



IPC-9121

# Troubleshooting for Printed Board Fabrication Processes

Developed by the Printed Board Process Effects Handbook  
Subcommittee (7-21) of the Process Control Management  
Committee (7-20) of IPC

**Supersedes:**  
PCL Sections of IPC-PE-740A -  
December 1997

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

Contact:

IPC

## Table of Contents

<b>1 GENERAL INTRODUCTION</b> .....	1-1	<b>3 ARTWORK AND IMAGING</b> .....	3-1
1.1 IPC-9121 Format Example .....	1-1	3.1 Phototools .....	3-1
<b>Issue:</b> Photoresist under-exposure .....	1-1	3.2 General Process Effects (Common with Silver and Diazo Phototools) .....	3-2
1.2 Guidelines for Effective Troubleshooting and Process Control .....	1-1	<b>Issue:</b> Feature size dimensions too large (larger than CAD data) .....	3-2
1.3 Parameter Analysis .....	1-2	<b>Issue:</b> Feature size dimensions too small (smaller than CAD data) .....	3-4
1.3.1 Brainstorming .....	1-2	3.3 Diazo Phototools .....	3-4
1.3.2 Process Audit .....	1-3	<b>Issue:</b> Over-sized exposed features over entire copy .....	3-4
1.3.3 Initial Capability Study .....	1-3	<b>Issue:</b> Over-sized exposed features on center of copy .....	3-5
1.3.4 Optimization .....	1-3	<b>Issue:</b> Poor edge sharpness (blurred images) ....	3-5
1.3.5 Confirmation and Final Capability Assessment .....	1-3	<b>Issue:</b> Image gain, background discoloration in clear area – uniform high background (clear area) density .....	3-5
1.3.6 Parameter Control .....	1-3	<b>Issue:</b> Low $D_{MAX}$ (inadequate image density) 100% of the time .....	3-6
1.3.7 Corrective Action Plan .....	1-3	<b>Issue:</b> Low $D_{MAX}$ some of the time .....	3-6
1.4 Applicable Documents .....	1-3	<b>Issue:</b> Pinholes or voids in image .....	3-6
1.4.1 IPC .....	1-3	<b>Issue:</b> Specks in clear area of film .....	3-6
<b>2 DESIGN AND DOCUMENTATION</b> .....	2-1	<b>Issue:</b> Image distortion .....	3-7
2.1 Design .....	2-1	<b>Issue:</b> Straight lines, not part of CAD data, showing on processed film .....	3-7
2.2 Layout Problems .....	2-2	<b>Issue:</b> Random yellow spots in image area .....	3-7
2.2.1 Location of Holes and Terminations .....	2-2	<b>Issue:</b> Ammonia processor not developing properly, even with correct heating/ temperature .....	3-7
<b>Issue:</b> Components and PTHs are not referenced to datum or grid outline .....	2-2	<b>Issue:</b> Film sticking in processor .....	3-7
2.2.2 Electrical Description Inconsistency .....	2-4	3.4 Silver Halide Film (Master and Working Phototools, Laser Raster Plotted) .....	3-7
<b>Issue:</b> Layout does not match schematic or logic diagram or CAE file .....	2-4	<b>Issue:</b> Black lines too wide (clear lines too narrow) .....	3-8
2.2.3 Tooling Hole Location .....	2-5	<b>Issue:</b> Clear lines too wide (black lines too narrow) .....	3-8
<b>Issue:</b> Tooling holes not established or wrong size .....	2-5		
2.3 Electrical .....	2-6		
<b>Issue:</b> Electrical arcing between adjacent conductors .....	2-6		
<b>Issue:</b> Unable to achieve functionality/ reliability using high-speed/frequency (HS/HF) devices .....	2-6		
<b>Issue:</b> Conductor crosstalk and board radiation ( $Kr^2$ ) .....	2-6		

<b>Issue:</b> Low image density ( $D_{MAX}$ too low) .....	3-8	<b>Issue:</b> Specks or deposits on processed glass plate .....	3-12
<b>Issue:</b> Clear areas not clear enough ( $D_{MIN}$ too high) .....	3-8	3.7 Glass – Hard-Surface Image on Glass .....	3-13
<b>Issue:</b> Milky white color in clear area .....	3-8	<b>Issue:</b> Ragged lines .....	3-13
<b>Issue:</b> Pinholes .....	3-9	<b>Issue:</b> Pinholes or voids .....	3-13
<b>Issue:</b> Poor line edge quality .....	3-9	3.8 LDI and Other Digital Imaging Technologies ..	3-13
<b>Issue:</b> Black speck redeposit in clear area – irregular shape .....	3-9	<b>Issue:</b> Resist image has irregular (distorted) areas .....	3-14
<b>Issue:</b> Silver pepper spots in clear area – round shape .....	3-9	<b>Issue:</b> Evidence of skipped image pixels, rows .....	3-14
<b>Issue:</b> Yellow, orange/yellow or brown deposits in clear areas of film .....	3-9	<b>Issue:</b> Problems with front-to-back image registration on the top and bottom of the board .....	3-14
<b>Issue:</b> Powder deposits on film (yellow or white) .....	3-9	<b>Issue:</b> Incomplete polymerization of resist in exposed areas .....	3-14
<b>Issue:</b> Black line abrasion .....	3-10	<b>Issue:</b> The resist image has pinholes/voids .....	3-14
<b>Issue:</b> Streaking .....	3-10	<b>Issue:</b> Image lines have a scalloped (step-pattern) appearance, especially on angled lines .....	3-14
<b>Issue:</b> Image not sharp .....	3-10	<b>Issue:</b> Blurred image .....	3-14
<b>Issue:</b> Lines not straight .....	3-10	<b>4 HANDLING AND STORAGE</b> .....	4-1
<b>Issue:</b> Pinholes in phototool .....	3-10	<b>Issue:</b> Dent in copper foil .....	4-1
<b>Issue:</b> CAD database incompatible .....	3-10	<b>Issue:</b> Wrinkles in flex circuit coverlay .....	4-2
<b>Issue:</b> Long or slow CAD database conversion .....	3-10	<b>Issue:</b> Dent induced during lamination .....	4-2
<b>Issue:</b> The phototool will not produce a clear image .....	3-10	<b>Issue:</b> Damaged in packaging .....	4-3
3.5 Silver Halide Films – Protective Coatings .....	3-11	<b>Issue:</b> Blowholes in lam stack due to entrapped moisture .....	4-3
<b>Issue:</b> Finished, laminated (with protective coating) artwork film is curved or bent .....	3-11	<b>Issue:</b> Electrical test witness marks in wire-bond keep-out area .....	4-3
<b>Issue:</b> Protective coating film wrinkled or shrunken .....	3-11	<b>Issue:</b> Electrical test/excessive repeats (bed of nails) damage finish .....	4-3
3.6 Glass – Silver Halide .....	3-11	<b>Issue:</b> Receiving inspection defeating protective packaging (opening and poor resealing of desiccated packages) .....	4-3
<b>Issue:</b> Line width incorrect (over-sized or under-sized) .....	3-11	<b>Issue:</b> Inadequate packaging for protection of boards in storage in handling (different finishes) .....	4-3
<b>Issue:</b> Low image density .....	3-11		
<b>Issue:</b> Pinholes .....	3-12		
<b>Issue:</b> Poor-quality line edge .....	3-12		
<b>Issue:</b> Uneven density, mottle or streaks .....	3-12		

<b>5</b>	<b>BASE MATERIALS</b>	5-1	5.4.6	Chemical and Thermal Resistance	5-7
5.1	General	5-1	<b>Issue:</b>	Measles or crazing	5-7
5.1.1	Resins	5-1	<b>Issue:</b>	Weave exposure	5-7
5.1.2	Reinforcements	5-1	<b>Issue:</b>	Pits in laminate resin surface	5-8
5.1.3	Metal Foils	5-1	<b>Issue:</b>	Laminate voids	5-8
5.2	Prepreg/B-stage	5-2	<b>Issue:</b>	Excess resin smear on copper in the hole wall	5-8
5.3	Laminate	5-2	<b>Issue:</b>	Cracks in copper foil	5-9
5.4	Problems Associated with Base Materials	5-2	<b>Issue:</b>	Plating separation from resin in holes	5-9
5.4.1	Material Identification	5-2	5.4.7	Electrical	5-9
<b>Issue:</b>	Laminate label is difficult to remove	5-2	<b>Issue:</b>	Dielectric thickness did not meet design	5-9
<b>Issue:</b>	Material does not match label	5-2	<b>Issue:</b>	Impedance values on finished board do not match design	5-10
<b>Issue:</b>	Material imaged and etched upside down	5-2	5.4.5	Metal Surface Defects	5-6
5.4.2	Dimensional Stability	5-3	<b>Issue:</b>	Pits and dents in the metal surface	5-6
<b>Issue:</b>	Laminate exhibits dimensional change after processing	5-3	<b>Issue:</b>	Scratches in metal surface or treatment	5-6
5.4.3	Mechanical Stability	5-3	<b>Issue:</b>	Wrinkles in metal surface	5-6
<b>Issue:</b>	Bow and twist of laminate	5-3	<b>Issue:</b>	Resin spots on metal surface or areas of un-etched metal	5-6
<b>Issue:</b>	Fractures around drilled holes	5-3	<b>Issue:</b>	Shiny spots on copper-clad laminate	5-7
<b>Issue:</b>	Laminate thickness too thin at cross-section	5-4	<b>Issue:</b>	Haze on foil surface after cleaning or lack of imaging resist adhesion	5-7
5.4.4	Foreign Material/Inclusions	5-4	5.4.6	Chemical and Thermal Resistance	5-7
<b>Issue:</b>	Copper or zinc embedded in the laminate resin	5-4	<b>Issue:</b>	Measles or crazing	5-7
<b>Issue:</b>	Etch pits in laminate	5-4	<b>Issue:</b>	Weave exposure	5-7
<b>Issue:</b>	Treatment transfer	5-5	<b>Issue:</b>	Pits in laminate resin surface	5-8
<b>Issue:</b>	Dark spots within laminate or prepreg	5-5	<b>Issue:</b>	Laminate voids	5-8
5.4.5	Metal Surface Defects	5-6	<b>Issue:</b>	Excess resin smear on copper in the hole wall	5-8
<b>Issue:</b>	Pits and dents in the metal surface	5-6	<b>Issue:</b>	Cracks in copper foil	5-9
<b>Issue:</b>	Scratches in metal surface or treatment	5-6	<b>Issue:</b>	Plating separation from resin in holes	5-9
<b>Issue:</b>	Wrinkles in metal surface	5-6	5.4.7	Electrical	5-9
<b>Issue:</b>	Resin spots on metal surface or areas of un-etched metal	5-6	<b>Issue:</b>	Dielectric thickness did not meet design	5-9
<b>Issue:</b>	Shiny spots on copper-clad laminate	5-7	<b>Issue:</b>	Impedance values on finished board do not match design	5-10
<b>Issue:</b>	Haze on foil surface after cleaning or lack of imaging resist adhesion	5-7			

