MRB on MCM Leakage Current Problem

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SLAC

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The Problem

- Of 357 MCM boards which have been burned in, 8 developed a short between layers 7 and 8 during the burn-in. These are the AVDDA and bias voltage planes
- An additional 3 had shorts found at Teledyne before burn-in
- These are documented in NCR's 128, 142, and 146
- This is about a 3% failure rate.

Summary

- Smoking gun has not been found
- Boards with shorts will not be used
- For future board production, are introducing two process changes that may prevent future problems
  - Dry boards before reflow soldering
  - Make the insulating layer thicker and two-ply
- Non-failed MCMs will be used for flight based on assumption that the burn-in caught most if not all the failures.

List of failed boards

SN	Date of first test at Teledyne	Date of final test at Teledyne	Date sent to Zentek for rework	Date of post burn-in test	MCM type	Current (nA) / voltage (V)
559	9/7/04 passed	9/14/04 passed				
610	6/15/04 failed					169 / 15
612	9/1/04 passed	9/7/04 passed		10/5/04	short	.4 mA/120
644	6/1/04 passed	6/4/04 passed	6/30/04	8/2/04 failed	short	2000 / 2
682	6/15/04 passed	6/18/04 passed	7/7/04	8/18/04 failed	short	302 / 2
687	6/15/04 passed	6.18/04 passed	7/7/04	8/18/04 failed	short	465 / 2
688	8/18/04 passed	6/23/04 passed	7/7/04	8/12/04 failed	short	1723 / 2
701	6/24/04 passed	6/28/04 passed	7/7/04	8/17/04 failed	short	1902 / 2
703	6/24/04 passed	6/28/04 passed	7/7/04	8/12/04 failed	short	517 / 2
11275	9/22/04 failed					1999/ 30
11505	7/21/04 passed	7/23/04 failed				881 / 10
The following GOOD boards are shown for comparison						
622	5/5/04	5/11/04		6/1/04		34 / 200
623	6/8/04	6/15/04		7/8/04		34 / 200

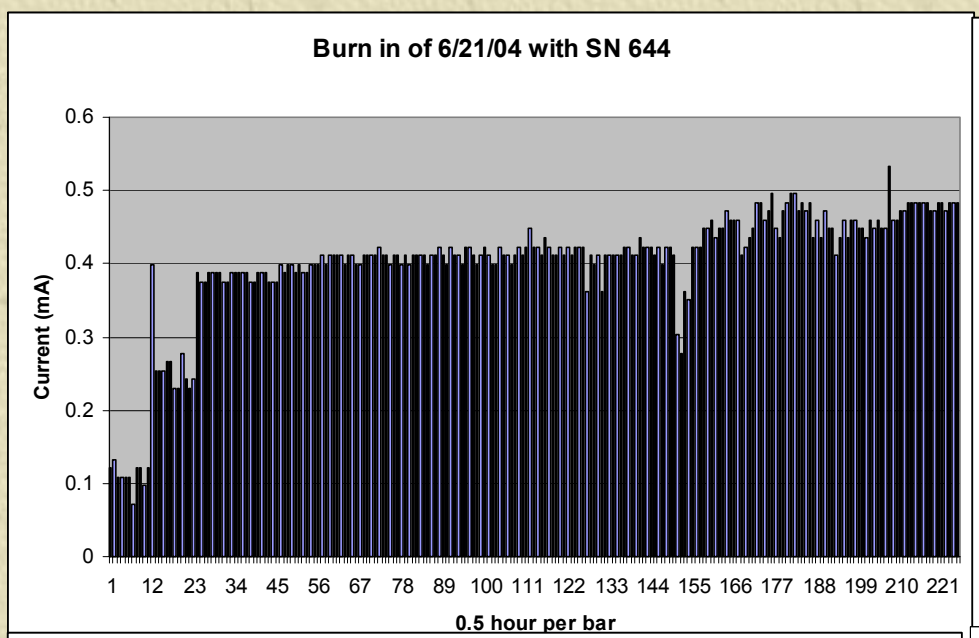
Pre-Burn-in Tests

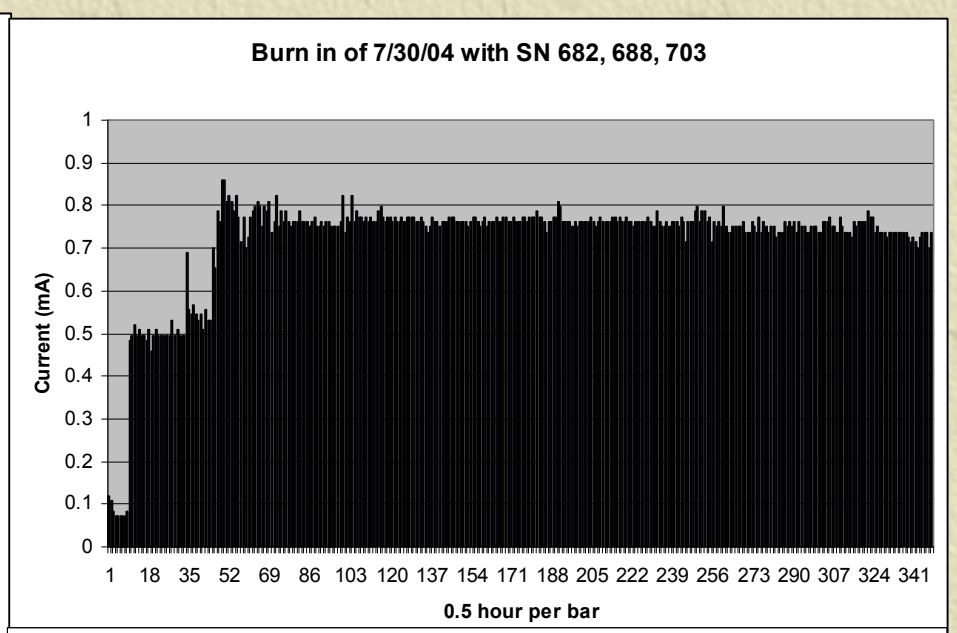
- Bare boards tested to 250 volts
- Twice at Teledyne and once at SLAC 200 V is applied and the current measured and recorded.
- The 8 boards which failed during burn-in looked completely normal on the first two these tests, but failed the last one which is done after burn-in (and resistor rework).

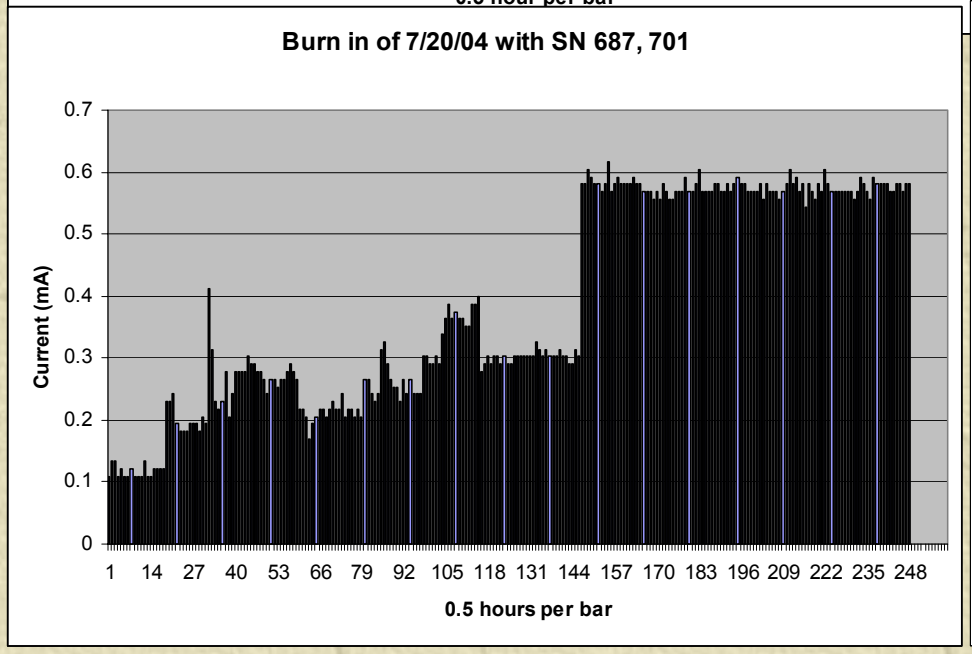
Burn-in

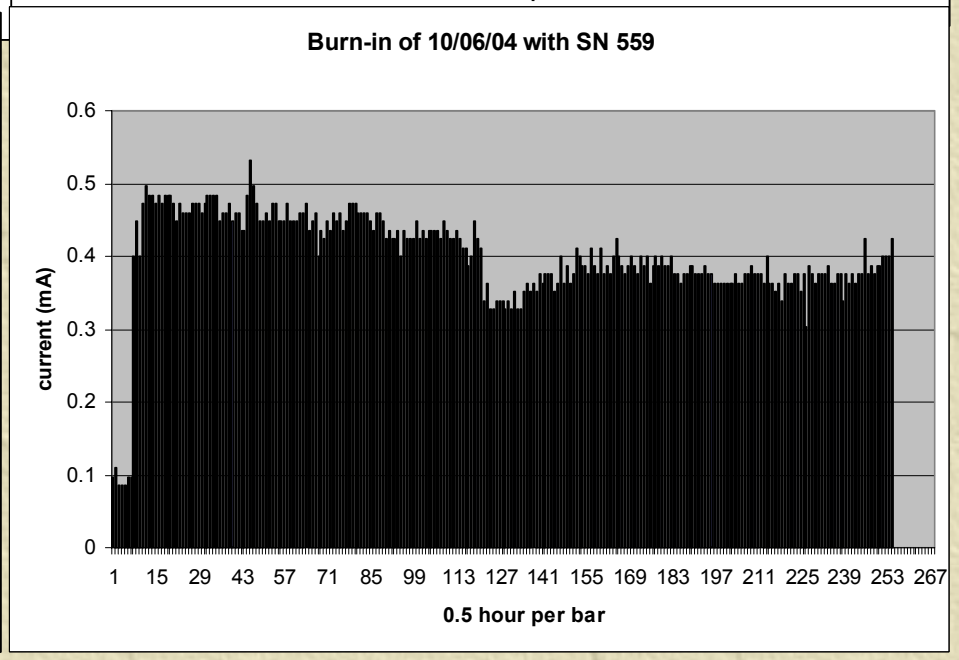
- The burn-in is done for 7 days at 85° C with 120 V between layers 7 and 8.
- 36 boards are done in parallel. The total bias current of the 36 boards is recorded.
- Batches with failed board(s) show a current increase after 2, 3.5, 4, 6, 10, 20, and 75 hours of the 168 hour burn-in.

