Surface preparation is critical for conformal coating protection

Robert (Dusty) Askin

Senior Materials Engineer

Sean Clancy, Ph.D.

Chemist and Project Manager

SMTA Intermountain Chapter Meeting

March 24, 2016

PROTECTION FROM THE INSIDE OUT®

Why should you prepare the surface?

A.K.A., Why does cleanliness matter?

- Poor cleanliness and surface preparation affects all of the following:
  - Loss of adhesion / delamination of the coating
  - Corrosion of the electronics (whether or not they are submerged in a liquid)
  - Long-term reliability, especially in harsh environments

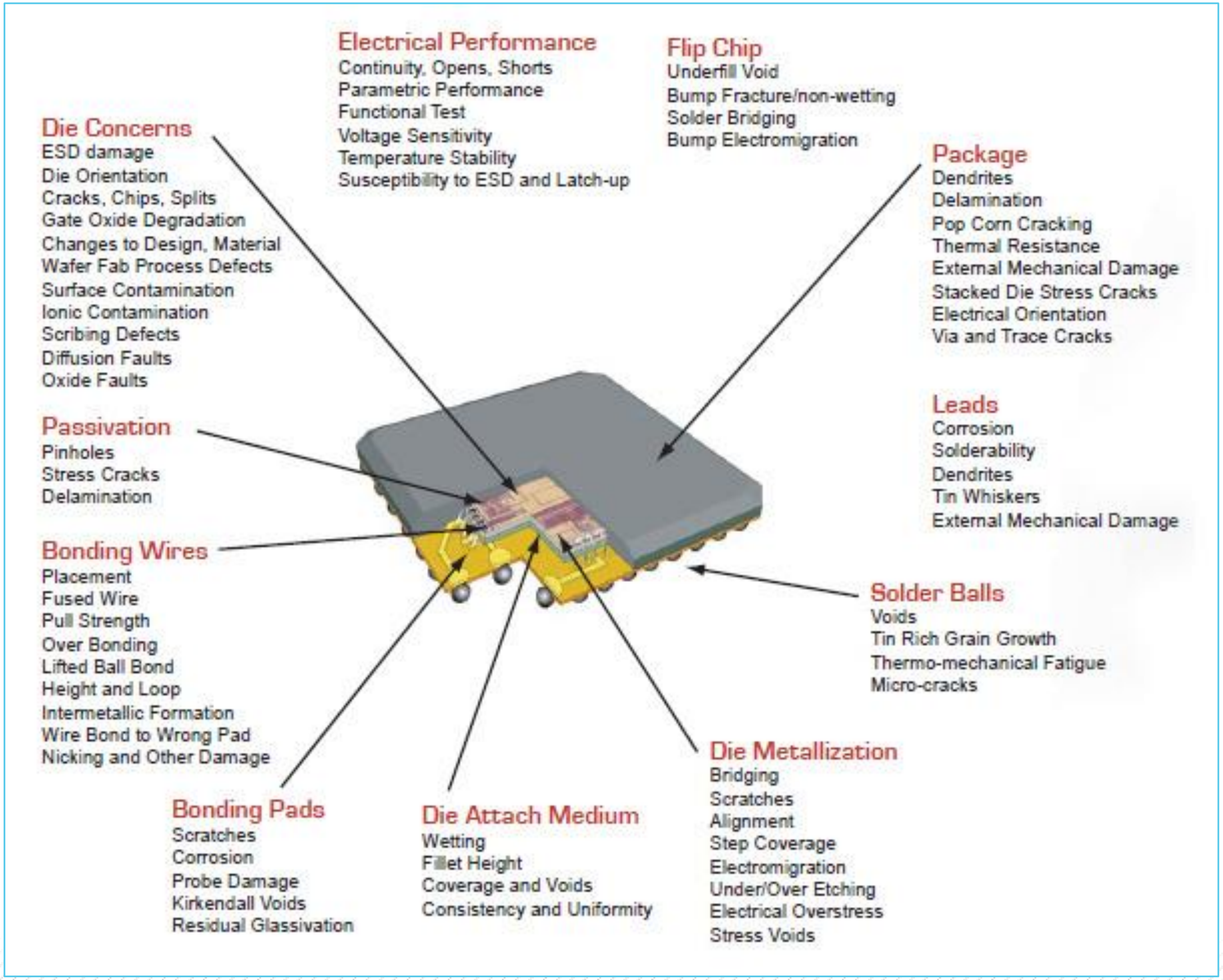
How should you prepare the surface?

- Tailor the cleaning method to the contamination
  - Know your dirt
  - Mixed contaminants might require multiple cleaning steps
  - Sensitive substrates / components can’t handle all cleaning methods

- Tailor the surface preparation to both the substrate and conformal coating
  - Match chemistries to materials
  - Match methods to substrates

Electronics Manufacturing Failure Analysis

Image reference: http://www.eag.com/mte/failure-mechanisms.html



Agenda

- Surface preparation in other fields
- Technical data sheets – cleanliness & surface preparation
- Industry standards on cleanliness
- Cleanliness test methods
- Dendrites
- Failure analysis (FA) case studies
- Cleaning methods and effectiveness
- Types of substrates
- Plasma cleaning and activation, followed by adhesion promotion
- Surface preparation and conformal coatings at IPC APEX 2016
- Useful resources
- Q & A

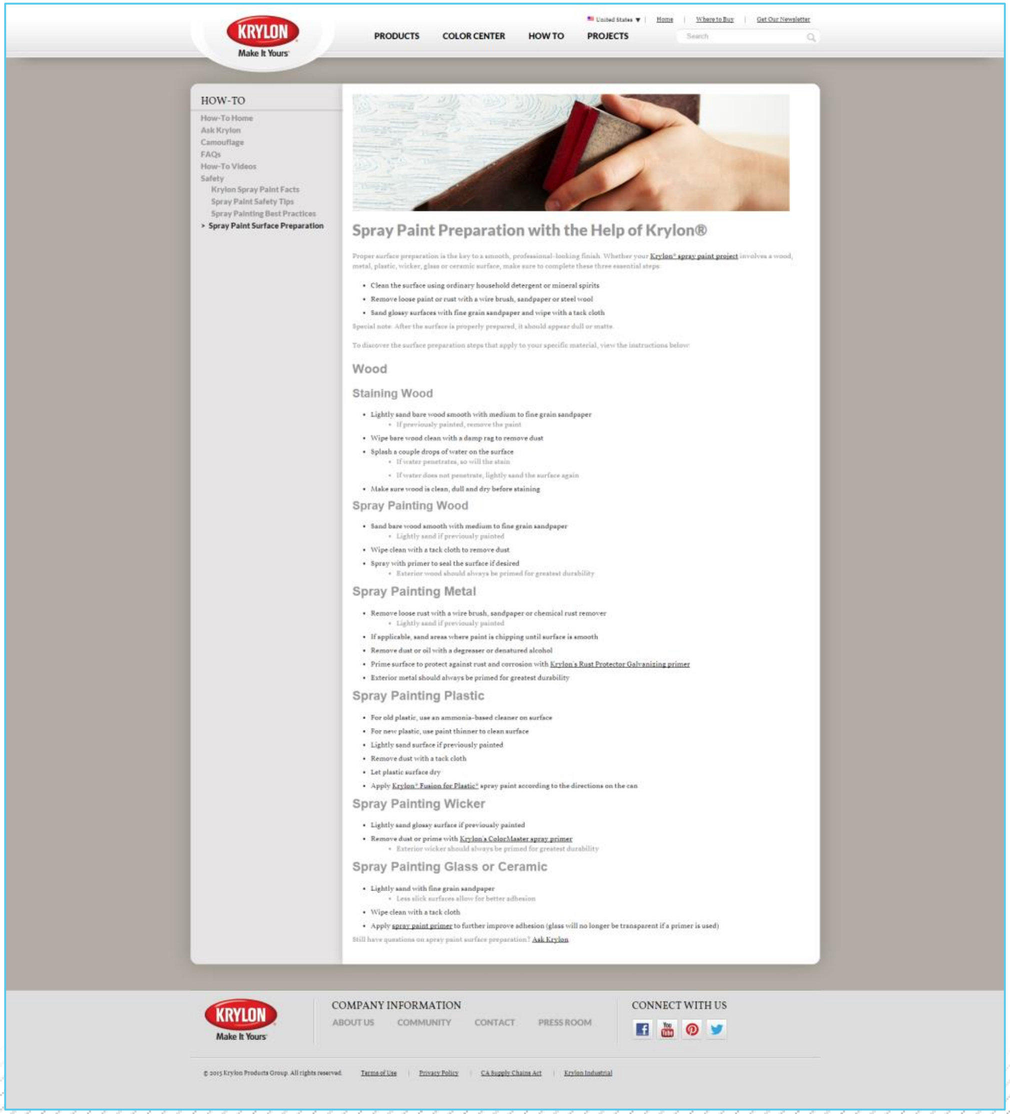
Surface Preparation in Other Fields

Meringues

- "10 Fool-Proof Tips for Making Perfect Meringues"
  - http://communitytable.parade.com/281479/smccook/10-fool-proof-tips-for-making-perfect-meringues/ (This article is also the source of image on the left.)
  - Step 1 – "Always use a spotlessly clean bowl, completely free from grease"
- "Pavlova"
  - https://www.exploratorium.edu/cooking/eggs/pavlova-pop.html
  - "Fat interferes with the formation of a good foam—and fat clings to plastic. No matter how carefully you clean a plastic bowl, odds are good that a bit of grease remains behind. It's preferable—and easier!—to use a glass or stainless steel bowl to produce a fluffy meringue. Egg yolks also contain fat, so when you separate the eggs, try to make sure that none of the yolk ends up in your egg whites."

Krylon Spray Paint

http://www.krylon.com/how-to/spray-paint-surface-preparation/



- "Spray Paint Preparation with the Help of Krylon®"
  - http://www.krylon.com/how-to/spray-paint-surface-preparation/
  - "Proper surface preparation is the key to a smooth, professional-looking finish."

  - Staining Wood
  - Spray Painting Wood
  - Spray Painting Metal
  - Spray Painting Plastic
  - Spray Painting Wicker
  - Spray Painting Glass or Ceramic

  - Generally, their process involves:
    - Clean the surface
    - Roughen surface
    - Remove any debris
    - Apply primer
    - Apply paint

Technical Data Sheets – Cleanliness & Surface Preparation

Dow Corning

http://www.dowcorning.com/DataFiles/090276fe801cf803.pdf

HZO
PROTECTION FROM THE INSIDE OUT™

Product Information
Electronics

DOW CORNING

Dow Corning® 3140 RTV Coating

FEATURES & BENEFITS

- Good flowability
- Room temperature cure
- No added solvents
- UL 94 V-1, IPC-CC-830 and MIL-A-46146 tested
- No mixing required
- Room temperature cure, no ovens required
- Faster in-line processing with optional heat acceleration
- Able to flow, fill or self-leveling after dispensing
- Can be considered for uses requiring added flame resistance, IPC or Mil Spec testing

COMPOSITION

- One part
- Polydimethylsiloxane adhesive

One-part, translucent adhesive or coating with good flowability, good flame resistance, UL, IPC and Mil Spec tested

APPLICATIONS

Suitable for:

- Protection of corrosion-sensitive components.
- Protection of rigid and flexible circuit boards
- Improved pin/solder joint coverage
- Thin-section encapsulation.
- Pin sealing

TYPICAL PROPERTIES

Specification Writers: These values are not intended for use in preparing specifications. Please contact your local Dow Corning sales office or your Global Dow Corning Connection before writing specifications on this product.