<b>6 MECHANICAL OPERATIONS</b> .....	6-1	<b>Issue:</b> Caking dust .....	6-13
6.1 Drilling .....	6-1	<b>Issue:</b> Router bit discoloration .....	6-13
6.1.1 Dimensional .....	6-2	<b>Issue:</b> Breaking bits .....	6-13
<b>Issue:</b> Hole not located properly (misregistration) .....	6-2	6.4 Shearing .....	6-14
<b>Issue:</b> Improper hole size .....	6-3	<b>Issue:</b> Panel not square .....	6-14
6.1.2 Hole Quality .....	6-3	<b>Issue:</b> Panel lift .....	6-14
<b>Issue:</b> Excessive resin smear .....	6-3	6.5 Beveling .....	6-14
<b>Issue:</b> Fiber protrusion in hole .....	6-4	<b>Issue:</b> Copper foil lifting .....	6-14
<b>Issue:</b> Nailheading .....	6-4	<b>Issue:</b> Rough bevel .....	6-14
<b>Issue:</b> Haloing (delamination of copper around holes) .....	6-5	<b>Issue:</b> Uneven bevel .....	6-14
<b>Issue:</b> Rough hole walls .....	6-6	6.5.1 Processing .....	6-15
<b>Issue:</b> Burrs (> 1 % of hole diameter) .....	6-7	<b>Issue:</b> Excessive feed pressure required .....	6-15
<b>Issue:</b> Debris or residue in hole .....	6-7	6.6 Scoring .....	6-15
<b>Issue:</b> Holes not round .....	6-8	<b>Issue:</b> Score lines misplaced .....	6-16
<b>Issue:</b> Connected curl chip on top of board .....	6-8	<b>Issue:</b> Improper setup .....	6-16
6.1.3 Processing .....	6-8	<b>Issue:</b> Score depth fluctuates from line to line .....	6-16
<b>Issue:</b> Drill bits breaking .....	6-8	<b>Issue:</b> Web thickness varies across one line .....	6-16
<b>Issue:</b> Excessive numbers of chipped drill bits .....	6-8	<b>Issue:</b> Improper score angle .....	6-16
6.2 Punching (Pierce and Blank) (Dimensional) .....	6-9	<b>Issue:</b> Cutter wheels have marked the panel surface .....	6-16
<b>Issue:</b> Undersized holes/features .....	6-9	6.7 Case Drilling .....	6-17
<b>Issue:</b> Improperly located hole/feature .....	6-9	<b>Issue:</b> Hole not properly located .....	6-17
<b>Issue:</b> External dimensions out-of-spec .....	6-10	<b>Issue:</b> Improper hole size .....	6-17
<b>Issue:</b> Missing holes/features .....	6-10	<b>Issue:</b> Holes not drilled .....	6-17
<b>Issue:</b> Edge delamination .....	6-10	<b>Issue:</b> Holes not drilled through .....	6-17
<b>Issue:</b> Fibers and/or roughness along edge .....	6-10	<b>Issue:</b> Blind via holes drilled through .....	6-17
<b>Issue:</b> Surface dents and scratches .....	6-11	<b>Issue:</b> Burrs .....	6-17
6.3 Routing .....	6-11	6.8 Water-Jet Cutting/Profiling .....	6-18
<b>Issue:</b> Feature out of tolerance .....	6-11	<b>Issue:</b> Finished board dimension out of tolerance .....	6-18
<b>Issue:</b> Crazing .....	6-11	<b>Issue:</b> Incomplete cut through substrate .....	6-18
<b>Issue:</b> Rough edges of punched holes .....	6-12	<b>Issue:</b> Haloing, crazing, delamination or rough edges .....	6-18
<b>Issue:</b> Cusp forms on the edge where “pin-less” routing pressure foot clamps .....	6-12	<b>Issue:</b> Excessive nozzle wear .....	6-18

<b>7 HOLE PREPARATION AND PROTECTION</b> .....	7-1	7.4 Electroless Processes .....	7-15
7.1 Desmear Using Alkaline Permanganate .....	7-1	7.5 Hole Metallization (Conditioning) .....	7-15
7.1.1 Solvent/Hole Cleaner .....	7-1	<b>Issue:</b> Hole Wall Pullaway .....	7-15
7.1.2 Permanganate .....	7-1	7.5.1 Bath Control (Includes Cleaner/Conditioner, Micro-Etch Solutions and Rinses) .....	7-16
7.1.3 Neutralizer .....	7-1	<b>Issue:</b> Excessive foam from cleaner conditioner solution being carried down the line .....	7-15
7.1.4 Glass Etch .....	7-1	<b>Issue:</b> Appearance of particles in cleaner/ conditioner solution .....	7-16
7.2 Plasma Desmear .....	7-2	<b>Issue:</b> Micro-etch solution etching too slowly or not at all .....	7-16
7.3 Hole Formation .....	7-2	<b>Issue:</b> Excessive etch rate and temperature rise in peroxide-sulfuric etch .....	7-16
<b>Issue:</b> Insufficient smear removal, leading to a smooth hole wall surface .....	7-2	7.5.2 Hole Conditions .....	7-17
<b>Issue:</b> Uneven smear/resin removal .....	7-3	<b>Issue:</b> Glass or epoxy voids observed following electroless or after copper plating .....	7-17
<b>Issue:</b> Excessive resin removal .....	7-3	<b>Issue:</b> Blistering or flaking of copper over glass or epoxy due to improper conditioning ..	7-18
<b>Issue:</b> Recessed glass fibers .....	7-4	7.5.3 Surface Conditions .....	7-18
<b>Issue:</b> Excessive etchback .....	7-4	<b>Issue:</b> Fingerprints and soils not removed by cleaner/conditioner or micro-etch .....	7-18
<b>Issue:</b> Wicking-plating chemistry along glass fibers .....	7-5	<b>Issue:</b> Micro-etch leaving a streaked surface .....	7-18
<b>Issue:</b> Wedge void/separation of B-stage .....	7-6	<b>Issue:</b> Scum left on surface after persulfate etch .....	7-18
<b>Issue:</b> Negative etchback .....	7-6	<b>Issue:</b> Copper surface still shiny after microetch .....	7-19
<b>Issue:</b> Drill smear .....	7-7	<b>Issue:</b> Copper-to-copper bond failure after electroplate .....	7-19
<b>Issue:</b> Poor plating, drill wall quality .....	7-8	7.6 Hole Catalyzation (Sensitizing) (Includes Predip, Catalyst, and Accelerator Baths and Rinses) .....	7-19
<b>Issue:</b> Low adhesion of electroless copper .....	7-8	7.6.1 Bath Control .....	7-19
<b>Issue:</b> Nailheading .....	7-8	<b>Issue:</b> Silvery film forms on top of catalyst bath .....	7-19
<b>Issue:</b> Glass fiber protrusion and glass gouging (caused by similar issues) .....	7-9	<b>Issue:</b> Catalyst bath turns clear; dark film forms on bottom of tank .....	7-19
<b>Issue:</b> Glass gouge (torn-out glass bundles) ...	7-9	<b>Issue:</b> Appearance of particles in accelerator solution .....	7-19
<b>Issue:</b> Debris or residues in hole .....	7-10		
<b>Issue:</b> Hole(s) not located properly (from drilling) .....	7-11		
<b>Issue:</b> Voiding in the via/Lack of copper plating coverage .....	7-12		
<b>Issue:</b> Resin residue at bottom of blind via ...	7-12		
<b>Issue:</b> Void on resin-rim area .....	7-13		
<b>Issue:</b> Lack of copper coverage on glass/ Resin has sufficient plating (as seen with backlight technique) .....	7-13		
<b>Issue:</b> Void on glass and resin .....	7-14		
<b>Issue:</b> Flaking electroless copper due to excessive blistering/poor adhesion .....	7-14		

