component placement.	Provide sufficient spacing between components to facilitate repair equipment and tools.

E PROBLEM	CAUSE	ACTION
Delicate component bodies crack during the thermal cycles of assembly.	Insufficient lead stress relief for through-hole components.	Redesign through-hole component lead spacing to provide additional lead stress relief.
	Improper land design for surface mount components.	Redesign SMT land per IPC-SM-782.

F PROBLEM	CAUSE	ACTION
Small components exhibit poor solder joint formation.	Small components shadowed by larger components.	Relocate smaller components so that they are not shadowed by larger components.
	Improper land design.	Redesign land pattern per IPC-2221 & 2222 and IPC-SM-782.

2.6.2 Moving Substrates

A PROBLEM	CAUSE	ACTION
Feature locations beyond tolerance.	Instability of laminate material during processing.	Use higher performance laminate material with greater x-y stability.
	Board too large.	
	Improper board aspect ratio.	

B PROBLEM	CAUSE	ACTION
Panel array is too flexible for soldering operation.	Array designed in the wrong axis for soldering operation flow.	Rotate boards on panel array.
	Too much material removed between breakaway tabs.	Increase number of breakaway tabs. Leave copper strips between boards on panel arrays.

2.6.2 Moving Substrates (continued)

C	PROBLEM	CAUSE	ACTION
Optical alignment at assembly is erratic.		Inconsistent fiducial design.	Design fiducials in accordance with IPC-2221 & 2222 and IPC-SM-782.
		Inconsistent fiducial finish.	Place fiducial control limits on master drawing.

2.6.3 Assembly Process

A	PROBLEM	CAUSE	ACTION
Solder joints crack when excising PWB from a panel array.		Improper excising methodization.	Utilize excising fixture.
		Improper excise design.	Provide low force breakaway tab design.

B	PROBLEM	CAUSE	ACTION
Cold solder joints on power or ground connections for through hole components.		Improperly designed thermal connections to power or ground planes.	Redesign thermal connections per IPC-2221 & 2222.

C	PROBLEM	CAUSE	ACTION
Reflow soldered surface mount lands with via connections demonstrate solder depletion after wave solder.		Reflow solder migrating into vias during wave solder operation.	Provide thermal barrier (neck down) from via to surface mount land. Plug or mask via with solder mask. Provide solder mask dam across via connection to surface mount land.

D	PROBLEM	CAUSE	ACTION
Inconsistent solder paste deposition on surface mount assembly.		Solder mask too thick.	Solder mask thickness should be no greater than 0.051 mm. Consult PWB supplier.
		Screen print legend interferes with solder paste stencil contact to board.	Discontinue use of screen print legend. Alternatively, use etched pin one identification and map referencing.

E	PROBLEM	CAUSE	ACTION
Inconsistent solder volume when wave soldering surface mount components.		Incorrect component orientation.	Orient components in accordance with IPC-SM-782.

F	PROBLEM	CAUSE	ACTION
Components damaged by assembly fixturing.		Components intrude in assembly fixturing area.	Add a breakaway portion of board material to facilitate assembly fixturing.

2.7 PRINTED BOARD FABRICATION

2.7.1 Holes

A PROBLEM	CAUSE	ACTION
Hole breakout in lands.	Incorrect annular ring calculation.	Recalculate using hole diameter (finished hole for external; drilled hole for internal lands) plus two annular rings and a manufacturer allowance.
	Incorrect standard fabrication allowance.	Recalculate using appropriate standard fabrication allowance per correct class identified in table of IPC-2221 & 2222.

B PROBLEM	CAUSE	ACTION
Holes in lands break out at conductor interfaces, resulting in open conductor continuity.	Insufficient annular ring specified in design.	Recalculate annular ring in accordance with IPC-2221 & 2222. Fillet conductor or use square lands with corner entry. (See Figure 2-4.)

C PROBLEM	CAUSE	ACTION
Barrel cracks in PTH after thermal stress.	Incorrect laminate material called out.	Use a higher performance laminate material with lower z-axis expansion.
	Improper hole diameter-to-board thickness ratio.	Reduce hole aspect ratio.
	Removal of non-functional lands on internal layers.	Add non-functional lands on internal layers.

D PROBLEM	CAUSE	ACTION
Holes off location causing hole breakout or shorting of lands to conductors.	Undimensioned, ''off standard grid'' are not specified by originator/designer; and/or incomplete notes.	Contact user/customer to determine correct location of holes; request update to documentation and purchase order/shop order.
	CAM data delivered does not match current design data.	Contact user/customer to determine correct location of holes; request update to documentation, CAM data, and purchase order/shop order.

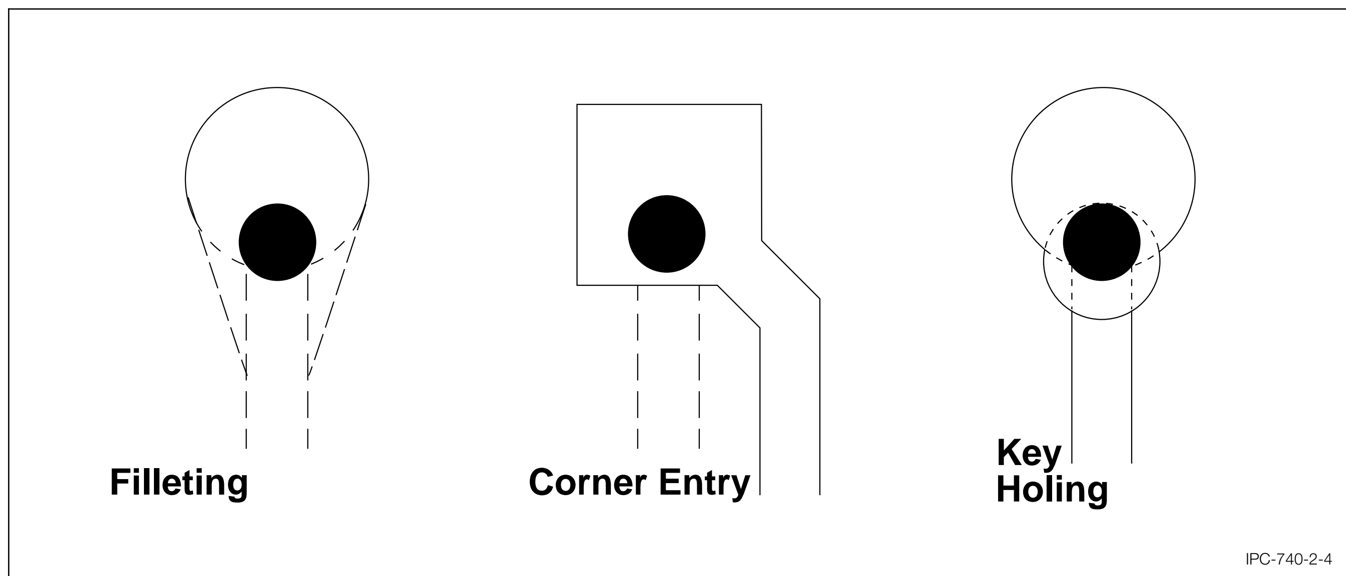

Figure 2–4 Modified Land Shapes

2.7.2 Conductors

A PROBLEM	CAUSE	ACTION
Edge conductors cut or damaged after board edge routing.	Conductors too close to board edge.	Locate conductors from board edge in accordance with design standard.
	Tolerance on edge too broad.	Tighten edge tolerance.

2.7.3 Construction

See Section 13.6 for design related problems at lamination.

A PROBLEM	CAUSE	ACTION
Unable to meet overall board thickness requirement.	Excessive dimensional detail specified in layer lay-up.	Define only overall board thickness and critical layer dimensions required for electrical criteria, leaving flexibility for fabricator to meet end requirements. (See IPC-2221 & 2222)

2.8 BOARD PHYSICAL CHARACTERISTICS

A PROBLEM	CAUSE	ACTION
Installed printed board assembly bows and fails in a horizontally mounted application.	Design incorporated material use that was not sufficiently rigid, with components mounted, in operational conditions.	Either select a different material, or incorporate stabilizing stiffeners or frames.

2.9 DOCUMENTATION

2.9.1 Printed Board Master Drawing

Printed board master drawings should be prepared, considering the following IPC standards:

- IPC-D-325 Documentation Requirements for Printed Boards
- IPC-D-300 Printed Board Dimensions and Tolerances
- IPC-D-350 Printed Board Description in Digital Form
- IPC-D-351 Printed Board Drawings in Digital Form

A check list should be developed between users (customers) and suppliers (vendors) which includes all documentation items needed, to determine that all details are covered, prior to beginning work. A documentation review based on such a check list, should reduce undesirable fabrication delays.

2.9.1.1 General

A PROBLEM	CAUSE	ACTION
Cannot begin fabrication of printed board because minimum conductor width and spacing are not detailed on the drawings, or are in conflict with applicable specifications and/or artwork supplied.	Design to documentation error and/or appropriate design principles not followed. Example: A board is designed with conductors on 25 mil centers, and there is no manufacturing tolerance allowed between end product conductor width and spacing requirements.	Inspect artwork compared to the master drawing, contact customer to agree on whether conductor width is measured at base or top, then request that the originator of the design/documentation make the appropriate changes. Also request update to original purchase order/shop order.

2.9.1.1 General (continued)

B	PROBLEM	CAUSE	ACTION
Cannot begin fabrication of printed board because board thickness measurement method and location are not defined. (For example: Over conductors and platings, or at laminate?)		Details are incomplete, or relevant specification omitted from drawing details.	Request that the originator of the design/documentation make the appropriate changes. Also request update to original purchase order/shop order.

C	PROBLEM	CAUSE	ACTION
Unable to complete and deliver printed boards because test methods, test patterns, and inspection criteria are not documented.		Details are incomplete, or relevant specification omitted from drawing details.	Contact originator/customer and evaluate the need for test method and inspection definition. Request that the originator of the design/documentation make the appropriate changes. Also request update to original purchase order/shop order.

D	PROBLEM	CAUSE	ACTION
Unable to determine process capability to fabricate printed board, because manufacturing allowances are unknown.		Details are incomplete; manufacturing allowances incorporated into the design were not documented on the master drawing.	Request that the originator of the design/documentation make the appropriate changes. Also request update to original purchase order/shop order. If the originator is unable to supply information, evaluate artwork tooling compared to end product requirements to determine designed manufacturing allowance, and then determine if processes are capable of producing the printed boards within required tolerances.

E	PROBLEM	CAUSE	ACTION
Cannot begin fabrication of printed boards, because finish/plating requirements are unknown or unclear. (This relates to bare copper, tin/lead reflowed, solder coating (HASL), organic solderable protective coatings (OSP), etc.)		Incomplete and/or inadequately defined drawing notes.	Contact originator/customer to determine requirements for finishes and platings. Request update to documentation and purchase contract or shop order. (User/customer and supplier/vendor should work together to determine best choice of finishes and platings.)

F	PROBLEM	CAUSE	ACTION
Unsupported or optionally plated holes are mistakenly or unnecessarily plated.		Incomplete or incorrect notes on master drawing.	Contact originator/customer to request clarification; request update to documentation and purchase order/shop order.

2.9.1.2 Tolerances

A PROBLEM	CAUSE	ACTION
Unable, or difficult to produce printed boards within tolerances specified on master drawing.	Tolerances specified are inadequate or unreasonable. Originator/designer did not provide the customary, industry standard manufacturability allowances.	Contact originator/customer to request a tolerance analysis, based on manufacturability requirements. Request documentation change, as well as an update to the original purchase order/shop order. (Specified tolerance should be appropriately reflected in cost and price.)

B PROBLEM	CAUSE	ACTION
Unable to determine applicable manufacturing and acceptability tolerances.	Documented individual dimension tolerances are in conflict with accumulative tolerances.	Contact originator/customer and resolve conflict. (Suggested changes should be defined, prior to contact.)

C PROBLEM	CAUSE	ACTION
Unable to produce printed board to "Class" of tolerance specified in drawing notes.	Dimensions and tolerances specified on master drawing conflict with specification "Class" of build required by drawing notes.	Contact originator/customer and resolve conflict. (Suggested changes should be defined, prior to contact.)

D PROBLEM	CAUSE	ACTION
Unable to drill holes to size and tolerance, while maintaining annular ring requirements.	Hole legend tolerances are in conflict with available drill sizes.	Select correct drill bit for meeting the minimum annular ring; determine changes to be made to hole legend documentation; send to originator/customer for negotiation; request update to documentation and purchase contract or shop order. (Agree upon whether "Minimum annular ring" meaning includes plating, or not.)

2.9.1.3 Specifications

Evaluation of true end product functional, performance, and reliability requirements should be made, before any specification and/or related class is invoked. While specifications must address actual needs, they should be as flexible as possible, with as little restrictions as possible, to allow for developments in manufacturing and process technology.

A PROBLEM	CAUSE	ACTION
Unable to maximize manufacturing capability, or optimize construction and assembly choices to obtain best solutions for end product functionality and performance.	User defined manufacturing and process specifications attempt to define too many details, and are therefore restrictive or prohibitive to supplier technology for optimization.	User/customer and supplier/vendor should work together in developing specifications, in order to cover basic minimum requirements, while allowing flexibility in manufacturing and processing for optimization. Use industry standards, such as IPC, "as is," or draw from these standards when developing user specifications.

2.9.1.3 Specifications (continued)

B	PROBLEM	CAUSE	ACTION
Unable to determine acceptance criteria.		Specification requirements are in conflict with Master Drawing requirments.	Contact user/customer to resolve conflicts; determine if deviations are needed; request an update to documentation and purchase order or shop order.
		Acceptance, test, and inspection requirements are not defined.	Contact user/customer to determine if this is an omission. If specific actions are required, request update to documentation. Otherwise, acceptance, test, and inspection actions by the manufacturer should be based on statistically based process control.

2.9.2 Printed Board Assembly Documentation. Printed board assembly documentation should adequately define the following:

- Lead bend criteria.
- Clearance of components between the board and the bottom of the component.
- Cleaning requirements and test for cleanliness.
- Type of solder mask and conformal coating and imperfections that are allowed.
- Requirements for complete filling in the solder hole, or solder filling around the lead.
- The use of jumper or haywires and how they must be secured to the boards.
- The masking of components or areas of the board that do not get conformal coating.
- Requirements for stress relief bends on wires, components, etc.
- Location, identification and orientation of all components.
- The definition of projection or lead projection of straight through leads.
- For surface mounted components, the thickness of solder paste, solder callout, flux, inadequately defined, including all locations of solder paste/creams.
- For connectors that require keys, the assembly drawing should show the exact key position and assembly instructions.
- Any hardware that becomes part of the assembly and the torque requirements necessary to prevent damage to the printed board assembly.
- Bow and twist end product requirements after assembly.
- Electrical requirements for end product testing of the assembly, including go/no-go tests as well as diagnostics.
- Applicable ordering data.
- Structural details when required for support and rigidity.
- Markings (serial number, dash number, etc.) to be added as a result of the assembly operation.

A	PROBLEM	CAUSE	ACTION
Incomplete definition of assembly requirements.		Deficiencies in assembly master drawing.	Develop a checklist for master assembly drawings for printed board assembly drawings, or standard assembly specification. Evaluate each master drawing against the checklist or the specification to eliminate any inconsistencies, conflicts, or contact potential customer for missing information.

2.10 INSPECTION AND TEST

A	PROBLEM	CAUSE	ACTION
Unable to perform inspections and tests.		Master drawing/specification does not describe inspection and test requirements nor any deviations that may have been granted to the specification(s) invoked.	Examine the details of the master drawing to make certain that all features of the end product meet the detailed design and performance requirements of the applicable specifications. If conflicts or deviations are noted, they should be documented and resolved with the originator/customer.

B	PROBLEM	CAUSE	ACTION
Unable to perform and complete testing of printed boards.		Incomplete definition of test coupons, frequency of use, and tests to be performed.	Contact originator/customer; request update to documentation to add complete details, as agreed; also request update to purchase order/shop order.

2.11 RELIABILITY

A	PROBLEM	CAUSE	ACTION
Installed printed board assembly experiences intermittent failures; returns to operational condition after being removed and reinstalled.		Printed board producing electromigration, due to either insufficient protection (permanent polymer coatings and/or conformal coating) in a hostile environment; and/or contaminants from fabrication or assembly processes.	Re-evaluate operating environment, and redesign to add appropriate, compatible coatings. Examine fabrication and assembly process specifications for cleaning and testing requirements.

B	PROBLEM	CAUSE	ACTION
Installed printed board assembly fails in operational environment where equipment experiences shock and vibration.		Design principals for component mounting for shock and vibration not followed.	Use robust components, and provide proper mounting and support for components, per guidelines specified in IPC-2222 & 2221.

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Section 3
Phototooling

3.0 PHOTOTOOLING

Refer to IPC-D-310 for complete information regarding phototooling.

3.1 MATERIALS AND PROCESSES

3.1.1 General

A PROBLEM	CAUSE	ACTION
Image density line widths.	Image density too low.	Check that processing procedure conforms to manufacturer's recommendations. Check that exposure parameters are correct. Check processing equipment to ensure proper operation. Check processing chemistry and temperatures. Do not expose diazo film to white light before developing. Be sure diazo film is not overexposed; use step tablet.
	Background density too high.	Check that processing procedure conforms to manufacturer's recommendations. Check processing equipment. Check processing chemistry and temperatures. Do not expose silver film to white light before developing; do not overexpose to safelights. Do not expose diazo film to ammonia vapors before imaging.

3.1.2 Diazo Film

Diazo film is used for the working phototool, where the ability to see through the image to register the phototool on the board is required.

High quality diazo phototools, when properly exposed and processed, should have the following characteristics: D_{MAX} greater than 4.0 density, D_{MIN} below 0.15 density in the UV portion of the spectrum.

A PROBLEM	CAUSE	ACTION
Loss of line width over entire copy (image lines have become thinner or spaces larger).	Incorrect exposure.	Check for overexposure (positive image) or underexposure (negative image), using a 21-step tablet to determine proper exposure time.
	Bad original.	Evaluate original for unsharp edges.
	Reflective surface being employed on back-up board causing light bounce-back.	Change back-up board or check that matte black imaging board is behind diazo film.
	Master and film not emulsion-to-emulsion.	Check master and film for emulsion side. Place in contact emulsion-to-emulsion. Check that vacuum draw down is complete.

B PROBLEM	CAUSE	ACTION
Loss of line width at outer edges of copy.	Exposure equipment out of calibration.	Evaluate light fall-off from center to edges of exposure unit.
	Film too large for the equipment used.	UV light too close to film for size of film being used.
	Vacuum frame not functioning properly.	Check vacuum parameters and set-up.

3.1.2 Diazo Film (continued)

C PROBLEM	CAUSE	ACTION
Poor edge sharpness (blurred images).	Master and film not emulsion-to-emulsion.	Check master and film for emulsion side. Place in contact emulsion-to-emulsion. Check that vacuum draw down is complete.
	Bad original copy.	Check for poor edges on original.
	Vacuum frame not functioning properly.	Check for out-of-contact print as this will cause fuzzy or blurred edges. Check vacuum for poor pressure and hose for pinholes.
	Reflective surface being employed on back-up board causing light bounce-back.	Change back-up board or check that matte black imaging board is behind diazo film.
	Air pockets trapped between films during exposure.	Check for dirt on image tray. Check for indentations or warping of black image board behind film. Add ‘‘bleeder’’ strips to allow trapped air to escape. Try drawing down gradually or for a longer time.

D PROBLEM	CAUSE	ACTION
Image gain: background discoloration in clear area (D_{MIN} too high) - uniform high background (clear area) density.	Underexposure.	Increase exposure time to burn out residual diazo. Use 21-step tablet.
	Film exposed to ammonia vapor prior to processing.	Film stored too close to ammonia; remove storage of film away from possible ammonia contamination. If diazo master is being used, residual ammonia may remain in film. Air out prior to placing in contact with another piece of film.
	Background of master is opaque to UV light. High $D\text{-}_{MIN}$ on master.	Increase exposure time to permit passage of light through background of master. Replace master.
	Exposure to excessive heat prior to processing.	Keep film stored in cool, dry environment.
	Over-age film.	Obtain new product.

E PROBLEM	CAUSE	ACTION
Low D_{MAX} (inadequate image density): 100% of the time.	Improper development.	Check processor for poor development. Check ammonia supply and strength, ascertaining that it is at least 26° Baumé. Check film plane temperature; should register 60–71°C. Insure sufficient passes through processor.
	Incorrect exposure.	Make sure film is not overexposed.
	Improper material or material handling.	Evaluate film to assure that it is capable of 4.0+ UV density.
	Film exposed to white room light prior to processing.	Use yellow lights or yellow shields in the processing area.
	Master does not have adequate density in image area, causing light to pass through and reducing diazo image density.	Replace master.
	Improper film cleaner.	Film cleaner may be reducing image. Check cloth for excessive yellow which indicates coating is being removed. Change to supplier recommended film cleaner.

3.1.2 Diazo Film (continued)

F PROBLEM	CAUSE	ACTION
Low D_{MAX}: some of the time (occasionally one film will not block light after several exposures).	Incorrect development procedure.	Review development techniques of all employees handling films. Review when ammonia is turned off in developer and length of time before film is passed through developer when it is turned on again. Pass through ammonia to achieve original color.
	Improper material storage.	Be sure no light has struck film.
	Equipment not functioning properly.	Check temperature of developer - should be above 60-71°C - at film plane (not thermostat on developer). Use of temperature tapes is best check.

G PROBLEM	CAUSE	ACTION
Pinholes or voids in image.	Pinholes in original artwork master.	Check original artwork for pinholes. Opaque (touch up) if necessary. Image second film to see if pinholes reproduce - identical position indicates pinhole in original artwork.

H PROBLEM	CAUSE	ACTION
Specks in clear area of film.	Dust or particles on master or vacuum frame glass.	Clean exposure frame, film and original using anti-static film cleaner or glass cleaner. Review clean room procedures for area.
	Image dots on clear areas of original artwork master.	Eradicate or physically remove from master. Increase exposure to burn through existing dots.

J PROBLEM	CAUSE	ACTION
Image distortion.	Environment - temperature and humidity.	Install and maintain temperature and humidity controls to meet the film manufacturer's recommendations.
	Lack of equilcharate after processing.	Allow film to equilcharate for 10 minutes after development.
	Precondition of film.	Stabilize film for a minimum of 8 hours or open shelving in photo lab environment.
	Developing temperature.	Temperatures exceeding 77°C can cause distortion; reduce temperature if necessary.
	Insufficient equilibrium after processing.	Expose film to room air for 15 minutes after processing.

K PROBLEM	CAUSE	ACTION
Straight (stray) lines showing on processed film.	Usually caused by stripped or pasted-up masters. The edges of the paste-up cause distortion of the light.	Increase exposure time to burn through cut-lines. Physically remove lines from first duplicate and use the corrected dupe to make another print.

L PROBLEM	CAUSE	ACTION
Random yellow spots in image area.	If yellow spots appear after exposure onto photo-resist, cause is particles of resist adhering to phototool.	Check resist laminated boards for loose resist chips and remove.
	Improper film cleaner.	Check film cleaner. Do not apply directly to film. Apply to cloth and clean film. Some cleaners will bleach film image.

3.1.2 Diazo Film (continued)

M	PROBLEM	CAUSE	ACTION
Ammonia processor not developing properly, even with proper heat and temperature.		Too much exhaust.	Exhaust fan too strong, drawing ammonia out of the developer.
		Blocked feed tubes to processor.	Feed tubes blocked, causing improper ammonia feed to chamber. Call for service.
		Pump not operating properly.	Repair/service pump.

N	PROBLEM	CAUSE	ACTION
Film sticking in processor.		Processor too hot.	Adjust temperature to 60-71°C on film plane using temperature tapes.
		Dirty slip screen.	Deposits on slip screen causing film to stick. Remove and clean slip screen if developer has one.

3.1.3 Silver Halide Film

Silver halide film is more versatile than diazo film. It can be imaged directly on photoplotters, contact frames, cameras, step-and-repeat machines, modifiers, etc. Most silver halide films are negative working (they reverse the image tone). All silver halide films must be processed (develop, fax, wash, dry) after exposure. Silver halide photoplotted films are suitable for first generation phototools. High quality silver halide films, when properly exposed and processed, should have the following characteristics:

- D_{MAX} greater than 3.8 density UV.
- D_{MIN} below 0.10 density UV.
- Sharp line edges, with minimal low density fringe.
- Fine line resolution to at least 1-mil line and space.
- Low pinhole levels.
- Scratch resistant structure.
- Anti-static protection to resist dirt and dust attraction.
- Good dimensional stability.

The following information is based on contact copies only, not master creation. (See Section 3.2.11 for laser-generated artwork.)

A	PROBLEM	CAUSE	ACTION
Line width - oversized or undersized.		Incorrect exposure.	Check for proper exposure settings on plotter.
		Incorrect development time.	Verify correct development time in processor.
		Incorrect development temperature.	Verify correct development temperature in processor.
		Improper developer dilution.	Ensure correct chemical mixing.
		Insufficient developer replenishment.	Check replenishment settings on processor and proper mixing.
		Exposed through the base side.	Ensure film is exposed to the emulsion side.

3.1.3 Silver Halide Film (continued)

B PROBLEM	CAUSE	ACTION
Low image density.	Incorrect exposure.	Verify that correct exposure is used.
	Improper development.	Use recommended developer time and temperature.
	Incorrect developer replenishment.	Check replenishment settings on processor and proper mixing.
	Exposed through the base side.	Ensure film is exposed to the emulsion side.

C PROBLEM	CAUSE	ACTION
Pinholes.	Pickoff in processing.	Clean crossovers and racks in processor. Check processor for correct crossover and film guide alignment. Check wash tank for bioslime. Treat with biocide. Replace filters in processor recirculation, and in incoming water line. Run tacky, roller transport clean-up sheets through processor, on a daily basis.
	Dirt on film during exposure.	Check for dust inside exposure machine. Vacuum as needed.
	Flakes in fixer.	Check electrolytic silver recovery for proper operating amperage.

D PROBLEM	CAUSE	ACTION
Poor line edge quality. (See Figures 3-1 and 3-2).	Incorrect exposure.	Check line width and exposure.
	Underdeveloped.	Follow manufacturer's recommendation for development, time, temperature, and developer concentration.
	Safelight fog.	Check darkroom safelights.
	Plotter out of focus.	Check plotter focus.

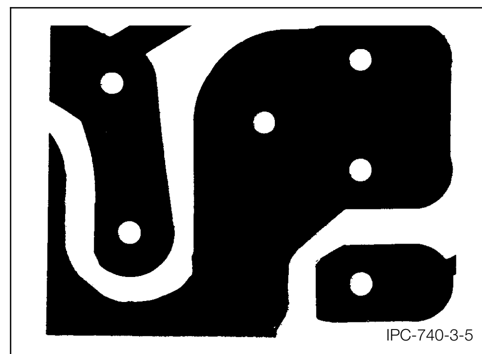

Figure 3–1. Ragged edges.

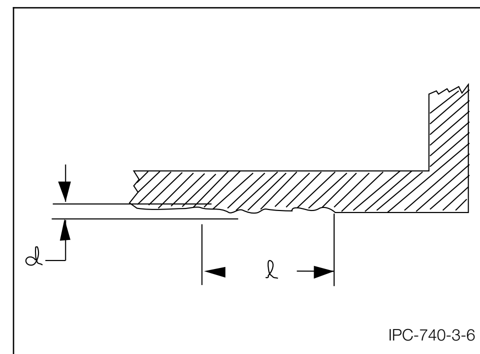

Figure 3–2. Ragged edge.

3.1.3 Silver Halide Film (continued)

E PROBLEM	CAUSE	ACTION
Black speck redeposits in clear area - irregular shape. (See Figure 3-3).	Silver and gel particles in solutions.	Replace recirculation filters in processor. Run tacky, roller transport clean-up sheets through processor, on a daily basis.
	Dirty or inadequate wash water/tank.	Dump and clean wash tank and rack. Install clean filters on incoming water line.
	Dirt buildup on rollers.	Clean racks and crossovers in processor.

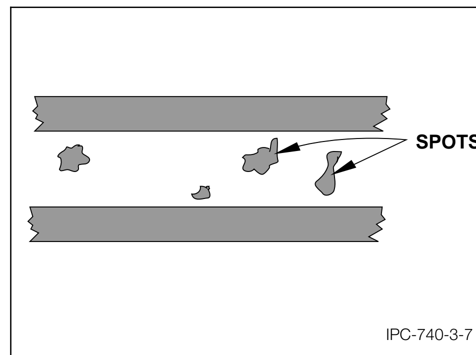

Figure 3–3. Spots or flecks.

F PROBLEM	CAUSE	ACTION
Silver pepper spots in clear area - round shape.	Under-replenished developer.	Insure proper developer replenishment to processor.
	Overdeveloped film.	Check developer time and temperature.
	Oxidized developer.	Check recirculation pump on processor for proper operation.

G PROBLEM	CAUSE	ACTION
Yellow, orange-yellow, or brown deposits in clear areas of film.	Bioslime in wash tank.	Clean wash tank. Treat water with biocide. Run tacky, roller transport clean-up sheets through processor, on a daily basis.
	Bioslime in blender replenishment unit.	Clean water reservoir in blender with diluted household bleach.

H PROBLEM	CAUSE	ACTION
Powder deposits on film (yellow or white).	Sulfurized fixer.	Check fixer tank for particulates. Check electrolytic silver recovery unit for excessive plating amperage.
	Salts in wash water.	Dump and replace recirculating wash water tank.

J PROBLEM	CAUSE	ACTION
Black line abrasion.	Entrance roller scratch.	Check entrance rollers to processor for dirt, burrs, or hesitation.
	Cassette feed scratch.	Check film-cassette loading mechanism for potential scratching.
	Rough handling.	Insure good film handling practices to avoid scratching prior to processing.

3.1.3 Silver Halide Film (continued)

K PROBLEM	CAUSE	ACTION
Poor dimensional stability.	Relative humidity variations.	Check humidity control for proper operation.
	Temperature variations.	Check temperature control.
	Dryer temperature set incorrectly.	Reset dryer temperature. Consult film manufacturer.
	Inadequate film equilibration procedures.	Ensure adequate film equilibration before and after processing.
	Improper vacuum draw in exposure frame.	Use longer/slower vacuum drawdown before exposure.

3.1.4 Glass - Silver Halide

Silver halide emulsion coated on glass is designed to produce phototools where maximum dimensional stability is desired. Insensitivity to relative humidity (RH) makes glass an ideal substrate for extremely critical size holding applications.

Glass is much more stable than film, as a comparison of humidity and temperature coefficients will show:

- Glass has a zero humidity coefficient.
- Polyester film base, 7-mil thick, has a humidity coefficient of 0.0008% per % RH.
- Glass has a thermal coefficient of 0.0008% per degree Celsius, as compared to 0.0018% per °C for polyester film, or about double that of glass.

Glass is used to produce either first generation phototools on flat-bed photoplotters, or to produce second generation phototools in a contact frame when imaged from a film original. High quality silver halide glass plates, when properly exposed and processed, should exhibit: (1) D_{MAX} greater than 4.0 density UV, and (2) D_{MIN} below 0.10 density UV.

A PROBLEM	CAUSE	ACTION
Line width incorrect - oversized or undersized.	Incorrect exposure.	Check for proper exposure settings on plotter, or contact frame.
	Incorrect development time.	Verify correct development time.
	Incorrect development temperature.	Verify correct development temperature.
	Improper developer dilution.	Insure correct chemical mixing.
	Exhausted or unreplenished developer.	Mix fresh developer, or add replenishment.
	Exposed through the base side.	Ensure glass plates are exposed to emulsion side.
	Fall off in exposure near edges of contact frame.	Check exposing lamp for uniformity using a light meter. Or, expose and process plate with step tablets in center and around the outer edges of the glass.
	Light source too close to glass for size of glass being used.	Increase distance from lamp to glass.

3.1.4 Glass - Silver Halide (continued)

B PROBLEM	CAUSE	ACTION
Low image density.	Incorrect exposure.	Verify that correct exposure is used.
	Improper development.	Use recommended developer time and temperature.
	Improper developer dilution.	Insure correct chemical mixing.
	Exhausted or unreplenished developer.	Mix fresh developer, or add replenishment.
	Exposed through the base side.	Ensure glass exposed to emulsion side on plotter.

C PROBLEM	CAUSE	ACTION
Pinholes.	Pickoff in processing.	Avoid any contact with emulsion while wet. Handle glass only by edges when tray processing.
	Dirt or dust in exposing area.	Vacuum as needed. Clean exposing frame, glass cover, and film original.

D PROBLEM	CAUSE	ACTION
Poor line edge quality.	Incorrect exposure.	Check line width and plotter exposure.
	Incorrect development.	Follow manufacturer's recommendation for development, time, temperature, and developer concentration.
	Poor contact between film and glass.	Check contact frame for adequate contact and vacuum drawdown.
	Safelight fog.	Check darkroom safelights.
	Plotter out of focus.	Check plotter focus.

E PROBLEM	CAUSE	ACTION
Uneven density, mottle, or streaks.	Non-uniform immersion into developer.	Immerse glass plate into developer tray using one continuous movement, without stopping or hesitating.
	Non-uniform immersion into fixer.	Immerse glass plate into fixer tray using one continuous movement, without stopping or hesitating.
	Poor agitation.	Rock tray continuously throughout entire development time, using front-to-back and side-to-side rocking motions.
	Poor stop action of development.	Add acid hardener to fixer solution. Or use an acid ''Stop Bath'' between the developer and fixer processing steps. A Stop Bath (5% acetic acid) will usually ensure good stop action of development and minimizes potential streaks or other uneven continuation of development when going directly from developer to fixer.
	Exhausted fixer.	Mix fresh fixer.

F PROBLEM	CAUSE	ACTION
Specks or deposits on processed glass plate.	Crystals of fixer as a result of insufficient washing.	Re-fix and re-wash. The white crystals, or frosty appearance, may not show up for possibly weeks or months after processing.
	Hard water. Calcium or magnesium scales.	May require water softener to supply fresh water.
	Emulsion particles of gelatin and silver (high temperature wash water).	Use colder wash water, 18° to 21°C. Warm water can cause gelatin to lift off the glass around the edges. These gel particles can be redeposited back onto the plate emulsion.

3.1.5 Glass - Hard Surface Image on Glass

Hard surface photomasks are noted for excellent dimensional stability and surface durability. Types of hard surface photo tools are chrome, iron oxide and silicon dioxide. Initial high costs are offset by longer life expectancy.

A PROBLEM	CAUSE	ACTION
Ragged lines.	Resist lift.	Metal surface not clean enough - use heavy duty glass cleaner. It is best to apply resist immediately after metal deposition.
	Resist not properly developed.	Develop resist according to manufacturer's recommendations.
	Metal etching not complete.	Metal etchant is spent. Phototool not etched long enough. Agitate phototool during etching to bring fresh solution to surface.

B PROBLEM	CAUSE	ACTION
Pinholes or voids.	Dust or particles in exposure area.	Clean exposure frame, glass and original.
	Bad original artwork master.	Check original artwork and touch up if necessary.
	Bad material.	Check fully exposed glass sheet - inspect for air bubbles - voids.

3.2 ARTWORK

This section is divided into five parts. The first contains problems of a general nature. The second part discussed problems associated with manually generated artwork (i.e., ‘‘taped up,‘‘ etc.). The third part is on photoplotter generated artwork while the fourth deals with problems specific to laser-generated artwork. The final section discusses problems associated with the rework and repair of artwork.

Board artwork utilizes a system of punched holes which describe the center of the board. This punch system provides a means of interlayer registration. The punched holes must be parallel and symmetrical to the underlay centerline. Each punched underlay should be pinned and examined for buckling, which would prevent it from laying completely flat. With extensive use, the punched hole may wear or widen. This will result in misregistration between layers.

3.2.1 General

A PROBLEM	CAUSE	ACTION
Poor feature definition.	Poor workmanship for manual artwork. Dirt adhered to edges of top.	Photocopy tape master to eliminate tape adhesive squeeze-out which picks up dirt.
	Improper exposure.	The following items should be evaluated for automatic artwork: • Check light (laser) source and calibrate. • Run test plots to evaluate plotter movement related to conductor ends and flashed features. • Evaluate plotter commands to avoid double exposure. • Clean all lenses and filters.

B PROBLEM	CAUSE	ACTION
Incorrect feature location.	Non-dimensional stability positioning grid for land patterns.	Check grids being used for doing hand taping; inspect and calibrate.
	Tape was stretched (tape creep).	Institute procedures to avoid tape stretching. Avoid curved section or switch to non-creep tape.
	Artwork material deformed either at incoming or by improper handling.	Institute procedures, humidity and temperature control, and proper storage conditions for handling of artwork media. Incorporate improved registration system.

C PROBLEM	CAUSE	ACTION
Missing features.	Lands left off the master, either in hand taping or in plotter-generated artwork.	Institute proper checking procedures, comparing artwork layers to design layout or to other artwork layers. Contact customer.
	Missing plating bar for connector contacts.	Supplier to determine board profile and add plating bar as needed.
	Missing coupons on the artwork, as required by the master drawing.	Determine coupon requirements, make step and repeat master for production, and add coupons, as necessary. Examine location of coupons on the production master to make certain that they adequately represent the end product board.
	Nomenclature is missing from the symbolization master.	Send symbolization master back to customer or get permission to add nomenclature (after checking that location does not interfere with existing circuit pattern).

D PROBLEM	CAUSE	ACTION
Incorrect registration between layers of double-sided or multilayer boards.	Entire layer does not register because the artwork was generated at different times.	Institute procedures to ascertain that all artwork revision levels are the same generation from the original. Keep artwork masters in sets, so that if one in a set changes, the whole set is reproduced.
	Misregistration of localized area on artwork due to manual changes of a particular area, without change to remaining circuitry.	Institute checking procedures to verify registration of the entire pattern, either through manual checks (negative to positive comparisons) or by automatic optical inspection equipment.
	Center of lands left open to provide registration checking capability. Manufacturing wants the lands to be solid to avoid drill movement caused by the etched inside of the ‘‘doughnut.’’	Institute procedures for automatic artwork generation by using apertures that are solid. For manual artwork generation, institute procedures to fill in open areas of land patterns.

3.2.2 Manually Prepared Artwork

Artwork can have many changes made over a long period of time. Most problems stem from knife cuts in the base material, foreign material, aging or degradation of the artwork set, or incorrect transfer when creating the circuit pattern.

A PROBLEM	CAUSE	ACTION
Foreign material in knife cuts.	Cuts in the base which have, over a period of time, become filled with foreign matter. These cuts are now clearly visible and would be imaged in a reduced film.	Avoid knife cuts which would create the potential for this problem. Cleaning is usually not possible since the foreign material is very difficult to remove from the base.

B PROBLEM	CAUSE	ACTION
Poor conductor edges.	Poor knife cuts or scribe marks evident in the conductor edge and the base material. (Small slivers of material such as this can cause problems during board manufacture.)	Cuts should be made without damaging the base material.

C PROBLEM	CAUSE	ACTION
Burrs.	A poor knife cut at the trace intersection has left a burr.	Rework artwork. (Conditions such as this are unacceptable.)

D PROBLEM	CAUSE	ACTION
Poor conductor corners.	Poorly constructed (cut) conductor that appears as a notch in the corner of the trace.	Rework artwork.

E PROBLEM	CAUSE	ACTION
Pinholes caused by foreign material on base (foreign material on the artwork base consists of any material other than the intended circuit which has sufficient size or density to potentially resolve on the image during camera reduction).	Dirt is present in an amount sufficient to cause many pinholes on the reduced film.	Keep the amount of dirt overall which is present on the artwork at a minimum.

F PROBLEM	CAUSE	ACTION
Excessive density of base material.	A scratch on a drafting aid pad is still present (the incomplete removal of pads, traces or drafting aids can produce excessive density on the base material).	Areas on the artwork that have been changed should always be completely free of foreign material.

G PROBLEM	CAUSE	ACTION
Overlapping drafting aids.	Overlapping drafting aid base material has increased the density in the overlap area. In addition, foreign material has become trapped under the edge of the base.	Avoid adding unnecessary layers of material.

3.2.2 Manually Prepared Artwork (continued)

H PROBLEM	CAUSE	ACTION
Extruded tape adhesive.	Adhesive from the trace has begun to extrude from under the tape. (The residue will image on the film reduction as an unsharp or fuzzy trace. In time, foreign material will become attached which will further degrade the edge sharpness.) This will lead to partial polymerization and resist scum during the photoresist developing process.	Minimize pressure when applying tape. Photograph taped artwork as soon as possible after it is generate

J PROBLEM	CAUSE	ACTION
Trapped dust particles.	Exposed adhesive around land has trapped dust particles. This will result in an uneven, fuzzy edge.	Re-tape original artwork in defective areas. (Defects of this type are impossible to correct on the reduced film image.)

K PROBLEM	CAUSE	ACTION
Aging or degradation defects.	Loose tape. The tape connecting the pads has loosened and slipped down from the intended position.	Once the adhesive has loosened, it should be completely cleaned from the base and new tape placed in that position.
	Folded tape. The corner of the tape connection has folded back. (This corner will continue to pull back until a minimum width condition is created. In addition, the newly exposed tape adhesive will attract and trap foreign material.)	Repair defective artwork. Improve artwork handling procedures.
	Tape intersection gaps. Tape intersections, due to aging, become rejects. Shrinkage of the tape has left a gap in the conductor.	Rework with overlapped tap.

L PROBLEM	CAUSE	ACTION
Legend defects.	Broken letters. Transfer letter has broken during application.	Correct the artwork before other process steps are performed. (The resulting gap is very difficult to correct on the reduced film image.)
	Misplaced transfer material.	Part of a logo has been inadvertently placed in an unintended area. (Loose or accidentally placed image material may cause conductor shorts on the board if not corrected.) Care should be taken when working with transfer material to ensure placement only in intended locations. Remove/replace excess transfer material.
	Poor inking. The ink used to make the marking pattern has chipped and lifted, causing an incomplete image and poor edges.	Rework artwork. Use transfer material.

3.2.3 Photoplotter-Generated Artwork

A PROBLEM	CAUSE	ACTION
Magnetic tape incompatibility with plotter.	Wrong tape format for driving NC plotters that are used externally.	Run test samples with outside plotters to determine that data format is compatible with the controllers processing the tape-to-plotter commands.

B PROBLEM	CAUSE	ACTION
Tape reader unable to convert the digital data into plotter commands.	Tape has been damaged due to improper handling.	Develop adequate control procedures for handling to avoid tape damage.

C PROBLEM	CAUSE	ACTION
Errors on final plot.	Modifications to the tape are inadequately checked, creating errors in the final plot.	Institute checking procedures by re-plotting with line plotter to verify that all changes have been adequately incorporated into the magnetic tape.

3.2.4 Laser-Generated Artwork

The generation of circuit patterns on silver halide media by means of a scanning laser spot offers unique benefits to producers of printed board artwork. Laser technology offers high-speed photoimaging, independent of circuit complexity. Step and repeat patterns may be accomplished quickly with the same accuracy as the CAD data base. Any roughness caused by exposure contours is repeatable, orderly, predictable and does not show on the final board.

A PROBLEM	CAUSE	ACTION
"Streaking."	Underexposure.	Increase exposure.

B PROBLEM	CAUSE	ACTION
"Unsharp" image.	Vibration in equipment.	Air cushion equipment and maintain proper control environment.
	Improper processing (underdeveloped or overdeveloped).	Check processor settings.
	Incorrect exposure (underexposure or overexposure).	Check exposure setting.
	Damaged, misaligned or out of focus optics.	Have plotter serviced.

C PROBLEM	CAUSE	ACTION
Non-straight lines.	Plotter out of calibration.	Check plotter calibration.
	Contamination problem.	Check film and platen for foreign debris.
	Loss of vacuum.	Check vacuum for proper hold down. Check over entire vacuum system for leaks.
	Inadequate pattern resolution for line width(s).	Check plotting resolution.

D PROBLEM	CAUSE	ACTION
Pinholes in artwork.	Dirt or dust particles in system.	Review cleanliness and maintenance procedures of environment of plotter and processor. Establish procedures if necessary.

3.2.4 Laser Generated Artwork (continued)

E	PROBLEM	CAUSE	ACTION
CAD data base incompatible.		Software problem.	Contact formatter of Gerber data.

F	PROBLEM	CAUSE	ACTION
Long or slow CAD data base conversion.		Inefficient CAD data base, i.e., drawn features, stroked ground planes.	Contact manufacturer for hardware/software tuning.

3.2.5 Repair and Modification of Artwork

A	PROBLEM	CAUSE	ACTION
Poor quality line definition after touch-up.		Quality of workmanship is not sufficient with brush or ink touch-up.	Institute adequate touch-up procedures and adequately inspect all changes and repairs or modifications made to artwork. Institute better manufacturing procedures, including better cleanliness standards, to reduce need for touch-up.
		Circuitry may be too fine to adequately repair or modify.	Discard artwork master and regenerate correctly.

B	PROBLEM	CAUSE	ACTION
Incorrect revision level of production masters or artwork released to the production floor.		Inadequate change control.	Institute change control procedure, commensurate with data control and release activities. Include change symbol and/or revision level on artwork master for ease of identification.

C	PROBLEM	CAUSE	ACTION
Unauthorized changes to artwork.		Improper changes made to localized areas to ensure that registration is maintained.	Institute procedures to have adequate checks made to ensure registration.

3.3 PRODUCTION MASTER

3.3.1 Reduction Problems

A	PROBLEM	CAUSE	ACTION
Improper reduction.		Two dimensions given on enlarged artwork are not within the capability of the camera lens to adequately reduce to meet the tolerances of both the “x” and “y” coordinates. (This is usually related to artwork master changes.)	Measure enlarged artwork to determine the compatibility of the “x” and “y” dimensions.
		The copy board of the camera is not parallel to the axis of the lens in the film.	Run test plots using a set of concentric squares on the copy board. Then rotate the concentric squares 90 degrees and re-shoot. Compare the film copies (negative to positive) to ascertain any differences between squares shot in one direction vs. squares shot in 90 degrees rotated.

3.3.1 Reduction Problems (continued)

B PROBLEM	CAUSE	ACTION
Inability to line up a scale properly to check the reduction mark.	Poorly designed reduction marks that do not permit one to properly measure distances on the frosted glass back of the camera.	Use correct reduction symbols or marks. Avoid asking for reductions where one must measure to the edge of a symbol, a practice which is not recommended. Some cameras are only equipped to do a scaled reduction (2x, 4x, 10x, etc.); however, on those cameras that can do actual reduction, one must check the reduction marks to ascertain that the copy on the frosted glass matches the requirements.

3.3.2 Artwork Modifier Problems

A PROBLEM	CAUSE	ACTION
Conductor pattern incorrectly compensated.	All conductors and lands are increased simultaneously. (A great amount of control is required in order to enlarge conductors the appropriate minimum distance.)	Depending on the type of equipment used, or whether one is shooting through a plate glass to increase the distance from the contact image, various test patterns should be developed to correlate the exact relationship between the technique being used and the required thickness that a conductor must be increased.

B PROBLEM	CAUSE	ACTION
Modified artwork has conductor patterns that are increased such that the spacing is reduced excessively.	The modifying artwork has very tight spacing that cannot tolerate increased conductors.	Determine end product spacing requirements, and make certain that these are commensurate with the process control after conductors have been enlarged. Measure at least 15 different locations on the board being produced, and make certain that the size of the final production panel will not be impacted by different locations.

3.3.3 Step-And-Repeat Problems

A PROBLEM	CAUSE	ACTION
Poor layer-to-layer registration between step-and-repeat masters.	Tolerance accumulation between the various steps.	Run a test plot of the equipment to determine that the step-and-repeat tolerances are adequate for the job intended.
	Incorrect orientation of the original master in the chase.	Check orientation of the original master in the chase.
	Layer-to-layer registration between step-and-repeat masters produced at different times.	Do all step-and-repeat operations of the same part in the same environment (preferably the same day) so that the step-and-repeat masters are a set which comes from the same lot of raw material, is processed on the same day, and sees the same environmental exposure.
	Size limitations of the step-and-repeat camera and its ability to produce multiple image masters from a copy that is larger than the chase of the equipment.	Determine capability of camera.
	Improper development.	Check developing procedures to determine that the developed product is not being mishandled.

B PROBLEM	CAUSE	ACTION
Image distortion.	From both dimensional distortion and edge definition.	Check the relationship of parallelism between the chase and the unexposed film copy board. Clean all lenses. Verify, through tests, both accuracy of equipment and of the lens system. Have step-and-repeat camera calibrated, both optically and mechanically.

3.3.4 Coupons Versus End-Product Quality

Coupons are placed on a production panel to verify the quality of the end product board. Coupons are therefore used to check process controls and should be representative of the product they are verifying. Coupons are put on the production master, coming either directly from the artwork supplied, or arranged by the manufacturer.

A PROBLEM	CAUSE	ACTION
Coupons are drilled accurately, but there is hole breakout in the lands of some printed boards.	Modified artwork has overcompensated in coupon areas (most likely on outer edges of board).	Review and correct.
	Inaccurate step-and-repeat pattern.	Determine the accuracy of the step-and-repeat patterns so that the relationship of the lands on all boards is consistent with the location of the coupons.
	Over/under expansion of artwork due to environmental conditions.	Position coupons so that all features are located within 0.051 mm radius of the true grid position established by the layer. For the composite production master, all the centers of lands should coincide within 0.076 mm radius of the true grid position when measured at 20°C + 1°C and 50 + 5% RH after the material has been stabilized.

B PROBLEM	CAUSE	ACTION
Coupons have good plating in the hole, but plating problems exist on the end-product board.	Coupons are not necessarily representative of the end product board.	Coupons should contain representative samples of the finest board features. Make sure the smallest hole size is represented in the coupon area (this provides the largest aspect ratio). Coupon areas should be drilled last, after all holes (for that drill size) have been drilled in the board area (then worst case drilling should be represented). If the board is a multilayer, the coupon should have representative ground plane areas for those layers that are voltage or ground planes. (See Figures 3-4 and 3-5.) Where possible, coupon holes should be first and last ones drilled. All hole sizes should be represented. See IPC-2221 & 2222 for complete information regarding test coupons.

3.3.4 Coupons Versus End Product Quality (continued)

C	PROBLEM	CAUSE	ACTION
Plating thickness on coupon areas not representative of that on the rest of the panel.		Coupons in high current density areas of the panel.	Coupons may need borders or "thieving" so that they are not isolated as high current density areas.

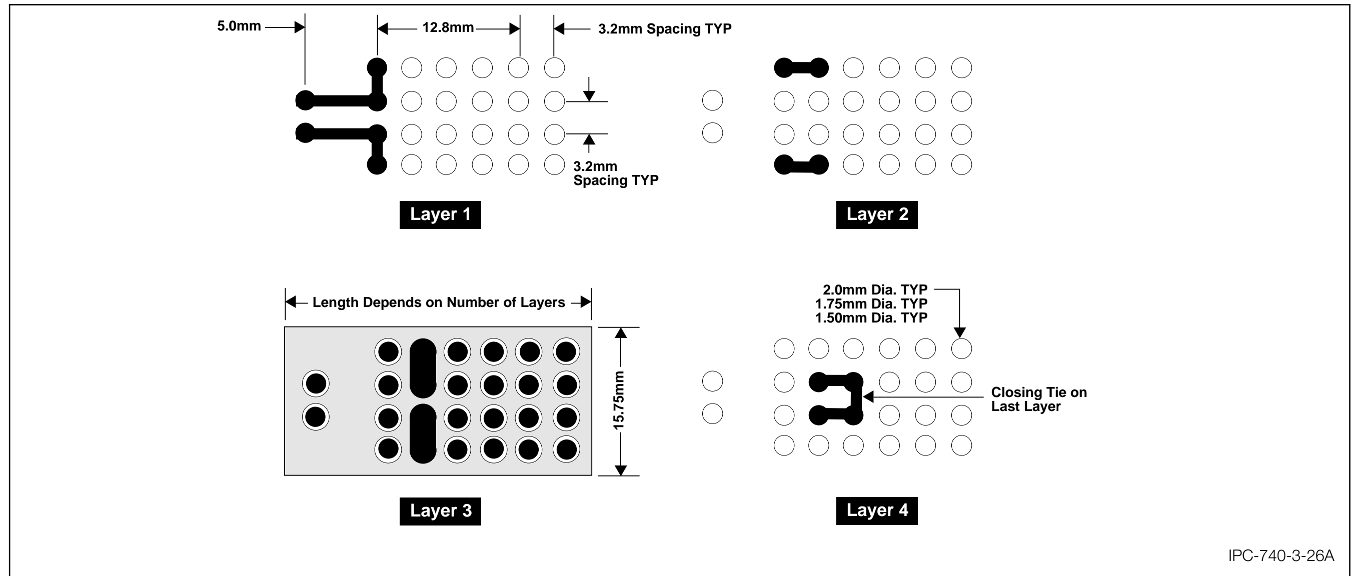

Figure 3–4 Test Coupon D, 4 layer board.

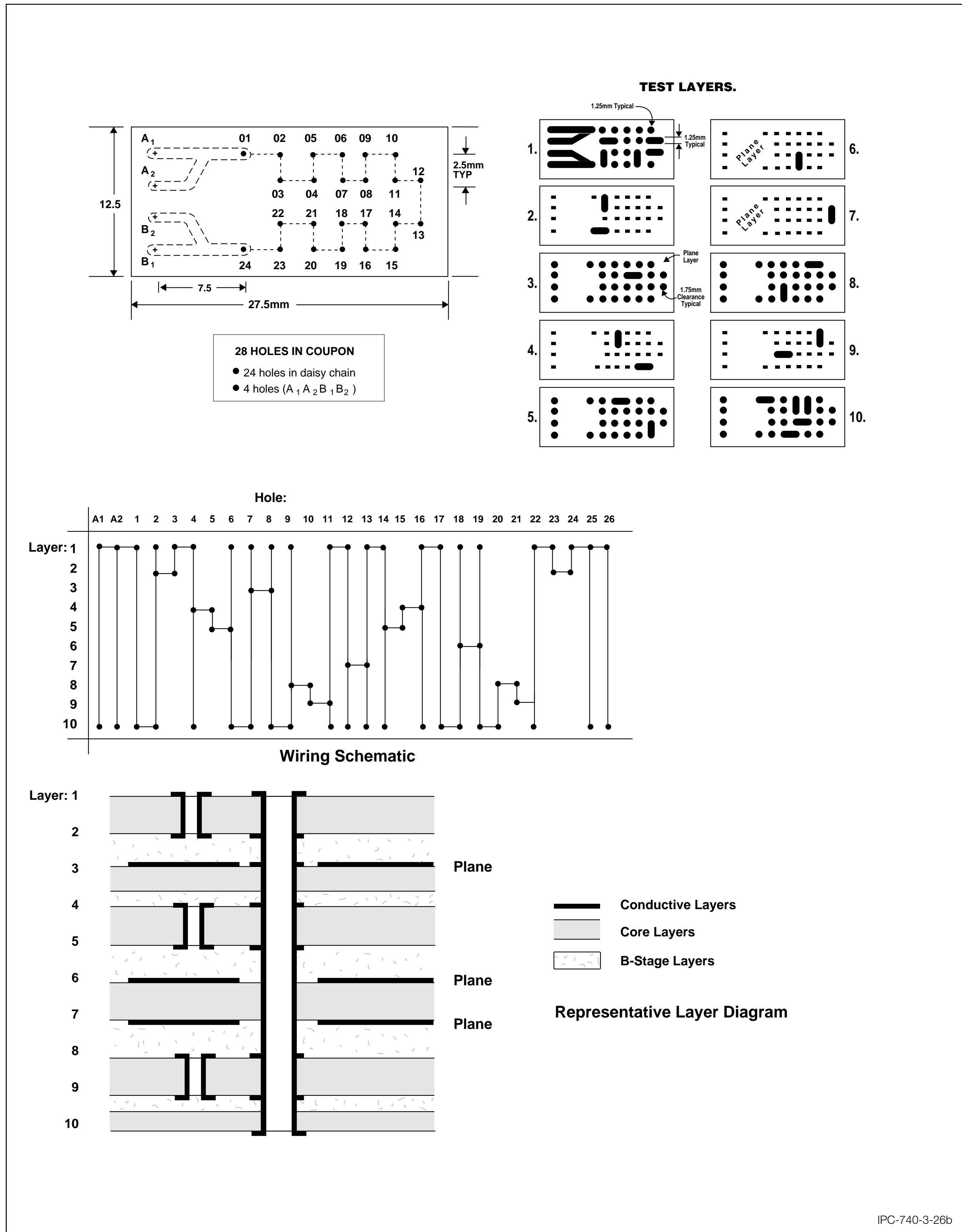

Figure 3–5 Test Coupon D, 10 layer board.

3.3.5 Measurement, Inspection and Touch-Up

Many times, problems associated with the production master relate to the inspection and measurement techniques used to verify that the production master is ready for manufacturing use. These problems relate to the environment in which the production master is verified, as well as the equipment used to make measurements. Frequently, handling techniques and procedures for touch-up create more problems than were noted in the original master. In addition, touch-up personnel must be totally trained to understand when and when not to touch up a production master.

A PROBLEM	CAUSE	ACTION
Production masters do not agree in size dimensions.	Size(s) has been affected by humidity and/or temperature.	Check temperature and humidity controls of room in which measurement is being done. Allow masters to stabilize and reinspect.
	Incorrect measurements made.	Calibrate all measurement tools to verify their accuracy.
	Variations in raw materials and/or developing procedures.	Perform all operations for the same part in the same environment (preferably the same day) so that the masters are a set which comes from the same lot of raw material, is processed on the same day, and sees the same environmental exposure.

B PROBLEM	CAUSE	ACTION
Pinholes in the end product board for artwork.	Pinholes on production masters. (Possible contamination during exposure.)	Examine production masters and touch-up pinholes, using appropriate brush sizes and ink.
	Touch-up ink not working correctly.	Check touch-up ink used to verify viscosity as well as permeability.
	Poor or sloppy touch-up.	It is advisable to set up appropriate procedures and institute a touch-up training program to avoid excessive touch-up. Also establish decision as to when production masters should be re-shot rather than touched up

3.3.6 Direct Imaging (Magnetic Tape) Problems

Problems associated with direct imaging are similar to laser generated artwork. (See 3.2.4.)

3.4 WORKING PHOTOTOOL, PRODUCTION MASTER

3.4.1 Handling-Related Problems

The working phototool is used on the production floor and is usually a copy of the production master. It has a life cycle in that, as the working phototool is used to expose various products, it is subject to wear. Some of this wear comes from the handling of the phototool.

A PROBLEM	CAUSE	ACTION
The phototool will not produce a clear image.	Fingerprints or dust on the phototool.	Clean phototool with appropriate film cleaning solution.

B PROBLEM	CAUSE	ACTION
Imperfect images on the exposed panel.	Scratching or mutilation (through folding or rolling) of the phototool.	Institute correct handling procedures. When training all personnel, stress the importance of the care that must be taken when using the phototool. When storing, put a slip sheet between phototools.

3.4.2 Normalizing-Related Misregistration

Problems associated with the phototool due to misregistration of the various layers relate to allowing the working film of the phototool to normalize to the environment in which it will be used. Many times a set of phototools has one layer re-shot; this is then added to the set and misregistration occurs because that individual film has not normalized to the same stability levels as the remaining films of the set.

A	PROBLEM	CAUSE	ACTION
Misregistration between layers of multilayer boards.		Film not normalized.	Allow film photo working tools to stabilize in the environment for 8 hours before use.

B	PROBLEM	CAUSE	ACTION
Film growth.		Increase in temperature and/or humidity.	Maintain the same temperature and humidity in all film handling areas.

C	PROBLEM	CAUSE	ACTION
Film shrinkage.		Decrease in temperature and/or humidity.	Maintain the same temperature and humidity in all film handling areas.

3.4.3 Quality of Contact Prints

Problems associated with contact prints relate to the number of prints that one can get from a given working phototool. Much of this relates to the handling of the phototool and to the equipment to expose the phototool.

A	PROBLEM	CAUSE	ACTION
Image is scratched.		Improper handling.	Verify the number of contact prints that have been made from the phototool. Examine the phototool for scratches, nicks, pits or dents. Review procedure for handling phototools.

B	PROBLEM	CAUSE	ACTION
Incorrect imaging on the photoresist of the panel.		Phototool not in intimate contact with panel.	Check that emulsion of the working photo tool is in contact with the panel resist during exposure.
		Touch up ink came off on photoresist.	Verify that touch up has been accurately accomplished and that the touch up material is still in place.

3.4.4 Protective Coatings

Sometimes it is necessary to protect the working tool so that it can be cleaned without damage to corrections or the artwork itself, and to greatly increase its contact life. It is not necessary to use a protective coating on hard surface phototools.

There are liquid and film protective coatings. The liquid type is only usable on silver films. Both types are highly transparent and must be applied under very clean conditions to prevent the introduction of defects.

A PROBLEM	CAUSE	ACTION
Finished laminated (with protective coating) artwork film is curved or bent.	Excess tension or stress during lamination of protective coating.	Operation of the laminator should be accomplished with minimum tension on all controls (laminate and release films).

B PROBLEM	CAUSE	ACTION
Protective coating film wrinkled or shrunken.	Excess tension or stress during lamination of protective coating.	Operation of the laminator should be accomplished with minimum tension on all controls (laminate and release films).

3.4.5 Pinning/Registration/Sandwiches

A PROBLEM	CAUSE	ACTION
Obliterated tooling.	Interior tooling holes are covered during resist lamination.	Use a self-centering photoresist cutting tool.

B PROBLEM	CAUSE	ACTION
Sporadic tooling hole registration shift (protective film to protect working film emulsion).	Dry resist laminator was used to apply the protective film to the working film while the heat shoes were warm.	Operate the resist laminator cold, and with proper roll tension.

C PROBLEM	CAUSE	ACTION
Misregistration of sandwich.	Misregistered lands when film is used in sandwich.	Reinspect and re-pin. If still inadequate, discard and make new master.

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Base Materials
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Section 4
Base Materials

4.1 GENERAL

The raw materials used in the manufacture of printed circuit boards are comprised of three basic building blocks; resin, reinforcement and metal cladding. The materials can be specified in combinations to meet particular applications of electrical, mechanical, thermal or processing parameters. Some of the problems associated with raw materials are chronic, systemic problems caused by the inherent physics of the materials used. Other problems associated with raw materials are commonly caused by an improper assignment of a particular material to an application. It is important to understand the limitations of these materials as well as the needs of the end use.

4.1.1 Resins

Resins are used to impregnate the selected reinforcement. The selection of a particular resin is dependent on the desirable electrical, temperature and process parameters.

Epoxy resins are the most commonly used. The difunctional base resin may be modified with additives to achieve higher thermal properties or improved chemical resistance. Tetrafunctional, multifunctional epoxy resins or Bismaelimide Triazine (BT) are added to epoxy resins to achieve higher thermal properties. Difunctional epoxy resins have a T_g range of 120 - 130°C. The modified epoxies have T_g ranges of 130 - 150°C or 150 - 190°C. The primary process parameters that are affected when changing between these resins is the lamination cycle and hole cleaning process prior to electroless copper.

Higher temperature resin systems may require more adjustments to the printed circuit processes such as: lamination cycle, baking, hole cleaning, drilling and routing. Polyimide resin and Cyanate Ester are the most commonly used high temperature resin systems. These resins have T_gs in the 250°C range. Polyimide can be blended to improve processing conditions, however the blending lowers the T_g.

PTFE (polytetrafluoroethylene), commonly referred to as Teflon(TM), is used for microwave applications and has significantly different processing conditions than the other resins.

4.1.2 Reinforcements

The most common reinforcement material used is a woven fiberglass cloth. Glass filaments are extruded in different diameters. These filaments are combined together to create yarn bundles of specific filament counts, these yarns are twisted in certain cloth styles. The yarns are then woven on looms in a standard over / under basket weave. The weaving process involves stretching out long yarns in one direction. These yarns are commonly referred to as the ''Warp,'' ''Grain,'' or ''Machine'' running direction of the cloth. The other yarns, perpendicular to the warp, are the ''Fill,'' ''Woof'' or ''Cross'' yarns. These yarns are in the width of the roll of cloth. Once woven the cloth is treated with a ''Finish'' to make it compatible to accept the resin.

There are non-woven cloths available to overcome the dimensional movement associated with the woven cloth. These fabrics are comprised of either random fibers or perpendicular yarns that are not woven. Kevlar, Aramid or carbon fibers are alternatives to the fiberglass materials.

4.1.3 Metal Foils

Electrodeposited copper foils are available in a variety of weights. Copper is typically manufactured and sold by weight in ounces per square foot or increments thereof. The weight is converted to thickness with a factor determined by the density of the foil, which equates to 0.00135 for one ounce copper. These foils are plated onto a drum which creates a smooth side and the opposite side has a profile of the crystals or copper teeth. A treatment is then applied to one or both sides of the foil. The purpose of the treatment is two-fold, it improves the adhesion of the resin to the copper and creates a barrier layer between the copper and the resin. A coating is then applied to the copper to prevent oxidation during the lamination or baking processes. The copper foil is available with different elongation and tensile properties that need to be considered with the thermal properties of the application and selection of the resin system.

Rolled copper foil is available which eliminates the profile on the one side of the foil. Some of the thicker copper is only available in rolled form.

Very thin foils are typically provided on a carrier, which enables processing and handling of the foil. The carrier may be either peelable or etchable and it is important to inquire which will be provided.

Specialty metal foils may be required for special applications. Some of the varieties available are: ED Nickel, Tin plated copper foil, coated foils, resistor layer and combinations such as ''Copper-Invar-Copper'' or ''Copper-Molybdenum-Copper.''

4.2 PREPREG OR ''B-STAGE''

Prepreg or ''B-Stage'' is comprised of a reinforcement that has been impregnated with resin and partially cured. It is

important to understand the characteristics of the prepreg to insure it is matched to lamination processing conditions. Characteristics to be considered are: the ratio of resin to glass (resin content percent or impregnation weight), degree of cure (melt viscosity, gel time, resin flow) and resultant pressed thickness (scaled flow). The value for scaled flow is a measure of material consistency, the actual value in production lamination may differ slightly based on specific lamination process parameters or board designs.

Temperature and humidity control of storage conditions for the partially cured material is important to prevent changing the prepreg characteristics and insure consistent performance during use.

4.3 LAMINATE

Laminate or core material is made of prepreg and metal foil that have been bonded together during a pressing operation and fully cured. The combinations of resins, reinforcements and metal foils are almost infinite. The printed circuit design and specifications need to be reviewed to insure appropriate selection of material.

4.4 PROBLEMS ASSOCIATED WITH THE BASE MATERIALS

4.4.1 Material Identification

A	*PROBLEM*	*CAUSE*	*ACTION*
Laminate label difficult to remove.		The adhesive backing on the labels is not easily or completely removable.	Use labels with different adhesive. Change requirement to metal impression or ink stamp material.

B	*PROBLEM*	*CAUSE*	*ACTION*
Material does not match label.		Material was mislabeled.	Check product identification and work flow procedures. Check stock for additional problems.

C	*PROBLEM*	*CAUSE*	*ACTION*
Material imaged and etched upside down.		Differential foil weights not identified clearly.	Standardize on marking either the heavier or lighter foil. Instruct operators on the standard marking.
		Marking of differential foil weights is removed during the preclean operation.	Change marking requirement to metal impression stamp.

4.4.2 Dimensional Stability

A PROBLEM	CAUSE	ACTION
Laminate exhibits dimensional change after processing.	Dimensional change parallel to warp direction differs from the fill direction.	Check the identity of the warp direction of the laminate. Characterize the movement and compensate artwork.
	Material movement due to stress relief after etching.	Retain as much copper on the panel as possible for mechanical strength. Bake laminates prior to processing. Use thicker laminate.
	Designed annular ring is inadequate for manufacturability.	Review design to increase pad diameter. Review design to decrease hole diameter. Contact material supplier to review alternative material options available.
	Mechanical scrubbing distorts material.	Reduce brush pressure. Evaluate chemical cleaning of material.
	Incomplete cure of the material.	Verify degree of cure via Differential Scanning Calorimetry (DSC) or Thermal Mechanical Analysis (TMA). Press and/or bake material at time and temperature appropriate for the specific resin system.
	Moisture absorption prior to lamination. (This is extremely critical to the higher temperature resin systems.)	Verify drying conditions after oxide. Pre-bake prior to lamination to eliminate moisture. Use weight loss to determine optimum time and temperature parameters. Minimize hold times in uncontrolled temperature and humidity environments between pre-bake and lamination processes. If required, store in conditions similar to those recommended for the particular prepreg resin system.
	Weave distortion.	Inspect raw cloth for uniform square weave and no bagging or sagging. Monitor tension during the treating operation.
	Excessive resin flow during lamination.	Adjust lamination pressure and/or prepreg flow parameters.

4.4.3 Mechanical Stability

A PROBLEM	CAUSE	ACTION
Bow and Twist of Laminate Material.	Materials are stacked vertically.	Store horizontally on shelves.
	Materials with mixed grain directions.	Match the grain direction of the glass cloth for all plies within a laminate. Avoid using square sheets or panels where grain direction traceability can be lost.
	Asymmetrical glass fabrics in laminate.	Review construction options for the desired laminate thickness. Change laminate thickness to insure symmetry of glass cloth.
	Different copper weights on opposite sides of laminate.	Review laminate construction lay up. Change to thicker glass cloth against thinner copper.
	Inconsistent wet out of glass cloth during impregnation and treating.	Cross-section and inspect for complete wet out of glass bundles and uniform resin thickness. Monitor across the web variation of resin content.
	Material warped due to exposure to heat operations while panel is not properly supported.	Insure that panels are properly supported whenever exposed to temperatures which exceed the T_g of the resin system.
	Material warped due to moisture absorption prior to processing.	Pre-bake material prior to processing at temperatures appropriate for the specific resin system.
	Excessively rapid cool down of material after reflow or HASL operations.	Control rate of cooling to avoid too rapid or uneven cooling of the panel.

4.4.3 Mechanical Stability (continued)

B	PROBLEM	CAUSE	ACTION
Lifted circuits or low foil bond strength.		Treatment on foil incompatible with resin system.	Specify foil treatment that has been tested as being compatible.

C	PROBLEM	CAUSE	ACTION
Fractures around drilled holes.		Drilling feeds and speeds are too aggressive for the resin system.	Reduce drilling feed and speed rates. Investigate ‘‘peck’’ drilling part of the way through the board at a time. Drill all holes ‘‘first stage’’, prior to plating, before metal removal.

D	PROBLEM	CAUSE	ACTION
Laminate thickness too thin at cross section.		Material thickness specified did not account for the differences between mechanical measurements with micrometer, foil profile and cross section measurements.	Increase the nominal laminate thickness specified to account for the difference. Specify purchase of material by cross section measurements. Specify low profile copper to minimize difference.

4.4.4 Foreign Material / Inclusions

A	PROBLEM	CAUSE	ACTION
Copper or Zinc embedded in the laminate resin. (See Figure 4-1.)		Usually caused by a large nodule (tooth) that has broken off the copper foil and become embedded in the resin.	Evaluate for intended application. Review the profile of the copper foil for consistency and dimension. (Use low or very low profile foil, if required for application.)

Figure 4–1. Copper or zinc inclusion in laminate.

Figure 4–2. Etch pits in laminate.

B	PROBLEM	CAUSE	ACTION
Etch pits in the laminate. (See Figure 4-2.)		A large copper nodule is etched away leaving a pit or white spot in the laminate.	Evaluate for application. Review copper profile. Specify low or very low profile foil.

C	PROBLEM	CAUSE	ACTION
Treatment Transfer.		Imbalance in the process that generates the treatment on the foil allowing separation.	Evaluate for acceptability. Contact material supplier.

4.4.4 Foreign Material / Inclusions (continued)

D PROBLEM	CAUSE	ACTION
Dark spots within the laminate or prepreg.	Contamination of dirt from raw materials or laminator's plant.	Evaluate for intended application. Perform audit of operation for cleanliness. Instruct supplier to review quality of incoming raw materials.
	Darkened resins from reaction vessels or treater ovens.	Evaluate for intended application. Review preventative maintenance frequency for cleaning of treater ovens.
	Lint, fiber or hair in the laminate or prepreg. (See Figures 4-3 & 4-4.)	Evaluate for intended application. Review clean room practices. Review static electricity levels in the prepreg sheeting and lay up operations.

Figure 4–3. Dark spots within laminate.

Figure 4–4. Lint within laminate.

4.4.5 Metal Surface Defects

A PROBLEM	CAUSE	ACTION
Pits and dents in the metal surface.	Dirt or contaminant on press plates or foil. Foil conforms to defect during lamination leaving a dent.	Specify appropriate "Grade" of material. Review plate cleaning process. Minimize exposure of plates and foil to environment during lay up operation.

B PROBLEM	CAUSE	ACTION
Scratches in the metal surface or treatment. (See Figure 4-5.)	Handling during the manufacturing process or storage.	Review equipment, conveyors, shelves and tables for sharp edges that could scratch laminate. Review proper handling procedures with operators.

Figure 4–5 Scratches on copper treatment.

Figure 4–6 Shiny spots on copper foil.

4.4.5 Metal Surface Defects Metal Surface Defects (continued)

C PROBLEM	CAUSE	ACTION
Wrinkles in the metal surface.	Improper handling of the foil during lay up.	Review proper handling procedures with operators.
	Movement of the laminate stack during press loading.	Inspect handling and loading equipment for proper operation. Instruct operators in proper method for transporting stacks of laminate.

D PROBLEM	CAUSE	ACTION
Resin spots on metal surface or areas of unetched metal.	Resin dust on metal surface during lay up operation.	Vacuum or heat seal edges of prepreg to minimize dust during lay up.
	Pinhole in metal foil allows resin to bleed through to surface during lamination.	Check incoming foil for pin holes. Check for proper handling of foil during process. Minimize kinking of foil that could create micro cracks in the foil allowing bleed through. Check sheeter for dirt on rollers that may puncture foil.

E PROBLEM	CAUSE	ACTION
Shiny spots on the copper clad laminate. (See Figure 4-6.)	This is caused by a high resin spot on the prepreg due to broken filaments or chafed ends etc. in the glass cloth. This condition is not known to cause defects in the inner layer process, unless a wrinkle in the copper foil is present. Severe conditions can abrade the treatment on the back side of the foil.	Determine acceptability within the process. Inspect prepreg for resin lumps caused by broken filaments. Select glass styles and resin contents to minimize condition. Work with glass manufacturer for long term elimination of broken filaments.

F PROBLEM	CAUSE	ACTION
Haze on foil surface after cleaning or lack of imaging resist adhesion.	Improper control of the laminate pre-cleaning process.	Review process variations by chemical analysis. Modify bath make up frequency or incorporate feed and bleed system.
	Laminate pre-cleaning process does not include chemistry to remove oxidation inhibitor.	Consult supplier to determine proper pre-cleaning chemistry for foil.
	Uneven application of the oxidation inhibitor on the foil surface.	Verify process control of the foil treatment process.

4.4.6 Chemical and Thermal Resistance

A PROBLEM	CAUSE	ACTION
Measles or crazing.	Reinforcing fibers are separated from the resin at the weave intersections due to thermally induced stress.	Check material handling and processing procedures for excessive temperatures.
	Inadequate wet-out or coverage of the glass yarns with resins especially at the intersection of the yarn cross overs.	Provide improved wet-out of the glass. Consider pre-wet rollers prior to the resin dip pan. Increase resin content percent.

B PROBLEM	CAUSE	ACTION
Weave exposure.	Resin content of material is insufficient.	Increase resin content of prepreg to insure adequate butter coat for protection against processing chemistry. Select finer weave glass style for facing plies.

4.4.6 Chemical and Thermal Resistance (continued)

C	PROBLEM	CAUSE	ACTION
Pits in the surface of the laminate resin.		A large copper nodule remains attached to the copper foil during lamination, but is etched away, thus leaving a small pit or white spot in the laminate surface.	Evaluation acceptability for application. Verify uniformity and consistency of foil profile.

D	PROBLEM	CAUSE	ACTION
Laminate voids. (See Figure 4-7.)		Dry prepreg, aged prepreg or advanced state of cure.	Verify prepreg storage conditions. Control storage and use conditions. Verify current flow performance to values when received. Adjust specifications for prepreg flow. Set requirements to limit shelf life of the prepreg.
		Crazed or fractured prepreg.	Inspect prepreg for fractures prior to use. Verify that packaging methods provide adequate support during shipment. Instruct operators on proper handling methods.
		Low pressure areas.	Verify thickness uniformity of press plates.

Figure 4–7 Laminate voids.

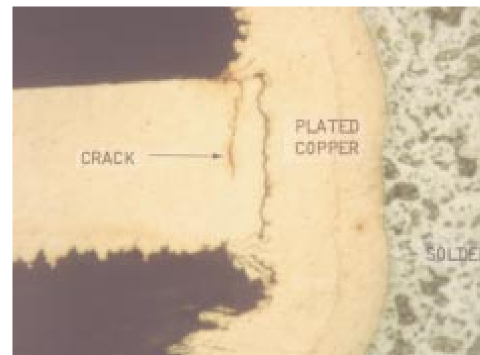

Figure 4-8 Foil innerlayer cracking.

E	PROBLEM	CAUSE	ACTION
Resin smear on the copper in the hole wall.		Drilling temperatures too high for resin system causing excess smear.	Check drill quality and quantity of holes before tool changes. Adjust drilling feed and speed rates. Use drill entry foil to dissipate heat build up. Monitor entry and exit rates, allow drill bit to cool between holes. Verify complete laminate cure prior to drilling.

F	PROBLEM	CAUSE	ACTION
Cracks in the copper foil. (See Figure 4-8.)		Thermal expansion of the resin is not matched to the elongation of the foil.	Reduce retained resin content in the board. Select glass styles with lower resin content. Specify foil that meets high temperature elongation requirements.
		Mechanical stresses induced during drilling or subsequent processes.	Reference Section 5.1 to reduce chipload, etc. during drilling. Review all thermal processes; baking, reflow, solder leveling, wave solder for conditions of oven temperature.

G	PROBLEM	CAUSE	ACTION
Plating separation from resin in holes.		Hole cleaning process is not matched to resin system. Resin systems with improved chemical resistance require more aggressive cleaning.	Contact material and chemical suppliers for recommended processing parameters to insure compatibility.

4.4.7 Electrical

A PROBLEM	CAUSE	ACTION
Dielectric thickness did not meet design.	Too much flow during lamination.	Review flow parameters on prepreg. Adjust lamination pressure to reduce flow. Adjust heat rise during lamination.
	Filling of the circuitry was not taken into consideration when calculating resultant dielectric thickness.	Subtract copper thickness from dielectric thickness for signal layers. Subtract percentage of copper etched away from dielectric thickness for plane layers. Adjust glass styles and resin contents to achieve desired dielectric thickness.

B PROBLEM	CAUSE	ACTION
Impedance values on finished board do not match design.	Line widths were not held to proper dimension.	Modify artwork to allow for etching factor. Specify low or very low profile copper foil to improve line definition during etching.
	Values used for dielectric constant in calculations were not appropriate for resin system or percentage of retained resin in the board.	Verify dielectric constant values for specific resin system and reinforcement. Adjust dielectric constant values based on retained resin in the board.
	Dielectric thickness not to design.	Determine if the violation is in the prepreg or core material dielectric. Verify lamination and prepreg parameters. Verify laminate thickness and tolerance. Take into account foil profile when specifying nominal laminate thickness. Modify construction as required to obtain appropriate thickness.

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Mechanical Operations
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Section 5
Mechanical Operations

5.0 MECHANICAL OPERATIONS

5.1 DRILLING

Many elements impact the accuracy and the quality of the drilling operation. This section describes these elements and the corrective action needed to ensure the desired hole characteristics. Table 5-1 provides a correlation between drilling process variables and drilling process effects. For more information on Drilling Guidelines, see IPC-DR-572.

Table 5-1 Drilling Variables and Effects

	Drilling Process Effects											
Drilling Process Variables	Hole Smear	Hole Contamina-tion	Excessive Drill Temperature	Excessive Drill Wear	Drill Breakage	Nail Heading Rifling Burrs	Hole Wall Rifling Gouging Tearing	Delamination	Drill Wander	Hole Location Accuracy	Hit Rate	Pink Ring
Drill Bit SFM (rpm)	•		•	•							•	
Feed Rate/Chip Load	•		•	•	•	•	•	•	•		•	•
RPM Fall Off	•		•									
Stack Height	•		•		•				•	•	•	•
Number of Holes	•		•		•	•						•
Entry Material	•	•	•	•								•
Backup Material	•	•	•	•		•						•
Base Material	•		•	•				•				•
Drill Design	•		•	•	•	•	•	•	•	•		•
Drill Geometry	•		•	•	•	•	•	•	•	•		•
Clean Resharps	•		•	•	•							
Foot Pressure					•	•						•
Adequate Vacuum		•		•			•					•
Spindle Run-Out	•		•	•	•				•	•		
Stroke Dwell Top/ Bottom	•		•	•	•							
Feed Variation					•	•	•	•	•	•		•
Machine X & Y Instability										•	•	
X-Y Position Accuracy										•		
Fixturing										•		
X-Y-Z Acceleration											•	

* Note: Table 5-1 is not all-inclusive and does not consider interaction of the key variables.

5.1.1 Dimensional

A	PROBLEM	CAUSE	ACTION
Hole not located properly, misregistration. (See Figure 5-1.)		Drill bit wanders.	Check spindle run-out. Reduce stack height. Increase rotary speed (rpm) or decrease feed rate (ipm). Inspect/sharpen drill bits. Inspect drill bits for proper concentricity. Check that innerlayer lands are solid (no doughnuts). Check to see that drill bits are seated properly in chuck. Shorten drill bit flute. Use drill bit with higher flex strength. Correct machine alignment and/or stability.
		Improper entry material.	Use smoother entry material that is more homogeneous.
		Board reinforcement size too large.	Use board material with smaller size glass reinforcement.
		Material has shifted.	Check post-drilling operations.
		Improper tooling.	Check tooling hole size and location.
		Drill tape incorrect/worn.	Check drill tape locations, software, etc. Check tape reader.
		Improper inspection procedures.	Check X-ray equipment for proper parallax.
		Drill resonance.	Drill at different rpm.
		Dirty or worn collet.	Clean or replace collet.

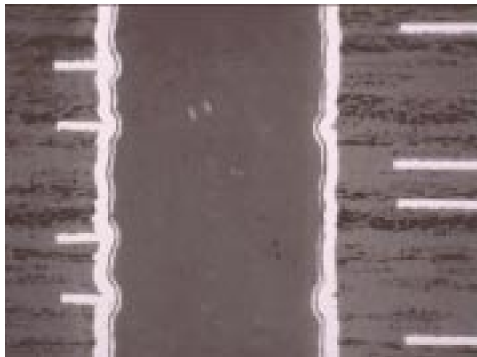


Figure 5-1 Misdrilling/ Misregistration

Figure 5–2 Resin smear

B	PROBLEM	CAUSE	ACTION
Improper hole size.		Wrong drill bit size used.	Correct as necessary, inspect drills before use. Check N/C equipment for proper commands.
		Improper feeds/speeds.	Optimize feed/speed relationship.
		Worn drill bits.	Replace drill bits. Limit number of hits per drill bit.
		Drill bits resharpened too many times or past acceptable flute length.	Limit number of times drill bit can be resharpened or supply dimensional sharpening limit.
		Excessive spindle run-out.	Rebuild spindle.

Example 5-1: Economic Considerations for Goal Analysis

In this example for drill registration improvement, the following economic parameters were considered.

