

Design for Manufacturability for PCBs

IPC Designers Council North Alabama Meeting

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DfM for PCBs Webinar Overview

- In the electronics industry, the quality and reliability of any product is highly dependent upon the capability of the manufacturing supplier. Manufacturing issues are one of the top reasons that companies fail to meet warranty expectations, which can result in severe financial pain and eventual loss of market share. What a surprising number of engineers and managers fail to realize is that focusing on processes addresses only part of the issue. Design plays a critical role in the success or failure of manufacturing and assembly.
- Designing printed boards today is more difficult than ever before because of the increased lead free process temperature requirements and associated changes required in manufacturing. Not only has the density of the electronic assembly increased, but many changes have taken place throughout the entire supply chain regarding the use of hazardous materials and the requirements for recycling. Much of the change is due to the European Union (EU) Directives regarding these issues. The RoHS and REACH directives have caused many suppliers to the industry to rethink their materials and processes. Thus, everyone designing or producing electronics has been or will be affected.
- This webinar provides focused insight into some areas where design plays an important role in the manufacturing process. This workshop addresses the increasingly sophisticated PCB fabrication technologies.

Instructor Biography

- Cheryl Tulkoff has over 22 years of experience in electronics manufacturing with an emphasis on failure analysis and reliability. She has worked throughout the electronics manufacturing life cycle beginning with semiconductor fabrication processes, into printed circuit board fabrication and assembly, through functional and reliability testing, and culminating in the analysis and evaluation of field returns. She has also managed no clean and RoHS-compliant conversion programs and has developed and managed comprehensive reliability programs.
- Cheryl earned her Bachelor of Mechanical Engineering degree from Georgia Tech. She is a published author, experienced public speaker and trainer and a Senior member of both ASQ and IEEE. She holds leadership positions in the IEEE Central Texas Chapter, IEEE WIE (Women In Engineering), and IEEE ASTR (Accelerated Stress Testing and Reliability) sections. She chaired the annual IEEE ASTR workshop for four years and is also an ASQ Certified Reliability Engineer.
- She has a strong passion for pre-college STEM (Science, Technology, Engineering, and Math) outreach and volunteers with several organizations that specialize in encouraging pre-college students to pursue careers in these fields.

Webinar Outline

MODULE 1: INTRODUCTIONS

- Intro to Design for Manufacturability

MODULE 2: INDUSTRY STANDARD DESIGN RULES

- Overview of Industry Standard Organizations
- Examples: IPC, JEDEC, ISO
- Description of common standards in use

MODULE 3: DFM TASKS

- Types of Review Processes
- DfM Examples

Module 1: Introduction

Introduction to Design for Manufacturability (DfM)

Design for Manufacturability

- **Definition**
 - The process of ensuring a design can be consistently manufactured by the designated supply chain with a minimum number of defects
- **Requirements**
 - An understanding of best practices (what fails during manufacturing?)
 - An understanding of the limitations of the supply chain (you can't make a silk purse out of a sow's ear)
- **Criticality**
 - Failure to perform DfM increases the risk of a defective product or lot reaching the end customer
 - Warranty costs can be significant

DfM Failures

- DfM is often overlooked in the design process for some of the following reasons:
 - Design team often has poor insight into supply chain (reverse auction, anyone?)
 - OEM requests no feedback on DfM from supply chain
 - DfM feedback consists of standard rule checks (no insight)
 - DfM activities at the OEM are not standardized or distributed

Introduction to Design for Manufacturability (DfM)

- DfM is the process of proactively designing products to:
 - Optimize all of the manufacturing functions: supplier selection and management, procurement, receiving, fabrication, assembly, quality control, operator training, shipping, delivery, service, and repair.
 - Assure that critical objectives of cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction are known, balanced, monitored, and achieved.
- Successful DFM efforts require the integration of product design and process planning into a cohesive, interactive activity known as Concurrent, Collaborative, or Simultaneous Engineering.
 - If existing processes are to be used, new products must be designed to the parameters and limitations of these processes regardless of whether the product is built internally or externally.
 - If new processes are to be utilized, then the product and process need to be developed concurrently and mindfully (carefully considering the risks associated with “new”)

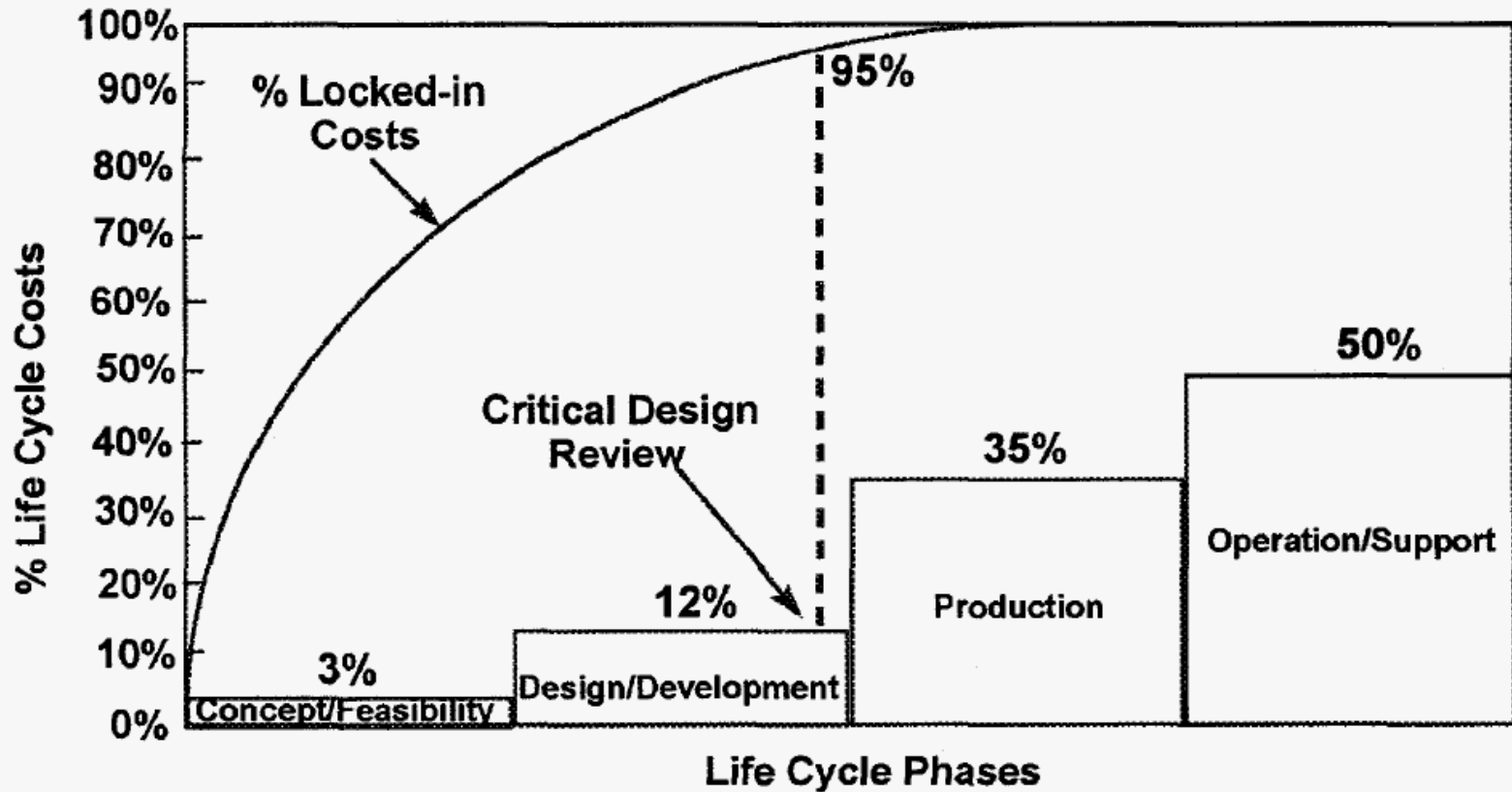
Why DfM?

- *DfM is a proven, cost-effective strategic methodology.*
- **Early effective cross functional involvement:**
 - Reduces overall product development time (less changes, spins, problem solving)
 - Results in a smoother production launch.
 - Speeds time to market.
 - Reduces overall costs.
 - Designed right the first time.
 - Optimizes # of parts
 - Optimizes # of process steps and use of correct, efficient steps
 - Reduces labor costs to repair and resolve issues
 - Improves overall production efficiency.
 - Build right the first time = less rework, scrap, and warranty costs.
 - **Improved quality and reliability results in:**
 - Higher customer satisfaction.
 - Reduced warranty costs.