Property	Unit	Result
One or Two-Part	-	One
Color	-	Clear to slightly hazy smooth viscous liquid
Viscosity	cP Pa-sec	34,400 34.4
Specific Gravity (Cured)	-	1.05
NVC (Non Volatile Content)	%	95.7
Tack-Free Time at 25°C	minutes	116
Tensile Strength	psi	434
Elongation	%	419
Durometer Shore A	-	31.6
Tensile Modulus	psi	103
Unprimed Adhesion – 180 Degree Peel Strength	ppi	40
Dielectric Strength	volts/mil kV/mm	385 15
Volume Resistivity	ohm*cm	2.1 x 10 (14)
Dielectric Constant at 100 Hz	-	2.52
Dielectric Constant at 100 kHz	-	2.52
Dissipation Factor at 100 Hz	-	0.004
Dissipation Factor at 100 kHz	-	0.001
Agency Listing	-	IPC-CC-830B, U: 746

PREPARING SURFACES

All surfaces should be thoroughly cleaned and/or degreased with *Dow Corning*® brand OS Fluids, naphtha, mineral spirits, methyl ethyl ketone (MEK) or other suitable solvent. Solvents such as acetone or isopropyl alcohol (IPA) do not tend to remove oils well, and any oils remaining on the surface may interfere with adhesion. Light surface abrasion is recommended whenever possible, because it promotes good cleaning and increases the surface area for bonding.

A final surface wipe with acetone or IPA is also useful. Some cleaning techniques may provide better results than others; users should determine the best techniques for their particular applications.

Industry Standards on Cleanliness

- *Section 8 – Cleaning Process Requirements*
  - It could be reasonably asked why an assembly should be concerned about the "cleanliness" of the manufactured electronic assemblies. The answer is that the quality and reliability of the hardware produced depends on knowledge of what residues are present and what impact those residues may have on electronics assemblies. The concept itself is not new:
    - A metal chassis with residual grease or oils will not have applied paint adhere to it.
    - A coating of dirt can interfere with transmission of data in electro-optic equipment.

- *Section 8 – Cleaning Process Requirements*
  - Ionic residues can result in corrosion, electrochemical migration, or electrical leakage under humid conditions.
  - Non-ionic residues, such as oils, can interfere with bonding operations such as adhesives or conformal coating.
  - Particulate residues, such as paper fibers, can absorb moisture in service, resulting in unintended electrical shorts.

IPC-HDBK-001E – Feb. 2012

Handbook and Guide to Supplement J-STD-001

PROTECTION FROM THE INSIDE OUT™

- In all practicality, it is impossible to remove all residues from an assembly.
- J-STD-001 does NOT require you to clean. Most often, the requirement to clean comes from the end item user or customer of the hardware.
- If an assembler desires to use a no-clean assembly process, it is usually prudent for the assembler to generate a materials and process compatibility study showing that the no-clean hardware meets all requirements in the uncleaned state.

IPC-HDBK-001E – Feb. 2012

8.0.4 – J-STD-001E Section 8 Demystified (What "no-clean" really means!)

- Next, let us address the issue of no-clean assembly processes. It could reasonably be argued that since a no-clean assembly is not required to be cleaned, none of Section 8 is applicable.
- However, in all practicality, most customers of no-clean hardware are (or should be) aware of the detrimental consequences of some residues.
- Even a no-clean assembly would require some form of chemical analysis/assay.
- Because a no-clean assembly process has no ability to address detrimental residues from bare board fabrication, component manufacture operations, or assembly process residues, it is critical for a no-clean assembler to understand the residues present on the manufactured assembly.
- A savvy assembler will have performed reliability studies identifying the residues present and their impact on reliability and have that information documented and on file for review.
- *A no-clean assembler is dependent upon clean materials from further up in their supply chain, when they're not cleaning and their flux residues have been proven to not be detrimental to reliability. - Sean*

- *Section 8 – Cleaning Process Requirements*
    - 8.1 – Cleanliness Exemptions
    - 8.2 – Ultrasonic Cleaning
    - 8.3 – Post-Solder Cleanliness
    - 8.3.1 – Foreign Object Debris (FOD)
    - 8.3.2 – Flux Residues and Other Ionic or Organic Contaminants
    - 8.3.3 – Post-Soldering Cleanliness Designator
    - 8.3.4 – Cleaning Option
    - 8.3.5 – Test for Cleanliness
    - 8.3.6 – Testing
    - 8.3.6.1 – Rosin Flux Residues
    - 8.3.6.2 – Ionic Residues (Instrument Method)
    - 8.3.6.3 – Ionic Residues (Manual Method)
    - 8.3.6.4 – Surface Insulation Resistance (SIR)
    - 8.3.6.5 – Other Contamination

IPC J-STD-001F – July 2014

Requirements for Soldered Electrical and Electronic Assemblies

- 8.3.6.2 – Ionic Residues (Instrument Method)
- 8.3.6.3 – Ionic Residues (Manual Method)

- There is a Pass/Fail limit for cleanliness for assemblies soldered with rosin-based fluxes (ROL0 or ROL1).
    - Less than 1.56 micrograms NaCl equivalent per cm^2
    - Less than 10.06 micrograms NaCl equivalent per in^2

- When another flux is used the limit is established by the Manufacturer or User and supported by historical data (indicating that the cleaning and testing processes are proven, well established, and in control), or by process qualification test data that are available for review.

- Always better to have as low a result as possible

- Section 3 – Handling Electronic Assemblies
  - Protecting the Assembly – EOS/ESD and Other Handling Considerations
    - 3.3 – Handling Considerations
      - 3.3.1 – Handling Considerations – Guidelines

Avoid contaminating solderable surfaces prior to soldering. Whatever comes in contact with these surfaces must be clean. When boards are removed from their protective wrappings, handle them with great care. Touch only the edges away from any edge connector tabs. Where a firm grip on the board is required due to any mechanical assembly procedure, gloves meeting EOS/ESD requirements may be required. These principles are especially critical when no-clean processes are employed.

Care must be taken during assembly and acceptability inspections to ensure product integrity at all times. Table 3-4 provides general guidance.

Table 3-4 Recommended Practices for Handling Electronic Assemblies

1. Keep workstations clean and neat. There must not be any eating, drinking, or use of tobacco products in the work area.
2. Minimize the handling of electronic assemblies and components to prevent damage.
3. When gloves are used, change as frequently as necessary to prevent contamination from dirty gloves.
4. Do not handle solderable surfaces with bare hands or fingers. Body oils and salts reduce solderability, promote corrosion and dendritic growth. They can also cause poor adhesion of subsequent coatings or encapsulates.
5. Do not use hand creams or lotions containing silicone since they can cause solderability and conformal coating adhesion problems.
6. Never stack electronic assemblies or physical damage may occur. Special racks may be provided in assembly areas for temporary storage.
7. Always assume the items are ESDS (Electrostatic Discharge Sensitive) even if they are not marked.
8. Personnel must be trained and follow appropriate ESD practices and procedures.
9. Never transport ESDS devices unless proper packaging is applied.

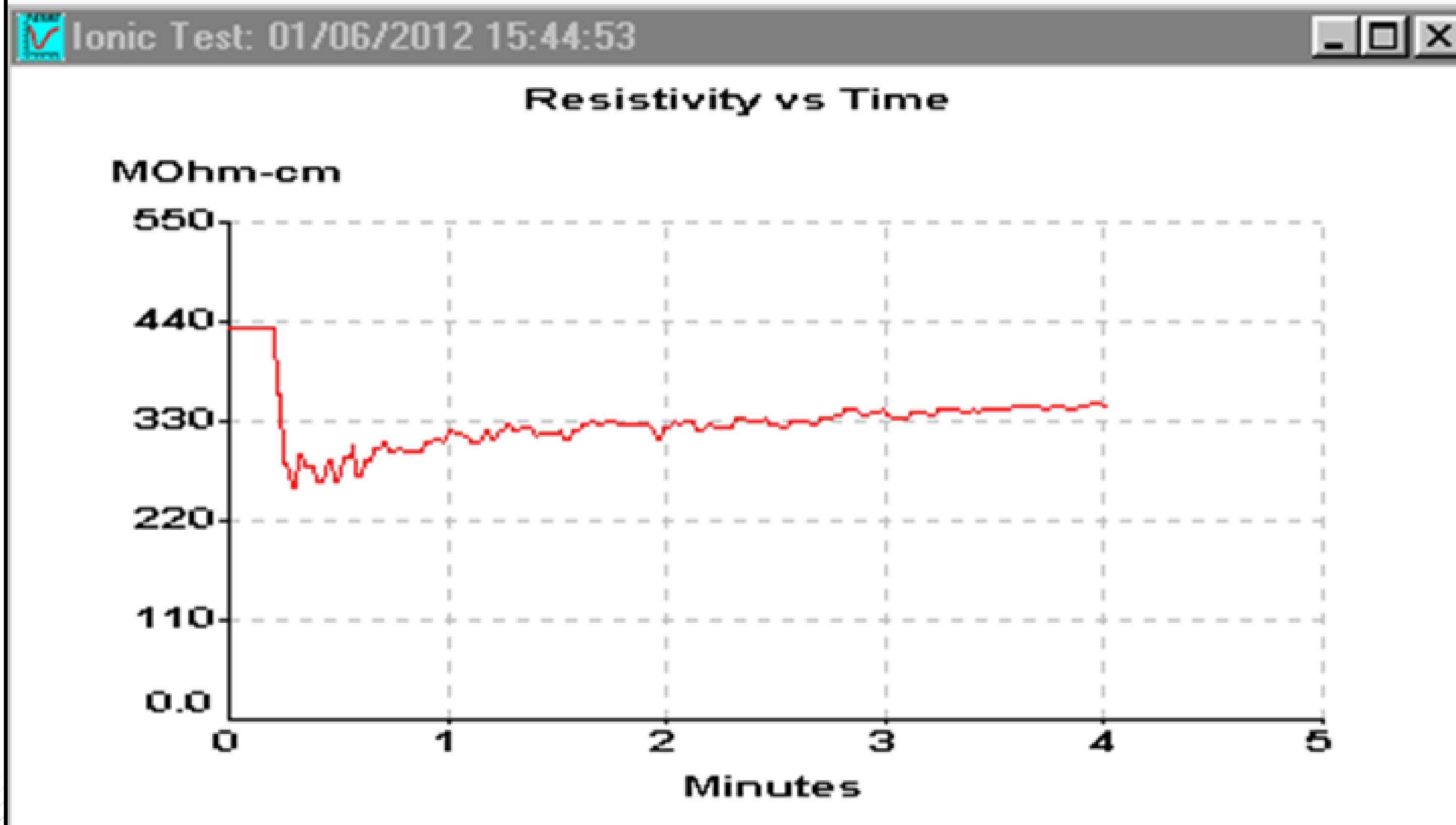
Cleanliness Test Methods

Resistivity of Solvent Extract (ROSE)

