IPC Midwest 2011

Testing the Long Term Reliability of an Environmentally Friendly PCB Final Finish

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Executive Summary:
The new plasma polymer PCB final finish that eliminates harsh chemicals and waste streams also promises to eliminate creep corrosion, but will it stand the test of time? Before any new product or process can be implemented, it must be tested extensively to demonstrate its fitness for use. Performance from the beginning to end of the product life cycle must be measured or simulated. For the new PCB finish, the gamut of testing included characterizing the application process, storage robustness, corrosion resistance, solderability and joint reliability. Methods used to test the coating included FTIR, EDX, mixed flowing gas, steam aging, wetting balance, thermal aging, shear testing, and micro sectioning with both SEM and optical microscopy. Over a year's worth of testing performed by two independent US laboratories is presented in this paper. It details the purpose, method and results of each test and discusses the findings with respect to long-term performance.

Semblant™

Testing the Long Term Reliability of an Environmentally Friendly PCB Final Finish

LATEST DEVELOPMENTS IN PLASMA FINISHING OF PCB

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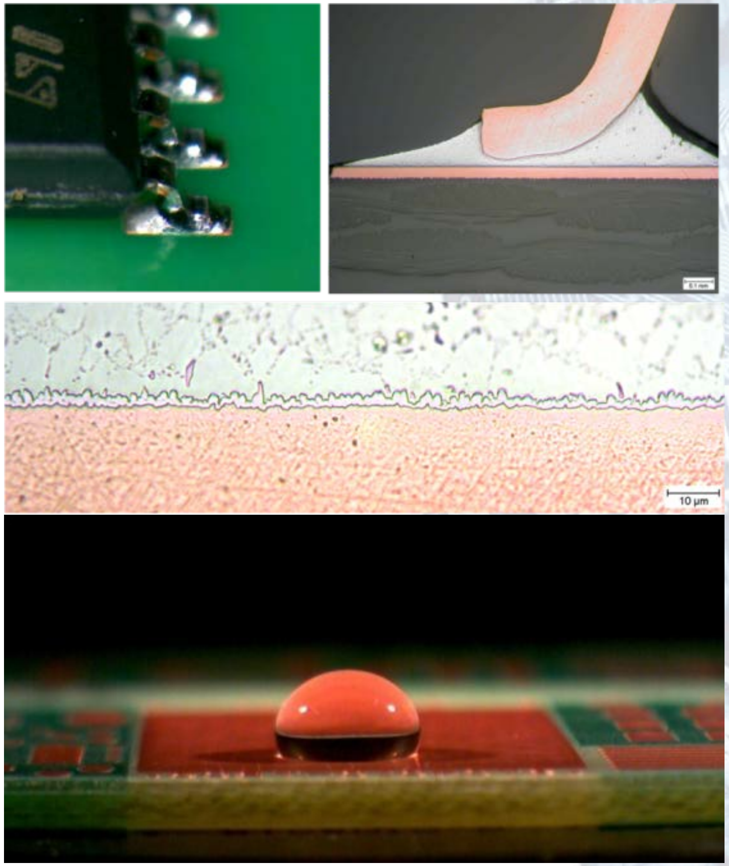
Christopher Group
Santa Ana, CA

CHRISTOPHER

Plasma Coating Performance Features

- **New patented technology for surface finish**
- **Simple process**
- **Ultra thin coating (40nm)**
- **Strong, reliable solder joints (lead-free)**
- **Superior corrosion protection**
  - **Creep corrosion inhibitor**
- **Reduced process cost**
  - **Low energy consumption**
  - **Dry, room temperature process**
  - **Reduced consumables**
  - **No precious metals**
- **Multiple reflow**
- **Extended shelf life**



Environmentally Responsible

- Film deposited by plasma polymerization
- No hazardous waste
- No waste water
- No solvents
- No greenhouse gases
- Non-toxic exhaust can be vented directly to the atmosphere or run through a chemical scrubber
- High throughput system (~350,000 panel/year)

Plasma Polymerization

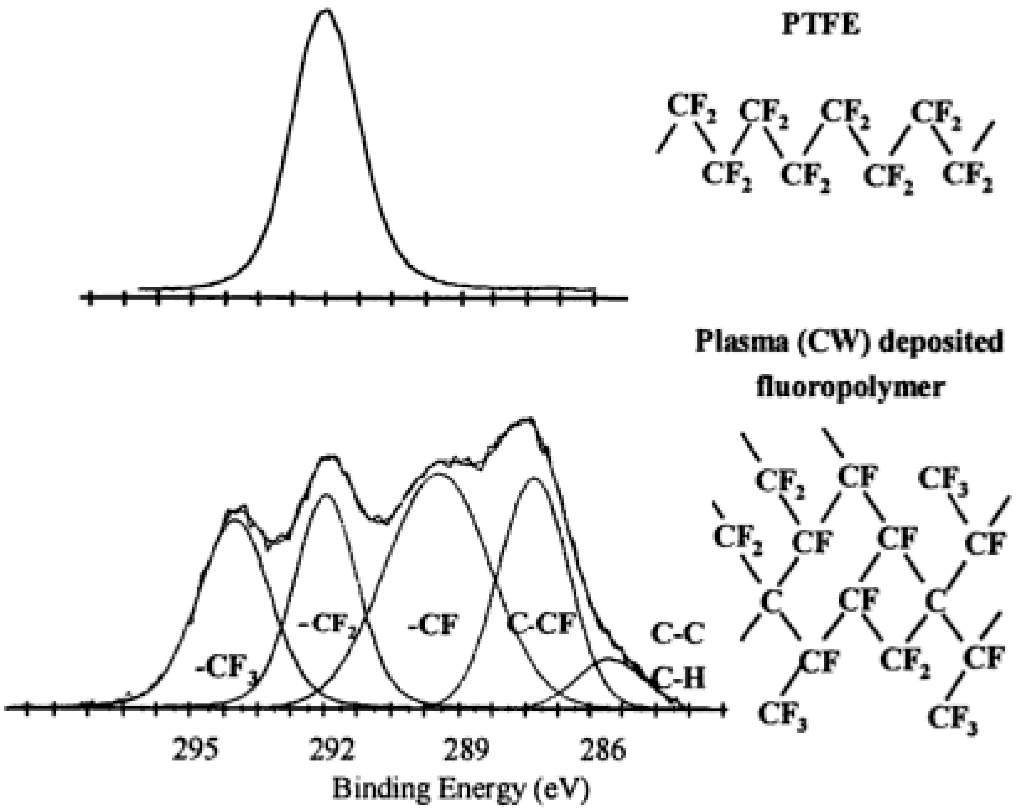


Figure 2.1. Chemical structure and ESCA (Electron Spectroscopy for Chemical Analysis) C1s spectra for PTFE and a fluorocarbon coatings plasma-deposited in CW conditions.

Ref: Plasma Polymer Films, Imperial College Press

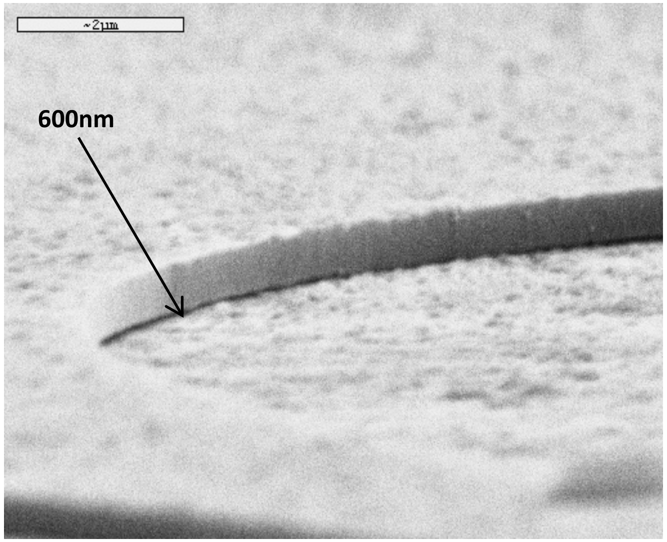
The plasma polymer is a unique class of material

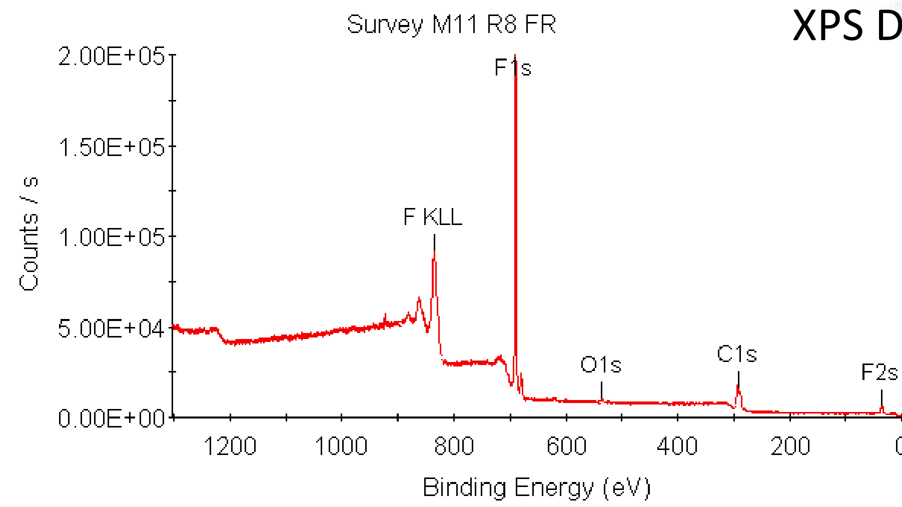
- **Conditions in the plasma chamber allow formation of structures that cannot be made using traditional polymerization reactions**
- **Plasma polymers tend to be highly cross-linked, randomly branched and contain un-reacted functionality**

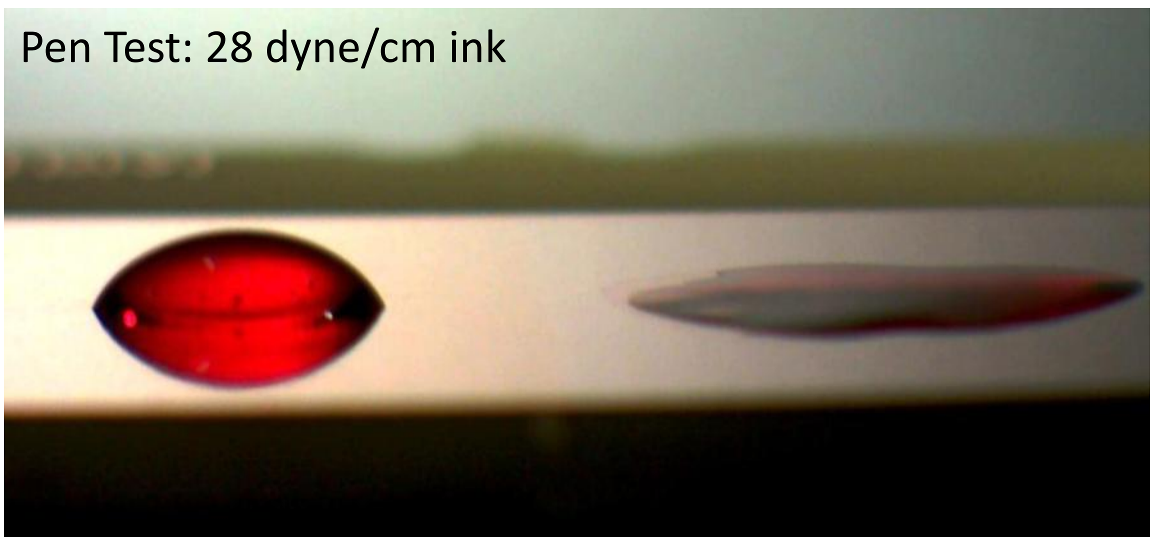
The Plasma Finish is a hybrid PTFE-like material

