iNEMI®
International Electronics Manufacturing Initiative

Investigation of Factors That Influence Creep Corrosion

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IMPACT, Taipei
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Advancing manufacturing technology

Thrust Area: Miniaturization TIG: Board Assembly	Creep Corrosion Project Current in Phase 3: Investigation of Factors That Influence Creep Corrosion	Nov-11

Goal: Phase 3: Understand the sensitivities of the identified factors to Creep Corrosion. Correlate experimental test conditions to environment classification standards.

Strategy

- Survey of the occurrence of creep corrosion in the industry
- Inclusive of global applications
- Investigation of environmental conditions related to creep corrosion (temperature, relative humidity, atmospheric concentration of sulfide)
- Investigation of the surface finishes related to creep corrosion
- Investigation of manufacturing factors related to the incidence of creep corrosion (e.g. flux, processing, operations)

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Project Co-Lead: Mason Hu, Cisco; Simon Lee, Dow

Issues

- Due to RoHS transition, the SnPb based PWB finish will move to Pb-free compatible finishes
- Corrosion of electronics in many areas in Asia
- However, there is very little agreement on the test methods and conditions
- This project seeks to establish a standard test methodology to facilitate further investigation of this problem.

Graphics

Tactics

- Phase 1 Survey to collect the data on creep corrosion failures and related factors in the electronics industry
- Phase 2 Use the output of Phase 1 to analyze and understand the root cause of creep corrosion
- Phase 3 Investigate the factors that influence creep corrosion, using adjusted MFG test conditions.

Milestones and/or Deliverables	Plan	Actual
Phase 1 Survey	May '10	Done
Phase 2 Identify factors & establish experimental plan	Nov '10	Done
Phase 3 Experiments to Investigation of Factors That Influence Creep Corrosion	Jan '12	On going

For more information of this project, visit http://www.inemi.org/project-page/creep-corrosion-phase-3

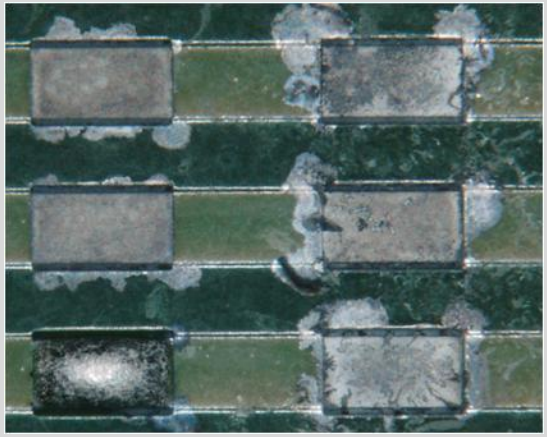
Project Members
Phase 1: Industrial Survey
Phase 2: Primary Factors to Creep Corrosion

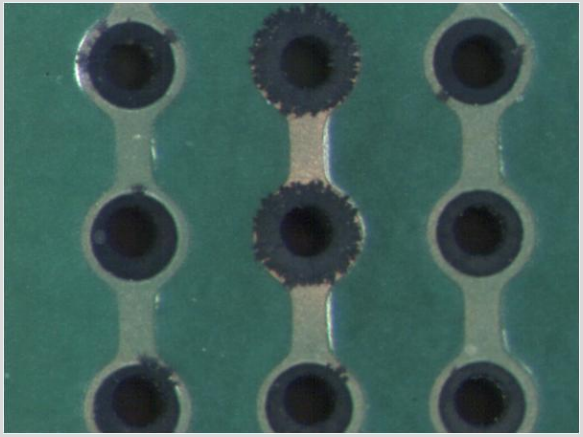
Project Members
Phase 3: Investigation of Factors That Influence Creep Corrosion

Definition

Creep Corrosion:

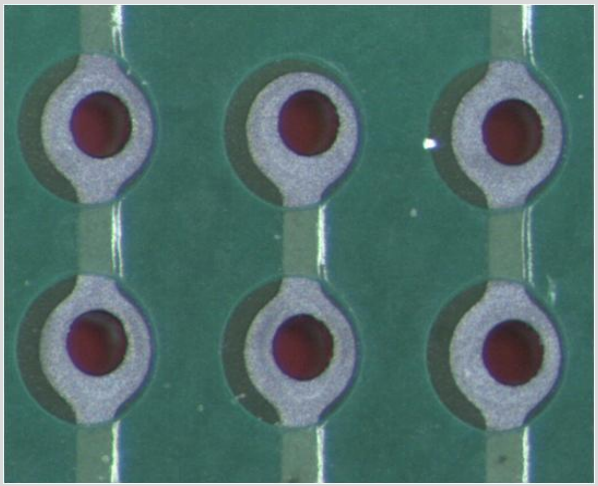
Copper creep corrosion is when the corrosion products spread onto the solder mask beyond the edge of the pad or via.





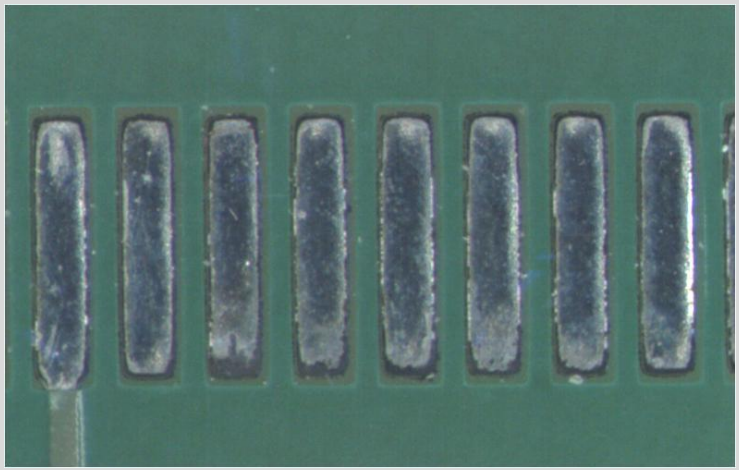
Corrosion:

Corrosion product on the surface of the pad or via. But no spread of the material onto adjacent surfaces.



