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reliability designed, reliability delivered

Contamination and Cleanliness

Developing Practical Responses to a Challenging Problem

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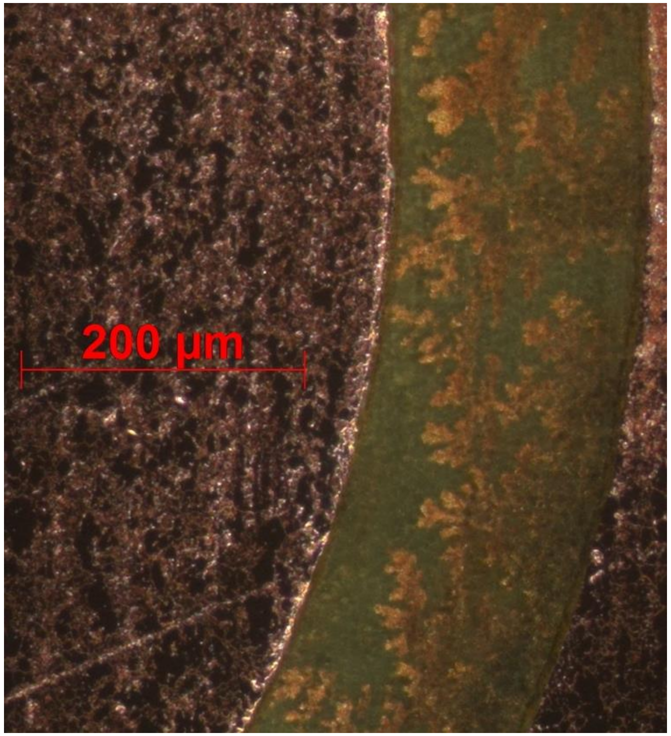
DfR Solutions Open House

March 9, 2016

Why Discuss Contamination and Cleanliness?

- Believed to be one of the primary drivers of field issues in electronics today
  - Corrosion
  - Electrochemical Migration (ECM)
  - Especially in the automotive industry



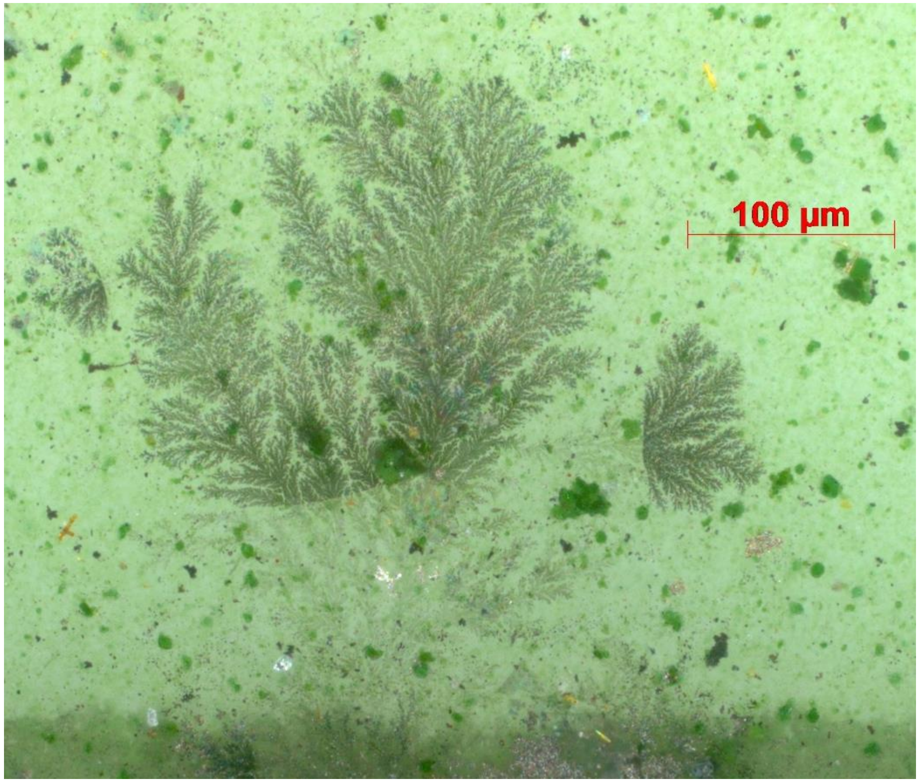
Dendrites growing between PCB layers, connecting annular ring to plane

- Intermittent failures result in no fault found (NFF) returns
  - Self-healing behavior
  - Difficult to find root cause

Why Continue to Discuss Contamination and Cleanliness?

- Pervasive issue across many diverse technologies
  - PCBs and PCBAs
  - LCDs
  - Switches
  - Wiring
  - Just to name a few!

- It may get worse in the future



Silver dendrites on a shorted thick film sensor

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Contamination and Cleanliness in the Future

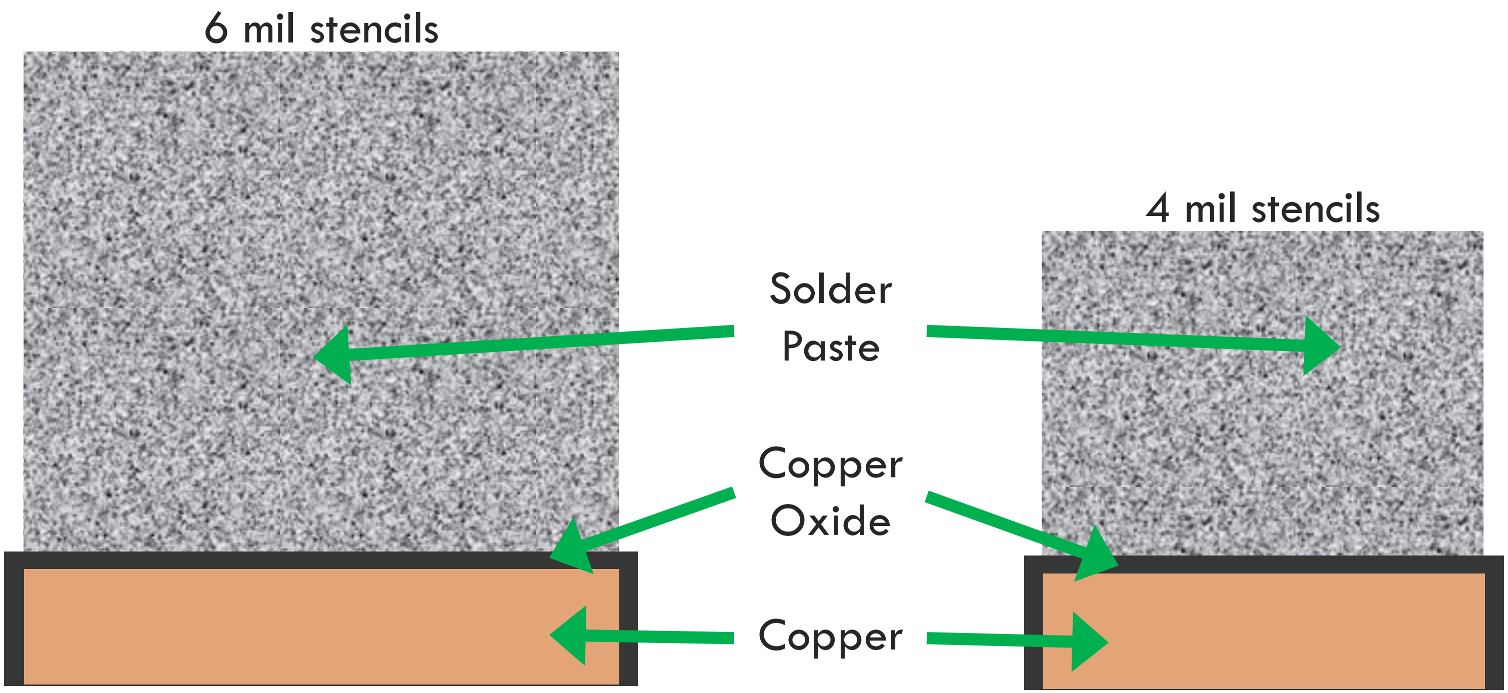
- A continuing decrease in pitch between conductors
  - 0.5mm → 0.4mm → 0.3mm
  - Makes future packaging more susceptible

- Increasing use of leadless packages like QFNs and LGAs
  - More difficult to clean underneath
  - May lead to more concentrated contamination

- Increasing production of electronics in countries with polluted and tropical environments

- Transition to Pb-free and smaller bond pads which may require more aggressive flux chemistries

Example Size Issue: Higher Activity Flux



- Reduced bond pad area (reduced by x^2)
  - Requires smaller volumes of solder paste (reduced by x^3)
  - But copper oxide thickness remains the same
- Less solder paste means less flux which may lead to use of higher activity flux

Example Component: QFNs and Dendritic Growth

- Large areas, multi-I/O, and low standoff features can trap flux under the QFN
- Processes using no clean flux should be requalified
- Processes not using no clean flux will likely experience dendritic growth without modification of cleaning process
  - Changes in water temperature
  - Changes in saponifier
  - Changes to impingement jets

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What is Electrochemical Migration?

- DfR definition: movement of metal through an electrolytic solution under an applied electric field between insulated conductors

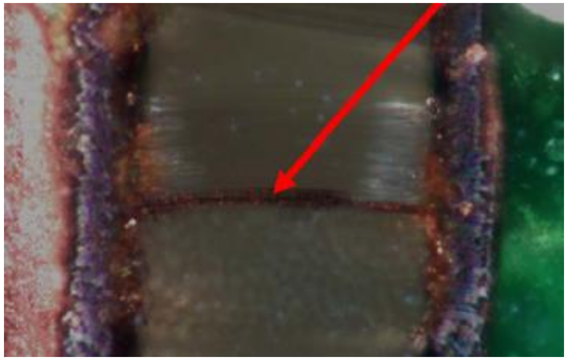
- Electrochemical migration can occur on or in almost all electronic packaging
  - Die surface
  - Epoxy encapsulant
  - Printed board
  - Passive components

ECM Terms

- A number of terms are used

- Dendrites and dendritic growth
  - Typically describes ECM along a surface
  - Produces “tree-like” or “feather-like” patterns

- Conductive anodic filaments (CAF)
  - Typically describes migration within a printed circuit board (PCB)



CAF following glass fiber bundle

Electrolytic Solution

- Composed of water and dissolved ions
- Where does the water come from?
  - Ambient moisture in the air
  - Evaporation of absorbed moisture (surface ECM)
- Measurement (techniques)
  - Adsorption -- Quartz crystal, Ellipsometry
  - Absorption -- Weight gain
- Measurement (units)
  - Adsorption -- Monolayers of moisture, or areal mass density (ng/cm^2); 1 monolayer = 31 ng/cm^2
  - Absorption -- Percent change in weight
- How much water?
  - Very dependent upon relative humidity
  - Can be relatively insensitive to temperature, even for moisture absorption (numerous internal interfaces, faster diffusion)

Deliquescence

- Deliquescence is the absorption of atmospheric moisture until complete dissolution
  - Process behind constant humidity salts for humidity calibration
  - Resulting resistance change can be several orders of magnitude (der Marderosian, 1977)
- Each inorganic compound has a different equilibrium %RH
- For example, HCl contaminated substrates showed dissolution of contaminants at 70%RH (Zamanzadeh, 1989)

Compound	Temperature (°C)	Relative h
$LiCl.H_2O$	20	15
KF	100	22.9
NaBr	100	22.9
$CaCl_2.6H_2O$	24.5	31
$CaCl_2.6H_2O$	5	39.8
KBr	100	69.2
NaCl	20	75
KCl	80	78.9
KBr	20	84
KCl	0	88.6
NaF	100	96.6

Condensation

- What is condensation?
  - When surface moisture becomes visible?
  - The amount of adsorbed moisture at 100%RH?