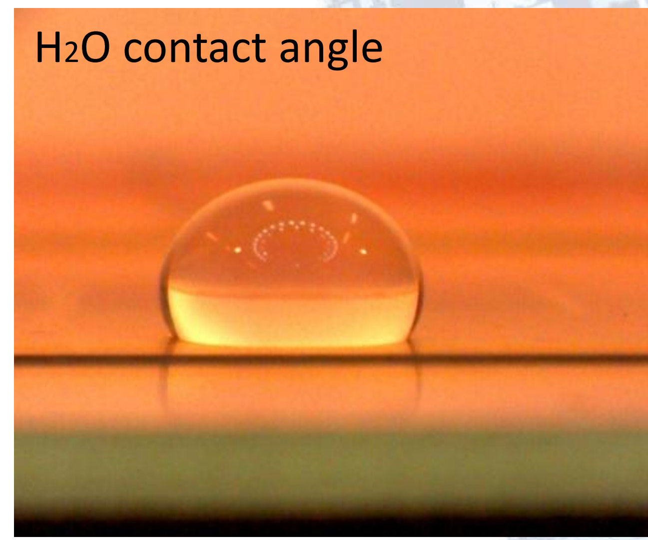
Plasma Finish retains desirable properties while allowing best quality solder joints

Plasma Coating Properties



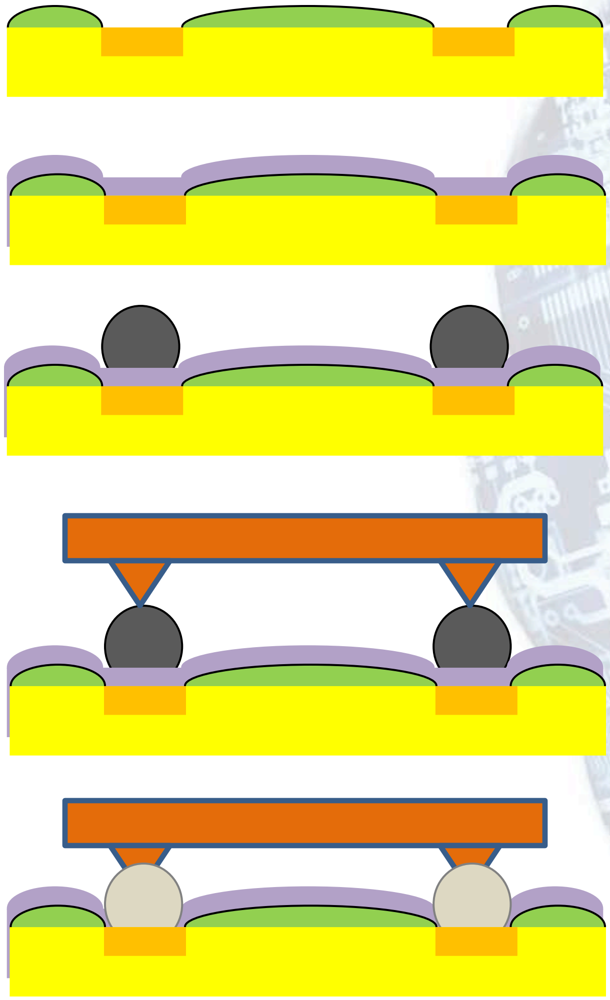






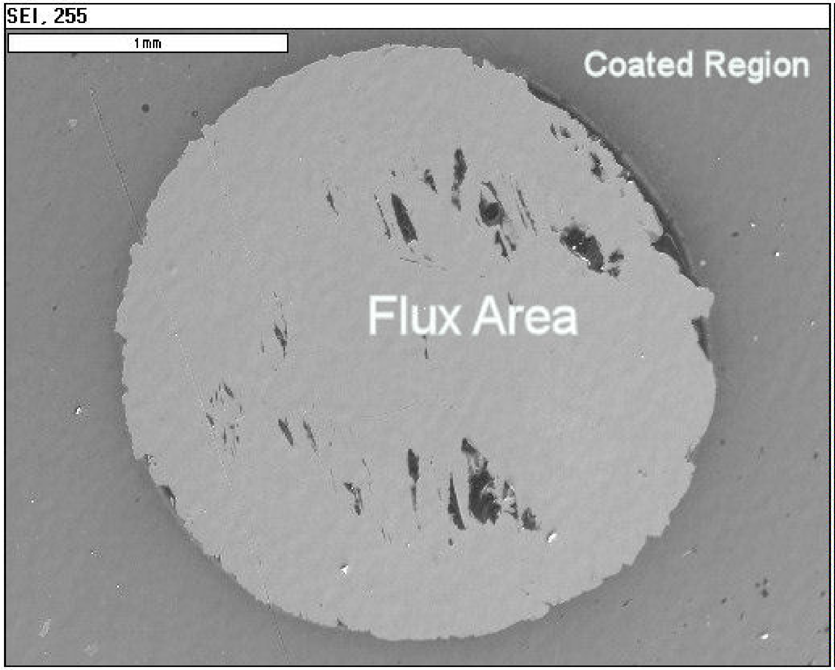
Plasma Coating - Assembly Process

- Solder Mask printed on PCB
- Plasma Coating Deposition
  - 40nm film thickness
- Solder Print
- Pick & Place
- Solder Reflow
  - Heat + Acidic Flux removes SPF

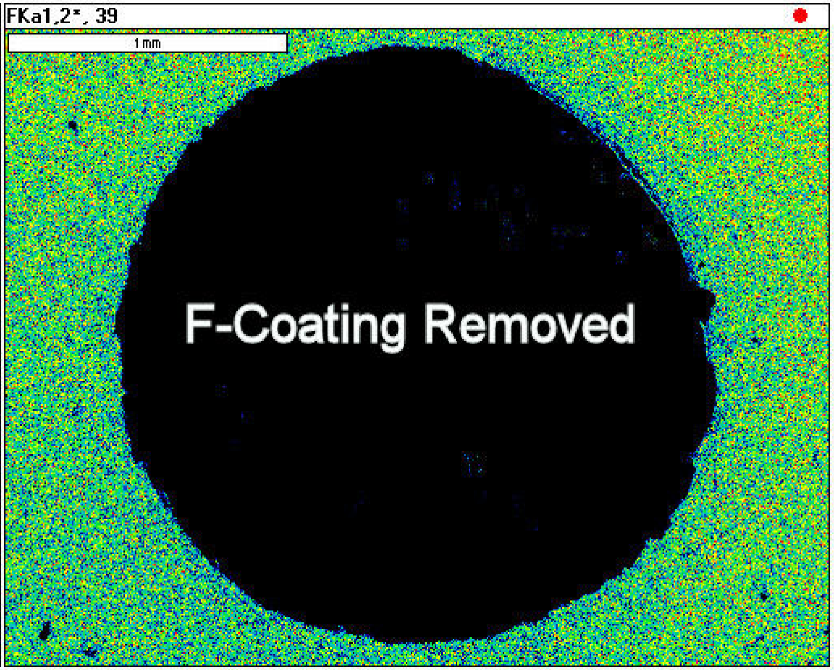


Plasma Coating Removal by Flux + Heat

- Copper test coupons with Plasma Coating
- Liquid Flux + reflow
- Remove Flux and elemental analysis of surface



SEM



BEI – Back-Scattered Electron Image

PLASMA COATING CLEANLINESS

Ionic Cleanliness
Surface Insulation Resistance
Electrochemical Migration – bare PCB

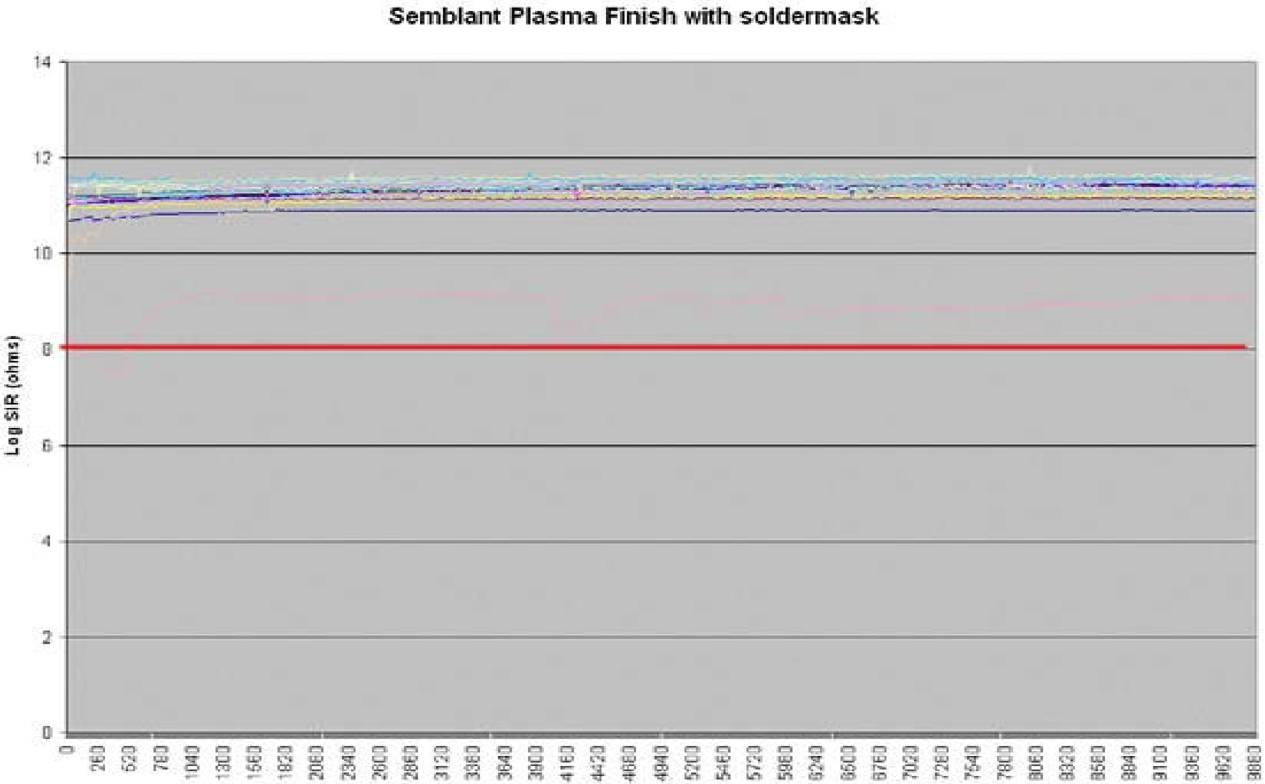
Ionic Cleanliness / Surface Insulation Resistance

Ionic cleanliness as per IPC TM – 650 2.3.28
Limit = 10ug/cm2

Table 1 – Anionic Contaminants on Surface of Circuit Board
Results in $\mu g/cm^2$

Sample ID	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}
Control	<0.01	0.01	<0.01	0.02	0.02	<0.01	0.02
Sample 1	0.94	0.02	<0.01	0.20	<0.01	<0.01	0.05
Sample 2	0.27	0.04	<0.01	0.43	<0.01	<0.01	0.02