Burn-in Currents – 270kΩ limits I to 0.4 mA

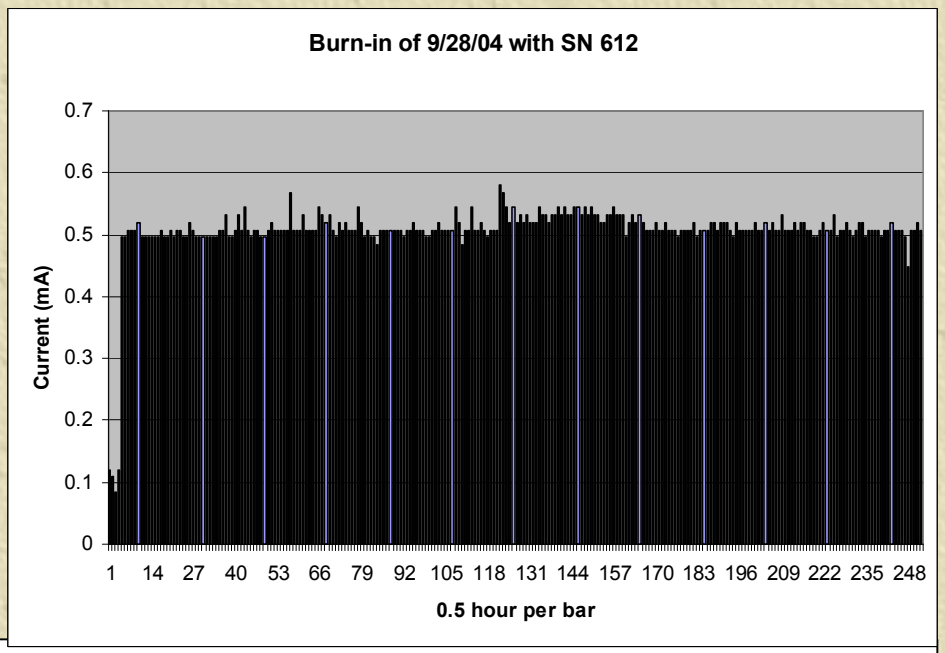


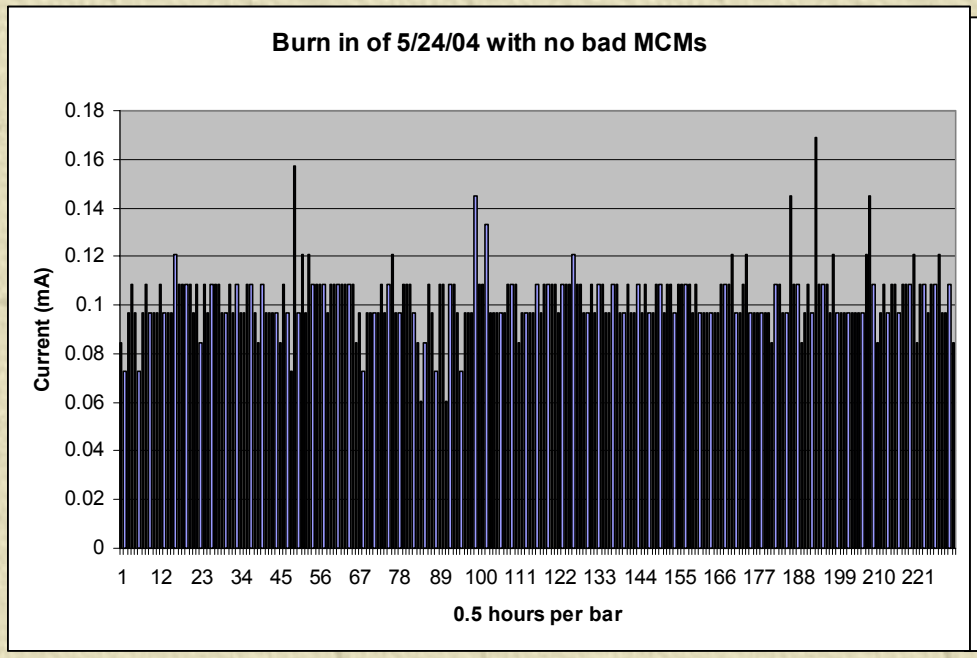


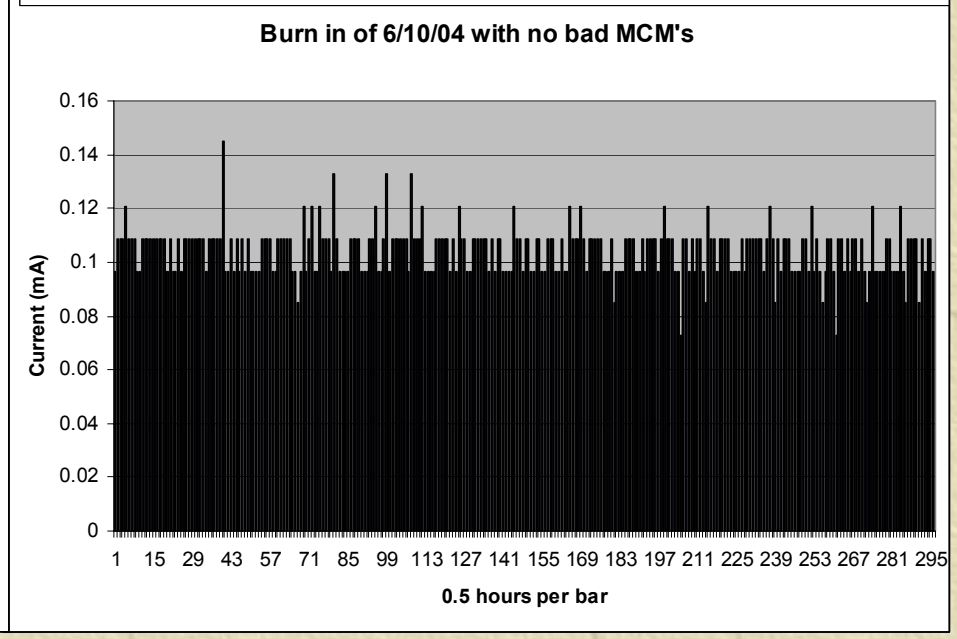




Burn-in Currents – 270kΩ limits I to 0.4 mA







Destructive Physical Analysis

- 6 of the 8 boards had the problem site located by putting several amps of current through them (bypassing the 270k resistor).
- This showed the problems were in random places, not by vias.
- One of these was sectioned, but the damage seen is properly attributed to the heating from the large current.

DPA – blister in SN 688 after amps passed through it

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DPA – Section of SN 688 after amps passed through it

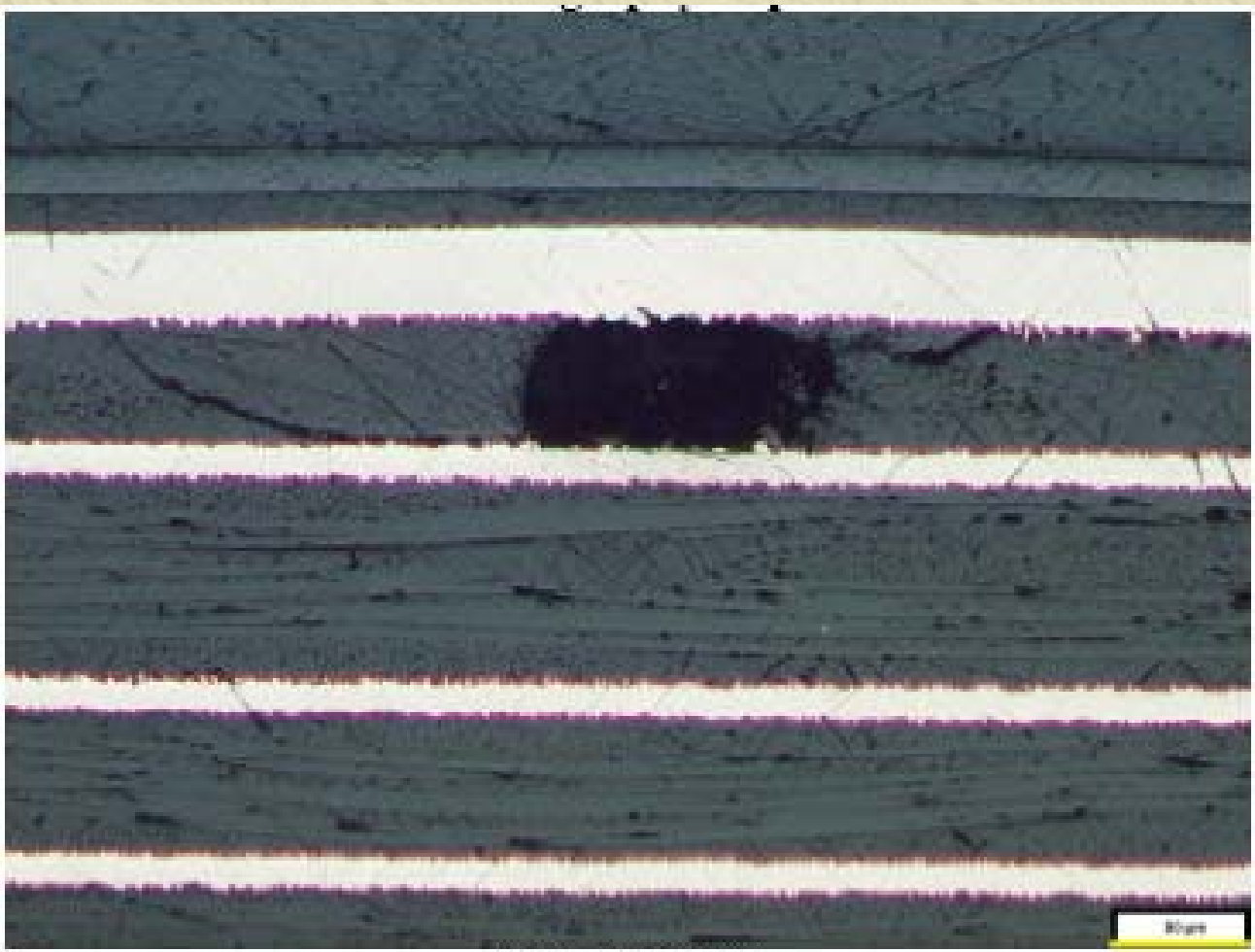

Figure 5 at 100X
Third 1200 Grit SiC grind sequence

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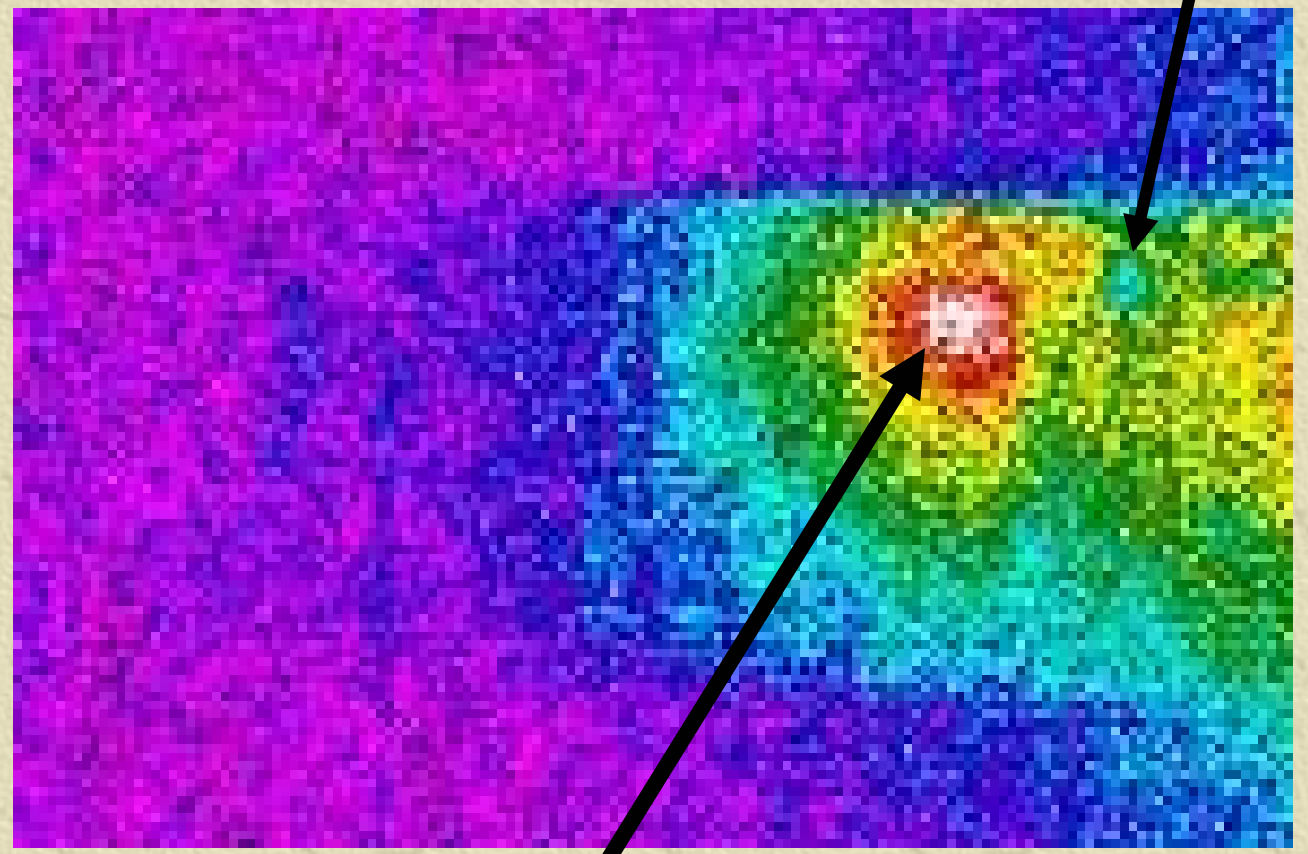
DPA of last two

