

Conformal Coatings: Taming the Factory Demons

**IPC/SMTA Chapter Meeting
May 2014**

**Jason Keeping, Celestica
Doug Pauls, Rockwell Collins**

Ground Rules

- **What makes for a Bad/Ineffective Instructor?**
 - Irrelevant material
 - Sage on the Stage complex
 - Boring / monotone / ignores class
 - Does not engage class
- **What makes for a Bad/Ineffective Student?**
 - Cell phones / portable electronic devices
 - Side conversations
 - Snoozing
- Your instructors will strive to be good instructors; you strive to be good students
- Will have breaks – the head cannot absorb more than the butt can withstand



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Agenda

- Design Practices
- Preparing for Conformal Coating – assemblies and facilities
- Methods of Application – pros and cons of each
- Methods of Curing – pros and cons of each
- Evaluating the Cured Film – defects and process indicators
 - New definitions being pursued for J-STD-001 and IPC-A-610
- Process Control Items
- Present Industry Research
- General Discussion



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DESIGNING FOR CONFORMAL COATING (DfCC)



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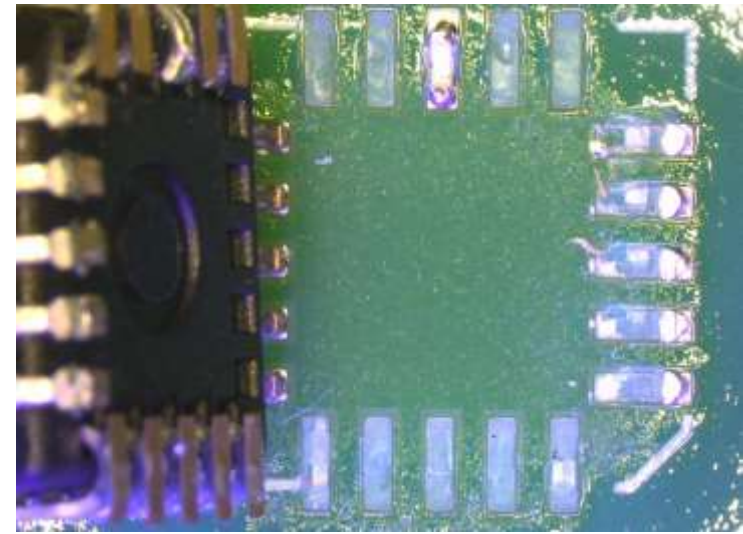
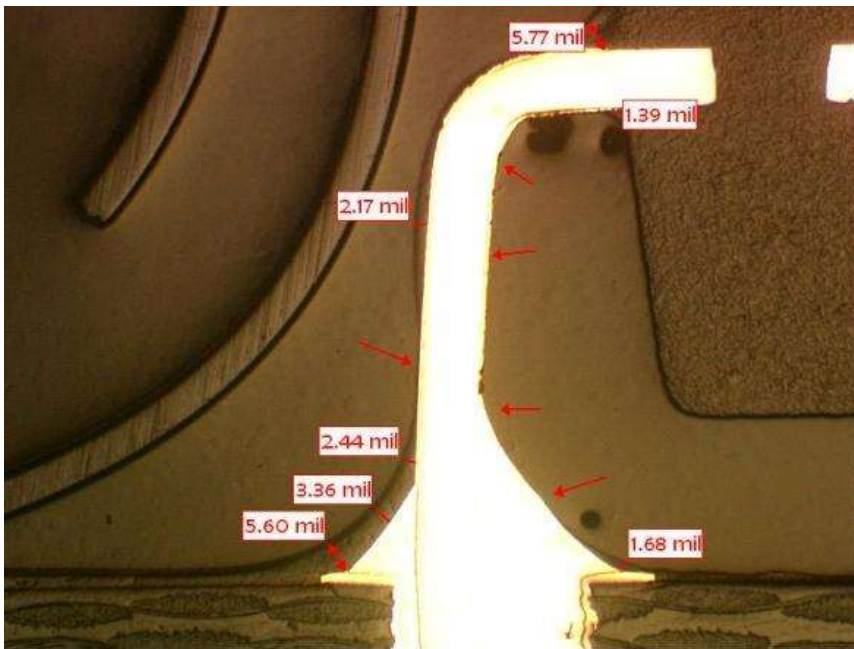
Components Not Normally Coated

- Electromechanical components (e.g. actuators.)
- Components sensitive to the additional capacitance of conformal coat (e.g. RF filters)
- Mating sockets, pins, test points, grounding points
- Connectors
- Potentiometers and variable capacitors
- Photodiodes, sensors, and other optical devices
- Open (unsealed) components (e.g. switches and relays)
- Batteries
- RF Boards (dielectrics)
- Flex part of rigid flex
- Mounting surfaces and mounting hardware
- Displays
- Windows of programmable devices
- Spacers and fasteners
- Wires for stress relief
- EMI shields
- Mounting holes
- Components stressed by coating (e.g. glass bodied diodes)

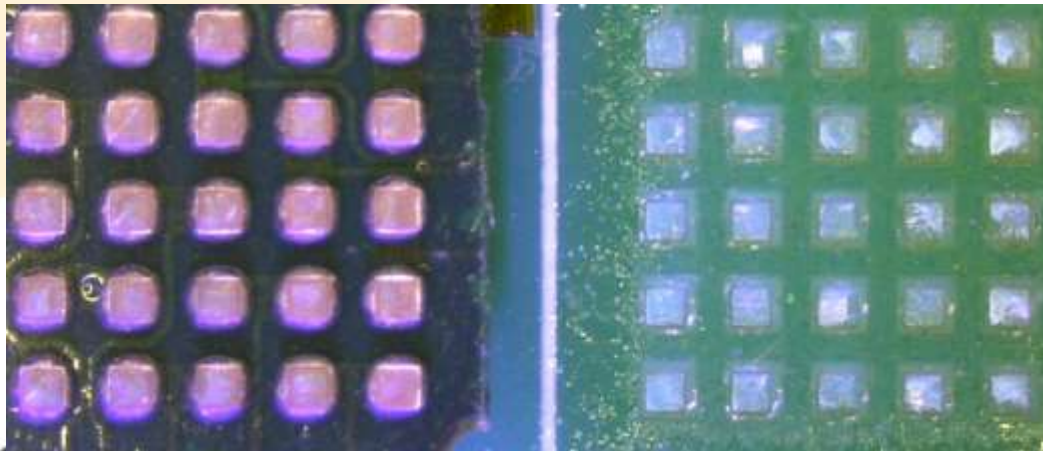
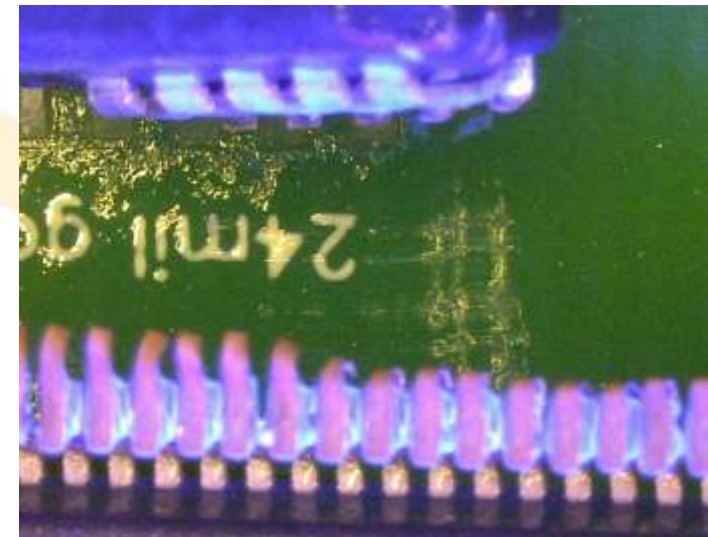
Component Issues

- **Moisture / Temperature Ratings**
 - Led to Lead Free Requirements
 - Baking Requirements (Moisture removal)
- **Sealed vs. Unsealed Components**
 - Tolerances
 - Remedial approaches (sealants)





SEDRP 2213 - Tin Whisker Mitigating Composite Coating Project



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What Constitutes a Good Drawing

- Requires no operator “interpretation”
- Drawing should indicate where coating **MUST** go
- Drawing should indicate where coating **MUST NOT** go (keep out zones)
- Drawing should indicate the tolerance in the keep out zones
- The quality system used should indicate what is to be done when coating falls within the tolerance area of a keep out zone

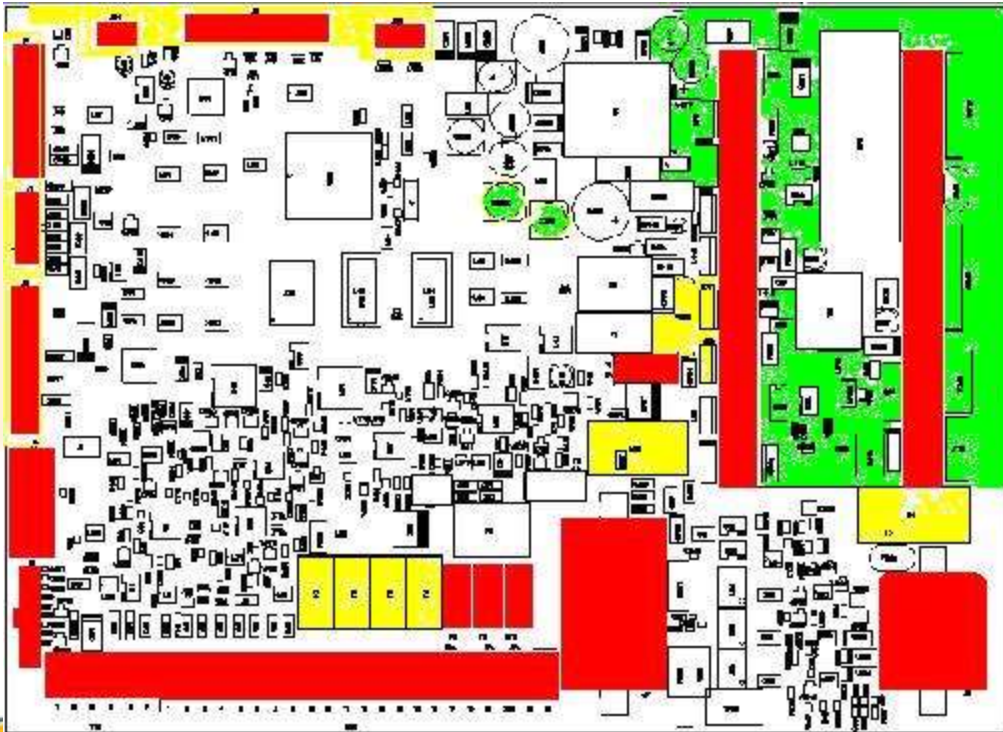


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Engineering Drawings and Notes

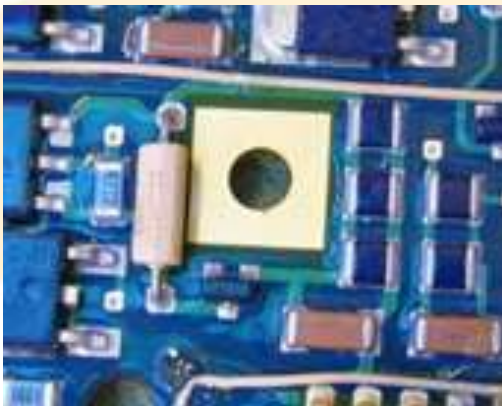
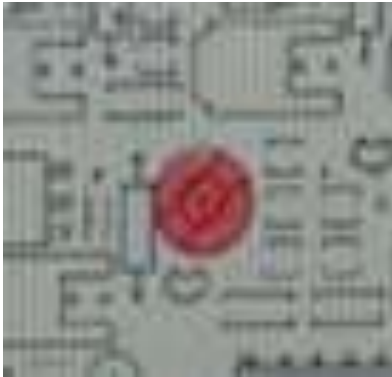
- Engineering Drawing:
 - Any “keep-outs” must be very clearly delineated
 - The drawing should leave no question as to where coating goes and where not
- Tolerance:
 - What is the tolerance on the keep-outs?



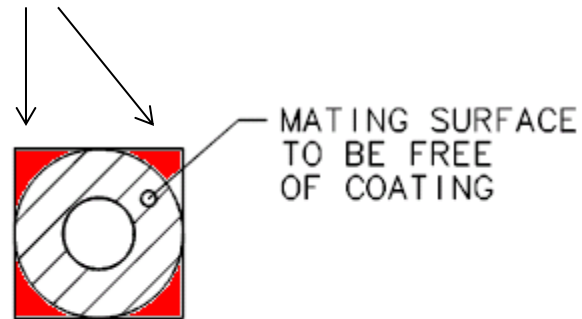
- Red - Customer requested area to not be coated (keep-out)
- Yellow - Optional areas to be coated (if coated not a defect, but not required)
- Green - Please ensure this area is coated, due to height profile/topology concerns or reliability requirements.

Engineering Drawings and Notes

- What about when the shapes don't match?

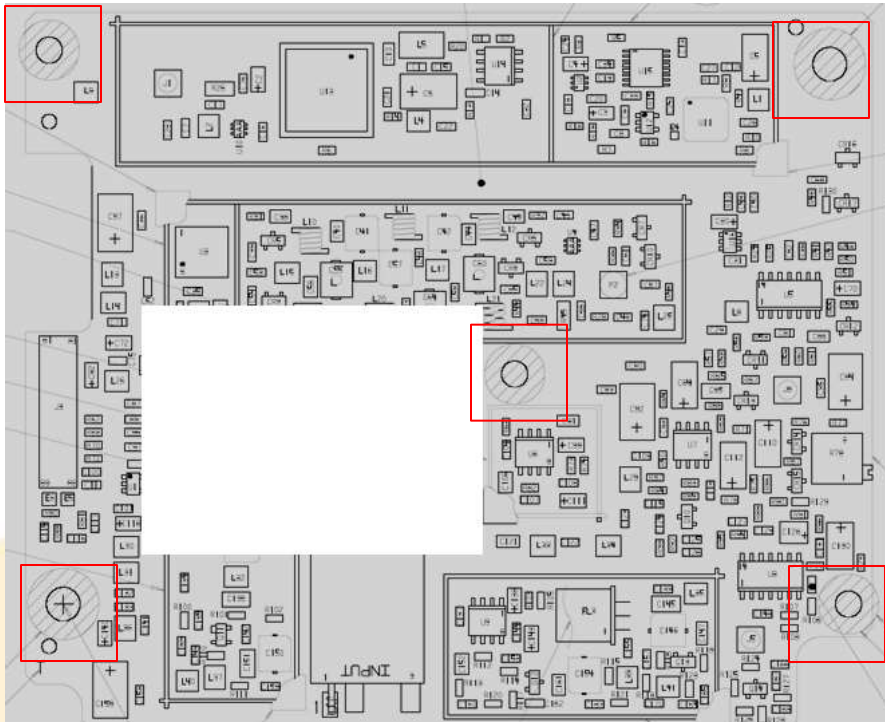


Is this coated, or not?