SIR: Temperature-humidity-bias (THB) test 40C/93%RH at 12VDC for 168 hours



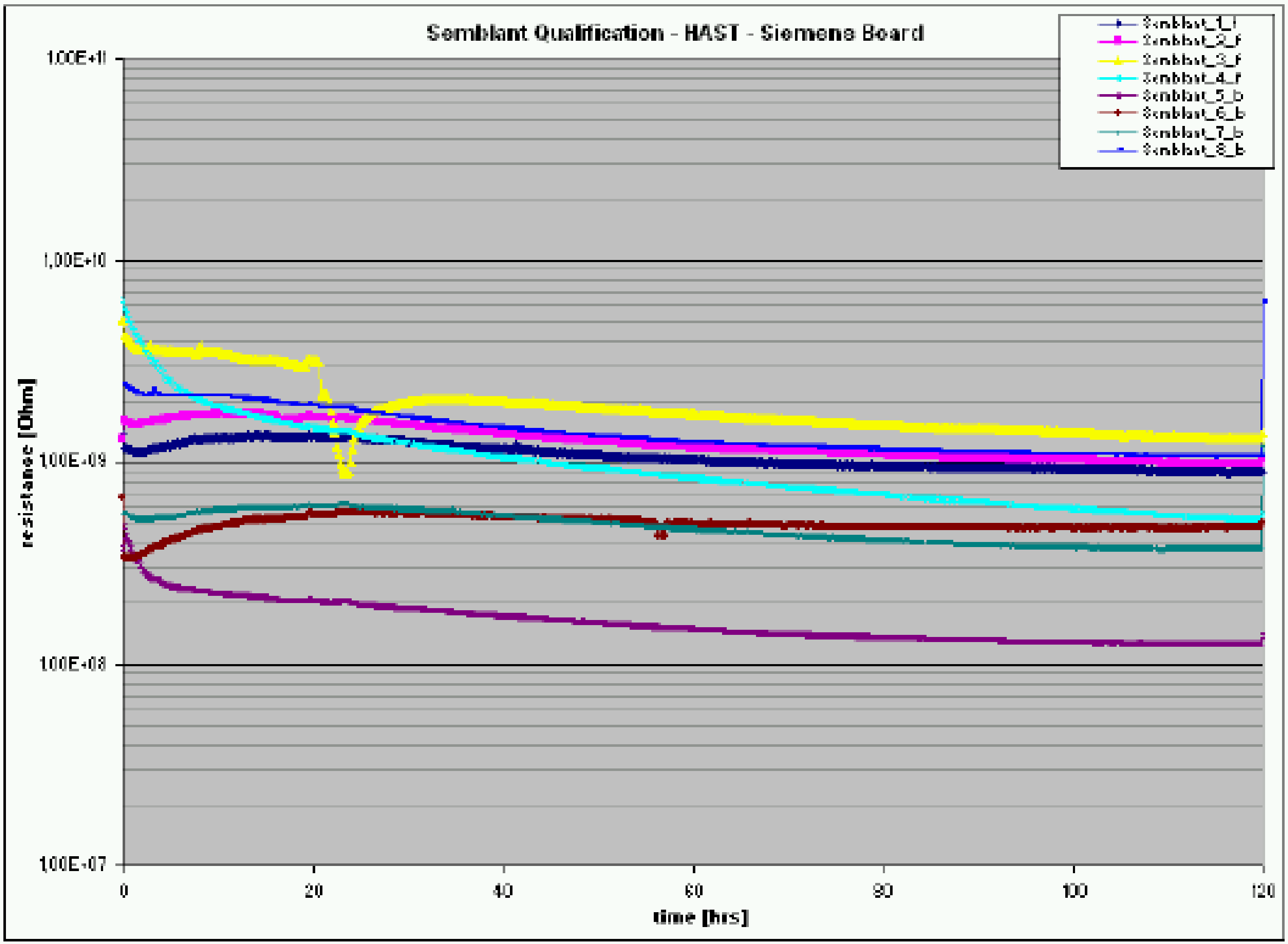
Electrochemical Migration Testing at bare PCB

- **ECM testing of SPF coating has been completed to confirm that SPF does not cause ECM**
- **No testing completed on PCB assemblies to determine if SPF prevents ECM**

Test Parameter:

	Siemens Board
Pretreatment	NA
Test Parameter	130°C/85%RH/3,5VDC/120hrs
Pass/Fail Criteria	insulation resistance optical inspection
Tested Structures	4 line-2-line structures front 4 line-2-line structures back

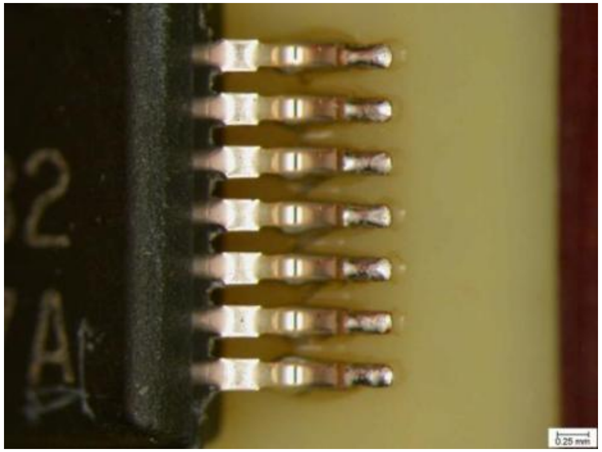
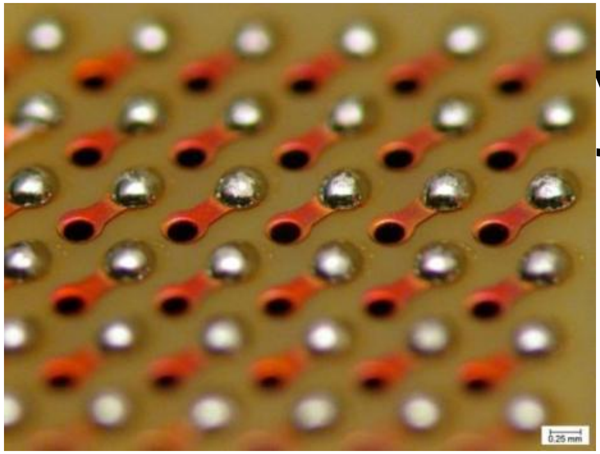
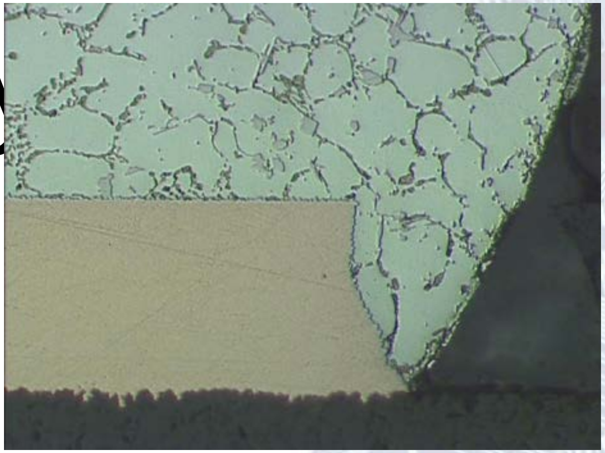
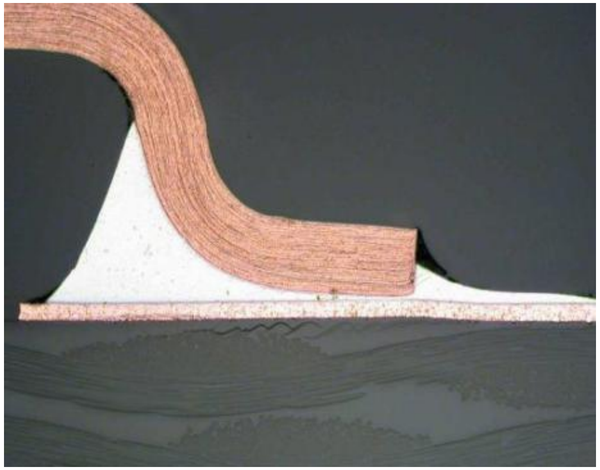
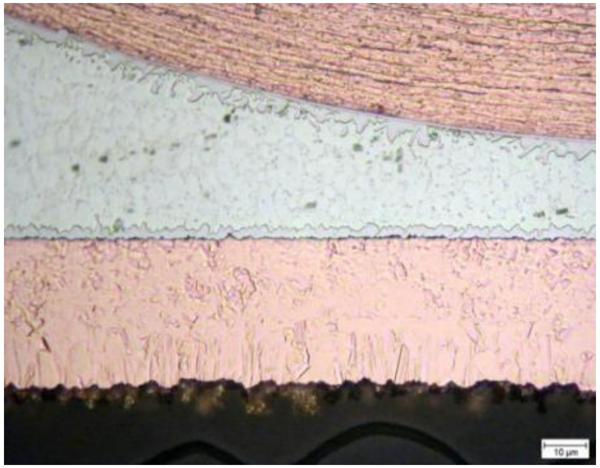
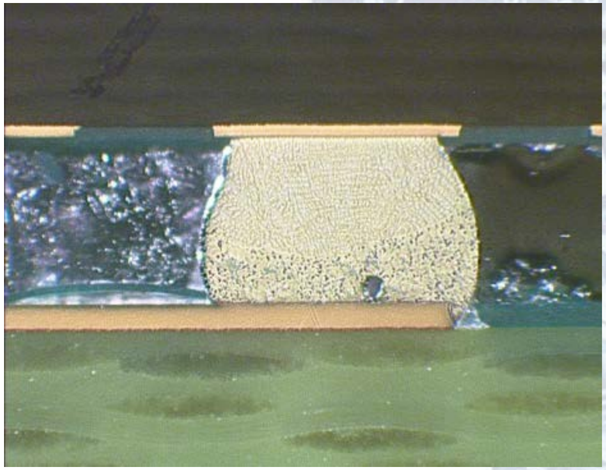
ECM Testing at bare PCB level



Resistance measured between the Copper traces

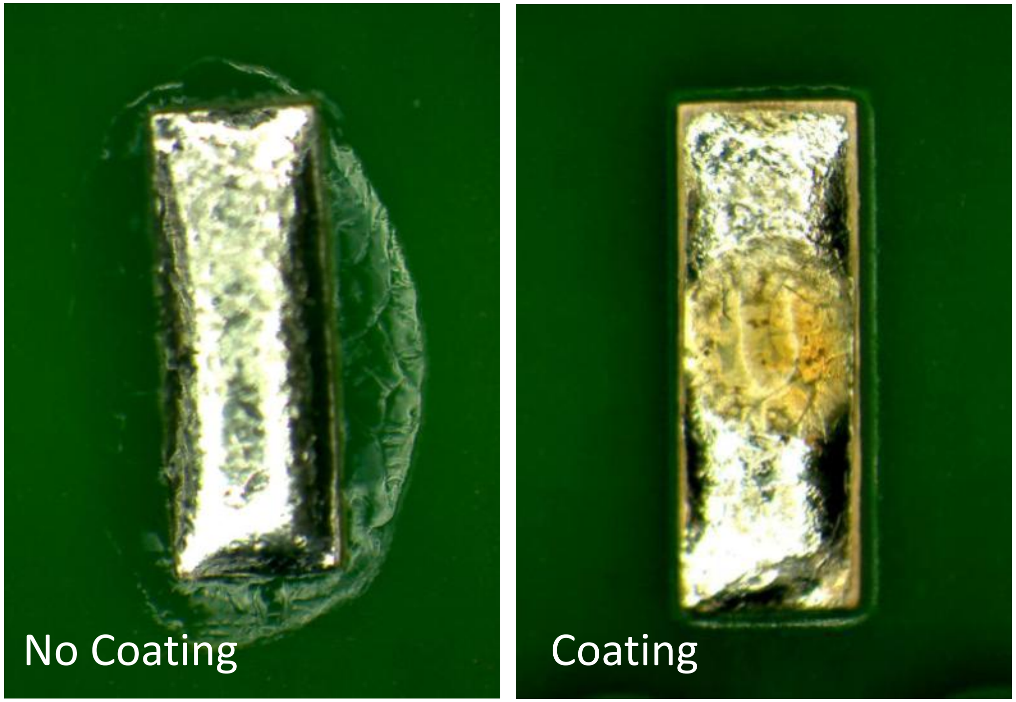
- No significant drop in resistance over time
- Insulation resistance ≥ 100 Mega Ohm

