Reliability Implications of Pinhole Defects in Soldermask

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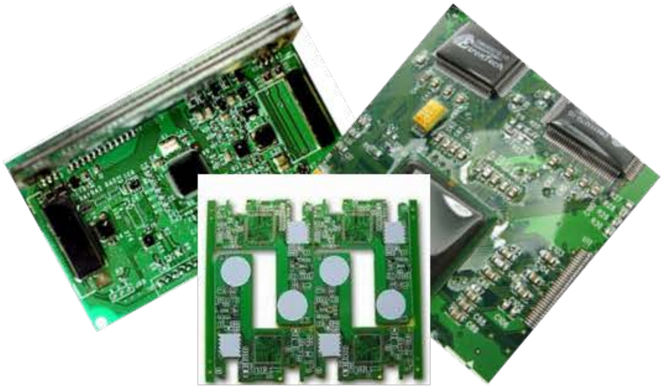
What are the Raw Material Risks ?

- Today, PCB suppliers handle a range of customers with different end use environments
  - Telecommunications
  - Automotive
  - Consumer electronics
  - Medical
  - Industrial, others…



- PCB manufacturers' objective – minimize variety of solder masks to as few as possible (not just soldermask, other materials as well).
- Unfortunately, subsequent assembly steps such as finishes, fluxes, solder materials are often overlooked.
- New class of solder mask defects are influencing the reliability of the finished end product.

What is the Subsequent Process Risk?

- After solder mask application, PCBs are exposed to process steps:
  - Surface finish
  - Wave soldering and reflow processes
  - Local/selective wave solder and rework operations
- Blowholes can act as acceptors and reservoirs.
- Interaction of process chemicals.

Problem Statement

- Application of soldermask and its cure process usually involves thermal, electro-magnetic and some mechanical process steps:
  - Debubbling in still air
  - Dry bake in oven
  - UV exposure cure
- However, quicker turnaround schedules, higher throughputs and uncontrolled process can cause issues such as:
  - Inadequate cure of the solder mask
  - Out-gassing and blowhole creation
  - Uneven coverage of the finished solder mask
- Existing standards for soldermask quality acceptability do not address the specific non-standard process conditions that introduce anomalies.

Soldermask – Purpose and Benefits

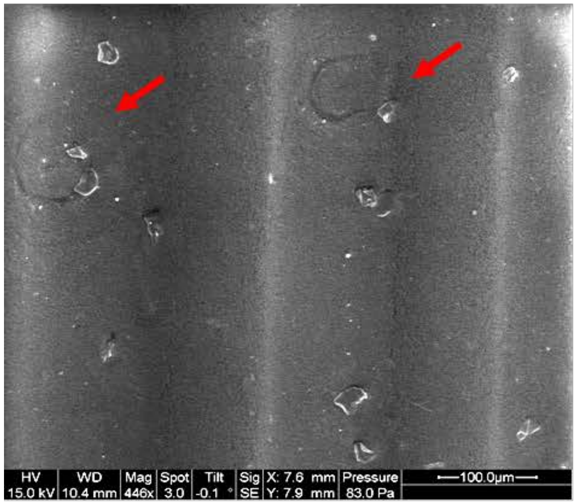
- Solder mask is used for large scale, automated soldering
- Adheres to metallization and organic substrates.
- Protects PCB from dust, debris and ambient.
- Prevents unintended solder shorts.
- Passivates non-solderable surfaces and protects from corrosion.
- Adhesion to conformal coats.
- Green, blue or other colors.
- UL ratings, RoHS compliance.
- Finishes, matte, gloss, others.
- Chlorine or Sulfur components.
- IPC, MIL-PRF spec on thickness, adhesion, blistering and outgas.

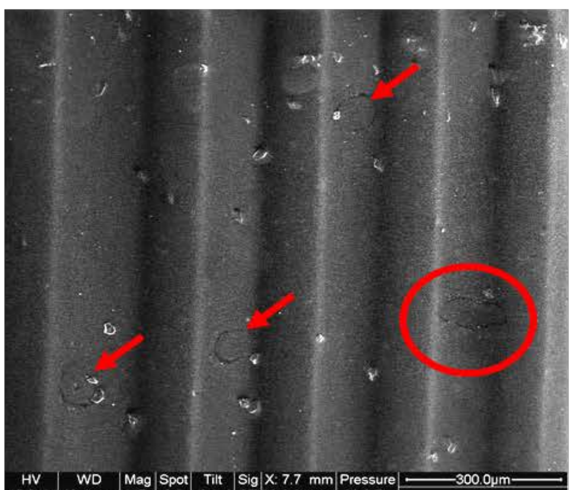
Soldermask Blowholes

Typical Acceptability Criteria

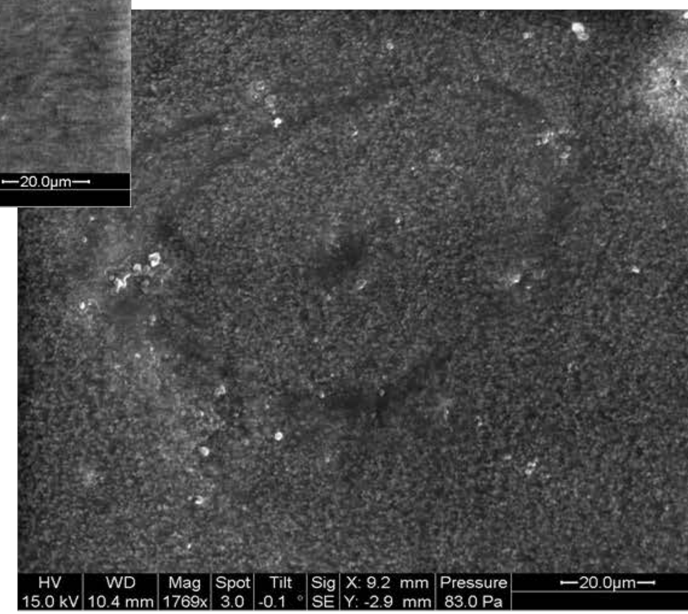
Test	Equipment	Industry Standard or Criteria	Acceptability Criteria
Visual inspection	Visual check	IPC-A-600	No soldermask peel
Adhesion test	Tape	DIN-IEC-60326 Part 2	No soldermask peel
Hardness test	Pencil test H – 9H	IPC-SM-840	AABUS
Solderbility	Preheat and solder float at 260ºc / 10sec	ANSI/J-STD-003 ,IPC-TM-650 Test Method 2.6.8D	No soldermask peel
Adhesion of Soldermask	Temp chamber, grid cutter, post-finish	IPC-SM-840	AABUS
Ionic contamination	Omega meter	TR-NMT-000078 BELLCORE 14.5	0.5 μg/cm²
ECM	Temp 40° C / 92% RH /504 hrs. / DC 100 V		1MΩ
SIR	40° C / 85%RH / 24 hours / DC100V		3MΩ

Blowholes in Solder Mask



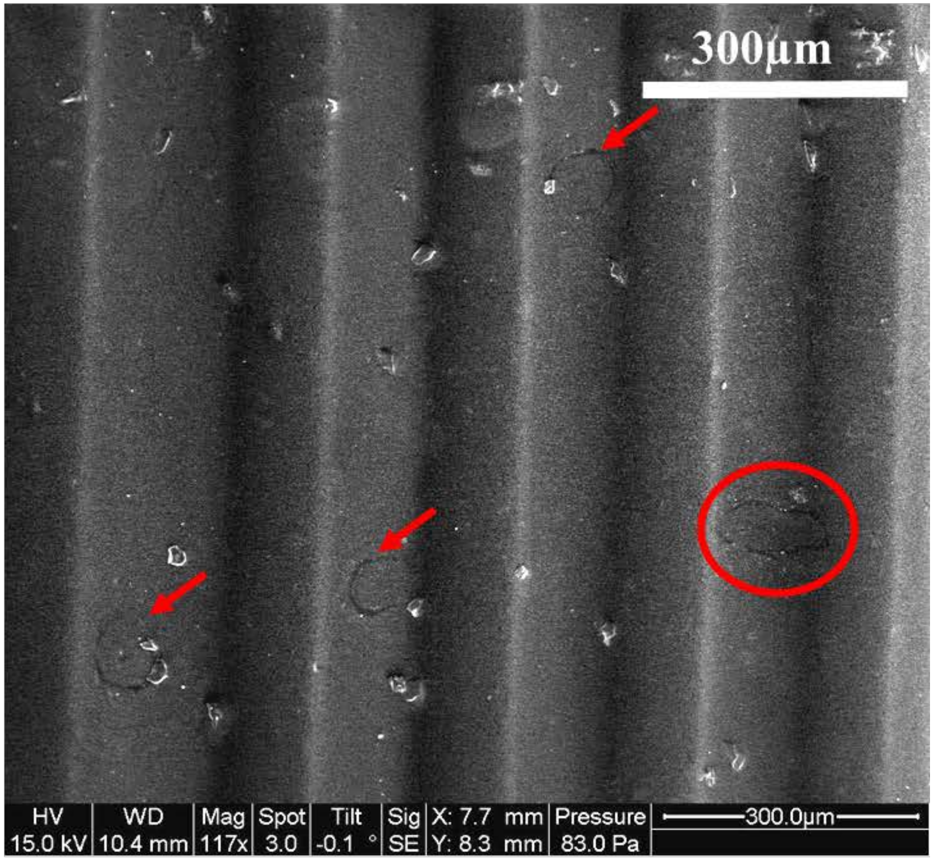


- Solder mask blowholes are localized at specific regions of PCB
- Most consist of a ring and a dot in the center.