- Done much more carefully, limiting current to ~mA and using thermal imaging or Squid imaging to locate the problem
- Site of short still shows damage from the current and original cause not clear
- More details on following slides

DPA of SN 612 by Kolos group

Section 2

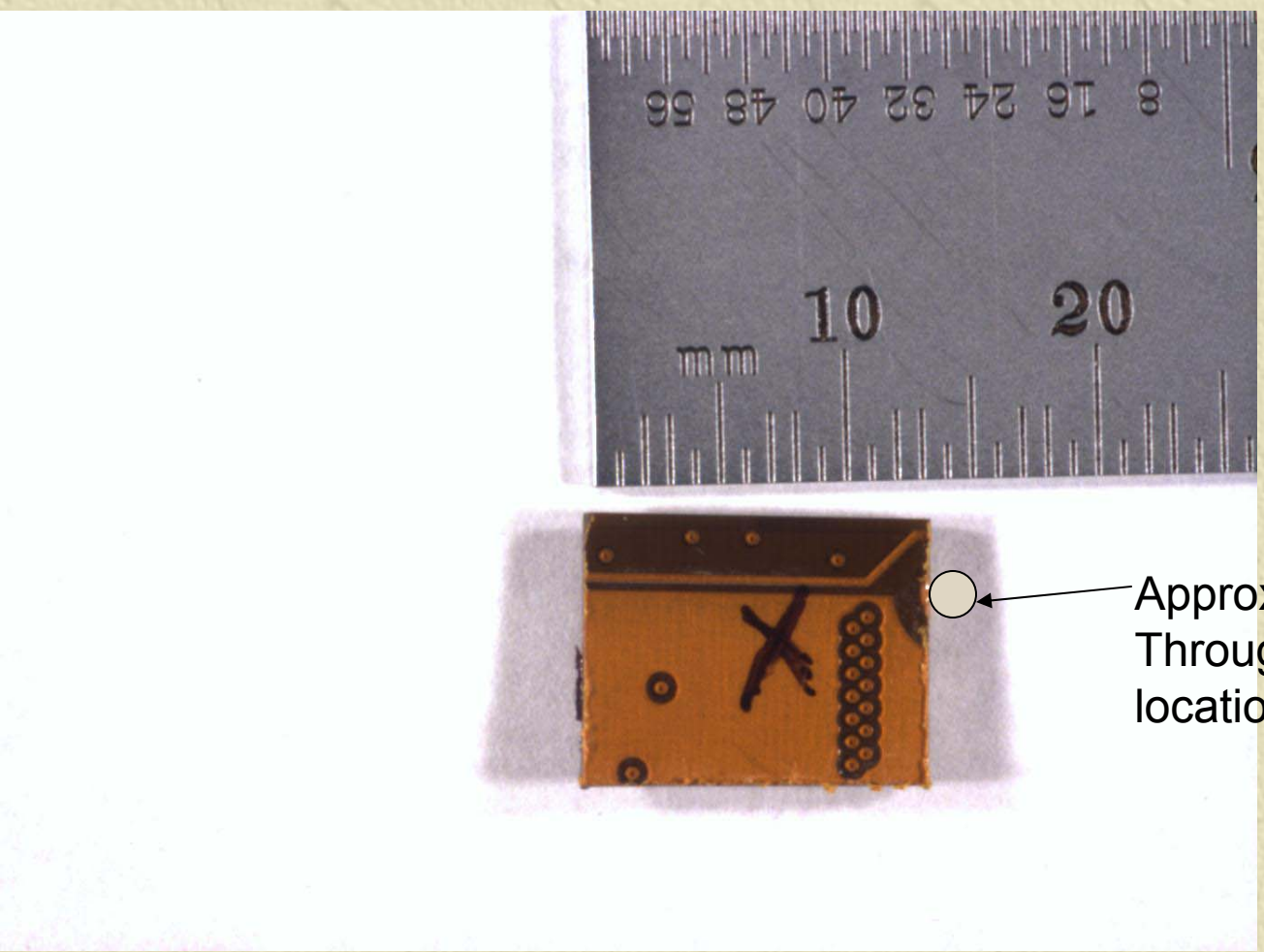
Through Hole



Infra-Red image of SN 612 short provided by Jack Shue/563 from IR test results.

Hot Spot 1.2°C

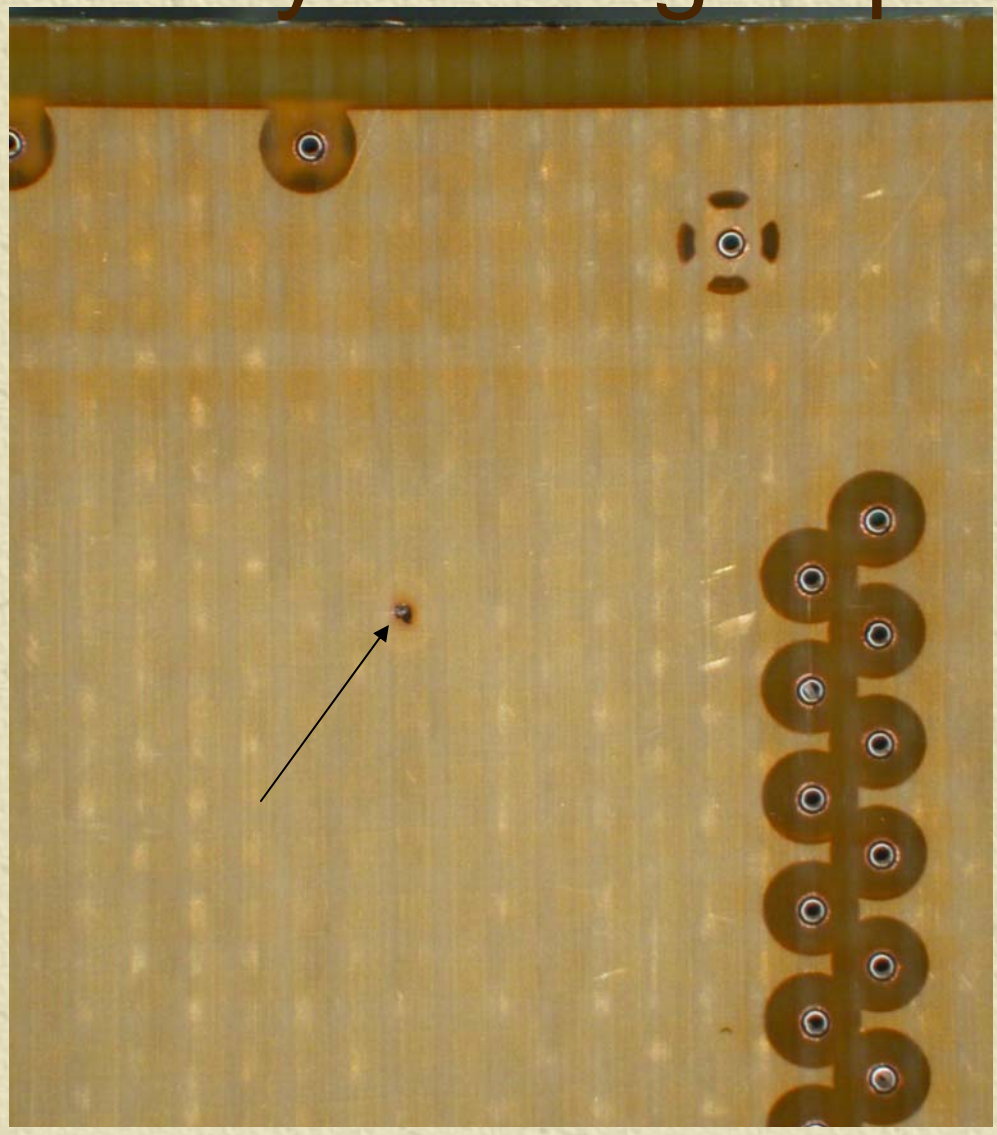
Section from SN 612 which exhibited short



Approximate Through hole location

DPA of SN 612 by Kolos group

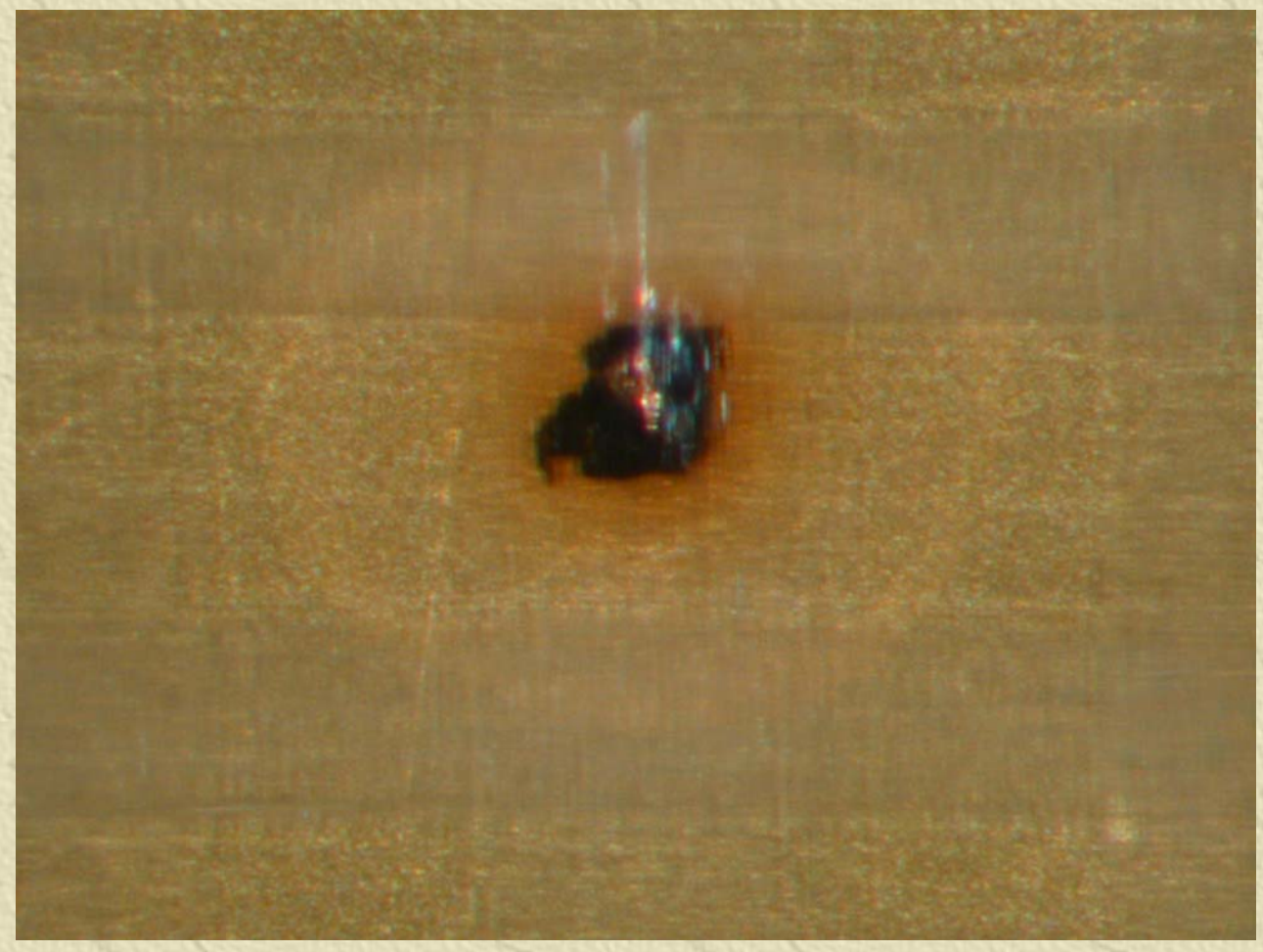
The copper of layer 8 was polished off.