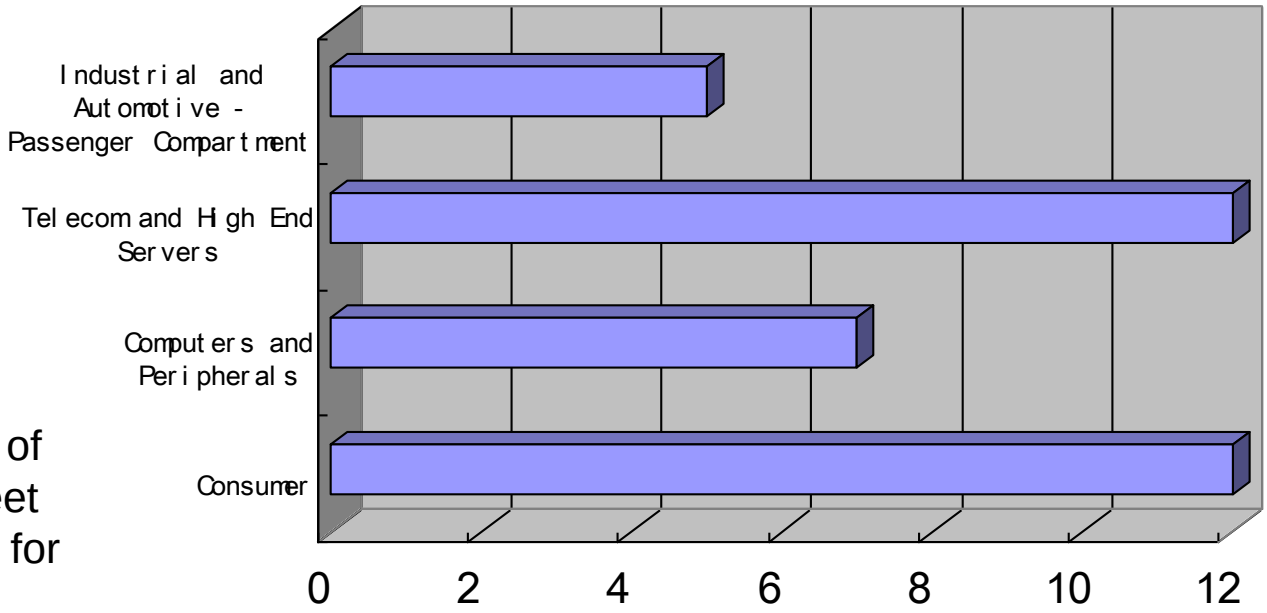
Edge Corrosion:

Corrosion products only along the edge of the pads.



Phase 1 Survey- Creep corrosion

- **Creep Corrosion Survey released in Dec 2009.**
- **4 different product types were surveyed.**
- **45 respondents and 67% of them have seen creep corrosion failures.**

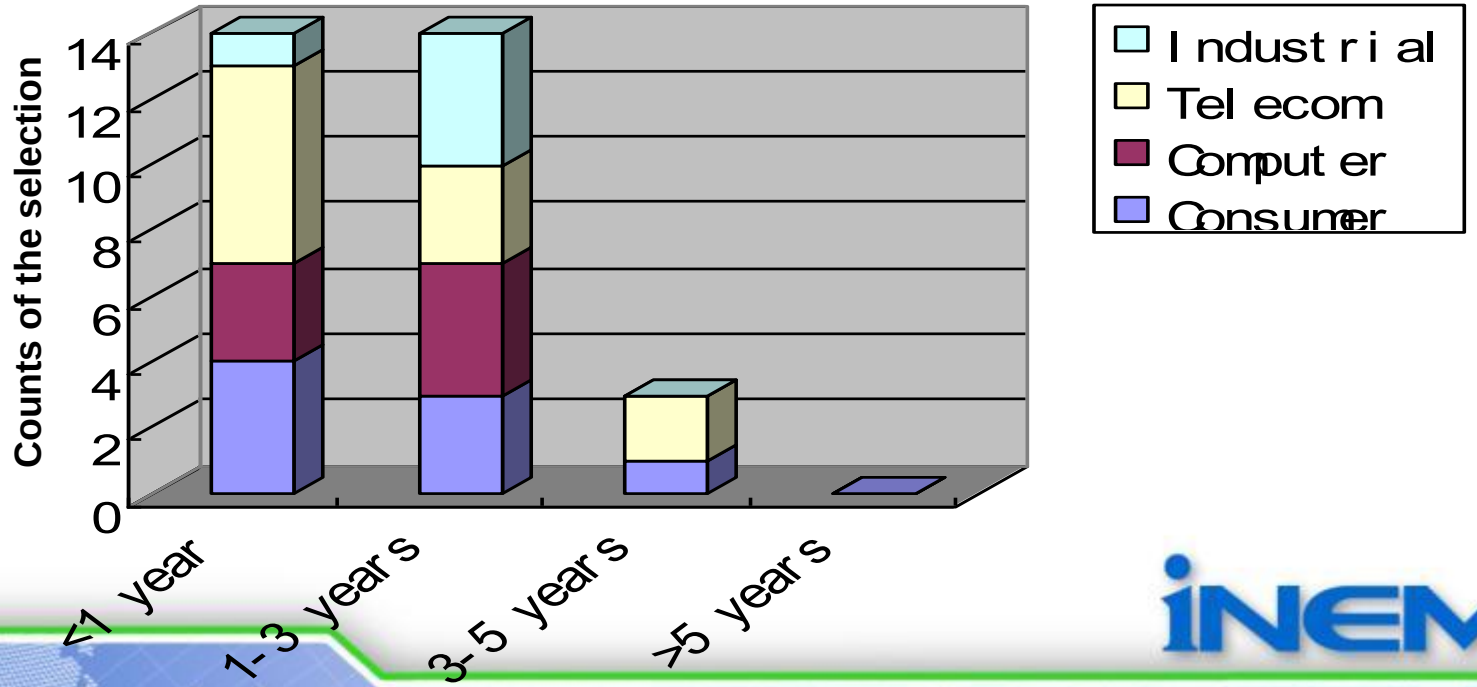


Bar chart with number of respondents which meet creep corrosion failure for each product type.

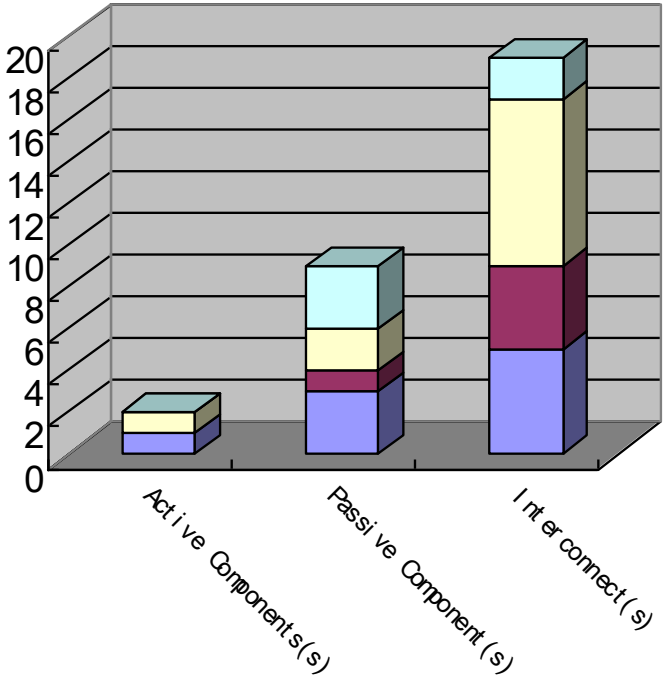
Phase 1 Survey- Creep corrosion-The life to failure

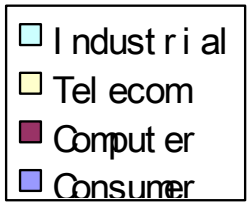
Q: Please provide the average service time to failure for this product due to creep corrosion?

