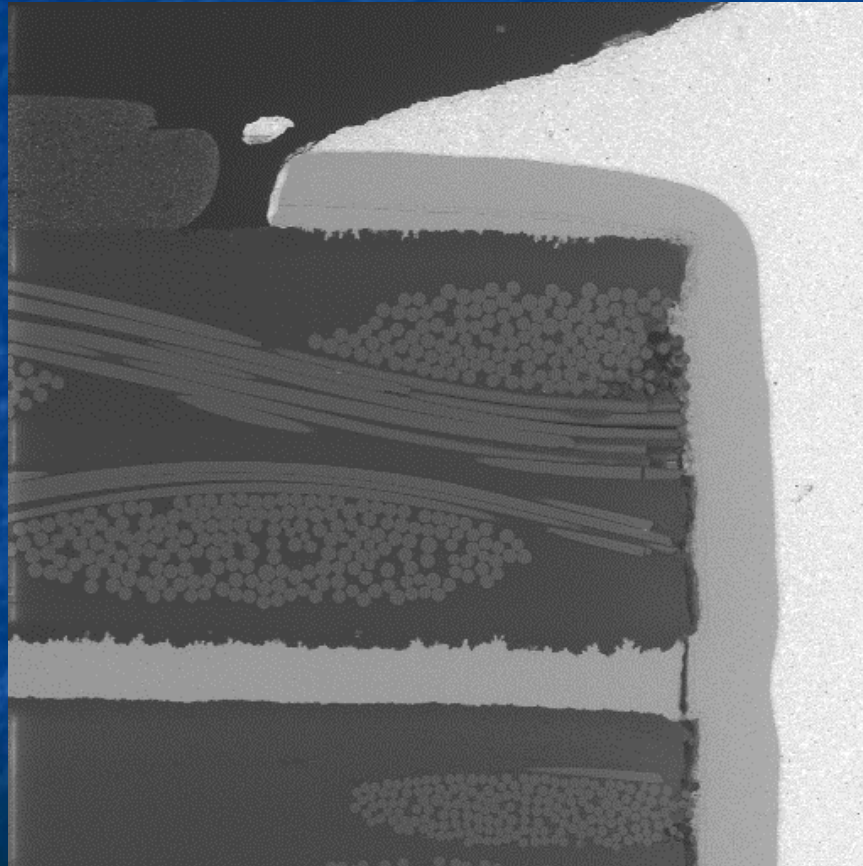


Images of Failures in Microelectronics Packaging and Assembly

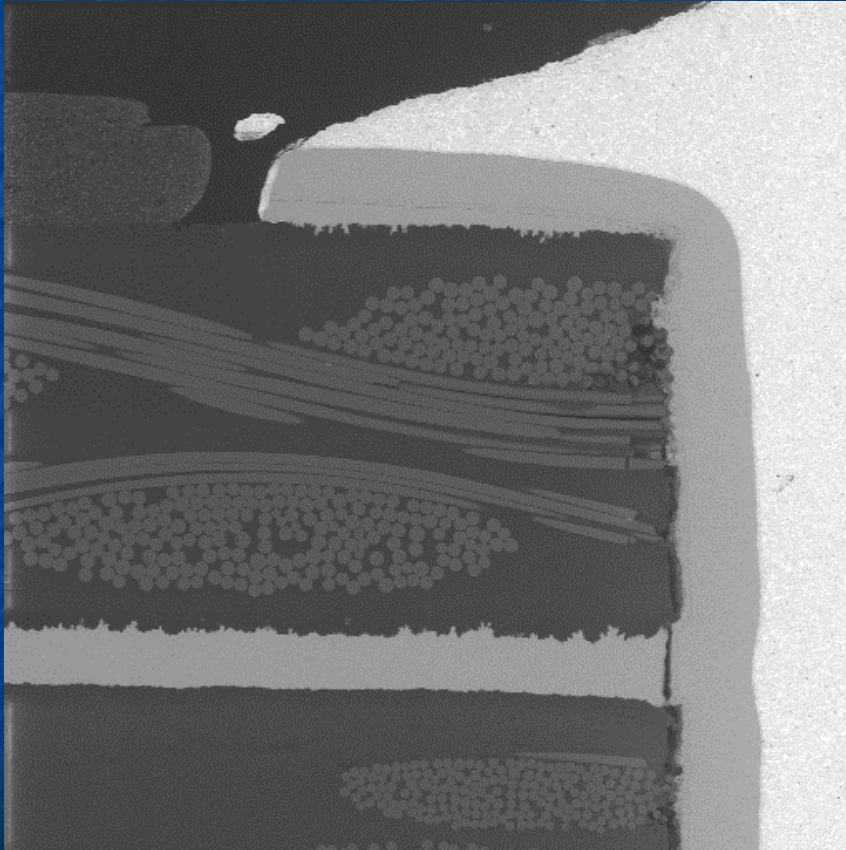
Ed Hare, Ph.D./[SEM Lab, Inc.](http://www.semlab.com)

IMAPS NW - Feb. 11th 2004
Redmond, WA

What is this?

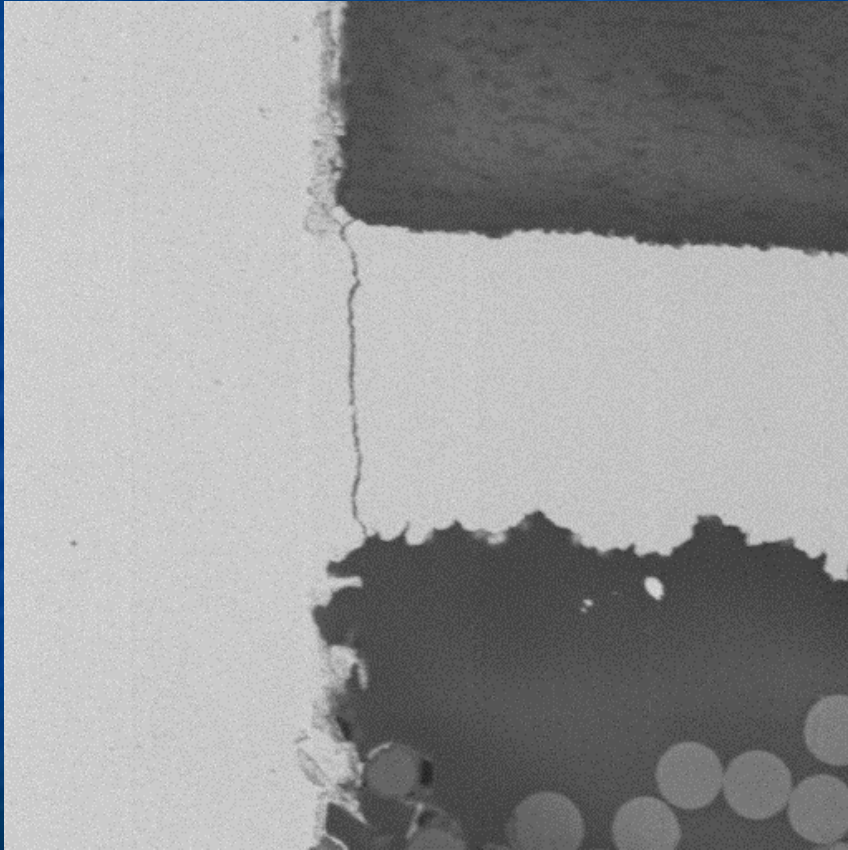


Inner Layer Separation



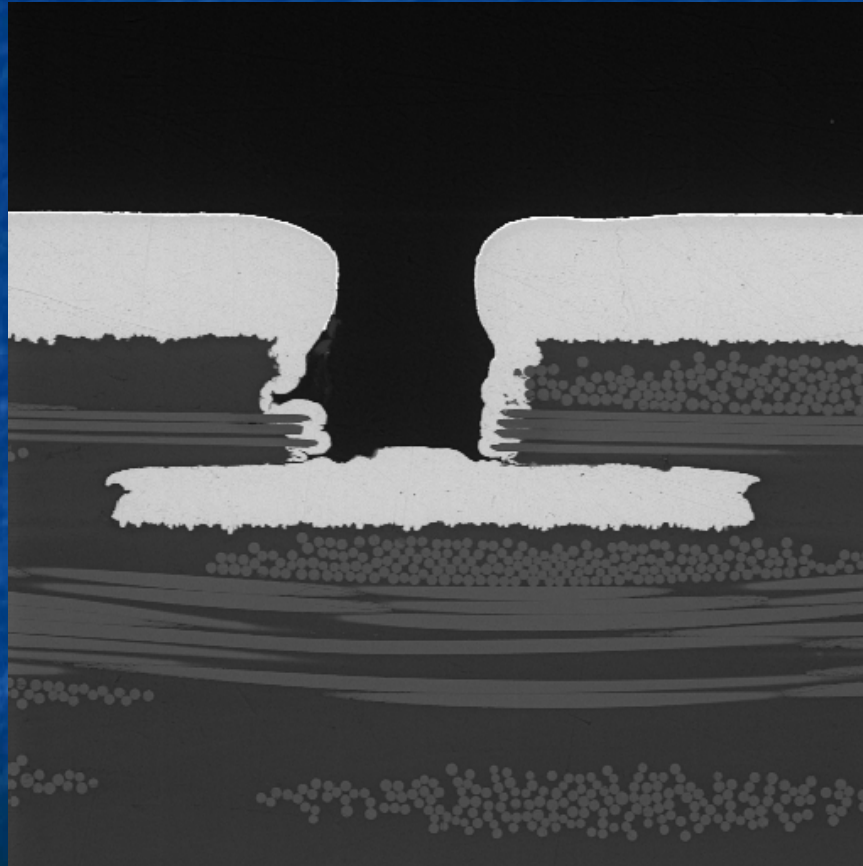
- Between laminate copper and electroless copper
- Found Ca & S residues at failed interface

Inner Layer Separation

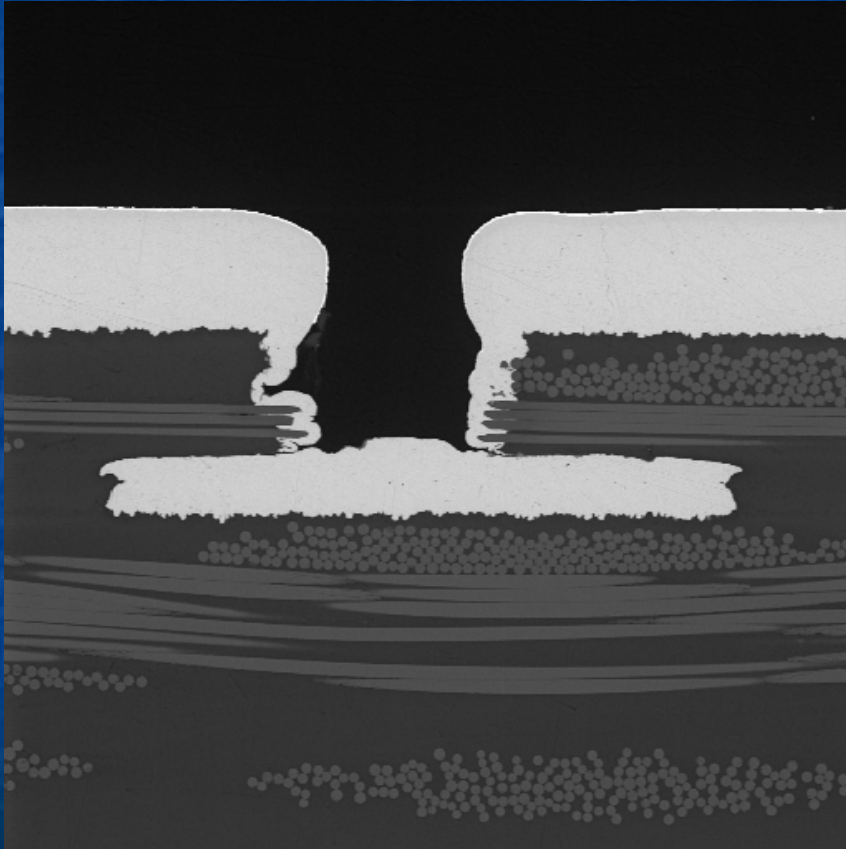


- QC coupon mount from PWB fabricator
- “lines of demarcation”
- Missed during routine QC examination

What is this?

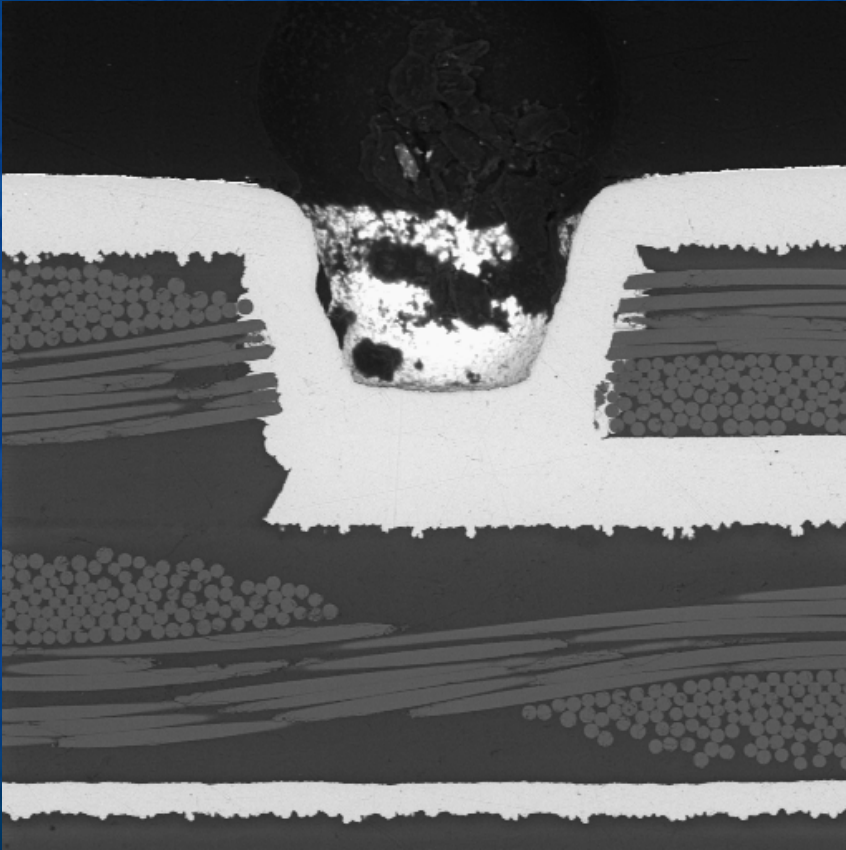


Microvia



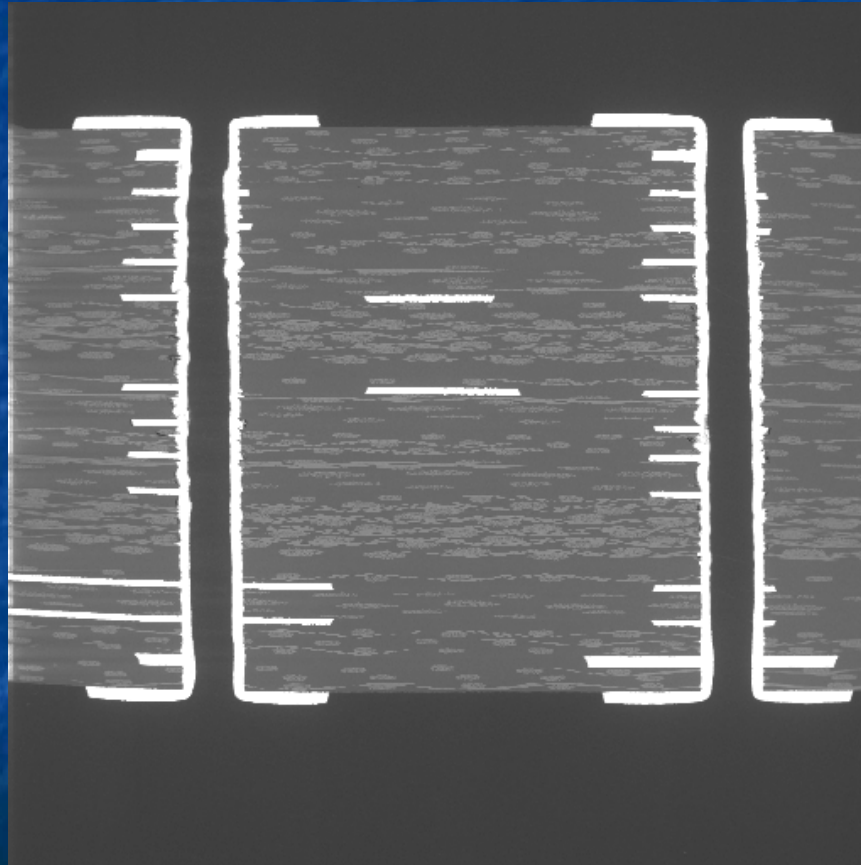
- This is a poorly fabricated microvia
- There is little or no copper plating connecting to the layer-2 pad

Microvia

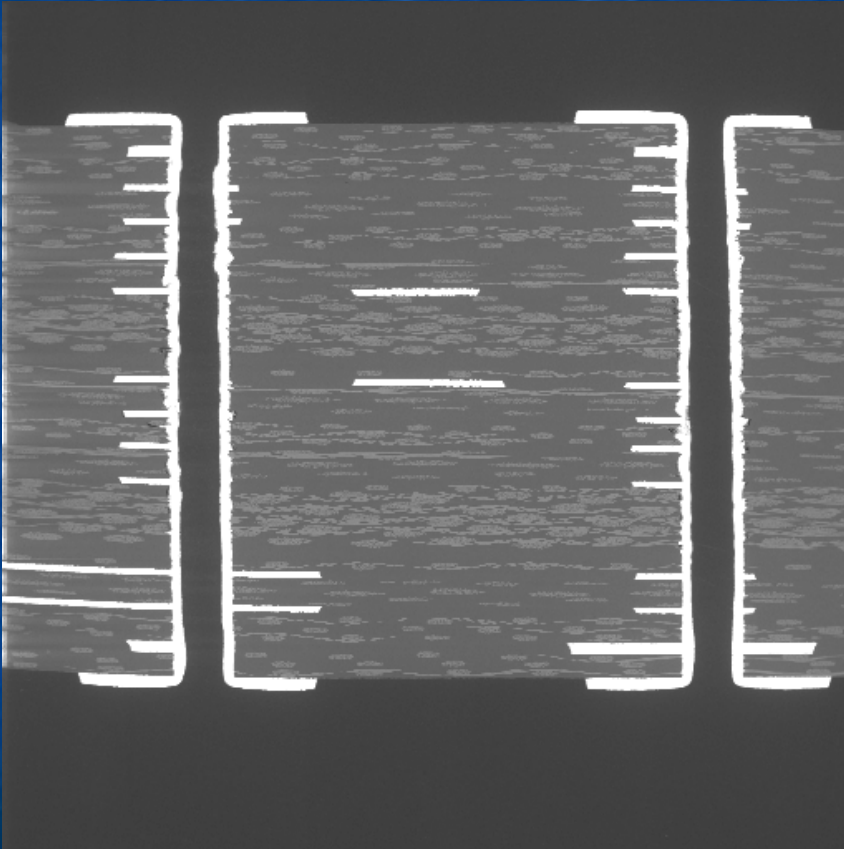


- This is a “good” microvia
- There is uniform copper plating connecting to the layer-2 pad

What is this?