Ionograph System (Alpha Metals, Purchased by SCS); solution resistance change over time

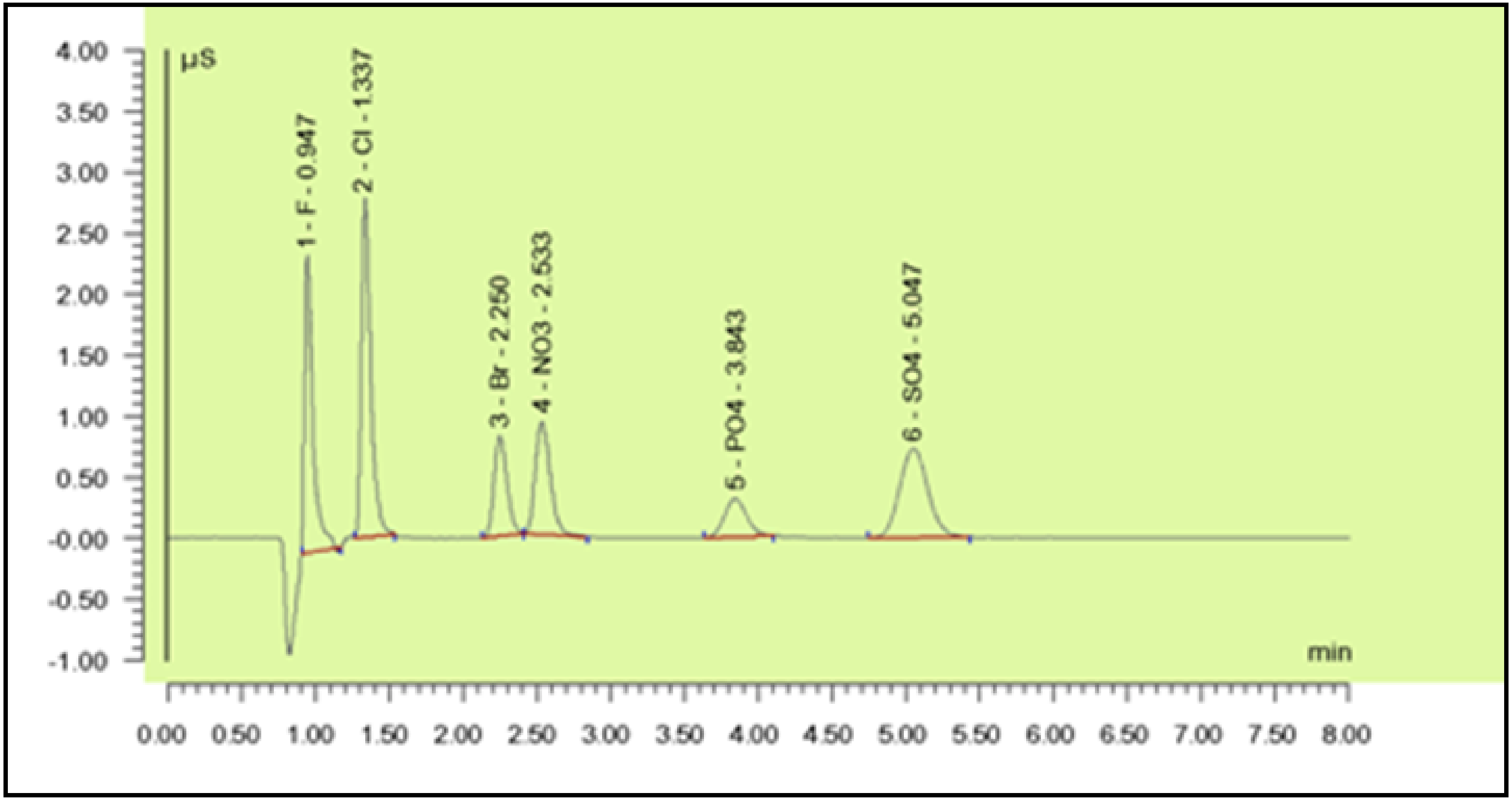
PROTECTION FROM THE INSIDE OUT™

Lot no.:		Current result:	5.32 µg NaCl/sq
Description:	Ionic Test: 01/06/2012 15:44:53	Fail Point:	N/A
Time:	16:06:28	Pass/Fail:	Pass
Date:	06 Jan 2012	Elapsed time:	00:04:02



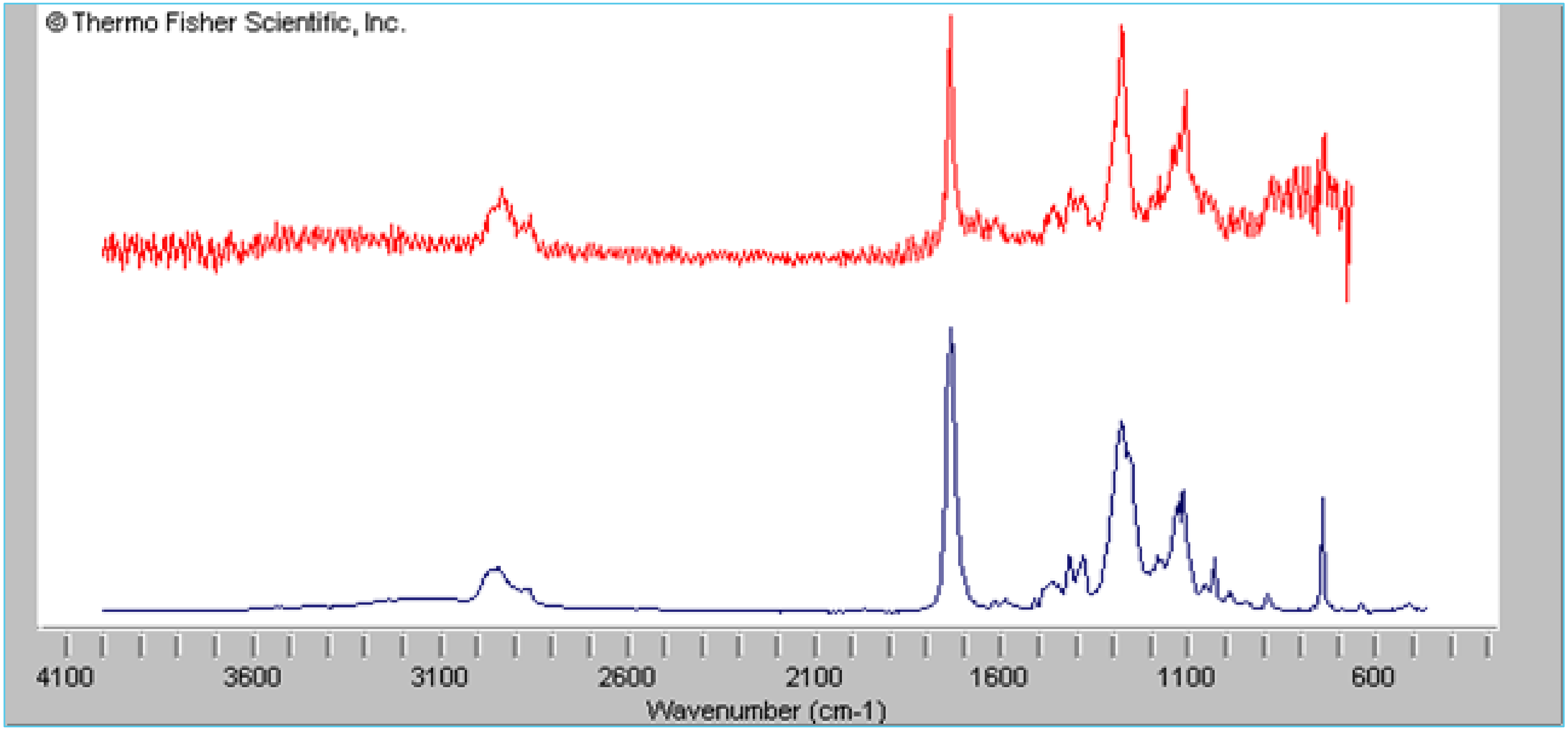
Ion Chromatography

Anions shown below, can also check for cations and weak organic acids (WOAs) in extract



