Experience with defects in copper plating at HTS/FNAL

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Experience with defects in copper plating at HTS/FNAL

- FNAL has not had many copper plating related failures at HTS
  - 2 Coupler failures at HTS, low gradient quench induced by field emission
    - Both couplers had been reworked by CPI in the areas of failure
    - Rework of effected areas likely the cause of failure, not initial plating quality
- Because of failures studies of plating quality were done performed at SLAC
  - Ultrasonic cleaning (UC) effect on Cu plating and power distribution
    - Studies showed aggressive effect of US process, (continuous Cu removal)
    - Unpredictable power distribution within tank volume
  - Exercise of bellows(cold end) loosens up copper particles
    - Experiments at SLAC showed an increase in particle generation with as little as 10 motion cycles (+/- 5mm)
    - Generated particles were larger in size than those generated in cleaning
  - Plating process has a great impact on plating quality
    - Standard plating vs periodic reversal produces dramatic differences
    - Order of magnitude difference in particle genration depending on process
    - Plating process control and documentation highly important

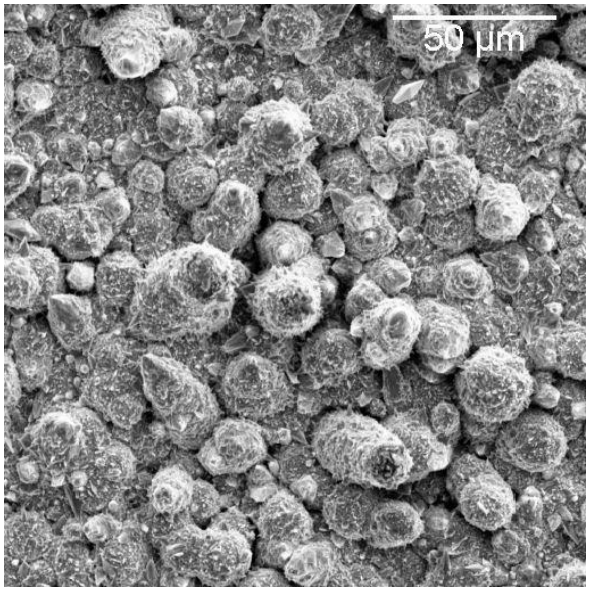
Experience with defects in copper plating at HTS/FNAL

2 Coupler failures at HTS, low gradient quench induced by field emission.
Both couplers had been reworked by CPI in the areas of failure.
It is possible the rework process caused damage to the effected areas.

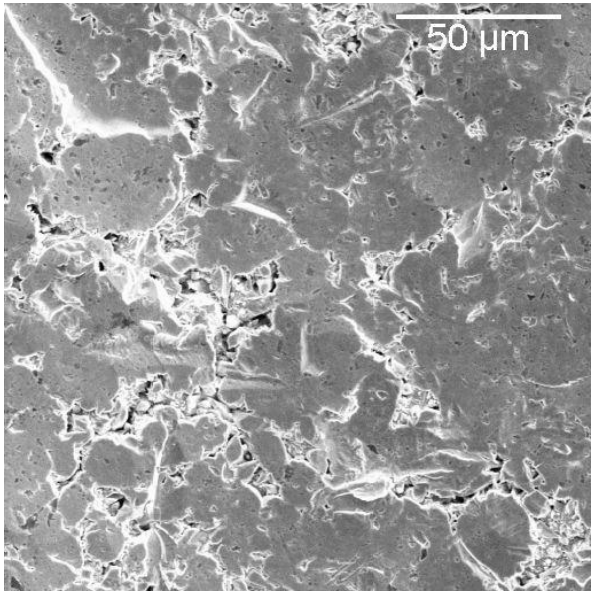
FC01, vapor trail, missing Cu

FC10, uneven/missing plating, Cu flakes were found on antenna tip

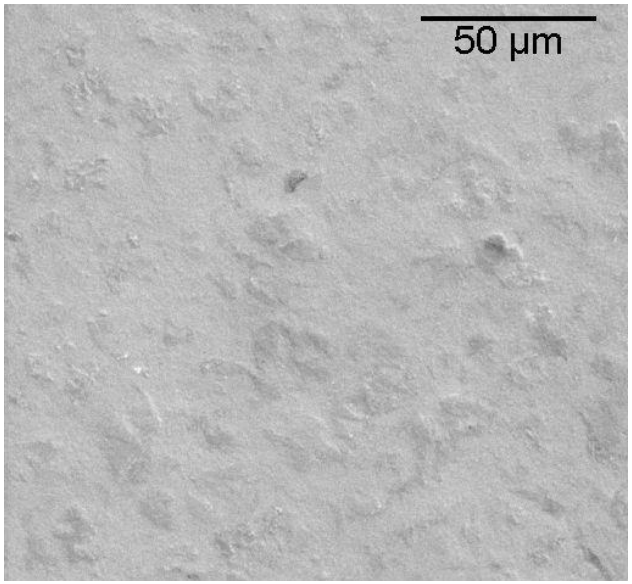
Process driven differences in plating surface finish



CPI not post bead-blasted coupon



CPI post bead-blasted coupon



SLAC not post bead-blasted coupon

The vendor non-bead blasted surface is much rougher than that resulting from the SLAC platting process. This is likely the result of SLAC doing a periodic-reverse polarity change during the platting (25 seconds 'forward' plating followed by 5 seconds of 'reverse' platting), which the vendor does not do. The vendor bead-blasted surfaces are smoother, but crevasses and sharp edges are produced. Inspection after ultrasonic cleaning did not show significant difference, which suggests the ultrasonic cavitations are not too strong as to significantly erode the surface.

Test Results, particle generation

- Below table lists the particle counts averaged over both the three ultrasonic baths and the coupons of a given type:

Coupon Sample	Ave. # Particles > 25 µm per mm²	Ave. # Particles 10-25 µm per mm²	Ave. # Particles < 10 µm per mm²
Vendor Bead Blasted	12	40	47
Vendor Non Bead Blasted	3.2	14	30
SLAC 30 mm Platting	0.55	2.3	3.0
SLAC 10 mm Platting	0.46	1.8	2.6

- The results show the vendor bead-blasted coupons have the highest count as may be expected given that the surface 'nodules' are flattened by the beads. The vendor non bead blasted values are somewhat smaller, and the SLAC non bead blasted values are at least an order of magnitude smaller, consistent with the smoother surface.
- Interestingly, the particles counts in all cases did not necessarily decrease with repeated ultrasonic cleaning, which may mean the ultrasonic power level is too high for this soft copper.