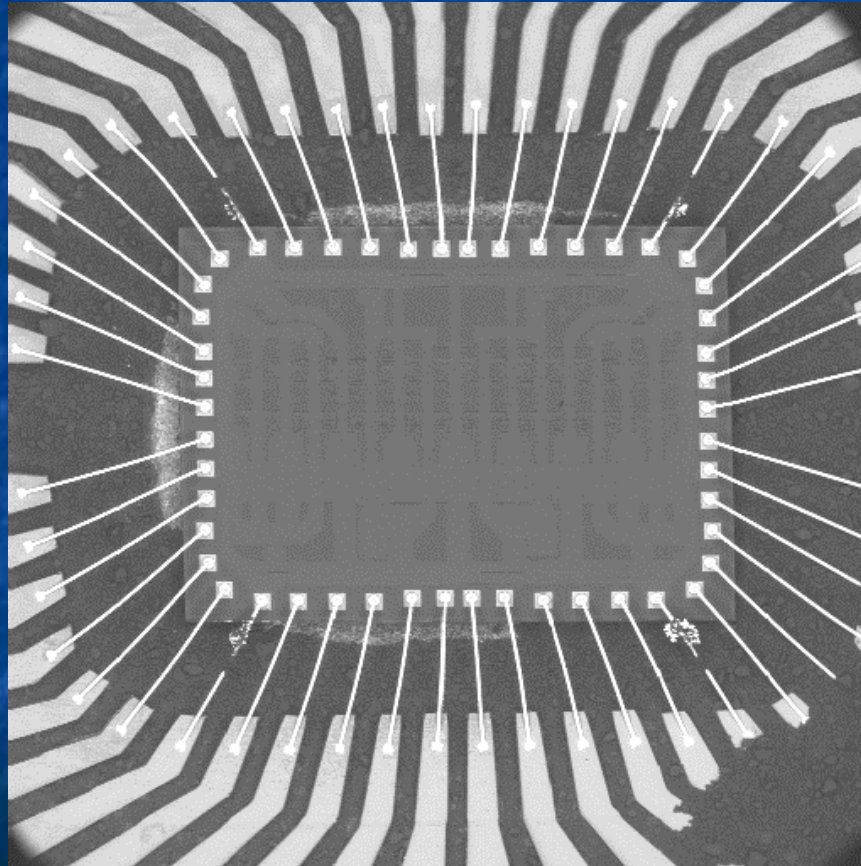


Drill Breakout

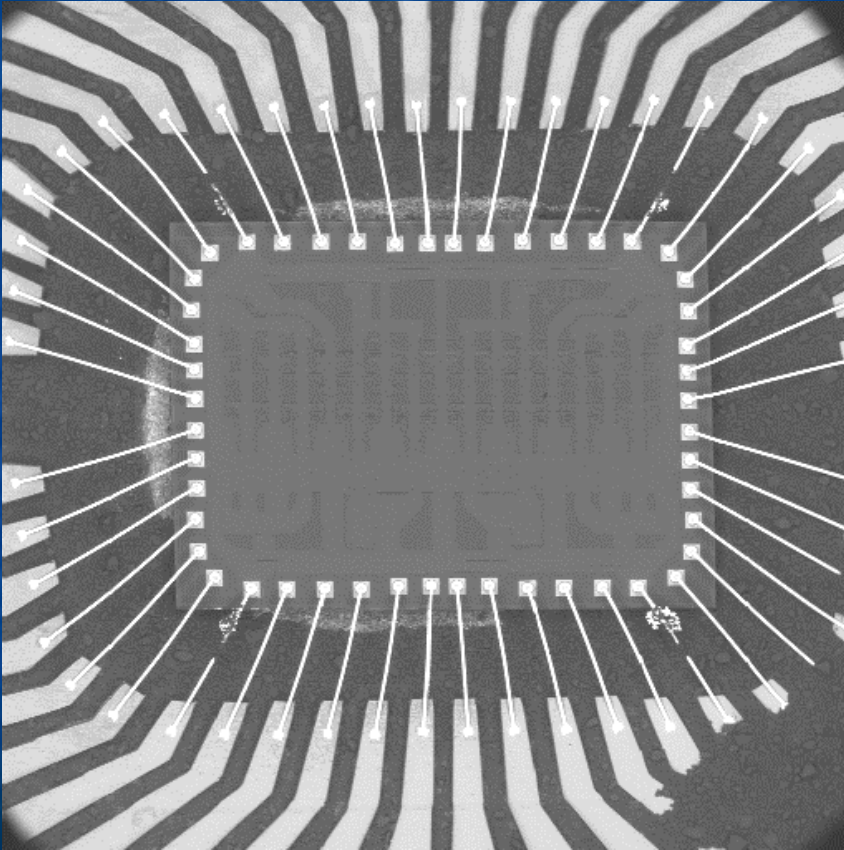


- The inner layer lands probably should have been larger diameter in this design
- This condition fails Class 3 criteria in IPC-A-600 (min. annular ring 0.001 in)

What is this?

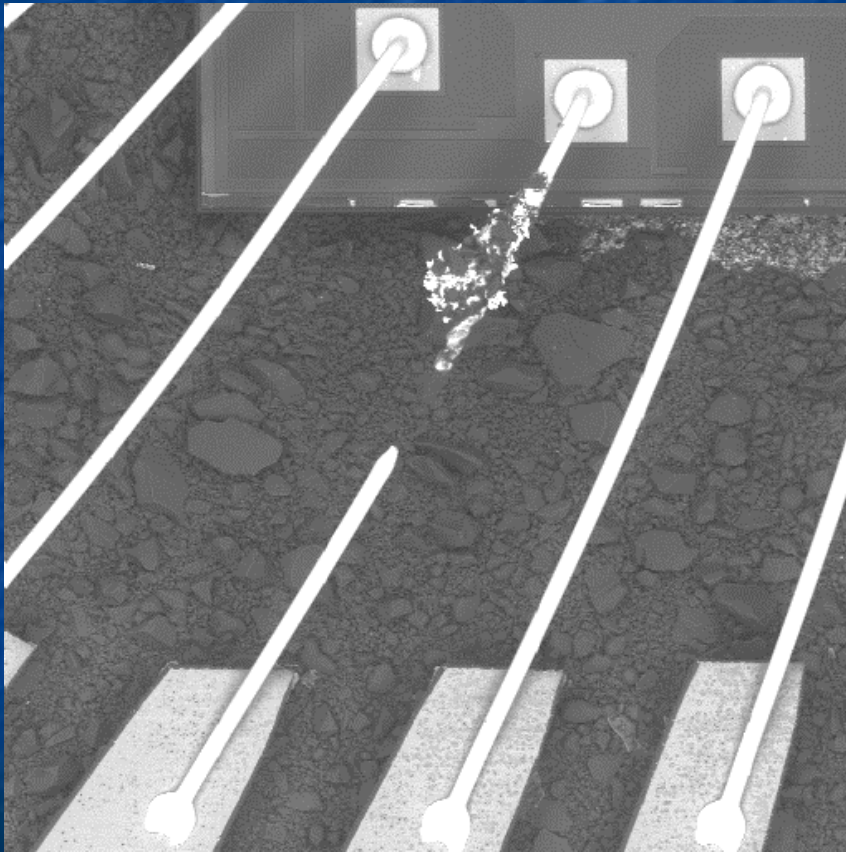


EOS Failure



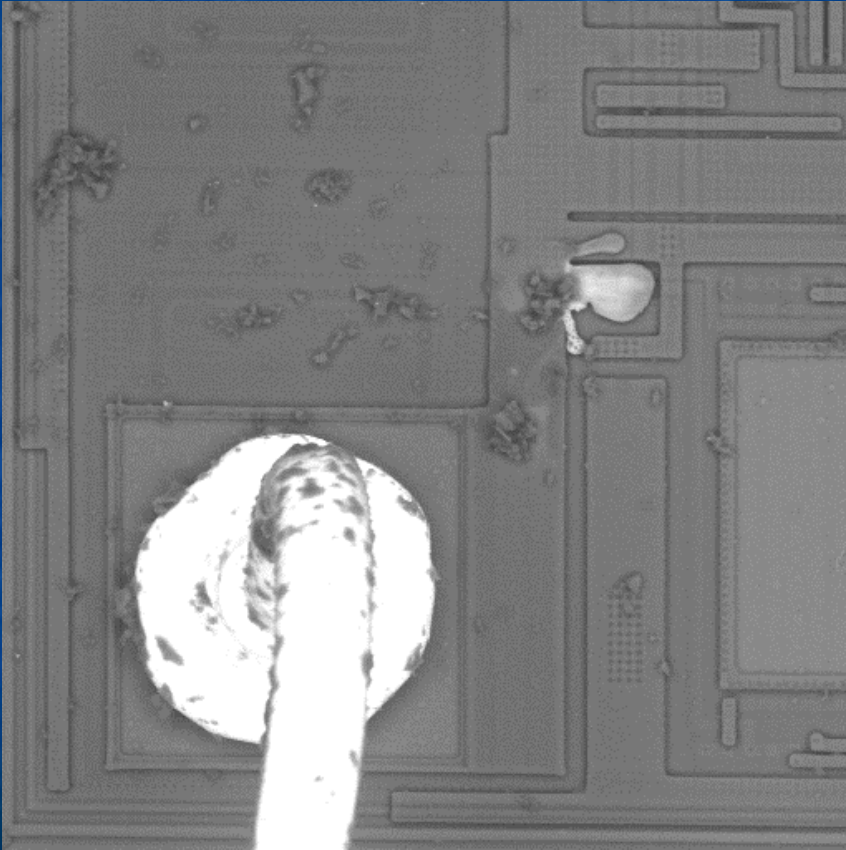
- All four Vcc wire bonds are fused open
- There is no damage on the die
- Excessive current failure likely due to latch-up

EOS Failure



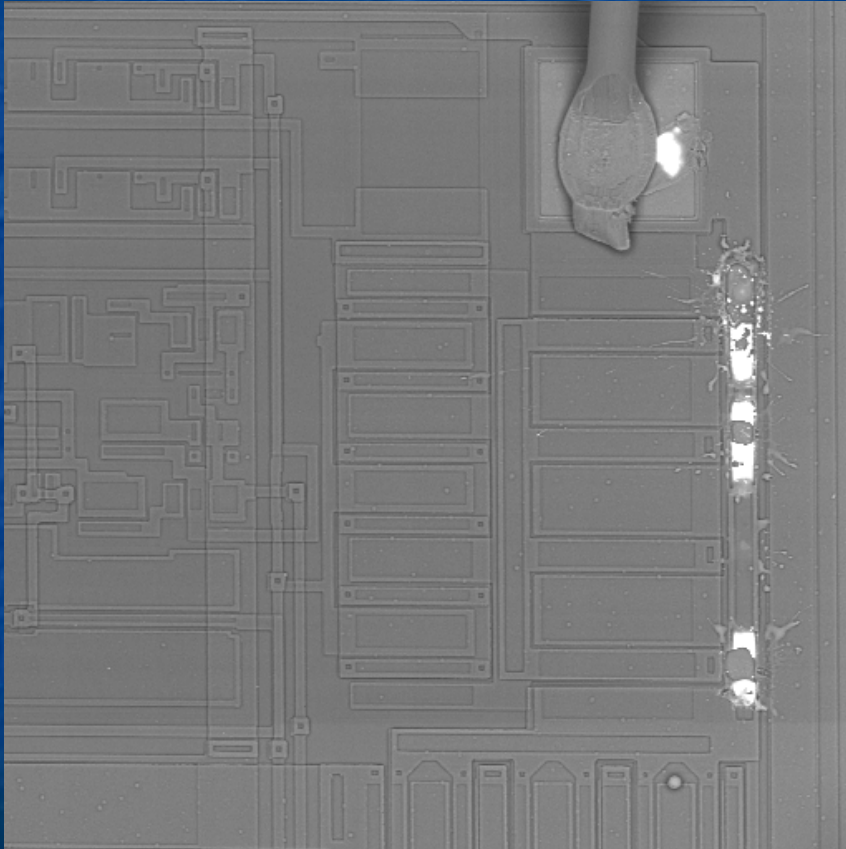
- Vcc wire bond is fused open
- Fusing current of 1-mil gold wire is \sim 0.75 amps

EOS Failure



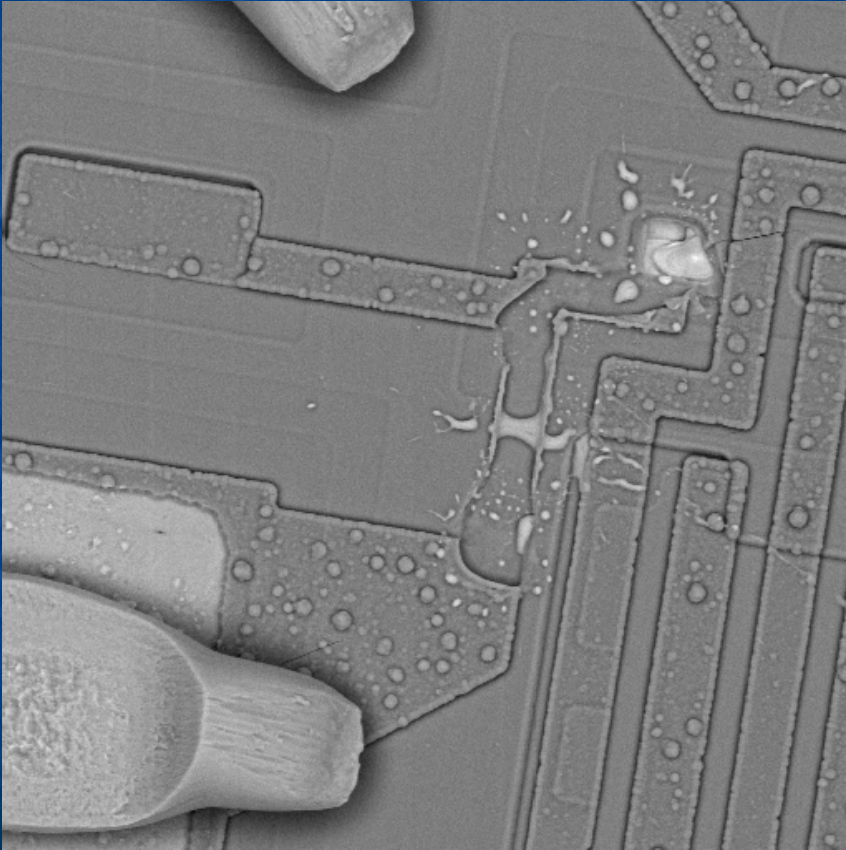
- A short segment of metallization was fused open
- Likely caused by a voltage transient

EOS Failure



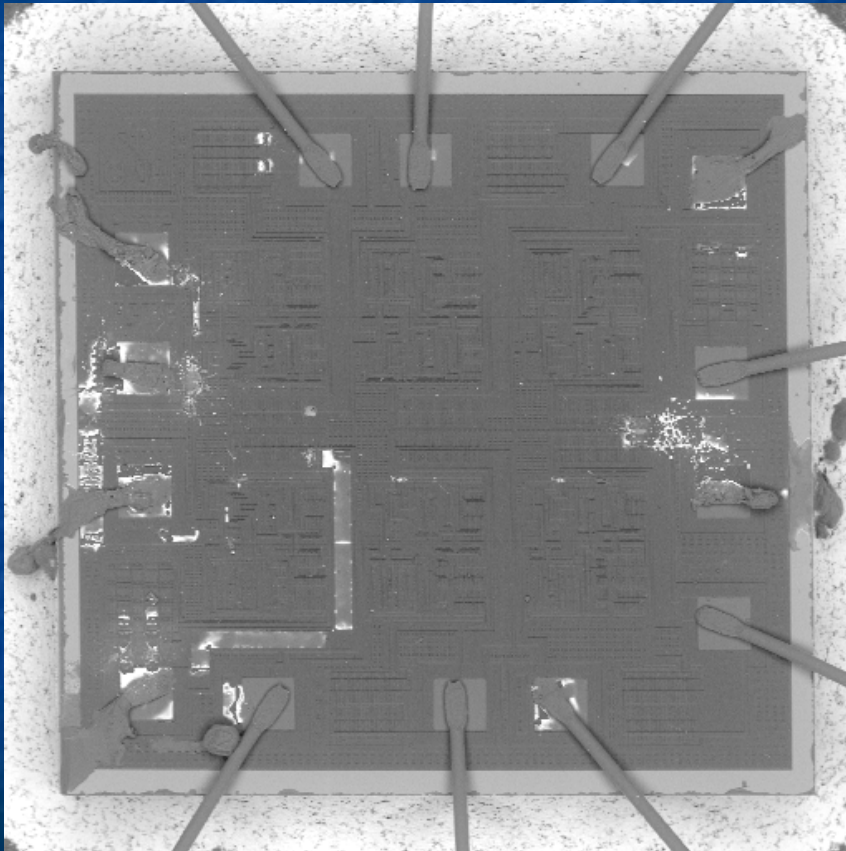
- A short segment of metallization was fused open
- Likely caused by a voltage transient

EOS Failure



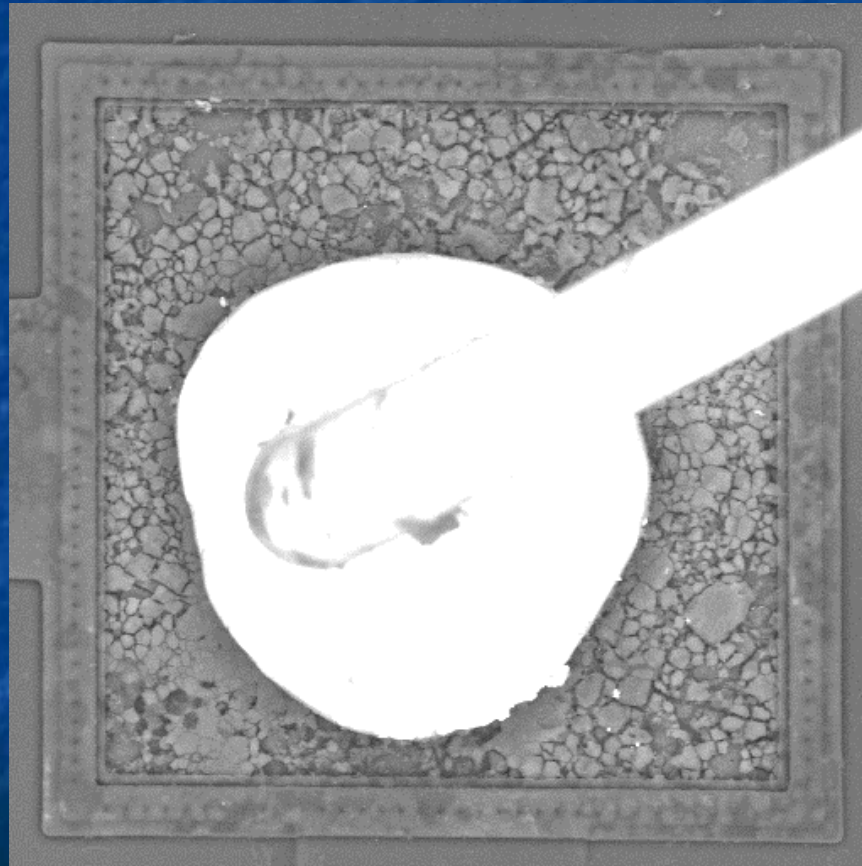
- A short segment of metallization was fused open
- Likely caused by a voltage transient or ESD