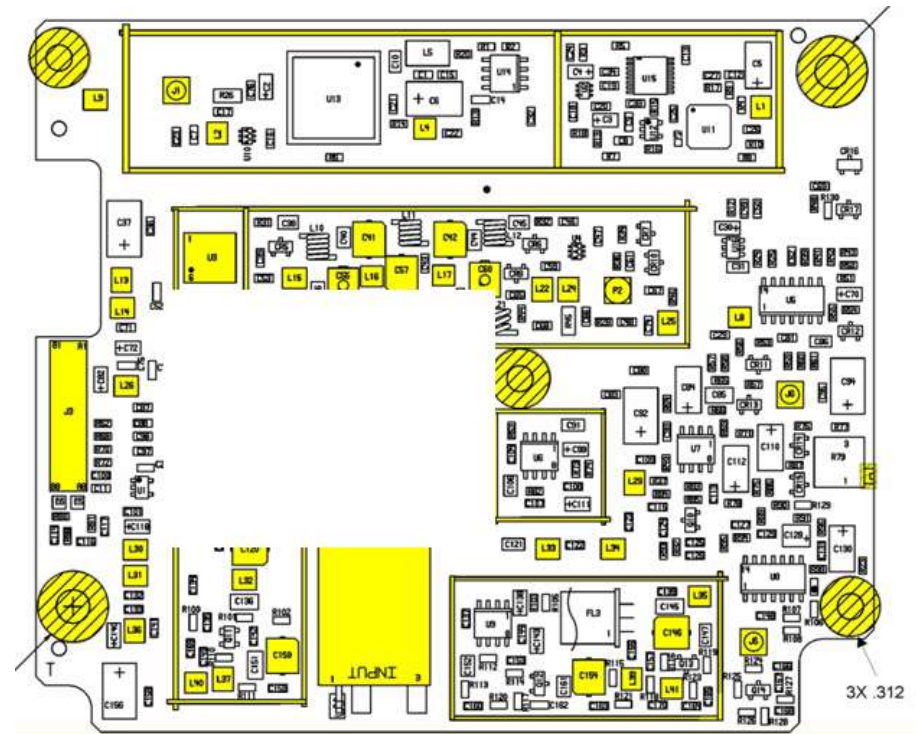


CLAD MOUNTING PAD

Engineering Drawings and Notes



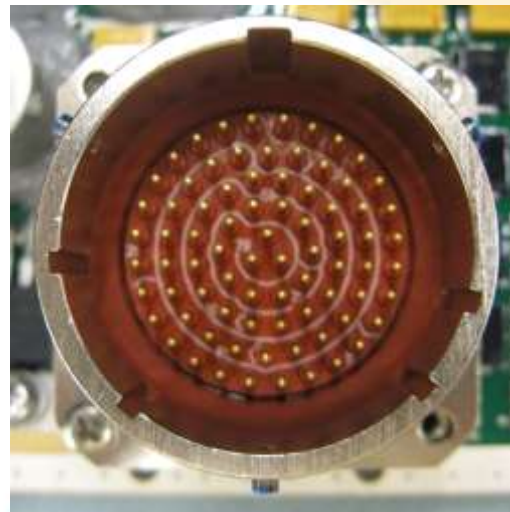
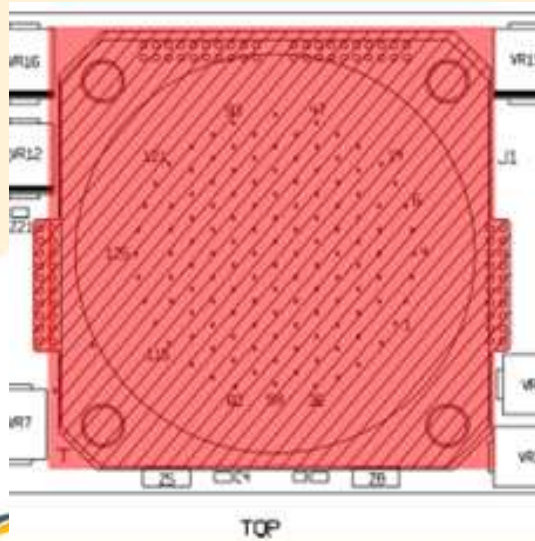
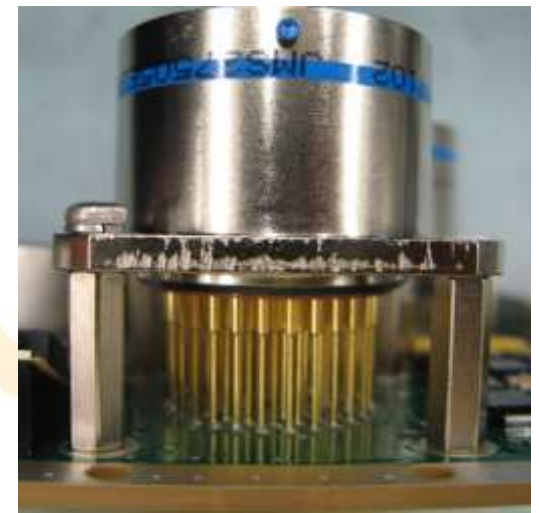
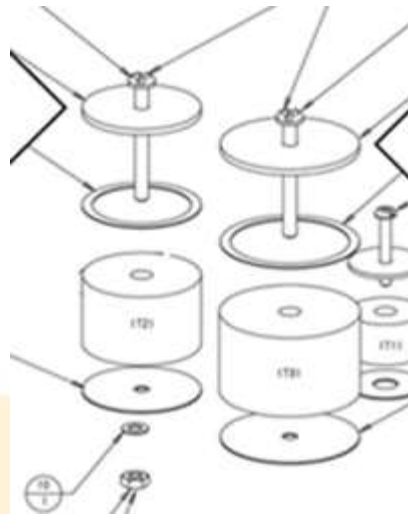
The Engineering Drawing



The Reality When Components Added

Engineering Drawings and Notes

- Coverage: 2D vs. 3D



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Engineering Notes

- Designers Can Be Confusing
 - On one drawing can have three different meanings for cross-hatching
 - Z-Height restrictions, Segregation Zones, coating keep outs
- Agreement between customer, user and contractor need to be up-front on definition of coverage.
 - is coating required on the sides of metallic locations
 - is coating required on the sides of hermetically sealed locations
 - is coating required below/beneath components
 - is coating required on the backside of leads
- Engineering drawings may list cure notes.
 - These notes need to be confirmed per material, process and thickness of the application that is applied. (Select, Dip, Spray)
 - In general, don't let your design engineers use Engineering Notes to define the manufacturing process



Break #1 – 10 minutes



Apache Longbow

'Whoever said the pen is mightier than the sword, obviously never encountered automatic weapons.' General MacArthur

FACILITIES CONSIDERATIONS



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Facilities Considerations

- Environmental, Health and Safety (EH&S)
 - ALL coating operations must be setup with the health of the operator as paramount
 - Conformal coating processes may involve the following EHS issues:
 - Employee exposure to the solvent and/or resin materials
 - Fire safety considerations if the solvent is flammable or combustible
 - Air emissions from the volatilized solvent (e.g. VOCs, HAPs, etc.,)
 - Waste management from used brushes or other applicators, spray gun cleanup mixtures, unused coating solution and used masking tape.
 - Material content declaration (MCD) requirements
 - In the European Union, these include RoHS, WEEE, ELV, REACH and EuP
 - Greenhouse Gas (GHG) reporting
 - Equipment design and construction
 - Emissions from Curing Operations
 - Reaction byproducts, ozone from UV

				Product Identification
HEALTH	*	2		Acute Numerical Health Rating and Chronic Hazard Indicator (*) (in the same or separate boxes)
FLAMMABILITY		3		Flammability Rating
REACTIVITY		0		Reactivity Rating
PERSONAL PROTECTION		H		Personal Protective Equipment Codes

Facilities Considerations

- Occupational Safety and Health Administration (OSHA)
 - Applying conformal coatings by spraying is subject to the 1910.107 Spray Finishing using Flammable and Combustible Materials standard of US OSHA
 - Wearing a respirator requires compliance to several US OSHA requirements in their 1910.134 Respiratory Protection standard including
 - medical clearance to wear a respirator 134(e); annual fit testing 134(f); required training 134(k); and respirator maintenance 134(h).
 - The label for each hazardous chemical that is classified shall include the signal word, hazard statement(s), pictogram(s), and precautionary statement(s) specified for each hazard class and associated hazard category.
 - Be aware that many of these will change in the next few years due to global harmonization laws
 - Property protection insurance carrier approval, US OSHA standard 1910.106 covers the storage and use of flammable liquids.



Facilities Considerations

- EPA
 - Waste from conformal coating, such as
 - mixture that results from cleaning the tooling
 - its container of the coating last applied.
 - Or unused or out-of-date coating solution.
 - Such wastes are typically classified as flammable wastes (US EPA waste code D001).
 - EPA definition of a flammable waste is a waste with a flash point below 140F (60C).
 - Contact of a solid absorbent material (e.g. wipes) with a flammable solvent means that the wipe material must be disposed of as a hazardous flammable solid waste.
 - Measures & regulates Greenhouse Gas (GHG) reporting
 - Quantifies average CO2 emissions per KWH of electricity by zip code
- Design for the Environment (DfE)
 - It may be very important to your customer that you manufacture product in an environmentally conscious manner

PREPARING ASSEMBLIES FOR COATING



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Surface Preparation

- What is desired is a **clean, dry** surface, free from materials, or surface conditions which may interfere with coating application, cure, or adhesion.
- Cleaning Considerations (see IPC-CH-65B)
 - Visual inspection criteria, component geometries, stand-off heights, non-hermetically sealed components; component issues and residues, surface tension and capillary forces; flux residue variability, wash chemistry types
 - Visible residue (coating materials, masking materials, FOD)
 - Invisible residues (silicones, oils)
- Dry
 - Does not have to be “bone-dry” unless the coating requires it
- Surface Conditions
 - Low surface energy on bonding surface
 - Mold release agents in parts
 - Effects on the solder mask from reflow processes (Sn-PB, LF)

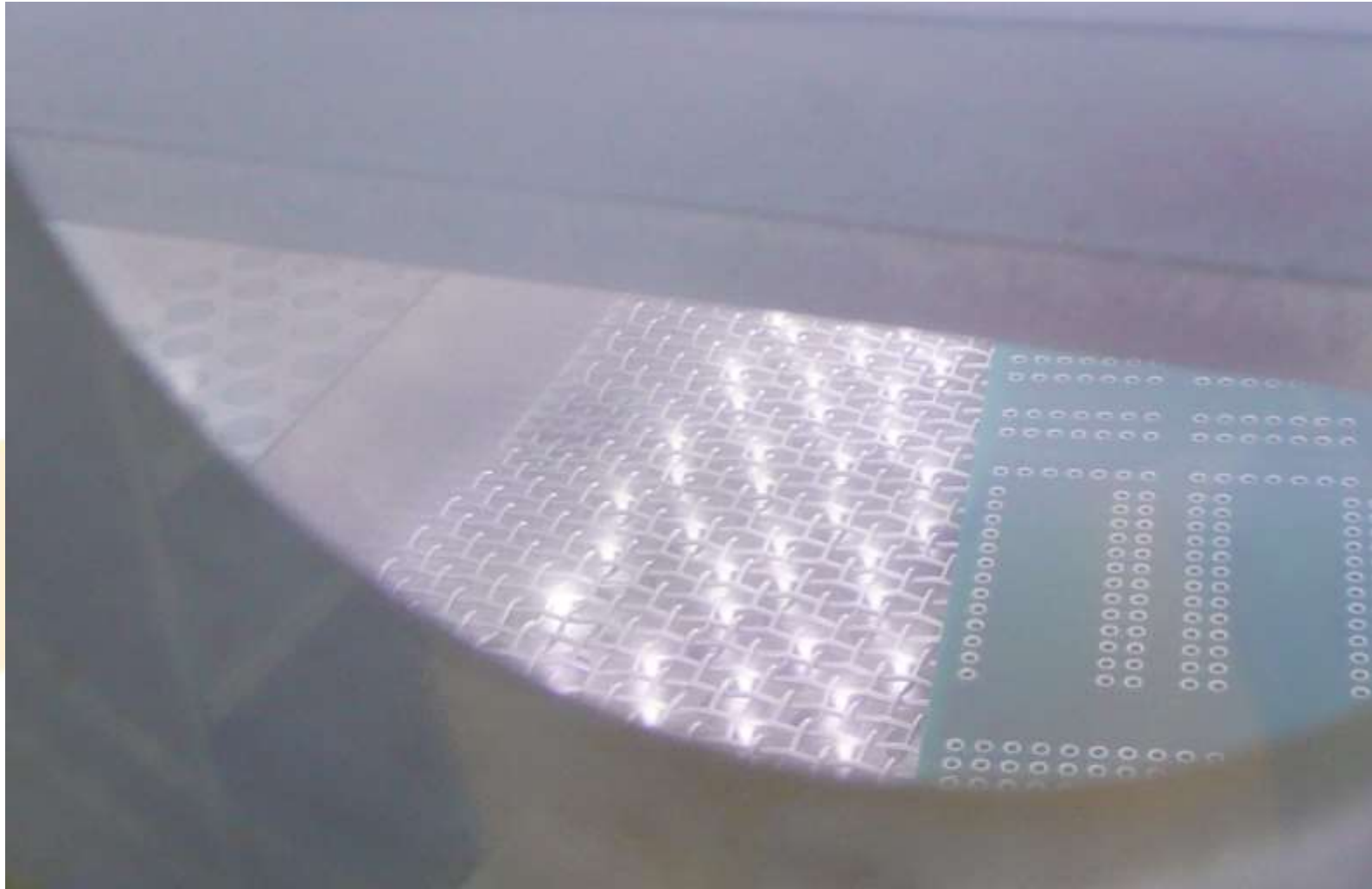
Baking Prior To Coating

- Baking
 - Validation methods – Know what happens in the oven
 - Flow of air in ovens with and without load – how consistent
 - Dripping in ovens – presence of drip plates changes air flow
 - Be aware of warm-up time (might be embedded in duration)
 - Separate ovens for Silicone materials
 - Outgassing products cause dewetting later
 - VM&P Naphtha or toluene good solvents
 - Chemical Release Soldermask (over bake)
 - Mold release and other such agents coming out
 - Happens when SnPb process converts to a lead free process without considering what it does to the solder mask
 - Bake Vs. rebake
 - Halogen free solder mask – much more hydrophilic
 - Defects in underfill from outgassing
 - Not sure if this same effect would happen with CC or potting
 - Do you have to bake or rebake is a topic of much debate

Plasma Processing

- Plasma
 - Mild surface etch which increases micro-roughness and can remove (ash) low levels of surface residues
 - Also serves to improve coating wetting
 - Performed in a vacuum (which can affect assemblies)
 - May impact more than just solder mask (components)
 - Plasma Balls (localized high density plasma)
 - Recommend Argon/Oxygen or Argon-Only for silver surfaces
 - Select the gasses carefully
 - Argon is more of a “sand blaster”
 - Oxygen more of an oxidizer
 - Hydrogen is a very reactive (but scary as hell)
- Surface Treatments – Primers or Coupling Agents

Plasma Balls



Handling Considerations

- Handling and Transportation Residues
 - Fixtures
 - Workstation Surfaces
 - Popcorn Day
 - Gloves
 - Transport containers (totes, bags,)
 - Operational procedures
 - “Personal” Residues: finger salts and oils, hairs, hand creams, FOD



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MASKING AND DEMASKING



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Common Masking Materials

- Water Soluble Masks
 - Not recommended
- Latex Peelable Masks
 - Be concerned about ammonia
- Hot melt Masks
- Tapes
 - Crepe masking tapes
 - Polyester masking tapes
- Polymeric Plugs and Covers
 - Generally quick and easy to use. Can peel accumulated coating off
- ALL masking and demasking procedures should be done under an ionized air blower – ESD generation
- Undesirable residues often show up as contributors to either coating dewetting during application or coating adhesion during thermal cycling