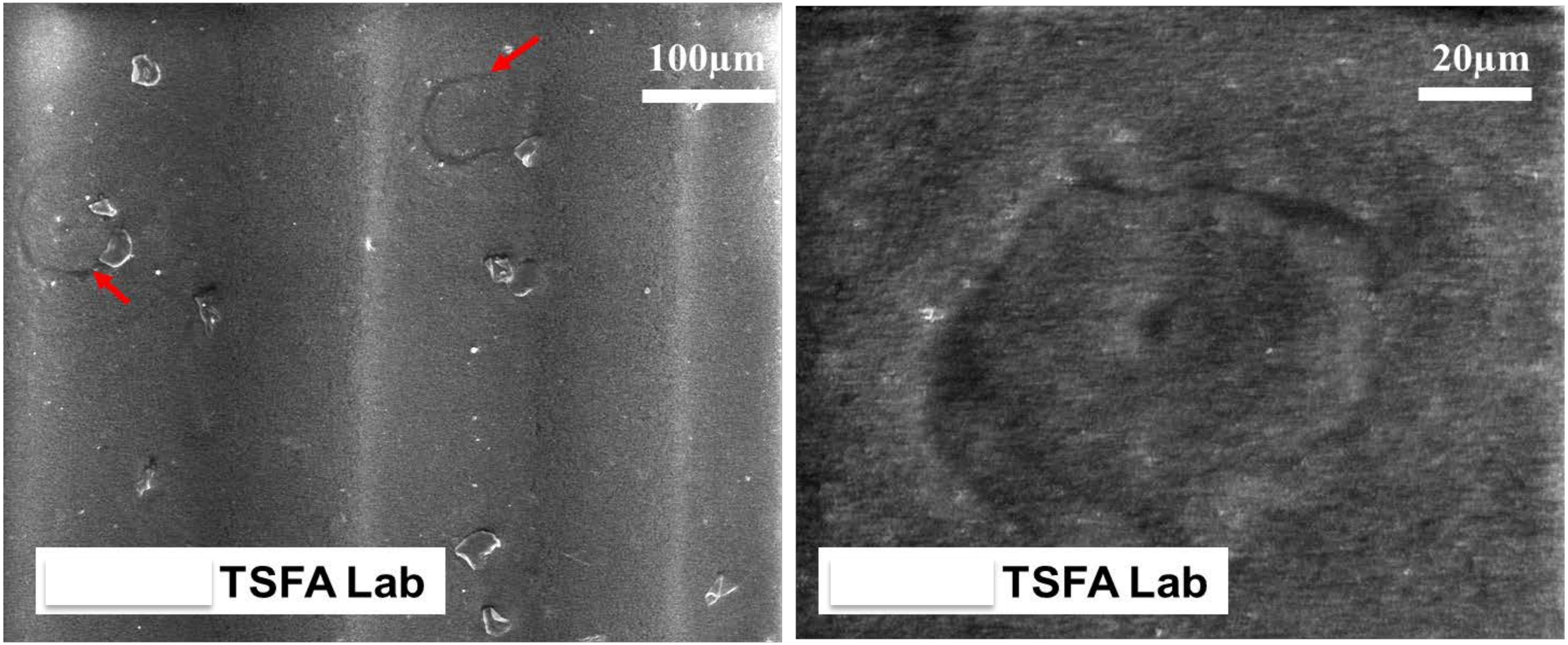
- In many instances, the blowholes are located on top of the traces (see circle).

Formation of Soldermask Blowholes



- Blowholes, can form at any location on the PCB, can be localized
- Blowholes can be located on top of a conductive trace.
- Worse, blowholes can be located between conductive traces.

Implications of Blowholes in Solder Mask



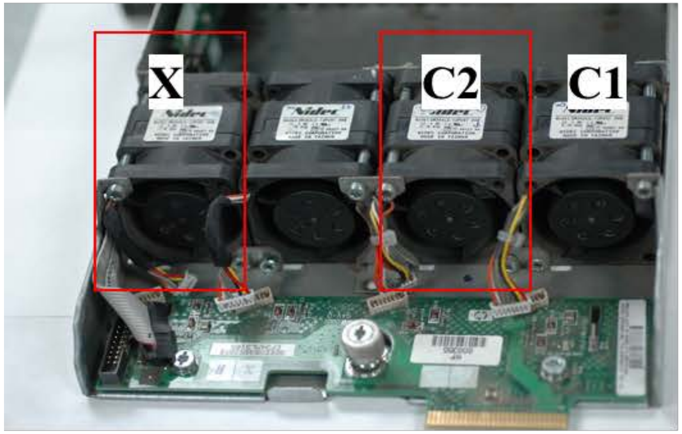
- In assembly, soldermask blowholes can allow in moisture, process cleaners and chemicals along with flux to wick between the soldermask and the conductive traces. This can cause fracture, or lifting of the soldermask at the edge.
- In field use, the blowholes can allow ambient contaminants, dust and potentially corrosive gases to accelerate the degradation process.

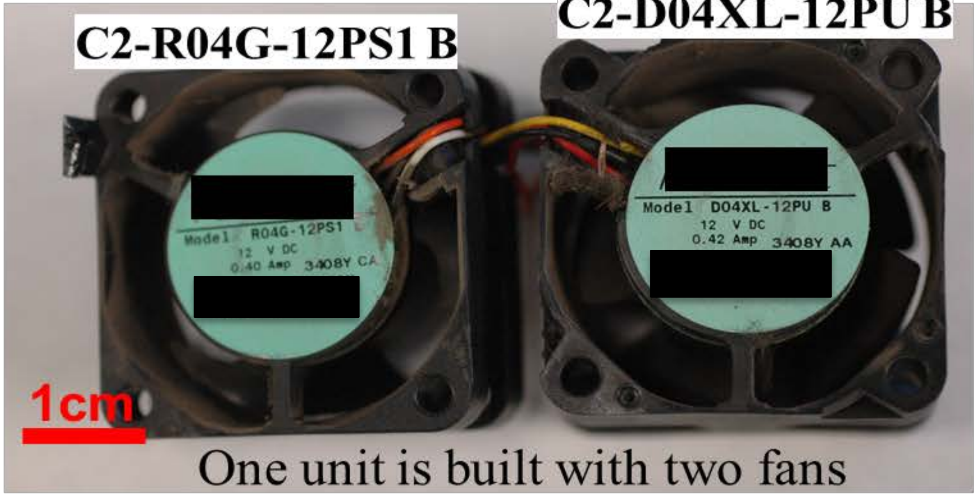
Case Study 1 – Overview

- Customer reported failures with two server cooling fan units, named C2 and X.
  - One unit is built with two fans, a D04XL-12PU B and a R04G-12PS1 B.
- Electrical and functional checks confirmed the issue.

	Rated Voltage (V)	Rated Current (A)	Measured Current (A)	Measured RPM
X-D04XL-12PU B	12	0.42	0	0
X-R04G-12PS1 B	12	0.4	0.25	12770
C1-D04XL-12PU B	12	0.42	0.301	12041
C1-R04G-12PS1 B	12	0.4	0.25	13150
C2-D04XL-12PU B	12	0.42	0	0
C2-R04G-12PS1 B	12	0.4	0.24	14003

Optical Inspection





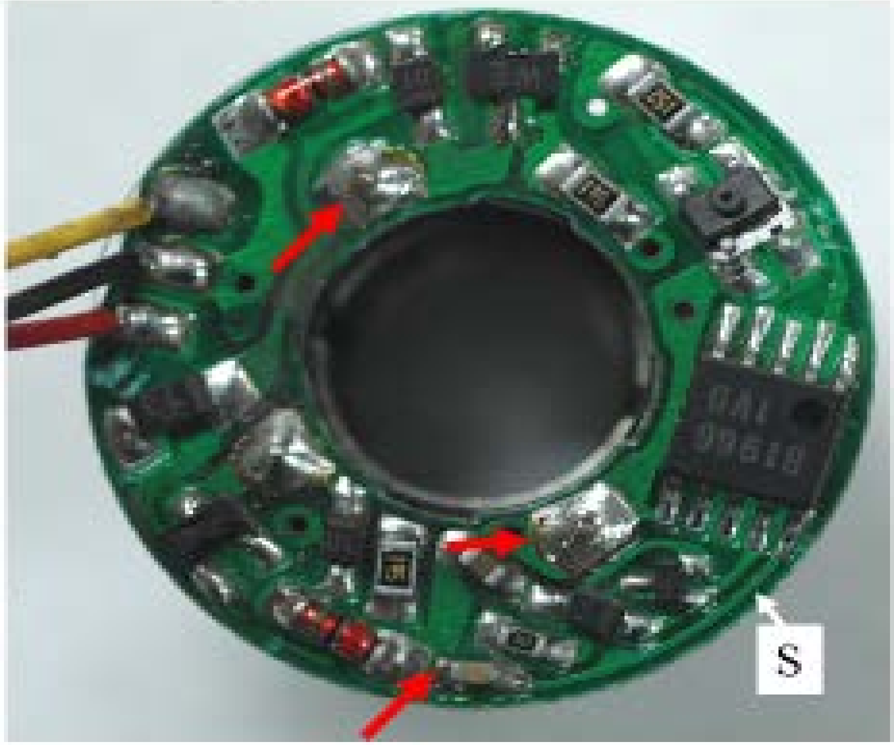
C2-D04XL-12PU B

C2-D04XL-12PU B and X-D04XL-12PU B were disassembled for further inspection and testing.