- **In-process Diameter True Position (DPT) Cpk**
- **Finished Diameter True Position (DPT) Cpk**
- **Direct cost per square foot**
- **Overtime per week**
- **Scrap dollars per week**
- **Panel square foot per equivalent head**
- **Overall operating efficiency**

The statistical tools required for the study were:

- **Gage accuracy and precision analysis and control**
- **Control charting individual moving range X-bar-R**
- **Statistical operating procedure**
- **SOP analysis, review, and control**
- **Cpk monitor and analysis**

The following goals were established as a part of the action plan:

- **Correct weak areas exposed**
- **Maintain strength in capable areas**
- **Establish consistent & capable process**
- **Maintain and improve process over time**

This included an end product parameter with a DTP of printed circuit board drilled holes to maintain consistent Cpk of 1.5 or greater; an in-process parameter with a DTP of in-process panels to hold USL of no more than 0.10 mm DTP; and UCL's are calculated for each drill machine.

The process parameters included:

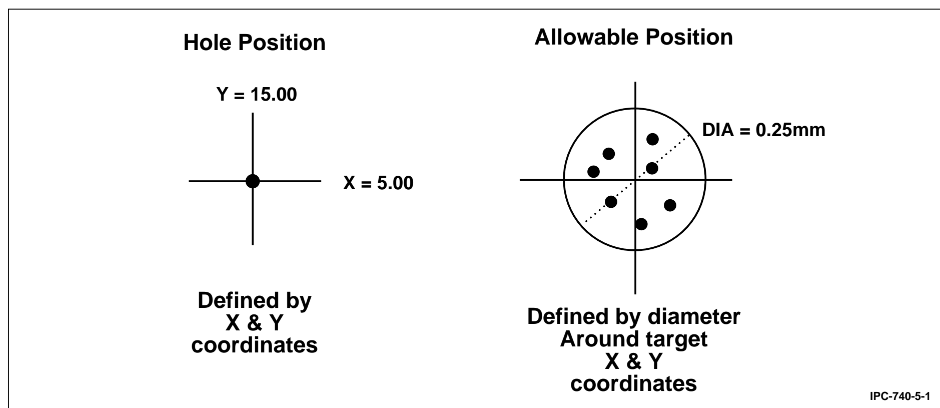
- **Static run-out of each drill spindle is controlled on individual-moving range charts.**
- **Each spindle is monitored and controlled individually.**

Diameter true position was determined according to hole position and allowable position as follows:

In order to accomplish improvement, basic SPC training courses for all drill department employees and management (8 hours minimum) was instituted.

- **Control charts were established for:**
  - **— In-process DTP**
  - **— Spindle run-out**
  - **— Drill depth**
- **Gage & measurement R&R analysis was implemented for:**
  - **— Cleaning and maintenance on gage performed**
  - **— Operators instructed on proper usage.**
  - **— Precision went from 35% to 9%.**
  - **— Long term gage control chart installed to control accuracy and precision**
- **Cross training matrix was established to include:**
  - **— Certified drill operator program**
  - **— All drill employees to become certified drillers**
  - **— Cross-training assures higher level of job satisfaction**
  - **— Increased department productivity also resulted**
- **Mechanical spindles replaced with air bearing spindles to maintain run-out of less than 0.008 mm**
- **Reaction plans for out of control conditions encountered when charting was developed.**
- **All SPC and continuous improvement activity was written into process procedures.**
- **Statistical operating procedure audits developed and implemented.**
- **Video tape analysis of setup and operating procedures.**
- **Supplier verification**
- **New equipment purchases using Cpk as prime consideration. New supplier chosen as result.**

Continued



Example 5-1: Economic Considerations for Goal Analysis (cont.)

The following is a result of a program regarding drill scrap:

	Before Program	After Program
Operator Error	631 ppm	0 ppm
Missing Hole	509 ppm	68 ppm
Hole Size Over Limit	472 ppm	292 ppm
Broken Drill	468 ppm	502 ppm
Internal Misregistration	466 ppm	137 ppm
Mislocated Hole	243 ppm	15 ppm

Results in One Year:

Repair and maintenance reduced 200%
Scrap reduced 120%
Productivity increased 20%
DPT Cpk increased from 33 to 42 mm

Participants learned that:

- **Product in-spec is not good enough anymore**
- **DTP variation due to both drilling and finishing processes - key to future improvement**
- **SPC and continuous improvement works in a job shop environment!!!**

5.1.2 Hole Quality

A PROBLEM	CAUSE	ACTION
Excessive resin smear. (See Figure 5-2.)	Improper feeds/speeds.	Optimize feed/speed relationship.
	Excessive dwell time in hole.	Change feed/speed relationship in order to reduce dwell time (change chip load). Reduce stack height. Check drill bit sharpness. Drill pilot holes before drilling final hole size. Check stroke dwell (bottom). Check RPM fall-off.
	Material not fully cured.	Bake material before drilling.
	Excessive number of hits.	Limit number of hits per drill bit.
	Drill bits resharpened too many times or past acceptable flute length.	Limit number of times drill bit can be resharpened (a common limit is total drill length).
	Backup and entry material.	Change material.
	Drill bit geometry.	Examine alternative geometries/design.

B PROBLEM	CAUSE	ACTION
Fiber protrusion in hole.	Withdrawal speed too slow.	Increase withdrawal speed.
	Worn drill bits.	Sharpen drill bits. Limit number of hits per drill bit. Change drill design.
	Spindle speed.	Optimize speed/feed relationship. Check spindle speed variation.
	Feed rate too high.	Slow down feed rate.

5.1.2 Hole Quality (continued)

C PROBLEM	CAUSE	ACTION
Nailheading. (See Figure 5-3.)	Withdrawal speed too slow.	Increase withdrawal speed.
	Incorrect chip load.	Optimize chip load.
	Worn or otherwise improper drill bits.	Sharpen or replace drill bits. Limit number of hits per drill bit. Change drill design.
	Spindle speed.	Optimize speed/feed relationship. Check spindle speed variation.
	Voids in laminate.	Replace laminate. Consult laminate supplier.
	Surface foot per minute (SFM) too high.	Check and modify SFM.
	Stack height too high.	Reduce stack height.
	Chip evaluation poor.	Poor entry and backup system. Replace entry and backup with cooler drilling material.

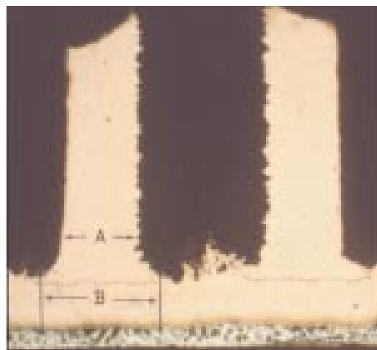


Figure 5–3 Nailheading

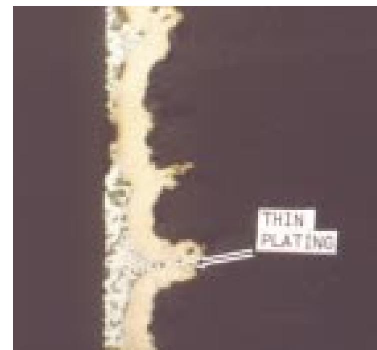


Figure 5–4 Rough Hole

D PROBLEM	CAUSE	ACTION
Haloing (delamation of copper around holes).	Thermo-mechanical stresses during drilling operation.	Replace/sharpen drills. Reduce heat generated by minimizing dwell time. (See 5.1.2 A.) Change hole drilling sequence (avoid drilling adjacent holes one after the other).
	Reinforcement material too large.	Use laminate with smaller reinforcement diameter (i.e., smaller diameter glass fibers).
	Poor quality laminate.	Replace laminate — consult laminate supplier(s).
	Chip load too high.	Check infeed rate.
	Drill slippage.	Check drill shank diameter and collet tension.
	Excessive stack height.	Reduce drill stack height.

E PROBLEM	CAUSE	ACTION
Rough hole walls. (See Figure 5-4.)	Excessive in-feed variation.	Maintain constant in-feed.
	Feed rate too high.	Optimize feed/speed relationship.
	Improper entry or material.	Change entry or material.
	Insufficient drill bit retention vacuum.	Check drilling machine's vacuum system. Check spindle speed variation.
	Retract rate.	Optimize retract/speed relationship.
	Chipped/bad drill bit.	Inspect drill bits prior to use. Improve drill bit handling practices.
	Excessive spindle run-out.	Check and clean spindle, collet and collet seat.

5.1.2 Hole Quality (continued)

F PROBLEM	CAUSE	ACTION
Burrs, greater than 1% of hole diameter. (See Figure 5-5.)	Dull or chipped drill bit(s).	Sharpen or replace drill bits. Limit number of hits per drill bit. Inspect drill bits prior to use. Improve handling practices and training, if necessary.
	Foreign material between stacked panels or loose stacking.	Improve material stacking procedures; clean laminate surfaces before stacking. Tighten stack.
	Incorrect chip load (too high).	Optimize chip load.
	Entry material too thin (burr on top of panel).	Use thicker overlay material.
	Defective pressure foot or low pressure (burr on top of panel).	Repair drilling equipment. Check springs, seals and line pressure.
	Incorrect or poor quality material (burr on bottom of panel).	Use harder/smoother material that is flatter. Change material after each machine cycle.
	Loose pins or non-perpendicular pins.	Replace pinning drill. Repair worn fixture.
	Pinning hole burrs.	Deburr pinning holes.
	Uncured laminate (entry burr).	Bake laminate or obtain better laminate.
	Chipped drill bit.	Check/replace drill bit.

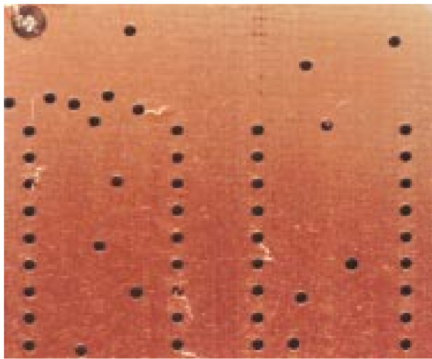


Figure 5–5 Burr from drilling

Figure 5–6 Connected curl chip

G PROBLEM	CAUSE	ACTION
Debris or residue in hole.	Improper entry or material.	Change entry or material.
	Impacted drill bit (with debris).	Change entry or material.
	Insufficient drill retention vacuum.	Check drilling machine's vacuum system.
	Pressure foot channels plugged.	Replace pressure foot.
	Drill bit spiral angle too low.	Check specifications; change type of drill bit.
	Excessive panel height.	Reduce stack height.
	Incorrect drilling parameters.	Increase feed and speed.
	Static charge.	Increase relative humidity to above 45%.
	Retraction rate too high.	Check and reduce retraction rate.

H PROBLEM	CAUSE	ACTION
Holes not round.	Drill spindle deflection.	Replace bearings in spindle.
	Non-concentric drill points or improper lip height.	Inspect drill bits.

J PROBLEM	CAUSE	ACTION
Connected curl chip on top of board. (See Figure 5-6.)	No entry material used.	Use overlay material.
	Improper drilling parameters.	Decrease in-feed rate (ipm)/increase rotary speed (rpm).

5.1.3 Processing

A PROBLEM	CAUSE	ACTION
Drill bits breaking.	Excessive spindle run-out.	Reduce spindle run-out.
	Equipment not operating properly.	Check pressure foot for sticking. Adjust pressure foot relative to drill bit tip. Check spindle speed variation. Check stability of machine axis during drilling cycle.
	Improper drill bit.	Check drill bit geometry. Inspect drill bit for defects. Use drill bit with proper flute length.
	Excessive speed/feed relationship.	Reduce feed rate.
	Excessive thickness being drilled.	Reduce stack height.

B PROBLEM	CAUSE	ACTION
Excessive numbers of chipped drill bits.	Improper handling.	Review/improve handling techniques. Institute training program.

5.2 PUNCHING (PIERCE AND BLANK)

Table 5-2 provides a correlation between punching process variables and punching process effects.

Table 5-2 Punching Variables and Effects

Punching Process Variables	Punching Process Effects											
	Edge delamination	Missing holes/slot	Misallocated holes/slot	Undersized hole/slot	Mispunched circuit	External dimensions out of space	Fibers on the board's edge	Dents on the surface	Surface scratches	Shear damage of the tool	Broken perforators	Excessive tool wear
Part tolerance			•	•		•				•		
Material thickness				•		•	•			•		•
Material type				•		•	•			•		
Hardness of tool components	•			•			•			•		•
Tool sharpening schedule	•			•		•	•	•		•		•
Tool timing	•	•			•	•	•					
Stripping pressure	•						•	•				
Tool revisions		•	•		•	•						
Pilot pins			•		•	•			•			
Punch press alignment	•									•	•	•
Horizontal play on the run	•									•	•	•
Die setup		•							•	•	•	•

5.2.1 Dimensional

A PROBLEM	CAUSE	ACTION
Undersized holes/ features.	Excessive after-punching hole "spring back."	Use appropriate punch size.
	Excessive wear of the tool components.	Check the hardness of the tool components and compare with die specifications (replace if necessary). Check if the die features are properly sized for the specific material type and thickness (reference die specs). Adjust the sharpening schedule to meet tolerance requirements for critical hole/feature. Resharpen punches.

5.2.1 Dimensional (continued)

B PROBLEM	CAUSE	ACTION
Improperly located hole/ feature.	Material not flat in press.	Correct material retention mechanism.
	Material improperly located in the press.	Check tooling system, tooling hole size, etc.
	Undersized pilot holes.	Check the pilot pin diameters and compare with the blueprint requirements.
	Tool revisions.	Check if the tool revision was incorporated properly. Correct the tool if necessary.
	Part tolerance.	Revise process capability and check part tolerance requirements. This is critical for multiple station dies or multiple die concepts.

C PROBLEM	CAUSE	ACTION
External dimensions out-of-spec.	Worn pilot pins.	Check if the pilot pins have the dimensions as required for the specific job. Replace if necessary.
	Improper height of the pilot pins.	Check if the height of the pilot pins meets specifications. Increase the pins' height as required.
	Tool sharpening schedule.	Adjust the sharpening schedule so parts stay in tolerance between sharpenings.
	Improper sizing of the tool components.	Check if the dimensions of the tool components are chosen in accordance with Die Specifications for the specific material type and thickness.

D PROBLEM	CAUSE	ACTION
Missing holes/ features.	Broken/missing punches.	Inspect upper die for broken or missing punches and replace if necessary. Insure removal of material slugs to prevent build-up of slugs.
	Tool revisions.	Check if the tool revision was correctly incorporated. Verify the location of the features inside the die with the feature location on the blueprint and correct if necessary.
	Improper setup (upper die setup too shallow).	Lower the shut height of the punch press.

5.2.2 Feature Quality

A PROBLEM	CAUSE	ACTION
Edge delamination.	Worn tooling.	Sharpen punches. Adjust tool sharpening schedule for the specific material type, material thickness and tolerance.
	Excessive wear of the tool components.	Check if the tool hardness meets your requirements. Replace the tool components if necessary, or adjust the sharpening schedule.
	Chipped or broken perforators.	Resharpen the tool past the chip level or replace the defective perforator.

5.2.2 Feature Quality (continued)

B PROBLEM	CAUSE	ACTION
Fibers and/or roughness along edges. (See Figure 5-7.)	Worn tooling.	Sharpen punches. Adjust tool sharpening schedule for the specific material type, material thickness and tolerance.
	Excessive clearance between die and punch.	Verify if the clearance between the perforators and the die features is correct. Modify the tool to reduce clearance if necessary.
	Stripping pressure of the blanking die too low.	Add more springs under the lower stripper plate.
	Improper tool timing.	Verify the die settings and compare with the settings suggested by the die manufacturer. Correct if necessary.
	Dirty tooling.	Improve material handling procedures.

C PROBLEM	CAUSE	ACTION
Surface dents and scratches.	Sharp pilot pins.	Correct the shape of the pilot pins. Assure that no sharp edges or needle points come in contact with the panel.
	Excessive shedder plate pressure.	Lower the pressure of the shedder plate by either removing the springs or lowering the pressure on the nitrogen power pack.
	Die maintenance.	Bevel all edges and countersink all die mounting features that come in contact with the panel during punching.

Figure 5–7 Rough edges of punched hole

5.3 ROUTING

5.3.1 Dimensional

A PROBLEM	CAUSE	ACTION
Feature out of tolerance.	Board shifting.	Increase pressure on pressure foot. Add internal tooling pins.
	Excessive board bow.	Reinspect board material. Improve board retention system.
	Incorrect template.	Check template size and shape.
	Incorrect N/C commands.	Check software/controller.
	Excessive tooling hole clearance.	Check tooling hole size. Check tooling pin size. Optimize tooling hole/pin relationship. For ‘‘pinless’’ routing, check for weak section that may be deflecting. Also, program may need modification.
	Improper router bit.	Check router bit for wear. Check router bit radius.
	Router bit run-out in spindle.	Clean collet. Repair/replace collet (worn or burred).
	Improper feed/speed relationship.	Optimize feed/speed relationship.

5.3.2 Feature Quality

A PROBLEM	CAUSE	ACTION
Crazing.	Improper entry/backup material.	Change entry/backup material.
	Worn router bit.	Replace with sharp router bit. Sharpen router bit.
	Improper bit type.	Change bit type. Consult router bit supplier for assistance.
	Improper board material.	Check reinforcement/resin content of board material.
	Improper feed/speed.	Optimize feed/speed relationship.
	Improper pressure foot or pressure.	Adjust as necessary.

B PROBLEM	CAUSE	ACTION
Rough edges.	Worn router bit.	Replace with sharper router bit. Sharpen router bit.
	Wrong type of router bit.	Change router bit.
	Excessive smear on router bit.	Check reinforcement/resin content of board material.
	Ineffective material removal system.	Increase suction of material removal system.
	Defective router bit.	Replace router bit.
	Wrong entry/backup material.	Change entry/backup material.
	Vibration.	Reduce routing machine vibration.
	Improper material retention.	Improve board hold-down system.

C PROBLEM	CAUSE	ACTION
A ''cusp'' forms on the edge where ''pinless'' routing pressure foot clamps.	Wrong clamping location.	Apply clamping pressure at a better location.
	Improper pressure foot force.	Check pressure foot during clamping mode.
	Defective pressure foot.	Check pressure foot for excessive friction on sliding parts caused by foreign material.
	Improper solder mask material.	Check solder mask friction (some UV inks have a very low coefficient or friction that can cause slipping).
	Improper X-Y feed rate during clamping.	Reduce feed rate to 10 ipm during the last 6.35 mm of clamping action.
	Improper vacuum hoses that cause the ''pinless'' foot to twist or drag.	Use longer or less stiff hoses.

5.3.3 Processing

A PROBLEM	CAUSE	ACTION
Caking dust.	Improper rotary bit speed.	Check recommended speed. (Increase rpm if necessary.) Check spindle speed calibration. Check to see if bit is slipping in the collet.
	Improper bit type.	Use ''up-draft'' bit.
	Improper routing parameters.	Check bit depth/flute length/stack height relationships. (Dust will be blocked if stack comes near the top of the effective flute length.)
	Wear in pressure feet and vacuum lines.	Check vacuum lines for holes.
	Improper position of stop ring or collar.	Check to see that there is a minimum of 20.3 mm from the top of the collar to the point of the bit.
	Improper pressure foot insert opening.	Check to see that there is sufficient clearance between the spindle nose and the pressure foot.

5.3.3 Processing (continued)

B PROBLEM	CAUSE	ACTION
Router bit discoloration.	Excessive heat.	Check for vacuum problems. Shorten travel of bit into backup material (usually 1.52 mm maximum). Reduce stack height. Change bit type to one with an open design with lots of chip clearance (for N/C routing with plunge cutting). Check for bit run-out. Check for buried copper layers that are clogging bit prematurely. (Hit-plunge into the epoxy glass only and then feed transversely into the copper areas.)

C PROBLEM	CAUSE	ACTION
Breaking bits.	Bit pulling out of collet.	Check collet/adjustment for wear or damage.
	Improper speed/feed parameters.	Reduce Z-axis depth. Check for bit run-out. Reduce transverse feed rate. Increase rotary bit speed (rpm).
	Improper router bit.	Change bit design type. Check bit for defective carbide.
	Machine malfunctions.	Check for dragging spindle, coolant pressure switch intermittent, cutoff and high-speed ''jerks'' caused by software or servo loop.
	Loose material.	Check for loose ''skeleton'' material that can be grabbed by the bit, and thus cause breakage.

5.4 SHEARING

5.4.1 Dimensional

A PROBLEM	CAUSE	ACTION
Panel not square.	Incorrect cutting blade angle.	Adjust cutting blade angle.
	Panel shift.	Improve material clamping mechanism.
	Shearing multiple panels simultaneously.	Shear panels separately.

5.4.2 Processing

A PROBLEM	CAUSE	ACTION
Panel lift.	Dull cutting blade.	Sharpen cutting tool.
	Improper clearance between cutting blade.	Optimize clearance.

5.5 BEVELING (see Figure 5-8)

5.5.1 Feature Quality

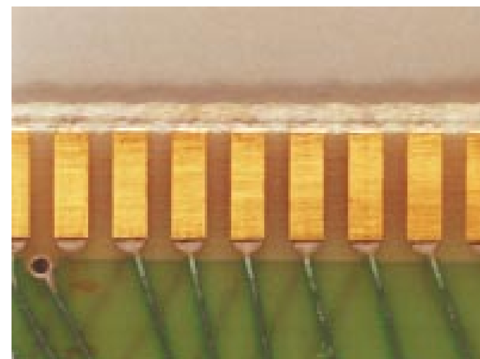


Figure 5–8 Bevel

A PROBLEM	CAUSE	ACTION
Copper foil lifting.	Dull cutter.	Sharpen cutter.
	Incorrect feed rate.	Optimize speed/feed relationship.

5.5.1 Feature Quality (continued)

B PROBLEM	CAUSE	ACTION
Rough bevel.	Dull cutter.	Replace with sharp cutters.
	Loose cutters or tooling block clamp.	Tighten as necessary.

C PROBLEM	CAUSE	ACTION
Uneven bevel.	Loose tooling block.	Tighten as necessary.
	Worn or damaged belts.	Replace belts.
	Worn guide rollers or bearings.	Replace pulley and/or bearing.
	Hold-down rollers worn or out of adjustment.	Adjust tension, recap wheels or replace bearings.
	Guide rail out of adjustment.	Adjust guide rail.
	Non-uniform board thickness.	Evaluate board specification for applicable end product equipment.

5.5.2 Processing

A PROBLEM	CAUSE	ACTION
Excessive feed pressure required.	Hold down rollers set too high.	Adjust for proper tension.
	Bearings bad.	Replace bearings.

5.6 SCORING

Table 5-3 provides a correlation between scoring process variables and scoring process effects.

Table 5-3 Scoring Variables and Effects

	Scoring Process Effects									
Scoring Process Variables	Mislocated score lines	Missing/extra score lines	V-out depth out of tolerance	V-outs misalligned	Web location out of tolerance	Excessive fibers after separation	Surface scratches	Dents on the surface	Panel damage	Cutter damage
Part tolerance	•		•		•					
Material thickness	•		•		•					
Material type										
Surface condition	•		•							
Edge/clamp area condition	•									
Panel warpage	•		•						•	•
Pilot hole dimensions	•									
Program revisions	•	•								
Pilot pin dimensions	•									
Pilot pin alignment	•									
Blade condition			•	•		•				
Air pressure supplied	•	•	•		•					
Measuring device/ technique	•		•		•		•			
Vacuum			•				•	•		
Set-up		•	•	•	•		•	•	•	•

5.6.1 Dimensional

A PROBLEM	CAUSE	ACTION
Score lines misplaced.	Pilot pins.	Check the pilot pins for wear and replace if necessary. Check the alignment of the pilot pins and realign if necessary.
	Pilot holes.	Inspect pilot hole size. Check pilot holes for plating and remove plating if necessary. Check pilot hole location with respect to panel's features. Redesign pilot pins to include taper, allowing for changes in the pilot hole diameter.
	Programming error.	Check the program data entry and verify with the job blueprint. Verify the program for proper revision and correct data entries if necessary. Verify machine offset and adjust if necessary.
	Panel shift during cutting.	Check the air pressure supplied to the machine and adjust as required. Check the clamping mechanism for wear and proper clamping force.
	Improper measuring technique.	Check panel alignment before measuring the line location. Check the measuring probe for wear and replace if needed. Calibrate the device as required.
	Missing and extra score lines.	Verify the line location as per blueprint. Check the machine settings against the approved data sheet and correct if necessary.

5.6.2 Web Thickness and Web Location

A PROBLEM	CAUSE	ACTION
Improper setup.	Wrong material thickness.	Verify the remaining material thickness per blueprint.
	Equipment out of adjustment.	Adjust the cutters in accordance with equipment manufacturer's specifications. Adjust the pilot wheels in accordance with equipment manufacturer's specifications.

B PROBLEM	CAUSE	ACTION
Score depth fluctuates from line to line.	Worn or damaged blades.	Check blade resharpening schedule and sharpen if necessary. Replace blades if excessively worn or damaged.

C PROBLEM	CAUSE	ACTION
Web thickness varies across one line.	Non-uniform pressure applied during operation.	Adjust the force exerted on panel by pilot wheels as per equipment manufacturer's specifications. Check air pressure supplied to the machine and adjust if necessary. Check the condition of the air-actuated cylinders engaging upper and lower cutters.
	Incorrect measurement.	Calibrate measuring device.

5.6.3 Score Angle

A PROBLEM	CAUSE	ACTION
Improper score angle.	Worn or damaged cutter blades.	Replace the cutter blades as per equipment manufacturer's specifications.

5.6.4 Surface Quality

A PROBLEM	CAUSE	ACTION
Cutter wheels have marked the panel surface.	Excessive force from guide wheels.	Adjust the force exerted by the guide wheels on the panel.
	Dirty rollers.	Check the rollers and clean if necessary.

5.7 LASER DRILLING

The problems encountered with laser drilling often have causes which are dependent on the specific laser system used and the drilling application. For this reason, it is important to consult with the laser manufacturer regarding the application and problems associated with the system capabilities.

This section deals primarily with the laser drilling of vias in thin core laminates.

5.7.1 Dimensional

A PROBLEM	CAUSE	ACTION
Hole not located properly.	Laser beam wanders.	Correct machine alignment and/or stability.
	Material shift.	Check post-drill operations.
	Improper tooling.	Check tooling hole size and location.
	Bad N/C data.	Check software and data.
	Improper inspection.	Check X-ray equipment for proper parallax. Check measurement equipment calibration.

B PROBLEM	CAUSE	ACTION
Improper hole size.	Wrong beam focus.	Correct as necessary.
	Wrong laser power.	Correct laser power level setting.

5.7.2 Hole Quality

A PROBLEM	CAUSE	ACTION
Holes not drilled.	Laser not firing.	Check for adequate laser power. Check laser shutter operation.
	Bad N/C data.	Check software and data.

B PROBLEM	CAUSE	ACTION
Holes not drilled through.	Board too thick.	Obtain correct thickness material.
	Laser power too low.	Correct laser power level setting. Check laser pulses per hole.
	Copper foil too thick.	Obtain correct thickness copper foil.
	Copper too reflective.	Oxide treat or dull the copper surface.

C PROBLEM	CAUSE	ACTION
Blind via holes drilled through.	Board too thin.	Obtain correct thickness material.
	Laser power too high.	Correct laser power level setting.
	Copper foil too thin.	Obtain correct thickness foil material. Check etched pattern registration.

D PROBLEM	CAUSE	ACTION
Burrs.	Laser power too high.	Correct laser power level setting.

5.8 WATER JET CUTTING/PROFILING

Waterjet cutting, as applied to PWBs, is defined as: ‘‘The severance of a substrate material by directing a highly collimated, fine stream of water, travelling at high speed under extreme pressure, upon it.’’ Substrate materials include all currently known materials.

For the purpose of this guideline, the standard waterjet without additive will be discussed, as applied primarily to non-metallic materials.

Waterjet cutting equipment and attendant positioning devices are complex systems. Troubleshooting provided here will serve as a general guide to address problems relating to cutting quality. Equipment-related problems should be resolved through appropriate operating and maintenance manuals.

5.8.1 Dimensional

A PROBLEM	CAUSE	ACTION
Finished board dimension out of tolerance.	Program error.	Measure board and correct dimensional error where needed.
	Improper tooling hole location.	Check tooling hole location against manufacturing drawings.
	Worn tooling pins.	Measure and replace if necessary.
	Excessive cutting.	Replace worn/improper nozzle size with new nozzle of appropriate size.
	Poor substrate support.	Replace support material.
	Board shift.	Check for excessive board warp. Secure board on tooling pins. Correct tooling pins to tooling hole tolerance.

5.8.2 Feature Quality

A PROBLEM	CAUSE	ACTION
Incomplete cut through substrate.	Low water pressure.	Adjust high pressure pump remote pressure compensator to minimum of 345 mPa.
	Leak in high pressure fittings.	Tighten or replace fitting, as appropriate.
	Excessive feed rate.	Reduce profiling rate based upon substrate material and thickness per equipment supplier’s specification.
	Damaged nozzle.	Replace with new sapphire orifice and ‘‘O’’ ring.

B PROBLEM	CAUSE	ACTION
Haloing, crazing, delamination, rough edges.	Worn nozzle and mounting ‘‘O’’ ring.	Replace nozzle and mounting ‘‘O’’ ring.
	Over-speed.	Reduce to specified level.
	Excessive nozzle body vibration.	Tighten nozzle and on/off valve mounting bolts.
	Poor board support.	Replace support material.

5.8.3 Equipment

A PROBLEM	CAUSE	ACTION
Excessive nozzle wear.	Contaminated water.	Check inlet water filtration system; replace dirty filters and flush system. Check water for heavy particulate or discoloration and treat as appropriate. Inspect water treatment system, if used, for proper performance.

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Section 6
Hole Preparation

6.0 HOLE PREPARATION

Hole preparation techniques consist of the removal of resin and at times any reinforcement material or other debris in the drilled hole. The processes used for this action include mechanical, chemical, plasma and electrochemical techniques. Some processes may be more suited to a particular material type and proper application of the process steps is critical to ensure adequate bonding of the subsequent electroless plating.

6.1 MECHANICAL

6.1.1 Deburring and Sanding

A PROBLEM	CAUSE	ACTION
Incomplete burr removal.	Burr too large.	Reduce burr size in drill operation by control of bit quality, feed and retraction rate, back-up and entry material. (See 5.1.2 F.)
	Incorrect brush selection.	Match grit and construction to maximize cutting of metal without excessive removal.
	Incorrect machine parameters.	Check wheel pressure, conveyor speed, brush wear (more pressure, slower speed, redress brush).

B PROBLEM	CAUSE	ACTION
Burr pushing in the hole.	Incorrect brush selection.	Match grit and construction to maximize cutting of metal without excessive removal.
	Incorrect machine parameters.	Check wheel pressure, conveyor speed, brush wear (more pressure, slower speed, redress brush).

C PROBLEM	CAUSE	ACTION
Excessive copper removal around hole circumference (“dishing”).	Incorrect brush selection.	Match grit and construction to maximize cutting of metal without excessive removal.
	Too much pressure or too slow a conveyor speed.	Readjust machine.
	Brush not cutting, needs dressing.	Dress wheels.

D PROBLEM	CAUSE	ACTION
Wheel or brush fibers in the hole.	Too much pressure.	Readjust machine.
	Incorrect dressing procedure.	Redress wheel following correct procedure. Consult brush supplier.
	Insufficient water blast pressure.	Check that pump is not “deadheaded” and check nozzle diameter for wear and clogging.

6.1.2 Vapor Hone and Abrasive Blast

A PROBLEM	CAUSE	ACTION
Residues/media on surface or inside of holes.	Clogged rinse nozzles.	Check nozzles and unclog if necessary.
	Insufficient water pressure.	Check water pressure to the machine.
	Conveyor speed too fast.	Adjust speed as necessary.

6.1.2 Vapor Hone and Abrasive Blast (continued)

B PROBLEM	CAUSE	ACTION
Incomplete removal of debris (hole wall) from holes.	Clogged media nozzles.	Check and clean nozzles.
	Improper media mix or selection.	Correct selection of media and/or mix.
	No media in system.	Replace media.

C PROBLEM	CAUSE	ACTION
Excessive removal of copper from panel surface (hole size enlargement).	Media selection wrong (too abrasive).	Correct media selection.
	Conveyor speed too slow.	Speed up conveyor.
	Pressure too high.	Reduce pressure or unclog nozzles, if necessary.
	Hand operation—operator not uniform in blast movement.	Improve removal procedures.

6.2 CHEMICAL HOLE PREPARATION The following covers processing problems that occur with chemical methods of multilayer drilled hole desmearing and hole roughening. Different resin and reinforcement types are included with the chemical removal methods that are commonly used on each type of material. Each subsection is divided into general problems associated with these areas and into problems specific to the chemistry used in these areas.

Smear removal or desmearing of a printed board involves removing the resin smear generated from the drilling operation. Etchback refers to the positive removal of resin and reinforcement material from a drilled hole, exposing the copper interconnections on three sides. Etchback is included in board fabrication when required as a design parameter. The range of 0.005 mm to 0.025 mm with 0.008 mm to 0.015 mm is generally the preferred condition.

''Negative'' or ''reverse'' etchback (Figure 6–1) refers to the condition where the copper interconnect is recessed into the drilled hole wall. This condition occurs because of the greater removal of copper (during the preplate copper etch cycle) than the depth of resin removal during the desmearing operation.

The following deals with the concept of etchback only in terms of incomplete or excessive resin and reinforcement removal.

Figure 6–1 Negative etchback

Table 6–1 Resin Removal Matrix

Chemical Removal Technique	Type of Resin			
	Epoxy	Polyimide Rigid	Acrylic	Polytetra-fluoroethylene (Teflon*)
Sulfuric Acid (see 6.2.3)	X			
Chromic Acid (see 6.2.4)	X			
Alkaline Permanganate (see 6.2.2)	X	X		
Fluorosulfonic Acid	X			
Tetra Etch** (see 6.2.7)				X
Plasma (see 6.3)	X	X	X	X

*Teflon is a registered trademark of E.I. DuPont de Nemours Co.
**Tetra Etch is a registered trademark of W. L. Gore and Associates.

6.2.1 Resin Removal General (see Table 6–1)

A PROBLEM	CAUSE	ACTION
Incomplete resin removal. (See Figure 6–2.)	Excessive smear—more than normal.	Check drilling operation for dull drill bits, wrong speeds and feeds, back-up material, etc. (See 5.1.2 A.) Check to see if lamination and post bake cure was properly performed (resin overcured).
	Low desmearing temperature or immersion time.	Ensure proper solution temperatures and immersion times are used for desmearing chemistry.
	Bath concentration(s) out of range.	Analyze and adjust per supplier's specifications.

B PROBLEM	CAUSE	ACTION
Excessive resin removal. (See Figure 6–3.)	Use of laminates and prepregs with different resin systems, either within one board or from board to board; may etch at different rates.	Control dwell times for specific resin systems. Control materials to eliminate mixing of resin systems (including different suppliers of same resin system or different formulations of one resin).
	Incomplete cure of resin system.	Control lamination and post bake parameters. (See Section 13.0.)

C PROBLEM	CAUSE	ACTION
Residue from resin removal processing.	Improper reduction/neutralization solution process times or temperatures.	Ensure proper processing times and temperatures are applied for the bath operating concentrations being used.
	Insufficient rinsing.	Check rinsing operation times and temperatures. May want to use heated rinses in some steps.
	Insufficient agitation of panels during processing.	Increase agitation of panels.

6.2.2 Alkaline Permanganate Desmearing/Etchback System

A PROBLEM	CAUSE	ACTION
Incomplete resin removal. (See Figure 6–2.)	Alkaline permanganate bath concentrations not in operating range.	Adjust concentrations per supplier specified operating ranges.
	By-product concentration too high.	Dump bath. Check method and procedure for regeneration. Consider electrolytic regeneration to reduce by-product build-up.
	Solvent/sensitizer bath is weak or spent.	Adjust per supplier specifications.
	Solvent/sensitizer bath is not designed for use with resin system being processed.	Consult supplier.
	Non-uniform temperature in solvent/ sensitizer or permanganate bath.	Install suitable agitation to ensure adequate bath mixing (elevated temperatures can result in considerable gradients in a bath). Light air agitation can be used in the permanganate bath.

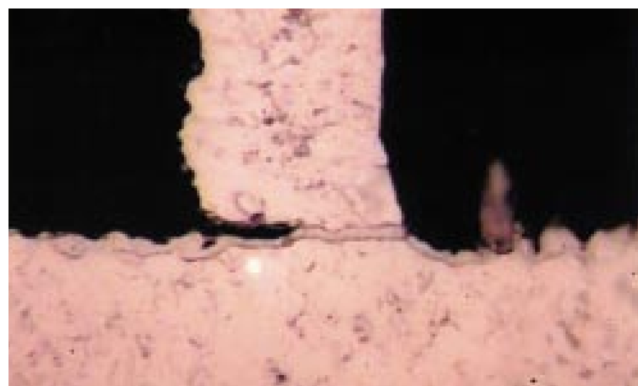

Figure 6–2 Incomplete resin removal

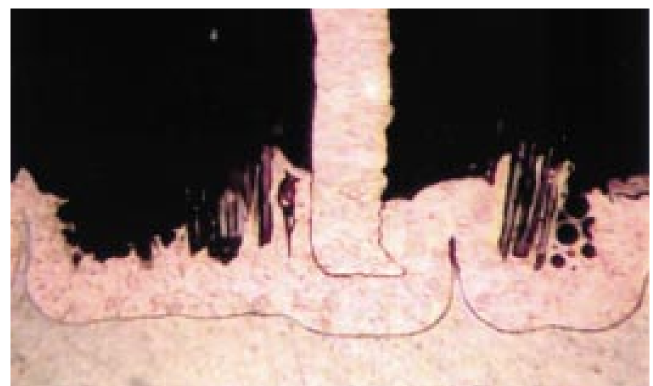

Figure 6–3 Excess resin removal

6.2.2 Alkaline Permanganate Desmearing/Etchback System (continued)

B PROBLEM	CAUSE	ACTION
Excessive resin removal. (See Figure 6–3.)	High alkaline or oxidizer concentration, possibly due to water evaporation from the solution.	Adjust concentrations to operating ranges.
	Over-aggressive solvent/sensitizer step for resin type.	Consult supplier for recommendations.
	Bath operating temperature(s) too high.	Adjust per specification, making sure there is sufficient agitation to ensure uniform temperature throughout.

C PROBLEM	CAUSE	ACTION
Residue from resin removal processing.	Neutralizer solution not in proper operating range.	Adjust per supplier's specifications.
	Neutralization solution is spent.	Dump and make up fresh solution.
	Manganate build-up in permaganate bath excessive.	Use/improve chemical or electrolytic regeneration.

D PROBLEM	CAUSE	ACTION
Excessive sludge formation in the permanganate bath.	Permanganate regeneration process is inadequate.	Investigate frequency and quantity of chemical regenerant additions of permanganate. Consider a constant feed via metering pump when bath is in use. If using electrolytic regeneration, recheck all operating parameters—system set-up may be inadequate for amount of material being processed.
	By-product from chemical regeneration has built up in bath.	Dump bath. Consult supplier for recommendations.
	Permanganate is crystallizing out of the bath (sometimes forms on the surface).	Check to make sure adds are properly dissolved. Check total permanganate concentration—may be at saturation for the operating temperature in use. Some crystallization at room temperature is not unusual.

6.2.3 Sulfuric Acid Desmearing/Etchback System

A PROBLEM	CAUSE	ACTION
Incomplete resin removal. (See Figure 6–2.)	Acid concentration too low (below 90%), possibly due to water contamination of bath from wet boards or moisture in the air.	If acid concentration is below 90%, dump acid. Make sure boards are dry going into the acid. Keep the acid tank tightly covered when not in use, to reduce absorption of moisture from the air. Use highest grade acid possible to reduce frequency of degradation.
	Neutralization solution spent, so that epoxy sulfonate residue is left in drilled hole.	Ensure neutralization solution is within recommended operating parameters.
	Wrong resin type for this desmear system.	Consult Table 6–1 under Section 6.2.1.
	Inadequate agitation to force the viscous acid through the holes.	Use agitation designed to force solution through the holes. Sulfuric acid does not work well on very small holes.

B PROBLEM	CAUSE	ACTION
Excessive resin removal. (See Figure 6–3.)	High sulfuric acid concentration, possibly due to change in manufacturer of acid.	Reduce immersion time to get proper resin removal.
	Excessive drip time before rinsing.	Since immersion time is so short, drip time can add considerably to etch rate. Incorporate drip time as part of process time.

6.2.3 Sulfuric Acid Desmearing/Etchback System (continued)

C PROBLEM	CAUSE	ACTION
Residue from resin removal processing.	Neutralization solution concentration not in proper operating range for process time and temperature used.	Adjust neutralizer according to manufacturer's instructions. Epoxy sulfonate residue results in incomplete smear removal.
	Neutralization solution spent.	Dump and remake solution.
	Rinse after sulfuric is cold.	Use warm water rinse.

6.2.4 Chromic Acid Desmearing/Etchback System

A PROBLEM	CAUSE	ACTION
Incomplete resin removal. (See Figure 6–2.)	Desmear chemicals not in operating range.	Ensure chromic acid desmear solution is within its limits.
	Cr^{6+} level too low due to bath dilution from wet boards.	Restore Cr^{6+} level by evaporation of excess water. Raise bath temperature 11.1°C and evaporate to reference level, or make up new bath.
	Cr^{6+} level too low due to reaction with epoxy smear (after extensive desmear production runs), e.g., Cr^{6+} + epoxy → Cr^{3+} + byproducts.	Replenish chemistry to proper operating range. Consider/investigate regeneration process to maintain Cr^{6+} concentration. If a system is in place, check operation and ensure proper working condition and adequacy for amount of work being processed.
	Inadequate agitation of solution and lateral movement of boards to displace solution from holes.	Use lateral motion of 17–20 rpm and 50.8 mm stroke. For large tanks (284 liters plus) also employ air sparger.
	Spacing too close between panels loaded on racks.	Design racks to form a rigid hold of panels with a preferred spacing of 19.0 mm. Highly significant for 0.25 mm to 0.51 mm holes.
	Iron contamination lowers etch rate. Main source: gradual breakdown of lead in lined carbon steel shell tank; solution exposed to steel. Other source: over-activity of solution (etch) to type 316 stainless steel rack.	Preventative for iron contamination is to use a titanium tank or liner. To determine contamination limit for iron, add iron concentration to Cr^{3+} concentration; if total exceeds limit for Cr^{3+} in the bath, consider the bath to be spent.
	Cr^{3+} (trivalent) level has reached its limit.	Solution is spent and must be replaced by a new bath. An attempt should be made to regenerate, as disposing of the solution is quite expensive.

B PROBLEM	CAUSE	ACTION
Excessive resin removal. (See Figure 6–3.)	Desmear bath too concentrated for the time/temperature operating conditions. Excessive water evaporation.	Check desmear bath for Cr^{3+} level. If too high, dilute with water to correct concentration. Or, adjust operating conditions to compensate.
	Error in makeup or replenishment quantities of chromic acid.	Adjust as above. Investigate cause(s) for error so future mistakes can be avoided.

6.2.4 Chromic Acid Desmearing/Etchback System (continued)

C	PROBLEM	CAUSE	ACTION
Residue from resin removal processing.		Inadequate desorption of Cr^{6+} and Cr^{3+} salts and their dissolution due to inadequate reduction and solubilization process time/temperature. Unchecked Cr salt residues are a cause of plating voids.	Check to ensure proper processing temperature/time at the specified bath operating concentration.
		''Reduction/solutionizing'' process solution concentration not in correct operating range. Residues of chromium salts can interfere in subsequent PTH processing, which can lead to plating voids.	Check (1) chromic acid reducer for correct concentration and (2) for established limits for the concentration of by-products. In case (2), if reducer solution limits are exceeded, new bath make-up is required.
		Insufficient rinsing.	Check rinsing operation time, temperature, flow rate and agitation. If line rinse water is cold (below 16°C), heated rinses may be required.
		Inadequate motion of solution through holes in panels.	Agitate solution and/or move panels laterally.
		Incorrect practice of inserting alkaline/organic solvent solution (designed for sulfuric acid process) between the chromic acid etch solution and the chromic acid reducer solution. This fixes Cr^{3+} in an insoluble form on the resin region and leads to PTH voids.	This practice must be forbidden. It has occurred due to insufficient knowledge of the nature of the chromic acid process.

Table 6–2 Reinforcement Removal Matrix

Chemical Removal Technique	Type of Reinforcement				
	Glass	Polyimide Quartz	Polyamide-imide (Kevlar*)	Polyester	Polyimide Film (Kapton*)
Ammonium Fluoride/Hydrochloric Acid (see 6.2.6)	X				
Hydrofluoric Acid	X				
Concentrated Alkaline Solution (see 6.2.7)					X
Plasma (see 6.3)			X		X

*Kevlar and Kapton are registered trademarks of E.I. duPont de Nemours Co.

6.2.5 Reinforcement Removal, General (see Table 6–2)

Reinforcement refers to the stiffening material that is impregnated with resin to make laminate. Woven fiberglass cloth is the most commonly used material, but chopped glass, paper, Kevlar*, polyester and woven quartz are also used.

A PROBLEM	CAUSE	ACTION
Incomplete reinforcement removal.	Too much reinforcement material (usually glass) due to excessive resin removal.	Check resin removal process for proper operation. (See 6.2.1-6.2.4.)
	Reinforcement etching process times too short or solution temperatures too low.	Check process times and temperatures in etching solution(s).
	Calcium fluoride (CaF_2) precipitation on glass fibers shielding underlying fibers from further etching (occurs in fluoride-based etching solutions).	Increase agitation of parts to remove calcium from etching site more quickly. Use acid dip following glass etch. Make fresh glass etching solution, as present bath is saturated with calcium.
	Variation in glass type within the multilayer board (some glass types are thicker than others and will etch more slowly).	Adjust operating time/temperature to compensate as necessary. Check multilayer lay-up to determine if more uniform glass types can be used.

B PROBLEM	CAUSE	ACTION
Excessive reinforcement removal.	Reinforcement etching process times too long or solution temperature too high.	Adjust process times and temperatures to the recommended operating ranges for the concentration of etching solutions used.
	Plasma etched board glass bundles highly activated toward glass etching. Therefore, regular process times are too long for these boards.	Establish proper process time for etching glass bundles on plasma etched boards.

C PROBLEM	CAUSE	ACTION
Residue from reinforcement removal processing.	Insufficient rinsing.	Check rinsing operation times and temperatures. May want to use heated or high pressure spray rinses for adequate solution removal.
	Insufficient agitation of part during processing.	Increase agitation.
	Calcium fluoride (CaF_2) precipitation on glass fibers shielding underlying fibers from further etching (occurs in fluoride-based etching solutions).	Increase agitation of parts to remove calcium from etching site more quickly. Use acid dip following glass etch. Make fresh glass etching solution, as present bath is saturated with calcium.

6.2.6 Ammonium Bifluoride/Hydrochloric Acid Reinforcement Removal

A PROBLEM	CAUSE	ACTION
Incomplete reinforcement removal.	Low ammonium bifluoride concentration.	Adjust to approximately 60 - 120 g/l.
	Low acid concentration.	Adjust Hydrochloric acid concentration.

B PROBLEM	CAUSE	ACTION
Excessive reinforcement removal.	Ammonium bifluoride concentration too high, possibly due to evaporation.	Dilute bath to proper concentration.

C PROBLEM	CAUSE	ACTION
Residue from reinforcement removal processing.	Calcium fluoride (CaF_2) precipitation on glass fibers.	Increase agitation of parts. Hydrochloric acid can be added to ammonium bifluoride solution to prevent this from occurring. (There is a maximum HCl limit that must be determined to avoid excessive ''pink ring''—attack of the oxide treatment on the innerlayers.)

6.2.7 Hole Roughening

All of the resin removal methods listed in Tables 6-1 and 6-2 can be used for hole roughening. The methods that are used specifically for hole roughening (as opposed to smear removal) are the Tetra Etch® etching of PTFE (polytetrafluoroethylene) surfaces and concentrated alkaline etching of polyimide (Kapton®) non-reinforced film.

Also see Sections 6.2.2 through 6.2.4 for information on alkaline permanganate, sulfuric and chromic acid methods.

A PROBLEM	CAUSE	ACTION
Insufficient hole roughening.	Improper process times or temperatures.	For Tetra Etch® decrease the processing temperature, since the etchant strength decreases with increasing temperature, due to decomposition of the etchant. For the other methods listed, generally increasing the process time or temperature will improve the surface roughening.
	Solution concentrations too low for process times and temperatures used.	Tetra Etch® strength decreases on exposure to atmosphere and heat. Oxygen and moisture react with it, generating heat which leads to its degradation. Therefore: 1) Restrict Tetra Etch exposure to air; 2) Allow only clean, dry parts to be processed through it; and 3) Ensure etch product shelf life is not exceeded and proper storage is maintained (consult supplier if necessary).

B PROBLEM	CAUSE	ACTION
Excessive hole roughening.	Hole to be roughened not as smooth as usual, due to poor drilling.	Check drilling process and adjust hole roughening process as required.
	Improper process times and/or temperatures.	Ensure correct process parameters are used.
	Solution concentrations too high for process time and temperatures used.	Ensure proper make-up of process solutions. Avoid water evaporation from solution which leads to concentration of chemicals.

C PROBLEM	CAUSE	ACTION
Residue from hole roughening process.	Improper rinsing.	Check rinsing operation times and temperatures. Use methanol, naphtha or fluorocarbon in the rinsing for the Tetra Etch® method, along with separate water rinses.

6.3 PLASMA HOLE PREPARATION

Plasma is a dry chemical process that can be used to etch any hydrocarbon substance. The four basic parameters that must be optimized for each type of substance and board type are: the gas mixture, RF power, processing time, and total pressure.

6.3.1 Plasma Smear Removal

A PROBLEM	CAUSE	ACTION
Incomplete smear removal (holes in all boards in a single chamber load affected). (Also see 6.3.1 D.)	Improper gas mixture and system pressure.	Optimize gas mixture and system pressure for board and resin type. Higher system pressure results in faster etch rate.
	Low RF power setting.	Raise RF power.
	Insufficient processing time.	Increase processing time.
	Coating on electrodes resulting in reflected power.	Clean electrodes every 4,000 to 6,000 hours of operation using a quick dip in sodium hydroxide.
	Moisture present, inhibiting etching of resin.	Bake out boards before plasma etching. Run a dummy load in plasma chamber at start of each production day or if unit cools to room temperature.
	Poorer drilling resulting in more smear.	Check quantity of smear present on boards before plasma processing.
	By-product buildup in plasma chamber.	Ensure vacuum pumps are working properly and getting good flow of plasma through chamber. Use a high speed vacuum pump.

B PROBLEM	CAUSE	ACTION
Excessive resin removal.	System pressure too high.	Adjust pressure to obtain proper results.
	Processing time too long.	Decrease processing time.
	High RF power setting.	Decrease RF power.
	Drilling process improved, resulting in better hole.	Check quantity of smear present on boards before plasma processing.

C PROBLEM	CAUSE	ACTION
Residue from plasma operation.	Incomplete oxidation or vaporization of organic polymers.	An oxygen purge at end of cycle should eliminate or reduce this condition.
	Inorganics in the board materials are not broken down by plasma and therefore remain.	Easily removed by strong water or air blast on the boards.

D PROBLEM	CAUSE	ACTION
Inconsistent smear removal. (Some boards have holes that are completely clean while other holes still have smear; some boards in a single chamber load have clean holes while other boards do not.)	Non-uniform dispersion of plasma through plasma chamber.	Check position of gas inlet ports and exhaust ports to see if gas flow is good through plasma chamber.
	Non-uniform temperature distribution throughout plasma chamber.	Check temperature throughout chamber through use of heat sensitive points or shielded thermocouples.
	Chamber design/board placement.	Lengthen process cycle. Revise board placement.

6.3.2 Side Effects

A	PROBLEM	CAUSE	ACTION
Board warpage from plasma.		Poor racking of boards.	Use full size racking instead of just clip.
		Boards reaching too high a temperature.	Check if boards shorted out to ground. Use lower power setting. Use lower system pressure.

B	PROBLEM	CAUSE	ACTION
Board blistering or delamination from plasma.		Moisture or volatiles trapped in board produce a vapor bubble when surrounding pressure is lowered.	Bake boards prior to plasma etching. (See Section 1.5 on baking.)

6.4 ELECTROCHEMICAL DEBURRING

6.4.1 General

A	PROBLEM	CAUSE	ACTION
Incomplete burr removal.		Insufficient electrolyte concentration.	Increase electrolyte concentration.
		Time cycle insufficient.	Increase time cycle.
		Current density too low.	Increase current density.
		Anode-to-cathode spacing too great.	Decrease anode-to-cathode spacing.

B	PROBLEM	CAUSE	ACTION
Exposed resin at hole interface.		Electrolyte concentration too high.	Reduce electrolyte concentration.
		Time cycle too long.	Reduce time cycle.
		Current density too high.	Reduce current density.
		Anode-to-cathode spacing too close.	Increase anode-to-cathode spacing.

C	PROBLEM	CAUSE	ACTION
Chemical polishing of copper surfaces.		Copper concentration in electrolyte too high.	Dump and remake solution.

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Section 7
Electroless Processes

7.0 ELECTROLESS PROCESSES

Symptoms appearing during or directly after the electroless process may be due to causes either prior to or during this process. Likewise, symptoms appearing at later stages of board manufacture may also relate back to causes during the electroless process. This section will refer to both types of problems. However, because of the multitude of possible problem areas throughout the board manufacturing process and the complex interrelationship of the processing steps, the problems encountered can only be touched in a general way.

Table 7–1 provides correlation between some of the variables related to the electroless copper process and the subsequent effects on the plated through-hole.

Table 7–1 Electroless Copper Process—Problem Sources and Subsequent Effects

	Electroless Voids	Bath Instability	Low Deposition Rate	Surface Peeling	Blisters in Holes	Hole Wall Pullaway	Rough Deposit	Interconnect Defects
Cleaner/Conditioner	X			X	X			X
Microetch				X				X
Catalyst	X							X
Accelerator	X							
Electroless Copper	X	X	X	X	X	X	X	X
Rinsing	X					X	X	X
Filtration	X	X					X	
Contamination/ Drag- in		X	X	X			X	
Workload		X	X					
Drilling/Deburr	X					X	X	X
Desmear/Etchback	X		X		X			
Resin Type	X		X		X			

7.1 HOLE METALLIZATION (CONDITIONING) (Includes Cleaner/Conditioner, Micro-Etch Solutions and Their Rinses)

7.1.1. Bath Control

A PROBLEM	CAUSE	ACTION
Excessive foam from cleaner/ conditioner solution being carried down the line.	Excessive solution dragout from bath.	Increase drip time over work tank.
	Insufficient rinse.	Check that water flows to rinse tank. Increase water flow. Increase rinse time and/or temperature where possible.
	Bath make-up incorrect.	Check make-up procedure for bath per supplier's instructions.

B PROBLEM	CAUSE	ACTION
Appearance of particles in cleaner/ conditioner solution.	Non-chelated cleaner/conditioners do not dissolve all soils which are removed from board.	Implement occasional filtration. Improve rinsing after deburr or vapor hone.

7.1.1 Bath control (continued)

C PROBLEM	CAUSE	ACTION
Micro-etch solution etching too slowly or not at all.	Persulfate micro-etch is saturated with copper or has lost activity.	Make up fresh persulfate.
	Peroxide-sulfuric micro-etch needs replenishment of peroxide and/or acid.	Analyze bath and replenish as needed.
	Peroxide-sulfuric micro-etch may be saturated with copper.	Allow copper sulfate crystals to precipitate overnight. A rotating two-bath system can eliminate loss of work time.
	Temperature too low.	Check temperature.
	Contamination by cleaner/conditioner.	See 7.1.1 A.

D PROBLEM	CAUSE	ACTION
Excessive etch rate and temperature rise in peroxide-sulfuric etch.	Peroxide content may be too high.	Analyze bath; bring into range.
	Surface area of work-load in bath may be too high.	Either decrease work loads, increase tank size, or supply external cooling.
	Excessive heating, leading to peroxide decomposition.	Check heaters.
	Stripping of electroless copper from rework can drag in palladium, which catalyzes peroxide decomposition.	Strip rework off-line.

7.1.2 Hole Conditions

A PROBLEM	CAUSE	ACTION
Glass or epoxy voids observed after electroless or later copper plating. (See 7.3.2 A, 7.3.2. B and 7.3.2 C.)	Incompatibility of cleaner/conditioner/catalyst/accelerator/copper combination.	Ensure compatibility by lab testing, or preferably by using a single supplier's PTH line.
	Insufficient catalyzation.	Check preceding processing solutions on the line for conformance to operating parameters. Increase catalyst strength or temperature within supplier's recommended limits. Inadequate or excessive acceleration.
	Insufficient conditioning.	Check operating parameters of cleaner/conditioner solution. Conditioner solution may be incompatible with rest of process. (See 7.3.2 A.)
	Insufficient or improper glass etching in desmear line.	Ensure correct glass etch solution parameters and etch time. Be sure to remove porous calcium sheath formed after typical glass etch processes. (See Section 6.2.5 A and 6.2.6 C.)
	Inadequate conditioning.	Check concentration and temperature of conditioner.

B PROBLEM	CAUSE	ACTION
Blistering or flaking of copper over glass or epoxy, due to improper conditioning. (See 7.3.2 E.)	Improper bath parameters.	Ensure correct temperature. Analyze electroless copper bath for all constituents.
	Process solution entrapment or humidity absorption by laminate materials.	Check laminate process, laminate storage, dwell time in process solutions.

7.1.3 Surface Conditions

A PROBLEM	CAUSE	ACTION
Fingerprints and soils not removed by cleaner/ conditioner or micro-etch.	Improper makeup or controls on bath.	Make up fresh baths or analyze and replenish.
	Temperature of cleaner/conditioner may be too low.	Check temperature.

B PROBLEM	CAUSE	ACTION
Micro-etch leaving a streaked surface.	Insufficient rinsing after cleaner/ conditioner step.	Increase rinse time, water flow and/or improve rack design to lessen solution entrapment. (Also see 7.1.1 A.)
	Incompatibility of surfactants in cleaner/ conditioner and micro-etch.	Use a single chemical supplier or ensure surfactant compatibility in "home-brew" lines.
	Incomplete removal of soils by cleaner.	Increase cleaner dwell time, concentration or temperature.
	High copper content in micro-etch.	Reduce copper content or make up new solution.

C PROBLEM	CAUSE	ACTION
Scum left on surface after persulfate etch.	No sulfuric acid post-dip.	Make up fresh sulfuric post-dip.
	Palladium contamination in peroxide sulfuric caused by rack stripping.	Do rack stripping off line and make-up new micro-etch.

D PROBLEM	CAUSE	ACTION
Copper surface still shiny after micro-etch.	Peroxide sulfuric micro-etch is saturated with copper.	Check copper levels and etch rates. Make-up new solution if required.
	Sulfuric acid concentration in peroxide-sulfuric too low.	Analyze and adjust.
	Etch rate in peroxide-sulfuric too slow.	Analyze peroxide concentration and adjust to higher concentration. Raise temperature.

E PROBLEM	CAUSE	ACTION
Copper-to-copper bond failure after electroplate.	Micro-etch etching too slowly or not at all.	Follow actions in Section 7.1.1 C.
	Poor rinsing either before or after micro-etch.	Increase rinse times or rinse flow rates.
	Persulfate or cupric chloride residues or oxidation products remaining on surfaces.	Follow persulfate or cupric chloride micro-etches with the appropriate acid to remove contamination.
	Residue on interconnect due to wetting agent drag-in (from cleaner/conditioner).	Improve rinsing between cleaner/conditioner and micro-etch.

7.2 HOLE CATALYZATION (SENSITIZING) (Includes Predip, Catalyst, and Accelerator Baths and Their Rinses)

7.2.1 Bath Control

A PROBLEM	CAUSE	ACTION
Silvery film forms on top of catalyst bath.	Oxidation of palladium.	Keep bath covered with a floating cover when not in use. Avoid aeration of bath. Switch to a ''salt-based'' catalyst.

B PROBLEM	CAUSE	ACTION
Catalyst bath turns clear; dark film forms on bottom of tank.	The colloidal catalyst has agglomerated and is no longer catalytically active. This is due to aeration, too-low catalyst strength, too-low Sn(ll) content and/or too-low chloride normality.	Keep bath covered with a floating cover when not in use. Avoid aeration of bath. Switch to a ''salty'' catalyst. Monitor and control Sn(ll) and catalyst strength, and chloride normality. Dump bath and remake.

C PROBLEM	CAUSE	ACTION
Appearance of particles in accelerator solution.	Excessive drag-in of catalyst can allow agglomeration of palladium in the accelerator solution.	Ensure adequate rinsing after catalyst. Occasional filtration should be implemented.

7.2.2 Hole Conditions

A PROBLEM	CAUSE	ACTION
Catalyst bath ineffective, as evidenced by electroless copper voids.	Low catalyst concentration.	Analyze and maintain within recommended range.
	Temperature too low.	Check temperature. Heat bath if needed.
	Acid normality of catalyst too low.	Increase acid normality to supplier's recommended level.
	Contamination by chromium from desmear/etchback line.	Employ better chromium neutralization and removal in desmear line. (See Section 6.2.2 C.)
	Conditioning inadequate.	Cleaner/conditioner out of control, or inappropriate cleaner/conditioner being used.
	Improper rinsing after catalyst.	Check with bath supplier for rinse water condition requirements.
	Entrapped air bubbles.	Force solution flow through holes; consider ''bump'' mechanism or ultrasonics.

B PROBLEM	CAUSE	ACTION
Improper acceleration, as evidenced by poor electroless copper adhesion.	High catalyst concentration.	Analyze and bring within recommended range.
	Excessive time in catalyst.	Decrease time in catalyst.

C PROBLEM	CAUSE	ACTION
Improper acceleration, as evidenced by electroless copper void.	Under-acceleration due to low accelerator concentration and/or low temperature.	Analyze and replenish; heat bath if necessary.
	Over-acceleration due to high temperature or excessive dwell time in accelerator, or high accelerator concentration.	Control temperature, reduce dwell time or ensure proper accelerator make-up.

7.3 HOLE METALLIZATION (Copper Deposition) (Includes Electroless Copper Bath and Rinses) When problems are encountered with a copper bath which is within its operating concentration ranges, bath contamination should be considered. Table 7–2 provides some relationships.

7.3.1 Bath Control

A PROBLEM	CAUSE	ACTION
Instability of solution (either plate-out or ''triggering'').	Improper bath make-up.	Follow chemical supplier's make-up instructions. Do not add ''homebrew'' solutions for any reason. If repeated instability occurs soon after make-up, contact supplier's representative. Check that chemicals are being stored per the supplier's recommendations.
	Improper replenishment.	Add only reagent grade chemicals, D.I. water and the proper proprietary additives. Thoroughly mix solutions after additions. Generally, it is best to add chemicals when no work is in the tank, or if required to add at that time, make additions in area away from work. Analyze and replenish often enough so that excessively large additions are not required at one time, and so that excess replenishments are not inadvertently made. Do not shock solution with a large addition. Follow supplier's bail-out recommendations; do not simply rely on evaporation to maintain solution level. If using automatic replenishment equipment, ensure that additions are being made to the tank in an area with good solution movement.
	Improper workloads.	Do not exceed supplier's maximum load density, usually 370 cm^2/l. Distribute workload as evenly as possible throughout the solution. Dense loading may isolate a portion of the solution, causing localized instability.
	Contamination.	Drain boards prior to entry into electroless copper solution. Water from rinses may contain both organic and inorganic contaminants. Follow recommended times of immersion in all proprietary preplate solutions and rinse thoroughly after each step. Palladium drag-in to electroless copper may cause instantaneous solution decomposition. Wash out sizing from all filter cartridges or bags. Washing is completed when foam no longer appears on water used to flush the cartridge or bag. Check that no catalytic parts (e.g., Cu-clad panels) have fallen into tank. Periodically remove all palladium from the racks. Clean all chemical addition containers before and after use. When possible, limit contamination from dust by covering bath.
	Poor maintenance.	Filter solution frequently. At least daily bath filtration is preferred; heavy throughput may require continuous filtration. Clean out (etch) the filter frequently to remove plated-out copper. Strip copper from tanks on regular basis. Once tank walls plate, plating will continue until all traces of copper and palladium are removed. Place tank in an area having a minimum of airborne particles. Small particles may initiate bath decomposition. When changing electroless copper bath solutions, rinse the plating tank with dilute nitric acid, then neutralize with dilute caustic solution. Aerate bath per supplier's instructions.
	Temperature too high.	Cool solution. However, note that excessive heating may cause severe and irreversible bath degradation which may necessitate dumping. May be sign of work overload. Hydrogen gas, evolved during plating, needs to be dissipated from solution between loads. If replenishment of chemicals is needed while bath temperature is high, make them in small increments. Do not shock the solution with a large addition.

Table 7–2 Critical Contaminants for the Electroless Copper Working Bath

CONTAMINANT	CONCENTRATION	SYMPTOMS
Cr^{+6}	1 ppm 3 ppm	Dark Color Voids
Sn^{+2}	0.5ppm 8 ppm	Dark color Decreased Stability
Pd^{+2}	0.04 ppm	Decreased Stability
Sb^{+3}	8 ppm	Decreased Rate
Fe^{+3}	40 ppm	Decreased Stability
NH_3	3 ppm	Decreased Rate Dark Color Voids
Peroxide Micro-etch	8 ml/l	Decreased Rate

7.3.1 Bath control (continued)

B *PROBLEM*	*CAUSE*	*ACTION*
Slow rate of deposition, possibly accompanied by a dark deposit.	Solution imbalance.	Analyze solution for all constituents, and replenish when required. Check for component over-replenishment. Follow supplier's bail-out recommendations.
	Low workloads.	Most solutions have a minimum workload for optimum rate, generally 125 cm^2/l. Run dummy racks to bring back bath activity and include dummy panels with work, if needed, to bring up to minimum level.
	Improper storage.	Many solutions require overnight storage at reduced bath strength, e.g., 60–70%, with replenishment to 100% just before running work.
	Temperature too low.	Heat solution, preferably indirectly. Remember that a ''room temperature'' plating bath has a minimum operating temperature usually 21–24°C. Check supplier's data sheet.
	Possible organic contamination. Source may be from oil on racks or from equipment travelling over tanks.	Turn off aeration and observe surface for evidence of oil. Dump bath. Clean racks before reuse; drain tank and rinse thoroughly before adding new copper bath.
	Excessive aeration	Reduce aeration rate to meet supplier's recommendation.

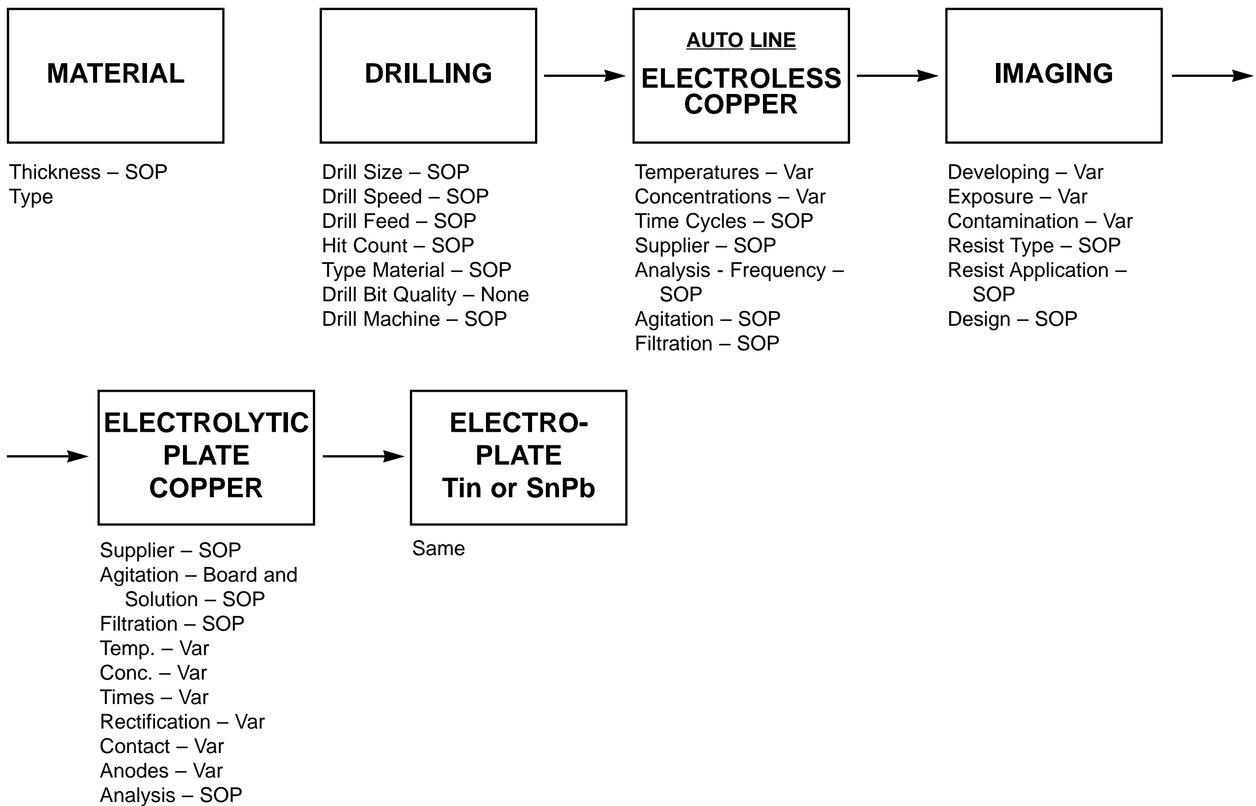
C *PROBLEM*	*CAUSE*	*ACTION*
Caustic or formaldehyde concentration changes markedly.	Change in work level.	Consumption of sodium hydroxide and formaldehyde by ''Canizzaro'' reaction, relative to consumption during plating, varies with level of work. Change replenishment schedule to maintain recommended concentrations despite changed work load.
	Excessive copper plate-out in the tank may be causing apparently high chemical usage.	Check tank for plate-out and remove if found.
	Improper sampling procedures.	Allow solution to mix after bath additions before sampling. Take sample at representative location in tank (away from replenishment lines). Check analysis procedures and recalibrate equipment (check against known standard).

Example 7–1: Reduction of Plated Through-Hole Failures

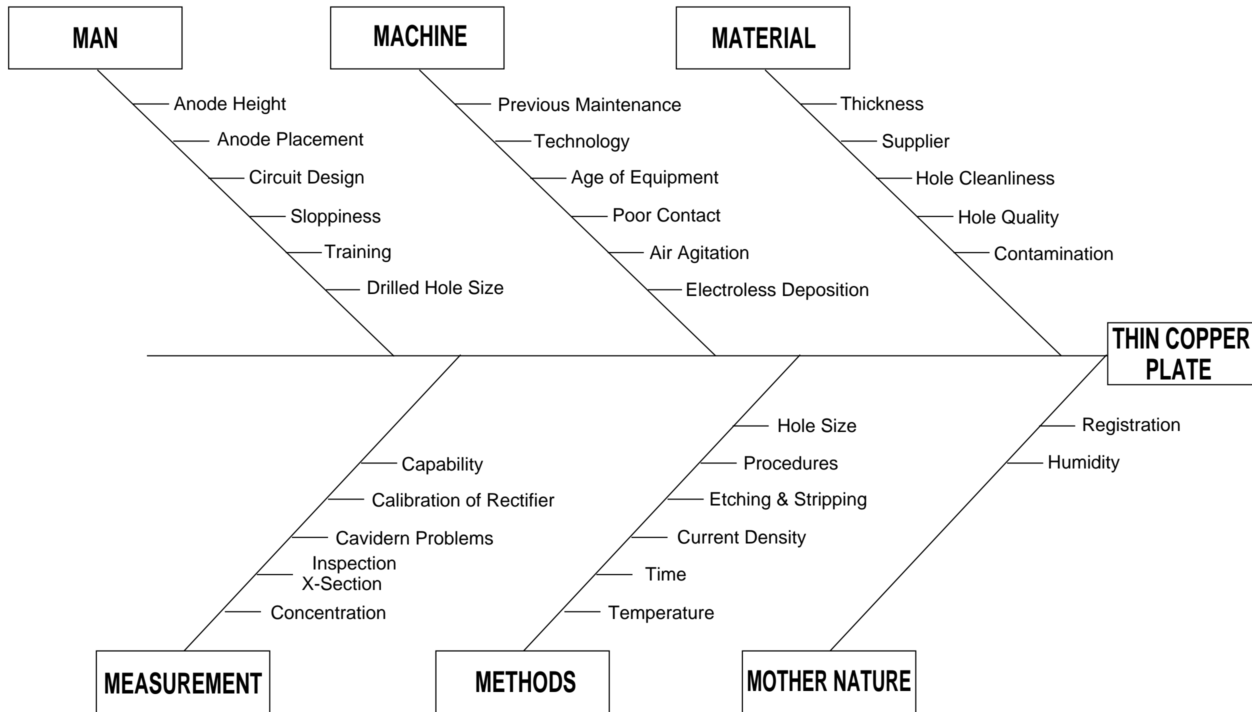
- **Problem: Major rejects due to plated through-hole failures**
- **Goal: Minimize rejects caused by plated through-holes**
- **Pareto analysis of plated through-hole failures**
  - **80% Thin copper plating in holes**
  - **10% Corner cracks after thermal stress**
  - **5% Rough hole walls (drilling?)**
  - **2% Inner layer separation**
  - **2% Voids in PTH barrels**
  - **1% Resin smear (drilling?)**
- **Revised Goal: Eliminate thin copper plating in holes (obtain 0.025 mm minimum in hole-no averaging)**
- **Observations:**
  —Defects created in the automatic plating line
- **Brainstorming**

  A team was assembled to identify factors which affect plating thickness.
- **Experimentation**

  Screening experiment:
  —Developed a screening experiment using the five variables considered most critical by the brainstorming group
  Optimization/Confirmation experiment: After completion of the screening experiment, a confirmation run and sanity check was performed.
- **Parameter Control**
  —Control charts were put into place for parameters which were found to be significant in the experiments.
  —Calibration schedules were created for critical devices.
  —A routine audit of adherence to SOP's was instituted.



Example 7–1: Reduction of Plated Through-Hole Failures (continued)



TRIGGER VALUE 8

		DB	Ted	Cindy	Paul	Cheryl	Irma	Phil	TSE	Tom	Gary	Ave
Anode Height		8	6	7	8	7	7	8	6	6	9	7.2
Anode Placement	SOP											
Circuit Design		10	5	6	9	8	9	9	6	10	8	7.8*
Electroless Temp.		7	6	8	5	8	6	5	5	5	5	6.0
Training	SOP											
Drilled Hole Size	Noise											
Prev. Main	SOP											
Technology	SOP											
Equipment Age	SOP											
Poor Contact		10	9	8	8	10	8	10	10	9	10	9.0
Air Agitation	SOP											
Electroless Conc.		6	6	6	6	6	8	5	5	8	5	6.1
Thickness Laminate	Noise											
Supplier	SOP											
Hole Cleanliness	(Burr)	10	9	9	9	10	6	9	8	7	8	8.5
Hole Smoothness		8	10	9	9	8	8	10	9	9	7	8.7
Concentration	Electroplate	7	10	7	6	7	9	9	6	10	6	7.7
Capability	SOP											
Calib. Rect.	Noise											
Cavidern Problems	SOP											
Inspection X-Sec.	SOP											
Contamination	Noise											
Hole Size	Noise											
Procedures	SOP											
Etch & Strip		4	4	4	3	5	4	5	7	9	4	5.0
Current Density		10	10	10	9	10	7	9	10	9	8	9.1
Time - Electroplate		9	10	9	10	10	9	9	10	10	9	9.5

7.3.2 Hole Conditions

A	PROBLEM	CAUSE	ACTION
Voids on both glass and resin areas. (See Figure 7–1.)		Incompatibility of cleaner/conditioner/ catalyst/accelerator/copper combination.	Ensure compatibility by lab testing, or preferably by using a single supplier's PTH line.
		Insufficient catalyzation.	Check preceding processing solutions on the line for conformance to operating parameters. Increase catalyst strength or temperature within supplier's recommended limits. Inadequate or excessive acceleration.
		Improper bath parameters.	Analyze copper bath for all constituents; replenish if necessary. Ensure correct temperature. Check specific gravity.
		Insufficient agitation in any or all process tanks.	Ensure adequate agitation.
		Bath is sluggish due to inactivity.	Run dummy racks, if needed, to increase bath activity prior to processing work.
		Chrome residues from desmear line have prevented proper catalyzation.	Improve chrome neutralization. (See 6.2.4.C.)
		Excessive blistering/adhesion failure of copper can cause flaking prior to inspection. This leads to a diagnosis of ''voiding,'' when the problem is actually poor adhesion.	Follow the actions specified in Section 7.3.2.E.
		Specific gravity of solution too high.	Bail-out 20% of copper solution. Make-up difference with fresh electroless copper solution.

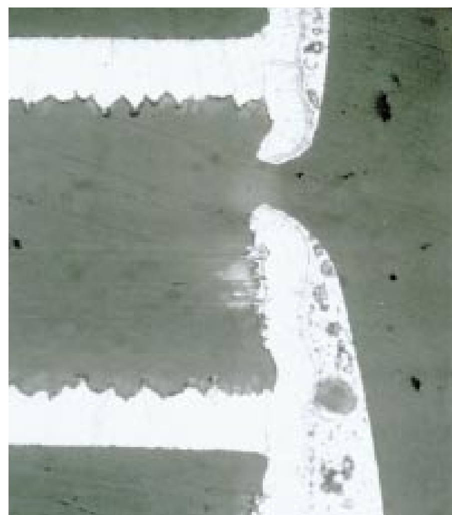


Figure 7–1 Void in hole

Figure 7–2 Glass voiding as seen using backlighting technique

7.3.2 Hole Conditions (continued)

B PROBLEM	CAUSE	ACTION
Voids on glass areas only. (See Figure 7–2.)	Insufficient conditioning.	Check operating parameters of cleaner/conditioner solution. Conditioner solution may be incompatible with rest of process. (See 7.3.2.A.)
	Insufficient or improper glass etching in desmear line.	Ensure correct glass etch solution parameters and etch time. Be sure to remove porous calcium sheath formed after typical glass etch processes. (See Section 6.2.5.A and 6.2.6.C.)
	Excessive etchback of resin.	If all resin is removed from glass bundle area, apparent micro-voids may occur in glass region. This is best diagnosed by SEM examination.
	Excessive glass etch.	If glass is etched back deeply into the hole wall, apparent and actual glass voids may occur in the recessed area due to solution not penetrating and/or gas entrapment.

C PROBLEM	CAUSE	ACTION
Voids on resin areas only.	Resin areas too smooth for catalyst absorption after sulfuric acid desmear.	Sulfuric desmear with inadequate hole clean afterwards, can lead to this condition. Investigate alternative multilayer board processing. (See Section 6.2.3.)
	Chrome residues from desmear left on resin.	Improper chrome neutralization. (See Section 6.2.4 C.)
	Plasma desmear residues left on resin.	Improve post-plasma cleanup. (See Section 6.3.1 C.)
	Inadequate conditioning.	Check concentration and temperature of conditioner.

D PROBLEM	CAUSE	ACTION
Ring wedge voids on multilayer boards on one side of innerlayer.	Attack by desmear line and PTH line chemicals on oxide.	Minimize concentration of hydrochloric and hydrofluoric acids, especially in heated baths during processing.
	Improper rinsing.	Improve rinsing. (See Section 1.6.)

E PROBLEM	CAUSE	ACTION
Blistering or flaking of copper deposit noted after electroless deposition or later, after cross-section of electroplated or thermal-stressed samples. (See Figure 7–3.)	Improper bath parameters.	Ensure correct temperature. Analyze electroless copper bath for all constituents.
	Specific gravity of the electroless copper solution is too high.	Low solution growth can lead to buildup of impurities and by-products in the copper bath. Adhere to recommended bailout schedule.
	Process solution entrapment or humidity absorption by laminate materials.	Check lamination process, laminate storage, dwell time in process solutions.
	Poor copper adhesion can result from improper desmear and PTH process and/or controls.	Review entire process. Enlist chemical supplier's aid.
	Electroless copper deposit is highly stressed.	Review entire process. Check electroless deposit rate panel. Switch to low dep electroless process.

7.3.2 Hole Conditions (continued)

F	PROBLEM	CAUSE	ACTION
	Rough (nodular and/or granular) deposit in holes after PTH and/or further plating. (Rough deposits may also be seen on surface.)	Poor drill control—epoxy smear, torn fibers in holes, general poor hole finish (double-sided boards), burring, and undersize holes. (See Figure 7–4.)	Institute proper drill resharpening or replacement cycle. Determine proper feed and speed for drill diameter being used, as well as for type and thickness of substrates being drilled. (See Section 5.1.2.) Assure laminate cure by baking prior to processing. (See Section 1.5.)
		Pumice grit not cleaned from holes and surfaces prior to electroless deposition.	Vapor blast, rinse with good agitation or use more vigorous (perhaps ultrasonic) cleaning to remove pumice prior to electroless processing.
		Glass fibers protruding into holes after resin etchback.	Balance desmear/etchback with glass etch so that an even hole wall surface results. SEM after hole preparation may be the best diagnostic tool. (See Section 6.)
		Poor control of electroless copper bath.	May indicate necessity of batch filtration of electroless bath. Particles in solution may codeposit. Operation with improper chemical balance of solution may cause codeposition of cuprous oxide, which is granular. May indicate improper board activation.
		Particles may be depositing over electroless copper prior to electroplate, causing rough appearance after electroplate.	Filter intervening process solutions where necessary. (Resist developer solutions in particular frequently contain excessive particulate matter which can be trapped in holes.)

Figure 7–3 Blister in plated through-hole

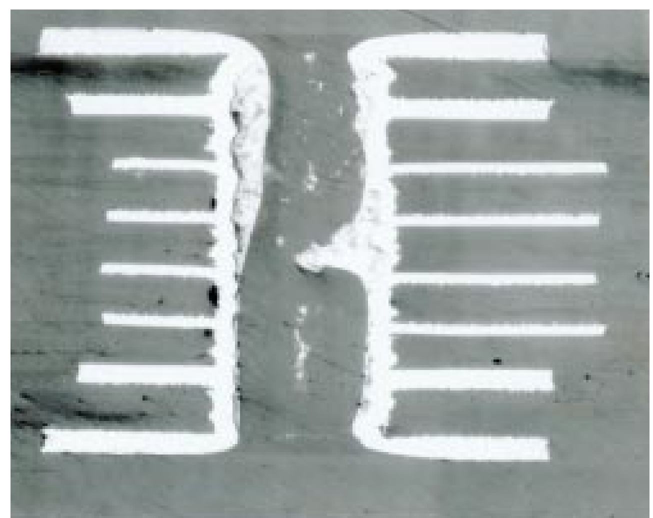


Figure 7–4 Rough hole wall due to poor drilling

7.3.3 Surface Problems

A PROBLEM	CAUSE	ACTION
Poor adhesion of electroless or electrolytic copper deposits to laminate copper.	Poor control in PTH conditioning/ microetch solutions and rinses.	Follow the actions specified in Section 7.1.1.
	Electroless copper deposit oxidizes prior to electroplate.	Install corrosion inhibitor, micro-etch, or minimally, an acid dip prior to electroplate.
	Films may be left on the electroless copper prior to electroplate, causing poor adhesion of electroplated copper.	Very thin residues may be left after development. Adhesion promoters from dry films are particularly tenacious. Check development process parameters and electroplate pre-clean parameters. (See Sections 9 and 10.)