Design Engineering Influence on Lifecycle Costs

- Design/product engineering typically accounts for only 8-10% of a product budget.
- Design decisions can determine up to 70-80% of the manufacturing cost of the product and have significant impact on quality, reliability and serviceability.
- These decisions determine cost throughout the lifecycle of the product. Once these costs are locked in, they are very difficult to change.
 - Require Engineering Change Orders (ECOs), design spins, supplier qualifications, and/or certification (UL, FDA) modifications
- Production decisions (material handling, process flow, assembly equipment) account for less than 20-30% of product costs.
- Total lifecycle cost, impacted by quality, and reliability, can be better managed and optimized by developing products and their associated manufacturing processes together with cross functional or collaborative teams aware of design for manufacturability and sourcing best practices.

Why DfM?

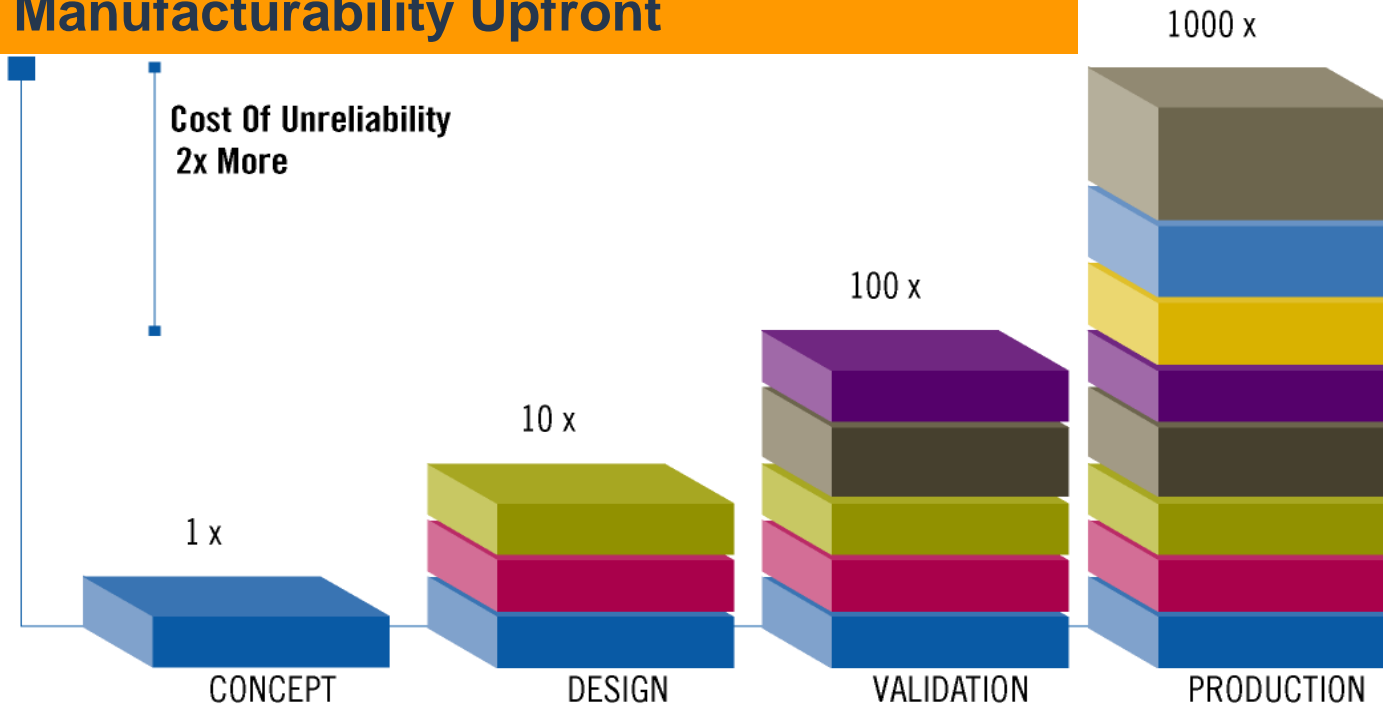


Architectural Design for Reliability, R. Cranwell and R. Hunter, Sandia Labs, 1997

DfR Solutions

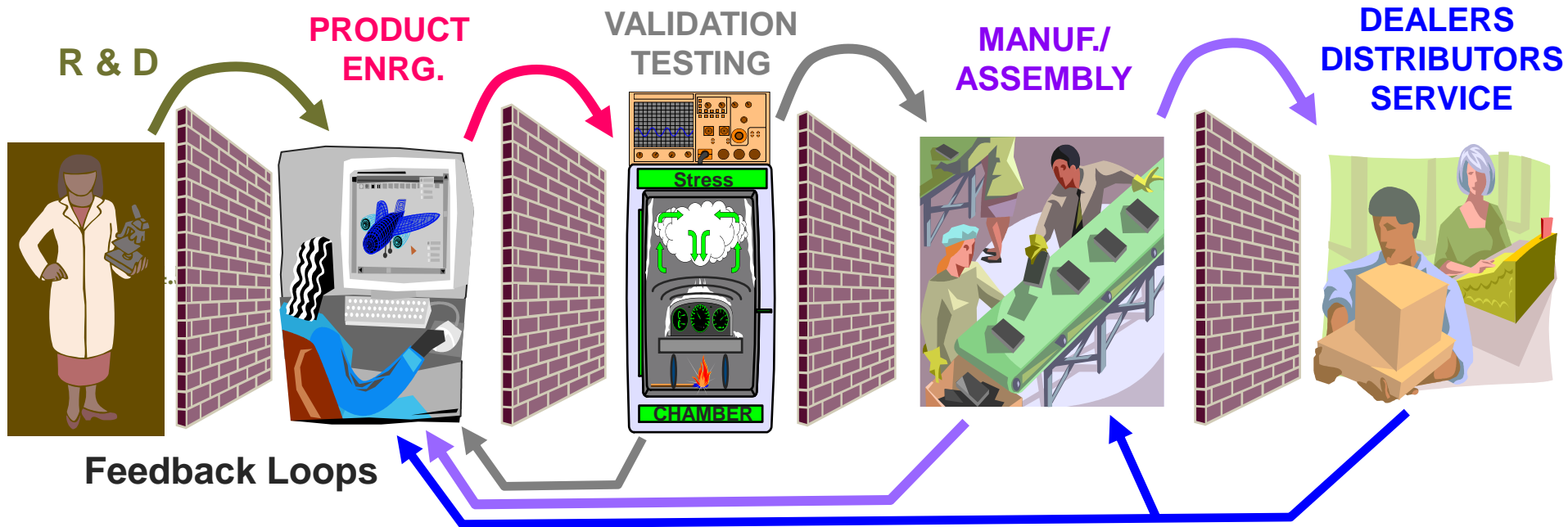
Why DfM? (cont.)

Reduce Costs by Improving Manufacturability Upfront



- Ideas/Sketches
- Engineering/Design
- Specs/Drawings
- Lost Market Share
- Verification/Testing
- Lost Production
- Warranty/Recall
- Prototype Parts

Old Style Product Development - “Sequential Over The Wall”



- Before DfM, it was “We designed it” ~ “You build it“!
- Design engineers worked independently, then transferred designs “over the wall” to the next department or external to the company (CM).
- Eventually manufacturing has to assemble the product.
 - Usually inherit a product not designed for their processes and too late to make changes.
 - Manufacturing forced struggle to meet yield, quality, cost or delivery targets.
 - Often required trial & error crisis management
 - Followed by launch delays, then quality and reliability issues.

Develop & Share Manufacturability Guidelines

- The foundation of a robust Design for Manufacturing system is a set of design guidelines and tasks to help the product team improve manufacturability, increase quality, reduce lifecycle cost and enhance long term reliability.
- These guidelines need to be customized to your company's culture, products, technologies, equipment and based on a solid understanding of the intended production system – whether internal or external.

Module 2: Industry Standard Design Rules

Industry Standards – IPC, JEDEC, ISO...

- **Make use of existing industry standards where possible**
 - Tried and true
 - Well tested and accepted
 - But – may represent only minimum acceptable requirements or concerns not relevant to your needs. Remember to modify and extend requirements as needed to customize for your product and environments!
 - Their forums provide opportunities to solicit free advice and feedback on issues you face and questions you have.



IPC Design Requirement/Guideline References

- The IPC is a global trade association dedicated to the competitive excellence and financial success of all facets of the electronic interconnect industry including design, printed circuit board manufacturing and electronics assembly. <http://www.ipc.org/>
- Provide a forum to brings together all industry players, including designers, board manufacturers, assembly companies, suppliers, and original equipment manufacturers.
- Provides resources to:
 - Management improvement and technology enhancement
 - Creation of relevant standards
 - Protection of the environment
 - Pertinent government relations.

IPC Design Requirement/Guideline References

○ **IPC-2221- Generic Standard on Printed Board Design**

- IPC-2221A is the foundation design standard for all documents in the IPC-2220 series. It establishes the generic requirements for the design of printed boards and other forms of component mounting or interconnecting structures, whether single-sided, double-sided or multilayer.
- **3 Performance Classes**
 - *Class 1 General Electronic Products* - consumer products,
 - *Class 2 Dedicated Service Electronic Products*
 - Communications equipment, sophisticated business machine, instruments and military equipment where high performance, extended life and uninterrupted service is desired but is not critical.
 - *Class 3 High Reliability Electronic Products*
 - Commercial, industrial and military products where continued performance or performance on demand is critical and where high levels of assurance are required...