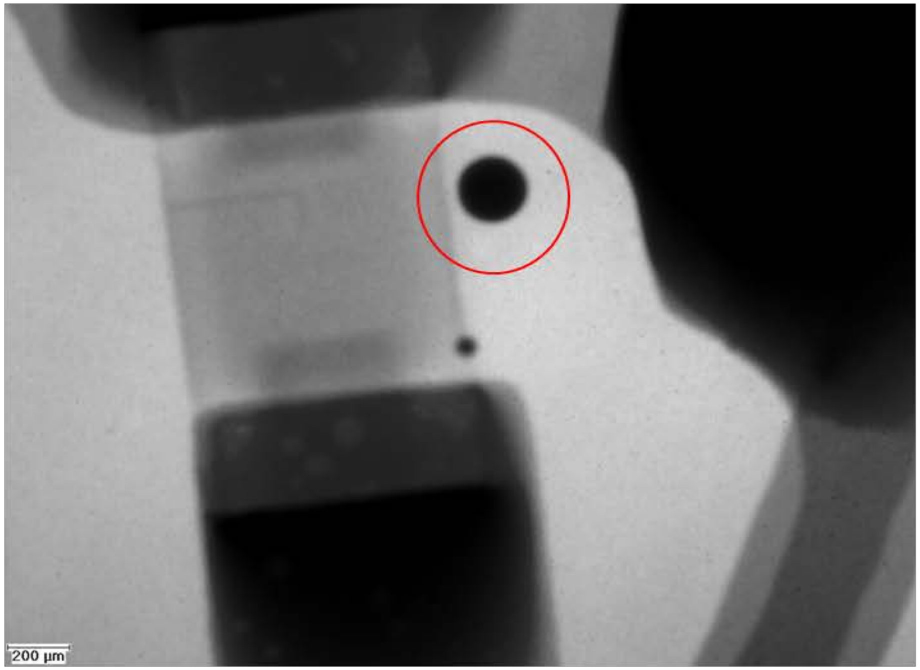
C2-D04XL-12PU B

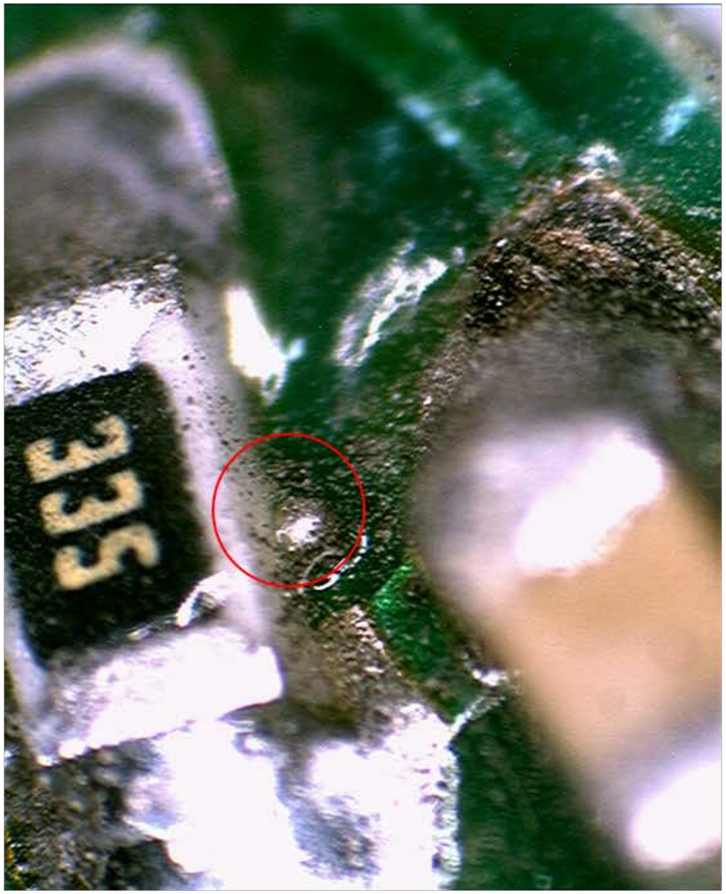
Disassembly and Inspection

- After disassembly, dust accumulation was observed on both the primary (P) and secondary (S) side of the fan PCB.
- EDS showed presence of Sulfur in the dust.



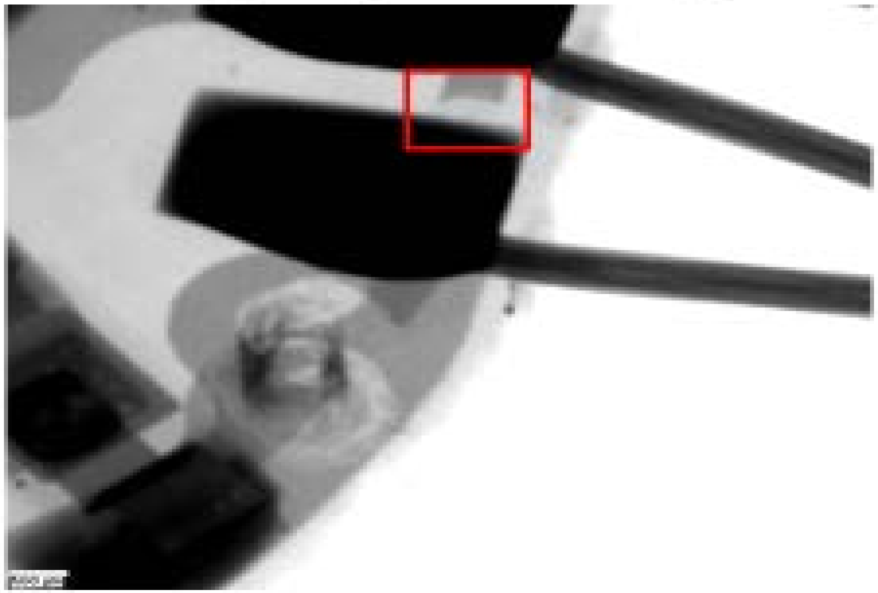
X-ray/Optical Inspection of C2-D04XL-12PU B

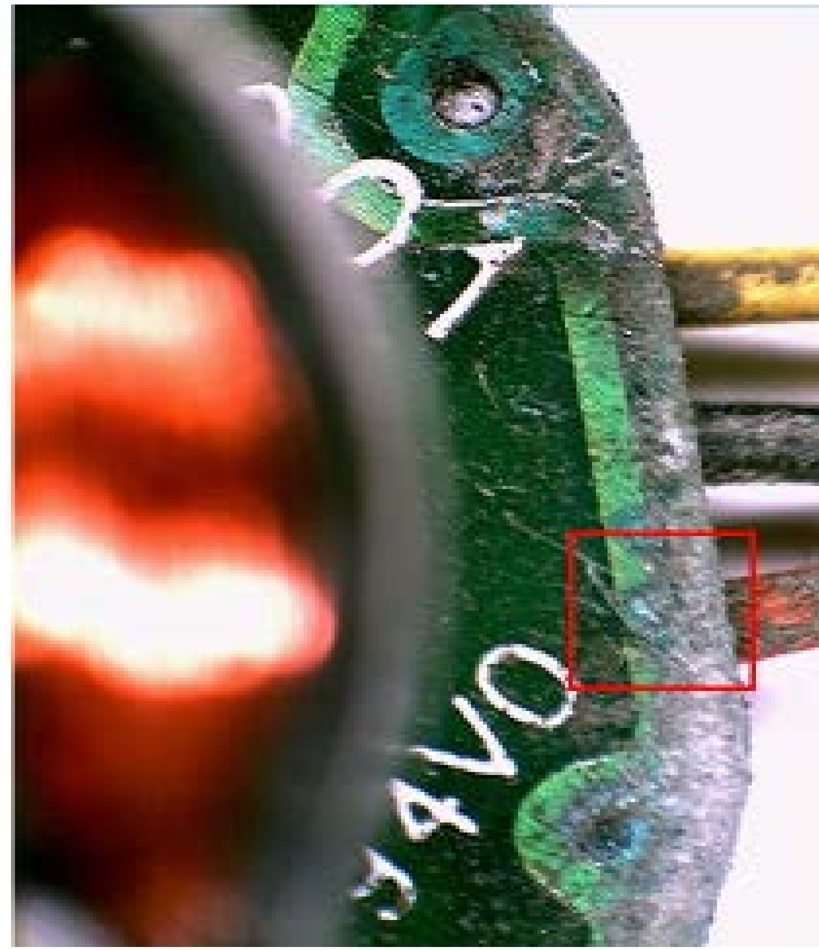




- Stray solder balls were observed on PCBA at several locations. Representative images shown.
- This is a workmanship quality indicator.

X-ray/Optical Inspection of C2-D04XL-12PU B





- Open circuit trace was observed in x-ray.
- Corresponding region on PCBA is shown in optical image on right.

