



IPC-9121

Troubleshooting for Printed Board Fabrication Processes

Developed by the Printed Board Process Effects Handbook
Subcommittee (7-24) of the Process Control Management
Committee (7-20) of IPC

Supersedes:

PCB 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

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

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

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

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

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

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

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

	Issue: 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			
	Issue: 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			
	Issue: 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			
	Issue: Poor dry film resist adhesion to the (un-scrubbed) electroless copper surface	8-11			
8.2.6	Solder Conditioning Before Fusing	8-12			
	Issue: Equipment corroded by chemistry	8-12			
8.2.7	Cleaning After Fusing or Hot-Air Solder Leveling (HASL)	8-12			
	Issue: Tin-lead still dark after solder conditioning/brightening step	8-12			
	Issue: Flux residue	8-12			
	Issue: White residue on board after cleaning	8-12			
	Issue: High ionic contamination levels, as evidenced by solvent extract resistivity testing	8-12			
8.3	Electrocleaning	8-13			
	Issue: Copper-to-copper peelers after pattern plating	8-13			
	Issue: Resist breakdown, edge-lifting, and under-plating during pattern plating	8-13			
	Issue: Resist image stripped in the electrocleaner	8-13			
	Issue: Step plating	8-13			
Notes for Section 8		8-14			
9	INTERCONNECT FORMATION	9-1			
9.1	Imaging	9-1			
9.1.1	Dry-Film Photoresist	9-1			
	Issue: Photoresist under-exposure	9-2			
	Issue: Resist scum/residue on panels after development	8-3			
	Issue: Poor tenting (insufficient resist bridging of PTHs) performance	9-4			
	Issue: Inability to completely develop-out unexposed resist areas	9-5			
	Issue: Photoresist image damage during development, image lifting and/or ragged circuit lines after development	9-6			
	Issue: Resist breakdown and lifting during etching	9-7			
	Issue: Resist breakdown, edge lifting and under-plating during pattern electroplate operation	9-8			
	Issue: Copper-to-copper peelers after pattern plating	9-9			
	Issue: Skip and step plating in developed-out circuit pattern	9-10			
	Issue: Photoresist residue on board after stripping	9-11			
9.1.2	Total Aqueous Resist	9-12			
	Issue: Incomplete development of unexposed resist	9-12			
	Issue: Photoresist image soft, dull in appearance, and easily damaged after development	9-13			
	Issue: Resist breakdown during pattern plating	9-14			
	Issue: Incomplete stripping	9-15			
	Issue: Redeposition of stripped resist back onto circuit pattern	9-16			
9.1.3	Liquid Photoresist	9-17			
	Issue: Resist breakdown in plating	9-17			
	Issue: Line width reduction or inability to develop-out unexposed resist	9-17			
	Issue: Photoresist image damage during development (image lifting and/or ragged circuit lines after development)	9-18			
	Issue: Copper-to-copper peelers after pattern plating	9-19			
	Issue: Skip plating in developed-out circuit pattern	9-19			
	Issue: Photoresist residue on board after stripping	9-19			
9.1.4	Screen-Printed Resist	9-20			
	Issue: Shadows or ghosts on screened boards	9-20			
	Issue: Ink deposit too heavy	9-20			
	Issue: Bubbles in screen-printed image	9-21			
	Issue: Large voids in resist image (fish eyes or craters)	9-21			
	Issue: Ink runs through screen	9-21			

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

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

10 ETCHING	10-1	Issue: Over-etching	10-9
10.1 Equipment-Related Effects and Effects From Other Processes	10-1	Issue: Under-etching	10-10
Issue: Nonuniform etch from side-to-side of panel	10-1	10.4 Peroxide-Sulfuric Etchants	10-10
Issue: Nonuniform etch (copper left on some areas of panel while other areas are etched properly)	10-1	10.4.1 Bath Control	10-10
Issue: Excessive undercut (over-etching conductor)	10-2	Issue: Excessive peroxide consumption	10-10
Issue: Panels skewing on conveyor	10-2	Issue: Blackening of tin-lead solder during etching	10-11
Issue: Copper left around circuit patterns	10-3	Issue: Slow, but uniform etch rate	10-11
Issue: Etch rate slows	10-3	Issue: Etchant solution temperature rises	10-11
Issue: Etchant attacks resist (on print-and- etch work)	10-3	Issue: Etchant temperature loss	10-11
Issue: Front of panel etches differently from back of panel	10-3	Issue: Excessive foam blanket	10-11
10.2 Cupric Chloride	10-4	Issue: 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	Issue: Building solution volume	10-12
Issue: Over-chlorination causing free chlorine in atmosphere around machine	10-4	Issue: Etchant solution volume drop	10-12
Issue: Sudden slowdown in etch rate	10-4	10.4.2 Improper Etching	10-12
Issue: Slow etching/Etch rate is not as fast as it should be but seems fairly steady	10-5	Issue: Nonuniform etch (copper left in some areas of panel while others are etched properly)	10-12
10.2.2 Improper Etching	10-6	Issue: 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
Issue: Over-etching	10-6	Issue: Fast etch rate, over-etch	10-12
Issue: 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	Issue: Etch rate very slow	10-13
Issue: Excessive crystallization in etcher	10-7	Issue: Excess foaming of etchant	10-13
Issue: Etchant no longer etches/Alkaline salts precipitate out of etchant and fall to bottom of etch sump (sludging)	10-8	Issue: Muddy-brown etchant color	10-13
Issue: Etch rate slows as boards are being processed	10-8	Issue: Sudden slowdown in etch rate	10-13
Issue: 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	Issue: Over-etching	10-14
		Issue: Under-etching	10-14
		10.6 Ammonium or Sodium Persulfate	10-14
		Issue: Slow etch rate	10-14