IPC Design Requirement/Guideline References

- IPC-4101 - Specification for Base Materials for Rigid and Multilayer Printed Boards
 - Covers the requirements for base materials that are referred to as laminate or prepreg. These are to be used primarily for rigid and multilayer printed boards for electrical and electronic circuits.
- IPC-7351 - Generic Requirements for Surface Mount Design and Land Pattern Standards
 - Covers land pattern design for all types of passive and active components, including resistors, capacitors, MELFs, SSOPs, TSSOPs, QFPs, BGAs, QFNs and SONs. The standard provides printed board designers with an intelligent land pattern naming convention, zero component rotations for CAD systems and three separate land pattern geometries for each component that allow the user to select a land pattern based on desired component density.
 - Includes land pattern design guidance for lead free soldering processes, reflow cycle and profile requirements for components and new component families such as numerous forms of chip array packages and "pull-back" QFN and SON devices.

JEDEC/IPC Joint Standards

- JEDEC is the leading developer of standards for the solid-state industry. Almost 3,300 participants, appointed by some 300 companies work together in 50 JEDEC committees to meet the needs of every segment of the industry, manufacturers and consumers alike. The publications and standards that they generate are accepted throughout the world. All JEDEC standards are available online, at no charge.
www.jedec.org
- Commonly referenced JEDEC/IPC Joint Standards standards:
 - J-STD-020D.01: JOINT IPC/JEDEC STANDARD FOR MOISTURE/REFLOW SENSITIVITY CLASSIFICATION FOR NONHERMETIC SOLID STATE SURFACE-MOUNT DEVICES:
 - This document identifies the classification level of nonhermetic solid-state surface mount devices (SMDs) that are sensitive to moisture-induced stress. It is used to determine what classification level should be used for initial reliability qualification. Once identified, the SMDs can be properly packaged, stored and handled to avoid subsequent thermal and mechanical damage during the assembly solder reflow attachment and/or repair operation. This revision now covers components to be processed at higher temperatures for lead-free assembly.
 - JS9704 : IPC/JEDEC-9704: Printed Wiring Board (PWB) Strain Gage Test Guideline
 - This document describes specific guidelines for strain gage testing for Printed Wiring Board (PWB) assemblies. The suggested procedures enables board manufacturers to conduct required strain gage testing independently, and provides a quantitative method for measuring board flexure, and assessing risk levels. The topics covered include: Test setup and equipment; requirements; Strain measurement; Report format

ISO Standards

- ISO (International Organization for Standardization) is the world's **largest developer** and publisher of **International Standards**. www.iso.org
- ISO is a **network** of the national standards institutes of **162 countries**, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.
- ISO is a **non-governmental organization** that forms a bridge between the public and private sectors. On the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations.
- Therefore, ISO enables a **consensus** to be reached on solutions that meet both the requirements of business and **the broader needs of society**.
- Some commonly used ISO Standards
 - ISO 9001: Quality Management Systems
 - ISO 14050: Environmental Management Systems
 - ISO 13485: Medical devices -- Quality management systems -- Requirements for regulatory purposes

Commonly Used Lab Test & Reference Standards

- IPC-TM-650: Test Methods Manual
 - Series available for free download at www.ipc.org
 - <http://www.ipc.org/ContentPage.aspx?PageID=4.1.0.1.1.0>
 - Section 1.0:Reporting and Measurement Analysis Methods
 - Section 2.1:Visual Test Methods
 - Section 2.2:Dimensional Test Methods
 - Section 2.3:Chemical Test Methods
 - Section 2.4:Mechanical Test Methods
 - Section 2.5:Electrical Test Metho
 - Section 2.6:Environmental Test Methods

Module 3: Overview of DfM Tasks

Common Types of DfM Review Processes

- **Informal “Gut Check” Review**
 - Performed by highly experienced engineers.
 - Difficult with transition to original design manufacturers (ODM) in developing countries.
 - “Tribal knowledge”
- **Formal Design reviews**
 - Internal team
 - External experts
- **Automated (electronic) design automation (ADA) software**
 - Modules automate DfM rule checking.
- **Electronic manufacturing service (EMS) providers**
 - Perform DfM as a service



Design for Manufacturability (DfM)

- **Formal DfM Reviews and Tools Sometimes Overlooked**
 - Organization may lack specialized expertise.
 - More design organizations completely insulated/disassociated from manufacturing.
 - Dependence on local experience.
- **DfM Reviews Needs to be Performed for:**
 - Bare Board
 - Circuit Board Assemblies
 - Chassis/Housing Integration Packaging
 - System Assembly
- **DfM Needs to be conducted in conjunction with the actual electronic assembly source.**
 - What is good DfM for one supplier and one set of assembly equipment may not be good for another.

DfM Example: Plated Through Hole vs. Microvia

- What should be the minimum diameter of a PTH in your design?
- What should be the maximum aspect ratio (PCB Thickness / PTH Diameter)?
- When should you switch to microvias?
- Answer: Depends!
 - Supplier
 - Reliability needs

PTH Diameter

- Data from 26 board shops
 - Medium to high complexity
 - 62 to 125 mil thick
 - 6 to 24 layer
- Results
 - Yield loss after worst-case assembly
 - Six simulated Pb-free reflows

Process Attribute	Hole/land (mils)	Count	Min	Q1	Median	Q3	Max
Yield Loss from Assembly Simulation (%) Threshold: Open	8 / 18	6	0.00	0.00	0.31	3.24	17.16
	10 / 20	15	0.00	0.00	0.00	1.13	4.60
	12 / 22	26	0.00	0.00	0.00	0.00	5.23
	13.5 / 23.5	26	0.00	0.00	0.00	0.00	4.09
	14.5 / 24.5	19	0.00	0.00	0.00	0.00	0.00
	16 / 26	11	0.00	0.00	0.00	0.00	0.00

Yield loss can results in escapes to the customer!

Are Microvias more reliable than PTHs?

- Depends!!
- Quality
 - Some fabricators have no problems
 - Some have more problems with microvias
 - Some have more problems with PTHs
 - Some have problems with both
- Reliability
 - A well-built microvia is more robust than a well-built PTH

PTH vs. Microvia

PTH Quality

Process Attribute	Hole/land (mils)	Count	Min	Q1	Median	Q3	Max
Defect Density (Defects per Million Vias)	8 / 18	6	25	60	177	380	737
	10 / 20	15	0	15	44	178	2947
	12 / 22	26	0	0	6	30	1013
	13.5 / 23.5	26	0	0	0	27	512
	14.5 / 24.5	19	0	0	0	17	173
	16 / 26	11	0	0	0	0	44

Microvia Quality

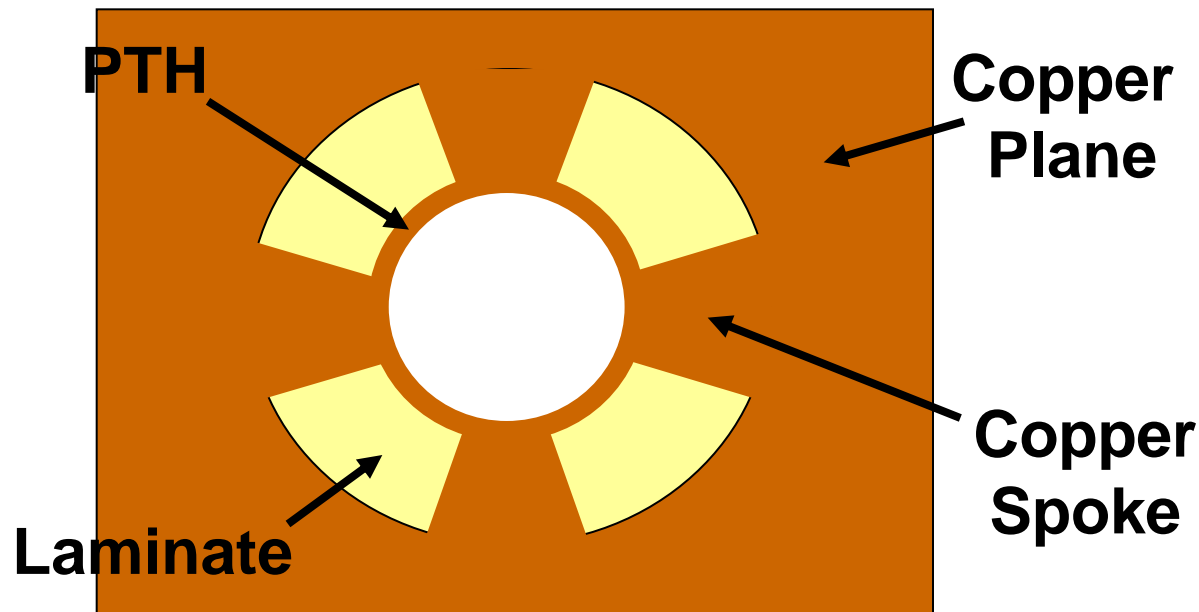
Process Attribute	Annular Ring (mils)	A	B	C	D	E	F	G
Defect Density (Defects per Million Vias)	2 / 8	7384	8007	26598	68	61	598	81
	3 / 9	5527	2558	1735	38	8	76	24
	4 / 10	2370	1187	17	23	0	53	0
	5 / 11	2092	372	0	15	0	91	32

Summary (PTH and Microvias)

- The capability of the PCB industry in regards to hole diameter tends to segment
 - Very high yield (>13.5 mil)
 - High yield (10 – 13.5 mil)
 - Lower yield (< 10 mil)
- If 8 mil drill diameter or less is required
 - Consider using PCQR² to identify a capable supplier
 - Consider using interconnect stress test (IST) coupons to ensure quality for each build
 - Consider transitioning to microvias (6 mil diameter)

DfM Examples (cont.)