7.6.2	Hole Conditions .....	7-20	<b>Issue:</b> Catalyst bath ineffective, as evidenced by electroless copper voids .....	7-20	<b>Issue:</b> Voids on resin .....	7-32
	<b>Issue:</b> Improper acceleration, as evidenced by poor electroless copper adhesion .....	7-20	<b>Issue:</b> Improper acceleration, as evidenced by electroless copper void .....	7-21	<b>Issue:</b> Voids on glass .....	7-32
7.7	Hole Metallization (Copper Deposition) (Includes Electroless Copper Bath and Rinses) .....	7-21			<b>Issue:</b> Rough deposit on panel surface after electroplating .....	7-32
7.7.1	Bath Control .....	7-22				
	<b>Issue:</b> Instability of solution (plate-out or triggering) .....	7-22				
	<b>Issue:</b> Slow rate of deposition, possibly accompanied by a dark deposit .....	7-23				
	<b>Issue:</b> Caustic or formaldehyde concentration changes markedly .....	7-24				
7.7.2	Hole Conditions .....	7-25				
	<b>Issue:</b> Voids in glass and resin areas .....	7-25				
	<b>Issue:</b> Caustic or formaldehyde concentration changes markedly .....	7-26				
	<b>Issue:</b> Voids on resin areas only .....	7-27				
	<b>Issue:</b> Ring wedge voids on multilayer boards on one side of inner layer .....	7-27				
	<b>Issue:</b> Blistering or flaking of copper deposit noted following electroless deposition or later, after cross-section of electroplated or thermal-stressed samples .....	7-28				
	<b>Issue:</b> Rough (nodular and/or granular) deposit in holes after PTH and/or further plating .....	7-29				
7.7.3	Surface Problems .....	7-29				
	<b>Issue:</b> Poor adhesion of electroless or electrolytic copper deposits to laminar copper .....	7-30				
	<b>Issue:</b> Striking on panels .....	7-30				
	<b>Issue:</b> Rough deposit on surface after PTH and/or further plating .....	7-31				
7.8	Hole Metallization (Rework) .....	7-31				
	<b>Issue:</b> Poor interconnect conductivity during final testing .....	7-31				
	<b>Issue:</b> Poor electroless copper adhesion after rework .....	7-31				
7.9	Direct Metallization Processes .....	7-32				
7.9.1	Nickel-Based Direct Metallization Processes .....	7-32				
	<b>Issue:</b> Sensitizer solution is cloudy or has precipitate .....	7-32				
	<b>Issue:</b> Voids on resin .....	7-32				
	<b>Issue:</b> Voids on glass .....	7-32				
	<b>Issue:</b> Rough deposit on panel surface after electroplating .....	7-32				
7.9.2	Carbon Black and Graphite Dispersion Processes .....	7-32				
	<b>Issue:</b> Excessive foam from cleaner/conditioner solution .....	7-33				
	<b>Issue:</b> Cleaner/conditioner solution is cloudy or hazy .....	7-33				
	<b>Issue:</b> Instability of carbon dispersion .....	7-33				
	<b>Issue:</b> Slow rate of deposition and/or no plating in electrolytic copper bath .....	7-34				
	<b>Issue:</b> High board resistance measurement .....	7-34				
	<b>Issue:</b> Voids in glass and resin areas .....	7-34				
	<b>Issue:</b> Voids in glass areas only .....	7-34				
	<b>Issue:</b> Voids in resin areas only .....	7-34				
	<b>Issue:</b> Ring voids on both double-sided and multilayer boards .....	7-34				
	<b>Issue:</b> Inner layer void on multilayer board .....	7-35				
	<b>Issue:</b> Rim voids .....	7-35				
	<b>Issue:</b> Wedge voids on multilayer boards .....	7-35				
	<b>Issue:</b> Interconnect defects .....	7-35				
	<b>Issue:</b> Rough deposit on surface after electroplating .....	7-35				
7.10	Conductive Polymers .....	7-35				
7.11	Full-Build Electroless Copper .....	7-36				
7.11.1	Additive Processing .....	7-36				
	<b>Issue:</b> Surface voids .....	7-36				
	<b>Issue:</b> Blistering .....	7-36				
	<b>Issue:</b> Background plating (extraneous copper) .....	7-36				
	<b>Issue:</b> Poor thermal-shock resistance .....	7-36				
	<b>Issue:</b> Poor insulation resistance .....	7-37				
	<b>Issue:</b> Nodules in electroless deposit .....	7-37				
7.11.2	Semi-Additive Processing .....	7-37				
	<b>Issue:</b> Surface voids .....	7-37				
	<b>Issue:</b> Surface/hole voids .....	7-37				
	<b>Issue:</b> Blistering .....	7-38				
	<b>Issue:</b> Poor insulation resistance .....	7-38				
	<b>Issue:</b> Shorts or open circuits .....	7-38				
	<b>Issue:</b> Low adhesion of electroless copper .....	7-38				
	<b>Issue:</b> Electroless copper bubbles on adhesive .....	7-38				

7.12	Electroplating .....	7-38	8.1.2	Drilling and Deburring .....	8-5
	<b>Issue:</b> Electrolytic Copper peels from base metal .....	7-38		<b>Issue:</b> Residual burr around drilled hole causes poor dry-film resist conformation, leading to opens in print-and-etch, shorts in pattern plating or tent failure in tent and etch .....	8-5
	<b>Issue:</b> Partial plating of circuit pattern (skip plating/step plating) .....	7-39	8.1.3	Scrubbing Electroless Copper Surface Before Pattern or Panel Plating .....	8-6
	<b>Issue:</b> Nonuniform plating distribution across surface of panel .....	7-39		<b>Issue:</b> Removal of electroless copper from surface or around holes (dishing or ring voids) .....	8-5
	<b>Issue:</b> Voids in holes (not seen after electroless copper) .....	7-40		<b>Issue:</b> Step plating or poor adhesion of plated copper .....	8-6
	<b>Issue:</b> Nodular copper plating .....	7-41		<b>Issue:</b> Electroless copper corrosion (oxidation) in the through-hole, leading to copper oxide removal during preelectroplate cleaning and through-hole voids .....	8-6
	<b>Issue:</b> Smear removal .....	7-42	8.1.4	Denoduling Panel-plated Electroplated Copper Before Tent and Etch .....	8-6
	<b>Issue:</b> Plating fold in PTH .....	7-42		<b>Issue:</b> Denoduling insufficient/incomplete .....	8-6
	<b>Issue:</b> Through-hole barrel plating issues due to insufficient resistance to thermal stresses .....	7-43		<b>Issue:</b> Dislodging of copper at through-hole bottom, leading to poor dry-film resist conformation, allowing etchant to get into the hole, creating copper voids .....	8-7
	<b>Issue:</b> Electroplated copper, corner or “knee” issues .....	7-44	8.1.5	Surface Preparation of Panel-Plated Electroplated Copper Before Tent and Etch (After Denoduling) .....	8-7
	<b>Issue:</b> Burrs or nodules in PTH .....	7-45		<b>Issue:</b> Through-hole copper voids .....	8-7
	<b>Issue:</b> Plating fold in PTH .....	7-46	8.1.6	Surface Preparation Before Fusing .....	8-8
	<b>Issue:</b> Failure to meet copper mechanical requirements (tensile/elongation/bend test, etc.) .....	7-46		<b>Issue:</b> Smearing of tin-lead on substrate .....	8-8
	<b>Issue:</b> Premature failure during thermal exposure/cycling-plated deposit thinner			<b>Issue:</b> Tin or tin-lead slivers, sometimes found as shorts during electrical test .....	8-8
	<b>Issue:</b> Columnar copper grain structure .....	7-47	8.2	Chemical Surface Preparation .....	8-8
	<b>Issue:</b> Nodules or bumps in critical contact area .....	7-48	8.2.1	General .....	8-8
	<b>Issue:</b> Excessive foam in plating solution .....	7-49		<b>Issue:</b> Excessive foaming .....	8-8
	<b>Issue:</b> Pits in plated metal .....	7-49		<b>Issue:</b> Cleaning action less than normal or not up to specifications .....	8-9
<b>8</b>	<b>SURFACE PREPARATION (CLEANING STRUCTURING)</b> .....	8-1		<b>Issue:</b> Equipment corroded .....	8-9
8.1	Mechanical Cleaning Surface Preparation .....	8-1	8.2.2	Innerlayer Surface Preparation Before Resist Application .....	8-10
8.1.1	General .....	8-2		<b>Issue:</b> For micro-etchant chemistries, copper surface not rough enough, causing poor resist adhesion .....	8-10
	<b>Issue:</b> Surface is uniformly rougher than desired for the application .....	8-2		<b>Issue:</b> For acidic cleaner/micro-etchant, residual organic contamination after cleaning, causing poor resist adhesion .....	8-10
	<b>Issue:</b> Surface is uniformly less rough than desired for the application (insufficient scrubbing) .....	8-3		<b>Issue:</b> For acidic cleaner/micro-etchant, residual chromate conversion coating after cleaning, causing poor resist adhesion .....	8-10
	<b>Issue:</b> Surface roughness (and cleaning action) is nonuniform .....	8-3			
	<b>Issue:</b> Tracking (streaky appearance) of panel surface .....	8-4			
	<b>Issue:</b> Innerlayer image dimensions distorted/shrunk vs. nominal (CAD data, phototool) dimensions .....	8-5			
	<b>Issue:</b> High residual chromate conversion coating level on copper surface, causing poor resist adhesion and/or poor multilayer bonder formation .....	8-5			