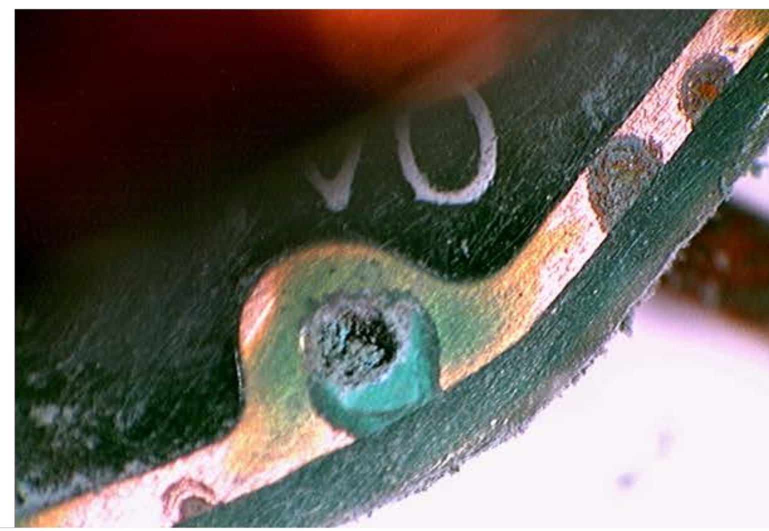
Tape Lift Analysis, Cleaning and Sanding of Suspect Region

Suspect Region (As-received)

Tape Lift-off Process

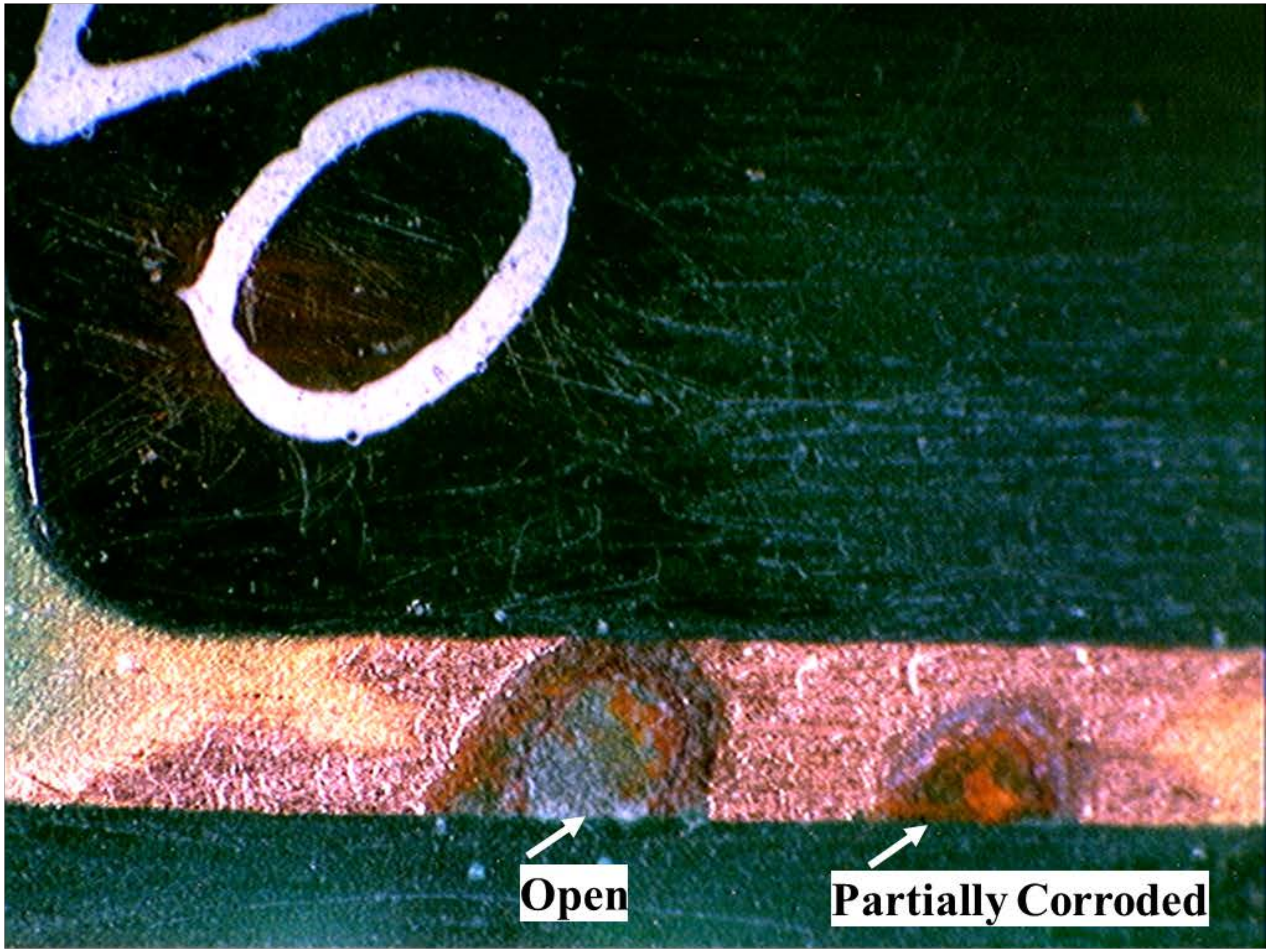
After Tape Lift-off

After Tape Lift-off and IPA Clean



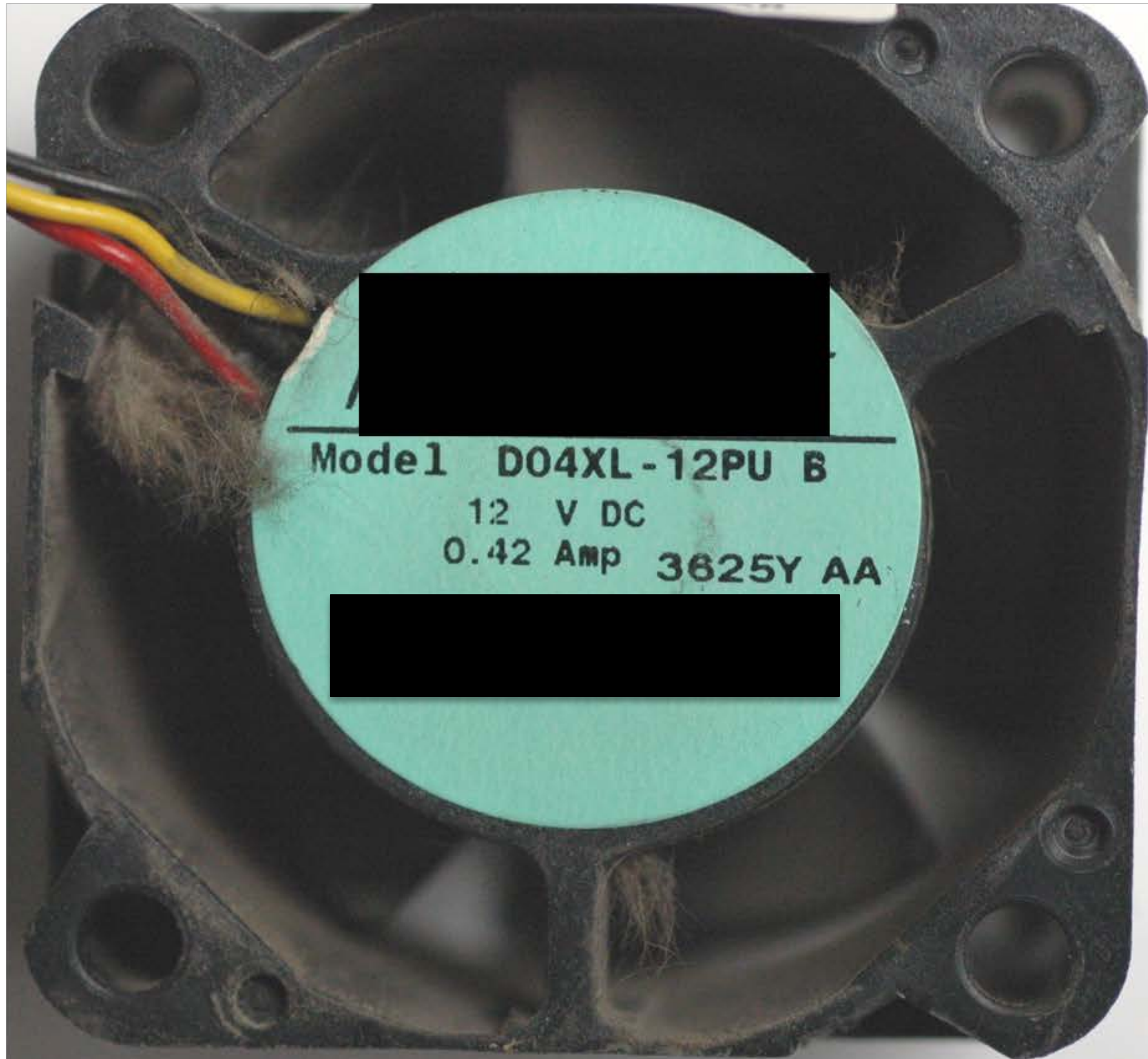
After Cleaning and Sanding with 600 Grit paper