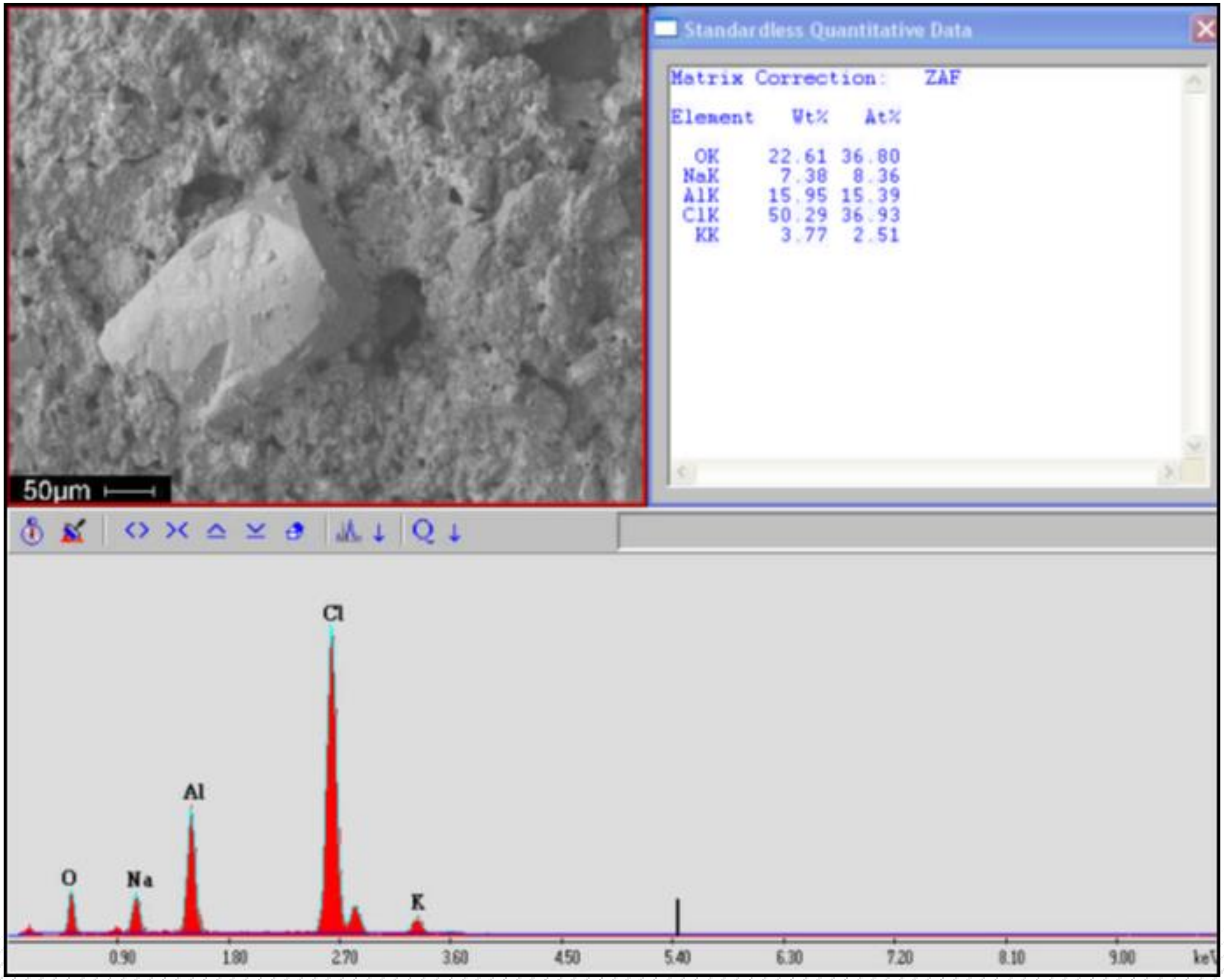
FTIR Spectroscopy

Identify pure organic compounds and less complex mixtures



SEM-EDS

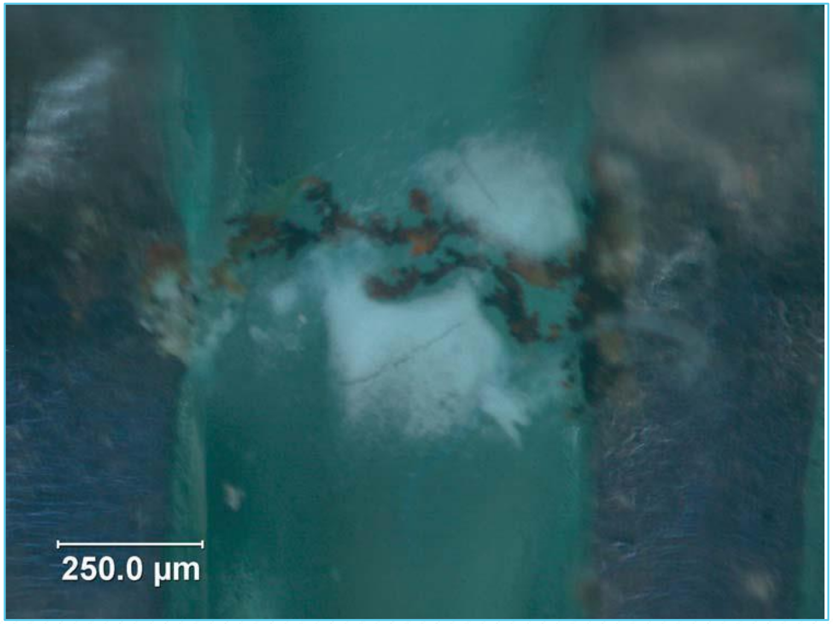
Imaging and elemental characterization

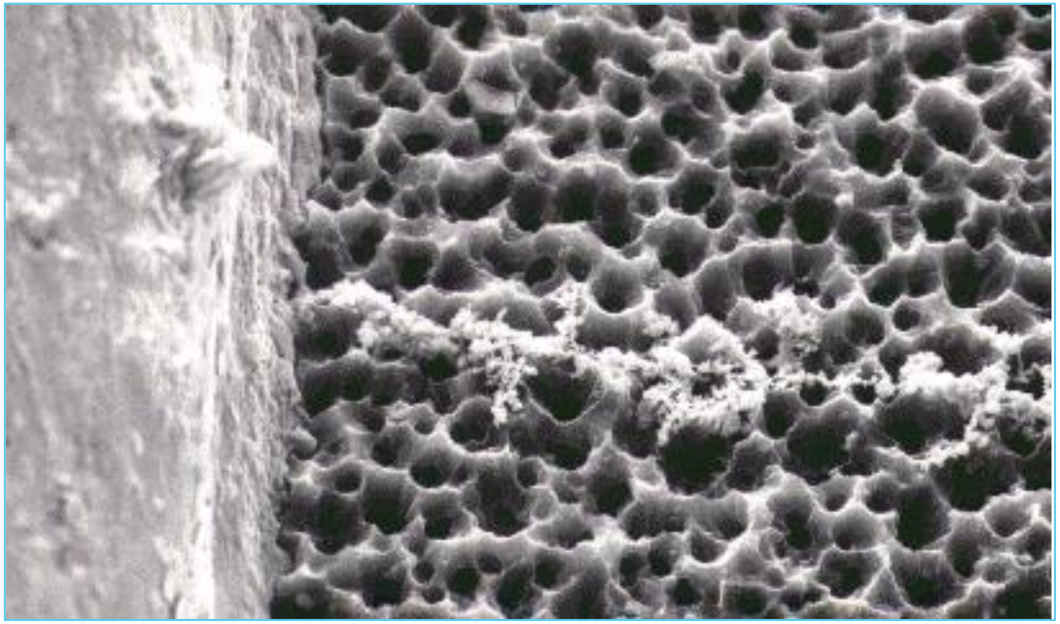


Dendrites

Dendrites

- Dendrites, also known as electrolytic metal migration, grow in the presence of free (mobile) ions, moisture, and an electrical bias
- All of the above must be present to produce dendrites
- Below are a couple example images of dendrites





Prevention of dendrites

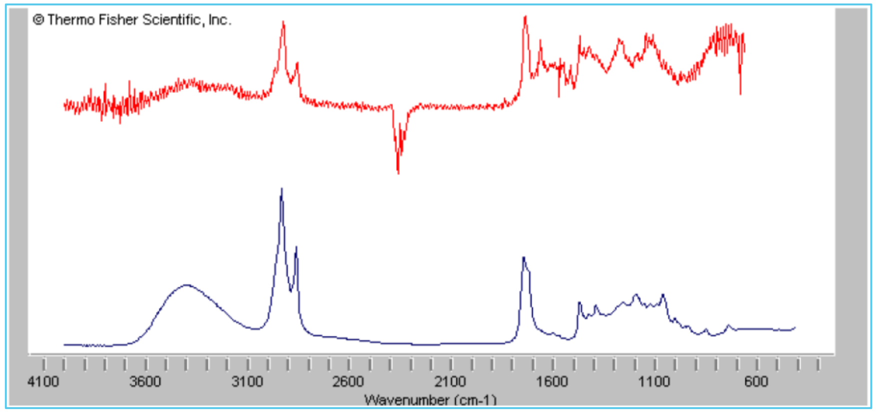
- Dendrites can be mitigated by removing or preventing any of the following from being present: free (mobile) ions, moisture, and an electrical bias
- Removal of ions is performed by cleaning the substrate, board, or assembly after soldering to remove flux and handling residues
- Removal of moisture is performed by keeping the assembly away from water and/or by protecting it with a conformal coating
- Removal of electrical bias is performed by disconnecting power by turning the assembly off and/or removing the battery.
- Removing any one of the three is sufficient to prevent dendrites from forming

FA Case Study 1

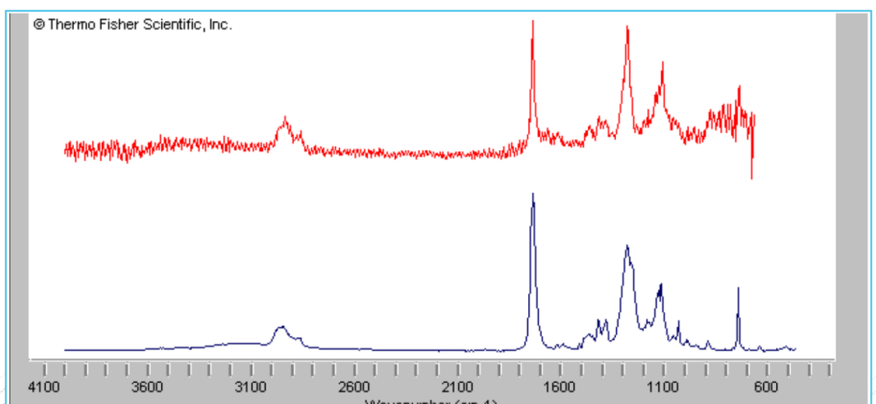
FA CS 1 – Contamination affecting adhesion

European defense contractor had adhesion issues with Parylene C

- Plasticizer, propylene glycol monooleate was found on one board.



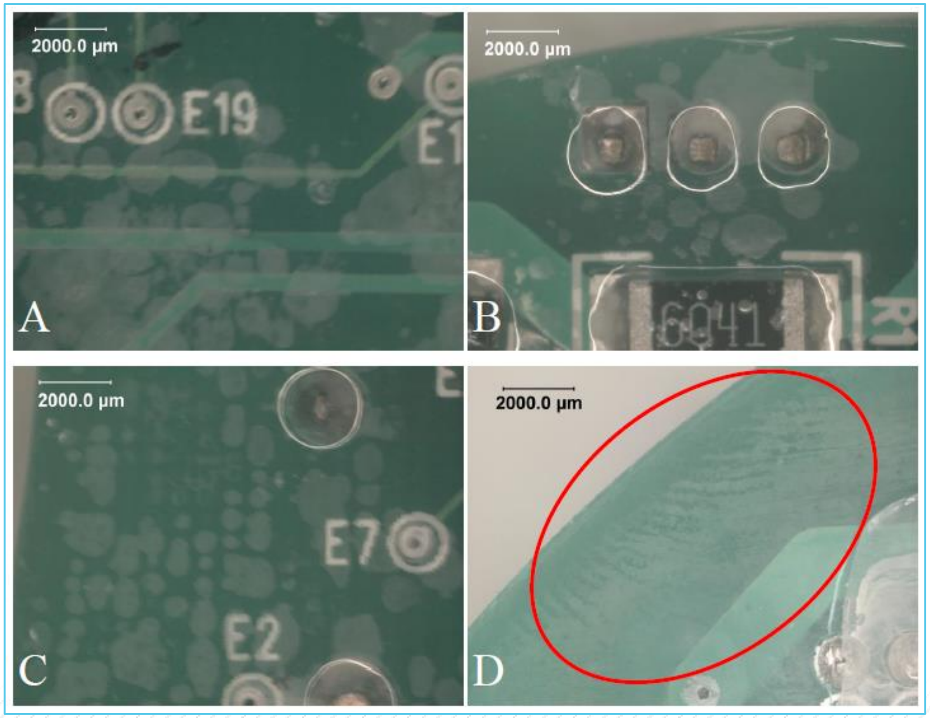
- Polyester resin was found on another board, both inhibiting Parylene C adhesion.