	<b>Issue:</b> For persulfate micro-etch, residual salts on the copper surface after cleaning and rinsing cause poor resist adhesion .....	8-10			
8.2.3	Surface Preparation of Imaged Innerlayers Before Multilayer Bonder Application .....	8-10			
	<b>Issue:</b> Nonuniform, spotty bonder (oxide or oxide alternative) formation .....	8-10			
8.2.4	Through-Hole Hole Wall Preparation (Desmear) Before Electroless Copper Plating .....	8-11			
	<b>Issue:</b> Plated through-hole copper is not well connected to the innerlayer copper and/or hole-wall dielectric resin, causing plated copper separation from the innerlayer copper and hole-wall pull-away .....	8-11			
8.2.5	Electroless Copper Surface Preparation Before Pattern or Panel Plating .....	8-11			
	<b>Issue:</b> Poor dry film resist adhesion to the (un-scrubbed) electroless copper surface .....	8-11			
8.2.6	Solder Conditioning Before Fusing .....	8-12			
	<b>Issue:</b> Equipment corroded by chemistry .....	8-12			
8.2.7	Cleaning After Fusing or Hot-Air Solder Leveling (HASL) .....	8-12			
	<b>Issue:</b> Tin-lead still dark after solder conditioning/brightening step .....	8-12			
	<b>Issue:</b> Flux residue .....	8-12			
	<b>Issue:</b> White residue on board after cleaning .....	8-12			
	<b>Issue:</b> High ionic contamination levels, as evidenced by solvent extract resistivity testing .....	8-12			
8.3	Electrocleaning .....	8-13			
	<b>Issue:</b> Copper-to-copper peelers after pattern plating .....	8-13			
	<b>Issue:</b> Resist breakdown, edge-lifting and under-plating during pattern plating .....	8-13			
	<b>Issue:</b> Resist image stripped in the electrocleaner .....	8-13			
	<b>Issue:</b> Step plating .....	8-13			
	<b>Notes for Section 8</b> .....	8-14			
<b>9</b>	<b>INTERCONNECT FORMATION</b> .....	9-1			
9.1	Imaging .....	9-1			
9.1.1	Dry Film Photoresist .....	9-1			
	<b>Issue:</b> Photoresist under-exposure .....	9-2			
	<b>Issue:</b> Resist scum/residue on panels after development .....	8-3			
	<b>Issue:</b> Poor tenting (insufficient resist bridging of PTHs) performance .....	9-4			
	<b>Issue:</b> Inability to completely develop-out unexposed resist areas .....	9-5			
	<b>Issue:</b> Photoresist image damage during development, image lifting and/or ragged circuit lines after development .....	9-6			
	<b>Issue:</b> Resist breakdown and lifting during etching .....	9-7			
	<b>Issue:</b> Resist breakdown, edge lifting and under-plating during pattern electroplate operation .....	9-8			
	<b>Issue:</b> Copper-to-copper peelers after pattern plating .....	9-9			
	<b>Issue:</b> Skip and step plating in developed-out circuit pattern .....	9-10			
	<b>Issue:</b> Photoresist residue on board after stripping .....	9-11			
9.1.2	Total Aqueous Resist .....	9-12			
	<b>Issue:</b> Incomplete development of unexposed resist .....	9-12			
	<b>Issue:</b> Photoresist image soft, dull in appearance, and easily damaged after development .....	9-13			
	<b>Issue:</b> Resist breakdown during pattern plating .....	9-14			
	<b>Issue:</b> Incomplete stripping .....	9-15			
	<b>Issue:</b> Redeposition of stripped resist back onto circuit pattern .....	9-16			
9.1.3	Liquid Photoresist .....	9-17			
	<b>Issue:</b> Resist breakdown in plating .....	9-17			
	<b>Issue:</b> Line width reduction or inability to develop-out unexposed resist .....	9-17			
	<b>Issue:</b> Photoresist image damage during development (image lifting and/or ragged circuit lines after development) .....	9-18			
	<b>Issue:</b> Copper-to-copper peelers after pattern plating .....	9-19			
	<b>Issue:</b> Skip plating in developed-out circuit pattern .....	9-19			
	<b>Issue:</b> Photoresist residue on board after stripping .....	9-19			
9.1.4	Screen-Printed Resist .....	9-20			
	<b>Issue:</b> Shadows or ghosts on screened boards .....	9-20			
	<b>Issue:</b> Ink deposit too heavy .....	9-20			
	<b>Issue:</b> Bubbles in screen-printed image .....	9-21			
	<b>Issue:</b> Large voids in resist image (fish eyes or craters) .....	9-21			
	<b>Issue:</b> Ink runs through screen .....	9-21			

<b>Issue:</b> Slow breakaway on printing .....	9-22	<b>Issue:</b> Excess pinholes, opens, etc. ....	9-29
<b>Issue:</b> Excessive pin-holing of screened resist during pattern plating .....	9-22	9.5 Copper Treatment to Improve Laminate Adhesion .....	9-29
<b>Issue:</b> Bleeding of plating resist onto conductor and/or lands .....	9-23	9.5.1 Double-Treated Copper/Laminator's Oxide .....	9-29
<b>Issue:</b> Very small voids in conductor patterns, extending through copper foil to substrate .....	9-23	<b>Issue:</b> Nonuniform treatment appearance prior to lamination .....	9-29
<b>Issue:</b> Ragged line definition .....	9-24	<b>Issue:</b> Poor resist adhesion .....	9-29
<b>Issue:</b> Ink is soft and easily marred .....	9-24	<b>Issue:</b> Un-etched copper .....	9-29
<b>Issue:</b> Resist failure in etching .....	9-24	9.5.2 Black or Red/Brown Oxide Coatings .....	9-30
<b>Issue:</b> Resist softens during plating cycle and/or plating occurs on resist .....	9-25	<b>Issue:</b> Nonuniform oxide appearance .....	9-30
<b>Issue:</b> Resist residue remaining on board surface after stripping .....	9-25	<b>Issue:</b> Oxide coating too thin .....	9-31
<b>Issue:</b> Nonuniform or inadequate cure on boards (resulting in plating or etching problems) .....	9-25	<b>Issue:</b> Oxide coating too thick .....	9-31
<b>Issue:</b> Skips or voids in print .....	9-25	9.5.3 Oxide Bath Control .....	9-31
<b>Issue:</b> Step plating (swirled pattern in copper) of printed resist panels in copper electroplate .....	9-26	<b>Issue:</b> Gray scum forms on top of solution ....	9-31
9.1.5 Laser Imaging of Photoresist .....	9-26	<b>Issue:</b> Solution concentration drops rapidly ...	9-31
9.1.6 Electrophoretically Deposited Photoresist .....	9-26	<b>Issue:</b> Color variation (of oxide coating) as bath ages .....	9-32
9.2 Inner-Layer Fabrication .....	9-27	9.5.4 Oxide Post-Treatment .....	9-32
9.2.1 Handling .....	9-27	<b>Issue:</b> Post-treated coating nonuniform in color .....	9-32
9.2.2 Inner Layer Problems .....	9-27	<b>Issue:</b> Oxide coating does not react to post-dip .....	9-32
<b>Issue:</b> Inner layers damaged in conveyORIZED equipment .....	9-27	<b>Issue:</b> High consumption of post-dip additive .....	9-32
<b>Issue:</b> Inner layers bow excessively .....	9-27	<b>Issue:</b> Low peel strengths on post-treated multilayer boards .....	9-32
<b>Issue:</b> Dimensional stability .....	9-27	<b>Issue:</b> Pink ring still evident after post-treatment .....	9-32
9.3 Print-and-Etch Inner Layers .....	9-27	9.5.5 ConveyORIZED Oxide Systems .....	9-33
9.3.1 Cleaning .....	9-27	<b>Issue:</b> Conveyor wheel marks on panels .....	9-33
9.3.2 Resist Residue on Inner Layers .....	9-27	<b>Issue:</b> Oxide coating blotchy or nonuniform ..	9-33
9.3.3 Imaging .....	9-27	<b>Issue:</b> Oxide too thin .....	9-33
9.4 Inner Layers With Buried and/or Buried Vias .....	9-28	9.5.6 Delamination Relating to Application of Oxide Coating .....	9-33
9.4.1 Drilling .....	9-28	<b>Issue:</b> Surface contamination .....	9-33
9.4.2 Plating .....	9-28	<b>Issue:</b> Improper development of oxide .....	9-34
<b>Issue:</b> Voids in through-hole copper plating ...	9-28	9.6 Metallic Protective Coatings .....	9-34
<b>Issue:</b> Uneven plating thickness .....	9-28	9.6.1 Tin-Lead Fusing .....	9-34
9.4.3 Etching .....	9-28	<b>Issue:</b> Little or no edge coverage after reflow .....	9-34
<b>Issue:</b> Panels coming out of etcher skewed ...	9-28	<b>Issue:</b> White haze or residue on solder after reflow, often as lead or tin oxide .....	9-34
<b>Issue:</b> Heavy excess copper on inner layers in spots, strips, etc. ....	9-28	<b>Issue:</b> Nonfused tin-lead; cold spots .....	9-35
<b>Issue:</b> Dish downs, scratches or other damage to pattern .....	9-28		