Optical Images of Open Trace

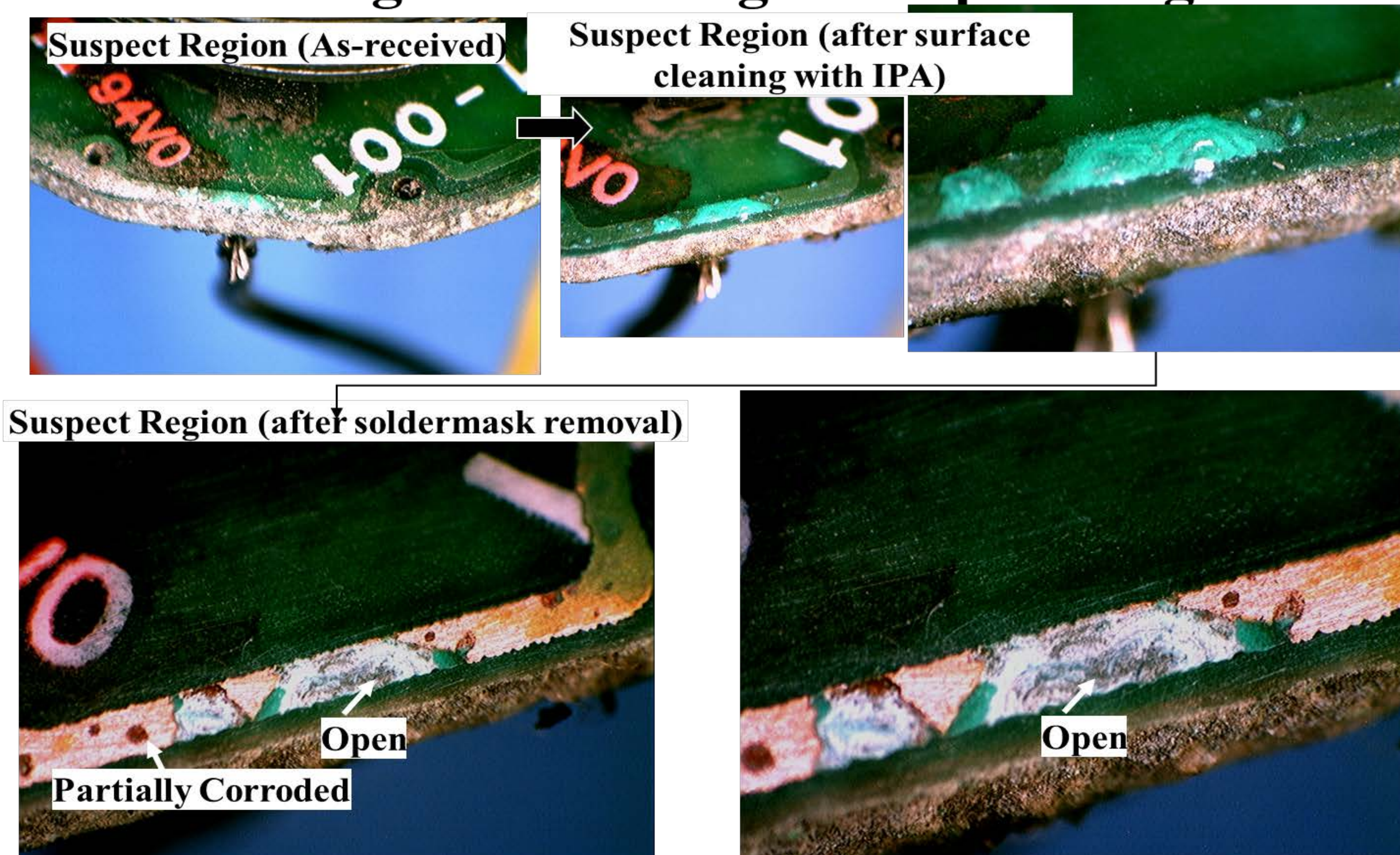


X-D04XL-12PU B
Disassembly and Inspection

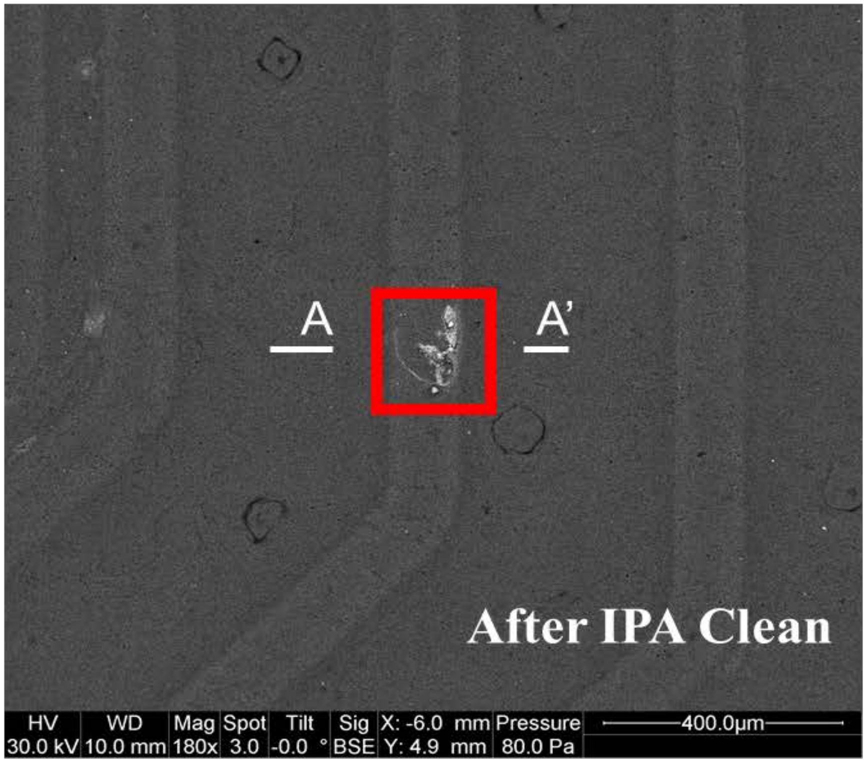
Optical Overview X-D04XL-12PU B

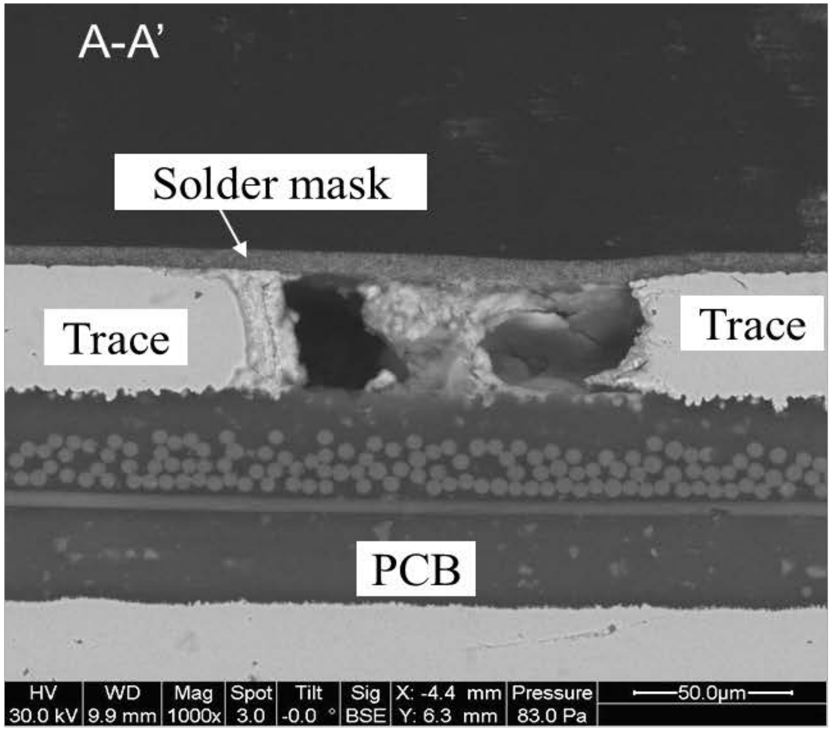


Cleaning and Sanding of Suspect Region



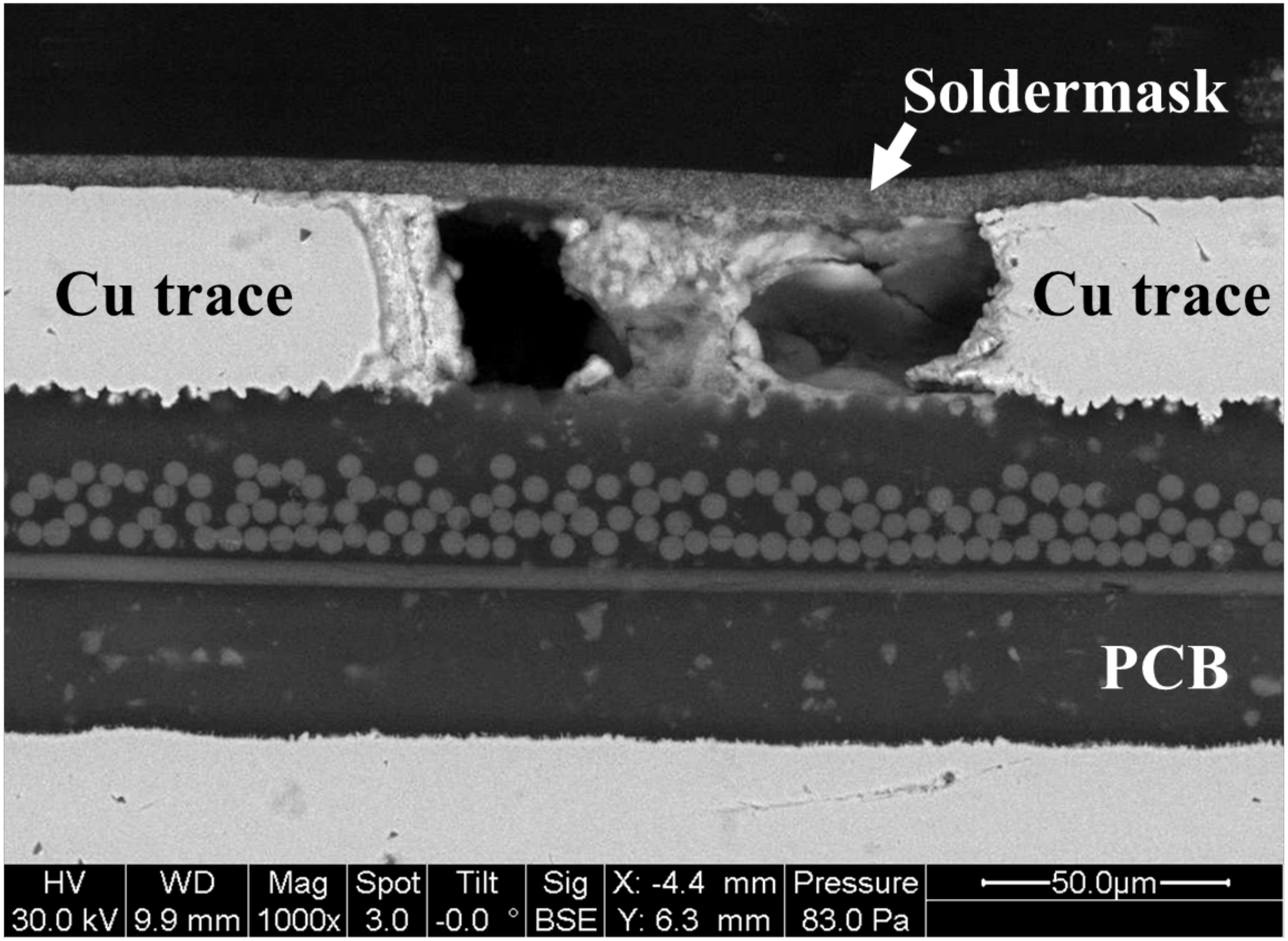
Holes Solder Mask and Trace Corrosion (Study 2)



