Extending Cantilevered Probe Card Life

An “Abrasive” Approach

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Overview

- Introduction
- Objectives / Approach
- Methodology Overview
- Implementation / Characterization
- End-User Customer Application
- Summary

Objectives

- Develop a systematic approach to improve cantilevered probe performance.
  – Economics and cycle time make cantilevered probe cards the most commonly utilized probe technology
- Characterize a methodology for extending cantilevered probe card life.
- Demonstrate improvements in probe card performance as well as probe card service life.
  – Assess the applicability to “best” wafer level test practices for specific end-user customers.

Approach

- Consider some basic concepts from spot welding
  - Re-visit the empirical model proposed by Babu, et. al (2001)

$$C_{RES} = \frac{(\rho_{pad} + \rho_{probe})}{4}\left[\left(\frac{\pi\sigma_{YS}}{\eta P}\right)^{1/2} + \frac{3\pi}{4\eta^{1/2}}\right] + \frac{\rho_{film}}{a\eta\pi}$$

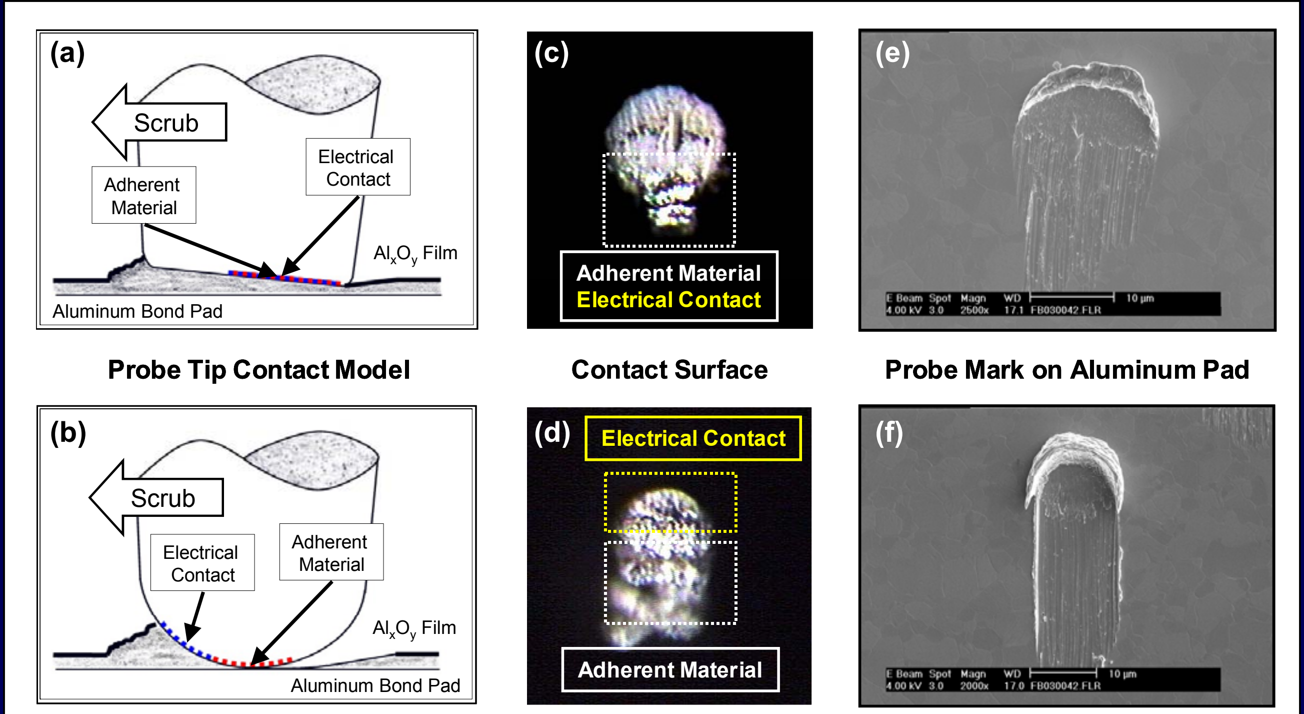
    - ρ_{pad}, ρ_{probe}, ρ_{film} = resistivity values
    - σ_{YS} = material yield strength
    - P = contact pressure
    - a = average radius of contacting asperities, or *a-Spot* size
    - η = number density of *a-Spots* that are in real contact
  - Contact pressure (P) is the applied force normalized by true contact area
  - η, a depend on the surface roughness of the contacting solids

Approach (cont.)

- Critical factors with applicability to cantilever probes.
  - Presence of contamination, e.g. oxides, residues, etc.
    - Probe tip shape plays an important role in displacing the contaminants from the true contact area
    - On-line cleaning methods can be used to “control” adherent contaminants and remove debris
  - *True* Contact Area = $\mathcal{F}$ (Tip Shape, Applied Force, Surface Finish)
    - *True* contact area of a flat tip probe is “large”; however, the applied pressure and *a-Spot* density are “low”
    - *True* contact area of a radius tip probe is “small”; however, the applied pressure and *a-Spot* density are “large”
  - Asperity density depends on the microscopic surface roughness
    - Smooth surfaces have a high asperity density
    - The increase in asperity density decreases the electrical C_{RES}
    - A “rough” finish facilitates material accumulation on contact surface.

Physical Contact Mechanisms

- A smooth, rounded tip allows the bond pad to deform easily around the probe tip and contact surface.
- Electrical contact region of the rounded shape is at the leading edge and across a smooth, "relatively clean" surface.