B PROBLEM	CAUSE	ACTION
Streaking on panels.	Gray streaking and bleeding out of rack suggest rack is made of correct stainless, but weldments of a different and porous material.	Coat weldments with PVC. Assure correct weld rod on new racks.
	Improper rack design retains excessive solution during PTH processing.	Drain boards sufficiently after dwell in process tanks and assure sufficient rinsing. Improve design on new racks.
	Excessive air agitation in electroless copper solution.	Reduce air.
	Poor rinsing between accelerator and electroless copper solution.	Do not use recycled water. Use fresh water, slightly tempered.

C PROBLEM	CAUSE	ACTION
Rough deposit on surface after PTH and/or further plating.	Poor control of electroless copper bath. (See Section 7.3.1A.)	May indicate necessity for batch filtration of electroless bath. Particles in solution may codeposit. Operation with improper chemical balance of solution may cause codeposition of cuprous oxide, which is granular. May indicate improper board activation.
	Particles may be depositing over electroless copper prior to electroplate, causing rough appearance after electroplate.	Filter intervening process solutions where necessary. Resist developer solutions in particular frequently contain excessive particulate matter which can be trapped in holes.
	Contamination and improper procedures during electroplating process.	See Section 10.1 and 10.2 for possible causes and corrective action.
	Poor rinsing after catalyst (causes tin/ palladium colloid to precipitate on surface).	Improve rinsing after catalyst.

7.4 HOLE METALLIZATION (REWORK)

The following includes symptoms observed either during or after the electroless copper process and directly related to reworking boards through electroless copper process.

A PROBLEM	CAUSE	ACTION
Poor interconnect conductivity during final testing.	Excessive etch of innerlayers during micro-etching for initial electroless layer, i.e., "reverse" or "negative" etchback.	Use less aggressive micro-etch to strip rework and monitor etch time carefully.
	Smear and smear removal residues remain on innerconnect surfaces.	Improve smear removal process. (See Section 6.)

B PROBLEM	CAUSE	ACTION
Poor electroless copper adhesion after rework.	Initial catalyst layer may have been left after stripping, causing a passive, difficult-to-adhere-to surface.	Ensure sufficient etch time and conditions to remove initial catalyst layer. Mechanically scrub.

7.5 SEMI-CONDUCTIVE COATINGS

Semi-conductive coatings are production proven direct metallization processes. They are chemically simplistic and environmentally friendly alternatives to the relatively complicated electroless copper process for the manufacture of printed wiring boards. In general, these processes contain no formaldehyde, strong chelators and are easier to operate and control. There are four main types of semi-conductive coatings:

—carbon black dispersion
—palladium based
—organic polymers
—graphite-based conductive colloid

This section will refer to the possible problems, causes and corrective action.

7.5.1 Palladium-Based

A PROBLEM	CAUSE	ACTION
Sensitizer solution is cloudy or has precipitate.	Temperature too high.	Check solution temperature; maintain within specified range. Solution may be permanently degraded when subjected to abnormally high temperature, requiring the solution to be dumped and remade.

B PROBLEM	CAUSE	ACTION
Voids on resin.	Metallization process out-of-specification.	Check all solution temperatures, dwell times and chemical parameters; maintain within specified ranges.
	Excessive etch rate.	Verify all chemical parameters, dwell time and temperature of micro-etch.
	Electrolytic copper chemical components and agitation out of specification.	Check all chemical parameters; verify solution agitation and rack agitation are functioning properly.
	Poor electrical connections at electroplating.	Verify that all plating racks, anodes, buss bars, etc., are making proper contact.

C PROBLEM	CAUSE	ACTION
Voids on glass.	Improper glass etch parameters.	Verify chemical parameters, dwell time and temperature.
	Insufficient sensitization and activation.	Verify chemical parameters, dwell times and temperatures.

7.5.1 Palladium-Based (continued)

D PROBLEM	CAUSE	ACTION
Rough deposit on panel surface after electro-plating.	Semi-conductive residues redeposit on boards or rollers.	Check filter cartridges and rollers in micro-etch module; change and/or clean as required. Check spray rinse chamber and nozzles for algae growth; clean as required.

7.5.2 Carbon Black Dispersion Process

Current carbon black dispersion technology is a production proven direct metallization process for the manufacture of printed wiring boards. The carbon black process is a complete replacement for the electroless copper bath and all of its associated process chemistries.

Carbon black technology was developed as a chemically simplistic alternative to the relatively complicated electroless copper process. Since the carbon black dispersion contains no heavy metals, chelators or formaldehyde, it can be considered an environmentally friendly alternative to the existing electroless copper process. A general horizontal process consists of the following steps: Cleaner/conditioner, Carbon black dispersion; Conditioner, Carbon black dispersion; Microetch, and Anti-tarnish. The conveyorized application is the most efficient and reliable mode for this type of technology.

A PROBLEM	CAUSE	ACTION
Excessive foam from cleaner/conditioner solution.	Excessive solution dragout from bath.	For vertical process, increase drip time. For horizontal process, decrease rate of flow into flood module.
	Insufficient rinsing.	Check that water is flowing into rinse tank. Increase water flow. Increase rinse time and/or temperature where possible.
	Bath concentration too high.	Check that bath is prepared in accordance with supplier's specifications.

B PROBLEM	CAUSE	ACTION
Cleaner/conditioner solution is cloudy or hazy.	Temperature is too high.	Check that bath temperature is as per supplier's specifications.
	Many cleaner/conditioners do not complex calcium and magnesium ions.	Use only deionized water for bath make-up and volume adjustments.

C PROBLEM	CAUSE	ACTION
Instability of Carbon Black suspension.	Low pH due to improper replenishment.	Add only replenisher supplied by chemical supplier. Never add acid to adjust pH down unless directed to do so by chemical supplier.
	Agglomeration of carbon black particles or large mean particle diameter due to excess levels of calcium and magnesium.	For vertical process, increase drip time to minimize drag-in of rinse water. For horizontal process, check that squeegee rollers are functional. Add only deionized water when making volume adjustments.

D PROBLEM	CAUSE	ACTION
Slow rate of deposition and/or no plating in electrolytic copper bath.	Incompatibility with electrolytic copper additive.	Check compatibility with chemical supplier.
	Incompatibility with acid cleaner in pattern plating line.	Check compatibility with chemical supplier.
	Insufficient conditioning.	Analyze conditioner bath and replenish or make up new as necessary.

7.5.2 Carbon Black Dispersion Process (continued)

E PROBLEM	CAUSE	ACTION
High board resistance measurements.	Insufficient cleaning and/or conditioning.	Analyze cleaner and conditioner bath and replenish or discard as necessary.
	Low solids in carbon black dispersion.	Analyze carbon black dispersion and replenish as necessary.
	Ionic contamination in carbon black dispersion.	Submit sample of bath to chemical supplier for complete analysis, or make up new bath.
	Excess aeration in carbon black dispersion bath.	Check recirculation pump for cavitation.

F PROBLEM	CAUSE	ACTION
Voids on both glass and resin areas.	Insufficient cleaning and/or conditioning.	Analyze cleaner and/or conditioner and replenish or make new as necessary. Check that operating parameters are per supplier specifications.
	Incomplete drying of board and holes.	Check that dryer temperature is as specified by supplier. Check that dwell time in dryer is adequate, based on board thickness and hole diameter.
	Insufficient agitation.	Ensure adequate agitation in all process baths.

G PROBLEM	CAUSE	ACTION
Voids on glass areas only.	Insufficient conditioning.	Analyze conditioner bath and replenish or make new as necessary. Check that operating parameters are per supplier specifications.
	Improper glass etching in desmear line.	Ensure that glass etch solution concentration and operating parameters are as recommended by chemical supplier.

H PROBLEM	CAUSE	ACTION
Voids on resin areas only.	Insufficient cleaning and/or conditioning.	Analyze cleaner and/or conditioner baths and replenish or make new as necessary. Check that operating parameters are per supplier's specifications.
	Permanganate residues remain on resin areas.	Check permanganate neutralizer parameters.

J PROBLEM	CAUSE	ACTION
Ring voids on both double-sided and multilayer boards.	Incomplete drying of board holes.	Check that temperature in dryer is per supplier specifications. Check that dwell time in dryer is adequate for board thickness and hole diameter.
	Excess aeration in carbon black suspension bath.	If there is a foam blanket on carbon black suspension bath, check recirculation pump for cavitation.
	Improper rack design.	If vertical process, check that rack design does not inhibit solution flow in the through-holes.

K PROBLEM	CAUSE	ACTION
Innerlayer void on multilayer board.	Excessive micro-etch, exposing non-conductive resin surface.	Reduce temperature or dwell time in micro-etch bath.

7.5.2 Carbon Black Dispersion Process (continued)

L PROBLEM	CAUSE	ACTION
Rim voids.	Excessive brush pressure during scrubbing operation.	Closely monitor brush pressure and follow chemical supplier's recommendation as to brush type.

M PROBLEM	CAUSE	ACTION
Wedge voids on multilayer boards.	Poor drill control and/or inadequate oxide and lamination cycles.	Work closely with chemical supplier(s) and follow recommendations to improve these processes.

N PROBLEM	CAUSE	ACTION
Interconnect defects.	Innerlayer recession or negative etchback.	Check operating parameters or all post-PTH micro-etch solutions.
	Carbon black residue on interconnects due to insufficient micro-etch.	Check operating parameters of post-PTH micro-etch.
	Resin smear on interconnects.	Optimize smear removal process.

P PROBLEM	CAUSE	ACTION
Rough deposit on surface after electroplating.	Dried carbon black residue on board surface.	Check operating parameters of post-PTH micro-etch. Check that nozzles in micro-etch spray chamber are not clogged. Check rollers on spray machine for dried carbon black residue; clean as required. Check and change filter cartridges on micro-etch. Check that rinse water is flowing and clean.

7.6 FULL BUILD ELECTROLESS COPPER

''Full Build'' refers to an electroless copper bath used to plate up the full thickness of copper required on the surface and in the holes of a PWB. Generally, these baths plate very slowly, taking 12–20 hours to plate 25µ of copper thickness. The slow speed is necessary to reduce stress in the plated copper and to create a tight grain structure with good ''thermal properties'' (i.e., percent elongation, tensile strength and thermal stress resistance).

7.6.1 Additive Processing

There are several different full-build electroless copper processes. The fully additive process begins with an unclad substrate and actual circuitry copper is added during the electroless copper operation only in the final circuit pattern. No copper is removed in an etch process.

A PROBLEM	CAUSE	ACTION
Surface voids.	Overetching of adhesive coating.	Decrease amount of etch by varying time, temperature or concentration.
	Inadequate thickness of adhesive coating.	Increase thickness of adhesive coating.
	Inadequate activity of electroless plating.	Check activity of electroless plating solution. Check level of activator.
	Overactivity in acceleration step.	Decrease activity of acceleration step.
	Incomplete removal of resist material.	Investigate image and developer step. (See Section 9.)

7.6.1 Additive Processing (continued)

B PROBLEM	CAUSE	ACTION
Blistering.	Underetching of adhesive coating.	Increase degree of etch by time, temperature or concentration.
	Overactivity of electroless plating bath.	Decrease activity of electroless plating. Check level of activator.
	Poor rinsing of adhesive etch.	Increase rinsing.
	Overactivity of acceleration step.	Decrease activity of acceleration step.
	Incomplete removal of resist material.	Investigate imaging operation. (See Section 9.)
	Large copper areas.	Relieve by cross hatching.
	Poor adhesion of electroless to base material.	Investigate swell/etch processing step.

C PROBLEM	CAUSE	ACTION
Background plating (extraneous copper).	Overactivity of electroless plating bath.	Check activity of electroless plating bath.
	Overactivity of activator solution.	Check activator solution.
	Contamination of electroless plating bath.	Dump and remake bath.
	Improper imaging.	Follow actions specified in Section 9.

D PROBLEM	CAUSE	ACTION
Poor thermal shock resistance.	Overactivity of electroless plating bath.	Reduce activity of electroless plating bath.
	Contamination of electroless plating bath.	Dump and remake electroless plating bath.

E PROBLEM	CAUSE	ACTION
Poor insulation resistance.	Conductivity due to incomplete removal of activator material in final etch.	Check concentration of final etch.

F PROBLEM	CAUSE	ACTION
Nodules in electroless deposit.	Overactivity of electroless plating bath.	Reduce activity of electroless plating bath.
	Contamination of electroless plating bath.	Dump and remake electroless plating bath.
	Inadequate filter—on electroless plating bath.	Improve level of filtration.

7.6.2 Semi-Additive Processing

All semi-additive processing involves some amount of etching of background copper. One method begins with ‘‘thin-clad’’ or a thinner than normal copper cladding on the substrate.

A PROBLEM	CAUSE	ACTION
Surface voids.	Burnoff of electroless copper deposit.	Check thickness of electroless copper deposit. Decrease voltage of reverse current cleaner. Decrease initial voltage of electrolytic copper.
	Overetching of adhesive coating or inadequate thickness.	Decrease degree of etch by varying time, temperature or concentration.
	Inadequate initiation of electroless copper plating.	Check level of activator. Check level of conditioner in preplate line. Check activity of electroless copper.
	Overactivity in acceleration step.	Decrease activity of acceleration step.
	Overetching in precleaning for electrolytic.	Decrease amount of etching.

B PROBLEM	CAUSE	ACTION
Surface/hole voids.	Under activation.	Analyze and adjust chrome neutralizer. Increase rinse after chrome. Increase concentration of cleaner/conditioner or catalyst. (Analyze and adjust.) Increase immersion time. (Insufficient immersion time in cleaner/conditioner or catalyst.) Lower time or concentration. (Accelerator concentration or immersion time excessive.) Check electroless copper temperature (possibly too low). Reduce air agitation in electroless copper. Change electroless bath (old or contaminated). Check supplier recommendations for clean cycle. (Preclean prior to electroplate too aggressive.)

C PROBLEM	CAUSE	ACTION
Blistering.	Underetching of adhesive coating.	Increase degree of etch by varying time, temperature or concentration.
	Overactivity in electroless copper.	Decrease activity of electroless copper. Check level of activator.
	Poor rinsing of conditioner.	Increase rinsing.
	Poor rinsing of adhesive etch.	Increase rinsing.
	Overactivity in accelerator step.	Decrease activity of acceleration step.

D PROBLEM	CAUSE	ACTION
Poor insulation resistance.	Incomplete removal of activator in final etch.	Check activity of etch solution.

E PROBLEM	CAUSE	ACTION
Shorts or open circuits.	Poor handling of electroless copper plated panels.	Handle carefully; deposit is thin.

7.6.2 Semi-Additive Processing (continued)

F PROBLEM	CAUSE	ACTION
Low adhesion of electroless copper.	Insufficient adhesive etch.	Increase chrome etch time. Raise chrome etch solution temperature. Change chrome bath (old or contaminated). Change activation line (old or contaminated).

G PROBLEM	CAUSE	ACTION
Electroless copper bubbles on adhesive.	Overactivation.	Analyze and adjust the catalyst concentration downward. Lower concentration of cleaner/conditioner. Increase accelerator concentration. (Analyze and adjust.) Reduce immersion time. (Immersion time in cleaner/conditioner or catalyst excessive.) Improve rinse after cleaner/conditioner or catalyst. Reduce formaldehyde concentration in electroless copper. (Analyze and adjust.)

7.7 DIRECT METALLIZATION DURING DRILL OPERATION

This new technology is not yet in widespread use, therefore potential problems, causes and effects are not yet known. A brief description of the process is given here.

Direct placement of a metallic film in the through-hole during the drilling operation eliminates the need for an electroless copper process or other semi-conductive coating. A special, low melting, metal alloy backup material is used. The drill passes through the laminate material as usual, and then into the alloy backup plate. During withdrawal the drill bit is lubricated by a film of the alloy and coats the hole wall as it moves upwards and out of the hole. This continuous film can then be directly overplated with copper, nickel, or other platable metal. Due to the lubricating effect of the metal backup plate, a low drilling temperature is maintained. No resin smear is created and drilled hole wall quality is excellent. Drill life is also extended due to the low drill temperature.

Some advantages of this technology include: elimination of the entire desmear/electroless process and its attendant equipment, chemistry, labor and waste treatment costs; improved drill quality and longer drill life; and improved throughput (by elimination of the relatively lengthy desmear/electroless process).

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Section 8
Cleaning Procedures

8.0 CLEANING PROCEDURES

Some type of cleaning is required in virtually every step of the printed circuit manufacturing process, from preparing the raw laminate for etch or plating resist to final assembly board cleaning before shipment. This section will attempt to cover most of the general cleaning problems that can occur in any of these steps and, where possible, any problems unique to a specific manufacturing step. Many cleaning procedures are integral within certain manufacturing processes, such as plating, and may also be covered in the section dealing with that process. If a specific problem is not covered in the section, it is suggested that the section dealing with that process also be consulted.

This section is divided into three main categories: mechanical cleaning, chemical cleaning, and electro-cleaning procedures. Each is further broken down into general problems and problems related to specific processes. It is suggested that the general section for each category be consulted first, since this section covers problems that occur in all cleaning processes, no matter where in the overall manufacturing process it is located. In most cases, the solution to a problem will be found in this section. Finally, if a problem is not covered in the general section, turn to the specific process section for problems unique to that process.

It is also suggested that Sections 1.4 on Handling and 1.6 on Rinsing be reviewed, as these can greatly affect the effectiveness of the cleaning process. Poorly rinsed cleaning solution often acts as a contaminant in subsequent processing steps. Excessively soiled boards will require much more cleaning than properly handled ones.

Section 8.0 deals with cleaning PWBs, while Section 18.0 covers the cleaning of printed wiring assemblies.

8.1 MECHANICAL CLEANING PROCEDURES

Abrasive particles can be applied directly for mechanical cleaning, or embedded in a resin matrix in the form of a brush. Direct application of loose grit as an aqueous slurry, usually happens by soft nylon brushes or water jet action. Fused pumice particles are typically brushed while unfused pumice is used in jet applications. Aluminum oxide can be used in either application.

Brush constructions distinguish between bristle brushes and compressed pad brushes with grit impregnated onto nylon fiber. The abrasive particles are typically silicon carbide in the grit size of 180 to 500. Coarse grit (low number) can be found in deburr operations while finer grit (300–500) is preferred for prelamination surface preparation.

Compressed pad brushes do not feature the individual bristles of a bristle brush but rather are constructed from a felt-like material containing the elements of fiber, resin, and grit. Compressed pad brushes typically come in the compressed disk construction or the compressed flap (lamellar) construction, showing slightly different weave patterns.

8.1.1 General

A PROBLEM	CAUSE	ACTION
Non-uniform scrubbing across panel.	Inadequate or uneven cooling water to brushes, causing sections of the brush to overheat.	Clogged cooling water nozzles. Clean and replace any that are not operating correctly. Check water inlet pressure to cooling water system. If pressure is inadequate, nozzles may not give full coverage on brushes. Permanent installation of water pressure indicator may be beneficial in severe cases. Check spray tube alignment in brush section. In most machines, the cooling water should be tangential to the brush, striking the board just before it goes under the brush.
	Brushes not dressed properly or out-of-round.	Check brush dressing by running a sheet of copper clad laminate the full width of the conveyor under the brush. With the conveyor off and cooling water on, bring the brush into contact with the board until about a 6.4 mm wide stripe is obtained on the board surface. (The stripe should be even across the entire board, plus or minus 1.6 mm. If it is not, then the brush needs dressing.) Compressed wheel brushes can be dressed in the machine with a dressing board. Bristle brushes cannot be dressed this way. Contact brush supplier for best procedure.
	Brush not parallel to backup roller.	Check with machine manufacturer for procedure for checking and adjusting backup roller.
	Improper conveyor loading by operators, causing brush to wear in one area faster than another.	Check brushing procedures. Ideally, work should be staggered across the entire conveyor width to even out brush wear.
	Voids in bristle brushes.	As bristle brushes wear, they may begin shedding bristles, leaving voids in the brush. Replace brush.
	Gouges in compressed wheels.	Turned up corners on laminate materials, especially innerlayers, can put gouges in brush surface. (Wheels can be redressed for small gouges. Larger gouges may require wheel replacement.)

B PROBLEM	CAUSE	ACTION
Tracking on panel surface.	Inadequate rinsing.	Check for clogged nozzles in rinse; clean and replace. Check to be sure there is adequate pressure to the rinse section so the nozzles give full coverage to the panel. Permanent installation of water pressure indicator may be beneficial in severe cases.
	Contaminated rollers.	Check rollers for dirt and copper particles. (Since different manufacturers use different materials for rollers, it is best to contact the manufacturer for the best cleaning procedure.)
	Drying with contaminated air.	Check placement of scrubber. (If it is in an area where etching or plating fumes are present, this could cause tracking problems where turbine type dryers are used. The only way to effectively prevent this is to move scrubber to a different area.)
	Contaminated water.	Check water supply. Most municipal water is adequate, but excessively hard water or recirculated water can cause problems. Consider filtration on incoming water.

8.1.1 General (continued)

C PROBLEM	CAUSE	ACTION
Scrubber not cleaning properly, as evidenced by no scrubbing, poor resist adhesion, step plating, or poor plating adhesion. (See Figure 8-1.) A clean, well-scrubbed panel should hold a continuous film of water for 15-25 seconds.	Bristle brushes not properly trimmed.	Brushes should be pre-trimmed at factory to expose abrasive, but it is possible to get one improperly trimmed or not trimmed at all. Running brush on copper over full width of conveyor for 20 to 30 minutes will usually expose abrasive.
	Too much brush pressure.	Adjust brushes to give 6.35 mm wide stripe on full width panel. (In the case of bristle brushes, too much pressure can bend bristles so abrasive doesn't contact board. Also high pressure can smear nylon from brush onto board surface.)
	Inadequate brush cooling water.	Check cooling water supply and re-expose abrasive as described above. (Overheating the brushes can cause nylon to flow over the abrasive and inhibit scrubbing.)
	Sulfuric acid rinse prior to scrubber.	Be sure board surface is completely rinsed before running into scrubber. (Sulfuric acid can cause nylon in brushes to degrade if there is a sulfuric acid rinse prior to scrubber.)

Figure 8–1 Water-break test.

8.1.2 After Electroless Plating/Resist Application

A PROBLEM	CAUSE	ACTION
Removal of electroless copper from surface or around holes ("dishing" or ring voids).	Over-aggressive scrubbing.	Use a finer grit brush and less brush pressure. (Electroless copper plating is very thin and over-aggressive scrubbing can easily remove it, especially around the edges of the holes where the brush pressure is highest.)

B PROBLEM	CAUSE	ACTION
Step plating or poor adhesion of plated copper.	Contaminated surface from scrubbing operation.	See 8.1.1 C.
	Tin-lead on brushes (from scrubbing tin-lead plated panels).	Use a separate scrubber if scrubbing tin-lead plated panels. If this is not possible, brushes should be dressed immediately after scrubbing the tin-lead.

8.1.3 Before Fusing

A PROBLEM	CAUSE	ACTION
Smearing of tin-lead on substrate.	Brush loaded with tin-lead and redepositing it on board.	Where smearing is noticeable, change brush. (Tin-lead plating is very soft and tends to load up brush. This can be minimized by using as fine a grit as available and minimum brush pressure.)

B PROBLEM	CAUSE	ACTION
Tin or Tin-lead slivers, sometimes found as shorts during electrical test.	Mechanical cleaning before fusing.	During the etch process the copper is etched under the tin-lead resist, leaving an overhang which is susceptible to breaking during the scrubbing process. There is no way to prevent this other than changing to a non-mechanical cleaning procedure. Using minimal brush pressure can reduce the problem.

8.2 CHEMICAL CLEANING PROCEDURES

There are literally hundreds of chemicals that can be, and are, used for cleaning in the printed board industry; many, if not most of which are proprietary. It is obviously impossible to cover all these in any but a very general manner. For questions on problems with specific proprietary chemicals, it is suggested that the supplier of the chemistry be contacted directly. Equipment manufacturers can also provide some answers on many of the more commonly used chemistries.

8.2.1 General

A PROBLEM	CAUSE	ACTION
Excessive foaming.	Chemistry designed for immersion tank operation used in conveyorized equipment.	Be sure the chemistry being used is designed for use in spray equipment.
	Surfactant or antifoam depleted.	Add more antifoam. Change solution. (In the case of proprietary cleaning solutions with built-in antifoams, excess foaming can be an indication that the solution is spent.)
	Pumps cavitating (solution level too low).	Check and adjust liquid level. Reconfirm solution concentration if a lot of water must be added.
	Cleaner drag-in to other process tanks (or chambers).	Use less wetted alkaline cleaners or use non-wetted acid cleaners. Improve rinsing. Reduce tank solution drag-out by increasing drip times (and possibly improved rack or basket design). In conveyorized equipment, check operation of pinch rollers between chambers.
	Excessive build-up of organic soils in cleaner.	Dump and remake cleaning solution.

8.2.1 General Chemical Cleaning Procedure (continued)

B	PROBLEM	CAUSE	ACTION
Cleaning action less than normal or not up to specifications.		Clogged nozzles causing loss of spray pattern.[1]	Check and clean nozzles.
		Chemistry not at operating temperature.[1]	Check temperature settings and heaters and/or cooling coils for proper operation.
		Water leak diluting chemistry.[1]	Check cooling coils for leaks and look for other sources of water leaks.
		Low fluid level causing pump to cavitate and lose pressure.[1]	Add chemistry to raise fluid level.
		Insufficient contact time in chemistry (conveyor speed too fast).[1]	Adjust conveyor speed to give at least minimum contact time. (In most spray chemistries the minimum time spent in the spray should be around 30 seconds. Immersion chemistries vary, but 2-5 minutes is a good average.) Confirm actual conveyor speed - do not rely on gauge or dial.
		Spent chemistry.[2]	Most cleaning chemicals are batch type cleaners and need to be changed periodically. The frequency of change for most chemistries will be based on the amount of work processed, typically 46.5 to 185.8 square meters of board.
		Chemistry not mixed to proper strength.[2]	Be sure that powdered materials are completely dissolved before use. (Also, it is relatively easy to make a mistake in measuring the chemicals when mixing a bath, resulting in a solution that is too strong or too weak.) [2]
		Wrong chemical for application.[2]	Following are some general recommendations: Innerlayer preparation - use strong acid cleaner to remove corrosion inhibitors on laminate copper; use hot alkaline cleaner to remove resist residues and handling soils. Electroless copper - proprietary cleaner-conditioners are usually acid and often contain mild chelators; do not use for other cleaning applications where the conditioner may cause problems. Plating - mild acid cleaners are used (compatible with resists), followed by very mild micro-etch, or a combination etching cleaner may be used.

1. Equipment related 2. Chemistry related.

8.2.2 Solder Conditioning Before Fusing

A	PROBLEM	CAUSE	ACTION
Equipment being eaten away by chemistry.		Solder conditioning chemicals not compatible with equipment.	Be sure chemistry being used is compatible with the equipment - including tanks, piping, pumps, nozzles, conveyor chain, heaters, racks, etc. (Most fluoride-based conditioners are not compatible with standard equipment available and require all plastic construction. Other combinations may or may not be compatible with equipment. Check with both chemical and equipment suppliers to be sure.)

B	PROBLEM	CAUSE	ACTION
Tin-lead still dark after solder conditioning/ brightening step.		Tin-lead alloy out of range.	See Section 10.3.
		Poor rinsing after tin-lead plating process.	Improve rinsing and drying steps after tin-lead plating.
		Solder conditioning chemistry spent or out of specification.	Adjust to within specifications or change bath.

8.2.3 Cleaning After Fusing or Hot Air/Oil Level

A PROBLEM	CAUSE	ACTION
Flux residue.	Cleaning solution temperature and/or concentration too low.	Adjust to within specification.
	Wrong flux used.	Review alternatives with flux supplier(s). Evaluate alternative chemistries.
	Water temperature too low.	Use warm to hot water to rinse.
	Excessive time between fluxing operation and final clean.	Clean boards immediately after fusing or leveling operation.
	Final rinse water contaminated, leaving spots on boards.	Consider D.I. rinse or water filtration or blow dry to remove water.

B PROBLEM	CAUSE	ACTION
White residue on board after cleaning.	Polymerized flux (fusing/leveling temperature too high or too long at temperature).	Decrease temperature and/or exposure time if excessive.

C PROBLEM	CAUSE	ACTION
High ionic contamination levels, as evidenced by solvent extract resistivity testing.	Flux residue after cleaning.	Follow actions described in 8.2.3 A.
	Final rinse water contaminated.	Consider D.I. rinse or water filtration or blow dry to remove water.
	Solder mask not properly cured.	See Section 16.1. (Some solder masks are incompatible with resistivity testing, as ionics continuously come out regardless of cure or test procedure.)
	Resistivity test equipment malfunctioning/ out-of-calibration.	Verify equipment operation and calibration.
	Boards contaminated during storage or from handling prior to resistivity test.	Improve handling and storage techniques. Consult resistivity equipment supplier for assistance. Resistivity test equipment may be improperly operated.
	Resistivity test equipment malfunctioning/ out-of-calibration.	Verify equipment operation and calibration.
	Boards contaminated during storage or from handling prior to resistivity test.	Improve handling and storage techniques. Consult resistivity equipment supplier for assistance. Resistivity test equipment may be improperly operated. Institute adequate training.

8.3 ELECTROCLEANING

These cleaning solutions are generally used in a preplate cleaning cycle just prior to pattern plating. The electrocleaning solution functions like a hot soak cleaner with a micro-etch. Many different types of electrocleaners are available. They operate at different temperatures, concentrations, current densities and a wide pH range. Most electrocleaners are used as anodic cleaners, with the printed circuit board functioning as the anode when electrical current is applied. Deplating of copper from the exposed copper surface and the generation of oxygen bubbles on that surface provide the cleaning action.

8.3.1 General

A PROBLEM	CAUSE	ACTION
Copper-to-copper peelers after pattern plating.	Operating outside of recommended range: low concentration, low temperature, low current density, short dwell time in solution, and/or spent solution.	Establish proper process conditions per supplier's recommendations (monitor the process and train operators in process control).
	Solution setup for cathodic cleaning.	Convert to anodic cleaning.
	Incorrect anode placement.	Redesign anode configuration and placement.
	Insufficient rinsing after electrocleaning.	Check rinse spray nozzles, pressure, and water temperature.

B PROBLEM	CAUSE	ACTION
Resist breakdown, edge-lifting, and underplating during pattern plating. (Also see Section 9.0.)	Out-of-control electrocleaner: high concentration, high temperature, long immersion time, high pH, and/or high current density.	Control per resist supplier data sheet and per supplier's specification of electrocleaner. Monitor solution temperature and pH.

C PROBLEM	CAUSE	ACTION
Resist image stripped in the electrocleaner. (Also see Section 9.0.)	Resist image not compatible with chemistry of electrocleaner (generally high pH).	Select electrocleaner per resist supplier's recommendations.
	Long immersion time and/or high temperature of electrocleaner.	Reduce immersion time and temperature.

D PROBLEM	CAUSE	ACTION
Step plating. (Also see 8.3.1 A.)	Insufficient rinsing after electrocleaning.	Check rinse spray nozzles, pressure and water temperature. Increase flow rate in rinse water soak tanks. Increase rinse time.

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Figure 9–18 Slow break away on printing 22

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Figure 9–24 Electrophoretic deposited resist illustration 27

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Section 9
Imaging

9.0 IMAGING

9.1 GENERAL

This section will discuss those process effects associated with the use of the following four primary systems:

Dry film photoresist
Liquid photoresist
Screen-printed resist
Electrophoretically deposited photoresist

9.2 DRY FILM PHOTORESIST

A dry film photoresist, as supplied, consists of a photosensitive layer sandwiched between a sheet of 1.0-mil polyethylene and 1.0-mil polyester. The polyethylene release sheet is removed and the photosensitive layer with polyester is laminated to a clean copper surface under heat and pressure. The artwork circuit pattern is then printed in the resist through exposure to UV light. After exposure the polyester is removed and the unexposed areas are washed out during development. The remaining exposed resist image functions as a plating resist or etch resist and is then stripped from the copper surface.

There are 3 classifications of dry film photoresist:

A. Solvent	Develop in 1,1,1-trichloroethane. Strip in methylene chloride blend.
B. Semiaqueous	Develop in alkaline solution containing a water-miscible solvent. Strip in similar chemistry with higher pH and elevated temperature.
C. Total aqueous	Develop in 1% sodium or potassium carbonate. Strip in 1 to 3% sodium or potassium hydroxide (or other, similar chemistry).

Environmental concerns have all but eliminated use of the solvent and semiaqueous types, except in unusual circumstances. The sections below are divided according to type with a section for problems common to all three types first.

9.2.1 Common Problems of Dry Film Photoresist

A PROBLEM	CAUSE	ACTION
Resist scum/ residue on panels after develop-ment. (See Figure 9–1.)	Underdevelopment.	Establish proper development time per supplier's data sheet.
	Phototools with low density in the opaque areas.	Check opaque density of phototools with a densitometer. Check circuit image edge acuity on the phototool.
	Photoresist exposed to white light prior to development.	Store resist-coated panels in non-white-light areas prior to development. Inspect the yellow room for light leaks.
	Redeposition of exposed resist from the panel edge.	Apply an unexposed border around the edge of panels to prevent flaking and chipping of exposed resist during development.
	Insufficient water rinse after development.	Check for plugged spray water rinse nozzles. Maintain a minimum water pressure in the spray rinse chamber of 138 kPa using direct fan spray nozzles. Maintain rinse temperature above 16°C.
	pH	Check pH of rinse water. Maintain per mfg. specifications.
	Spent developer.	Establish necessary process controls to prevent overloading of the developer solution with dissolved unexposed resist. Follow dry film supplier's recommendation for developer loading capacity.
	Plugged spray nozzles in the developer chamber.	Inspect and clean nozzles during routine maintenance of the developing unit. (Remove spray nozzles, change filter, clean or replace as required.)
	Photoresist laminated at elevated temperatures.	Calibrate dry film laminator roll temperature and establish per the dry film data sheet.
	Long hold times prior to development.	Check supplier's specification on hold times between resist lamination and development.
	Resist ''lock-in'' from wet lamination.	Check supplier's recommendations to determine if resist is compatible with wet lamination process.

Figure 9–1 Resist scum on panels

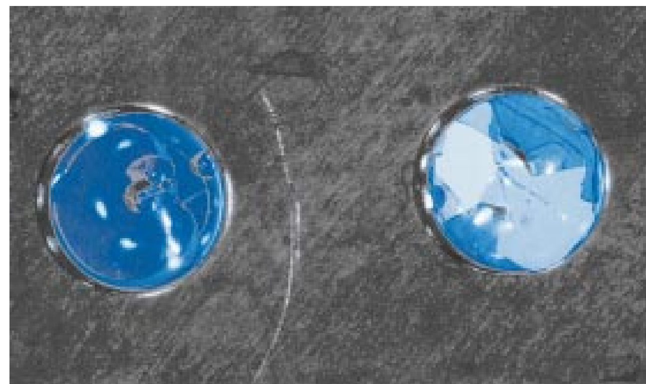


Figure 9–2 Poor tenting

9.2.1 Common Problems of Dry Film Photoresist (continued)

B PROBLEM	CAUSE	ACTION
Poor tenting (insufficient resist bridging of plated through-holes) performance. (See Figure 9–2.)	Burrs around plated through-hole.	Inspect holes after drilling for excessive burrs and establish proper deburring conditions.
	Moisture in holes at time of dry film lamination.	A low temperature bake may be necessary to completely remove moisture from the holes prior to dry film lamination.
	Insufficient resist thickness for proper bridging.	Convert to a dry film with increased thickness. (Thicker resists provide better tenting performance, but have less resolving power.)
	Imperfections in the clear areas of the phototool.	Inspect for defects (opaque defects in clear areas) and replace with complete phototool if necessary.
	Imperfections in the exposure frame.	Inspect for defects in the glass or polyester cover and clean or replace as required.
	Too much pressure and/or preheat during resist lamination.	Decrease pressure and/or heat.
	Long hold times prior to development.	Check supplier's specification on hold times between resist lamination and development.
	Spray pressures too high.	Examine developer chamber and rinse spray pressures. Check for damaged nozzles, i.e., needle-like spray pattern. It may be necessary to reduce spray pressure when developing tented panels.
	Equipment damage in developer.	Check for misaligned or damaged guides, rollers, etc.

C PROBLEM	CAUSE	ACTION
Inability to completely develop out unexposed resist areas. (See Figure 9–3.)	Overexposure.	Monitor exposure condition by means of a density step tablet or radiometer and set exposure per supplier's recommendation.
	Insufficient density on film phototool; wrong line widths on artwork.	Measure line width on the phototool and measure density of the opaque areas.
	Phototool emulsion not in intimate contact with the photoresist during exposure.	Train operators to always expose with the emulsion adjacent to the resist surface. Clean artwork after each exposure and wipe panels prior to exposure.
	Insufficient vacuum draw-down prior to exposure.	Use bleeder tubes/veins to aid in vacuum draw-down; replace defective glass or polyester in the exposure frame; inspect for vacuum leaks; allow sufficient time for proper vacuum draw-down prior to exposure.
	Buckles in the phototool due to poor placement of registration pins.	Correct film punching/registration hole placement.
	Photoresist-coated panel exposed to white lights prior to development.	Inspect the yellow room area for leakage of white light; establish yellow room conditions for handling and storage of resist-coated panels prior to development.
	Photoresist laminated at an elevated temperature causing thermal polymerization on the copper surface.	Maintain proper lamination temperature per supplier/s recommendation and periodically calibrate the roll temperature.
	Underdevelopment.	Establish proper development conditions per supplier recommendations.
	Resist resolution (technology limitation).	New resist.

9.2.1 Common Problems of Dry Film Photoresist (continued)

Figure 9–3 Line width reduction from incomplete development

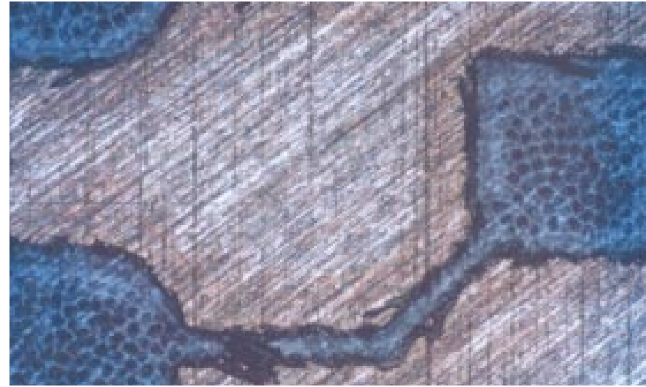


Figure 9–4 Photoresist image damage during development

D PROBLEM	CAUSE	ACTION
Photoresist image damage during development, image lifting and/or ragged circuit lines after development. (See Figure 9–4.)	Underexposure.	Use density step tablet to check exposure per supplier's recommendation. (Always establish exposure condition with the step tablet under clear areas of the phototool.)
	Overdevelopment.	Establish proper development conditions per supplier recommendations. (Time, temperature and concentration of the developing solution are critical process parameters which must be controlled for optimum development of any dry film resist.)
	No hold time between exposure and development.	Follow supplier's recommendation. (A minimum hold time of 15 minutes is required for some resists to allow for proper equilibration of the exposed resist image on the copper surface.)
	High developer temperature.	Measure temperature and control per the dry film data sheet.
	Inadequate surface preparation of the panel prior to dry film lamination.	Inspect panels prior to resist lamination for a clean water-break test. (A clean panel should hold a continuous film of water for 15-25 seconds; see Section 8.1.) Establish proper board scrubbing conditions per the equipment manufacturer's recommendation. Proper maintenance of the scrubbing unit is required to ensure adequate cleaning of copper panels prior to resist lamination.
	Insufficient roll pressure and/or temperature during dry film lamination.	Calibrate dry film laminator roll pressure per supplier recommendations. (Monitor lamination speed, temperature and pressure during processing.)
	Poor edge acuity on phototools.	Inspect phototools and replace if necessary.
	Opaque defects on phototools.	Inspect phototools and clean or replace.
	Equipment damage in developer.	Check developer chamber, rinse and dryer sections for misaligned or damaged guides or rollers.
	Particulate contamination laminated between resist and board.	Make sure boards have no particles on surface before lamination. Use board cleaner if necessary. Make sure edges of panels do not have loose copper.

9.2.1 General Problems of Dry Film Photoresist (continued)

E	PROBLEM	CAUSE	ACTION
Resist breakdown and lifting during etching. (See Figure 9–5.)		Improper handling.	Train operators to minimize contact with the circuit image after development. Rack - do not stack - panels after development to minimize contact with other developed panels. Keep fingers, hands and pointed objects away from the circuit image at all times.
		Improper cleaning.	Clean panels prior to dry film lamination either by mechanical scrub or chemical clean. (See Section 8.1.) Panels should pass water-break test. Immerse a cleaned panel in water, withdraw and determine if it holds a film of water for 15-25 seconds. Surface after cleaning should be slightly acidic (from a 5% sulfuric acid dip during the cleaning/scrubbing process).
		Underexposure.	Use a density step tablet to set exposure conditions per supplier recommendations. Adjust the developer speed, concentration and/or temperature per supplier specifications.
		Etching solution out of control - high pH of an alkaline etchant combined with high temperature.	Monitor etching process and maintain per supplier recommendation. (See Section 11.0.) Minimize the hold time between development and etching. Store panels in yellow-light areas before etching. (Excessive white-light exposure increases brittleness of the dry film, making it more sensitive to damage from improper handling.)
		Excessive hold times between development and etching.	Follow supplier recommendation for hold times. (Some resists are more sensitive to this particular hold time. Excessive hold times increase the probability of damage due to handling and storage.)
		Ammoniacal etcher replenishment chamber out of control.	Check pH of etchant. Make sure replenishment chamber is well vented (ammonia is a very good stripper).
		Wrong resist for ammoniacal etching.	Check supplier's specification to verify that resist is compatible with etchant.
		Resist actually damaged before etcher.	See Section 9.2.1 D.

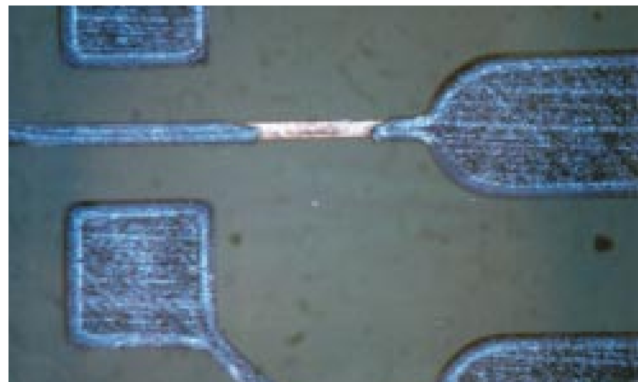


Figure 9–5 Resist breakdown and lifting during etching

Figure 9–6 Resist breakdown, edge lifting, and underplating during pattern electroplate operation

9.2.1 Common Problems of Dry Film Photoresist (continued)

F PROBLEM	CAUSE	ACTION
Resist breakdown, edge lifting and under-plating during pattern electroplate operation. (See Figure 9–6.)	Inadequate prelamination cleaning, causing poor adhesion to electroless copper.	Clean panels prior to dry film lamination either by mechanical scrub or chemical clean. (See Section 8.1.) Panels should pass water-break test. Immerse a cleaned panel in water, withdraw and determine if it holds a film of water for 15-25 seconds. Surface after cleaning should be slightly acidic (from a 5% sulfuric acid dip during the cleaning/scrubbing process). (Also see 9.2.1 E.)
	Improper dry film lamination - speed, temperature and pressure.	Monitor lamination conditions. Set lamination conditions per dry film supplier specifications.
	Underexposure.	Use a density step tablet to establish exposure conditions and set per dry film supplier's recommendations. (Maintain the exposure condition with one step of the recommended step tablet reading.)
	Overdevelopment.	Continuously monitor development condition. Set temperature, concentration and conveyor speed per supplier's recommendations. Use the resist breakpoint in the development chamber as an ongoing process control.
	Out-of-control hot soak cleaner in the preplate cleaning line - high temperature, high concentration and/or long immersion times. Incompatible cleaner.	Establish cleaning condition per dry film data sheet and data sheet from supplier of hot soak cleaner.
	Out-of-control electro-cleaner - high concentration, high temperature, long immersion time and/or current density.	Control per dry film data sheet and supplier of the electro-cleaner. (Monitor this process daily.)
	Incompatible antitarnish for resist.	Verify that antitarnish at end of electroless copper line is compatible with resist per supplier's recommendations. Make sure antitarnish is compatible with plating line hot soak cleaning.
	Excessive micro-etch.	Adjust plating line micro-etch per dry film supplier's recommendations.
	Resist lifting during gold plating.	See Section 10.6.4 K.
	Poor adhesion to unscrubbed electroless copper.	Make sure electroless copper line has adequate rinses and an acid bath to ensure neutralization of copper surface. (See resist vendor recommendations.)

9.2.1 General Problems of Dry Film Photoresist (continued)

G PROBLEM	CAUSE	ACTION
Copper-to-copper peelers after pattern plating. (See Figure 9–7.)	Inadequate preplate cleaning prior to copper pattern plating.	Establish the proper preplate cleaning process. Dry film suppliers recommend: • Hot soak cleaner • Micro-etch • Acid dip The acid dip generally consists of 10% sulfuric acid. Sufficient rinsing is required between each process tank. No rinse is required between the sulfuric acid dip and acid copper sulfate plating bath. Control of the micro-etch is critical in eliminating peelers. This solution is required to provide a virgin copper surface for electroplating. Concentration, temperature and immersion time in the micro-etch bath are critical. (Also see Sections 8.2 and 10.1.1.)
	Electro-cleaning process out-of-control—short immersion time and/or low current density.	Establish proper process conditions per supplier's recommendations. (Monitor the process and train operators in process control.)
	Excessive hold time between dry film lamination and development.	Schedule production to minimize the hold time between lamination and development. (Increased time in the mild etching solution or in the electro-cleaner may be needed for panels with hold times or more than one week between lamination and development.) (See Example 9–1)
	Underdevelopment.	Adjust development speed for proper breakpoint. Verify proper development chemistry.
	Overdevelopment.	Adjust developer breakpoint per supplier's recommendations. Check developer concentration, pH and temperature.
	Insufficient developer rinsing.	Check rinse spray nozzles, pressure and water temperature.

Figure 9–7 Copper-to-copper peelers after pattern plating

Figure 9–8 Skip plating

9.2.1 Common Problems of Dry Film Photoresist (continued)

H PROBLEM	CAUSE	ACTION
Skip and step plating in the developed-out circuit pattern. (See Figure 9–8.)	Polymerized resist residue in the developed-out circuit pattern.	Inspect phototool for scratches, nicks and cuts in the circuit image. Add opaque borders to the phototool to prevent exposure of the resist at the panel edge. (Exposed resist extending beyond the edge of the panel will chip and flake during development and redeposit back into the circuit pattern.)
	Unpolymerized resist residue in the circuit pattern.	Establish correct breakpoint in the developer per dry film supplier's recommendations. Both under- and overdevelopment can cause step plating. (Also see Sections 9.2.1.C, 9.2.1.G.)
	Shop oil and fingerprints not removed from board during preplate cleaning.	Establish optimum hold time in the hot soak cleaner during preplate cleaning. (Temperature, concentration and immersion time should be controlled per supplier recommendations.)
	Touch-up ink spillover into the circuit pattern.	Train operators in the proper procedure for applying touch-up ink to the developed resist image. Use touch-up ink per supplier's recommendation. (Some inks require UV cure and others a thermal bake to prevent seepage into the developed-out circuit pattern.)
	Plating defects (such as pits, rough plating, etc.) from panel copper plating may lead to resist adherence in crevices.	Inspect parts prior to photoresist lamination. Possible rework method is to redevelop at 2X development speed. For small areas, try touch-up with Q-tip and 1/2 concentration developer. May require complete reprocessing - scrub bare board. Investigate plating process to resolve original problem. (See Section 10.2.)

9.2.1 Common Problems of Dry Film Photoresist (continued)

J PROBLEM	CAUSE	ACTION
Photoresist residue on the board after stripping. (See Figure 9–9.)	Short stripping time.	Establish optimum strip time with boards processed through print-and-etch or pattern plating. (Adjust the strip time with increased loading of the stripper solution. The optimum strip time will generally change with different resist types and thicknesses. Inspect first article for adequate stripping.)
	Over-plating during pattern plating.	Increase thickness of dry film to prevent over-plating. Improve method for controlling current density during pattern plating to prevent over-plating. (See Section 10.0.) Increase time in stripper solution (consider a presoak of boards in stripper prior to a fresh stripper bath). Investigate alternate stripping chemistry.
	Excessive exposure of developed resist to white lights.	Store panels in yellow- light areas prior to pattern plating. Minimize hold time between pattern plating and stripping. Increase strip time.
	Baking of the resist after development.	Eliminate or minimize bake time and temperature. Increase strip time.
	Wrong stripper chemistry.	Investigate alternate stripping chemistry based on dry film supplier's recommendations.
	Stripper solution out-of-control – spent stripper, low temperature, short immersion time.	Establish process controls per supplier's recommendations (monitor process to ensure control). Inspect first article for adequate stripping.
	Redeposition of stripped resist.	Replace stripper bath, clean out immersion tank or spray unit. Improve filtration method of stripper bath. Control stripper chemistry per supplier's recommendations. Aqueous and semi-aqueous resists require adequate rinsing immediately after panels are removed from the stripping solution. Solvent resist requires a clean rinse in the stripper chemistry prior to existing solvent stripping equipment.
	Excess hold time between lamination of the photoresist and subsequent stripping of the resist.	Reduce throughput time; improve scheduling.

Figure 9–9 Photoresist residue on board

Example 9–1 Improvement in Photoresist Imaging

- **Problem**
  Excessive scrap is produced in the production of multilayer boards
- **Goal**
  Reduce scrap and increase yield
- **Identification of problem's cause**
  The scrap boards from a full week's production were analyzed to determine the exact causes of failure.
  Defect Analysis (Pareto)
  Last week = 185 non-conforming (scrap)
  11 Due to drill misregistration
  85 Inner layer Image Problems
  55 Outer Layer Image Problems
  30 Layer to Layer Misregistration
  Conclusion: Concentrate efforts on reviewing process for forming conductors
- **Process Analysis**
  A process flow diagram was drawn for whole multilayer process. The problem solving task group jointly decided whether each process step was significant to solving the problem or insignificant. For innerlayer conductor formation these steps were considered significant: surface prep, photoresist lamination, photo imaging, etching
- **Process Review**
  The various controlling parameters for each of the above steps were listed. From this list cause and effect diagrams were constructed.

Each member of the problem solving team ranked each lamination parameter from 1 to 10. The parameters that receive high group scores were considered for further study (group value higher than 6).
The seven parameters chosen for resist lamination are: speed, pressure, temperature, surface of rolls, space of rolls, rate, resist type

- **Controlled Experiments**
  A fractional factorial design experiment was constructed with the seven chosen variables. The response chosen was the number of anomalies per board.
  Results of experiment found 3 factors to be most significant of various levels:

Speed	**1.5 meters/min**	**vs. 2.5 m/min**
Temperature	**110°C**	**vs. 60°C**
Pressure	**2.0 bar**	**vs. 1.0 bar**

  A confirmation run (or sanity check) involving testing the worse parameters verified the above results
- **The next experiment run was a full factorial of the three significant process steps designed and run. The results were used to set the exact levels for each step**
- **Path forward**
  —set up SPC charts for newly identified parameters
  —monitor yield after changes
  —review and test next important process step, surface prep, photoimaging, etching

9.2.2 Total Aqueous Resist

Develop in a 1% solution of sodium or potassium carbonate and strip in a 1-3% solution of sodium/potassium hydroxide or a solution containing an ethanolamine. (See Example 9–2.)

A PROBLEM	CAUSE	ACTION
Incomplete development of unexposed resist.	Underdevelopment.	Establish proper development conditions per dry film supplier's recommendations.
	Wrong chemistry.	Establish proper developer makeup procedure per dry film supplier's data sheet.
	Low solution temperature.	Establish temperature per dry film data sheet. Measure solution temperature and calibrate temperature readout of developing equipment.
	Spent developer solution.	Dump spent solution and replace with fresh makeup. Monitor the breakpoint and adjust with increased loading of resist. Check feed and bleed system for correct operation.
	Plugged spray nozzles in the developing unit.	Inspect, clean and/or replace defective nozzles, as required, during routine maintenance of the developing equipment.
	Excess anti-foam.	Limit the addition of anti-foam to approximately 0.25 ml/liter at any one time. (Excessive foaming shortly after an anti-foam addition may be caused by mechanical problems with the equipment. Check for cracks in the piping leading to the pump or pump housing unit.)
	Low spray pressure.	Monitor pump spray pressure and maintain per equipment manufacturer's recommendation.
	Hard water used for make-up chemistry.	Use demineralized water for make-up to avoid precipitation. Refer to IPC-AC-62, Section II on water hardness.
	Phototool improperly developed (low Dmax).	Expose and develop Diazo per supplier's recommendation (underdevelopment gives this problem.) (Also see Section 3.0.)

Example 9-2 Solvent to Aqueous Conversion of Innerlayer Imaging Processes

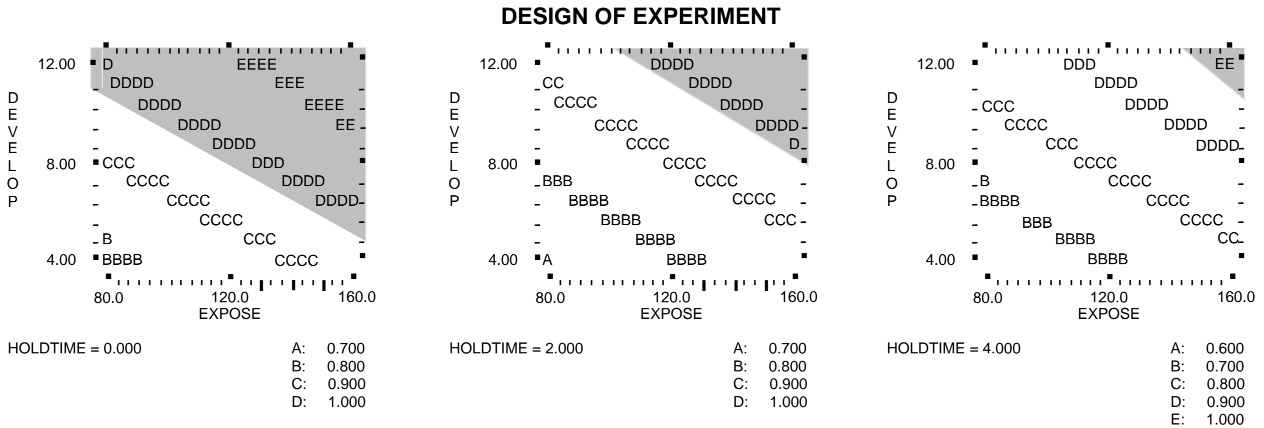
- **Problem:**
  Conversion of innerlayer imaging process from solvent to aqueous basis risks yield reduction through resist lift/failure in ammoniacal etcher
- **Goal:**
  Establish initial imaging process set points offering maximum resist survival probabilities through existing ammoniacal etch process, consistent with established finished line width parameters and minimum dislocation of established (successful) image-area operating practices.
- **Parameter Diagnostics:**
  New process for this shop, so no internal historical data existed.
- **Measurement System Evaluation:**
  A special 18 x 24 test panel artwork was designed with 280 25.4 x 25.4 mm pattern blocks per side of 5 mil lines and spaces in alternating orientations. To reduce opportunities for error in limited-duration test, one inspector made all judgments as to "Survival" (defined as no visible evidence of resist degradation after the first etching pass at a two-ounce etch rate, when examined through a 5-power illuminated hand lens). In blind repeat tests on separate days repeatability was judged acceptable.
- **Variable Selection:**
  For the purpose of this initial study, etch conditions were to be considered "fixed." Experience from similar conversions elsewhere was considered an adequate basis for key variable selection at this preliminary stage. These variables were:
  Photoresist Exposure Level (mj)
  Developer Breakpoint (conveyor speed)
  Hold time (develop through etch, days)
- **Optimization:**
  Using the listed variables and a commercially available designed experimentation program, a 17-run experiment was performed at the set points shown below, with the results indicated.

ETCH SURVIVAL EVALUATION

	Controlled			Characteristic
Run	**Expose**	**Develop**	**Holdtime**	**Survival**
1	80.00	4.000	0.000	0.8380
2	120.000	4.000	0.000	0.9640
3	160.00	4.000	0.000	0.9950
4	80.00	8.000	0.000	0.9880
5	120.00	8.000	0.000	0.9890
6	160.00	8.000	0.000	0.9980
7	80.00	12.000	0.000	1.0000
8	120.00	12.000	0.000	0.9980
9	160.00	12.000	0.000	1.0000
10	80.00	4.000	4.000	0.2250
11	120.00	4.000	4.000	0.6820
12	160.00	4.000	4.000	0.8410
13	80.00	8.000	4.000	0.7890
14	160.00	4.000	4.000	0.9520
15	80.00	12.000	4.000	0.9930
16	120.00	12.000	4.000	0.9980
17	160.00	12.000	4.000	1.0000

Example 9-2 Solvent to Aqueous Conversion of Innerlayer Imaging Processes (continued)

DESIGN OF EXPERIMENT



MAXIMUM SURVIVAL

Value Maximum	Factors	Lower Limit	Upper Limit
160.	Expose	80.00	160.0
12.0	Develop	4.000	12.00
0.00	Holdtime	0.000	4.00
	Characteristics		
1.17	Survival		

Starting factor values: 120.0, 8.000, 2.000

- **Analysis/Discussion**
  The results support the contention of aqueous resist manufacturers that, in the absence of flex, maximum chemical resistance is achieved at high exposure levels and a relatively late (75% in this case) breakpoint, with minimum delays in process. Survival is not the only requirement of an imaged line, however. Line width considerations and controllability of the develop step itself prompted a slight retreat from the conditions insuring maximum survivability to those achieving an acceptable line width and reasonable process delays, while still potentially yielding 100% survival.

- **Parameter Control**
  The existing solvent-based imaging process had adequate corresponding controls in place for exposure level and hold times. Developer breakpoint control was reinforced through additional operator training and increased frequency of breakpoint checks, with results recorded at specified intervals.

- **Conclusions**
  Optimizing a process often involves a compromise between competing maxima. In this case, an “X-Stat” designed experiment was used to define the limits of the process “window” which permitted us to set conditions which allowed both 100% survival of a 0.11 mm innerlayer line and acceptable line reproduction of a 0.11 mm innerlayer and acceptable line reproduction and process delay times. This resulted in setpoints of:
  120 millijoule exposure
  65% ± 10% breakpoint
  2 day maximum (post develop) hold times

Lowering the pH of the rinse following the replenisher section was found to have a positive effect on resist survival in marginal cases.

9.2.2 Total Aqueous Resist (continued)

B	*PROBLEM*	*CAUSE*	*ACTION*
Photoresist image soft, dull in appearance, and easily damaged after development. (See Figure 9–10.)		Underexposure.	Use density step tablet to establish optimum exposure condition per dry film data sheet.
		Elevated solution temperature.	Control solution temperature per supplier's specification. (All aqueous resists do not develop at the same temperature.)
		Incorrect developing solution makeup – solution more concentrated than recommended or different chemicals used in preparing the 1% makeup.	Make up solution per the dry film data sheet; analyze freshly made up solution to monitor makeup procedure and monitor solution pH.
		Overdevelopment.	Establish proper development condition with recommended breakpoint. (Monitor development breakpoint as a process control. Adjust conveyor speed to maintain a consistent breakpoint.)
		No hold time between exposure and development.	Enforce supplier's recommended hold time (if required); increase the exposure level to reduce the dependence on a hold time for in-line processing.
		Premature lifting of polyester coversheet during board trimming or handling.	Instruct operators to develop panel and rework panel through prelamination cleaning and lamination.

C	*PROBLEM*	*CAUSE*	*ACTION*
Resist breakdown during pattern plating. (See Figure 9–11.)		Hot, mildly alkaline soak cleaner in the pre-plate cleaning line.	Replace with recommended acid cleaner per dry film supplier's recommendation. (Also see Section 9.2.3.3.)
		Long immersion time, high concentration and/or high temperature of the hot soak cleaner in the pre-plate cleaning line.	Obtain the recommended list of cleaners and operating conditions for use with the total aqueous dry films from supplier. (Hot acid cleaners are preferable.)
		Out of control electro-cleaner in the pre-plate cleaning line: high temperature, high current density, high concentration, and/or long immersion time.	Control electro-cleaner for proper activation of the exposed copper surface without stripping the resist image. (Aqueous resists have a narrow process window in this cleaning solution.) Establish operating conditions per the supplier's data sheet.

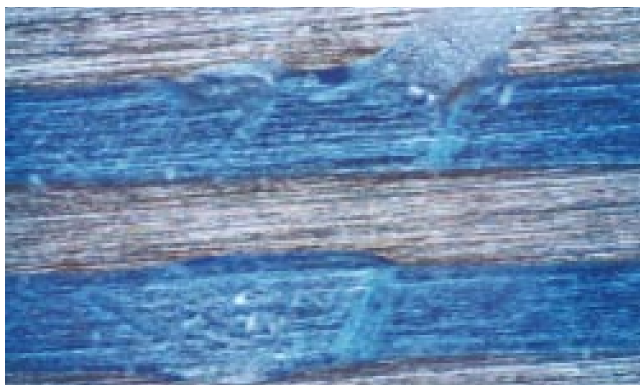


Figure 9–10 Photoresist image soft, dull in appearance

Figure 9–11 Resist breakdown during pattern plating

9.2.2 Total Aqueous Resist (continued)

D PROBLEM	CAUSE	ACTION
Incomplete stripping. (See Figure 9–12.)	Wrong chemistry.	Establish optimum stripping chemistry per dry film supplier's data sheet and in-house testing.
	Low solution temperature.	Maintain solution temperature per supplier's recommendation. Calibrate temperature controller and monitor solution temperature.
	Spent solution.	Establish stripper loading capacity and schedule changeover to fresh solution. Monitor loading of stripper chemistry and enforce necessary process controls per supplier's recommendation.

E PROBLEM	CAUSE	ACTION
Redeposition of stripped resist back onto the circuit pattern. (See Figure 9–13.)	Insufficient water rinsing after stripping.	Increase the water pressure and length of rinse chamber after stripping. Dump spent solution and replace with fresh makeup; inspect and clean or replace water rinse nozzles as required.
	Inadequate filtration of stripper solution.	Improve solution filtration method; change filters frequently; use solution overflow wire to trap large particles of stripped resist; investigate available equipment designed to remove resist particles.
	Wrong chemistry.	Utilize stripper chemistry per supplier's recommendation.
	Panels dry between strip solution and the water rinse.	Eliminate dead space and venting between the strip chamber and the rinse chamber in conveyorized equipment. Minimize the hold time between the strip tank and water rinse when manually stripping in a deep soak tank; flood the stripped board surface with water immediately after the panel leaves the hot stripping solution.
	Incorrect stripping breakpoint (stripping time not long enough).	Verify that stripper breakpoint is 50% or less.

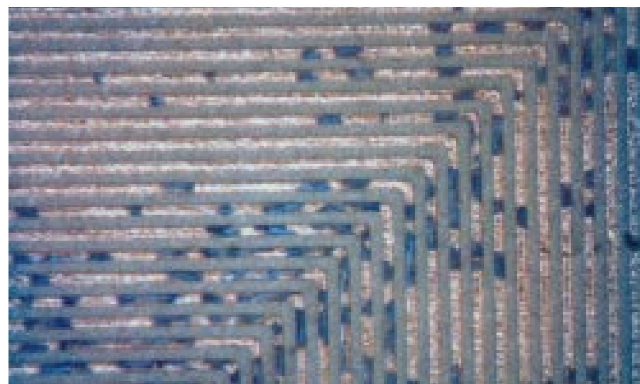


Figure 9–12 Incomplete stripping

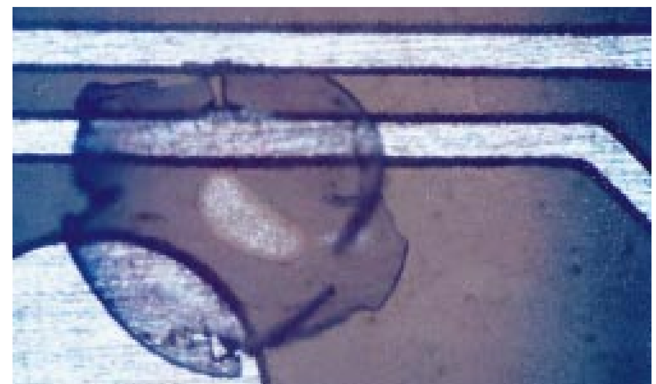


Figure 9–13 Redeposition of stripped resist

9.2.3 Semi-Aqueous Resist

Develop in an alkaline solution containing a water-miscible solvent and strip in the same type of chemistry with high pH and an elevated temperature. (See Example 9–2.)

A PROBLEM	CAUSE	ACTION
Incomplete development.	Underdevelopment.	Establish proper development conditions per supplier recommendations; developer breakpoint should occur between 25-50% of the developer chamber.
	Incomplete developer solution makeup.	Makeup per dry film data sheet and establish proper monitoring procedure.
	Low solution temperature.	Set solution temperature per dry film data sheet and calibrate equipment temperature controller.
	Spent developer solution.	Change spent solution; establish solution life based upon resist thickness and dry film usage. Establish schedule for changeover of developer solution to prevent excessive loading - or install a feed and bleed system to maintain the bath.

B PROBLEM	CAUSE	ACTION
Photoresist image soft and easily damaged after development.	Underexposure.	Use density step tablet to establish proper exposure level per dry film data sheet.
	Elevated temperature and/or increased strength of developing solution.	Set developer temperature per supplier recommendation. Measure temperature of working solution with thermometer and calibrate temperature controller. Measure pH of developer solution and establish proper procedure for developer makeup.
	Overdevelopment.	Establish development condition per dry film data sheet. Monitor breakpoint between 25-50% of the length of the developer chamber.

C PROBLEM	CAUSE	ACTION
Breakdown and under-plating during pattern plating.	Hot alkaline cleaner in the pre-plate cleaning line.	Replace alkaline cleaner with neutral or hot acid cleaner as the hot soak cleaner prior to the micro-etch. (Install hot soak cleaner per dry film data sheet. Hot alkaline cleaners will act as resist strippers for semi-aqueous and total aqueous dry film resists. These cleaners should be avoided.)

D PROBLEM	CAUSE	ACTION
Incomplete stripping.	Wrong stripper chemistry.	Use recommended strippers per supplier and dry film data sheet.
	Low solution temperature.	Control temperature per supplier's recommendation.
	Spent stripper chemistry.	Establish stripper loading capacity and schedule changeover to fresh solution. Monitor loading of stripper chemistry and enforce necessary process controls per supplier's recommendation.

E PROBLEM	CAUSE	ACTION
Redeposition of stripped resist back onto the circuit pattern.	Insufficient water rinsing after stripping.	Increase the water pressure and length of rinse chamber after stripping. Dump spent solution and replace with fresh makeup; inspect and clean or replace water rinse nozzles as required.
	Inadequate filtration of stripper solution.	Improve solution filtration method; change filters frequently; use solution overflow wire to trap large particles of stripped resist; investigate available equipment designed to remove resist particles.
	Wrong chemistry.	Utilize stripper chemistry per supplier's recommendation.

9.2.4 Solvent Resist

Develop in 1,1,1-trichloroethane and strip in methylene chloride blend.

A PROBLEM	CAUSE	ACTION
Photoresist scum after develop-ment.	Water in the solvent.	Analyze incoming solvent for water content. Inspect dryer for adequate removal of water from the solvent before it enters the developing unit. Eliminate seepage of water into the clean solvent chamber from the water rinse chamber. Sample solvent periodically and analyze for water content; review analytical results with solvent supplier.
	Improper solvent temperature.	Maintain developing solution at 18.3°C ± 5, or as recommended by dry film supplier.
	Contaminated incoming solvent.	Sample incoming solvent and analyze for water content and purity of the 1,1,1- trichloroethane. Review results with solvent supplier.
	Dissolved resist in the clean solvent rinse chamber. (The clean solvent chamber functions as a rinse for the board prior to the water rinse.)	Increase flow rate of clean solvent into the clean rinse. Check rollers between chambers and adjust to minimize seepage into the clean solvent chamber.
	Rinse water temperature too high.	Maintain temperature under 21°C.

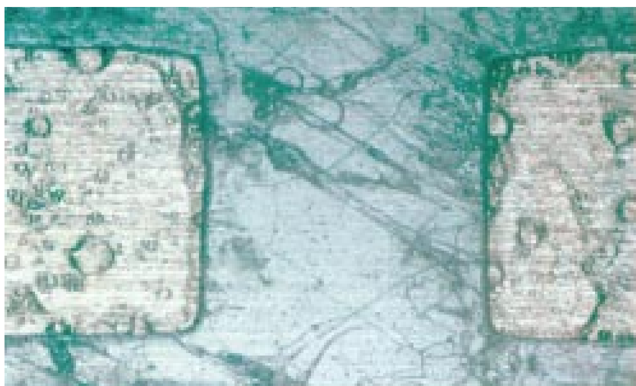


Figure 9–14 Photoresist scum after development

9.3 LIQUID PHOTORESIST

A photosensitive liquid photoresist can be applied to a clean copper surface for printing of the desired circuit pattern. Application methods include dip coating, controlled withdrawal, flow coating, roller coating, spray coating, and whirl or spin coat. After application and drying (if recommended) the artwork circuit pattern is printed in the resist through exposure to UV light. During development the unexposed areas are washed out. The remaining exposed image functions as an etch or plating resist and is subsequently stripped from the board.

Negative and positive resists are available. Negative resists utilize the exposed resist image for etching and plating. Positive resists use the unexposed image for plating and etching. Negative and positive working resists also differ in the required developing and stripping chemistries. Negative resists are generally solvent-based while positive resists require alkaline aqueous processing.

9.3.1 Common Problems of Liquid Photoresist

A PROBLEM	CAUSE	ACTION
Resist breakdown in plating.	Non-uniform resist thickness.	Follow supplier's recommendation for application of photoresists. (Control viscosity, temperature, etc., of the liquid for uniform coating. Establish optimum conditions for application per supplier recommendations.)
	Incomplete drying after application.	Dry per supplier's recommendation.

B PROBLEM	CAUSE	ACTION
Line width reduction or inability to develop out unexposed resist. (See 9.2.1 C.)	Underdevelopment.	Establish proper development conditions per supplier's data sheet. (Monitor temperature of developer solution and time.)
	Elevated drying temperature.	Monitor convection or infrared drying oven and set per supplier's recommendation.

C PROBLEM	CAUSE	ACTION
Photoresist image damage during development (Image lifting and/or ragged circuit lines after development).	Underexposure.	Establish proper exposure setting per supplier's recommendation. (Density step tablets provide ongoing process control.)
	Overdevelopment.	Establish proper development conditions per supplier's data sheet. (Time, temperature and concentration of the developing solution are critical process parameters which must be controlled.)
	Elevated developer temperature.	Monitor temperature and control per data sheet.
	Inadequate surface preparation prior to application of liquid photoresist.	Inspect panels prior to resist application for a clean water break test. (A clean panel should hold a continuous film of water for 15 to 25 seconds. Establish proper board cleaning conditions per the equipment manufacturer's recommendation. Proper maintenance of the cleaning unit is required to ensure adequate cleaning of copper panels prior to resist application.) (Also see Section 8.0.)
	Insufficient application and drying of resist.	Adjust application method and control drying per supplier's recommendations. Control viscosity/solids content, temperature, etc., for uniform coating thickness.

9.3.1 Common Problems of Liquid Photoresist (continued)

D	PROBLEM	CAUSE	ACTION
Resist breakdown and lifting during etching. (See 9.2.1 E.)		Inadequate surface preparation.	Inspect panels prior to resist application for a clean water break test. (A clean panel should hold a continuous film of water for 15 to 25 seconds. Establish proper board cleaning conditions per the equipment manufacturer's recommendation. Proper maintenance of the cleaning unit is required to ensure adequate cleaning of copper panels prior to resist application.) (Also see Section 8.0.)

E	PROBLEM	CAUSE	ACTION
Resist breakdown, edge lifting and underplating during pattern plating. (See 9.3.1 D.)		Underexposure.	Use density step tablet to monitor exposure conditions and set per supplier's recommendation. (Maintain exposure condition within one step of the recommended step tablet reading.)
		Overdevelopment.	Establish proper development conditions per supplier's data sheet. (Time, temperature and concentration of the developing solution are critical process parameters which must be controlled.)
		Out-of-control hot soak cleaner in the preplate line - high temperature, high concentration and long immersion times.	Establish cleaning conditions per photoresist data sheet and hot soak cleaner data sheet.
		Out-of-control electro-cleaner in the preplate line - high temperature, high concentration, long immersion time and/or high current density.	Establish cleaning conditions per photoresist data sheet and supplier of electro-cleaner data sheet. (Monitor this process daily.)

F	PROBLEM	CAUSE	ACTION
Copper-to-copper peelers after pattern plating. (See Figure 9-7.)		Inadequate preplate cleaning prior to copper pattern plating.	Establish proper preplate cleaning process. Recommended preplate cleaning includes: Hot soak cleaner Micro-etch Acid dip. The acid dip generally consists of 10% sulfuric acid. Sufficient rinsing is required between each soak cleaner. No rinse is required between the sulfuric acid soak and acid copper sulfate bath. Control of the micro-etch is critical in eliminating peelers. This solution is required to provide a virgin copper surface for electro-plating. Concentration, temperature, and immersion time in the micro-etch bath are critical. (Also see Sections 8.2 and 10.1.1.)
		Electro-cleaning process out-of-control – short immersion time and/or low current density.	Establish cleaning conditions per photoresist data sheet and supplier of electro-cleaner data sheet. (Monitor this process daily and train operators in process control.)
		Excessive hold time between resist application and development.	Schedule production to minimize hold time. (Increase time in the micro- etch bath or in the electro-cleaner.)

9.3.1 Common Problems of Liquid Photoresist (continued)

G PROBLEM	CAUSE	ACTION
Skip plating in the developed-out circuit pattern.	Polymerized resist residue in the developed-out circuit pattern.	Inspect phototool for scratches, nicks and cuts in the circuit image.
	Unpolymerized resist residue in the circuit pattern.	Establish proper development conditions per supplier's recommendations. (Establish optimum developer solution concentration, temperature and time.)
	Shop oil and fingerprints not removed from board during preplate cleaning.	Establish optimum hold time in the hot soak cleaner during preplate cleaning. Temperature, concentration and immersion time should be controlled per supplier's recommendation. (Also see Section 8.2.)
	Touch-up ink spillover into the circuit pattern.	Train operators in the proper procedure for applying touch-up ink. Use touch-up ink per supplier's recommendation. (Some inks require UV cure and others a thermal bake to prevent seepage into the developed-out circuit pattern.)

H PROBLEM	CAUSE	ACTION
Photoresist residue on the board after stripping.	Short immersion time.	Establish optimum strip time and monitor process. (Adjust the strip time with increased loading of the stripper solution. Inspect first article for adequate stripping.)
	Excessive bake temperature after development.	Monitor baking temperature and adjust per supplier's recommendation. Increase strip time.
	Wrong stripper chemistry.	Strip in chemistry specified by photoresist data sheet.
	Stripper solution out-of-control - spent stripper, low temperature, short immersion time.	Establish process controls per supplier's recommendations (monitor process to ensure control). Inspect first article for adequate stripping.
	Redeposition of stripped resist.	Replace stripper bath; clean out immersion tank or spray unit. Improve filtration method of stripper bath. Control stripper chemistry per supplier's recommendations.

9.4 SCREEN PRINTED RESIST

The resist image can be transferred to a clean copper surface through a screen stencil of the desired circuit pattern. The liquid ink is forced through open areas in the screen to form the desired circuit pattern on the copper surface. The screen is then removed and the resist image cured. UV and thermal cure resist systems are available. The UV type is a 100% solids system that requires exposure to strong UV light for curing. The thermal type requires a high temperature bake to drive off solvents and cure.

9.4.1 Common Problems of Screen Printed Resist

A PROBLEM	CAUSE	ACTION
Shadows or ghost on screened boards. (See Figure 9-15.)	Excessive flow of ink under stencil while printing.	Adjust pressure and angle of squeegee to reduce ink lay down.
	Improper technique.	Flood (flow coat only) immediately before printing.
	Screen fabric too coarse.	Use proper fabric as recommended by ink supplier.
	Inadequate stencil cavity.	Change from direct to direct/indirect stencil.
	Excessive ink lay down.	Minimize deposit with proper squeegee hardness, angle, pressure, flooding, etc.
	Screen moves due to incorrect breaking of work.	Sharpen squeegee to shear ink. Increase off-contact distance (snap-off distance). Adjust screen tension (note - this can only be done during the screen making process).
	Poorly mixed ink.	Follow supplier's recommendation for mixing.

B PROBLEM	CAUSE	ACTION
Ink deposit too heavy.	Screen fabric too coarse.	Use supplier recommended fabric. (For stainless steel, make sure percent open area and wire diameter are correct.)
	Squeegee too soft or not sharp.	Select squeegee durometer and sharpness per ink supplier's data sheet.
	Squeegee angle too low.	Increase angle (more vertical).
	Excessive ink applied to screen during flood stroke (flow coat).	Adjust flood bar to apply only minimum amount of ink to screen.
	Squeegee pressure during print stroke too low.	Adjust pressure for desired thickness.

C PROBLEM	CAUSE	ACTION
Bubbles in the screen printed image. (See Figure 9-16.)	Contaminated screen.	Use virgin screen.
	Screen fabric coarse.	Use supplier recommended fabric. (For stainless steel, make sure percent open area and wire diameter are correct.)
	Excessive print speeds.	Use lower viscosity ink, different technique or different fabric. Slow down print speed if possible.
	Old ink, shelf life exceeded.	Change to newer lot number. Improve inventory rotation.

9.4.1 Common Problems of Screen Printed Resist (continued)

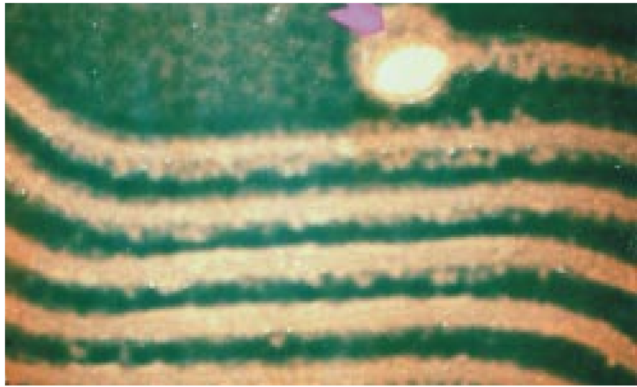


Figure 9–15 Shadows or ghosts

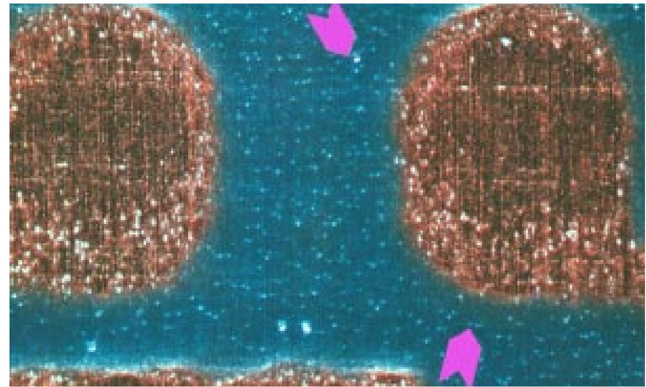


Figure 9–16 Bubbles in screen printed image

D PROBLEM	CAUSE	ACTION
Large voids in the resist image (fish eyes or craters).	Contaminated panel.	Clean panel. Recheck preparation and panel handling prior to screening.

E PROBLEM	CAUSE	ACTION
Ink runs through screen. (See Figure 9-17.)	Screen fabric too coarse.	Use supplier recommended fabric.
	Screen left flooded for long periods of time.	See supplier's recommendation in data sheet for maximum flood period.

F PROBLEM	CAUSE	ACTION
Slow break away on printing. (See Figure 9–18.)	Viscosity of ink too great.	Stabilize ink at room temperature. Use lower viscosity ink.
	Insufficient off-contact (snap-off distance).	Increase peel-off on presses equipped with automatic peel-off.
	Old ink beyond shelf life.	Change to newer lot number. Improve inventory rotation.
	Print speed too fast or surface area too great.	Slow down print speed. Use larger screen frame for panel size, to improve peel-off.
	Too much ink lay down.	Use finer mesh screen. Use harder squeegee.

Figure 9–17 Ink runs through screen

Figure 9–18 Slow break away on printing

9.4.1 Common Problems of Screen Printed Resist (continued)

G PROBLEM	CAUSE	ACTION
Excessive pinholing of screened resist during pattern plating. (See Figure 9-19.)	Viscosity too high to permit flowing of resist.	Adjust viscosity per supplier's recommendation.
	Viscosity too low for dry cycle (thermal type).	Monitor dry cycle and adjust per supplier's recommendation.
	Inadequate surface preparation prior to screen printing.	Make sure that surface of copper is free of all contaminants, particularly those which might be volatilized during curing. (Utilize water break test as defined in 9.2.1 D.)
	Incompatibility between ink and plating bath.	Consult product data sheet and suppliers for ink and bath compatibility.
	Current density too high.	Recalculate required current density and monitor during plating.

H PROBLEM	CAUSE	ACTION
Bleeding of plating resist onto conductors and/or lands. (See Figure 9–20.)	Screen tension too loose.	Follow manufacturer's recommendation for screen tension.
	Improper blotting of screen.	Follow screen ink supplier's recommendation.
	Screen image clearance around pads too small.	Measure stencil and artwork and replace as required.
	Screen too close to work.	Increase space as required in supplier's data sheet.
	Screening area too warm.	Maintain screen room between 21 and 24°C or as recommended by screen ink supplier.

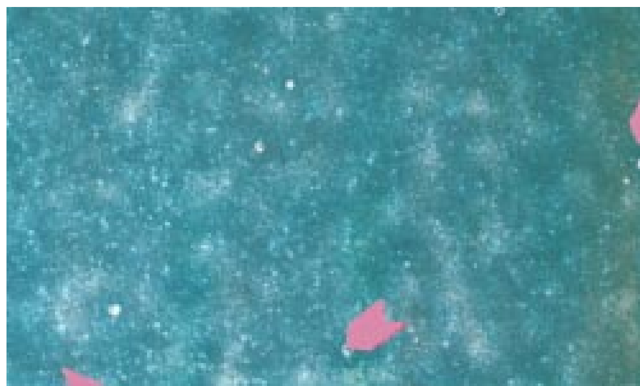


Figure 9–19 Excessive pinholing

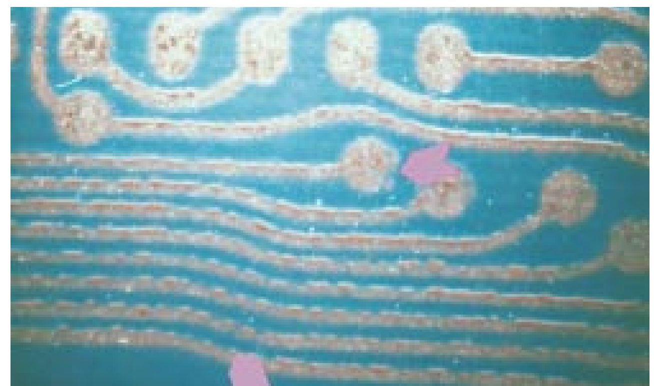


Figure 9–20 Bleeding of plating resist onto conductors

9.4.1 Common Problems of Screen Printed Resist (continued)

J PROBLEM	CAUSE	ACTION
Very small voids in conductor patterns, going through copper foil to substrate. (See Figure 9-21.)	Small unwashed spots on screen which produce voids in the screened image, thus allowing etch out of copper.	Clean screen. Verify screen prior to release over light table. Verify each screen setup by screening on white paper and inspecting over a light table.