~15x

Low magnification image of particle within laminate between layers 7 & 8 for SN 612

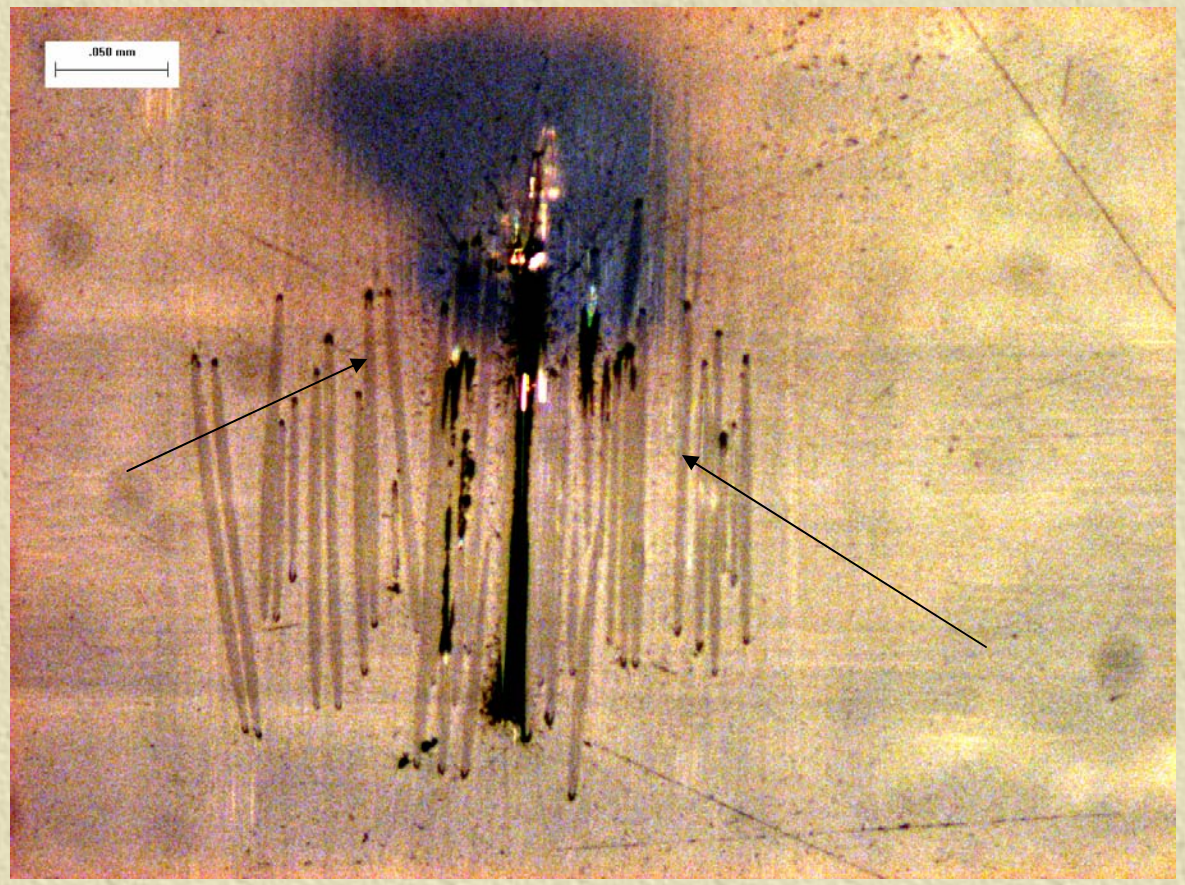
DPA of SN 612 by Kolos group



~160x

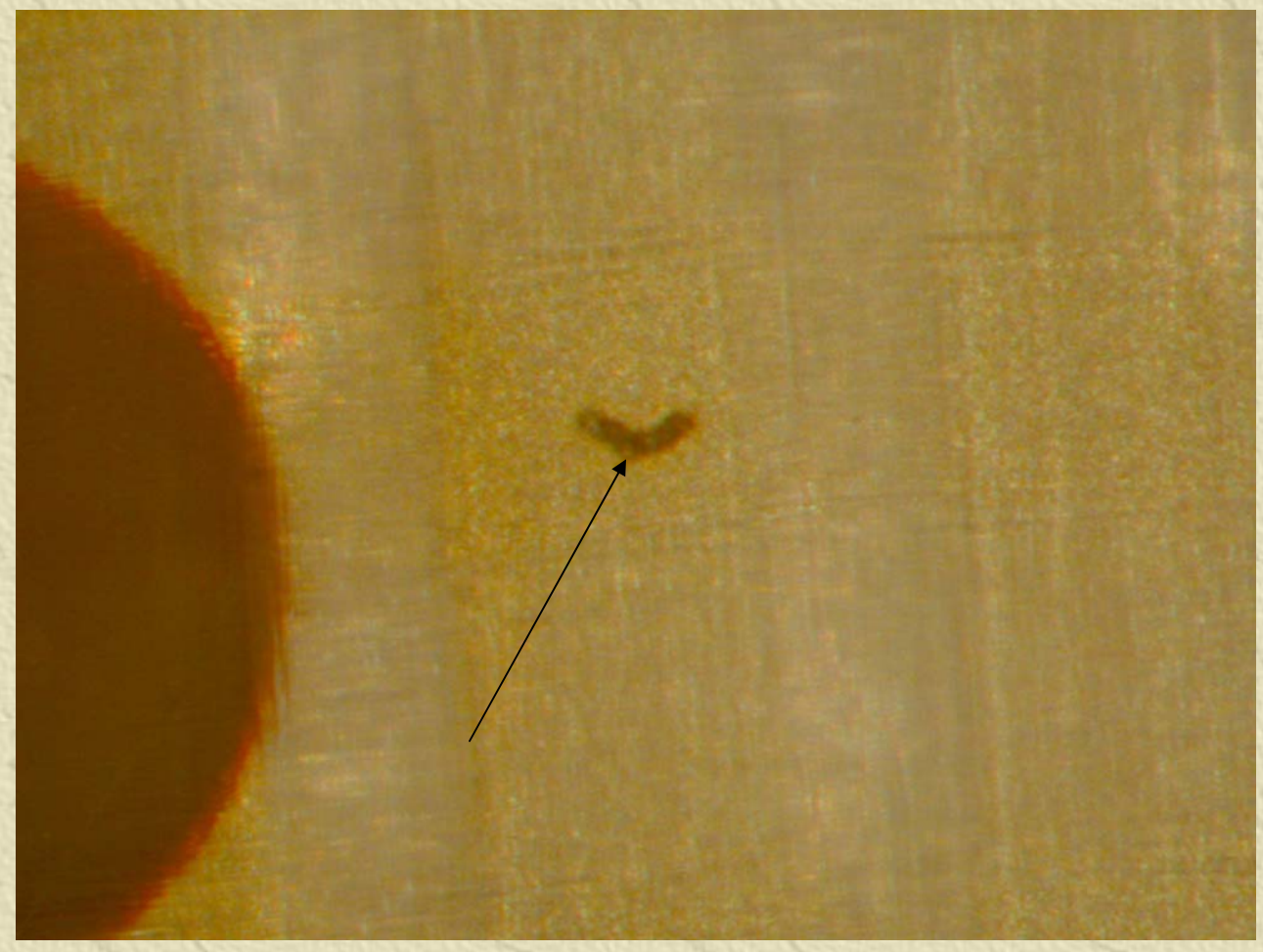
Magnified image of particle between layers 7 & 8, note copper color

DPA of SN 612 by Kolos group



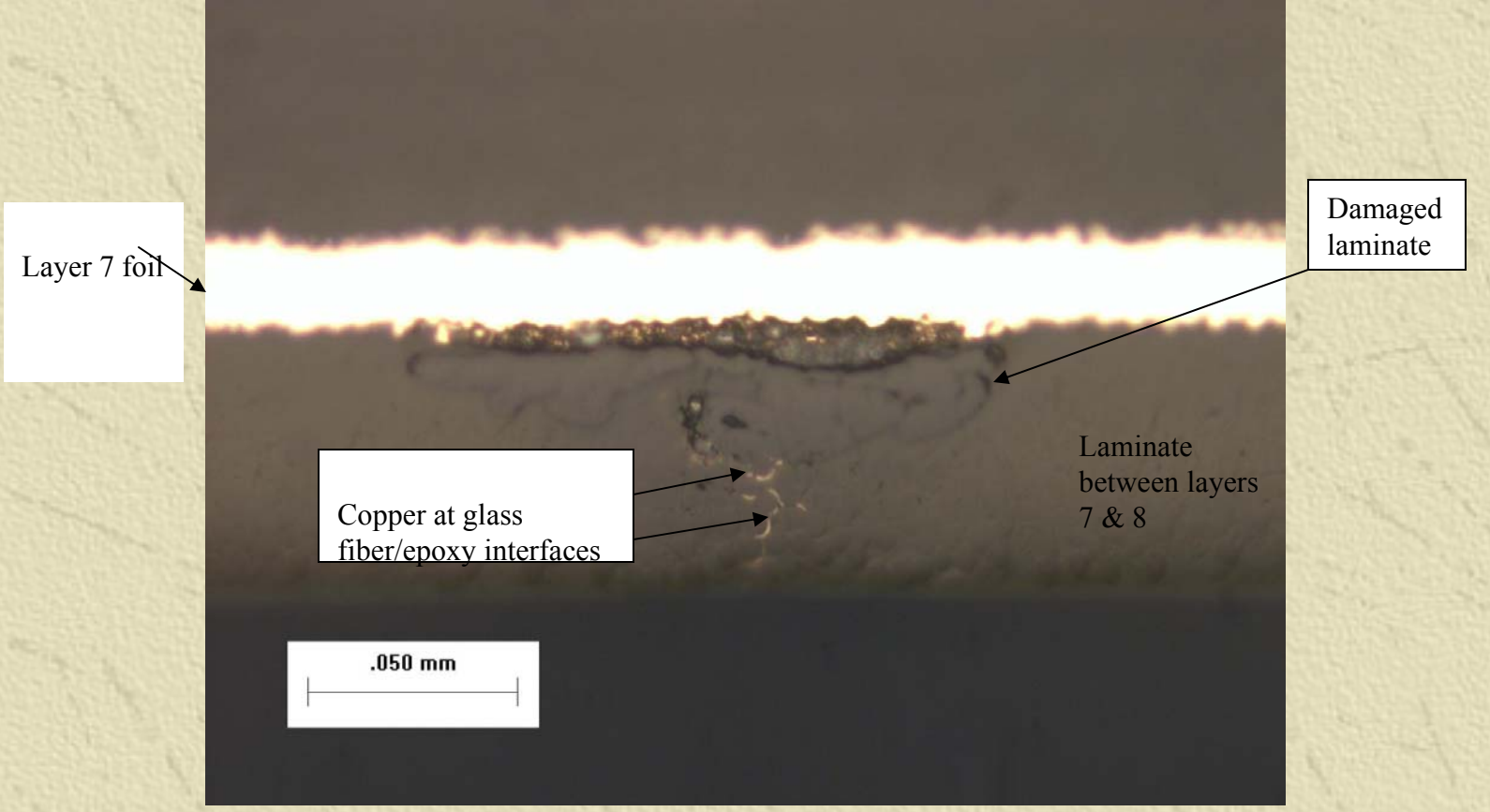
Optical surface image showing copper particle protrusion through polished surface just below layer 8. Arrows indicate shadow of subsurface particle shown in previous slides. Linear pattern in vertical direction are exposed laminate fibers