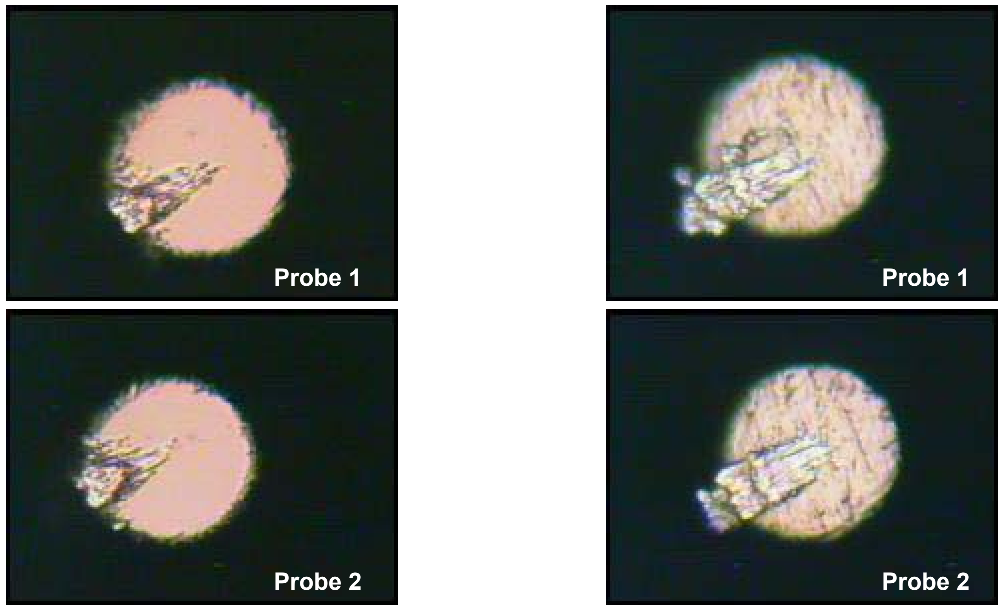
Adapted from Maekawa, et al., 2000

Adapted from Stalnaker, et al., 2003

Effect of Surface Roughness

- Surface roughness affects pad material accumulation.

Surface finish obtained with 0.5-µm AlO_2 lapping film | **Surface finish obtained with 3-µm AlO_2 lapping film**



100 TD on Aluminum Bond Pad | **100 TD on Aluminum Bond Pad**

- Flat, tipped probes with a ***TOO*** smooth surface finish will not properly penetrate the bond pad surface oxides.

Probe Tip Shape Factors

- Rounded and radius tipped, cantilevered probes have shown advantages over flat tips for wafer sort.
  - More stable contact resistance
  - A smooth surface finish that penetrates the surface oxides
  - Smaller probe marks and reduced pad damage
  - Reduced need for on-line cleaning
  - Probe tip maintenance can be achieved using proven non-destructive on-cleaning practices
- As with any technology there are some disadvantages.
  - Higher unit pressure, may require a reduction in probe force
  - Potential for deeper probe marks that could damage underlying IC stack
  - Reduced reflective probe tip area that may require modifications of algorithms on the prober and analyzer
  - “Standard” on-line / off-line abrasive cleaning damages the probe shape

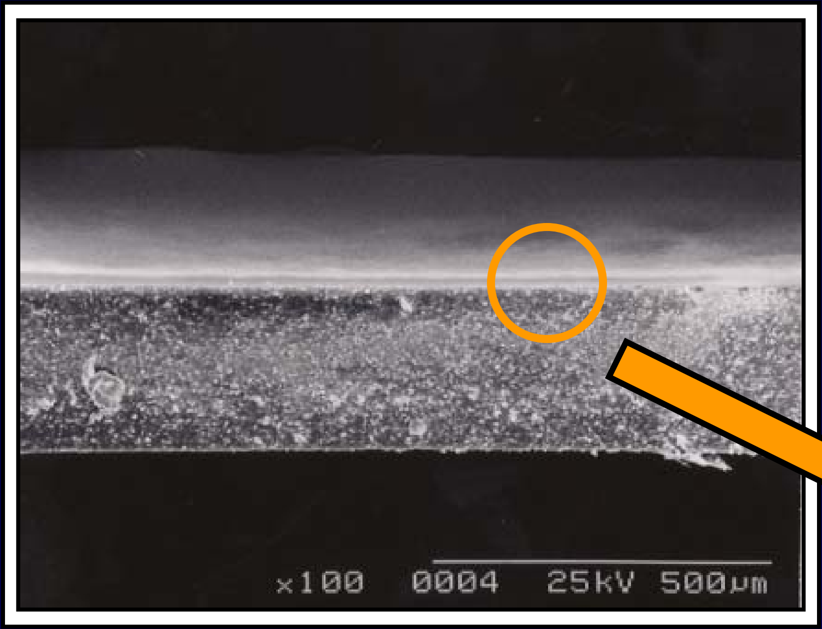
Developing a Rounded Tip Shape

- Electrochemical machining and polishing
  - "Gang Process" – the probe card is built with shaped tip probes
    - Probes must be "tweaked" into specification without lapping operations.
    - Extra care must be taken to avoid damaging the tip shape.
  - "In Spider" – probes are shaped after the probe card has been built
    - Manual etch operation in which probes are individually radiused by an experienced technician; however, the tip shapes can be inconsistent.
    - Probe tips are "etched" *in-situ*; however, damage can occur to the PCB due to capillary action (wicking) of the electro-chemicals.
    - Probe-to-Probe (tip shape, tip length, etc.) variability can occur.

Developing a Rounded Tip Shape (cont.)