- Utilize thermal reliefs on all copper planes when practical
 - Reduces thermal transfer rate between PTH and copper plane
 - Allows for easier solder joint formation during solder (especially for Pb-free)
 - Allows for better hole fill



Courtesy of D. Canfield (Excalibur Manufacturing)

PCB Surface Finishes – Selection Influences Failures!

- **Definition:** A coating located at the outermost layer and exposed copper of a PCB.

- Protects copper from oxidation that inhibits soldering
- Dissolves into the solder upon reflow or wave soldering.
- SnPb HASL (Hot Air Solder Leveling) being replaced by other finishes due to technology and RoHS-Pb-free trends.

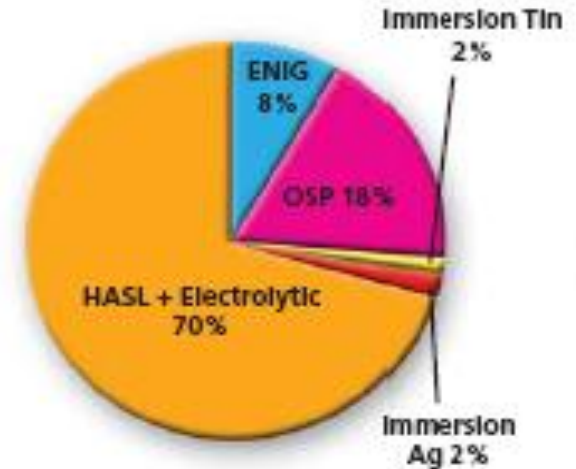
- **Options (no clear winner)**

- Electroless nickel/immersion gold (ENIG)
- Immersion tin (ImSn)
- Immersion silver (ImAg)
- Organic solderability preservative (OSP)
- Pb-free HASL
- Others (ENEPIG, other palladium, nano finishes etc.)

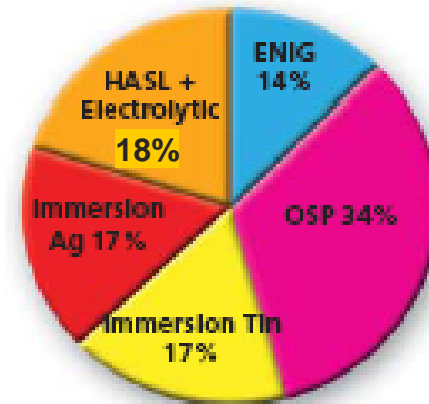
- **Most platings, except for Pb-free HASL, have been around for several years**

Surface Finishes, Worldwide

2003



2007

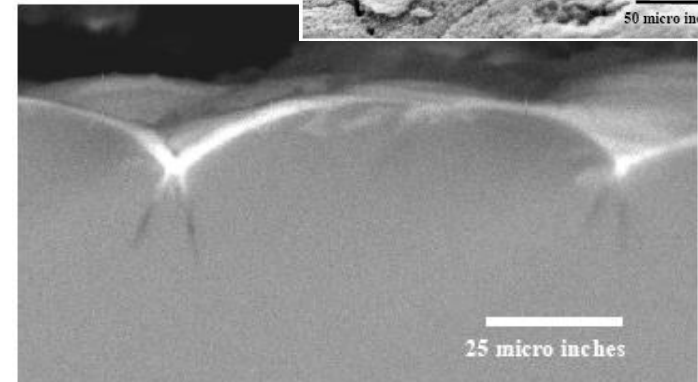
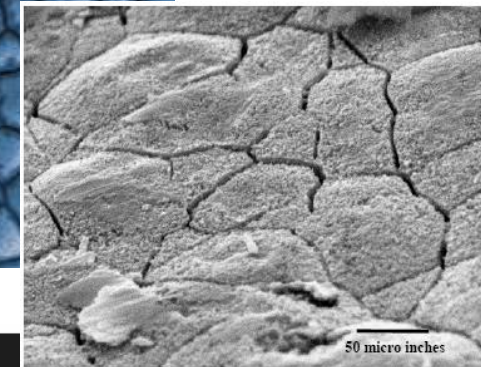
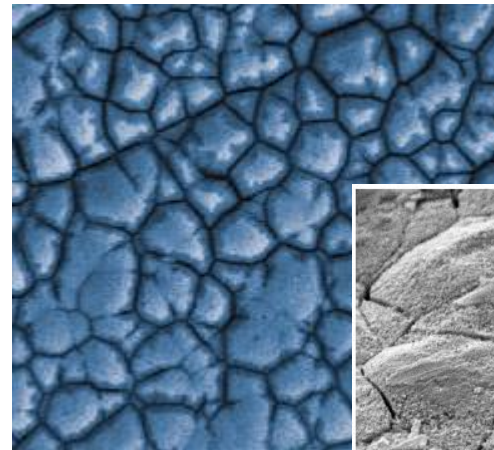


J. Beers
Gold Circuits

DfR Solutions

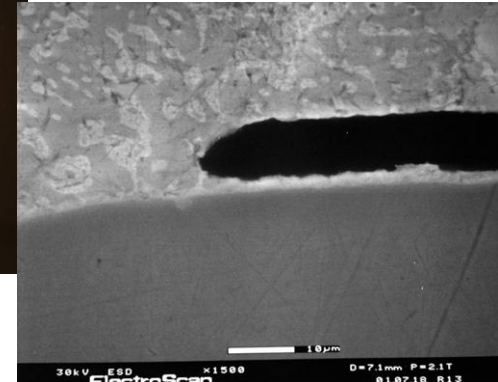
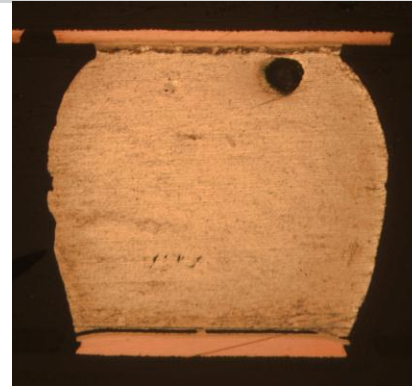
ENIG (Primary Issue)

- Solder Embrittlement
 - Not always black pad
- Not explained to the satisfaction of most OEMs
- Numerous drivers
 - Phosphorus content
 - High levels = weak, phosphorus-rich region after soldering
 - Low levels = hyper-corrosion (black pad)
 - Cleaning parameters
 - Gold plating parameters
 - Bond pad designs
 - Reflow parameters?
- Results in a severe drop in mechanical strength
 - Difficult to screen
 - Can be random (e.g., 1 pad out of 300)
- Board fabricators need to be on top of numerous quality procedures to prevent defects.