DPA of SN 612 by Kolos group



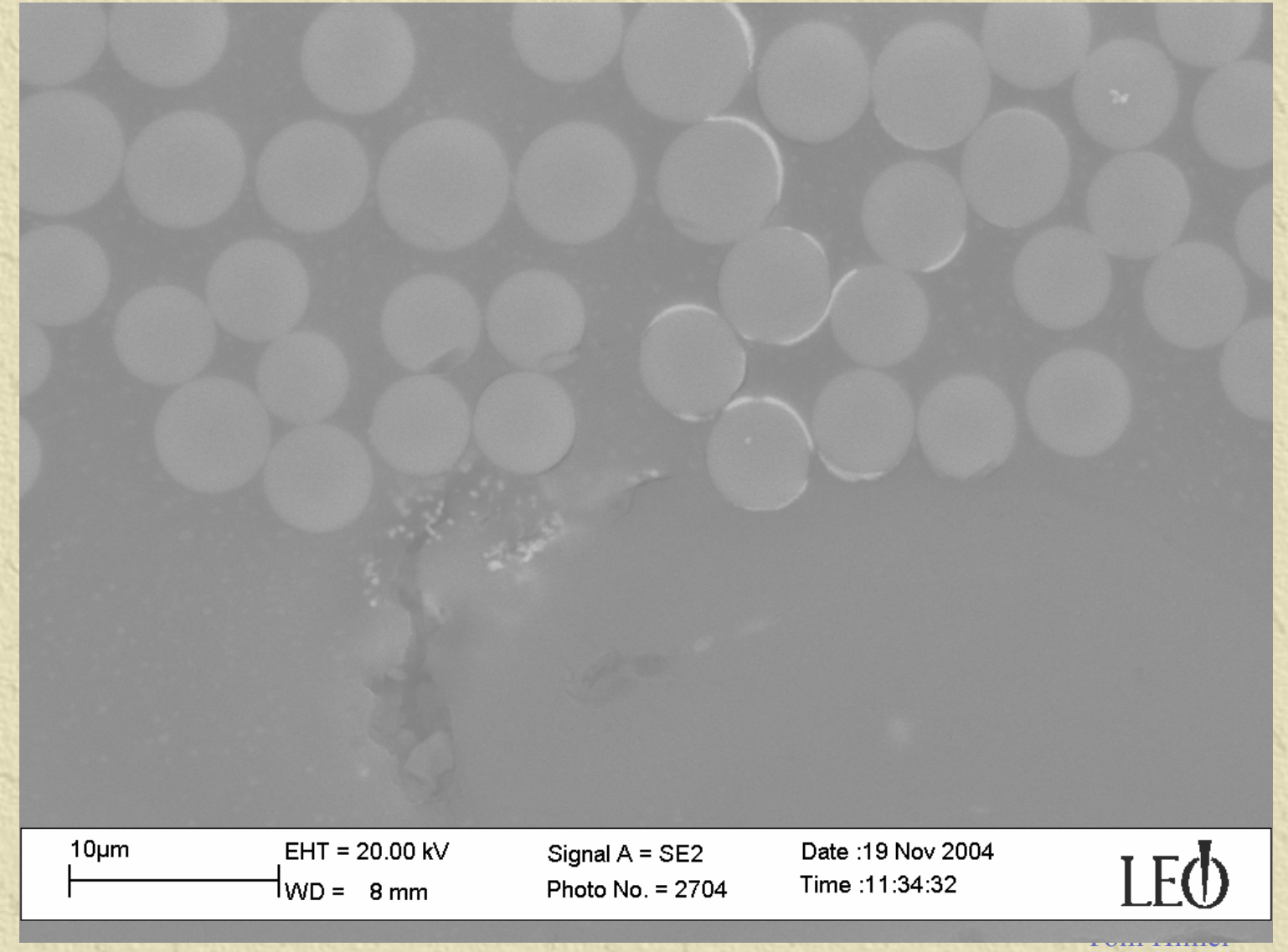
~160x

Arrow indicates additional particle in SN 612 section laminate.



The side section (profile of the copper particle) shows considerable laminate damage adjacent to the central area which has copper deposited among the glass fibers of the board section. I will be checking with Henning's friend at CALCE to determine whether this is CAF, but I think the copper deposit is too thick to be that mechanism. May have been deposited by the same occurrence which heated the adjacent laminate.

SEM image of SN 612



SEM analysis of SN 612

- Copper was found in the shorted area and around the glass fibers. The copper can be seen as high brightness features, especially in the images taken at higher voltages.
- High concentrations of Zn, and Cl were found in the shorted area, even in the epoxy resin. The areas away from the shorted area have no Zn or Cl.
- Suspected RA flux with zinc chloride activator, but not used in the board construction
- There were balls of copper suggesting it had been molten and that the copper is all from heating due to current running through the layer.

Picture of CAF from NPL report MATC(A)155

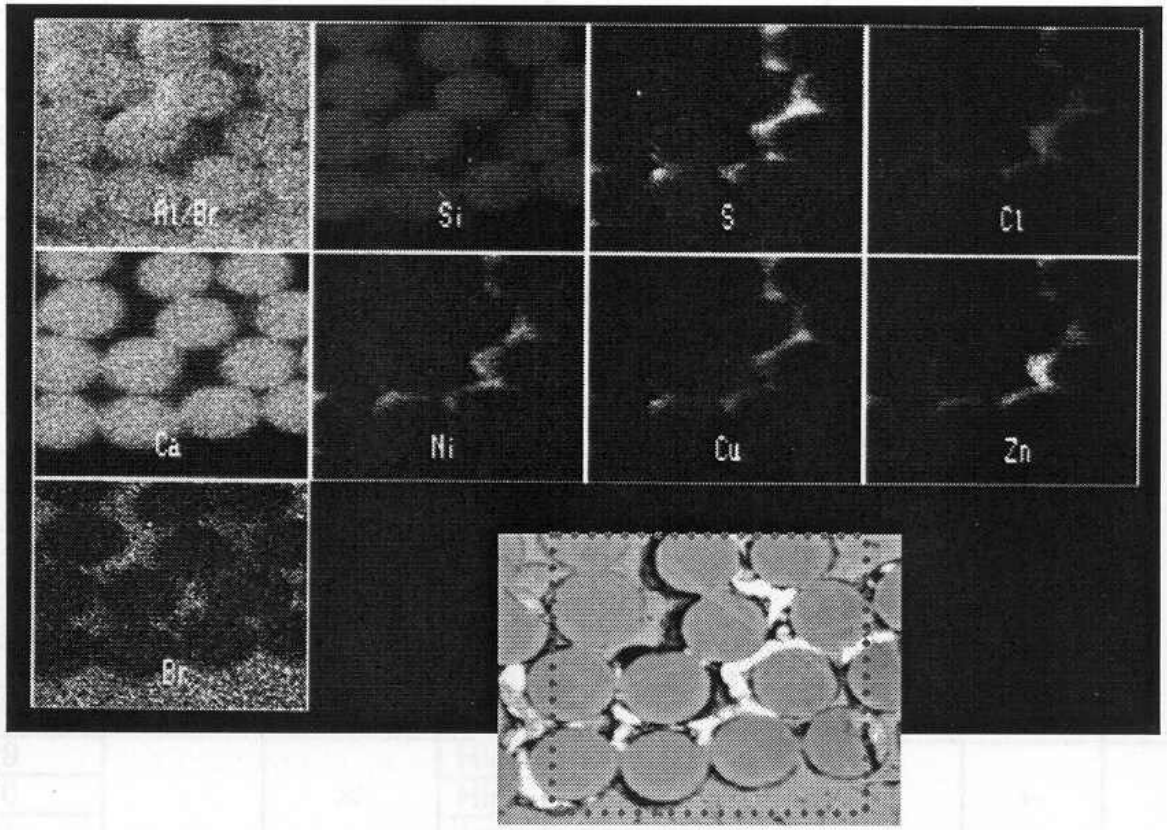
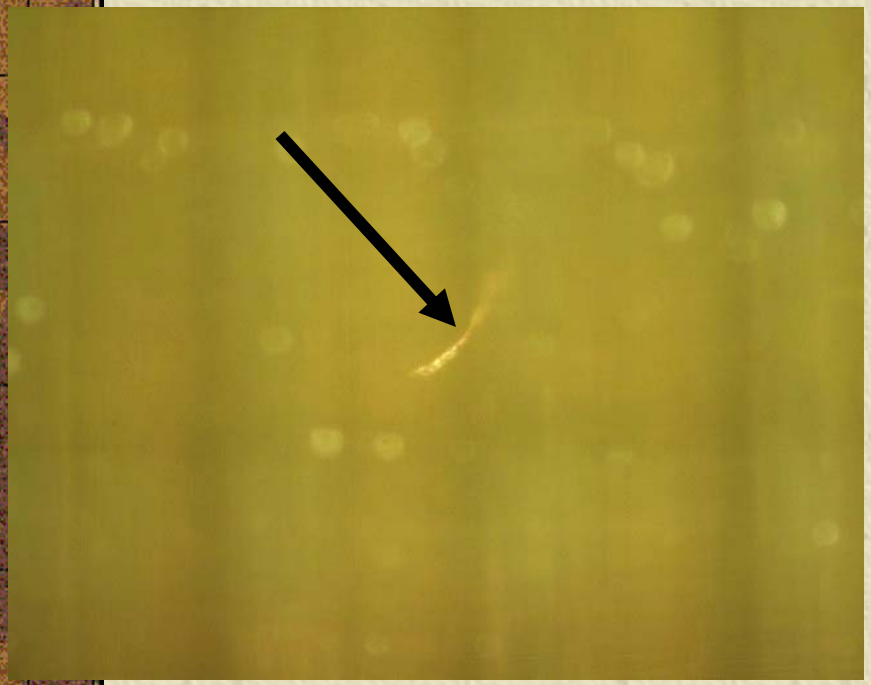