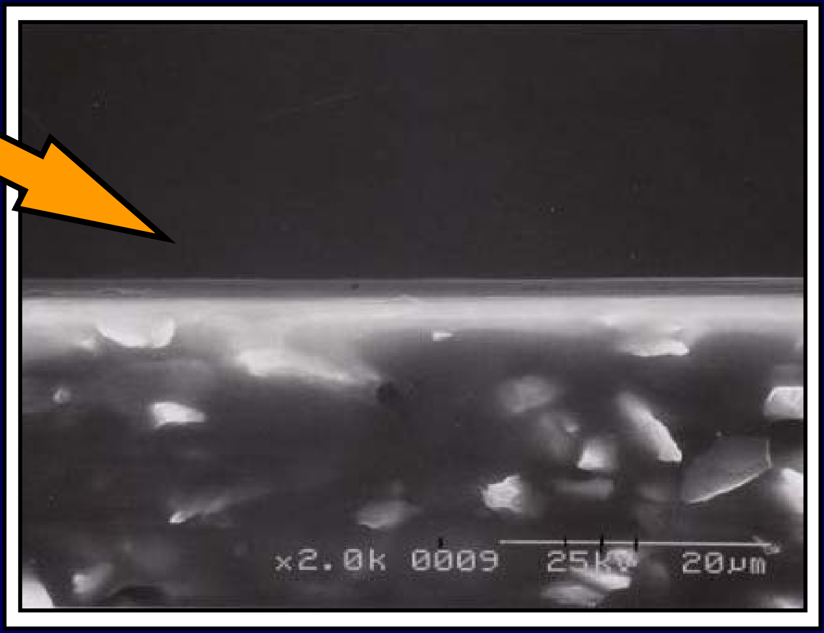
- Material removal using “abrasive” methods
  - Porous, “sponge-like” material impregnated with abrasive particles
    - Inconsistent and un-even material removal.
    - Structural properties of open-cell foam can cause significant tip sharpening.
  - Polymeric material, with spatially distributed abrasive particles
    - Polymer matrix provides uniform pressure distribution along tip length
    - Predictable material removal rates to attain semi-radius and fully radiused probe tips.

Developing a Rounded Tip Shape (cont.)

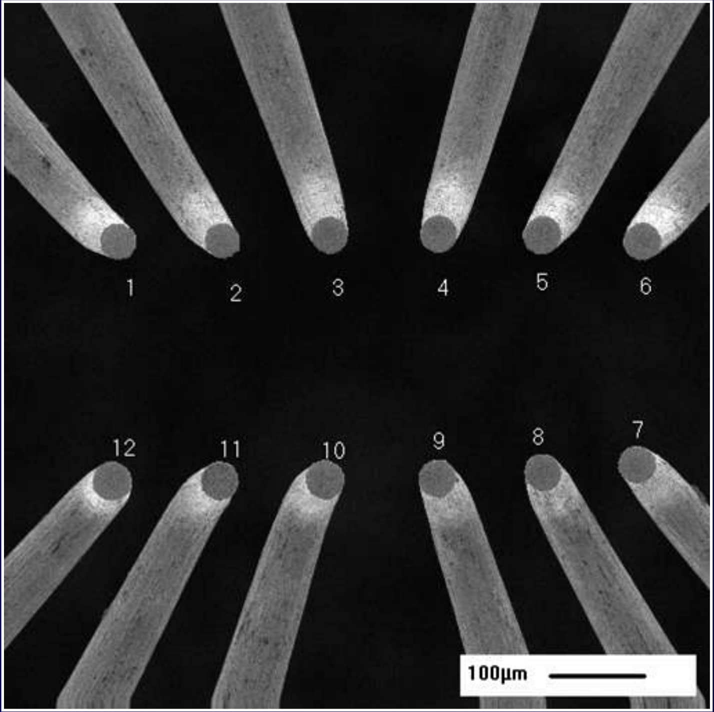


Highly cross-linked polymeric material (Probe Form™)

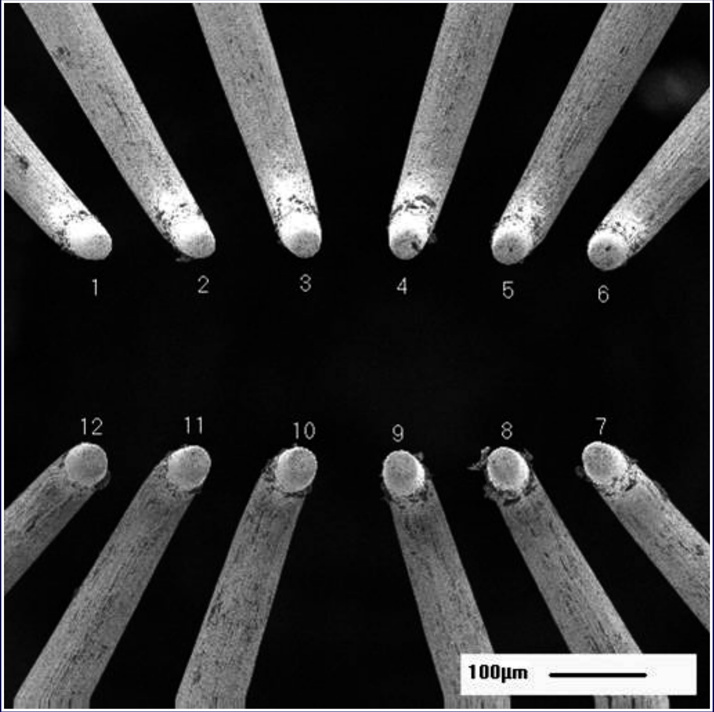
Spatially Distributed Abrasive Particles



Developing a Rounded Tip Shape (cont.)