K PROBLEM	CAUSE	ACTION
Ragged line definition. (See Figure 9–22.)	Poor stencil image, worn or improperly made.	Fabricate new screen using direct/indirect combination.
	Poor line definition in the original artwork.	Correct artwork and remake screen.

Figure 9–21 Very small voids

Figure 9–22 Ragged line definition

9.4.1 Common Problems of Screen Printing Resist (continued)

L	PROBLEM	CAUSE	ACTION
Ink soft and easily marred. (See Figure 9–23.)		Improper curing.	Adjust oven temperature or UV cure speed per supplier's recommendations.
		Too heavy ink deposit.	Reduce thickness as required.
		Poor surface preparation (poor image adhesion).	Review surface preparation method and handling prior to screen printing.

M	PROBLEM	CAUSE	ACTION
Resist failure in etching.		Improper curing or too heavy an ink deposit.	Adjust as required per supplier's recommendation.
		Incompatibility with etching solution (alkaline).	Check compatibility in supplier's data sheet and change etchant or ink as required.
		Poor adhesion due to inadequate surface preparation.	Verify panels passed the water break test after normal surface preparation. Review surface preparation method and handling prior to screen printing.

Figure 9–23 Ink soft and easily marred

9.4.1 Common Problems of Screen Printed Resist (continued)

N PROBLEM	CAUSE	ACTION
Resist softens during plating cycle and/or plating occurs on resist.	Inadequate cure cycle for resist.	Review and adjust cure cycle per manufacturer's recommendations. (Also see 9.4.1 Q.)
	Alkaline cleaner in use prior to electroplating.	Switch to acid cleaner.
	Solvent in preclean solution.	Contact preclean supplier for assistance. Change preclean to non-solvent type.
	Preclean parameters incorrect (too high temperature or cycle too long).	Adjust preclean parameters per ink manufacturer recommendations.
	PH of plating bath out of balance (too high).	Check bath and adjust.
	Ink incompatible with plating cycle.	Evaluate alternate plating resist ink for compatibility with electroplating process.

P PROBLEM	CAUSE	ACTION
Resist residue remaining on the board surface after stripping.	Incompatible stripping solution.	Use chemistry per ink supplier's data sheet.
	Spray pressure in conveyorized unit too high.	Reduce spray pressure in chamber; add more nozzles at chamber entrance.
	Saturated stripping solution and/or plugged nozzles.	Monitor solution loading and conduct preventative maintenance with careful inspection of spray nozzles. Improve filtration system. Change out bath if saturated.
	Low solution temperature.	Adjust as specified on data sheet.
	Ink is trapped by overplated copper (especially small, surrounded areas of resist).	Presoak boards to soften and remove the bulk of the resist, then strip normally. Investigate alternate stripper chemistry that will better dissolve the ink. Optimize copper plating process to minimize overplating. (See Section 10.2.)
	Over-cured resist.	Adjust cure cycle per supplier recommendations.

Q PROBLEM	CAUSE	ACTION
Non-uniform or inadequate cure on boards (resulting in plating or etching problems).	Poor oven air circulation or inadequate exhaust (thermal cure).	Improve air circulation and exhaust (clean inlet and outlet, open damper, check for adequate operation of blower). Space boards further apart to compensate.
	UV reactor bulbs old, reflectors dirty, etc.	Check lamp output using a radiometer (should be done regularly). Clean the system.

R PROBLEM	CAUSE	ACTION
Skips or voids in print.	Resist not completely filling openings in mesh.	Use finer mesh screen. Use harder squeegee. Print with squeegee at an angle to circuitry (snowplow). Use flood stroke before printing.

S PROBLEM	CAUSE	ACTION
Step plating (swirled pattern in copper) of printed resist panels in copper electroplate.	Ink not properly cured.	See 9.4.1.Q.
	Panels were stacked together immediately after curing (especially UV) before being allowed to cool completely.	Change procedure to prevent stacking of panels after curing.
	Resist leaching into plating bath.	Review ink cure process. Carbon treat copper baths regularly. (See Section 10.0.)

9.5 ELECTROPHORETICALLY DEPOSITED PHOTORESIST

Electrodeposition of organic coatings works much like a plating process. The parts to be coated serve as one electrode and the tank or auxiliary electrode serve as the oppositely charged electrode. The parts to be coated are immersed into a coating tank by conveyor or program transfer system. The charged organic particles are electrolytically attracted to the parts oppositely charged and are deposited. Electrodeposition continues until sufficient coating thickness is applied so as to insulate the article being finished and then the process is completed.

It follows that electrodeposited coatings can be either anionic or cationic in nature (see Figure 9-31). When first introduced in the early 1960s, commercial electrodeposition coatings were limited to anionic systems. The theoretical qualities of cationic electrodeposition were recognized early in the development, however the existing technology and the complexity of the systems did not indicate early success for developing commercial coatings.

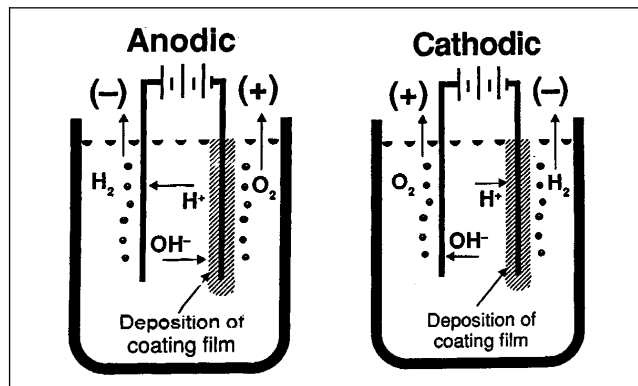


Figure 9–24 Electrophoretic deposited resist illustration

In cationic systems, the applied potential causes the positively charged polymer ions to move to the cathode. While the coating is being deposited, hydrogen is simultaneously evolved. There is no dissolution of metal from the substrate so the presence of metal ions in the coatings and the bath are avoided (refer to diagram). When applied, the cationic systems are alkaline in nature and tend to be inherent corrosion inhibitors.

In anionic systems, oxygen gas is liberated and metal from the anode is dissolved with subsequent inclusion of metal ions in the deposited coating. Electrodeposited anionic coatings are acidic in nature.

9.6 LASER IMAGING OF PHOTORESIST

Introduced in the late 1970s for imaging dry film photoresists, laser imaging of photosensitive materials has become an accepted technology used in the printing industry. This technology utilizes a computer-controlled high energy laser to image these resists. Today newspapers, magazines and other printed materials are printed with plates generated from laser-imaging equipment.

Direct laser imaging technology as first introduced would eliminated the need for (1) artwork-generating equipment, and (2) conventional exposure equipment. Computer-generated circuit patterns are imaged in the dry film photoresist without the use of production masters. Magnetic tape containing data on the circuit pattern is transferred to the computer controlled laser. The computer reads this data and prints the design circuit pattern in boards laminated with dry film photoresist. Current laser equipment will print one side of the board during exposure. No double-sided laser exposure units are available. Each board requires two separate exposures in order to image both sides. Normal dry film processing through lamination, development, plating, etching and stripping is not altered by the laser imaging step.

Major advantages touted are increased resolution, direct imaging without the use of artwork and increased automation of the imaging process.

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Section 10
Electroplating

10.0 ELECTROPLATING

Electroplating in the manufacture of printed wiring is used to build up a metallic pattern on copper-clad substrates. Plating acceptability is judged by plating thickness, adhesion, ductility and the presence of inclusions, nodules, voids or cracks. Factors that affect these criteria are board surface preparation, board racking and handling, and solution filtration and control.

Problems common to all plating are grouped under the general subsection 10.1. Problems related to a specific metal to be plated are grouped under the subsection for that metal.

10.1 GENERAL

A	*PROBLEM*	*CAUSE*	*ACTION*
Metal-to-metal adhesion failure (peelers).		Inadequate preplate cleaning process.	Use hot soak cleaner to remove oils and fingerprints. Use micro-etch to remove contamination from copper surface. Check activity (etch rate) of micro-etch. Check activity of electro-clean.
		Carry-over of wetting agents from hot soak cleaners/insufficient rinsing.	Check rinsing procedures. Increase water flow and incorporate spray rinse. Increase temperature of rinse water. Use multiple overflow rinse tanks followed by spray rinse.
		Entry into plating bath without power on.	Review proper plating procedure.
		Excessive current density.	Review proper plating procedure. Turn rectifier power down to low setting.
		Persulfate residues.	Use 5-10% sulfuric acid dip after persulfate micro-etch.
		Inadequate water rinsing after developing photoresist.	Increase water spray pressure. Check for plugged nozzles and good spray pattern. Increase water temperature to at least 16°C.

10.1 GENERAL (continued)

B PROBLEM	CAUSE	ACTION
Partial plating of circuit pattern (skip plating/step plating).	Resist residues.	Recheck resist development times and procedures. Check density of phototool lines. Check for plugged spray nozzles in developer unit.
	Fingerprints and oils.	Use hot soak cleaner in preplate cleaning process. Improve handling procedures.
	Excessive organics in plating bath.	Run Hull cells on plating bath, especially copper pyrophosphate. Carbon treat per supplier's recommendation. Control additive level.
	Touch-up ink smeared on circuit pattern.	Review touch-up materials and procedures.
	Underexposure of photoresist.	Review exposure procedure. (See Section 9.0.)
	Plating bath chemistry out of control.	Run chemical analysis on plating bath and adjust per supplier's specifications.
	Carry-over of wetting agents from hot soak cleaner.	Increase rinse time and use spray rinse on withdrawal of the panel.
	Bleed-out of developer residuals from resist surface.	Use 30-minute minimum hold time after development to allow equilibration. Use low temperature bake to accelerate solvent removal (10 minutes at 94°C).
	Contaminated photoresist developing solution.	Increase solution regeneration, keeping the last chamber clean.

C PROBLEM	CAUSE	ACTION
Uneven plating thickness (side-to-side).	Area not equal on both sides of cathode, especially on boards with ground plane on one side and circuitry on other side.	Balance area on both sides of cathode. Balance anode-to-cathode area on each side of cathode by moving anodes. Reverse one-half of the boards in rack to balance total cathode areas on both sides. Consider independent side-to-side rectification.

D PROBLEM	CAUSE	ACTION
Thin plating.	Insufficient current or time in the plating bath.	Verify areas on panel used to determine current and ensure that proper current density and process time are being used.
	Poor electrical contact between boards and racks or between racks and cathode bar.	Check all electrical contacts including rectifiers, panels, etc.

10.1 GENERAL (continued)

E PROBLEM	CAUSE	ACTION
Deposit distribution poor across surface.	Poor geometric disposition of anodes with respect to work load.	Establish variations by non-destructive thickness determinations. Re-position anodes in accordance with results of thickness tests.
	Poor electrical contacts to anodes.	Check each connection between anode and anode rail using a voltmeter during operation. Clean and remake connections, ensuring consistent voltage drop for all anode rail connections.
	Insufficient acid for metal content.	Determine acid content and increase to within supplier recommendations.
	Excess metal content for current density.	Determine metals content. Dilute the bath or operate with inert anodes until levels are within supplier recommendations. Remove soluble anodes during idle periods.
	Excessive agitation.	Reduce agitation.
	Poor agitation pattern.	Examine sparging system and adjust agitation to produce more uniform flow over the work piece.

F PROBLEM	CAUSE	ACTION
Solution foaming.	Air in pump/filter system.	Overhaul the pump and pipe work to prevent air leaks. Examine the level of liquid in the sump with respect to the sump intake and raise level if necessary.
	Excessive solution turbulence.	Reduce agitation and re-design overflows to prevent cascading and aeration of solution.

G PROBLEM	CAUSE	ACTION
Partial plating "Mousebites."	Photoresist under-exposure.	See Section 9.0.
	Low pressure sprays in developing, including rinsing.	Improve spray pressure. Consult with supplier(s) of photoresist and developing solution.
	Poor drying after the developing operation, leaving a dried on "pattern" on the panel.	Improve drying.
	Residual anti-tarnish from electroless copper operation.	Insure complete removal of anti-tarnish during developing. Consult with all suppliers involved.

10.2 COPPER ELECTROPLATING

10.2.1 General

A PROBLEM	CAUSE	ACTION
Voids in holes.	Insufficient electroless copper.	Balance electroless bath constituents. Lengthen time in electroless bath. Lower current upon electrolytic bath entry if sufficient thickness of electroless copper cannot be obtained. Air bubble entrapment (improve solution and/or panel movement to force solution through holes). (Also see Section 7.0.)
	Particles in solution.	Filter bath. Spray rinse boards prior to electroplating. Check all preplating solutions for suspended matter.
	Dissolution of electroless copper.	Check concentrations of pretreatment line solutions such as preplate acid dips. Also, do not use incompatible acid dips, such as fluoboric acid or proprietary dry acid salts containing nitrides or fluorides. Due to corrosive nature of solution to copper, live entry into tank is recommended. Parts left in copper plating bath with no current on. Reduce time in micro- etch.
	Extensive time in acid pre-dip.	Reduce time.

B PROBLEM	CAUSE	ACTION
Burned copper deposit.	Current density too high, or uneven plating pattern, resulting in high current density areas on panels.	Decrease current. Optimum current density depends on degree of agitation, board configuration and operating current density range of proprietary brightener system in use. Add thieving in high current density area of panel.
	Poor plating bath and part agitation.	Increase air flow to raise solution 25.4 to 38.1 mm above level at rest. Use filtered, low pressure air. Agitate cathode bars if possible (perpendicular to panel face). Check anode-to-cathode distance; at 30 ASF, minimum recommended distance is 0.15 meters.

C PROBLEM	CAUSE	ACTION
Nodular copper plating.	Inadequate filtration allowing deposition of particles from the bath.	Plating bath requires continuous filtration with a filter capacity of 2-3 bath turnovers per hour.
	Anodes not bagged or bags torn.	Bag anodes and check for tears, as per supplier's recommendation.
	Contamination of bath.	Check tank for foreign objects (i.e., boards, clips, racks, tools, etc.). Check solutions prior to plating for suspended particulate matter which may have been dragged in. Wash sizing from anode bags and filter cartridges prior to use.

D PROBLEM	CAUSE	ACTION
Pitted copper plating.	Insufficient or non-uniform air agitation in bath.	Increase air agitation and ensure its uniform distribution.
	Grease or oil contamination.	Carbon treat bath. Determine source of contamination (hot oil? grease from hoist?) and eliminate.
	Improper filtration.	Filter bath continuously to remove any nodules and/or particles from solution.

10.2.2 Copper Sulfate

A PROBLEM	CAUSE	ACTION
Burned deposits.	Copper concentration too low for current density being used.	Maintain copper sulfate level per supplier's recommendation, or lower current density. (Add liquid copper sulfate concentrate if available. If not, carbon purify copper sulfate salts prior to additions to plating tank.)
	Acid content too high.	Dilute bath. Maintain acidity per supplier's recommendation.
	Temperature too low.	Heat solution. Optimum operating temperature generally is 21-26°C.
	Brightener additives out of balance.	Add high current density additive component to reduce edge burning. Add low current density additive component to reduce burning on panel faces (circuits). Evaluate all additive additions in test cell prior to adding to plating tank.
	Anodes too long or too many.	Anodes should be 50.8-76.2 mm shorter than panels. Tighten anode bags. Remove some anodes from solution. Anode-to-cathode ratio should not exceed 2:1.
	Insufficient solution agitation.	Increase/improve agitation.

B PROBLEM	CAUSE	ACTION
Poor thickness distribution.	Poor throwing power due to: Copper content too high; Acid content too low; Temperature too high; Metallic contamination; or Hole aspect ratio too high for existing conditions.	Dilute bath. Add sulfuric acid. Chill bath. Dummy plate bath at low current density. (See 10.2.2 J.)
	One side of panel heavier deposit than other.	Check cathode areas - calculate per side. Balance anode-to-cathode area on each side (2:1 ratio), or reverse one-half of the racks or boards to balance total cathode areas on two sides. Consider dual (side-to-side) rectification.
	Poor leveling.	Add leveler component of additive system if available. Increase current density. Analyze bath for chlorides; adjust per supplier's specification. Increase anode area. Filter bath. Check cleaning solution prior to plating tank.
	High current density areas on board.	Add ''thieving'' if possible (must be within 12.7 mm of circuit). Use anode or cathode shields to even the current flow. Improve racking - increase contact area; use picture frame racks or copper core racks to improve current distribution.
	Stagnant solution boundary layer.	Increase air agitation. Check location of air spargers.
	Uneven current distribution.	Design anode shields to make resistance of solution more uniform. Check racks for points of high contact resistance.

Example - 10-1 REDUCTION OF COPPER THICKNESS VARIATION

- Goal: Reduce the variation of electroplated copper thickness by 50% and establish a process capability of 1.33 or greater.

- Parameter Diagnostics: An examination of historical data revealed that all three common sources of variation were contributing to this problem. Not only was the variation across a panel excessive (within a piece), but the variation between panels on a rack were excessive (piece to piece) and the thickness and variation changes from day to day (over time). In this situation, diagnostics of the sources of variation did not reduce the amount of work required but it did better define the problem.

- Measurement System Evaluation: The only through-hole method available at this time is microsection. Because of the time involved getting data, Beta Backscatter will be used to measure surface thickness instead.

  A Measurement System Evaluation per the requirements of PC-90 was performed where 3 different operators measured 10 locations on 3 separate days. The total variation in the gage was found to be less that 20% of the tolerance window and was considered acceptable.

- Brainstorming: A team was assembled that consisted of 3 platers, a chemist, a quality engineer, a manufacturing supervisor and 2 engineers. During the brainstorming session, the factors that are listed in Table 10-1 were identified as possibly affecting thickness variation.

  A ranking of these variables was performed and the following factors were felt to be important by the brainstorming team.

  —Copper Concentration
  —Sulfuric Acid Concentration
  —Air Flow Rate
  —Current Density
  —Robber Geometry
  —Shielding
  —Racks
  —Flight Bars
  —Rectifier Ripple

- Initial Capability Assessment: The process under study was panel plating of double sided boards. For our initial capability assessment, 50 panels were plated over a period of 2 days as time became available on the plating line. Five areas on each side of the panel were measured on Beta Backscatter and the average and standard deviation of those 10 readings recorded. Since our goal was to reduce variation, it is the standard deviation across a panel that is our response. The Average Variation was .270 mils with a standard deviation of .135. Since we do not have an actual specification limit for this parameter, we establish a goal of .5 mils variation across a panel. This results in Cpk of .56. This defines our beginning position.

- Optimization:

  Using the 9 variables identified during the brainstorming session, an L27 Orthogonal Array was defined using the following settings for those parameters.

Factor	*Level 1*	*Level 2*	*Level 3*
Copper Concentration	Low	Med	High
Sulfuric Acid Concentration	Low	Med	High
Current Density	Low	Med	High
Robber Geometry	12.7 mm Wide	25.4 mm Wide	51.0 mm Wide
Shielding	None	Design 1	Design 2
Racks	1	2	3
Flight Bars	1	2	3
Rectifier Ripple	Low	Med	High

Analysis of the experimental results showed that the significant factors were Copper Concentration, Air flow Rate, Current Density and Shielding. The other factors in the experiment were set using other criteria such as cost or availability.

- Confirmation and Final Capability Assessment:

  After completion of the experiment, a confirmation run and sanity check was performed. All factors except the 4 found to be significant were held at their normal levels.

Confirmation Run	*Sanity Check*	
Copper Concentration	High	Low
Air Flow Rate	High	Low
Current Density	High	Low
Shielding	Design 2	None

If the experiment were correctly performed, there would be a significant difference between these two sets of parameters. A total of 30 panels were plated at each set of conditions and measured with Beta Backscatter. These results are listed below.

Confirmation Run	*Sanity Check*	
Variation across a Rack	.149	.277
Standard Deviation	.091	1.44
cpk	1.44	.516

Parameter Control: Now that the results have been confirmed, a plan for control must be established. The

use of shields and the set point for current density are SOP that are controlled through documentation. The Copper Concentration and Air Flow Rate are parameters that need control. The following control plans were established.

Copper Concentration: Incease frequency of analysis from once per day to once per shift until stability is established. Plot data as Individual Value and Moving Range chart. Any evidence of lack of control is cause for immediate cessation of plating and adjustment of the solution.

Air Flow Rate: Add the recording of this value to the Plating Logbook. The plating tank has five stations with separate air spargers. Measurements of all five stations will be done once per hour and recorded on Xbar and R chart with subgroup of 5.

Table 10-1: Acid Copper Sulfate Electroplating Variables and Effects

	Responses										
	Overall Thickness	Physical Properties	Adhesion	Voiding	Thickness Variation	Aspect Ratio	Pink Ring	Roughness and Pitting	Folds & Inclusions	Innerlayer Separation	Solder-ability
Copper Concentration	X	X			X	X					
Sulfuric Concentration	X	X			X	X	X				
Chloride Concentration	X	X				X					
Additive Concentration		X			X	X					
Frequency of Analysis	X	X				X					
Metallic Contaminants		X	X			X					X
Organic Contaminants		X	X			X		X	X		X
Air Sparger Configuration		X			X	X					
Cathode Rod Agitation	X	X			X						
Air Flow Rate					X	X		X	X		
Filter Turnover		X									
Filter Micron Size		X						X			
Filter Pipe Location								X	X		
Anode Location					X						
Current Density	X	X			X	X		X	X		
Anode Rod Connections	X				X						
Amperage Setting	X	X			X						
Amperage Pattern	X				X	X					
Plating Time	X	X									
Robber Geometry		X			X						
Shielding	X	X			X						
Cathode Rod Connections	X				X						
Racks					X						
Flight Bars					X	X					
Rectifier Connections	X				X						
Saddle Location					X						
Spacing Uniformity					X						
Temperature Control	X	X	X				X				
Rectifier Ripple	X	X			X	X		X	X		
Microsection Process	X		X		X	X					
Optics of Microscope	X				X	X					
Dwell Time after ELCU			X							X	
Cleaner Temperature			X	X			X			X	
Cleaner Dwell Time			X	X			X			X	
Type of Cleaner			X	X			X			X	
Rinse Water Contaminants	X		X	X			X	X	X		
Rinse Times	X		X	X			X	X	X		
Agitation in Rinse Water			X	X			X	X	X		
Microetch Type			X	X			X			X	
Microetch Dwell Time			X	X			X			X	
Microetch Agitation			X	X			X			X	
Microetch Concentration			X	X			X			X	
Copper Conc in Microetch			X	X			X			X	
Sulfuric Dwell Time				X			X			X	

10.2.2 Copper Sulfate (continued)

C PROBLEM	CAUSE	ACTION
Nodular copper plating. (See Figure 10-1; also see Section 10.2.1C.)	Low anode phosphorous content. (Phosphorous increases tenacity of the anode film.)	Ensure phosphorous content in anodes is between 0.04% and 0.06%.
	Wrong type of anode used for plating bath.	Run functional test on anode. (Check supplier's recommendation.)
	Contamination from anodes.	Keep tops of anode bags above solution level. Change bags at regular intervals; inspect for holes. Some types of anodes can cause noduling.

D PROBLEM	CAUSE	ACTION
Pitted copper plating. (See Figure 10-1; also see Section 10.2.1C.)	Small, fine air bubbles in tank (especially if pitting is localized, on a particular area of panels or tank).	Major potential source is an air leak in pump. This is difficult to track down. Do not use air stones or similar to increase air agitation in tank.
	Incomplete resist development, resulting in "mouse bites."	Review photoresist steps in Section 9.0.
	Poor preplate cleaning.	Review acid cleaner and micro-etch steps, and their respective rinses.

E PROBLEM	CAUSE	ACTION
Streaked copper plating.	Additives out of balance (typically overdose).	Check with additive supplier to see if removal of some additive can be done by carbon treatment.
	Photoresist not compatible with high sulfate plating solution, causing leach-out into plating bath.	Assure resist compatibility with acid copper sulfate solution.
	Drag-in of cleaning solution due to insufficient rinsing.	Check rinses for adequate flow of clean water and adequate time in rinse. Consider spray rinses.
	Tanks, filters, racks, etc., may not be compatible with acid copper sulfate solution.	Assure solution compatibility of equipment prior to use.
	Contamination of solution from anode bag sizing.	Wash sizing from anode bags and filter cartridges prior to use.
	Incomplete removal of resist adhesion promoters.	Review adequacy of preclean cycle.

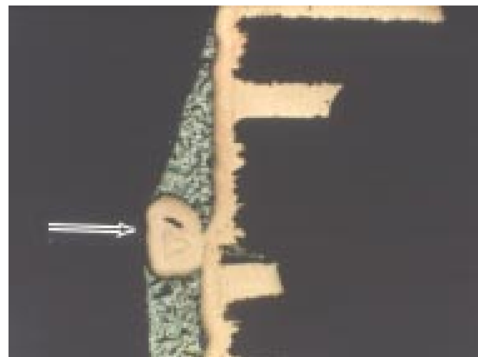

Figure 10-1. Nodules from copper plating.

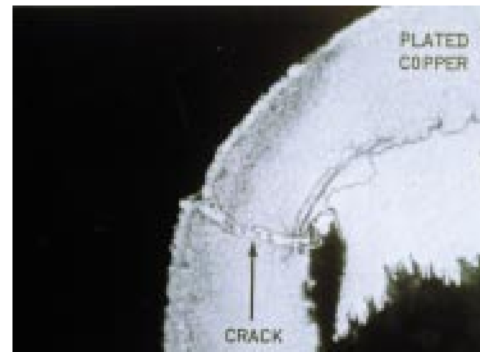

Figure 10-2. Microsection of corner crack.

10.2.2 Copper Sulfate (continued)

F PROBLEM	CAUSE	ACTION
Brittle copper plating, as indicated by cracks in copper after thermal stress. (See Figure 10-2.)	Organic contamination of plating bath from brightener breakdown products, photoresist, or cleaning solutions.	Implement routine carbon treatment of plating bath at intervals recommended by vendor.
	Excessive amounts of some brighteners/ additives for copper.	Check with additive supplier for method to remove some of the brightener.
	Plating current density out of recommended range.	Check additive supplier's recommended current density range.
	Not plating in recommended temperature range (21-26°C).	Check plating bath temperature before and after plating to assure operation in proper temperature range.
	Insufficient additive.	Run Hull Cell or electrochemical analysis of additives and make adds as necessary.
	Copper ion concentration too low.	Improve solution movement and agitation to compensate.
	Insufficient thickness of copper on the plated hole wall.	Generally, 0.8 mil is considered a minimum thickness.
	Laminate/multilayer has excessive z-axis expansion.	Review material requirements, customer specifications, and lamination procedures, and discuss with laminate supplier.

G PROBLEM	CAUSE	ACTION
Copper plating has low tensile strength.	Impurities in solution may be causing internal discontinuities in deposit.	Implement continuous filtration of 2-3 bath turnovers per hour for copper plating bath.
	Metallic contamination.	Dummy plate bath at low current density. (See 10.2.2 J.)

H PROBLEM	CAUSE	ACTION
Copper plating has enlarged grain structure.	Low additive content.	Run Hull Cell or electrochemical analysis of additives and make adds as necessary.
	Plating bath temperature too high.	Assure plating in recommended temperature range for additive system in use. Cooling coils may be required, especially during the summer.
	Plating at too high a current density.	Check operating current density and ensure it is in recommended range for additive system in use.

J PROBLEM	CAUSE	ACTION
Inorganic contamination.	Arsenic (As) - 7-8 ppm may cause rough deposits. Antimony (Sb) - 7-8 ppm may cause brittle deposits. Chlorides (Cl) - 150-200 ppm may cause poor leveling and anode polarization. Iron (Fe) - 7500 ppm may cause anode polarization, Lead (Pb) - Precipitates, creating particulate. Nickel (Ni) - Will reduce throwing power. Silver (Ag) - May cause brittle deposits in trace amounts. Tin (Sn) - Will cause dark, rough deposits. Zinc (Zn) - Will reduce throwing power.	Most of the impurities listed may be removed by low current density plating or chemical precipitation. (Consult supplier for recommended procedures.)

10.2.2 Copper Sulfate (continued)

K PROBLEM	CAUSE	ACTION
Lack of response to additive.	Anode polarization - high voltage/low amps on rectifier.	Adjust anode area to maintain 2:1 anode-to-cathode area ratio. Balance copper metal to sulfuric acid ratio to maintain 10 or more acid to 1 metal. Check for metallic contaminants: i.e., Fe, Ni, Zn. Anodes should be phosphorized, 0.03-0.06% P. Check bath temperature. After adjusting necessary parameters, remove and thoroughly clean anodes, then rebuild anode film per additive supplier's recommendations.
	Chlorides out of balance. (May be indicated by narrow bright range.)	Maintain level of chloride per supplier's recommendation, usually 50-80 ppm.
	Temperature too high.	Cool solution with chiller or water coil. Maintain temperature between 21-26°C.
	Solution needs carbon treatment.	Carbon treat per supplier's recommendation.

L PROBLEM	CAUSE	ACTION
Excessive additive consumption.	Additive strength low due to old additive (shelf life expired).	Check manufacture date of additive and replace with fresh. Implement controlled inventory of additive.
	Additive being oxidized at anodes.	Check anodes for bare copper spots. (Anodes should have uniform brown/black film.)

10.2.3 Pyrophosphate

A PROBLEM	CAUSE	ACTION
Teardrop formation in pyrophosphate around holes.	Decomposition of plating solution, brought about by loss of agitation of bath during cool down.	Maintain bath agitation during shutdown.

B PROBLEM	CAUSE	ACTION
Burned deposits. (Also see 10.2.1B.)	Copper concentration too low.	Add copper pyrophosphate concentrate if available. Carbon purify additions prior to adding to plating tank (if copper pyrophosphate salts are used).
	Ammonia content too low.	Add ammonium hydroxide. Increase feed adjustment valve opening if ammonia cylinders are used.
	Temperature too low.	Raise temperature using circulation equipment (air agitators, impeller) to move solution past heaters (localized overheating will cause solution breakdown). (Operating temperature range is 43-55°C.)
	Solution imbalance.	If orthophosphate content is above supplier's recommended level, dilute bath by removing a portion and replenishing with new (ortho free) plating solution. Pyrophosphate-to-copper ratio may be high. Add copper solution.
	Solution contaminated.	Organic contamination - carbon treat and filter solution. Metallic contamination - dummy plate to remove contaminants (typically Pb, Sn, Ni).

10.2.3 Pyrophosphate (continued)

C	PROBLEM	CAUSE	ACTION
Poor thickness distribution.		Poor throw due to: Low pyrophosphate:copper ratio; High pH; High ammonia; Low temperature; Low voltage; Metallic contamination.	Correct with additions of pyrophosphate. Add pyrophosphoric acid or proprietary solutions for pH adjustment. Raise temperature until enough ammonia has been driven off (60°C). Maintain at 43-55°C. Maintain operating range at typically 2-5 volts. Dummy solution.
		Skip plating due to: High ammonia; High pH; Organic contamination; Excess peroxide.	Heat solution to dispel ammonia. Add pyrophosphoric acid. Carbon treat or peroxide. Heat solution to 60°C.
		One side of panel heavier deposit than other.	Check cathode areas - calculate per side. Balance anode-to-cathode area on each side, 2:1 ratio, or reverse one-half of the racks or panels to balance total cathode areas on two sides.

D	PROBLEM	CAUSE	ACTION
Nodular copper plating. (Also see 10.2.1C.)		Voltage not in operating range.	Voltage should be 2-5 volts at operating current density. Check concentrations of bath constituents.
		Low pH.	Raise pH by additions of ammonia or proprietary pH adjusting solutions.

E	PROBLEM	CAUSE	ACTION
Pitted copper plating. (Also see 10.2.1D.)		Residual peroxide in bath.	Remove by heating solution to 60°C.
		High pH.	Lower pH to 8.0-8.5 by additions of pyrophosphoric acid or proprietary pH adjusting solutions.

F	PROBLEM	CAUSE	ACTION
Banded copper plating.		Organic contamination or cyanide contamination.	Treat with hydrogen peroxide and carbon.
		Low pyrophosphate-to-copper ratio.	Raise pyrophosphate-to-copper ratio.

G	PROBLEM	CAUSE	ACTION
Brittle copper plating.		Organic contamination.	Peroxide and carbon treat plating bath.
		Excess ammonia in bath.	Raise bath temperature to remove excess ammonia.
		Metallic contamination.	Dummy bath at low current density.

H	PROBLEM	CAUSE	ACTION
Low efficiency.		Anodic (dark film on anodes) or wrong type of anodes.	Pyrophosphate-to-copper ratio too low. Add ammonia. Oxygen-free, high-purity copper is recommended for use.
		Cathodic (slow plating rate) from: Hydrogen peroxide in solution; or Organic contamination.	Heat to 60°C. Treat solution with carbon or peroxide.

10.2.3 Pyrophosphate (continued)

J	PROBLEM	CAUSE	ACTION
Buildup of orthophosphate in solution.		Overheating of solution.	Make sure that air agitation is on when heaters are on. Circulate solution through filter pumps to increase agitation. Install impeller near heater if necessary. Check thermostat to maintain temperature within range of 43-55°C.
		Solution imbalance.	Maintain pyrophosphate-to-copper ratio between 7 to 1 and 8 to 1. Keep solution pH between 8.0 and 8.5.

10.2.4 Fluoborate

A PROBLEM	CAUSE	ACTION
Burned deposits. (Also see 10.2.1B.)	Copper concentration too low.	Add copper fluoborate concentrate. Maintain copper fluoborate level at 45-80 g/l (12-22 g/l copper).
	Acid content too high.	Dilute bath. Maintain acidity at 325-375 g/l fluoboric acid.
	Temperature too low.	Heat solution to 24°C. (Operating range is 18-30°C.)
	Current density too high.	Lower current density. (Typical current density for pattern plating is 60 ASF; for panel plating, 30 ASF.)

B PROBLEM	CAUSE	ACTION
Poor thickness distribution.	Poor throwing power due to: Copper content too high. Acid content too low. Temperature too high. Current density too high.	Dilute bath or use some inert (graphite) anodes. Add fluoboric acid. Chill bath (consult equipment manufacturer for compatibility of cooling equipment with copper fluoborate solutions). Lower current.
	One side of panel heavier deposit than other.	Check cathode areas - calculate per side. Balance anode-to-cathode area on each side, 2:1 ratio, or reverse one-half of the racks or panels to balance total cathode areas on two sides.

C PROBLEM	CAUSE	ACTION
Nodular copper plating. (Also see 10.2.1C.)	Wrong anodes.	Be certain anodes are high purity, oxygen-free copper.

D PROBLEM	CAUSE	ACTION
Pitted copper plating. (Also see 10.2.1D.)	Residual peroxide in bath.	Remove by heating solution to 60°C.

E PROBLEM	CAUSE	ACTION
Coarse (brittle) deposits.	Organic contamination of plating bath.	Carbon treat.
	Contamination of plating bath by screening materials.	Make sure inks are dry prior to plating tank entry. (Fluoboric based materials may attack certain resists. Above 50°C, dry film resists are attacked.)
	Chloride contamination.	Add a small amount of silver fluoborate to precipitate silver chloride, and filter solution. (Dummy excess silver at 2 ASF. Don't use HCl dip prior to plating in this solution - use fluoboric acid dip.)

10.2.4 Fluoborate (continued)

F PROBLEM	CAUSE	ACTION
Enlarged grain structure in copper deposit.	Grain refiner low.	Add grain refiners.
	Overdose of hardener additives.	Check with additive supplier.

G PROBLEM	CAUSE	ACTION
Hardness of copper deposit decreases.	High temperature.	Lower bath temperature to proper operating range.
	High acid content.	Check acid content of bath.
	Low current density.	Raise current density.
	Hardening agent low.	Add hardening agent.

H PROBLEM	CAUSE	ACTION
Tensile strength of copper decreases.	High temperature.	Lower bath temperature to proper operating range.
	High acid content.	Check acid content of bath.
	Low current density.	Raise current density.

10.3 TIN-LEAD

The 63:37 tin-lead alloy on printed wiring boards is plated most commonly from fluoborate- or organic sulfonate-based plating baths. The following is divided into general problems encountered in tin-lead plating and problems specific to each type of process.

10.3.1 General

A PROBLEM	CAUSE	ACTION
Areas on boards with insufficient tin-lead plate.	Plating area is too irregular, with high and low current density areas.	Run plating distribution across panel and assess current density; add thieving if possible.
	Surface to be solder plated is contaminated.	Make sure that copper-plated panel is free of contamination and oxides prior to going into tin-lead plate. (Minor oxidation will allow tin-lead plate, but will cause dewetting at the fusing operation, and the surface will exhibit inconsistent solderability.) In make-up of persulfate microetch, do not use cold water or a build-up of copper sulfate will result. This will cause a copper sulfate residue on the board surface. Water should be tempered to between 21 and 26.7°C.
	Photoresist problem - adhesion promoters remain.	Check for good cathode contact or masking within the tank. Check for bleed out of photoresist. Check cleaning cycle.
	Organic contamination in the bath.	Carbon treat bath per vendor’s recommendations.

10.3.1 General (continued)

B PROBLEM	CAUSE	ACTION
Burned or rough deposits.	Current density too high.	Plate at lower current density.
	Addition agent out of balance.	Run Hull cell and make additions according to vendor's recommendations.
	Anodes too long, resulting in high current density on lower portion or panel in bath.	Adjust anode lengths or production loads so that anodes are 50.8-76.2 mm shorter than panel.
	Lack of adequate filtration or agitation.	Implement adequate filtration and cathode bar agitation.
	Low metal content in bath.	Analyze and adjust to specification. Investigate possible causes of low metal (i.e., excess stannic tin formation, insufficient anode area, lead sulfate formation).
	Sulfate contamination from acid copper bath (insoluble lead sulfate is formed which can co-deposit on the surface).	Eliminate by improved rinsing between plating baths.
	Anode sludge in bath.	Locate and remove any anode bags with holes or tears and replace. Poor parts handling and careless maintenance may contribute to ripped anode bags.

C PROBLEM	CAUSE	ACTION
Metal content in bath increasing.	Anode area too high.	Adjust anode-to-cathode area ratio according to bath manufacturer's recommendations (usually 1:1 or 1.5:1).
	Anode area too low, making anodic current density too high - this can raise the metal content.	Review anode-to-cathode ratio as above.
	Plating at a current density that consumes more of one of the metals - then more frequent adjustment of the other metal is made and total metals increase.	Alter anode alloy composition to compensate, or adjust current density.
	Excessive stannic tin formation throws metal ratio in the bath out of balance.	Investigate causes of excessive stannic formation, such as air introduction through agitation or leaking pump seal, or introduction of oxidants to the bath. Consult chemical supplier regarding the availability of a suitable antioxidant to prevent the stannic formation.

D PROBLEM	CAUSE	ACTION
Incorrect plated alloy composition.	Incorrect tin and lead concentrations in plating bath, possibly due to wrong anode composition or oxidation of stannous tin.	Check anode composition; usually the anode supplier can do this analysis. Analyze lead and stannous tin content of bath and adjust to specification. Investigate possible causes for formation of stannic tin that would remove tin from solution. (Also see 10.3.3D.)
	Incorrect current density being used.	Check with addition agent vendor for proper current density range (a high current density will result in a deposit with high tin content and vice versa).

E PROBLEM	CAUSE	ACTION
Dark tin-lead deposit.	Metallic contamination (usually copper) in bath.	Dummy plate the bath at low current density (2 ASF).
	Lack of brightener.	Analyze for brightener and add as required.
	Organic contamination.	Carbon treat plating bath.
	Lead content of plated deposit too high.	See 10.3.1D for cause and action. Plating at too low current densities will result in a lead-rich deposit.

10.3.1 General (continued)

F PROBLEM	CAUSE	ACTION
Voids or occlusions in plated deposit.	Organic contamination of plating bath, due to breakdown of addition agents or photoresist leach-out.	Carbon treat bath and add fresh addition agent according to vendor's recommendations.
	Addition agent concentration too high. Hull cell analysis shows rough streaked deposits in high current density area.	Check with vendor for proper addition agent concentration. Carbon treatment may be necessary.

G PROBLEM	CAUSE	ACTION
Poor reflow. (Also see 14.1.)	Wrong plated alloy composition.	Check current density and metal ratio. (Also see 10.3.1D and 10.3.3C.)
	Low addition agent.	Check in plating test cell and adjust as necessary.
	Plated deposit too thin.	Plate to required thickness.
	Contaminated copper surface (beneath the tin-lead plate).	Review/improve rinsing and cleaning procedures between copper and tin-lead plate steps.
	Metallic contamination.	Dummy plate bath at low current density. Investigate and minimize sources of contamination.

H PROBLEM	CAUSE	ACTION
Metal content in bath decreasing.	Insufficient anode area.	Review anode-to-cathode area and adjust per vendor recommendations.
	Anodes have polarized.	Filter bath, change anode bags, scrub down anodes, clean all electrical connections.
	Anode bags are clogged or are of too fine a weave.	Change anode bags. Napped bags generally have too fine a weave to permit good solution exchange during plating. Always scrub and clean anodes before returning them to the bath.

J PROBLEM	CAUSE	ACTION
Poor solderability. (Also see 10.3.1G.)	Excessive formation of copper-tin intermetallic, perhaps due to a thin deposit, exposure to high temperatures (accelerated formation), or shelf life.	Plate a minimum 0.008 mm. A reasonable expected shelf life of reflowed parts is 6-12 months. Shelf life of non-reflowed parts is considerably shorter.

10.3.2 Fluoborate-Based Baths

A PROBLEM	CAUSE	ACTION
Rough deposit. (Also see 10.3.1B.)	Insoluble lead fluoride formed in bath and co-deposited.	Saturate plating solution with boric acid by hanging a bag of boric acid crystals in bath. This ensures that no free fluoride will be present to allow formation of lead fluoride.
	Uneven plating pattern on part being plated, resulting in high current density areas on panel.	Add current thieves where possible to ensure a uniform plating area across the part.
	Treeing.	See 10.3.2D.
	Addition agent low - Hull cell analysis shows crystalline deposit in low current density area.	Check with supplier for proper level of addition agent.
	Copper contamination.	Dummy plate bath at low current density.
	Overactive copper surface. (Occurs when surface receives additional scrubbing or micro-etching between copper and tin-lead plate.)	Lighten scrubbing action. Reduce micro-etch time.
	Anode sludge or other particulate matter in bath.	Check/change anode bags and filtration.

B PROBLEM	CAUSE	ACTION
Turbid or cloudy plating solution.	Fluoboric acid content low, resulting in stannic tin formation and cloudy plating bath.	Check and adjust fluoboric acid content.
	Low boric acid concentration, resulting in the formation of lead fluoride.	Adjust boric acid by saturating the plating solution. (See 10.3.2A).
	Sulfate introduced (probably from tap water), resulting in the formation of insoluble lead sulfate.	Use deionized or distilled water for bath make-up, rinsing before plating, and in fluoboric acid dip prior to plating tank. Rinse boards from copper plate thoroughly.
	Excessive air in bath (will oxidize stannous to stannic tin).	See 10.3.2E.

C PROBLEM	CAUSE	ACTION
Poor throwing power.	Fluoboric acid concentration low.	Check and adjust fluoboric acid content to specification.
	High salt content in bath.	Check total metal content; adjust through dilution if necessary.
	Addition agent not in proper range.	Check with addition agent vendor for correct operating concentrations.
	Copper contamination.	Dummy plate bath at low current density.
	Low boric acid concentration.	Add boric acid via anode bag.
	Chloride contamination 75ppm.	Dilute bath to reduce concentration. Investigate source of contamination and eliminate.

D PROBLEM	CAUSE	ACTION
Treeing (in high current density areas).	Low addition agent.	Check and adjust per vendor specification.
	Excessive current density.	Lower current density; recalculate plating area if required.
	Fluoboric acid concentration low.	Analyze plating solution and adjust to specification.

10.3.2 Fluoborate-Based Baths (continued)

E	PROBLEM	CAUSE	ACTION
Excessive foam on bath surface.		Excessive solution agitation.	Reduce agitation so that air is not drawn into the solution.
		Sucking air in through pump seal.	Repair pump seal. NOTE: Air in bath will cause loss of stannous tin from solution.

F	PROBLEM	CAUSE	ACTION
Loss of lead from bath.		Low boric acid concentration.	Fill anode bag with boric acid and hang in corner of tank.
		Sulfate in tap water removing lead (sulfate) from bath.	Use deionized or distilled water only for bath makeup, additions, and rinsing prior to plating.
		Wrong anode composition - possibly pure tin anodes mixed in with others.	Check composition of all anodes.

G	PROBLEM	CAUSE	ACTION
Dark tin-lead deposit. (Also see 10.3.1E.)		Metallic contamination in bath. Some limits of contamination are: Fe 150ppm, Ni 100ppm, Cr 5ppm, Zn 150ppm, Cu 20ppm.	Dummy plate to remove copper. Other metals may only be removed by dilution. Investigate source(s) of contamination and eliminate.

10.3.3 Organic Sulfonic Acid (OSA) Based Baths

A	PROBLEM	CAUSE	ACTION
Dark tin-lead deposit. (Also see 10.3.1E.)		Plating resist contamination. Leaching of the resist in the bath may show up as dark bands in the 5-15 ASF range on a Hull cell.	Carbon treat plating bath. Dummy plating at low current density (5-10 ASF) may help (consult vendor if necessary).
		Metallic contamination.	Dummy plate to remove. Investigate contamination sources and eliminate. The following levels will cause the problem: copper - 40 ppm; zinc - 20 ppm; iron - 80 ppm; nickel - 80 ppm.

B	PROBLEM	CAUSE	ACTION
Poor reflow. (Also see 10.3.1G.)		Alloy shift (in the 5-15 ASF range), probably caused by resist leaching.	See 10.3.3A.
		Bright areas of plating.	Organic contamination will cause a matte tin-lead to plate bright. Carbon treat bath. Investigate and minimize source(s) of organic contamination.
		Excess additive co-deposited.	Reduce replenishment rates.
		Metallic contamination from titanium anode baskets.	See 10.3.3C.

C	PROBLEM	CAUSE	ACTION
Titanium anode baskets dissolving.		Extreme high and/or low plating voltages.	Check all electrical connections, including rack points, for low resistance. Verify correct anode-to-cathode ratio and plating current density. Check rectifier.
		Improper filling of anode baskets.	If tin-lead anode level in basket is allowed to fall, the basket will act as an anode and dissolve. Maintain proper anode level.

10.3.3 Organic Sulfonic Acid (OSA) Based Baths (continued)

D PROBLEM	CAUSE	ACTION
Excess formation of stannic tin (does not necessarily interfere with plating except in extreme cases where a drop in plating efficiency may occur).	Introduction of air into bath.	Reduce/ eliminate all sources of air such as excess or turbulent rack agitation, any air bubbling, or leaking pumps.
	Anti-oxidant level too low.	Consult with chemical supplier for appropriate anti-oxidant and its recommended concentration.
	Bath temperature too high (100°F).	Control bath temperature within specification. Consult supplier for appropriate anti-oxidant if high temperature operation is required.
	Remove excess stannic tin with a vendor-recommended flocculating agent, followed by filtration.	

E PROBLEM	CAUSE	ACTION
Poor throwing power.	Insufficient additive.	Adjust additive per vendor recommendations.
	Metals concentration too high for operating current density used.	Raise current density. Dilute bath to lower metals concentration.
	Excessive anode area may contribute to increasing metals.	
	Low acid content.	Adjust per vendor recommendation.

F PROBLEM	CAUSE	ACTION
Tarnishing or staining.	Improper rinsing of parts.	Improve rinsing procedures. Consider the use of a vendor-recommended post rinse to eliminate acid and additive film on parts after plating.

G PROBLEM	CAUSE	ACTION
Deposit composition incorrect. (Also see 10.3.1D.)	Organic contamination in bath (This can affect composition without any other defects being apparent.)	Filter the bath through carbon pads or carbon-packed filter cartridges.

10.3.4 High-Speed Tin-Lead Plating

A PROBLEM	CAUSE	ACTION
Grainy deposit.	Low addition agent.	Check concentration of addition agent.
	Improper agitation.	Check with vendor for proper operating condition.
	Solution contamination.	Carbon treat or filter as necessary.

B PROBLEM	CAUSE	ACTION
Burning. (Also see 10.3.2A.)	Low addition agent.	Add addition agent as necessary.
	Lack of solution agitation.	Increase agitation as necessary.

C PROBLEM	CAUSE	ACTION
Improper alloy ratio. (Also see 10.3.1.4.)	Low addition agent.	Add addition agent to correct level.
	Improper metal ratio in plating bath.	Correct as necessary.

10.3.5 High Throw Tin-Lead Plating

A PROBLEM	CAUSE	ACTION
Burning. (Also see 10.3.1B.)	Current density too high.	Lower amperage; recalculate plating area if necessary.
	Low additive.	Examine in plating test cell.
	Chemical imbalance.	Analyze for tin-lead, fluoboric acid.

B PROBLEM	CAUSE	ACTION
Roughness. (Also see 10.3.2A).	Precipitation in bath.	Check filtration system; check boric acid level.

10.4 TIN

10.4.1 General

Tin can be deposited from both acid and alkaline baths. The alkaline baths are sodium or potassium stannate-based and are not used for printed circuit manufacture. Acid baths can be sulfate- or fluoborate-based, or more recently, OSA-based. A bright acid sulfate bath produces a finish similar to reflowed tin-lead. Advantages of bright acid tin are good solderability, low porosity, an easily cleaned surface (of fingerprints), and good resistance to corrosion and tarnish. It is most commonly used in the SMOBC process, as a metallic etch resist then stripped off prior to solder mask application.

10.4.2 Bright Acid Sulfate Tin

A PROBLEM	CAUSE	ACTION
Pitting.	Excess starter or brightener.	Dummy plate at 20-30 ASF. Dilute or replace the bath (generally the wetters in the bath prevent successful carbon treatment to remove the brightener).
	Bath constituents out of balance.	Adjust stannous sulfate and sulfuric acid concentrations to within vendor's specifications.
	Bath temperature too low.	Keep bath at optimum temperature.
	Improper acid dip.	Analyze acid dip and adjust to within 5-10%. Verify proper rinsing after acid dip.
	Non-uniform agitation.	Increase solution agitation. Adjust cathode agitation based on vendor's recommendations.
	Metallic contamination.	Dummy plate bath at medium current density (15-30 ASF).
	Insoluble particles in bath.	Improve solution filtration.
	Base metal pitting.	Inspect parts prior to plating.
	Oil contamination.	Carbon treat or replace bath.
	Low make-up additive.	Add make-up additive in small increments.

10.4.2 Bright Acid Sulfate Tin (continued)

B PROBLEM	CAUSE	ACTION
Poor throwing power.	Tin concentration too high or sulfuric acid concentration too low in bath.	Analyze for tin and/or sulfuric acid and adjust per vendor's specifications.
	Current density too low.	Recalculate plating area and verify recommended current density. Check out rectifier and all connections. Increase current density slowly until optimum is reached.
	Bath temperature too high.	Lower temperature with cooling coils to maintain vendor recommended temperature.
	Metallic contamination.	Dummy plate bath at medium current density to remove.
	Anode-to-cathode distance too great.	Move anode bars closer to work surface.
	Non-uniform agitation.	Increase/improve solution agitation. Adjust cathode agitation based on vendor's recommendations.
	Low starter or make-up brightener.	Adjust based on Hull Cell results.

C PROBLEM	CAUSE	ACTION
Burned, dull or streaked deposits in high current density areas.	Tin or sulfuric acid concentration too high.	Analyze for tin and sulfuric acid, and adjust per vendor's specifications.
	Current density too high.	Recalculate plating area and adjust to within range.
	Temperature too high.	Lower temperature to within optimum range.
	Low starter or replenisher.	Adjust based on Hull cell results.
	Poor agitation.	Increase solution agitation. Adjust cathode agitation based on vendor's recommendations.

D PROBLEM	CAUSE	ACTION
Rough plating.	Impure anodes.	Use only pure tin anodes. Use only monel or plastisol-coated titanium anode hooks.
	Particulate contamination in bath.	Improve solution filtration. Check anode bags for holes; replace dirty bags.
	Current density too high.	Recalculate plating area and adjust to optimum.

E PROBLEM	CAUSE	ACTION
Black streaking or burn in the high current density areas, with poor throwing power (see 10.4.2B) or skip plate in the low current density areas.	Excessively high brightener.	Dummy plate the bath at 20-30 ASF. Dilute or replace the bath.
	Low starter.	Adjust based on Hull cell results.
	Metallic contamination.	Dummy plate bath at medium current density.

F PROBLEM	CAUSE	ACTION
Overall dullness or haze.	Tin or sulfuric acid concentration too low.	Analyze for tin and sulfuric acid and adjust to vendor's specifications.
	Low starter.	Adjust based on Hull cell results.
	Copper contamination.	Dummy plate at 15-20 ASF.

10.4.2 Bright Acid Sulfate Tin (continued)

G PROBLEM	CAUSE	ACTION
Poor solderability.	Excess starter and/or brightener.	Dummy plate bath at 20-30 ASF. Dilute or replace bath.
	Improper rinsing or post treatment.	Improve rinsing. Consult vendor for recommended post treatment.
	Excessive thickness of deposit.	Recommended tin thickness is 0.1 to 0.2 mils. (Consult vendor for variations.)
	Metallic contamination.	Dummy plate bath at 30-40 ASF. For heavy metals, dummy at 5-10 ASF. Eliminate source or contamination.
	Chloride contamination in bath.	Consult vendor.
	Improper soldering temperature.	Check and confirm soldering temperature.

H PROBLEM	CAUSE	ACTION
Stained parts (may appear as dark streaks).	Improper rinsing or post treatment.	Improve rinsing. Consult vendor for recommended post treatment.

J PROBLEM	CAUSE	ACTION
Low current density area dullness.	Low starter or brightener.	Add based on Hull cell results.
	Heavy metal contamination.	Dummy plate bath at 5-10 ASF.
	High tin or low sulfuric acid concentration.	Analyze for tin and/or sulfuric acid and adjust to vendor's specifications.
	Chloride contamination.	Consult vendor.
	Current density too low.	Recalculated plating area. Increase current density.
	Insufficient anode area.	Add more anodes.
	Bath temperature too high.	Lower temperature to optimum.
	Poor pretreatment.	Check process. Consult vendor.

K PROBLEM	CAUSE	ACTION
Anode polarization.	Impure stannous sulfate or sulfuric acid used.	Verify quality of chemicals; use only pure grade. Consult vendor.
	Sludge build-up or clogged anode bags.	Remove and replace anode bags.
	Excess starter and/or brightener.	Dummy plate bath at 20-30 ASF. Dilute or replace bath.

10.5 NICKEL

10.5.1 General

Nickel plating on printed boards is often used as a barrier layer to prevent diffusion between copper and gold. Nickel under rhodium improves the corrosion and wear resistance. The nickel deposit surface will passivate easily, so subsequent plating should follow immediately to prevent poor adhesion.

There are two types of nickel solutions used in board plating: the Watts (sulfate) bath and the sulfamate bath. Bright, low stressed, ductile deposits are obtained with either type. Some baths are operated with insoluble anodes and do not contain chlorides.

10.5.2 Sulfamate Nickel Baths

A PROBLEM	CAUSE	ACTION
Deposit roughness or treeing. (See 10.5.2B.)	Undissolved nickel carbonate or boric acid in the bath.	Introduce nickel carbonate or boric acid through a filter or a bag suspended in the solution.
	Anodes unbagged; holes in anode bags.	Bag anodes in leached polypropylene, dynel or nylon bags. (Sulfur depolarized anodes should be double bagged.)
	Inadequate bath filtration.	Filtration rate should be at least one solution turnover per hour through 5-10 micron filters.
	pH out of range.	Lower pH wth sulfamic acid; raise with nickel carbonate. Check vendor's specification sheet for correct range.
	Iron hydrate in bath.	Lower pH, if out of range. Improve filtration.

B PROBLEM	CAUSE	ACTION
Burned deposits.	Low temperature.	Raise temperature to within range specified by vendor.
	Poor agitation.	Increase solution agitation. Institute cathode rod agitation.
	Current density too high.	Recalculate plating area and follow vendor's recommendations. Make sure correct number of panels is being plated for the current setting. Current density may be too high for the amount of agitation.
	Incorrect positioning of anodes or plated work (poor current distribution).	Anodes should be slightly shorter than work being plated. Anode to cathode area should be 2:1. Panels should never touch anodes but should be equidistant from each side. In the case of single-sided boards or jobs with more plating area on one side than the other, every other panel on the rack should be flipped to ''even out'' the current distribution.
	Nickel concentration too low.	Raise concentraion to vendor's specification by addition of nickel sulfamate solution.
	Boric acid content too low.	Raise concentration; an anode bag of boric acid should be suspended in the nickel bath at all times. A decrease in temperature may have caused precipitation of boric acid. Control temperature carefully.
	Metallic impurities such as iron or aluminum.	Follow vendor's recommendations for removal.
	Organic contamination.	Batch carbon treat or use carbon filter cartridges to remove. Determine source of contamination (excess wetting agent, cleaner drag-in, oil on surface, hot oil reflow in same room) and correct.
	Inadequate ''thief'' around circuit pattern.	Adjust photo tooling or add extra thieving to rack.
	Low on replenisher.	Adjust using Hull cell. Verify amp-hour adds to bath.

10.5.2 Sulfate Nickel Baths (continued)

C PROBLEM	CAUSE	ACTION
Pitting of deposit.	Organic contamination.	Batch carbon treat or use carbon filter cartridges to remove contamination. Determine source of contamination (e.g., cleaner drag-in) and correct.
	Low antipit or wetting agent.	Add according to vendor's recommendations by estimating concentration using tension test, or based on Hull cell results.
	Low boric acid.	Raise concentration. (An anode bag of boric acid should be suspended in the bath at all times.) A decrease in bath temperature may have caused precipitation of boric acid. Therefore, control temperature carefully.
	High pH.	Lower pH with sulfamic acid. Check filtration system for air leaks.
	Metallic contamination.	Dummy plate bath at 2 to 5 asf (0.2 to 0.5 A/dm^2) using corrugated cathodes.
	High ammonia concentration. (Ammonia is a by-product of sulfamate nickel plating.)	(In amounts greater than 1000 ppm it may cause pitting in high density operations.) There is no method to remove it from the bath. Therefore, in order to prevent or minimize production of ammonia, maintain pH, nickel concentration and temperature at optimum values and avoid use of inert anodes if possible.

D PROBLEM	CAUSE	ACTION
Poor adhesion (nickel peeling from copper).	Poor cleaning.	Inspect cleaning and etching procedure. Verify adequate rinsing after all process steps in pre-clean cycle.
	Fingerprints.	See above actions for cleaning. Have line operators wear gloves when racking panels.
	Chromium contamination.	Follow vendor's recommendations for removal.
	Oil on surface and/or organic contamination of nickel baths.	Skim tank surface. Batch carbon treat or use carbon filter cartridges to remove. Determine source of contamination. Have work enter bath ''live'' at approximately 1- 3 volts of rectifier.
	Intermittent current during plating (can also cause nickel-to-nickel peel).	Clean anode and cathode bars. Check all electrical connections and bussing. Check proper operation of rectifier. Clean rack contacts. (Check rack integrity (breaks under plastisol). Replace any stripped thumbscrews. When racking panels, connection must be made on copper metal. Screws should not be over resist or ink.)

E PROBLEM	CAUSE	ACTION
Dark plate.	Metallic contamination.	Dummy plate bath at 2 to 5 asf (0.2 to 0.5 a/dm^2) using corrugated cathodes. Follow vendor's recommendations as necessary.
	Low pH.	Raise with nickel carbonate. Add through filter or bag suspended in the bath.
	Low boric acid.	Raise concentration. (An anode bag of boric acid should be suspended in the nickel bath at all times.)

10.5.2 Sulfamate Nickel Baths (continued)

F PROBLEM	CAUSE	ACTION
Poor throwing power.	Low pH.	Raise pH with nickel carbonate. (Add through a filter or a bag suspended in the bath.)
	Low temperature.	Raise temperature to vendor's recommendation.
	Low nickel content.	Raise nickel concentration by addition of nickel sulfamate solution.
	Metallic contamination.	Dummy plate bath at 2 to 5 asf (0.2 to 0.5 A/dm^2) using corrugated cathodes.
	Poor electrical contact.	Clean rack contents. Check rack integrity (breaks under plastisol). Replace any stripped thumb screws. Clean anode and cathode bars. When racking panels, connection must be made on copper metal. Screws or clips should not be over resist or ink.

G PROBLEM	CAUSE	ACTION
Low cathode efficiency (low disposition rate).	Low pH.	Raise pH with nickel carbonate (Add through a filter or bag suspended in the bath.)
	Chromium contamination.	Follow vendor's recommendations for removal.
	Metallic contamination.	Dummy plate bath at 2 to 5 asf (0.2 to 0.5 A/dm^2), using corrugated cathodes.
	Current density too low.	Recalculate plating area and make necessary corrections. Make sure correct number of panels is being plated for the current setting.
	Hydrogen peroxide contamination (used in metals treatment).	Heat bath to 66°C until removed.

H PROBLEM	CAUSE	ACTION
Low anode efficiency.	Anodes polarized.	Low current density. Increase concentration by adding nickel chloride or vendor's propriety additive.
	Chloride concentration too low.	Raise concentration by adding nickel chloride or vendor's proprietary additive.
	Wrong type of anodes.	Use sulfer depolarized anodes, if possible. Increase chloride concentration.

10.5.2 Sulfamate Nickel Baths (continued)

J PROBLEM	CAUSE	ACTION
Difficulty in maintaining concentration parameter.	Low nickel concentration.	Increase drip time slightly to reduce dragout losses. Avoid use of inert anodes if possible. Maintain anode-to-cathode area at 2:1.
	Low boric acid concentration.	An anode bag of boric acid should be suspended in the nickel bath at all times. (Keep it away from filter intake and plating area of bath.) A decrease in bath temperature can cause precipitation of boric acid. (Control the bath temperature carefully.)
	pH rises.	The pH of nickel sulfamate should rise slowly with use.
	pH tends to drop.	Amount of sulfamate acid is too large. Poor anode corrosion: increase chloride concentration. (See 10.5.2H.)
	Metallics.	Cover copper anode or cathode bars with stainless steel or plastisol to prevent corrosion. Lead sulfamate is very soluble. Thus, keep anything containing lead away. Titanium coil heaters are sometimes attacked in sulfamate solution under heat-exchange conditions. Therefore, if appropriate, change or protect heaters.
	Ammonia.	Maintain pH, nickel concentration and temperature at optimum values. Avoid use of inert anodes and high current densities if possible.
	Organics.	Drag-in of cleaners (improve rinsing). Do not hot oil reflow in the same room, as this will contaminate all plating and cleaning solutions. Do not use unbleached filters or anode bags. Not all carbon fines removed after carbon treatment. (Refilter bath and dummy plate to check.)

K PROBLEM	CAUSE	ACTION
Brittle deposits.	High pH.	Lower pH with sulfamic acid.
	Low boric acid.	Raise concentration.
	Organic contamination.	Batch carbon treat or use carbon filter cartridges.
	Metallic contamination.	Dummy plate bath at 2 to 5 asf (0.2 to 0.5 A/dm^2) using corrugated cathodes.

10.5.3 Sulfate (Watts) Nickel

A PROBLEM	CAUSE	ACTION
Deposit roughness or treeing. (Also see 10.5.3B.).	pH out of range.	Lower pH with sulfuric acid; raise with nickel carbonate. (Check vendor's specifications for correct range.)
	Inadequate bath filtration.	Filtration rate should be at least one solution turnover per hour through 5-10 micron filter.
	Anodes unbagged; holes in anode bags.	Bag anodes in bleached polypropylene, dynel or nylon bags. Sulfur depolarized anodes should be double-bagged.
	Undissolved nickel carbonate or boric acid in bath.	Introduce nickel carbonate or boric acid through a filter or anode bag suspended in the solution. (Care should be taken to keep the bag away from filter inlets, and out of the plating part of the tank.)
	Iron contamination.	Raise pH and filter, per vendor recommendations.

10.5.3 Sulfate (Watts) Nickel (continued)

B PROBLEM	CAUSE	ACTION
Burned deposits.	Low bath temperature.	Raise temperature to within range specified by vendor.
	Poor agitation.	Increase solution agitation. Institute cathode rod agitation.
	Current density too high.	Recalculate plating area and follow vendor's recommendations. Make sure correct number of panels is being plated for the current setting. Lower current density if it is too high for the amount of agitation.
	Incorrect positioning of anodes or plated work (poor current distribution).	Be sure that anodes are slightly shorter than work being plated. Anode-to-cathode area ratio should be 2:1. Be sure that panels do not touch anodes. In the case of single-sided panels or jobs with more plating area on one side than the other, every other panel on the rack should be flipped to ''even out'' the current distribution.
	Nickel concentration too low.	Raise concentration to optimum by addition of nickel sulfate.
	High pH.	Adjust pH with sulfuric acid per vendor specifications.

C PROBLEM	CAUSE	ACTION
Pitting in the deposit.	Organic contamination.	Remove by carbon treatment.
	Low anti-pit or wetting agent.	Add according to vendor's recommendations by estimating concentration using tension test, or based on Hull cell results.
	Poor agitation.	Increase agitation.
	Low nickel or boric acid content.	Analyze and make additions as necessary.
	Low pH.	Raise pH using nickel carbonate.
	Poor surface preparation.	Inspect cleaning line for contamination and ''out-of-spec'' baths. Avoid excessively strong acid dips.

D PROBLEM	CAUSE	ACTION
Poor adhesion (nickel peeling from copper).	Poor cleaning.	Inspect cleaning and etching procedure. Verify adequate rinsing after all process steps in pre-clean cycle.
	Fingerprints.	See above actions for cleaning. Have line operators wear gloves when racking panels.
	Chromium contamination.	Follow vendor's recommendations for removal.
	Oil on surface and/or organic contamination of nickel baths.	Skim tank surface. Batch carbon treat or use carbon filter cartridges to remove. Determine source of contamination. Have work enter bath ''live'' at approximately 1 to 3 volts on rectifier.
	Intermittent current during plating (can also cause nickel to nickel peel).	Clean anode and cathode bars. Check all connections and bussing. Check proper operation of rectifier. Clean rack contacts. Check rack integrity (breaks under plastisol). Replace any stripped thumbscrews. When racking panels, connection must be made on copper metal (thumbscrews should not be over resist or ink).

10.5.3 Sulfate (Watts) Nickel (continued)

E PROBLEM	CAUSE	ACTION
Brittle deposits.	High pH.	Lower pH with sulfuric acid, added in small increments.
	Organic contamination.	Carbon treat bath per vendor's recommendations.

F PROBLEM	CAUSE	ACTION
Low cathode efficiency (low deposition rate).	Low pH.	Raise pH with nickel carbonate.
	Metallic contamination; inorganic impurities.	Dummy plate bath at 2-5 ASF (0.2-0.5 A/dm^2) using corrugated cathodes. Follow vendor's recommendation for removal.
	Current density too low.	Recalculate plating area and make necessary corrections. Make sure correct number of panels are being plated for the current setting.

G PROBLEM	CAUSE	ACTION
Nonuniform plate.	Inorganic impurities.	Dummy plate bath at 2-5 ASF (0.2-0.5 A/dm^2) using corrugated cathodes. Follow vendor's recommendation for removal.
	Poor cathode contact.	Clean anode and cathode bars. Check all connections and bussing. Check proper operation of rectifier. Clean rack contacts. Check rack integrity (breaks under plastisol). Replace any stripped thumbscrews. When racking panels, connection must be made on copper metal (thumbscrews should not be over resist or ink).

H PROBLEM	CAUSE	ACTION
Dark low current density area.	Copper contamination.	Dummy plate bath at 2-5 ASF (0.2-0.5 A/dm^2) using corrugated cathodes.

10.6 GOLD PLATING

10.6.1 General

Gold is deposited on printed boards for its excellent resistance to corrosion and tarnish, its low electrical contact resistance and its good electrical conductivity. There are both acid and alkaline plating solutions. In addition, there are formulations for strike, hard and soft gold plates. Hard gold baths contain either cobalt or nickel as hardeners, and are used where the contact is subject to wear (i.e., connectors, tabs or fingers, sliding switches). Soft gold baths plate a 24K gold and are used in direct chip attachment applications.

Insoluble anodes are used in gold baths and metal replenishment is accomplished by adding gold salts. Anodes usually are made of platinized titanium or platinized tantalum. Carbon anodes are sometimes used but are not recommended.

10.6.2 Gold Strike

A	PROBLEM	CAUSE	ACTION
Gold peeling from nickel.		Nickel passivated from nickel.	Do not allow parts to dry between nickel and gold plate. Keep drip times between nickel and gold plate to a minimum. Check nickel activator (acid between nickel and gold) for cleanliness and activity. See that panels enter gold strike ‘‘live’’ with approximately 4 volts on rectifier.
		Improper cleaning.	Thoroughly check entire cleaning cycle. Verify proper rinsing after each process tank.
		Oil on surface or organic contaminants in gold strike.	Skim tanks to remove any surface contamination. Carbon treat gold strike using carbon filter cartridges.
		Very high or very low levels of stress reducer in nickel bath.	Analyze for stress reducer and adjust as necessary. Remove excessive stress reducer by carbon treatment.
		High pH of gold strike.	Maintain pH of gold strike according to vendor’s specifications.

10.6.3 Hard Gold

A	PROBLEM	CAUSE	ACTION
Gold peeling from gold (failure between strike and hard gold, or failure between hard and soft gold layers).		Gold strike on panel not properly activated.	See that panels enter subsequent gold baths ‘‘live.’’ Inspect rinses between baths for contamination. Do not allow panels to dry between tanks.
		Oil on surface or organic contaminants in bath.	Skim tanks to remove any surface contamination. Carbon treat hard gold using carbon filter cartridges.
		High pH of hard gold.	Maintain pH of bath according to vendor’s specifications.

B	PROBLEM	CAUSE	ACTION
Cloudy deposits or burning in the high current density area.		Poor agitation.	Increase solution agitation.
		High pH.	Reduce pH according to vendor specifications.
		Cobalt or brightener concentration too low.	Adjust according to vendor’s recommendations.
		Inorganic contamination.	Consult vendor for possible remedy. Replace bath. Investigate possible source(s) of contamination and eliminate.

C	PROBLEM	CAUSE	ACTION
Dullness in high or low current density areas.		Organic contamination.	Carbon treat bath.
		High pH.	Reduce pH according to vendor specifications.
		Underlying metal is dull (the thin gold plate will mimic the surface beneath it).	Improve plating of the underlying metal. (See 10.3 and 10.5).

D	PROBLEM	CAUSE	ACTION
Decrease in deposit hardness.		Low hardener concentration.	Adjust according to vendor’s recommendations.
		Organic contamination.	Carbon treat bath.
		High pH.	Reduce pH according to vendor specifications.
		Current density too high.	Keep current density within vendor’s specifications. Recalculate plating area.
		Inorganic contamination.	Consult vendor for possible remedy. Replace bath. Investigate possible source(s) of contamination and eliminate.

10.6.3 Hard Gold (continued)

E PROBLEM	CAUSE	ACTION
Increase in deposit hardness.	High hardener concentration.	Adjust according to vendor's recommendations.
	Low gold concentration.	Adjust gold according to vendor specifications.
	Low pH.	Raise pH to within specifications.
	Low solution specific gravity.	Raise specific gravity to within specification.
	Low current density.	Recalculate plating area and adjust current density to within vendor specifications.

F PROBLEM	CAUSE	ACTION
Poor efficiency.	Low gold concentration.	Adjust gold according to vendor specifications.
	High cobalt-to-gold ratio.	Adjust according to vendor's recommendations.
	Metals contamination.	Consult vendor for possible remedy.

G PROBLEM	CAUSE	ACTION
Rough plate. (See Figure 10-3.)	Rough copper or nickel underplate.	Follow action items of 10.5.3A and 10.5.3B on roughness and burning of nickel. Follow action items 10.2.2A and 10.2.1B on roughness and burning of copper.
	Particulates in bath.	Increase solution filtration. Carbon treat bath.

H PROBLEM	CAUSE	ACTION
Poor throwing power.	Low solution density (specific gravity).	Raise specific gravity to within vendor's specifications.

J PROBLEM	CAUSE	ACTION
Higher than normal efficiency.	Low hardener content.	Adjust according to vendor's recommendations.
	Organic contamination.	Carbon treat bath.

K PROBLEM	CAUSE	ACTION
Stressed deposits.	High cobalt-to-gold ratio.	Adjust according to vendor's recommendations.
	Organic contamination.	Carbon treat bath.

L PROBLEM	CAUSE	ACTION
Pitting. (See Figure 10-4.)	Pitted nickel underplate.	Follow action items in 10.5.3C on pitting of nickel.

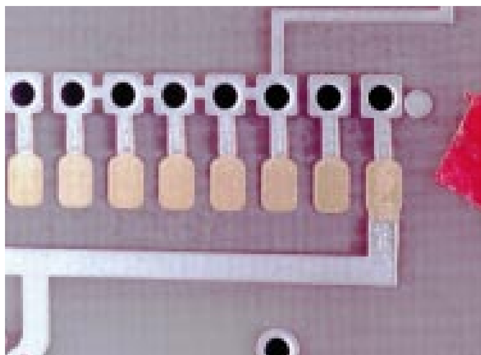

Figure 10–3. Rough plating.

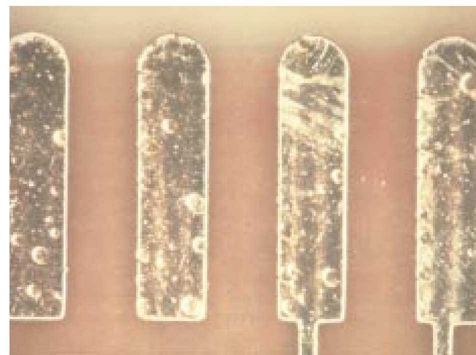

Figure 10–4. Hard gold pitting.

10.6.3 Hard Gold (continued)

M PROBLEM	CAUSE	ACTION
Resist lift during plating, resulting in gold plating under the resist.	Wrong type of resist used.	Solvent and semi-aqueous resists generally work better than full-aqueous resists (however, aqueous resists are available that will work). Consult both resist vendor and gold bath vendor for recommendations on best resist type and application method.
	Gold concentration too low, resulting in poor efficiency (this causes formation of hydrogen bubbles which tend to lift the resist).	Adjust gold concentration to within specification, or to top end of range. See 10.6.3F.
	Poor resist adhesion.	Improve surface preparation before resist lamination. Improve resist lamination procedure according to vendor's recommendations. Control exposure and development according to vendor's recommendations.
	Plating current density too high, causing gassing that lifts resist.	Lower current density according to vendor's recommendations.
	Insufficient agitation in gold bath.	Maximize solution agitation, following vendor's recommended procedures.
	Resist too old or aged.	Institute good inventory practices. Store resist in cool, dry area. Minimize amount stored and improve turnover.

10.6.4 Soft (bondable) Gold

A PROBLEM	CAUSE	ACTION
Gold peeling from gold (failure between strike and soft gold, or failure between hard and soft gold layers).	Gold strike on panel not properly activated.	See that panels enter subsequent gold baths "live." Inspect rinses between baths for contamination. Do not allow panels to dry between tanks.
	Oil on surface or organic contaminants in bath.	Skim tanks to remove any surface contamination. Carbon treat hard gold using carbon filter cartridges.

B PROBLEM	CAUSE	ACTION
Burning in high current density areas.	Low gold concentration.	Adjust gold according to vendor specifications.
	Poor agitation.	Increase solution agitation.
	Current density too high.	Keep current density within vendor's specifications. Recalculate plating area.
	Organic contamination.	Carbon treat bath.

C PROBLEM	CAUSE	ACTION
Dark reddish color in high current density areas.	Current density too high.	Keep current density within vendor's specifications. Recalculate plating area.
	Bath temperature too low.	Raise temperature to within specification.
	Low gold concentration.	Adjust gold according to vendor specifications.

D PROBLEM	CAUSE	ACTION
Failure to pass heat test or wire bond test.	Codeposition of other metals.	Consult vendor for possible remedy.
	Inadequate gold thickness.	Increase plating time; improve efficiency.
	Organic contamination.	Carbon treat bath.

10.6.4 Soft (bondable) Gold (continued)

E	PROBLEM	CAUSE	ACTION
Poor efficiency.		Low gold concentration.	Adjust gold according to vendor specifications.
		Metals contamination.	Consult vendor for possible remedy.

F	PROBLEM	CAUSE	ACTION
Rough plate. (See Figure 10-3.)		Rough copper or nickel underplate.	Follow action items of 10.5.3A and 10.5.3B on roughness and burning of nickel. Follow action items 10.2.2A and 10.2.1B on roughness and burning of copper.
		Particulates in bath.	Increase solution filtration. Carbon treat bath.

G	PROBLEM	CAUSE	ACTION
Poor throwing power.		Low solution density (specific gravity).	Raise specific gravity to within vendor's specifications.

H	PROBLEM	CAUSE	ACTION
Pitting (see Figure 10-4).		Pitted nickel underplate.	Follow action items in 10.5.3C on pitting of nickel.

J	PROBLEM	CAUSE	ACTION
Porous gold deposit.		Inadequate gold thickness.	Check thickness and confirm as cause. Increase plating time; improve efficiency. (Gold plate directly over copper must be thicker than gold plated over nickel, as the copper tends to migrate into the gold.)
		Contaminants in or on surface to be plated.	Inspect cleaning line. Do not pumice scrub prior to gold plating.
		Particulates in gold bath.	Improve filtration. If using carbon anodes, switch to platinized titanium or tantalum.
		Incorrect operating parameters.	Operate according to vendor's recommendations.

K	PROBLEM	CAUSE	ACTION
Resist lift during plating, resulting in gold plating under the resist.		Wrong type of resist used.	Solvent and semi-aqueous resists generally work better than full-aqueous resists (however, aqueous resists are available that will work). Consult both resist vendor and gold bath vendor for recommendations on best resist type and application method.
		Gold concentration too low, resulting in poor efficiency (this causes formation of hydrogen bubbles which tend to lift the resist).	Adjust gold concentration to within specification, or to top end of range. See 10.6.4E.
		Poor resist adhesion.	Improve surface preparation before resist lamination. Improve resist lamination procedure according to vendor's recommendations. Control exposure and development according to vendor's recommendations.
		Plating current density too high, causing gassing that lifts resist.	Lower current density according to vendor's recommendations.
		Insufficient agitation in gold bath.	Maximize solution agitation, following vendor's recommended procedures.
		Resist too old or aged.	Institute good inventory practices. Store resist in cool, dry area. Minimize amount stored and improve turnover.

10.7 CONTACT PLATING (TAB OR FINGER PLATING)

The general process for tab plating involves: 1) masking-off of the board (to protect areas that will not be tab-plated), 2) tin-lead removal from finger area, 3) cleaning of the area, and 4) nickel and gold plating of the fingers. Many of the general cleaning and plating problems, such as peeling, are similar to those already discussed in other sections. This section will be devoted to those process effects associated specifically with tab plating.

10.7.1 Preparation/Masking (Taping or Photoresist Application - Also see 9.2 and 16.4)

A PROBLEM	CAUSE	ACTION
Bleed under the tape, causing tin-lead discoloration.	Tape does not conform to circuitry, or adhesion of the tape is not good.	Change tape; content of adhesive is insufficient. Tape old; adhesive failure. Tape not properly stored in low temperature/humidity area. Insufficient pressure used to apply tape. Speed too fast to properly apply tape. Heat necessary to get tape to conform to dense or high circuitry. Storage between taping, rolling and plating too long; re-roll tape.
	Mask not sufficient to dwell in the stripping or plating cells, causing tape adhesion failure.	Investigate long dwell in plating or stripping cell(s).

B PROBLEM	CAUSE	ACTION
Discoloration of tin-lead/copper butt line after selective plating and reflow.	Tin-lead stripper bleed under butt line discoloring tin-lead, or plating chemical bleed under the tape.	Use better taping techniques. (See 10.7.1 A). Increase stripping speed.

10.7.2 Tin-Lead Stripping

A PROBLEM	CAUSE	ACTION
Incomplete stripping of tin-lead.	Insufficient current in electrolytic stripping.	Increase current. Reduce speed of conveyor or increase dwell time.
	Electrolytic stripper spent (HCl).	Add sodium chloride (30-60 g/l). Dump and make a new stripper if copper content over 2500 ppm.
	Chemical stripper spent.	Dump and make new stripper.
	Speed and dwell time incorrect.	Decrease conveyor speed; increase dwell time.
	Tin-lead reflowed and chemical stripping being used (reflowed tin-lead strips very slowly).	Use electrolytic stripping.
	Tin-lead too thick for stripping parameters.	Decrease tin-lead thickness if practical or increase stripping time/activity.

B PROBLEM	CAUSE	ACTION
White smut on copper not removed by stripper.	Old or spent stripper.	Dump and make new stripper. Remove smut with an etch. Remove smut with mechanical brushing.
	Strip time too long; stripper spent.	Discard stripper.

10.7.2 Tin-Lead Stripping (continued)

C PROBLEM	CAUSE	ACTION
Copper attacked and unusually rough.	Stripper attacks copper; excessive dwell time in stripper.	Change stripper type to less aggressive type. Increase conveyor speed/decrease dwell. Reduce current in electrolytic cell.
	Tin-lead deposit uneven; not uniform so removal is not uniform.	Check tin-lead plating and etching parameters.
	Stripper hot from overloading.	Stripper bath heats up during use. Reduce work load or increase bath volume.

10.7.3 Cleaning

A PROBLEM	CAUSE	ACTION
Copper oxidation, pitting, surface contamination.	Improper cleaning procedure.	Use a copper cleaner; etch or scrub prior to nickel plating.
	Improper stripping of tin-lead.	Adjust so that electrolytic stripping does not remove excessive copper.
	Improper mechanical scrubbing.	Provide sufficient scrubbing prior to plating (brushes not adjusted properly).

10.7.4 Plating

This section covers problems specific to the plating of tabs or contact fingers. Additional information can be found in Section 10.5 (Nickel plating) and 10.6 (Gold plating).

A PROBLEM	CAUSE	ACTION
Nickel-to-copper peel.	Improper copper cleaning.	Follow action items in Section 10.7.3 A.
	Incomplete removal of tin-lead.	Follow action items in Section 10.7.2 on tin-lead stripping.
	Nylon smear on copper.	Adjust brushes.

B PROBLEM	CAUSE	ACTION
Fingerprint impressions found on tabs.	Organic or oxide soils on electrolytic copper or nickel.	Improve cleaning and handling during electrolytic processes.

C PROBLEM	CAUSE	ACTION
Burning of nickel. (Also see Sections 10.5.2 B and 10.5.3 B.)	Low bath temperature.	Raise temperature to within range specified by supplier.
	Poor agitation.	Increase solution agitation.
	Current density too high.	Recalculate plating area and follow supplier's recommendations. Lower current density if it is too high for the amount of agitation.
	Incorrect positioning of anodes or plated work (poor current distribution).	Use bottom anodes. Make sure anodes are straight and not bent towards parts.
	Nickel concentration too low.	Raise concentration to optimum by addition of nickel sulfate. Use soluble anodes to prevent excess build-up of bath volume.

10.7.4 Plating (continued)

D	PROBLEM	CAUSE	ACTION
Nickel-to-gold peel.		Nickel passivated.	Do not dwell too long between nickel and gold plate. Use gold strike. Eliminate nickel contaminated with sulfate breakdown products.
		Current density in gold incorrect.	Correct current density to prevent burning or immersion deposits.
		Incomplete removal of lead during strip.	Improve cleaning and scrubbing. (See 10.7.2 A).
		Solution bleed from under tape during plating operation.	Follow action items in Section 10.7.1 A.