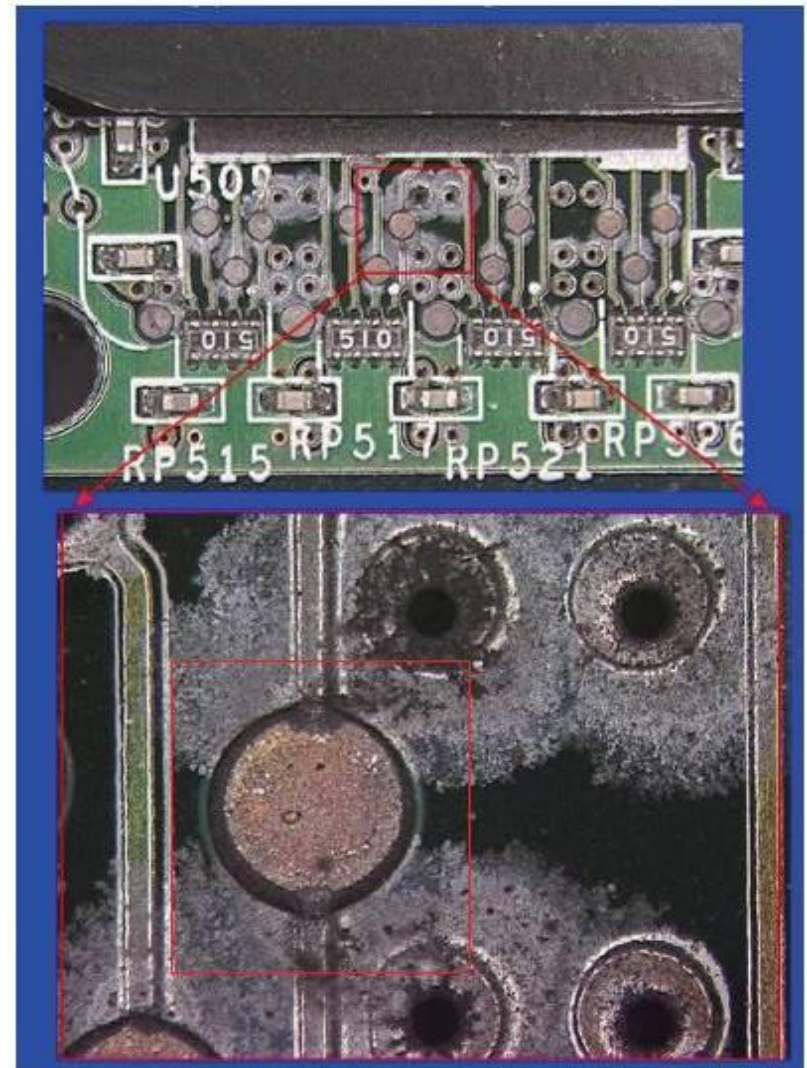
Other ENIG Failure Mechanisms

- **Insufficient nickel thickness**
 - Potential diffusion of copper through the nickel underplate
 - Can reduce storage time and number of reflow cycles
- **Bond pad adhesion**
 - Problem with corner balls on very large BGAs (>300 I/O)
- **Reduced plated through hole reliability (stress concentrators)**
- **Dewetting**
- **Crevice corrosion (trapped residues)**
- **Poor performance under mechanical shock / drop**



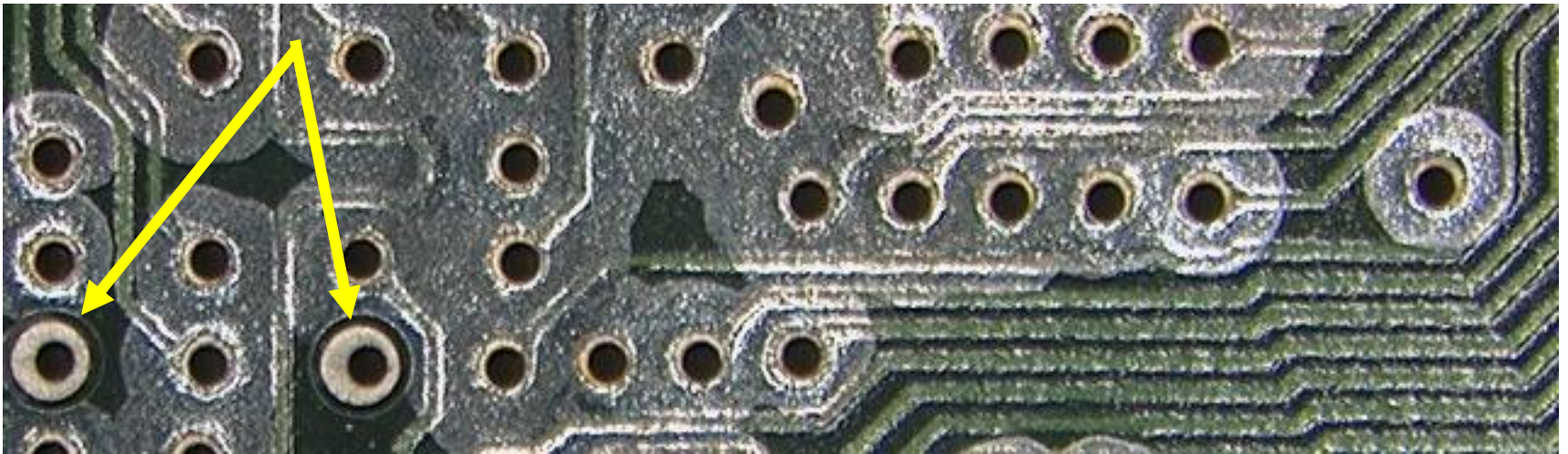
Sulfide Corrosion and Migration of Immersion Silver

- Failures observed within months
 - Sulfur-based gases attack exposed immersion silver
 - Non-directional migration (creepage corrosion)
- Occurring primarily in environments with high sulfur levels. Not recommended for these applications.
 - Rubber manufacturing
 - Waste treatment plants
 - Petroleum refineries
 - Coal-generation power plants,
 - Paper mills
 - Sewage/waste-water treatment
 - Landfills
 - Large-scale farms
 - Modeling clay



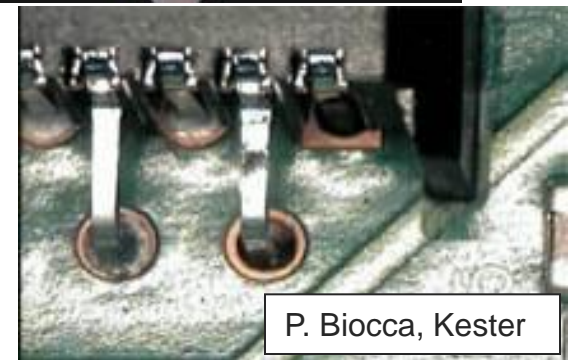
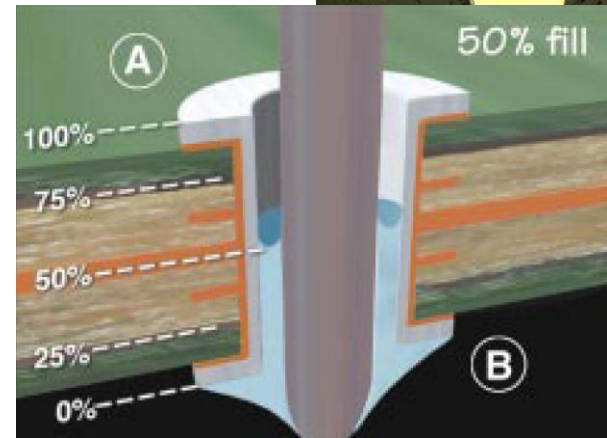
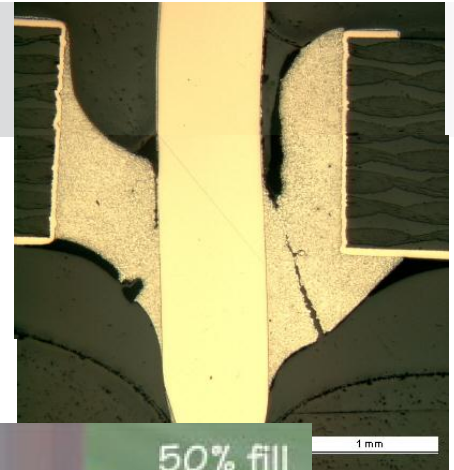
Influence of Board Design and Manuf. Process

- No corrosion observed on non-solder mask defined pads (see yellow arrows)
- Similar behavior observed during crevice corrosion on ENIG boards.



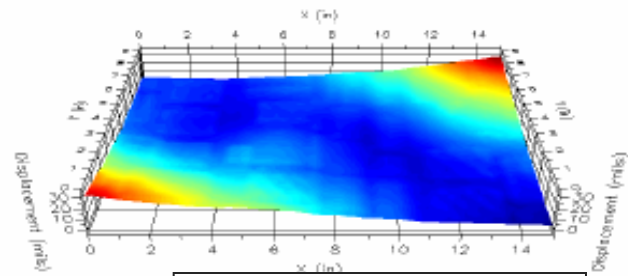
OSP & Hole Fill

- Fill is driven by capillary action
- Important parameters
 - Hole diameter, hole aspect ratio, wetting force, thermal relief
 - Solder will only fill as long as its molten (key point)
- OSP has lower wetting force
 - Risk of insufficient hole fill
 - Can lead to single-sided architecture
- Solutions?
 - Changing board solderability plating
 - Increasing top-side preheat
 - Increasing solder pot temperature (some go as high as 280C)
 - Changing your wave solder alloy