- Water film thickness ranges (metals)
  - Minimum: 10 monolayers of moisture
  - Dew: ~1,000 monolayers of moisture
  - Raindrops: ~10,000 monolayers of moisture
- When does condensation occur?
  - At 100%RH
  - When a surface temperature is below the dew point temperature
  - The presence of cracks and delamination adds capillary action
  - Hygroscopic materials present higher risks

Surfaces and Materials

- The influence of the surface on ECM is poorly quantified
  - Possible variables include roughness, porosity, and surface energy
- Hydrophobic surfaces are superior
- Solder mask and FR4 epoxy selection is rarely based on ability to resist ECM
- CAF does influence material selection
  - Epoxy/glass fiber interface
  - Possibility of delamination

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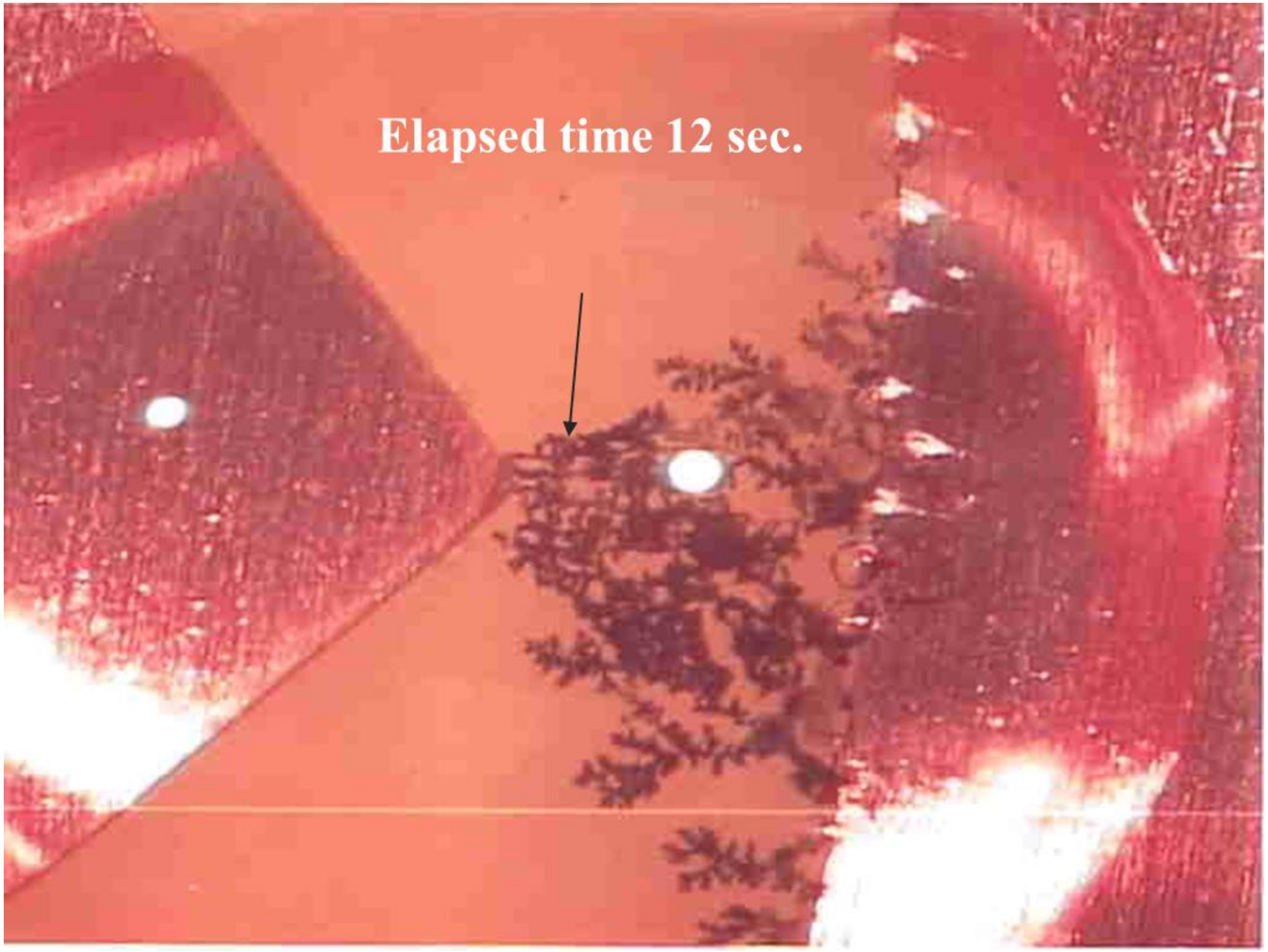
Dendritic Growth during Water Drop Test



Foresite; http://www.residues.com

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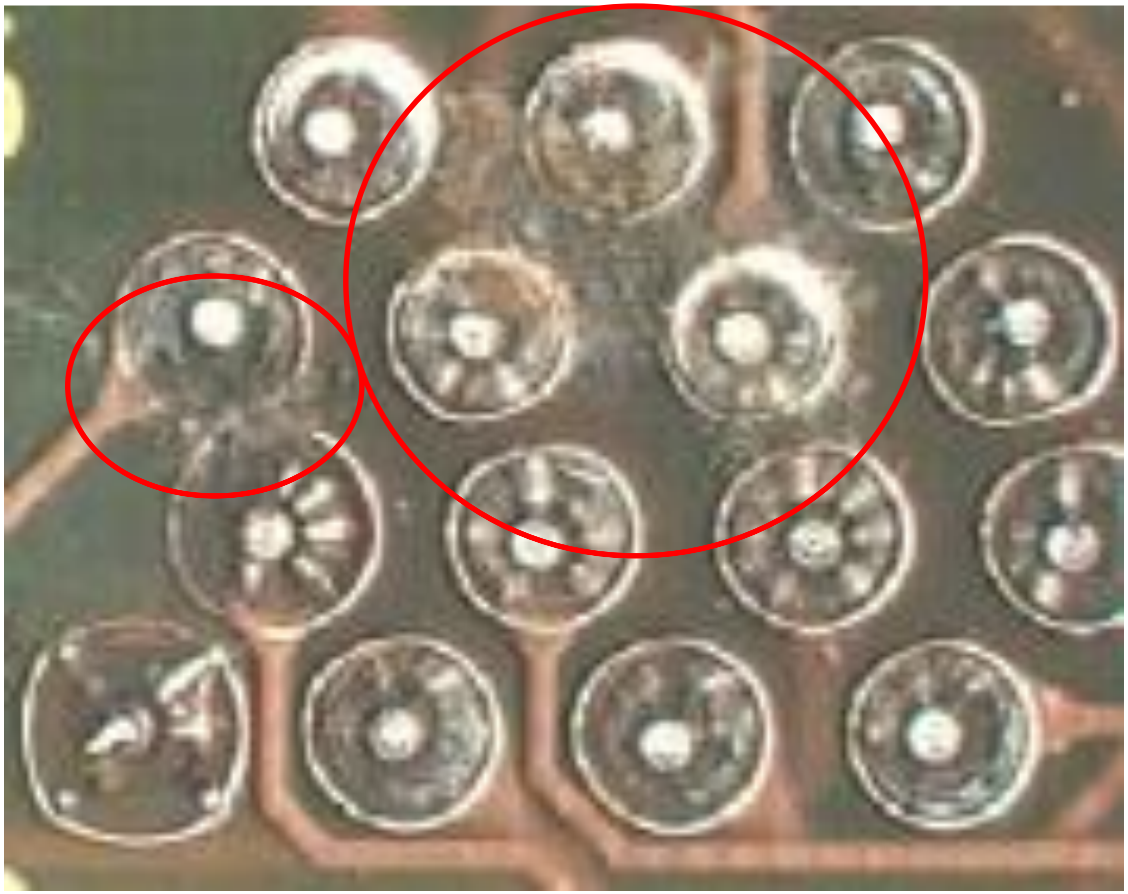
Migration Over Conformal Coating



Pin to pin migration over conformal coating

Electric Field Voltage and Distance

- Voltage is a primary driver in two processes
  - Electrodissolution (oxidation reaction)
  - Ion Migration

- Electrodissolution
  - Applied voltage must exceed EMF
  - 0.13 V for Sn/Pb, 0.25 V for Ni, 0.34 V for Cu, 0.8 V for Ag, and 1.5 V for Au

- Ion migration
  - Applies a force on the ions
  - Velocity of ions is a function of electric field strength

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Electric Field Strength

Logic devices

- Previous generation
  - **6.4 V/mm** (SO32, 1.27 mm pitch, 5 VDC)
- Current generation
  - **20 V/mm** (TSSOP80, 0.4 mm pitch, 3.3 VDC)

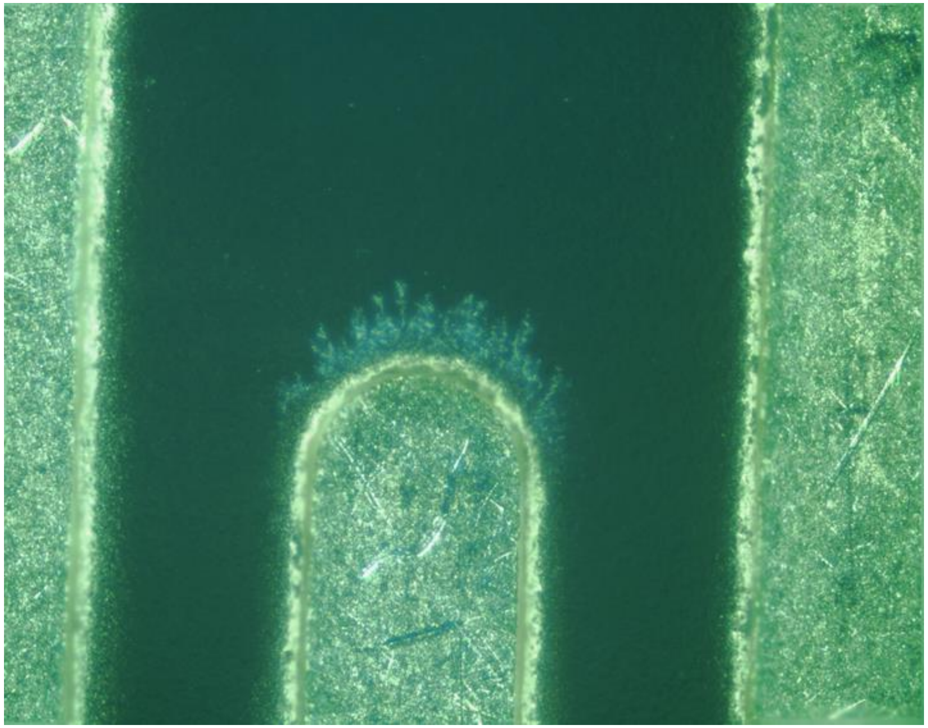
Power devices

- Previous generation
  - **64 V/mm** (SOT23, 1.27 mm pitch, 50 VDC)
- Current generation
  - **140 V/mm** (QFN, 0.4 mm pitch, 24 VDC)