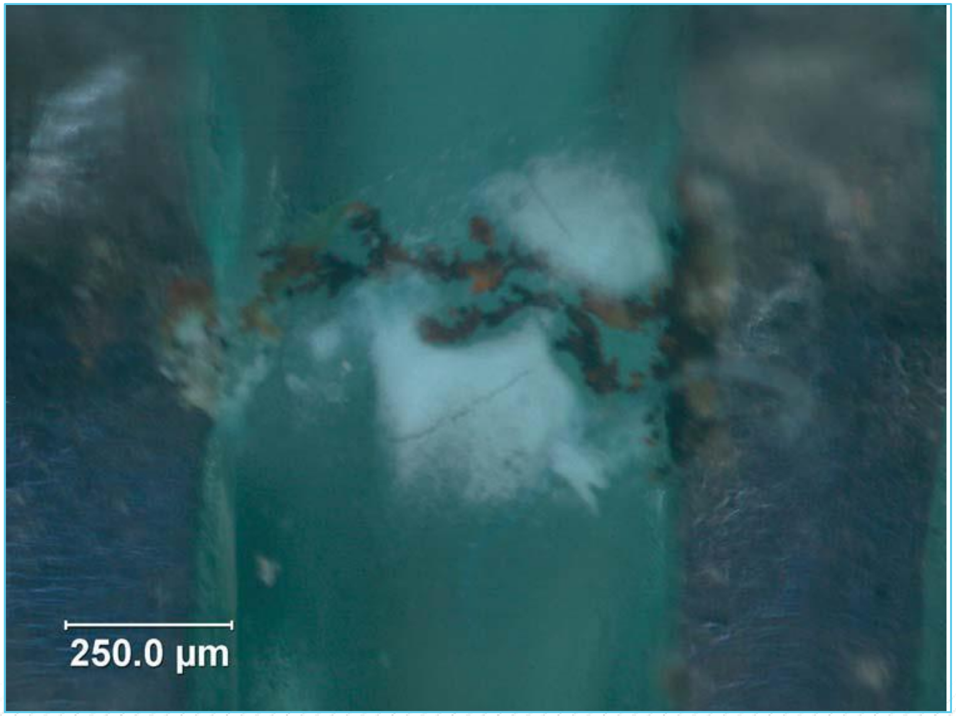


FA Case Study 2

FA CS 2 – Contamination affecting adhesion, incomplete coverage, & harsh environment

- Sensor module system that failed on an oil rig.
- Conformal coating delaminating from assembly.
- Partial fingerprint (potential source of oils) found.
- Incomplete coverage in ocean environment lead to dendrites.





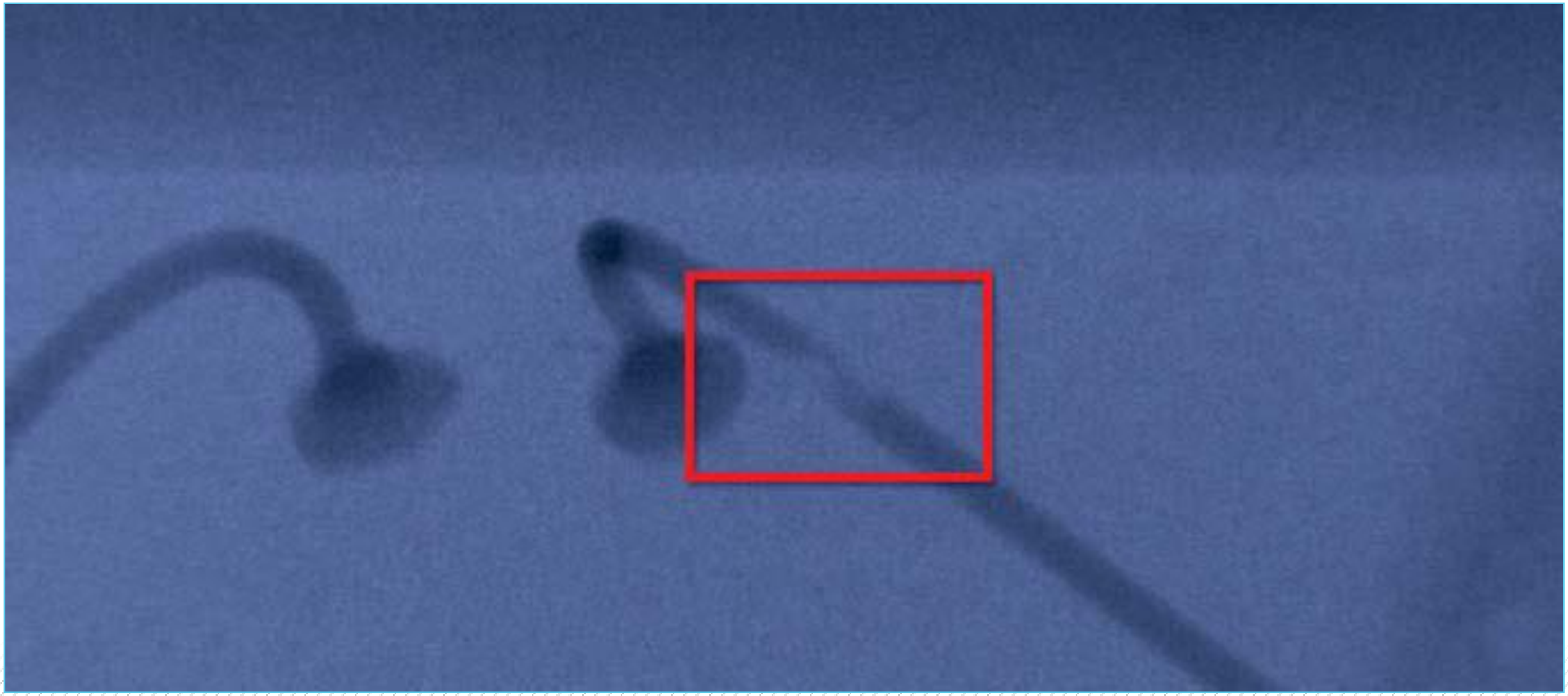
FA Case Study 3

FA CS 5 – Chloride sensitive component on an assembly washed with tap water

- A major, multinational corporation with a medical device division, had a contract manufacturer who did clean the assemblies after reflow / soldering, but used tap water.
- The contract manufacturer said: "We've always done it this way and never had a problem before!"
- Washing with tap water is not a standard industry practice.
- The composition of the tap water is extremely variable and dependent on the municipal water utility provider, the quality of the pipes from the water treatment plant through the city, building, and equipment.
- If there's ever a question of biological contamination or contagion, the municipal water provider many times dumps large quantities of concentrated bleach into the system, and most of the time, without notice.
- It just so happened that the medical device manufacturer had optoisolator components on the assembly that were very sensitive to chloride ions.

FA CS 5 – Chloride sensitive component on an assembly washed with tap water

- Chloride from the tap water leached in the package of the component and corroded a wire bond, damaging the assembly.
- The assembly was fine under visual inspection, but the damage was observed under X-ray imaging.



Cleaning Methods and Effectiveness

Cleaning Methods

- Warm deionized (DI) water
- Semi-aqueous wash with cleaning chemistry (saponifiers, surfactants, etc.), followed by a clean DI water rinse
  - Batch
  - Inline
  - Ultrasonic agitation
- Vapor degreaser
  - Vapor-phase soldering
- Aerosols defluxers
- Isopropanol (IPA) swabs

Types of Substrate Materials

Substrate Materials

- Electronic components – generally robust against all cleaning methods, but items likes MEMS, displays, and optical components can be sensitive
- Solder Mask – very robust, can be discolored by plasma. A known point of contamination and delamination concerns if it is not cured correctly or is too low in surface energy.
- Other Conformal Coatings – Many conformal coatings are very low surface energy. Others can inhibit cure on other coatings (silicones and acrylics, for instance).
- Solder Joints – Combined with the standoff gap of chips and components, these are areas most likely to hold contaminants both before cleaning (flux) and after (the detergent or solvent)
- Other Metallic Surfaces – copper and silver can be discolored by aqueous / acidic / basic solutions in cleaning environment or oxygen in the plasma.

Surface Modification Methods

Surface Modification

Physical

Physical

Why do it? – It gives conformal coatings physical roughness to latch onto. This is particularly important with conformal coatings that do not chemically adhere to most surfaces (such as parylene).

- Abrading surface – Brushing, blasting, sanding – these are macroscopic effects
- Plasma roughing – bombardment by active Argon atoms causes roughening at the molecular level

Surface Modification

Chemical

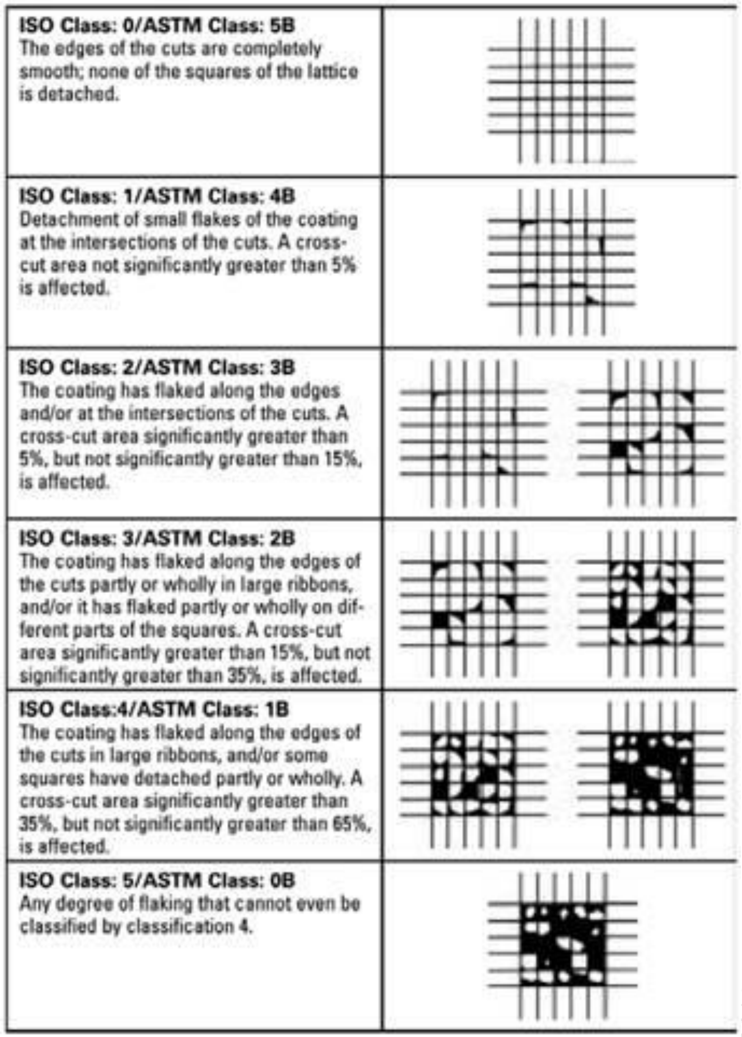
Chemical

Why do it? – It gives conformal coatings a chemically attractive surface on which to bond. Chemical bonds are far stronger than most physical bonds.