EOS Failure

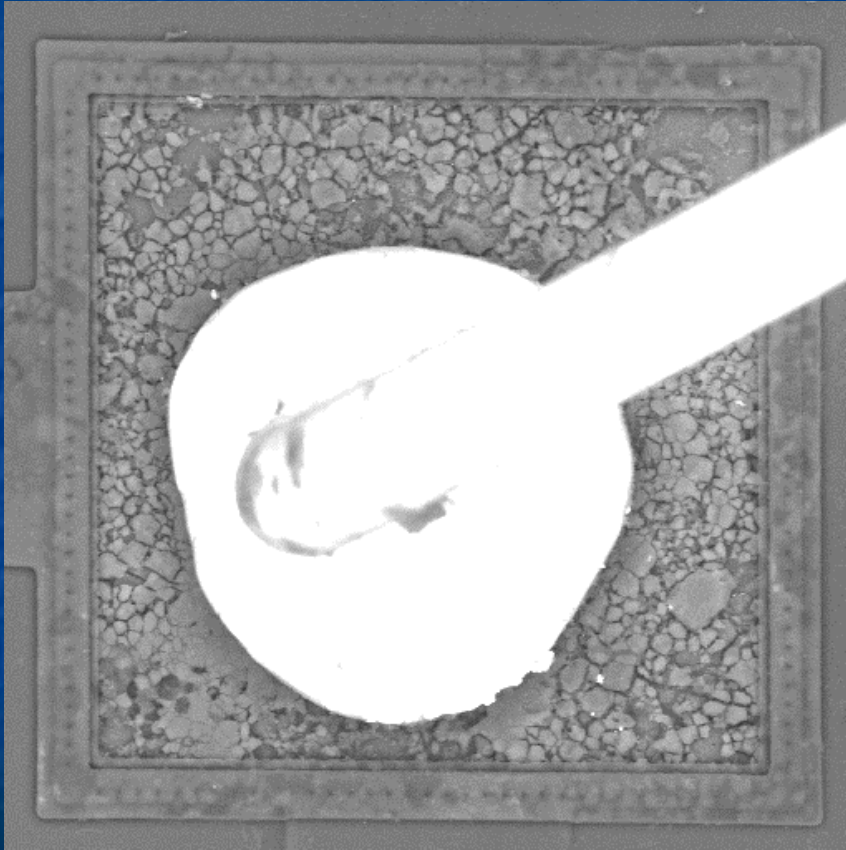


- Gross electrical overstress damage

What is this?

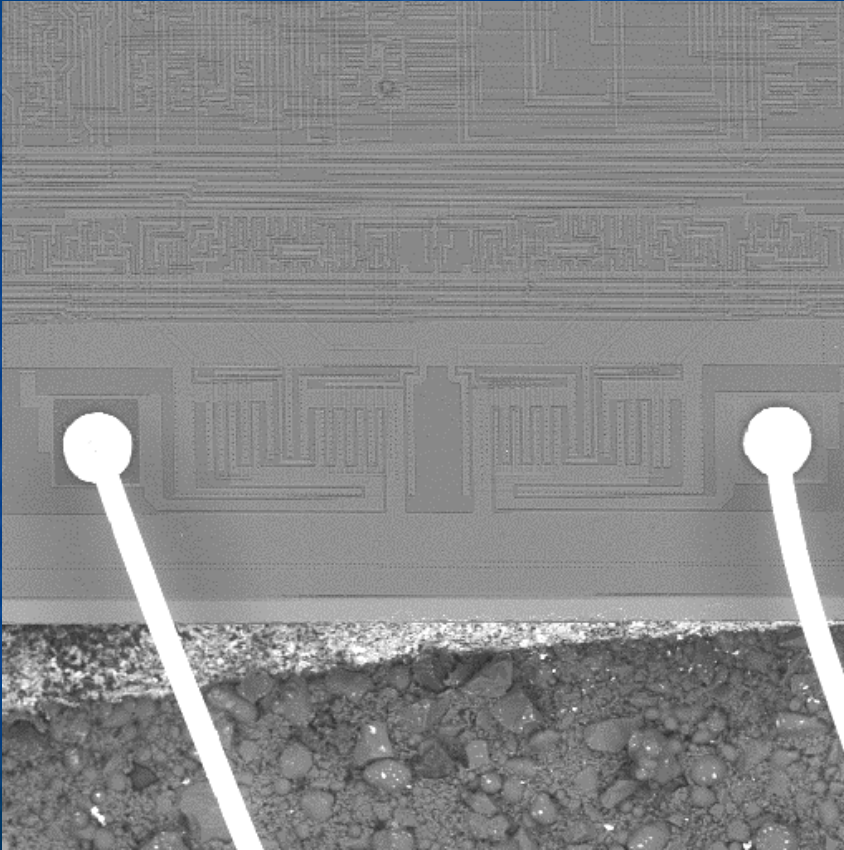


Bond Pad Corrosion



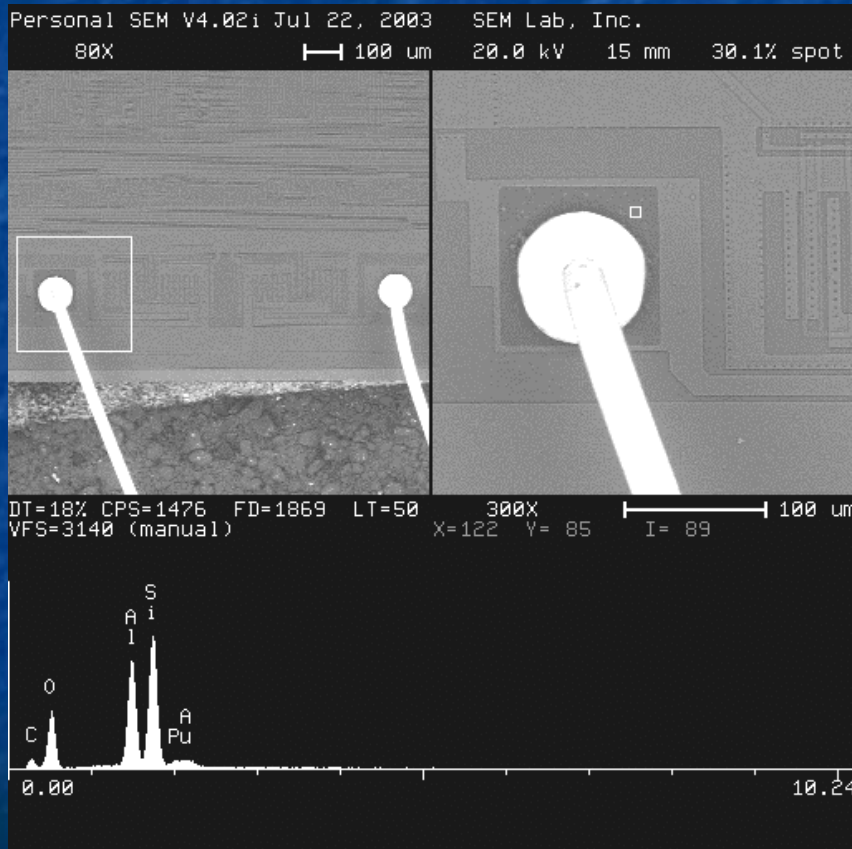
- Contributing causes –
 - * moisture
 - * “pop-corn” damage
 - * internal delam
 - * P contamination

Bond Pad Corrosion



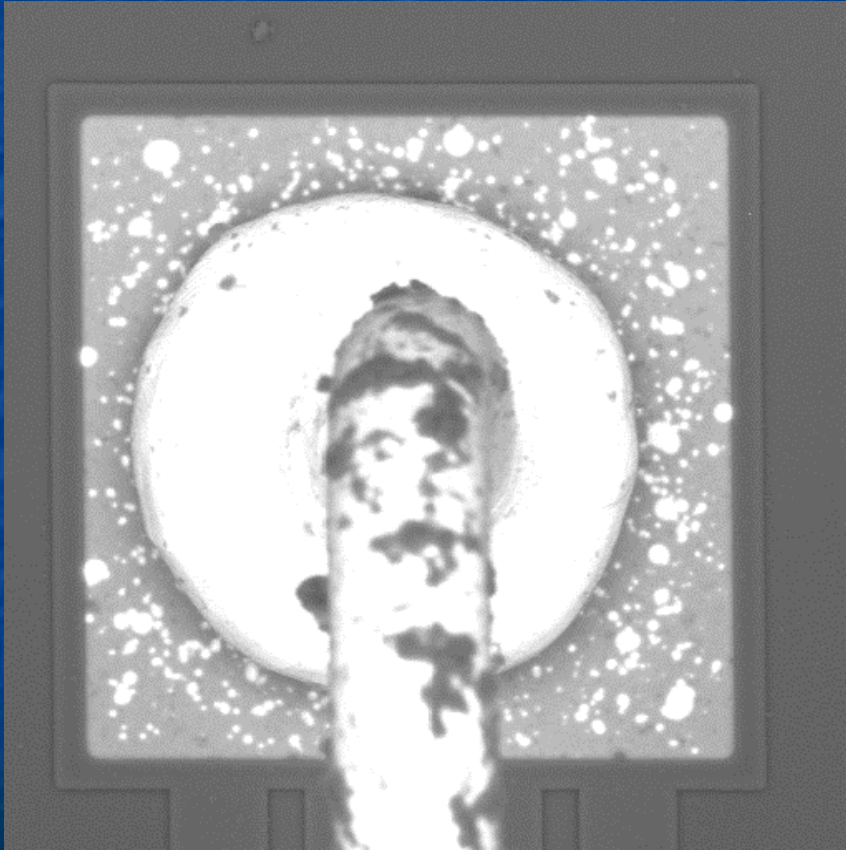
- How to avoid –
 - * MSD control
- Use CSAM imaging and F/A to diagnose

Bond Pad Corrosion



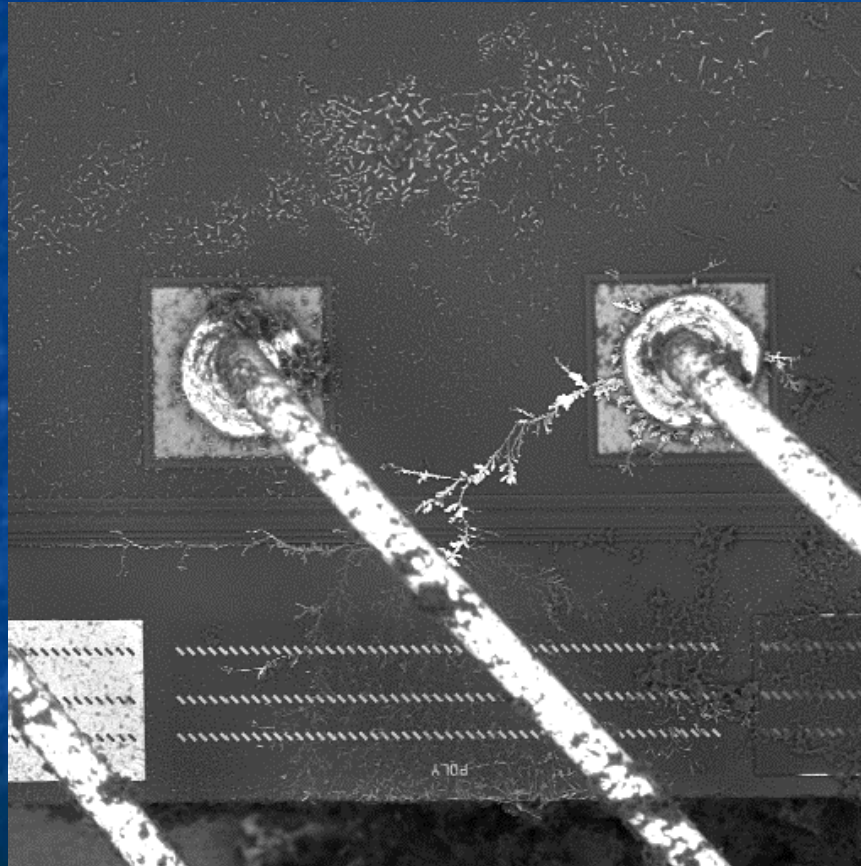
- Trace of P
- P due to molding compound or residual from IC fab

Bond Pad Corrosion

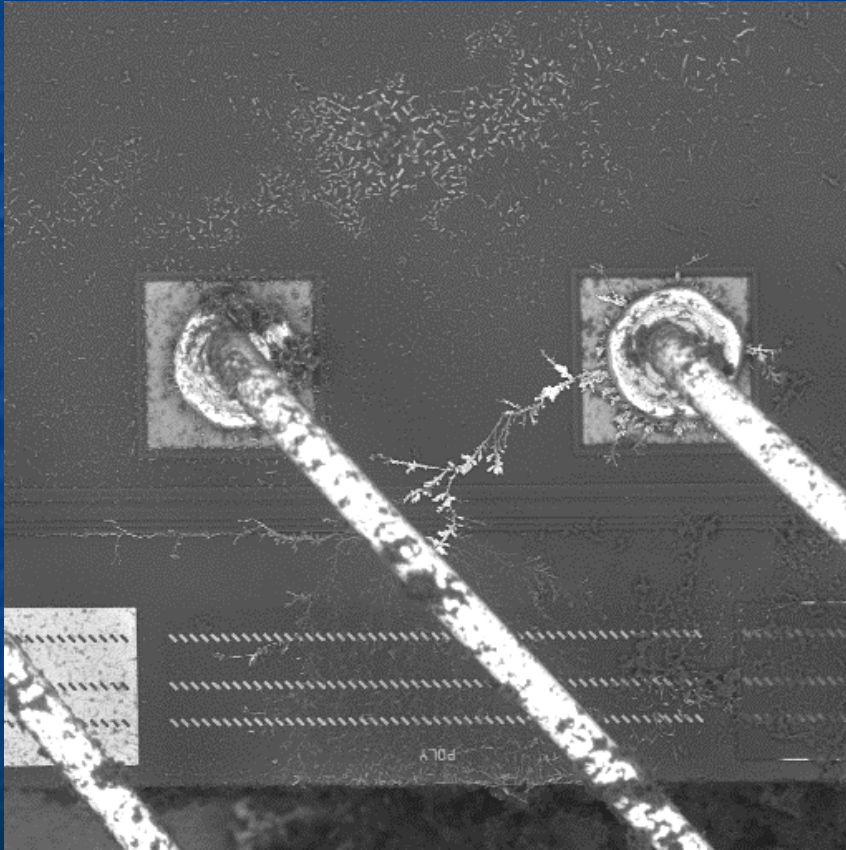


- Bright spots are Ti-W barrier layer where Al is missing

What is this?

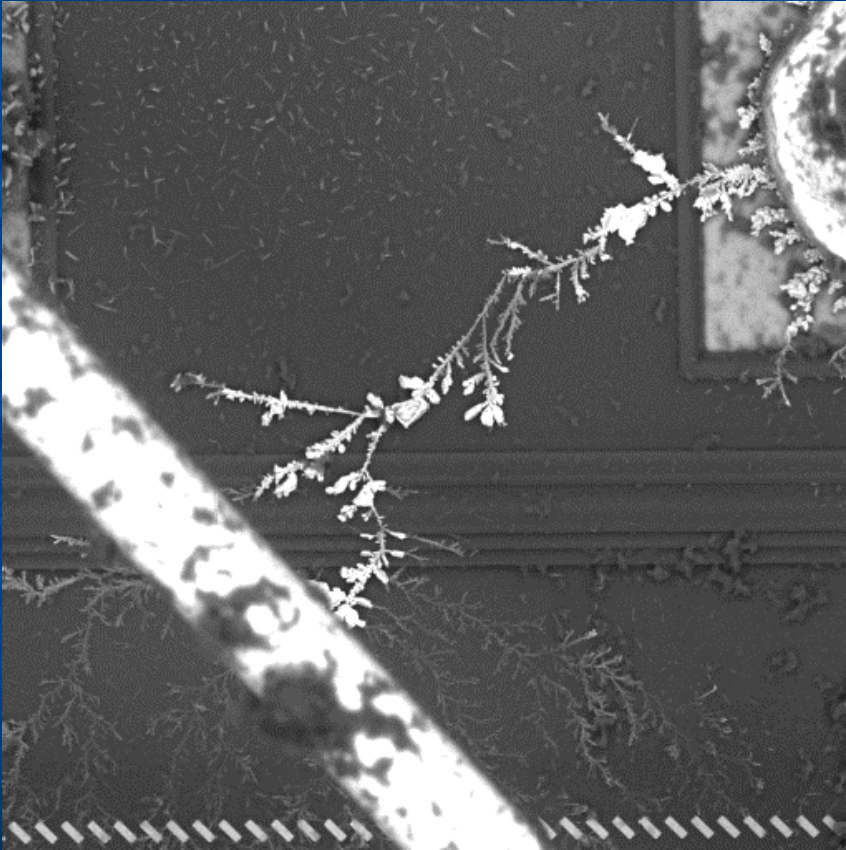


Dendritic Growth on IC Die



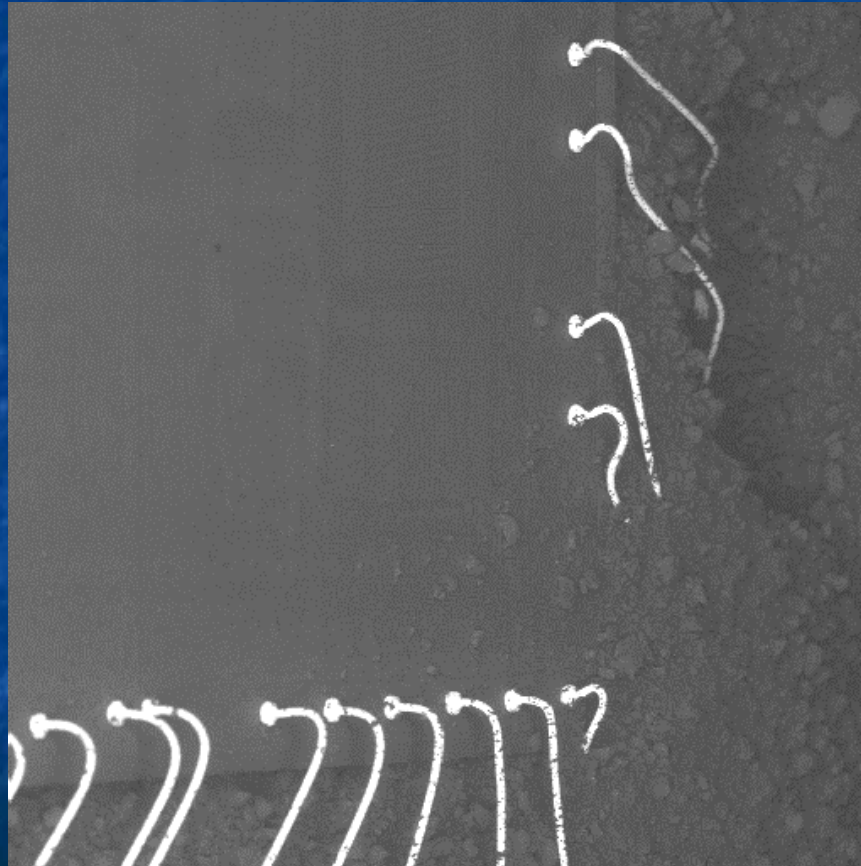
- Silver and copper dendrites
- For all the same reasons as bond pad corrosion