- Copper traces: **240 V/mm** (0.5 mm spacing, 120 VDC)
- IPC-2221A allows **600 V/mm** (0.05 mm spacing, 30 VDC)

Electric Field and Dendrites

- Immersion silver (Ag) plating
- 85C / 85%RH / 10VDC
- Observation
  - Migration only at tip of comb pattern
  - Dendrites stopped growing
- Why?
  - Maximum electric field strength



Contamination

- Two concerns
  - Hygroscopic contaminants
  - Ionizable contaminants that are soluble in water (e.g. acids and salts)

- Ionic contaminants of greatest concern:
  - Primarily anions; especially the halides chloride and bromide
  - Very common in electronics manufacturing process
  - Decreases pH; few metal ions found in dendrites are soluble at middle to high pH; copper dendrites require pH less than 5 to form
- Silver(I) ions are soluble at relatively high pH, the reason it form dendrites more easily than other metals

- Cations primarily assist in the identifying the source of anions
  - Example: Ca and Mg suggest tap water

Sources of Contamination

Ion	Possible Sources
Cl	Board Fab, Solder Flux, Rinse Water, Handling
Br	Printed Board (flame retardants), HASL Flux
Fl	Teflon, Kapton
PO_4	Cleaners, Red Phosphorus
SO_4	Rinse Water, Air Pollution, Papers/ Plastics
NO_4	Rinse Water
Weak Organic Acids	Solder Flux

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Sources of Contamination on PCBs

- Etching
  - Chloride-based: Alkaline ammonia (ammonium chloride), cupric chloride, ferric chloride, persulfates (sometimes formulated with mercuric chloride)
  - Other: Peroxide-sulfuric acid
- Neutralizer
  - Hydrochloric acid
- Cleaning and degreasing
  - Hydrochloric acid, chlorinated solvents (rare)
- Photoresist stripping
  - methylene chloride as a solvent
- Oxide
  - Sodium chlorite
- Electroless plating
  - Sodium hypochlorite (in potassium permanganate)
  - Palladium chlorides (catalyst)

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Bromide and PCBs

- Surface processes
  - Solder masks and porosity, marking inks, and fluxes

- Flame retardant
  - FR-4 epoxy typically uses a brominated bisphenol A (TBBA) epoxy resin
  - IPC-TR-476A: “Bromide in epoxy resin can diffuse to the surface during a high temperature process such as soldering”

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Fluxes and Contamination

- Fluxes are very different, but all are acidic
  - Solder paste flux
  - Flux-core solder wire
  - Liquid flux for wave
- Optimum behavior
  - Maximum activity during reflow; minimum activity after reflow
  - Difficult balancing act
- Flux nomenclature
  - Rosin only (RO)
  - Rosin, midly activated (RMA)
  - Rosin activated
  - Water soluble
  - Low residue (no-clean)

J-STD-004 Flux Classification: RO and RE

Materials of Composition[2]	Flux/Flux Residue Activity Levels	% Halide[3] (by weight)	Flux Type[3]	Flux Designator
Rosin (RO)	Low	0.0%	L0	ROL0
		<0.5%	L1	ROL1
	Moderate	0.0%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	0.0%	H0	ROH0
		>2.0%	H1	ROH1
Resin (RE)	Low	0.0%	L0	REL0
		<0.5%	L1	REL1
	Moderate	0.0%	M0	REM0
		0.5-2.0%	M1	REM1
	High	0.0%	H0	REH0
		>2.0%	H1	REH1

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J-STD-004 Flux Classification: OR and IN

Materials of Composition[2]	Flux/Flux Residue Activity Levels	% Halide[3] (by weight)	Flux Type[3]	Flux Designator
Organic (OR)	Low	0.0%	L0	ORL0
		<0.5%	L1	ORL1
	Moderate	0.0%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	0.0%	H0	ORH0
		>2.0%	H1	ORH1
Inorganic (IN)	Low	0.0%	L0	INL0
		<0.5%	L1	INL1
	Moderate	0.0%	M0	INM0
		0.5-2.0%	M1	INM1
	High	0.0%	H0	INH0
		>2.0%	H1	INH1

J-STD-004 Test Requirements

Table 3-2 Test Requirements for Flux Classification

Flux Type	Copper Mirror	Corrosion	Quantitative Halide[1] (Cl-,Br-,F-,I-) (by weight)	Conditions for Passing 100 MΩ SIR Requirements [2]	Conditions for Passing ECM Requirements
L0	No evidence of mirror breakthrough	No evidence of corrosion	<0.05%[3]	No-clean state	No-clean state
L1			≥0.05 and <0.5%		
M0	Breakthrough in less than 50% of test area	Minor corrosion acceptable	<0.05%[3]	Cleaned or No-clean state[4]	Cleaned or No-clean state[4]
M1			≥0.5 and <2.0%		
H0	Breakthrough in more than 50% of test area	Major corrosion acceptable	<0.05%[3]	Cleaned	Cleaned
H1			>2.0%		

1. This method determines the amount of ionic halide present (see Appendix B-10).
2. If a printed circuit board is assembled using a no-clean flux and it is subsequently cleaned, the user should verify the SIR and ECM values after cleaning. J-STD-001 may be used for process characterization.
3. Fluxes with halide measuring <0.05% by weight in flux solids may be known as halide-free. If the M0 or M1 flux passes SIR when cleaned, but fails when not cleaned, this flux **shall** always be cleaned.
4. Fluxes that are not meant to be removed require testing only in the no-clean state.

Flux Types and Use

- About 5% of the market uses rosin fluxes
  - Preferred in the early days of electronics manufacturing
  - Insoluble residues encapsulated contaminants
  - Hydrophobic surface
  - Quasi-conformal coating
  - Their use has decreased because of environmental concerns about the solvents required to clean rosin
- About 25% uses water soluble fluxes
- About 70% of the market uses no-clean fluxes
  - 80-90% in consumer, computer, telecom markets
  - Their use is increasing
  - Fine pitch, low clearance, and high density greatly decrease cleaning effectiveness
  - Electronics industry is very cost sensitive (eliminate one process, increase throughput)

Flux Residues

- Some residues of no-clean soldering
  - Resin or rosin encapsulant
  - Water-soluble carboxylic acids
  - Hygroscopic polyethylene glycol ethers
- Potential weak organic acids (WOAs)
  - Benzoic, Butyric, Formic, Lactic, Malonic, Oxalic, Propionic, Succinic, Citric, Glutaric, Adipic, Malic
- The perfect no-clean flux residue
  - Acids are fully neutralized during soldering process
  - Residual wetting agents are minimized
  - Ions are completely and permanently trapped in hard residue

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No Clean Flux

- Typically, no clean means the flux has passed the surface insulation resistance (SIR) and electrochemical migration (ECM) tests specified in J-STD-004 without cleaning
- However there is no industry standard definition of no-clean
- Anyone can call anything no-clean

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Why No Clean Isn't Always No Clean

- Application, application, application
- TM-650 2.6.3.3 defines two types of applications
  - **Liquid flux –** (wave, cored wire, etc.): 'Coat the test pattern with a thin coating of liquid flux'
  - 'Thin' coating is not defined: 0.5 mil? 1 mil? 3 mil?
  - It is to the advantage of the flux supplier to use as little flux as possible (solderability is not being tested)
  - **Solder paste –** 'Stencil print using a 6 mil stencil'
- If your application is using a different amount of flux, or different profile, you may get different results
- Flux thickness is typically self-limiting, but not always

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No Clean Flux Entrapment

- The IPC-B-24 test coupon specified in TM-650 2.6.3.3 is not representative of an actual product

- For the halides or weak organic acids to 'deactivate', the solvents need to evaporate
  - Large components with low standoffs may have insufficient volume or airflow to allow evaporation
  - Activated flux residues will have a lower pH and higher water soluble ionic content

- Works in conjunction with amount of flux
  - Too much flux under low standoff components makes evaporation even harder

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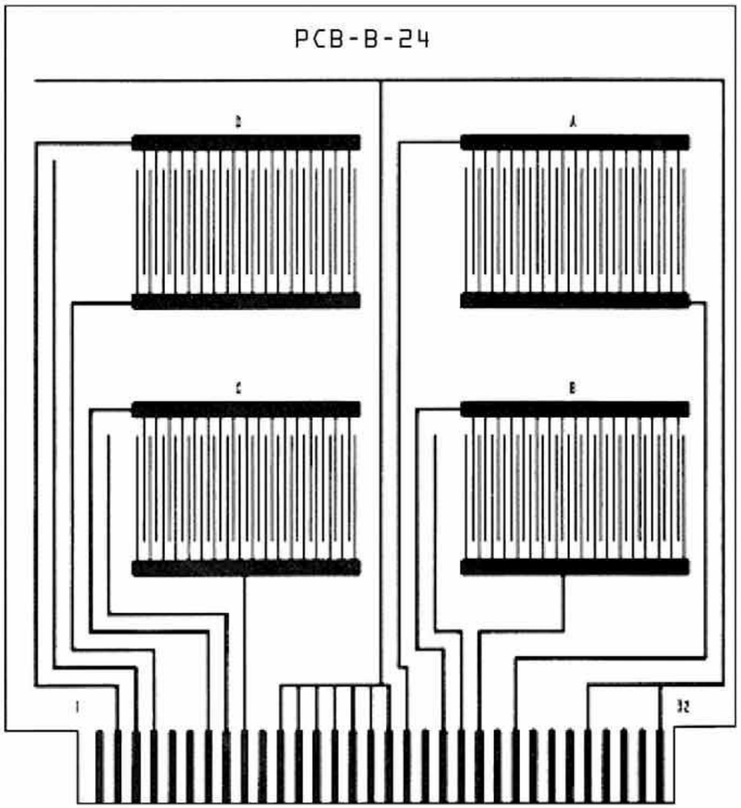
Testing

- The spacing on the IPC-B-24 coupon is a generation behind
  - 0.5mm vs. 0.4mm on many QFPs, QFNs, and CSPs
- Applied voltage is 25V/mm
  - Not even close to electric fields seen in today's power devices
- No solder mask (can react and collect flux residues)
- Anode and cathode are the same size



- Resistance between conductors shall be more than 100 megohms
  - How sensitive is your circuit?