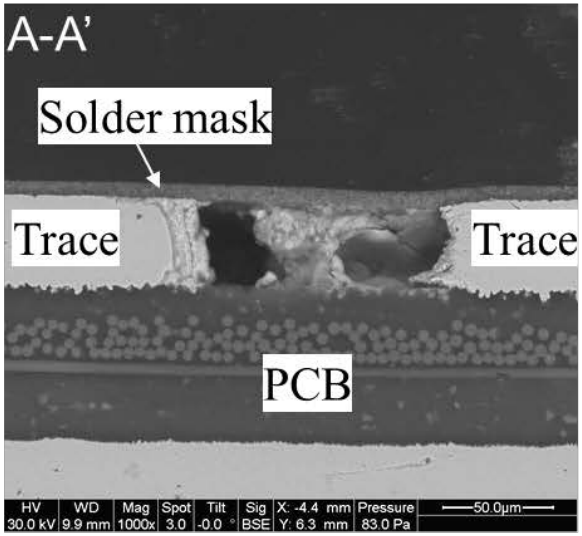


- After residues were removed with a swab, a crack/opening was observed in the solder mask.
- Residues were initially located on top of this opening, suggesting that the source was underneath the solder mask, the metallic trace.
- Note the location of blowholes close to the cracked surface.

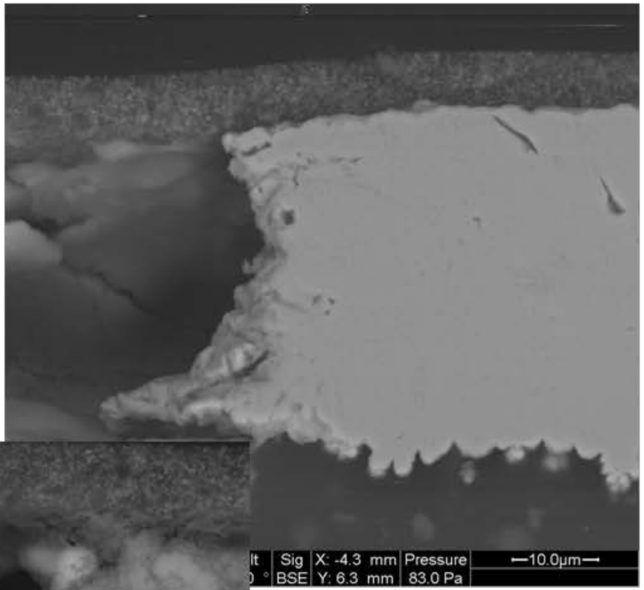
Cross-section of Corroded Region



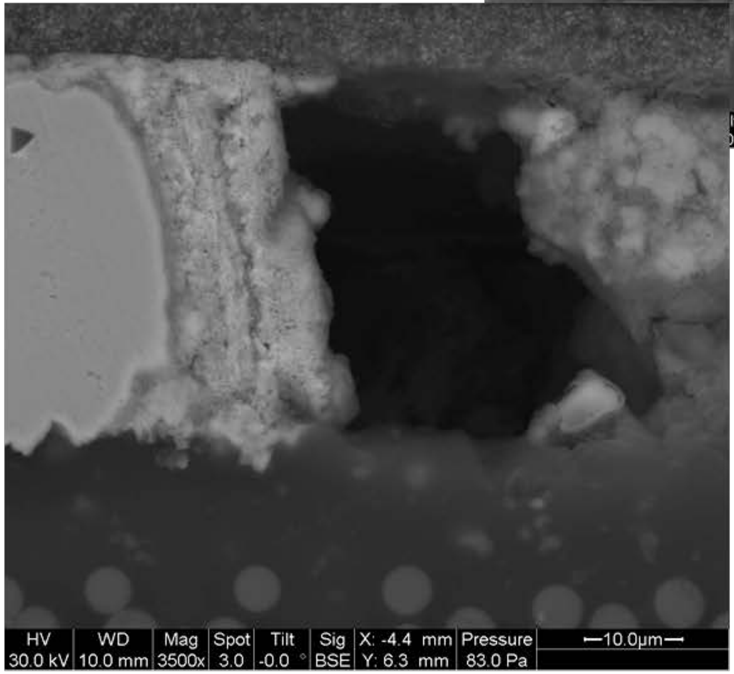
Cross-section of Trace With Damaged SM

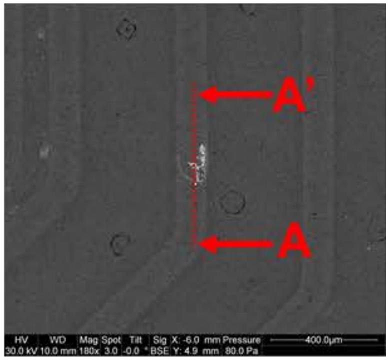


- Solder mask appears to be tented above the corroded trace.

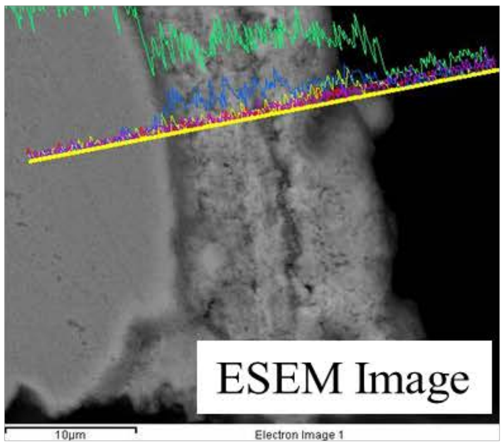


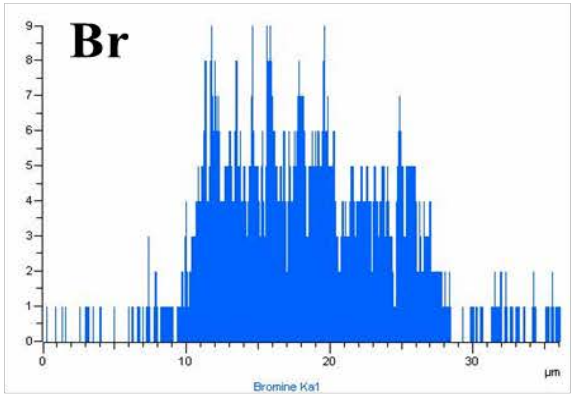
- The corrosion product was "pushed" out from underneath the soldermask to the surface.