Dendritic Growth on IC Die

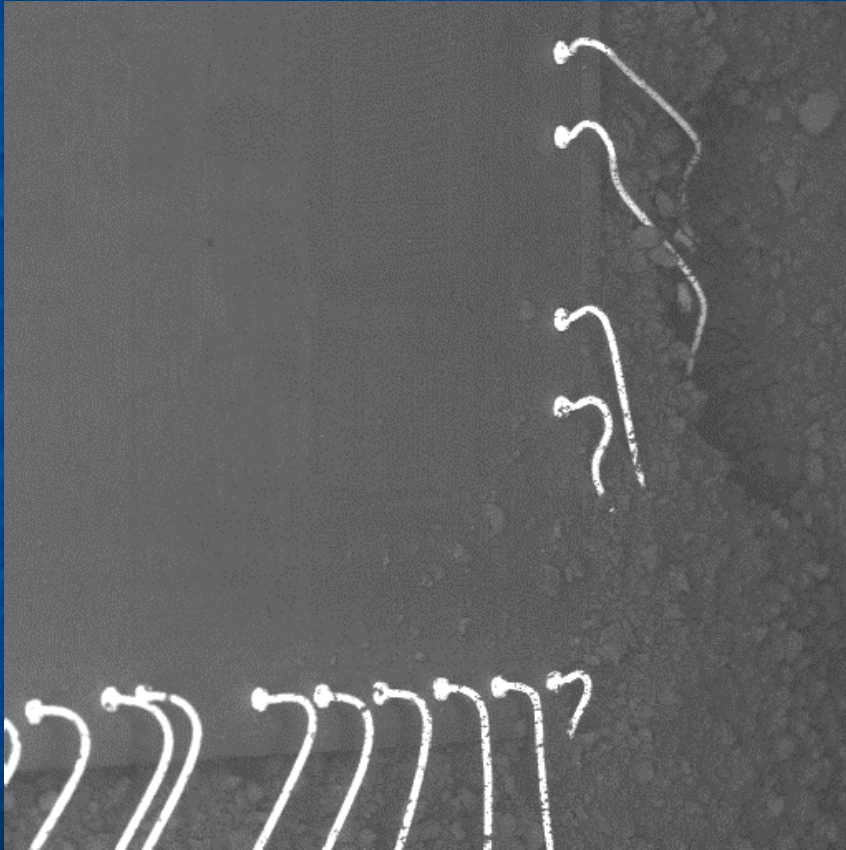


- ... or most of the same reasons as bond pad corrosion
 - moisture
 - ionic contamination
 - bias
 - internal delam

What is this?

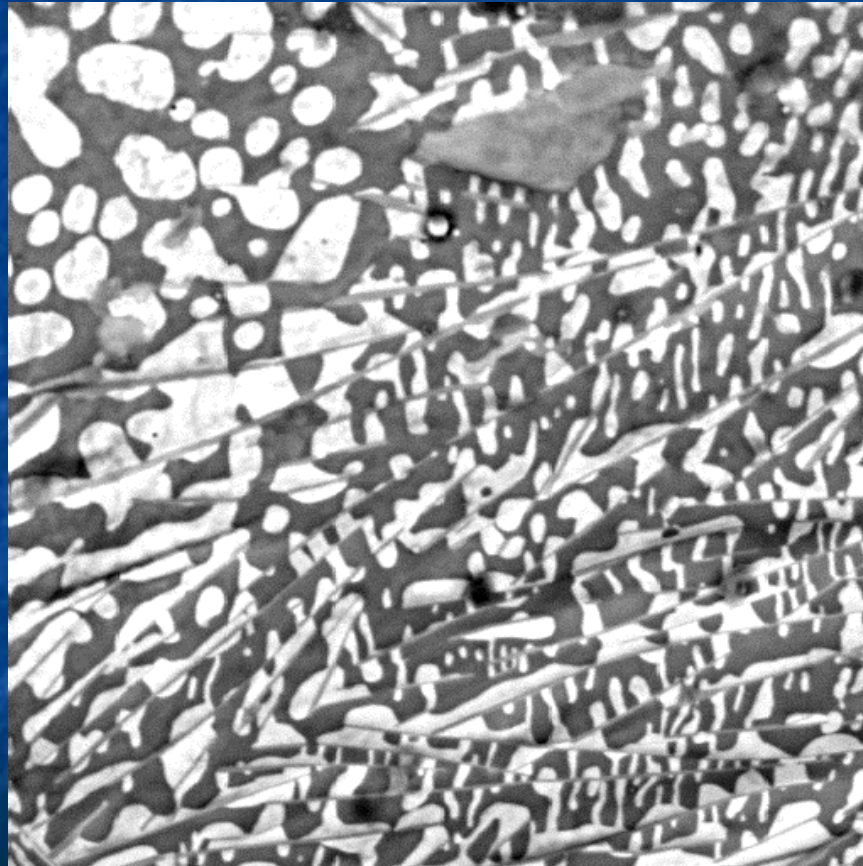


Bond Wire Sweep

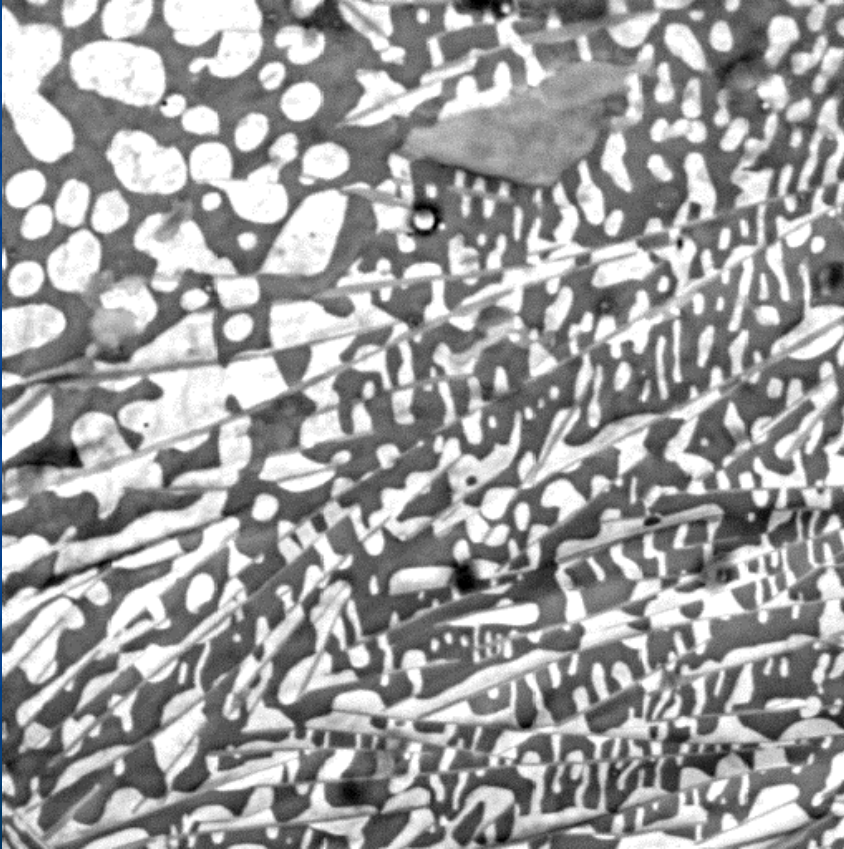


- Bond wires are swept by the injection molding compound

What is this?

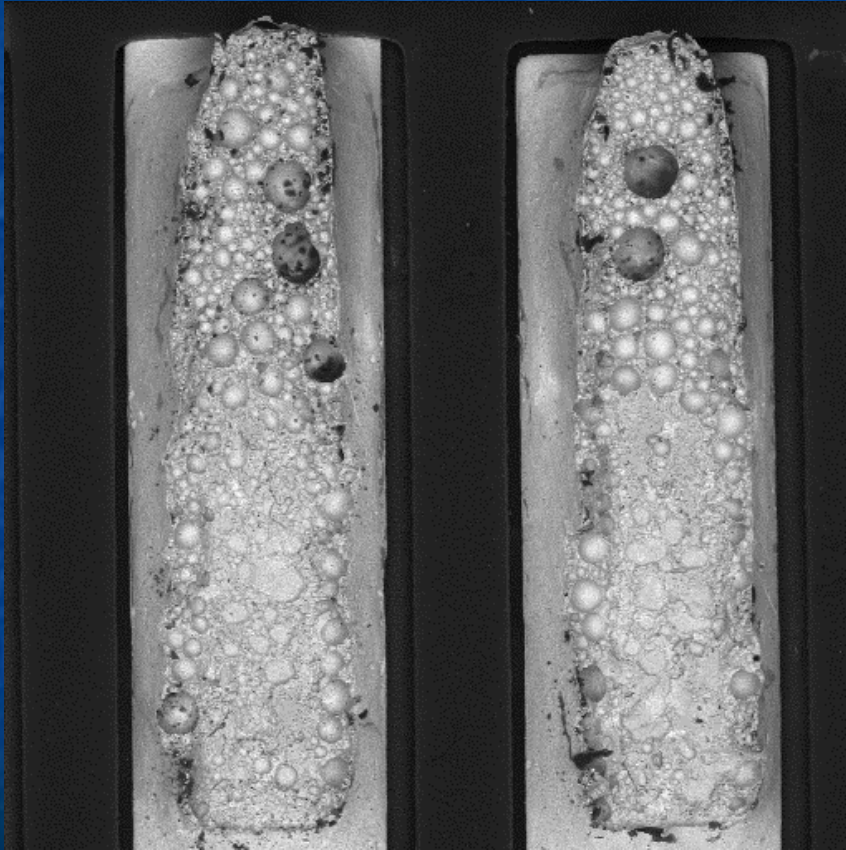


Gold Embrittlement



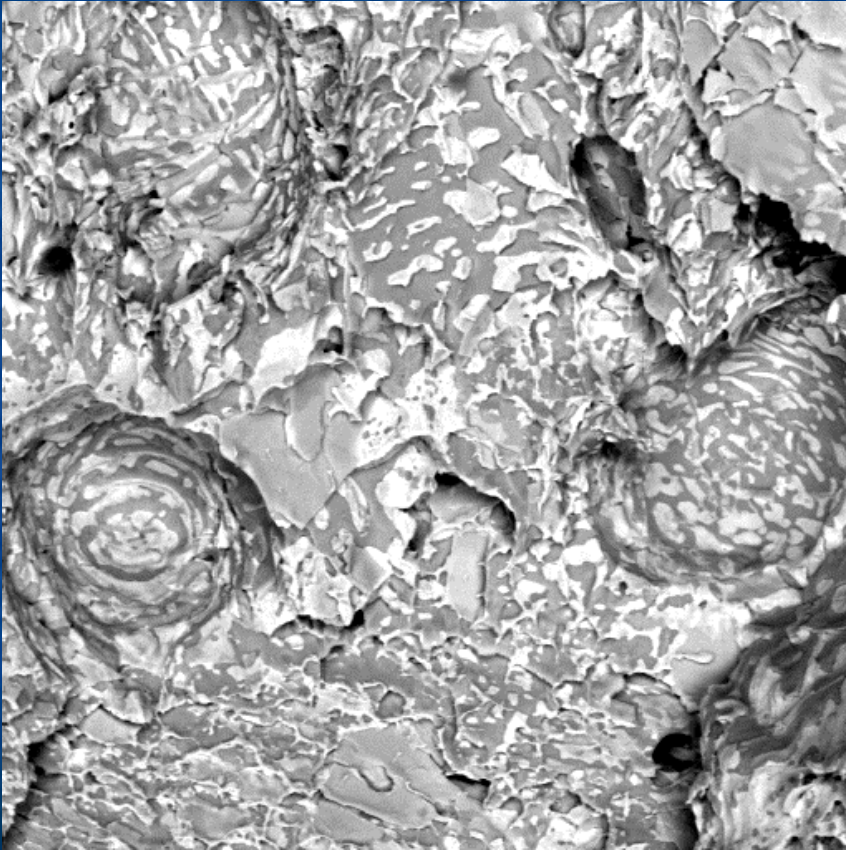
- This is gold-embrittled eutectic Sn-Pb solder
- AuSn₄ & AuSn₂ platelets dispersed throughout the microstructure

Gold Embrittlement



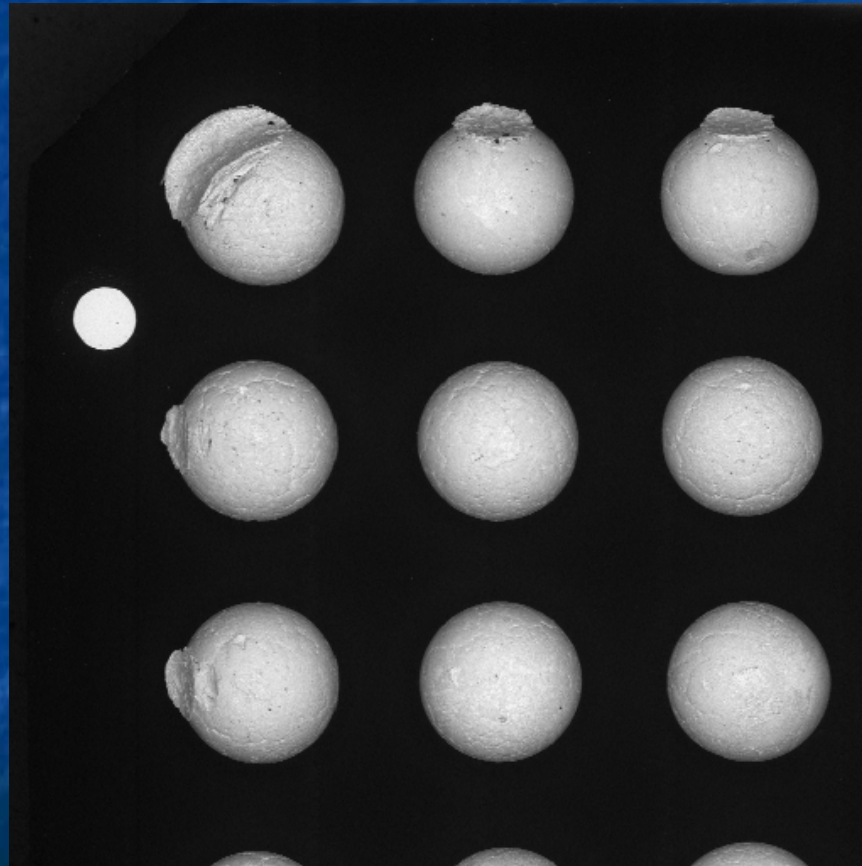
- Theory – the gold-embrittlement caused voiding!
- AuSn4 & AuSn2 platelets trap volatiles

Gold Embrittlement

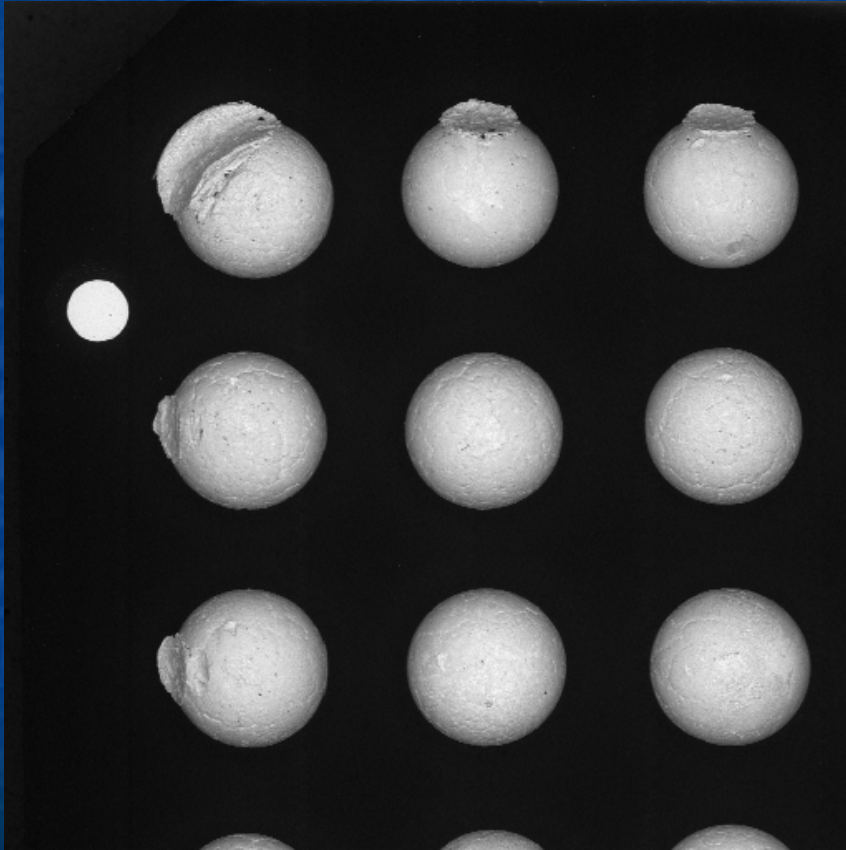


- Theory – the gold-embrittlement caused voiding!
- AuSn_4 & AuSn_2 platelets trap volatiles

What is this?