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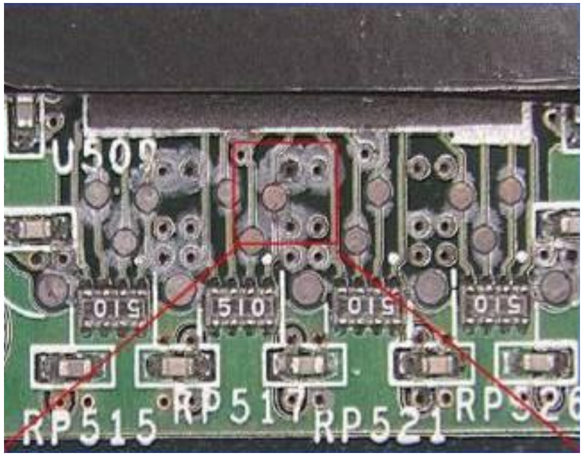
Testing (Continued)

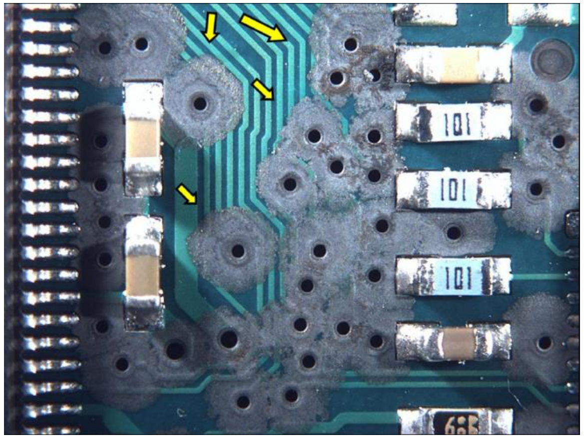
- Filament growth is allowed as long as it does not decrease conductor spacing by more than 20%

- Yes, you read that correctly: A flux can cause dendritic growth and still be called a no-clean flux

Creep Corrosion and Pollutants

- Recent field issues with printed circuit boards (PCBs) plated with immersion silver
  - Sulfur-based creepage corrosion
- Failures in customer locations with elevated levels of sulfur-based gases
  - Rubber manufacturing
  - Sewage/waste-water treatment plants
  - Vehicle exhaust fumes (exit / entrance ramps)
  - Petroleum refineries
  - Coal-generation power plants
  - Paper mills
  - Landfills
  - Large-scale farms
  - Automotive modeling studios
  - Swamps





P. Mazurkiewicz , ISTFA 2006

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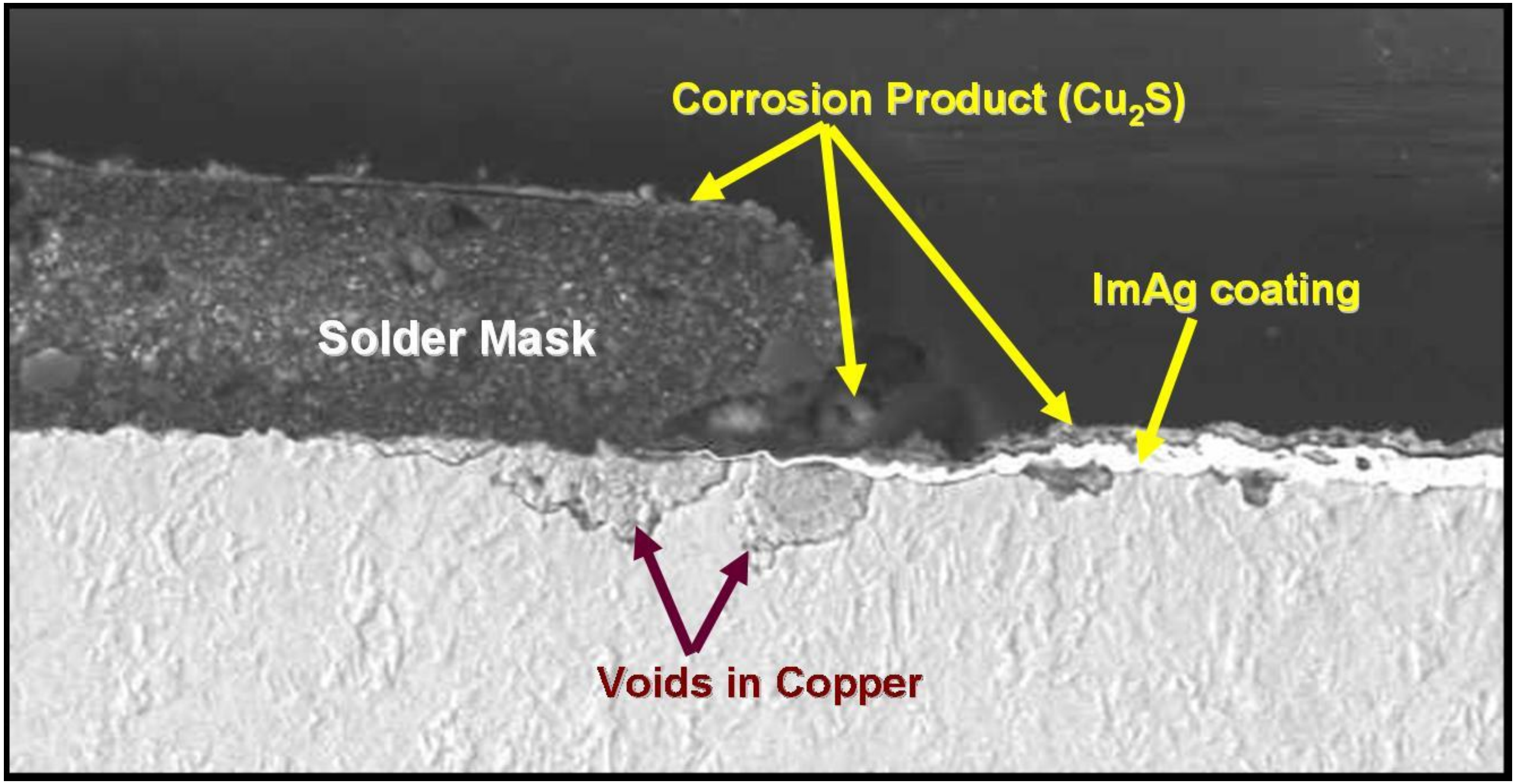
Creep Corrosion Example

- Exposed copper was consumed forming copper sulfide



PCB Cleanliness Control and Industry Specs

- IPC-6012C, Qualification and Performance Specification for Rigid Printed Boards, Section 3.9
  - Requires confirmation of board cleanliness before solder resist application
  - When specified, requires confirmation of board cleanliness after solder resist or solderability plating

- Board cleanliness before solder resist shall not be greater than 1.56 $\mu g/cm^2$ (10 $\mu g/in^2$) of NaCl equivalent (total ions)
  - Based on military specifications from more than 30 years ago
  - Calculated to result in 2 megohm surface insulation resistance (SIR)
  - Doesn't correlate to 100 megohm SIR test, or does it?

- Board cleanliness after solder resist shall meet the requirements specified by the customer

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DfR Solutions Cleanliness Guidelines

Contaminant	Upper Control Limit** (µg/in^2)	Maximum Level (µg/in^2)
Bromide	10	15
Chloride	2	4
Fluoride	1	2
Nitrate	4	6
Nitrite	4	6
Phosphate	4	6
Sulfate	4	6
Total Weak Organic Acids	50	100

***Upper control limits may be considered maximum levels for high reliability applications or products used in uncontrolled environments*

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Major Appliance Manufacturer Guidelines

	Incoming PCB	Processed PCB	
Contaminant	Maximum Level (ug/in^2)	Maximum Level (ug/in^2)	Upper Control Limit (ug/in^2)
Ammonium	<0.5		<2
Bromide	3	10	8
Calcium	<0.5		<1
Chloride	2.5	3.5	3
Fluoride	<0.5		<1
Magnesium	<0.5		<1
Nitrate	<0.5		<2
Nitrite	<0.5		<1
Phosphate	<0.5		<1
Potassium	<3		<3
Sodium	<3		<3
Sulfate	3	3	2
Total	5	18	14
Weak Organic Compounds	200	200	50

And Now for Something Completely Different (or Not)

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Cleanliness Makes a Difference When Miniaturization Kicks In

Mike Bixenman, DBA
KYZEN Corporation

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Agenda

- Device Reliability Matters
- Process Residues
- Real Time SIR
- Test Data Examples
- Conclusions

DEVICE RELIABILITY MATTERS

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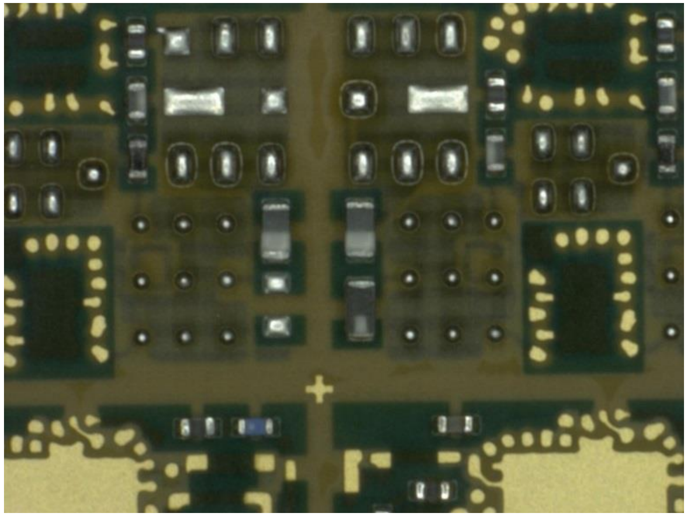
Design Engineers

- Circuit / System PCB designer's objective is to
  - Increase device functionality in a smaller form factor
- Higher density / Smaller form factor drive
  - Higher risk
  - Intermittent electronic performance
  - Signal integrity loss
  - Increase failure mode opportunities



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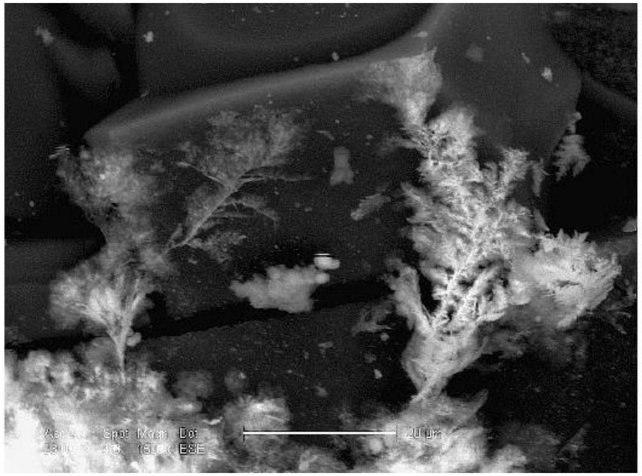
Spacing Between Conductors