Masking Aids



Masking - Seal and Peel



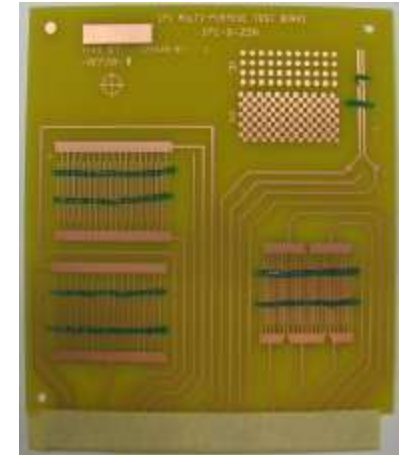
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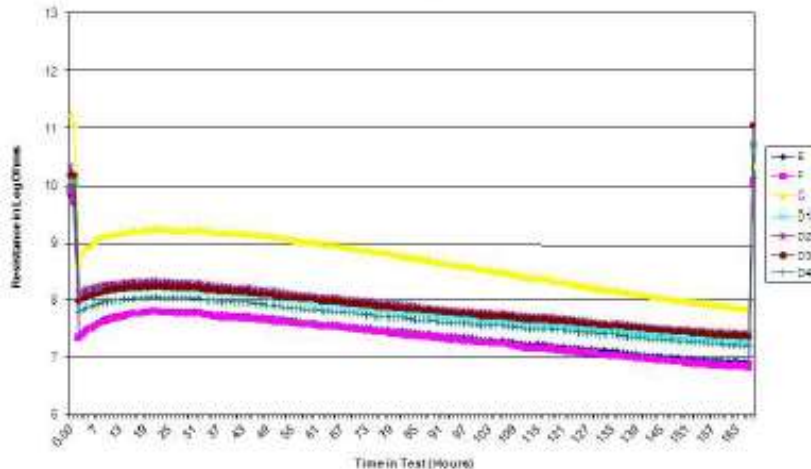
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UV Curable Masking Compounds

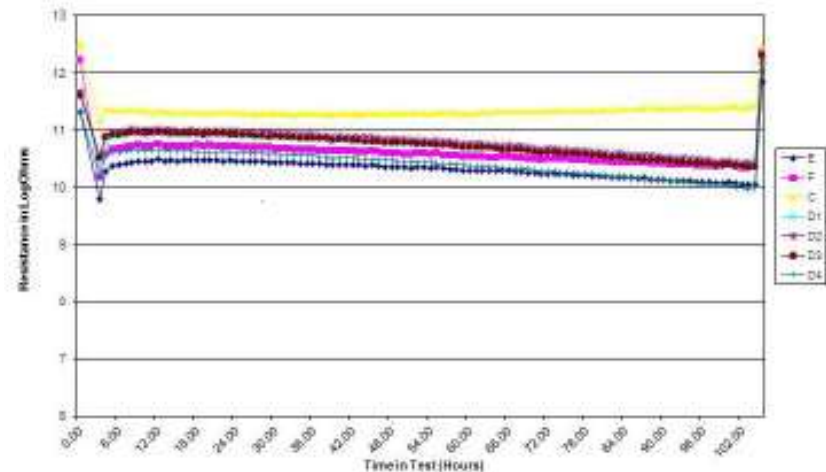
- UV curable masking agents becoming more common
- Need to evaluate:
 - Is it compatible with the proposed solvent system?
 - Are there effects if you over-radiate the material?
 - Does it leave harmful residues?
 - Ion Chromatography
 - SIR testing (e.g. B24 boards)
 - If the material remains (e.g. under connectors) is it harmful?



Dymax EMAX 906-B Evaluation
Irradiated for 30 seconds; left on board
Sample #1



Dymax EMAX 906-B Evaluation
Irradiated for 60 seconds; mask removed
Sample #3

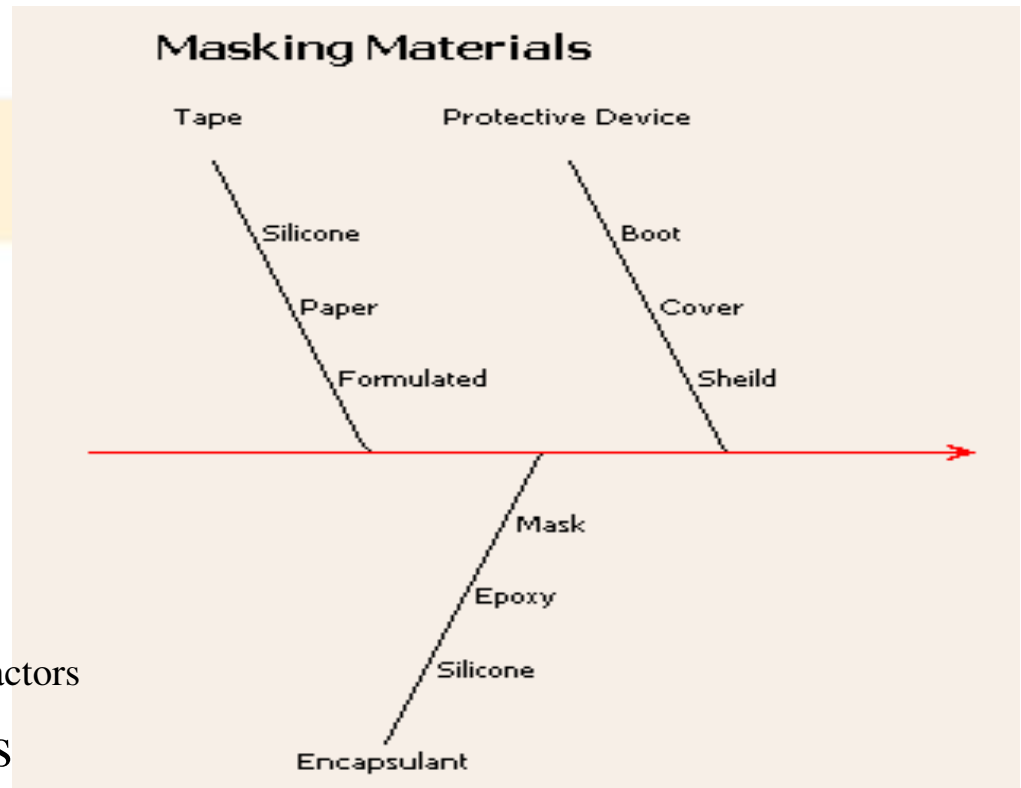


Masking Material Selection

- There are three main streams for masking materials.
- Each of these main stream materials should be tested for various manufacturing process outputs, such as:
 - Residue from Masking Materials
 - Timing (to de-mask)
 - ESD Controls
 - Fixturing



Level [^] Factors = 3 levels [^] 9 factors
≅ 20 thousand variations

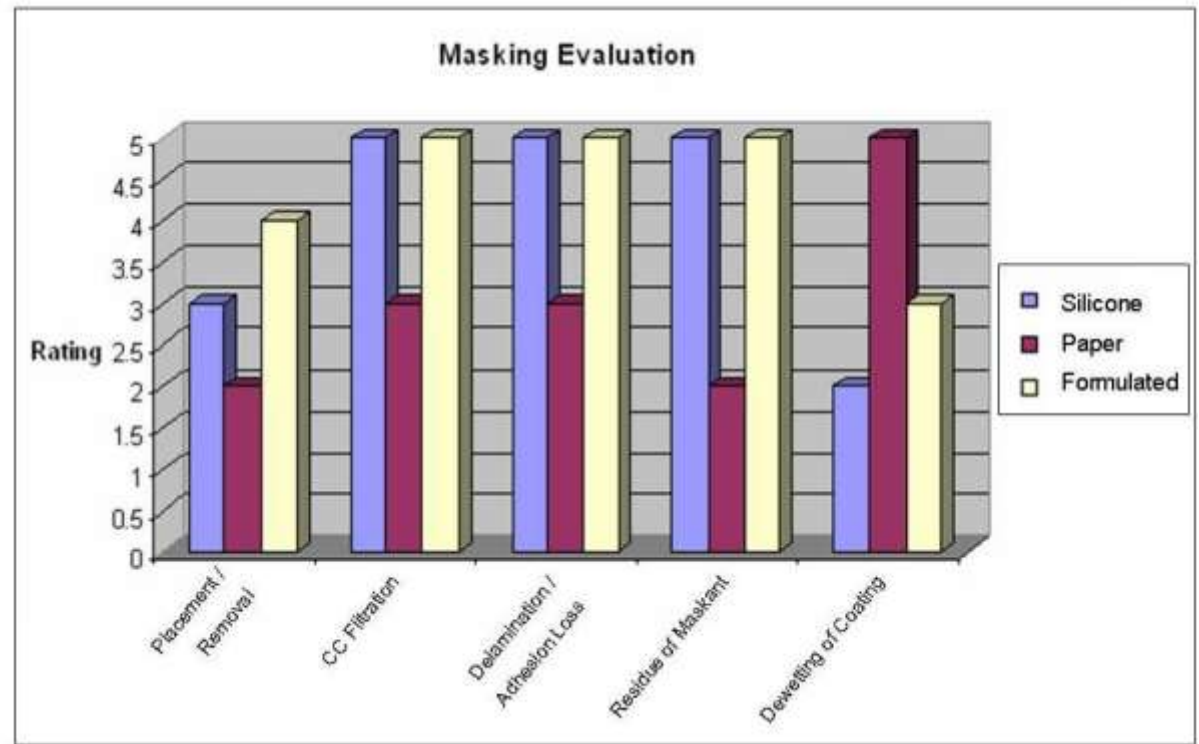


Masking Materials

- There were five outcome variables for various masking materials that were tested as shown below.
 - Placement / Removal
 - Delamination / Adhesion loss
 - CC Filtration
 - Residue
 - CC Dewetting



Masking after Coating (dewetting)

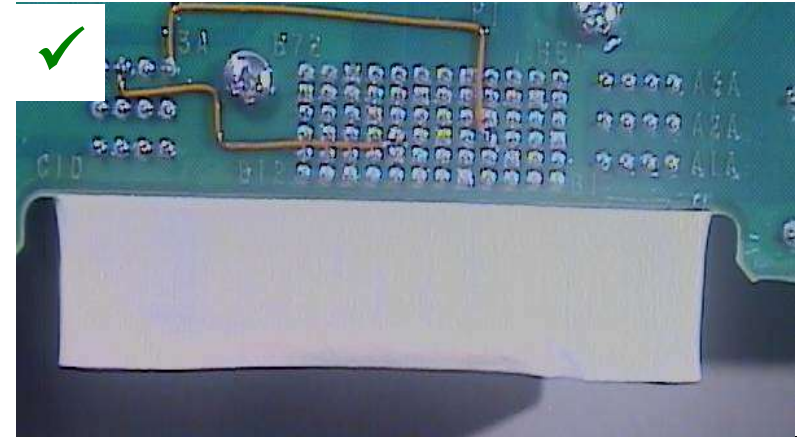


Masking Standards

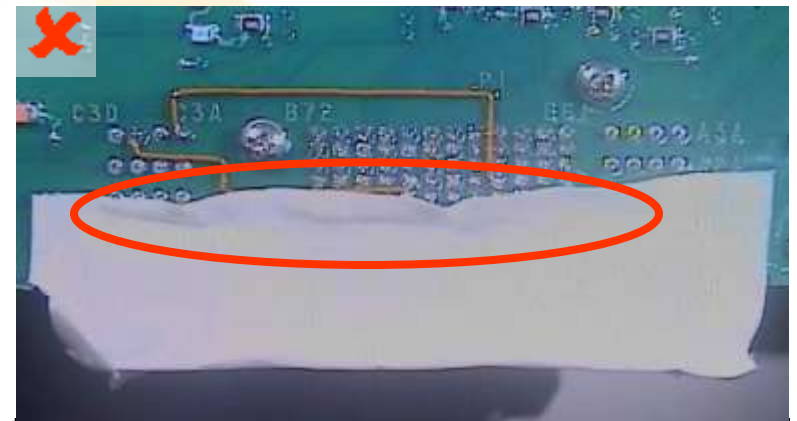
General Masking Requirements

1. All masking applications regardless of size must be:
 - centered over required locations (with no more than 1/8" extension beyond limits)
 - having no pin or larger gaps within the material that will allow coating leakage.
 - created with complete smooth seals along all edges to component, printed circuit board and shell surfaces and be tear free.
2. All masking applications must be flush (thoroughly pressed) to either component, printed circuit board or shell surfaces unless specified otherwise prior to processing to the next step of either Conformal Coating to aid in prevention of material flow into undesired locations

1. Masking Edge Connectors



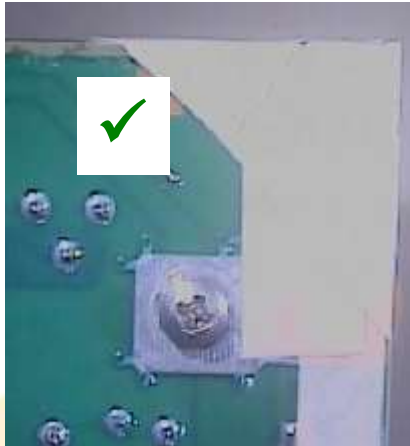
Acceptable: Masking is smooth, completely covers the connector & does not interfere with the near by parts/components.



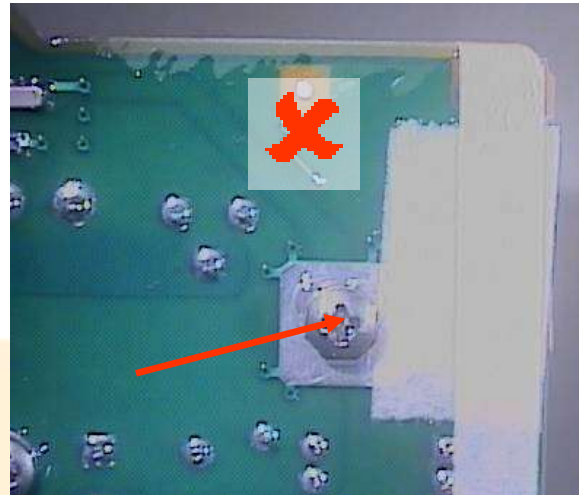
Defect: Excess masking covering near by parts or components which call for no masking.

Masking Standards

2. Ejectors



Acceptable: Masking covers the entire area that is required for masking.



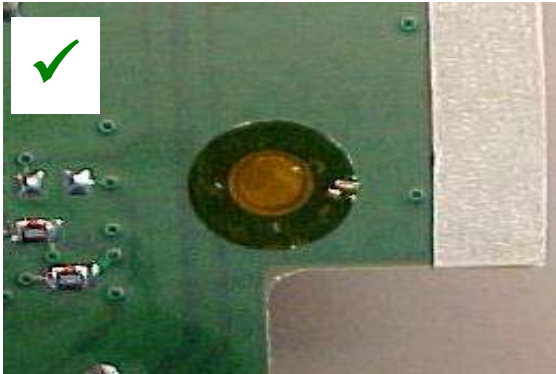
Defect: Missing masking on required masking part/area.