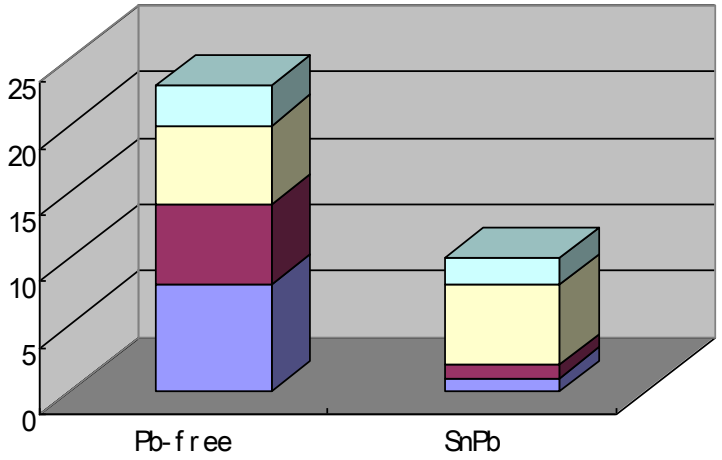
- **31 available answers.**
- **The life to failure is less than 5 years, in most of the cases (about 90%) less than 3 years.**
- **These are designed for 5-10 years of the average life, Clearly creep corrosion results in early field failures.**



Phase 1 Survey- Creep corrosion-where on the brd







Q: Please select the device where the creep corrosion failure was observed on this product.? Is this product assembled using Pb-free or SnPb processes?

- **Interconnect(s) such as PCB, connectors, etc. are the major locations where creep corrosion failure was observed.**
- **Creep Corrosion was observed on both Pb free and SnPb processes.**
- **Predominantly in non soldered locations (exposed surface finish) on PCB. Also observed at improperly soldered locations.**

Phase 1 Survey- Creep corrosion- Summary

- **Creep corrosion is a common failure mode in various product types (from consumer, computer to telecom and industrial applications).**
- **Most of the creep corrosion failures are less than 3 years in field, and the electrical short is the major failure signature.**
- **Failures are reported globally. Large number of responses correlated to air pollution levels/industrial areas. Some reported failures from indoor office area. Few of the respondents correlated failures with high sulfur environments.**
- **Typical failure locations are the exposed PCB surface finish areas on the motherboard. Also those regions that were improperly soldered/touched up showed corrosion. Corrosion of silver terminals on passive components was also reported. Seen both on Pb-Free and Sn-Pb assembly processes.**
- **ImAg surface finish was most frequently reported for creep corrosion. Failures observed on PCB's with OSP surface finish in harsh environments.**
- **None of the failures were induced by overly aggressive design features.**

Technical findings from Telephonic Interviews

- **All the respondents agree that it is an environmentally driven problem.**
  - **Presence of Sulfur, humidity have been mainly attributed for all the problems.**
  - **The role played by flux is unclear.**
    - **Some of the respondents(4/8) mentioned there is no role played by flux/residue in the failures. However few (4/8) of the respondents acknowledged that aggressive fluxes could accelerate the reactions.**
  - **No clarity on the role of rework and related process parameters**
  - **No standard test method to evaluate creep corrosion. Standard MFG unable to recreate creep on consistent basis. Clay test and modified MFG are being experimented with.**

Phase 2 - Factors discussed

- Failure mechanism study
  - Temperature
  - Contaminant concentration
  - Humidity
  - Surface finish
  - Flux
  - Voltage impact?
  - Air flow
  - Assembly – thermal profile
  - Rework
  - Soldermask geometry
  - Soldermask material, surface (matte, glossy)
- Mitigation method study
  - Conformal coating
  - Over spray chemicals to isolate the circuitry
  - Carbon pack (local to the equipment) to filter air at the inlet
  - Fill vias/cover with soldermask (still need test points, there may be alternatives)
  - Surface finish
- Test method study
  - clay test (used by Dell, Alcatel-Lucent)
  - modified MFG test (IPC 3-11g)
  - Something new? Or team up with others?
- Environment monitoring and control (clean the air)
  - ASHRAE
  - LBNL (failure rate vs. environment)
- Acceleration study to bridge environment to product life

Phase 3: Investigation of Factors That Influence Creep Corrosion

- **Scope of Work**
  - Perform laboratory based experiments to further investigate the sensitivities of the influencing factors identified in Phase 1 and 2.
  - Several factors will be studied in Phase 3, including surface finish, flux, solder mask geometry, solder paste coverage, reflow and wave soldering and MFG test conditions (corrosive gas concentration, humidity, temperature).
- **The team believes more experiments, based on previously published work, could help us:**
  - understand the sensitivities of the already identified contributing factors
  - validate the effectiveness of a few mitigation approaches
  - correlate experimental test conditions to environment classification standards (e.g. ISA G1, G2)
- **Phase 3 will be ended in Q1 of 2012**

Experimental Plan

Chamber Uniformity Test (3 runs)

- H_2S = **1700 ppb**; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 5 days
- H_2S = **500 ppb**; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 5 days
- H_2S = **1000 ppb**; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 5 days

Formal MFG Test (3 runs planned)

- H_2S = 1200 ppb; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 20 days
- H_2S = 1200 ppb; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 20 days
- H_2S = 12[illegible] 20 ppb; SO_2 = 2[illegible] days — To be determined