- Wider spacing
  - Has been our friend and saving grace
  - Greater insulation between these conductors and pads
- Standoff heights are approaching one mil
  - Smaller cubic volume area to outgas volatiles
  - Prevent the volatilization of flux additives such as
    - Inhibitors (against oxidation / corrosion)
    - Activators (promotes wetting)
    - Thermal stabilizers
  - Flux residues may not be fully deactivated

Mobile Ions

- Form leakage currents and or voltages
  - Especially for devices operating in humid environments
- Flux residue
  - Contain activators / ionic materials
  - When trapped under a part can lead to shorts across adjacent pads, or voltage/current leakage pathways



Barbini, D. (2015). SMTA LED Conference

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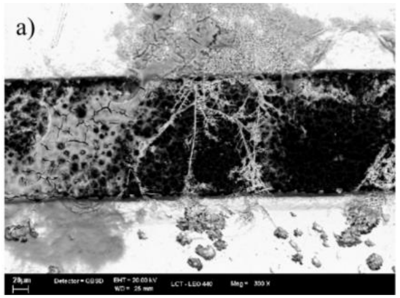
Electronic Devices

- Long term reliability / warranty expectations
  - Need an improved industry test specification
  - Accurate risk assessment
- The problem is that the risk assessment is a
  - Multi-variable issue influenced by
    - Flux type
    - Flux make up (activators and inhibitors)
    - Activation temperature
    - Component type and placement
    - The type and criticality of the circuit in which the component is operating in
    - Wash conditions
    - Solder paste volume
    - PCB cleanliness and component contamination

PROCESS RESIDUES

Electronic Hardware Advances

- Cleanliness and Contamination
  - Primary driver of electronic device field issues
  - Products
    - Do more
    - Weigh less
    - Physically smaller
  - Pervasive
    - Observed on all electronic devices
  - Will continue to get worse



http://www.sbmicro.org.br/jics/html/artigos/vol6no2/7.pdf

Caswell, G. 2015.
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High Density Interconnects

- Miniaturization driven by
  - Smaller devices
  - Mini-components
  - Thinner materials
- Multiple via processes includes
  - Via in pad
  - Blind via technology
  - More PCB real estate to place smaller components closer together
  - Decreased component size and pitch allow for more I/O in smaller geometries
- This means
  - Faster signal transmission
  - Significant reduction in signal loss
  - Crossing delays

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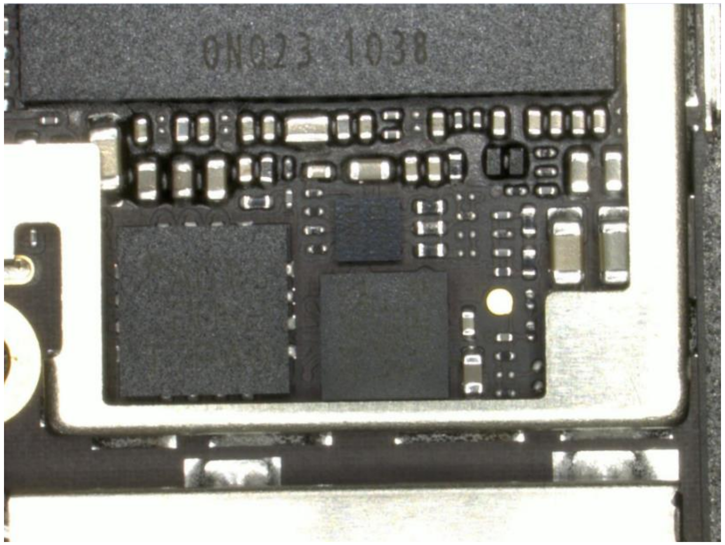
Contamination

- Contamination is more problematic due to
  - Reduced distance between conductors
- Intermittent behavior from current leakage lends itself to
  - No-fault found returns
- These failures can be driven by
  - Self-healing behavior
  - Difficult to diagnose



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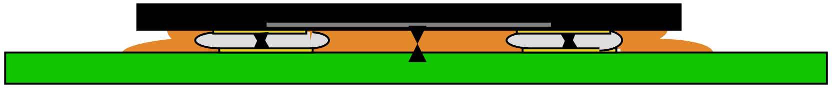
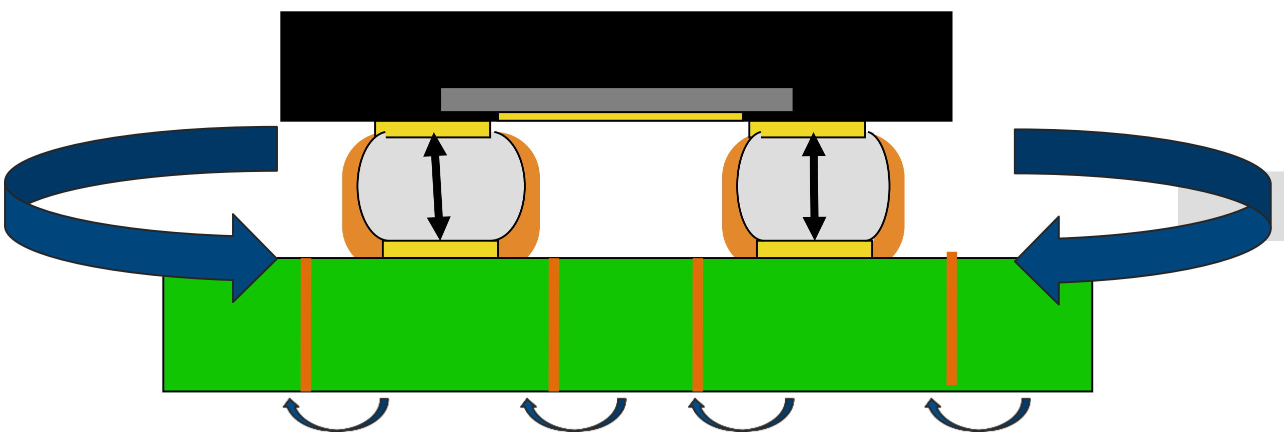
Z-Axis Gap Height

- Flux residue under BTC is a function of
  - Attractive and repulsive capillary forces
- When the Z-Axis is less than 2 mils
  - Flux residue capillary forces attract during reflow
  - Heavy flux residue deposits accumulate in the
    - Streets
    - Interconnecting pads
- Attractive force renders
  - Significant level of flux residue
  - Underfills component with flux residue
  - Flow channels closed



Repelling Capillary Force

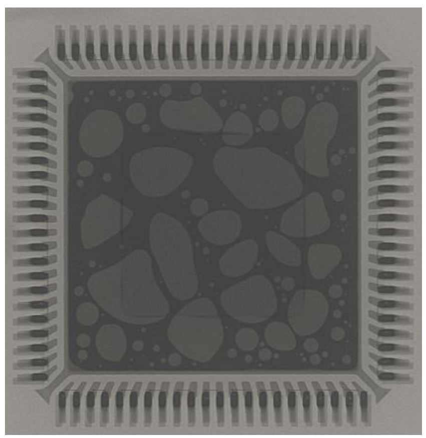
- High standoff gaps
  - Flux outgases during reflow
  - Capillary forces are negative
  - Residues burn off with residue forming around solder pads



DfR Solutions

Voiding / Flux Activity

- Voiding
  - Large voids form when flux does not have a channel to outgas
- Flux Activity
  - No Clean flux residues must outgas
  - Trapped residues are active and should be cleaned



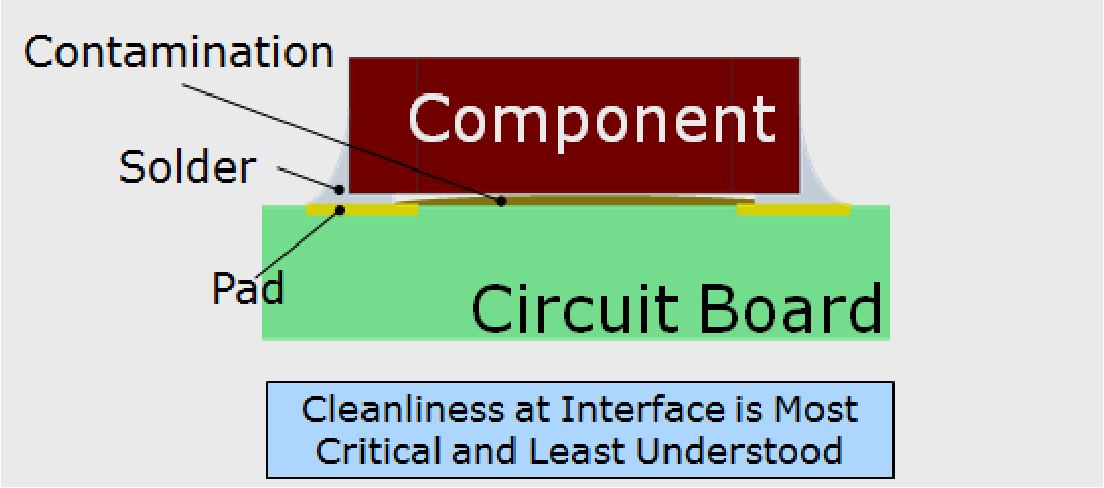
Kummerl, S. (June, 2014). Texas Instruments Advanced Packaging Trends. SMS Emerging Technology Forum.