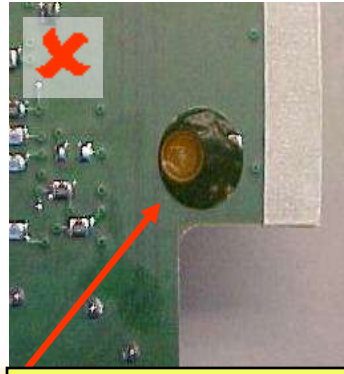
Defect: Excess masking covering areas that are not required for masking.

Masking Standards

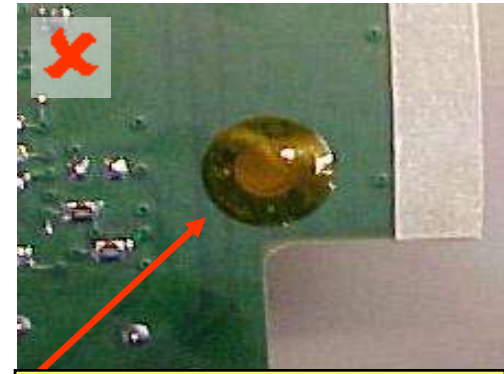
3. Mounting Holes



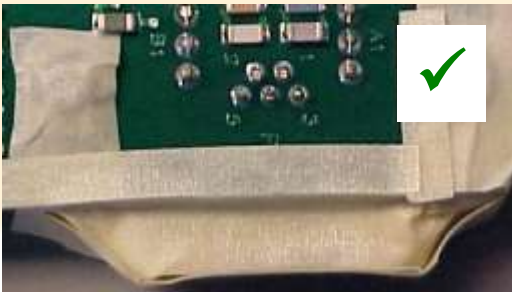
Acceptable: Masking is centered and sealed onto the board.



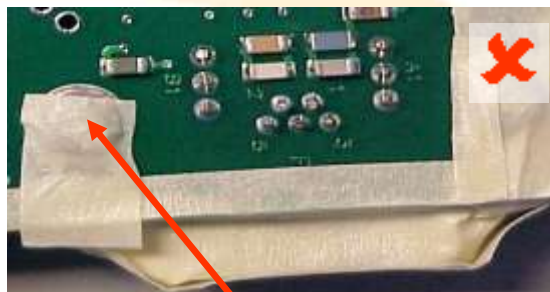
Defect: Masking is not centered.



Defect: Masking is centered, but not sealed thoroughly.



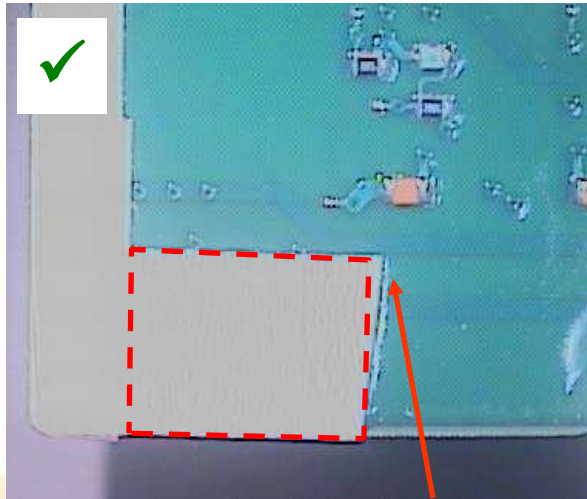
Acceptable: Masking is sealed and covers the entire screw.



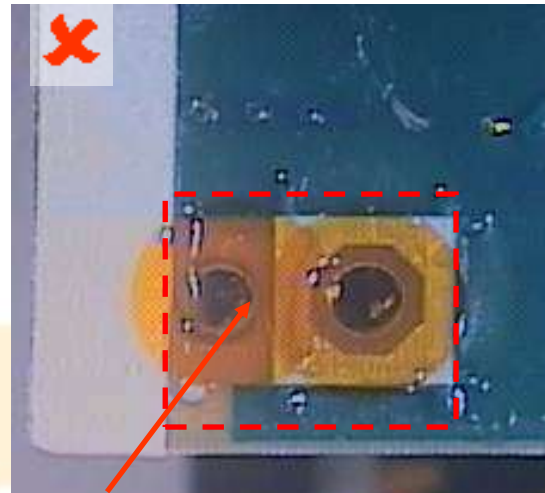
Defect: Masking is not sealed and did not cover the entire screw.

Masking Standards

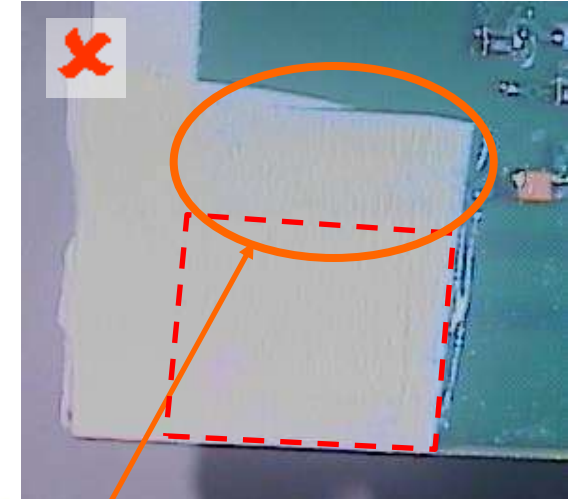
4. Land / Pad Locations



Acceptable: A little portion of masking extending beyond the required area is acceptable as long as it does not cover any nearby parts or components and is within 1/8" of the required location.



Defect: Using circular masking dots on a squared pad that needs to be completely covered.



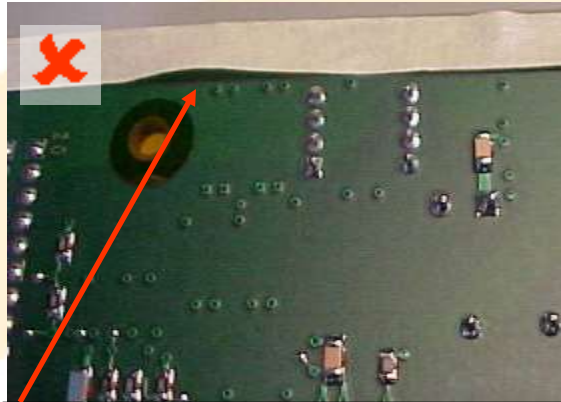
Defect: Excess masking covering more than the area required.

Masking Standards

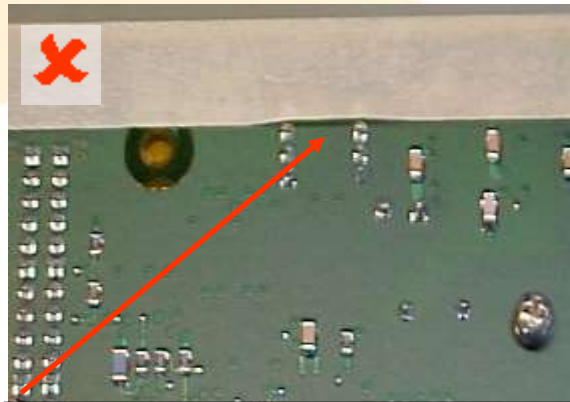
5. Assembly Sides & Edges



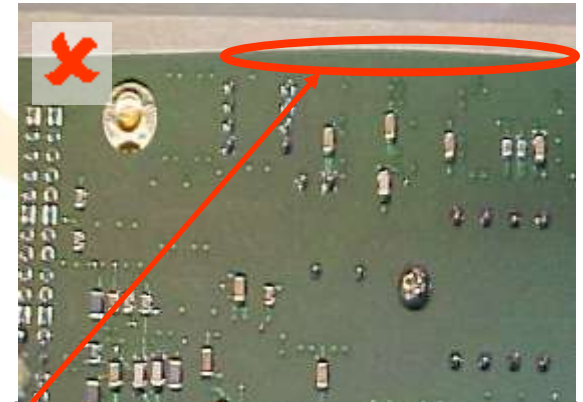
Acceptable:
Masking is straight
and covers just the
required area.



Defect: Masking is not flush with
assembly board edge.



Defect: Masking covering adjacent
components.



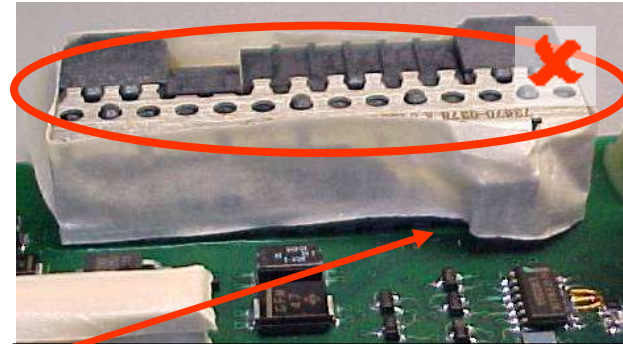
Defect: Masking skewed or missing
from required locations.

Masking Standards

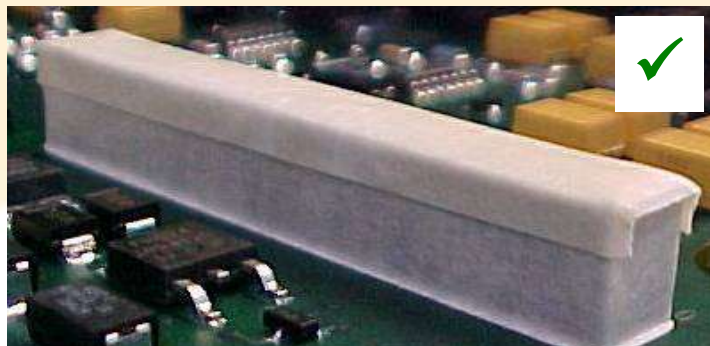
6. Component body - Connectors



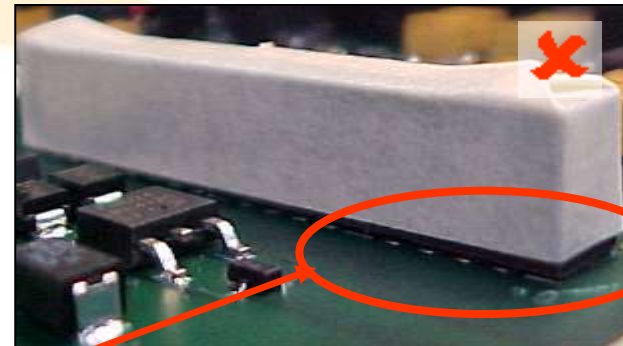
Acceptable: Masking is flush with the board surface and completely covers the connector.



Defect: Masking missing and is not flush onto the board.



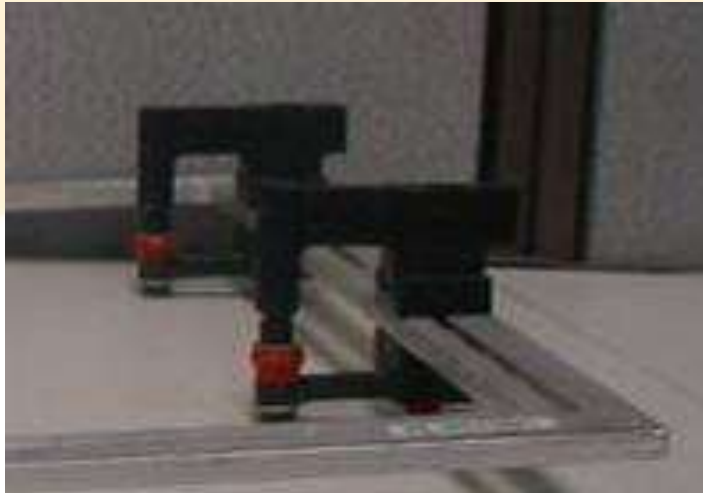
Acceptable: Masking is flush with the board surface.



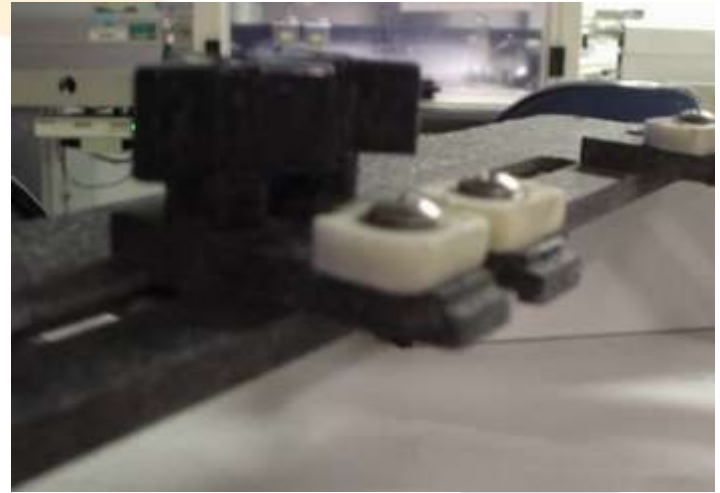
Defect: Masking is not flush with the board surface.

Fixturing

- Component
 - Leads or component package
- Assembly
 - Flat by edge supports
 - Flat by tooling pin supports
 - Vertical for dip coating



Tooling hole Support



Edge Support

Masking for Parylene / Vapor Deposition

- Masking for a Vapor Deposition process is MUCH more complicated than other methods – Must Be Gas Tight
 - Highly skills and labor intensive process...!! Big cost factor
- Masking Considerations
 - Need to mask more than just keep-out locations (tooling holes, mechanical parts)
 - Specific fixturing required
 - Chamber maintenance
 - Due to vacuum nature, all components need to be validated if are hermetic sealed or not
 - Can not use or have outgassing materials present
 - May mean you have to vacuum bake prior to coating

Storing Prepped Assemblies Till Ready

- How do you store cleaned assemblies if there is a significant lag between final clean and coating onset?
 - Do you re-use ESD bags? If so, are they clean? Are you sure?
 - Do you use ESD Totes? Do you ever clean them?
 - Do you use ESD Mats? Do you ever clean them? Does the cleaning chemical get on the assemblies?
 - Do you use ESD foams to cushion boards? Are they clean?
 - If left in the open (benchttop or shelves) is your environment “clean”?
 - Particulates, chemical vapors, insects, moisture

Demasking

- Depending on the masking process and coating used, there are different masking techniques and issue:
 - If boots or covers are used, there may be material build-up, reducing flexibility or ability to seal, or may get FOD from flaking
 - For Solvent based coatings, the material can be re-touched to mend feathering
 - Scoring may be required for higher strength materials
 - Various tapes may leave residues that need to be removed
 - Liquid masks may be now part of the design
 - Usually has to be done with ESD controls in place (ionizers)

Break #2 – 10 minutes



'You've never been lost until you've been lost at Mach 3.'
- Paul F. Crickmore (SR71 test pilot)-