E	PROBLEM	CAUSE	ACTION
Non-uniform gold deposit.		Incorrect relationship of anodes to panels.	Increase/decrease anode spacing. Use bottom anodes. Straighten bent anodes to maintain uniform spacing.
		Low electrolyte.	Correct electrolyte balance per supplier's recommendations.
		Insufficient agitation.	Maximize agitation of bath and panel according to supplier's recommended procedures.
		High current density.	Reduce current density.
		Too high or too low gold metal content in bath.	Correct according to supplier's recommendations.

10.8 MISCELLANEOUS PLATING SOLUTIONS

10.8.1 Rhodium

Electroplated rhodium is hard, non-tarnishing and corrosion resistant. It possesses a low constant contact resistance (1 milliohm), and excellent wear resistance. Rhodium is generally plated over silver, nickel and/or gold. Baths are fairly strong acid solutions and are sulfate and/or phosphate based.

A	PROBLEM	CAUSE	ACTION
Brittle and/or stressed deposits.		Low metal contamination.	Analyze bath and maintain concentration according to specification.
		Low acid.	Low acid tends to precipitate the rhodium salts. Keep pH well below 2.
		Low bath temperature or very high temperature.	Maintain temperature at optimum.
		Contamination.	Carbon treat to remove organic contamination. Activated carbon tends to remove some rhodium from the bath. There is no effective method to remove metallic contaminants.

B	PROBLEM	CAUSE	ACTION
Streaked deposits.		Metallic contamination.	There is no effective method for removal. Prevent by using a gold strike prior to rhodium plate.

10.8.1 Rhodium (continued)

C PROBLEM	CAUSE	ACTION
Peeled deposits.	Poor pre-clean.	Inspect clean line. Verify proper rinsing after each process tank.
	Nickel is passivated.	Do not allow parts to dry between electroplating baths. Keep drip times between tanks to a minimum. Check nickel activator (acid after nickel plate) for cleanliness.
	High stress in rhodium plate.	Follow action items in Section 10.8.1A.

D PROBLEM	CAUSE	ACTION
Rhodium plate too thin.	Poor efficiency.	Increase rhodium metal concentration. Increase solution agitation.
	Incorrect current density.	Recalculate plating area.

10.8.2 Palladium

Palladium is gaining some acceptance as a substitute for gold on contacts or fingers. Compared to gold, palladium electrodeposits exhibit better wear resistance and equal corrosion resistance in certain environments, and good electrical properties.

A major disadvantage is the formation of an insulating polymer film on the surface, thereby increasing contact resistance. This problem can be overcome with design changes and/or by the use of a thin deposit of gold over the palladium. Plating baths are generally alkaline with an ammonia base.

A PROBLEM	CAUSE	ACTION
Bath decomposition.	Organic contamination.	Carbon treat bath.

10.8.3 Tin-Nickel Alloy Plating

The alloy deposit consists of 65% tin to 35% nickel; this composition remains fairly constant over a wide range of operating conditions. The deposit is highly corrosion and tarnish resistant, and is solderable.

A PROBLEM	CAUSE	ACTION
Dull, black, brittle or milky deposits.	Low fluoride.	Run Hull cell; follow vendor's recommendations.
	Contamination due to copper.	Dummy plate at 3 to 5 ASF.
	Tin content too low.	Adjust per vendor recommendations.
	Contamination from wetting agents and brighteners from other electrolytes.	Filter bath through activated carbon. Contamination should absolutely be avoided. No oxidizing agents such as hydrogen peroxide or potassium permanganate should ever be added.

B PROBLEM	CAUSE	ACTION
Roughness.	Suspended matter in bath.	Improve solution filtration.
	Metallic contamination.	Follow vendor's recommendations. The bath will dissolve most metals. Avoid leaving work in the tank with current off. Avoid dropping work in the tank.

10.8.3 Tin-Nickel Alloy Plating (continued)

C	PROBLEM	CAUSE	ACTION
Powdery gray deposit.		Current density too high.	Lower current density; recalculate plating area if necessary.
		Nickel content too low.	Adjust nickel concentration as required.

10.8.4 Palladium-Nickel

Palladium-nickel is also gaining acceptance as a substitute for gold. It exhibits characteristics that make it acceptable used on PC tabs or fingers. The hardness of the palladium-nickel coating is greater and the porosity lower than the standard hard gold finish. The deposit also exhibits excellent solderability.

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Section 11
Etching

11.0 ETCHING

Most process problems that appear during the etching stage of printed circuit production can be traced to one of two general areas. The most common and obvious cause of etching problems is the etching equipment itself, either through component failure or misadjustment. The second most common cause of problems during the etching step are problems which occur during prior processing steps but are not detected until the boards are processed through the etcher. An example would be resist scum left on the board during the stripping of a plating resist, which can cause uneven etching to occur.

This section will outline some of the problems that can occur during the etching process with the most probable cause(s) and actions that can be taken to correct them. When the cause of a problem can be traced to a prior process step, it will be noted as such and the reader directed to the appropriate section if necessary.

This section is organized by etching chemistries. The first subsection deals with general problems that can be encountered with any chemistry used for etching, and should be referred to first. The following subsections deal with specific problems relating to cupric chloride, ammoniacal, sulfuric/peroxide and ferric chloride, etching baths, respectively. A final miscellaneous section deals with problems associated with etching chemistries and equipment not in wide use or not applicable to one of the subsections above. Each subsection is further divided into the problems relating to bath control, over-etching, under-etching and residues left on the board surface.

11.1 GENERAL

11.1.1 Equipment-Related Effects and Effects from Other Processes

A	*PROBLEM*	*CAUSE*	*ACTION*
Non-uniform etch from side-to-side of panel.		Spray nozzles clogged.	Check and clean nozzles as necessary.
		Spray tubes out of alignment.	Follow equipment manufacturer's recommendations for spray tube adjustment.
		Conveyor wheel alignment. (If conveyor wheels are not staggered from rod to rod, wheels can mask those areas of the board.)	Rearrange wheels in staggered pattern so no two wheels are in line.
		Spray tube flow adjustments not set properly (if equipment has provisions for individual spray tube adjustment).	Check spray pressures in each spray tube and adjust accordingly.
		Leak in spray tube, causing loss of spray pressure. (Most common place for this to occur is where the spray tube connects to the manifold feeding the spray tubes.)	Check spray tubes for leaks, especially at junction of spray tube and manifold, and repair or replace spray tube if necessary.
		Low solution level causing pump cavitation.	Restore solution volume.

11.1.1 Equipment-Related Effects and Effects from Other Processes (continued)

B *PROBLEM*	*CAUSE*	*ACTION*
Non-uniform etch (copper left on some areas of panel while other areas are etched properly).	Improper developing or stripping of panels prior to etching, leaving a resist scum on the panel surface.	Check developing or stripping processes in shop. (See Section 9.0 on Imaging.)
	Poor quality artwork. (This could be a cause of improper developing or stripping, leaving a resist scum on the panel surface.)	Carefully inspect artwork and artwork preparation procedures. (See Section 3.0 on Photo-tooling.)
	Improper cleaning of panels. (Residues left on panel surface after precleaning, prior to resist application.)	Check cleaning procedures. (See Section 8.0 on Cleaning and Section 9.0 on Imaging.)
	Non-uniform copper plating on panel (panel plate operations).	Follow actions specified in Section 10.2.
	Touch-up ink on rollers.	Check dryness of touch-up ink on panels. Clean rollers if necessary.

C *PROBLEM*	*CAUSE*	*ACTION*
Excessive undercut (over-etching). (See Figure 11–1.)	Improper spray angle, spray tubes out of adjustment, or improper spray nozzles - depending on type of equipment.	Check manufacturer's recommendations for spray tube adjustment or proper nozzles.
	Excessive spray pressure.	Check spray pressure. (In most spray etchers, pressure should be between 20 and 30 psig.)
	Resist breakdown along edges of traces or resist lifting on edges.	Spray pressure too high. (See above). Also may be caused by cleaning and developing problems. (See Sections 8.0 and 9.0 on Cleaning and Imaging, respectively.)

Figure 11–1 Overetched conductor

11.1.1 Equipment-Related Effects and Effects from Other Processes (continued)

D PROBLEM	CAUSE	ACTION
Panels skewing on conveyor.	Machine not level.	Check to see if conveyor is level and level up machine if necessary.
	Spray tubes out of alignment in oscillating equipment, causing uneven pressure on board.	Check alignment and follow manufacturer's recommendation for adjusting spray.
	Worn conveyor gears causing the conveyor rod to stop rotating.	Replace worn gears.
	Bent or warped conveyor rods.	Replace bent rods.
	Inoperative dragout rollers.	Replace or repair.
	Internal baffles set too low and catching on boards as they pass.	Adjust baffles.
	Unbalanced top and bottom spray pressures. (Too much bottom spray pressure can lift lighter boards.)	Check and adjust spray pressures.

E PROBLEM	CAUSE	ACTION
Copper left around circuit patterns.	Resist not completely stripped from panels. (If the copper has overplated the resist edge it will trap the resist and prevent proper stripping.)	Check for complete resist removal. If necessary, consider using a thicker resist. (Also see Section 9.0 on Imaging and Section 10.2 on Copper plating.)
	Conveyor speed too fast.	Check/adjust speed.

F PROBLEM	CAUSE	ACTION
Etch rate slows.	Wrong thickness of copper on panel.	Confirm copper thickness and adjust conveyor speed accordingly. Two ounce copper etches slower than one ounce.

G PROBLEM	CAUSE	ACTION
Etchant attacks resist (on print-and-etch work).	Etch resist improperly cured or dried.	Check/confirm proper cure of resist. Check proper lamination, exposure and development of photoresist (Section 9.0.)

H PROBLEM	CAUSE	ACTION
Front of panel etches differently from back of panel.	Different copper thicknesses, front-to-back of panel.	Adjust spraying action to compensate, or etch one side at a time at correct parameters for that thickness (etch each side facing upwards and shut off bottom spray nozzles).
	Differential spray pressures.	Check spray pressures. Check for clogged nozzles. Use test panels to confirm uniform etching.
	Resist mylar cover sheet left on one side of panel (print-and-etch operation).	Insure mylar sheet is removed. Check removal equipment or operator.

11.2 CUPRIC CHLORIDE

11.2.1 Bath Control

A PROBLEM	CAUSE	ACTION
Overchlorination causing free chlorine in atmosphere around machine.	Dirty ORP probes.	Check probes. If a layer of oxidation can be seen on the tips, carefully rub off with a pencil eraser.
	ORP probes not standardized.	Probes should be standardized at installation and the standardization should stay steady over a long period of time. However, the probes can become unstandardized and should be checked if constant overchlorination is a problem.
	Electrical interference causing probes to give false readings.	Use shielded cable from probes to junction and from junction to remote box. If shielded cable is being used, check grounding of shield. Check with supplier for guidelines.
	Leak in chlorine plumbing to etcher.	Leaks in the chlorine plumbing can be easily detected and located by holding a cloth soaked with ammonia close to suspected areas. If chlorine is present, the cloth gives off a white vapor.
	Leak in solenoid valve to chlorine gas supply, allowing a constant flow of chlorine to etcher.	Replace or repair valve.

B PROBLEM	CAUSE	ACTION
Sudden slowdown in etch rate.	Supply problems with regeneration chemicals causing either slow regeneration or none at all.	Check to see if chemistry is adequate and replace empty drums or cylinders. If using chlorine gas, check cylinders to see if they are frozen (frost on the outside of the cylinder is a good indication of this). Defrost by circulating room temperature air around cylinder with a fan (never apply direct heat to cylinder). If cylinder freezing is a constant problem, then the system is demanding chlorine faster than the cylinder can provide it. The solution is to manifold several cylinders together or obtain an evaporator. Check the solenoid valves that supply the chemistry to see if they are jammed or not operating correctly. Fix or replace as necessary.
	Water leak diluting etchant.	Check specific gravity of etchant which should be in the range of 30-32 Baumé (1.261-1.283 s.g.). If it is considerably less than this, then a water leak is a definite possibility. Check cooling coil and other possible water sources.

C PROBLEM	CAUSE	ACTION
Slow etching. (Etch rate is not as fast as it should be, but seems to be fairly steady.)	Millivolt setting too low on ORP control. (The ORP setting should not be much below 500 millivolts. If it is, then bath may not be regenerating to full potential.)	Reset ORP controller to higher setpoint. (For cupric chloride this should be between 500 and 540 millivolts.) Check with equipment manufacturer for guidelines.
	Etchant being slowly diluted by slow leak in cooling water coil.	Check water inputs to etcher for leaks. (Also see Section 11.2.1.B.)
	Under high production conditions, boards can drag-in enough water from previous steps to dilute etchant.	Install extra drag-out rollers or air curtain. Check with equipment supplier.
	Specific gravity of etchant too high (should be between 30 and 32 degrees Baumé).	Make sure water make-up control is operating properly. Dilute etchant to proper range with water.

11.2.2 Improper Etching

A PROBLEM	CAUSE	ACTION
Over-etching. (See Figure 11-1.)	Conveyor speed too slow.	Check to see if conveyor speed is at proper setting. (This can be very important if several different thicknesses of copper are being processed during the day.) Check speed calibration. If conveyor setting is correct, check chemistry and other equipment parameters such as spray pressure. (See 11.2.1 on bath control.)
	Hydrochloric acid content of etchant higher than normal.	Check free HCl content of etchant. (In normal regenerated cupric chloride the free HCl content should be very low; in the range of 0.1 N or less. If significantly higher, check HCl valves for leaks. Check with equipment supplier for guidelines.)
	Etchant specific gravity lower than normal. (The etch rate of cupric chloride increases as the solution is diluted until the solution reaches a specific gravity of 26 Baumé, at which point it begins to fall off.)	Check to see that operating specific gravity of cupric chloride solution is 30-32 Baumé at 54°C. (If specific gravity is less than this, then the increase in etch rate may be enough to cause over-etching.) Check water inputs for leaks. Add copper to solution to bring specific gravity back to 30-32 Baumé.
	Etchant over-regenerated. (If the etcher is well ventilated, it is possible to over-regenerate the chlorine without release into the work area.)	Check the millivolt reading of the etchant. (Normal operating condition is 500-540 millivolts. Readings consistently higher than this show over-regeneration and a higher than normal etch rate. See 11.2.1.A on overchlorination for possible causes and corrective actions.)

B PROBLEM	CAUSE	ACTION
Under-etching.	Conveyor speed too fast.	Check conveyor speed setting to be sure it is set correctly for the thickness of copper being etched. (See 11.2.1 on Bath control.)
	Etchant not at operating temperature.	Check etchant temperature. Check for possible heater malfunction.
	Etchant specific gravity too high. (As specific gravity rises, etch rate drops.)	See that specific gravity is between 30 and 32 Baumé at 54°C. Check to see if specific gravity control and water make-up are operating correctly. Dilute etchant to proper range.
	Spray pressure lower than normal.	Check spray pressure adjustments to see if they have been changed. Check for a pump problem or a leak in plumbing. Make sure etchant volume is correct in etcher sump. (Low fluid level may cause pump to cavitate and lose pressure.)
	Etchant under-regenerated.	Check millivolt reading of etchant. (If below 500 consistently, see 11.2.1.B and 11.2.1.C for possible causes and corrective action.)

11.3 ALKALINE (AMMONIACAL) ETCHANTS

11.3.1 Bath Control

A PROBLEM	CAUSE	ACTION
Excessive crystallization in etcher.	Etchant pH too low. (For most alkaline etchants, if the pH falls below the supplier's recommended minimum operating pH, usually around 8.0, excessive crystallization can result.)	Check replenisher solution supply - be sure that supply tanks or drums are not empty. Check replenisher supply plumbing - check for clogged lines or bad solenoids to be sure solution is reaching etcher when called for. Check replenisher controller for proper operation. Check etcher venting - excess venting can draw off ammonia from etching solution and lower the pH. (Venting should be set just high enough to keep the work area comfortable and no higher.) Check/calibrate pH meter.

B PROBLEM	CAUSE	ACTION
Etchant no longer etches. Alkaline salts precipitate out of etchant and fall to bottom of etch sump (sludging).	Excess water getting into etcher sump. (Excess water dilutes etchant and lowers pH to a point where alkaline salts no longer stay in solution, destroying etch bath.)	Check for unwanted water inputs. (The two most common sources are leaks in the cooling coil and drag-in from boards entering the etcher, especially if an in-line stripper and rinse are being used.) Make sure panels are dry prior to entering the etcher. Check cooling coil for leaks (generally the machine must be emptied first).
	Excessively low pH.	See 11.3.1.A for causes and corrective actions for low pH.

C PROBLEM	CAUSE	ACTION
Etch rate slows as boards are being processed. (If etcher is allowed to sit for several hours, etch rate returns to normal then begins to slow again.)	Impeded air flow into etcher. (Oxygen is a necessary ingredient for the replenishment process. It is possible, in an effort to prevent ammonia fumes from escaping the etcher, to block the needed air flow into the etcher.)	Check with machine and/or chemistry supplier for the best way to control fumes without cutting oxygen supply to etchant. Correct placement of venting is very important.

D PROBLEM	CAUSE	ACTION
Resist coming off in etcher (when using dry film or screened ink as etch resist).	pH of etch bath too high. (Some fully aqueous dry films and some types of UV curable screen inks will soften and peel if the etchant is at or above the upper end of the pH operating range for most alkaline etchants. The resists have been run in alkaline etchants by keeping the etchant pH at the lower end of the pH range, around 8.1.)	Check with etchant supplier for the best way to accomplish this for the particular etchant being used.
	Ammoniacal etcher replenishment chamber out of control.	Check pH of replenishment chemistry. Make sure replenishment chamber is well vented (ammonia is a good resist stripper).
	Wrong resist for ammoniacal etching.	New alkaline-resistant dry films are available that allow etching at a pH of 9 or above. Check with supplier to verify that resist is compatible with etchant. Investigate alternate materials.

11.3.2 Improper Etching

A PROBLEM	CAUSE	ACTION
Over-etching. (See Figure 11-1.)	Conveyor speed too slow.	Check to see if conveyor speed is set properly for the thickness of copper being etched.
	Etchant pH higher than normal. (Etchant pH has little effect on etch rate but it does have an effect on the amount of undercut per side. As pH increases, undercut increases, which could be mistaken for over-etching.)	Check pH of etchant and, if above normal, run etcher and ventilation without adding copper until pH returns to former level.
	Etchant specific gravity lower than normal. (As above, specific gravity has little effect on overall etch rate within the operating parameters of the etchant but does have an effect on undercut. As specific gravity goes down, undercut per side increases.)	Check specific gravity of etchant and, if lower than normal, add copper to etcher with replenisher feed valve turned off to bring specific gravity back to former level. Check operation of replenishment controller.

11.3.2 Improper Etching (continued)

B PROBLEM	CAUSE	ACTION
Under-etching. (See Figure 11-2.)	Conveyor speed too fast.	Check to see if conveyor speed is set properly for the thickness of copper being etched.
	Etchant pH lower than normal. (Etchant pH has little effect on etch rate but it does have an effect on the amount of undercut per side. As pH decreases, undercut also decreases, which could be mistaken for under-etching.)	Check pH of etchant solution. (See 11.3.1.A for causes and corrective actions for low pH.)
	Etchant specific gravity higher than normal. (As above, specific gravity has little effect on overall etch rate within the operating parameters of the etchant but does have an effect on undercut. As specific gravity increases, undercut per side decreases.)	Check specific gravity of etchant and, if higher than normal, add replenisher solution to bring it back to normal levels. Check for proper operation of replenishment controller.
	Etchant not up to temperature.	Check/correct etchant temperature. Check for possible heater or controller malfunction.
	Spray pressure lower than normal.	Check spray pressure adjustments to see if they have changed. Check for pump malfunction or leak in plumbing. Low fluid level may cause pump to cavitate and lose pressure; check level controls and replenisher/spent pump system for correct operation.

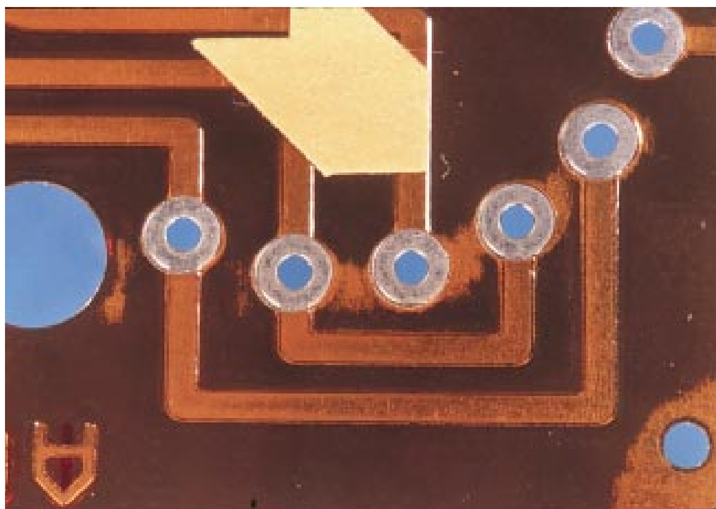

Figure 11–2 Underetched conductors showing excess copper

11.4 PEROXIDE-SULFURIC ETCHANTS

11.4.1 Bath Control

A PROBLEM	CAUSE	ACTION
Excessive peroxide consumption.	High temperature of etchant solution induces peroxide decomposition by ''blow-off.''	Maintain temperature within supplier's recommended limits. Check/confirm proper operation of temperature controller and heater.
	Repeated, prolonged high temperature exposure has led to decomposition of the peroxide stabilizer.	Consult supplier for recommended addition of stabilizer. If peroxide level cannot be maintained readily, bath should be dumped and replaced with a fresh batch.
	Bath may have become contaminated with a material that is catalytic for peroxide decomposition, such as organic contaminants or certain metals.	Ensure proper bath cleanliness, minimal organic drag-in (such as from cleaners), no cross-contamination of solutions, proper equipment construction (i.e., no materials being attacked and dissolved by the bath). Check for dissolved metals using atomic absorption analysis.

B PROBLEM	CAUSE	ACTION
Blackening of tin-lead solder during etching.	Tin-lead alloy ratio may be out of balance.	Check tin-lead plating bath controls. (See Section 10.3.)
	Solder attack inhibitor may be depleted from etchant bath.	Analyze and replenish inhibitor per supplier specifications.
	Copper contamination in the tin-lead plate.	Check for copper contamination in solder bath and follow recommendations outlined in Section 10.3 describing dark plating.
	Resist stripper activates tin-lead prior to etching.	Do not use a resist stripper that contains hydroxide.

C PROBLEM	CAUSE	ACTION
Slow, but uniform etch rate.	Replenisher concentration too low.	Analyze bath for peroxide and replenish as necessary.
	Bath temperature too low.	Check for correct operating temperature. Confirm proper operation of temperature controller and heaters.
	Acid content too high, limiting solubility of copper.	Allow acid normality to drop into accepted range (consult supplier for procedure). Review acid addition operation.
	Rate promoter concentration too low.	Check replenishment pumps and ensure correct addition rate.
	Copper content too high, i.e., etchant solution is near saturation level.	Analyze for copper content in etch tank. Check that solution transfer rate to chill tank is satisfactory. Ensure that solution returning from settling tank to etch tank is sufficiently low in copper content. Check/confirm proper operation of entire copper removal process.
	Chloride contamination of etchant.	Consult supplier for remedy. Use only deionized water for makeup.

11.4.1 Bath Control (continued)

D	PROBLEM	CAUSE	ACTION
Etchant solution temperature rises.		Transfer pumps (to chiller) not operating properly.	Check proper operation of transfer pumps.
		Overflow line from recovery system to etcher may be plugged with copper sulfate crystals.	Clean all lines and piping; confirm proper operation.
		Recirculation rate or cooling rate is inadequate.	Check for adequate water flow through cooling coils. Investigate recirculation and transfer process to ensure adequacy. Temperature of solution in the recovery system should be cool, about 21°C.

E	PROBLEM	CAUSE	ACTION
Etchant temperature loss.		Recirculation rate to recovery system is too high.	Investigate recirculation and transfer process per supplier recommendations. Check that solution in recovery system is not too cool (should be 21°C).
		Bath heating system is malfunctioning, is inadequate or thermostat set wrong.	Check/confirm temperature controller and heater operation in bath.
		Bath cooling system malfunction.	Check that bath cooling coils are functioning properly.

F	PROBLEM	CAUSE	ACTION
Excessive foam blanket.		Over replenishment of proprietary additives.	Reduce replenishment rate to within supplier recommendations to gradually reduce foam blanket.
		Contaminants have caused some peroxide decomposition that has contributed to the foaming action.	See 11.4.1.A for causes and corrective actions.

G	PROBLEM	CAUSE	ACTION
Crystals (copper sulfate) not precipitating readily in immersion equipment. (Instead, very fine particles form a gel-like mass in the chill and/or settling tanks.)		Too rapid chilling that causes extremely fine crystal formation.	Raise temperature of chill tank slightly. Introduce solution into chill tank with better mixing. Ensure that acid normality of etchant solution is within supplier's recommended limits.

H	PROBLEM	CAUSE	ACTION
Building solution volume.		Introduction of water from unwanted sources.	Check for leaks in cooling coils (both bath and recovery system). Ensure correct placement of squeegees and/or rollers between etch chamber and rinse chambers (before and after etch); ensure no rinse water is draining back into the etch chamber.

J	PROBLEM	CAUSE	ACTION
Etchant solution volume drop.		Overflow line from recovery system to etcher is blocked with crystals.	Check and clean the line. Establish regular maintenance procedure if necessary. Check for inadequate removal of copper in the recovery process. (See 11.4.1.C.)

11.4.2 Improper Etching

A PROBLEM	CAUSE	ACTION
Nonuniform etch (copper left in some areas of panel while others are etched properly). (Also see Section 11.1.1.B.)	Spray nozzles are clogging with copper sulfate crystals.	Check for adequate removal of copper in the recovery process (see 11.4.1.C.)
	High copper concentration in etcher.	Copper concentration should not be over 45 g/l. Cool bath and crystallize out copper sulfate. Consult supplier if necessary. (See 11.4.1.C.)
	Replenisher concentration below specification.	Check and adjust per supplier specification. (See 11.4.1.D if peroxide concentration continues to drop.)

B PROBLEM	CAUSE	ACTION
Nonuniform etch on very thick copper-clad panels 200 microns or greater). Variation in line width from bottom to top of vertically positioned traces.	Gas evolution leading to variable solution flow near line edges.	Agitate work to ensure release of gases. Improve solution impingement and flow.

C PROBLEM	CAUSE	ACTION
Fast etch rate, over-etch.	Peroxide level too high.	Analyze/adjust peroxide level. Check proper operation of replenishment process.
	Bath temperature above range.	Check/confirm proper operation of temperature controller, heaters and cooling system. Make sure cooling water flow and temperature is adequate. (Also see 11.4.1.D.)
	Excessive replenishment of etch rate promoter.	Check/adjust pump replenishment rates. Consult supplier if necessary.
	Exotherm near board surface in immersion equipment is causing localized overheating and subsequent excessive etch rate.	Agitate work to reduce localized exotherm. Improve solution agitation. Ensure that work load is within supplier's recommendations.

11.5 FERRIC CHLORIDE

11.5.1 Bath Control

A PROBLEM	CAUSE	ACTION
Etch rate very slow.	Spent bath.	Change bath. (Ferric chloride used to etch copper cannot be regenerated. As more and more metal is added to the bath, the etch rate becomes slower and slower until it stops etching. Theoretically, ferric chloride can hold about 120 g/l of etched metal, but generally the etch rate is so slow that by the time 60 g/l is etched, the bath needs to be changed.)

11.5.1 Bath Control (continued)

B PROBLEM	CAUSE	ACTION
Excess foaming of etchant.	Additives or contaminants that cause foaming. (There are several grades and suppliers of ferric chloride solutions available.)	Be sure that an etching grade of ferric chloride is being used. (If not, try a different lot of ferric chloride.) Sometimes the addition of approximately 1 ml/liter of octyl alcohol will suppress foaming without affecting etch characteristics. (As a general rule, ferric chloride etchants should not foam under most conditions.)

C PROBLEM	CAUSE	ACTION
Muddy-brown etchant color.	Buildup of insoluble ferrous and cuprous chlorides in etch bath. (This sludge can accumulate on the bottom of the etcher, interfering with heating and cooling and can also clog nozzles.)	Add approximately 0.5% by volume concentrated hydrochloric acid to redissolve the ferrous and cuprous chlorides.

D PROBLEM	CAUSE	ACTION
Sudden slowdown in etch rate.	Water leak diluting etchant.	Check to see that specific gravity of etchant is in the range of 40-42 Baumé (1.381-1.408 s.g.). (If it is considerably lower than this, a water leak is a definite possibility.) Check cooling coil and other possible water sources.

11.5.2 Improper Etching

A PROBLEM	CAUSE	ACTION
Over-etching. (See Figure 11-1.)	Conveyor speed too slow.	Check etch rate of chemistry and set conveyor speed to proper rate. Check all equipment parameters, especially spray pressure.
	Hydrochloric acid content of etchant higher than normal.	Check free HCl content of etchant. (Normally the free acid content of ferric chloride is very low, in the range of 0.1 N or less. If significantly higher, check procedures for adding HCl.)
	Etchant specific gravity lower than normal. (The etch rate of ferric chloride increases as the solution is diluted until the solution reaches a specific gravity of about 36 Baumé.)	Check to see that specific gravity of etchant is in the range of 40-42 Baumé (1.381-1.408 s.g.). (If it is considerably lower than this, a water leak is a definite possibility.) Check cooling coil and other possible water sources.

B PROBLEM	CAUSE	ACTION
Under-etching. (See Figure 11-2.)	Conveyor speed too high.	Check etch rate of chemistry and set conveyor speed to proper rate. (Also see 11.5.1 on bath control.)
	Etchant not up to temperature.	Check/adjust etchant temperature. Check for possible heater malfunction.
	Etchant specific gravity too high.	Indication of spent bath. (See 11.5.1.A.)
	Spray pressure lower than normal.	Check spray pressure adjustments to see if they have been changed (readjust if necessary). Check pump operation or leaks in plumbing. Low fluid level may cause pump to cavitate and lose pressure.

11.6 MISCELLANEOUS ETCHING SOLUTIONS

11.6.1 Ammonium or Sodium Persulfate

(These materials are most often used as micro-etches, rarely as a final etch. See the individual plating sections for more information on micro-etching.)

A PROBLEM	CAUSE	ACTION
Slow etch rate.	Decomposition of bath.	Persulfate etch baths decompose slowly on sitting, especially if not used often. A bath 2 to 4 weeks old may have decomposed past use. Make up new bath. Institute regular bath changes to prevent recurrence.
	Bath was overheated which accelerates decomposition.	Operate bath below 38°C for best bath life.

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Section 12
Innerlayer Fabrication

12.0 INNERLAYER FABRICATION

The fabrication of individual clad laminate cores into the component layers of a multilayer board is generally accomplished through a ‘‘print-and-etch’’ process, however, many innerlayers contain blind and/or buried vias. Problems associated with innerlayer fabrication are often related to handling of the generally thin core (0.05–0.41 mm) material and the susceptibility of this material to machine damage. The main dangers inherent in innerlayer fabrication are undetected defects being hidden in the multilayer package.

12.1 GENERAL

12.1.1 Handling Innerlayers are difficult at best to process because the material is thin and easily bent by the forces of water and air, as well as human touch. Recent improvements in conveyorized equipment make its use essential for as much of the process as possible.

12.1.2 Innerlayer Problems – General

A	*PROBLEM*	*CAUSE*	*ACTION*
Innerlayers damaged in conveyorized equipment.		Not enough top rollers or guides in equipment to keep innerlayers in place against the force of the sprays.	Inspect machine for top rollers. Make sure guide wires are in place.
		Incorrect operation of the machine.	Always turn top sprays on first and off last when innerlayers are in machine (i.e., checking developer break point).
		Thin innerlayers may not have the rigidity to withstand certain conveyorized equipment.	Attach a rigid substrate to one side of the innerlayer with tape. Insert the rigid portion first and it will pull the innerlayer behind without damage. Consider increasing border of copper on the innerlayer to provide additional rigidity. Secure innerlayers into frames made of rigid laminate that serve to keep innerlayer taut while traversing through the machine(s).

B	*PROBLEM*	*CAUSE*	*ACTION*
Innerlayers bowed excessively.		Innerlayers not supported adequately during bake-out.	Use fixture to handle innerlayers by tooling holes during bake-out.
		Excessive stress after etch due to back-to-front imbalance of copper pattern.	Check design; modify multilayer construction if possible to minimize.

C	*PROBLEM*	*CAUSE*	*ACTION*
Dimensional stability.		Panel was scrubbed too hard causing it to stretch.	Lighten scrub process - use pumice scrub, or a chemical clean process to replace scrub operation.
		Movement due to stress relief.	Provide adequate copper border for support and resin venting.
		Improperly cured laminate.	Prebake prior to any fabrication. Consult laminate supplier.

12.2 PRINT AND ETCH INNERLAYERS

12.2.1 Cleaning Cleaning innerlayers will ensure adequate adhesion of the photoresist. In addition, it is important to remove the antitarnish coating on the laminate copper so that subsequent etching and oxiding (or other bonding treatment) processes are not affected. (Also see Section 8.0 for more information on cleaning and Section 1.6 on rinsing.)

12.2.2 Resist Residue on Innerlayers Review causes and follow action items described in Sections 9.2, 9.3, and 9.4 on imaging, developing and stripping of resist.

12.2.3 Imaging Imaging problems are similar to those occurring on double-sided rigid boards. (See Section 9.0.)

12.3 INNERLAYERS WITH BLIND AND/OR BURIED VIAS

12.3.1 Drilling Drilling problems are similar to those experienced when drilling thin, double-sided rigid boards. (See Section 5.1.)

12.3.2 Plating Plating problems are similar to those occurring on double-sided rigid boards (see Section 10.0), with some additional handling and racking concerns due to the thin material. Unique problems arise as a result of the chemical etchback process. To minimize plating problems, appropriate steps must be taken to thoroughly rinse and clean the through-hole after etchback.

12.3.2 Plating

A	*PROBLEM*	*CAUSE*	*ACTION*
Voids in through-hole copper plating.		Chemicals used for resin etchback are preventing electroless copper deposition.	Review rinse steps during and after chemical etchback process. (See Section 6.0.)

B	*PROBLEM*	*CAUSE*	*ACTION*
Uneven plating thickness.		Panels bowed in plating racks (because they are thin).	Clamp panels on opposite ends to hold rigidly in racks. Check to make sure air agitation is not buffeting the panels excessively.

12.3.3 Etching

Etching problems are similar to those occurring on double-sided rigid boards, for both print-and-etch innerlayers and innerlayers with blind and/or buried vias. The main exception is where thinness of the material affects the operation. (See Section 11.0.)

A	*PROBLEM*	*CAUSE*	*ACTION*
Panels coming out of etcher skewed.		Unbalanced spray pressures.	Adjust spray pressures so that upper spray is slightly higher than lower spray.

12.3.3 Etching (continued)

B PROBLEM	CAUSE	ACTION
Heavy excess copper on innerlayers in spots, strips, etc.	Poor developing.	All or part of cover sheet left on photoresist through developer. Inadequate rinse and dry after developing. Follow actions detailed in Section 9.0.
	Panels overlapped in developer and/or etcher. Increase distance between panels.	Check roller for worn spots.
	Mechanical problems with equipment.	See Section 8.0 or 9.0 for general remedies for mechanical problems.

C PROBLEM	CAUSE	ACTION
Dishdowns, scratches or other damage to pattern.	Imaging cleanliness and handling.	Follow actions detailed in Section 9.0.
	Poor handling after develop, before etch.	If possible, do not handle innerlayers between develop and etch. Do not push or slide them across rollers. Do not force into racks. Do not stack.

D PROBLEM	CAUSE	ACTION
Excess pinholes, opens, etc.	Thin resist.	Consider using thicker resist or longer exposure times. Follow actions detailed in Section 9.0.
	Inadequate cleanliness of imaging room. Dust and particulate matter interferes with imaging.	Eliminate dust generating processes from the imaging area. (Also see Section 9.0.)

12.4 COPPER TREATMENT TO IMPROVE LAMINATE ADHESION

Innerlayer copper surface treatment is an acceptable method for improving the interlaminate adhesion of multilayer boards. There are four types of surface treatments that are available. One type, a laminator's oxide (called ‘‘double-treated’’), can be purchased as part of the incoming laminate material. Special handling of the treatment surface throughout the print and etch process is necessary.

A second type can be developed on the etched and stripped innerlayer to produce a black oxide. Black oxides provide both the required surface passivation of the copper and the increased surface area required for good lamination.

A third type produces a red-brown oxide on etched and stripped innerlayers. The required increase in surface area necessary for good lamination must be provided by proper surface treatment to the underlying copper by means of an aggressive etchant or mechanical abrasion.

Finally, a relatively new process uses an immersion tin type of coating to treat the copper surface for lamination.

12.4.1 Double Treated Copper/Laminator's Oxide

A PROBLEM	CAUSE	ACTION
Non-uniform treatment appearance prior to lamination.	Oils on the surface from handling.	Degrease through suitable cleaner as recommended by supplier.
	Attack of the treatment coating through the process.	Alkalinity of resist stripper too high. Do not use mild etchant in the process. Do not use strong acid. Do not mechanically scrub the surface. Do not do anything to affect the treatment coating.

12.4.1 Double Treated Copper/Laminator's Oxide (continued)

B	PROBLEM	CAUSE	ACTION
Poor resist adhesion.		Oils contaminating the surface.	See 12.4.1.A.

C	PROBLEM	CAUSE	ACTION
Unetched copper.		Resist binder on surface due to increased surface area of copper.	Develop at slower speed or under more aggressive conditions, such as elevated temperature, spray pressure or concentration. Consult supplier for recommendations.

12.4.2 Black or Red/Brown Oxide Coatings

To obtain an effective oxide treatment, care must be exercised to ensure that the copper surfaces are clean prior to immersion in the oxide bath. Poor oxide coatings are almost always related to inadequate cleaning and rinsing.

A	PROBLEM	CAUSE	ACTION
Non-uniform oxide appearance. (See Figure 12-1.)		Concentration and temperature of oxide too low.	Adjust per supplier specifications.
		Resist residues on surface. (See Figure 12-2.)	Improve precleaning using a hot alkaline soak cleaner.
		Heavy tarnish on surface.	Increase etch rate in micro-etch. Increase micro-etch aggressiveness by change in concentration, temperature or dwell time.
		Copper surface treatment inadequate for red/brown oxide.	Improve micro-etching of copper surface. Consult supplier for recommended micro-etch and operating parameters. Improve surface roughness by implementing pumice scrubbing before entering line.
		Oxidation or tarnish occurring on the panel prior to entering the oxide solution.	Switch to short DI water rinse between acid deoxidation and oxide solution; minimize delay.
		Sulfate residues left on surface of copper.	Use HCl for deoxidizing acid prior to entering oxide solution.
		Poor cleaning and micro-etching.	Increase cleaning capacity. Maintain persulfate-type micro-etch. Use of peroxide-sulfuric type micro-etches may increase mottling.
		Stratification of solution; inadequate solution movement.	Implement mixing of solution using pump or impeller type agitation.
		Galvanic reaction.	Stray currents in steel tank. Insulate heating element from tank; insulate rack from tank.
		Particulate copper oxide in solution.	Filter tank to remove particulates.
		Innerlayers stuck together during oxidizing.	Rack layers further apart or improve agitation.
		Dwell times in solution too high or too low.	Review recommended times; excessive time produces loosely adherent oxide.
		Mottling due to variations in red/brown oxide formation on copper surface.	Use an alkaline predip just prior to oxide solution. This is generally recognized as a cosmetic defect, and although not desirable, does not cause a reliability problem.

12.4.2 Black or Red/Brown Oxide Coatings (continued)

B PROBLEM	CAUSE	ACTION
Oxide coating too thin.	Bath operating parameters not in specification (temperature, concentration, immersion time).	Adjust per supplier's recommendation.
	Low caustic or high oxidizer concentration.	Adjust to optimum.
	Oxidizer-to-caustic ratio too high.	Adjust to optimum per supplier specification.
	PH too low prior to oxide application.	Improve rinsing between acid dip and oxide steps.
	Panels too close together on racks, possibly touching and sticking together (affects adequate cleaning, etching and rinsing).	Rack panels at least 9.14 mm apart and make sure they cannot stick together. Insure adequate solution movement between panels during processing and rinsing.

C PROBLEM	CAUSE	ACTION
Oxide coating too thick.	Excessive immersion time.	Reduce time per supplier recommendation.
	High caustic or low oxidizer concentration in oxide bath.	Adjust to optimum.
	Oxidizer-to-caustic too low.	Adjust to optimum.
	Drag-in of micro-etch into oxide bath.	Improve rinsing, racking and drip times.
	Redeposition of oxide crystals from inadequate filtration.	Improve bath filtration.

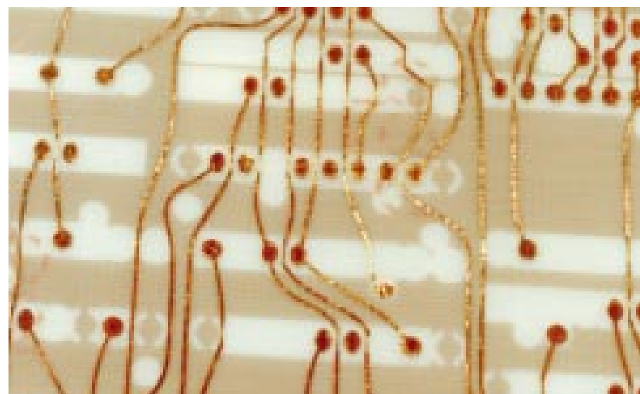

Figure 12–1 Non-uniform oxide coating

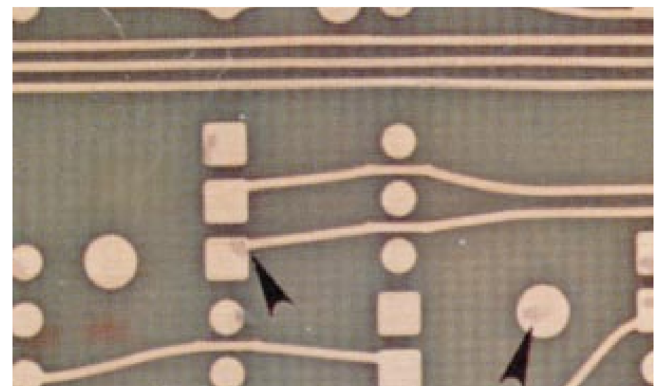

Figure 12–2 Resist residues on surface

12.4.3 Oxide Bath Control

Problems related to oxide bath control can usually be resolved by following the supplier's recommendations. Some brown oxide solutions can be prepared in-house. In these cases, it is usually best to simply dump, clean and refill the tanks when the results are less than satisfactory.

A PROBLEM	CAUSE	ACTION
Gray scum forms on top of solution.	Too much air introduced into the bath (the scum is a carbonate caused by reaction of sodium hydroxide with air).	Reduce solution agitation. Do not agitate bath with air.

12.4.3 Oxide Bath Control (continued)

B PROBLEM	CAUSE	ACTION
Solution concentration drops rapidly.	Air mixing.	Do not use air agitation or any type of violent agitation that will draw air into the bath. When adding water to the bath, keep hose close to surface to reduce air entrainment.
	Incorrect analysis procedure.	Try increasing the quantity of indicator when titrating for chlorite concentration.

C PROBLEM	CAUSE	ACTION
Color variation (of oxide coating) as bath ages.	Carbonate build-up in bath.	See 12.4.3.A to reduce carbonate build-up. Consult supplier for carbonate analysis procedure.
	Copper build-up in bath.	Adjust caustic in bath to proper specific coating weight.

12.4.4 Oxide Post Treatment

Oxide post treatment processes are designed to make standard oxide coatings acid resistant. By making the oxide coating acid resistant, multilayer boards should not exhibit pink ring when the post treatment process is properly operated within specifications. The post treatment process (as the name implies) is applied to the innerlayer immediately after oxide treatment, usually in a continuous sequence. The post treatment system chemically changes the cupric oxide coating to a mixture of cuprous oxide and elemental copper. The post treatment process, in addition to making the oxide coating acid resistant, can improve adhesion between the copper circuitry and prepreg.

A PROBLEM	CAUSE	ACTION
Post-treated coating non-uniform in color.	Oxide coating non-uniform and streaked.	Improve rinsing after oxide processing. (See 12.5.2.A.)
	Post dip solution has lower activity (sluggish).	Raise solution temperature. Increase concentration of post dip ingredients. Raise pH of bath to within supplier specifications.

B PROBLEM	CAUSE	ACTION
Oxide coating does not react to post dip.	Inadequate rinsing between oxide and post dip.	Increase rinsing times. Adjust rinse to remove alkaline residues.
	Post dip solution is spent.	Make up new bath.

C PROBLEM	CAUSE	ACTION
High consumption of post dip additive.	Drag-in of oxide bath.	Improve rinsing. Increase lag time between oxide and post treatment. Adjust rinse prior to post dip per supplier's recommendation.
	Oxide coating too thick.	Adjust oxide bath parameters to reduce weight gain of coating.

D PROBLEM	CAUSE	ACTION
Low peel strengths on post-treated multilayer boards.	Oxide coating too thick.	Adjust oxide bath parameters to reduce weight gain.
	Oxide coating producing large needle-like crystal structures similar to black oxide process.	Adjust oxide formulations per supplier recommendations to obtain a smaller grain structure.

12.4.4 Oxide Post Treatment (continued)

E PROBLEM	CAUSE	ACTION
Pink ring still evident after post treatment.	Oxide coating not properly reduced.	See 12.4.4.A, 12.4.4.B, 12.4.4.C.
	Prelamination bake temperature too high.	Reduce prelamination bake temperature per supplier's recommendation. Use an antioxidant if higher bake temperatures are required.

12.4.5 Conveyorized Oxide Systems

A PROBLEM	CAUSE	ACTION
Conveyor wheel marks on panels.	Contamination of sumps in pre-treatment section of line, especially organic contaminants.	Clean and degrease chemical clean sumps and all conveyor wheels, particularly those wheels between the chemical cleaning stations. Use only chemicals that pass quality control test for certified analysis. Use commercially available oxide chemistries.
	Conveyor wheels contaminated with foreign chemistry.	Clean and degrease conveyor wheels, especially those between chemistry stations. Check chemistry sumps for contamination; see above.
	Condensate leaking from vent system into chemical clean sumps.	Isolate vent systems for the different chemistries, i.e., do not ventilate acid chemistries in the same venting system.

B PROBLEM	CAUSE	ACTION
Oxide coatings blotchy or non-uniform.	Oxide chemical concentration too low. (Typically, conveyorized immersion oxide chemistries are run at 25% higher concentrations than dip systems.)	Increase oxide chemistry concentration by 10% increments until results are satisfactory.
	Inadequate rinsing.	Check quality and flow rate of rinse water. Check for and clean any clogged nozzles.
	Rinse water contaminated.	Check quality of rinse water.
	Vent system condensate dripping on panels.	Isolate vent systems for the different chemistries, i.e., do not ventilate acid chemistries in the same venting system.

C PROBLEM	CAUSE	ACTION
Oxide too thin.	Solution impingement too high (prevents the formation of the oxide).	Sparge for even impingement. Lower pump pressure. Consider alternate nozzle design to reduce impingement force.

12.4.6 Delamination Relating to the Application of the Oxide Coating

A PROBLEM	CAUSE	ACTION
Surface contamination.	Alkaline surface left on oxide.	Improve rinsing after oxide application; monitor pH of final rinse and maintain below pH of 9.
	Chlorite residues on surface.	Improve rinsing.

B PROBLEM	CAUSE	ACTION
Improper development of oxide.	Black oxide crystals too long causing fracturing. (See Figure 12-3).	Shorten dwell time, concentration or temperature in oxide. Investigate alternate bath chemistry.
	Inadequate surface area produced by process.	Increase micro-etch rate or improve etch topography on copper innerlayer surface.
	Inadequate surface treatment.	Follow action items detailed in 12.4.2.A for oxide coatings.

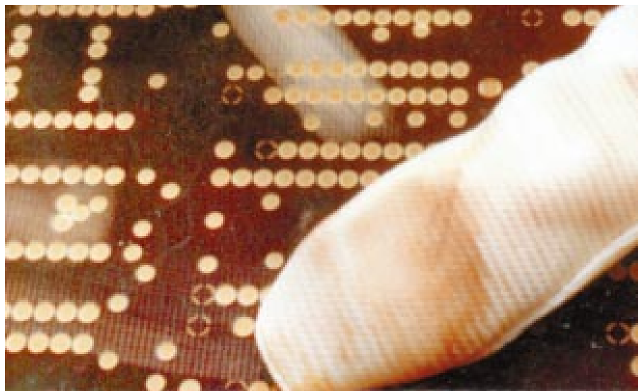

Figure 12–3 Loose black oxide crystals

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Section 13
Lamination

13.0 LAMINATION

Typical problems encountered in the lamination process of printed wiring boards involve improper thickness, poor interlaminated adhesion, blisters, voids and misregistration. Most of these problems can be overcome by material selection, improved cleanliness, reduction in the amount of volatiles, innerlayer copper surface treatment or modification of the press cycle. Depending upon the problem, one or more specification may be required.

Figure 13-1. Misregistration of innerlayers as evidenced by shifted lands.

Table 13-1 provides correlation between some of the variables found in the lamination processes and subsequent effects on the laminated boards.

13.1 GENERAL

13.1.1 Misregistration (see Figure 13-1)

Misregistration may be observed as layer-to-layer not matching, or the drilled hole pattern not matching the lands on the internal layers. Breakout or thinning of the annular ring often occurs when misregistration is present. The coordination of all tooling and tooling concepts from the first operation such as punching/drilling tooling holes to component hole drilling must be considered. Often misregistration believed to be caused by the lamination is traced to pre-lamination or post-lamination operations. Dimensional stability tests on as-received thin laminate often are not correlatable with dimensional changes exhibited after the lamination process; the curing of the resin and the lamination cycle may cause dimensional changes that are greater than any seen in the as-received material testing. Prelamination treatments that involve scrubbing or bending may stretch the thin laminate and it will then shrink after it is etched and baked dry. Example 13-1 shows an actual trouble-shooting problem and how it was resolved.

IPC-2221 & 2222, coupon F describes an in-process process control method for monitor and control of registration.

Table 13–1 Laminate Process - Problem Sources and Subsequent Effects

Source	*Mis-registration*	*Internal Delamination or Blisters*	*Bow and Twist*	*Laminate Voids*	*Resin Starvation (Unfilled Areas)*	*Panel Thickness*	*Surface Imperfec-tions*
Tooling	X					X	X
Press Cycle	X	X	X	X		X	
Heat Lagging	X	X				X	
Material	X	X	X	X	X	X	X
Adhesion Treat (oxide)		X					
Cleanliness		X					X
Drying Internal Layers Prepreg	X	X (See Discussions)	X	X			
Storage Internal Layers Prepreg	X	X X		X X	X		X
Lay-up Skill	X		X		X	X	X
Multilayer design	X		X		X	X	
Undercured prepreg		X	X				

Example 13–1:

Problem:

— Random hole to pad breakout was observed in an 8 layer .46 x .61 meter multilayer board.

— Bow 2nd twist requirement was not within requirements of 0.5%.

Multilayer Production Problem

A large order for an 8 layer multilayer board is being built. Foil lamination processes are used and this board is made on one panel: .46 x .61 meter (The board is .42 x .53 meters with the following cross section.)

There is a low yield due to hole breakout. This is random and occurs on layers 2 & 3 and 6 & 7. Bow and twist requirements have failed (not on every lot) occasionally. The customer needs twist of 0.5%, while they can be as bad as 1.5%.

Analysis:

A D.O.E. experiment was performed which identified the following major factors as being critical to the product requirements:

- Humidity
- Humidity and Temperature Interaction
- Kiss Cycle
- Kiss Cycle and heat Interaction
- Diameter of Tooling Holes

Results:

— Improvement was found after controlling the humidity at 30%, optimizing the Kiss cycle and strict control of the tooling hole size.

A project team was set up to study the problem and set up a project strategy to resolve it. The team came up with the following strategy: (See Figure 2.)

PROJECT STRATEGY

1. Problem Selection → Management Decree
2. Problem Definition → No Useful Historical Data
3. Flow Charted → General
4. Flow Charted → Specific
5. Brainstorm → Cause and Effect Program
6. Identified Critical Factors → Prioritize
7. Measurement System Evaluation → X-Ray *(must be <DOE)*
8. Initial Capability Assessment
9. DOE → and Confirmation Plan
10. Control Plan

PROBLEM

Hole Breakout on Layers 2/3 & 6/7

Assumptions: Design Specified

Specification: 5% Breakout of Diameter of Drilled Hole

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Figure 2

There was no historical data available on the problem so a designed experiment (D.O.E.) was needed to determine the important parameters that need to be controlled and at what levels.

The general process was flowcharted as shown below: (See Figure 3.)

And then the specific process where the problem occurs (lamination) was flow charted. (See Figure 4.)

Using this flowchart a brainstorming session was held to identify all the probable causes and effects that might contribute to the problem. The critical factors were identified and prioritized. (See Figure 5.)

These were: 1) tool hole diameter, 2) drying of prepreg,

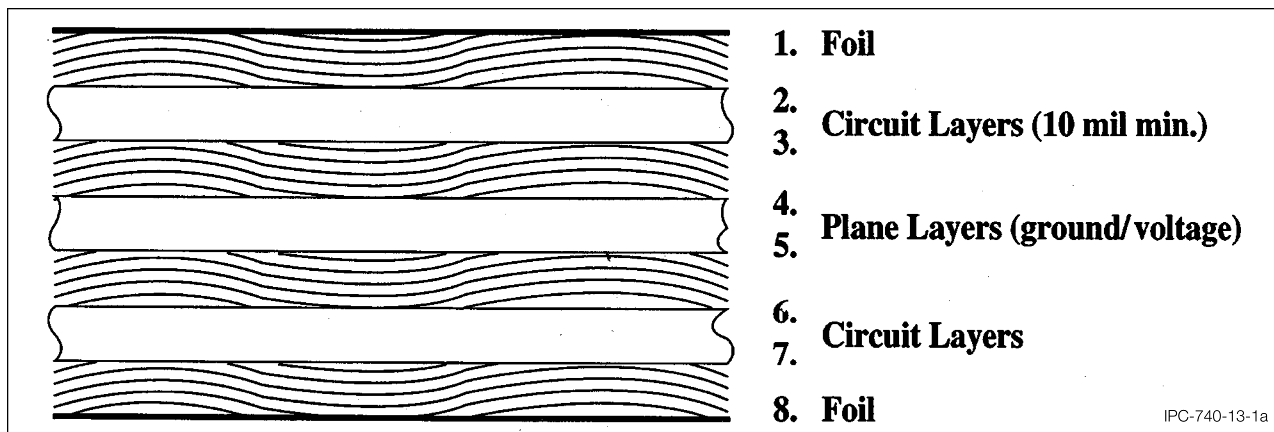


Figure 1

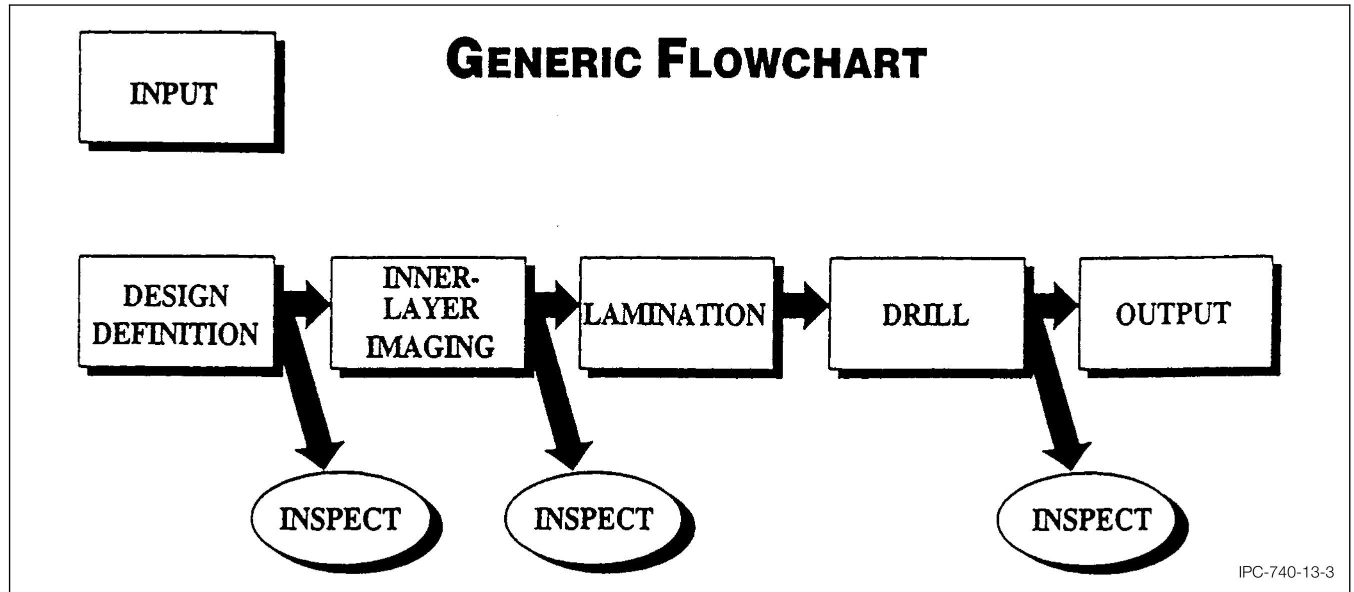


Figure 3

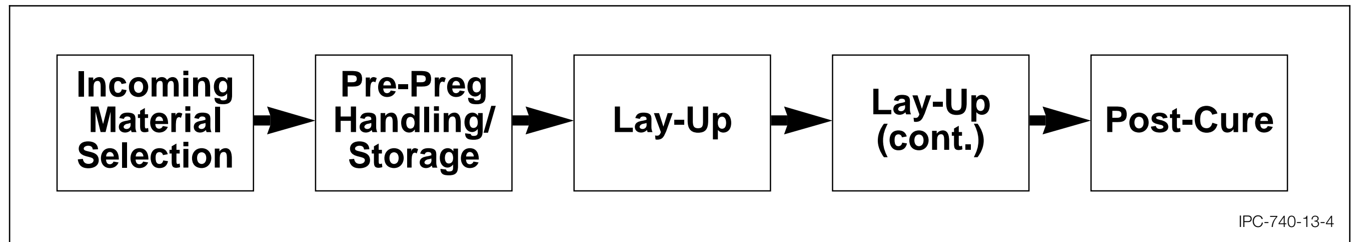


Figure 4

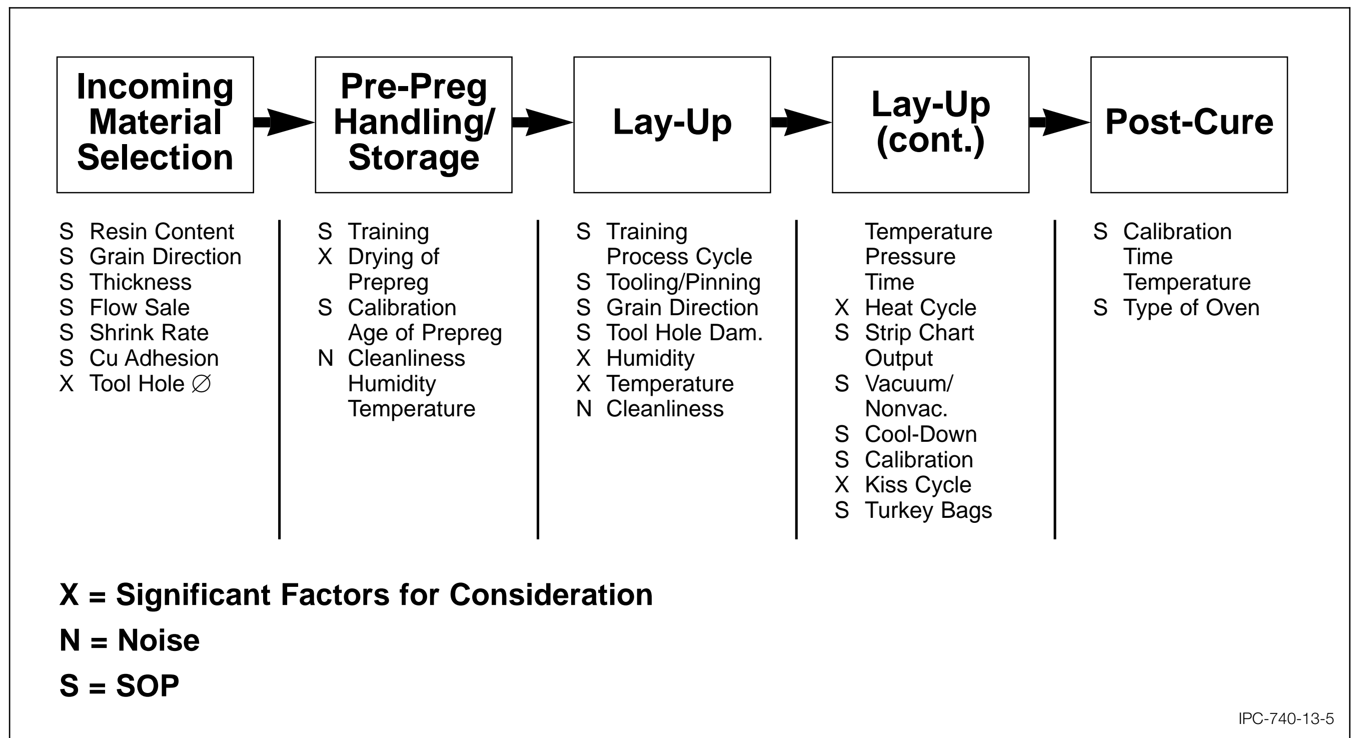


Figure 5

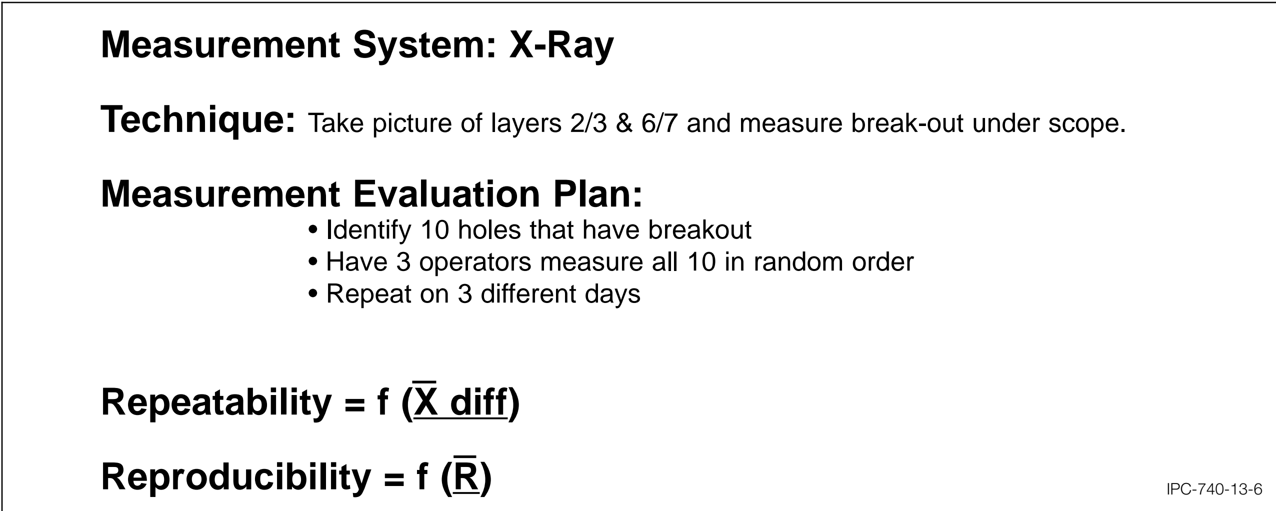
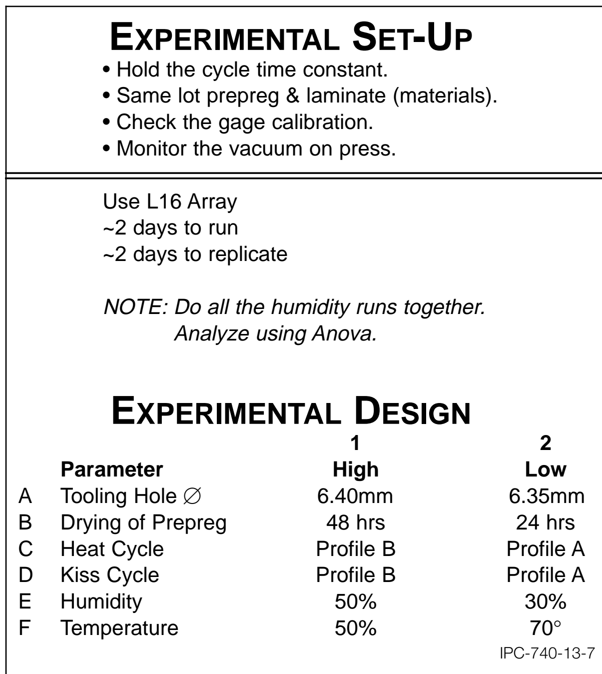


Figure 6



	Parameter	1 High	2 Low
A	Tooling Hole ∅	6.40mm	6.35mm
B	Drying of Prepreg	48 hrs	24 hrs
C	Heat Cycle	Profile B	Profile A
D	Kiss Cycle	Profile B	Profile A
E	Humidity	50%	30%
F	Temperature	50%	70°

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Figure 7

3) heat cycle, 4) Kiss cycle, 5) humidity and 6) temperature.

The results were to be measured by x-ray and a plan set up to evaluate the measuring system. (See Figure 6.)

The parameters of the experimental set-up were determined and the high and low values of the six critical factors for the experimental design were set (see Figure 7) using these high and low values on L_{16} array was used to set-up the test runs. In this case there were to be 16 test runs made with 20 panels per run done over 2 days with a second reapplication run made on the two days following. (See Figure 8.)

At this point an estimate of the experimental cost was done and the experiment modified to reduce the cost, mainly by reducing the sample size to 5 panels per run and contracting an outside site to measure the difference between hole and land centers. (See Figure 9.)

The results of the D.O.E. found that humidity, kiss cycle, and tooling hole diameters had the most important effects on the process. A confirmation run was done using the best parameters for each of the three followed by a sanity check at the worst parameters.

Once the data was confirmed a control plan was set-up to test these conclusions in production.

At the end of the two week period outlined in the control plan, the results would be analyzed to see if there was an improvement in the hole to pad breakout specifications (i.e., twist < = 0.5%). If yes, then the new control parameters would be incorporated into the manufacturing cycle. If more improvement were needed then the project cycle would be started again.

L_{16} (2^{15})

Factors

	A	B	C	D	E	F	G	H	I	J						Result DAY 1 R_1	Result DAY 2 R
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	—	—
2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	—	—
3	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2	—	—
4	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	—	—
5	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	—	—
6	1	2	2	1	1	2	2	2	2	1	1	2	2	2	2	—	—
7	1	2	2	2	2	1	1	1	1	2	2	2	2	1	1	—	—
8	1	2	2	2	2	1	1	2	2	1	1	1	1	2	2	—	—
9	2	1	2	1	2	2	2	1	2	1	2	1	2	1	2	—	—
10	2	1	2	1	2	1	2	2	1	2	1	2	1	2	1	—	—
11	2	1	2	2	1	2	1	1	2	1	2	2	1	2	1	—	—
12	2	1	2	2	1	2	1	2	1	2	1	1	2	1	2	—	—
13	2	2	1	1	2	2	1	2	1	1	2	2	2	1	2	—	—
14	2	2	1	1	2	2	1	2	1	1	2	2	2	1	2	—	—
15	2	2	1	2	1	1	2	1	2	2	1	2	1	1	2	—	—
16	2	2	1	2	1	1	2	2	1	1	2	1	2	2	1	—	—

SAMPLE SIZE

- Holes on panel not independent
  ∴ 1 sample = 1 panel

n = f (Variation of parameter, desired precision and allowable risk)

∴ = If need to detect a 1/2 σ difference in means with a 5% risk

$n \simeq 20$

Recommendation: Contract measurement of relative location of hole and land centers

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Figure 8

EXPERIMENTAL COST

- 16 runs x 2 x 20 panels = 640 panels x $40 ≃ $25,600
- 4 days minimum production time – 2 operators, 1 engineer ≃ $1,200
- Testing $10/picture ≃ $32,000
- Total ≃ $70,000

EXPERIMENTAL MODIFICATION

- Contract site to measure difference between hole and land centers
- Reduce sample size to n ≃ 5
- Reduce testing cost by half
- Reduce experimental cost to ≃ $20,000

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Figure 9

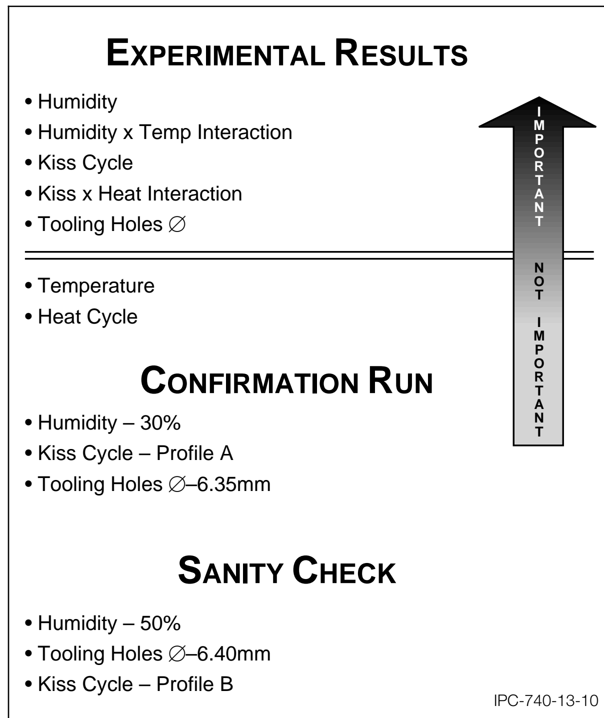

Figure 10

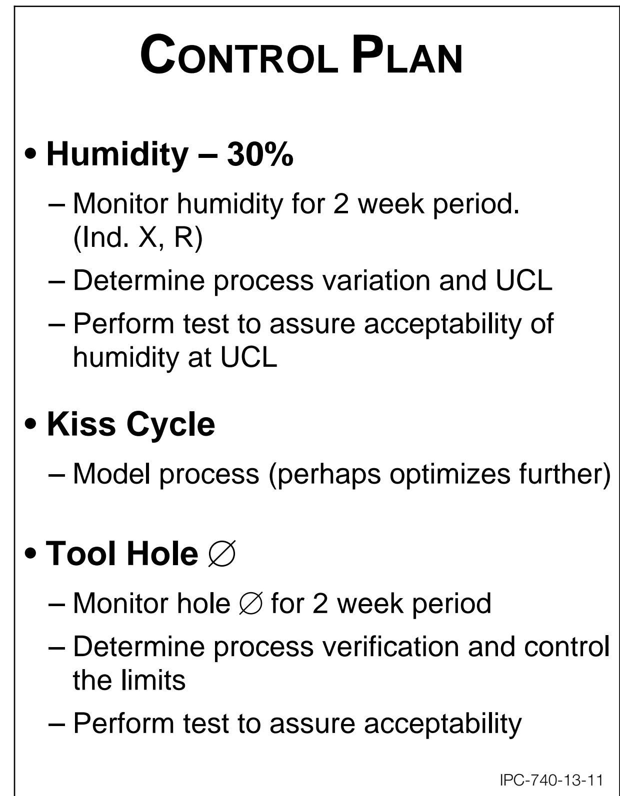

Figure 11

13.1.2 Blisters/Delamation and Interlaminate Adhesion (see Figure 13-2)

The bond strength between the cured prepreg and the laminate or copper surfaces must be sufficient to withstand all processing steps including drilling, routing and later assembly operations such as soldering. Delamination may be observed immediately after lamination or it may not be seen until the board is etched and the fusible plating is reflowed or a solder coating is applied. Delamination may be in the form of blisters or may be raised edges and non-adherent surfaces internally in the board. Many of the problems result from improper bond enhancement treatment (most often oxide). See Section 12 on internal layer processing for many of the problems related to this treatment.

13.1.3 Bowing/Twisting

The laminated panel or board may exhibit warping or twisting which may make it unusable as an assembled product or it may not be able to be loaded with components by automated equipment. Boards are at times straightened after fabrication by heating and holding during cooling, but if the warp is inherent in the design or lay up, during pre-solder drying or soldering, the warp and/or twist will return. If the cause is related to fast cool-down or caused by bowing during post cure, straightening by reheating is an acceptable correction.

13.1.4 Laminate Voids

Small voids may be exhibited in the prepreg or at the prepreg and laminate surface. These may expand when subjected to soldering or reflow. Small voids in the board may bridge the conductors, pick up moisture, and cause electrical shorts.

13.1.5 Resin Starvation

Resin starvation is when areas are not filled by prepreg and resin during lamination. This is the result of not having enough resin to fill the area between internal layers. The glass cloth may act as a non-compressible mechanical stop clamped between border copper or internal circuit conductors.

13.1.6 Panel/Board Thickness

The panel can be too thick or Panel/Board thickness too thin overall, or it may have a large variation in thickness from on edge to the other. Another common feature is characterized as ‘‘footballing’’ in which the laminated panel is much thicker in the middle than at the edges.

13.1.7 Surface Imperfections

Imperfections in the copper surface of the laminated panel can cause outer layer imaging or etching problems. Pits or dents can cause poor resist adhesion or off contact exposure during imaging creating opens or shorts. Resin on the copper surface may not be removed by the etching causing extraneous copper. Electroless copper will adhere to the resin on the surface similar to in the holes and a separation between the copper foil and the electroplate will occur that may not be detectable.

13.2 HANDLING

Handling damage during lamination is often related to the difficulty in transporting and/or processing large sheets of copper clad laminate without marring the copper surface. When damage does occur, the process steps should be observed to determine at what point in the process the damage occurs. The corrective action is then usually obvious.

13.2.1 Misregistration

A PROBLEM	CAUSE	ACTION
Misalignment of the innerlayers on one piece of core to the innerlayers on another.	Operator carelessly forcing innerlayer on to lamination alignment pins.	Instruct operator in proper lay-up technique for multilayer boards.

13.2.2 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Resin fractures after lamination.	Careless handling, either manual or mechanical, of thin laminate or prepreg.	Check procedures to be sure materials are handled with care. Check conveyorized equipment for possible roller pressure.

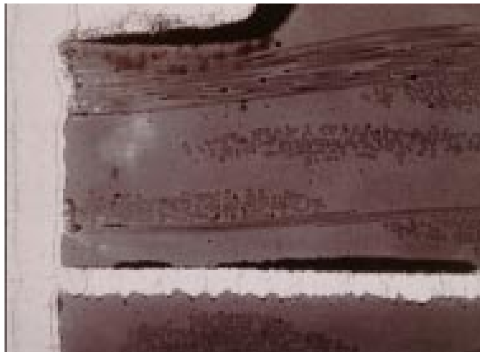

Figure 13–2. Delamination of polyimide multilayer board

13.2.3 Laminate Voids

A PROBLEM	CAUSE	ACTION
Random series or line of voids, particularly a problem in spacing with 1 or 2 plies of low flow prepreg.	Prepreg with folds, creases, or breaks causing loss of resin along the flaw.	Handle prepreg with great care to avoid damage to resin coat.

13.2.4 Surface Imperfections

A PROBLEM	CAUSE	ACTION
Scratches on surface of panels after lamination or post bake.	Sharp surface on which panels are placed.	Check all surfaces of tables, carts or racks. Instruct operators in proper handling methods.

13.3 EQUIPMENT

Lamination equipment and techniques have improved in recent years, with vacuum lamination methods being widely adopted in order to improve the quality of the higher technology products with greater circuit density. This equipment or technique may include totally enclosed vacuum assisted hydraulic presses, autoclaves or simple vacuum bags in standard heated-platen, hydraulic presses. These methods considerably decrease those defects associated with entrapped air and volatiles and allow the use of a lower laminating pressure which improves internal registration.

13.3.1 Misregistration

A PROBLEM	CAUSE	ACTION
Innerlayer image not aligned with drilled hole pattern.	Press cycle requires too high operating pressures. Pressure cannot be decreased without causing laminate voids or blisters. Other prepreg specifications have been tried.	Investigate vacuum lamination under lower pressures. Possibly using bags to justify capital expenditure for equipment.

13.3.2 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Blisters or delam at the oxide or laminate interface with the cured prepreg.	Entrapped volatiles or air.	Use vacuum lamination techniques.

13.3.3 Laminate Voids

A PROBLEM	CAUSE	ACTION
Holes in blind or buried via layers are not filled to the extent required by specification.	Entrapped air.	Use vacuum lamination techniques in which the air is evacuated from the lamination package before lamination pressure is applied.

13.4 MATERIAL

Many laminating problems are material related, either through improper selection, application or processing. When a problem is determined to be material related, many times it can be resolved with the cooperation of the raw material supplier. Material for multilayer printed boards has become very complex. The four major categories: epoxies, polyimides, bismaleimide triazine (BT) and cyanate esters - have a wide variety of resins and additives used to modify their processing, thermal and electrical characteristics.

Information as to processing these materials is often only available from the material supplier and general rules as to pre-treatment or press cycles may not always apply. An example is related to drying the prepreg: many epoxy-resin prepregs will have poor flow characteristics if they are vacuum dried, while many polyimide-resin prepregs are benefitted by vacuum drying prior to lamination. The supplier of the material must be consulted before setting pre-treatment or lamination schedules.

13.4.1 Misregistration

A PROBLEM	CAUSE	ACTION
Circuits moved during lamination.	Resin flow too high.	Use lower flowing resin system. Adjust operating parameters to match new material.
	Instability of core material used.	Bake core material prior to use, to insure full cure. Monitor dimensional stability and T_g testing by supplier.

13.4.1 Misregistration (continued)

B PROBLEM	CAUSE	ACTION
Misalignment of holes to innerlayer image.	Laminate construction not optimum for design.	Select laminate construction (e.g., 106/2313 for 0.005) that provides best registration.

13.4.2 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Separation of the prepreg and the innerlayer laminate or oxide surface.	Prepreg style adjacent to copper circuitry too low in resin content (e.g., 7628) resulting in insufficient amount of resin to provide wet-out of the oxide surface.	Use a prepreg style which has more surface resin such as 2313 or lighter.

13.4.3 Bow and Twist (Warped)

A PROBLEM	CAUSE	ACTION
Panel or board warped or twisted after lamination or final routing.	Different internal layers are cross-plied.	Check incoming material for warp (machine) and fill direction. If the fabricator cuts the panels, check his direction and orientation to master sheet. Do not use panels that have the same X and Y dimension (square).
	Prepreg is cross-plied from layer to layer. Note: In some specific applications and constructions, cross-plying has been used to control X and Y dimensional change without resulting in rejectable bow and twist.	Check incoming material; check prepreg cut operator; do not use square sheets. Check lay-up operators for conformance to planning.
	Resin systems and dimensional change characteristics may vary among suppliers.	Within a given lot or panel do not use different suppliers of prepreg or laminate.

13.4.4 Laminate Voids

A PROBLEM	CAUSE	ACTION
Entrapped air in prepreg.	Insufficient resin content of prepreg.	Increase resin content of prepreg to allow better flow of resin during lamination.
	Resin content of prepreg not adequate to fill areas void of copper.	Use light weight fabric (106 or 1080), which has a higher percentage of resin, against 57 grams or greater copper.
	Entrapped volatiles or moisture in the prepreg.	Some prepreg systems may be vacuum dried; but many epoxy prepregs depend on moisture to increase flow. These should be kept at a controlled humidity recommended by the prepreg supplier.

B PROBLEM	CAUSE	ACTION
Holes in a heat sink or restraining core do not fill during lamination.	Not enough resin to fill the holes.	Use a prepreg that has sufficient resin to squeeze in and fill the holes during lamination. Vacuum lamination aids filling. Prefill the holes with a paste made up of resin and filler and cure prior to laminating.

13.4.5 Resin Starvation

A PROBLEM	CAUSE	ACTION
Internal frosty appearance most seen in areas where there is little circuitry. The frost appearing area can be an area where there is no resin on one of the layers or the resin may be a mass of small voids.	Insufficient resin volume to fill the area between the internal layers before the copper areas stop against the glass cloth and stop further compression.	Use a higher resin content prepreg. Calculate approximate volume of resin to fill and, using unpressed prepreg volume and glass cloth thickness data, determine if sufficient resin is present. Adjust if necessary. Use more sheets of prepreg.

13.4.6 Panel Thickness

A PROBLEM	CAUSE	ACTION
Panel overall and dielectric thicknesses too thin. Excessive amount of cured resin framing panel.	Gel time too long for standard process.	Check material per vendor specs; change to material with shorter gel time.
	Prepreg has high resin content.	Check material per vendor specs; change to material with lower resin content.

B PROBLEM	CAUSE	ACTION
Panel is thicker or thinner than specification.	Internal layers have too much variance in thickness.	Order or select core material for internal layers which have a tighter tolerance around desired thickness.

C PROBLEM	CAUSE	ACTION
Dielectric thickness is violated.	Differences in measurement techniques between laminate suppliers and board manufacturers. Laminate material is typically measured mechanically using a micrometer which will yield a measurement across the highest points of the laminate surface. Microsection measurements may be taken at the minimum dielectric thickness between conductive layers.	Communicate acceptability requirements to laminate supplier.

13.4.7 Surface Imperfections

A PROBLEM	CAUSE	ACTION
Pits, dents, epoxy or scratches on the surface of panels.	Copper foil or pad cap is damaged as received from supplier.	Inspect incoming copper foil or core material for surface defects. Contact supplier regarding acceptability criteria.

13.5 TOOLING

Problems caused by tooling are usually not catastrophic. Modification of tooling is generally done to increase the manufacturability and yield of a part. Because of this there are probably as many acceptable tooling concepts for board lamination as there are laminators. Tooling must be in good repair and clean. Tooling materials may vary depending on heat transfer required and durability needed. Tooling should be designed so that high stresses will not occur during lamination cycles between portions of the different lamination fixtures. The different thermal expansions of aluminum and steel or rate of heat flow in the fixtures may cause pins to bend and parts to distort during lamination. Examine the tooling materials/design and board materials to insure that thermal expansions do not cause dishing and warping of the internal layers during lamination. The number of restraining pins improves registration at lay-up but may often cause misregistration unless allowed to float in one axis (i.e., slots in panels and/or fixtures pointing toward the center).

13.5.1 Misregistration

A	PROBLEM	CAUSE	ACTION
Misalignment of the innerlayers on one piece of core to the innerlayer on another.		Sloppy tooling holes on tools, parts or artwork.	Ensure tooling holes are in good condition. Follow actions detailed in Sections 3.2.4 and 3.4.2. Sharpen hole punches. Allow material to stabilize before punching.
		Tooling pins too small for tooling holes.	Check and/or replace pins. Evaluate dimensional clearance relationship between size of tooling holes in parts and size of tooling pins.
		Shrinkage of etched innerlayer material.	Investigate use of post-etch innerlayer punching. Investigate use of center-line tooling system.