11 LAYERING AND LAMINATION	11-1	Issue: 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
Issue: Breakout due to no annular ring	11-2	Issue: Circuits moved during lamination	11-9
11.1.2 Blisters/Delamination and Inter-laminate Adhesion	11-3	Issue: Misalignment of holes to innerlayer image	11-9
11.1.3 Bow/Twist	11-3	Issue: Dielectric spacing violation	11-9
11.1.4 Laminate Voids	11-3	Issue: Conductive anodic filament (CAF) ...	11-9
11.1.5 Resin Starvation	11-3	Issue: Resin starvation	11-3
Issue: Resin starvation	11-3	11.4.2 Blisters/Delamination	11-10
11.1.6 Panel/Board Thickness	11-3	Issue: 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	Issue: Panel or board warped or twisted after lamination or final routing	11-10
Issue: Pits	11-4	11.4.4 Laminate Voids	11-10
11.1.9 Measling	11-4	Issue: Entrapped air in prepreg	11-10
Issue: Measling	11-4	Issue: 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	Issue: Internal frosty appearance (seen mostly in areas with little circuitry)	11-10
Issue: 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	Issue: Panel overall and dielectric thicknesses too thin/Excessive amount of cured resin framing panel	11-11
Issue: Resin fractures after lamination	11-5	Issue: Panel is thicker or thinner than specification	11-11
Issue: Delamination	11-6	Issue: Dielectric thickness is violated	11-11
11.2.3 Laminate Voids	11-7	11.4.7 Surface Imperfections	11-11
Issue: A random series or line of voids, particularly a problem in spacing with one or two plies of low-flow prepreg	11-7	Issue: Pits, dents, epoxy or scratches on panel surface	11-11
11.2.4 Surface Imperfections	11-7	11.5 Tooling	11-11
Issue: Scratches on surface of panels after lamination or post-bake	11-7	11.5.1 Misregistration	11-12
11.3 Equipment	11-7	Issue: Misregistration	11-12
11.3.1 Misregistration	11-7	Issue: Internal layers reversed backwards, upside down	11-12
Issue: Misregistration	11-7	Issue: Inner-layer images smaller or larger than drilled-hole pattern	11-12
Issue: Controlled-depth drill too deep, violating minimum dielectric spacing requirement	11-8	Issue: Innerlayer(s) randomly misregistered in localized areas	11-12
Issue: 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	Issue: Panel will not lay flat after lamination	11-13
Issue: 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			
	Issue: Depressions in copper surface after lamination	11-13			Issue: 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			Issue: Delamination of prepreg and constraining cores, such as copper-invar- copper and copper-molybdenum-copper
	Issue: Innerlayer images smaller or larger than drilled-hole pattern	11-13			11-20
	Issue: Misregistration of layers on different cores	11-14			Issue: Micro-voids in laminated multilayer boards
	Issue: 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
	Issue: Blisters appear between boards on a panel	11-14		Issue: White areas of air entrapment in prepreg	11-20
	Issue: Separation occurs over large copper area	11-14		Issue: Blisters and delamination at the oxide or laminate interface with the cured prepreg	11-21
11.6.3	Bow and Twist (Warped)	11-15		Issue: Fractures visible after lamination ...	11-21
	Issue: 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		Issue: Voids – air or moisture in prepreg areas	11-22
	Issue: Micro-voids in laminated multilayer boards	11-15	11.8.3	Panel Thickness	11-22
11.6.5	Resin Starvation	11-15		Issue: Excess bead of flow around panel edges/Panel has excessive taper (thicker at center, thinner at edges)	11-22
	Issue: 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
	Issue: Panel is thicker or thinner than specification	11-15		Issue: Lifted circuits or low foil bond strength	11-22
	Issue: Panel is thinner at the edges than the center	11-15		Issue: Localized separation at copper foil/prepreg interface	11-22
	Issue: Panel is thinner than specification ..	11-15	11.9.2	Surface Imperfections	11-22
	Issue: High spots within a panel	11-16		Issue: 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
	Issue: Improper etch leading to spacing violation	11-16		Issue: White areas of air entrapment in the prepreg	11-22
	Issue: Innerlayer images smaller or larger than drilled-hole pattern	11-16	11.10.2	Bow and Twist (Warped)	11-23
	Issue: Etched image on innerlayers randomly misregistered to drilled- hole pattern	11-17		Issue: 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
	Issue: Localized separation at prepreg/ oxide interface	11-17		Issue: Panel overall thickness incorrect	11-23
	Issue: Separation at prepreg/innerlayer oxide interface	11-18		Issue: Some boards/panels are thick, and some are thin	11-23

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

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

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

1 GENERAL INTRODUCTION	1-1
1.1 IPC-9121 Format Example.....	1-1
Issue: 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

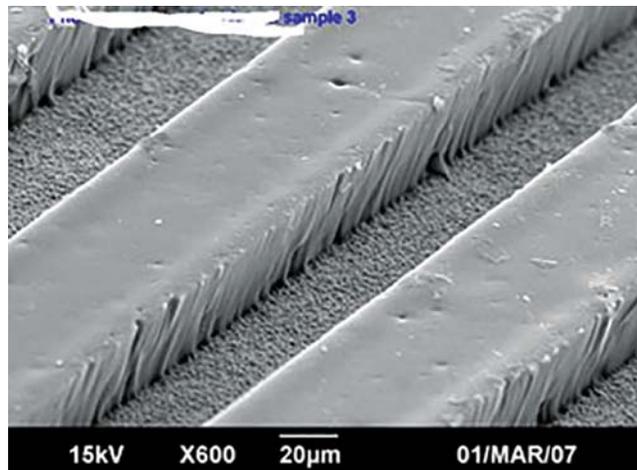


Figure 1-1

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.