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METHODS OF APPLICATION



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Coating Application Methods

Brushing

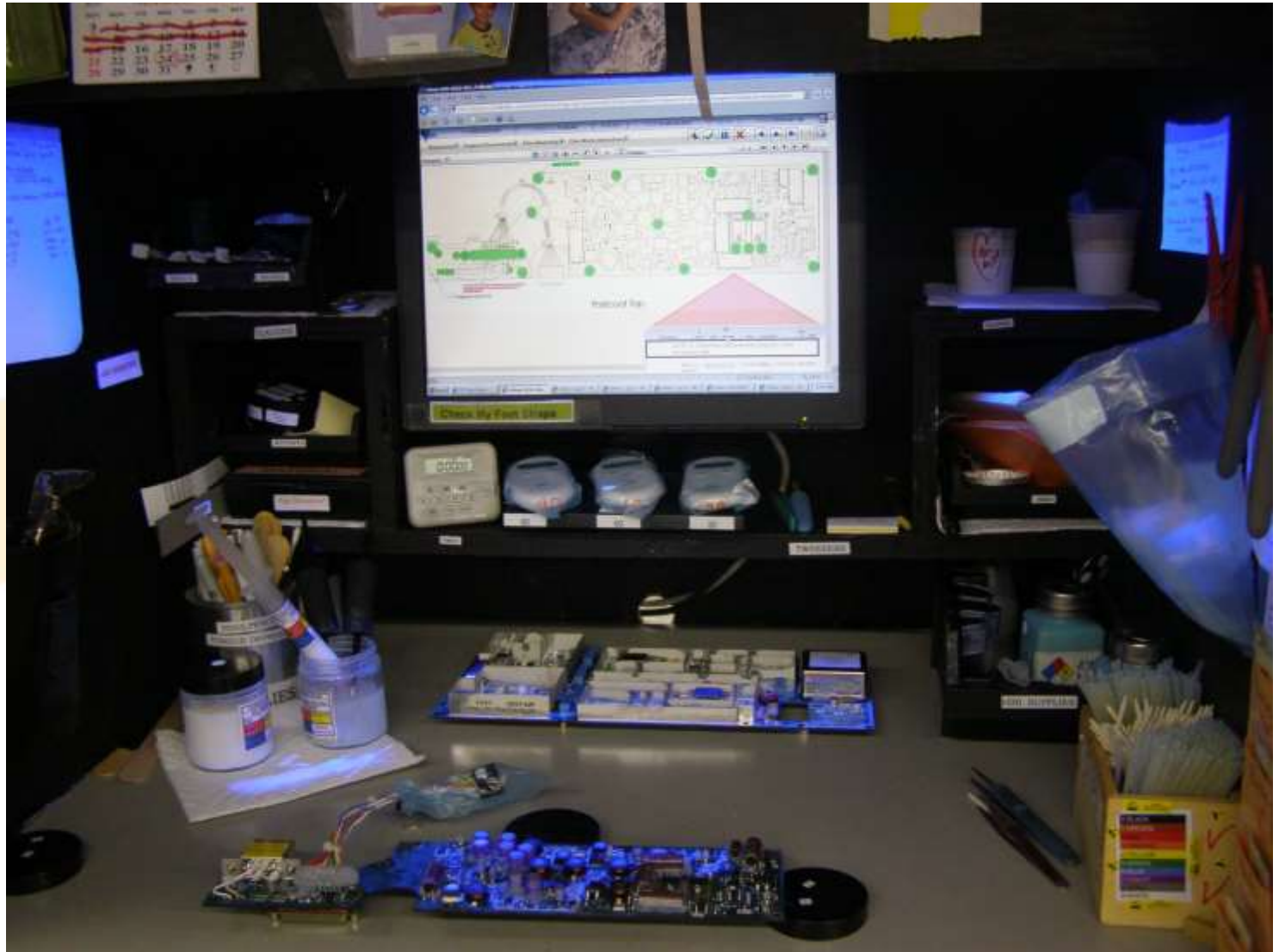
Brushing is the least efficient application method because of difficulty in achieving uniform coverage (hence, uniform coating thickness) and controlling bubbling.

While this operator dependent method is not practical for high-volume production, it is suited to short run, prototype and touch-up after repair/rework. This method also works well for high topography assemblies (power supplies)

Particular attention should be paid to the underside of components and lead wires. Care must be exercised to avoid deposit of brush fibers in the coating.



Typical Workstation



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Coating Application Methods

Brushing

Advantage	Disadvantage
Very simple and low start-up costs	Difficult to control the material thickness
Good for low-volume high-mix production	Easy to create voids and bubbles
Good for rework or touchup application	Brush can be the cause of residual FOD (bristles)
Can protect against airborne FOD	Operator experience dependent
Very good for small parts or for where masking needs are onerous	Part to part variability
	Tends to push a lot of coating under parts

Video of Brush Coating / Syringe Coating



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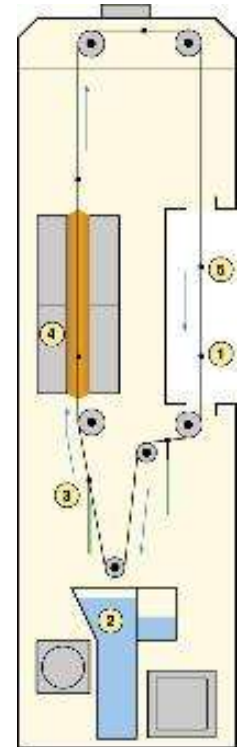


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Coating Application Methods

Dipping

This method, in which the masked assembly is immersed in a tank of liquid coating material and withdrawn, ensures uniform coverage and predictable, repeatable film thickness. Variables include rates of immersion and withdrawal and viscosity of the liquid material. The assembly should be immersed slowly to allow the coating material to displace the air surrounding components, remain immersed until bubbling has ceased, and then withdrawn. Typical immersion and withdrawal speeds are 2 to 12 inches per minute for the first dip, with subsequent dips made at higher speeds. Immersion and withdrawal speeds depend on the size and complexity of the assembly. Timing may be manual or automated.



Coating Application Methods

Curtain coating

This is a way to apply material to board. The material will continuous fall like material curtain. Then the conveyer will move the board pass though that curtain. Material can reuse in this case. But the viscosity need to be close monitored. The contamination of material reuse is critical to create the defect.



Coating Application Methods

Dipping / Curtain

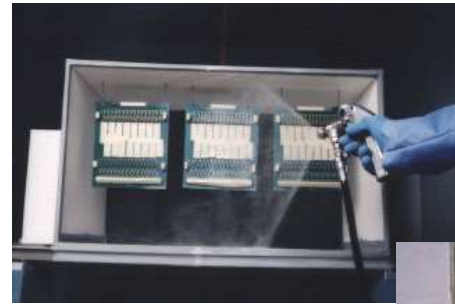
Advantage	Disadvantage
Good for coverage even on complex shapes/parts within assembly	Open to environmental impacts - temperature / humidity
Good for low volume production	Material viscosity must be monitored
Relatively not expensive	Coating reservoir can become contaminated
System not complicated / easy design	Masking and preparation required
Reused material / process savings	

- Parts are immersed in a tank of coating and then withdrawn at a controlled rate
- Can be manual or automated process

Coating Application Methods

Manual Spray

Spraying manual is the most popular and the fastest method for applying conformal coatings. With the proper combination of solvent dilution, nozzle pressure, and pattern, reliable and consistent results are obtainable. For high-volume production, spray coating is readily automated.



Coating Application Methods

Manual Spray

Advantage	Disadvantage
Can move the nozzle from front to Back for better coverage	Need to contain excess over-spray or any harmful vapors.
System not complicated	Cannot control the material thickness easily
Material viscosity is very stable	Material wastage / loss in process
Aerosol is good for rework	Masking required to be completed
With proper training, you can coat difficult 3D assemblies	Usually much higher in VOCs as dilution is needed for spray
Reasonable implementation cost	Thin material may require multiple coat/cure cycles to get desired thickness.
Angled spray may provide better coating on high topography assemblies	Usually need some form of disposable backing which can be FOD or hazardous waste

Video of Manual Spray



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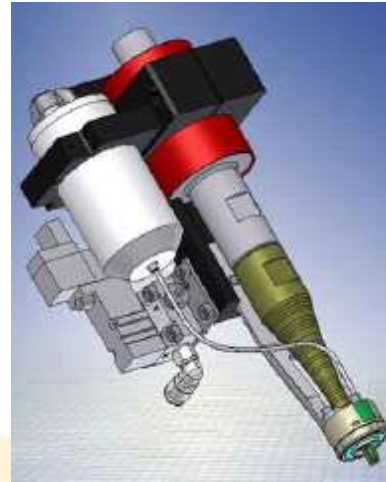


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Coating Application Methods

Automated Dispensing

Automated or selective coating is well suited for high volume applications where repeatability, speed and efficiency are essential for success. Selective coating use programmable robotic X-Y-Z positioning system to accurately manipulate the applicator in and around the product being coated. By using an automated system, repeatability is introduced and speed is greatly enhanced. With proper programming, material waste can be greatly reduced and in many cases masking can be completely eliminated.



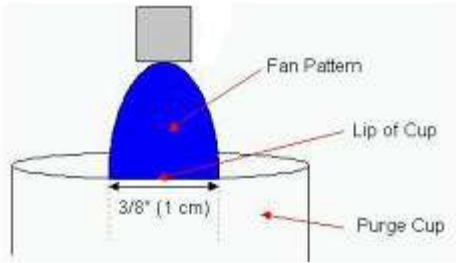
Coating Application Methods

Automated Dispensing



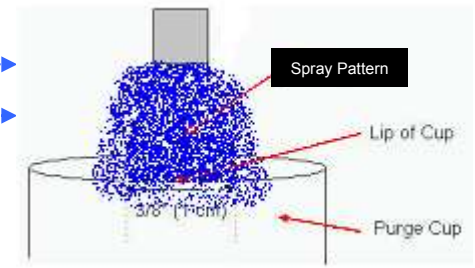
Coating Application Methods

Process Range for Conformal Coating format.



Process Window

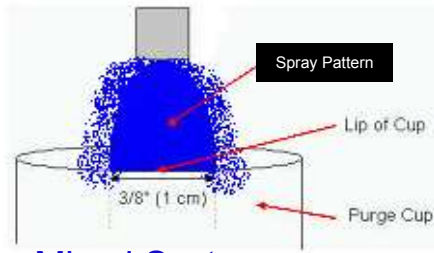
Cycle Time, Masking requirements



Cycle Time \approx 2min

Masking \approx none

Ideal for functional coverage

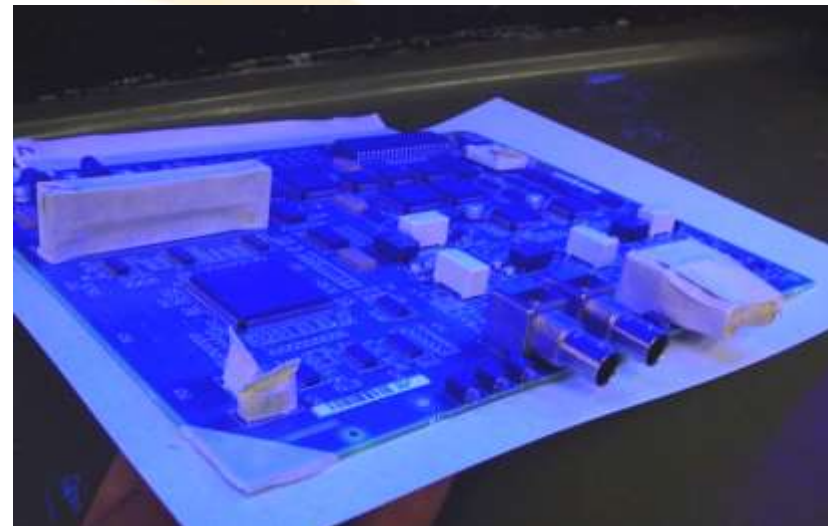


Mixed System

Cycle Time \approx 15min

Masking \approx 100%

Ideal for complete coverage



Coating Application Methods

Automated (Spray) Dispensing

Nozzle/Spray Nozzle

Spray coating is usually used for to medium to low-volume production. Masking is required due to overspray of nozzle design. Spray application difficult to coat under components, since top down view and will require slightly more maintenance.

The type of feed system, nozzle speed, temperature of material and atomization pressure used will affect the applied thickness.



Coating Application Methods

Automated (Spray) Dispensing

Advantage	Disadvantage
Repeatable process for complete topside surface coverage	Masking may be required
System not complicated to program	Material wastage / loss in process
Process can be applied for in-line operations with curing	Need to contain or exhaust excess over-spray or any harmful vapors.
	Cycle time greater than select application
	Usually requires fixturing for repeated spray

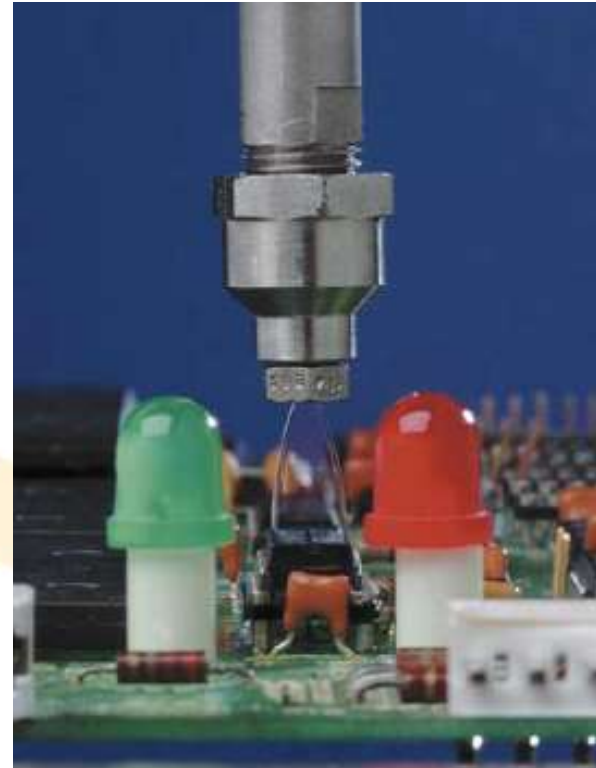
Coating Application Methods

Automated (Selective) Dispensing

Nozzle/Film coating nozzle

Select coating can be used for moderate to high-volume applications and often eliminates the need for masking because the material is dispensed only on selected areas of the circuit.

Coating thickness is affected by material viscosity, fluid temperature, pressures used, nozzle speed and dispense head configuration.



Coating Application Methods

Automated (Select) Dispensing

Advantage	Disadvantage
Repeatable process for functional topside surface coverage	Not ideal for side coverage requirements
Limited material loss in process	Higher system costs than spray application
Process can be applied for in-line operations with curing	System more complicated to program than for spray applications
Cycle time less than spray application	
Limited masking required	

Video of Automated Spray



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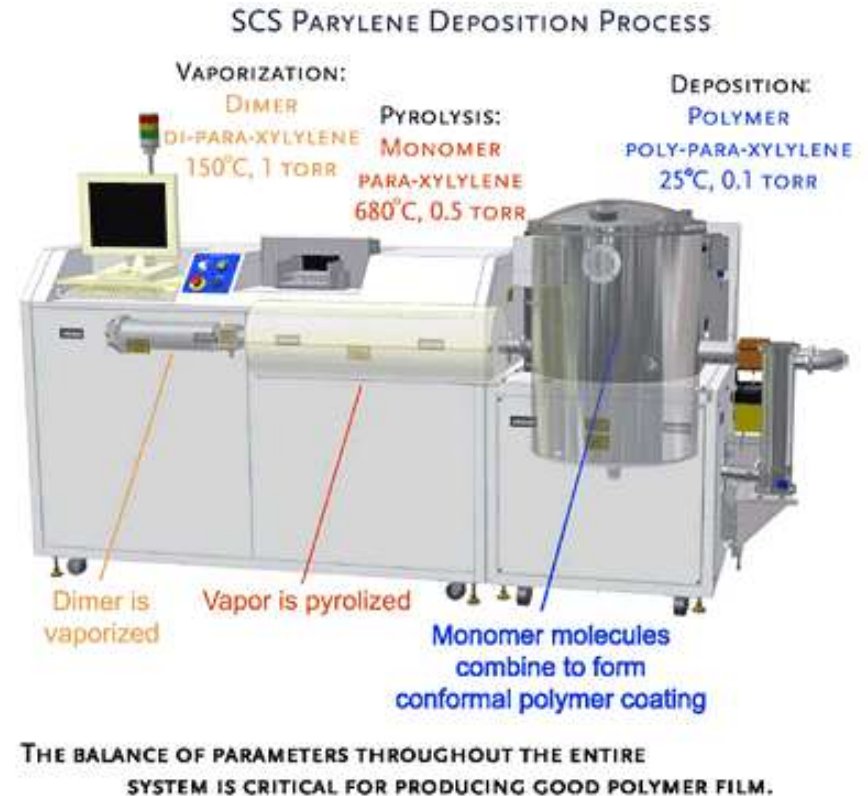


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Coating Application Methods

Vapor deposition

Parylene is applied at room temperature with deposition equipment that controls the coating rate and ultimate thickness. Polymer deposition takes place at the molecular level. The required thickness of a coating can vary based on the application, but thickness can range from the hundreds of angstroms to several mils, with the typical coating being in the microns range.