"SIR" AT THE SOURCE OF RESIDUE

DfR Solutions

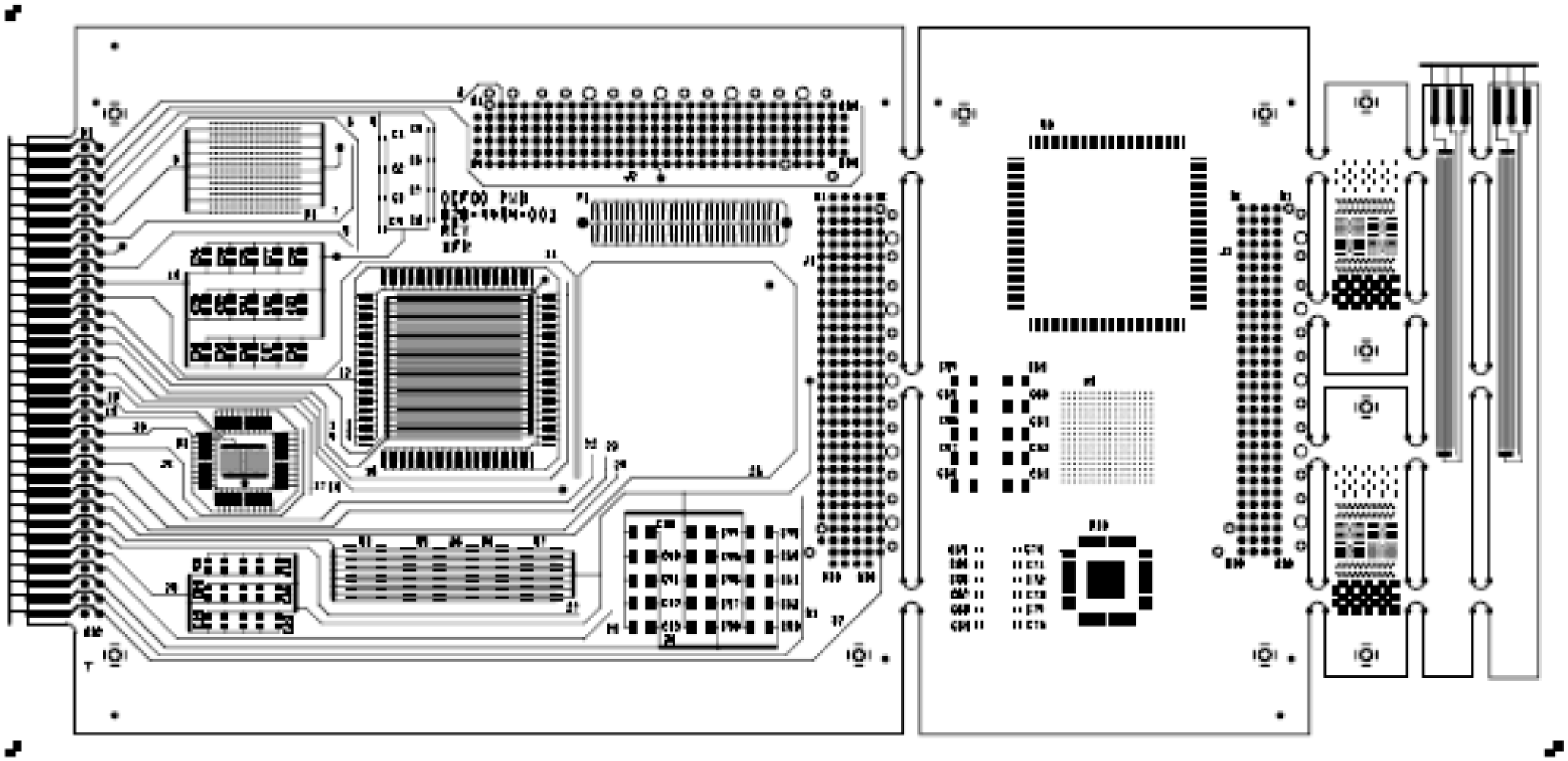
Flux Entrapment

- Flux residue trapped between component body and board
- Ionics in flux residue can
  - Exacerbate contamination levels under part
  - Bridge residue between conductors
  - Can lead to high resistance shorts across pads



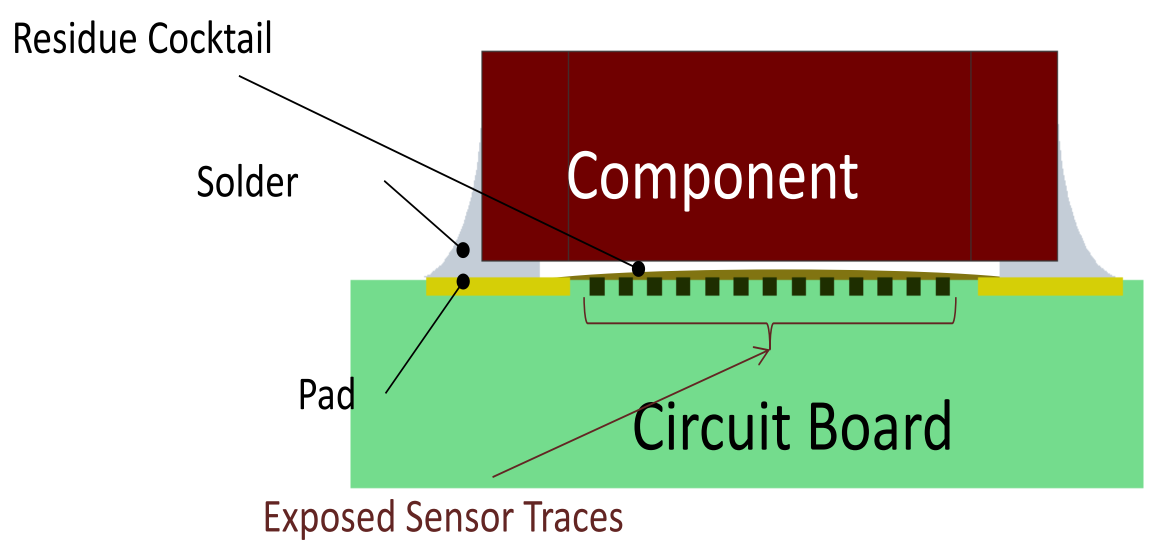
McMeen (2014). IPC/SMTA Cleaning Conference

IPC-B-52 Rev B1



Test Board

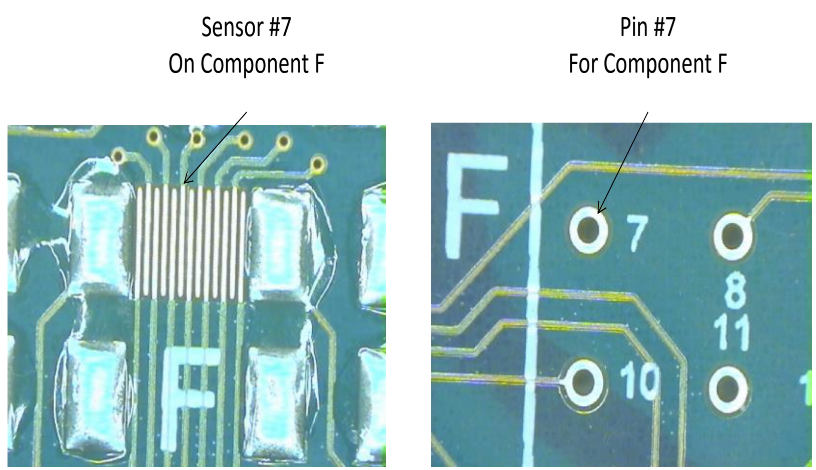
- Sensors placed under bottom termination
- Real time SIR data



McMeen (2014).
IPC/SMTA Cleaning
Conference

Conductor Spacing

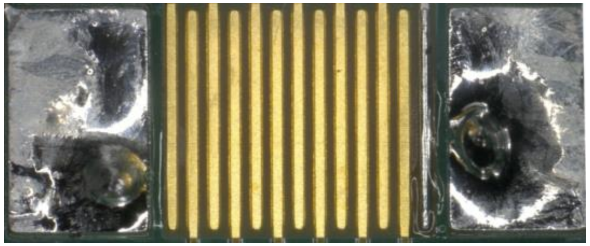
- Test board
  - Has parallel exposed sensor traces
  - Traces are .005” (.127 mm) wide
  - Separated by .005”
  - Gap distance can be measure at various points



DfR Solutions

Residue under Bottom Termination

1 ft./min clean



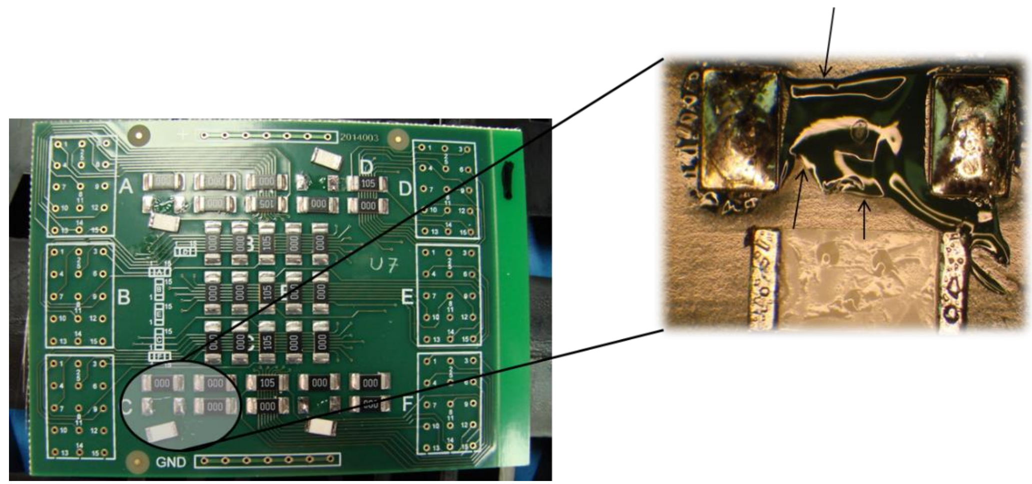
5 ft./min clean

8 ft./min clean

Research Presents

- New methods to
  - Test Resistance drop due to Contamination
  - Voltage Bias
  - Humidity Effects
  - Ionic Residues
  - Line Spacing
  - Temperature
  - Time

McMeen (2014).
IPC/SMTA Cleaning
Conference



Test Data Examples

Test #1

- QFN Test Board
- Test Electrochemical drivers
  - Voltage Bias
  - Humidity
- Two identical boards placed into chamber
  - One connected to a voltage source
  - One board not connected to a voltage source
  - 200 hour exposure
  - Electrical resistance measured at 100-hour increments

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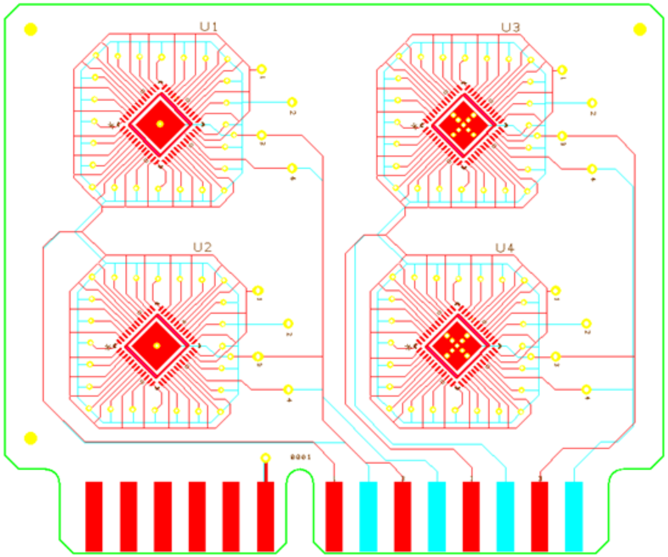
QFN Test Board