<b>Issue:</b> Blow holes occur in fused solder .....	9-35	<b>Issue:</b> Flux density changes frequently .....	9-40
<b>Issue:</b> Dewetted solder surface after fusing ...	9-35	9.8 Immersion Coatings .....	9-40
<b>Issue:</b> Galvanized finish .....	9-35	9.8.1 Immersion Tin .....	9-40
<b>Issue:</b> Dull finish .....	9-35	<b>Issue:</b> Solder on gold tabs/Poor coverage or skip plating .....	9-40
<b>Issue:</b> White residue on board surface .....	9-35	<b>Issue:</b> Low tin thickness on part .....	9-40
<b>Issue:</b> Plugged holes .....	9-35	<b>Issue:</b> Unusually low stannous concentration in bath .....	9-40
<b>Issue:</b> Flat reflow .....	9-36	<b>Issue:</b> Darkening or unusual color of bath .....	9-40
<b>Issue:</b> Pumped reflow nodules (volcanoes) ....	9-36	<b>Issue:</b> Dark spots on tin .....	9-41
<b>Issue:</b> Grittiness after reflow .....	9-36	<b>Issue:</b> Dark or stained deposits .....	9-41
9.6.2 Infrared Fusing .....	9-36	<b>Issue:</b> Chipping, peeling on nonadherent deposits .....	9-41
<b>Issue:</b> Incomplete reflow .....	9-36	9.8.2 Immersion Gold .....	9-41
<b>Issue:</b> Dewetting/puddling .....	9-36	<b>Issue:</b> Poor coverage or skip plating .....	9-41
<b>Issue:</b> Delamination of multilayer panels .....	9-36	<b>Issue:</b> Slow plating rate .....	9-41
9.6.3 Hot-Oil Reflow .....	9-37	9.8.3 Immersion Tin-Lead .....	9-42
<b>Issue:</b> Boards not reflowing .....	9-37	<b>Issue:</b> Thin deposit (< 4 $\mu\text{m}$ ) .....	9-42
<b>Issue:</b> Dewet/pull-back of reflowed solder ....	9-37	<b>Issue:</b> Wrong alloy composition in deposit ....	9-42
<b>Issue:</b> Delamination .....	9-37	<b>Issue:</b> Deposit will not fuse .....	9-42
9.6.4 Vapor-Phase Fusing .....	9-37	<b>Issue:</b> Loss of deposit adhesion .....	9-42
<b>Issue:</b> Boards not reflowing .....	9-37	<b>Issue:</b> Nonuniform thickness of tin-lead deposit .....	9-42
<b>Issue:</b> White haze after reflow .....	9-37	9.9 Electroless Coatings .....	9-43
<b>Issue:</b> Dewetting after reflow .....	9-37	9.9.1 Electroless Nickel .....	9-43
9.7 Solder Leveling .....	9-37	<b>Issue:</b> Lack of continuous plating or skip plating (poor coverage) .....	9-43
9.7.1 Hot-Air Leveling .....	9-37	<b>Issue:</b> Roughness of plating .....	9-43
<b>Issue:</b> Webbing/balling of solder .....	9-37	<b>Issue:</b> Slow plating rate .....	9-43
<b>Issue:</b> PTH not soldered .....	9-38	<b>Issue:</b> Nickel plate is peeling .....	9-44
<b>Issue:</b> Lands not completely soldered .....	9-38	<b>Issue:</b> Pitting .....	9-44
<b>Issue:</b> Poor coverage of surface or holes .....	9-38	<b>Issue:</b> Streaked deposit .....	9-44
<b>Issue:</b> Plugged holes .....	9-38	<b>Issue:</b> Dull deposit .....	9-44
<b>Issue:</b> Dewetting of solder .....	9-38	<b>Issue:</b> Frosted deposits .....	9-44
<b>Issue:</b> Solder mask blisters/poor adhesion after leveling .....	9-38	9.9.2 Electroless Tin .....	9-44
<b>Issue:</b> High ionic contamination levels/ poor electrical properties .....	9-39	<b>Issue:</b> Thin tin deposit .....	9-44
<b>Issue:</b> Solder on leveled panel has a grainy appearance .....	9-39	<b>Issue:</b> Poor fusing .....	9-44
<b>Issue:</b> Solder on gold tabs .....	9-39	<b>Issue:</b> Bath has darkened .....	9-44
9.7.2 Machine/Material Problems .....	9-39	<b>Issue:</b> Salts crystallizing .....	9-45
<b>Issue:</b> Plugged air knives .....	9-39	<b>Issue:</b> Skip plating/poor coverage .....	9-45
<b>Issue:</b> Copper contamination builds up rapidly in solder .....	9-39	<b>Issue:</b> Slow plating rate .....	9-45
<b>Issue:</b> Excessive smoke generated during leveling operation .....	9-39		

<b>10 ETCHING</b> .....	10-1	<b>Issue:</b> Over-etching .....	10-9
10.1 Equipment-Related Effects and Effects From Other Processes .....	10-1	<b>Issue:</b> Under-etching .....	10-10
<b>Issue:</b> Nonuniform etch from side-to-side of panel .....	10-1	10.4 Peroxide-Sulfuric Etchants .....	10-10
<b>Issue:</b> Nonuniform etch (copper left on some areas of panel while other areas are etched properly) .....	10-1	10.4.1 Bath Control .....	10-10
<b>Issue:</b> Excessive undercut (over-etching conductor) .....	10-2	<b>Issue:</b> Excessive peroxide consumption .....	10-10
<b>Issue:</b> Panels skewing on conveyor .....	10-2	<b>Issue:</b> Blackening of tin-lead solder during etching .....	10-11
<b>Issue:</b> Copper left around circuit patterns .....	10-3	<b>Issue:</b> Slow, but uniform etch rate .....	10-11
<b>Issue:</b> Etch rate slows .....	10-3	<b>Issue:</b> Etchant solution temperature rises .....	10-11
<b>Issue:</b> Etchant attacks resist (on print-and- etch work) .....	10-3	<b>Issue:</b> Etchant temperature loss .....	10-11
<b>Issue:</b> Front of panel etches differently from back of panel .....	10-3	<b>Issue:</b> Excessive foam blanket .....	10-11
10.2 Cupric Chloride .....	10-4	<b>Issue:</b> 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 .....	10-12
10.2.1 Bath Control .....	10-4	<b>Issue:</b> Building solution volume .....	10-12
<b>Issue:</b> Over-chlorination causing free chlorine in atmosphere around machine .....	10-4	<b>Issue:</b> Etchant solution volume drop .....	10-12
<b>Issue:</b> Sudden slowdown in etch rate .....	10-4	10.4.2 Improper Etching .....	10-12
<b>Issue:</b> Slow etching/Etch rate is not as fast as it should be but seems fairly steady .....	10-5	<b>Issue:</b> Nonuniform etch (copper left in some areas of panel while others are etched properly) .....	10-12
10.2.2 Improper Etching .....	10-6	<b>Issue:</b> Nonuniform etch on very thick copper-clad panels $\geq 200 \mu\text{m}$ /Variation in line width from bottom to top of vertically positioned traces .....	10-12
<b>Issue:</b> Over-etching .....	10-6	<b>Issue:</b> Fast etch rate, over-etch .....	10-12
<b>Issue:</b> Under-etching .....	10-7	10.5 Ferric Chloride .....	10-13
10.3 Alkaline (Ammonial) Etchants .....	10-7	10.5.1 Bath Control .....	10-13
10.3.1 Bath Control .....	10-7	<b>Issue:</b> Etch rate very slow .....	10-13
<b>Issue:</b> Excessive crystallization in etcher .....	10-7	<b>Issue:</b> Excess foaming of etchant .....	10-13
<b>Issue:</b> Etchant no longer etches/Alkaline salts precipitate out of etchant and fall to bottom of etch sump (sludging) .....	10-8	<b>Issue:</b> Muddy-brown etchant color .....	10-13
<b>Issue:</b> Etch rate slows as boards are being processed .....	10-8	<b>Issue:</b> Sudden slowdown in etch rate .....	10-13
<b>Issue:</b> Resist coming off in etcher (when using dry-film or screened ink as etch resist) .....	10-8	10.5.2 Improper Etching .....	10-14
10.3.2 Improper Etching .....	10-9	<b>Issue:</b> Over-etching .....	10-14
		<b>Issue:</b> Under-etching .....	10-14
		10.6 Ammonium or Sodium Persulfate .....	10-14
		<b>Issue:</b> Slow etch rate .....	10-14