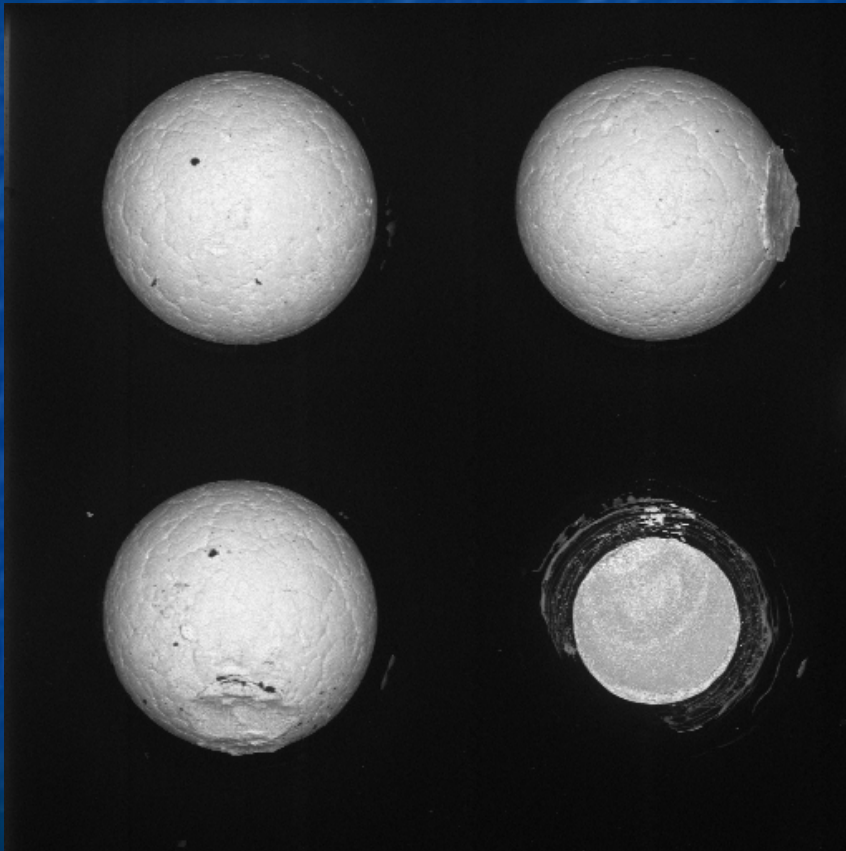


BGA Mechanical Damage



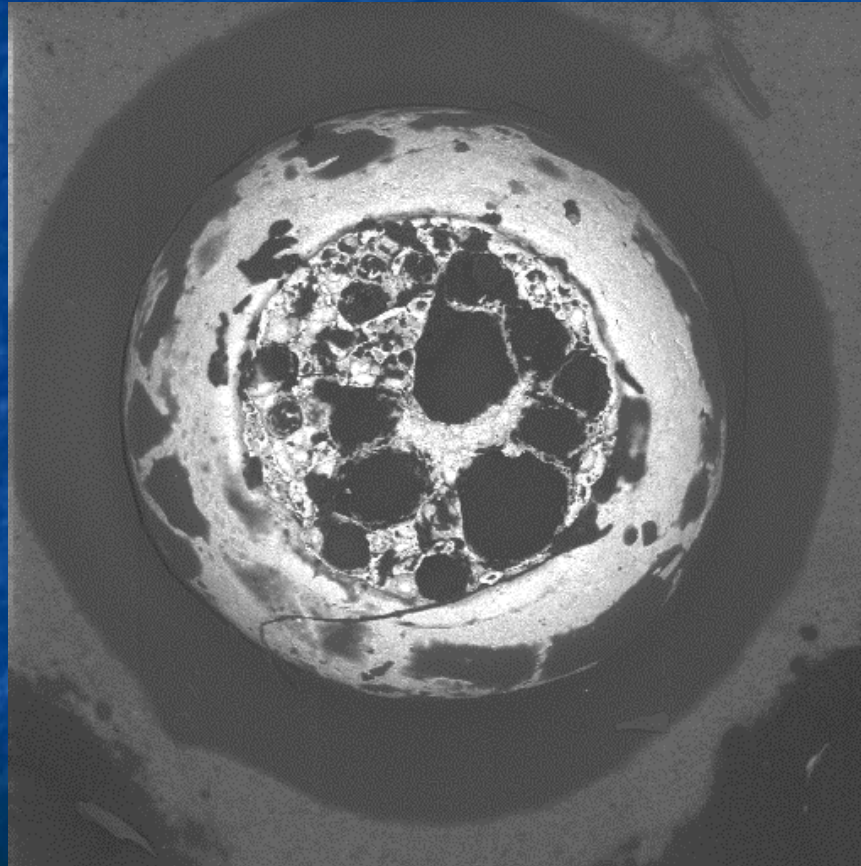
- Probably tool damage
- Most extreme cases had missing balls

BGA Mechanical Damage

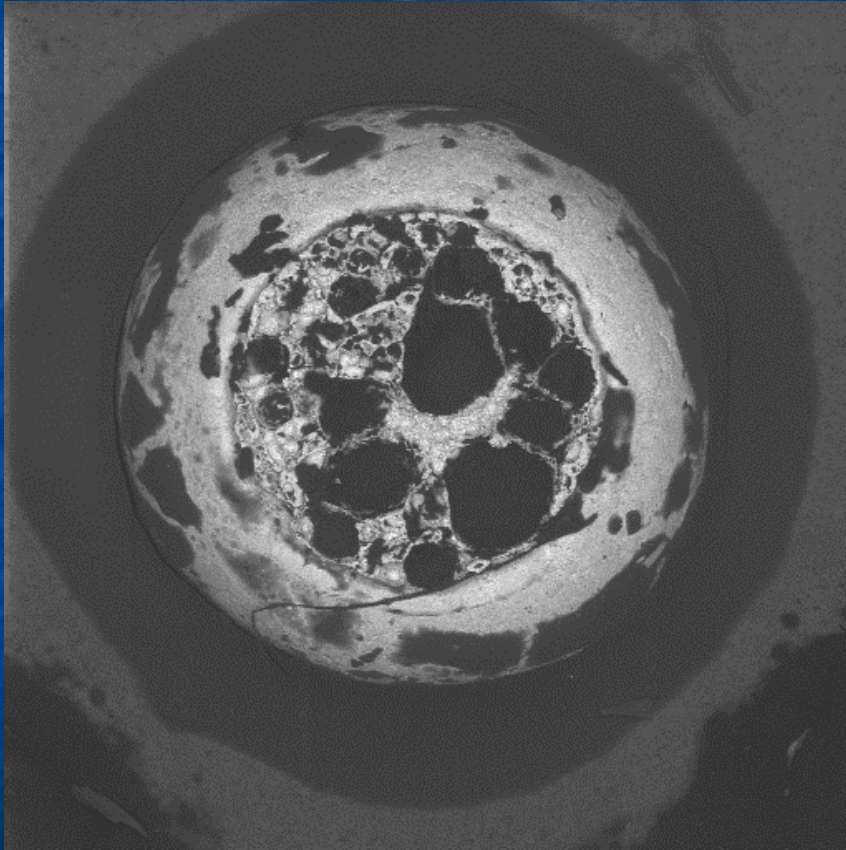


- Corner has a missing ball

What is this?

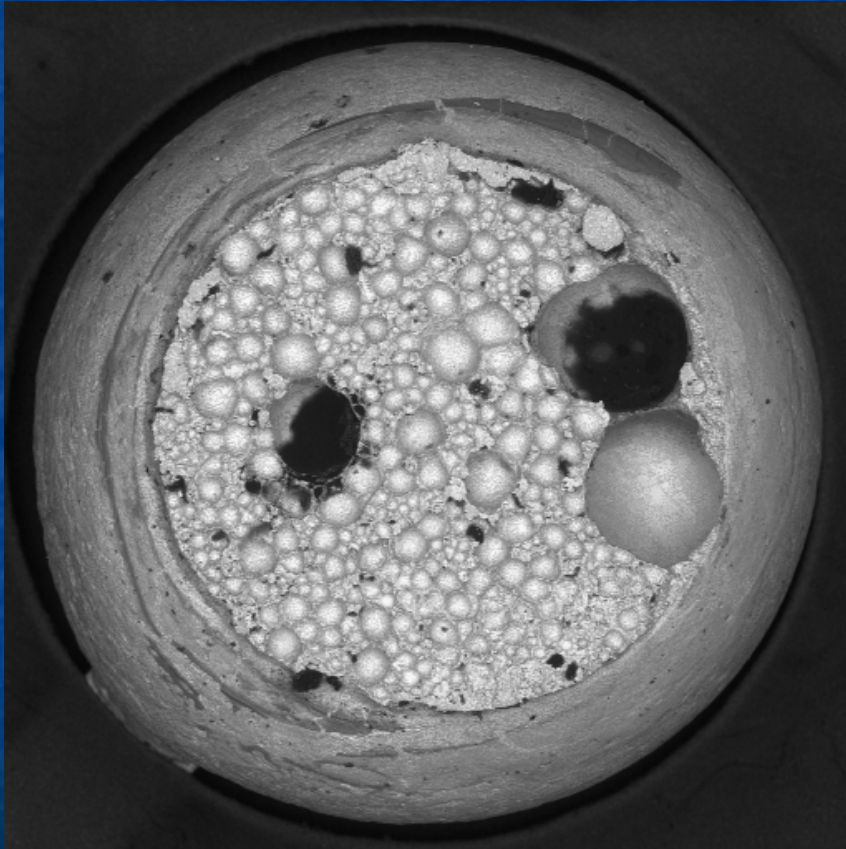


BGA Solder Joint Failure



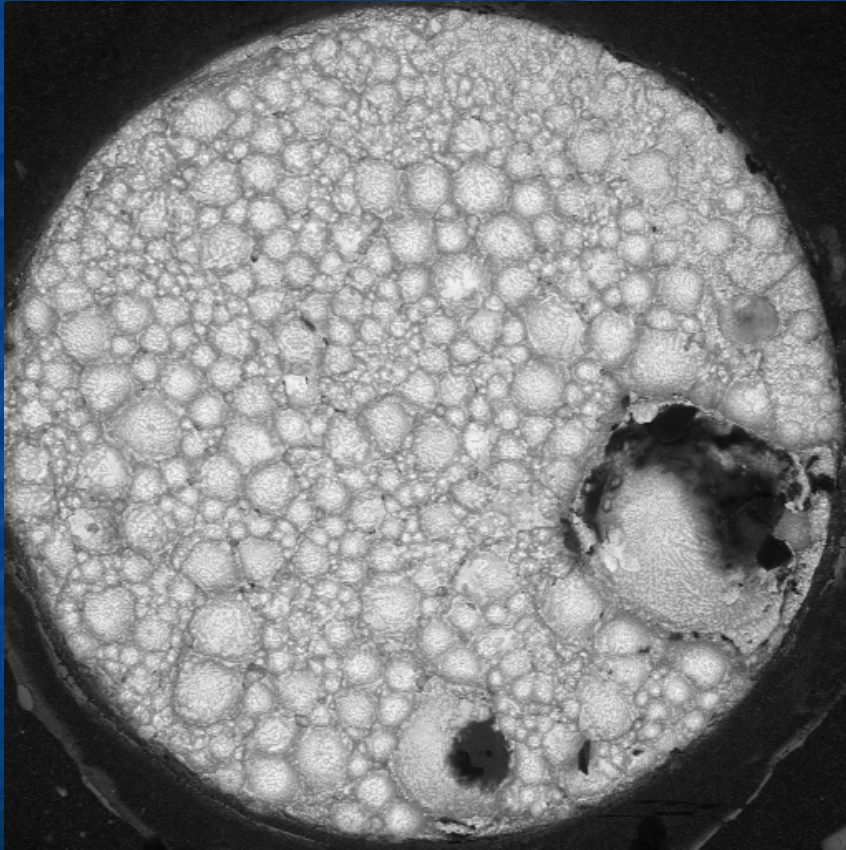
- BGA solder joint failed at the BGA substrate
- Entrapped material includes flux and mask constituents
- Probably flux and mask are chemically incompatible

BGA Solder Joint Failure



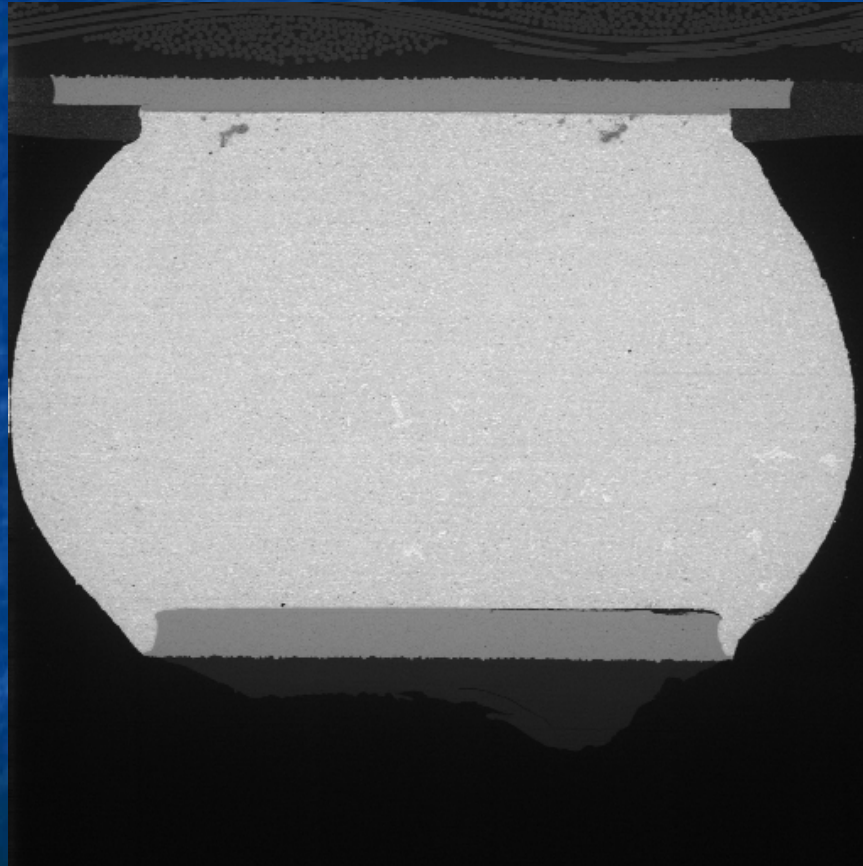
- This is a different example
- Entrapped material likely debris from plastic trays

BGA Solder Joint Failure

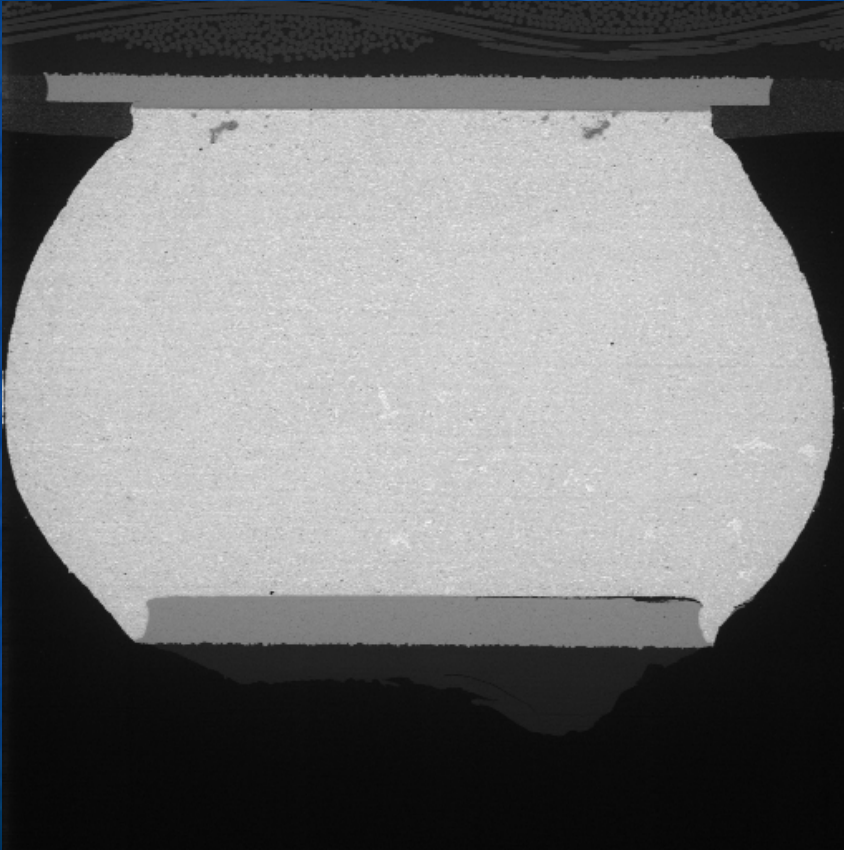


- This is the fracture surface at the BGA substrate (different location)
- IPC specifications allow up to 25%

What is this?