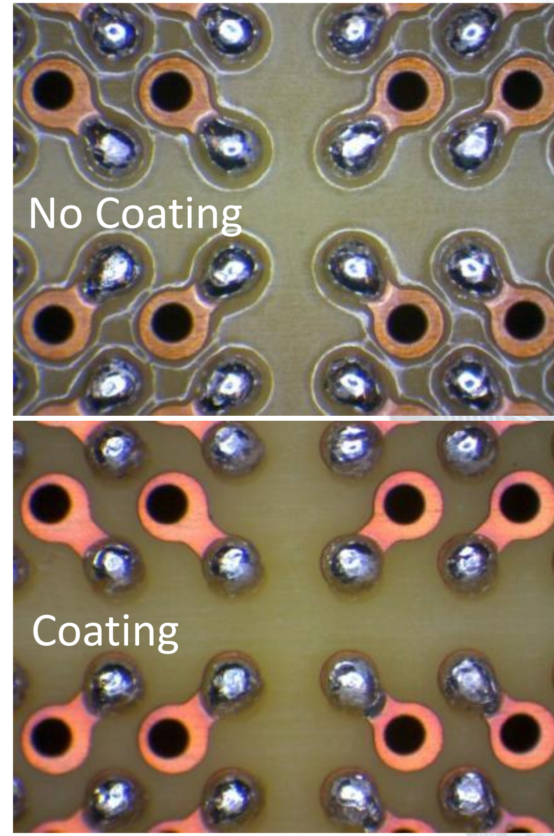
SOLDERABILITY

BGA pictures courtesy of Rockwell Collins

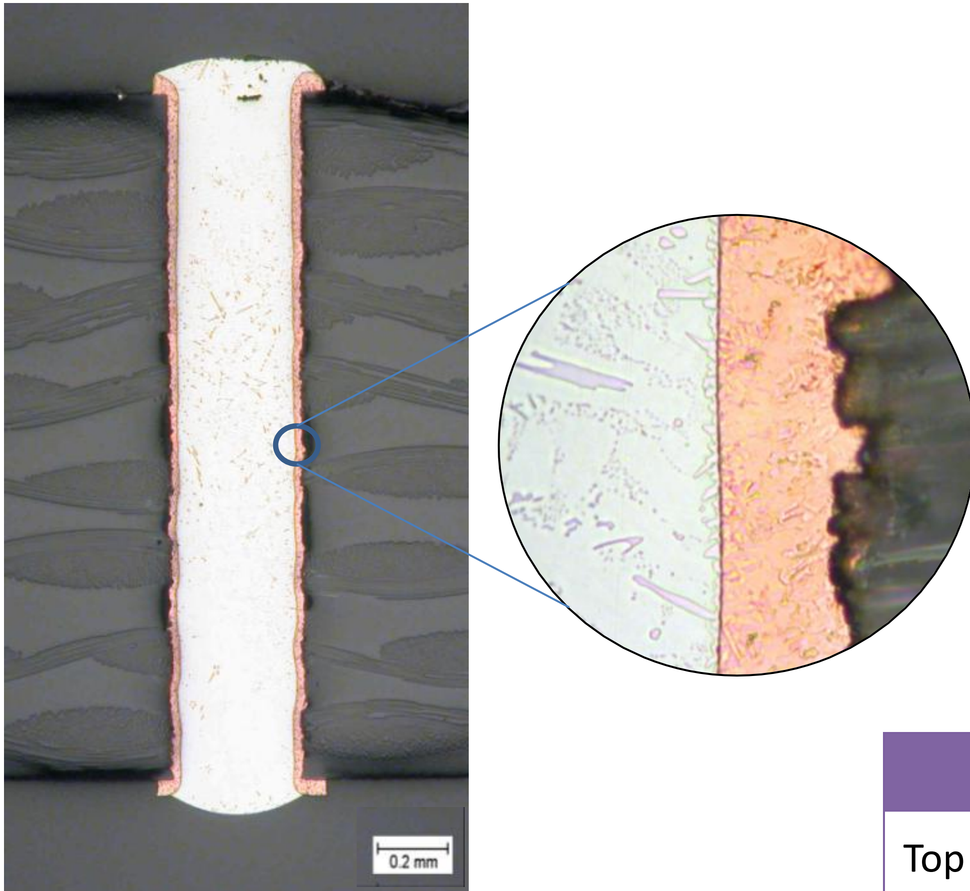
Flux Residue





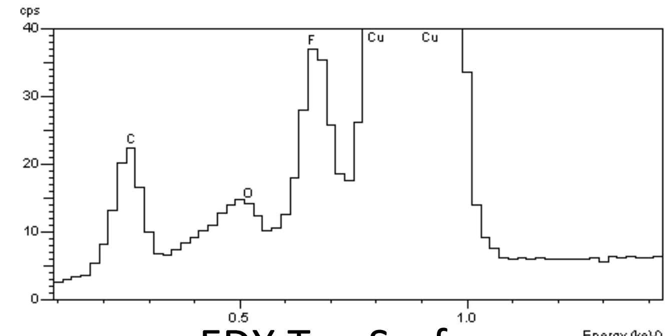
- Hydrophobic nature of the plasma coating prevents flux from spreading along surface
- Flux residue remains on surface of solder, possibly reducing requirement for cleaning