<b>11 LAYERING AND LAMINATION</b> .....	11-1	<b>Issue:</b> Holes in blind or buried via layers are not filled to the extent required by specification .....	11-8
11.1 General .....	11-2	11.4 Material .....	11-8
11.1.1 Misregistration .....	11-2	11.4.1 Misregistration .....	11-9
<b>Issue:</b> Breakout due to no annular ring .....	11-2	<b>Issue:</b> Circuits moved during lamination ....	11-9
11.1.2 Blisters/Delamination and Inter-laminate Adhesion .....	11-3	<b>Issue:</b> Misalignment of holes to innerlayer image .....	11-9
11.1.3 Bow/Twist .....	11-3	<b>Issue:</b> Dielectric spacing violation .....	11-9
11.1.4 Laminate Voids .....	11-3	<b>Issue:</b> Conductive anodic filament (CAF) ...	11-9
11.1.5 Resin Starvation .....	11-3	<b>Issue:</b> Resin starvation .....	11-3
<b>Issue:</b> Resin starvation .....	11-3	11.4.2 Blisters/Delamination .....	11-10
11.1.6 Panel/Board Thickness .....	11-3	<b>Issue:</b> Separation of the prepreg and the innerlayer laminate or oxide surface .....	11-10
11.1.7 Surface Imperfections .....	11-3	11.4.3 Bow and Twist (Warped) .....	11-10
11.1.8 Pits .....	11-4	<b>Issue:</b> Panel or board warped or twisted after lamination or final routing .....	11-10
<b>Issue:</b> Pits .....	11-4	11.4.4 Laminate Voids .....	11-10
11.1.9 Measling .....	11-4	<b>Issue:</b> Entrapped air in prepreg .....	11-10
<b>Issue:</b> Measling .....	11-4	<b>Issue:</b> Holes in a heat sink or restraining core do not fill during lamination .....	11-10
11.2 Handling .....	11-5	11.4.5 Resin Starvation .....	11-10
11.2.1 Misregistration .....	11-5	<b>Issue:</b> Internal frosty appearance (seen mostly in areas with little circuitry) .....	11-10
<b>Issue:</b> Misalignment of the innerlayers on one piece of core to the innerlayers on another piece of core .....	11-5	11.4.6 Panel Thickness .....	11-11
11.2.2 Blisters/Delamination .....	11-5	<b>Issue:</b> Panel overall and dielectric thicknesses too thin/Excessive amount of cured resin framing panel .....	11-11
<b>Issue:</b> Resin fractures after lamination .....	11-5	<b>Issue:</b> Panel is thicker or thinner than specification .....	11-11
<b>Issue:</b> Delamination .....	11-6	<b>Issue:</b> Dielectric thickness is violated .....	11-11
11.2.3 Laminate Voids .....	11-7	11.4.7 Surface Imperfections .....	11-11
<b>Issue:</b> A random series or line of voids, particularly a problem in spacing with one or two plies of low-flow prepreg .....	11-7	<b>Issue:</b> Pits, dents, epoxy or scratches on panel surface .....	11-11
11.2.4 Surface Imperfections .....	11-7	11.5 Tooling .....	11-11
<b>Issue:</b> Scratches on surface of panels after lamination or post-bake .....	11-7	11.5.1 Misregistration .....	11-12
11.3 Equipment .....	11-7	<b>Issue:</b> Misregistration .....	11-12
11.3.1 Misregistration .....	11-7	<b>Issue:</b> Internal layers reversed backwards, upside down .....	11-12
<b>Issue:</b> Misregistration .....	11-7	<b>Issue:</b> Inner-layer images smaller or larger than drilled-hole pattern .....	11-12
<b>Issue:</b> Controlled-depth drill too deep, violating minimum dielectric spacing requirement .....	11-8	<b>Issue:</b> Innerlayer(s) randomly misregistered in localized areas .....	11-12
<b>Issue:</b> Innerlayer image not aligned with drilled-hole pattern .....	11-8	11.5.2 Bow and Twist (Warped) .....	11-13
11.3.2 Blisters/Delamination .....	11-8	<b>Issue:</b> Panel will not lay flat after lamination .....	11-13
<b>Issue:</b> Blisters or delamination at the oxide or laminate interface with the cured prepreg .....	11-8		
11.3.3 Laminate Voids .....	11-8		

11.5.3	Surface Imperfections .....	11-13			
	<b>Issue:</b> Depressions in copper surface after lamination .....	11-13			<b>Issue:</b> Lighter colored areas (stains) over the innerlayer oxide surface that cannot be distinguished as delamination without destructive testing by cross- section analysis for separation .....
11.6	Multilayer Design .....	11-13			
11.6.1	Misregistration .....	11-13			<b>Issue:</b> Delamination of prepreg and constraining cores, such as copper-invar- copper and copper-molybdenum-copper ....
	<b>Issue:</b> Innerlayer images smaller or larger than drilled-hole pattern .....	11-13			11-20
	<b>Issue:</b> Misregistration of layers on different cores .....	11-14			<b>Issue:</b> Micro-voids in laminated multilayer boards .....
	<b>Issue:</b> Circuits moved during lamination ..	11-14	11.8	Prepreg (B-Stage) Preparation .....	11-20
11.6.2	Blisters/Delamination .....	11-14	11.8.1	Blisters/Delamination .....	11-20
	<b>Issue:</b> Blisters appear between boards on a panel .....	11-14		<b>Issue:</b> White areas of air entrapment in prepreg .....	11-20
	<b>Issue:</b> Separation occurs over large copper area .....	11-14		<b>Issue:</b> Blisters and delamination at the oxide or laminate interface with the cured prepreg .....	11-21
11.6.3	Bow and Twist (Warped) .....	11-15		<b>Issue:</b> Fractures visible after lamination ...	11-21
	<b>Issue:</b> Panel or board warped or twisted after lamination or final routing .....	11-15	11.8.2	Laminate Voids .....	11-22
11.6.4	Laminate Voids .....	11-15		<b>Issue:</b> Voids – air or moisture in prepreg areas .....	11-22
	<b>Issue:</b> Micro-voids in laminated multilayer boards .....	11-15	11.8.3	Panel Thickness .....	11-22
11.6.5	Resin Starvation .....	11-15		<b>Issue:</b> Excess bead of flow around panel edges/Panel has excessive taper (thicker at center, thinner at edges) .....	11-22
	<b>Issue:</b> Internal frosty appearance of prepreg .....	11-15	11.9	Copper Foil Preparation .....	11-22
11.6.6	Panel Thickness .....	11-15	11.9.1	Blisters/Delamination .....	11-22
	<b>Issue:</b> Panel is thicker or thinner than specification .....	11-15		<b>Issue:</b> Lifted circuits or low foil bond strength .....	11-22
	<b>Issue:</b> Panel is thinner at the edges than the center .....	11-15		<b>Issue:</b> Localized separation at copper foil/prepreg interface .....	11-22
	<b>Issue:</b> Panel is thinner than specification ..	11-15	11.9.2	Surface Imperfections .....	11-22
	<b>Issue:</b> High spots within a panel .....	11-16		<b>Issue:</b> Epoxy present on surface after lamination .....	11-22
11.7	Innerlayer Preparation .....	11-16	11.10	Lay-Up .....	11-22
11.7.1	Misregistration .....	11-16	11.10.1	Blisters/Delamination .....	11-22
	<b>Issue:</b> Improper etch leading to spacing violation .....	11-16		<b>Issue:</b> White areas of air entrapment in the prepreg .....	11-22
	<b>Issue:</b> Innerlayer images smaller or larger than drilled-hole pattern .....	11-16	11.10.2	Bow and Twist (Warped) .....	11-23
	<b>Issue:</b> Etched image on innerlayers randomly misregistered to drilled- hole pattern .....	11-17		<b>Issue:</b> Panel or board is warped or twisted after lamination or final routing .....	11-23
11.7.2	Blisters/Delamination .....	11-17	11.10.3	Panel Thickness .....	11-23
	<b>Issue:</b> Localized separation at prepreg/ oxide interface .....	11-17		<b>Issue:</b> Panel overall thickness incorrect ....	11-23
	<b>Issue:</b> Separation at prepreg/innerlayer oxide interface .....	11-18		<b>Issue:</b> Some boards/panels are thick, and some are thin .....	11-23