Coating Application Methods

Vapor Deposition

Advantage	Disadvantage
Uniform coverage on all surfaces (component sides, lead surfaces)	Masking required to be completed
Excellent material properties	Batch-mode with limited volume
No harmful vapors during process	Material / Equipment expensive in cost
	Requires specific processes for rework
	Material thickness unknown, until after application

METHODS OF CURING



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Methods of Curing

- Air Cure
 - Solvent evaporation
 - Reactive (2 part) coatings
- Thermal Curing
 - Infrared lamps
 - Ovens
 - Standard forced air ovens
 - Class A ovens
 - Can be used to accelerate cure of 1 and 2 part coatings
- Ultraviolet (UV) Energy
 - UV energy initiates the cure reaction
 - Recommend UV coatings that have a secondary cure mechanism

Air Curing Advantages and Disadvantages

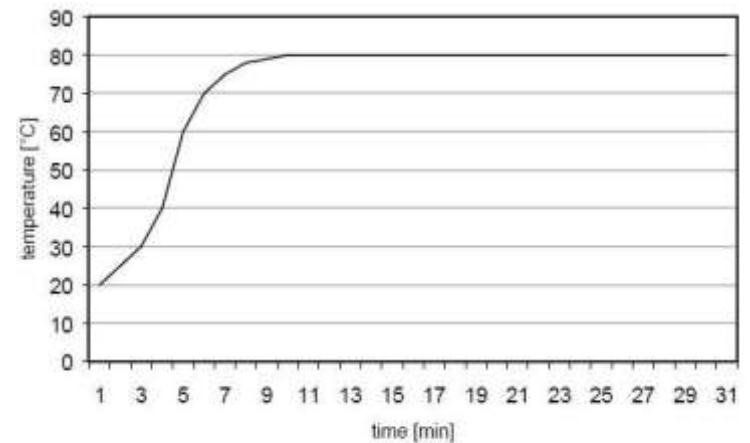
Advantages	Disadvantages
No equipment cost	Long cure process
Slower tack time allow for void release	Space allocation (work in progress)
Room temp or near room temp	Ventilation - coating emission
	Product handling
	Need to guard against airborne FOD

Curing Processes

Heat Curing

Heat cure improves wetting and lowers viscosity. Additionally for truly rapid curing, less than 2 minutes, temperature in excess of 150° C must be used. These temperatures may be high enough to damage some components.

The temperature and duration time for curing will be recommended from manufacturer technical information.



model temperature profile for the curing of
ELPEGUARD® conformal coatings



Heat Curing Advantages and Disadvantages

Advantages	Disadvantages
Can be low equipment cost	Space allocation
Fast tack cure time	Ventilation - coating emission
Accelerated cure schedule	Product handling
	Can result in bubbles and voids if time between tack free and onset of cure too short
	If dealing with flammable vapors – will need a Class A (explosion-proof) oven

Curing Processes

Moisture Curing

Moisture-curing systems, a minimum of 30% relative humidity is required for the curing areas. For this reason, plant locations in cold and dry climates should avoid selecting conformal coating formulations, which require moisture-cure and the associated equipment, and operating expenses of humidification. These materials cure by using moisture in the air. On exposure to the air, the coating will begin to cure.

TYPICAL PROPERTIES

Specification Writers: Please contact your local Dow Corning sales office or your Global Dow Corning Connection before writing specifications on these products.

Dow Corning [®] Brand Product	Product Form	Color	Viscosity, centipoise or mPa·s	Durometer	Specific Gravity	RT Tack Free Time, minutes	RT Cure Time, minutes ¹	Heat Cure Time, minutes ^{2,3}	UL Reference ⁴	
									Flammability Classification	UL 746C Approval
RTV Elastomeric Conformal Coatings										
3-1753 Conformal Coating	1-part RTV cure	Clear	385	25 A	0.99	15	30	1 @ 60°C/ 15% RH	94 V-1	Yes
3-1765 Conformal Coating	1-part RTV cure	Clear	150	25 A	1.03	6	30	2 @ 60°C/ 15% RH	94 V-1	Yes
3-1744 Conformal Coating	1-part RTV cure	Translucent	60,000	35 A	1.04	15	60	5 @ 60°C/ 15% RH	94 V-0	Yes
3-1953 Conformal Coating	1-part RTV cure	Lt. Straw/ Translucent	360	26 A	0.99	10	30	2 @ 60°C/ 15% RH	94 V-0	No
3-1965 Conformal Coating	1-part RTV cure	Lt. Straw/ Translucent	110	29 A	0.99	6	30	2 @ 60°C/ 15% RH	94 V-0	No
3-1944 Conformal Coating	1-part RTV cure	Lt. Straw/ Translucent	60,000	29 A	1.03	15	60	5 @ 60°C/ 15% RH	94 V-0	No



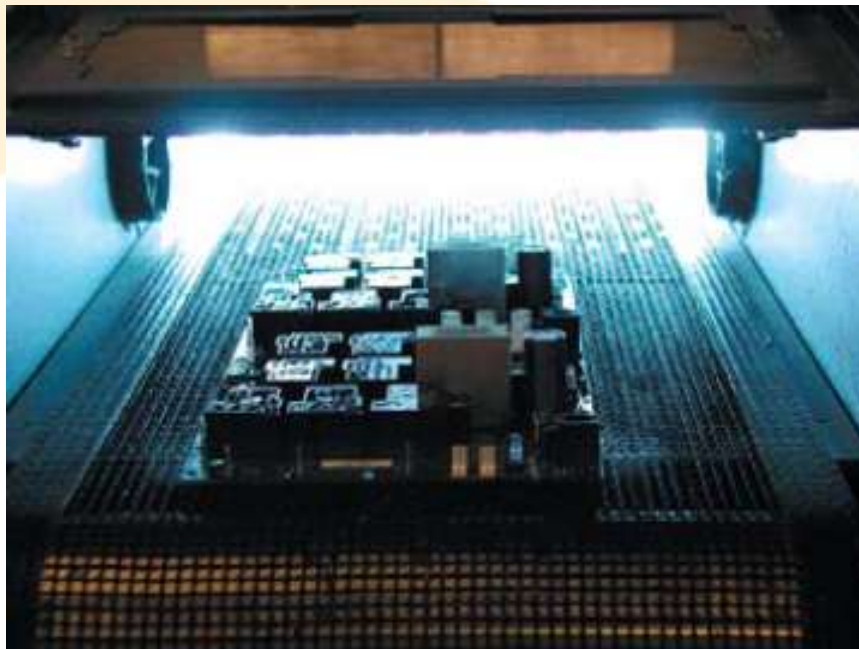
Moisture Curing Adv. & Disadvantages

Advantages	Disadvantages
Minor equipment cost	Need to Control humidity & temperature
Accelerated cure schedule to air cure	Space allocation
	Ventilation - coating emission
	Degree of cure varies depending on thickness

Curing Processes

UV Curing

A high mass placed suddenly into a small oven can cause overload, requiring a prolonged time for the assembly to be brought up to specified temperature. UV-curing ovens must be specified to meet the specific requirements for irradiation curing of the particular material used, e.g. wavelength and energy intensity. Issues exist with shadowing and below component area curing if secondary curing not available within material properties.



UV Curing Advantages and Disadvantages

Advantages	Disadvantages
Very fast	Shadowing – incomplete cure
Room temp or near room temp	Generation of ozone from equipment
No coating emissions	Intense UV light – amber glasses
	May result in undesirable odors

Validation of Methods of Cure

- How do you know when the conformal coating layer is cured?
- Most TDS show coatings don't reach "full" properties for 3-30 days or more
- Tack - Free
 - Simple contact will not alter coating surface
 - Full physical and chemical properties not achieved
- Full Cure
 - Physical and chemical properties achieved
- How to validate cure
 - DSC (Differential Scanning Calorimetry)
 - TGA (Thermogravimetric Analysis)
 - Performance based tests (e.g. SIR)
 - Adhesion
 - IPC 2.4.1.6 - Adhesion, Polymer Coating
 - ASTM D 3330 Peel Adhesion of Pressure-Sensitive Tape of 180° Angle
 - ASTM D 3359 Measuring Adhesion by Tape Test

Break #3 – 10 minutes



TRADITION

Just because you've always done it that way
doesn't mean it's not incredibly stupid

motifake.com



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Surface Mount Technology Association

COATING TOUCH UP AND EVALUATING THE CURED FILM



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SMTA
Surface Mount Technology Association

Coating Touch Up Issues

- Usually cosmetic issues – a touched up area looks like a touched up area. Will be an issue if the perception is that a coating has to be cosmetically flawless.
- If recoating after component replacement, have to make sure area is clean and dry, and that the replacement coating overlaps the old coating by at least 1/8 inch
- Touch up may be done by untrained operators

COATING DEFECTS, CAUSES, AND REMEDIES

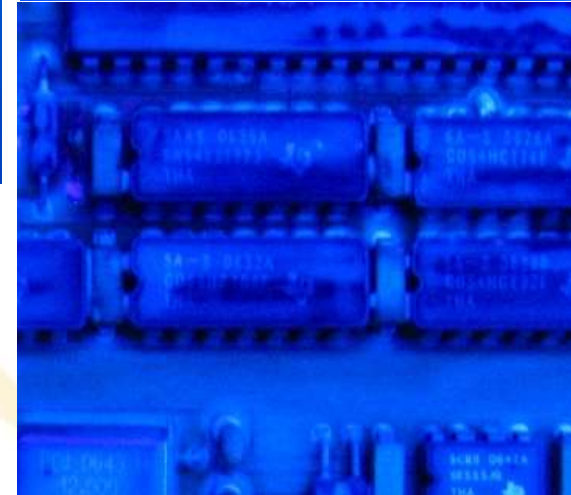
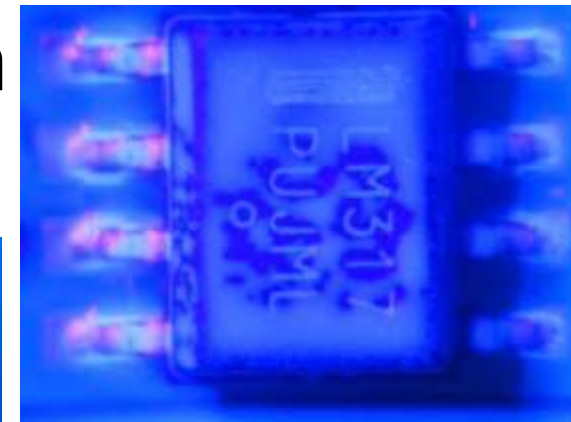
(THIS GETS UGLY)

Good decisions come from experience, and experience comes from bad decisions.



Coating Defects and Inspection

- **Uniformity**
- Dewetting
- Fisheyes
- Inadequate coverage
- Bubbles and Voids
- Cracks and Ripples
- Orange Peel
- Delamination
- Creep Corrosion



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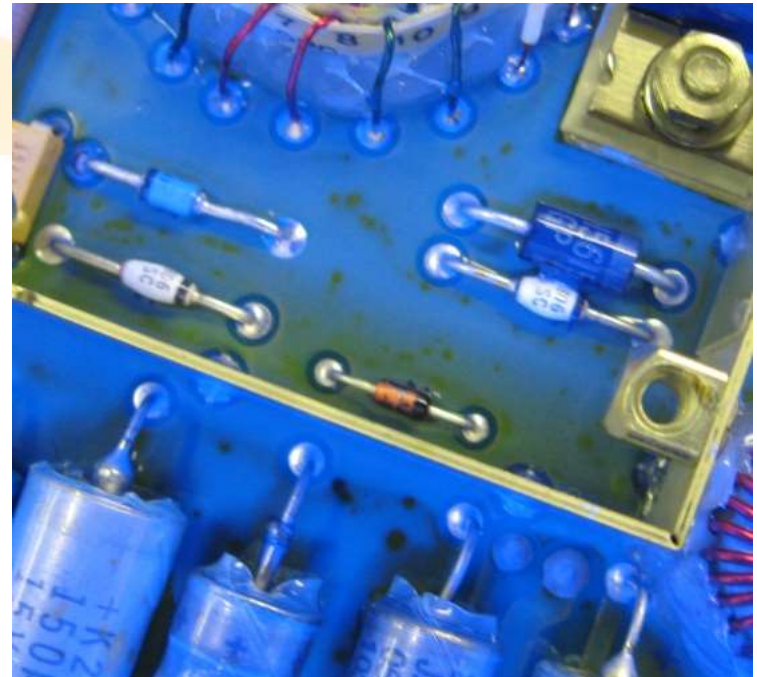
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What Causes This? - Uniformity

- Most release agents on components
- Localized residues (silicones, oils)
- Sharp surfaces or solder points
- Liquid based coating – gravity (solder points)
- Improper mixture of two part materials
- Variations in Surface Tension or Surface Energy
- Alloy of the component leads (reflectivity)
- Uneven coating application (e.g. brush)
- Dryness of the surface
- Do not recommend using the “blue-ness” as a measure of thickness.