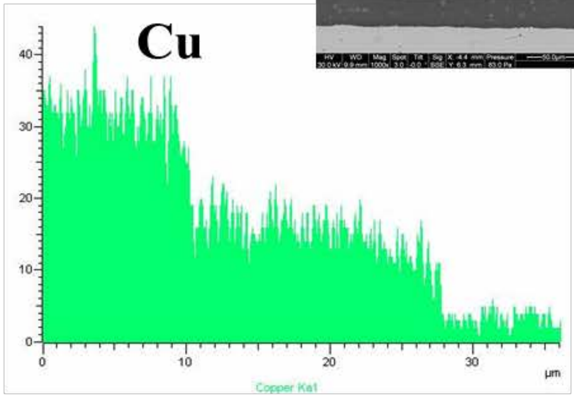


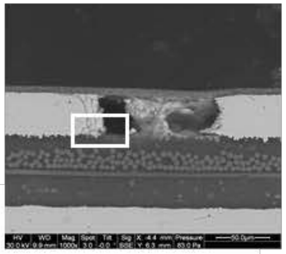


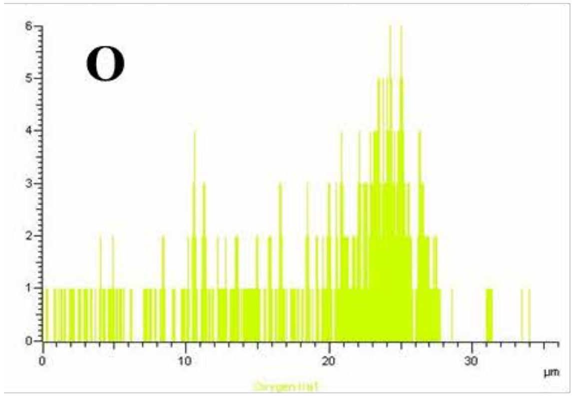
EDS Line Scan on Corroded Trace

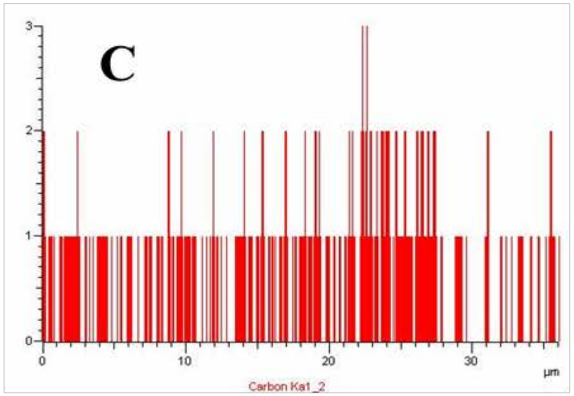


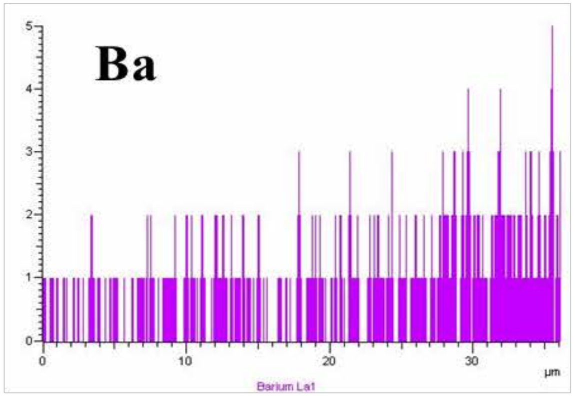










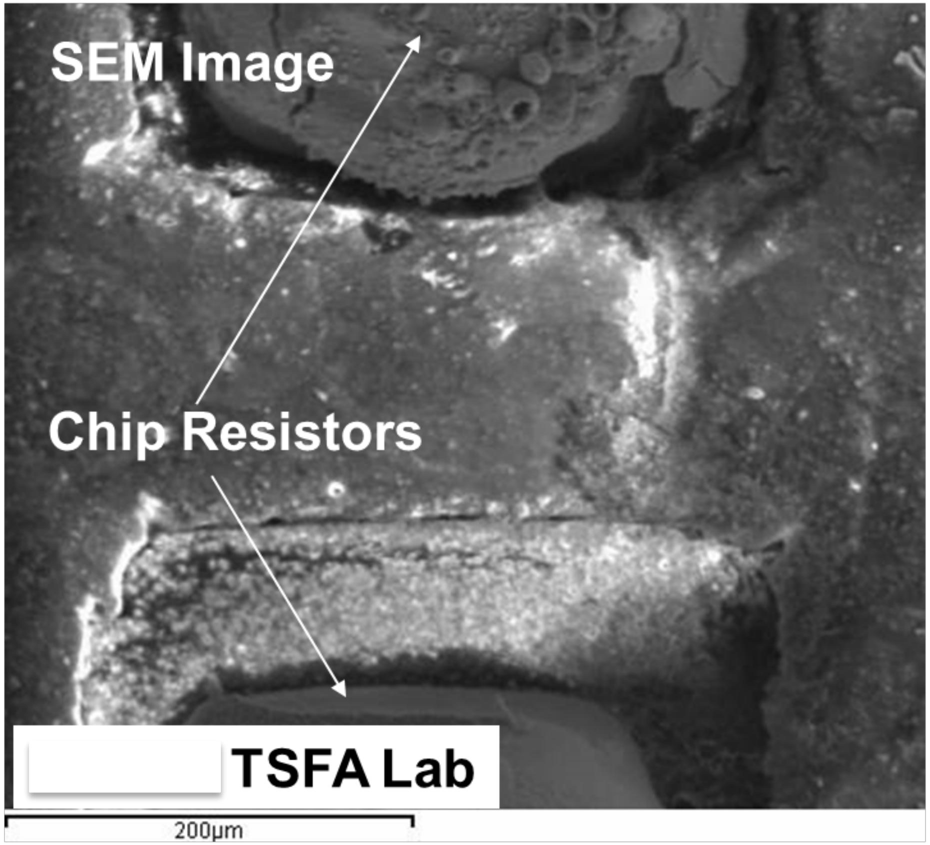


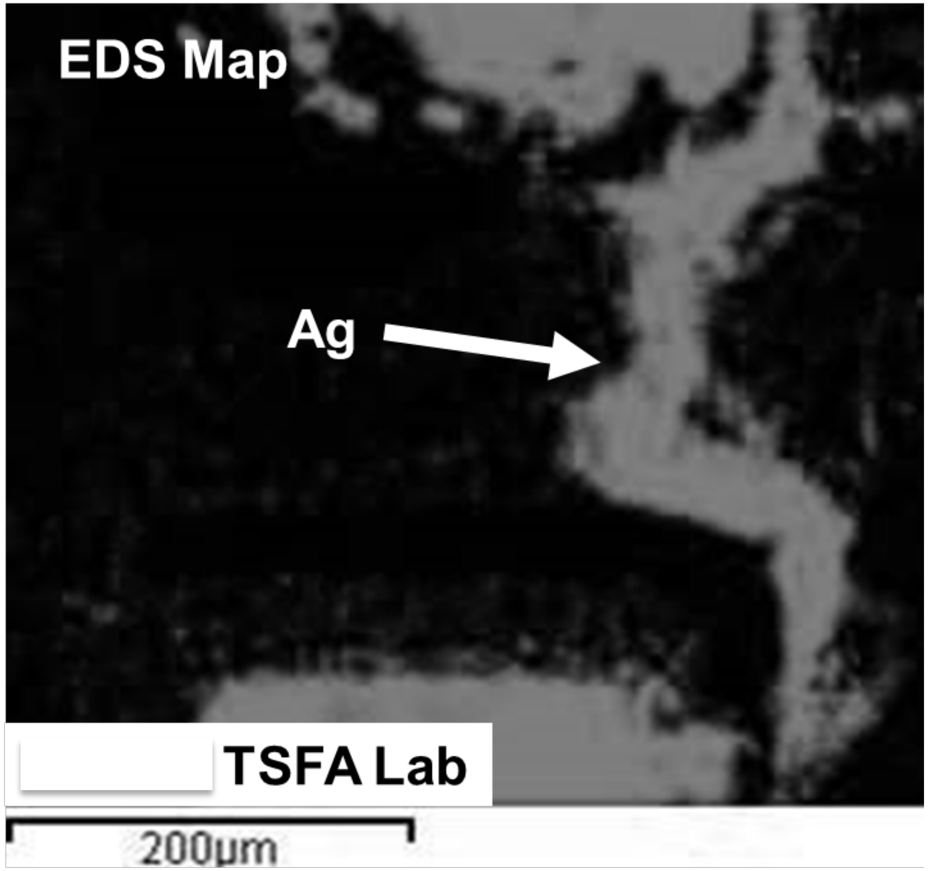
- The corrosion product was “pushed” out from underneath the soldermask to the surface.

Explanation of Corrosion Based Trace Open Failure Mechanism

- If the solder mask contains defects such as pin holes or poor edge coverage, moisture can be absorbed under the SM.
- The absorbed moisture comes into contact with the trace.
  - Under a voltage potential, an electrolysis reaction initiates.
  - This acidic reaction dissolves the Cu trace into a Cu ion solution under the SM.
  - The reaction is sustained and will continue as metallic copper is exposed and there is a voltage potential.
- This issue requires exposed metal, moisture and a voltage potential.
- Hygroscopic dust or dust containing ionic contaminants can accelerate this reaction.

Soldermask Defect Assisted ECM Failure (Study 3)





- Energy dispersive x-ray spectroscopy (EDS) mapping of a dendrite shows that it is composed of silver.
- Silver from Sn-3.5Ag solder.

Summary
Effective Inspection and Goals

- Goals of soldermask risk inspection should include:
  - Identify the prevalence of soldermask defects in PCB
  - Identify most effective defect inspection methods
  - Recommendations on manufacturing process and material flow downs.
- What are currently accepted methods of solder mask?
- How close are documented results to spec?
- Effectiveness of current inspection methods and protocols for detecting solder mask defects:
  - Blow holes
  - Inadequate conductor coverage
  - What are the techniques that can bridge the gap between current methods and prevent escapes?

Thank you

Questions?