B	PROBLEM	CAUSE	ACTION
Internal layers reversed, backwards, upside down.		Operator lay-up incorrect.	Change location of tooling pins to eliminate symmetry in lamination plates. Add a notch to one coupon on the panel's innerlayers to define a standard ''zero'' location. Stamp identification mark into the board at one standard corner.

C	PROBLEM	CAUSE	ACTION
Innerlayer images smaller or larger than drilled hole pattern.		Insufficient number of pins.	Add additional pins to restrain layers.
		Pin diameter too small.	Increase pin diameter.

13.5.1 Misregistration (continued)

D	PROBLEM	CAUSE	ACTION
Innerlayers randomly misregistered in localized areas.		Tooling holes unsupported. Innerlayers tearing or pulling away from pins.	Make sure tooling holes/slots have a copper clad area (anchor) around the holes to restrain movement.
		Tooling holes do not fit over the tooling pins without stretching or tearing.	Use slotted holes on innerlayers at four positions pointing toward the center.
		Material expanding and contracting at different rate than pinned tooling causes distortion during cure.	Use slotted pin (plus offset hole) system.
		Tooling pins too short (package too thick) to seat in one or both plates.	Replace with longer pins. Reduce quantity of panels per stack. If multiple packages in fixture, determine if separator plates can be eliminated.
		Laminating pressure causes cores to shift.	Improve tooling, i.e., more and/or larger pins.

13.5.2 Bow and Twist (Warped)

A	PROBLEM	CAUSE	ACTION
Panel will not lay flat after lamination.		Tooling hole spacing in plates and material unmatched.	Check tooling hole spacing of each.
		Stressed innerlayers due to improper lay-up or misregistration of tooling holes to pins.	Use care and never force the innerlayer onto pins; check for proper registration punched holes to tooling pins prior to lay-up.

13.5.3 Surface Imperfections

A	PROBLEM	CAUSE	ACTION
Depressions in the copper surface after lamination.		Foreign material on lamination plates.	Sand or scrape plate surfaces as necessary to remove foreign material. Before use, vacuum and wipe off foreign material.
		Dents or spurs on lamination plates.	Resurface or replace lamination plates.

13.6 MULTILAYER DESIGN

13.6.1 Misregistration

A	PROBLEM	CAUSE	ACTION
Innerlayer images smaller or larger than drilled hole pattern.		Innerlayer pad-to-hole relationship does not allow for manufacturing tolerances.	Make sure that the board design incorporates sufficient size to permit innerlayer shrinkage over panel size. Increase pad diameter. Incorporate a predetermined shrinkage factor into the master artwork tooling for innerlayers. Reduce panel size, quantity of boards up on a panel to yield acceptable design limits.
		Too much resin flow.	Increase core material thickness and decrease amount of prepreg. Select prepreg styles with more fiberglass and less resin.
		Unnecessary use of resin-rich prepreg.	Limit use of resin-rich prepreg in build-up.
		Resin system has a volume change during cure.	Determine dimensional change in each layer and compensate production photo-tool for change that is determined.
		Inherent stability of core material laminates not adequate.	Consider package lay-up with grain (machine) direction of prepreg cloth perpendicular to that of laminate innerlayers. Review for impact on flatness.

13.6.1 Misregistration (continued)

B	PROBLEM	CAUSE	ACTION
Layers on different cores are misregistered.		Differences in retained copper percentages after etching.	Determine and apply shrink factors for signal/signal, signal/ground and surface layers.
		Copper foil is greater than 1 oz. on some layers.	Evaluate package design for substituting a thicker, more stable laminate as the innerlayer with heavy foil cladding.

C	PROBLEM	CAUSE	ACTION
Circuits moved during lamination.		Lower copper bond to laminate.	Test material to vendor specification. Design conductors wider.

13.6.2 Blisters/Delamination

A	PROBLEM	CAUSE	ACTION
Blisters appear between boards on a panel.		Air entrapped in low pressure area.	Add copper vent pattern (dots) between boards to reduce amount of resin required to fill.

B	PROBLEM	CAUSE	ACTION
Separation occurs over large copper area.		Unnecessarily large coppers areas - bond to copper poorer than bond epoxy to epoxy.	Consider cross hatching out any nonfunctional areas.

13.6.3 Bow and Twist (Warped)

A	PROBLEM	CAUSE	ACTION
Panel or board warped or twisted after lamination or final routing.		Design of board is unsymmetrical. Unbalance of power/ground planes and signal layers within the board.	Board must have a balanced construction. It is good practice to add redundant layers in order to make the board symmetrical from the center line of the total thickness. Number and weight of copper layers should be mirror-imaged about the center of the package. Circuit density on equivalent layers relative to center plane should also be symmetrical.
		Prepreg, glass style and number of plies, unbalanced in package.	Prepreg content should be mirror-imaged about the center plane of the package.
		Core laminates unbalanced in package.	Number and thickness of cores should be mirror-imaged about the center of the package.

13.6.4 Laminate Voids

A	PROBLEM	CAUSE	ACTION
Micro-voids in laminated multilayer boards.		Entrapped air in laminated panel due to innerlayer borders not adequately vented to allow flow of air and resin.	Add dot, dome vent pattern to innerlayers to allow resin flow and evacuation of air and moisture.

13.6.5 Resin Starvation

A	PROBLEM	CAUSE	ACTION
Internal frosty appearance of prepreg.		Insufficient resin to fill.	Add border copper on one side of internal layer only.
		Uneven pressure distribution due to copper thickness stack up at edges of panel.	Cut prepreg so that some sheets fit inside border copper.

13.6.6 Panel Thickness

A	PROBLEM	CAUSE	ACTION
Panel is thicker or thinner than specification.		Design is incorrect.	Check design for compatibility of requirements to material selection.
		Wrong core material used.	Use correct core material.

B	PROBLEM	CAUSE	ACTION
Panel is thinner at the edges than the center.		Excess flow at the edges of the panel.	Add wider border copper with less vents to restrict resin flow at the edges.

C	PROBLEM	CAUSE	ACTION
Panel is thinner than specification.		Copper thickness on signal layers with sparse circuitry being incorporated in thickness estimate.	Don't count signal layer copper in thickness estimates. Adjust build up construction accordingly.

D	PROBLEM	CAUSE	ACTION
High spots within a panel.		High spots may occur with heavier prepreg of lower resin content at unetched locations that are common to most innerlayers - glass cannot be compressed.	Look for dryness and measling. Substitute thinner cloth prepreg with higher resin for some of the plies in each dielectric opening. Cross hatch copper on those innerlayers where copper is nonfunctional.
		With high resin content prepreg, high spots are found at etched locations common to most of the innerlayers through the package; therefore resin tends to remain at these points of lower pressure; look for voids.	Leave unetched copper on innerlayers in these locations, if possible.

13.7 INNERLAYER PREPARATION

13.7.1 Misregistration

A	PROBLEM	CAUSE	ACTION
Innerlayer images smaller or larger than drilled hole pattern.		Movement of material due to insufficient support of remaining copper on innerlayers.	Add copper borders to stabilize layers during lamination. Add wider external and internal borders.
		Film changes size due to temperature and humidity variations in the imaging area.	Implement environmental controls per film vendor's recommendations. Use imaged glass phototools.
		Shrinkage of etched innerlayer material.	Bake all innerlayer core material at 163°C for 1 hour at temperature (FR-4) under weight, before processing.

13.7.1 Misregistration (continued)

B PROBLEM	CAUSE	ACTION
Etched image on innerlayers randomly misregistered to drilled hole pattern.	Film distortion during imaging.	Check film to master artwork, CAD data or print dimensions.
	Film stretching while applying vacuum.	Trim film to panel size. Provide vacuum path by placing string around panel.
	Film stretching during squeezing of air out of printer cover.	Use less pressure on squeegee.
	Tooling holes incorrectly located. Artwork mismatched with respect to opposite sides of a core or to location of tooling holes in core.	Pin all artworks together to check for alignment. Correct artwork or punching operation. Rework film or panels with correct tooling hole locations. Improve operator performance if mismatch is due to mishandling.
	Dams, vent pattern incorrectly placed, thus causing uneven resin flow.	Move dams. Use vented border copper pattern with overlapping metal areas on front and back.
	Core material distorted during pre-cleaning operation.	Reduce brush pressure during scrubbing. Eliminate compressed roll or bristle type scrubbing operations, as they tend to stretch thin core materials. Investigate chemical cleaning of innerlayers to eliminate scrubbing.
	Innerlayers change size during wet processing and baking.	Verify oven temperature and duration. Consult vendor for recommendations.

13.7.2 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Localized separation at prepreg/oxide interface.	Innerlayer surfaces contaminated with foreign material from operators hands.	Wear clean gloves and handle innerlayers by edges only. (Instruct all personnel to avoid touching innerlayer bonding surfaces when laying up innerlayers and prepreg for lamination. Visually inspect oxide coating for evidence of contamination prior to lay-up.)
	Individual panels touching each other in the oxide racks so the total surface is not exposed to the various solutions.	Use racks with wider spacings or use alternate spaces so the panels do not touch each other. Consider rack agitation.

13.7.2 Blisters/Delamination (continued)

B PROBLEM	CAUSE	ACTION
Separation at prepreg/innerlayer oxide interface.	Innerlayer copper surface not prepared properly.	Lightly etch copper surfaces or add and oxide treatment to copper surfaces. For epoxy multilayers a black oxide treatment may be acceptable. Polyimide multilayer boards require a red/brown oxide treatment. (See Section 12.2.)
	Etching chemical residue not adequately rinsed off. Residual chemicals, once dried, may not be visually noticeable.	Check spray rinses for proper operation. Very thorough rinsing is necessary to remove etchant chemicals.
	Photo resist not sufficiently removed.	Check resist stripper bath for maintenance.
	Inadequate cleaning at the beginning of the oxide process. This is usually an alkaline clean to remove greases and oils.	Check bath for contamination. Greases and/or oils on the copper surface will interfere with the subsequent micro-etch process.
	Inadequate rinsing after alkaline clean. Alkaline materials are difficult to rinse off.	Use a double tap water rinse (reverse cascade). The water temperature should be about ambient.
	Insufficiently aggressive micro-etch to roughen the copper surface giving it adequate surface area for bond enhancement.	Check bath concentration and dwell time.
	Too long a dwell in the rinse after micro-etch, causing the copper to pre-oxidize which hinders proper oxide formation on the copper.	Shorten dwell time in water rinse.
	Improper oxide chemistry (conventional black oxides do not give good bonds to polyimide).	Use brown or bronze oxide for improved results with polyimide and other high performance systems.
	Oxide coating is too thick and fragile. Heavy oxide fractures during lamination.	Check bath analysis, oxide thickness and weight. Determine if proper oxide is used. Consult chemical supplier. (See Section 12.) Reduce dwell times, temperatures or concentrations to give a light brown or bronze color. Maintain the bath at the proper make up level by routine analysis. Contact chemical supplier for information on oxide reducing/converting chemistries for post dips after oxide.
	Contamination of internal layer surface, or poor rinsing at oxide treat.	Determine if residues from oxide remain or if surfaces are contaminated in processing area.
	Insufficient rinsing after oxide. The oxide chemicals, particularly caustics, need to be thoroughly rinsed off.	Immediate hot water rinse (spray or bath with plenty of agitation) followed by subsequent cool water and deionized rinses. Tap water may be too cold to provide thorough rinsing. Temperatures below 18°C are to be suspect. Check the incoming tap water for alkalinity. Too high alkalinity will cause inefficient rinsing.
	Innerlayers have a high moisture or volatile content. Moisture absorbed in the laminate and/or adsorbed onto the nodular structure of the oxide will contribute to delamination.	After oxide bake innerlayers (oven dry, at 121°C for 90 mins.) to remove volatiles. Do not bake in stacks. Innerlayers should be baked in racks to allow for air circulation. After baking, store in a dry (less than 10% Rh) environment until lamination.
	Improper drying of internal layers or, after drying, storing them too long without protection.	Set time limit between drying and lamination. If internal layers must be stored, protect from environment with packaging and desiccant or dry box storage. Desiccate innerlayers after oven drying. Polyimide, Cyanate Ester and some multifunctional epoxies should be vacuum dried for 12 to 16 hours at 98.2 kPa prior to lay-up.

13.7.2 Blisters/Delamination (continued)

C	PROBLEM	CAUSE	ACTION
Lighter colored areas (stains) over the innerlayer oxide surface that cannot be distinguished as delamination without destructive testing by cross section analysis for separation.		Improper rinsing or post treatment.	Improve rinsing. Consult chemical supplier for recommended post treatment.
		Innerlayers touching racks during oxide process preventing chemicals from reacting with copper surface.	Evaluate addition of agitation to oxide line. Evaluate locations of rack bars with respect to panel size and utilization.

D	PROBLEM	CAUSE	ACTION
Delamination of prepreg and constraining cores, such as Cu-Invar-Cu or Cu-Mo-Cu.		High stress between material after cooling below laminating temperature overcomes bond strength.	Use special bond enhancement treatment on the constraining core material. The preferred treatment is a nodular plating like that applied to the copper foil on the laminate. It is often called laminator side or double treat.

13.7.3 Laminate Voids

A	PROBLEM	CAUSE	ACTION
Micro-voids in laminated multilayer boards.		Entrapped moisture in panel.	Bake innerlayers prior to lamination of multilayer boards. Keep innerlayers dry in a controlled environment until lamination.

13.8 PREPREG (B-STAGE) PREPARATION

13.8.1 Blisters/Delamination

A	PROBLEM	CAUSE	ACTION
White areas of air entrapment in the prepreg.		High humidity in prepreg storage area.	Implement environmental controls to lower relative humidity in prepreg storage area.
		Prepreg has a high moisture content.	Dry prepreg by storing in dry (less than 10% Rh) environment for 48 hours minimum. Use prepreg within 15 minutes of removing from the dry environment.
		Prepreg stored at high temperature for long time which advances cure.	Store prepregs in temperature and humidity controlled environment. Retest all prepreg older than 6 months.

B	PROBLEM	CAUSE	ACTION
Blisters and delamination at the oxide or laminate interface with the cured prepreg.		Prepreg has advanced due to age or improper storage.	Check shelf life, gel time or scale flow and replace prepreg, if necessary.
		Prepreg has too fast of a gel time for press cycle or flow is inadequate.	Check gel time and resin flow.

C	PROBLEM	CAUSE	ACTION
Fractures visible after lamination.		Improper handling of prepreg creating areas of missing resin.	Instruct operators on proper handling techniques. Review storage conditions for potential causes of fractures.

13.8.2 Laminate Voids

A	PROBLEM	CAUSE	ACTION
	Voids - air or moisture in prepreg areas.	Uncontrolled storage conditions, moisture absorbed into material.	Desiccate for 12 hours minimum (monitor bead closely for reduced flow). Use a special area or enclosure for prepreg storage. Follow vendor recommendations for temperature and humidity. If stored below room temperature, allow to stabilize before use. Keep in moisture proof wrapping until use.
		High solvent content in prepreg.	Test material for volatile content. Replace with new prepreg.

13.8.3 Panel Thickness

A	PROBLEM	CAUSE	ACTION
	Excess bead of flow around panel edges. Panel has excessive taper (thicker in center, thinner at edges).	Moisture absorption by prepreg.	Store all prepreg in temperature and humidity controlled environment.

13.9 COPPER FOIL PREPARATION

13.9.1 Blisters/Delamination

A	PROBLEM	CAUSE	ACTION
	Localized separation at copper foil/ prepreg interface.	Contamination of the copper treatment surface.	Wear clean gloves and handle copper foil by edges only. (Instruct all personnel to avoid touching copper treatment bonding surfaces when laying up copper foil and prepreg for lamination. Visually inspect copper treatment for evidence of contamination prior to lay-up.)

13.9.2 Surface Imperfections

A	PROBLEM	CAUSE	ACTION
	Epoxy present on surface after lamination.	Resin dust broken off prepreg and present in lay-up areas.	Panel prepreg and punch tooling holes in separate area from lay-up.

13.10 LAY UP

13.10.1 Blisters/Delamination

A	PROBLEM	CAUSE	ACTION
	White areas of air entrapment in the prepreg.	High humidity in lay up area.	Implement environmental controls to lower relative humidity in lay up area.
		Prepreg left out too long during lay up.	Lay up in controlled environment and optimize throughput.
		Contamination of prepreg.	Apply mold release to tooling pins or fixture in area separate from lay-up.

13.10.2 Bow and Twist (Warped)

A PROBLEM	CAUSE	ACTION
Panel or board is warped or twisted after lamination or final routing.	Prepreg is unbalanced as to lay-up and glass styles.	Check lay-up sheet. Verify operator is using proper number of prepreg sheets and not interchanging glass styles to achieve desired thickness.

13.10.3 Panel Thickness

A PROBLEM	CAUSE	ACTION
Panel overall thickness incorrect.	Wrong number of sheets of prepreg used.	Instruct operator as to the correct number of plies. Double check ply count during package lay-up.
	Wrong type of prepreg used.	Check prepreg to verify that correct glass style is being used. Insure that prepreg is identified with glass style. Remove any loose prepreg from lay up area.
	Incorrect number of prepreg plies in one or more spacings.	Determine package thickness prior to laminating; check before loading into press.

B PROBLEM	CAUSE	ACTION
Some boards/panels thick, some thin.	Mixing prepreg lots having widely different values.	Avoid mixing prepreg with values on opposite extremes of tolerances. Tighten tolerances of prepreg properties.

13.10.4 Surface Imperfections

A PROBLEM	CAUSE	ACTION
Cured epoxy present on copper surface following lamination.	Epoxy dust in lay up areas. Cleanliness at lay-up and particles of resin from the prepreg.	Continually vacuum and wipe fixtures and work surfaces. Buff or sand plates at regular intervals or as needed; protect plates from possible damage. Minimize handling of prepreg in lay up area. Isolate copper foil and separator plates from prepreg storage. Arrange lay up station such that copper foil and plates are above level that prepreg is handled such that resin dust will not fall on copper foil or plates. Lay-up package in clean room with filtered air flow and having positive air pressure.
	Static Charges.	Determine appropriate method for elimination.

B PROBLEM	CAUSE	ACTION
After cleaning, black spots of oxide are seen on surface. The oxide is impregnated with resin. Occurs when the outer layers are processed on the innerlayer cores. Does not appear black if foil or single sided cap constructions are used.	Resin particles from the prepreg contaminates the surface of the panel.	Use vacuum cleaning and/or anti-static. Clean the lay-up area and holding tables, etc. Store the external layers separately, away from prepreg and remove from storage only as each one is used. Cleaning such as brushes with abrasive will help clean. Vapor honing is a good cleaning method. Acid soaks will undercut the oxide, but the acid clean must be performed before drilling or pink ring and hole delamination will occur.

13.11 PRESSING

13.11.1 Misregistration

A PROBLEM	CAUSE	ACTION
Circuits moved during lamination.	Press platens not parallel.	Have platens realigned.
	Resin flow too high.	Change press cycle to decrease heating rate. (Use lower flow resin system.)
	Side-by-side placement of fixtures in a press opening (significant thickness variation between fixtures).	Press only one package/stack height per opening; use equivalent tooling.
	Non-centered or unsymmetrical placement of fixtures in press with floating platens.	Load fixtures, one or more, so that the packages are centered or symmetrical about the center of the platens.

B PROBLEM	CAUSE	ACTION
Innerlayer images smaller or larger than drilled hole pattern.	High rate of heat rise may increase dimensional change.	Verify heat rise with thermocouple in lamination package. Verify with the supplier that the press cycle is optimum for the prepreg/laminate system.
	Lamination pressure too high.	Laminate at lowest possible pressure to get good flow, fill and achieve proper dielectric thickness. Autoclave or vacuum assisted hydraulic lamination cycles laminate at 60% or pressure used for full hydraulic lamination.
	Laminating pressure causes cores to shift.	Check equipment for overshoot in pressure.
	Press cycle not optimized for registration.	(Polyimide) Step cure in press under pressure. Laminate 90 minutes at 182°C followed by appropriate post cure in press.

C PROBLEM	CAUSE	ACTION
Innerlayers randomly misregistered in localized areas or each layer is different in each laminated panel.	High pressure lamination causes localized stress and high resin flow which causes the heat softened innerlayer to shift and distort.	Use lower pressures with vacuum lamination.

13.11.2 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Entrapped air in between circuit boards, in low pressure areas.	Uneven copper distribution on innerlayers.	Add venting or dams in between circuits boards on panel to equalize pressure distribution.

13.11.2 Blisters/Delamination (continued)

B PROBLEM	CAUSE	ACTION
Entrapped air or volatiles following lamination.	Improper press cycle.	Check timers, temperature and pressure per vendor's recommendations.
	Heating elements malfunction.	Fit all heating elements with ampmeters to monitor function.
	Changing pad stock supplier without rechecking rate of rise.	Verify rate of rise for all pad stock manufacturers.
	Changing pad stock thickness or type without rechecking rate of rise.	Verify rate of rise for all pad stock types and thicknesses to be used.
	Reusing pad stock too often.	Profile rate of rise with new pad stock and repeat profile for pad stock that has seen multiple heat cycles. When in doubt, discard pad stock after 1 use.
	Panel stack height changed.	Verify rate of rise for all size stack heights.

C PROBLEM	CAUSE	ACTION
Blisters and delamination at the oxide or laminate interface with the cured prepreg.	Poor wet out of the surfaces by the melted and uncured prepreg during the press cycle.	Determine if press cycle produces a good wetting and impregnation around the oxide. Too slow of a heat rise will cause resin to be partially cured during initial heating and never reach maximum fluidity. Contact material supplier for best heat rise rate. Remove heat lagging to increase heat rise or start with a higher platen temperature, or increase power in the case of an autoclave. A kiss cycle should be investigated.
	Undercured prepreg on laminated multilayer.	Check glass transition temperature (T_g). Check press cycle for time at temperature. Contact material supplier for correct cure cycle.
	Oxide breakdown, post cure temperature too high particularly with Polyimides or Cyanate Ester.	Check for proper platen temperatures in the press. Check thermocouple calibration.

13.11.3 Bow and Twist (Warped)

A PROBLEM	CAUSE	ACTION
Panel or board warped or twisted after lamination or final rout.	Lamination lay-up may cause a premature gelling of the prepreg nearest to platens.	Adjust heat lagging so that heat input is as even as possible.
	Cool down cycle is too fast.	Slow cool down rate so that both sides of the laminated panel go through the glass transition temperature at approximately the same time. Cool down rate should be slower than the heat rise rate during lamination.

13.11.3 Bow and Twist (Warped) (continued)

B PROBLEM	CAUSE	ACTION
Panel will not lay flat. Baking of panels does not remove warp, indicating stresses induced during lamination cycle.	Uneven cooling.	Check cooling rates of press platens and adjust water flow.
	Improper matching of heat rise to cool down rate.	Run temperature profiles with a recording thermocouple. Attempt to match cooling and heating rates. Slow rate of cool-down as much as possible as temperature approaches and drops past material's glass transition temperature, usually 110 - 135°C for epoxy boards.
	Cooling laminated panels without pressure.	Keep press closed during cooling cycle.
	Fixture removed from press too soon.	Allow to remain in press or transfer quickly to cool-down press under full pressure. Wait until package can be handled without gloves (don't rely on temperature gauges.)
	Excessively slow heat rise rate: warp or twist found only in top and bottom panels in a tooling fixture.	Speed up heat input by removing press padding; check that tooling is not excessively massive and acting as a heat sink.
	Heat input differential between top and bottom platen.	Compensate with press pads or correct discrepancy in platens.

13.11.4 Laminate Voids

A PROBLEM	CAUSE	ACTION
Small laminate voids can be seen from the surface or when back lighted. Microsectioning and viewing the area around the hole often reveals unseen laminate voids. Can be defined as the absence of resin.	Entrapped volatiles or air which are compressed into small spherical or football shaped voids.	Use vacuum lamination techniques. Check press cycle, too fast of a heat rise rate can cause gaseous reactions to occur. Use a ''kiss'' press cycle and a slow transition, 1 to 2 minutes when changing from low to high pressure.
	Heat rise too slow allowing resin to advance in cure when it should be flowing.	Increase the heat up rate by reducing the heat lag material or increasing the platen temperature setting.

B PROBLEM	CAUSE	ACTION
Incomplete hole fill of blind vias or heavy metal planes during lamination.	Air entrapment.	Use vacuum lamination to evacuate air. Fill holes with liquid resin prior to lamination. Use cast adhesive.

13.11.5 Resin Starvation

A PROBLEM	CAUSE	ACTION
Overall dry appearance to the prepreg, possibly including exposed glass weave.	Pad stock not sufficient.	Profile the cycle using various quantities of kraft paper on top and bottom of stack.

13.11.6 Panel Thickness

A	PROBLEM	CAUSE	ACTION
Panel overall and dielectric thicknesses too thin. Excessive amount of cured resin framing panel.		Incorrect press cycle.	Decrease temperature heating rate.

B	PROBLEM	CAUSE	ACTION
Panel overall thickness too thick or too thin.		Lamination pressure incorrect.	Check that lamination pressure is per specification. Increase or decrease lamination pressure.
		Press cycle allows too much resin to remain or too much to squeeze out. Check bead and look for voids, haziness, or edge dryness.	Check press cycle. Fast heat rises often cause the panels to be thinner. Slow heat rises cause the panel to be thicker. Adjust heat input rate by changing amount of press padding used.

C	PROBLEM	CAUSE	ACTION
Panel is thinner on one edge and thicker on opposite edge.		Platens are not parallel.	Determine parallelism of platens by squeezing lead wire between surfaces and adjust as necessary. Check that floating platens are not stuck or hanging up on an obstruction.
		In multi-platen presses, the laminating package is not loaded directly above the one below. Packages (books) are not centered.	Provide operator with either centering gauge or adjust pushers of automatic presses.

D	PROBLEM	CAUSE	ACTION
Panel is much thinner on edges than in the center.		Resin in prepreg at the edge melts first and because flow is not blocked at the edges it is squeezed out leaving thinner areas.	Use a press cycle with a ''kiss'' technique in which the prepreg resin at the edges has begun to thicken when high pressure is applied. The center should be at its lowest melt viscosity so the flow at the edges is restricted.

E	PROBLEM	CAUSE	ACTION
Panel is thinner in the center than at the edges.		Laminating plates have a permanent dishing due to long term use.	If dishing is not too bad the surfaces of the plates against the laminate may be reversed periodically. Plates may have to be replaced.

F	PROBLEM	CAUSE	ACTION
Some boards/panels thick, some thin.		Inconsistent pressing techniques.	Standardize and document press procedure for optimum performance; train personnel to avoid variations.

G	PROBLEM	CAUSE	ACTION
Circuit image transfer (from second conductor layer to surface layer in a package) creating non-uniform thickness within a panel.		Too much pressure.	Carefully reduce pressure; monitor bead to maintain desired flow.
		Too little prepreg cushion.	Substitute thinner prepreg with higher resin content; monitor flow to avoid thickness variations.
		Excessive flow (check for dry or hazy edges).	Reduce pressure. Shorten flow window (duration of resin flow) by increasing heat rise rate - use less press padding. Change to prepreg with lower flow and/or shorter gel time.
		Lack of separator plates between packages in a multi-package fixture.	Add 0.8 – 1.6 mm separator plates.

13.12 POST LAMINATION BAKE

13.12.1 Blisters/Delamination

A PROBLEM	CAUSE	ACTION
Separation of prepreg to the innerlayer laminate or oxide surfaces.	Oxide breakdown due to too high temperature during post cure, particularly Polyimides and Cyanate Ester.	Check oven for proper temperature and calibration. Check for overshoot.

B PROBLEM	CAUSE	ACTION
Fractures after lamination.	Incorrect post cure, material is over cured.	Follow manufacturer's recommendations for proper cure and post cure of material. Check T_g to confirm proper cure.

13.12.2 Bow and Twist (Warped)

A PROBLEM	CAUSE	ACTION
Panel will not lay flat.	Improper positioning of panels during post-cure stress relief. Panels hung or racked rather than horizontal and weighted.	Warpage can be removed by heating the panel above its T_g in a press and then cooling down to room temperature under pressure. Establish proper procedure for post curing panels.
	Post cure allows panel to bow.	Maintain panels flat and weighted if necessary to keep flat until cooled.
	Inadequate stress relief.	Verify that all panels are subjected to a post lamination stress relief bake of 157 - 163°C (for FR-4) for a minimum of 1 hour at product temperature, under weight.

13.12.3 Surface Imperfections

A PROBLEM	CAUSE	ACTION
Panels are stained after post bake.	Excessive heat during post baking.	Do not exceed 163°C for FR-4.

B PROBLEM	CAUSE	ACTION
Dents in the copper surface after post bake.	Debris in between panels during post bake. The material softens during post bake and will conform to debris.	Bake panels before trim or edge finishing. Wipe panels with tack cloth after trim or edge finishing to remove debris.

13.13 SUBSEQUENT PROCESSING

13.13.1 Misregistration

A PROBLEM	CAUSE	ACTION
Holes drilled after lamination skewed or rotated to the innerlayer image.	Drill machine tooling locators and/or holes are not correct, if they are all the same.	Verify tooling locations on drill machine with locations to an internal panel. An internal panel may be drilled separately to help verify location.
	Drill machine tooling locators and/or holes are differently located for each drill head position.	Verify that tooling locations on drill machine are the same for each drill head.
	The tooling locators for the punched/drilled tooling holes is not coordinated with artwork locators and may differ with each artwork.	Verify that tooling holes, artwork and press fixtures are dimensionally coordinated. A useful technique called post-etch-punch punches the tooling holes after etching and locates them from the etched pattern.

13.13.1 Misregistration (continued)

B	PROBLEM	CAUSE	ACTION
Holes do not match innerlayer circuit image.		Layer misregistration due to innerlayer instability.	Establish datum point for drilling reference in center of board or panel.

13.13.2 Blisters/Delamination

A	PROBLEM	CAUSE	ACTION
Drilling, routing, post curing and fusing or solder coating causes delam or blistering.		Poor adhesion between cured prepreg and oxided copper.	Not all oxides will withstand the cure temperatures used for some resin systems; the only acceptable type for most systems is the red - brown oxide. Check oxide with supplier to insure proper use.

B	PROBLEM	CAUSE	ACTION
Fractures in the material after drill.		Drill bit geometry wrong for the material.	Check for proper primary and secondary web thickness and margin relief.
		Drill feeds and speeds too aggressive for polyimide or cyanate ester.	Use 1 mil chipload at 450 sfm as starting point.

C	PROBLEM	CAUSE	ACTION
Delamination is present in cross sections, however visual examination of boards shows no delamination. Boards pass solder shock.		Microsection techniques may induce delamination which is not actually present in the board.	Condition samples at 121 to 149°C to sufficiently remove moisture. Cut specimens from the panel using router tools or diamond wafering saws. Do not punch microsection specimens in polyimide or cyanate ester. Sand using graduated grits of paper using light pressure to avoid damage to specimens.

13.13.3 Bow and Twist (Warped)

A	PROBLEM	CAUSE	ACTION
Board bows and distorts during reflowing and baking.		Prepreg undercured during lamination cycle.	Check press cycle for time at temperature. Check glass transition temperature (T_g).
		Panels processed at too high a temperature for resin system.	Check temperatures of processing conditions. Contact material supplier for recommendations on maximum processing temperatures or alternative resin systems.

13.13.4 Voids in Plated Through Holes

A	PROBLEM	CAUSE	ACTION
Voids in plated through holes visible at microsection.		Under cure can contribute to resin smear.	Check T_g to ensure complete cure prior to drilling.
		Incomplete plasma cleaning caused by moisture present in the MLB.	Bake MLB at 120°C for 1 hour minimum prior to plasma treatment.
		Residue remaining from the plasma operation.	Oxygen purge for 4 to 5 minutes following the plasma treatment. Vapor hone holes after plasma to remove debris.
		Poor adhesion of electroless copper to the hole wall.	Micro-etch of the hole wall with a permanganate process to micro texture the surface. Check for adequate agitation in the electroless bath.

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Section 14
Metallic Protective Coatings

14.0 METALLIC PROTECTIVE COATINGS

This section deals with metallic coatings as final finishes that protect and preserve copper surfaces for assembly processes and/or to prevent long term corrosion or deterioration of circuit patterns. Covered here are all aspects of bare board solder reflow and leveling, as well as immersion and electroless metal processes. Electroplated final finishes, such as tin-nickel or nickel-gold, are covered in Section 10.0. Non-metallic protective coatings can be found in Section 15.0.

14.1 TIN-LEAD FUSING

Fusing is the process whereby a co-plated deposit of tin and lead is melted and amalgamated into solder. Tin-lead when plated should be a dull, light gray, whereas the fused solder should be bright and shiny.

14.1.1 General

A PROBLEM	CAUSE	ACTION
Little or no edge coverage after reflow.	Ammoniacal etch salts left on board after etching.	Make sure replenisher rinses and water rinses on etcher are working properly. (See 11.5.)
	Exposed edge copper is dirty or oxidized.	Adequately clean and activate metal surfaces before fusing.
	Tin-lead plating too thin.	Increase plated thickness to a minimum 0.008 mm; follow actions specified in Section 10.3.
	Inadequate fluxing prior to reflow.	Flux per supplier's recommendations or customer's requirements.

B PROBLEM	CAUSE	ACTION
White haze or residue on solder after reflow, often as lead or tin oxide.	Improper neutralization after alkaline etching.	Review solder brightener and rinsing procedures.
	High pH in alkaline etch.	Maintain pH of etchant within specification.
	Poor rinsing after immersion tin process.	Ensure adequate rinsing after immersion tin.
	Water or moisture in flux.	Replace flux. Panels should be dry prior to fluxing and reflow.
	Organic contamination in tin-lead plating bath.	Carbon treat bath per supplier recommendations. (See 10.3.)
	Contaminated flux.	Replace flux; investigate source(s) of contamination.

C PROBLEM	CAUSE	ACTION
Non-fused tin-lead; cold spots.	Improper plated alloy composition.	Analyze plated alloy composition and check tin-lead plating bath parameters. (See 10.3.1D.)
	Fusing temperature too low.	Generally maintain above 232°C.
	Plated surface is oxidized.	Incorporate a solder conditioning step prior to fusing.
	Copper contamination in solder plate.	Dummy plate bath per supplier recommendations. (See 10.3.)

D PROBLEM	CAUSE	ACTION
Blow holes occur in fused solder.	High concentration of organics in the tin-lead plating bath leads to co-deposition with the alloy, and are boiled out from the alloy during fusing.	Carbon treat tin-lead bath per supplier recommendations. (See 10.3.)

14.1.1 General (continued)

E PROBLEM	CAUSE	ACTION
Dewetted solder surface after fusing.	Dirty copper surface under tin-lead plating.	Ensure clean surface for tin-lead plating; rinsing must be adequate. (Also see Section 10.3.)
	Sulfate drag-in to tin-lead bath.	Change pre-dip to eliminate sulfates. If rinse water is contaminated with sulfates, deionized water should be used.
	Lead fluoride on plated surface.	Increase boric acid content in tin-lead bath to eliminate. (See 10.3.2A.)
	Metallic contamination of the tin-lead plate.	Check Cu, Ni, and Fe levels; dummy plate at low current density to remove.
	Chromate on base copper (when tin-lead is plated over base laminate copper).	Flash copper-plate base copper.

F PROBLEM	CAUSE	ACTION
Galvanized finish.	High tin in deposit.	Adjust tin-to-lead ratio in bath per supplier recommendations. (See 10.3.1D.) Reduce current density below 20 ASF.

G PROBLEM	CAUSE	ACTION
Dull finish.	High lead in deposit.	Adjust tin-to-lead ratio in bath per supplier recommendations. (See 10.3.1D.)
	Plated deposit too thin.	Adjust plating thickness to 0.008 mm minimum. (See 10.3.)
	Current density too low during plating.	Adjust current density to above 12 ASF.
	Contaminated surface.	Check rinsing after etch and/or solder brightener strength.

H PROBLEM	CAUSE	ACTION
White residue on board surface.	Contaminated flux or water in flux.	Replace flux.
	Improper rinsing before reflow.	Check etching/solder brightener procedure.
	Improper washing after reflow.	Use a warm water rinse after reflow.
	Overheated flux/rosin, especially on black ground planes.	Adjust reflow parameters or replace flux.

J PROBLEM	CAUSE	ACTION
Plugged holes.	Heavy tin-lead plate, greater than 0.013 mm.	Maintain plated tin-lead thickness between 0.008 mm and 0.013 mm.

K PROBLEM	CAUSE	ACTION
Flat reflow.	Thin plating, less than 0.005 mm.	Maintain plated tin-lead thickness between 0.008 mm and 0.013 mm.
	Organic contamination in the tin-lead bath and deposit.	Carbon treat bath per supplier recommendations. (See 10.3.)

L PROBLEM	CAUSE	ACTION
Pimpled reflow “volcanoes” or nodules.	Organic contamination in the tin-lead bath and deposit.	Carbon treat bath per supplier recommendations. (See 10.3.)
	Excessive amounts of replenisher or additive in tin-lead bath.	Carbon treat bath and reduce additions.

M PROBLEM	CAUSE	ACTION
Grittiness after reflow.	Copper contamination in the tin-lead bath and deposit.	Dummy-plate the bath at 2-4 ASF.
	Surface contamination of deposit.	Review rinsing and storage conditions prior to reflow.

14.1.2 Infra-red Fusing

A PROBLEM	CAUSE	ACTION
Incomplete reflow.	Improper tin-lead composition.	Correct tin-lead bath, anode composition, or current density as required. (Also see Section 10.3.1D.)
	Conveyor too fast.	Slow down conveyor until the panel border appears un-reflowed but all of the board circuitry is reflowed.
	Non-uniform heating of board.	Check lamps. Board design problem; use alternate fusing method.

B PROBLEM	CAUSE	ACTION
Dewetting/ puddling.	Contamination on the copper surface under the solder.	Reflow at low temperature or remove solder and hot air level. Copper surface must be clean prior to tin-lead plating. (See 10.0.)
	Too much lead in solder (wrong composition). (See 10.3.1D.)	Solder strip, solder dip and hot air level to repair.
	Too much solder on the panel.	Remove excess by scrubbing. Control tin-lead plating thickness to 0.008-0.013 mm. (See 10.3.)
	Contamination in tin-lead bath, resulting in contaminated plate.	Carbon treat the bath to remove organic contaminants. Dummy plate bath at low current density to remove metallic contaminants.

C PROBLEM	CAUSE	ACTION
Delamination of multilayer panels.	Preheat too short.	Increase dwell by slowing conveyor or obtaining longer preheat section.
	No prebake used.	Prebake panels for 1-4 hours at 121-135°C.
	Board temperature too high.	Match conveyor speed and lamp control voltage. Always run a leader panel (copper clad or similar) through machine first to act as a heat sink.
	Panel not laminated properly.	Follow actions detailed in Section 13.0 on Lamination.

14.1.3 Hot Oil Reflow

A PROBLEM	CAUSE	ACTION
Boards not reflowing. (Also see 14.1.1C.)	Oil temperature not high enough.	Raise oil temperature.
	Dwell time not long enough.	Increase dwell time in hot oil.

B PROBLEM	CAUSE	ACTION
Dewet/pull-back of reflowed solder. (Also see 14.1.1E.)	Fresh reflow oil.	Add flux to the fresh oil to shorten the break-in period, e.g., lower the surface tension.
	Improper board withdrawal from oil.	Tilt board when exiting oil.

C PROBLEM	CAUSE	ACTION
Delamination.	Preheat pot temperature too low/high, or dwell time too short (excessive thermal stress to board).	Match preheat to oil temperature to ensure gradual heat up.
	Pre-reflow bake too short, not done, or dwell too long between bake and reflow.	Re-bake one hour minimum prior to reflow.

14.1.4 Vapor Phase Fusing

A	PROBLEM	CAUSE	ACTION
Boards not reflowing. (Also see 14.1.1C.)		Improper fluid composition/vapor not at reflow temperature.	Check fluid vapor point and adjust if necessary.
		Board mass too great for fluid point in use.	Follow machine supplier recommendations.

B	PROBLEM	CAUSE	ACTION
White haze after reflow. (Also see 14.1.1B.)		Organics in tin-lead plate.	Wipe off haze (haze is normal after vapor phase reflow). Use a solder cleaner (as opposed to solder brightener) prior to reflow.

C	PROBLEM	CAUSE	ACTION
Dewetting after reflow. (Also see 14.1.1E.)		Surface not clean.	Evaluate types of flux used. If no flux is used, confirm that tin-lead surface is very clean.

14.2 SOLDER LEVELING

14.2.1 Hot Air Leveling

A	PROBLEM	CAUSE	ACTION
Webbing/balling of solder.		Board too dry.	Apply more flux; check application procedure for deficiencies.
		Solder mask not completely cured.	Increase cure time, temperature or energy level of solder mask. (Also see 16.1 for more information.)
		Flux surface tension incompatibility since too much solvent evaporation.	Use a more viscous flux. Consult flux supplier.

B	PROBLEM	CAUSE	ACTION
Plated-through hole not soldered.		Unstripped tin-lead residues in holes.	Extend dwell time in stripper. Replenish or replace stripper solution. Improve solution agitation and parts agitation during the stripping operation.
		Lead fluoride residues from peroxide-type tin-lead stripper left in holes.	Use a post-dip bath after stripper that will dissolve the residue (usually not necessary if a spray conveyorized operation). Improve solution agitation and parts agitation during the stripping operation to keep the loose residue from redepositing.
		Incomplete removal of copper-tin intermetallic layer during the stripping operation.	Extend dwell time in second step of tin-lead stripping operation. Replenish/replace stripping baths if spent.
		Photoimageable solder mask developer residues.	Ensure developer breakpoint is per supplier specification. Determine efficiency of developer rinsing step; improve if necessary.

C	PROBLEM	CAUSE	ACTION
Lands not completely soldered.		Solder mask residue on pads.	Work with solder-mask supplier to improve solder mask application process. (Also see Section 16.1.) Use acid precleaner which produces low micro-etch and will not cause attack on previously soldered boards.

14.2.1 Hot Air Leveling (continued)

D	PROBLEM	CAUSE	ACTION
Poor coverage of surface or holes.		Surface contamination.	Review cleaning procedure prior to HAL.
		Low flux activation.	Change out flux bath or make up with a more active flux.
		Flux viscosity incorrect.	Consult supplier for a different viscosity flux.
		Solder contact time too short.	Increase dwell time.

E	PROBLEM	CAUSE	ACTION
Plugged holes.		Low air knife pressure.	Increase air pressure.
		Low volume of air.	Increase size of ballast for air storage.
		Clogged air knife.	Remove obstruction. Set up a regular maintenance schedule to keep air knives clean.
		Air temperature too low.	Check heater operation and temperature gauge.

F	PROBLEM	CAUSE	ACTION
Dewetting of solder.		Copper surface may be contaminated with organic residues.	Check operation of preclean process. Use both a cleaner and micro-etch for optimum surface preparation.

G	PROBLEM	CAUSE	ACTION
Solder mask blisters/poor adhesion after leveling.		Undercured solder mask.	Consult sections in 16.1 dealing with incomplete solder mask cure and adhesion failure.

H	PROBLEM	CAUSE	ACTION
High ionic contamination levels/ poor electrical properties.		Incomplete removal of flux during post-clean.	Check cleaning equipment for plugged spray nozzles or other mechanical failures. Use warm water and light brushing for best (aqueous) flux removal. Clean immediately after solder operation (with only a slight cool down) so that flux residues do not absorb into board. Consider adding a rinse aid to the first warm water rinse. Consider using a DI final rinse.
		Solder mask/flux incompatibility.	Consult both solder-mask and flux suppliers for recommendations. Some solder masks are more impervious to flux and hot air leveling than others.

J	PROBLEM	CAUSE	ACTION
Solder on leveled panel has a grainy appearance.		Copper contamination in solder >0.02%.	Improve solder “combing” procedure to remove copper (should be done at least daily). Consult machine supplier for best procedure. If copper contamination is excessive (>0.03%), change out solder. Raise temperature of solder pot as a temporary “fix” (may affect other things such as board warpage).

K	PROBLEM	CAUSE	ACTION
Solder on gold tabs.		Loose tape.	Use heat and pressure when applying solder mask tape.
		Air pressure loosens tape.	If possible, keep taped area out of solder. Strips of tape should run vertically, so that air pressure cannot lift edge.

14.2.2 Machine/Material Problems

A	PROBLEM	CAUSE	ACTION
Plugged air knives.		Leveling flux carbonizes at high temperatures.	Change to a flux that is more stable at high temperature.

14.2.2 Machine/Material Problems (continued)

B	PROBLEM	CAUSE	ACTION
Copper contamination builds up rapidly in solder.		Poor rinsing after preclean.	Review rinsing procedure: if too short, copper from the micro-etch will be left on the surface; if too long, a copper tarnish will form that will dissolve into the flux and solder.
		High acid content in flux that dissolves excess copper.	Switch to low acid flux.
		Excessive micro-etch which creates a rougher, larger copper surface (more area to dissolve in flux and solder).	Review/adjust micro-etching procedure.
		Excessive time between fluxing and actual leveling process (more time for copper to dissolve in flux).	Improve process. Reduce excess time or clean panels and re-flux if time is excessive.

C	PROBLEM	CAUSE	ACTION
Excessive smoke generated during the leveling operation.		Flux incompatibility.	Change type of flux.

D	PROBLEM	CAUSE	ACTION
Flux density changes frequently.		Excess water dragged into flux.	Make sure panels are fairly dry before fluxing.
		Excessive solvent evaporation.	Keep flux container closed as much as possible. Change flux if necessary.

14.3 IMMERSION COATINGS

Immersion coatings are non-electrolytic and plate by a chemical displacement reaction with the base metal (usually copper).

14.3.1 Immersion Tin

Immersion tin coatings are generally thin, between 0.8 - 2.5 microns. Solderability is good, providing parts are used before excessive copper-tin intermetallic is formed.

A	PROBLEM	CAUSE	ACTION
Poor coverage or skip plating.		Improper cleaning.	Check clean line.
		Improper rinsing.	Improve rinsing.
		Base metal activation inadequate.	Check base metal activation and cleaning process.
		Bath parameters out-of-spec.	Analyze and adjust if possible. If not, dump bath and remake.
		Immersion tin bath is old or past its life.	Dump and remake.

B	PROBLEM	CAUSE	ACTION
Low tin thickness on part.		Low tin concentration in bath.	Add tin salts per supplier specification.
		Tin on panel is redissolving in tin bath.	Acid concentration in the bath is too high. Analyze and adjust (dilute if necessary).

14.3.1 Immersion Tin (continued)

C PROBLEM	CAUSE	ACTION
Unusual low stannous concentration in bath.	Oxidation of stannous tin to stannic.	Remove any source of air to bath, such as too vigorous mixing (do not air agitate). Excessive temperatures can cause oxidation of tin. Monitor temperature; keep bath stirred to prevent hot spots.
	Too much tin plated out.	Log square footage to determine usage rates. Remember to include thieving area on panel and area on copper racks (plastisol-coated racks preferred).
	Undissolved salts in tank.	Stir to dissolve; check temperature.
	Poor sample taken for analysis (due to nonuniform solution concentration).	Stir bath prior to sampling. Make sure sample is representative.

D PROBLEM	CAUSE	ACTION
Darkening or unusual color of bath.	High temperature.	Monitor temperature closely. Keep bath stirred to prevent hot spots. Check operation of heaters and thermostat.
	High iron contamination.	Eliminate source of metal. It may be necessary to discard the bath.
	Leaching of photoresist into the bath.	This should not harm the bath but may be a sign of under-cured resist.

E PROBLEM	CAUSE	ACTION
Dark spots on tin.	Rinse tank was used for other operations.	Rinses for immersion tin must be dedicated to the operation. (Even spray rinse tanks can have chemicals on the bottom that splash up on parts.)

F PROBLEM	CAUSE	ACTION
Dark or stained deposits.	Metallic contamination, especially iron.	Dump and remake bath. Eliminate source of metal.
	High caustic content in resist stripper after immersion tin.	Analyze resist stripper for caustic content and adjust if out of range. Improve rinsing between tin bath and resist strip. (Sulfide may be too high, possibly caused by poor rinsing after immersion tin and dragging of salts into stripper.) Keep stripping time to a minimum. Consider alternate, low caustic resist stripper.
	Poor rinsing.	Rinse parts well after immersion tin and after resist stripping.
	Parts exposed to hydrochloric acid vapors.	Keep parts away from tanks of HCl.

G PROBLEM	CAUSE	ACTION
Chipping, peeling on non-adherent deposits.	Poor precleaning.	Check clean line; institute micro-etch step to improve cleaning.
	Copper or iron plated in deposit (high metallic contamination in bath).	Dump and remake bath.
	Wrong type rack (i.e., stainless steel) used, or pinholes in plastisol coating on rack.	Use only plastisol-coated racks in good repair.

14.3.2 Immersion Gold

A PROBLEM	CAUSE	ACTION
Poor coverage or skip plating.	Improper cleaning.	Check clean line; institute micro-etch step to improve cleaning.
	Improper or inadequate rinsing.	Improve rinsing; check flow, agitation, water quality.

B PROBLEM	CAUSE	ACTION
Slow plating rate.	Low gold or electrolyte concentration; pH or temperature out of range.	Analyze and replenish bath. Check and adjust to operating range.
	Nickel or copper contamination level exceeded.	Dilute bath to lower contaminant concentration, or dump bath for reclaim and make up new bath.

14.3.3 Immersion Tin-Lead

Immersion tin-lead produces a flat, uniform, solderable coating on all feature surfaces and edges. Typical thickness of the fused alloy is 4 to 8 microns; composition of the alloy is 65 to 75% tin. It is a viable alternative to hot air solder leveling, electrodeposition/selective stripping, or inhibitor coatings for maintaining solderability of printed wiring boards.

A PROBLEM	CAUSE	ACTION
Thin deposit (less than 4 microns).	Bath chemistry is low.	Replenish bath per supplier specifications.
	Pre-dip is contaminated.	Change pre-dip/eliminate source of contamination.
	Long dwell times in preplate chemistry and/or rinses.	Operate process according to supplier specifications.
	Different copper substrate than usual electrolytic copper.	Check deposit thickness on standard electrolytic copper and adjust immersion time if different.

B PROBLEM	CAUSE	ACTION
Wrong alloy composition in deposit.	Bath chemistry out of balance.	Adjust bath per supplier recommendations.
	Copper substrate not cleaned properly.	Review preplate process. Check micro-etch initiation rate (should begin outgassing within 20 seconds).
	Pre-dip is contaminated.	Change pre-dip/eliminate source of contamination.
	Different types of copper substrates may plate with different ratios of tin and lead.	Check deposit thickness on standard electrolytic copper and adjust bath chemistry per supplier specifications.

C PROBLEM	CAUSE	ACTION
Deposit will not fuse.	Wrong alloy composition.	See 14.3.3.B.
	Deposit too thin.	See 14.3.3.A.
	Fusing process is out-of-specification.	See 14.1.

D PROBLEM	CAUSE	ACTION
Loss of deposit adhesion.	Deposition rate too high.	Adjust bath chemistry per specification to control deposition rate.
	Bath out of balance or near end of normal bath life.	Adjust bath parameters per supplier recommendations, or dump and re-make.
	Underlying copper surface not clean.	Ensure that cleaning is adequate by comparing a scrubbed vs. preplate-treated parts. Adjust pre-plate clean line as necessary.

E PROBLEM	CAUSE	ACTION
Non-uniform thickness of tin-lead deposit.	Non-uniform cleaning of the underlying copper surface.	Review/correct cleaning process.
	Non-uniform structure/composition of the copper substrate.	Determine if thickness non-uniformity is acceptable. If not, resolve copper substrate non-uniformity.
	Age of the bath can affect thickness uniformity on pads around holes.	Consult supplier for recommendations if the level of non-uniformity is unacceptable.

14.4 ELECTROLESS COATINGS

Electroless processes differ from immersion coatings in that they are auto-catalytic. Thickness of deposit is not limited to the extent of the displacement reaction with copper. Instead the electroless metal will continue to plate on itself. Much thicker deposits are obtainable than with immersion coatings.

14.4.1 Electroless Nickel

A PROBLEM	CAUSE	ACTION
Lack of continuous plating or skip plating (poor coverage).	Bath parameters not being followed (pH and chemical concentrations).	Readjust to supplier's operational parameters.
	Copper surface not clean of oil or inhibiting film.	Reclean copper using chemical cleaners or mechanical scrubbing.
	Resist/solder mask on copper inhibiting nickel plate.	Strip solder mask/resist if possible.
	Bath temperature too low.	Raise temperature per supplier specifications.
	Bath overstabilized.	Work bath to reduce stabilizer content. Raise bath temperature to increase activity.
	Improper rinsing.	Check rinse water quality, temperature, flow rate and rinsing times.
	Metallic contamination.	Bath should be dummied or discarded.
	Organic contamination.	Cool bath, carbon treat and filter per supplier recommendations.
	Too much air agitation.	Reduce air agitation.

B PROBLEM	CAUSE	ACTION
Roughness of plating.	Contaminated make-up water.	Water may require filtration and/or carbon treatment. Use only deionized water for bath make-up.
	Excessive solution replenishment.	Add replenisher slowly and mix thoroughly.
	Localized overheating.	Check bath temperature in more than one location in bath. Improve bath agitation, especially around and under heaters. Use low-watt-density heaters.
	Contaminated filter cartridges or bags.	Change filters.
	High orthophosphite concentration.	Dump bath and re-make.
	Particulate contamination in bath.	Filter through 5-micron (or less) filter; use continuous filtration.
	High bath pH which causes the formation of nickel hydroxide and creates a turgid solution.	Lower pH and raise complexor level in bath.

C PROBLEM	CAUSE	ACTION
Slow plating rate.	Low nickel or replenisher.	Analyze and adjust solution per supplier specifications.
	Recommended level of orthophosphite exceeded.	Dump bath and re-make.
	Low pH.	Adjust to within range.
	Bath temperature too low.	Raise temperature to within recommended range.
	Low square-footage loading of bath (with work to be plated).	Increase loading to recommended level. Use dummy panels if necessary. If work load is always low, consider ways to permanently reduce solution volume to fit work load (i.e., smaller tank).

14.4.1 Electroless Nickel (continued)

D	PROBLEM	CAUSE	ACTION
Nickel plate is peeling.		Poor cleaning of substrate.	Reclean substrate; remove all contaminants.
		Brittle deposit.	Plating rate is too fast — slow down deposition rate (reduce temperature and/or concentrations). Solution is too old; dump and re-make.

E	PROBLEM	CAUSE	ACTION
Pitting.		Heavy metal contamination.	Dummy plate or discard solution.
		Base metal is pitted.	Check base metal for surface defects and address these if necessary.
		Organic contamination on surface.	Cool bath, carbon treat and filter per supplier recommendations.

F	PROBLEM	CAUSE	ACTION
Streaked deposit.		Gas streaks.	Increase bath or work agitation.
		Improper cleaning.	Improve cleaning and/or rinsing steps prior to plating.
		Low surface area (work load in bath).	Increase work load in bath - use dummies if necessary.

G	PROBLEM	CAUSE	ACTION
Dull deposit.		Organic contamination.	Cool bath, carbon-treat and filter per supplier recommendations.
		Improper or poor cleaning.	Improve cleaning cycle.

H	PROBLEM	CAUSE	ACTION
Frosted deposits.		Metallic contamination.	Dummy plate or discard solution.
		Low work load.	Increase work load in bath - use dummies if necessary.
		Too much air agitation.	Reduce air agitation.

14.4.2 Electroless Tin

Electroless tin baths begin plating as immersion but plate up much thicker. The thickness is sufficient for reflow.

A PROBLEM	CAUSE	ACTION
Thin tin deposit.	Low tin concentration.	Analyze bath for tin and adjust as necessary.
	Low bath temperature.	Increase bath temperature.
	Plating time too short.	Increase plating time.
	Poor preclean.	Analyze and adjust, or replace precleaner.

B PROBLEM	CAUSE	ACTION
Poor fusing.	Fusing temperature too low.	Reflow temperature must be at least 260°C to reflow tin.
	Thin deposit.	Follow actions detailed in 15.4.2.1.
	Excessive formation of copper-tin intermetallic.	Improve inventory conditions (cool, dry, short).

C PROBLEM	CAUSE	ACTION
Bath has darkened.	Localized overheating.	Use agitation with an immersion heater. Do not exceed bath temperature of 60°C.

D PROBLEM	CAUSE	ACTION
Salts crystallizing.	Low bath volume.	Add deionized water to proper volume.

E PROBLEM	CAUSE	ACTION
Skip plating; poor coverage.	Improper cleaning.	Improve cleaning and rinsing steps prior to plating.
	Stainless steel rack is creating a galvanic effect.	Use plastisol-coated racks or titanium.

F PROBLEM	CAUSE	ACTION
Slow plating rate.	Bath parameters out-of-specification.	Analyze and adjust solution per supplier specifications.
	Low bath temperature.	Increase temperature.
	Immersion time too short.	Increase immersion time.
	Bath is old.	Dump and re-make bath.

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Section 15
Non-Metallic Coatings

15.0 NON-METALLIC PROTECTIVE COATINGS

15.1 PERMANENT SOLDER RESIST

Permanent polymer coatings (solder resists) are heat resistant organic coatings applied to a finished printed board prior to assembly of components, in order to limit the area of solder wetting during the soldering operation. Solder resists minimize soldering defects, such as bridging between lines and lands, and reduce solder consumption and contamination. These masks provide improved visual background for easier inspection and may protect narrow conductors during handling.

Solder resists have been formulated specifically to remain on the printed board throughout its useful life, as well as function as resists to molten solder. Ideally, a solder resist should also:

A. Improve, or at least not significantly diminish, electrical properties of the printed board, such as dielectric strength, dielectric constant, moisture resistance, insulation resistance, etc.

B. Not degrade the UL flammability rating of the board or assembly.

C. Exhibit hydrolytic stability, fungus resistance, etc.

D. Be compatible with any conformal coating material which may be used.

Most of these criteria are met by most commercially available liquid and dry film solder masks, when they are applied and cured in a manner consistent with the supplier's recommendations. The criteria for these solder resist can be found in IPC-SM-840.

15.1.1 Screen Printable Solder Resists (Thermal and UV Cure)

Screen printable solder resists are created by printing the solder resist through a stenciled screen of very fine mesh and fairly highly tensioned. The process is similar to that for screen printing a primary image prior to plating. (See Section 9.4.) The materials are cured by either an oven bake or by exposure to a UV light source.

A	PROBLEM	CAUSE	ACTION
Misregistration. (See Figure 15-1.)		Off location tooling holes or pins, or wrong size pins.	Re-register screen and tooling pins. Find pins that fit snugly and reset registration. Tooling holes and pins must match for optimum registration.
		Screen tool incorrect (pattern misregistered, incorrectly stepped, too large or too small, or optic targets off).	Remake tool correctly. Separate panels with bad targets and print them at the end of the job. Report condition to make sure it is not repeated.
		Too much off-contact to screen.	Reduce off-contact.
		Too much squeegee pressure.	Reduce pressure. Raise squeegee stop if machine is so equipped.
		Image too large for overall screen/frame dimension.	Increase screen/frame size to 5-6X larger than image on all sides or 2X total image area.
		Squeegee too soft (thermal cure inks).	Use harder squeegee (higher durometer).
		Squeegee too hard (UV cure inks).	Use lower durometer squeegee.
		Screen mesh too large; too much ink lay down.	Correct screen mesh and percent open area to supplier's recommendations.
		Loose or incorrectly tensioned screen.	Remake screen and properly tension it prior to applying stencil.

15.1.1 Screen Printable Solder Resists (Thermal and UV Cure) (continued)

B PROBLEM	CAUSE	ACTION
Incomplete cure (thermal cure inks).	Dwell time too short in oven bake.	Increase dwell time. Make sure oven is up to temperature before starting timer.
	Temperature too low.	Increase temperature to supplier's recommendations. Confirm actual temperature using a thermocouple. Check oven calibration.
	Improper mixture of epoxy and hardener.	Use supplier's recommended mixture and mixing procedures. Insure that measuring procedures are correct. Make sure the ink is thoroughly mixed before screening.
	Poor oven air circulation.	Reorganize oven contents to improve circulation. It may be necessary to rack panels further apart. Check blower and exhaust operation. Check air intake and filters.

C PROBLEM	CAUSE	ACTION
Incomplete cure (UV cure inks).	Conveyor speed too fast for solder mask type or thickness of deposit.	Reduce speed or thickness.
	Solder mask color too intense; colorant absorbing curing energy.	Reduce thickness of applied mask. Contact mask supplier.
	Light source too low in intensity.	Reduce conveyor speed through curing unit to compensate. Increase number of lamps. Replace old lamps (check output of lamps daily using a radiometer). Clean, readjust and focus reflectors.
	Moisture under solder mask.	Prebake to remove moisture.

D PROBLEM	CAUSE	ACTION
Adhesion failure.	Surface of panel contaminated.	If applied to plated metal, clean panel with a mechanical scrub. Clean panel with mild acid or alkaline wash or degrease (pH of wash to be specified by solder mask supplier).
	Insufficient cure.	See Sections 16.1.1.B or 16.1.1.C.
	Incompatible solder mask for metal substrate (i.e., copper or solder).	Consult supplier and solder mask data sheet for recommended uses. Solder mask type must be compatible with metal substrate.
	Moisture on panel, under mask (especially along closely spaced conductors).	Prebake panels to remove moisture.

15.1.1 Screen Printable Solder Resists (Thermal and UV Cure) (continued)

E	PROBLEM	CAUSE	ACTION
Solder resist on lands or in holes.		Screen tool incorrect (artwork does not match panel).	Remake tool.
		Excessive squeegee pressure and/or off-contact.	Reduce squeegee - and off-contact pressure.
		Squeegee too soft, or dull or rounded.	Use higher durometer squeegee. Sharpen squeegee.
		Screen mesh too open; too much ink lay down.	Correct screen mesh and percent open area to supplier's recommendations.
		Excessive time delay between prints while in flood mode.	Do not flood screen until ready to print.
		Excessive flood pressure.	Reduce flood pressure.
		Ink on underside of screen.	Clean screen. Blot screen more frequently.
		Excessive solder mask bleed.	Check ink viscosity. Verify original artwork clearance. Cure as soon as possible after application, before ink has a chance to ''flow.''
		Stencil pattern breakdown.	Remake screen.
		Too much or uneven off-contact to screen.	Reduce off-contact.
		High temperature and/or humidity in print area.	Maintain constant room temperature and humidity per supplier recommendations, so that screen pattern does not expand or contract. Monitor and record constantly.

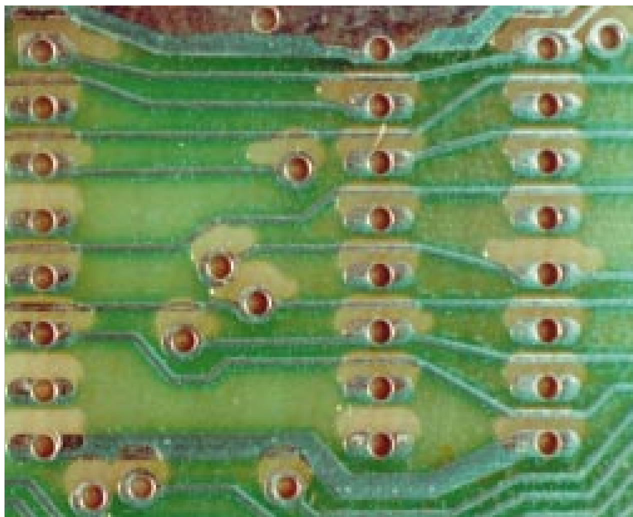

Figure 15–1 Misregistered solder mask

15.1.1 Screen Printable Solder Resists (Thermal and UV Cure) (continued)

F PROBLEM	CAUSE	ACTION
Solder mask adhesion failure after hot air leveling.	Incorrect application or solder resist selection for process.	Choose solder resist designed to withstand hot air leveling. Apply per supplier's recommendations.
	Insufficient cure of solder resist.	See Sections 15.1.1.B and 15.1.1.C.
	Insufficient prebake of panel prior to hot air leveling.	Adjust prebake cycle accordingly.
	Dwell in molten solder too long (typical times are 2-4 seconds).	Decrease dwell time.
	Temperature too high in molten solder.	Decrease temperature.
	Overcure of solder mask (may become brittle).	Reduce cure to supplier's recommendations. (See Section 15.1.1.G.)

G PROBLEM	CAUSE	ACTION
Overcure of solder mask.	Temperature too high; time too long in oven bake (thermal cure masks).	Reduce time and/or temperature per supplier recommendations.
	Too long in cure unit; light source too intense (UV cure resists).	Increase conveyor speed; reduce intensity.

H PROBLEM	CAUSE	ACTION
Insufficient moisture/ insulation resistance.	Solder resist exposed to organic/inorganic materials that have destroyed resistance and attacked resin in solder mask.	Limit exposure of solder resist to cleaning materials determined to be detrimental to solder mask in use.
	Solder resist not properly mixed, screened, or cured.	Apply and cure ink per supplier's recommendations. (Also see 15.1.1.A through 15.1.1.G.)
	Solder resist design will not meet moisture/insulation resistance requirements.	Evaluate new solder resist that meets IPC-SM-840 specifications.

J PROBLEM	CAUSE	ACTION
Skipping.	Very high plated features.	Angle squeegee and adjust pressure to compensate. Try a different durometer squeegee. (Always re-check registration after adjustments.) (Also see Section 10.0 on plating.)
	Incorrect printing direction - printing perpendicular to direction of conductors.	Print parallel to conductor length for best fill. If conductors go in both directions, print on a slight diagonal.
	Print stroke too fast or slow.	Reset stroke speed.
	Old or outdated ink.	Remove old ink, clean screen and replace with fresh ink. Check inventory procedures; mark shelf life on containers.
	Uneven or insufficient squeegee pressure.	Reset pressure (re-check registration). Check squeegee for uneven wear; resharpen or replace if necessary.
	Dirt on screen or ink is dried in.	Clean screen. Limit amount of time delay in non-flood mode (or wash screen if there is a delay).
	Wrong squeegee durometer (too hard).	Take out squeegee and check the durometer. Change squeegee if necessary. Use of a dual durometer will help to provide rigidity while maintaining correct durometer along print edge.
	Room environment too hot or too cold (for ink viscosity).	Maintain constant room temperature and humidity per supplier recommendations. Monitor and record constantly.

15.1.1 Screen Printable Solder Resists (Thermal and UV Cure) (continued)

K PROBLEM	CAUSE	ACTION
Boards sticking to screen.	Improper off-contact.	Adjust off-contact for better snap-off.
	Poorly tensioned screen.	Remake screen and properly tension it prior to applying stencil.
	Excessive print speed.	Slow down print speed until optimum snap-off occurs.
	Excessive delay between prints (ink may begin to dry, making it sticky).	Limit delay time or wash off screen.
	Warped panels or old/no tape holding panels in place; poor vacuum.	Change or add tape.
	Room temperature too high.	Maintain constant room temperature and humidity per supplier recommendations. Monitor and record constantly.

15.1.2 Dry Film Solder Resist

The problems identified in this section are applicable to either solvent or aqueous dry film solder resist. For special problems related to exposure and development. (See Section 9.2 on Imaging.)

A PROBLEM	CAUSE	ACTION
Air entrapment during lamination. (See Figure 15–2.)	Board design is too complex for hot roll lamination.	Use vacuum lamination.
	Insufficient vacuum caused by faulty pump.	Fix pump or replace oil.
	Insufficient vacuum caused by clogged vacuum lines or sticking solenoids.	Clean residues from vacuum lines and solenoids.
	Warped boards.	Place board with warped bow side up. Refer to Section 4.0 on Base Materials and Section 13.0 on Lamination to address bow and twist (warpage) problem.
	Platen temperature is too low.	Raise platen temperature to increase film flow.
	Cycle time is too short.	Lengthen cycle time to achieve higher board temperature and more film flow.
	Clearance inside vacuum chamber is too great.	Use shims to decrease clearance (total clearance inside chamber should be 40-80 mils).
	Circuit traces are too high for the thickness of the mask being used.	See Section 10.2 to address excessive copper thickness on traces. NOTE: A 3-mil thick mask will typically conform to a 4-mil high circuit line. A 4-mil mask will typically conform to a 5-mil high circuit line.
	Vacuum chamber not sealing.	Check to see if the edge of the board being laminated is completely inside the chamber. Check vacuum lines to see if one has collapsed. Check vacuum line clamps. Vacuum valves contaminated and need to be cleaned. Check for ''O'' ring damage. Cut diaphragm; replace the cut diaphragm. Diaphragm not correctly sealed when installed; needs to be resealed. Vacuum pump has dirty oil and needs to be changed.

15.1.2 Dry Film Solder Resist (continued)

B PROBLEM	CAUSE	ACTION
Wrinkles in solder resist after vacuum lamination. (See Figure 15-3.)	Panels are warped.	Place board with warped bow side up. Refer to Section 4.0 on Base Materials and Section 13.0 on Lamination to address bow and twist (warpage) problem.
	Panels move as they are being pulled into vacuum chamber.	Slow down the film advance by reducing air pressure to the advancing mechanism.
	Uneven or too great tension on dry film solder resist rolls.	Reduce or even out tension on dry film solder resist rolls.
	Vacuum laminator not exactly level.	Precisely level vacuum laminator.
	Dry film solder resist rolls not aligned exactly parallel, causing dry film solder resist to feed into vacuum chamber not exactly straight.	Precisely align rolls of dry film solder resist.
	Grippers ‘‘jerk’’ film as it is fed into vacuum chamber.	Make sure grippers are tight and track is well lubricated. Make sure top and bottom sheets are exactly aligned so resist does not stick to top or bottom blankets, causing jerkiness.
	Excessive heat at lamination.	Make sure board exit temperatures are 71°C or less as measured on the last exiting metal edge within 1 second after completion of the cycle. Lower heat setting on dial. Remove boards from the vacuum chamber quickly after lamination.
	Free space is too large.	Reduce free space to a range of 1.02 to 2.03 mm.
	Dirty vacuum chamber.	Clean vacuum chamber; typically once per day.
	Dirty gripper feet, not releasing the film in time, causing it to be pushed back toward the vacuum chamber.	Clean gripper feet.
	Poor trimming practice on the part of the operator.	The operator must not restrict the film and board travel at the time of vacuum lamination. Wait for the hold down arm to hold the film prior to the start of trimming.

Figure 15–2 Air entrapment

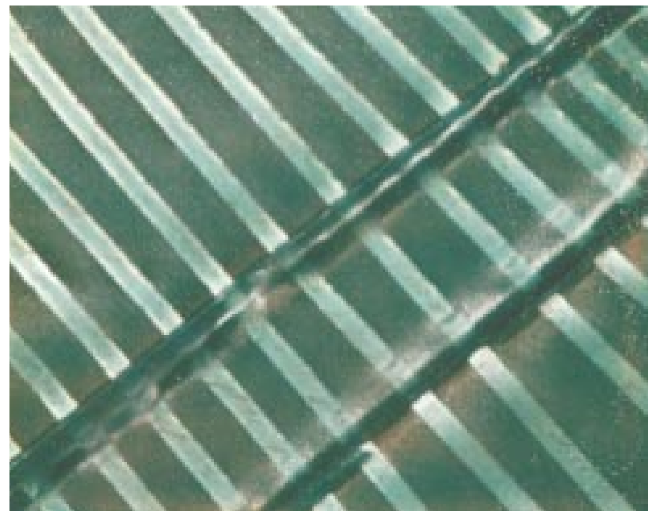

Figure 15–3 Wrinkles after vacuum lamination

15.1.2 Dry Film Solder Resist (continued)

C	PROBLEM	CAUSE	ACTION
Resist on lands. (See Figure 15-4.)		Phototool out of registration with land.	Make sure correct registration of phototool to board prior to exposure.
		Poor vacuum contact at exposure, allowing light to undercut the phototool.	Use clean polyester in the vacuum frames with bleeder veins (exposure should not start until small immovable Newton rings are present).
		Long exposure time.	Lower UV intensity of exposure lamps. Intensity should be 6 mw/cm^2 through clear artwork.
		D-max of diazo artwork too low.	Check D-max of artwork, should be >4.0 on absolute scale.

D	PROBLEM	CAUSE	ACTION
Exposure time too long.		Faulty exposure system lamps.	Replace lamps.
		D-min of diazo artwork is too high.	Check D-min of artwork and generate new artwork if necessary.

E	PROBLEM	CAUSE	ACTION
Development time too long. (See Figure 15-5.)		Dry film solder resist has partially polymerized during lamination step.	Reduce platen temperatures. Reduce cycle time. Check board exit temperature just out of vacuum chamber (for best results, it should be between 60-65.6°C).
		Dry film solder resist is exposed to white light or sunlight, causing partial polymerization.	Keep boards in yellow light environment or shrouded.
		Low spray pressure, typically caused by plugged filter or cone nozzles rather than high pressure fan nozzles.	Change filter. Replace cone nozzles with high pressure direct fan spray nozzles.
		During exposure, light has scattered through transparent laminate, causing partial polymerization (“shoot-thru” or “ghosting”) in pad area on reverse side.	Reduce exposure time.
		Developing solution is spent or too low in temperature.	Check developer solution; raise temperature, if necessary.

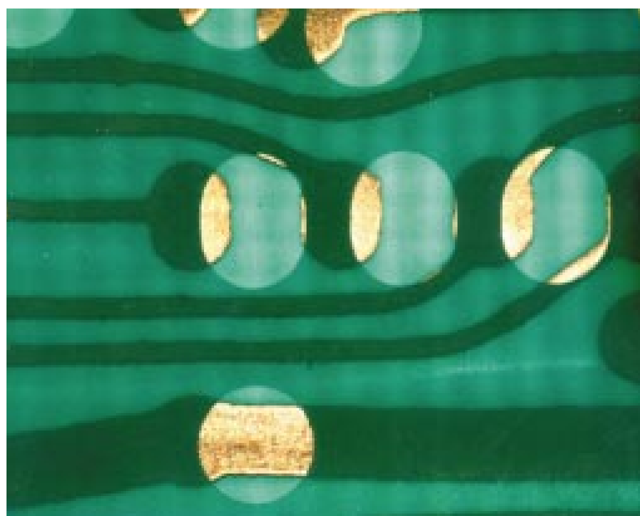

Figure 15–4 Resist on lands

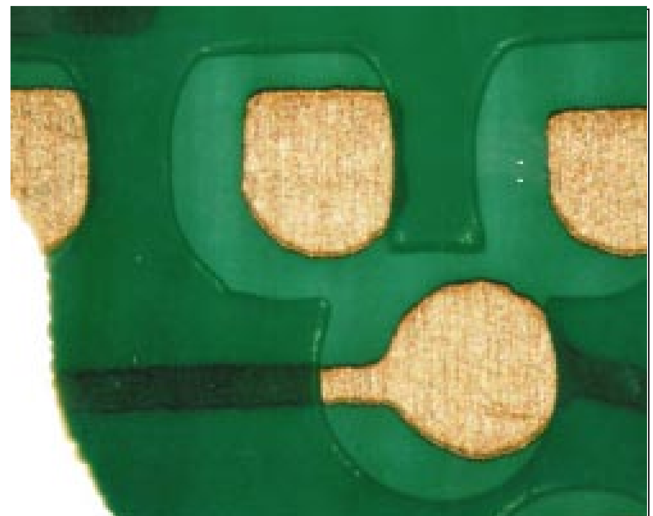

Figure 15–5 Development time too long

15.1.2 Dry Film Solder Resist (continued)

F	PROBLEM	CAUSE	ACTION
Solder resist breakdown during post soldering operations. (See Figure 15-6.)		Dirt, oxides, grease, water on board surface prior to solder mask application.	Make sure boards are clean and dry prior to solder resist application.
		Flux is too aggressive.	Use less activated flux.
		Preheat of solder temperature is too high.	Reduce preheat and/or solder temperature. (Also see Section 14.0.)
		Residual moisture in solder mask prior to soldering.	Bake boards for 1 hour at 121°C.
		Defluxing medium is attacking solder resist.	Do not use defluxing media containing methylene chloride; also, reduce time in defluxing medium.

G	PROBLEM	CAUSE	ACTION
White residues on solder resist. (See Figure 16–8.)		Overbaked flux or flux reaction products.	Reduce preheat and/or solder temperature.
		Time delay between soldering and defluxing.	Deflux as soon after soldering as possible.
		Defluxing time or solution is insufficient to remove residues.	Use 1,1,1-trichloroethane or fluorocarbons for rosin fluxed; use warm detergent rinses for water-soluble fluxes. Consult flux supplier for recommended chemistry. (Also see Section 14.0.)

H	PROBLEM	CAUSE	ACTION
Bleed-through exposure (also called ghosting or shoot-thru), where ink is exposed by light from the other side of the board, through the laminate.		Exposure too high.	Check Stouffer step for correct exposure. Consult supplier.
		Laminate too translucent (this condition rarely occurs on multilayer boards, but mainly on double-sided).	Use opaque or UV-blocking laminate. Process panels single-sided (consult supplier for procedure). Evaluate alternative LPI inks. When processing single-sided boards, protect the uncoated side with an opaque material.

Figure 15–6 Solder resist breakdown

Figure 15–7 White residues on solder resist

15.1.2 Dry Film Solder Resist (continued)

J PROBLEM	CAUSE	ACTION
Undercutting or over-development.	Under exposure.	Check Stouffer step for correct exposure per supplier recommendations.
	Over-development.	Check/maintain developer breakpoint per supplier recommendation. Reduce developer temperature/time as necessary.
	Insufficient hold time after exposure.	Follow supplier recommendations.

K PROBLEM	CAUSE	ACTION
Residue (scum or tracking) left on panel after development.	Under development or over exposure.	Check operating parameters - break point, temperature, concentration. (See Section 15.1.3J.)
	Ghosting or shoot-thru.	See Section 15.1.3K.
	Stray UV light.	Use in yellow or safe light. Cover panels during hold and transportation times.
	Incomplete drying of panel after development.	Follow supplier's recommendations.
	Inadequate rinsing after development.	Check water supply to developing machine. Temperature should be above 15.6°C at all times. Check operation of sprays, filters, etc. Use recirculating rinses with caution - make sure the water is changed or turned over frequently. Make sure exit rollers from developing chamber are in place so that excess solution is not dragged into the rinse chambers.
	Contaminated exit rollers.	Clean rollers. Do not allow machine to run partially developed boards.
	Recirculation of filler.	Clean sediment from bottom of sump.

L PROBLEM	CAUSE	ACTION
Adhesion failure at solder leveling operation.	Insufficient final cure.	Review supplier recommendations and all cure parameters. Profile curing oven using thermocouples. Profile UV reactor using light meter.
	Surface contamination prior to coating.	Check surface preparation. (See Section 8.0 on Cleaning.) Panels should pass water break test after surface prep.
	Solder resist coating area is not clean - dirt on panels.	Institute better housekeeping and methods to keep panel surfaces dirt and dust free. Consider installing clean room.
	Panels not completely dry prior to coating with solder mask.	Improve drying conditions, either at surface preparation step or immediately prior to coating (a short low temperature oven bake is acceptable).
	Improper solder mask ratio/mixing.	Review supplier specifications and shop procedure.
	Coating too thin.	Check thickness over traces (or other high points on panel). Generally 0.7 mils is considered a minimum acceptable thickness.
	Solder mask too brittle, most likely due to excessive final cure.	Review supplier recommendations and all cure parameters. Profile curing oven using thermocouples. Profile UV reactor using light meter.

15.1.3 Liquid Photoimageable (LPI) Solder Resist

A PROBLEM	CAUSE	ACTION
Uneven coating (machine application).	Turbulence of air at flash off.	Flash off extraction too violent or incorrectly directed.
	Board interrupted in flight.	Check for protrusions on conveyor system (usually collection trough incorrectly fastened down).
	Wrong panel temperature.	Drop or raise temperature as needed.
	Poor surface preparation.	Check equipment and solutions.
	Improper grounding of panel (electrostatic).	Check grounding bristles.

15.1.3 Liquid Photoimageable (LPI) Solder Resist (continued)

B PROBLEM	CAUSE	ACTION
Exposed features (traces, pads) on board after solder resist application (skipping - screen print operation).	Squeegee pressure too low.	Increase squeegee pressure.
	Squeegee speed too fast.	Slow squeegee speed.
	Excessive off-contact.	Reduce off-contact to 3.2 mm maximum.
	Squeegee stroke perpendicular to trace.	Re-orient print snowplow.

C PROBLEM	CAUSE	ACTION
Final film thickness too thin.	Screen mesh too high (fine).	Decrease mesh count (90 to 110 is typical); use polyester.
	Excessive squeegee pressure.	Reduce squeegee pressure.
	Squeegee speed too fast.	Slow squeegee speed.
	Resist is not properly filling the screen mesh pores.	Increase flood pressure. Slow flood bar speed.

D PROBLEM	CAUSE	ACTION
Final film thickness too thick.	Screen mesh too coarse.	Increase mesh count.
	Insufficient screen tension.	Check/adjust screen tension to 25N/cm.
	Excessive squeegee pressure (causing squeegee to roll).	Reduce squeegee pressure.
	Excessive flood pressure.	Reduce flood stroke pressure.
	Dull squeegee.	Resharpen or replace squeegee.

E PROBLEM	CAUSE	ACTION
Pinholes or light areas in resist coating.	Percent open area of fabric too low.	Increase percent open area.
	Excessive squeegee speed.	Slow print stroke.
	Improper board cleanliness.	Check/review surface prep procedures.
	Debris on screen or lodged in mesh pores.	Clean screen.
	Air bubbles in printed resist.	Ink may have been mixed too vigorously, entrapping air. Allow ink to settle before use. Institute a debubble time prior to tack-dry, if necessary.

F PROBLEM	CAUSE	ACTION
Resist is still tacky after drying (tack-dry).	Panels still warm.	Allow panels to cool to room temperature before testing dryness.
	Dry time/temperature insufficient.	Run matrix to optimize.
	Insufficient air flow in oven.	Rack and position panels parallel to air flow, so none are blocking it. Check blower operation; repair or replace if necessary. Make sure air intake filter and outflow are clean and allowing sufficient air flow. Run tests to determine optimum temperature/time for reduced air flow conditions.
	Slow temperature recovery in oven.	Increase dry time to accommodate recovery. Check oven door seals for leaks. Oven elements may be broken; replace as necessary.
	Cold spots/temperature gradients in oven.	Run temperature profile of oven using thermocouple and adjust loading.
	Excessive coating thickness.	Check screening parameters (see 15.1.4D) and adjust for 0.7-1.2 mils deposition.

15.1.3 Liquid Photoimageable (LPI) Solder Resist (continued)

G PROBLEM	CAUSE	ACTION
Bubbles or craters in dried resist film (usually in thickest areas of the resist). Bubbles or craters following the tack dry are caused by air entrapment in the dried resist film. When they appear after exposure it is usually the result of solvents left in the dried film which volatilize and move the film surface when under vacuum.	Excessive print/flood speed.	Reduce print/flood speed.
	Poor screen release.	Increase off-contact. Check screen tension. Slow squeegee speed.
	Excessive mixing of ink.	Slow stirring speed. Reduce mixing time. Allow to sit prior to screening.
	Tack dry cycle too short or temperature too low.	Increase tack dry time/temperature.
	Insufficient air flow in oven.	Increase air flow. Test to determine optimum dry cycle for reduced air flow (can be affected by number of panels, spacing and direction).
	Tack dry temperature too hot (results in skinning over of mask, causing inefficient solvent release).	Reduce temperature accordingly.

H PROBLEM	CAUSE	ACTION
Phototool sticks to panel; solder resist film marring.	Excessive heat rise during exposure cycle (also causes misregistration due to thermal expansion).	Check internal cooling system for correct operation. Bulbs past life - replace. Reflectors dust/dull - clean reflectors to a high mirror finish.
	Excessive vacuum.	Reduce vacuum.
	Resist coating not properly dried.	See 15.1.3F.
	Panel temperature too high.	Allow panels to cool to room temperature before exposing.
	Phototools have matte finish.	Use gloss/gloss phototools. Use a release compound (e.g., Pledge).