- Plasma – Gas determines function – Oxygen gives O-, Water gives –OH, fluorinated gives hydrophobic, etc. Generally very uniform coverage.
- Primer – Accelerates curing reactions in materials requiring chemical reactions to achieve adhesion, e.g. epoxy or silicone. Speeds time and effectiveness of “full adhesion” development. Full coverage not as important.
- Adhesion Promoter – Many chemistries available. For parylenes, generally a variation of silanes functionalized to bridge substrates and parylenes. Precise application (1-10 monolayers) can be difficult to achieve.

Experiments Performed by HZO

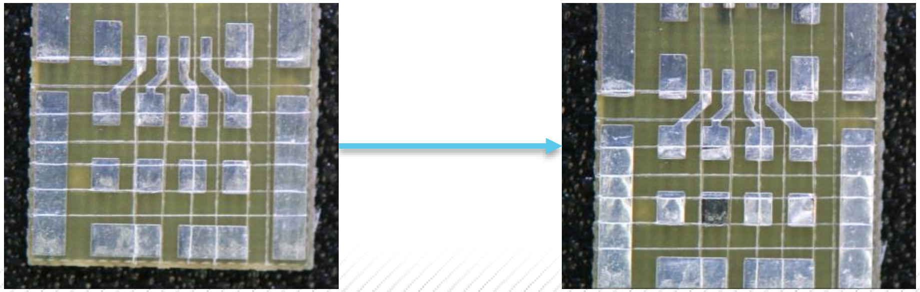
Cleaning and Adhesion Testing



ASTM D3359 comparison chart

Illustrates cross-hatch cut pattern and resulting tape peel-off delamination.

- Coated boards were cross-hatch cut with a razor blade and guide.
- Tape was placed by hand and removed.
- Images were taken by CCD microscope before tape application and after tape removal.
- Images were compared to the guide at left to categorize extent of delamination.



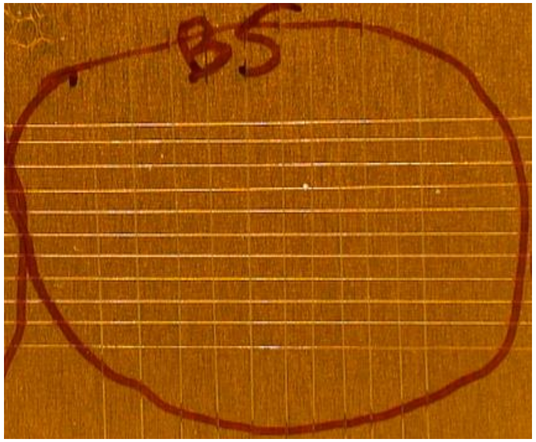
Traditional Cleaning

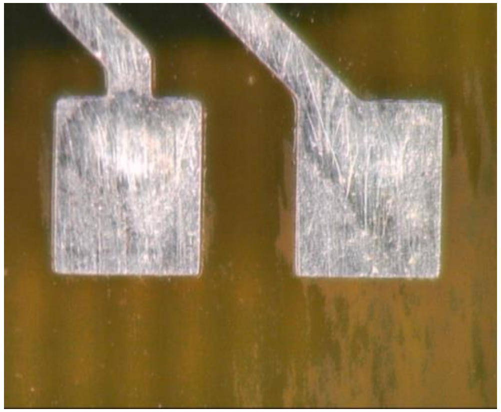
- Ultrasonic cleaning with de-fluxing detergent
- Effectively recovered adhesion results after contamination with flux

Classification	% of Area Removed	Surface of Cross-cut Area From Which Flaking has Occured for 6 Parrallel Cuts & Adhesion range by %	As Received	Flux Applied	Fluxed & Ultrasonic
5B	0% None		4 (27%)	-	3 (20%)
4B	Less than 5%		7 (46%)	-	8 (53%)
3B	5 - 15%		4 (27%)	-	4 (27%)
2B	15 - 35%		-	-	-
1B	35 - 65%		-	-	-
0B	Greater than 65%		-	14 (100%)	-

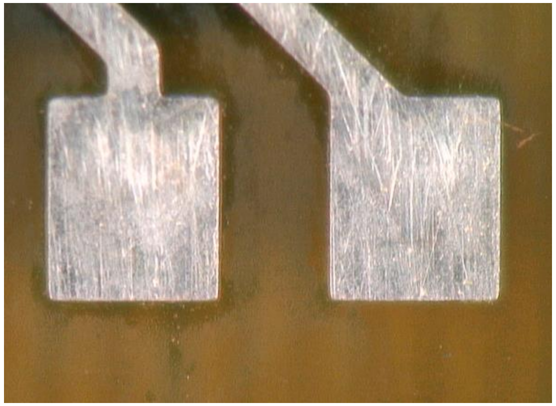
Plasma Cleaning and Activation

- Plasma effectively removes organic residues – synthetic grease visibly reduced in as little as 10 minutes.
- Plasma had VERY LITTLE impact on flux residues – contamination still visible even after 30 minutes.
- Plasma greatly improved adhesion on low surface energy substrates such as polyimide

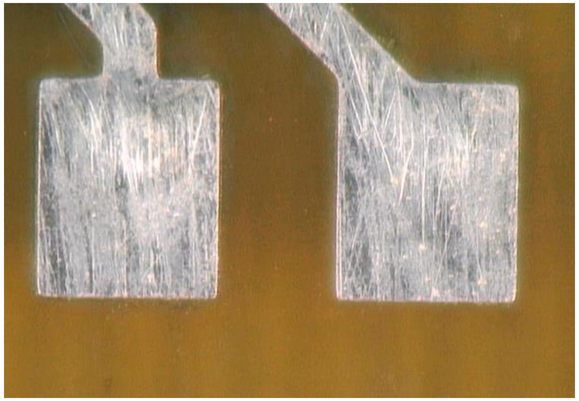




No exposure



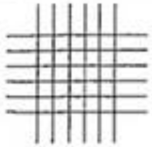
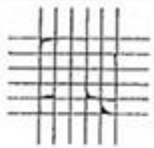
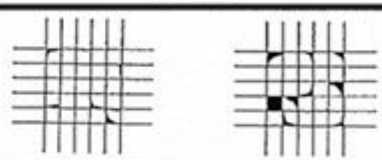
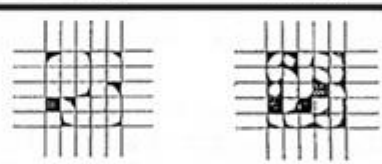
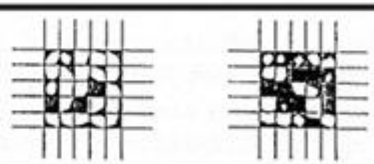
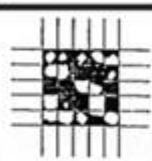
5 minutes

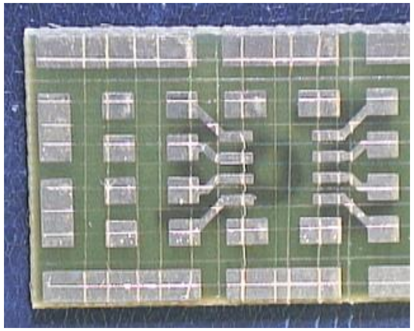


15 minutes total

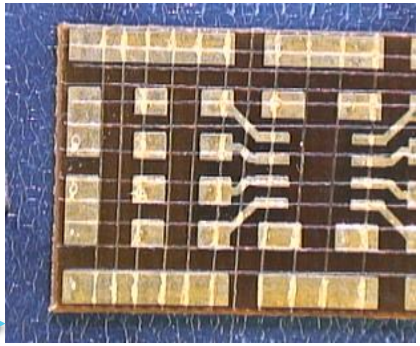
Results - Explanation

(average representations only)

Classification	% of Area Removed	Surface of Cross-cut Area From Which Flaking has Occured for 6 Parrallel Cuts & Adhesion range by %
5B	0% None	
4B	Less than 5%	
3B	5 - 15%	
2B	15 - 35%	
1B	35 - 65%	
0B	Greater than 65%	

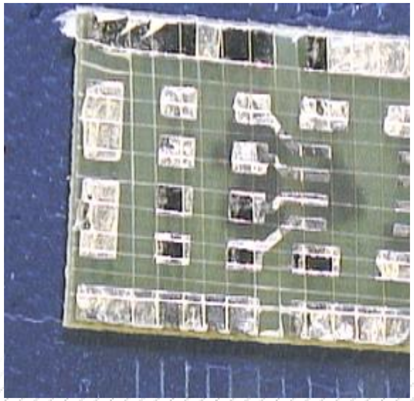


Plasma cleaned + Promoter

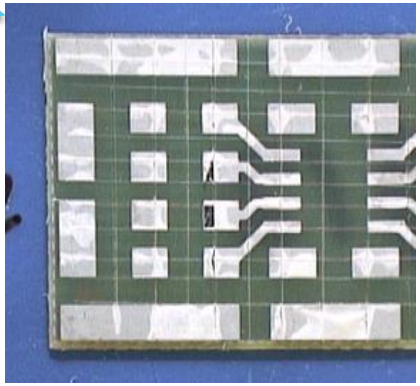


Very dirty board with Plasma cleaning

Adhesion promoter on as received boards



As received boards



Surface Preparation and Conformal Coatings at IPC APEX 2016

PD06
Robust Coating Processes In The Factory: Methods, Critical Parameters, Problems and Remedies

Douglas Pauls
Rockwell Collins

Sunday, March 13
2:00 pm - 5:00 pm
Room: S224

Doug Pauls, Rockwell Collins

PROTECTION FROM THE INSIDE OUT™

APEX EXPO IPC 2016

Invisible Problems

FORWARD THINKING

- Items that can compromise coating adhesion or coating wetting
  - Component Cleanliness
    - Mold release agents, transferred contaminants, plating residues
    - Can be addressed with localized cleaning (may need special solvents), or plasma pre-treat or mild abrasive blasting (ESD-safe)
    - Slick shiny surfaces are often a challenge for coating adhesion
    - Beware of topical antistatic materials on DIP tubes and feeder trays
  - Bare Board Cleanliness
    - General Cleanliness – IPC-5704
    - **Surface Energy of Solder Masks**
    - **Cure of Solder Masks**
  - Packaging Residues – Can usually be addressed with standard cleaning
    - Bags, boxes, salt air from shipping
    - Contact with shipping films
    - Refer to IPC-1601 on shipping practices

Doug Pauls, Rockwell Collins

APEX EXPO IPC 2016

Dyne Pens – Test for Surface Energy

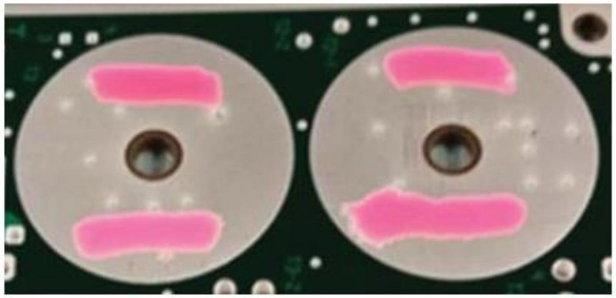
FORWARD THINKING FOR TOMORROW'S TECHNOLOGY