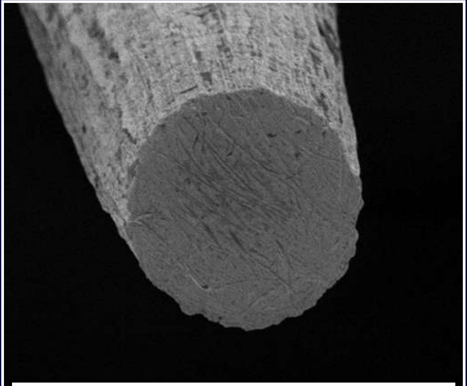
Tungsten-Rhenium (WRe)
Flat Tip Probes (As Built)

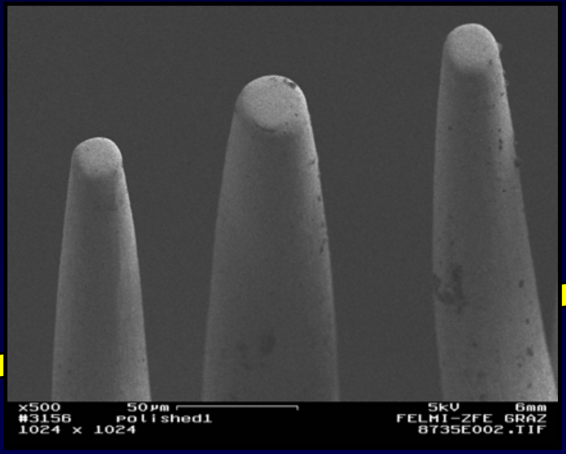


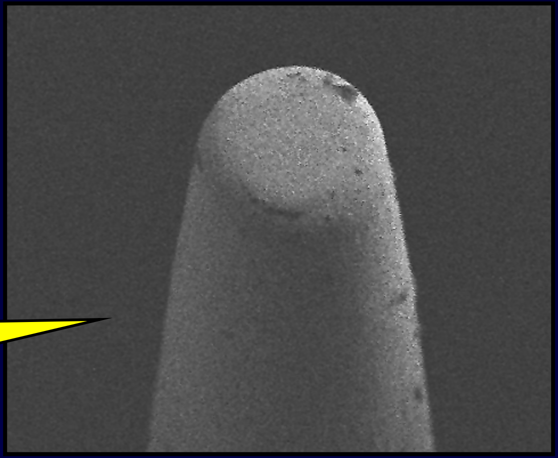
Reshaped to Semi-Radius Tip
with Probe Form™

Developing a Rounded Tip Shape (cont.)