11.10.4	Surface Imperfections .....	11-23	<b>Issue:</b> Panel is thinner in the center than at the edges .....	11-30	
	<b>Issue:</b> Cured epoxy present on copper surface following lamination .....	11-23	<b>Issue:</b> Some boards/panels thick, some thin .....	11-30	
	<b>Issue:</b> After cleaning, black spots of oxide seen on surface .....	11-24	<b>Issue:</b> Circuit image transfer (from second conductor layer to package surface layer) creating nonuniform thickness within a panel .....	11-31	
11.11	Pressing .....	11-24	11.12	Post-Lamination Bake .....	11-31
11.11.1	Misregistration .....	11-24	11.12.1	Blisters/Delamination .....	11-31
	<b>Issue:</b> Circuits moved during lamination ..	11-24		<b>Issue:</b> Separation of prepreg to the innerlayer laminate or oxide surfaces .....	11-31
	<b>Issue:</b> Innerlayer images smaller or larger than drilled-hole pattern .....	11-24		<b>Issue:</b> Fractures after lamination .....	11-31
	<b>Issue:</b> Innerlayers randomly misregistered in localized areas, or each layer is different in each laminated panel .....	11-24	11.12.2	Bow and Twist (Warped) .....	11-31
11.11.2	Blisters/Delamination .....	11-24		<b>Issue:</b> Panel will not lay flat .....	11-31
	<b>Issue:</b> Entrapped air between circuit boards, in low-pressure areas .....	11-24	11.12.3	Surface Imperfections .....	11-31
	<b>Issue:</b> Entrapped air or volatiles following lamination .....	11-25		<b>Issue:</b> Panels stained after post-bake .....	11-31
	<b>Issue:</b> Blisters and delamination at the oxide or laminate interface with cured prepreg .....	11-26	11.13	Subsequent Processing .....	11-32
11.11.3	Bow and Twist (Warped) .....	11-26	11.13.1	Misregistration .....	11-32
	<b>Issue:</b> Panel or board warped or twisted after lamination or final rout .....	11-26		<b>Issue:</b> Holes drilled after lamination are skewed or rotated to the innerlayer image .....	11-32
	<b>Issue:</b> Panel will not lay flat – baking panels do not remove warp, indicating stresses induced during lamination cycle ...	11-27		<b>Issue:</b> Holes do not match innerlayer circuit image .....	11-32
11.11.4	Laminate Voids .....	11-27	11.13.2	Blisters/Delamination .....	11-32
	<b>Issue:</b> Small laminate voids seen from the surface or when back-lighted .....	11-27		<b>Issue:</b> Drilling, routing, post-curing/fusing or solder coating cause delamination or blistering .....	11-32
	<b>Issue:</b> Incomplete hole fill of blind vias or heavy-metal planes during lamination ...	11-28		<b>Issue:</b> Fractures in material after drill .....	11-32
11.11.5	Resin Starvation .....	11-29		<b>Issue:</b> Delamination is present in cross-sections, visual examination shows no delamination, boards pass solder shock .....	11-32
	<b>Issue:</b> Weave exposure .....	11-29	11.13.3	Bow and Twist (Warped) .....	11-33
	<b>Issue:</b> Overall dry appearance of prepreg, possibly including exposed glass weave ....	11-29		<b>Issue:</b> Board bows and distorts during reflow and bake .....	11-33
11.11.6	Panel Thickness .....	11-30	11.13.4	Voids in PTHs .....	11-33
	<b>Issue:</b> Panel overall and dielectric thicknesses too thin, excessive amount of cured resin framing panel .....	11-30		<b>Issue:</b> Voids in PTHs visible at microsection .....	11-33
	<b>Issue:</b> Panel overall thickness too thick or too thin .....	11-30	11.14	Electrical .....	11-33
	<b>Issue:</b> Panel is thinner on one edge and thicker on the opposite edge .....	11-30		<b>Issue:</b> Dielectric thickness did not meet design .....	11-33
	<b>Issue:</b> Panel is much thinner on edges than in the center .....	11-30		<b>Issue:</b> Impedance values on finished board do not match design .....	11-33
				<b>Issue:</b> Whiskers extending into the open beyond the recessed edge-plating area .....	11-34

<b>12 FINAL FINISHES</b> .....	12-1	<b>Issue:</b> Solder on leveled panel has a grainy appearance .....	12-6
12.1 Tin-Lead Fusing .....	12-1	<b>Issue:</b> Solder on gold tabs .....	12-6
<b>Issue:</b> Little or no edge coverage after reflow .....	12-1	12.2.2 Machine/Material Problems .....	12-7
<b>Issue:</b> White haze or residue on solder after reflow, often as lead or tin oxide .....	12-1	<b>Issue:</b> Plugged air knives .....	12-7
<b>Issue:</b> Nonfused tin-lead/Cold spots .....	12-1	<b>Issue:</b> Copper contamination builds up rapidly in solder .....	12-7
<b>Issue:</b> Blow holes occur in fused solder .....	12-1	<b>Issue:</b> Excessive smoke generated during the leveling operation .....	12-7
<b>Issue:</b> Dewetted solder surface after fusing .....	12-2	<b>Issue:</b> Flux density changes frequently .....	12-7
<b>Issue:</b> Galvanized finish .....	12-2	12.3 Immersion Coatings .....	12-8
<b>Issue:</b> Dull finish .....	12-2	12.3.1 Immersion Tin .....	12-8
<b>Issue:</b> White residue on board surface .....	12-2	<b>Issue:</b> Poor coverage or skip plating .....	12-8
<b>Issue:</b> Plugged holes .....	12-2	<b>Issue:</b> Low tin thickness on part .....	12-8
<b>Issue:</b> Flat reflow .....	12-2	<b>Issue:</b> Unusual low stannous concentration in bath .....	12-8
<b>Issue:</b> Pumped reflow noldules (volcanoes) .....	12-3	<b>Issue:</b> Darkening or unusual color of bath .....	12-9
<b>Issue:</b> Grittiness after reflow .....	12-3	<b>Issue:</b> Dark spots on tin .....	12-9
12.1.1 Infra-red Fusing .....	12-3	<b>Issue:</b> Dark or stained deposits .....	12-9
<b>Issue:</b> Incomplete reflow .....	12-3	<b>Issue:</b> Chipping, peeling on nonadherent deposits .....	12-9
<b>Issue:</b> Dewetting/Puddling .....	12-3	12.3.2 Immersion Gold .....	12-9
<b>Issue:</b> Delamination of multilayer panels .....	12-3	<b>Issue:</b> Poor coverage or skip plating .....	12-9
12.1.2 Hot-Oil Reflow .....	12-3	<b>Issue:</b> Slow plating rate .....	12-9
<b>Issue:</b> Boards not reflowing .....	12-3	12.4 Electroless Coatings .....	12-10
<b>Issue:</b> Dewet/Pull-back of reflowed solder .....	12-3	12.4.1 Electroless Nickel .....	12-10
<b>Issue:</b> Delamination .....	12-4	<b>Issue:</b> Lack of continuous plating or skip plating (poor coverage) .....	12-10
12.1.3 Vapor-Phase Fusing .....	12-4	<b>Issue:</b> Roughness of plating .....	12-11
<b>Issue:</b> Boards not reflowing .....	12-4	<b>Issue:</b> Slow plating rate .....	12-11
<b>Issue:</b> White haze after reflow .....	12-4	<b>Issue:</b> Nickel plate is peeling .....	12-11
<b>Issue:</b> Dewetting after reflow .....	12-4	<b>Issue:</b> Stray plating .....	12-12
12.2 Solder Leveling .....	12-4	<b>Issue:</b> Pitting .....	12-12
12.2.1 Hot-Air Leveling .....	12-4	<b>Issue:</b> Streaked deposit .....	12-12
<b>Issue:</b> Webbing/Balling of solder .....	12-4	<b>Issue:</b> Dull deposit .....	12-12
<b>Issue:</b> PTH not soldered .....	12-5	<b>Issue:</b> Frosted deposits .....	12-12
<b>Issue:</b> Lands not completely soldered .....	12-5	12.4.2 Electroless Tin .....	12-13
<b>Issue:</b> Poor coverage of surface or holes .....	12-5	<b>Issue:</b> Thin tin deposit .....	12-13
<b>Issue:</b> Plugged holes .....	12-5	<b>Issue:</b> Poor fusing .....	12-13
<b>Issue:</b> Solder mask blisters/poor adhesion after leveling .....	12-6	<b>Issue:</b> Bath has darkened .....	12-13
<b>Issue:</b> High ionic contamination levels/poor electrical properties .....	12-6	<b>Issue:</b> Salts crystallizing .....	12-13
		<b>Issue:</b> Skip plating; poor coverage .....	12-13
		<b>Issue:</b> Slow plating rate .....	12-13