J PROBLEM	CAUSE	ACTION
Excessive sidewall growth.	Over-exposure.	Check/control using Stouffer step tablet to supplier's recommendations.
	Under-development.	See 15.1.3K.
	Poor vacuum.	Check/adjust vacuum. Inspect quality of phototool and exposure frame.
	Phototool upside down.	Expose with emulsion side in contact with resist.

15.1.3 Liquid Photoimageable (LPI) Solder Resist (continued)

K PROBLEM	CAUSE	ACTION
Incomplete development.	Developing solution is spent.	Analyze and adjust or dump and remake.
	Incorrect operating parameters.	Check/adjust temperature, concentration and developing time (conveyor speed) per supplier specifications.
	Clogged nozzles or poor spray pressure.	Check filter and nozzles for blockage. Use only fan spray nozzles.
	Over-exposure.	Check/control using Stouffer step tablet to supplier's recommendations.
	Too long a hold between exposure and development steps or between coating and exposure steps.	Review LPI ink requirements with supplier. Improve shop process scheduling as necessary to prevent delays.
	Resist was exposed to stray UV light.	All fluorescent lights should be yellow (preferred) or covered with UV shields.
	Resist was over-baked at the tack dry step.	Review tack dry process. (See 15.1.3F.) Remember the first side sees double dry time.
	Bleed-through or shoot-through or ghosting prevents proper development.	See 15.1.3H.

L PROBLEM	CAUSE	ACTION
Bleed-through exposure (also called ghosting or shoot-thru), where ink is exposed by light from the other side of the board, through the laminate.	Exposure too high.	Check Stouffer step for correct exposure. Consult supplier.
	Laminate too translucent (this condition rarely occurs on multilayer boards, but mainly on double-sided).	Use opaque or UV-blocking laminate. Process panels single-sided (consult supplier for procedure). Evaluate alternative LPI inks. When processing single-sided boards, protect the uncoated side with an opaque material.

M PROBLEM	CAUSE	ACTION
Undercutting or over-development.	Under exposure.	Check Stouffer step for correct exposure per supplier recommendations.
	Over-development.	Check/maintain developer breakpoint per supplier recommendation. Reduce developer temperature/time as necessary.
	Insufficient hold time after exposure.	Follow supplier recommendations.

N PROBLEM	CAUSE	ACTION
Residue (scum or tracking) left on panel after development.	Under development or over exposure.	Check operating parameters - break point, temperature, concentration. (See Section 15.1.3K.)
	Ghosting or shoot-thru.	See Section 15.1.3L.
	Stray UV light.	Use in yellow or safe light. Cover panels during hold and transportation times.
	Incomplete drying of panel after development.	Follow supplier's recommendations.
	Inadequate rinsing after development.	Check water supply to developing machine. Temperature should be above 15.6°C at all times. Check operation of sprays, filters, etc. Use recirculating rinses with caution - make sure the water is changed or turned over frequently. Make sure exit rollers from developing chamber are in place so that excess solution is not dragged into the rinse chambers.
	Contaminated exit rollers.	Clean rollers. Do not allow machine to run partially developed boards.
	Recirculation of filler.	Clean sediment from bottom of sump.

15.1.3 Liquid Photoimageable (LPI) Solder Resist (continued)

P PROBLEM	CAUSE	ACTION
Film surface marring. (Also see Section 15.1.3H.)	Under exposure.	Check Stouffer step for correct exposure per supplier recommendations.
	Developer and/or temperature too high.	Check solution and rinse temperature; follow supplier specifications.

Q PROBLEM	CAUSE	ACTION
Solder resist left in holes after development.	Excessive ink in holes.	Use dot pattern during screening operation (check to make sure all holes have dot pattern).
	Poor registration during screening or exposure operations.	Under development. (See Section 15.1.3K.)
	Inadequate spray pressure during development.	Check/clean nozzles, filter. Review nozzle configuration. Adjust spray pressure as necessary.

R PROBLEM	CAUSE	ACTION
Adhesion failure at solder leveling operation.	Insufficient final cure.	Review supplier recommendations and all cure parameters. Profile curing oven using thermocouples. Profile UV reactor using light meter.
	Surface contamination prior to coating.	Check surface preparation. (See Section 8.0 on Cleaning.) Panels should pass water break test after surface prep.
	Solder mask coating area is not clean - dirt on panels.	Institute better housekeeping and methods to keep panel surfaces dirt and dust free. Consider installing clean room.
	Panels not completely dry prior to coating with solder mask.	Improve drying conditions, either at surface preparation step or immediately prior to coating (a short low temperature oven bake is acceptable).
	Improper solder mask ratio/mixing.	Review supplier specifications and shop procedure.
	Coating too thin.	Check thickness over traces (or other high points on panel). Generally 0.7 mils is considered a minimum acceptable thickness.
	Solder mask too brittle, most likely due to excessive final cure.	Review supplier recommendations and all cure parameters. Profile curing oven using thermocouples. Profile UV reactor using light meter.

S PROBLEM	CAUSE	ACTION
Unsoldered lands after solder leveling operation resist on lands.	Under development.	See Section 15.1.3K.
	Resist was over-baked at the tack dry step, leaving a film of resist that does not develop off cleanly.	Review tack dry process. (See 15.1.3F.) Remember that the first side sees a double dry time.

15.2 TEMPORARY PROTECTIVE COATINGS

15.2.1 Inhibitor Coatings

Two types of inhibitors currently in use are benzotriazole and imidazole; both are organic nitrogen compounds. Inhibitor coatings are extremely thin and essentially invisible on a copper surface. They protect the copper by bonding chemically to it, thus preventing a copper-oxygen reaction. The coating is applied by either a dip or spray, generally followed by a rinse. The coating remains only on the copper surfaces.

A PROBLEM	CAUSE	ACTION
Insufficient anti-tarnish protection, as evidenced by tarnishing or poor solderability.	Surface not clean prior to application.	Clean surface using degrease, mild acid wash, or micro-etch prior to application. Remove coating in mild acid or alkaline solution, rinse and reapply coating.
	Coating applied is too thin.	Increase concentration of material in application tank. Raise temperature and/or increase immersion time. Change bath (the material is easily contaminated and may break down over time).
	Coating type incorrect for application.	Contact supplier for specific application requirements.
	Coated boards were exposed to high humidity conditions.	Store coated parts in low humidity, less than 50%.
	Excessive storage time.	The coating is fragile and tends to break down over time, depending on the relative humidity and temperature of storage. Best conditions are low RH and room temperature storage.
	Coating was mechanically damaged by scratching, fingerprints or other excessive handling.	The coating is monomolecular in nature and therefore easily damaged. Extra care must be taken in handling and packaging.

B PROBLEM	CAUSE	ACTION
Difficulty in removing coating.	Coating applied too thick.	Reduce the concentration in application tank.
	Incorrect solution used to remove coating.	Benzotriazole coatings can be removed in alkaline or acid-based solutions. Contact supplier for recommended removal procedure.
	Insufficient concentration, temperature or dwell time in removal solution.	Increase concentration, temperature and/or dwell time per supplier's recommendations.

15.2.2 Rosin-/Resin-Based Coatings (Prefluxes)

Prefluxes are used extensively as a copper protectant and are generally supplied in diluted form in a solvent carrier. Application is by brush, spray or roller coating, and is non-selective. The preflux coating provides good oxidation protection of the copper by forming a barrier to moisture.

A PROBLEM	CAUSE	ACTION
Poor solderability.	Surface not clean prior to application of coating.	Check operating parameters of cleaning solution (i.e., micro-etch) and bring up to specification.
	Coating applied too thick on panel.	Reset the application rollers. Make sure Baume of material is correct.

B PROBLEM	CAUSE	ACTION
Water spots.	Dryer prior to application of coating is not operating properly.	Repair/modify dryer operation. Check filter for cleanliness and change if necessary.
	Contaminated drying chamber (or chamois rollers).	Check for clean rinsing. Clean dryer chamber. Chamois rollers are not recommended for use as they tend to redeposit contamination.

15.2.2 Rosin-/Resin-Based Coatings (Prefluxes) (continued)

C PROBLEM	CAUSE	ACTION
Spotting or tarnishing prior to drying.	Dirty rinses.	Flush and clean rinses.
	Low acid content of dragout rinse.	Analyze and adjust.
	Excessive time between rinsing and dry steps.	Adjust conveyor speed or reduce hold time as necessary.
	Spent cleaning bath.	Make up per specification.

D PROBLEM	CAUSE	ACTION
Excessive haloing around lands.	Solder resist bleed on pads.	See Section 15.1.

E PROBLEM	CAUSE	ACTION
Dark deposit of coating.	Contaminated coating material.	Clean out tank or chamber. Change filter.

F PROBLEM	CAUSE	ACTION
Skipping of deposit.	Misadjusted application roller.	Readjust roller.

15.2.3 Chromate Inhibitor Coatings

These coatings are usually found on bare copper laminate and are used to protect the copper from severe oxidation. This coating usually must be removed before subsequent processing, i.e., oxide or plating.

A PROBLEM	CAUSE	ACTION
Insufficient anti-tarnish protection, tarnishing solderability poor.	Surface not clean prior to application.	Clean surface using degrease, mild acid wash, or micro-etch prior to application.
	Coating applied is too thin.	Increase concentration of material in application tank.
	Coating type incorrect for application.	Contact supplier for specific application requirements.

B PROBLEM	CAUSE	ACTION
Difficulty in removing coating.	Coating applied too thick.	Reduce the concentration in application tank.
	Incorrect solution used to remove coating.	Contact supplier for recommended removal procedure.
	Insufficient concentration, temperature or dwell time in removal solution.	Increase concentration, temperature and/or dwell time per supplier's recommendations.

15.2.4 Copper Oxidation (also see Section 12.4)

Copper oxidation prior to solder resist application serves a dual purpose: 1) to improve solder resist adhesion; and 2) to protect the copper pads until the soldering operation. It is removed during the cleaning steps immediately preceding hot air leveling.

A PROBLEM	CAUSE	ACTION
Non-uniform appearance after oxidation process.	Improper surface preparation prior to oxidation.	Improve preclean by the implementation of a scrub or chemical preclean.
	Bath operated outside of recommended limits.	Adjust temperature and chemical concentration to supplier recommended limits.
	Insufficient dwell time.	Increase dwell time to supplier's recommendations.
	Incorrect chemical for the application.	Evaluate alternate chemical formulas for uniformity.

15.2.4 Copper Oxidation (also see Section 12.2) (continued)

B PROBLEM	CAUSE	ACTION
Unacceptable bonding of solder resist to oxide coating.	Crystal structure too long to support adequate bonding.	Reduce bath temperature, concentration or dwell time.
	Poor adhesion, spotty failure due to contamination of surface (typically seen after hot air leveling). Salt residues left behind from poor rinsing. Moisture entrapment in oxide structure.	Improve rinsing (DI water may be required). Bake prior to solder mask application.

C PROBLEM	CAUSE	ACTION
Difficulty in removing copper oxidation from areas not required to be coated.	Acid concentration too low, dwell time too short, temperature too low to adequately remove oxidation.	Increase concentration, temperature or dwell time per supplier's recommendations.
	Resist residues deposited on copper oxidation.	Improve the developing procedure or evaluate screen printing technique.
	Nonuniform solder deposit in hot air leveling due to copper contamination.	Utilize a preclean or mold micro-etch prior to hot air leveling.

D PROBLEM	CAUSE	ACTION
Creepage along conductor traces where copper oxide has been erroneously removed.	Too long a dwell time in the acid used to remove copper oxide off of the pads, or too high a concentration or temperature.	Reduce dwell time, acid concentration, or temperature, as applicable.

15.3 TEMPORARY SOLDER RESISTS

15.3.1 Tape

A PROBLEM	CAUSE	ACTION
Tape not adhering to surface.	Contaminated surface.	Mechanical or chemical clean.
	Inadequate adhesive strength.	Change to tape with better adhesion.
	Insufficient application pressure.	Increase manual application pressure or employ mechanical means of application.
	Irregular or excessive conductor profile.	Use tape with thicker adhesive layer. Increase application pressure. Use alternate method for applying the tape, or liquid resist coating.
	Wet surface prior to application.	Dry before coating.
	Chemical attack of tape.	Investigate compatibility with chemistry in use. Consider changing to a more compatible tape.

B PROBLEM	CAUSE	ACTION
Adhesive (gum) squeeze-out.	Excessive application pressure.	Increase applicator roll clearance. Reduce application pressure. Employ alternate tape adhesive.
	Soft adhesive (gum) layer.	Use tape with harder or thinner gum layer.

15.3.1 Tape (continued)

C	PROBLEM	CAUSE	ACTION
Inadequate residue removal.		Excessive heat exposure during processing.	Reduce/remove high-temperature exposure. Use tape with improved temperature resistance.
		Gum/backing separation.	Use tape with gum adhesion to carrier. Use tape with less adhesion to substrate, if practical.
		Aged tape in use.	Rotate tape stock. Do not store in high temperature environment.
		Tape on substrate too long.	Minimize time between application and removal.

D	PROBLEM	CAUSE	ACTION
Edges ragged and not uniform.		No adhesion.	Follow actions specified in Section 15.3.1.A.
		Tape stretch during application.	Use alternate tape with increased dimensional stability. Use less tension when applying tape.
		Chemical attack of tape.	Use tape that is more compatible with the chemistry being employed.

E	PROBLEM	CAUSE	ACTION
Difficult tape removal. (Also see 15.3.1C.)		Excessive tape adhesion.	Increase tape gum/carrier thickness. Employ tape with a ''less aggressive'' gum. Fold tape leading edge to create a ''pull tab.''

15.4 NOMENCLATURE (LEGEND) - NON-METALLIC MATERIALS

15.4.1 Screen-printed

A	PROBLEM	CAUSE	ACTION
Ink smearing or squish.		Squeegee durometer too low.	Use 80 durometer squeegee.
		Excessive pressure on the squeegee or floodbar.	Take off all pressure and reset. Recheck register.
		Ink viscosity too low.	Change to higher viscosity ink. Allow epoxy inks to sit for a while - viscosity may increase.
		Print speed too slow.	Speed up print and flood strokes.
		Insufficient peel-off (too low), causing panel to stick to screen.	Increase peel-off; recheck register.
		Off-contact too low.	Check off-contact; raise if necessary.
		Paper flash (may also appear as a double image).	Clean screen before processing further.
		Excessive time delay between prints while screen is in flood mode.	Train operators to limit time between flood and print.

15.4.1 Screen-printed (continued)

B PROBLEM	CAUSE	ACTION
Legend skipping.	Ink dried in screen, between impressions.	Clean screen thoroughly. Increase stroke speed; print faster if possible. Do not leave ink on screen during breaks.
	Improper flooding or insufficient ink in screen.	Add ink; check flood pressure.
	Plated conductor pattern is excessively thick in areas.	Increase squeegee pressure. Try a different durometer squeegee, if necessary. Check registration after any adjustments. Address plating problems per Section 10.0.
	Print stroke too fast.	Slow down squeegee stroke speed.
	Uneven or insufficient squeegee pressure.	Reset squeegee pressure; check registration.
	Incorrect squeegee durometer.	Try another durometer squeegee (start with 80).

C PROBLEM	CAUSE	ACTION
Poor or changing registration.	Wrong size registration pins used, causing panels to shift.	Change to snug-fitting registration pins and recheck register.
	Optic targets off.	Separate panels with bad targets from others, and print them at the end of the job using different pinning holes if possible.
	Excessive squeegee pressure.	Reset squeegee pressure; recheck register.
	Poor screen tension, including baggy screen, loose screws on screen, or a screen that has been excessively pulled or released.	Screen must be entirely remade. Return to screen making department.
	Incorrect off-contact.	Remeasure off-contact; adjust if necessary.
	Insufficient peel-off.	Check to see if screen is sticking to panel during print stroke. Add peel-off if necessary.
	Warped panels.	Bake panels under heavy weight for 1 hour above T_g. Cool panels under weight also. Source of warping must be investigated - check all areas where panels may be baked at high temperature, including lamination, solder mask and fusing/leveling.
	Old or no tape on screen.	Replace tape.

D PROBLEM	CAUSE	ACTION
Boards sticking to screen.	Improper off-contact.	Re-measure off-contact; adjust if necessary.
	Screen tension too low.	If tension is low, screen must be remade (tension cannot be tightened without distorting screen pattern).
	Print speed too fast.	Slow down print stroke.
	Excessive delay between prints (ink becomes sticky).	Print faster, if possible.
	Warped panels, affecting off-contact.	See 15.1.1J.
	Room temperature too high.	Control room temperature and humidity for optimum registration and best ink performance.

16.4.2 Photoimageable The photoimageable legend resists behave very similarly to dry film primary resists during the application, imaging and development steps. Refer to Section 9.0 for more information.

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Component Mounting
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Section 16
Component Mounting

16.1 GENERAL

This section deals with the mounting of both leaded and surface mount components. Sections 16 through 19 address assembly-related issues.

The following publications are recommended for more complete information regarding printed board assembly processes:

IPC-CM-770 Component Mounting Guidelines for Printed Boards

IPC-S-816 SMT Process Guideline and Checklist

16.1.1 Electrostatic Discharge (ESD) Concerns

The following are ESD concerns: 1) Has process machinery been properly grounded? 2) Have work stations and storage areas been properly grounded? 3) Are other environmental controls (i.e., ionizers, humidifiers, etc.) in place to reduce the occurrence of ESD? 4) Have operators and all other employees who may handle components or surface mount assemblies been properly trained to use ESD precautions such as wrist straps or other similar preventative measures? 5) Have the component packaging and assembly containers been reviewed for potential ESD problems? 6) Have ESD sensitive parts been identified and sufficiently protected?

16.1.2 Component Leads

The following are concerns regarding component leads: 1) Has component lead co-planarity been addressed following manual or automatic lead forming operations? 2) Has component lead solderability concerns in relation to handling been reviewed and precautions taken where deemed necessary?

16.1.3 Storage

The following are concerns regarding storage: 1) Have the effects of the storage environment on components, materials or assemblies been reviewed within your manufacturing environment? 2) Does your handling system have a method for monitoring shelf life issues of stored components or assembly materials to prevent unacceptable material from being issued into the manufacturing environment 3) Would the use of date codes on assembly materials and components be beneficial in ensuring timely usage?

16.2 COMPONENT PREPARATION

16.2.1 Pre-Tinning

A	*PROBLEM*	*CAUSE*	*ACTION*
Leads do not accept solder.		Gold plate is too thin.	Verify gold thickness to meet specification requirements.
		Lead is contaminated.	Degrease/clean. Use aggressive flux to pre-tin lead.

B	*PROBLEM*	*CAUSE*	*ACTION*
Leads do not float.		Pins are contaminated inside of connector.	Clean connector pins of contamination by solvent; soak or degrease.

16.2.2 Pre-Forming

A	*PROBLEM*	*CAUSE*	*ACTION*
Bent IC Leads.		Excess Tinning on leads.	Clean out track.

B	*PROBLEM*	*CAUSE*	*ACTION*
Improper lead bend.		Not Centered on reel. Does not holding lead.	Adjust centering. Adjust die.

C	*PROBLEM*	*CAUSE*	*ACTION*
Nicked leads.		Dull or worn guides.	Replace guides.

16.2.2 Pre-Forming (continued)

D	PROBLEM	CAUSE	ACTION
Incorrect stress relief.		Improper employee training. Worn equipment.	Re-train employee. Replace equipment.

E	PROBLEM	CAUSE	ACTION
Cracked or fractured meniscus.		Tool too close to body.	Re-train/adjust tool.

16.2.3 Pre-Cutting

A	PROBLEM	CAUSE	ACTION
Uneven leads.		Tracking out of adjustment.	Adjust tracking.

B	PROBLEM	CAUSE	ACTION
Burrs on leads.		Dull die. Dull cutters.	Replace or sharpen die. Replace or sharpen.

C	PROBLEM	CAUSE	ACTION
Leads with flanged ends.		Dull cutters.	Replace or sharpen.

D	PROBLEM	CAUSE	ACTION
Leads too long or too short.		Operator error, miss-adjusted tool.	Retrain operator/ adjust tool.

16.3 BOARD PREPARATION

16.3.1 Pre-Assembly Bake

Epoxy glass boards with gold-plated connector tabs may turn reddish or purple around and above the gold tabs during prebake wave soldering. Contaminants may attack the board material itself, due to baking, as exhibited by exposure of the glass cloth on the board surface.

A	PROBLEM	CAUSE	ACTION
Discoloration due to surface contamination.		Solder stripper solution or vapors wicked up under the masking above the gold tabs.	Ensure good masking of boards to be selectively stripped of solder. Keep in solder stripper just long enough to remove solder. (See Section 10.7.)
		Plating solution or vapor wicked under masking.	Ensure good masking of board area; keep in plating baths just long enough to plated required thickness. (See Section 10.7.)

16.3.1 Pre-Assembly Bake (continued)

B PROBLEM	CAUSE	ACTION
Residue at incoming inspection. Incoming residue may be associated with either the manufacture of the boards and components, or their handling and storage.	Residue on components or boards.	Preclean components or boards. Work with supplier to eliminate residue.
	Residue found after storage.	Preclean; modify storage conditions.

16.4 COMPONENT INSERTION (THROUGH-HOLE)

16.4.1 Manual/Semi-Automatic

A PROBLEM	CAUSE	ACTION
Terminals and eyelets, swaged base split. (See Figure 16-1.)	Terminal/eyelet material is too hard.	Terminals/eyelets must be annealed.
	Tooling is incorrect for particular hardware.	Check supplier's literature for correct tooling.
	Board is delaminated around plated-through hole.	Install proper length hardware.

B PROBLEM	CAUSE	ACTION
Terminal and eyelets, mounts are cracked.	Hardware torqued too tightly.	Torque to allow for heat expansion.

Figure 16-1. Split terminal.

16.4.2 Automatic Insertion (Through-Hole)

A	PROBLEM	CAUSE	ACTION
Miss-insertion.		Plugged PWB holes.	Clean holes.

B	PROBLEM	CAUSE	ACTION
Reversed Part.		Reel installed backward.	Correct reel.

C	PROBLEM	CAUSE	ACTION
Part off-center.		Part cut off-center.	Adjust cutter.

D	PROBLEM	CAUSE	ACTION
Damaged part.		Machine miss-adjusted.	Adjust machine.

E	PROBLEM	CAUSE	ACTION
Miss-insertion.		Equipment misaligned.	Re-align.

F	PROBLEM	CAUSE	ACTION
Over crimp.		Cut/clinch out of adjustment.	Re-adjust.

G	PROBLEM	CAUSE	ACTION
Under crimp.		Formers or cutters dull.	Replace/ sharpen.

H	PROBLEM	CAUSE	ACTION
Leads too long or too short .		Software wrong.	Check program.

J	PROBLEM	CAUSE	ACTION
Inaccurate component placement (all or many components on a board) .		Poor fiducials on board. ''Sloppy'' placement because of old belts and worn parts on placement machine. Board guide rails out of alignment.	Review with board supplier. Check vision camera operation. Institute/maintain an adequate preventive maintenance program. Stop gap solution is to program ''off-sets'' to compensate. Re-adjust alignment.

K	PROBLEM	CAUSE	ACTION
Inaccurate component placement (occasional component on board) .		Leads on component are skewed. Component has coplanarity problem.	Reforming may be necessary

L	PROBLEM	CAUSE	ACTION
Inaccurate component placement (one component type affected).		Turret nozzles out of alignment.	Check feeder system.

16.4.2 Automatic Insertion (Through-Hole) (continued)

M PROBLEM	CAUSE	ACTION
Feeder is not feeding parts correctly (sensor will stop the machine).	Component tape threaded incorrectly.	Re-thread tape.

N PROBLEM	CAUSE	ACTION
Machine stops; component not picked up.	Reel loaded in incorrect feeder location (or wrong reel). Fiducials not read because circuit board has been loaded in wrong orientation. Tape jam.	Check documentation and load corret reel in correct feeder location. Verify correct set-up. Make sure board is oriented as specified in documentation. Remove excess tape from jammed feeder. Make sure tape is threaded properly.

16.5 COMPONENT PLACEMENT SURFACE MOUNT

16.5.1 Adhesive Application

In surface mount technology, the most prevalent use of adhesives is for component retention prior to, and during, bottom side wave soldering. The most common method of adhesive application is automatic syringe dispensing. Hand syringe dispensing is also used for lower volumes and rework/repair operations. Pin transfer is another method often used in high volume, low mix operations. Control of adhesive location and material properties for effective dispensing are the most common difficulties encountered. This section presents a general listing of problems encountered in the adhesive application process, potential causes, and suggestions for corrective actions. These solutions may be related to equipment, materials, design, or prior processes.

16.5.1.1 Dispensing

A PROBLEM	CAUSE	ACTION
Stringing (most frequently related to both dispenser and adhesive).	Dispenser pressure too high.	Reduce pressure.
	Dispensing period too long.	Increase nozzle tip size.
	Nozzle too far from substrate.	Reduce distance of nozzle to substrate.
	Nozzle drools.	Use vacuum suck back.
	Adhesive on soldering surface.	Change direction of nozzle travel.
	Tip length too long.	Shorten tip.
	Viscosity of adhesive too high.	Lower viscosity. Increase reservoir temperature.
	Viscosity of adhesive too low.	Reduce reservoir temperature.
	Plastic flow of adhesive (dribble).	Choose more thixotropic material.
	Air in adhesive.	Remove air by centrifuging.

B PROBLEM	CAUSE	ACTION
Nozzle clogging (most frequently related to down time, curing, and foreign matter).	Down time too long.	Follow adhesive manufacturer's recommendation.
	Reaction with nozzle or tip.	Anaerobic action - do not use copper or brass; use passivated stainless steel or plastic.
	Reaction by absorption of moisture (epoxy).	Keep nozzle tip closed during down time.
	Mixing of two different adhesives.	Thoroughly clean system when changing adhesives.

16.5.1.1 Dispensing (continued)

C PROBLEM	CAUSE	ACTION
Skipping and insufficient adhesive (most frequently related to clogged nozzle).	Clogged nozzle, bubbles, and foreign material.	Remove cured adhesive, lumps, air.
	Worn or bent nozzle tip.	Replace tip.
	Insufficient height and/or excessive spread.	Dispense adhesive on top of original dot (double dispense). Increase viscosity or select a more thixotropic adhesive. Cool reservoir.
	Variation in dot size.	Check dispenser output for consistency.
	PWB not flat.	Obtain flat boards. Check hold down.
	Viscosity too high for nozzle tip and pulse rate.	Reduce viscosity of adhesive. Heat reservoir. Select another adhesive.

D PROBLEM	CAUSE	ACTION
Excessive adhesive (most frequently related to thixotropic properties of adhesive, temperature of reservoir, and equipment controls).	Low viscosity.	Lower reservoir temperature. Increase adhesive viscosity. Select adhesive with higher thixotropic ratio.
	Dispenser pressure too high.	Lower pressure.
	Tip size too large.	Reduce tip size.
	Excessive spread.	Select another adhesive.

E PROBLEM	CAUSE	ACTION
Insufficient cure (most frequently related to insufficient curing energy leaving soft, gummy, or tacky adhesive).	Insufficient energy.	Adjust cure time/temperature. Check output of UV lamps.
	Too much energy which damages components.	Reduce temperature. Select another adhesive with different cure cycle.
	Local heat sinks.	Move components on PWB.
	Heat sensitive components.	Move components to bottom side, IR heat tip side.

F PROBLEM	CAUSE	ACTION
Lost components (most frequently related to insufficient cure, poor bond or adhesive, or non-wetted component).	Insufficient cure.	Check time/temperature and energy level of cure cycle.
	Adhesive bond.	Decrease time between placement and cure.
	Adhesive dot too low with insufficient component contact.	Print second dot on top of original dot. Increase tip size. Use high dot profile adhesive and high viscosity for initial tack.
	Fast speed and stop in X-Y movement.	Increase initial tackiness of adhesive. Reprogram/reduce speed of placement.
	Poor placement of component.	Realign equipment.
	Uncured adhesive (UV).	Place two dots either side of component.
	Adhesive bond/strength.	Check PWB and component cleanliness/bondability with adhesive.
	Adhesive shrinkage during cure.	Select another adhesive.

G PROBLEM	CAUSE	ACTION
Adhesive voids (most frequently related to the presence of moisture in adhesive or on surfaces).	Moisture in adhesive.	Check adhesive for excess moisture. If excessive, cease use and determine and eliminate source of moisture.
	Absorbed moisture on bare PWB.	Bake PWB before using adhesive. Check solder mask for porosity.
	Absorbed moisture on surface of component.	Bake components before assembly.

16.5.1.2 Pin Dip Transfer

A PROBLEM	CAUSE	ACTION
Stringing (most frequently related to withdrawal rate and viscosity).	Rate of pin withdrawal.	Correct speed of vertical travel.
	X-Y movement during withdrawal.	Correct horizontal movement.
	Viscosity too high.	Reduce viscosity.
	Flow properties do not match pin travel.	Select adhesive with proper properties.
	Viscosity too low.	Increase viscosity so adhesive does not drip.

B PROBLEM	CAUSE	ACTION
Skipping and insufficient adhesive (most frequently related to amount of adhesive on pins).	Pin size too small.	Increase pin size.
	Pin shape incorrect.	Select different pin shape.
	Pin does not wet.	Clean pin and/or change material.
	Pin immersion incorrect.	Check position and reservoir depth.
	Reservoir withdrawal rate incorrect.	Check rate of withdrawal.
	Withdrawal from PWB incorrect.	Reduce speed of withdrawal.
	Insufficient adhesive on pin.	Adjust viscosity and thixotropy.
	Adhesive drops off during transfer.	Increase viscosity.

C PROBLEM	CAUSE	ACTION
Excessive adhesive (most frequently related to flow properties of adhesive and variations in temperature of the reservoir).	Pin size too large.	Reduce pin size.
	Too much adhesive on pin.	Reduce depth in reservoir.
	Adhesive reservoir/pin plate not co-planar.	Level adhesive reservoir.
	Pins have become rough.	Replace pins.
	Build up of adhesive on pin.	Clean pins.
	Decreased distance between pin and PWB.	Correct spacing.
	Viscosity increased.	Adjust viscosity.
	Wrong pins used.	Replace pins.

16.5.2 Solder Paste Application

Several solder paste application techniques are used to transfer solder paste to areas being joined. The most commonly used methods include: stencil printing, screen printing, and syringe dispensing. Less common techniques, such as direct pin transfer and wheel transfer, are used for some special applications. With the trend toward use of components having closer and closer lead spacing, error-free application of solder paste is more difficult and the direct relationship between poor quality application and final yield is more apparent. Poor application can cause five common defects: insufficient solder, excess solder, shorts, opens, and solder balls. Each of these defects can be the result of one or more of the following symptoms: insufficient solder paste deposited, excess solder paste deposited, wet-bridging, or misplaced solder paste. Each of these symptoms can be the result of a variety of causes.

16.5.2.1 Stencil Printing

TABLE 16-1. General Guideline of Stencil Thickness for Various Applications

STENCIL	COMPONENTS
8-20 mils	Chip components only
8 mils	Leaded with 31 mil pitch
6 mils	Leaded with 20-25 mil pitch
<6 mils	Finer lead spacing

16.5.2.1 Stencil Printing (continued)

A PROBLEM	CAUSE	ACTION
Insufficient solder paste deposited. In order for enough solder paste to be deposited in the area to be soldered, the volume of the stencil opening should be approximately equal to the desired amount of wet solder paste.	Stencil too thin.	Increase stencil thickness. (See Table 16-1 for guidelines for stencil thickness.)
	Stencil opening too small.	Increase stencil opening.
	Stencil defects.	Check quality of stencil.
	Squeegee blade too soft.	Use higher durometer squeegee. (Soft squeegee blades pressure deform and scoop solder paste out of the large stencil holes, particularly when used with high squeegee pressure. Squeegee blades with a durometer hardness less than 80 are considered soft.)
	Wrong squeegee or the beveled edge is not as specified. (Either the squeegee tip's beveled-angle relative to its central axis is smaller than spec or the depth of cut is not large enough to produce a small angle of attack during print stroke and force paste far enough into the through-holes.)	Verify that the squeegee is wrong and replace.
	High squeegee travel speed.	Consult solder paste supplier for recommended speed for a given formulation.
	Snap-off distance too small.	Increase the starting distance between the stencil and circuit board, and correspondingly increase the squeegee pressure to force the stencil to the circuit board and solder paste through the holes.
	Improper squeegee pressure.	Decrease pressure until a thin layer of solder paste is left on the stencil after making a pass. Pressure should then be increased slowly until all of the paste is cleaned of the stencil after each pass.
	Clogged stencil from paste drying in aperture holes.	Clean stencil and record wait time since last print.
	Paste bead not rolling, which can be caused by a combination of aging paste and too high squeegee speed.	Check paste viscosity and replace if needed (slower squeegee speed makes paste work longer).
	Foreign material blocking stencil hole.	Check stencil opening for blockage, clean stencil and locate source of problem.
	High solder paste temperature (as temperature increases, the viscosity of solder paste will decrease).	Adjust temperature to compensate.
	Not enough solder paste on stencil. (If too little solder paste is used, it is difficult to get proper roll in front of the squeegee and some holes may be skipped.)	A round bead of solder paste, approximately 12.7 to 25.4 mm in diameter, is normally recommended.
	Too little tackiness.	Consult supplier regarding formulation. Try increasing the flux percent or raising the solder paste temperature.
	Too much tackiness.	Consult supplier.
	Large or irregular solder particles. (Particles which are too large or irregular may have difficulty being forced into small stencil openings.)	Examine solder paste under a 10x to 100x microscope. Consult supplier.
	Viscosity too high.	As a temporary solution, lower viscosity by increasing the solder paste temperature, adding thinner to increase the flux percent, stirring vigorously, or increasing the squeegee speed.

16.5.2.1 Stencil Printing (continued)

A	PROBLEM	CAUSE	ACTION
		Viscosity too low.	Use a harder squeegee blade. Consult solder paste supplier regarding a permanent change in viscosity.
		Low percent metal. (Even though the stencil opening may be properly designed for printing, solder pastes having too low a percentage of metal may not give a sufficiently large joint after reflow.)	Consult supplier.
		Bubbles in solder paste. (Bubbles can prevent the correct quantity of solder paste from being deposited in the stencil holes by displacing solder paste.)	Consult supplier if bubbles continue to be observed after several squeegee passes.
		Low solder paste temperature. (Solder paste used at lower than normal operating temperatures will have a higher than published viscosity. The lower viscosity may cause the solder paste to slide on the stencil and not be pushed through the holes.)	Consult solder paste supplier for alternatives if the solder paste or environment cannot be warmed up.

B	PROBLEM	CAUSE	ACTION
Excess solder paste deposited. Excess solder after reflow or solder shorts caused by excess solder paste deposits and wet bridging. Although it is very difficult to create excessively heavy fillets by any means other than depositing too much solder paste, there are many reasons for the creation of solder shorts or bridges: improper reflow profile, excessive component placement pressure, component movement, improper solder paste, or incorrect solder paste application. There are many signs of incorrectly applied solder paste, including: large deposits, wet bridges, smeared print, or misplaced print.		Damaged stencil.	Look for damage in the fragile stencil areas between adjacent holes. Replace stencil if necessary.
		Stencil defects. (If the stencil is not properly imaged or etched, inconsistency will exist from opening to opening.	Replace stencil.
		Inadequate stencil frame size.	Use a larger frame size. Decrease the snap-off distance. (Inconsistent print thickness and wet bridging is possible when using large snap-off distances.)
		Stencil not centered in frame (common when using fixed rail in-line assembly systems).	Use on-contact print with the corresponding stencil thicknesses and print parameters.
		Improper tension of screen border.	Re-mount stencil.
		Squeegee speed too fast. (At high squeegee speeds, solder paste will shear thin and heat up, lowering the viscosity. This may deteriorate print definition.)	Decrease squeegee speed. If this is not possible, consult solder paste supplier for further recommendations.
		Environment too warm.	If the room temperature cannot be controlled, the solder paste supplier should be consulted. Otherwise, adjust room temperature per supplier specifications.
		Heat generated by screen printer. (Some screen printers generate heat after prolonged use, which affects the solder paste and stencil.)	Consult the equipment manufacturer for recommendations or the solder paste supplier for a solder paste designed for higher operating environments.

16.5.2.1 Stencil Printing (continued)

B	PROBLEM	CAUSE	ACTION
		Squeegee pressure too low. (With the stencil not in contact with the board, excess solder paste is extruded into an area between the stencil and the board.)	Increase squeegee pressure.
		Squeegee blade angle too small. (With flat blade squeegees, as the angle of the blade to stencil plane decreases, the amount of deformation of the blade increases. Excess solder paste will be deposited if the blade is not able to push the stencil into contact with the board or wipe the stencil clean.)	Increase squeegee angle.
		Incorrect solder particle size.	As the size of the stencil openings decrease, the size of the solder particles in the paste should also be decreased. Solder particles having a diameter in the range of 45-75 microns are recommended for most applications where stencil openings are greater than 14 mils wide. Most solder paste suppliers can provide several particle size ranges.
		Viscosity too low (may be difficult to control the quantity of solder paste deposited and wet bridging).	Reduce operating temperature or squeegee speed (both of these both affect viscosity).
		Solder paste too tacky.	Consult solder paste supplier for material recommendations.
		Board warpage. (Gaps between the stencil and circuit board may fill up with solder paste resulting in a smear, wet bridge, or excess deposit.)	Use vacuum plate to compensate for minor warpage. Off-contact printing with increased squeegee pressure also helps compensate for board warpage. Investigate cause of board warpage.
		Inconsistent circuit board surface.	Work with board supplier to obtain a more uniform surface.
		Circuit board pattern misalignment (does not normally cause difficulties with 50-mil center devices, but can cause problems when doing fine pitch assembly).	Use a vision system to realign the stencil for every print. Reduce effect by decreasing snap-off distance and squeegee pressure.
		Lack of solder mask between pads (i.e., solder mask dams are missing).	This makes a clean, consistent print nearly impossible. Consider redesign; address with board supplier.
		Inconsistent solder pad height (on hot air leveled boards with solder deposit, heights can vary from 1-3 mils. Inconsistent height is a problem, because stencil openings are not normally the same size as the pad and some part of the stencil usually comes in contact with the solder deposit, leaving other areas of the stencil away from the board. Solder paste is then squeezed under the stencil in the areas that do not meet the board.)	Work with circuit board supplier to address this problem. Bare copper or thin solderable coatings have more level surfaces.
		Dried out paste.	Test viscosity to verify that paste is not within specs. Replace old paste with fresh. Record length of time paste was used for future reference. Check container seal and ensure that it seals properly in future.
		Moisture absorption. Paste may have absorbed moisture from room. (Moisture can cause paste viscosity problems.)	Check room humidity (should be under 50% R.H.). Check that water is not condensing on paste inside refrigerator. Check container seal. Test viscosity to verify that paste is not within specs.

16.5.2.1 Stencil Printing (continued)

C PROBLEM	CAUSE	ACTION
Solder paste will not roll in front of the squeegee. If the solder paste does not roll in front of the squeegee, then it is more difficult to fill the holes in the stencil. The solder paste may skip over the holes.	Squeegee speed too fast.	Check speed and adjust to specification if needed.
	Paste not mixed enough.	Paste needs to be mixed before use to get good consistency. Paste can be much thicker before it is worked, causing bead not to roll.
	Too little solder paste on the stencil.	A minimum amount is required to allow the solder paste to come in contact with both the squeegee and board without adhering to one or the other.
	Incorrect solder paste tackiness.	Consult supplier regarding tackiness. (If tackiness is too low, then the solder paste will not be able to adhere to the stencil. If the solder paste cannot adhere to the stencil, then it will slide over the stencil rather than roll. A solder paste which is too tacky will adhere too strongly to the walls of the stencil hole and not transfer cleanly.)
	Viscosity too high.	Viscosity should be balanced with tackiness to yield solder paste with the best printing characteristics possible. Consult supplier. As a temporary step, lower viscosity by increasing solder paste temperature, adding thinner to increase flux percent, stirring vigorously, or increasing the squeegee speed.
	Solder paste particle size too large.	Consult supplier regarding a smaller particle size paste. It is best to use the largest particle size available which will still print cleanly.

D PROBLEM	CAUSE	ACTION
Solder paste adheres to the squeegee at the end of the stroke. In order for either diamond or flat blade squeegees to perform in a bi-directional print mode they must be able to lift cleanly away from the solder paste at the end of the stroke. Solder paste must remain on the stencil for the return pass.	Insufficient solder paste on the stencil.	A minimum amount is required to allow the solder paste to come in contact with both the squeegee and board without adhering to one or the other.
	Solder paste viscosity too high.	Viscosity should be balanced with tackiness to yield solder paste with the best printing characteristics possible. Consult supplier. As a temporary step, lower viscosity by increasing solder paste temperature, adding thinner to increase flux percent, stirring vigorously, or increasing the squeegee speed.
	Solder paste is too stringy for application.	Consult solder paste supplier.

16.5.2.1 Stencil Printing (continued)

E PROBLEM	CAUSE	ACTION
Solder paste hanging up in the stencil holes. A balance of properties: tackiness, viscosity, stencil design, and print parameters contribute to the solder paste's ability to release cleanly from the stencil holes. Rarely is there only one cause.	Stencil too thick. (Most solder pastes will adhere to the walls of the stencil hole.)	Stencil thickness must be decreased as the dimensions of the stencil hole are decreased.
	Snap-off distance too small.	Increase snap-off distance (a larger snap-off distance will pull the solder paste out of the hole before it has a chance to set up). Higher viscosity and lower tackiness solder pastes also print more cleanly.
	Solder paste viscosity too high. (Solder paste with a viscosity too high may have difficulty being forced to the bottom of the stencil hole or may set up and have difficulty transferring.)	Viscosity should be balanced with tackiness to yield solder paste with the best printing characteristics possible. Consult supplier. As a temporary step, lower viscosity by increasing solder paste temperature, adding thinner to increase flux percent, stirring vigorously, or increasing the squeegee speed.
	Too long between prints.	Clean stencil. Record length of time since last print and modify operator stencil cleaning procedures if required.
	Foreign material clogging hole.	Inspect stencil to find type of material and source (fiber from cleaning cloth, board debris, etc.). Clean area or whole stencil as required.
	Paste lumps clogging hole.	Clean area or stencil as needed. Replace paste if problem repeats.
	Poorly etched stencil with jagged edges.	Make new stencil. Determine etching problem.

F PROBLEM	CAUSE	ACTION
Lateral deposit skips. It is very common to have poor print quality in only one section of the circuit board while the rest of the circuit board is printed cleanly. A number of factors can contribute to this.	Improperly made stencil.	Make sure that the stencil is not too thick for the width of the opening being printed. (Also see Section 17.5.2.1A.)
	Damaged stencil.	Examine the area of the stencil which is having consistent problems to see if it is bent, buckled or dented (even slightly). Determine whether to accept the poor quality print or make a new stencil.
	Inconsistent vacuum.	If vacuum is inadequate, inconsistent or there is a leak, then part of the board may not be level. Make sure that no vacuum holes are in the same location as via holes in the circuit board.
	Squeegee blade not level (as evidenced by one side of stencil not wiping clean or large streaks of solder paste remaining on stencil).	Adjust squeegee blade to level. (Some squeegee blade holders use bolts to hold the blade securely. When tightened, the bolts may put pressure on the soft rubber squeegee blade causing it to deform.)
	Circuit board not planar. (Gaps between the stencil and circuit board may fill up with solder paste resulting in a smear, wet bridge, or excess deposit.)	Use vacuum plate to compensate for minor warpage. Off-contact printing with increased squeegee pressure also helps compensate for board warpage. Investigate cause of board warpage.

16.5.2.1 Stencil Printing (continued)

G PROBLEM	CAUSE	ACTION
Inconsistent print when the squeegee travels in opposite directions.	Inconsistent squeegee speed.	Time speed of squeegee in both directions to make sure the speeds are identical. Adjust if necessary. Consult equipment manufacturer if speed cannot be easily adjusted.
	Inconsistent travel distance.	Distance the squeegee travels past the stencil pattern should be identical in both directions. This will reproduce the amount of stencil peel and solder paste set-up time in both directions.
	Inconsistent squeegee angle.	Independent adjustments to squeegee angle can be made on screen printers having a double flat blade system. Independent blades are used to print in either direction. In a screen printer, which has a single-diamond blade squeegee, problems may arise when the squeegee is not tight or some of the fixturing parts have begun to wear. It is not uncommon to find the angle of the squeegee blade changing slightly when printing in opposite directions as the print head rocks in a worn or loose fixture.

H PROBLEM	CAUSE	ACTION
Paste strings and blobs on stencil and/or board.	Old paste. (Aging paste can be identified by increased viscosity and loss of creamy texture. Old paste has a much greater problem with strings and blobs.)	Verify paste problem by visual or viscosity. Check and replace paste as needed.
	Paste sticking to squeegee on trailing edge.	Check squeegee stroke and clean outer edge of squeegee blade.

J PROBLEM	CAUSE	ACTION
Uneven marks on stencil.	Loose squeegee mounting bracket.	Tighten bracket and secure so that it cannot loosen.
	Loose squeegee lock screws.	Tighten lock screws.
	Excess squeegee pressure.	Check pressure and adjust.
	Row of lands across stencil, causing squeegee to catch as it wipes over top.	Loosen squeegee head castings and angle them so that squeegee blades are slightly skewed. Both squeegees must be angled same amount (0.200 slant end-to-end is sufficient).
	Paste not spread across stencil, causing squeaky shoe effect where there is no paste.	Spread paste completely across stencil so that squeegee is lubricated for its full width.

K PROBLEM	CAUSE	ACTION
Paste misalignment.	X, Y, theta have lost home position.	Re-home axes.
	Vision system cannot read fiducial.	Check threshold, histogram and fiducial reflection. Adjust threshold and try to find fiducial with computer. Check for excess solder.
	Panel moving from interference during transport.	Find interference point. Check for board warpage (bow and twist).
	Distortion due to board fabrication.	Check panel against stencil for alignment. If any problem is suspected, check panel fiducial spacings on optical measuring system.
	Distortion due to stencil fabrication.	Measure stencil fiducial spacings using an optical measuring system.

16.5.2.1 Stencil Printing (continued)

L PROBLEM	CAUSE	ACTION
Fringes of solder balls around lands.	Paste building up around lip of stencil (due to stencil misregistration, recessed pockets around lands from solder mask keepout, or paste inside openings that adheres to some paste along walls).	Clean bottom of stencil, check for recurrence.
	Vacuum sucking through via holes.	Close off vacuum ports under via holes.
	Excess pressure that pushes paste through holes and under stencil.	Check squeegee pressure and adjust. Clean bottom of stencil.
	Thin flux that flows through hole and under stencil, causing sticky surface that does not allow stencil to release cleanly.	Check paste viscosity. Clean bottom of stencil.
	Stencil movement during print, which smears paste after printing along underside of stencil.	Check for stencil movement during print cycle. Clean bottom of stencil.
	Previous bridging. (Can be found when residue is left on bottom of stencil from previous bridging problem.)	Clean bottom of stencil and find cause of previous bridging. (See 16.5.2.1P.)

M PROBLEM	CAUSE	ACTION
Paste fringing on stencil after printing.	Squeegee flatness.	Check and adjust flatness.
	Squeegee level.	Check squeegee level if rigid mounting is used.
	Squeegee pressure.	Check that drive cylinder is actuating fully and there is enough lubrication to move smoothly. Check squeegee pressure and raise if necessary.
	Stencil flatness.	Check stencil flatness, adjust stencil frame when required.
	Paste distribution on stencil. (If more paste is on one side than another, paste can make squeegee ''hydroplane'' on one side.)	Redistribute paste so it is evenly spread across width of squeegee ''hydroplane''.
	Check for tall hot air leveled (HAL) feature on board.	Check board, have excess solder removed, watch similar problems with other boards. Address with board supplier if necessary.
	Stencil damage.	Verify problem and try to flatten damaged area if possible. Order new stencil if needed.
	Board warpage (bow and twist).	Verify problem; reject board if bow and twist is too bad.
	Squeegee durometer.	Use lower durometer squeegee if blade is too hard to correct for board, stencil or flatness variations.
	Stencil apertures oversized.	Measure stencil apertures width. Compare with design value.

N PROBLEM	CAUSE	ACTION
Thin streaks of paste across stencil.	Worn squeegee with small nicks.	Replace squeegee if more than 20% of stencil shows streaks.

P PROBLEM	CAUSE	ACTION
Air bubbles in paste.	Paste not releasing from squeegee at endpoints.	Clean squeegee; try newer blade.
	Excess squeegee speed.	Check squeegee speed and adjust.
	Air mixed in during vigorous stirring.	Stir paste again, using slow steady stroke. Do not stir top to bottom so that air could get trapped and mixed in.

16.5.2.1 Stencil Printing (continued)

Q	PROBLEM	CAUSE	ACTION
Paste bridging.		Excess fringing. (When paste fringe problems go uncorrected, fringes become large enough to connect adjacent lands.)	Clean bottom of stencil. Clean board. Note how long since last time stencil backside was cleaned and check pasted boards more frequently for signs of fringing.
		Tall hot air level (HAL) feature. (Bump of solder left on board from HAL process can lift stencil and cause paste to fill underneath.)	Clean bottom of stencil. Clean board. Check board for tall bump of solder (check comb patterns, box features, vias, bridges). Remove excess solder before reusing.
		Solder mask void. (If solder mask does not cover around land, pocket is formed next to land that can fill with paste and create bridge.)	Clean bottom of stencil. Clean board. Check board for solder mask voids and reject if there are any voids between lands.
		Stencil damage.	Clean board. Check problem area for stencil damage. If damage is found, attempt to re-flatten area. Make new stencil if long-term problems are suspected.
		Uneven stencil.	Clean bottom of stencil. Clean board. Check flatness of stencil frame and adjust.
		High squeegee pressure.	Clean bottom of stencil. Clean board. Readjust squeegee pressure or decrease squeegee speed.
		Previous misalignment of stencil presses solder paste between stencil and solder mask surface, causing solder balls in the paste to deform.	Clean stencil thoroughly. Use Scotch brite pad if necessary to remove all solder.
		Poor gasketing between stencil and board.	Decrease squeegee downstop and go to off contact printing.

R	PROBLEM	CAUSE	ACTION
Reduction of printed area.		Stencil clogging. (Also see 16.5.2.1E.)	Clean stencil.

S	PROBLEM	CAUSE	ACTION
Uneven print across board.		Non-level squeegee.	Check squeegee level for fixed squeegee and horizontal play for floating squeegee.
		Uneven squeegee blade.	Check squeegee flatness.
		Uneven paste distribution.	Redistribute paste along full squeegee stroke.
		Unlevel board.	Check board flatness.

T	PROBLEM	CAUSE	ACTION
Ridges around top of paste bricks.		Paste drying in stencil.	Check for noticeable paste residue inside stencil openings. Remove and clean stencil.
		Bad stencil etch.	Check stencil etch profile under microscope. If etch ridge is noticeable (greater than 1 mil) reject stencil.
		Low stencil tension.	If mesh tension is less than 30 N/cm, then tension is suspect.
		High snap-off.	Check and adjust snap-off.

16.5.2.1 Stencil Printing (continued)

U	PROBLEM	CAUSE	ACTION
Foreign material in paste on board.		Small pieces of steel wire broken off frayed ends of stencil border mesh from scraping paste.	Cut off frayed part of border mesh and put adhesive over any ends still exposed.
		Board fab debris on panel or eraser shavings from preprocessing.	Check for debris on board (eraser shavings, board fab).
		Wipe fibers caught in stencil holes, probably from using wrong type of wipe to clean backside.	Check backside of stencil for stray fibers from cleaning the stencil. Only cloth should be used, never paper wipes.

V	PROBLEM	CAUSE	ACTION
Excess flux on panel.		Separated flux that was not mixed in dispenser canisters before they were mounted on machine is common problem.	Remove paste from stencil and mix flux with rest of paste. Remaining paste in canister also may have to be squirted out and mixed to give correct viscosity. Paste in canisters must be mixed thoroughly.

W	PROBLEM	CAUSE	ACTION
Paste covering land but metallization showing through.		Squeegee pressure too high.	Check and adjust squeegee pressure.
		Squeegee level not parallel to board (fixed angle squeegee).	Check and adjust squeegee level.
		Squeegee durometer too soft.	Check squeegee durometer. Use harder squeegee if needed.
		Stencil flatness.	Check and adjust stencil flatness.
		Tall HAL solder on boards.	Check height of HAL solder and review with board supplier if out of specification.

X	PROBLEM	CAUSE	ACTION
Paste slump.		Paste viscosity from supplier too low.	Consult paste supplier.
		Paste thinning from excess working on stencil.	Replace paste and consult with supplier.

16.5.2.2 Screen Printing

Screen printing is different from stencil printing. Screen printing always requires the use of a snap-off and has different limitations in the type of circuitry which can be printed. It is difficult to print solder paste onto very large land areas with a stencil and, conversely, difficult to print small areas with a screen. Softer squeegees are used when screen printing, because the solder pastes are less viscous, more conformance is required, and screens are easily damaged. Most of the mechanics of screen printing are identical with stencil printing with the exceptions mentioned below.

A PROBLEM	CAUSE	ACTION
Insufficient solder paste deposited.	Insufficient emulsion thickness.	Thickness of print should be approximately equal to the thickness of the emulsion, plus the thickness of the screen weave. Small increases or decreases in this value can be achieved by either changing snap-off distance or squeegee pressure. Large changes in print thickness must be done by increasing the amount of emulsion.
	Insufficient snap-off distance.	Increase snap-off distance so that solder paste will be pulled out of the screen as soon as the squeegee passes.
	Wire blocking opening in a very small hole.	If the area to be printed is less that two screen openings wide, the average open area will be constricted. Consider using a stencil.
	Emulsion too thick for application. (If the thickness of the screen is too great for narrow openings, solder paste will hang up in the openings and not transfer completely.)	Increase snap-off distance (will help somewhat, but may not be enough). Increase width of opening with respect to thickness of emulsion. Use thinner emulsion.
	Improper screen manufacture. (Openings in the screen are not complete due to improperly placed emulsion.)	Inspect screen for defects. Repair/remake if necessary.
	Damage to screen bent wires, (swollen emulsion from solvents in the solder paste or cleaning material, or large particles of solder or other material wedged in the screen openings).	Screens are more fragile than stencils and wear more rapidly with use. Remake screen if necessary.
	Solder paste too viscous. (Solder pastes used in screen printing have a lower viscosity than those used with stencils.)	Consult supplier for lower viscosity paste. (Thicker solder pastes have a tendency to set up in the screen weave and not transfer consistent amounts of material.)
	Solder particles too large for the screen used.	Solder particles should be no larger than one half the average diameter of the openings. Consult with supplier if this is suspected.
	Solder paste metal content too low.	The most common method of decreasing solder paste viscosity to facilitate screen printing is to decrease the metal content. In doing this, the volume of solder after reflow is decreased. This may result in insufficient fillet size.

16.5.2.2 Screen Printing (continued)

B	PROBLEM	CAUSE	ACTION
Excess solder paste deposited. Excess solder after reflow or solder shorts caused by excess solder paste deposits and wet bridging. Excess solder and solder shorts occur when too much solder paste is deposited.		Emulsion too thick.	Use thinner emulsion. (The nominal thickness of solder paste deposited is equal to the screen weave thickness plus the emulsion thickness.)
		Excess snap-off or insufficient squeegee pressure. (Excessive snap-off distance will lead to distortion in the printed pattern and misalignment.)	Alter snap-off distance and squeegee pressure. (By using a high snap-off in combination with a low squeegee pressure, it is possible to extrude the low viscosity solder paste used in screen printing to a greater thickness than would normally be expected.)
		Improper screen design or manufacture.	Inspect screen for areas which should have emulsion, but do not. Repair/remake screen.
		Damaged screens (scratches, holes, bent screen, etc.).	Install a new screen.

C	PROBLEM	CAUSE	ACTION
Misaligned solder paste deposits.		Screen stretching. (Screens are constantly being stretched, because they are used in off-contact mode.)	Decrease snap-off distance and squeegee pressure (this reduces the amount of friction between squeegee and screen).
		Excess snap-off or insufficient squeegee pressure (will lead to distortion in the printed pattern).	Reduce snap-off distance and/or increase pressure.

16.5.2.3 Syringe Dispensing

Syringes are used both in repair operations and programmable multipoint dispensing. The most important things are continuous dispensing and consistent sized deposits.

A	PROBLEM	CAUSE	ACTION
Solder paste flow stops.		Dispensing pressure too high.	Solder paste responds best to low pressure and longer shot times, as opposed to high pressure and short shot times. The high pressure is more likely to separate the flux from the solder paste.
		Solder paste separation (common when very small diameter needles must be used).	Shorten length of the needle in order to reduce the amount of friction. Investigate dispensing equipment which does not stress the solder paste as much as direct pressure dispensing.
		Solder paste stops coming out of the tube before it is empty.	This means that separation of the flux from the powder has started to occur. Try increasing the dispensing pressure. It is better to use a preventative method to stop initial separation.
		Incorrect solder paste formulation for dispensing.	The rheological properties of pastes used in stencil printing and syringe dispensing are very different. Check to make sure the correct paste is being used.
		Solder powder particles too large for needle size.	Use larger needle or smaller powder particles.

B	PROBLEM	CAUSE	ACTION
Dispenser has difficulty delivering consistent amounts with each shot (a sure sign is solder paste strings when the dispensing head moves from one pad to another).		Incorrect solder paste formulation or incorrect solder paste size.	Consult with solder paste supplier.
		Air entrapped in the solder paste.	Do not over mix paste in such a way as to draw air into it.
		Solder paste not designed for the dispensing application.	Consult supplier.

16.5.2.3 Syringe Dispensing (continued)

C PROBLEM	CAUSE	ACTION
Solder paste deposit not rounded enough.	Improper needle tip design.	Use a beveled needle, which dispenses solder paste to one side of the needle, not directly under the needle.
	Solder formulation not tacky enough and doesn't slump.	Use a solder paste which self-rounds or slumps slightly.

D PROBLEM	CAUSE	ACTION
Solder paste deposit not peaked enough.	Improper needle tip design.	Use a flat-tipped needle.
	Solder formulation too tacky and slumps.	Use a different formulation which is less tacky and doesn't slump.

E PROBLEM	CAUSE	ACTION
Solder paste will not adhere to the pad.	Too high a pressure.	Use a lower pressure for dispensing.
	Incorrect solder formulation.	Use a different formulation that is more tacky.

16.5.3 Component Placement (Surface Mount)

Surveys have indicated that a major portion of soldered assembly defects result from manufacturing operations prior to soldering. Component placement has been identified as the most prevalent source of these defects. This has become increasingly evident with the increased use of fine pitch technology. This section presents a general listing of problems encountered in the component placement process, potential causes and suggestions for corrective actions. These solutions may be related to equipment, materials, design or prior processes. Accordingly some of the solutions cannot be immediately implemented on the shop floor.

16.5.3.1 Component Orientation/Alignment

A PROBLEM	CAUSE	ACTION
Wrong component orientation.	Placement program problems.	Verify correct revisions. Add rotational data to program. Change rotational data in program.
	Different board/program version.	Verify correct version.
	Components in feeder have wrong orientation.	Correct orientation of components.
	Components have mixed orientations at pickup location.	Orientate components in feeder.
	Board marking incorrect.	Verify orientation with both assembly drawing and schematic.

B PROBLEM	CAUSE	ACTION
Cocking of passive chip components.	Improper epoxy placement/amount.	Check epoxy dispenser. Examine epoxy mound size and shape detail.
	Board bow and twist.	Check board bow and fixture if necessary.
	Excessive solder flow on one side.	Check solder paste and application method. Reduce amount of solder deposition.
	Board is not setting properly on support pins.	Check that the support pins are adjusted properly.
	Height of component not correct.	Check the height value in program.
	Part not pushed down in paste or part pushed down with too much force.	Observe and adjust accordingly.

16.5.3.1 Component Orientation/Alignment (continued)

C PROBLEM	CAUSE	ACTION
Component Misalignment.	Placement teach is not accurate.	Reteach placement.
	Board is misregistered.	Verify board loading equipment and tooling.
	Incorrect pickup chuck selected.	Modify program to use correct chuck for pickup or may require vision alignment.
	Component is rotated.	Verify correct rotation data in placement program.
	Board revision different than program.	Verify program versions.
	Equipment needs calibration.	Calibrate to manufacturer's maintenance instructions. Check pulleys/gears for slippage on shafts.
	Incorrect data file used.	Load correct data file.
	Machine placement tolerance is not adequate for accurate/acceptable placement.	Equipment cannot be used for the required accuracy or placement. Acquire equipment with an acceptable placement accuracy.
	Vision system is not working.	Check electrical connections and fuses: a) Check target sizes/composition; verify compliance; b) Camera is not looking at the component heads; software problem. Verify component within field.
	Placement teach is above board surface.	Reteach placement.
	Board is misregistered.	Verify fiducials.
	Incorrect footprint on board.	Verify with design standards and/or latest parts list and schematic.
	Incorrect component picked up.	Verify with parts list and assembly drawing.
	Component is rotated.	Review component loading process.
	Board revision different than program.	Verify board version.
	Incorrect registration to datum.	Check image/datum relationship.
	Improper tooling hole size.	Re-tool; check procedure to avoid tooling hole damage.
	Plating in tooling holes.	Plug or tape tooling holes prior to plating.
	Assembly equipment out of tolerance.	Check equipment and tooling calibration.
	Improper component lead form.	Check incoming inspection and component handling (lead forming) procedures.
	Part does not match land pattern.	Reinspect component.
	Improper solder/flux viscosity.	Check solder paste characterization.
	Improper epoxy cure.	Test epoxy cure cycle.

16.5.3.2 Component Verification

A PROBLEM	CAUSE	ACTION
Missing component.	Vacuum pickup not on.	Verify there is vacuum at pickup.
	No components at pickup location.	Restock feeder.
	Component not picked up.	Reprogram for correct pickup.
	Feeder malfunction from: a) Low/off air pressure; b) No electricity; c) Waste tape is clogging; or d) Excessive vibration or low vibration.	Verify correct pressure/vacuum fat feeder. Verify power is turned on at feeder and verify feeder is correctly connected. Remove excess tape and re-thread. Remove jammed component. Adjust vibratory feeder vibration control.
	Incorrect chuck used.	Modify program to use correct chuck.
	No placement data.	Add placement data to program.
	Incorrect placement location.	Reteach correct placement data.
	Component did not release from chuck.	Clean chuck and/or check for vacuum release.
	Different board/program version.	Verify correct board/program version.
	Unsecured components.	Check thermal profile. Check tweezer grip.

B PROBLEM	CAUSE	ACTION
Wrong component placed.	Wrong pickup callout.	Verify/change pickup location.
	Incorrect sequence step order.	Verify sequence program.
	Different board/program version.	Verify correct board/program version.
	Incorrect placement location.	Verify/change placement location.
	Component from previous pickup stuck to chuck.	Clean chuck; vacuum pickup tip.
	Incorrect data file used.	Verify correct program.
	Wrong component put into feeder.	Inspect/verify components in feeders.
	Wrong components mixed in with correct parts.	Inspect/verify components numbers.
	Parts list is incorrect.	Update program with latest parts list.

16.5.3.3 Component Condition After Placement

A PROBLEM	CAUSE	ACTION
Damaged component.	Pickup/placement head damaged component.	Verify pickup and component placement. Z-axis locations are not impacting components; adjust height of pickup/placement. Pickup head may not be correct for particular component; use pickup head designed for that component type/style.
	Component leads are bent, or missing.	Adjust pressure of damaged, or missing ‘‘square off’’ fingers. Verify that pickup head is correct for that component. Fragile leads require vision alignment, not mechanical alignment. Verify at incoming or missing inspection. Improve handling procedures. Review excising die. Check pitch limit in program and set to proper value.
	Component was damaged prior to placement.	Inspect components prior to placement. Discard damaged components.

16.5.3.3 Component Condition After Placement (continued)

B PROBLEM	CAUSE	ACTION
Metallized termination of ceramic component cracked or separated from component body.	Improper printed board support.	Attach stiffeners to printed board or provide support in fixture to minimize flexing and subsequent tensile fracture of component body during component insertion or testing.
	Improper design parameters.	Provide balanced metal coverage on two sides of printed board to avoid bowing and subsequent tensile stress on component termination-component body interface.

C PROBLEM	CAUSE	ACTION
Cracked multilayer ceramic component with crack(s) originating under the metallized termination.	Thermal shock/excessive heat.	Maintain temperature time rate of change greater than 4°C per second or preheat to ~150°C. If manually soldering do not touch termination with soldering iron.

D PROBLEM	CAUSE	ACTION
Cracked multilayer ceramic component with crack(s) originating between the metallized terminations.	Hard pickup tip/jaws.	Replace hard pickup tip and/or jaws with plastic or other compliant material.
	Improperly adjusted tool.	Adjust pickup tip to avoid impact with component body.
	Improper tool adjustment.	Adjust pickup jaws to avoid compressive fracture of component body.
	Improper printed board support.	Attach stiffeners to printed board or provide support in fixture to minimize flexing and subsequent tensile fracture of component body during component insertion or testing.

16.5.3.4 Machine Errors

A PROBLEM	CAUSE	ACTION
Can't read fiducial(s).	Header data not correct.	Check shape, size and keep-out distance in header file.
	Fiducial has bad quality.	Try cleaning with eraser.
	X/Y location of the fiducial relative to the primary tooling pin is not correct.	Check that the distance from the primary tooling pin to the center of the fiducial(s) matches the data in the sequence file.
	X0/Y0 not correct in Proper Value File.	Check fiducial operator screen reading by using a known good board with correct fiducial sequence data.

B PROBLEM	CAUSE	ACTION
Mis-pick from tape feeder.	The tape pocket not in the correct position.	Set the tape in the correct relationship to the feeder.
	The cover tape is not pulled back.	Tighten the cover tape and restart.
	The cover tape is torn because the tape is winding at an angle onto the cover tape reel.	See that the cover tape is winding on the reel in an even manner.

C PROBLEM	CAUSE	ACTION
Tooling pin error.	The tooling pins are not going through the holes on the boards, the pins are not adjusted properly, or the board has different tooling pin hole locations.	In order to run the board, adjust the tooling pin location.

16.5.3.4 Machine Errors (continued)

D PROBLEM	CAUSE	ACTION
Panel stuck on conveyor.	Conveyor width is not adjusted properly.	Adjust the conveyor width.

16.6 CHIP-ON-BOARD (Unpackaged Chip Components)

16.6.1 Wire Bonding

A PROBLEM	CAUSE	ACTION
Low bond strength.	Impurities in gold plate, or surface contamination.	Analyze plate for trace metals. Check for correct plating parameters. Micro-etch surface and re-bond.
	Insufficient wire deformation.	Check elongation of wire. Use stabilized wire.
	Low interface temperature during bonding.	Adjust bonding equipment. Confirm correct board pre-heat.
	Wire contamination.	Inspect/clean wire.
	Gold plate too thin.	Increase plating time; specify minimum thickness.

B PROBLEM	CAUSE	ACTION
No bond.	Surface defect in gold plate (pit, nodule, scratch, etc.).	Manually re-bond to another spot on site. Review plating cycle. (See Section 10.0.)
	Surface contamination.	Reclean part. Micro-etch gold and re-bond.

C PROBLEM	CAUSE	ACTION
Tailing and sagging of wire (Tailing occurs when the wire breaks a few mils from the bond rather than at the bond.)	Improperly stabilized wire used.	Use wire with proper elongation.

D PROBLEM	CAUSE	ACTION
Have good pull strength, but fail after thermal cycle (Aluminum wire bonds).	Intermetallics form when sufficient gold and aluminum are present.	Use thinner gold plate when bonding with aluminum wire.
	Thallium in gold plate, that migrates to the gold surface during thermal cycle.	Convert to thallium-free gold bath. (Also see Section 10.0.)
	Metal contamination in gold plate migrates to the gold surface during thermal cycle.	Replace gold bath. Consult with supplier for possible remedy.

16.6.2 TAB Bonding

A PROBLEM	CAUSE	ACTION
Cracked die member during thermocompression bonding.	Mismatch of the four planes - die bond pad bumps, bumped or plated leads, contact pads, and die chuck or die holding fixture.	

16.6.2 TAB Bonding (continued)

B PROBLEM	CAUSE	ACTION
Poor quality bond when using a reflow soldering process for TAB bonding.	Non-uniform solder thickness which may cause board burning or cold joints. Too thick solder may also cause bridging; too thin solder may cause poor wetting and difficult inspection (no fillets).	Adjust solder paste application process. Adjust tin-lead plating process. (See Section 10.3.)
	Purity of solder.	Inclusions in plating may cause weak bonds, solder balls or bridging. Clean up plating bath and plating operation. (See Section 10.0.)
	Substrate is not stable; cannot withstand bonding temperature cycle or die attach cure temperature.	Investigate alternate bonding method or different substrate.
	Board not flat.	Consider rework options. Investigate cause of warpage. Correct process or design of board.
	Thermal mass of board may require substrate heating.	Investigate board design limitations.
	Incorrect flux used.	Consult with flux supplier.

C PROBLEM	CAUSE	ACTION
Poor pull strength of gold/tin thermocompression bond.	Tin whiskering.	See Section 10.0.
	Oxidation of the tin surface, caused by long term exposure to air.	Should not affect bondability or quality of the bond, although there will be a slight color change in the melted tin plate. Re-clean surface prior to bonding. Refer to Section 10.0.
	Formation of copper-tin intermetallic.	Not a reversible condition. Prevent by limiting exposure to heat and high humidity. Insufficient tin plating thickness.
	Lead breaks, not bond.	Lead pull strengths do not reflect bond strength; they only represent the copper yield strength of the lead.
	Contamination of surfaces.	Re-clean bonding surfaces. Prevent further contamination.
	Lack of co-planarity.	Correct setup and maintenance of the thermode planarity is required.

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Section 17
Soldering

17.1 GENERAL

This section deals with the mounting of both leaded and surface mount components. Sections 16 through 19 address assembly-related issues.

The following publications are recommended for more complete information regarding printed board assembly processes:

IPC-CM-770 Component Mounting Guidelines for Printed Boards

IPC-S-816 SMT Process Guideline and Checklist

17.1.1 General Observed Conditions

A PROBLEM	CAUSE	ACTION
Component loses marking.	Component not cleaned prior to marking.	Degrease with chlorinated/fluorinated solvent.
	Ink improperly mixed.	Mix ink per supplier's recommendations.
	Ink out-of-date.	Check batch code data.
	Ink not compatible with base material.	Check supplier's recommendation.

B PROBLEM	CAUSE	ACTION
Lead does not solder.	Lead contaminated with hand soils and/or grease, or hand cream (silicone base).	Degrease with chlorinated or fluorinated solvents. Mechanically clean (mild abrasive).

C PROBLEM	CAUSE	ACTION
Defective solder joints.	Moisture in substrate.	Bake prior to soldering.
	Poor land pattern design/metallization.	Develop test to evaluated design-to-component lead relationship.

D PROBLEM	CAUSE	ACTION
Rosin solder connection.	Rosin entrapped in separation between surfaces being joined.	Evaluate soldering procedure, rosin type and solder characteristics.

E PROBLEM	CAUSE	ACTION
Nonwetting/ dewetting.	Surface contamination.	Clean and test for cleanliness.
	Plating/coating impurities.	Test for solderability and evaluate storage/handling procedures. Test copper for iron contamination.
	Improper flux activity.	Run test program to evaluate flux activity.
	Protective coating not removed.	Check storage and incoming inspection procedures.

17.2 SOLDERING MATERIALS

17.2.1 Adhesives (See Section 16.5.1, Adhesive Application)

17.2.2 Solder Paste (Also see Section 16.5.2, Solder Paste Application)

A	PROBLEM	CAUSE	ACTION
Flux on top of paste.		Formulation problem. (If flux collects on top of paste, it means that flux is liquid enough to allow powder to settle to bottom.)	Mix paste well, if still in jar (make sure that there is no crust on top). If paste is in dispensers, it can be squeezed into a jar and mixed, otherwise, a stir rod can be placed in nozzle end to mix paste inside canister. Work with paste supplier to correct problem. Separation can be slowed by storing paste in refrigerator.

B	PROBLEM	CAUSE	ACTION
Crust on top of paste.		Packaging problem. Paste can develop crust on surface if caps are not screwed tightly.	Make sure that all paste containers are tightly sealed and all jars contain plastic plungers to reduce possible air contact area.
		Exposure of paste to high temperatures during shipping/storage.	Have paste shipped overnight from supplier, to minimize exposure. Control storage conditions.
		Improper storage after paste has been used.	Use plunger to keep air contact to a minimum. Keep all sides in jar clean of paste.
		Poor paste flux formula.	Monitor paste amount with crusting problems. If crusting is significant problem, notify supplier.

17.2.3 Flux (See Section 17.4, Wave Soldering)

17.2.4 Solder (See Section 17.4, Wave Soldering)

17.3 MANUAL (HAND) SOLDERING

A	PROBLEM	CAUSE	ACTION
Terminal does not accept solder.		Terminal/eyelet is improperly plated.	Must be plated with acid tin or tin-lead to be solderable. (See Section 10.0.)
		Terminal/eyelet surface is oxidized and will not activate with (RMA, RA) flux.	Part must be pre-tinned, using adequate strength flux.

B	PROBLEM	CAUSE	ACTION
Connection surface will not accept solder.		Surface contaminated with soils.	Degrease.
		Tin/tin-lead plate too thin.	Hand solder surface using appropriate flux.

17.4 WAVE SOLDERING

Wave soldering of surface mount assemblies is easy to do, providing that the boards and all components have solderable metallic surfaces; the board design meets recommended guidelines for land layout geometry; the components have been properly placed using a proper adhesive which is correctly cured; and the wave soldering machine is under correct process control. This means using good flux at the correct specific gravity and solder with verified purity, selecting preheat settings, and matching the temperature of the solder wave with a conveyor speed so that this relationship provides sufficient heat for the correct time duration to perform acceptable solder joints. Verifying that all of these are under proper process control is the first overall requirement or guideline for mass production wave soldering of surface mount assemblies and for providing acceptable quality solder joints.

17.4.1 Equipment Related Problems

A	PROBLEM	CAUSE	ACTION
Solder skips. A solder skip occurs where a solder joint did not form. Solder skips are usually observed in random locations and may be caused by the wave soldering equipment, the materials, or poor process control.		Turbulent wave OFF.	Turn Turbulent wave ON.
		Vibratory device in second wave OFF.	Turn ON vibratory wave device.
		Turbulent wave too low.	Increase height of turbulent wave.
		Turbulent nozzle clogged.	Clean flux or dross in nozzle.
		Carrier bent or damaged.	Send carrier/fixture to repair.
		Conveyor fingers bent.	Replace bent fingers.
		Rails not level or parallel over nozzles.	Reset rails level/parallel.
		Waves/nozzles not level.	Reset pot and nozzles level.
		First wave height lower in spots.	Pull pump and nozzles. Clean out pot.
		Conveyor width too tight.	Adjust conveyor width.
		Conveyor speed too fast for flux volatiles.	Reduce conveyor speed.
		Board not run best direction (orientation).	Turn SMA 90, 180 or 270 degrees.

B	PROBLEM	CAUSE	ACTION
Solder bridges.		Wave height/exit conditions incorrectly set.	Set exit flow wave dynamics properly.
		Slow conveyor speed washes off too much flux.	Increase speed so waves leave flux on.
		Conveyor too fast or insufficient preheat.	Decrease speed - better solder drainage.
		Carrier bent or damaged.	Send carrier/fixture to repair.
		Conveyor fingers bent.	Replace bent fingers.
		Rails not level or parallel over nozzles.	Reset rails level/parallel.
		Waves/nozzles not level.	Reset pot and nozzles level.
		Board not run best direction (orientation, i.e., conductors perpendicular to conveyor travel).	Turn SMA 90, 180 or 270 degrees.
		Dross recirculating from pot to wave onto SMA.	Pull pump and nozzles and clean out pot.
		Hot air knife after wave set incorrectly.	Reset air knife.
		Insufficient flux applied.	Increase flux application.

17.4.1 Equipment Related Problems (continued)

C PROBLEM	CAUSE	ACTION
Unfilled via holes.	Non-uniform fluxing across bottom of board.	Check foam specific gravity bubbles, crest uniform.
	Conveyor too fast or insufficient preheat.	Decrease speed for more heat in holes.
	Vibratory device in second wave OFF.	Turn ON vibratory wave.
	Set-point for vibratory device too low.	Increase power.
	Carrier bent or damaged.	Send carrier/fixture to repair.
	Conveyor fingers bent.	Replace bent fingers.
	Rails not level or parallel over nozzles.	Reset rails level/parallel.
	Waves/nozzles not level.	Reset pot and nozzles level.
	Insufficient flux applied.	Increase flux application.

D PROBLEM	CAUSE	ACTION
Solder wave over-flooding board.	Board too large or assembly too heavy.	Install stiffeners.
	Pallet, carrier or fingers adjusted too tight.	Readjust for board expansion.
	Wave height set too high or conveyor too low.	Adjust wave (lower) or conveyor (raise).
	Conveyor speed too slow.	Optimize conveyor speed.
	Preheat settings too high.	Optimize preheat.
	Pallet not equipped with center support device.	Redesign pallet.
	Center support device not adjusted correctly.	Readjust.

E PROBLEM	CAUSE	ACTION
Grainy or disturbed joints.	Vibration or jerky action in conveyor.	Clean and lubricate in conveyor chains.
	Removing assembly from conveyor too early.	Allow assembly to travel conveyor to conveyor end to permit solidification of all joints.
	Excessive solder temperature/slow cooling rate.	Reduce temperature; increase cooling.
	Too much liquid flux in holes.	Provide more preheat to volatilize flux thinners.

F PROBLEM	CAUSE	ACTION
Cold joints.	Preheat temperature too low.	Check and adjust.
	Conveyor speed too high.	Check and adjust.
	Low flux activity.	Use more aggressive fluxes.

G PROBLEM	CAUSE	ACTION
Solder balls on assembly. (Solder balls may be found on either the top-side or the bottom-side of the assembly. Solder balls on the assembly are more common when a low solids flux or a preparations fluid is used.)	Solder splash into pot rebounding onto board.	Adjust anti-splash gates.
	Insufficient Activator.	Increase conveyor speed. Increase flux activator/solids content. Increase quantity of flux applied. Reduce air knife pressure.
	Vibratory device in second wave set too high.	Reduce energy level to vibrator.

17.4.1 Equipment Related Problems (continued)

H PROBLEM	CAUSE	ACTION
Cracked chip components or plastic-bodied leaded components.	Pre-heat profile too steep.	Reduce ramp rate by adding more pre-heaters, reducing conveyor speed, or decreasing solder temperature.

J PROBLEM	CAUSE	ACTION
Solder projections.	Improper cooling.	Check conveyor speed.

K PROBLEM	CAUSE	ACTION
Excessive or insufficient solder.	Improper conveyor speed, wave shape configuration, and/or machine angle (when wave soldering).	Check and evaluate equipment.

L PROBLEM	CAUSE	ACTION
Overheated solder connection.	Too much heat applied.	Reduce heat/change soldering temperature/preheating.

17.4.2 Material/Prior Process Related Problems

A PROBLEM	CAUSE	ACTION
Solder skips. (Also see 17.4.1A.)	Flux solids too high.	Change to low solids flux.
	Flux specific gravity gone too high.	Add thinner to correct specific gravity.
	Solder purity exceeds contamination limits.	Refresh and maintain the pot.
	Analysis period exceeded.	Send solder sample for analysis.
	Oil contaminated (on waves needing oil).	Drain and replace oil, if used.
	Warped boards.	Do not use warped boards.
	Adhesives on SMD pads.	See Section 16.5.1.
	Too much adhesive.	See Section 16.5.1.
	Solder mask smear on pads.	Improve incoming acceptance procedure.
	Lands not solderable.	Don’t use unsolderable boards. Consult with board supplier.
	Component lead/terminations not solderable.	Use only solderable parts.
	Component(s) too large for pad.	Use correct parts as specified.
	Components misaligned.	See Section 16.0.
	Parts placed or skewed too close together, or placed off the lands.	Correct placement machine problem. (See Section 16.0.)

17.4.2 Material/Prior Process Related Problems (continued)

B PROBLEM	CAUSE	ACTION
Solder bridges.	Flux - some low solids fluxes cause bridge.	Try a different flux.
	Oil contaminated (on waves needing oil).	Drain and replace oil, if used.
	Flux thinned out too much.	Specify gravity or titrate.
	Warped boards can cause poor exit flow.	Do not use warped boards.
	Pads not solderable.	Don't use unsolderable boards.
	Component leads/terminations not solderable.	Use only solderable parts.
	Component(s) too large for pad.	Use correct parts as specified.
	Components misaligned.	See Section 16.0.
	Parts placed or skewed too close together, or placed off the pads.	Correct placement machine problem. (See Section 16.0.)
	Solder mask deficiencies.	Check incoming inspection. Re-evaluate solder mask selection/application criteria.
	Solder contaminated.	Check for trace metals in the solder, e.g., copper, aluminum.
	Improper laminate/solder mask cure.	Properly cure laminate and solder mask prior to soldering.

C PROBLEM	CAUSE	ACTION
Unfilled via holes.	Flux specific gravity gone too high.	Add thinner to correct specific gravity.
	Solder purity exceeds contamination limits.	Refresh and maintain the pot.
	Analysis period exceeded.	Send solder sample for analysis.
	Oil contaminated (on waves needing oil).	Drain and replace oil, if used.
	Warped boards - causes assembly to lift off wave.	Do not use warped boards. Consult board supplier.
	Solder mask smeared on pads around holes.	Verify incoming acceptance report; consult board supplier to correct.
	Holes not solderable or "weak knee" condition.	Do not use unsolderable boards.
	Poor plating (not continuous) in barrel of holes.	Use good boards that pass solder float test.
	Solder mask or other contamination in holes.	Use good boards that pass solder float test. Consult with board supplier to remedy situation.

D PROBLEM	CAUSE	ACTION
Solder wave overflooding board.	Boards warped.	Stiffen or fixture board.
	Heavy parts designed in center of board.	Redesign heavy parts to edges.
	Multilayer ground/power planes not balanced.	Redesign boards to balance, or relieve ground/power planes.
	Holes or cutouts in board.	Mask these areas.
	Board dimensions not optimized.	Change length-width ratio. Use stiffeners.

17.4.2 Material/Prior Process Related Problems (continued)

E PROBLEM	CAUSE	ACTION
Grainy or disturbed joints.	Solder alloy contaminated.	Analyze and correct solder composition.
	Water or contamination in fluxer air supply.	Check and clean air filter on inlet air line.
	High lead in board solder coat.	Check board solder coating. Consult with board supplier.
	High gold content.	Follow gold removal process per ANSI/J-STD-001.
	Moisture in board material causing outgassing.	Bake boards prior to wave soldering.
	Chip terminations contaminated.	Do not use contaminated parts.
	Contamination on some component leads.	Do not use contaminated parts. Pre-tin.
	Off-spec solder on bare board.	Analyze and correct.

F PROBLEM	CAUSE	ACTION
Cold joints.	Contaminated or unsolderable leads/pads.	Verify solderability per J-STD-002 or J-STD-003.

G PROBLEM	CAUSE	ACTION
Solder balls on assembly. (Also see 17.4.1G.)	Flux solids content too low.	Correct specific gravity. Change flux type.
	Flux contaminated.	Drain fluxer and refill with fresh flux.
	Solder resist not cured correctly.	Check at incoming and correct with supplier.
	Solder resist not compatible with flux.	Change solder mask or flux.