DfR Solutions

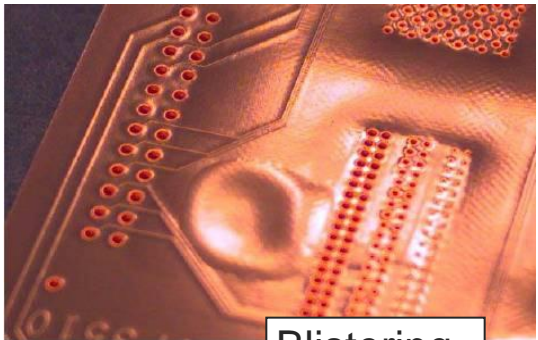
Printed Board Robustness Concerns



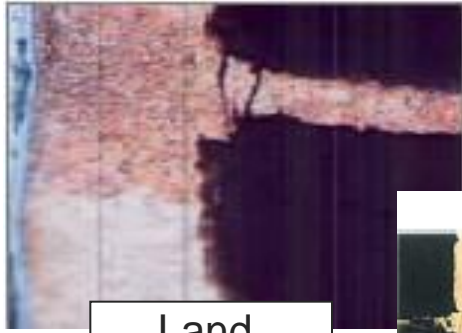
Increased Warpage



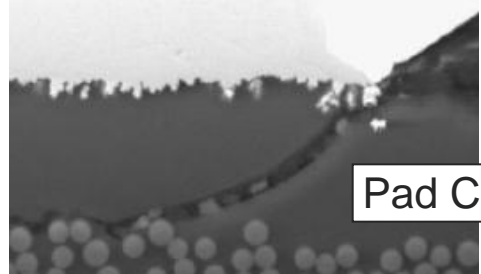
Solder Mask Discoloration



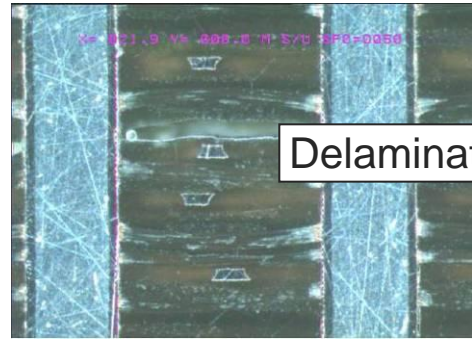
Blistering



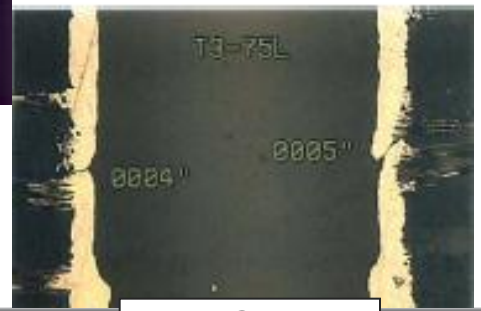
Land Separation



Pad Cratering



Delamination



PTH Cracks

Printed Board Damage

- Predicting printed board damage can be difficult
 - Driven by size (larger boards tend to experience higher temperatures)
 - Driven by thickness (thicker boards experience more thermal stress)
 - Driven by material (lower Tg tends to be more susceptible)
 - Driven by design (higher density, higher aspect ratios)
 - Driven by number of reflows
- No universally accepted industry model

PCB Robustness: Laminate Material Selection

Board thickness	IR-240~250°C	Board thickness	IR-260°C
≤60mil	Tg140 Dicy All HF materials OK	≤ 60mil	Tg150 Dicy HF- middle and high Tg materials OK
60~73mil	Tg150 Dicy NP150, TU622-5 All HF materials OK	60~73mil	Tg170 Dicy HF –middle and high Tg materials OK
73~93mil	Tg170 Dicy, NP150G-HF HF –middle and high Tg materials OK	73~93mil	Tg150 Phenolic + Filler IS400, IT150M, TU722-5, GA150 HF –middle and high Tg materials OK
93~120mil	Tg150 Phenolic + Filler IS400, IT150M, TU722-5 Tg 150 HF –middle and high Tg materials OK	93~130mil	Phenolic Tg170 IS410, IT180, PLC-FR-370 Turbo, TU722-7 HF –middle and high Tg materials OK
121~160mil	Phenolic Tg170 IS410, IT180, PLC-FR-370 Turbo TU722-7 HF –high Tg materials OK	≥131mil	Phenolic Tg170 + Filler IS415, 370 HR, 370 MOD, N4000-11 HF –high Tg materials OK
≥161mil	PhenolicTg170 + Filler IS415, 370 HR, 370 MOD, N4000-11 HF material - TBD	≥161mil	TBD – Consult Engineering for specific design review

1. Copper thickness = 2OZ use material listed on column 260 °C
2. Copper thickness ≥= 3OZ use Phenolic base material or High Tg Halogen free materials only
3. **Twice lamination product use Phenolic material or High Tg Halogen free materials only (includes HDI)**
4. Follow customer requirement if customer has his own material requirement
5. DE people have to confirm the IR reflow Temperature profile

J. Beers, Gold Circuits

PCB Robustness: Material Selection

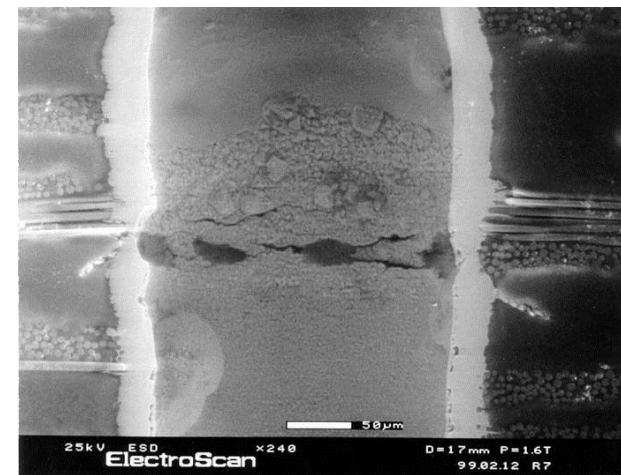
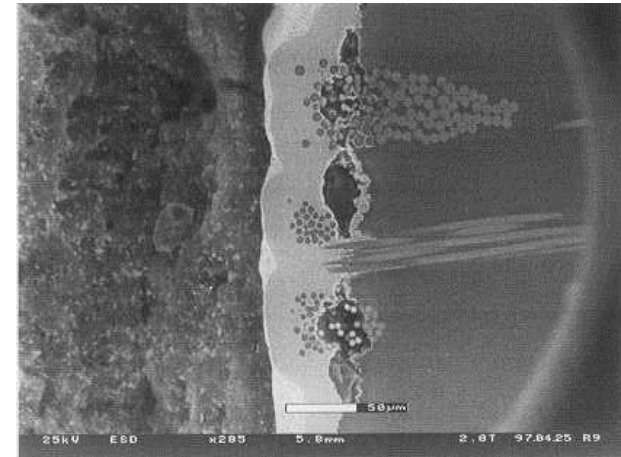
- The appropriate material selection is driven by the failure mechanism one is trying to prevent
 - Cracking and delamination
 - Plated through fatigue
 - Conductive anodic filament formation

Cracking and Moisture (cont.)

- Storage of prepregs and laminates
- Drilling process
 - Moisture is absorbed by the side walls (microcracks?)
 - Trapped after plating
- Storage of PCBs at PCB manufacturer
- Storage of PCBs at CCA manufacturer

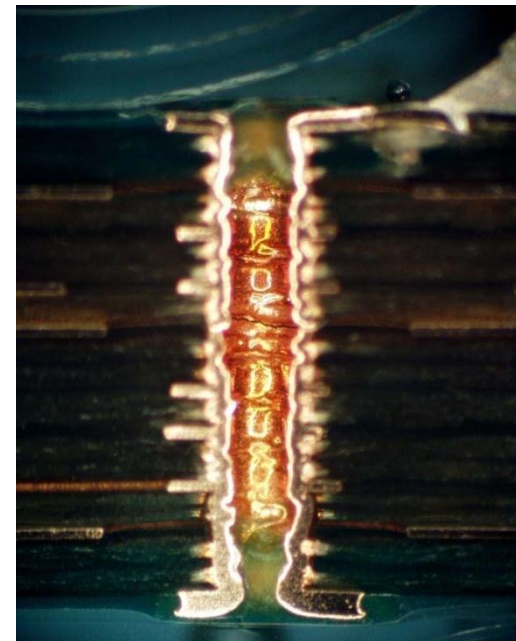
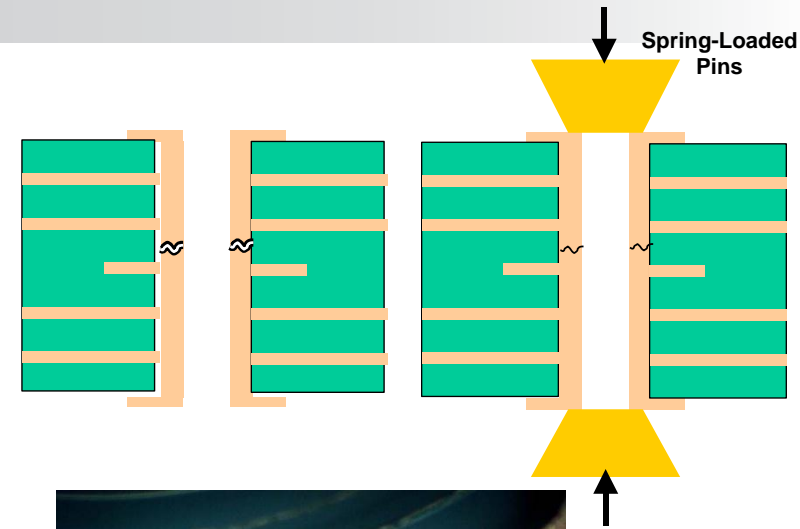
Plated Through Holes (PTH)