<b>13 NONMETALLIC COATINGS</b> .....	13-1	<b>Issue:</b> Final film thickness too thin .....	13-15
13.1 Permanent Solder Resist .....	13-1	<b>Issue:</b> Final film too thick .....	13-15
13.1.1 Screen-Printable Solder Resists (Thermal and UV Cure) .....	13-1	<b>Issue:</b> Pinholes or light areas in resist coating .....	13-15
<b>Issue:</b> Misregistration .....	13-2	<b>Issue:</b> Resist still tacky after drying (tack-dry) .....	13-16
<b>Issue:</b> Incomplete cure (thermal-cure inks) .....	13-3	<b>Issue:</b> Bubbles or craters in dried resist film (usually in thickest areas of the resist) .....	13-17
<b>Issue:</b> Incomplete cure (UV-cure inks) .....	13-3	<b>Issue:</b> Phototool sticks to panel/Solder resist film marring .....	13-17
<b>Issue:</b> Adhesion failure .....	13-4	<b>Issue:</b> Excessive sidewall growth .....	13-18
<b>Issue:</b> Solder resist on lands or in holes .....	13-4	<b>Issue:</b> Incomplete development .....	13-18
<b>Issue:</b> Solder mask adhesion failure after hot-air leveling .....	13-5	<b>Issue:</b> Bleed-through exposure (also called ghosting or shoot-through), where ink is exposed by light from the other side of the board, through the laminate .....	13-18
<b>Issue:</b> Over-cure of solder mask .....	13-5	<b>Issue:</b> Under-cutting or over- development .....	13-18
<b>Issue:</b> Insufficient moisture/insulation resistance .....	13-5	<b>Issue:</b> Residue (scum or tracking) remains on panel after development .....	13-19
<b>Issue:</b> Skipping .....	13-6	<b>Issue:</b> Film surface marring .....	13-19
<b>Issue:</b> Boards sticking to screen .....	13-6	<b>Issue:</b> Solder resist remaining in holes after development .....	13-20
13.1.2 Dry-Film Solder Resist .....	13-7	<b>Issue:</b> Adhesion failure at solder leveling operation .....	13-21
<b>Issue:</b> Air entrapment during lamination .....	13-7	<b>Issue:</b> Unsoldered lands after solder leveling operation resist on lands .....	13-22
<b>Issue:</b> Wrinkles in solder resist after vacuum lamination .....	13-8	13.2 Temporary Protective Coatings .....	13-22
<b>Issue:</b> Resist on lands .....	13-9	13.2.1 Inhibitor Coatings .....	13-22
<b>Issue:</b> Exposure time too long .....	13-9	<b>Issue:</b> Insufficient anti-tarnish protection, as evidenced by tarnishing or poor solderability .....	13-22
<b>Issue:</b> Development time too long .....	13-10	<b>Issue:</b> Difficulty removing coating .....	13-23
<b>Issue:</b> Solder resist breakdown during post-soldering operations .....	13-11	13.2.2 Rosin-/Resin-Based Coatings (Pre-fluxes) .....	13-23
<b>Issue:</b> White residues on solder resist .....	13-12	<b>Issue:</b> Poor solderability .....	13-23
<b>Issue:</b> Bleed-through exposure (ghosting or shoot-thru), where ink is exposed by light from the other side of the board through the laminate .....	13-12	<b>Issue:</b> Water spots .....	13-23
<b>Issue:</b> Under-cutting or over- development .....	13-12	<b>Issue:</b> Spotting or tarnishing prior to drying .....	13-23
<b>Issue:</b> Residue (scum or tracking) left on panel after development .....	13-13	<b>Issue:</b> Excessive haloing around lands .....	13-23
<b>Issue:</b> Adhesion failure at solder- leveling operation .....	13-14	<b>Issue:</b> Dark deposit on coating .....	13-23
13.1.3 Liquid Photoimageable (LPI) Solder Resist .....	13-14	<b>Issue:</b> Skipping of deposit .....	13-23
<b>Issue:</b> Uneven coating (machine application) .....	13-14		
<b>Issue:</b> Exposed features (traces, pads) on board after solder resist (skipping screen-print operation) .....	13-15		

13.2.3 Chromate-Inhibitor Coatings ..... 13-24  
**Issue:** Insufficient anti-tarnish protection, tarnishing solderability poor ..... 13-24  
**Issue:** Difficulty removing coating ..... 13-24

13.2.4 Copper Oxidation ..... 13-24  
**Issue:** Nonuniform appearance after oxidation process ..... 13-24  
**Issue:** Unacceptable bonding of solder resist to oxide coating ..... 13-24  
**Issue:** Difficulty removing copper oxidation from areas not required to be coated ..... 13-24  
**Issue:** Creepage along conductor traces where copper oxide has been erroneously removed ..... 13-24

13.3 Temporary Solder Resists ..... 13-25

13.3.1 Tape ..... 13-25  
**Issue:** Tape does not adhere to surface ..... 13-25  
**Issue:** Adhesive (gum) squeeze-out ..... 13-25  
**Issue:** Inadequate residue removal ..... 13-25  
**Issue:** Edges ragged and not uniform ..... 13-25

**Issue:** Difficult tape removal ..... 13-25

13.4 Nomenclature (Legend) – Nonmetallic Materials ..... 13-26

13.4.1 Screen-Printed ..... 13-26  
**Issue:** Ink smearing or squishing ..... 13-26  
**Issue:** Legend skipping ..... 13-26  
**Issue:** Poor or changing registration ..... 13-27  
**Issue:** Boards stick to screen ..... 13-27

**Tables**

Table 6-1 Drilling Variables and Effects ..... 6-1

Table 6-2 Punching Variables and Effects ..... 6-9

Table 6-3 Scoring Variables and Effects ..... 6-15

Table 7-1 Electroless Copper Process—Problem Sources and Subsequent Effects ..... 7-15

Table 7-2 Critical Contaminants for Electroless Copper Working Bath and Their Symptoms than expected ..... 7-21

Table 11-1 Laminate Process – Problem Sources and Subsequent Effects ..... 11-1

# Table of Contents

## Section 1

<b>1 GENERAL INTRODUCTION</b> .....	1-1
1.1 IPC-9121 Format Example.....	1-1
<b>Issue:</b> Photoresist under-exposure .....	1-1
1.2 Guidelines for Effective Troubleshooting and Process Control .....	1-1
1.3 Parameter Analysis.....	1-2
1.3.1 Brainstorming .....	1-2
1.3.2 Process Audit.....	1-3
1.3.3 Initial Capability Study.....	1-3
1.3.4 Optimization.....	1-3
1.3.5 Confirmation and Final Capability Assessment ..	1-3
1.3.6 Parameter Control .....	1-3
1.3.7 Corrective Action Plan.....	1-3
1.4 Applicable Documents.....	1-3
1.4.1 IPC .....	1-3

# Troubleshooting for Printed Board Fabrication Processes

## Section 1 – General Introduction

### 1 GENERAL INTRODUCTION

This handbook provides problems, causes and possible corrective actions related to PWB manufacturing processes. To keep this document current, readers are encouraged to submit process problems with photos as well as proposed causes and solutions to the IPC 7-24 Printed Board Process Effects Handbook Subcommittee. Submissions will be considered for document revisions.

**1.1 IPC-9121 Format Example** This document follows the general format seen below. In instances where there is no photo, a photo is not necessary or one could not be found. Readers are encouraged to submit photos which they feel best describe an adverse process effect. Potential test methods for discovery and verification are included in tables where applicable.

#### Issue: Photoresist under-exposure

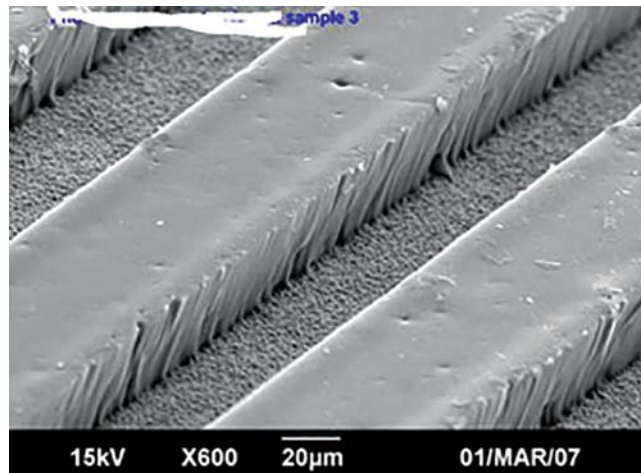


Figure 1-1

CAUSE	ACTION
UV source inadequate	Check exposure intensity/wavelength/duration
Expose intensity inadequate	Review, reinstated exposure control procedures
Expose time inadequate	Review, reinstated exposure control procedures
Oxygen exposure of photoresist prior to exposure	Review photoresist shelf life
Potential test methods (discover)	Potential test method (verification)
AOI (line/space reproduction) Etch-outs	AOI Periodic UV photometer and step tablet exposure checks

**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 major problem is encountered. This section suggests steps to effectively find the cause of a problem and to solve it permanently. Refer to IPC-9191 for suggested methodology for statistical process control (SPC).

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

2. 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.
3. Develop a clear, concise problem statement that quantifies the problem whenever possible and reduces the scope of the investigation to a manageable size.
4. Gather all pertinent data and facts.
  - Use SPC, historical data, records, logs, etc.
  - This includes temperature charts, analysis records, maintenance logs, etc.
5. Perform a causal analysis:
  - Producing out-of-specification parts requires immediate action (i.e., shut down the process).
  - Out-of-control processes require determination whether the process can continue to operate.
  - Severe process variation requires evaluation of the severity and effect of the problem on the final product.
6. Develop an action plan which includes 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:
  - Disposition of the defective material (repair, scrap, replace, etc.).
  - Checking the effect on scheduled delivery.
  - Informing the effect on scheduled delivery.
  - Request for nonconformance authority or Material Review Board (MRB) action.
  - Establish a corrective action plan to reduce or eliminate the likelihood of recurrence.
7. Conduct a Measurement System Evaluation, which is a means used to detect and identify the problem. This includes not only the measuring apparatus, but also:
  - The sampling method.
  - The operator (and his/her instructions).
  - Accuracy and calibration of equipment.
  - Environmental factors (e.g., lighting, temperature, and relative humidity (RH))
8. 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. IPC-9191 discusses this subject in greater detail.

**1.3 Parameter Analysis** The purpose of parameter analysis, as detailed in IPC-9191, is to establish cause-effect relationships and to identify, isolate and rank major sources of variation. Common sources are:

- Positional variation (within a piece).
- Cyclical variation (piece to piece).
- Temporal variation (over time).

**1.3.1 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 (i.e., “fishbone” diagram for root cause analysis). The ranking of these factors by the problem-solving team should be used to establish those factors that will be studied experimentally. The problem-solving team should, at a minimum, include manufacturing engineers, quality engineering and operators who are intimate with the process. The team should take care to openly consider new ideas on the problem.

Situations may occur in which the formation of a brainstorming team is inappropriate. Only someone with troubleshooting experience 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.