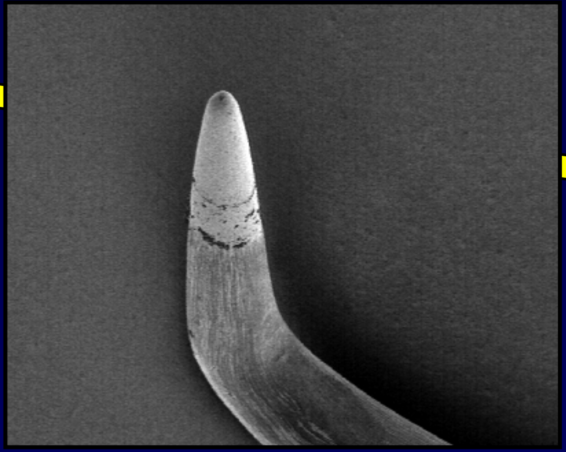
Semi-Radius Tips

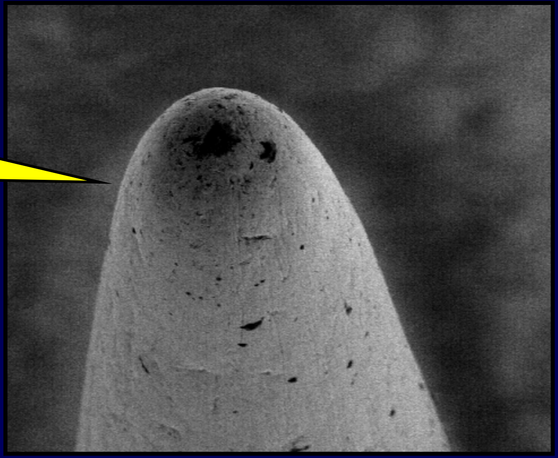






Flat Tip Probes

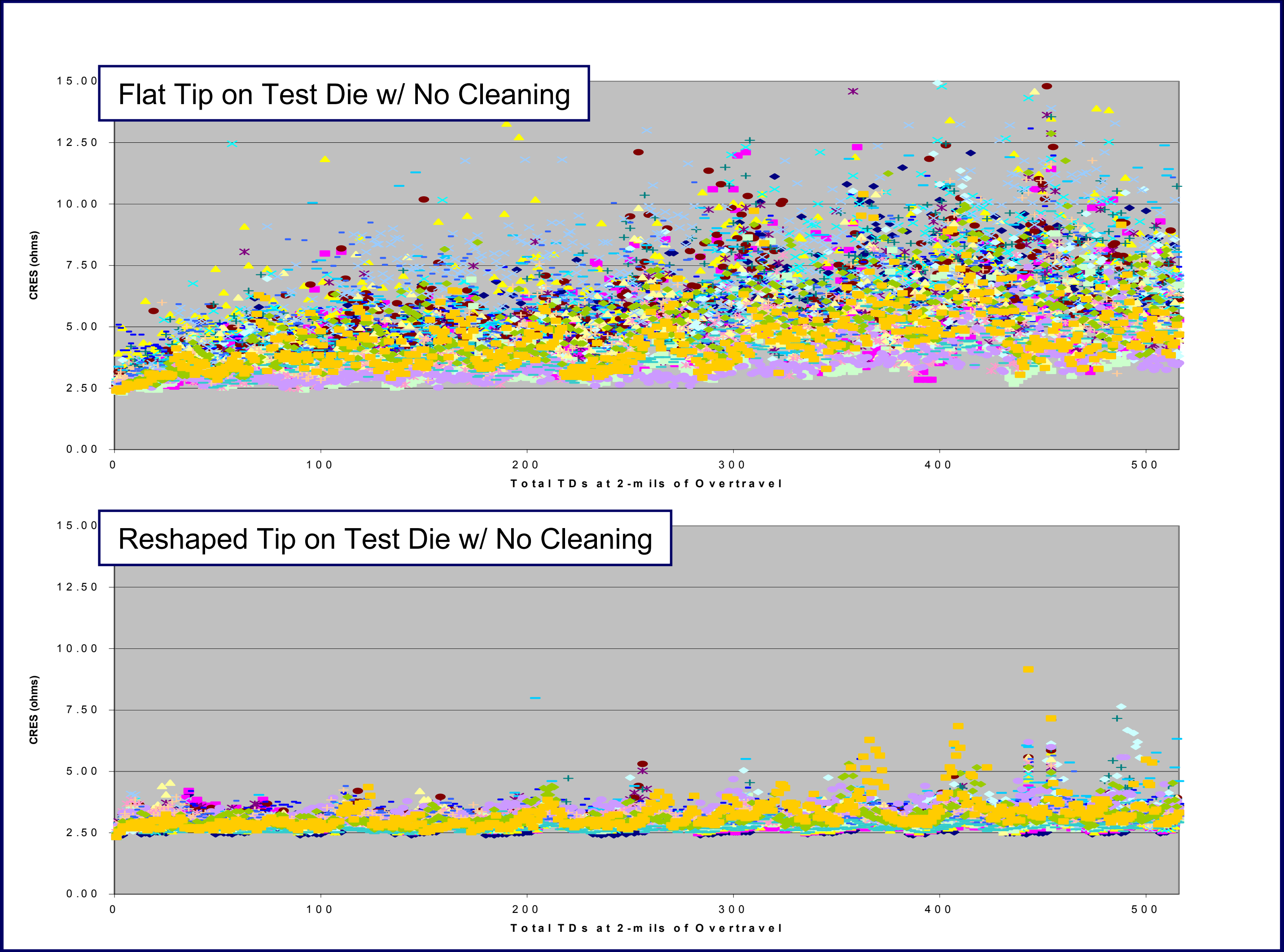




Full Radius Tips

Radius tip images courtesy of AMI Semiconductor

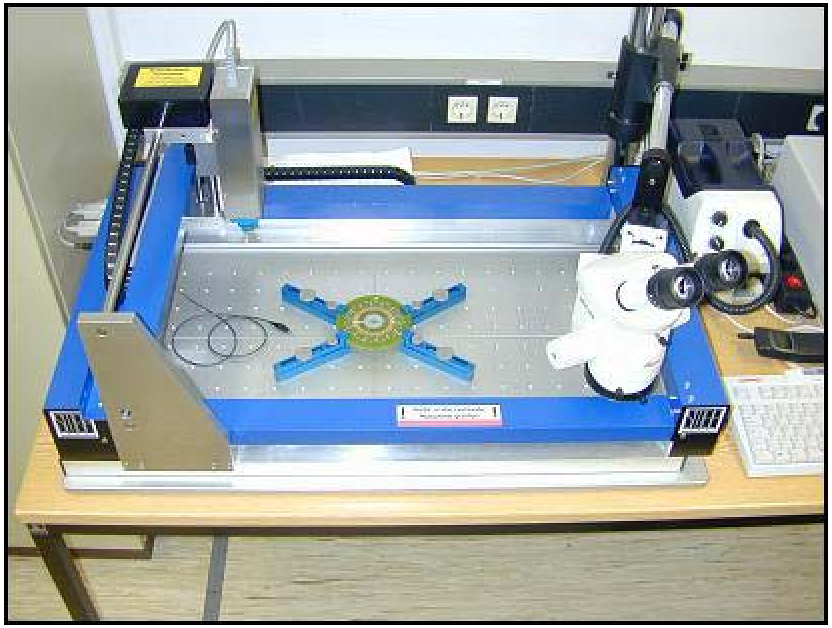
Rounded Tip Shape – CRES Stability



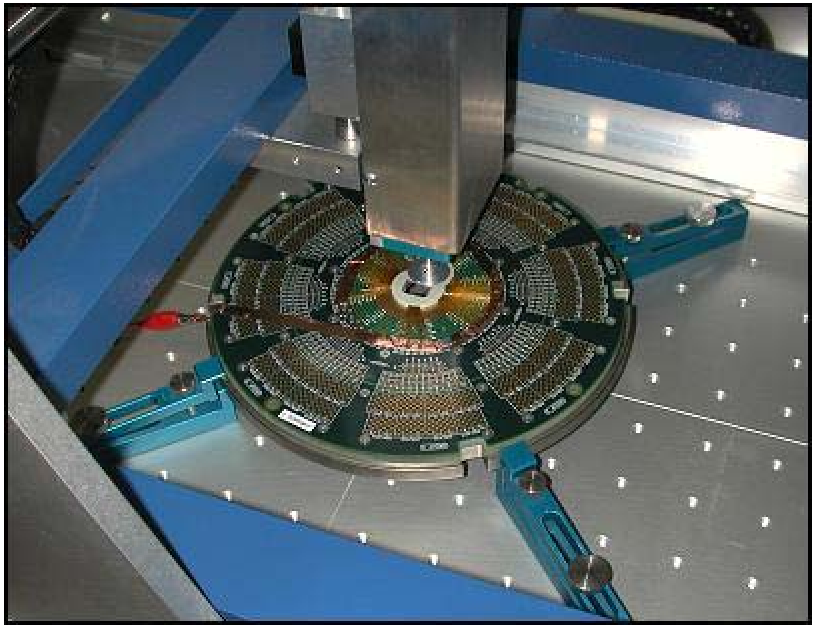
Tip Shape Forming and "Refreshing"