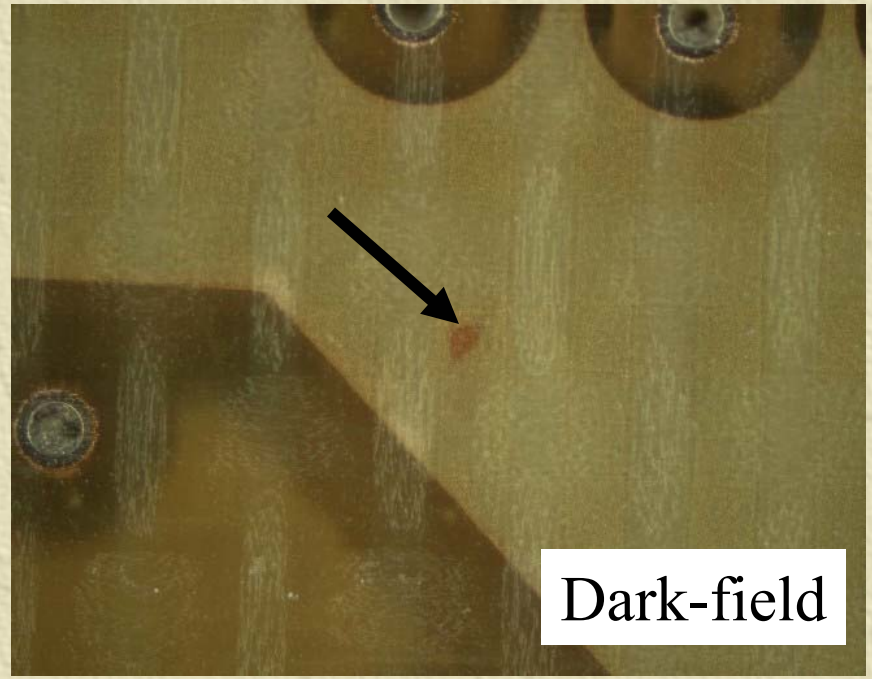
Figure 14. Optical and EDAX images of microsection showing presence of many elements associated with the CAF

Could it be Conductive Anodic Filamentation (CAF)?

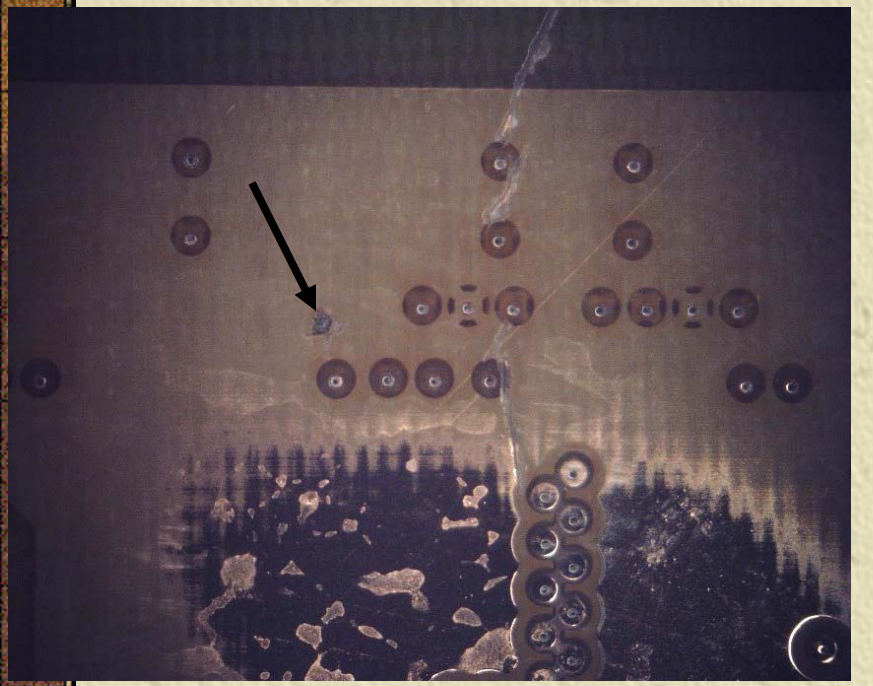
Summary of DPA of SN 559 by Keith Rogers at CALCE

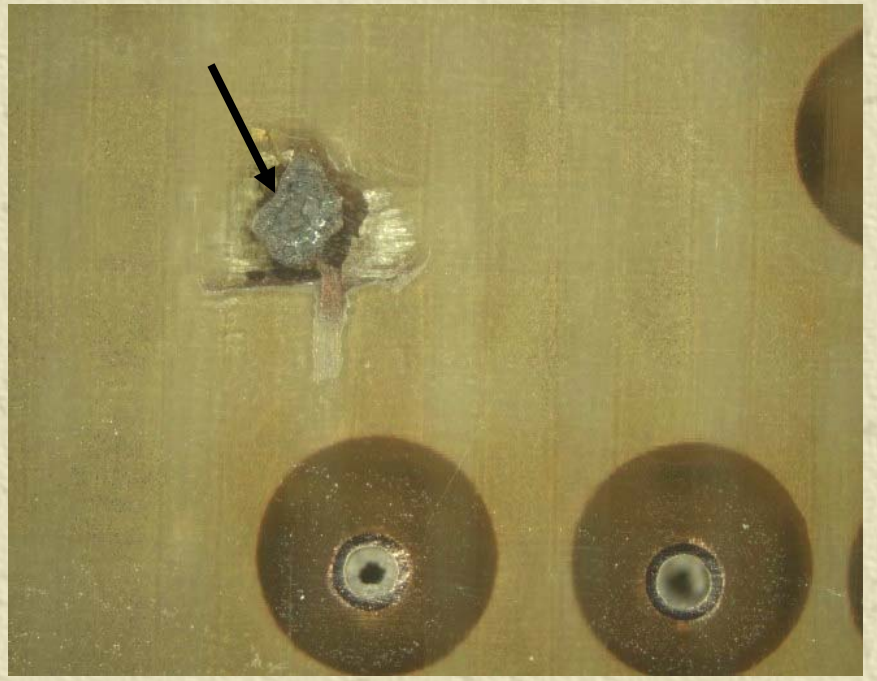
Based on what I saw during the cross-sections and my previous experience, I believe that there are some rather large particles embedded in the resin. EDS analysis of these particles indicate that they are some form of silica. Optical photos show that some of these particles are just as large as the vertical distance between the planes. It is very likely that some of these particles are actually larger than the gap between the planes and during the lamination process, the pressing of the laminates together can squeeze and crack these particles which bridge the vertical gap between the planes. Once a crack is formed, moisture can accumulate and allow the copper on the positive plane to ionize and go into solution, moving towards the negatively biased plane where the soluble copper ions change back to solid copper particles after passing through a ph gradient (from low at the positive side to high at the negative side). This copper migration through these cracks can cause the short circuits experienced. Note: silica is often used in prepreg to match the CTE. It is NOT used in the Arlan 35N of the MCM.