Solderability - Via Fill

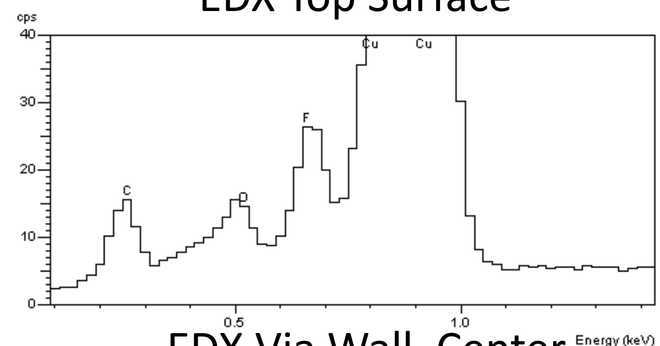


Aspect ratio: 5:1

Coating Thickness Through Via



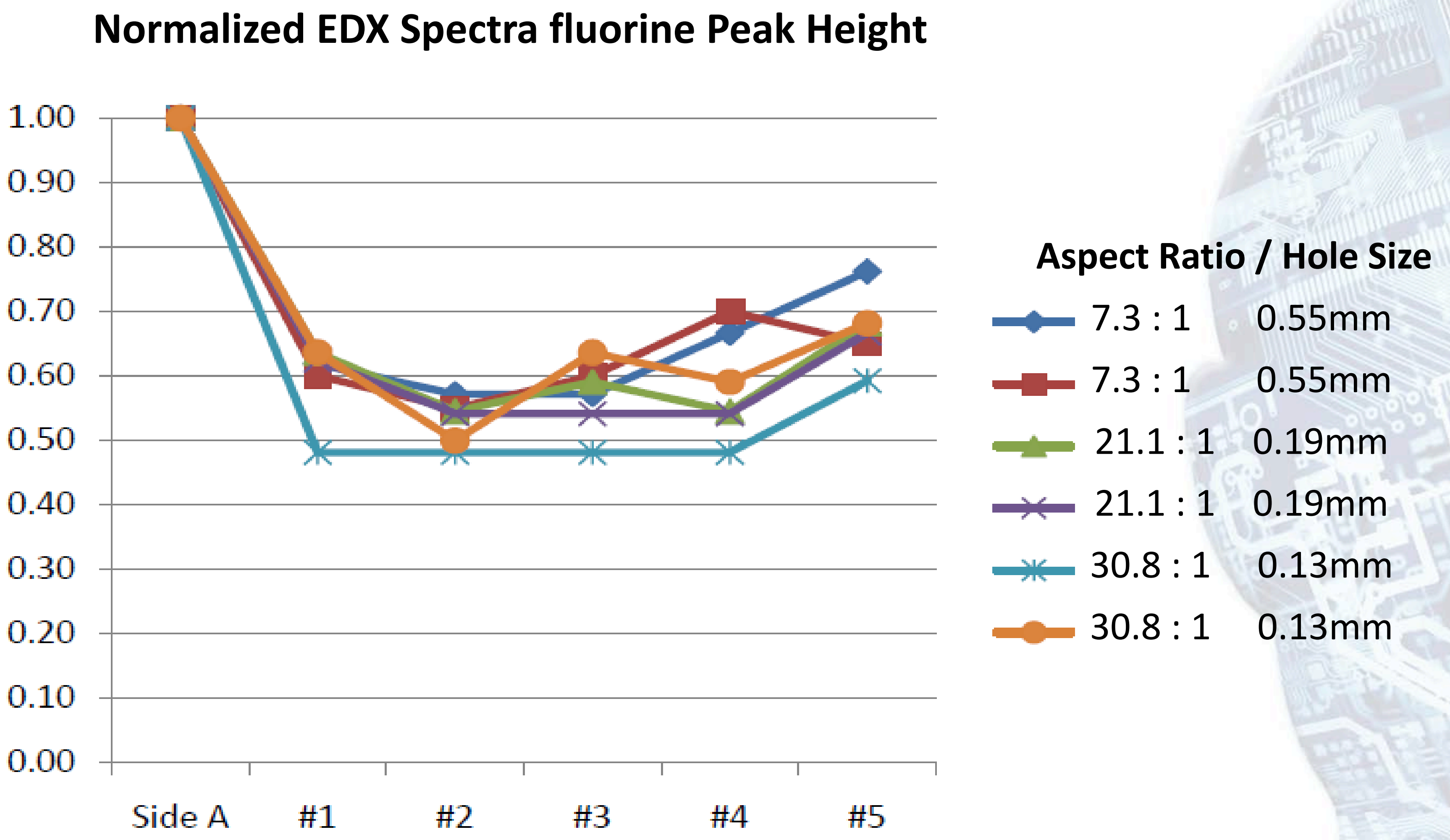
EDX Top Surface



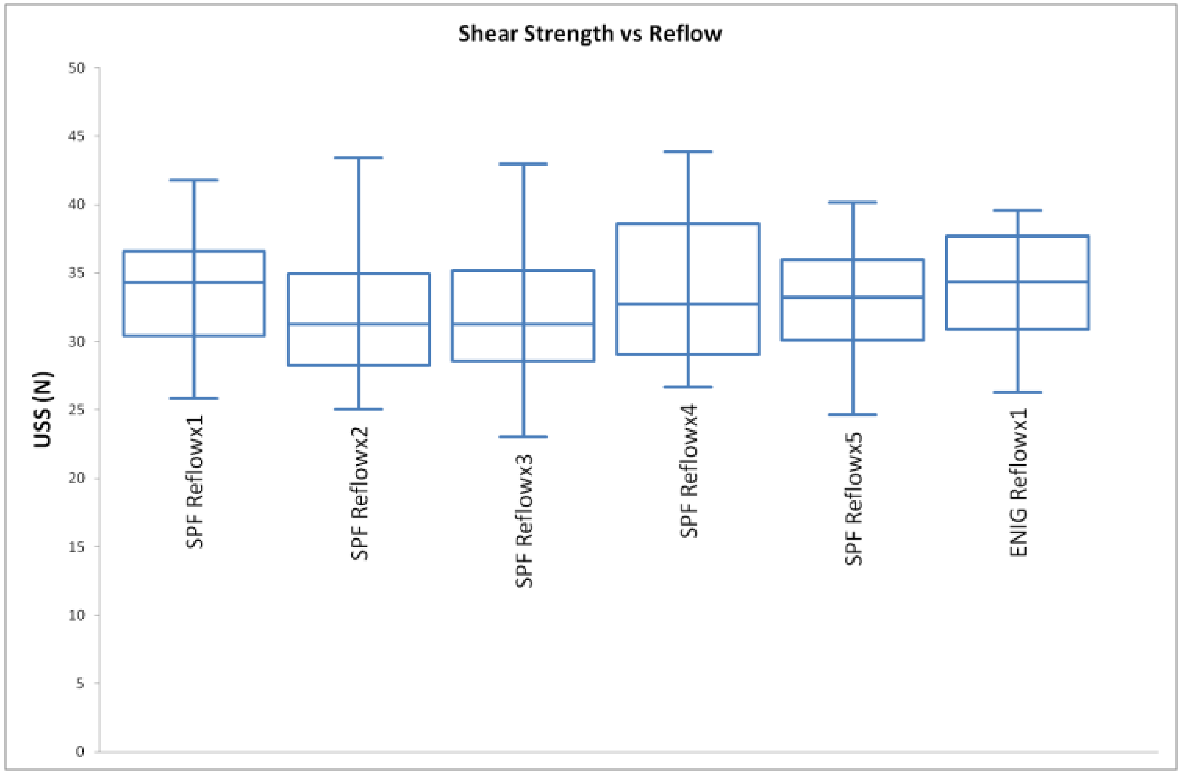
EDX Via Wall, Center

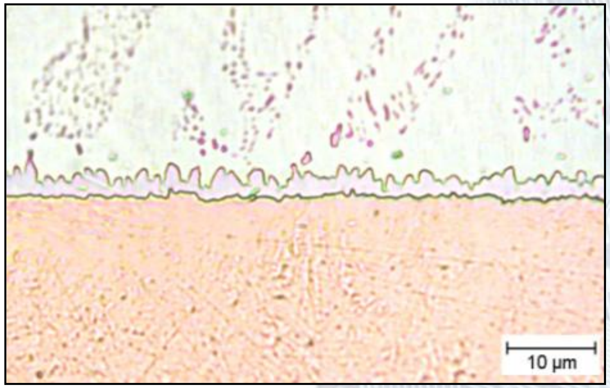
	F (cps)	% of full coating
Top Surface	38	100
Via Wall, Center	27	73

Via Hole Deposition

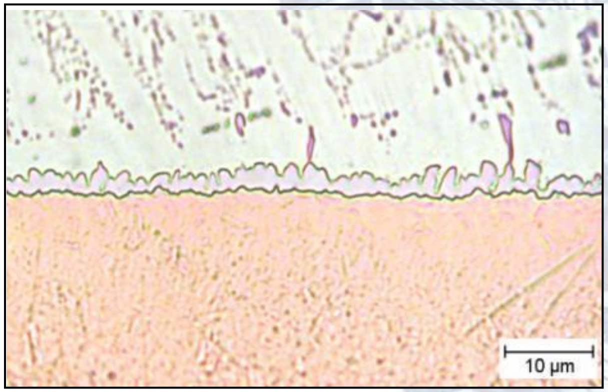


Solder Joint Strength - 5 Reflows





1st reflow

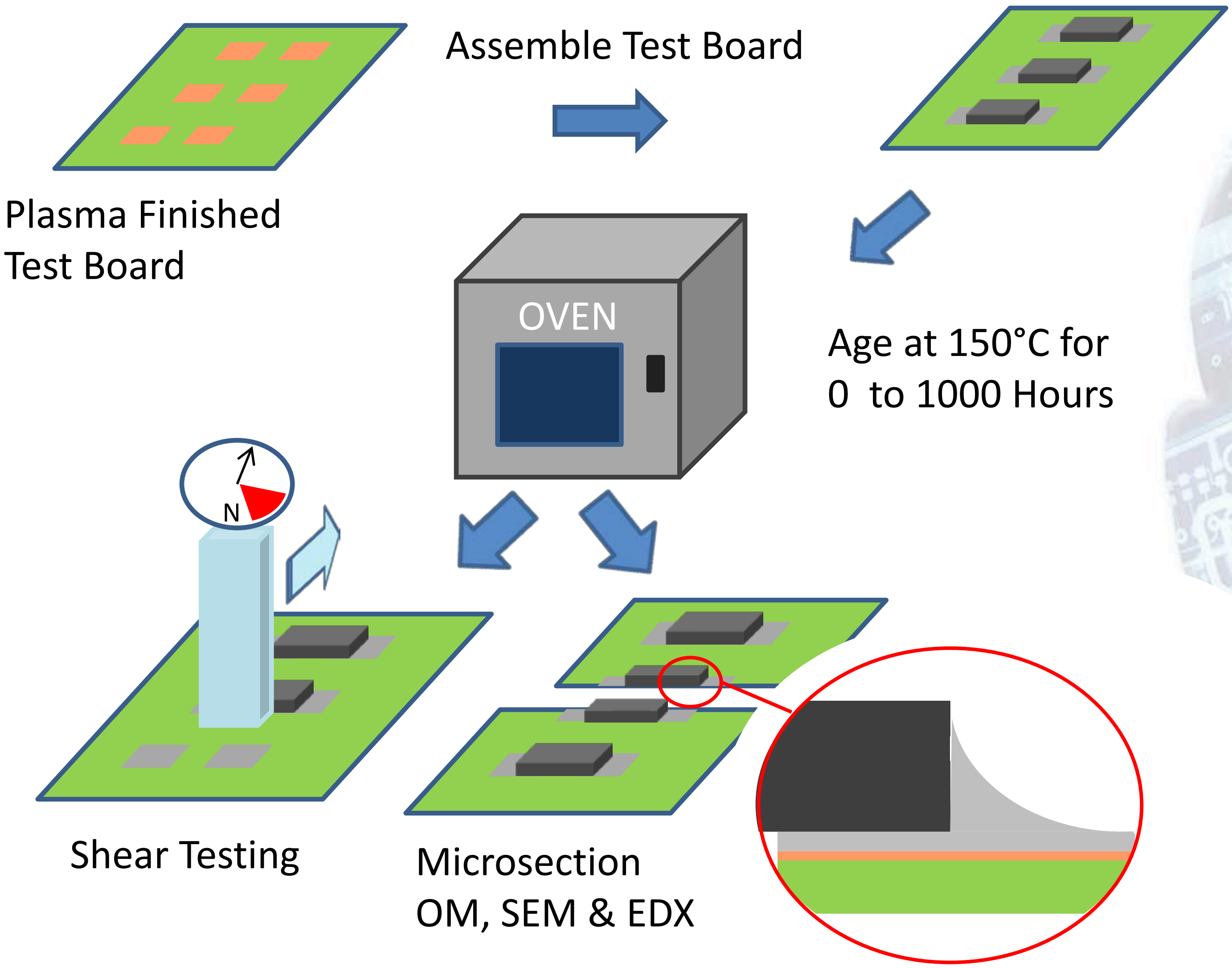


5th reflow

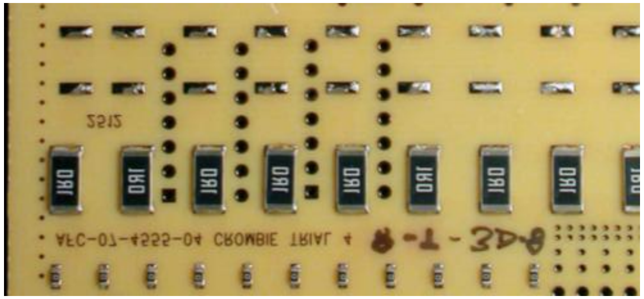
- Multiple reflows have no impact on shear strength