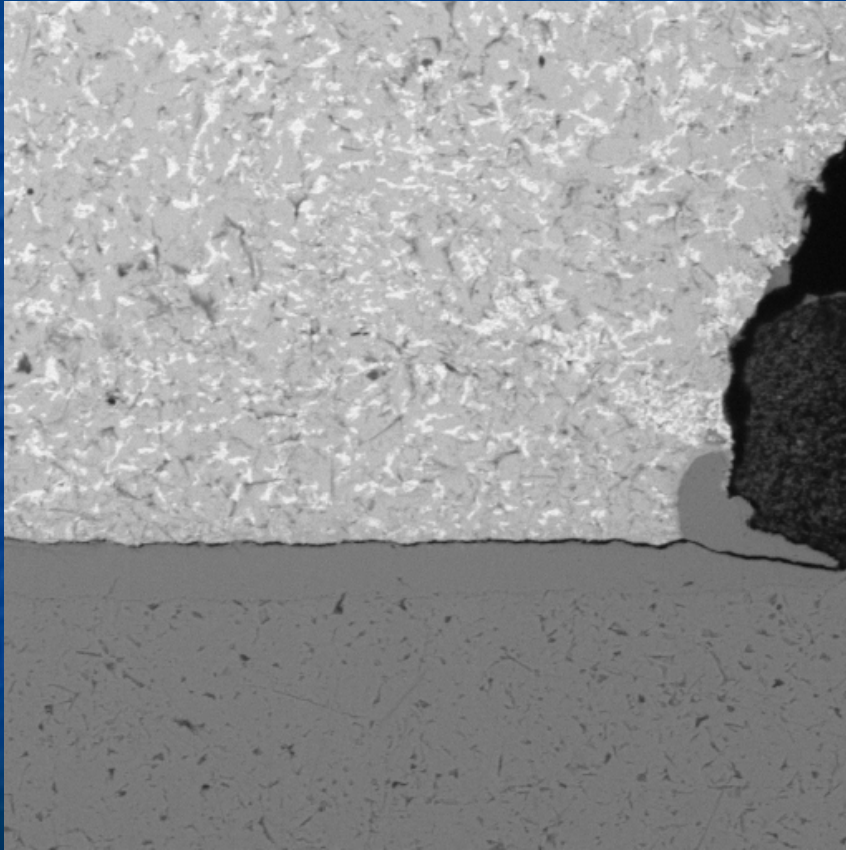


ENIG Black Pad Syndrome



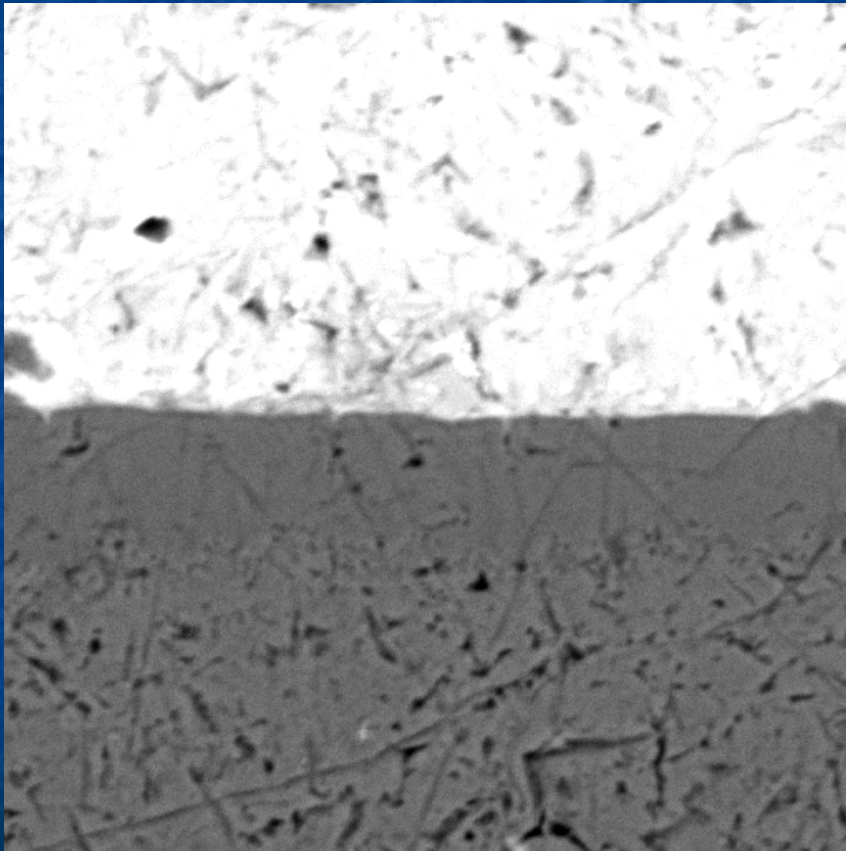
- Brittle fracture at the solder/PWB pad interface
- More specifically between the Ni_3Sn_4 IMC layer and the P-rich EN

ENIG Black Pad Syndrome



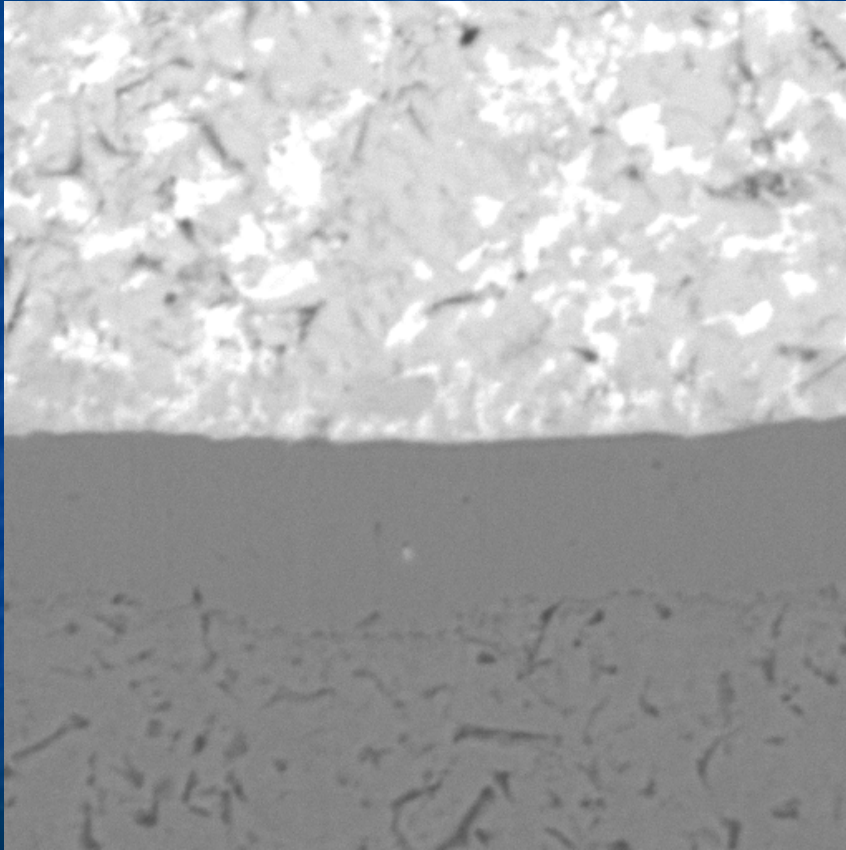
- Very fine line brittle fracture at the solder/PWB pad interface

ENIG Black Pad Syndrome



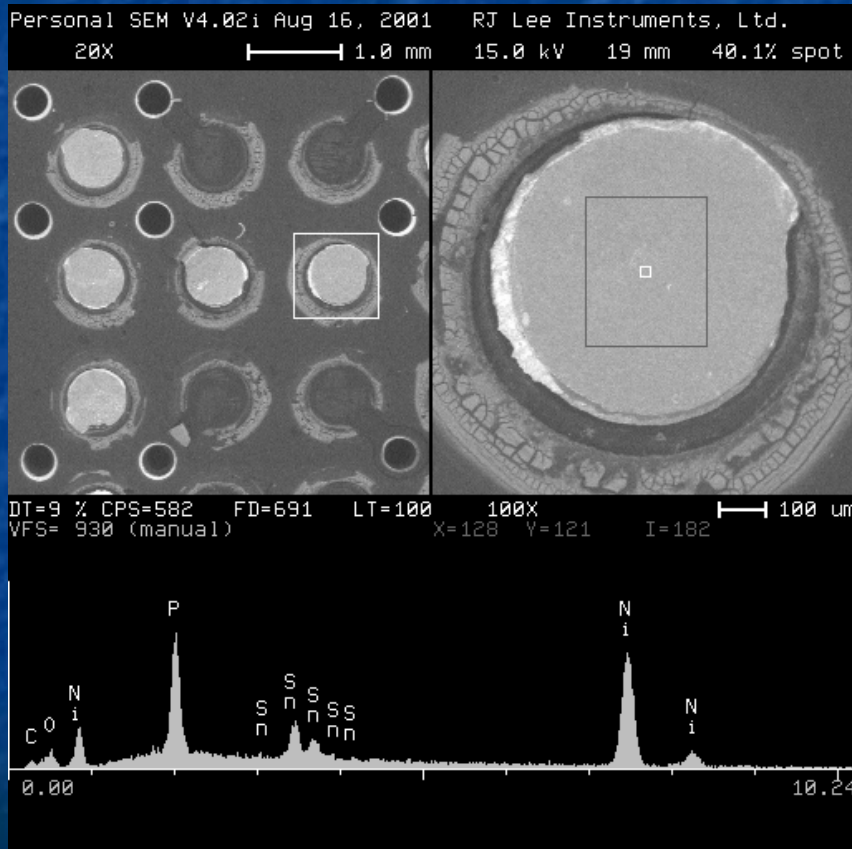
- Very thin (~ 0.25 micron) P-rich EN layer in contact with the Ni_3Sn_4 IMC layer

ENIG Black Pad Syndrome



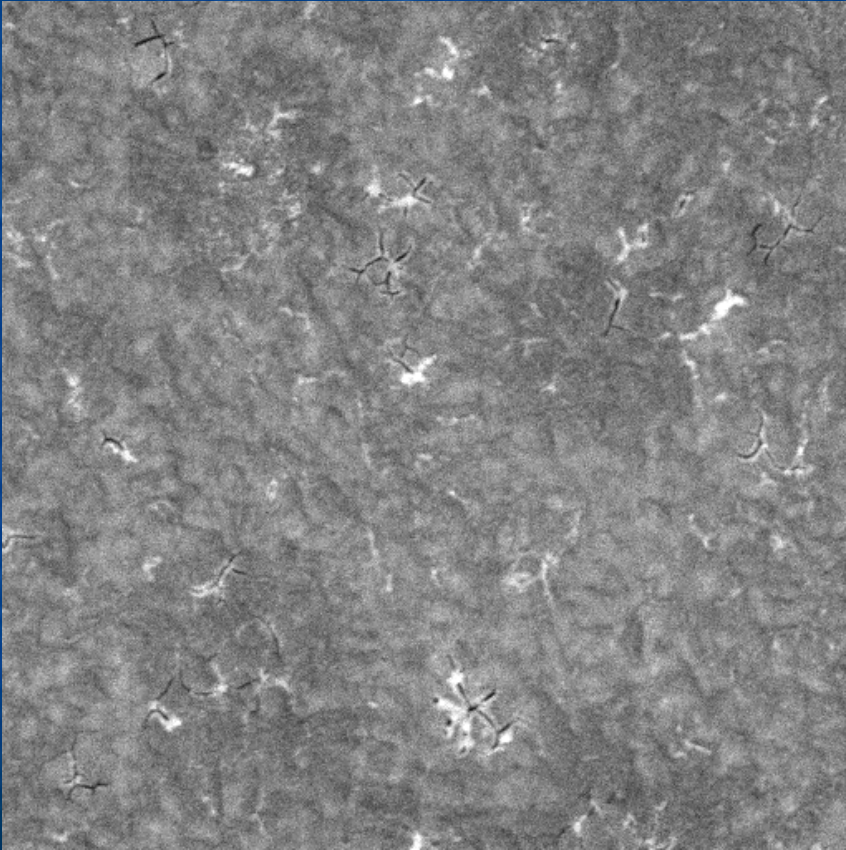
- 2nd example
- Very thin (~ 0.25 micron) P-rich EN layer in contact with the Ni_3Sn_4 IMC layer

ENIG Black Pad Syndrome



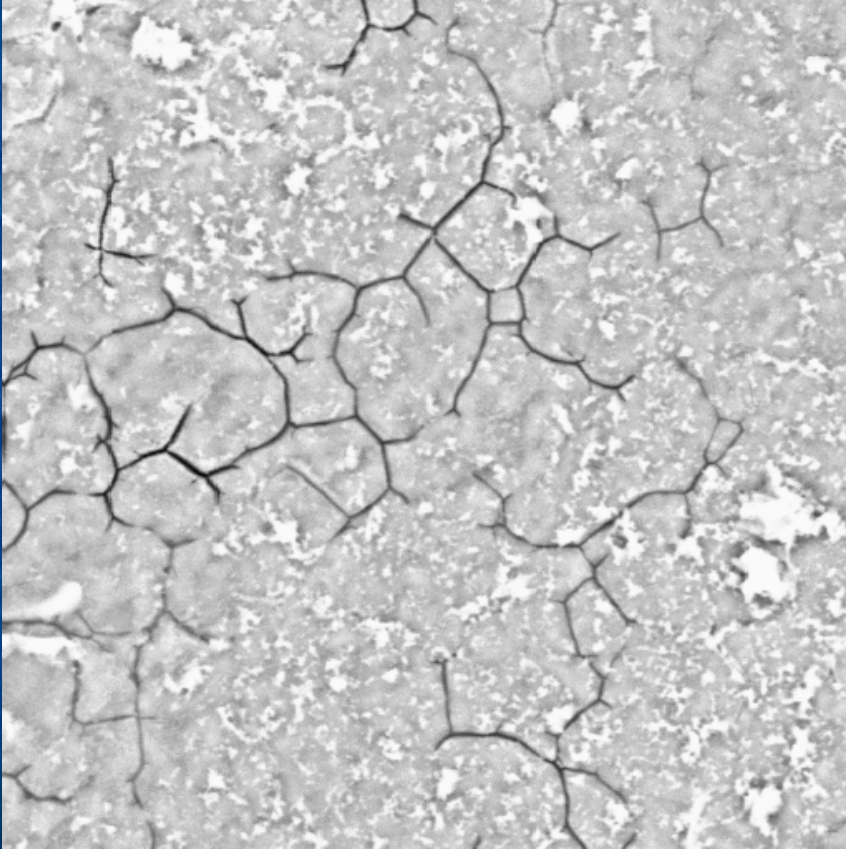
- ~ 18 wt% P at the fracture surface versus 7 – 9 wt% P for EN bulk

ENIG Black Pad Syndrome



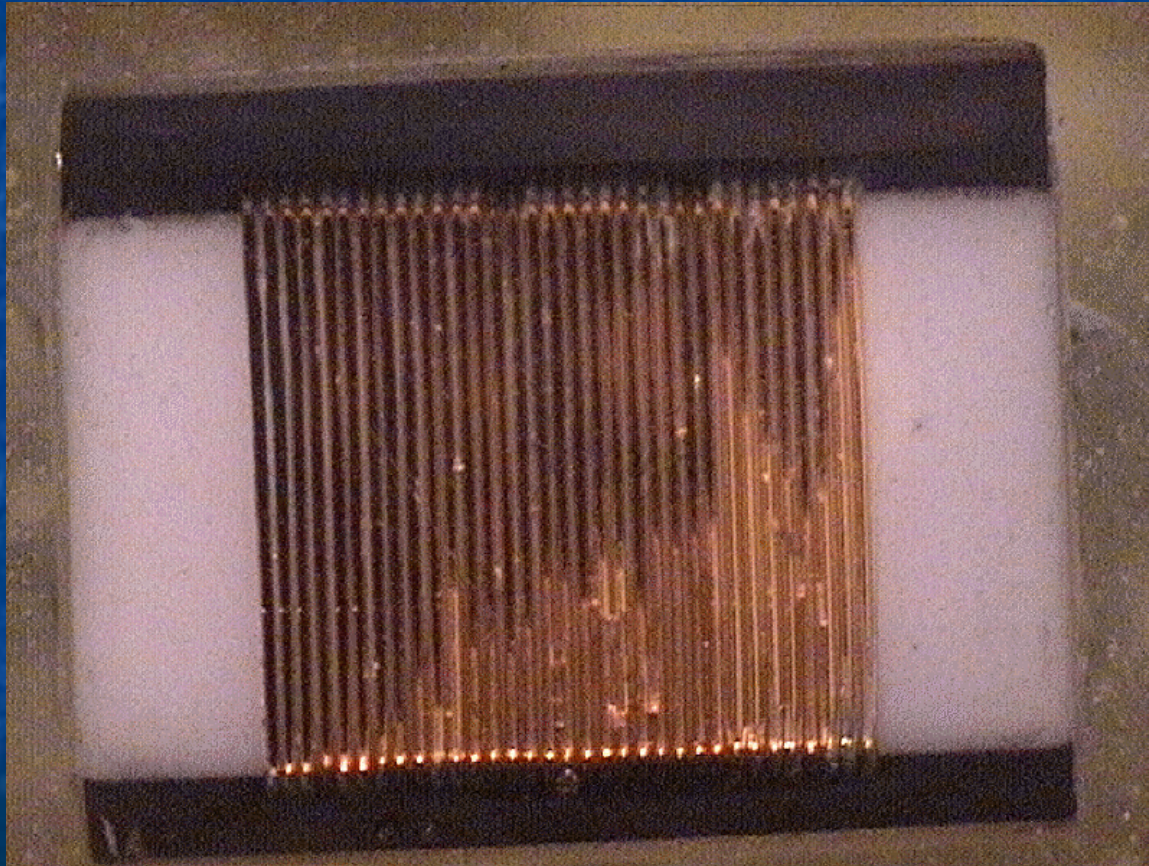
- IG spiking
- Hyper-etching of EN in IG bath

ENIG Black Pad Syndrome

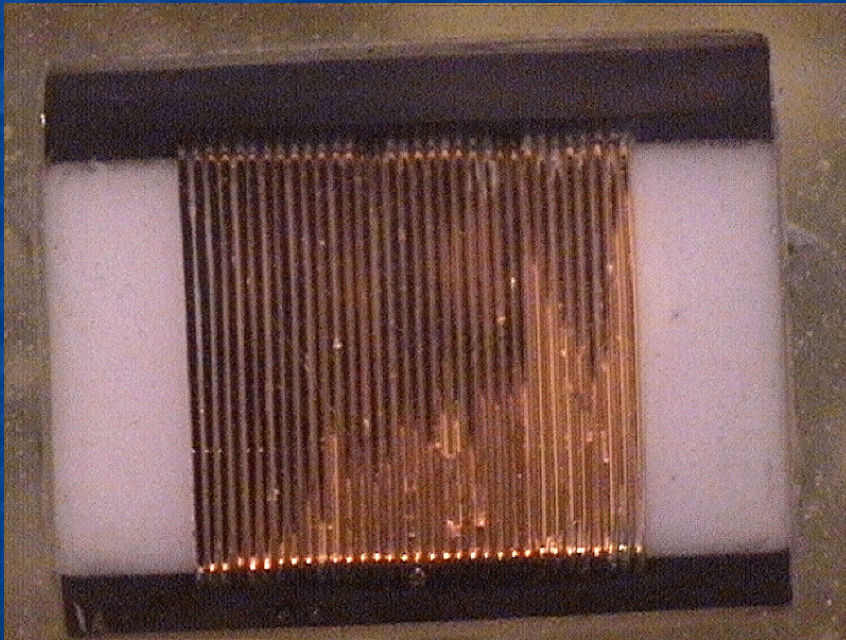


- 2nd example
- IG spiking
- Hyper-etching of EN in IG bath

What is this?