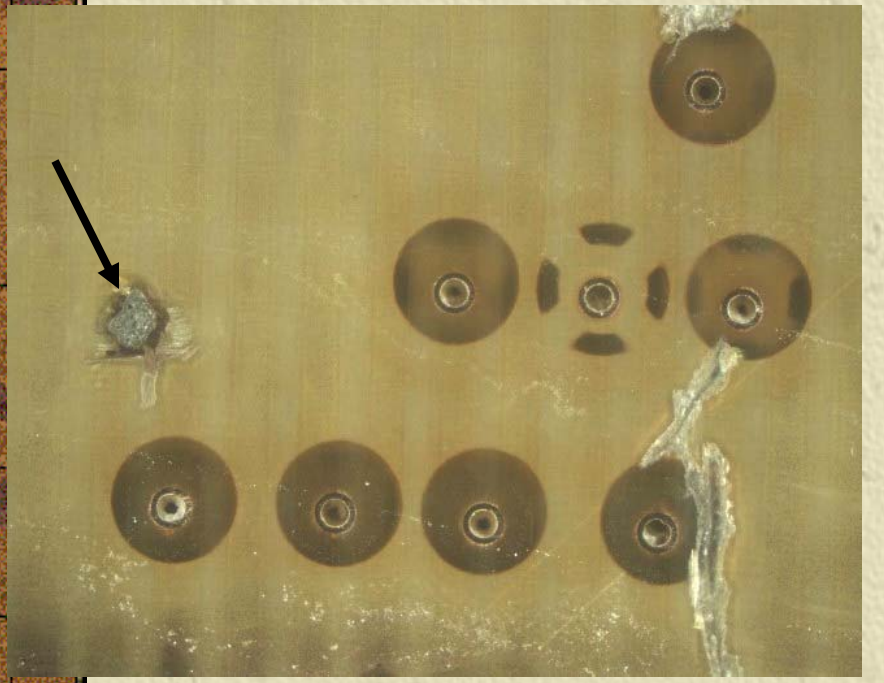


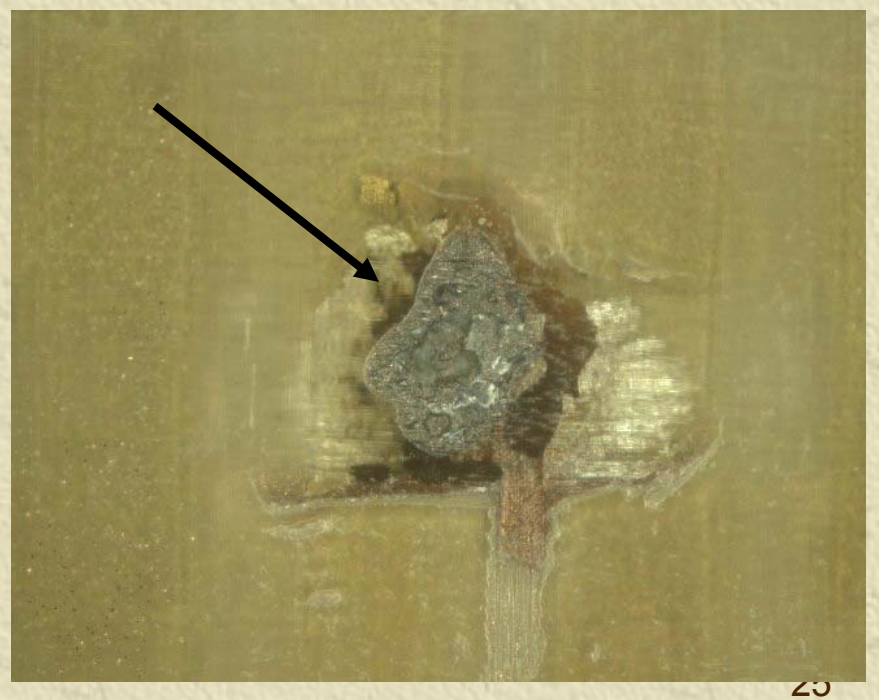

Dark-field


Bright-field









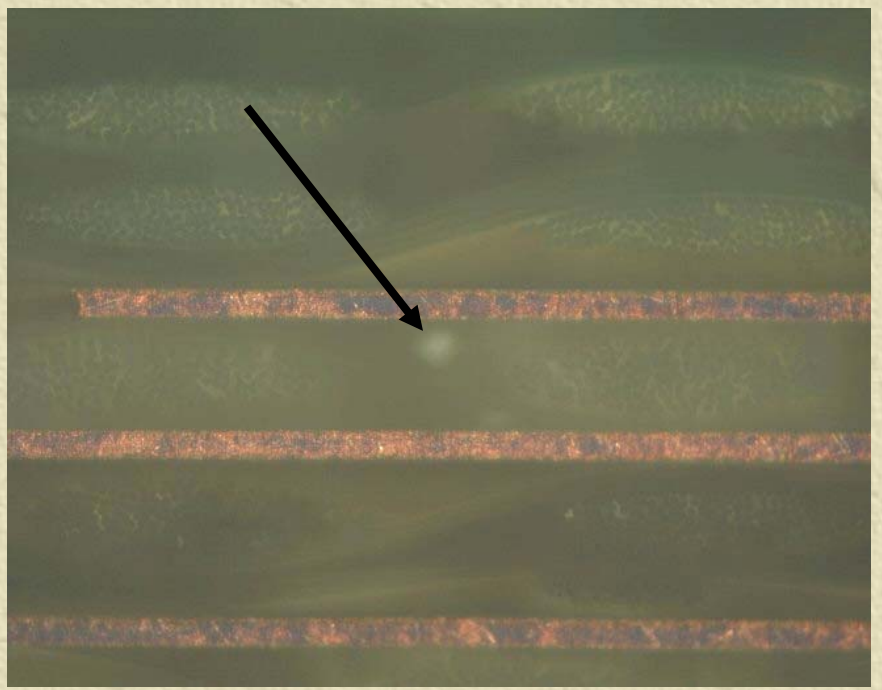


Photo focused on the surface

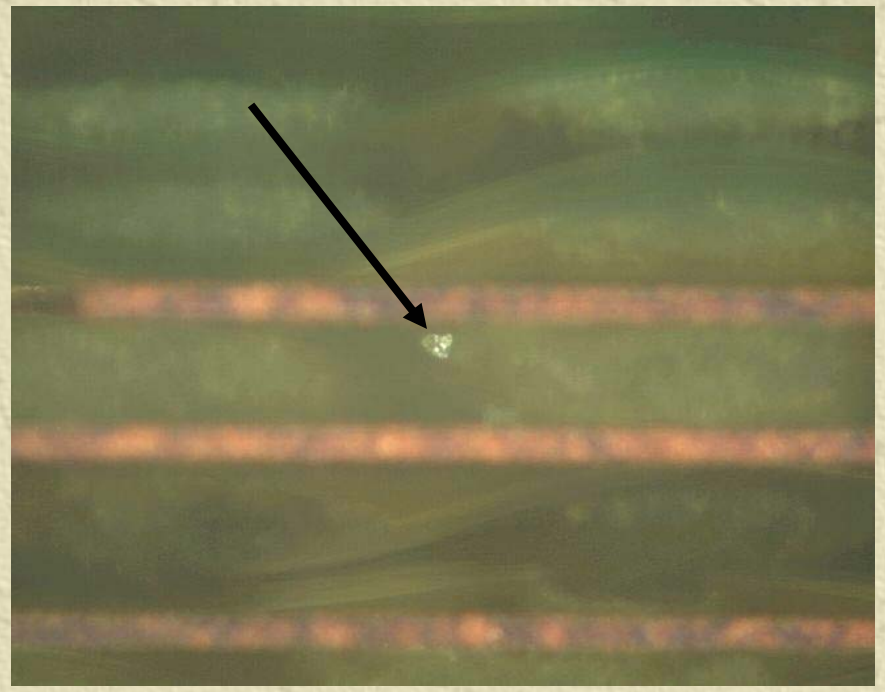
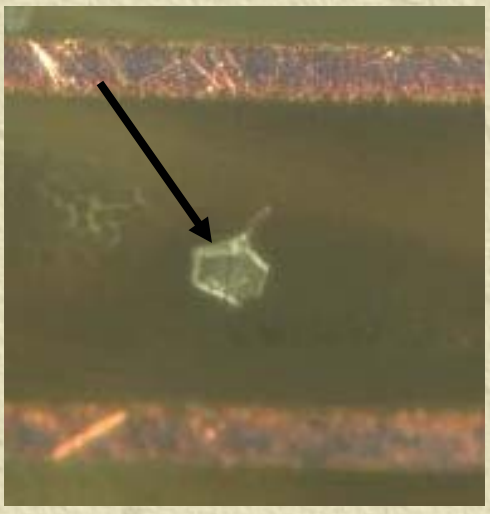
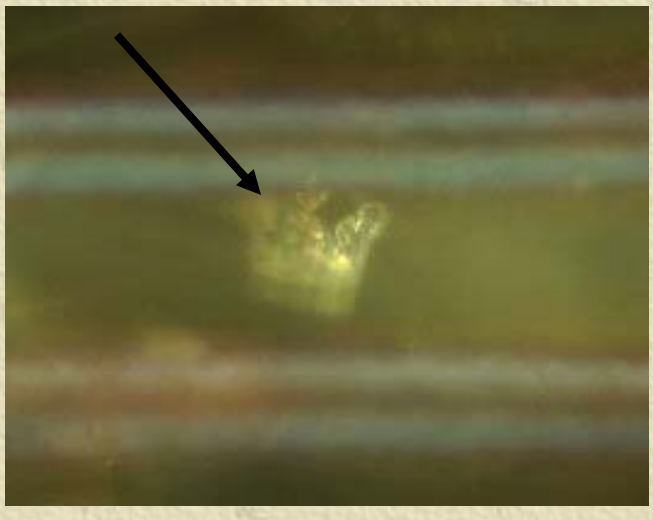
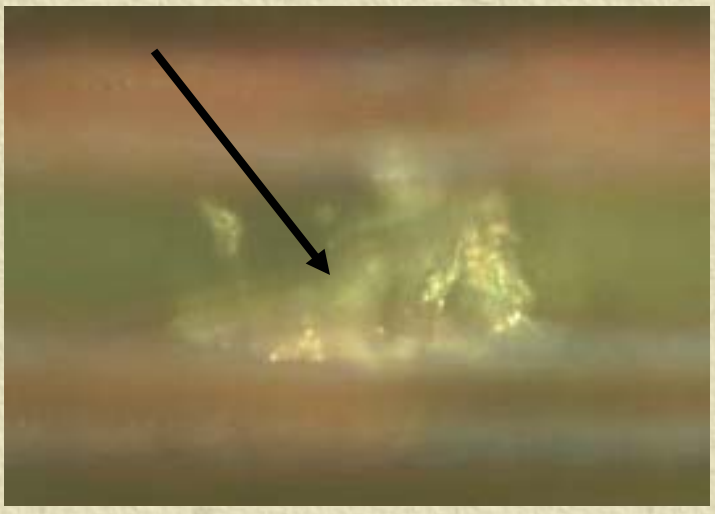


Photo focused on particle below the surface





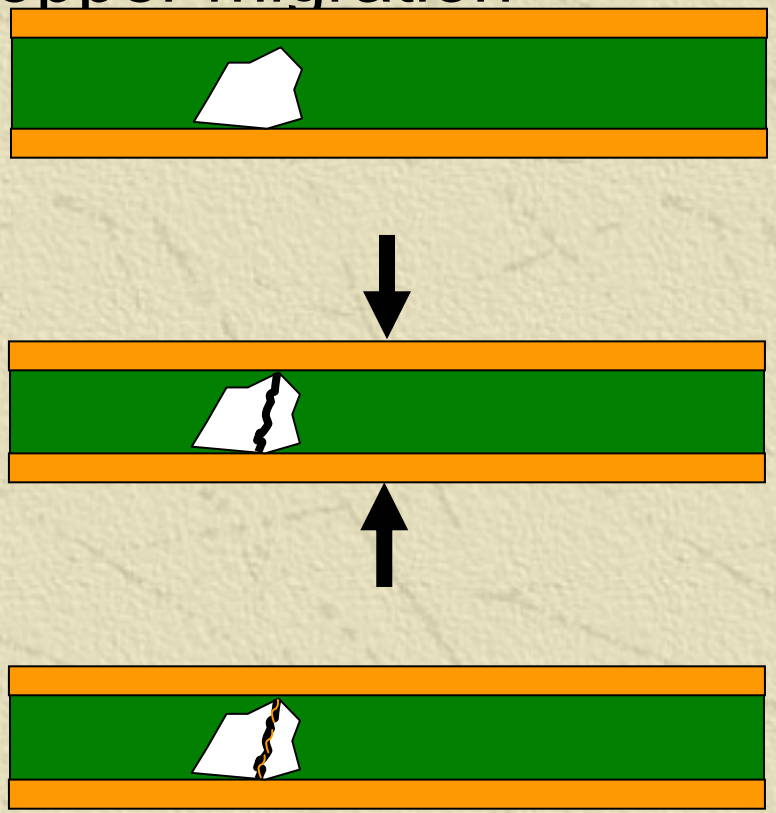


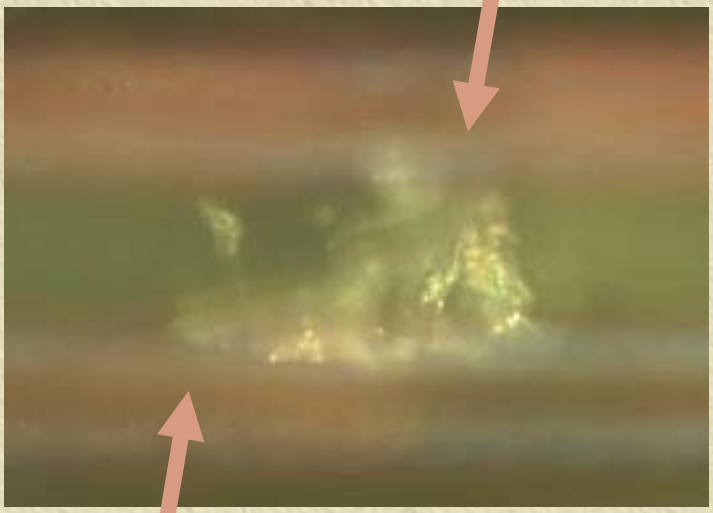
Photos of other particles embedded in the resin show that some almost bridge the vertical distance between the planes.