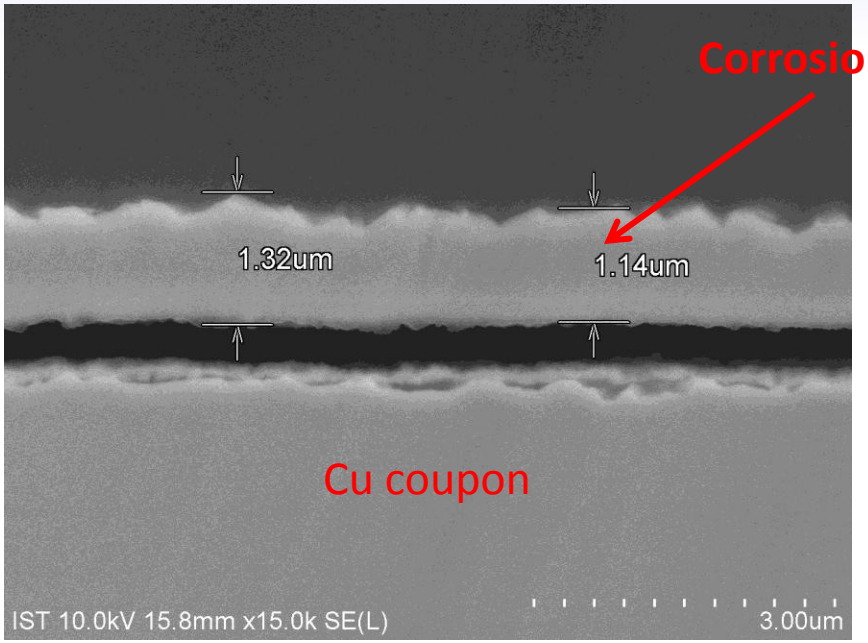
Test Chamber Setup for Formal MFG Test

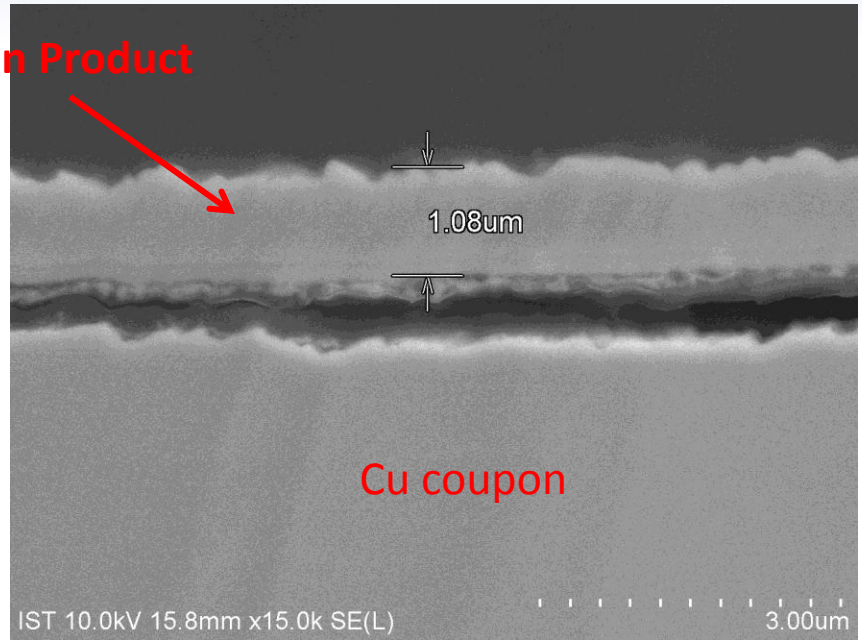
Corrosion Product Thickness
Weight Gain vs. Coulometric Reduction

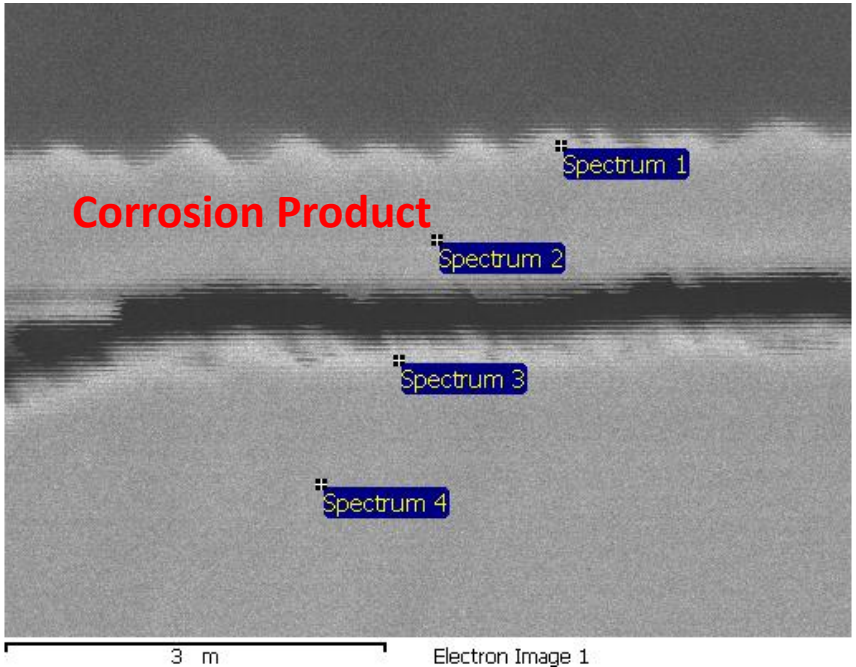
	Ag 2	Ag 3	Ag4	Ag 5	Ag 6
Ag_2S wt gain, angstroms	630	910	580	1170	720
Ag_2S coulometeric reduction, angstroms	513	538	535	546	636

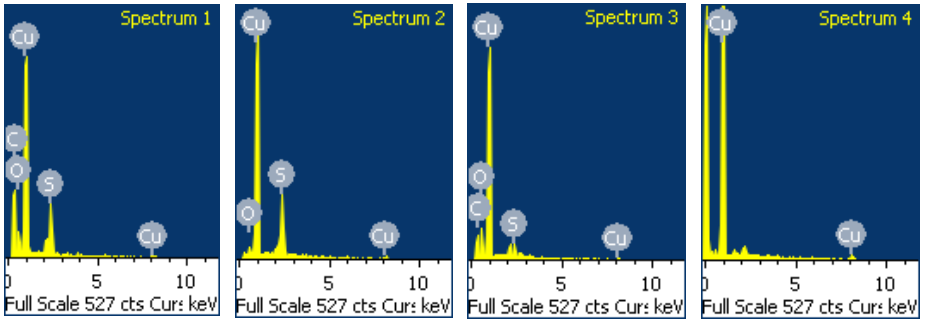
	Cu 2	Cu 3	Cu 4	Cu 5	Cu 6	Cu 7	Cu 8
Cu corrosion product thickness wt gain, angstroms	17410	15880	15630	15060	17840	17790	18990
Cu2S Coulometeric reduction, angstroms	--	14603	20361	14127	20574	16574	22181

Corrosion Product – Cu Coupon









Spectrum	In stats.	C	O	S	Cu	Total
Spectrum 1	Yes	30.99	6.78	11.09	51.14	100.00
Spectrum 2	Yes		2.50	19.06	78.45	100.00
Spectrum 3	Yes	14.99	8.35	2.94	73.72	100.00
Spectrum 4	Yes				100.00	100.00
Max.		30.99	8.35	19.06	100.00	
Min.		14.99	2.50	2.94	51.14	

All results in weight%

Formal MFG Test Matrix – 1st Run

H_2S = 1200 ppb; NO_2 = 200 ppb; Cl_2 = 20 ppb; SO_2 = 200 ppb; 40℃, RH 70-75%, 20 days

Identification	Finish	Flux
I-R	ImAg (Immersion silver)	Rosin flux
I-O	ImAg (Immersion silver)	Organic acid flux
O-R	OSP (Organic solderability preservative)	Rosin flux
O-O	OSP (Organic solderability preservative)	Organic acid flux
H-R	Pb-free HASL (Hot air solder leveling)	Rosin flux
H-O	Pb-free HASL (Hot air solder leveling)	Organic acid flux