- TPR02 – "Probe Refresher"
  - Computer controlled 3-axis stage with probe height sensor
  - Mobile microscope for probe tip inspection
  - Universal clamps accommodate probe-card types

System Overview

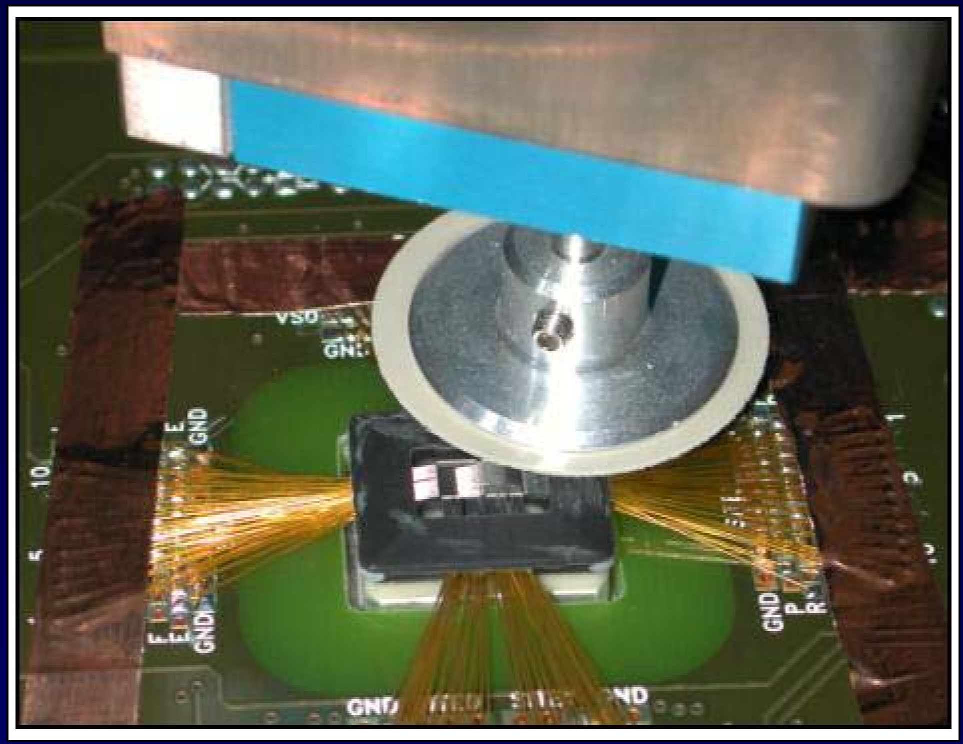


Fine Pitch Probe Card

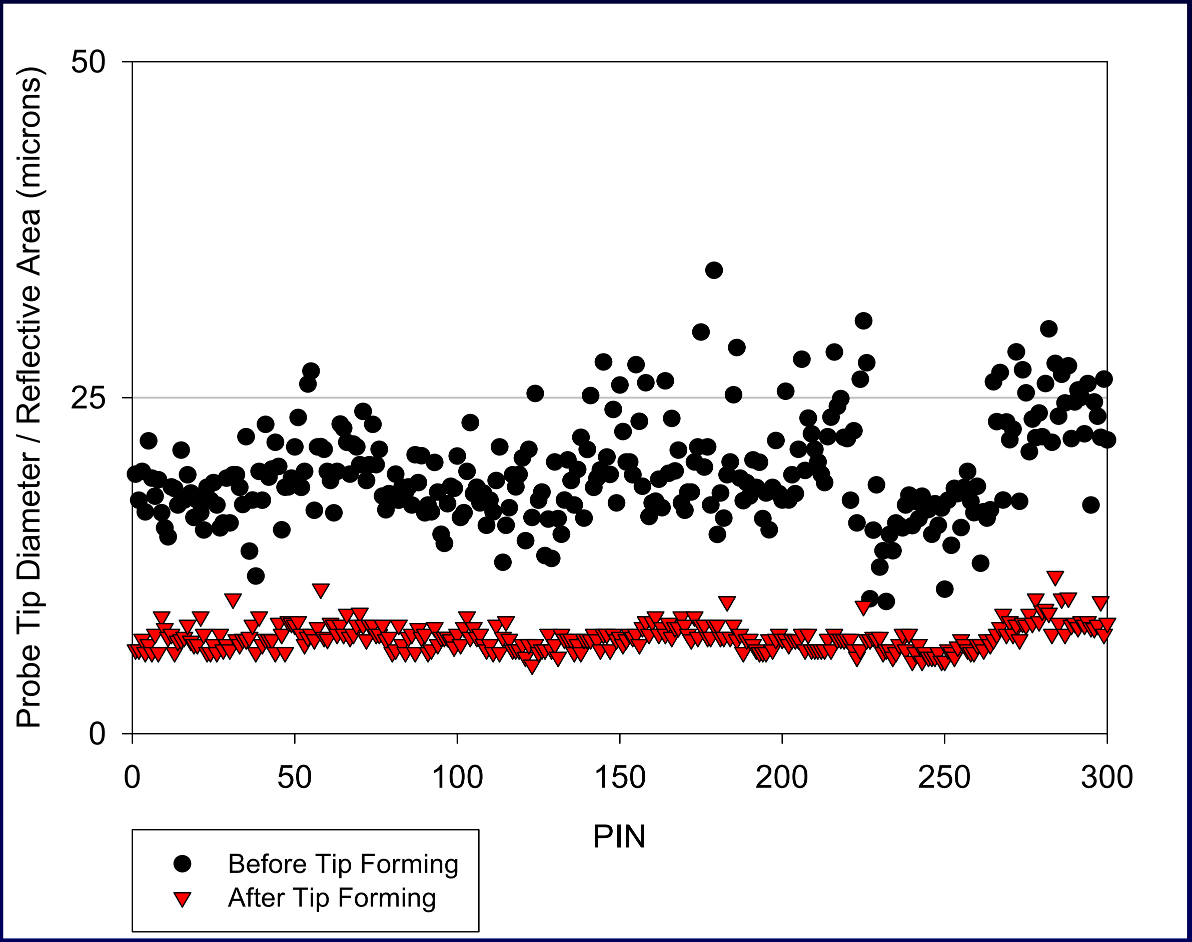