SOLDER JOINT RELIABILITY

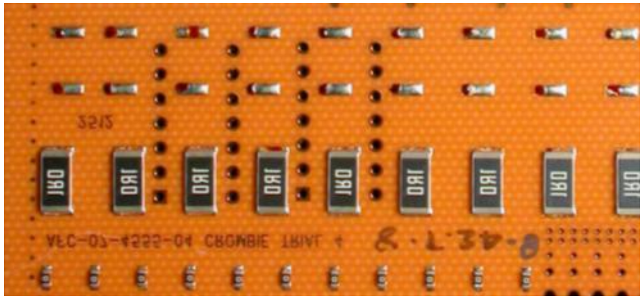
Joint Reliability Testing



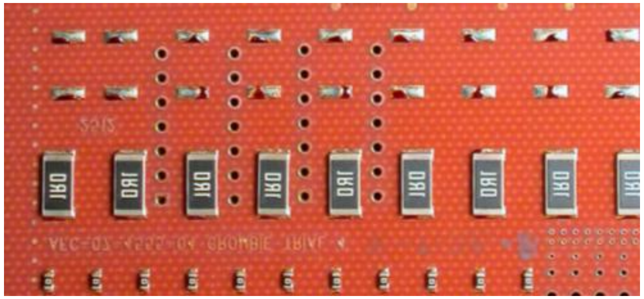
Reliability Test: 1000 hrs at 150C



0 hrs

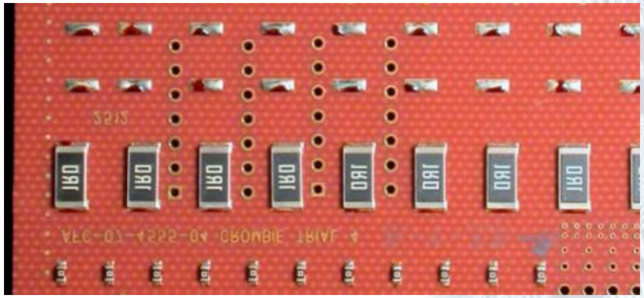


200 hrs

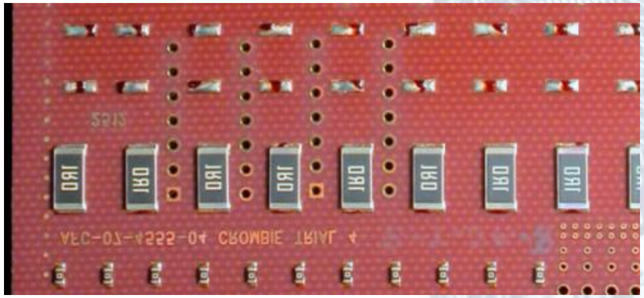


400 hrs

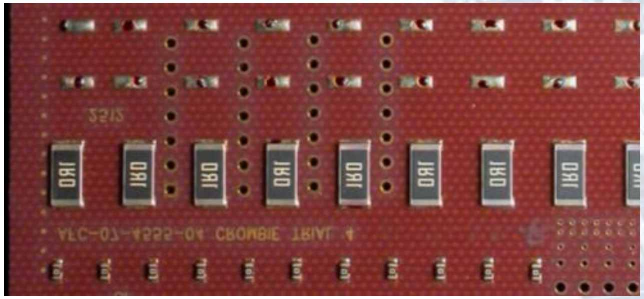
600 hrs



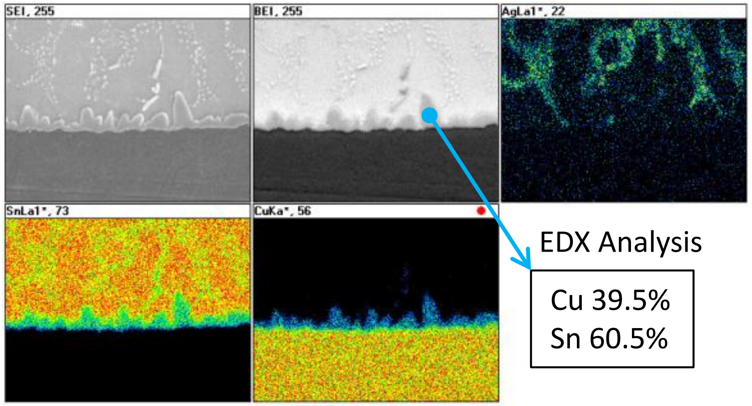
800 hrs



1000 hrs



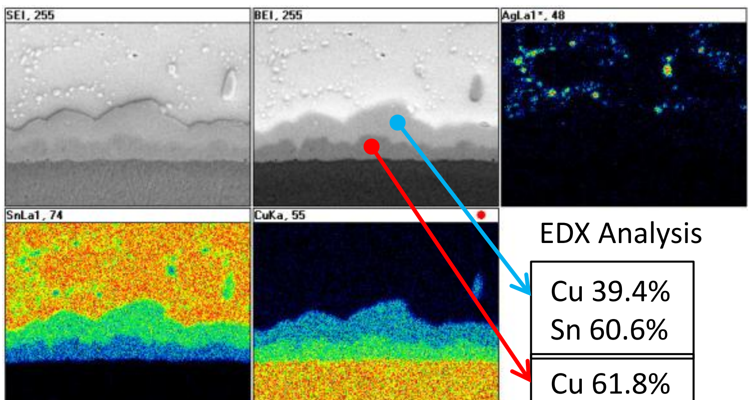
Reliability Test: 1000 hrs at 150C



EDX Analysis

Cu 39.5%
Sn 60.5%

Aging time 0 hours

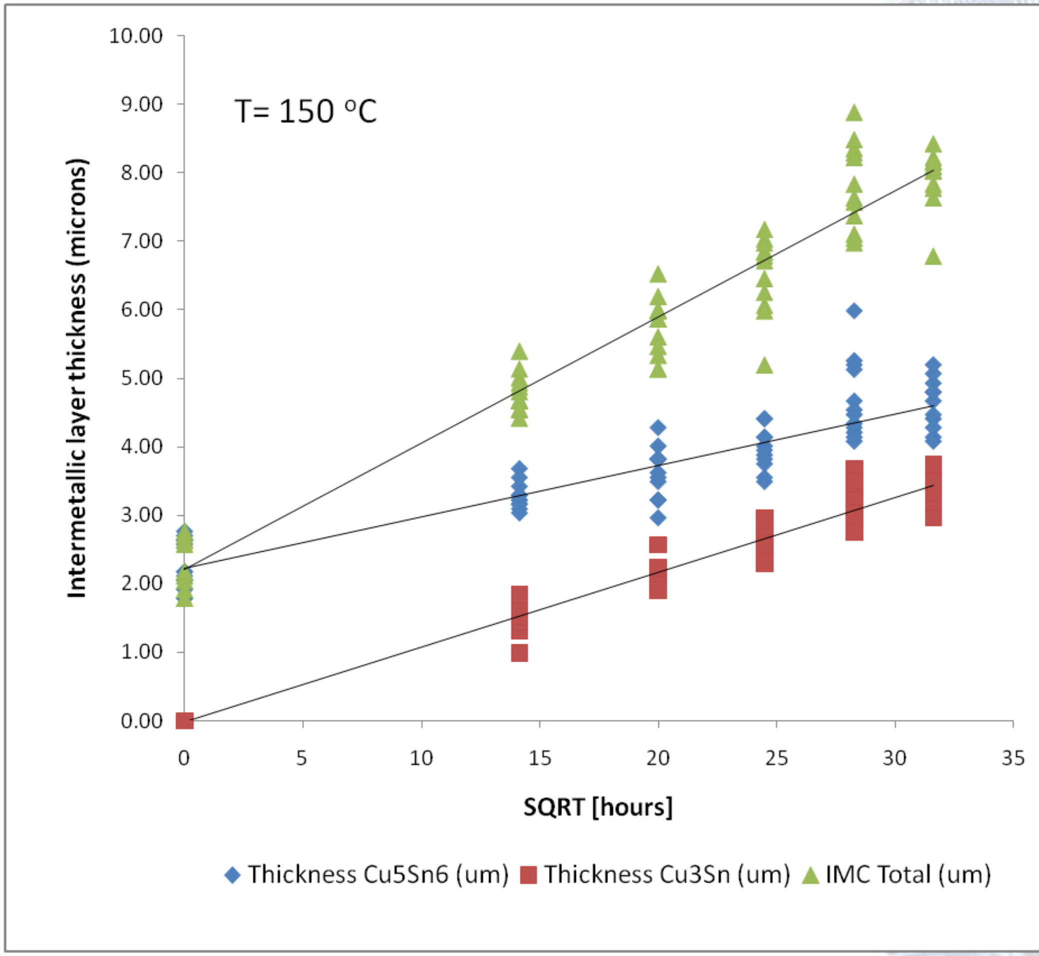


EDX Analysis

Cu 39.4%
Sn 60.6%

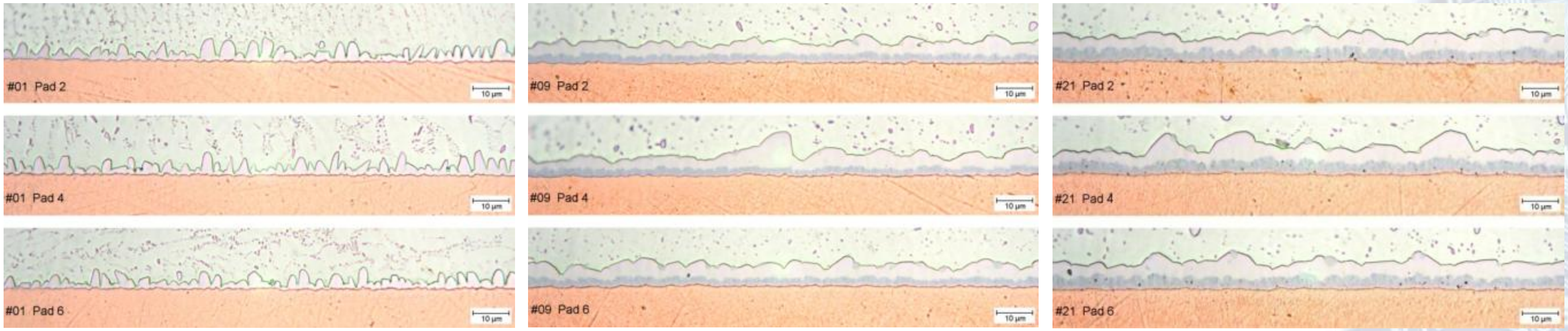
Cu 61.8%
Sn 38.2%

Aging time 1000 hours



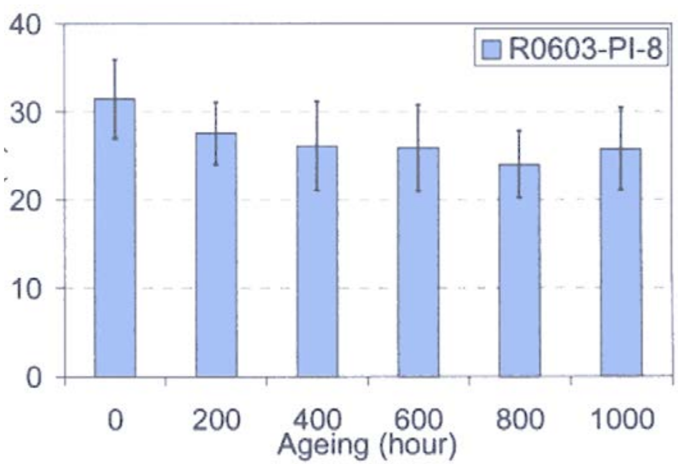
Reliability Test: 1000 hrs at 150C

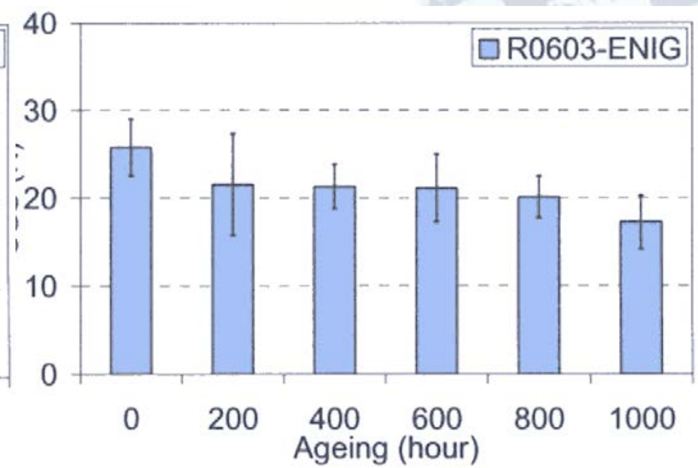
Cross Section OM 1000x of Solder Copper Interface (Quantum MicroMet)



0 Hours | 400 Hours | 1000 Hours

Ultimate Shear Strength Test on R0603 resistors (NPL)





Contact Resistance

Testing & results courtesy of Rockwell Collins

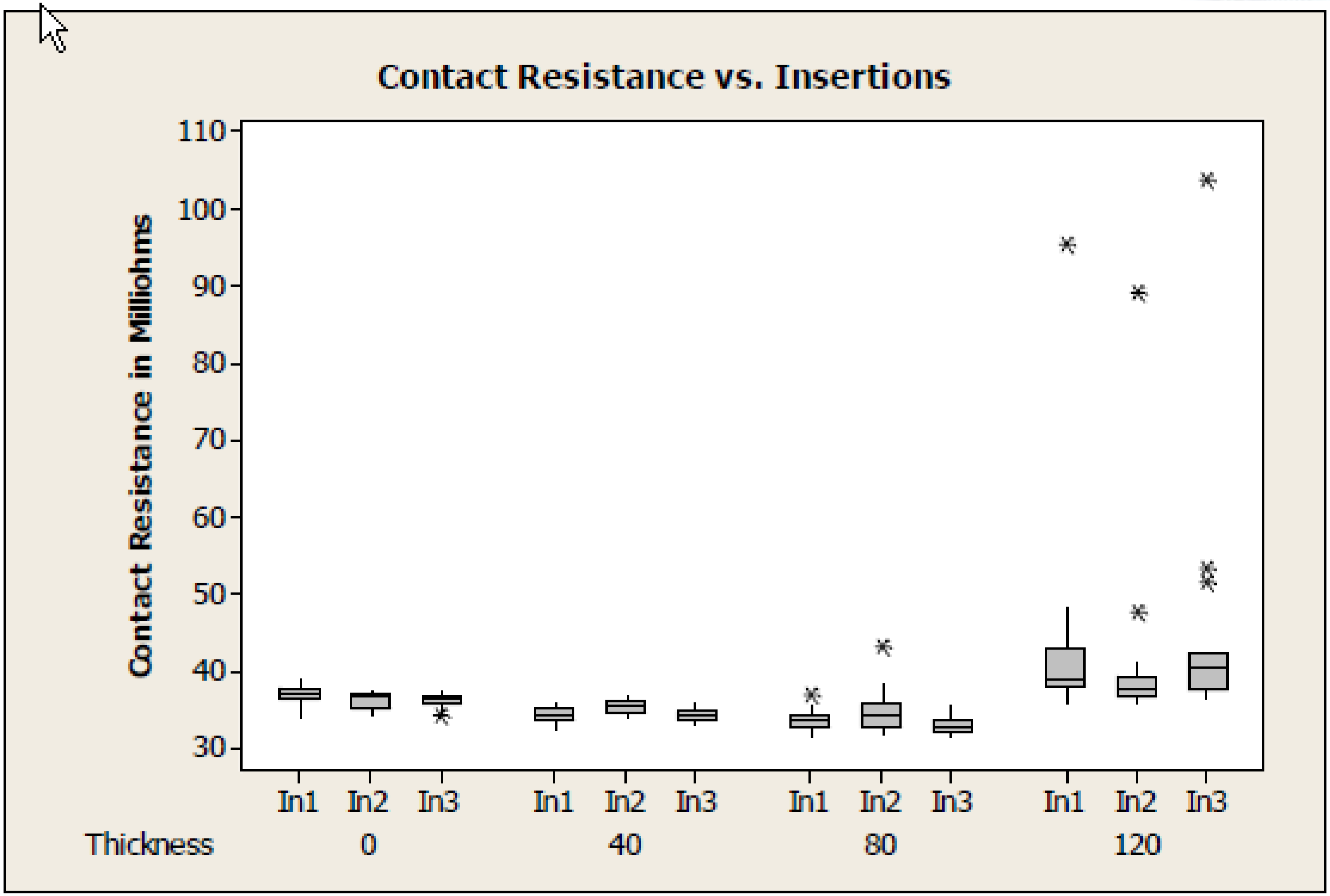
Contact Resistance

- A connector card was designed to mate to a Cinch Connector which is a 32 position edge card connector with gold contact fingers
- Sample setup
  - Control – no SPF
  - 40 nm SPF
  - 80 nm SPF
  - 120 nm SPF
- Contact resistance was measured using a calibrated low resistance multimeter (Agilent 34401) which used a four-point measurement method to overcome the resistance inherent in the test leads
- 3 insertions for each sample were measured
- Control sample was remeasured after 3 insertions of each SPF sample to check for build up of SPF material on the contact fingers of the connector