Formal MFG Test Result Summary – 1st Run

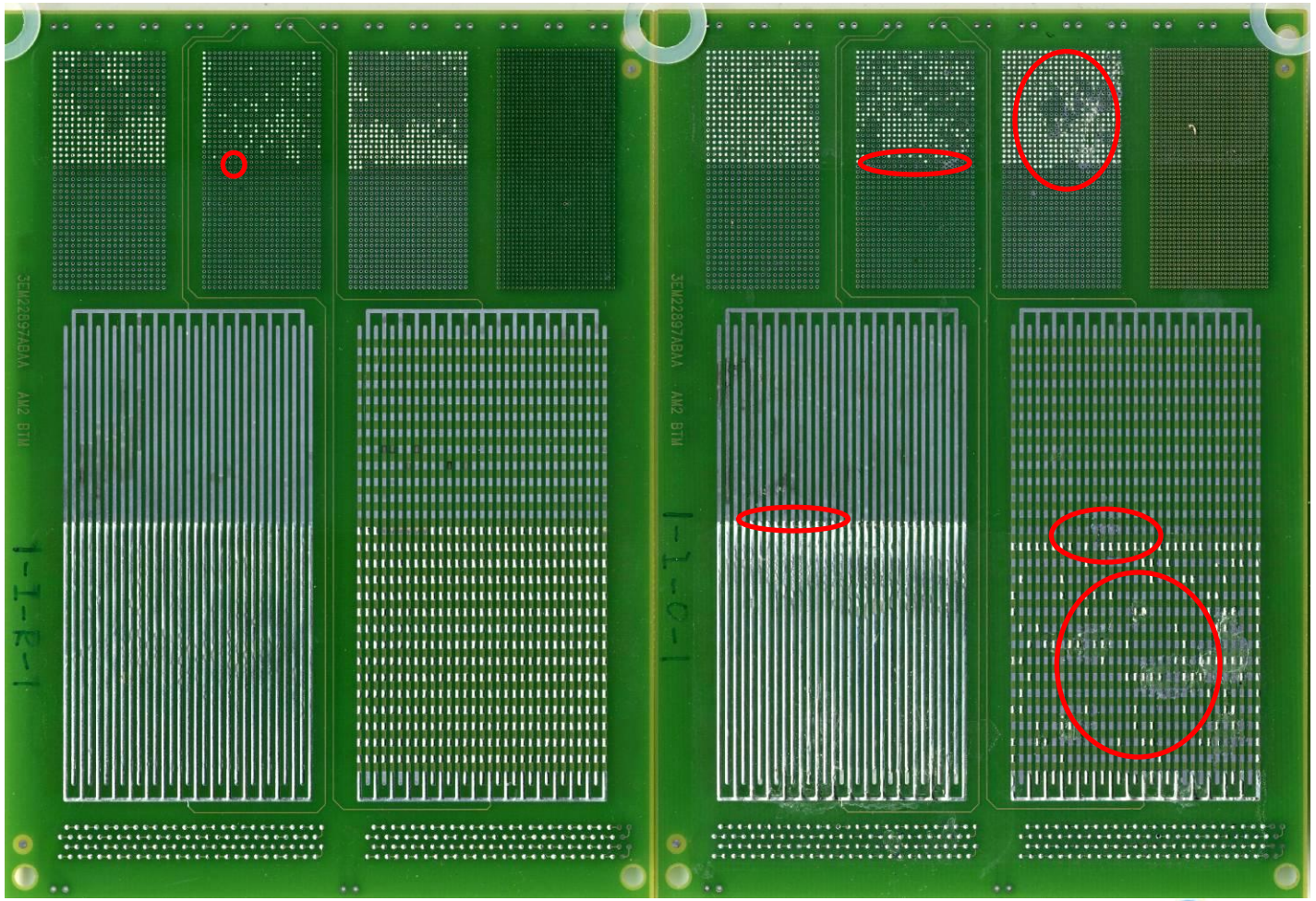
	Corrosion	Edge corrosion	Creep corrosion	Creep corrosion severity
ImAg + organic acid flux	Yes	No	Yes	High
ImAg + rosin flux	Yes	No	No	---
OSP + organic acid flux	Yes	No	Yes	Low
OSP + rosin flux	Yes	No	Yes	Low
Pb-free HASL + organic acid flux	No	Yes	Yes	High (in isolated areas)
Pb-free HASL + rosin flux	No	Yes	No	---

Short Detecting & Resistance Measurement

PCB	20th day - Short Detected on the patterns of the TVs												
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
1-I-R-1													
1-I-R-2													
1-I-R-3													
1-I-O-1						4.7K Ω	38K Ω		3.55K Ω				
1-I-O-2						600 Ω	48K Ω						
1-I-O-3						1.5K Ω	9.8K Ω						
1-O-R-1													
1-O-R-2													
1-O-R-3													
1-O-O-1													
1-O-O-2													
1-O-O-3													
1-H-R-1													
1-H-R-2													
1-H-R-3													
1-H-O-1				36K Ω									
1-H-O-2													
1-H-O-3													

High resistance short were detected in the areas having serious creep corrosion. It's consistent to the visual inspection. Resistance measurement can only be a reference.

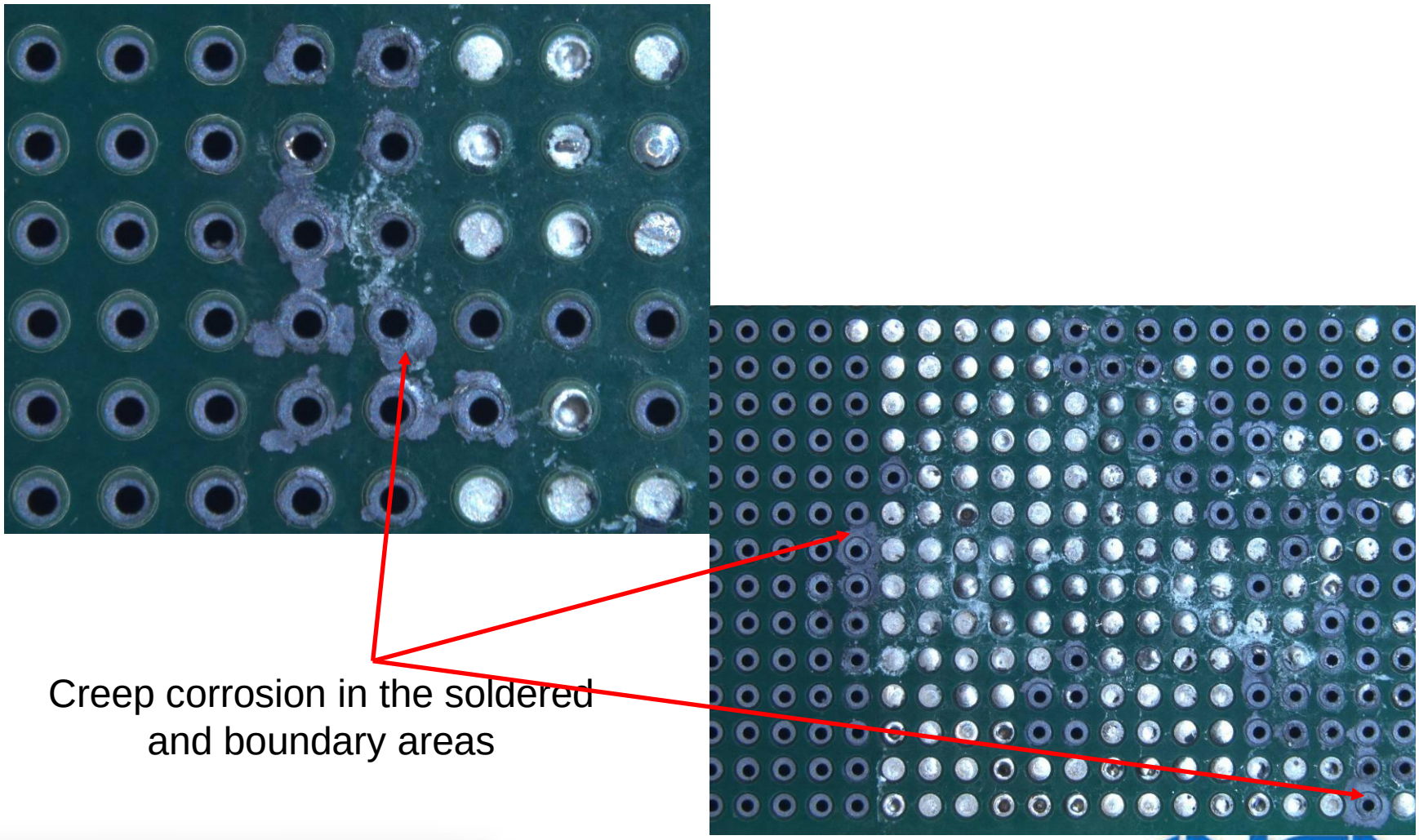
ImAg After 20 Days MFG Testing
Bottom Side