Conductive Path Formation – CALCE report

Particle provided a path for

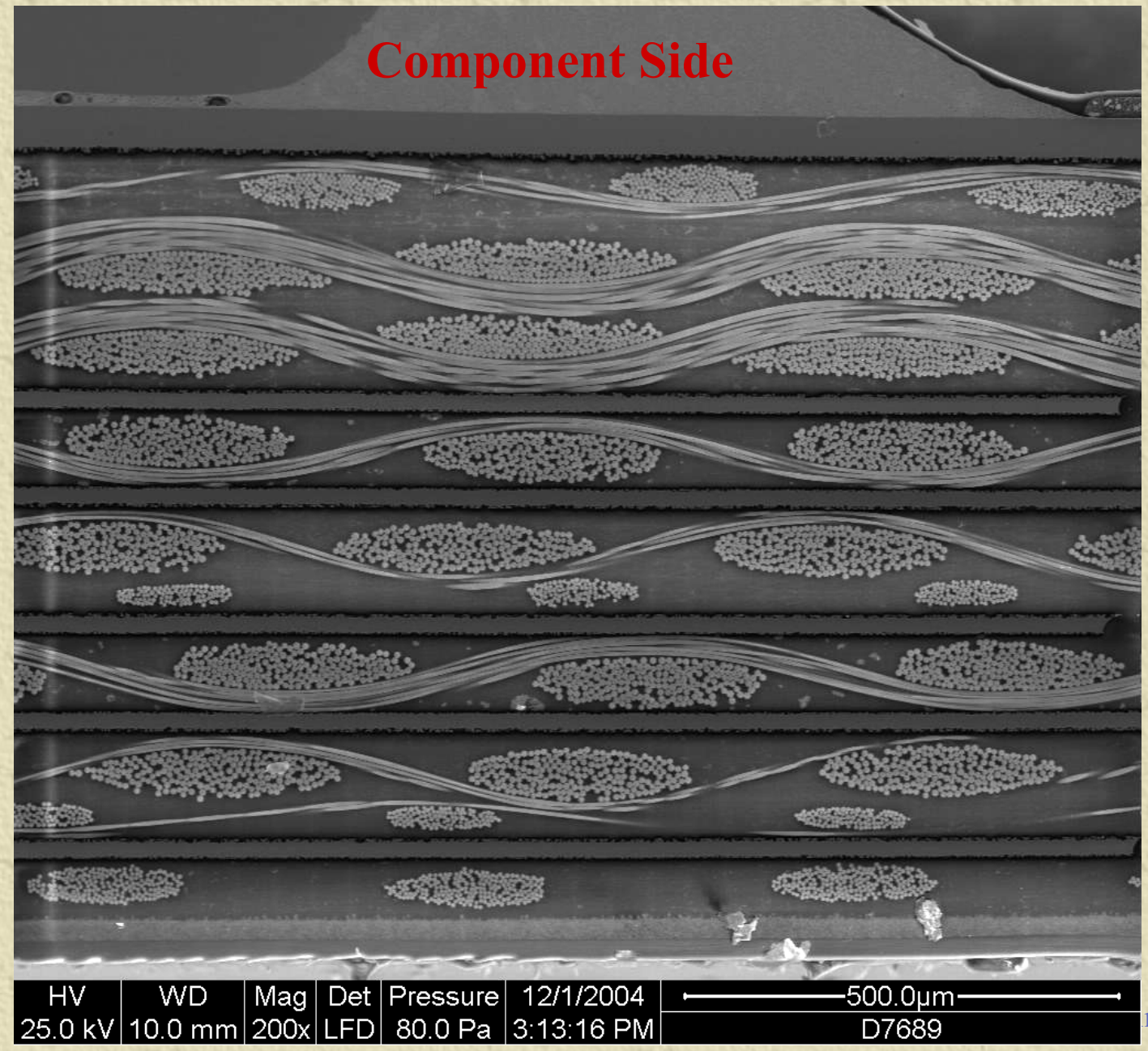
copper migration





- Delamination
  - Hydrolysis, crack initiation
- Particle cracking (relatively brittle)
  - Pressing
  - Reflow

E-SEM Cross-sectional Photo – 3 2-ply and 4 1-ply



1
2
3
4
5
6
7
8

mel

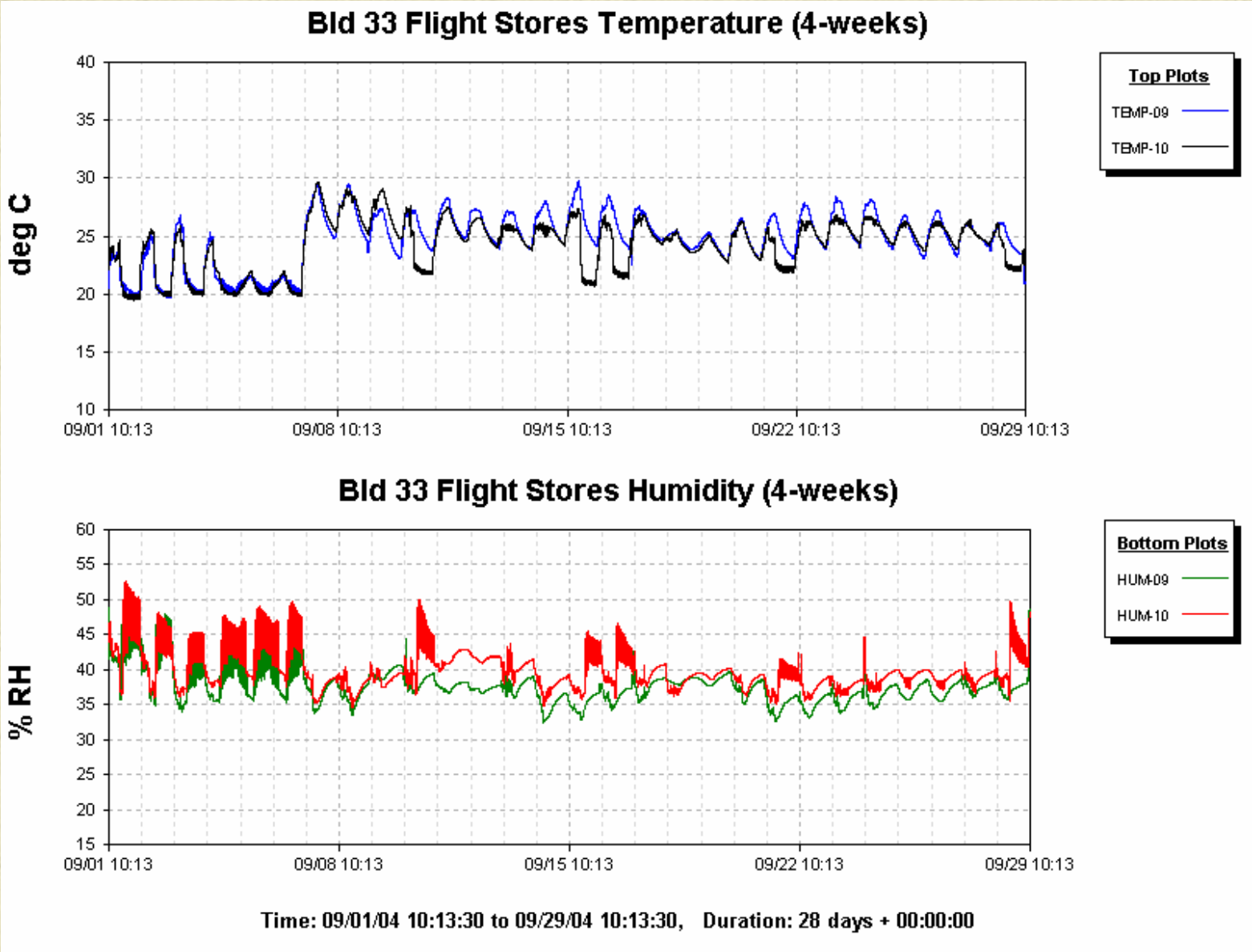
What is CAF?

- Growth of a copper salt filament from the anode to a cathode.
- Requires moisture in the board
- Requires an insulator flaw path along which to grow. Usually along the glass fiber/resin interface, often where it is damaged by drilling.
- Accelerated tests done at 85°C and 85% humidity for 1000 hours.

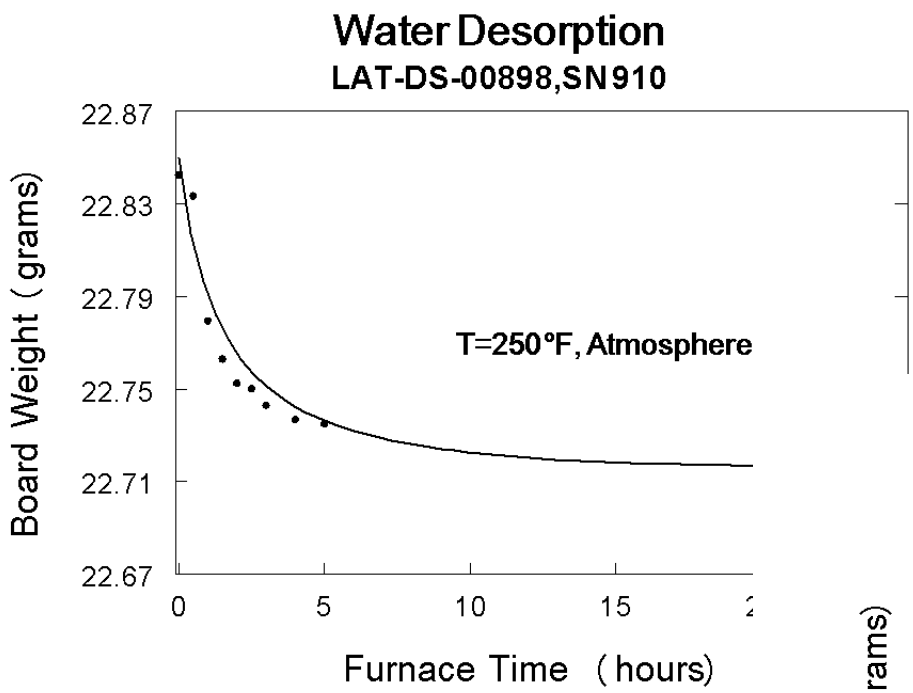
Are the Boards Moist Enough for CAF?

- They are exposed to ~40% humidity.
- One expert said not enough.
- Almost all experience is with FR4
- Polyimide is more hygroscopic
- One expert said >0.2% by weight was bad.
- Our boards have 0.4% moisture content
- Conclusion: YES

Humidity of bldg where bare boards are stored at SLAC

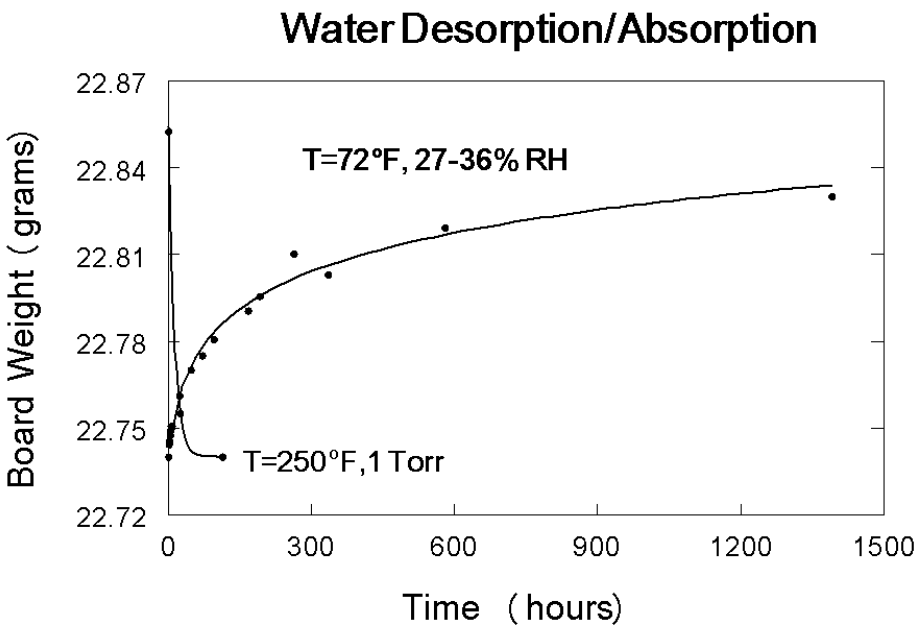


Moisture content of the Boards



Loses .1 g or 0.4% of weight.

A 4 hour bake at 250°F is long enough to remove moisture



100's of hours to absorb moisture.

Other Facts/Comments

- The insulation between layers 7&8 is 1 ply of prepreg that is 3 mils thick
- The IPC 2221 standard for 150 V is 8 mils
- 3 mils of polyimide should withstand 3 kV
- 3 mils of air breaks down at 225 V
- I applied ~1500 V to 1 bare board before it sparked on the surface
- Corona in a small void could cause further damage leading to breakdown
  - An accelerated test (with AC voltage) on 4 bare board found no problems.

Other Facts/Comments

- Moisture rapidly expanding during reflow soldering could cause damage which later makes the short.
  - Have added a 4 hour bake at 250°F before reflow to eliminate this possibility (for which there is no evidence).
- Conductive contaminants have been known to cause delayed shorts
- Voids in prepreg typically either don't exist or are so large they cause major problems
- The effect of a short is to kill ¼ of a layer due to 4 270kΩ isolation resistors on the board

Summary

- Smoking gun has not been found
- Boards with shorts will not be used
- For future board production, are introducing two process changes that may prevent future problems
  - Dry boards before reflow soldering
  - Make the insulating layer thicker and two-ply
- Non-failed MCMs will be used for flight based on assumption that the burn-in caught most if not all the failures.