Result (dynes/cm)	Effect
< 30	Good Luck. Coating adhesion poor in any climatic testing
30-35	Adhesion generally poorer, with increasing incidence of delamination under severe conditions
35-40	Adhesion generally good, with some intermittent delamination under severe conditions
> 40	Adhesion expected to be good
> 45	Excellent

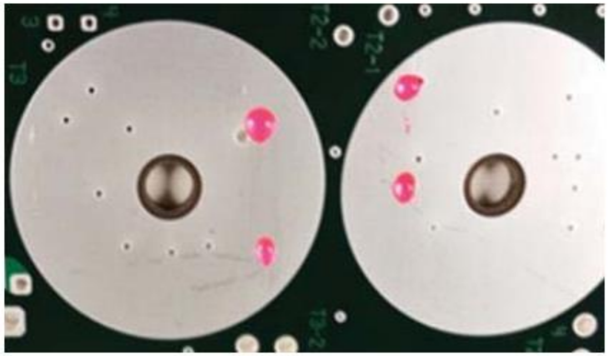
More information in ASTM-D-2578
Several good videos on YouTube

Doug Pauls, Rockwell Collins

Surface Energy Example



Good



Bad

Doug Pauls, Rockwell Collins

PROTECTION FROM THE INSIDE OUT™

APEX EXPO IPC 2016

PWB Solder Mask Cure Issues

FORWARD THINKING FOR TOMORROW'S TECHNOLOGY

- Most solder masks are UV cured followed by a thermal bake (bump)
  - If the fabricator does not monitor UV bulb strength, the mask does not cure properly and will absorb process chemicals which standard ionic cleanliness testers will not detect.
  - If this happens, there is really no practical way to recover. Scrap the boards.
- Do you have an issue?
  - Unheated Control
    - Virgin bare board and coat/cure the board. Does it coat well? Any dewetting?
  - Heated Control: take a bare board, run through 1-2 reflow passes with no cleaning and no exposure to fluxes/pastes.
    - Coat/Cure the board. Any differences in coating quality?
      - Bubbles, dewetting are indications of a solder mask problem.

Doug Pauls, Rockwell Collins

APEX EXPO IPC 2016

Surface Preparation

FORWARD THINKING

- What is desired is a **clean, dry** surface, free from materials, or surface conditions which may interfere with coating application, cure, or adhesion
  - For no-clean assemblies, you want the flux residues to be stable and set
- 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 (mold release, silicones, oils, adhesive cure by-products)
- Dry
  - Useful to use compressed ionized air to remove bulk water from under parts and entrapment areas
  - Does not have to be "bone-dry" unless the coating requires it, but it is best to err on the side of being too dry. If using unsealed parts, may want to bake out the cleaning agents
- Undesirable Surface Conditions
  - Low surface energy on bonding surfaces (e.g. Teflon sleeving)
  - Mold release agents in parts (often Teflon or silicone based)
  - Effects on the solder mask from excessive reflow processes (Sn-Pb, LF)

25

Doug Pauls, Rockwell Collins

APEX EXPO IPC 2016

Handling Considerations

FORWARD THINKING

- Handling and Transportation Residues
  - Fixtures – do they accumulate residues and how often cleaned?
  - Workstation Surfaces – how often cleaned, and with what
  - Gloves – often give a false sense of security
  - Operational procedures
  - "Personal" Residues: finger salts and oils, hairs, hand creams, FOD
    - An Investigation Into Hand Sanitizers and Hand Lotions and Potential Risks to High Performance Electronics – Apex 2009
  - Factory FOD
- If you don't remove the residues before coating, you can't after coating

27

Doug Pauls, Rockwell Collins

PROTECTION FROM THE INSIDE OUT™

APEX EXPO IPC 2016

Dewetting

FORWARD THINKING

- 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
  - Residues from upstream masking materials (tapes, peelable masks, temp solder masks)
- Outgassing / Oozing from entrapped liquids
- 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

78

Other Weird Stuff You Don't Find in Data Sheets

- Cure Inhibition
  - For any kind of coating that involves a chemical reaction as part of the cure process – existing residues on the board can poison that reaction
- Incompatibilities
  - What is the effect of the carrier solvent on components?
- No Clean Fluxes
  - The ability of a coating to bond to low solids flux residues depends on a number of factors:
    - The nature of the residue – hard or soft
    - Whether or not there is a detrimental interaction with the carrier solvents
    - Will the flux residue inhibit coating cure
- Some coatings may require a primer for adhesion
  - Parylenes and some silicones
  - How soon after cure does ESS/HASS occur?

PD14
Cleaning For Reliability: How Clean is Clean?

Mike Bixenman
Kyzen Corporation

Monday, March 14
9:00 am - 12:00 pm
Room: S227

Mike Bixenman, Kyzen Corporation

No-Clean Risks

- Many believe that
  - No-clean flux can be used in any manner and still be safe and reliable
- Contrary to this myth
  - No-clean flux, when used improperly, can lead to electrochemical migration and dendritic growth
  - Leads to electrical fails
- The important question
  - What is the proper use of no-clean flux?

Munson & Isaacs (2016). SMTA Pan Pac

Mike Bixenman, Kyzen Corporation

No Clean Flux Activation

- Is an activated No-Clean Flux benign?
  - Oxide removal occurs at low temperature
  - To render flux benign, higher temperature is needed
  - On highly dense boards, residues under bottom terminations may not reach the heat levels required to render the residue benign
  - To reach a benign state
    - Flux requires enough heat to cause residues to volatize the carrier and change the dicarboxylic acids to a clear glassy residue that is not mobile

Munson & Isaacs (2016). SMTA Pan Pac

Mike Bixenman, Kyzen Corporation

Fluxing Action

- During pre-heat
  - Flux solvents and moisture evaporate
- As temperature rises near liquidus
  - Activators remove oxide layers
  - Flux redox reactions takes place
- Bottom Termination Risks
  - Activators will
    - Partially outgas
    - Not reduce into a benign residue that is encapsulated it the resin layer
      - Metal/metal salts
      - Fluxing by-products
      - When mobilized, these species are conductive
  - With proper heat exposure, active residues will be encapsulated and non-active

Munson & Isaacs (2016). SMTA Pan Pac

Mike Bixenman, Kyzen Corporation

No Clean Flux Failures

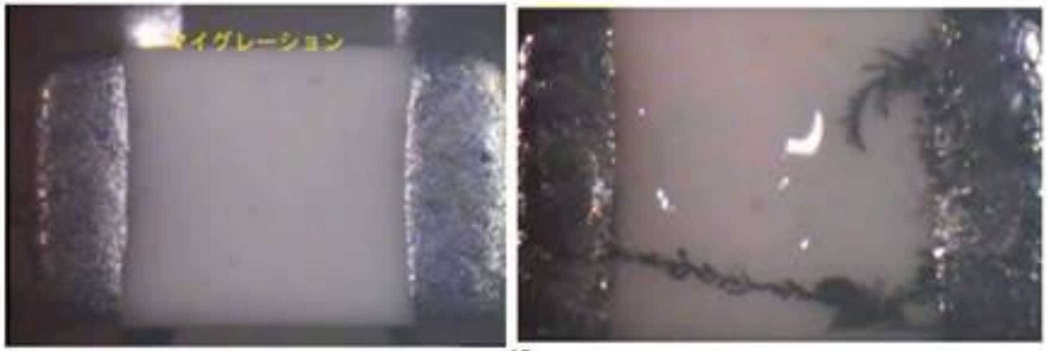
- Bottom Terminated Components
  - Planar board surfaces
  - When the Z-Axis if low (1-4 mils)
    - Channels for outgassing get blocked
    - Flux accumulates under the bottom termination
    - Flux can be wet and pliable
    - Moisture will mobilize stray ions
    - When biased, the ions will migrate
      - Resistance drops
      - Leakage starts
      - Over time, dendrites will bridge conductors and short the part

Munson & Isaacs (2016). SMTA Pan Pac

PROTECTION FROM THE INSIDE OUT™

Leakage Currents

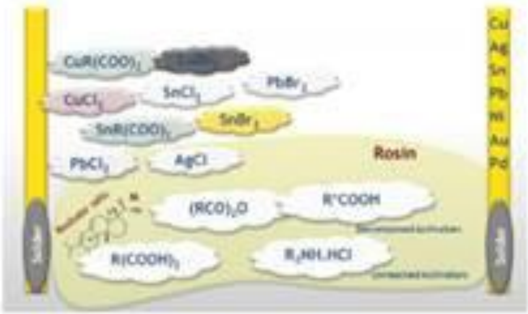
- Entrapped flux volatiles may not be
  - Not totally reacted
  - Active flux under the component
  - Increases the potential for ECM



19

Flux Redox Reaction

- Remaining residue
  - Excess flux, adipic acid and other flux by-products
  - Copper adipate
  - Copper oxide
  - Tin oxide
  - Copper / Tin
  - And, with halide activator
    - Di-ethyl-ammonium chloride
    - HCL
    - Diethyl ammonia
- What makes flux benign?



Tolla, B. (2015). Reactivity of No Clean Flux Residues. SMTAI

No-Clean Flux Summary and Challenges

- Numerous process steps
- Manner in which flux is used may or may not render a benign state
  - SMT Paste / Reflow
  - Wave
  - Selective wave
  - Robotic soldering
  - Hand repair soldering
  - Plated Through Hole mini-wave
  - Jumper wire
  - Handling

Mike Bixenman, Kyzen Corporation

Chemical Contaminants

- When ions are mobilized
  - The corrosion process is initiated
    - Oxidation and reduction of metal ions
    - When biased, mobilized metal ions migrate
    - Metallic fragments plate out until a dead short occurs
- Contamination Sources
  - Components
  - Printed Circuit Boards
  - Flux residues
  - Material handling
  - Upstream / Downstream
  - Touch up and Repair
  - Environmental conditions