1-I-R-1

1-I-O-1

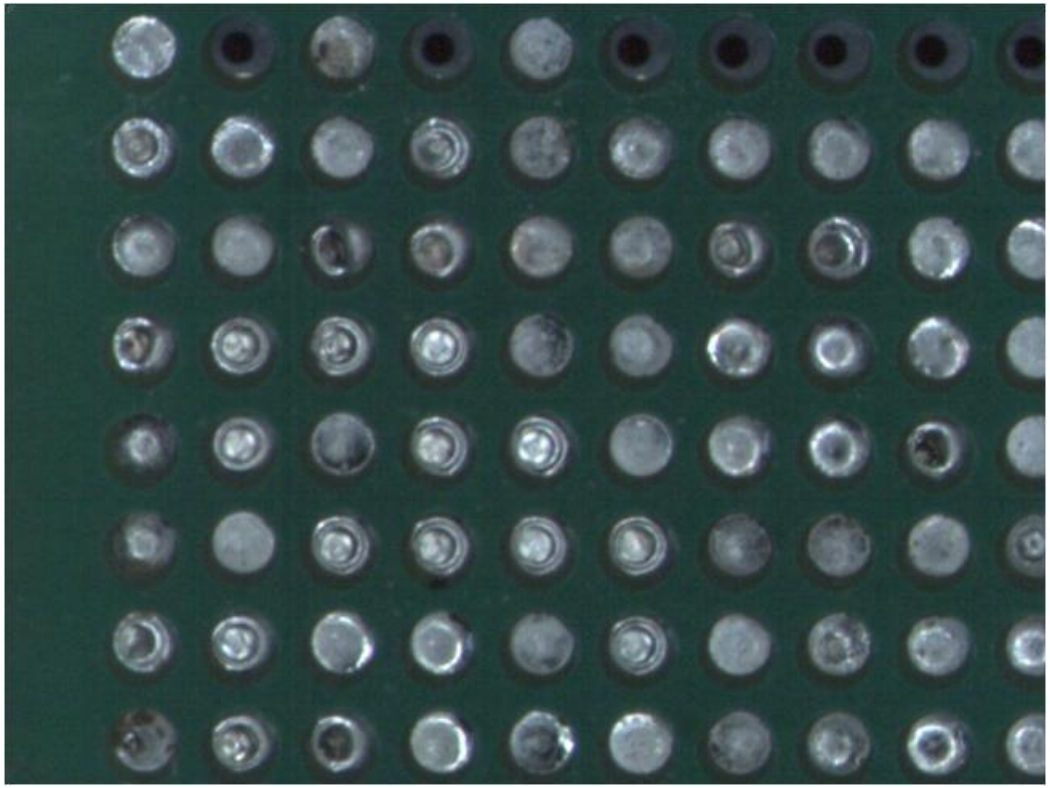
ImAg, Organic Flux, After 20 Days MFG Testing



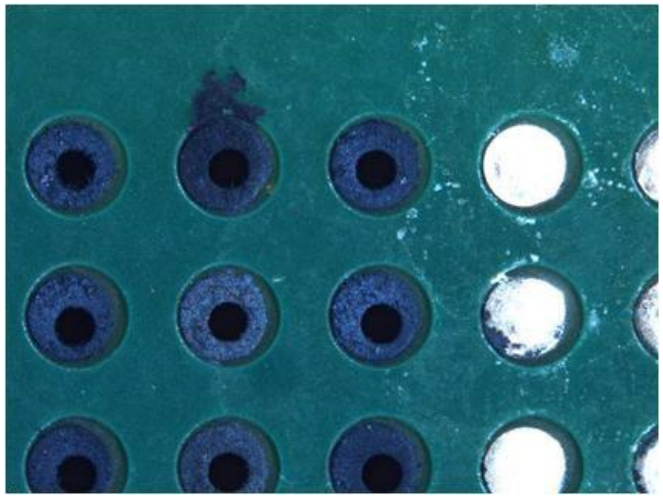
Creep corrosion in the soldered and boundary areas

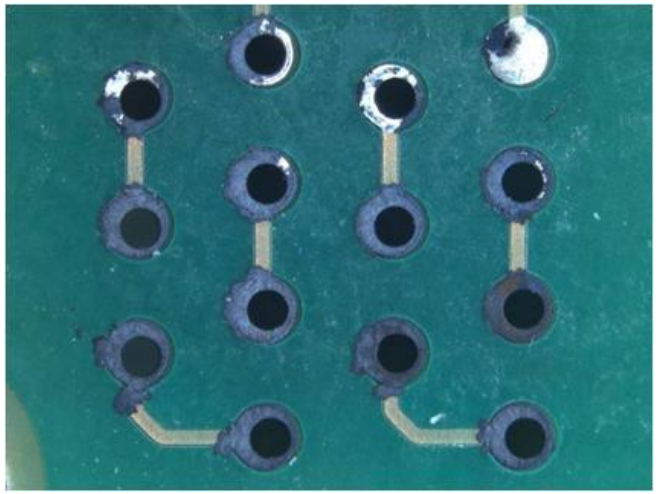
ImAg, Rosin Flux, After 20 Days MFG Testing

No significant creep corrosion. General tarnish.