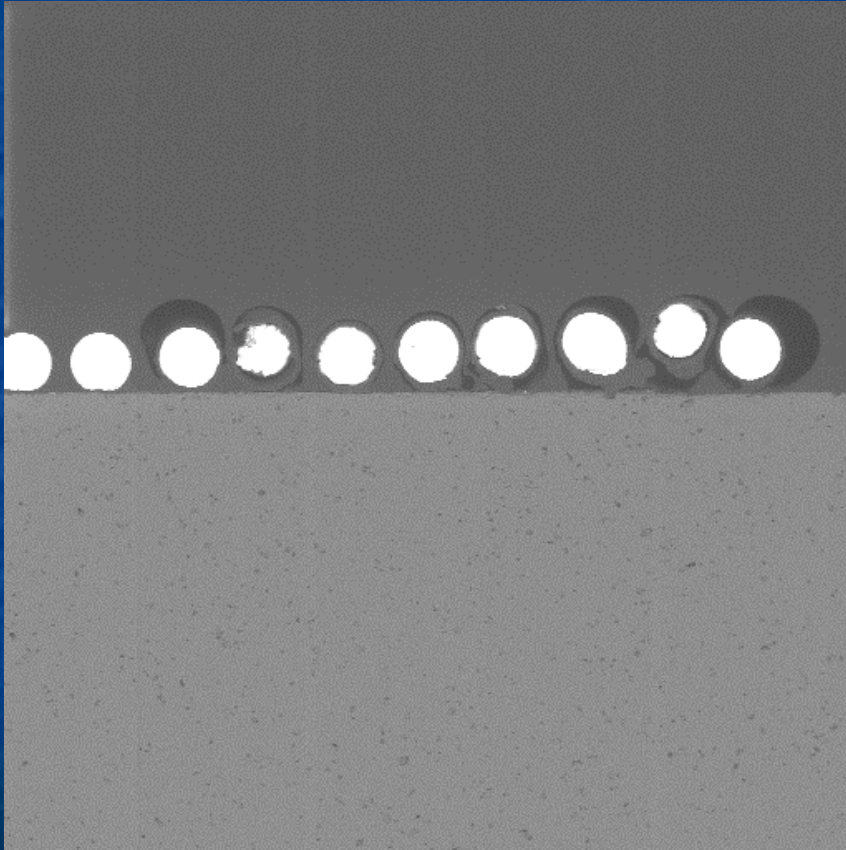


Failed SMD Inductor



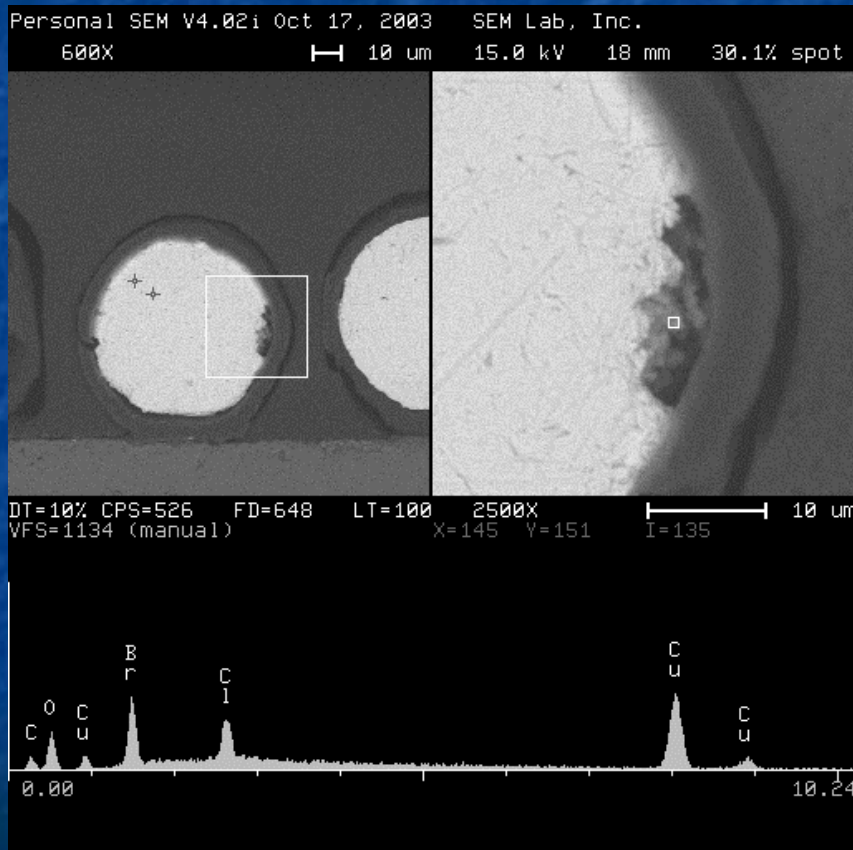
- Discoloration of magnet wire
- Open circuited coil

Failed SMD Inductor



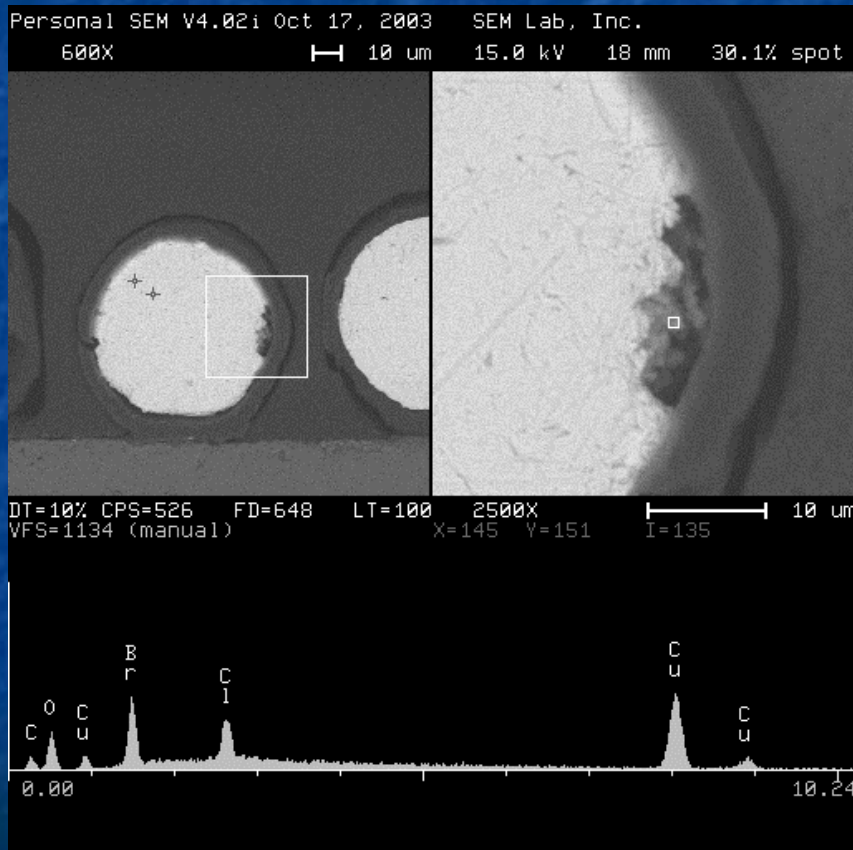
- Encapsulant voids around magnet wire
- Magnet wire cross-section reduced due to corrosion

Failed SMD Inductor



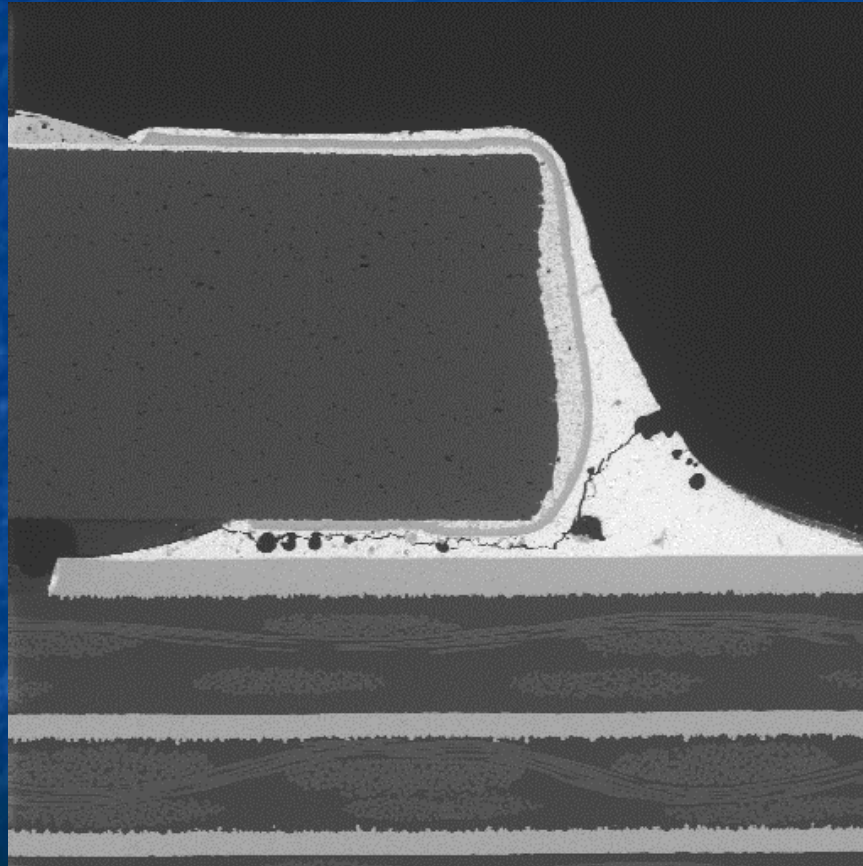
- Corrosion due to Cl & Br from activated flux that wicked into the coil

Failed SMD Inductor

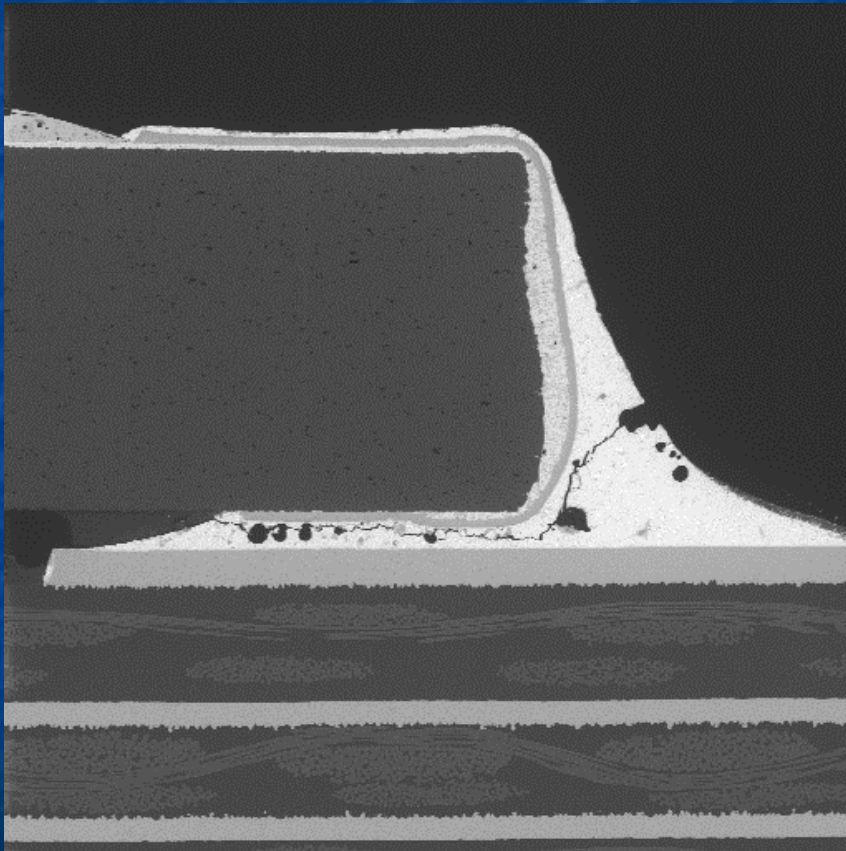


- Corrosion due to Cl & Br from activated flux that wicked into the coil

What is this?

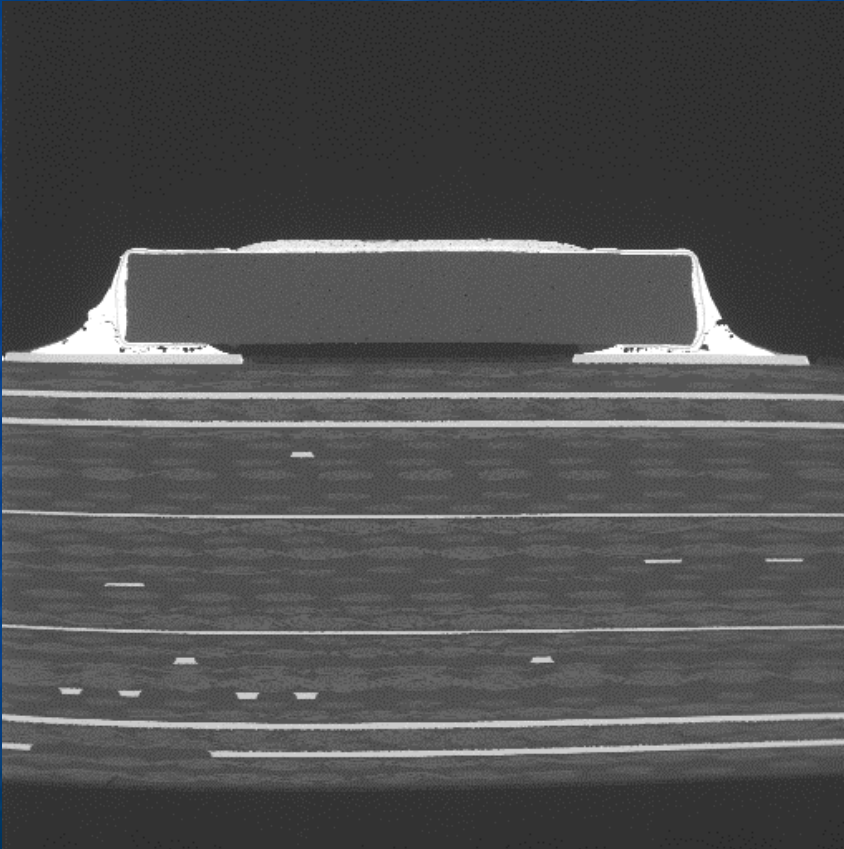


Failed Resistor Network Joint



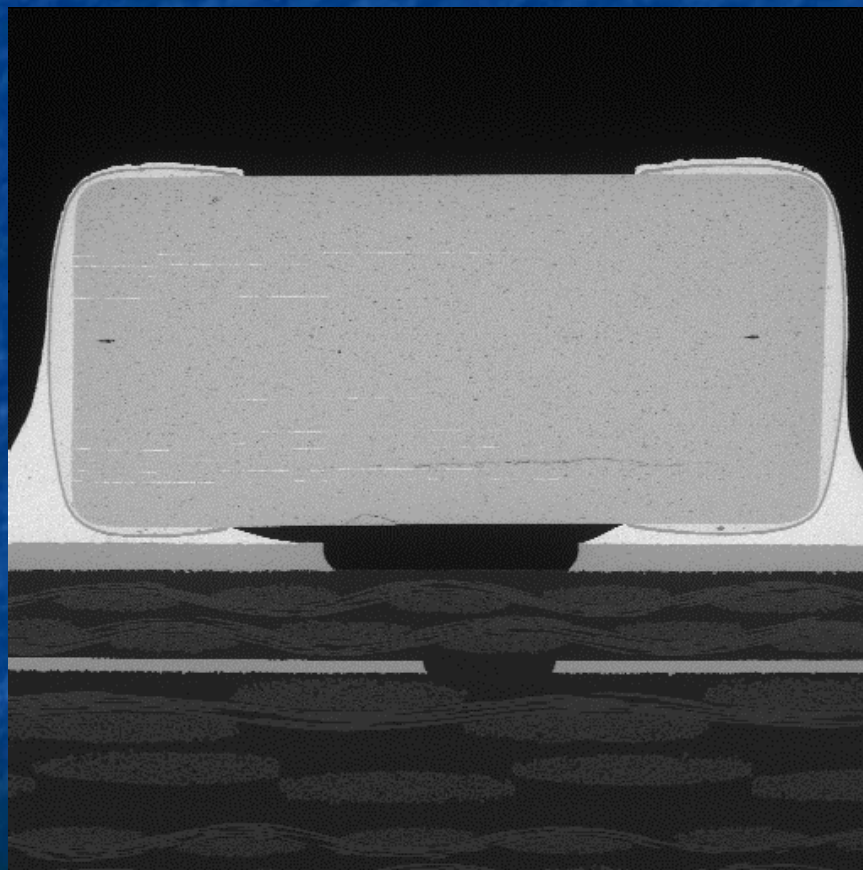
- Classic thermal fatigue failure
- Voids may be a contributing factor

Failed Resistor Network Joints

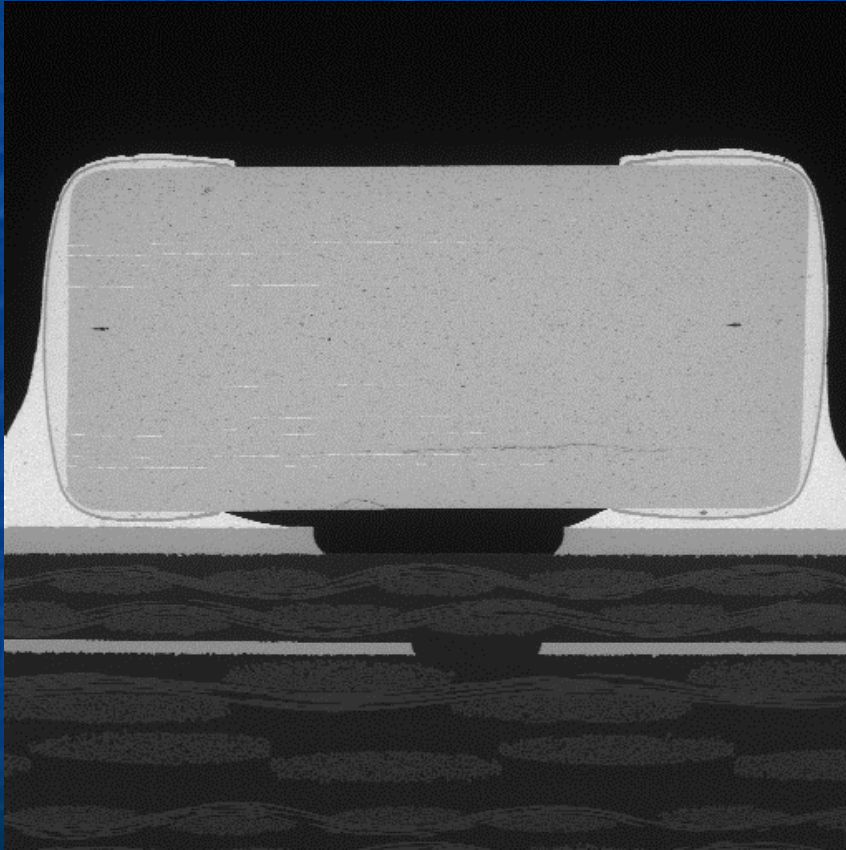


- Classic thermal fatigue failure
- Thermal expansion mismatch too large
- Failed after ~ 5 years of service

What is this?