Contact Resistance Setup

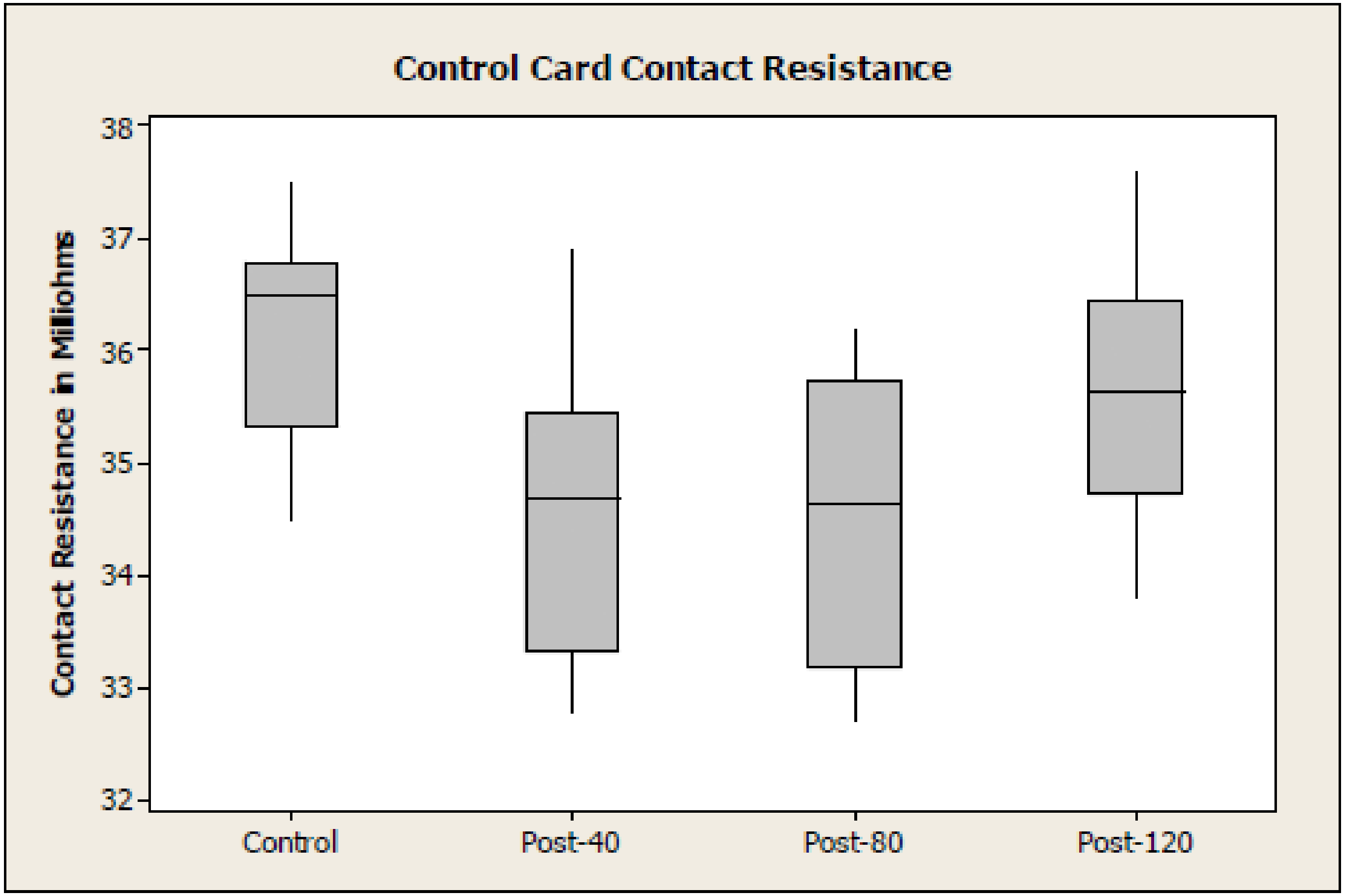
Contact Resistance

- Each box plot represents 16 measurements
- 40nm SPF does not effect contact resistance



Contact Resistance - Control

- **There is no appreciable buildup of the SPF coating on the edge card contact fingers after multiple insertions of SPF coated cards**



Contact Resistance Conclusions

- 40 nm coating does not cause an increase in contact resistance
- 80 nm coating - the spread of the data starts to increase to some extent. The overall contact resistance is still low, well within the normal variation of a connector contact resistance
- 120 nm coating - the variability in the data grows, with several outliers present. The contact resistance was still less than 110 milliohms
- There is no appreciable buildup of the plasma coating on the edge card contact fingers after multiple insertions of plasma-coated cards

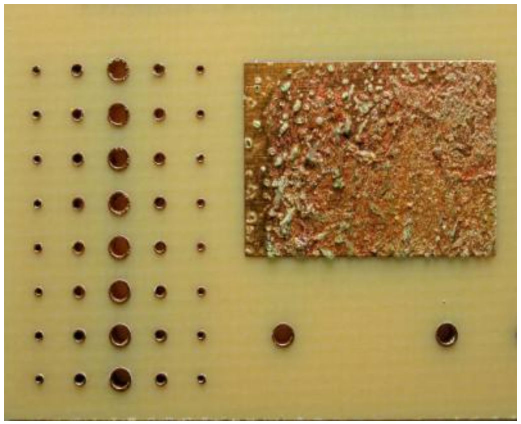
CORROSION RESISTANCE

Fluoropolymers are among the most chemically inert of all polymers and remain stable in almost all chemical environments.

- **Gas Phase SO2 Corrosion**
- **Mixed Flowing Gas**
- **Sulfur Clay**

Corrosion Resistance – Gas Phase SO_2

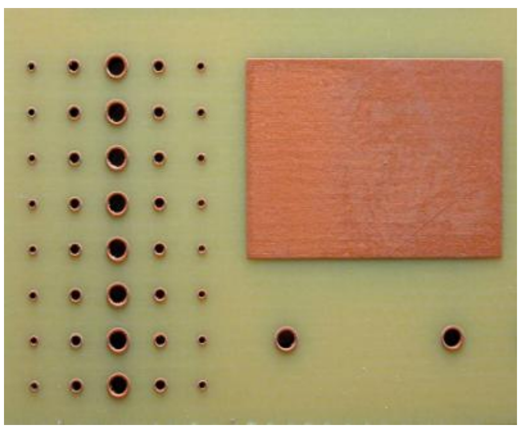
Gas phase SO_2 Test – Buffered Na_2SO_3, for 24 hours,   RH~80% at 41.5^oC