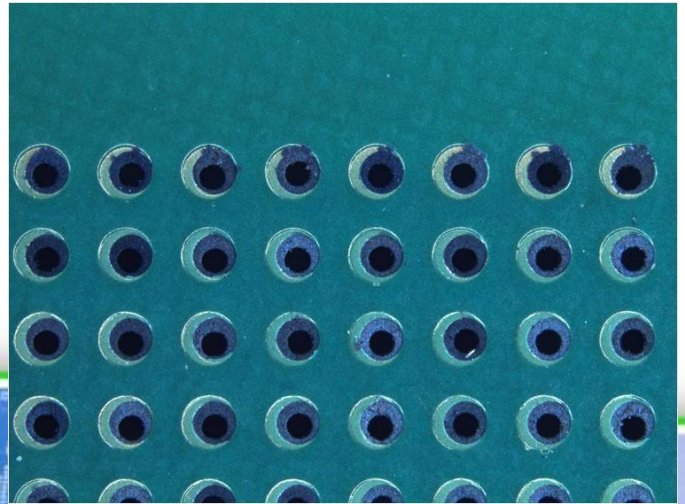


OSP, Organic Flux, After 20 Days MFG Testing



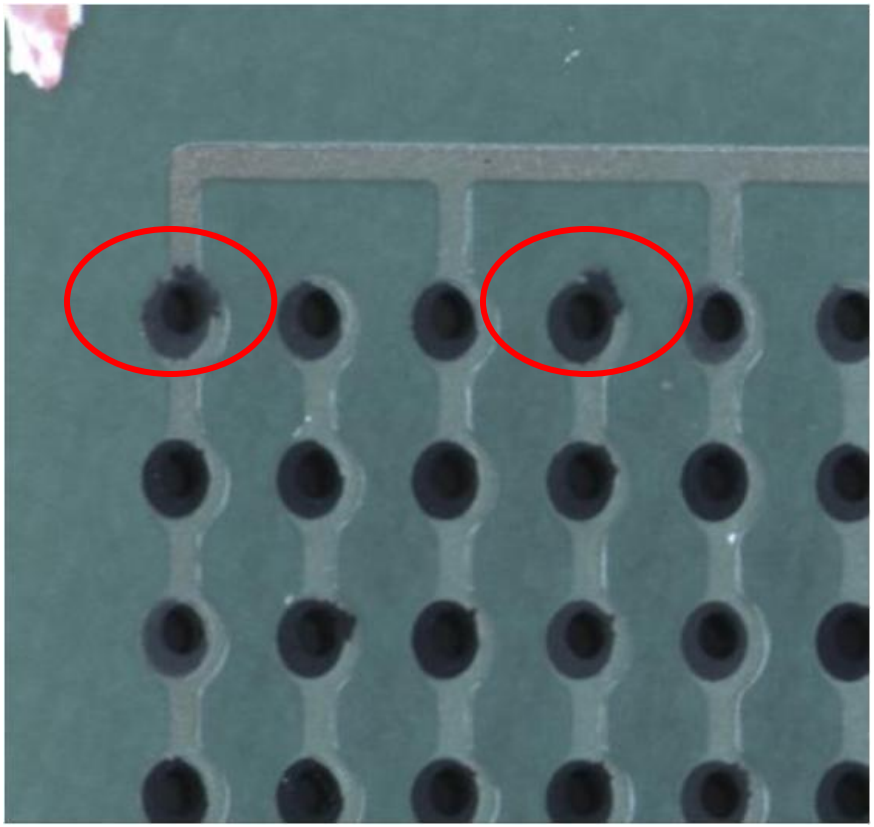


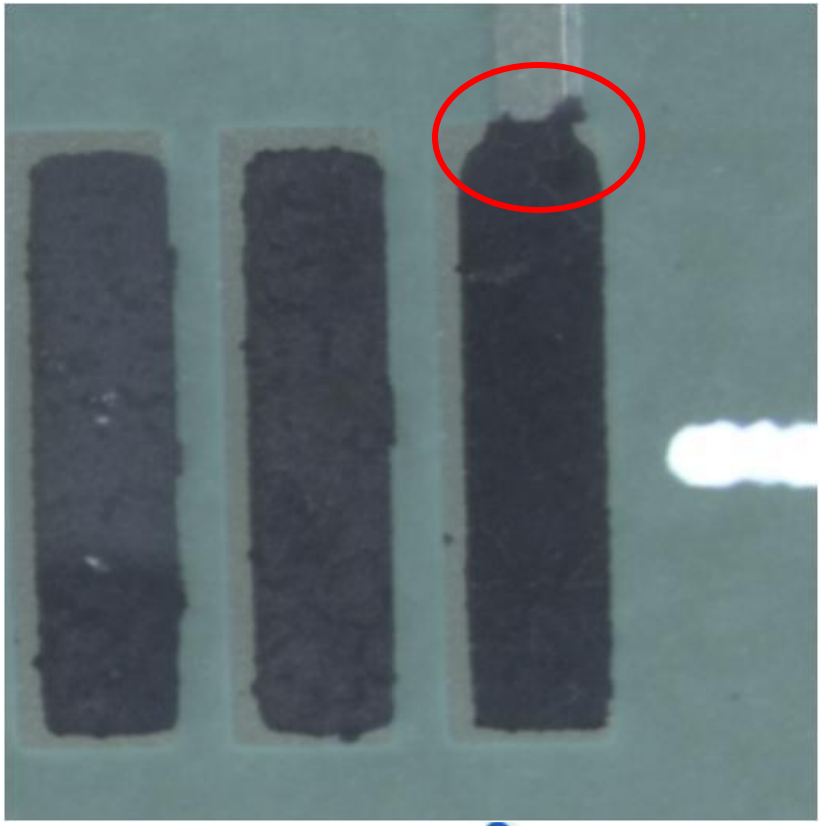
- Creep corrosion in soldered and boundary areas
- Minor creep corrosion in non-soldered areas
- The flak of corrosion products are semi-conducting and can cause short circuit.