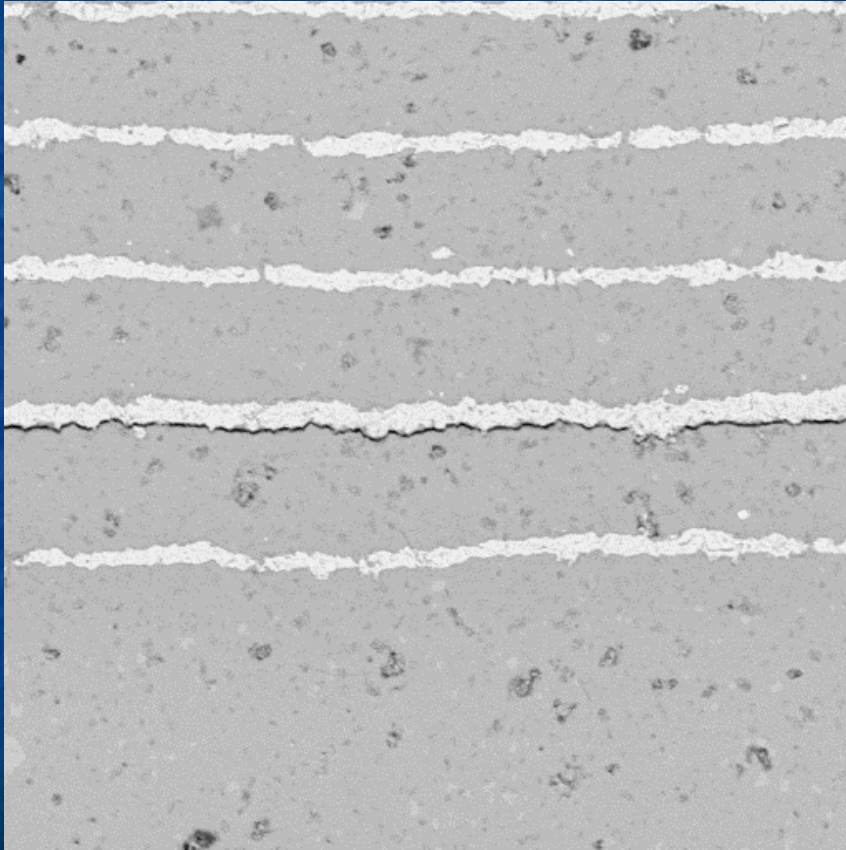


MLCC Knit Line Failure



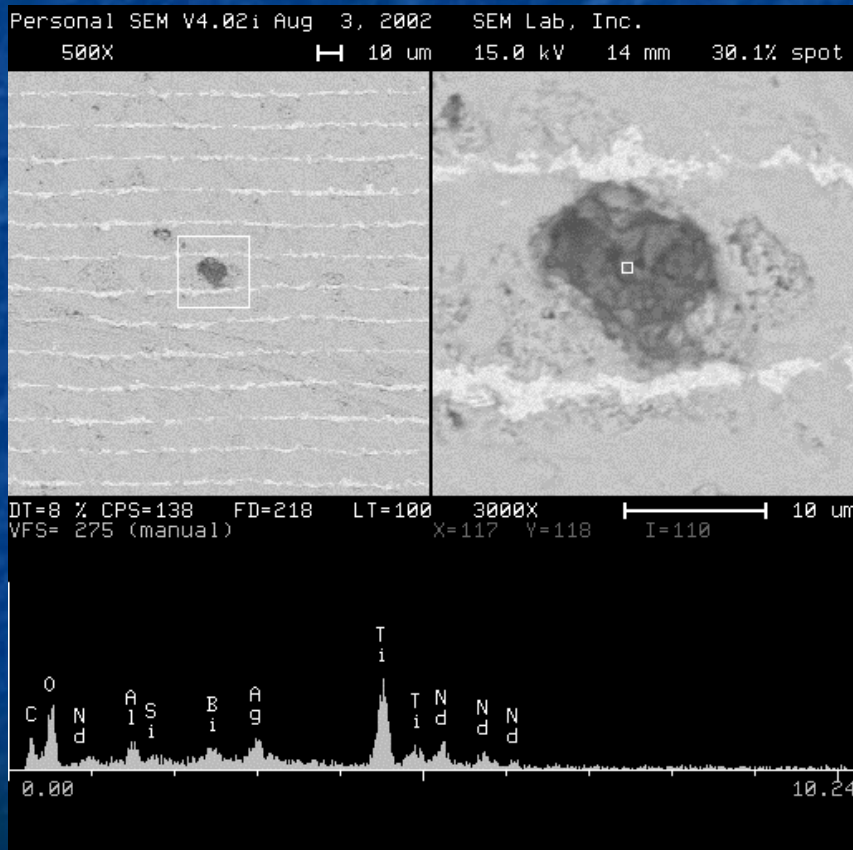
- MLCC manufacturing defect
- Crack propagates and crosses plates causing electromigration short

MLCC Knit Line Failure



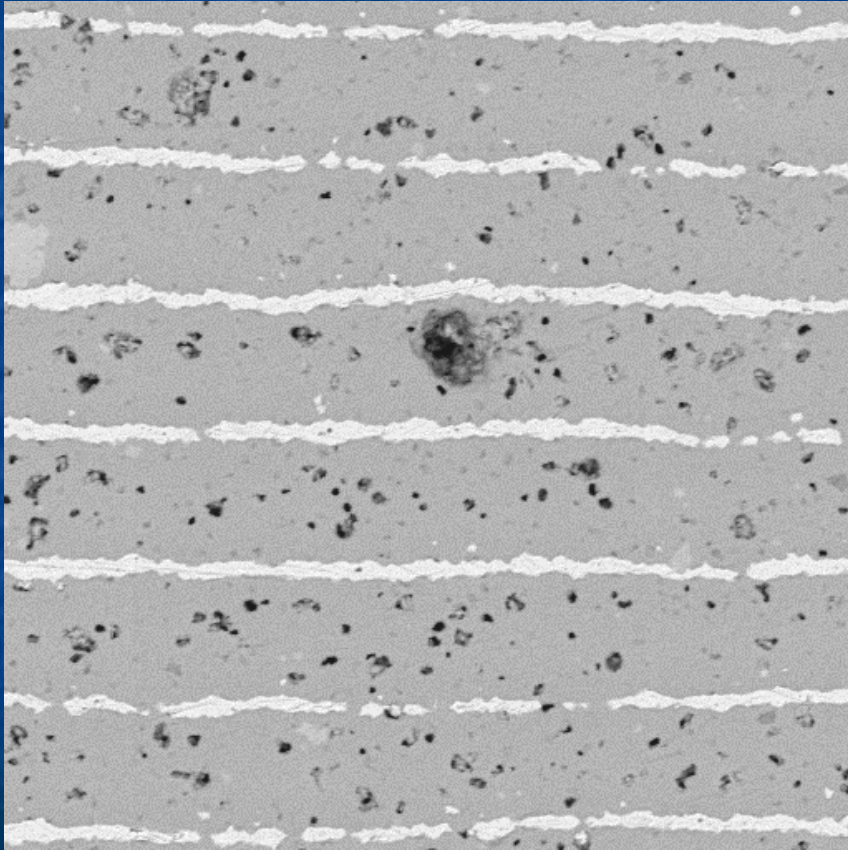
- Delamination between plate and dielectric

MLCC Dielectric Voids



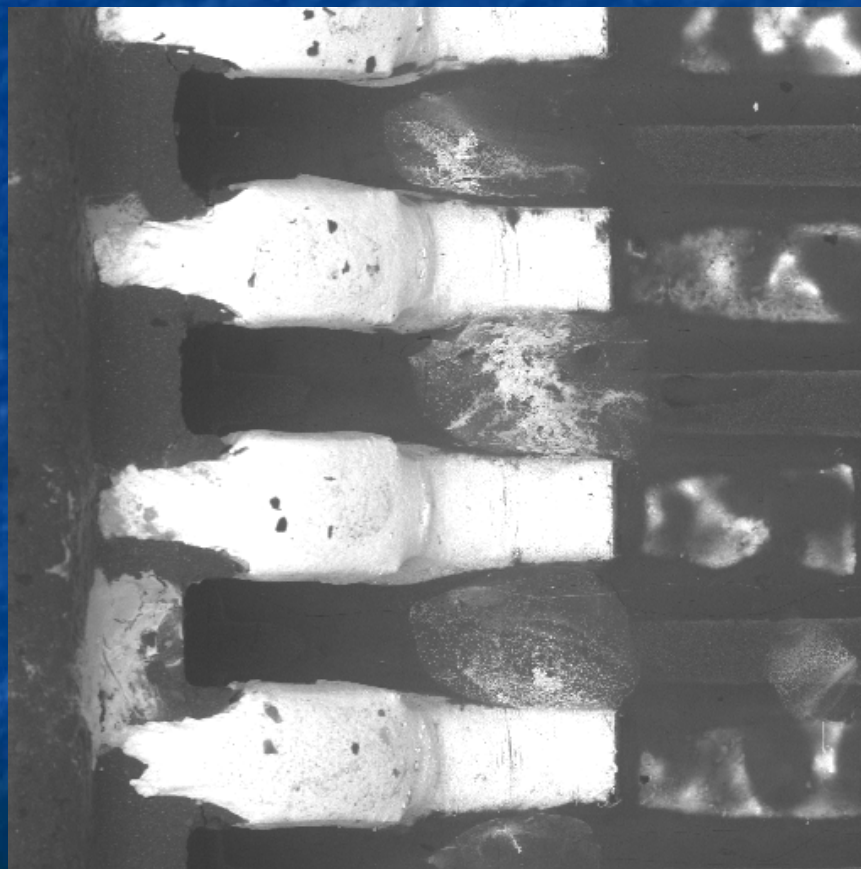
- Void bridges plates and creates electromigration path

MLCC Dielectric Voids

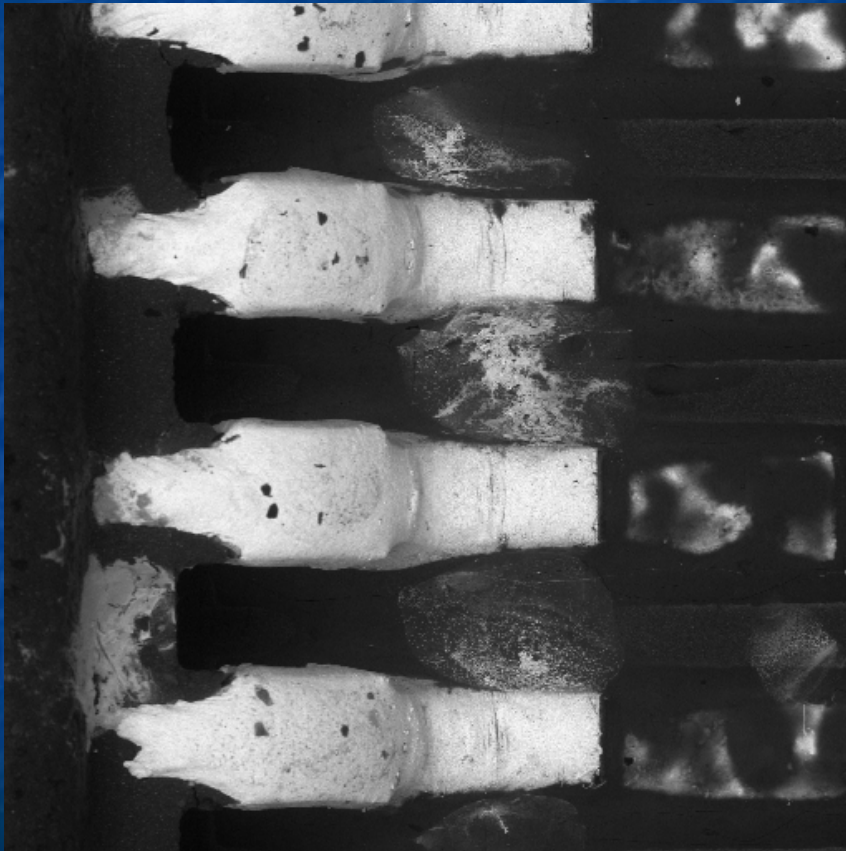


- Another example of MLCC dielectric voids

What is this?

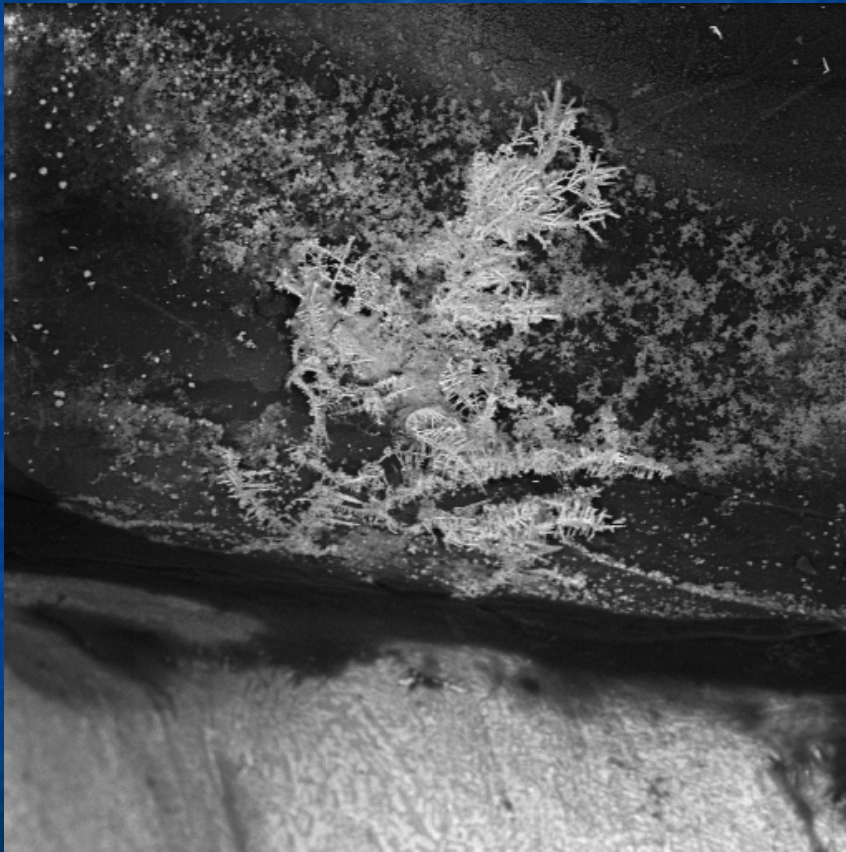


TSOP Electromigration Failure



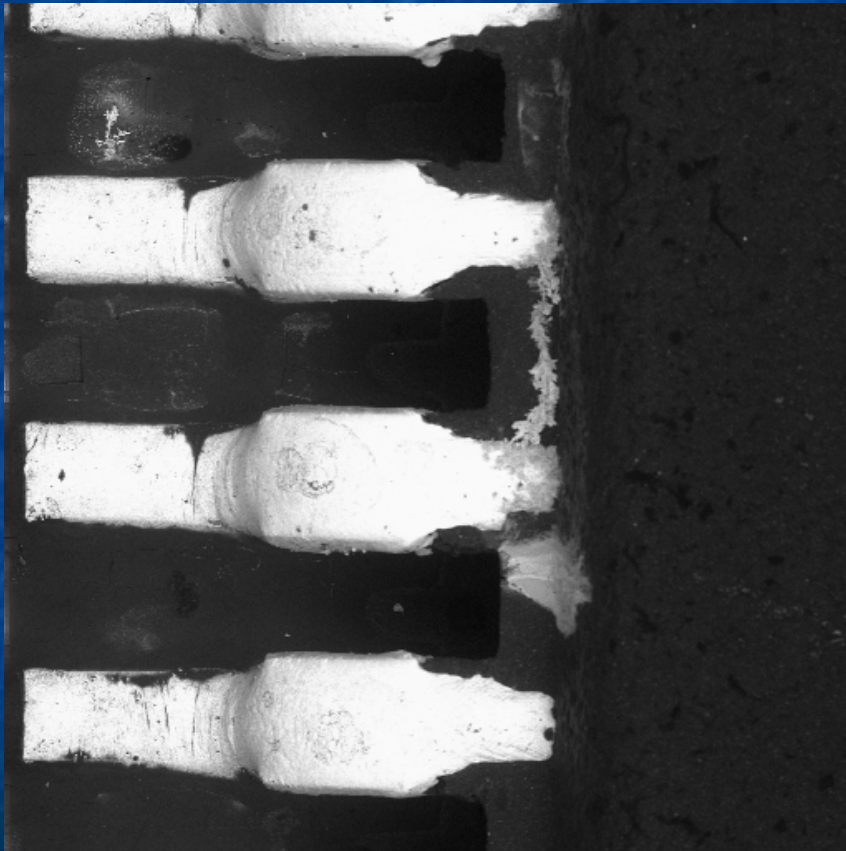
- Electrical leakage failures
- No Clean Flux, but likely activated flux used in touch up

TSOP Electromigration Failure



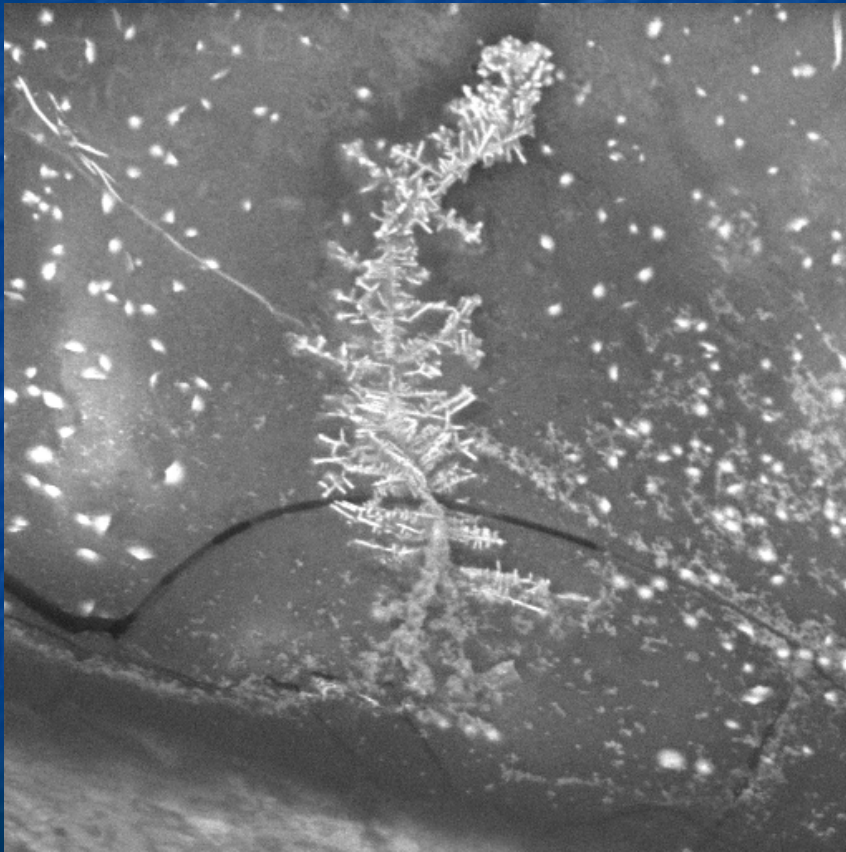
- Pb dendrites grow between signals and short them out
- Never mix No-Clean flux and activated flux

TSOP Electromigration Failure



- Its even growing across the mold flash up by the package body!

TSOP Electromigration Failure



- There is nothing quite like a pretty picture of a Pb-dendrite

CONCLUSIONS

- Dendrites? Go ahead, make my day ...
- Bond pad corrosion? Bring it on!
- Black pad syndrome? Not a HASL
- Ed Hare, Ph.D./[SEM Lab, Inc.](http://www.semlab.com)