Coating Defects and Inspection

- Uniformity
- **Dewetting**
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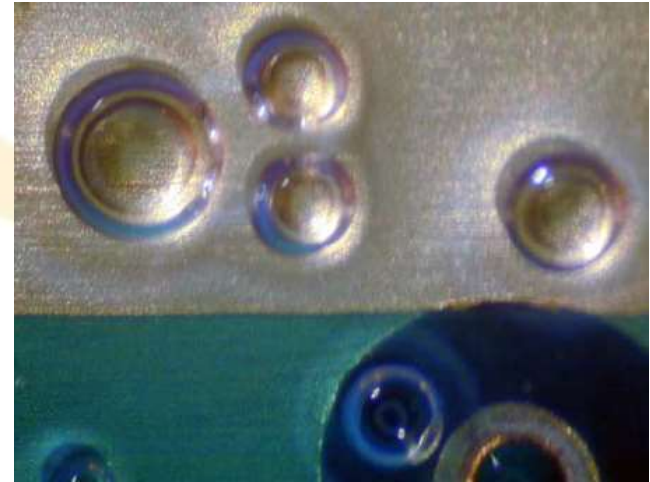


What Causes This? - Dewetting

- LOTS of things
- Residue on the coating surface (e.g. silicones, oils)
 - Silicone rich oils from moisture cure RTV silicones
 - Silicone adhesive residues wiped from assembly but not cleaned from assembly
 - Residues from paintbrushes (waxes, yesterdays coating)
 - Residual mold release agents on plastic components
- Liquid based coating, gravity
- Improper mixture of two part materials
- Variations in Surface Tension and Surface Energy
- Component surface finish
- Uneven coating application
- Chemical interaction between coating and coating surface

Coating Defects and Inspection

- Uniformity
- Dewetting
- **Fisheyes**
- Inadequate coverage
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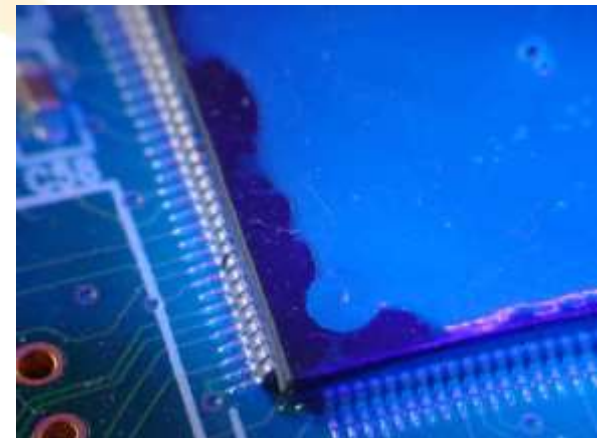
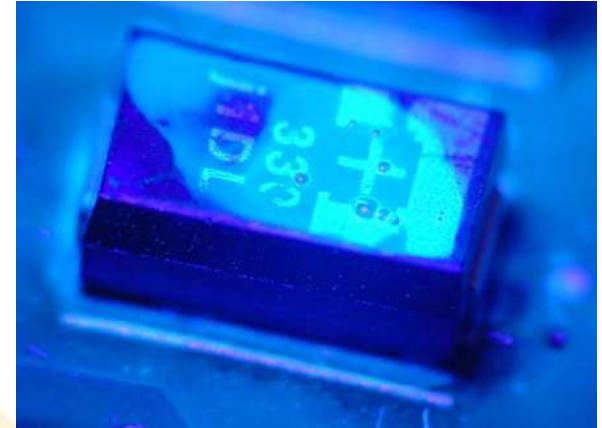


What Causes This? - Fisheyes

- Almost always a point contamination source
 - Spot of oil or wax
 - Drop of silicone rich material
 - Spray coating – oil or moisture in the air line
 - Contaminated coating containers
 - Contaminated solvent supplies
 - Contaminated mixing containers
- The point contaminant repels the coating
- Do NOT, repeat NOT, simply try to cover with more coating
 - Much like putting a band aid on an infected wound
 - Clean the point contaminant with a suitable solvent

Coating Defects and Inspection

- Uniformity
- Dewetting
- Fisheyes
- **Inadequate coverage**
- Bubbles and Voids
- Cracks and Ripples
- Orange Peel
- Delamination
- Creep Corrosion

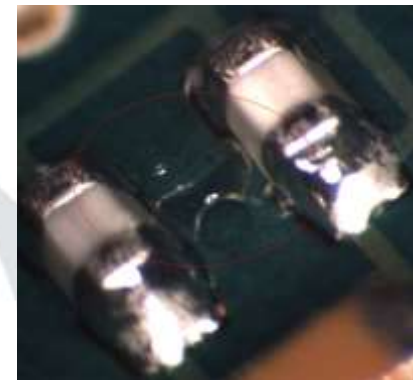
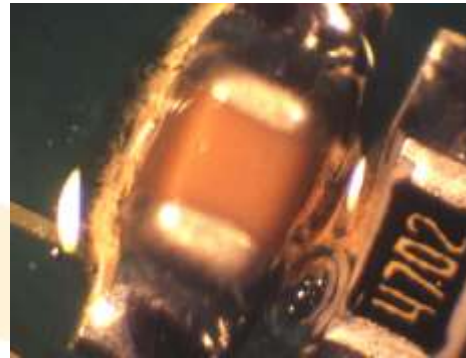


What Causes This? – Inadequate Coverage

- Liquid based coating, gravity
- Improper mixture of two part materials
- Surface Tension / Surface Energy
- Component surface finish
- Uneven coating application
- Residue on the coating surface
- Interaction between coating and coating surface
- Poor coating programming
- Improper fixturing
- Improper placement of assembly in coating area
- Wrong coating requirement interpretation

Coating Defects and Inspection

- Uniformity
- Dewetting
- Fisheyes
- Inadequate coverage
- **Bubbles and Voids**
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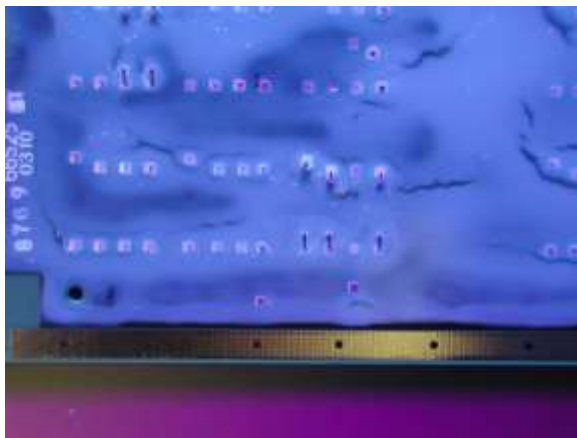
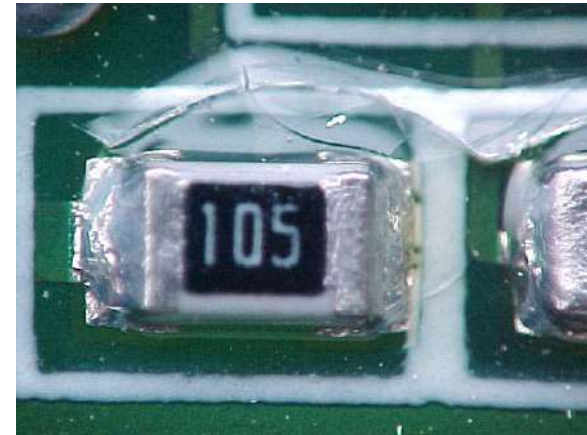


What Causes This? – Bubbles and Voids

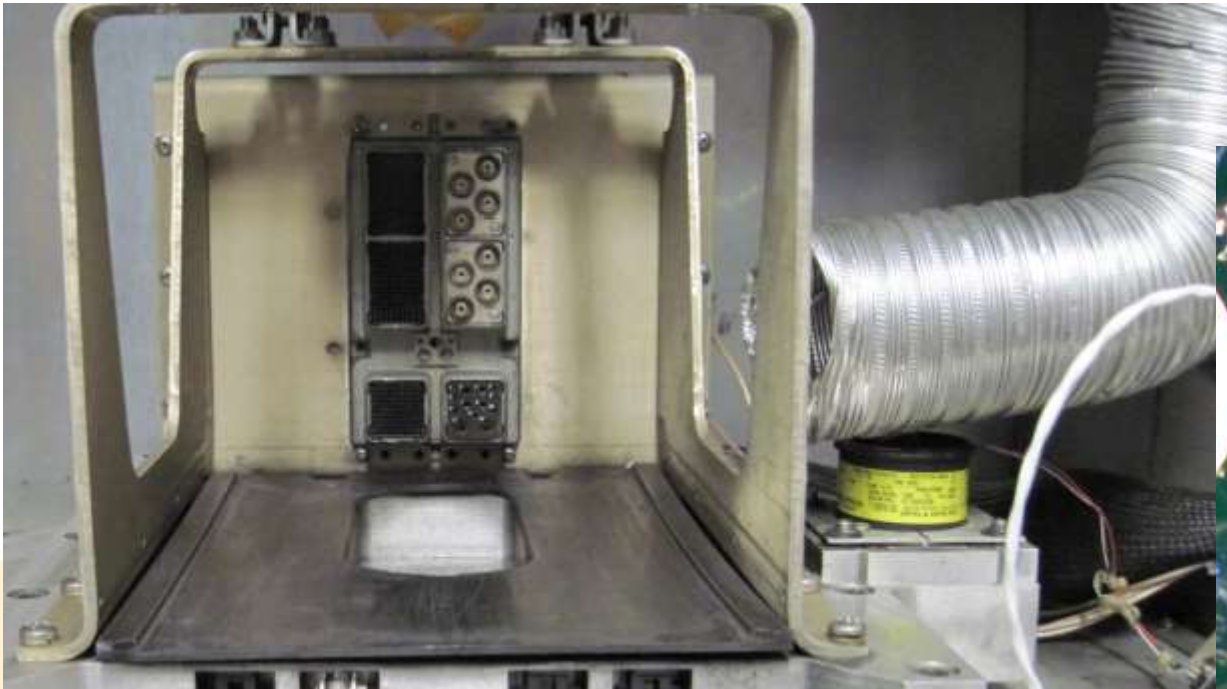
- Almost all bubbles and voids are caused by entrapped solvent trying to escape the coating
- Brush coating can entrain bubbles into the coating
- Most liquid coatings “skin over” on the top surface. Solvent must diffuse through this layer to escape.
 - Coating is too thick – takes progressively longer to diffuse
 - Coating came to tack free too fast – skins over more quickly
 - Coating goes into thermal cure while liquid solvent still present under components
 - Solvent responds to the heat with increased vapor pressure
 - Bubbles form to relieve that pressure
 - Outgassing from component/PWB (dryness)
 - Outgassing from entrapment sites (plastic sleeving)
 - Vacuum not strong enough (degassing)
- ESS/Test Induced

Coating Defects and Inspection

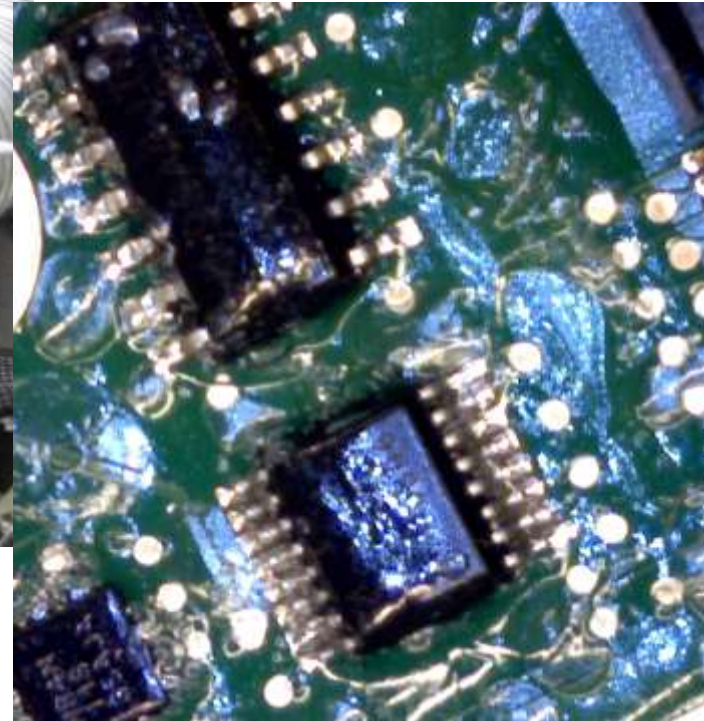
- Uniformity
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- Orange Peel
- Delamination
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Coating Defects and Inspection



HASS Test Setup – LN2 Chamber



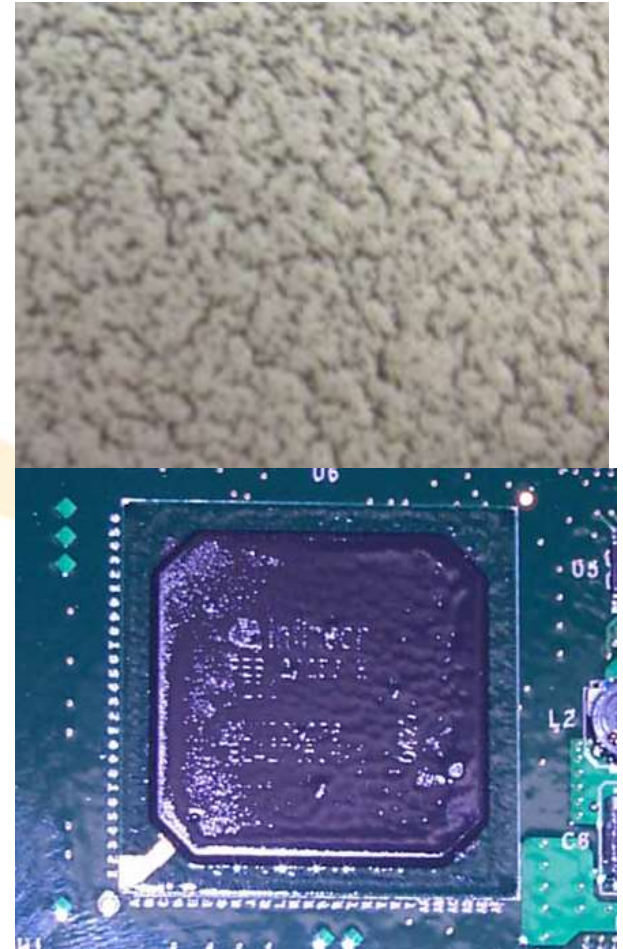
Effect of Freeze Spray

What Causes This? – Cracks and Ripples

- “Mudcracks”
 - Arises when attempts are made to force coating to a tack free condition too quickly
- Coating too thick (CTE related)
 - Two thin coats are MUCH better than 1 thick coat
- Thermal shock – rate of change of environment greater than the material can expand or contract
 - Recommend less than 40C/min
- Improper coating mixture
- Surface energy too low – minimal adhesion
- Flexing from vibration in ESS

Coating Defects and Inspection

- Uniformity
- Dewetting
- Fisheyes
- Inadequate coverage
- Bubbles and Voids
- Cracks and Ripples
- **Orange Peel**
- Delamination
- Creep Corrosion

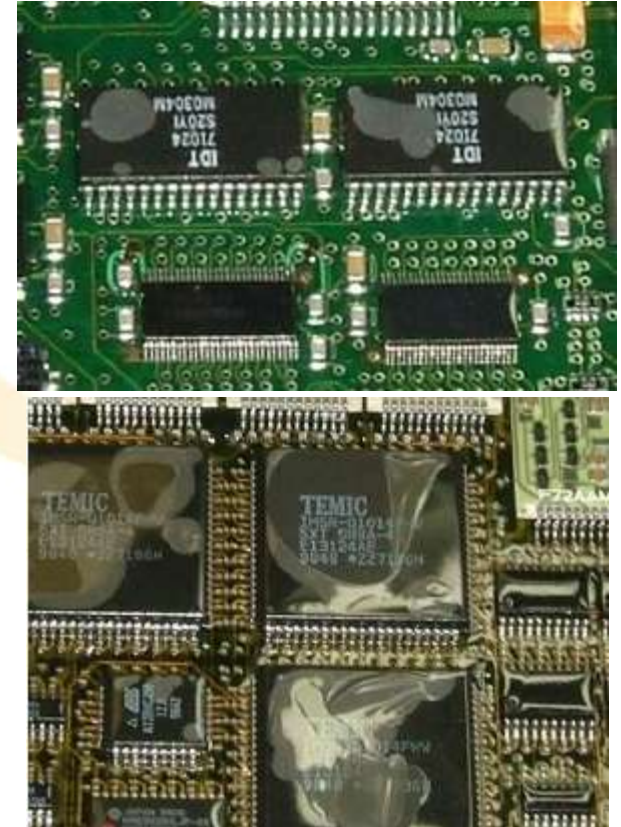


What Causes This? – Orange Peel

- Generally related to the evaporation rate of the solvent
 - Local environment is too dry during application
 - Improper coating mixture or solvent ratio
 - Substrate is too hot
- Can sometimes arise if second coat (e.g. touchup) is applied before the first coat is dry
- This visual effect is sometimes confused with “wrinkling”
 - Too high of thermal cure or
 - Too much thermal shock during plastic phase of curing