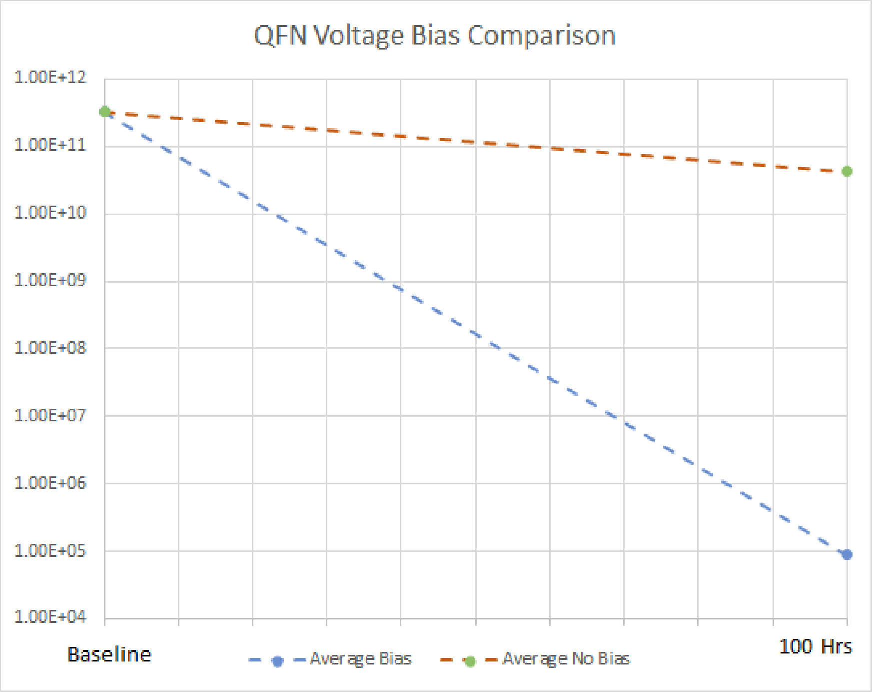
- 4 – 48 pin QFNs
- 0.5mm (.020") pitch
- Sensors placed between the
  - Ground lug and perimeter contacts
  - Electrical access of flux between center lug and perimeter pins
  - Intended to be non-soldered
  - Isolated from other pins



Bixenman, M. & McMeen, M. (2016). SMTA Pan Pac

Test #1 Data Findings

- Voltage + Humidity resulted in
  - Large resistance drop
- No Voltage + Humidity
  - Minimal resistance drop

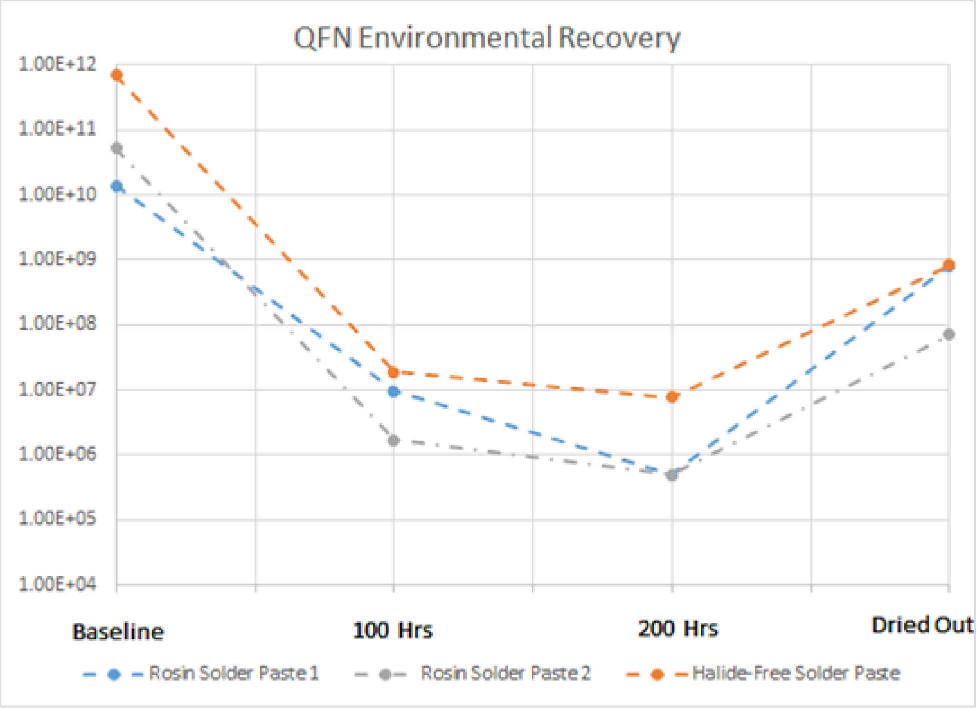


Test #2

- QFN Test Board
- Test impact of high humidity
  - Voltage + humidity
  - Two rosin based solder pastes
  - After 200 hours of exposure
    - Boards returned to dry condition
    - Determine if resistance levels recover

Test #2 Data Findings

- Humidity
  - Resistance levels drop
- Dry Condition – No Humidity
  - Resistance levels recovered
  - Not to the original level

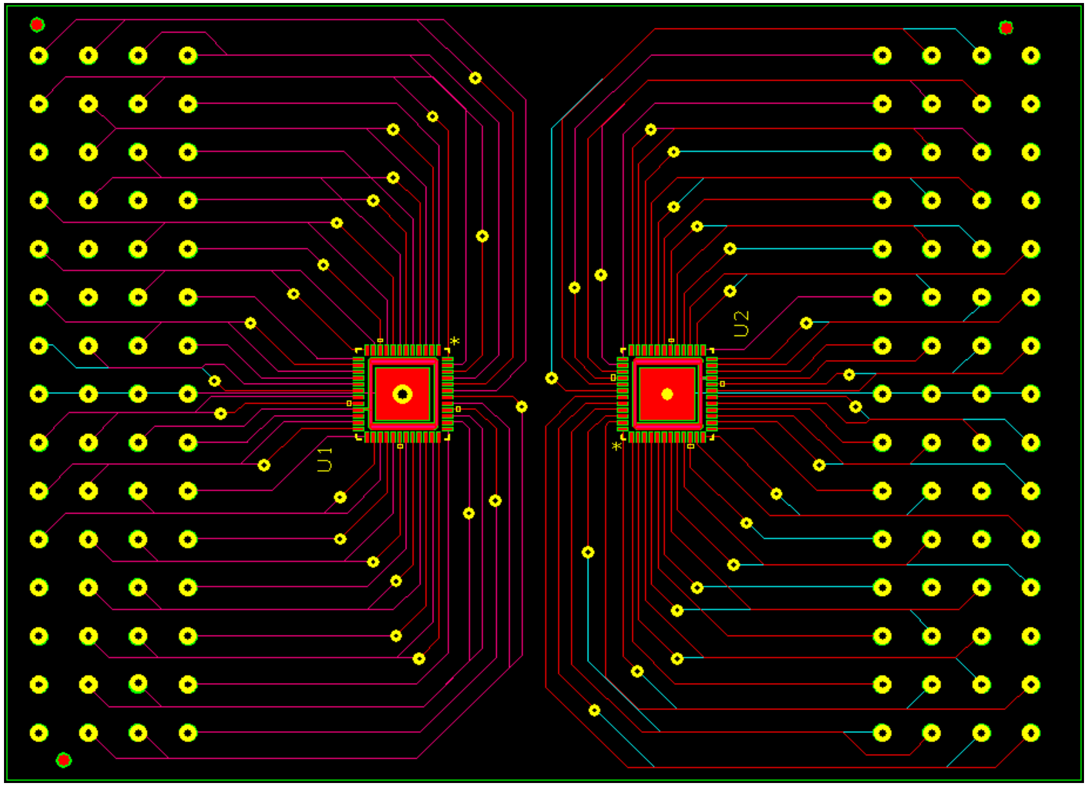


DfR Solutions

Test #3

- The test vehicle utilizes
  - QFN package with a large ground lead in the center
  - Part is 7mm square with 0.5 mm pin pitch
  - Ground lead serves as an
    - Electrical reference
    - Thermal path for the part
    - Large volume of solder
  - Flux devoid of ionic residue must
    - Activate
    - Vaporize
    - Evacuate/outgas

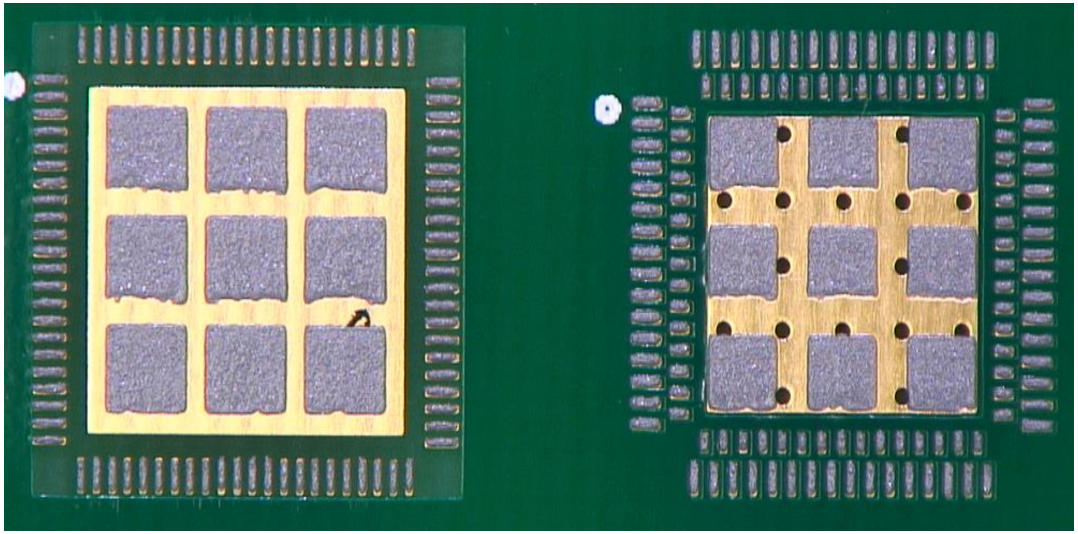
QFN Test Vehicle



McMeen, M. & Bixenman, M (2016). SMTA Pan Pac

Via Holes in the Ground Pad

- Provide a channel for flux to outgas
  - Flux renders a benign state
  - Dry and not wet and pliable
  - Less tendency to mobilize with moisture