H PROBLEM	CAUSE	ACTION
Cracked chip components or plastic-bodied leaded components.	Moisture entrapment.	Pre-bake parts per IPC-SM-786.
	Inadequate multilayer chip construction.	Refer to supplier, or change supplier.
	Pick and place machine impacting parts.	Review and adjust tweezer pressure and Z-axis speed or stop position.
	Warped boards.	Use boards within flatness specification.

J PROBLEM	CAUSE	ACTION
Solder projections.	Incorrect solder mixture.	Re-evaluate solder selection criteria. Evaluate tin-lead ratio; adjust accordingly.
	Solder contamination.	Evaluate solder for trace metals, e.g., copper, aluminum, and adjust appropriately.

K PROBLEM	CAUSE	ACTION
Lead does not accept solder.	Inadequate solder/tin plate (too thin), or flux does not activate surface.	Pre-tin lead using flux adequate for activating base material.
	Flux activity has been degraded.	Replace flux with fresh material.

17.4.3 Design Related Problems

A PROBLEM	CAUSE	ACTION
Solder skips. (Also see 17.4.1A.)	Lands/parts laid out too close.	Lay parts/pads farther apart.
	Design recommendations not followed.	Redesign where possible per specification. (See IPC-SM-782.)
	Pads too small or lands too far under part.	Extend lands out further.
	Larger part shadowing smaller one.	Alter layout.
	Body of part too high.	Specify lower profile part or redesign difficult parts onto top side for reflow.
	Solder mask too thick.	Specify thinner solder mask.
	Solder mask too close around land.	Re-dimension more land clearance.

17.4.3 Design Related Problems (continued)

B PROBLEM	CAUSE	ACTION
Solder bridges.	Lands/parts laid out too close.	Lay parts/lands further apart.
	Design alignment not followed.	Redesign where possible per specification. (See IPC-SM-782.)
	Bridge only across last two leads of SOIC.	Add dummy pads for drainage.
	Bridge only on last two quad pack leads.	Turn part 45 degrees and add dummy land.

C PROBLEM	CAUSE	ACTION
Unfilled via holes.	Solder mask too thick.	Specify thinner solder mask.
	Solder mask too close around pad.	Re-dimension more hole clearance.

D PROBLEM	CAUSE	ACTION
Solder projections.	Poor land pattern/component relationship.	Check incoming inspection. Re-evaluate land pattern features.

17.5 VAPOR PHASE SOLDERING

The vapor phase process has some unique characteristics. It has a fixed upper temperature determined by the boiling point of the fluid used. It is a rapid heating method and quite tolerant of large mass differentials on a given circuit board or assembly. It is a very uniform method of heating, as the vapor surrounds the components, heating from all sides. As with most mass soldering techniques, it has been found that preheat is an essential part of the process and typically this is provided with an infrared pre-heater. The accepted standard for preheat is a 2 to 3°C per second temperature rise to within 100°C of the reflow temperature, followed by a short stabilization and equalization period prior to reflow. To aid cooling of the assembly through liquidus, and to improve solder grain density and shorten liquidus time, many machines have a convection cool down system integral to the equipment.

17.5.1 Equipment/Process Related Problems

A PROBLEM	CAUSE	ACTION
No reflow of paste or preforms.	Inadequate reflow power.	Increase power setting. Verify that all heaters are working.
	Inadequate reflow time.	Reduce conveyor speed. Increase dwell.
	Boiling temperature too low.	Check for correct fluid temperature for application.

B PROBLEM	CAUSE	ACTION
Dull, graying, crystallized solder.	Excessive time in preheat causing solder oxidation.	Reduce preheat time.
	Excessive time in reflow causing excessive leaching.	Reduce reflow time.

C PROBLEM	CAUSE	ACTION
Opens (most frequently caused by lead coplanarity or solder wicking).	Wicking of solder to fine leads pulling solder away from joint.	Increase preheat temperature and/or time from joint (125° to 150°C). Vertical batch use 2% silver or special slow melt solder to slow solder melt.

17.5.1 Equipment/Process Related Problems (continued)

D PROBLEM	CAUSE	ACTION
Tombstoning (most frequently caused by unequal melt or solder paste quantity).	One side of component melting before the other.	Increase preheat and/or time at preheat.

E PROBLEM	CAUSE	ACTION
Solder balls (most frequently caused by outdated paste or insufficient preheat).	Solder flux spattering in reflow.	Increase preheat temperature and/or increase preheat time.

F PROBLEM	CAUSE	ACTION
Component alignment (most frequently caused by pad design or placement error).	Component float to one pad.	Increase preheat time and/or temperature.
	Conveyor vibration.	Clean conveyor rails. Check conveyor tension.
	Tunnel curtains (brush components).	Shorten curtains.

G PROBLEM	CAUSE	ACTION
Capacitor cracking (most frequently caused by thermal shock or placement handling).	Possible thermal shock.	Make sure preheat rate is 2 to 3°C per second to within 100°C of reflow. Use preheat on vertical batch units (oven).

H PROBLEM	CAUSE	ACTION
Plastic package cracking (most frequently caused by water entrapped in plastic).	Excessive reflow temperature.	Be sure fluid used is 215°C or below.
	No preheat.	Set preheat to achieve 2 to 3°C per second rise to within 100°C of reflow.

J PROBLEM	CAUSE	ACTION
Low surface insulation resistance (most frequently caused by flux entrapped under component).	Contaminated vapor phase soldering fluid.	Run plain substrate and retest. Replace or reclaim fluid if resistance too low.

K PROBLEM	CAUSE	ACTION
Insufficient solder fillets (most frequently caused by insufficient solder paste).	Solder wicking up leads.	Increase preheat time and/or temperature.

L PROBLEM	CAUSE	ACTION
Non-soldering (electrical open).	Missing/insufficient solder paste.	Check stencil for clogging.
	Faulty flux.	Check flux.
	Incorrect land/stencil design.	Check design and component.

17.5.2 Material/Prior-Process Related Problems

A PROBLEM	CAUSE	ACTION
No reflow of paste or preforms.	Solder melting point too high.	Check solder paste composition for correct melt temperature.

B PROBLEM	CAUSE	ACTION
Dull, graying, crystallized solder.	Excessive leaching of passive component terminations.	Select components with nickel barrier.
	Gold not removed from active components.	Solder coat components.
	Board plating too far from eutectic.	Check board plating composition. (See Section 10.3.) Consult with board supplier.
	Oxidized component terminations.	Reject components.

C PROBLEM	CAUSE	ACTION
Opens. (Also see 17.5.1C.)	Solder wicking to adjacent pad or down feed through hole.	Correct design deficiencies.
	Poor lead coplanarity.	Reject or reform components.
	Misregistered solder paste.	Correct application registration.
	Insufficient solder paste.	Check for plugged screen or stencil.

D PROBLEM	CAUSE	ACTION
Tombstoning. (Also see 17.5.1D.)	Unequal pad geometries cause unequal melt times.	Correct design.
	Solder resist under part causing teeter-totter effect.	Correct design.
	Unequal pad heating caused by leads or ground plane.	Correct design.
	Pads extend beyond component too far so component can pull off one end.	Correct design.
	Too much solder causes high tipping forces.	Reduce stencil thickness or solder mask too thick.
	Misregistration of solder paste - no paste on pad.	Check registration and cleanliness of screen.
	Misregistration of component - not on paste.	Check component location at pick-and-place.
	Solder resist on land (smear).	Reject fabricated board.
	Displaced components.	Check operator or transport handling systems.

E PROBLEM	CAUSE	ACTION
Bridges (most frequently caused by solder application registration tolerance).	Misregistered solder paste print.	Correct application registration.
	Too much solder.	Check solder application.
	Solder slumping.	Check solder paste.
	Inadequate land separation.	Correct design.
	Improper placement.	Check placement process.
	Board bow or twist.	Check rack support or adjacent wave height.

F PROBLEM	CAUSE	ACTION
Solder Balls. (Also see 17.5.1E.)	Oxidized solder paste.	Use fresh solder paste.
	Misregistration of solder paste.	Check application registration.
	Improperly cured solder resist.	Correct condition at board fabrication. Contact board supplier.

17.5.2 Material/Prior-Process Related Problems (continued)

G	PROBLEM	CAUSE	ACTION
Component alignment. (Also see 17.5.1F.)		Components float on pads.	Correct pad design.
		Components misplaced.	Correct pick-and-place alignment.
		Unequal solder melt.	Correct pad connection design.

H	PROBLEM	CAUSE	ACTION
Capacitor cracking. (Also see 17.5.1G.)		Poor capacitor construction.	Test capacitors for thermal shock.
		Capacitors cracking in placement.	Check centering jaws and placement pressure.
		Post handling cracking.	Do not bend boards after reflow.

J	PROBLEM	CAUSE	ACTION
Plastic package cracking. (Also see 17.5.1H.)		Excessive water vapor pressure.	Bake components or purchase pre-baked components. (See IPC-SM-786.)

K	PROBLEM	CAUSE	ACTION
Low surface insulation resistance. (Also see 17.5.1J.)		Flux entrapped under component.	Improve cleaning process. Reform leads to increase clearance.
		Board contamination prior to reflow.	Check incoming boards for contamination.
		Wrong flux specified for product type.	Check flux and cleaning method for particular application.

L	PROBLEM	CAUSE	ACTION
Insufficient solder fillets. (Also see 17.1.K.)		Too little solder paste.	Increase size of stencil openings. Increase stencil thickness. Check solder application.
		Solder wicking away from joint on board.	Correct design location of feed-throughs. Correct design of trace to pad connections. Use solder mask if not now using.

M	PROBLEM	CAUSE	ACTION
Non-soldering (electrical open).		Damaged component leads.	Check component lead integrity, especially lead coplanarity and lead skew.
		Component lead solderability.	Check solderability.
		Faulty PWB.	Check PWB land surface; consult board supplier.
		Board warp or twist.	Adjust wave height or rack support.

17.6 INFRARED/CONVECTION REFLOW SOLDERING

This process is generally carried out with in-line conveyorized equipment incorporating multiple heating zones with individual temperature controls. Heat sources used include short wavelength tubes, medium-to-longer wavelength panel secondary emitters, and/or heated air/nitrogen in the convection reflow systems. As with any mass soldering process, defects detected in the soldered assemblies are often related to prior process and material variables. The defects that relate to prior process or material are generally much larger in number and can be very difficult to classify after the fact. For example, once the assembly is soldered, it is hard to determine whether a component was out of position before reflow, or whether the solder paste deposit was properly registered. This section presents a general listing of problems encountered in the infrared/convection reflow soldering process. The causes and actions are divided into Equipment/process related and Material/prior-process related.

17.6.1 Equipment/Process Related Problems

A PROBLEM	CAUSE	ACTION
No reflow of solder paste/cold solder joints, nonwetting.	Reflow profile incorrect.	Increase/change reflow temperature.
	Thermal load too great.	Decrease product loading for machine capacity rate.
	Reflow temperature not high enough.	Adjust profile. Increase time above liquidus. Verify that all heaters are working.
	Machine being thermally overloaded.	Reduce rate of product input to match equipment thermal capacity and recovery capability.
	Board layout causing shadowing.	Re-orientation of board on conveyor. Change reflow profile. Select alternate reflow process.
	Heat sinking from board/parts.	Change reflow profile. Select alternate reflow process. Increase preheating stage.

B PROBLEM	CAUSE	ACTION
No solders: dewetting.	Excess time above reflow temperature.	Change profile to reduce time above reflow.

C PROBLEM	CAUSE	ACTION
Uneven reflow.	Incorrect profile for assembly.	Check profile, customize for each assembly.
	Poor heat transfer.	Check positioning of board to insure even heat transfer.
	Uneven heat transfer across oven.	Increase convective air across oven flow in oven.
	Thermal capacity and recovery capability.	Repair or replace oven.

17.6.1 Equipment/Process Related Problems (continued)

D PROBLEM	CAUSE	ACTION
Solder balls (often due to excessive outgassing of the paste or boards during reflow, or an excess of oxide on the paste particles, components, or boards).	Incomplete paste cure.	Pre-cure paste or change preheat portion of reflow profile for cure.
	Conveyor speed too high.	Reduce conveyor speed.

E PROBLEM	CAUSE	ACTION
Charring of board/ components (thermal damage to the boards or components during reflow can be due to oven temperature or uneven thermal transfer during reflow).	Oven temperature too high.	Reduce temperature setpoints. Shield affected areas from direct radiation. Increase conveyor speed.
	Loading rate too low for oven settings.	Check/change rate.
	Uneven/incorrect positioning of assemblies in reflow.	Check positioning to insure heat transfer.

F PROBLEM	CAUSE	ACTION
Damaged components.	Temperatures too high.	Change profile. Keep temperatures below limit for components.
	Components being damaged in pick and place operation.	Adjust pick and place equipment.

G PROBLEM	CAUSE	ACTION
Cracked joints. Physical damage to the solder joints can occur if the assemblies are moved while the solder joints are still liquid, or if the assemblies are handled in such a way as to damage the cooled solder joints.	Insufficient cool down after reflow.	Change thermal profile.
	Too rapid a cool down after reflow, e.g., immediate transfer to cleaner.	Change thermal profile.
	Dropping of board after oven.	Change handling procedures.

H PROBLEM	CAUSE	ACTION
Voids (result of entrapment of flux or other volatiles in the solder joints during reflow).	Insufficient paste cure.	Modify cure or reflow profile. Change paste.

J PROBLEM	CAUSE	ACTION
Opens. (Also see 17.6.2N.)	No reflow of solder.	See 17.6.1A and 17.6.2C.

17.6.1 Equipment/Process Related Problems (continued)

K PROBLEM	CAUSE	ACTION
Spatter (related to solder balling; see 17.6.1D and 17.6.2F).	Smearing during printing.	Adjust printing process.
	Printing of paste on non-solderable surface.	Check for alignment of printing.
	Paste not cured.	Check cure and/or change reflow profile.

L PROBLEM	CAUSE	ACTION
Tombstoning (the raising up of one end of a chip component during reflow).	Excess movement in reflow operation.	Reduce board motion during reflow.

17.6.2 Material/Prior-Process Related Problems

A PROBLEM	CAUSE	ACTION
No reflow of solder paste/cold solder joints.	Incorrect solder alloy.	Use solder alloy specified.
	Board layout causing shadowing.	Change component selection and placement.
	Heat sinking from board/parts.	Re-orientation of board on conveyor. Change reflow profile. Select alternate reflow process.

B PROBLEM	CAUSE	ACTION
No solder - solder not present.	Clogged stencil/dispenser.	Clean stencil/dispenser.
	Print process out of control.	Adjust squeegee pressure or durometer. Change print speed. Check stencil alignment. Check dispenser accuracy.
	Paste drying out.	Change process to reduce time paste remains on stencil. Increase humidity and reduce drafts in the screen printing area. Do not reuse old paste.
	Solder paste viscosity too high.	Obtain lower viscosity paste (consult paste supplier).
	Paste not "wetting" the stencil.	Change paste.
	Solder clogging stencil/dispenser.	Use different particle size paste. Check paste for unevenness of texture. Use different viscosity paste. Use paste with slower drying time.

C PROBLEM	CAUSE	ACTION
Nonwetting.	Lead not wetting.	Check part solderability. (See J-STD-002.) More active paste may be helpful.
	Board not wetting.	Check board solderability. (See J-STD-003.) More active paste may be helpful.
	Part may not be in contact with paste.	Check print accuracy. Check part placement. Check lead planarity/skew. Check board warp.

D PROBLEM	CAUSE	ACTION
Dewetting.	Board has excess intermetallics.	Increase solder thickness on board. Reduce storage time. Improve storage condition.
	Chip termination has poor leach resistance.	Use parts that have barrier layers. (See J-STD-002.)

E PROBLEM	CAUSE	ACTION
Uneven reflow.	Board layout causing shadowing.	Design change required.
	Heat sinking from board/parts.	Design change required.

17.6.2 Material/Prior-Process Related Problems (continued)

F	PROBLEM	CAUSE	ACTION
Solder balls. (Also see 17.6.1D.)		Incomplete paste cure.	Change paste.
		Moisture in boards.	Pre-bake boards.
		Entrapped solvents in boards.	Pre-bake boards.
		Oxidized paste.	Refer to J-STD-005 for incoming paste controls.
		Solder mask/paste interaction.	Change in paste or mask needed.

G	PROBLEM	CAUSE	ACTION
Charring of board/ components. (Also see 17.6.1F.)		Components incompatible with IR reflow.	Change components for compatibility.
		Moisture in packages: cracking.	Observe handling procedures in IPC-SM-786.

H	PROBLEM	CAUSE	ACTION
Cracked joints. (Also see 17.6.1G.)		Attempts to straighten warped board.	Change handling procedures.

J	PROBLEM	CAUSE	ACTION
Insufficient solder. (Also see 17.6.2B.)		Solder wicking away from solder joint.	Adjust design for lead/land ratio or land design. Change in paste/flux activation (lower). Move via hole.

K	PROBLEM	CAUSE	ACTION
Bridging.		Paste deposition process causing bridges.	Check process.
		Bent or misaligned leads.	Eliminate out-of-tolerance components.
		Paste slump.	See Section 16.5.2.1 and J-STD-005.
		Component misplacement.	See Section 16.0.
		Design spacing.	Review layout for possible change.

L	PROBLEM	CAUSE	ACTION
Voids. (Also see 17.6.1H.)		Paste solvent entrapment.	Change paste for different volatility.

M	PROBLEM	CAUSE	ACTION
Opens, electrical.		No or insufficient paste deposition.	Adjust paste deposition process. (Also see 17.6.2B and 17.6.2D.)
		Inaccurate parts placement.	Adjust placement. (See Section 16.0.)
		Poor board/part solderability.	Check/control solderability of boards and parts. (See J-STD-002 and J-STD-003.)
		Parts with lead skew or planarity problems.	Use only ‘‘in-tolerance’’ parts. Review component placement (Section 16.0).

N	PROBLEM	CAUSE	ACTION
Spatter. (Also see 17.6.1K.)		Moisture in paste.	Store paste only in dry conditions.
		Moisture/solvents trapped in board.	Pre-bake board.

P	PROBLEM	CAUSE	ACTION
Tombstoning.		Inaccurate placement of parts.	Adjust placement.
		Uneven solderability on pads or leads.	Check for solderability variations.
		Land design incorrect.	Redesign as required. (See IPC-SM-782.)

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Cleaning of Printed Board Assemblies
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Section 18
Cleaning of Printed Board Assemblies

18.1 CLEANING

Common industry approaches address electronic assembly cleaning with two processes, i.e., solder flux removal (post solder cleaning process) and pre-encapsulation (conformal coating, varnishing, potting) cleaning. The latter is employed as a finish cleaning step and other critical encapsulation, or as a general cleaning step for less sensitive magnetics parts.

The following publications are recommended for more complete information regarding printed board assembly cleaning:

IPC-SC-60 Post Solder Solvent Cleaning Handbook

IPC-SA-61 Post Solder Semiaqueous Cleaning Handbook

IPC-AC-62 Post Solder Aqueous Cleaning Handbook

18.1.1 Solder Flux Removal

PWBA's are cleaned after soldering to remove solder flux and flux reaction products. In some process scenarios, screened temporary masks, disintegratable tapes (''solder stops''), soluble component stabilizers (for in-line lead cutting) and solder shield fluids, as well as handling soils are also expected to be removed by this process. Removal of soils left from substrate or component fabrication may be accomplished, but cannot be assured. Hence, soils from these processes must be prevented by contamination control. The flux removal process chosen must be compatible with solder flux used and must not harm the materials of construction (laminate with metal conductors, electrical and mechanical components). Selection of cleaning media and techniques used must also consider health and safety of operating personnel and impact on the environment. Cleaning media can be selected from four basic groups, depending on the type of flux used. Rosin and resin-based fluxes can be removed by organic solvents or with semi-aqueous (organic solvent with water rinse) or with aqueous media containing additives (detergents). Water soluble fluxes are removed with plain water or water containing surfactants, dispersants and neutralizers. Techniques used may be manual, batch, or in-line processing with an array of equipment available on the market, and may use immersion in liquid or vapor, or spraying and use of centrifugal forces or ultrasonic energy. Adequate drying of parts after cleaning is an important part of the flux removal process. The prime purpose of this process is to remove flux and flux reaction products and other ionizable residues or hygroscopic matter to avoid formation of electrolytes and/or water surface films on assemblies during their performance under field conditions. Secondary objectives are improvement of product appearance (''aesthetics''). Common process problems that can be encountered originate in lack of process synchronization, lack of compatibility of the materials and components with the cleaning medium/technique used, and process maintenance and controls employed to keep important process parameters within a pre-established optimal window.

18.1.1 Solder Flux Removal (continued)

A	PROBLEM	CAUSE	ACTION
Flux residue (aqueous).		Detergent solution temperature too low (detergent not fully activated).	Check heater/temperature controller for correct setting. Check heater function. Increase wash section temperature to detergent vendor's recommended temperature range.
		Detergent solution temperature too high (active ingredients vaporized/lost).	Decrease wash section temperature to detergent vendor's recommended temperature range. Check heating/cooling function.
		Soldering temperature too high (flux polymerized/carbonized).	Decrease solder pot or iron temperature. Decrease exposure time at soldering temperature.
		Wash section spray nozzles or plenum obstructed.	Remove and clean nozzles or plenum.
		Wash section spray nozzles misaligned.	Realign nozzles with fan spray perpendicular to assembly travel.
		Spray pressure too low.	Adjust spray manifold or plenum pressure. Check and clean or replace filters.
		Conveyor speed too fast or batch wash cycle too short.	Reduce conveyor speed or increase batch cycle time.
		Wash section pressurized spray pump inoperative.	Check pump operation.
		Air knives inoperative or obstructed.	Repair or clean air knives.
		Final rinse (tap or D.I.) water contaminated.	Check final rinse water quality. Clean obstructed drain ports.
		Detergent concentration too low.	Increase detergent concentration level. Check automatic water and soap replenishing system for correct operation if available.
		Incompatibility of flux and saponifier (detergent).	Change detergent.
		Extended time between fluxing/soldering and cleaning.	Clean fluxed assemblies immediately after soldering, not to exceed 1 hour.

18.1.1 Solder Flux Removal (continued)

B PROBLEM	CAUSE	ACTION
Flux residue (solvent).	Soldering temperature too high (flux polymerized/carbonized).	Decrease solder pot or iron temperature. Decrease exposure time at soldering temperature.
	Solvent spray nozzles obstructed.	Remove and clean nozzles.
	Solvent nozzles misaligned.	Realign nozzles with fan spray perpendicular to assembly travel.
	Pressurized solvent spray pumps inoperative.	Check pump operation.
	Conveyor speed too fast or batch condensation spray cycle too short.	Reduce conveyor speed or increase batch condensation/spray cycle time.
	Distillate spray inoperative.	Check distillate sump solvent level. Check distillate pressure spray pump operation.
	Still inoperative; clean distillate not available.	Check still operation. Verify distillate not mixing with boiling solvent in sump.
	Solvent temperature too low.	Check solvent temperature/controller. Check solvent heaters for continuity.
	Low solvent spray volume.	Adjust pressure valve to spray manifold. Check filters for contamination.
	Filters depleted/plugged.	Check/replace filters as required.
	Extended time between fluxing/soldering and cleaning.	Clean fluxed assemblies immediately after soldering, not to exceed 1 hour.
	Assemblies too hot to allow vapor condensation.	Allow soldered assemblies to cool below solvent boiling temperature before vapor degreasing.
	Board design doesn't allow solvent to flow under components.	Redesign board/component mounting. Change to solvent with a lower surface tension.

C PROBLEM	CAUSE	ACTION
White residue (aqueous).	Detergent or saponification residues.	Check operation of air knives between wash and rinse sections. Check orientation of air knife curtain angles. Check operation of water (tap and D.I.) rinse sections. Decrease conveyor speed to increase rinse time.
	Polymerized flux (soldering temperature too high or too long at soldering temperature).	Decrease solder pot or iron temperature. Decrease exposure time at soldering temperature. Reflux prior to cleaning.
	Detergent attack on improperly cured laminate.	Check laminate properties. Check detergent concentration.
	Assembly cleaned after conformal coat primer application.	Eliminate potential of cleaning after priming.

D PROBLEM	CAUSE	ACTION
White residue (solvent).	Non-solvent soluble flux constituents/activators.	Evaluate different solvents. Reflux prior to cleaning. Consult flux vendor.
	Non-solvent soluble solder mask residue.	Evaluate different solder mask/solvent. Evaluate different solvents. Consult solder mask and/or flux vendor.

18.1.1 Solder Flux Removal (continued)

E	PROBLEM	CAUSE	ACTION
High solvent extract resistivity (aqueous).		Resistivity test equipment malfunctioning or out of calibration.	Verify equipment function/calibration.
		Flux residue after cleaning.	Follow actions outlined in 18.1.1.A.
		Final water rinse spray (tap or D.I.) contaminated.	Check final rinse water resistivity. Verify air knife function or orientation of air curtain. Check drain valves to ensure that contaminated water doesn't back flow into final rinse stage.
		Board orientation incorrect.	Orient board components perpendicularly to conveyor movement.
		Scale build-up in system.	Clean wash and rinse section thoroughly.
		Assemblies not cleaned prior to testing.	Alter product flow through shop.
		Assemblies contaminated in storage between cleaning and resistivity testing.	Isolate cleaned assemblies to prevent handling, packaging contamination.
		Resistivity test equipment improperly operated.	Institute adequate training.

F	PROBLEM	CAUSE	ACTION
High solvent extract resistivity (solvent).		Flux residue after cleaning.	Follow actions outlined in 18.1.1.B.
		Contaminated/depleted solvent.	Check stabilizer for acid level. Change solvents/filters.
		Solvent constituents out of balance.	Check specific gravity and add required constituent.
		Degreaser solvent inadequate for removing ionic contaminants.	Change to a different cleaning solvent (blends).

G	PROBLEM	CAUSE	ACTION
Component/PWB degradation (aqueous).		Ingestion of detergent into non-sealed components (breathing).	Heat all wash and rinse section solutions to the same temperature, or increase temperature. Mask prior to cleaning. Use sealed, non-alkaline sensitive components.
		Conveyor speed too slow.	Increase conveyor speed.
		Excessive pressure breaking components.	Decrease spray pressure. Decrease air knife flow rate/pressure.
		Components lodging in conveyor chain.	Use protective cages/baskets.
		Excessive heat deforming component bodies (plastic).	Decrease dryer temperature setting. Increase conveyor speed.
		Detergent attack on improperly cured laminate.	Check laminate properties. Check detergent concentration.
		Required process temperatures deforming component bodies.	Use components with higher temperature ratings.

H	PROBLEM	CAUSE	ACTION
Component/PWB degradation (solvent).		Ingestion of detergent into non-sealed components (breathing).	Mask prior cleaning. Increase conveyor speed. Use sealed, solvent-resistant components.
		Excessive spray pressure breaking components.	Decrease spray pressure.
		Components lodging in conveyor chain.	Use protective cages/baskets.
		Excessive heat deforming component bodies (plastic).	Change to lower boiling cleaning solvent. Increase conveyor speed.
		Solvent has ‘‘gone acid’’ (corrosive).	Test acid acceptance level. Check water separator function. Replace/regenerate dryer desiccant/molecular sieves. Clean degreaser.

18.1.1 Solder Flux Removal (continued)

J PROBLEM	CAUSE	ACTION
Excessive cleaner loss (aqueous).	Automatic water/detergent addition system malfunction (excessive overflow to drain).	Check system function and correct.
	Conveyor speed too fast (excessive dragout).	Reduce conveyor speed.
	Solution transfer plumbing leaks.	Check all unions and pump seals.
	Post wash air knife incapable of removing gross detergent solution prior to water (tap or D.I.) rinse.	Check air knife function. Check air knife/air curtain angle. Reduce conveyor speed.
	Air dryer section inoperative.	Check blower operation. Check air heater continuity.

K PROBLEM	CAUSE	ACTION
Excessive cleaner loss (solvent).	Refrigerant compressor inoperative (vapor loss).	Check compressor function.
	Conveyor speed too fast (assemblies wet).	Reduce conveyor speed.
	Freeboard height inadequate.	Modify (increase) freeboard height. Evaluate new equipment.
	Solvent transfer plumbing leaks.	Check all unions and pump seals. Check chilled water inlet/outlet temperature delta.

L PROBLEM	CAUSE	ACTION
Detergent foaming (aqueous).	Detergent concentration too high.	Reduce concentration to vendor's recommended level. Check operation of automatic detergent addition system, if applicable.
	Surfactant depleted.	Add more surfactant. Drain and recharge wash section. Check operation of automatic water addition system, if applicable.

18.1.2 Legend Ink Removal

A PROBLEM	CAUSE	ACTION
Inadequate removal (aqueous).	Conveyor speed too slow or batch wash cycle too long.	Increase conveyor speed or reduce batch wash cycle time.
	Component or board legend ink susceptible to alkaline detergent solution (aluminum filled).	Mask legend prior to cleaning. Increase conveyor speed or reduce batch wash cycle time. Change to compatible ink.
	Detergent concentration too high.	Reduce detergent concentration. Change detergents.
	Component or board legend ink improperly cured.	Increase cure temperature and/or time (consult vendor). Reapply legend.
	Legend ink improperly mixed.	Reapply legend. (See Section 15.4.)

B PROBLEM	CAUSE	ACTION
Inadequate removal (solvent).	Component or board legend ink susceptible to organic solvents (e.g., acrylic inks).	Increase conveyor speed or reduce batch wash cycle time. Change to a different cleaning solvent (blend). Change to compatible ink.
	Component or board legend ink improperly cured.	Increase cure temperature and/or time (consult vendor). Mask legend prior to cleaning. Reapply legend.
	Legend ink improperly mixed.	Reapply legend. (See Section 15.4.)

18.1.3 Pre-encapsulation Cleaning

This process is employed for fine cleaning of assemblies prior to conformal coating of PWBA's. For surface preparation prior to coating, emphasis is placed on removal of water soluble residues. Hence strong polar solvents, such as purified water, purified water with surfactants, or alcohols are used for this purpose. For cleaning prior to varnishing or potting of magnetic parts or assemblies, alcohols and other organic solvents are used instead of water to preclude rusting and entrapment of chemical reactants in ferromagnetic parts. Cleaning concepts, techniques and equipment employed are the same as used for the flux removal process. The cleaning operation is followed by adequate drying at elevated temperatures with or without vacuum. The objectives of this process are to reduce the amounts of surface residues to minimal values, and also remove nonpolar soils to assure adequate bonding. Process problems that can be encountered are similar to the ones mentioned for the flux removal process and are associated with part/material compatibility and process maintenance and controls within established windows and, especially, contamination control exercised between cleaning and polymer application. Process synchronization is an important part to achieve acceptable cleanliness, i.e., process and handling soils (from precleaning operations) that cannot be removed by this process, must either be prevented or removed by previous cleaning (part fabrication, assembly and soldering).

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Post Soldering Processes
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Section 19
Post Soldering Processes

19.0 POST SOLDERING PROCESSES

19.1 CONFORMAL COATING

Printed Wiring Assemblies that are sensitive to environmental effects are commonly coated with wet applied polymeric materials. These include acrylics, fluoropolymers, epoxies, polyurethanes, silicone and vacuum deposited paraxylylenes. They may be cured/dried by reaction with atmospheric moisture, reaction with air, by thermal cure, or by radiation cure, or by polymerization of a monomer in a vacuum.

Conformal coatings protect the printed wiring assembly from dirt, foreign material and liquid water. They are not a moisture vapor barrier but only serve to slow the moisture transmission rate down. Some conformal coatings may be used strictly for cosmetic reasons. At times, the improvement of the dielectric properties is also a purpose of a conformal coating. More details on conformal coatings are to be found in IPC-CC-830, which covers the following types:

Type	Generic Description
AR	Acrylic Resin
ER	Epoxy Resin
FC	Fluorocarbon Resin
SR	Silicone Resin
UR	Polyurethane Resin
XY	Paraxylylene

All of these polymeric films behave as semi-permeable membranes and are very sensitive to water soluble residues, which produce - via osmotic effects - mealing in the coating film. Residues that impair surface wetting and/or bond formation between the surfaces of the PWBA and the coating material, also degrade the quality of the coating film. Hence, when the flux removal process does not yield the high degree of surface cleanliness required for high quality protective coatings, or when additional contamination occurs between the flux removal process and commencement of coating, a final cleaning step must be employed before coating.

Inspection for Contaminant Since most coatings are now supplied with a fluorescent dye, problems such as pinholes, bubbles, ‘‘fish eyes’’ and soil particles are readily seen under ultraviolet light. Characteristically, these problem areas show up as follows:

Pinhole Small dark spot, usually with fluorescent ring indicating slightly heavier buildup around hole.

Bubble Bright fluorescent ring with light center.

“Fish eye” (dry spot) Bright fluorescent ring with dark center indicating dry area.

Soil particle Dark spot; if particle is oily or greasy, pullaway will occur.

Precoating Cleaning Options Each manufacturer should work out his own particular cleaning procedures to arrive at the one which works best. Those indicated in Table 19-1 will serve as a guide.

Common problems with coating arise from inadequate cleaning, part incompatibility, poor masking, human error, lack of contamination control, and lack of process controls to maintain a pre-established operations window. Most coating problems are directly or indirectly associated with surface cleanliness.

Solvent extract resistivity tests cannot be relied upon to predict adequate surface cleanliness and performance of the coating film, as some of the potentially encountered contaminants are non-ionic.

Most conformal coating problems are due to contamination. Thus, to ensure a trouble free operation, a good cleaning cycle prior to conformal coating is mandatory, as well as a clean coating/curing operation.

This section is divided into general problems, then those specific to different types of coatings.

Table 19–1 Contamination of Conformal Coatings

CONTAMINANT	TYPICAL EFFECTS	POSSIBLE CLEANING METHODS
Fingerprints.	Increase in leakage current. Corrosion. Blistering of coating during humidity cycling. Lifting of coating. Arcing under high voltage. Dewetting.	Very difficult to remove; better to avoid with nylon, lint-free gloves. Change gloves frequently. Can use alkaline detergent, followed by DI rinse; follow with fluorinated solvent rinse; dry in oven (120°C).
Solder flux.	Corrosion of conductors and discoloration. Bubbling, blistering and lifting of coating. Poor adhesion. Increase in leakage current. Ionization of residue (with activated flux). Arcing.	Vapor degrease with chlorinated solvents. Ultrasonic cleaners. Vapor degrease and soak with fluorinated solvent. Aqueous detergents in water for water-soluble fluxes.
Moisture.	Poor adhesion. Lifting of coating during humidity cycle. Increase in leakage current. Tacky surface after cure. Generalized bubbling throughout coating. Discoloration during humidity cycle.	Dry in air or mild heat prior to coating.
Solvent entrapment.	Generalized bubbling and pinholing due to volatalization of solvent during cure and temperature cycling. Craters. Blisters.	Air dry prior to heat application. Use thinner coating thickness per coat/cure cycle.
Oil and grease.	Poor adhesion. Pullaway from edges of board. Dry spots or ''fish eye.'' ''Orange peel'' effect. Moisture entrapment during humidity cycling.	Alkaline detergent. Vapor degrease.
Dust or dirt particles.	Apparent pinhole usually with pullaway. Observable under UV as small dark spot. Rough or ''gritty'' appearance.	Brush well with alkaline detergents, followed by clean DI water rinse.

19.1.1 General Problems

A PROBLEM	CAUSE	ACTION
Dewetting and/or adhesion loss.	Hydrophobic contaminants in general.	Clean with polar medium. Identify and eliminate source.
	Fluids or greases of silicone or fluorocarbon nature.	Identify and eliminate source. Tighten contamination control.
	Mold release.	Change to compatible mold release that can be removed by the cleaning method applied.
	Fingerprints.	Clean with bipolar medium or with detergent. Control personal cosmetics used (lotions, soaps). Improve handling procedures (finger cots, gloves).
	Lack of compatibility between conformal coating and solder resist.	Initiate compatibility testing. Change to compatible system. Etch non-bondable surfaces or change material to bondable types (some materials may require primers).
	Wash sump contamination.	Initiate new make-up. Establish optimal interval for new make-up.
	Primer contamination.	Use fresh primer. Establish optimal interval for changing primer.
	Absorbed/adsorbed moisture.	Remove hygroscopic residues. Optimize drying time/temperature. Prevent re-absorption/adsorption (dry atmosphere).

B PROBLEM	CAUSE	ACTION
Mealing.	Water soluble residues.	Clean with polar media. Coordinate compatibility of board process with assembly process. Review and improve handling (eliminate fingerprints). Improve overall contamination control.

C PROBLEM	CAUSE	ACTION
Bubbling Note: Build-up of wet coating around components is unavoidable and bubbles from solvent entrapment may be encountered.	Wet coating film is too thick.	Add thinner. Adjust spray gun and spray technique (spraying). Reduce withdrawal speed (dipping).
	Cure/drying is too fast.	Employ a room temperature solvent ''flash off'' prior to elevated temperature curing/drying. Reduce cure/drying temperature; increase time. Apply two thin coats rather than one heavy coat.
	Inadequate drying before coating.	Increase drying temperature and time. Apply coating and curing of TDI reacted urethanes in dry (<30% RH) environment. Avoid moisture readsorption before coating.

D PROBLEM	CAUSE	ACTION
Cob webbing.	Vapor pressure of thinner is too high.	Change to thinner with less vapor pressure. Add more thinner.
	Spraying technique.	Reduce spray distance. Adjust spray nozzle.

E PROBLEM	CAUSE	ACTION
Coating penetration under mask.	Maskant is not compliant to contour.	Change to pliable and conforming tape. Train personnel.
	Adhesive of tape is attacked by thinner of coating.	Evaluate tape compatibility and change to compatible type.
	Maskant inadequate for sealing.	Change to sealed components. Add components after coating. Change to liquid applied sealants and train personnel.
	Contamination under maskant.	Apply maskant to clean surfaces. Avoid recontamination from handling and atmospheric fall-out between cleaning and mask application.

19.1.1 General Problems (continued)

F PROBLEM	CAUSE	ACTION
Inconsistent coating thickness.	Spray technique.	Train personnel. Note: Spray coating is more an art than science and ''stands or falls'' with operator skills.
	Inconsistent withdrawal rate.	Establish optimal viscosity and withdrawal rate. Exercise controls to remain within the established parameters.
	Vacuum deposition (parylenes only) is too fast.	Slow down deposition rate.
	Inadequate amount of dimer (parylenes only).	Calculate correct amount.

G PROBLEM	CAUSE	ACTION
Milky appearance of coating film.	Presence of moisture.	Increase drying time/temperature prior to coating. Keep assemblies dry until coating is performed.
	Contaminated coating material.	Use fresh material. Employ age control.
	Air leak in deposition chamber (parylene only).	Find and seal leak. Service vacuum pump and trap. Maintain vacuum specified by equipment manufacturer.

H PROBLEM	CAUSE	ACTION
Incomplete cure.	Aged coating material.	Replace with fresh material. Exercise age control.
	Contaminated coating material.	Replace with fresh material.
	Inadequate time/temperature.	Consult with material supplier for optimal cure schedule.
	Inadequate power density for radiation cure.	Optimize distance and power density of UV source.
	Areas shielded from irradiation.	Change to UV curable coating with shadow cure.
	Cure inhibition by incompatible materials.	Review material call-out on drawing with regard to compatibility with coating material. Buffer coat incompatible materials or replace with compatible material.

19.1.2 Polyurethane Conformal Coatings

A PROBLEM	CAUSE	ACTION
Coating has runs or sags.	Excess material.	Lower viscosity of material by thinning prior to application.

B PROBLEM	CAUSE	ACTION
Coating does not wet some areas of some components on the PWB assembly.	Foreign material on board.	Improve cleaning process prior to conformal coating.
	Material incompatibility (some electrical components are made with silicone resin. Urethane conformal coatings may not wet these components well).	Change components to one which is not made with silicone resin, if possible.

C PROBLEM	CAUSE	ACTION
''Fish eyes'' in coating.	Foreign material on PWB assembly prior to conformal coating.	Implement improved cleaning process.

D PROBLEM	CAUSE	ACTION
Bubbles in coating.	Moisture or solvent entrapment.	Slow down cure by lowering temperature and increasing time. Apply coatings in thin layers, allowing time for moisture and solvent to evaporate between coatings.

E PROBLEM	CAUSE	ACTION
Poor adhesion.	Surface contamination.	Implement improved cleaning process.

19.1.3 Silicone Conformal Coatings

A PROBLEM	CAUSE	ACTION
Coating takes excessive amount of time to fully cure.	Insufficient moisture content in surrounding air.	Place coated assemblies in higher humidity environment.

B PROBLEM	CAUSE	ACTION
Silicone coated PWB assembly attracts foreign particles which cannot be removed by normal cleaning process.	Silicone conformal coatings have high tack and inherently attract foreign material.	Isolate PWB assemblies in clean environment after conformal coating.

19.1.4 Paraxylylene Conformal Coating

A PROBLEM	CAUSE	ACTION
Coating is on areas which do not require coating.	Paraxylylene coats all exposed areas during the application process.	Mask off areas that do not require coating with RTV silicone or tape. Remove after coating process.

B PROBLEM	CAUSE	ACTION
Coating exhibits poor adhesion to PWB assembly which had been previously coated with paraxylylene.	Coating does not adhere well to itself.	For paraxylylene coatings, one thick application is preferred over several thin applications.

C PROBLEM	CAUSE	ACTION
Coating chamber does not seal adequately.	Buildup of paraxylylene inside chamber affecting o-ring seal.	Remove buildup.

D PROBLEM	CAUSE	ACTION
High pressure in paraxylylene chamber.	Volatiles in part to be coated.	Remove volatiles prior to insertion in chamber or continue to pump down until volatiles are removed.

19.2 VARNISHING

Coils, torroids, transformers and similar magnetics devices used for power conversion, are often coated by dipping with and without vacuum and with and without pressure, with a variety of polymeric coatings containing organic solvents as vehicles (varnishes) or 100% solids (solventless) formulations to protect them against mechanical abuse and against environmental effects (corrosion, effects of moisture on electrical signals). These materials may be transparent, translucent or opaque (with pigments). Surface cleanliness is not as critical (except for high voltage devices) as need for conformal coatings. Typical process problems arise from lack of materials control (pot life, shelf life), contamination introduced into the dip tanks by masking materials, and materials compatibility. In cases where vacuum/pressure impregnation is employed, lack of process controls also will cause process problems.

19.3 POTTING AND CASTING

Some sub-assemblies/modules are totally encased by polymeric materials. This is referred to as potting when the module container becomes part of the potted assembly, or as casting when the potting container (mold) is removed after hardening of the encapsulants. In most cases, except for high voltage circuits, cleanliness of the encased surfaces is not important. Adhesion at the case/potting wall, however, is important to preclude moisture permeation. Excessive voids in the encapsulants also will promote moisture permeation. Hence common problems arise from materials compatibility with regard to adhesion and impregnation characteristics achieved with the technique employed. In high voltage applications, loss of adhesion yields laminar voids while incomplete volatile removal will yield bubbles that contain air and can be cause for premature failure from corona effects.

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Inspection and Test
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Section 20
Inspection and Test

20.0 INSPECTION AND TEST

There are times when evaluation or tests indicate the product tested is defective. This section addresses the various ways that improperly performed tests and inspections may indicate acceptable product as defective (false alarms) or defective product being accepted (misses). Included in this section are visual inspections, microsection preparation, examination of microsections, automatic optical inspection (AOI), and electrical, thermal, chemical and mechanical testing.

This section does not attempt to delineate the many defects that are the result of previous processing operations; defects that are found during inspection and test are covered in detail in the appropriate processing sections of this Handbook.

20.1 METHODS OF INSPECTION AND TEST

In the past, most inspection was performed by inspection personnel visually examining the printed board or internal layers for defects. Magnifications of up to 40x were used for visual inspection and microsections were examined optically at magnifications from 100x to 1000x. Electrical testing was largely limited to hand probing and, due to the labor involved, it was often limited to testing associated coupons rather than the entire circuit.

It has been recognized that visual inspection and manual electrical testing was not only inefficient, but was prone to error and missed defects. Today, except for boards with non-complex circuitry and short runs, almost all visual inspection and electrical testing is performed by automatic equipment which can repetitively, tirelessly and accurately inspect and test finished boards, internal layers and other in-process product.

Microsection examination still remains a manual task assigned to personnel with microscopes; general agreement has standardized magnification at 100x, with 200x for referee evaluations.

20.1.1 Equipment

Equipment used for printed board inspection and test has become very complex. Considerable knowledge and skill are required to operate it correctly. Many techniques are used to insure the equipment is operating properly; however, it is most desirable to have known standards and other instruments available to verify results. Calibration should be performed on a periodic schedule with records maintained as to calibration status; some equipment requires calibration with each lot or each new set-up.

20.1.2 Personnel

The inspectors, testers, laboratory technicians and operators who are inspecting and testing the printed boards or associated coupons should be well schooled in printed board processing and the inspection task. Valid inspection results and the correct naming of defects greatly enhances the trouble-shooting and corrective action efforts.

20.2 CLEANLINESS

20.2.1 Ionic Contamination

Most testing for ionic contamination is performed on automatic equipment designed for that purpose, although a manual method may also be used. Consistent, accurate and repetitive results require considerable practice when this test is performed manually. The method using the automated equipment has a standardization technique which makes errors less likely. (Also see IPC-TM-650, Test Method 2.3.25.)

20.2.1 Ionic Contamination

A PROBLEM	CAUSE	ACTION
Results indicate excessive contamination or wide variations in readings among test parts within the same lot.	Resistivity test equipment malfunctioning/ out-of-calibration.	Verify equipment operation and calibration.
	Boards contaminated during storage or from handling prior to resistivity test.	Improve handling and storage techniques.

20.2.1 Ionic Contamination (continued)

B	PROBLEM	CAUSE	ACTION
Machine keeps running and does not reach an endpoint, and/or readings are inconsistent.		DI water and alcohol not high enough in resistivity.	Test resistivity prior to running test. Change water/alcohol if necessary. If high readings persist, resin may need to be changed.
		Glassware, probes, etc., not sufficiently clean.	Test resistivity of water/alcohol after being in contact with glassware and probes for several minutes. Review cleaning procedures.
		Lack of operator skill causes inconsistent results.	Have operator do several practice runs on known clean and contaminated product. Standardize with values from equipment or pre-standardized product.
		Resistivity test equipment improperly operated.	Institute adequate training.

20.2.2 Organic Contamination

The test for organic contamination is required only in some specifications. Generally, considerable equipment is necessary to identify the contaminant and to determine if it is a harmful contaminant, such as fluxes, or whether it is a component of the laminate. (See IPC-TM-650, Test Methods 2.3.38 and 2.3.39.)

20.3 ELECTRICAL TESTING

Electrical testing consists of testing coupons for moisture and insulation resistance, insulation resistance as received, dielectric withstanding voltage, and the printed boards for isolation and continuity. Low resistance shorts (lack of isolation) are generally caused by defects in the area of imaging, etching, drilling or misregistration. High resistance shorts are most often the result of contamination or poor cleaning of printed boards or internal layers during processing. Dielectric withstand failures are seen when dielectric spacing is reduced by imaging, laminate or prepreg thickness or laminate voids. Refer to those sections for actions after reviewing probable cause.

20.3.1 Moisture and Insulation Resistance

Failure of this test is generally associated with cleanliness of the test coupon. Provided the printed board processing was adequate, the test coupon is often contaminated by handling, soldering of the electrical connections, or by moisture in the test chamber dripping on the coupon and causing high resistance shorts between the conductors. (Also see IPC-TM-650, Test Method 2.6.3.)

20.3.1 Moisture and Insulation Resistance

A	PROBLEM	CAUSE	ACTION
Resistance readings too low or below the requirement.		Excessive handling, such as fingerprints, smearing of solder between conductors, and external contamination.	Train operators and testers to handle parts on the edges with clean gloves. Keep parts separated in a clean environment when storing or transporting.
		Incomplete flux removal.	Check for flux residue. Clean several times using fresh flux remover and rinse with clean alcohol.
		Water dripping on coupon in the chamber.	Use a drip shield in the chamber to protect the test coupons.
		Incorrect test parameters and/or procedures.	Verify correct operation of test; calibrate all test parameters.
		Heavy scrubbing caused damage to the surface of the laminate.	Monitor scrubbing operations.
		Contamination under solder resist.	Test panels prior to solder resist for ionic contamination.

20.3.2 Insulation Resistance As Received

Failure is mainly associated with contamination which can occur during handling, provided the printed board and its internal layers were properly processed during fabrication. (See IPC-6012, Paragraph 3.9.4.)

20.3.2A

Resistance reading too low, below requirement or electrically shorted. (See Section 20.3.1A for Causes and Corrective Actions.)

20.3.3 Dielectric Withstand

A decrease in dielectric spacing or voids between conductors are the major causes of failure; refer to those areas of this Handbook after reviewing failure. (Also see IPC-TM-650, Test Method 2.5.7.)

20.3.3 Dielectric Withstand

A PROBLEM	CAUSE	ACTION
Coupons/circuits arc or short at test voltage.	Metallic bridges of tin-lead or other metal between test points on the surface.	Keep test coupons separated and place on a non-conductive surface for testing.

20.3.4 Surface Insulation Resistance

The SIR of a printed board is measured on one of the comb patterns on the IPC-B-25 test board (or similar) while in a humidity chamber, under conditions described in IPC-TM-650, Test Method 2.6.3. The surface insulation resistance is an indication of the cleanliness of the board surface and a function of the hygroscopic properties of the residues on the surface of the board.

A PROBLEM	CAUSE	ACTION
Resistance readings too low. (Also see Section 20.3.1A.)	Organic contamination from fusing fluids degrades high humidity SIR on test board.	Investigate alternate fusing fluids (consult suppliers for recommendations).

20.3.5 Electrical Continuity

Continuity failures within the printed board can be caused by nearly any of the operations performed during fabrication. Determination of whether failure is repetitive or random is helpful in deciding actions. Location of failure most often requires microsectioning or X-ray examinations. Corrective actions as indicated in the other sections of this Handbook are usually obvious after failure is located. Testing equipment, fixturing and using the wrong revision of HTE engineering are often a source of false reports. All failures should be verified by hand probing. (See IPC-6012.)

A PROBLEM	CAUSE	ACTION
Test shows failures that cannot be verified.	Fixture does not align test pins with lands.	Use overlays and visual aids to determine misalignment and correct fixtures. Check tooling holes in board for correct location.
	Test pins bent, damaged or will not provide sufficient contact.	Check fixtures periodically or before each run to determine damage and replace faulty pins.
	Incorrect test program or different revision of printed board being tested.	Check revision letters; check master board for correctness.
	Test equipment malfunction.	Always use a known good board to verify that the test equipment is properly functioning before testing the printed boards.

20.3.5 Electrical Continuity (continued)

B	PROBLEM	CAUSE	ACTION
Opens on surface that cannot be verified.		Dirty test fixture.	Clean pins; check connections.
		Surface contamination (nonionic).	Reclean boards to be tested.
		Solder mask smear or bleed across surface mount lands or in holes.	Remove solder mask in affected area and retest. Review solder mask application procedure. (See Section 16.0.)

20.3.6 Isolation (Shorts)

As with Continuity, shorts can be caused by a great many fabrication operations. After reviewing the type of short - high resistance (above 1000 ohms) or low resistance (below 100 ohms) - a determination can be made as to whether the short is metallic or a weak electrical carrier, such as ionic contamination. Physical evidence most often leads to the corrective actions as indicated in this Handbook. Equipment, fixturing and incorrect revisions cause many false failure reports. See the previous section on continuity. (Also see IPC-6012, Paragraph 3.9.2.2.)

A	PROBLEM	CAUSE	ACTION
Internal shorts on multilayer board.		Innerlayers with undetected shorts were used to fabricate multilayers.	Evaluate innerlayer inspection procedures to determine how faulty innerlayers were judged good. Visually examine innerlayers at a minimum magnification of 3 diopters (1-3/4 X). Use automatic optical inspection technique and equipment and/or electrically test 100%. Implement innerlayer inspection prior to lamination using positive film to detect shorts and negative film to detect opens.

B	PROBLEM	CAUSE	ACTION
Shorts on surface.		Surface contamination (ionic).	Re-clean boards to be tested.
		Grossly misaligned test pin(s).	Inspect and realign.
		Test pins or handling has smeared solder between conductors.	Check loading method of board onto test head, handle boards separately and do not place on hard surfaces.

20.4 VISUAL AND AUTOMATIC OPTICAL INSPECTION

20.4.1 Visual Inspection

Visual inspection is the only method that will detect many of surface and subsurface defects, such as laminate voids, delaminations, resin starvation, foreign materials, solder wetting of conductors, solder resist coverage, plating anomalies, and many dimensional requirements. Visual inspection of plating integrity in the holes is becoming very difficult as the boards become thicker and holes smaller. Microsectioning and electrical testing are required to detect plating problems in the smaller holes. Line width and spacing may also be sample checked by visual inspection; however, total conductor inspection for small voids and etchouts are better performed by automatic equipment. After evaluating any defect, refer to the sections of this Handbook for Cause/Action information.

20.4.1 Visual Inspection (continued)

A	PROBLEM	CAUSE	ACTION
Surface scratches and/or residues.		Handling has scratched conductor and or surface of board. Residues smeared across board.	Maintain a clean work station and provide easy access from containers to work station. Provide clean, renewable pads on which to place boards for inspection. Provide racks or separators.
		Foreign object such as inspection markers or tape residues produce a ''foreign material'' defect internally in the board.	Instruct operators on how to remove and clean inspection markers that may be left on acceptable product. Instruct lamination lay-up operators to visually check each layer (front and back) during lay-up.

B	PROBLEM	CAUSE	ACTION
Incorrect line width (or similar measurement).		Incorrect usage of side lighting creates a shadow that makes the conductor line seem wider.	Use proper lighting.
		Wrong magnification for measurement device.	Confirm correct power; have microscope professionally calibrated. Quick-verify by measuring something of precisely known width.

C	PROBLEM	CAUSE	ACTION
Voids in plated-through-holes.		Rough holes, such that dark shadows are cast that look like voids.	Microsection, or use a mirror or prism to see in the hole more effectively.
		Copper oxidation.	Confirm by microsection or backlighting techniques. (Dark spots that appear to be voids may be oxidation.) Institute use of an anti-tarnish after plating, prior to visual inspection. (Anti-tarnish compounds used should be compatible with long term storage and later soldering and conformal coating operations if the compounds are to be left on the board.)

D	PROBLEM	CAUSE	ACTION
Small surface imperfections (nodules or surface pits).		Extremely small surface imperfections may be difficult to identify.	They can be readily distinguished by using a small mirror or side light. The nature of the shadow will show the difference.

E	PROBLEM	CAUSE	ACTION
Bow and twist of double-sided board.		Rough handling.	See Introductory Section 1.4 on Handling.

F	PROBLEM	CAUSE	ACTION
Error in measurement of plated-through-hole diameter after using the tapered pin gauge.		Tapered gauge pin picked up the reflowed closure in the center of the plated-through-hole, producing error in measurement.	Correct measurement technique to reflect the use of pin gauges.

20.4.2 Automated Optical Inspection (AOI)

This equipment is capable of detecting defects in conductor width and spacing, annular ring, conductor voids, pinholes, and design rule deviations. These machines use different detectors, light sources, etc., to make inspection of finished boards and internal layers possible. Sometimes the conductors on both sides of thin internal layers will be detected from one side, causing errors. Ensure that source and detector are compatible with your laminate/product. (Also see IPC-AI-642.)

A PROBLEM	CAUSE	ACTION
Excessive violations.	Incorrect inspection parameters entered.	Check the actual parameters by measuring the pad size, conductor and spacing widths on the board. Enter the correct value(s) as necessary.
	Contamination on the panel.	Re-strip, micro-etch or scrub the panel to remove the contaminants.
	Panel misregistration.	Check the pinning on the table or try to relearn the panel.
	Incorrect signal setting.	Recalibrate the signal.
	Incorrect inspection area(s).	Check all inspect and do not inspect areas. Change as necessary.
	Inspection equipment viewing conductors on both sides of internal layer simultaneously.	Check with equipment supplier for best source and detector. Laminate can be furnished with blocking dyes that will accommodate most equipment.
	Equipment sees minor pits and depressions as pinholes on copper surfaces and buried via internal layers.	Check with equipment supplier; some adjustments and source/detectors can decrease error. Surface treat with oxide or a light surface etch. Review Section 10.0 determine cause of the pits, etc.

B PROBLEM	CAUSE	ACTION
Violations missed.	Misregistration.	Check the pinning/orientation of the panel on the table. Try relearning the panel.
	Contamination on the panel.	Re-strip, micro-etch or scrub the panel to remove the contaminates.
	Incorrect inspection area(s).	Check all inspect and don't inspect areas.
	Signal incorrectly set.	Reset the signal.
	Beyond the operating resolution.	Check your AOI system specifications. Change to a higher resolution.
	Incorrect parameter set up.	Check the current parameters and change them to meet your needs. Then re-scan the panel.
	Defect was found but not verified.	Re-scan to verify that the defect can be found, then check verification equipment.
	Power supply problem.	Check all power supplies.
	System logic problem.	Reset the system and scan again. Run a test panel to verify that the system is finding defects.
	Misplaced pseudo defect.	Check pseudo defects. Reclassify as necessary.

C PROBLEM	CAUSE	ACTION
Shorts missed.	The short may have been learned.	Relearn the panel with a new "Golden Panel."

20.4.2 Automated Optical Inspection (AOI) (continued)

D PROBLEM	CAUSE	ACTION
Missing power and ground defects.	Defective learned panel.	Relearn the panel with a new "Golden Panel."

E PROBLEM	CAUSE	ACTION
Marking unit problems.	Pen/ink unit is dry.	Replace pen/ink.
	Pen/ink unit not calibrated.	Recalibrate the marking unit. Reboot the AOI system.

F PROBLEM	CAUSE	ACTION
Verification problems.	AOI equipment failure.	Check AOI system. Run a test panel to ensure the system is functioning properly. Re-scan the panel(s).
	Marking Unit failure.	Check marking unit. Change pen/ink as necessary.
	Incorrect parameter set up.	Check the parameter set up on the AOI system. Make necessary changes. Re-scan the panel.
	Verifier error.	Check verification procedure. Re-scan the panel on the AOI to ensure that the defect(s) can be found. If the defect cannot be found, see Section 21.4.2B regarding missing violations.
	Verification equipment.	Check that the verification equipment is properly calibrated and functioning correctly. Use a high power microscope to view the panel defect areas.

20.5 THERMAL STRESS (Solder Float)

20.5.1 Coupon Conditioning and Thermal Stress

The thermal stress procedure is mainly used to test the integrity of the through-holes in the test coupon after floating it on molten solder. It also tests resistance to delamination and measling, and solderability of the holes. Failures may result from insufficient or improper conditioning in which the moisture absorbed by the coupon may not be adequately removed. (See IPC-TM-650, Test Method 2.6.8.)

A PROBLEM	CAUSE	ACTION
Blistering or measling of the laminate observed after thermal stress.	Insufficient moisture removal prior to test.	Dry boards at 135-149°C for 6 hours minimum to remove moisture. Moisture may be absorbed into the laminate and it is important to store coupons in a desiccator to prevent possible blistering or measling from reabsorption of moisture prior to floating.
	Fractures along edge of sample caused by shearing.	Sand the edges of samples or exclude from inspection area.

B PROBLEM	CAUSE	ACTION
Poor solderability on the lands and in the holes.	Extended drying at temperature.	Test solderability after several drying increments and determine the optimum drying cycle for your product.

20.5.1 Coupon Conditioning and Thermal Stress (continued)

C	PROBLEM	CAUSE	ACTION
Missing power and ground effects.		Temperature too high or time too long.	Check solder pot before the start of each test group with a secondary temperature measuring instrument. Use a timer that is set and actuated by the operator performing the solder float test.
		Bake not sufficient.	Bake of 6 hours may not be sufficient for thicker boards or older boards or multilayers with ground or power planes. Try baking for longer times.

20.6 MICROSECTIONING

The coupon is microsectioned and evaluated at the center of the plated through holes. Coupons which have been thermally stressed and those which have not been thermally stressed are often both viewed. Improper microsection preparation techniques may produce defects which are not actually present in the printed board or coupons. Other variations in technique can produce effects which mask defects in the plated through hole. (See IPC-TM-650, Test Method 2.1.1, and IPC-MS-810.)

20.6.1 Microsection Preparation

Mount preparation is of primary importance. Care must be taken not to induce stresses in the coupons from cutting the coupon or using excessive pressure during the mounting process. The mounting, grinding and polishing steps may be performed on multiple mounts using automatic metallographic equipment made for this purpose. The head pressure, rotation rate and the grinding/polishing abrasive size all have a major influence on microsection quality. Initial setups and evaluations for the best microsection must be made before committing the product coupons to microsection evaluation.

20.6.1 Microsection Preparation

A	PROBLEM	CAUSE	ACTION
Hole walls and internal foils distorted.		Poor quality coupon punch, or the initial cut is too close to holes.	Coupons are best routed or diamond-sawed. If punched, make sure punch is sharp and has a relief so that it does not contact lands. Allow sufficient space between coupon cut-out and holes. Do not punch any coupon thicker than 60 mils.

B	PROBLEM	CAUSE	ACTION
Voids in potting compound in the holes of mounted coupon, causing poor edge retention of hole walls. (See Figures 20-1 and 20-2.)		Voids in potting compound from not enough flow of compound through holes.	Increase flow of potting compound by using a vacuum or pressure encapsulation. Investigate alternate types of compound. Consult metallographic equipment supplier for assistance. Pour compound from one side and let flow through holes. If using two coupons in mount, pour compound between them.
		Incorrect epoxy resin/hardener ratio.	Carefully mix potting compound per supplier's recommendations.

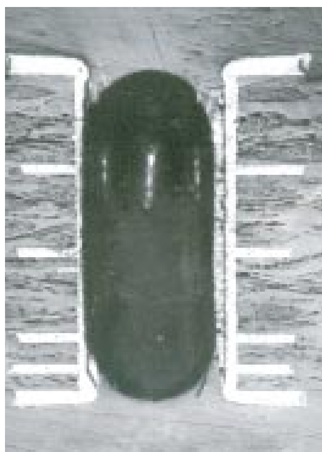

Figure 20-1. Potting compound void.

Figure 20-2. Plating torn away during microsection preparation because of potting compound void in hole.

20.6.1 Microsection Preparation (continued)

C	PROBLEM	CAUSE	ACTION
Mounted coupon ground past the center of the hole. (See Figure 20-3.)		Grinding operation too abrasive and/or too long.	Use care during grinding operation and measure frequently to avoid passing the center of the hole. (Larger plating thickness measurements are obtained on specimens not ground to the center of the hole.) If using automatic grinding equipment, follow manufacturer's recommendations to shorten grinding time. Check grinding grit in use.

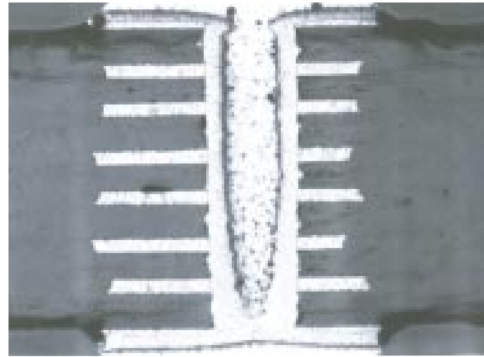

Figure 20-3. Coupon ground past center of hole.

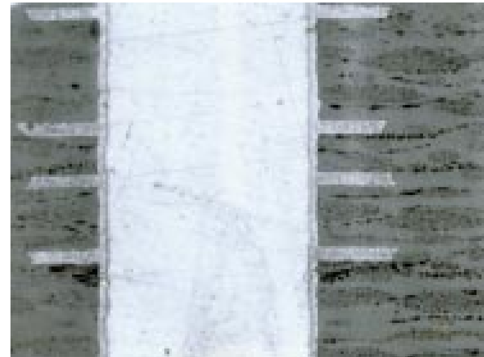

Figure 20-4. Scratches on mount surface.

D	PROBLEM	CAUSE	ACTION
Scratches on surface of mount that won't polish out. (See Figure 20-4.)		Grinding too heavy with coarse grit paper.	Use successively finer grit paper as the centers of the holes are approached.
		Polishing cloth is contaminated (scratches appear during the polishing steps).	Clean or replace polishing cloth. Prevent contamination from previous steps by cleaning thoroughly between sequential grinding/polishing operations. Always rinse the mount thoroughly and dry between each grinding/polishing step.
		Improper handling or storage of prepared mount.	Ensure proper storage and handling that avoids scratching the polished mount.
		Unfiltered water being used on polishing steps, contaminating the polishing cloth.	Use filtered or DI water during polishing steps.

E	PROBLEM	CAUSE	ACTION
Polished mount shows coupon with triangular-shaped holes.		Uneven (hand) pressure applied during grinding operation.	Train operator in proper grinding technique. Turn coupon 1/4 turn every few seconds during grinding. Apply only light pressure.
		Coupon is not perpendicular (it is tilted) in mount.	Review coupon mounting procedure. (See 20.6.1F.)

F	PROBLEM	CAUSE	ACTION
Tilted coupon; coupon is not upright or perpendicular in mount.		Tooling holes not drilled the same as the plated holes.	Drill all holes in coupon at same drill machine setup if possible.
		During mounting operation, coupons were not kept upright or perpendicular to bottom of mount cup.	Use clips or equivalent to ensure coupons are kept upright, especially during the pouring of the potting compound.

20.6.1 Microsection Preparation (continued)

G	PROBLEM	CAUSE	ACTION
Rounded edges and high metal areas with either hand or machine polishing.		Too much pressure applied during the polishing steps.	Decrease pressure. Only enough pressure should be applied as is needed to keep the coupon in place.
		Too much polishing.	Shorten polishing time.

H	PROBLEM	CAUSE	ACTION
Metal smeared at the interconnect.		Too much pressure during grinding and polishing operations.	Decrease pressure. A light chemical etch will remove light metal smearing. It may be necessary to repeat some grinding and polishing steps to remove the smear.

J	PROBLEM	CAUSE	ACTION
Poor edge retention.		Mounting compound has shrunk and left hole walls unsupported.	Check for correct mixture of compound. Low shrinkage mounting compound are available from metallographic suppliers.
		Voids in the potting compound.	See 20.6.1B.

20.6.2 Microsection Etching

Etching is a manual operation and requires considerable practice and skill by the technician. Over-etching or under-etching may cause the microsection to be incapable of being evaluated. The most commonly used etchant for printed board microsectioning is the ammonia/hydrogen peroxide solution. (See IPC-TM-650, Test Method 2.1.2.) Etch time depends on the dwell time and the age of the solution. The swab that holds the etchant should only be used to agitate the solution on the surface and not to rub the copper or mount surface.

A	PROBLEM	CAUSE	ACTION
Etchant appears uncontrollable, either too slow or too fast.		Inconsistent make-up procedures.	Make new etchant every four hours and let sit a few minutes before use. Check make-up chemistry in use; hydrogen peroxide and ammonia are supplied in several different strengths. Make certain ammonia and peroxide are fresh. After applying etchant to mount, rinse off thoroughly.

B	PROBLEM	CAUSE	ACTION
Dark line between plating and foil at electroless deposit line.		Surface has been over-etched.	Use a very short etch time and it may be necessary to evaluate twice. (See 20.6.2A.) Generally, microsections should be evaluated before and after etch.
		Electroless copper etches much faster than electroplated copper or foil.	Some types of electroless deposits are better etched with a mixture of chromic acid and sulfuric or hydrochloric acid. See metallographic handbooks or contact electroless copper supplier for recommendations.

20.6.3 Microsection Evaluation

The most important equipment for evaluation is the microscope. The better metallographic microscopes eliminate much of the viewer error and prevent ‘‘wrong calls.’’ Most evaluations are performed at 100X magnification, however referee and other resolutions may require higher magnifications. Special features such as polarizing lenses and dark field are very useful and often aid the evaluator. Since plating thickness, dielectric thickness and laminate voids are measured during the evaluations, measuring attachments are required; calibration scales must be available to the technician. Refer to IPC-A-600 for photomicrographs of acceptable (and unacceptable) microsections. (Also see IPC-TM-650, Test Method 2.6.8, regarding microsection evaluation.)

A PROBLEM	CAUSE	ACTION
Cracks in copper plating after thermal stress test. (See Figure 20-5.)	Insufficient polishing of mount; scratches or smeared tin-lead.	Re-polish mount.
	Solder temperature too high during test, or excessive float time.	Review thermal stress test procedure. (See IPC-TM-650, Test Method 2.6.8.)

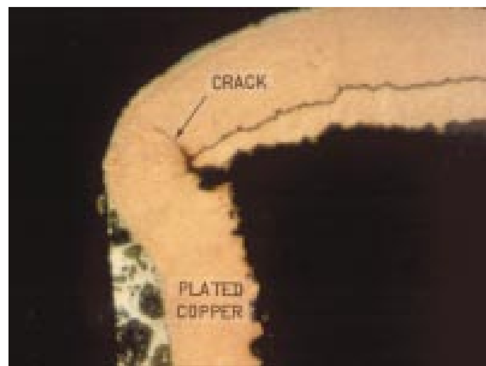

Figure 20-5. Corner crack in copper plating.

Figure 20-6. Innerlayer pull-away from barrel.

B PROBLEM	CAUSE	ACTION
Innerlayer pull-away from barrel after thermal stress test. (See Figure 20-6.)	Copper smeared or pulled during grinding of microsection.	Grind mounts with even, steady pressure; do not use excessive force.
	Coupons not baked prior to thermal stress test.	Coupons should be baked to remove moisture. (See IPC-TM-650, Test Method 2.6.8.)
	Incorrect solder temperature during thermal stress.	Confirm solder temperature with high-temperature thermometer (do not use alcohol thermometer).

C PROBLEM	CAUSE	ACTION
Plating measurement greater than expected; plating thickness out-of-spec.	Section not ground to center of hole. (See Figure 20-3.)	Measure hole diameter and compare with the drilled hole diameter specified. Adjustments may be necessary on grinding/polishing equipment.
	Microscope magnification incorrect.	Follow actions detailed in Section 20.4.1B.
	Plating is smeared from grinding operation.	Re-polish mount. In the case of soft metals such as gold or tin-lead, an overplate of copper or nickel before mounting the section will help prevent smear. Voids or bubbles in the mounting compound can result in insufficient ‘‘support’’ of the plated metal during grinding. Follow actions detailed in Section 20.6.1B.

20.6.3 Microsection Evaluation (continued)

D PROBLEM	CAUSE	ACTION
Resin smear shows in cross-section on a board that passed in-process check.	Over-etching of coupon mount, resulting in excessive etch of electroless copper.	Re-polish specimen and lightly etch. (See 20.6.2.)
	In-process check not totally reliable because porous smear allows penetration of sulfide or silver decoration solutions to copper innerlayers, giving false conclusions.	Consider microsectioning as in-process check; review Section 6.2.
	Non-uniform smear removal across panel, causing inconsistent results.	Check smear removal process for uniformity of removal. Follow actions detailed in Sections 6.2 and 6.3.
	The defect may not be resin smear but may be an interconnect defect attributable to some other cause.	Re-examine microsection and determine exact type of defect; many interconnect defects are wrongly classified as resin smear.

E PROBLEM	CAUSE	ACTION
Laminate voids.	Coupon not properly baked before thermal stress test.	Ensure proper bake of coupons before thermal stress. (See IPC-TM-650, Test Method 2.6.8.)

20.7 OTHER TEST METHODS

20.7.1 Thermal Shock

This is a test in which the change in electrical resistance is measured after 100 temperature cycles. (See IPC-TM-650, Test Method 2.6.7.2.) A change in resistance greater than 10% is specified as a failure. The instrumentation used must be of the proper type and sufficient accuracy to measure the change. With four-point connections and the size of circuitry in the coupons tested, readings are in the milliohm range. Slight variations in test conditions can cause variations in readings that could indicate failure when the sample tested is compliant.

A PROBLEM	CAUSE	ACTION
Resistance increases greater than 10%.	Instrumentation not reporting change accurately.	Always use the same instrument for before and after readings. Calibrate the instrument with the same standard for the first and last cycle readings. Make sure that the stabilization time is the same. Hold the chamber temperature so that the temperature is not only within the 5°C tolerance, but temperature for the first reading and the last reading should be nearly the same as is possible.

20.7.1 Thermal Shock (continued)

B PROBLEM	CAUSE	ACTION
Microsection exhibits defects.	Temperature excursions outside the limits for the material and/or product being tested.	The temperature to which the coupon is subjected may cause expansions with strains due to thermal expansion that may cause failure even if the temperature during measurement is correct. Exceeding the glass transition temperature (T_g) at any time during the test may greatly increase the likelihood of failure. Make sure that the test temperature is the one to be used for the specific laminate being tested.
	Coupon tests open.	Connection wires have broken. Re-solder connections and bring coupon to test temperature or repeat test with new coupon.

20.7.2 Tensile Strength and Elongation

This is a test for the quality of the copper plating and may relate to the ability of the plated hole wall to withstand the expansion that will occur during thermal stress and thermal shock. (See IPC-TM-650, Test Method 2.4.18, for test procedure.) The coupon must be free of inclusions, pits, nicks, scratches or other defects that will act as initiation points for premature failure.

A PROBLEM	CAUSE	ACTION
Tensile strength and elongation lower than required (or early failure on test equipment).	Test material (plated copper) not thick enough.	The thickness of the sample does not change the actual properties of the material; however, since very small defects will cause premature failure, plate the material to be tested to 0.025 minimum to 0.076 mm thickness.
	Crosshead speed not correctly set.	A fast rate of straining may produce early failure. Make sure that the crosshead speed is 0.61 meters/minute.
	Clamping places uneven strain on one side of test coupon.	The clamps should be supported so that they are free to rotate and distribute the strain evenly across the coupon during test.
	Sample cutter or etching causes nicks in the edge.	Inspect each coupon before testing for any edge defects that may cause failure.

20.7.3 Bond Strength of Surface Mount Lands

The integrity of the bond strength of the surface foil is tested to insure that the surface mount lands have adequate bond strength after processing. (See IPC-TM-650, Test Method 2.4.21.1.)

A PROBLEM	CAUSE	ACTION
Land exhibits low bond strength.	The test pins are not soldered near the center of the land or the shaft of the pin is not perpendicular with the board surface, which causes the pull on the land to be placed in the peel mode, which has a lower strength.	Center the pins near the center of the land and maintain perpendicularity with the board surface.
	Soldering degrades the bond strength.	Maintain soldering temperature per requirements and use as short of a time as possible with most of the heat being applied at the junction of the pin head and shaft.

20.7.4 Rework Simulation

This test simulates the solder-in and removal of a component five times. Operator skill is needed to prevent a failure of the test when the printed boards are made with a low glass transition temperature material such as difunctional epoxy. Solder operators must be trained in the specific soldering techniques used in this test. (See IPC-TM-650, Test Method 2.4.36.)

A PROBLEM	CAUSE	ACTION
Lifted lands and internal defects in the hole.	Using standard soldering iron tip temperatures or holding the iron on the land.	Check tip temperature with a secondary measuring device; do not depend on the dial setting on the iron. Apply the heat mainly to the wire and do not hold the soldering iron tip on the land. Provide the operators with practice pieces and training before allowing them to perform the test.

20.7.5 Gold Porosity Testing

There are two well-known methods for checking gold porosity. The nitric acid test, where samples are suspended over the acid, is generally considered a destructive test. The electrographic test, involving current and indicating solutions, can be a non-destructive test.

A PROBLEM	CAUSE	ACTION
Evidence of pores or basis metal along the edge of finger or conductor.	No gold along vertical edge of finger.	Unless gold is ‘‘conformal,’’ that is, plated on after final copper etch, there will be exposed basis metal along the edge.
	Test too severe.	Electrographic: check rectifier and current. Excess current will increase rate of ion migration. Nitric acid: check test method for correct exposure times.
	Final fabrication operations (i.e., punching or blanking) have loosened plating edge so that test solutions can get to basis metal (especially with tabs or fingers).	Inspect/sharpen dies or other fabrication equipment. Check severity of test method.

B PROBLEM	CAUSE	ACTION
‘‘Pores’’ follow a regular pattern on surface.	Sample part is defective.	Inspect parts closely for scratches, nicks, dents before testing.
	Surface contamination or poor cleaning.	Reclean parts to be tested.

20.7.6 Copper Hole Wall Thickness Using Caviderm Type Resistance Measurements

A constant current is applied through the hole under evaluation, and the voltage drop is measured. This voltage drop corresponds to the thickness of the plating in the hole. Only the average thickness of the lowest-resistance metal is given.

A PROBLEM	CAUSE	ACTION
Thickness reading goes off scale.	Inadequate contact of probe to hole pad surface.	Reposition board and take new reading.

20.7.6 Copper Hole Wall Thickness Using Caviderm Type Resistance Measurements (continued)

B PROBLEM	CAUSE	ACTION
Measured plating thickness out-of-specification.	Wrong hole diameter or board thickness entered.	Ensure proper board thickness and hole diameter used.

20.7.7 Plating Thickness (Beta Backscatter)

This method for measuring plating thickness involves irradiating the area of interest with beta rays and measuring the amount of radiation backscattered. The intensity of the backscattered radiation is proportional to the thickness of the plating.

A PROBLEM	CAUSE	ACTION
Improper plating thickness.	Measuring probe is not centered properly on the plated surface.	Move probe so that its measuring area is entirely on plated surface. If the area being measured is too small, a low reading will result.
	Machine not calibrated.	Calibrate equipment. Be sure to use the correct standard that is for the plating range to be measured.
	Rough, excessive, or uneven plating or scratches. (Tends to ''lift'' probe off surface, resulting in an incorrect reading.)	Move probe to smoother area.
	Readings taken in ''thief'' area of board.	Plating thickness in the copper border area is usually thicker than in the circuit area of the board.

20.7.8 Plating Thickness (X-Ray Fluorescence)

A beam of X-rays is directed at the plating area to be measured, causing the sample to give off fluorescent X-rays at wavelengths characteristic of the metal present. The intensity of the fluorescent X-rays is proportional to the amount of the metal present. This method can measure a smaller area than the backscatter method and is more accurate. Multiple layers of metal thicknesses can be measured at once, such as nickel and gold or copper and tin-lead. Tin-lead ratio can also be determined using X-ray fluorescence.

A PROBLEM	CAUSE	ACTION
X-ray measured copper thickness thicker than microsection shows on boards with nickel plating.	Filter not used when making copper thickness measurement.	Use correct filters for metals to be measured.

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Modification, Rework and Repairs
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Section 21
Modification, Rework and Repair

21.0 MODIFICATION, REWORK AND REPAIR

This section deals with those defects created by the rework, repair, or modification procedures. Complete and detailed guidelines for modification, rework and repair can be found in IPC-7711 & 7721.

21.1 TERMS AND DEFINITIONS

Terms and Definitions

The revision of the functional capability of a product in order to satisfy new acceptance criteria.

21.1.2 Rework

The act of reprocessing non complying articles, through the use of original or equivalent processing, in a manner that assures full compliance of the article with applicable drawings or specifications.

21.1.3 Repair

The act of restoring the functional capability of a defective article in a manner that precludes compliance of the article with applicable drawings or specifications.

21.2 COMPONENT REMOVAL AND REPLACEMENT

Selecting the optimum method for rework/repair depends on a variety of factors. These include: type and size of component; type of substrate; component mounting site; whether installing or removing the component; whether the component is being salvaged; applicable workmanship specifications; and EOS/ESD control requirements.

Every rework/repair method and its attendant equipment has advantages and disadvantages in each particular installation or removal situation. These can be evaluated in terms of their ability to achieve the process goals and guidelines, when used by a properly trained operator.

21.2.1 General Problems

A	*PROBLEM*	*CAUSE*	*ACTION*
Insufficient solder reflow to effect component removal.		High thermal mass condition.	Use pre-auxiliary heating.
		Insufficient heat from primary heating device.	Use more efficient heating method or device, or increase idle tip temperature.
		Insufficient heating time.	Increase heating time.

B	*PROBLEM*	*CAUSE*	*ACTION*
Component not removable after solder reflow or lifted lands upon attempted removal.		Solder resolidifying before removal can be effected.	Use method in which removal can be effected immediately upon complete reflow of all joints.
		Adhesive holding component.	Shear bond after heating to free component (i.e., theta movement).
		Not all joints have been reflowed.	Use alternate method, which provides rapid simultaneous reflow of all joints, followed by immediate removal to keep process time to a minimum. Assure that heated tip or air properly contacts and reflows all joints equally.

C	*PROBLEM*	*CAUSE*	*ACTION*
Lands being lifted or damaged during removal of old solder.		Lands being overheated.	Use lower temperature or alternate method which doesn't overheat lands.
		Lands subject to mechanical force while being heated.	Use alternate method or minimize mechanical force to which lands are subjected.

D	*PROBLEM*	*CAUSE*	*ACTION*
Insufficient or poor adhesion of solder on lands during pretinning operation.		Lands oxidized or contaminated.	Clean lands using appropriate method.
		Idle tip temperature of soldering iron too high.	Lower idle tip temperature.
		Improper size or shape of soldering tip.	Use appropriate size and shape tip.

21.2.1 General Problems (continued)

E	PROBLEM	CAUSE	ACTION
Dispersion or solderballing of solder paste during reflow.		Air temperature too hot.	Lower air temperature.
		No predrying of solder paste.	Predry solder using convective method.
		Old or defective solder paste.	Use fresh, accepted solder.

21.2.2 Conductive Heating Methods

A	PROBLEM	CAUSE	ACTION
Insufficient solder reflow to effect removal.		Insufficient thermal linkage between heating tip and work.	Improve thermal linkage with solder and/or select tip which provides more contact area.

B	PROBLEM	CAUSE	ACTION
Misalignment of component to land pattern during SMD installation.		Some leads are not tacked or the component is not being held in place.	Tack some leads or hold component in place during reflow, or use convective method.

C	PROBLEM	CAUSE	ACTION
Dispersion or solderballing of solder paste during reflow.		Soldering tip too hot.	Use convective method or lower tip temperature.

D	PROBLEM	CAUSE	ACTION
Blistering or measling of substrate, or lifted lands during installation or removal.		Preheat temperature too high.	Lower preheat temperature.
		Tip temperature too high.	Reduce tip temperature.
		Too much pressure applied.	Reduce pressure on tip and improve thermal linkage with solder joint(s).
		Poor contact with solder joints.	Assure good thermal contact with solder joint(s).

21.2.3 Convective Heating Methods

A	PROBLEM	CAUSE	ACTION
Insufficient solder reflow to effect SMD removal.		Insufficient air temperature.	Use more efficient heating method or increase air temperature.
		Insufficient air flow.	Increase air flow.
		Air nozzle too far from work.	Bring air nozzle closer to work.

B	PROBLEM	CAUSE	ACTION
Misalignment of component to land pattern during SMD installation.		Air velocity too high.	Lower air flow rate.

C	PROBLEM	CAUSE	ACTION
Dispersion or solderballing of solder paste during reflow.		Air velocity too high.	Lower air flow rate.

21.2.3 Convective Heating Methods (continued)

D	*PROBLEM*	*CAUSE*	*ACTION*
Blistering or measling of substrate, or lifted lands during installation or removal of component.		Preheat temperature too high.	Lower preheat temperature.
		Air temperature too high.	Reduce air temperature.
		Air volume or velocity too high.	Reduce air volume or velocity or use more focused convective heating method.

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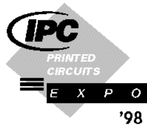

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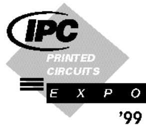

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