Coating Defects and Inspection

- Uniformity
- Dewetting
- Fisheyes
- Inadequate coverage
- Bubbles and Voids
- Cracks and Ripples
- Orange Peel
- **Delamination**
- Creep Corrosion

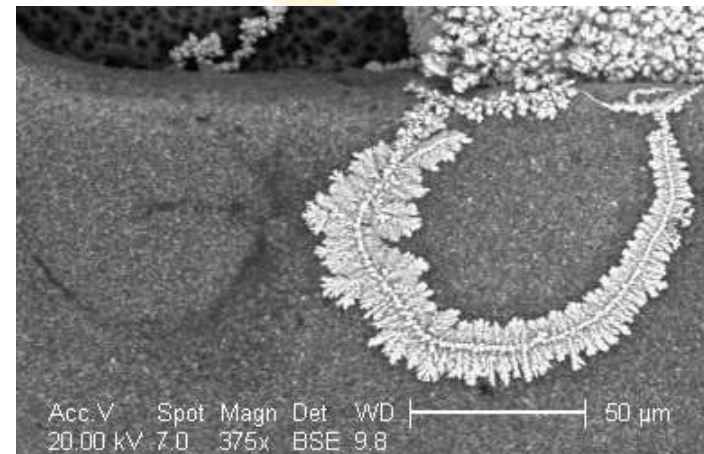
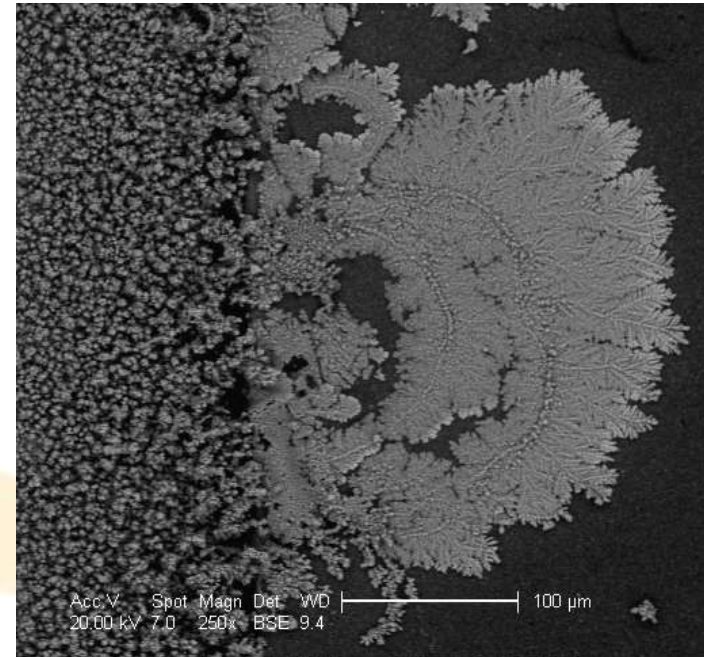


What Causes This? - Delamination

- Coating too thick
 - Coating/laminate interface was the last to cure
- Surface energy too low
 - Inherently “slick”, or from poor processing (solder mask)
- Contamination on coating surface that prevented a good bond to the surface
- Coating not adhering to previous coating layer
- ESS testing – super hot/cold air directly impinges on coating surface
- ESS testing – rate of change too fast ($>40\text{C}/\text{min}$)
- ESS testing – test extremes are beyond material bounds
- Blunt keratin at an oblique angle with variable force applied

Coating Defects and Inspection

- Uniformity
- Dewetting
- Fisheyes
- Inadequate coverage
- Bubbles and Voids
- Cracks and Ripples
- Orange Peel
- Delamination
- **Creep Corrosion**



What Causes This? – Corrosive Fumes

- Creep Corrosion is the migration of corrosion products on the surface of PCBs without bias in corrosive environment.
 - It can lead to premature failure by shorting.
- Typical causes:
 - Improper application of coatings, exposed PCB regions
 - Application environments trap corrosion products below coating
 - Local components / materials transfer corrosive products (below coating application)
 - Local environments add surface corrosion
- Can sometimes arise if second coat (e.g. touchup) is applied before the first coat is dry
 - Materials added, migrate within coating

Proposed for J-STD-001 and A-610

- This is still being debated but is the only thing remaining before going to Ballot.
- Improved definitions of what is a defect requiring disposition and what is a process indicator
 - Pretty is not a requirement, ugly is not a defect
- Quite a few submitted comments
- Areas of Contention
 - General issues with Wordsmithing
 - Inspection Conditions
 - Bubbles
 - What to do when you find a defect



Break – 5 min

1 H Halcion																	2 Td Tedium
3 Ac Actium	4 Cx Clorox											5 M Moron	6 Ct Carton	7 Fl Florentine	8 P Pylon		
9 Bg Belgium	10 Hx Hydrox	11 A Anodyne	12 Pk Pekingese	13 Su Sumerian	14 V Vinyl	15 Bs Bosporus	16 L Linoleum	17 As Asinine	18 Cr Crouton								
19 Dm Delirium	20 Am Aspartame	21 At Antipathy	22 Ch Chagrin	23 Ca Canadian	24 Tc Talc	25 Ge Geranium	26 An Antigen	27 Rp Rapine	28 Pr Princeton								
29 Bz Byzantium	30 Cn Collagen				31 Pz Pizzazz	32 Qt Quotidian	33 Gu Gummi	34 X Xena	35 Sn Sin	36 Vi Visine	37 Cd Celinedion						
38 Im Imodium	39 Fg Fahrverg-nügen				45 Sa Sanatorium	46 Ap Asparagus	47 He Hefnerium	48 Ae Antigone	49 Gr Grenadine								
												40 Gb Gambinium	41 Gv Genovesium	42 Bn Bonannium	43 Cb Colombium	44 Lu Luochesium	

Periodic Table of Rejected Element Names

- Sentient Metals
- Dingy Gases
- Al Kaline Metals
- Solid Gases
- Fey Metals
- Criminal Elements
- © Microsoft Corporation
- Consult Your Physician



PROCESS CONTROL

(GETS UGLIER)



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Process Control - Adhesion

- Testing Adhesion
 - Highly variable test (often depends on who does it)
 - Millie the Mouse vs. Bob the Gorilla
 - ASTM test is the root – “X” test and checkerboard test – tape based
- Viscosity control
 - Viscosity often directly relates to thickness
 - Thicker material = thicker coatings = process problems
 - High vapor pressure solvents – constantly changing viscosity if left out in the open or in a non-sealed container
 - Recommend not letting operators adjust viscosity

Measuring Coating Thickness

- Coupon Testing Method – almost everyone uses witness coupons
 - Micrometers
 - Can be highly variable
 - Compression of coatings, operator techniques, clutch settings
 - Eddy current testing
 - Done on ferrous coupons, manual is highly variable, automated better
 - Wet film gauge
 - Wet film to dry coating correlation needs to be completed
 - Both on test coupons along with production assemblies
 - Ultrasonic methods
 - Requires the temporary usage of a liquid gel, probe size, flat surface
 - Optical methods
 - Focus on the coating, then the substrate, calibrate difference
 - Knowledge of refractive index for all materials required.

Measuring Coating Thickness (cont'd)

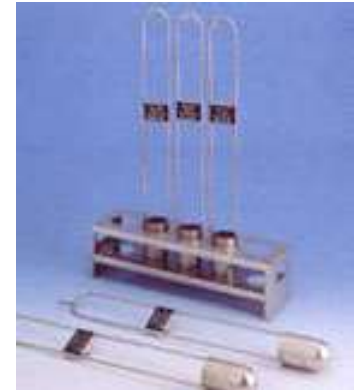
- On assemblies – almost everyone uses witness coupons
 - However correlation to the actual production materials is required
 - i.e. Different surface finish and topology between materials
- On assemblies
 - There is no practical method for measuring coating thickness on an assembly other than on a “flat unencumbered” area of the assembly
 - Most modern assemblies are so dense this is not practical
 - Most edges have connectors or components near by
 - Final users do not want new chemicals added to their process
 - Especially just for process controls
 - Fritz Byle, Astronautics, presented a paper on how this may be done on an assembly with a microscope (optical method)

Process Control Issues

- Working Life
 - Manual application of coatings with volatile solvents
 - Recommend not letting coating operators adjust viscosity
- Tools
 - Brushes (clean before first use to remove mfr residues)
 - Need to be cleaned regularly with a suitable solvent
 - ESD mats need to be cleaned and periodically replaced
 - OSHA has many requirements on operator protection / ventilation
- Containers
 - Flammable materials = suitable containers
- Wastes
 - If wipes/swabs, etc. come in contact with a flammable liquid, they must be treated as a solid flammable waste
- Handling Residues

Material Control

- Most common form of internally applied coating is acrylic, applied by selective/atomized spray
- Viscosity
 - Determined by resin to solvent ratio
 - Viscosity of base material can change by a factor of two by being left uncovered and out gassing
 - Viscosity of *mixture* needs to be directly measured and controlled
 - Solvent should be added until desired viscosity is reached, not by ratio
 - Viscosity can be measured by Zahn cup (cheap, easy) or by Brookfield spindle viscometer (very accurate, expensive)
 - Be aware not all Zahn #2 cups are the same



Environmental Control

- Cleanliness of area to be conformal coated is obviously a priority
- Humidity must be controlled to reduce moisture absorption and premature drying after cleaning prior to conformal coating
- Humidity control is critical with new Halogen Free materials.



Coating Application

- Key variables are head speed, head pressure, and viscosity, pot life
 - Viscosity of the mixture will change over time as solvent evaporates
 - Head speed and pressure determine rate of application and therefore thickness
 - All factors are interrelated
- Urethanes & Epoxies begin to polymerize quickly, resulting in shorter pot life

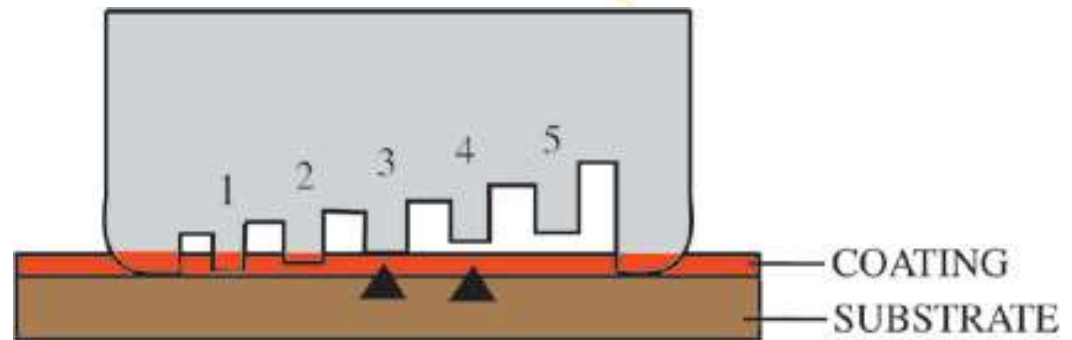


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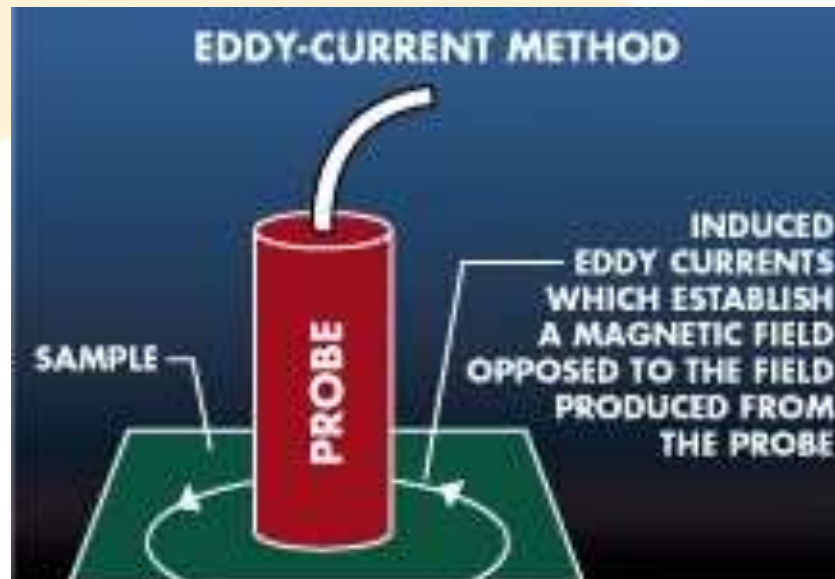
Thickness Control - Mechanical

- Coating thickness can be controlled through direct measure or use of coupons on either dry or wet coating material.
- Direct measurement (using micrometer/wet film gauge) is unreliable
 - Surface tension results in uneven deposits
 - Coating usually not fully cured when measured, can be deformed
- Apply coating to conductive coupon using same parameters:
(speed, pressure, viscosity)



Thickness Control - Inductive

- Eddy current meter allows for accurate, non-invasive testing
- Eddy current meter measures impedance change in circulating current in probe as a function of the coupling to the conductive plate
- Coupling changes as a function of coating thickness



UV Intensity Control - Microwave

- UV radiometers allows for accurate, non-invasive testing of the UV bulbs
- UV radiometers measure the UV exposure of the bulbs as a function of the light intensity that is being provided
- UV Intensity changes as a function of bulb degradation
- Good fab shops use these to monitor solder mask cure operation



Industry Studies/Activities

- CC State of the Industry – Coating Coverage
 - Led by Dave Hillman, Rockwell Collins for J-STD-001
- IPC-CC-830
 - Revision C under way – new classes of coatings
 - Possibility of MIL-I-46058 being revised
 - MIR and DWV Study on new coatings
- IPC 5-33AWG Group
 - Led by Jason Keeping/Doug Pauls/Fonda Wu/Amy Hagnauer
- Numerous studys on CC and Tin Whiskers
 - Both CALCE and IPC host tin whisker conferences
- New IPC task group on Low Pressure Molding
- Nanocoatings



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Reference Materials

- Best – participation in IPC/SMTA working groups
- IPC-HDBK-830: Revision A Published
- IPC-HDBK-850: Potting and Encapsulation
- IPC-AJ-820: Assembly and Joining Handbook
- Schutzlacke für elektronische Baugruppen – Manfred Suppa - English version available
- UL 746 and UL94
- Electronic Materials and Processes – Harper
- Printed Circuits Handbook - Coombs



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Your Instructors

Jason Keeping

Celestica

844 Don Mills Rd.

Toronto, Ontario M3C 1V7

Canada

416.443.7448

jkeeping@celestica.com

Doug Pauls

Rockwell Collins

400 Collins Road NE

MS 108-101

Cedar Rapids, IA 52498, USA

319.295.2109

dopauls@rockwellcollins.com



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Questions and Discussion



North Dakota's First Line of Defense Against Invasion From Canada



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