- **Voids**
 - Can cause large stress concentrations, resulting in crack initiation.
 - The location of the voids can provide crucial information in identifying the defective process
 - Around the glass bundles
 - In the area of the resin
 - At the inner layer interconnects (aka, wedge voids)
 - Center or edges of the PTH
- **Etch pits**
 - Due to either insufficient tin resist deposition or improper outer-layer etching process and rework.
 - Cause large stress concentrations locally, increasing likelihood of crack initiation
 - Large etch pits can result in a electrical open



Plated Through Holes (PTH)

- **Overstress cracking**
 - CTE mismatch places PTH in compression
 - Pressure applied during "bed-of-nails" can compress PTH
 - In-circuit testing (ICT) rarely performed at operating temperatures
- **Fatigue**
 - Circumferential cracking of the copper plating that forms the PTH wall
 - Driven by differential expansion between the copper plating (~ 17 ppm) and the out-of-plane CTE of the printed board (~ 70 ppm)
 - Industry-accepted failure model: IPC-TR-579



PCB Robustness: Qualifying Printed Boards

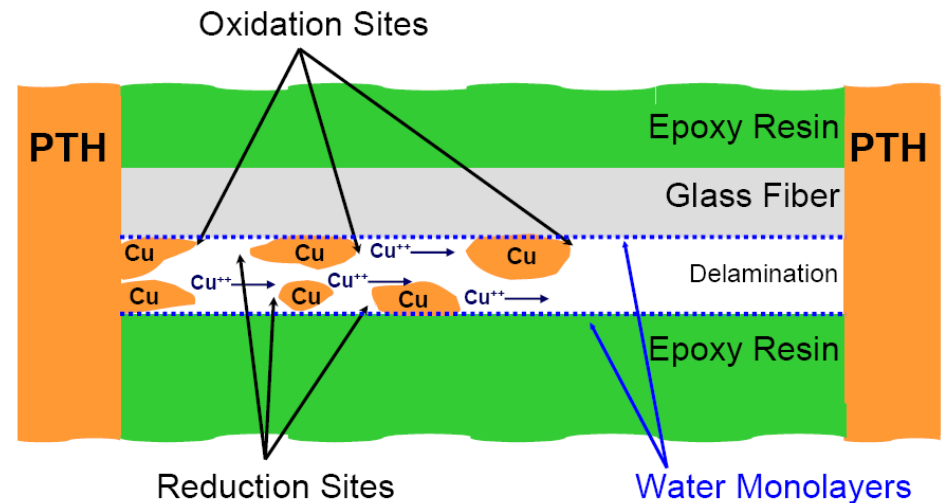
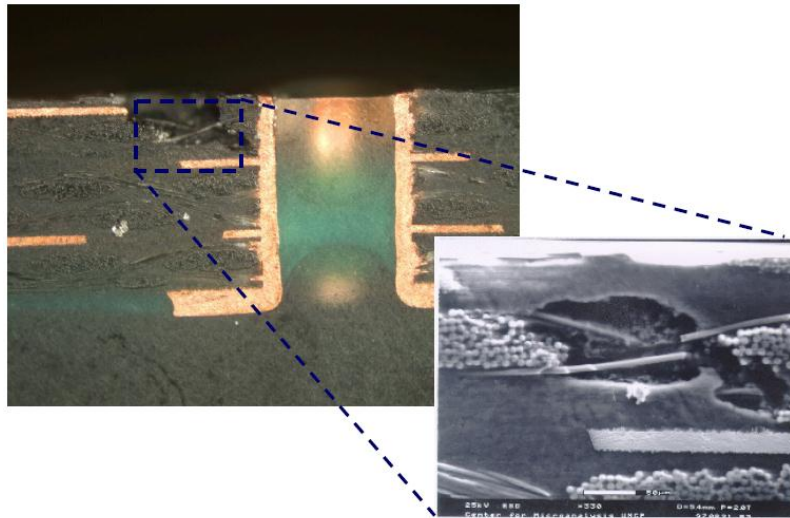
- This activity may provide greatest return on investment
- Use appropriate number of reflows or wave
 - In-circuit testing (ICT) combined with construction analysis (cracks can be latent defect)
 - 6X Solder Float (at 288C) may not be directly applicable
- Note: higher Tg / phenolic is not necessarily better
 - Lower adhesion to copper (greater likelihood of delamination)
 - Greater risk of drilling issues
 - Potential for pad cratering
- Higher reflow and wave solder temperatures may induce solder mask delamination
 - Especially for marginal materials and processes
 - More aggressive flux formulations may also play a role
 - Need to re-emphasize IPC SM-840 qualification procedures

Material Selection - Laminate

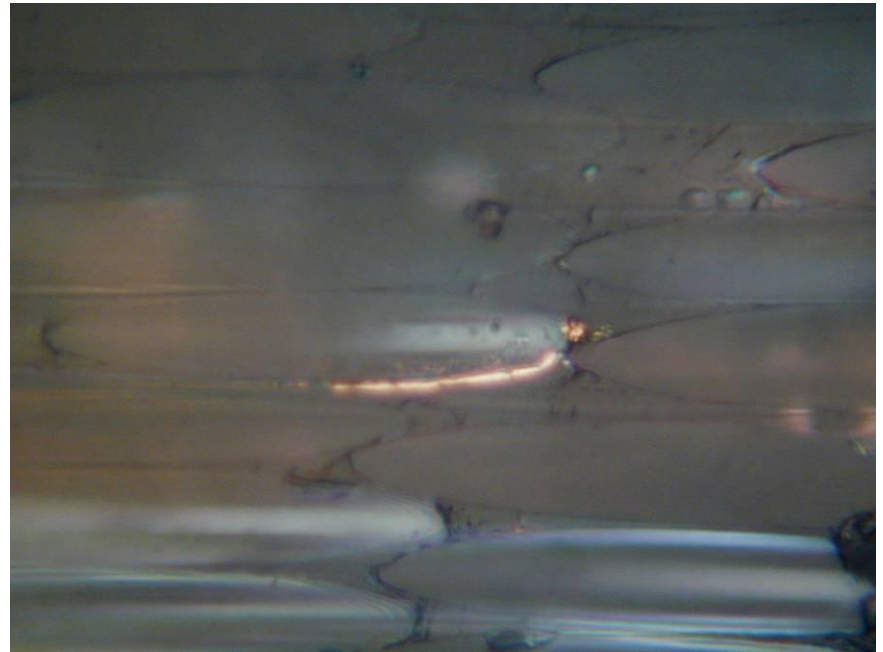
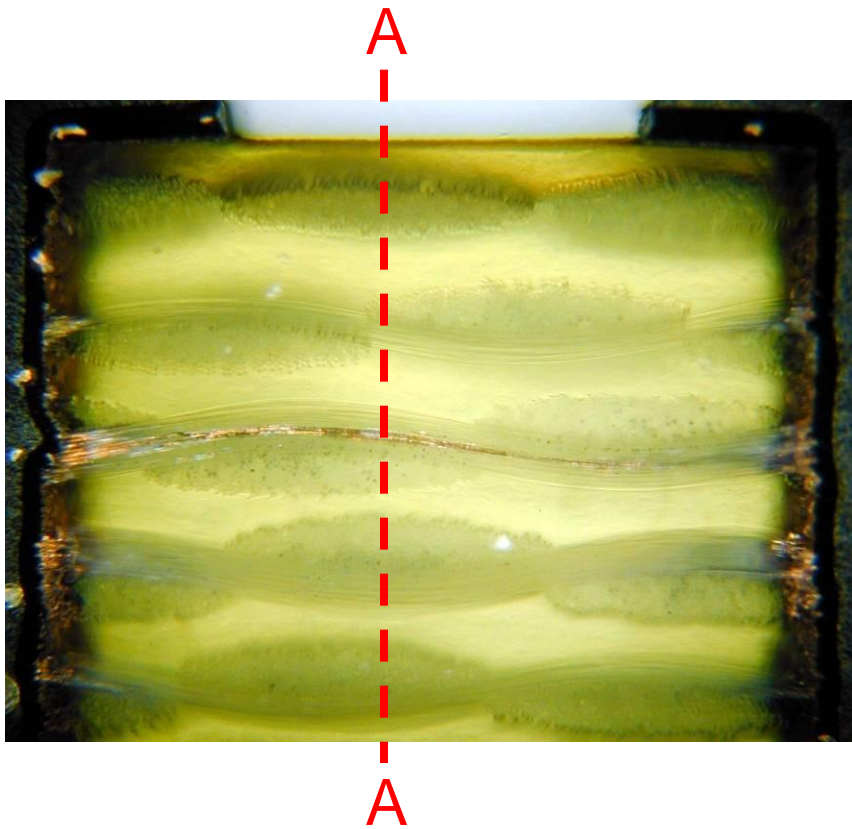
- Higher reflow and wave solder temperatures may induce delamination
 - Especially for marginal materials and processes
 - Not all RoHS compliant laminates are Pb-free process capable!
 - Specify your laminate by name – not type or “equivalent”
 - Role of proper packaging and storage
 - PCBs should remain in sealed packaging until assembly
 - Reseal partially opened bricks
 - Package PCBs in brick counts which closely emulate run quantities
 - PCBs should be stored in temperature and humidity controlled conditions
 - Bake when needed
 - Packaging in MBB (moisture barrier bags) with HIC (humidity indicator cards) may be needed for some laminates
- Need to re-emphasize IPC SM-840 qualification procedures