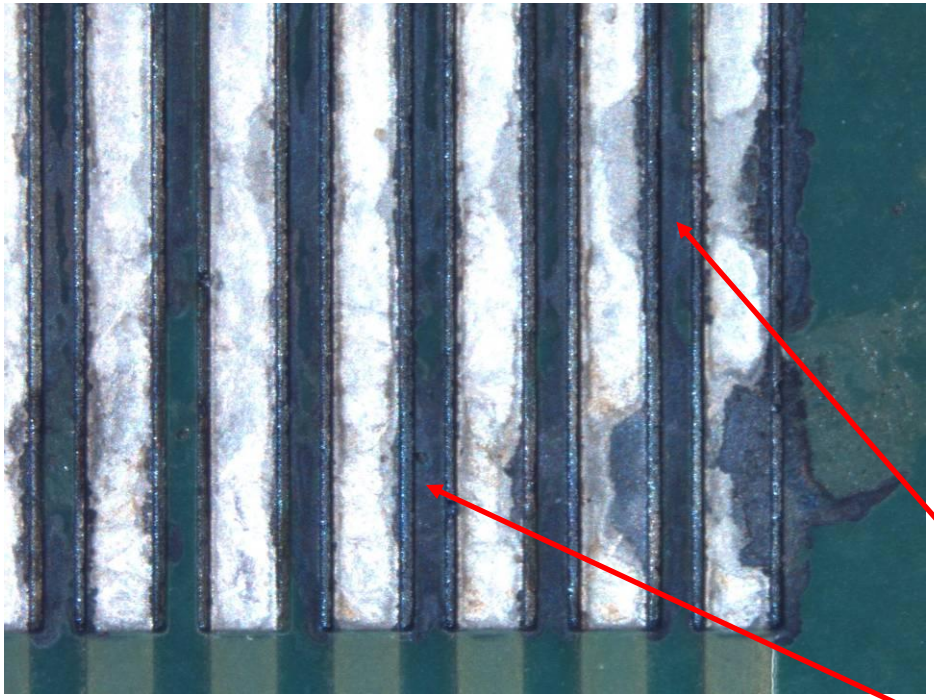
OSP, Rosin Flux, After 20 Days MFG Testing

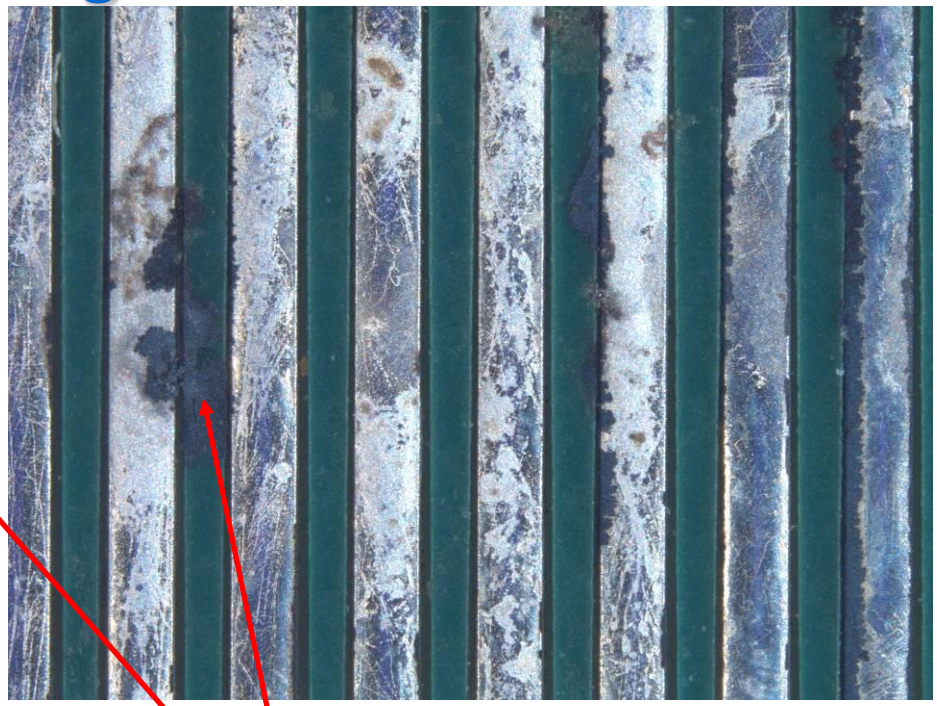
Minor creep corrosion, non solder or flux location

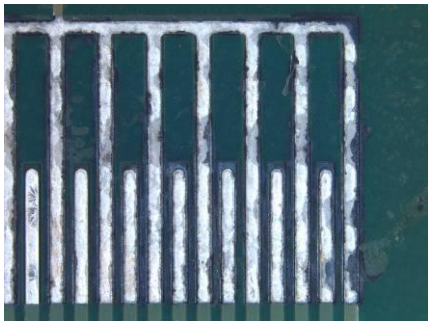




Pb-free HASL, Organic Flux, After 20 Days MFG Testing



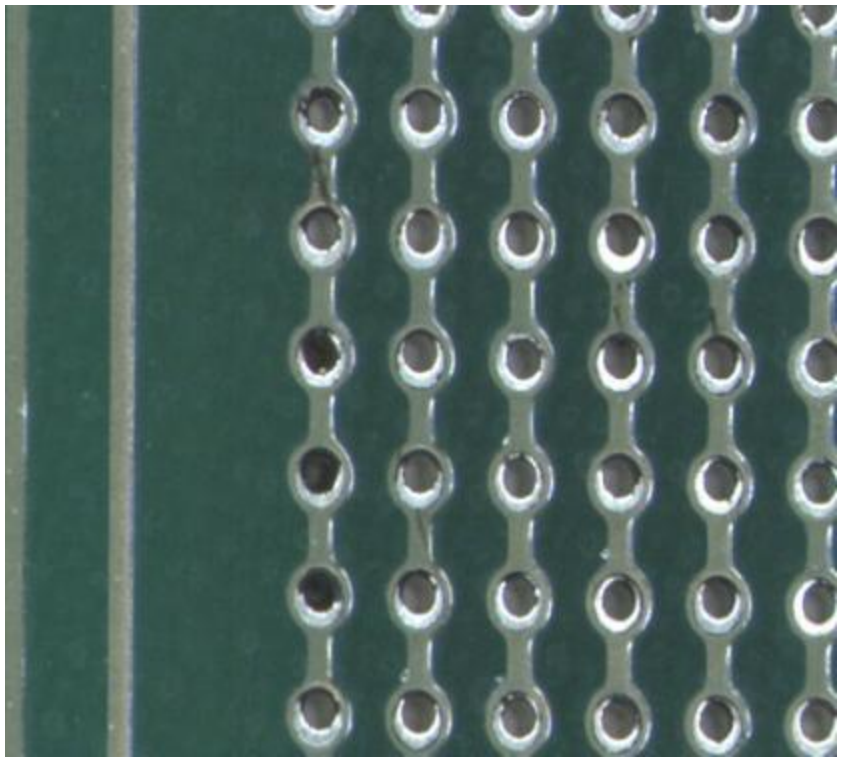




Creep corrosion and edge corrosion due to poor HASL coverage

Pb-free HASL, Rosin Flux, After 20 Days MFG Testing

No creep corrosion



Summary

- MFG test condition of the 1st formal run is chosen to reach the target of about 500nm/day corrosion rate on Cu coupons.
- Observed from the test Creep Corrosion, Corrosion, Edge Corrosion on the test boards. Electrical short were detected.
- Observed creep corrosion with all the finish types tested (ImAg, OSP, Pb-free HASL), however more creep corrosion occurred on boards with organic acid flux.
- Most severe creep corrosion was observed on ImAg boards with organic acid flux.
- Most serious creep corrosion locations have obvious flux residue. Most creep corrosion happened in soldered boundary area.
- Investigations are planned to evaluate issues identified in 1st formal run.

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