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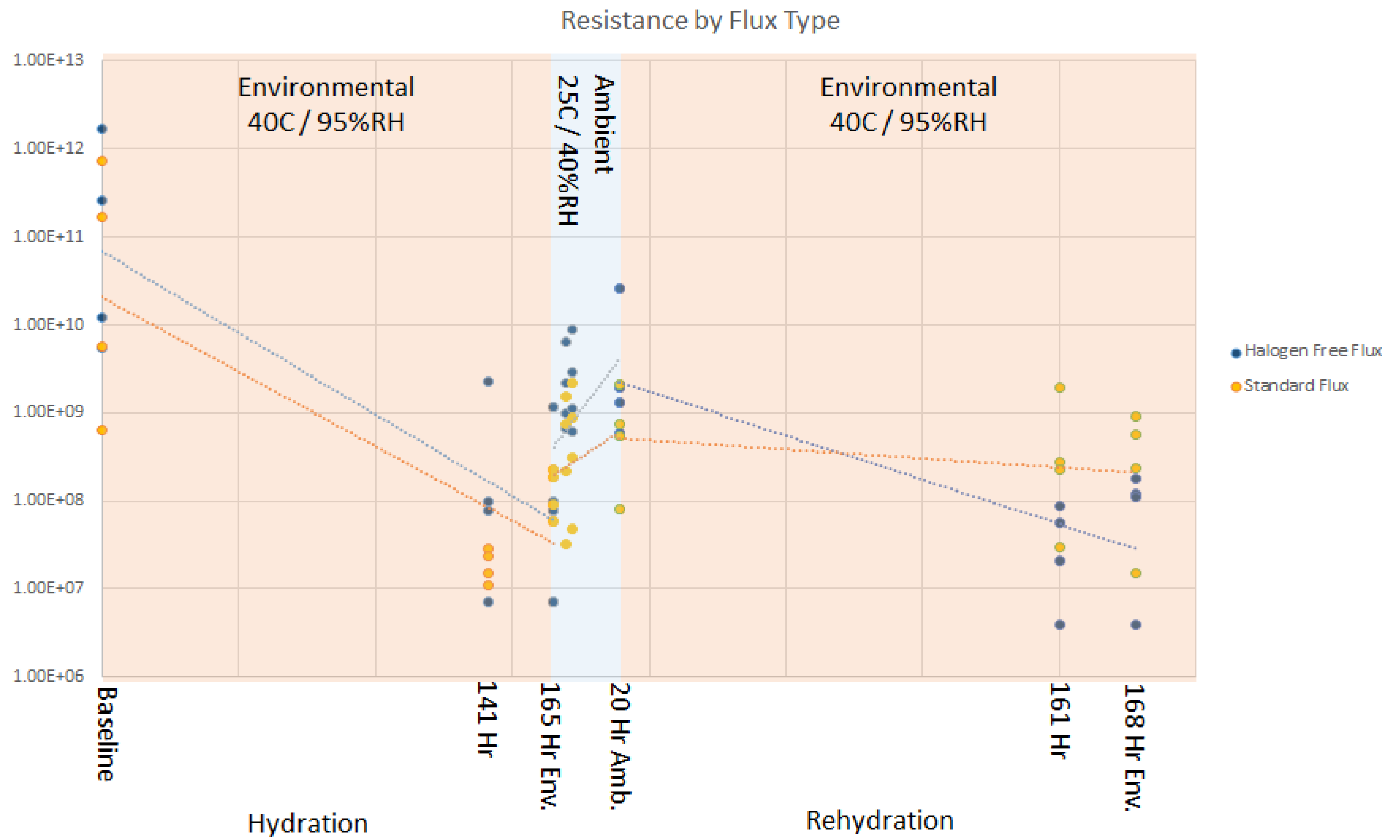
DOE Factors

- The influences of
  - Humidity on resistance measurements
  - No-clean flux types
    - Halide-free vs. standard
  - Propensity of test vehicles to return to baseline conditions after exposure to environmental accelerants (hysteresis)
  - Effectiveness of flux outgassing
- Ground Lug
  - Solid
  - Via hole to outgas

Environmental Testing

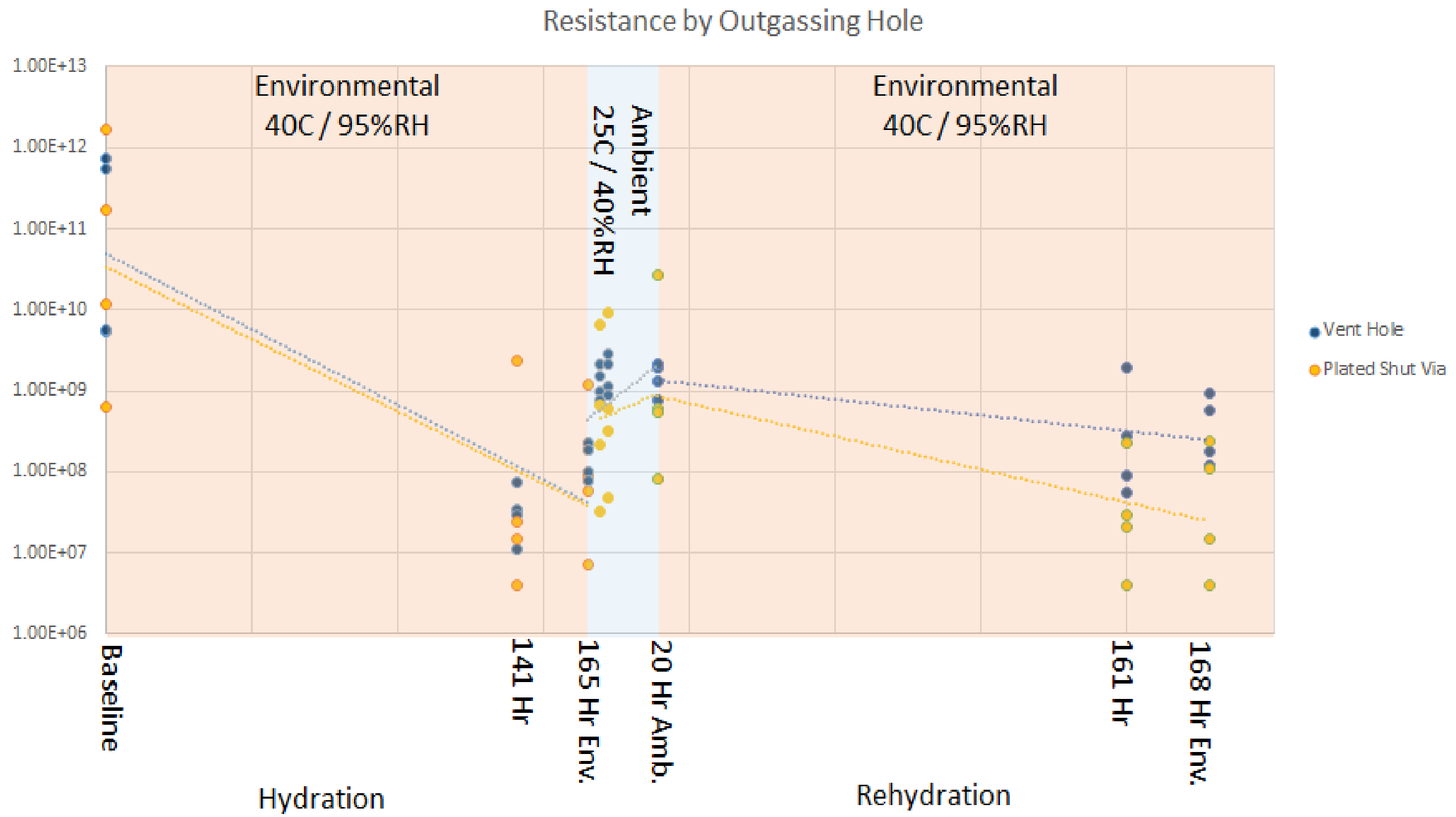
- The boards were subjected to a
  - Series of extended environmental stresses
  - Induce any flux residue-related electrochemical changes
  - 40°C and 95% relative humidity (non-condensing) for 168 hours (1 week)
  - 5VDC voltage bias was applied between the ground terminal and perimeter leads
  - Prolonged electromotive force to the residue
- The intent was to coax the alignment of ionic compounds using a persistent electric field
  - High impedance measurements
  - After the 168 hour exposure
    - Boards were return to ambient conditions (25°C and 40% RH) to dry out
    - Measurements were again taken at regular intervals to capture any subsequent recovery of electrical properties
    - After stabilization, the boards were returned to the environmental chamber for a final round of identical stresses and regular measurements

Resistance by Flux Type



Bixenman el al (2015). Cleanliness Makes a Difference when Miniaturization Kicks In. SMTAI (2015).

Resistance by Outgassing Hole



Bixenman el al (2015). Cleanliness Makes a Difference when Miniaturization Kicks In. SMTAI (2015).

Humidity

- The most prevalent observation has been
  - The need for humidity to coax electrochemical phenomenon
  - The absence of moisture can mask
    - The presence of flux residue by rendering it immobile
    - Innocuous compounds lay dormant until sufficiently hydrated
- It is also important to note that pure water has
  - Practical upper limit to its electrical resistance when it meets air
  - This limit is on the order of 10^6 (Mega) Ohms
  - Measurements above these values are attributed to causes other than water (i.e. flux residues)

Environmental Testing

- Drying Out Ions
  - Normalize at customarily acceptable SIR levels
  - After returning to a dry environment
    - The boards tend to dry out over the course of 24 hours
    - Allow SIR levels to generally return to above 10^8 (100 Mega) Ohms
  - This tendency to recover underscores
    - The need for humidity for accurate measurements
    - Subsequent environmental exposure
      - Induces a rapid return to less-than-acceptable SIR levels

Vent Hole

- Vent hole in the center of the grounding QFN lug
  - Positively influences the amount of volatile flux residues remaining under the BTC
  - SIR levels tend to be markedly improved over that of an unvented design
  - This observation reinforces the need for designs to incorporate such a novel design feature in an effort to improve long-term reliability

CONCLUSIONS

Electronic Devices

- Miniaturization speeds up failure
  - Highly dense interconnects
  - Environmental factors
- To build in quality
  - Definition of the finished product performance expectations is the starting point
  - What are the performance objectives in relation to size, speed, cost, mass, style and efficiency?
  - By first screening in reliability, the product can be designed for the end use environment
  - It is critical to plan for the environment in which the device will be used

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Ion Mobilization

- Corrosion process is initiated through
  - Oxidation and reduction of metal ions
- Ionic residues are mobilized based on
  - The strength of the ion-dipole forces of attraction with water
  - The intermolecular bond with water creates an electrolytic solution
  - When the electrolyte solution comes in contact with the solder alloy, component metallization and pad, metal oxides can dissolve into the electrolyte
  - The metals mobilized within the electrolyte can plate out in the form of dendrites
  - The leakage current from these dendrites reduces resistivity

Dry Environments

- Hydration / Carrier System
  - A fluid carrier system must be present in order to
    - Mobilize ions
    - Current leakage pathway
    - Water is the most viable carrier system
  - In dry conditions
    - Ions will not migrate
    - High levels of contamination lay dormant
    - Minimal risk

RT SIR Testing

- Site specific method
- Risk assessment under BTCs
  - Evaluate the cleanliness levels
  - Sensors can detect resistance losses
  - Will the residue be problematic if mobilized?
  - If cleaned, are the resistance levels maintained in the presence of humidity and bias?
  - This method allows for testing where failure takes place!

Thank you

- Mike Bixenman
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