PCB Conductive Anodic Filaments (CAF)

- CAF also referred to as metallic electro-migration
- Electro-chemical process which involves the transport (usually ionic) of a metal across a nonmetallic medium under the influence of an applied electric field
- CAF can cause current leakage, intermittent electrical shorts, and dielectric breakdown between conductors in printed wiring boards
- <20mil spacing hole to hole considered highest risk



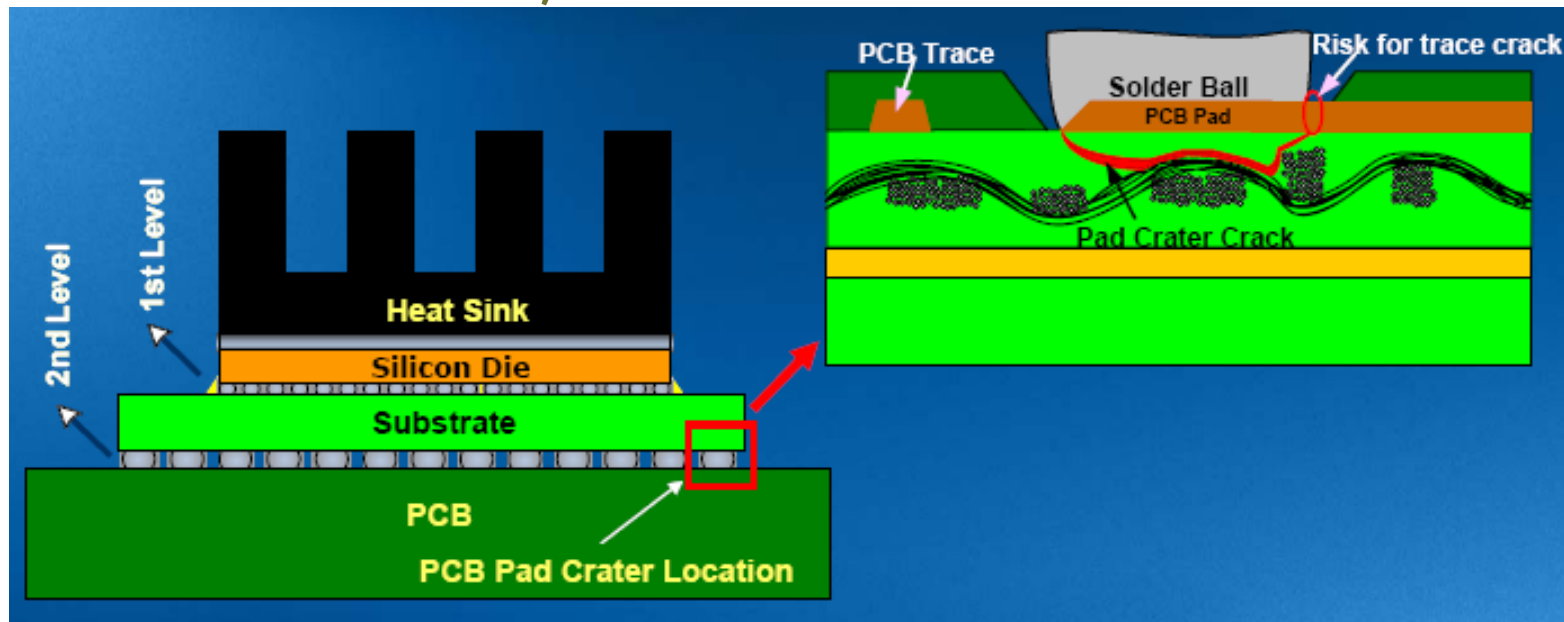
CAF: Examples



A:A Cross-Section

Strain & Flexure: Pad Cratering

- Cracking initiating within the laminate during a dynamic mechanical event
 - In circuit testing (ICT), board depanelization, connector insertion, shock and vibration, etc.

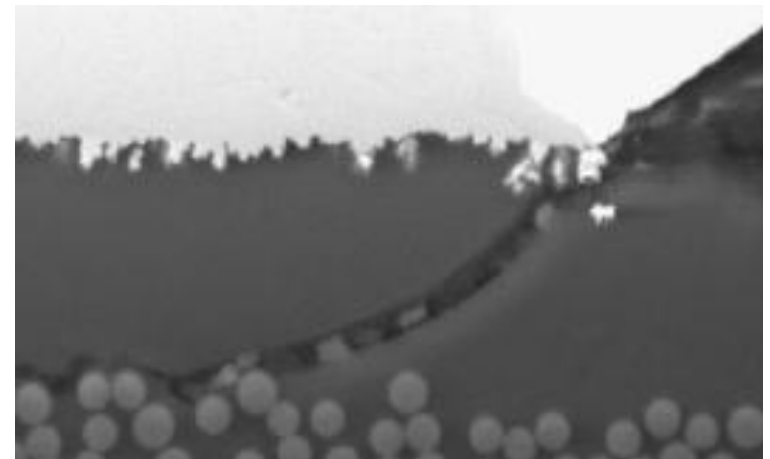
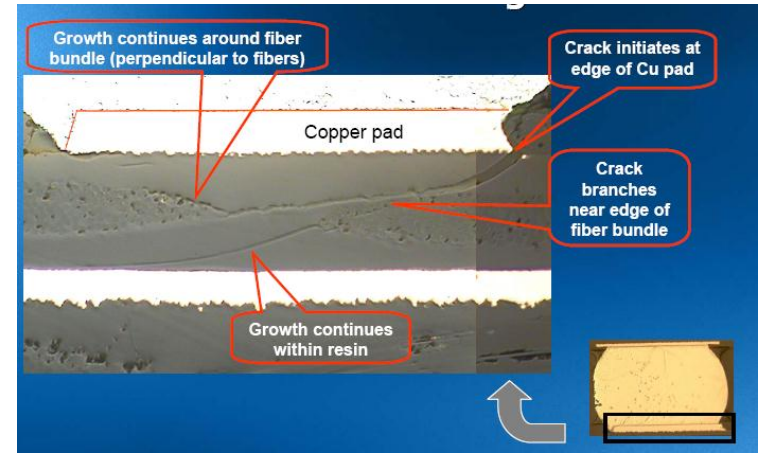


G. Shade, Intel (2006)

Pad Cratering

Intel (2006)

- Drivers
 - Finer pitch components
 - More brittle laminates
 - Stiffer solders (SAC vs. SnPb)
 - Presence of a large heat sink
 - Pad Design
- Difficult to detect using standard procedures
 - X-ray, dye-n-pry, ball shear, and ball pull



DfR Solutions

Solutions to Pad Cratering

- **Board Redesign**
 - Solder mask defined vs. non-solder mask defined
- **Limitations on board flexure**
 - 500 microstrain max, Component, location, and PCB thickness dependent
- **More compliant solder**
 - SAC305 is relatively rigid, SAC105 and SNC are possible alternatives
- **New acceptance criteria for laminate materials**
 - Intel-led industry effort
 - Attempting to characterize laminate material using high-speed ball pull and shear testing, Results inconclusive to-date

Summary & Recap

- DfM is a proven, cost-effective strategic methodology.
- Early, effective cross functional involvement:
 - Reduces overall product development time (less changes, spins, problem solving)
 - Results in a smoother production launch
 - Speeds time to market
 - Reduces overall costs
 - Designed right the first time
 - Reduces labor costs to repair and resolve issues
 - Improves overall production efficiency
 - Build right the first time = less rework, scrap, and warranty costs
 - Improves quality and reliability results in:
 - Higher customer satisfaction
 - Reduced warranty costs

Contact Information

- **Questions:**
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 - askdfr@dfrsolutions.com
 - www.dfrsolutions.com

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- **ANALYSIS INFORMATION**

This report may include results obtained through analysis performed by DfR Solutions' Sherlock software. This comprehensive tool is capable of identifying design flaws and predicting product performance. For more information, please contact DfRSales@dfrsolutions.com.

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*Best Regards,
Dr. Craig Hillman, CEO*

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