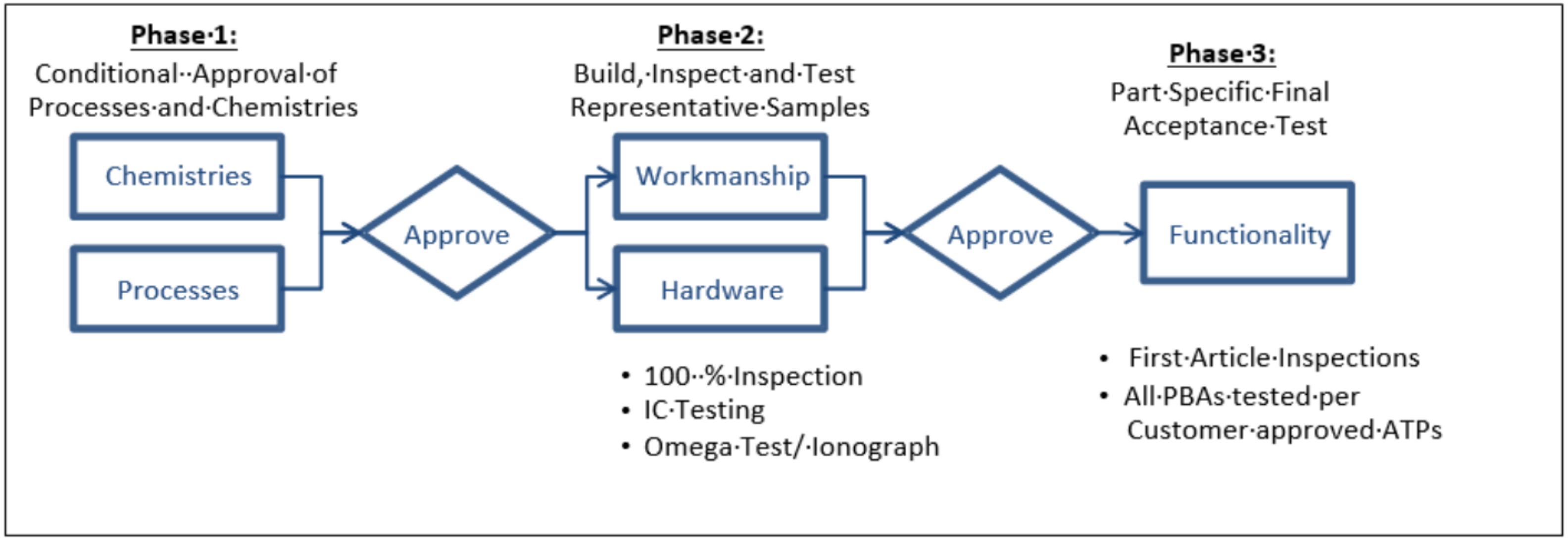
FORWARD THINKING

Cleaning Process Verification and Validation

- Is a new assembly or process as good or better than the qualified assembly process?
  - Many factors impact the decision
- No single method for validating a new process
- The testing depends on
  - Product being produced
  - The consequences of failure
  - The end-use customer

Three Phase Approach

- Process Validation for Cleanliness



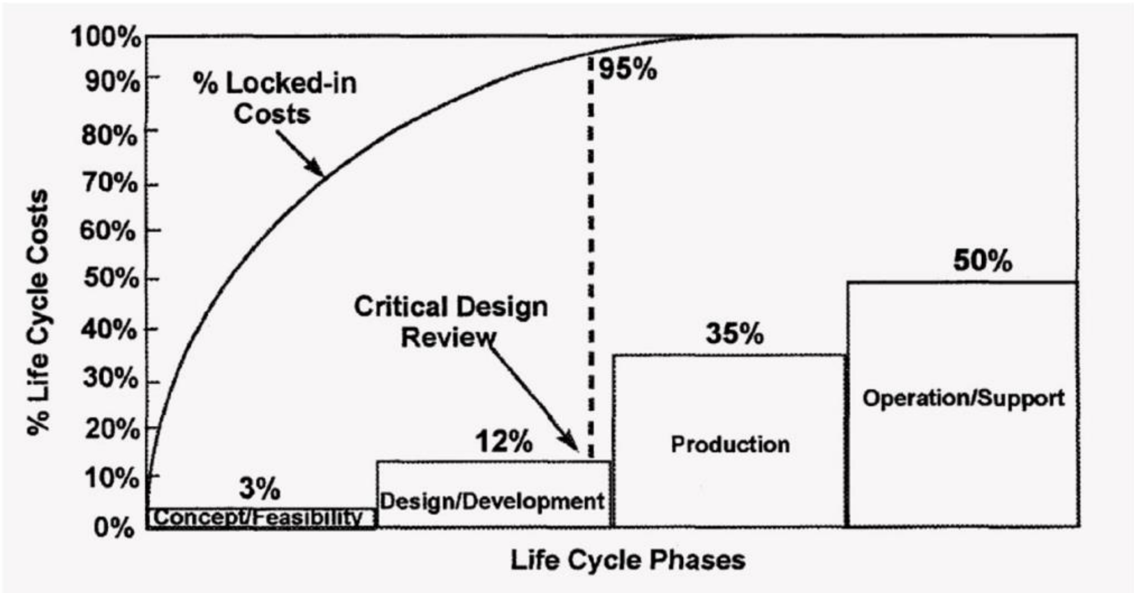
Process Qualification

- Costly
- Time consuming
- Unknowns
  - Cleaning performance under bottom terminations
  - Cleaning performance over time
  - Complexity of the product being cleaned
  - Reflow conditions
  - Material compatibility effects
  - Risk factors are not trivial

HZO
PROTECTION FROM THE INSIDE OUT™

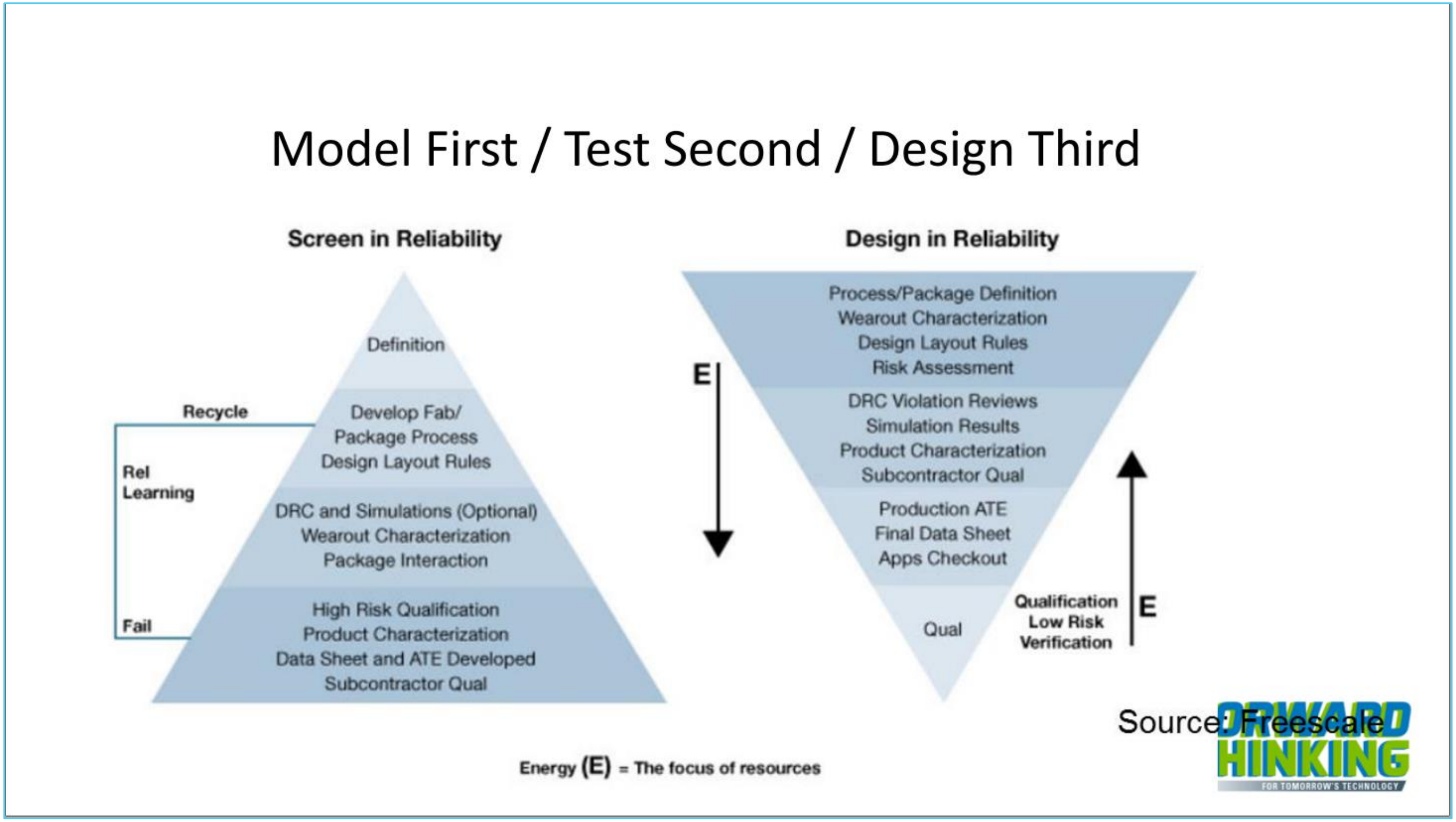
Design for Cleaning

- Model / Test / Design
- Section IV provides some insights that open the process window



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

Mike Bixenman, Kyzen Corporation



Other Items of Interest from IPC APEX 2016

Solder Mask Task Group, SM-840

- Rockwell Collins has specified the surface energy of all products to at least be 40 dyn/cm^2 and that has helped them greatly

- Continental specifies a surface energy after two passes through a lead-free reflow profile as a baseline value
  - Just temperature part of the reflow process, not talking about adding flux
  - Starts above 40, some drop below 30, some stay above 30
  - Just pass through reflow oven
  - Solder mask hardens and becomes more like glass
  - Degree of cure is important

- Per Doug Pauls, thermal cycling is a better test of adhesion than the cross-hatch test

- Strong interest in specifying surface energy ranges in next revision of SM-840

Other Items of Interest from IPC APEX 2016

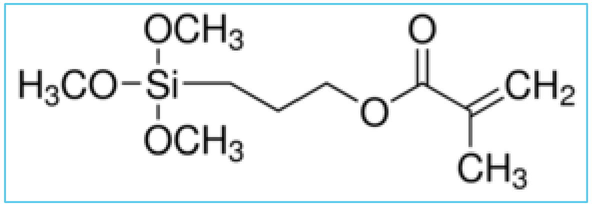
Buzz Session 1 – Conformal Coatings

- Moisture and Insulation Resistance (MIR) – Conformal Coating (IPC TM-650 2.6.3.4A) and Hydrolytic Stability – Conformal Coating (IPC TM-650 2.6.11.1) are used to test for compatibility of low residue no clean fluxes with conformal coatings
- Use ESD deionizers when unrolling tapes
- Stay away from masking tapes with silicone adhesives
- Need to consider the cost of coating and process vs. the products end use environment and cost of failure

Useful Resources

Adhesion Promotion

- The typical adhesion promoter used with parylene is Silane A-174, a.k.a. 3-(trimethoxysilyl)propyl methacrylate.



Useful Resources

- CALCE, Center for Advanced Life Cycle Engineering, at the University of Maryland
  - http://www.calce.umd.edu/
- CAVE3 at Auburn University, NSF Center for Advanced Vehicle and Extreme Environment Electronics
  - http://cave.auburn.edu/
- DfR Solutions
  - http://www.dfrsolutions.com/resource-center/
- Foresite, Inc.
  - http://foresiteinc.com/resources/article-and-case-study-archive/
- IPC TM-650 Test Methods Manual
  - http://www.ipc.org/test-methods.aspx
- NTS Resource Center
  - https://www.nts.com/resourcecenter

Any Questions?