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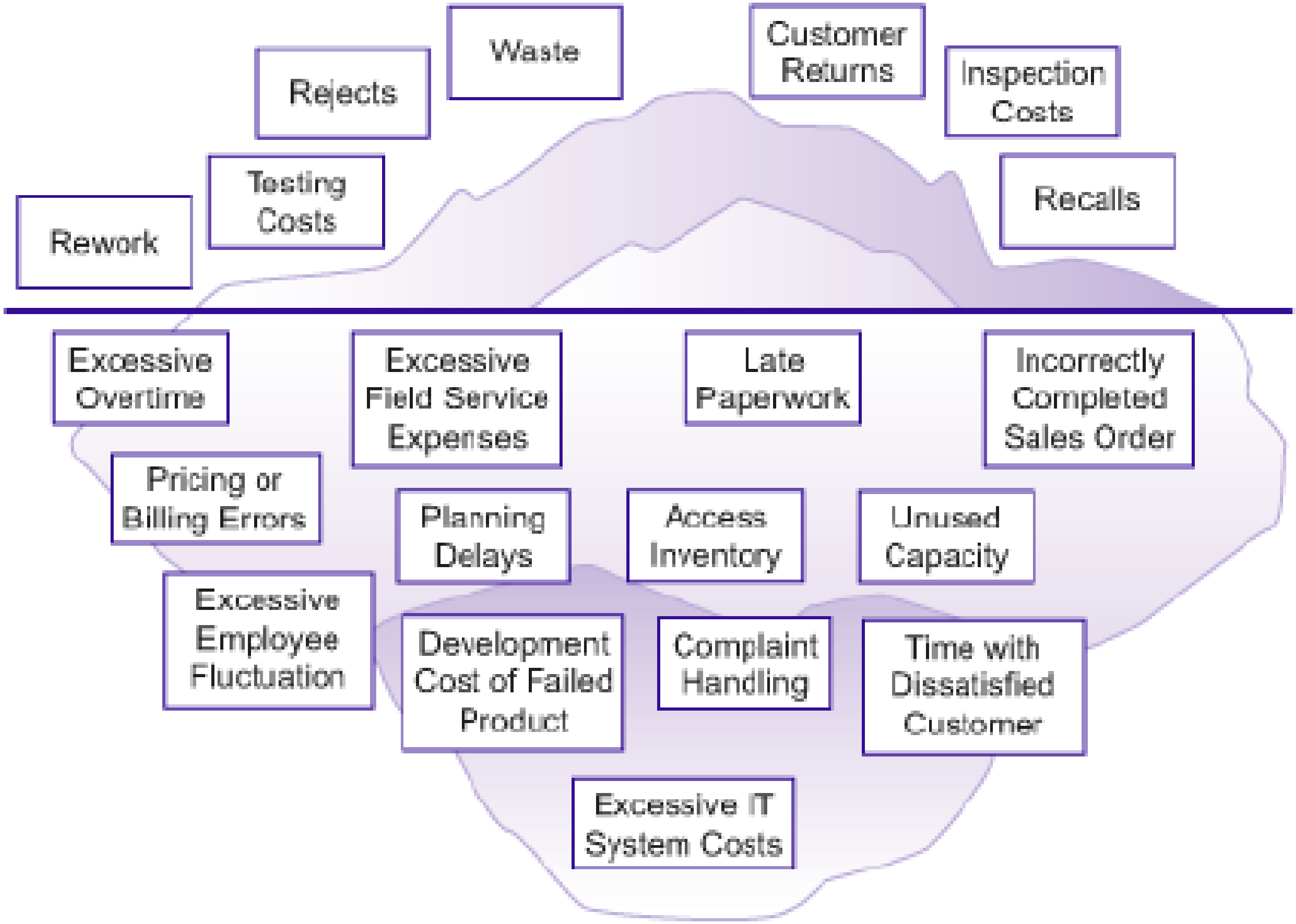
Backup Material

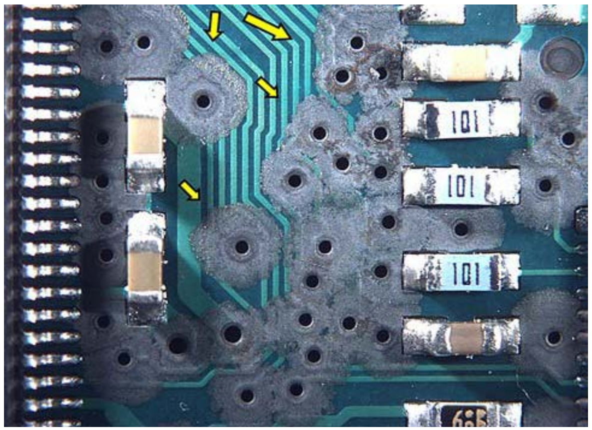
Iceberg Model of Cost of Poor Quality



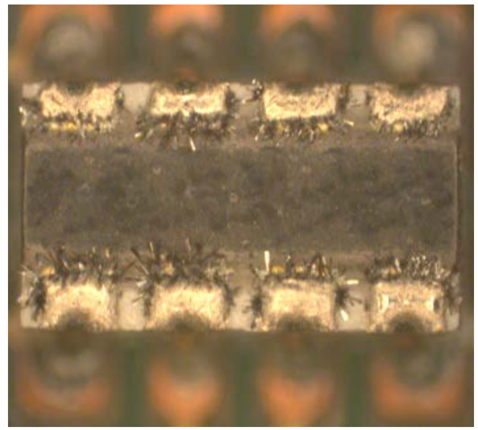
Ref: A. Buthmann, "Cost of Quality: Not Only Failure Costs," iSixSigma.

Electrochemical Migration and Corrosion

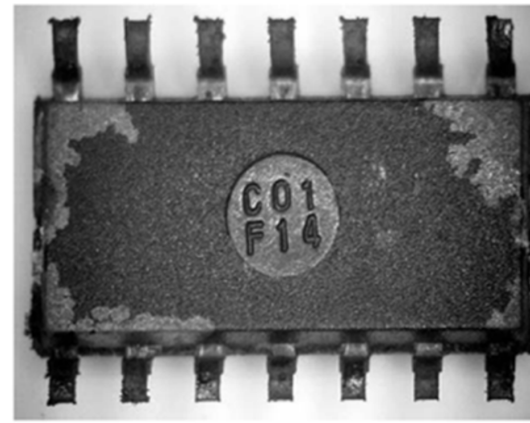
- Electrochemical migration and corrosion can impact electronic reliability



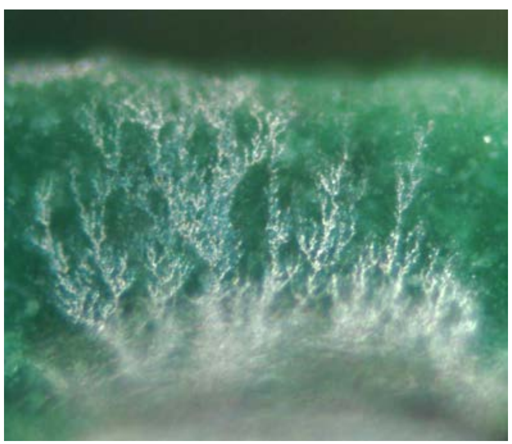
Creep Corrosion



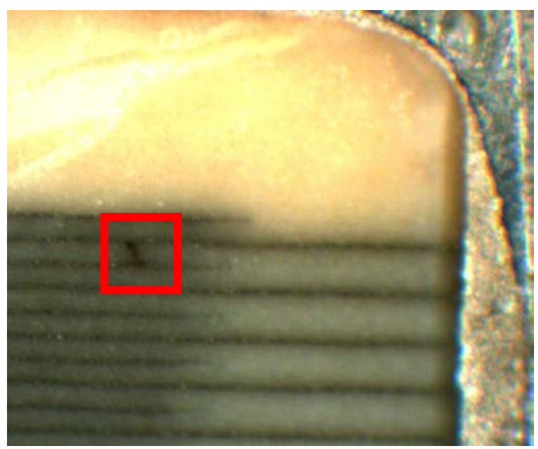
Silver Dendrites



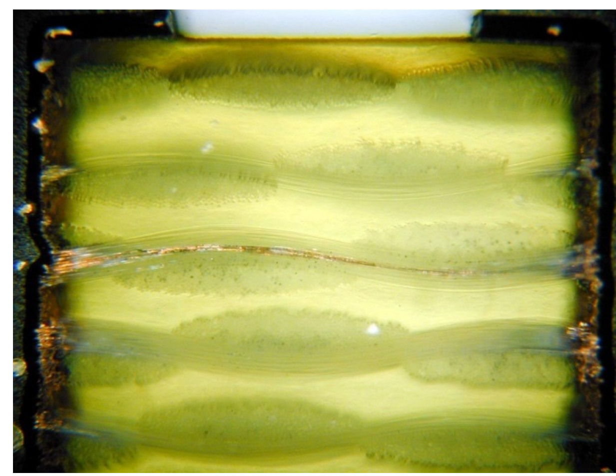
Creep Corrosion



Dendritic Growth



Silver Migration in MLCC



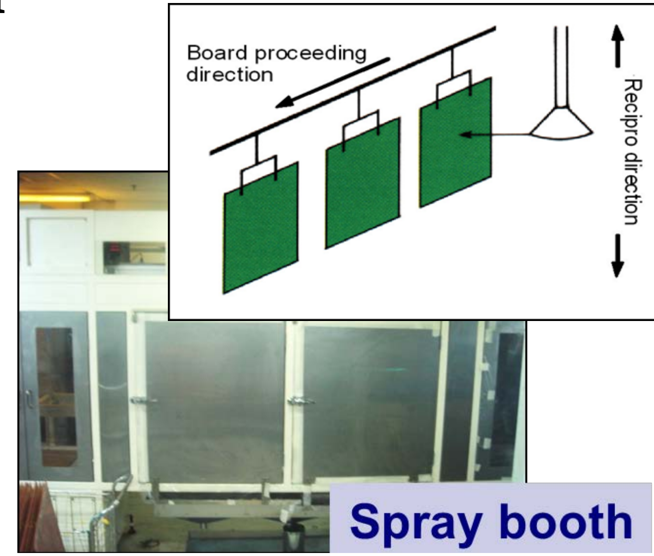
Conductive Filament Formation

Explanation of Corrosion Based Open Failure Mechanism

- Moisture absorption.
- Acidic reaction leads to Cu dissolution
- Sustained and will continue as long as moisture is available and there is a voltage potential, thus creating an open circuit.
- Requires (a) exposed metal, (b) moisture and (c) voltage potential.
- Hygroscopic dust or dust containing ionic contaminants can accelerate this reaction.

Application*

- Screen printing
  - Application
  - Pre-bake
  - Exposure, development
  - Bake
- Spray Application
  - PCB are attached to a conveyor (horizontal or vertical).
  - Mask in liquid phase is sprayed using centrifugal atomization nozzles.
    - Two sided or single side
  - Pre-bake, UV cure and bake.



Spray booth

Oven

* - material from Taiyo