Principle of Operation

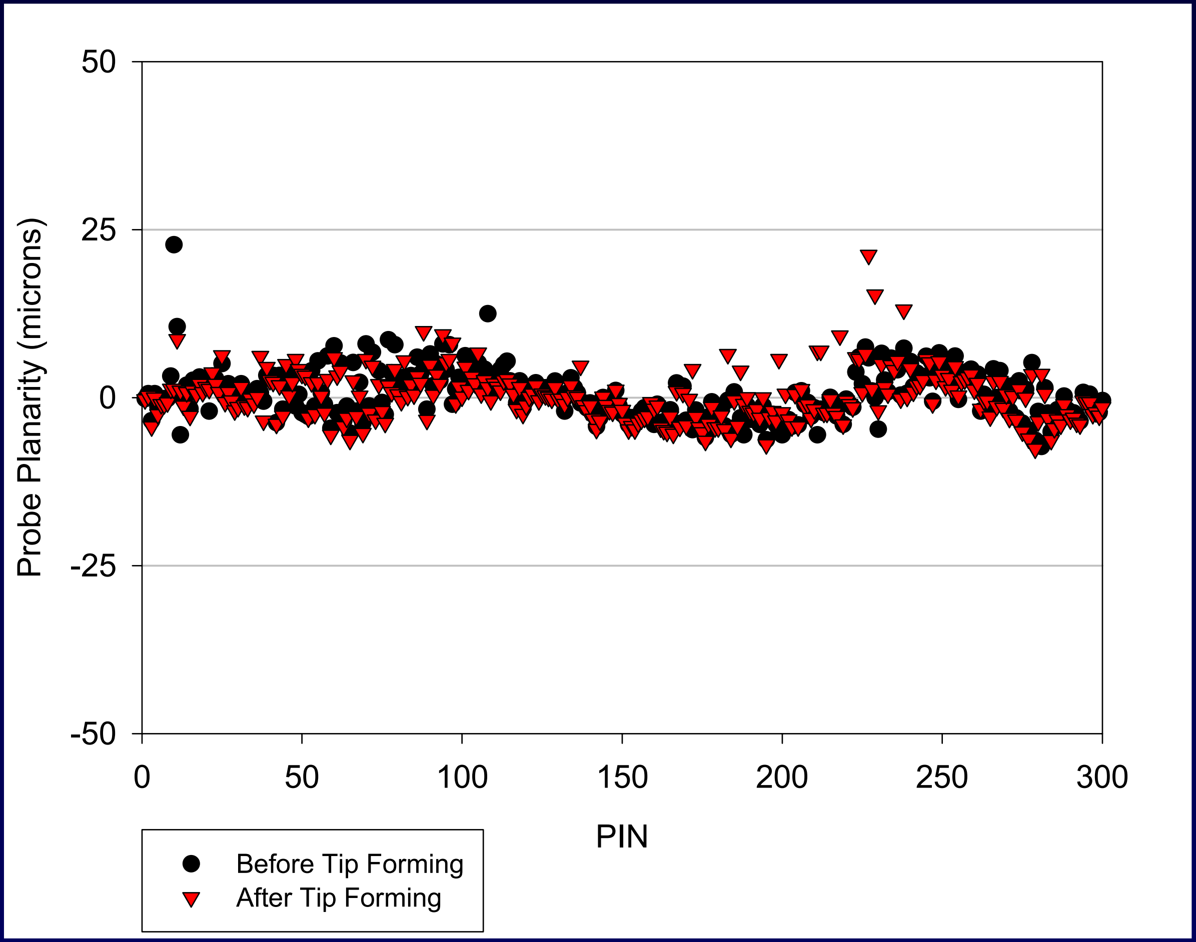
- Grinding head equipped with Probe Form™
  - Probe tips repeatedly inserted into the elastomeric material.
  - Embedded aluminium and adherent debris from wafer is removed.
  - Probe tips are quickly shaped (or reshaped) and polished.