ENEPIG board

ENIG board

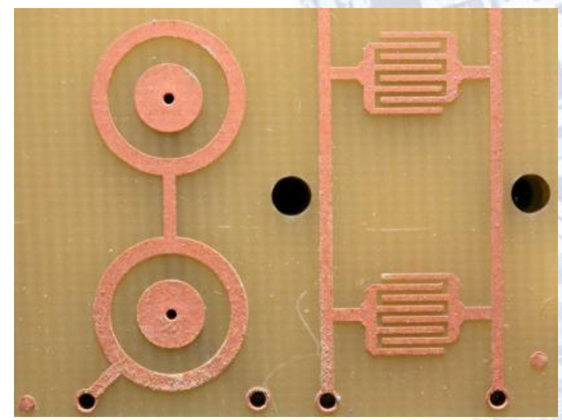
After 2 reflows



Plasma finished sample

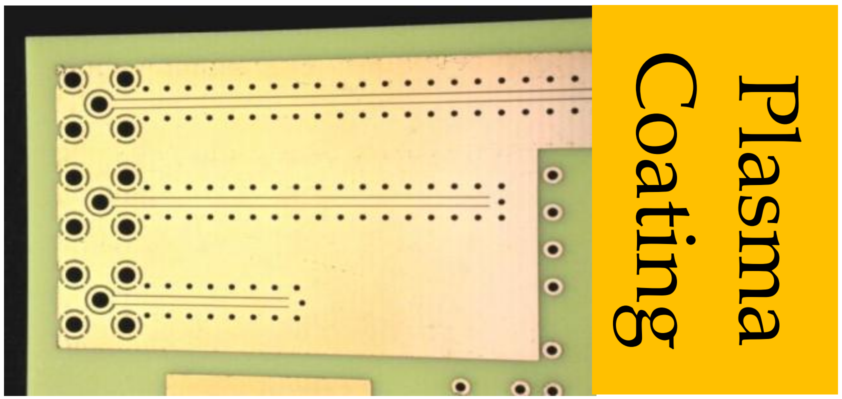
As coated

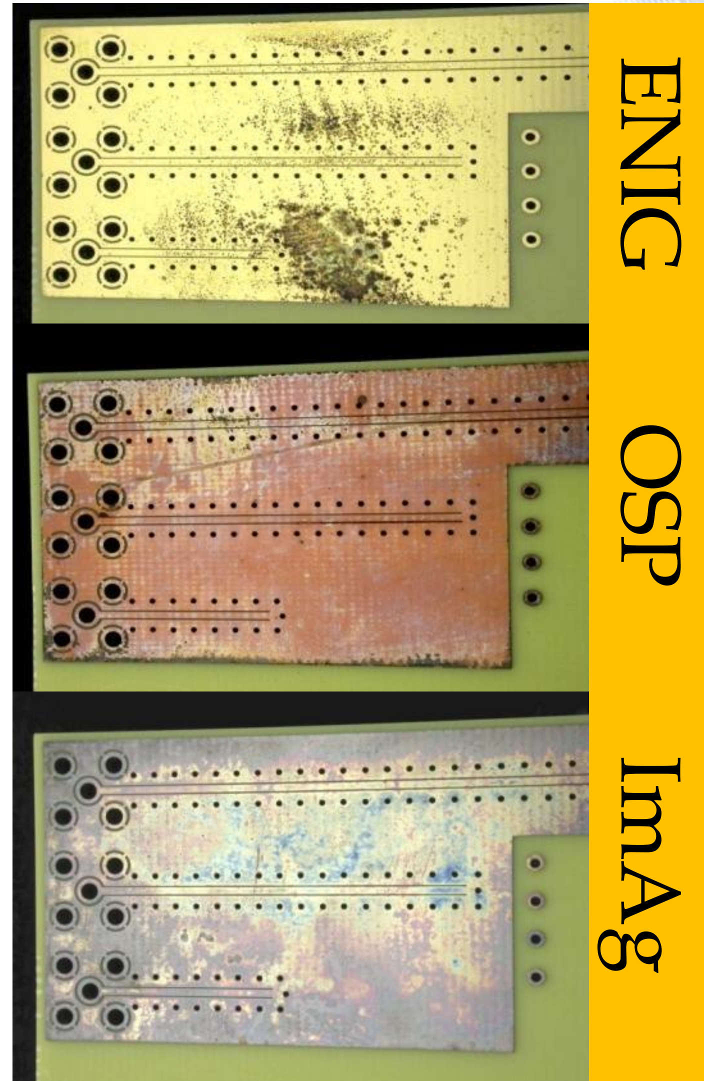
After 2 reflows



Mixed Flowing Gas: University of Limerick Stokes Institute

°C	% RH	Days	H_2S	SO_2	NO_2	Cl_2
30	70	20	100 ppb	200 ppb	200 ppb	20 ppb





% Surface Corrosion

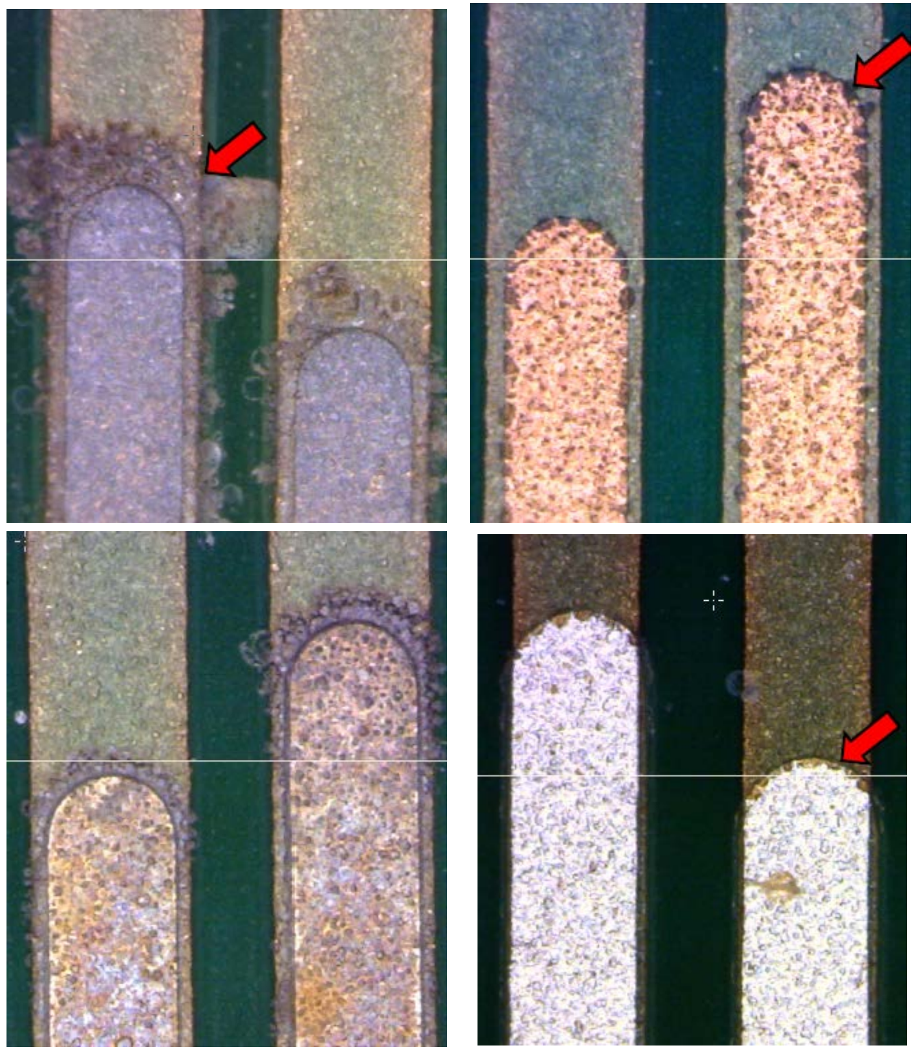
Exposure Time (days)	ENIG	OSP	ImAg	Plasma
5	4	9	90	0
10	10	17	100	0
15	25	33	100	1
20	30	44	100	3

Plasma Coating finish still acceptable at simulated 20 year life

Sulfur Clay Testing – 7 Days

Cu

Cu + Plasma Coating



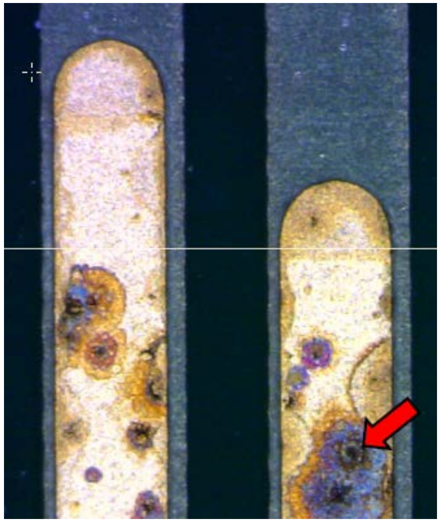
ImAg

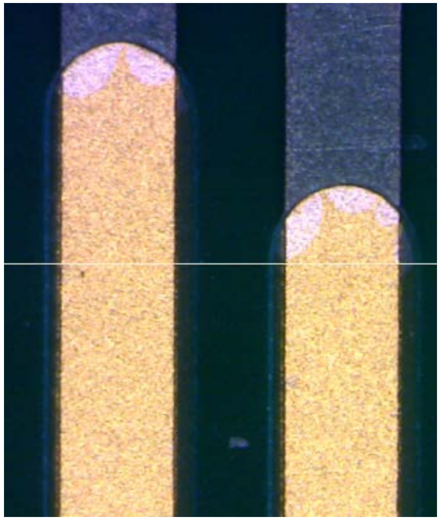
ImAg + Plasma Coating

Testing completed by DfR Solutions

Sulfur Clay Testing – 7 Days

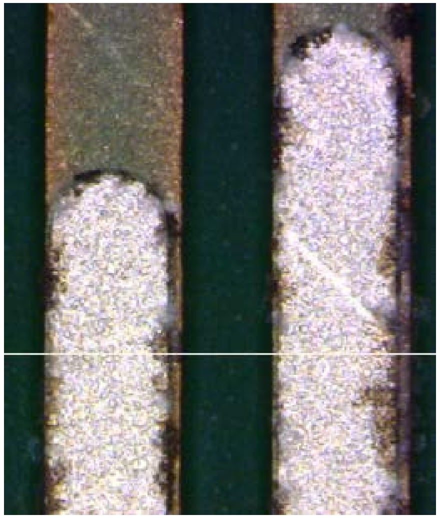
Hi P ENIG

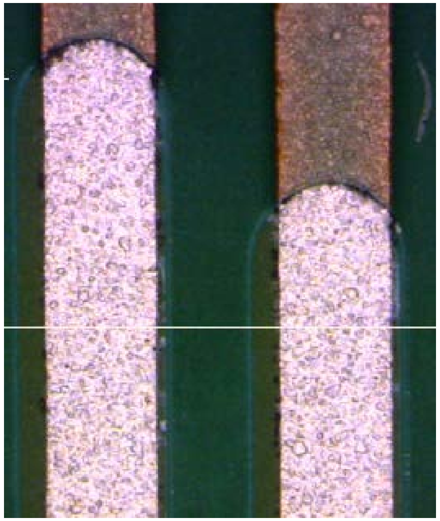




Hi P ENIG + Plasma Coating

ImSn



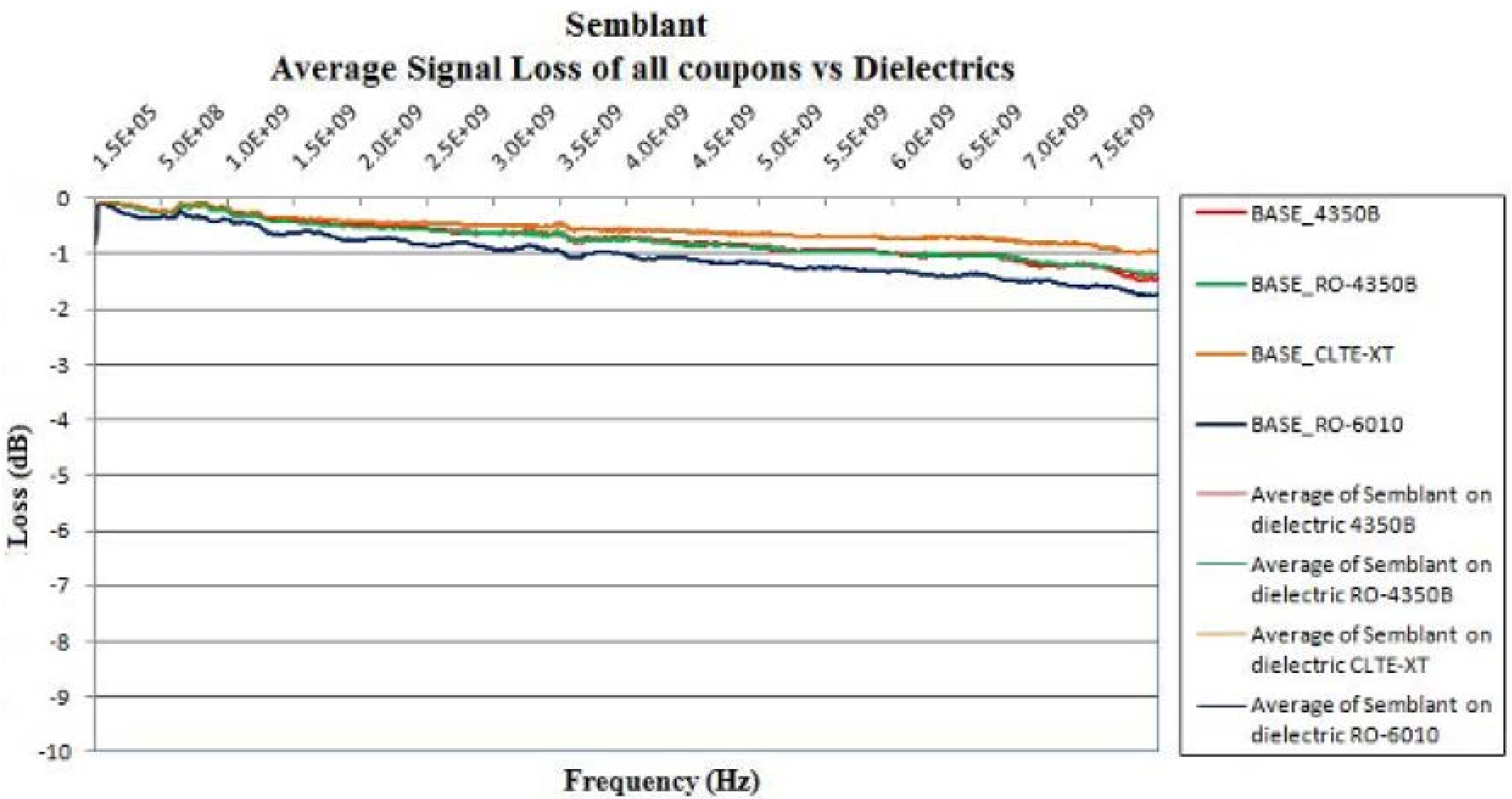


ImSn + Plasma Coating

Testing completed by DfR Solutions

RF Signal Loss

Plasma Coating caused no impact on signal loss for high RF up to 10 GHz (test limit)



Courtesy of Rockwell Collins

Summary

- New patented technology for surface finish
- Environmentally friendly
  - No hazardous gases
  - No hazardous waste
- Simple, controllable, reworkable process
- Excellent solderability
  - Multiple reflow
  - Good reliability and shear strength
- SPF coating does not affect contact resistance
- Superior corrosion resistance
  - SO_2 gas phase corrosion
  - Mixed flowing gas
  - Creep Corrosion
- No impact on high RF signal loss