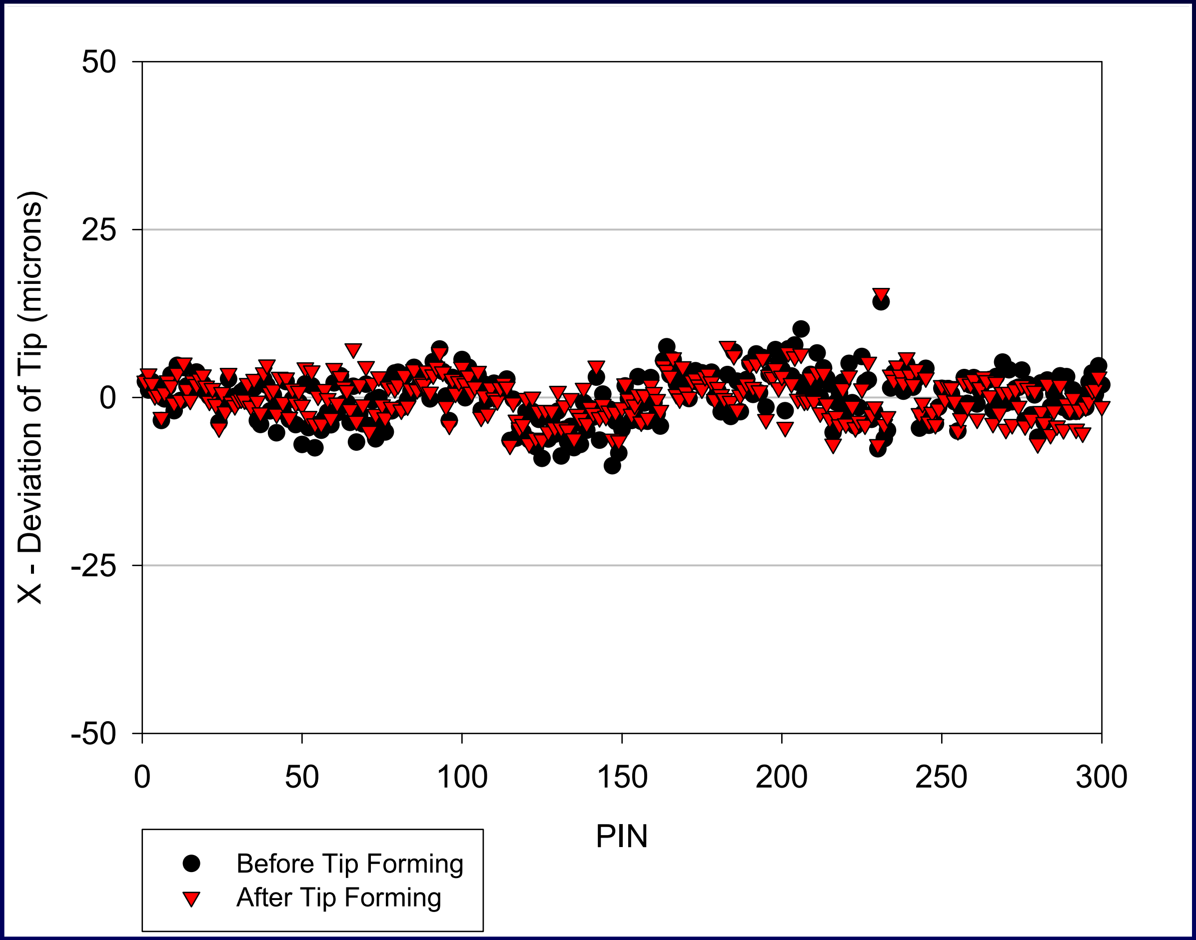
Tip Diameter (Reflective Area) “Reduction”



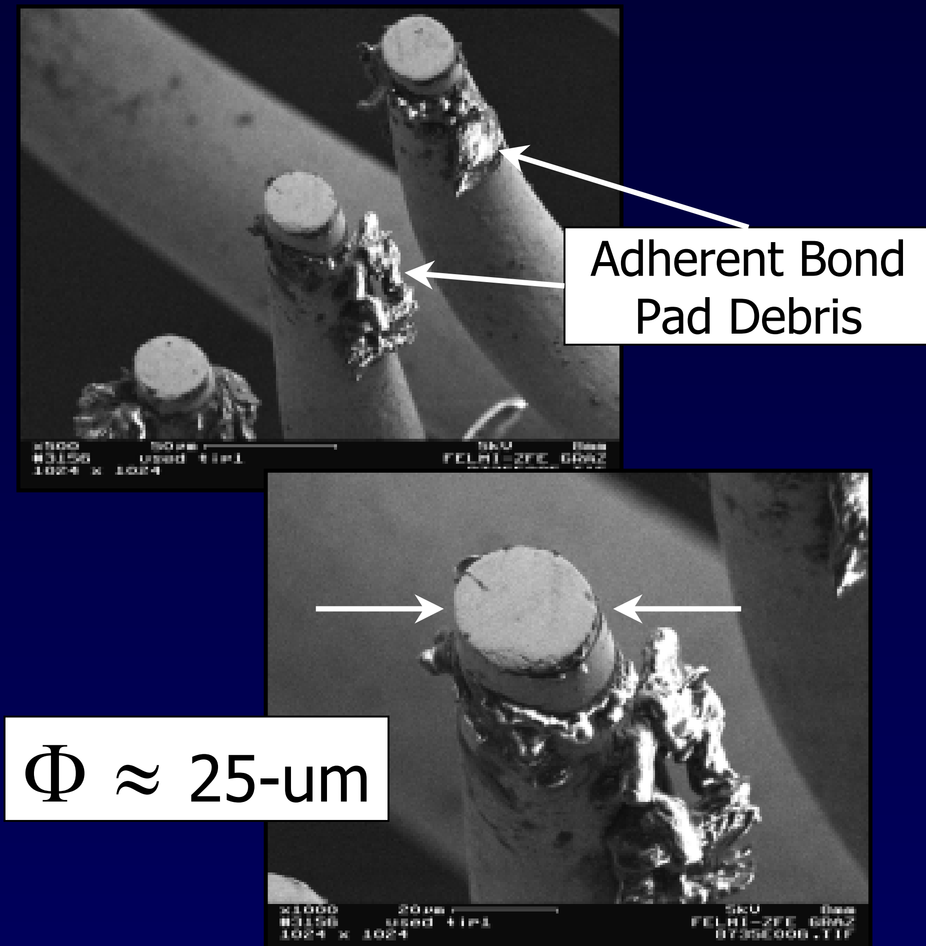
(no) Effect on Planarity

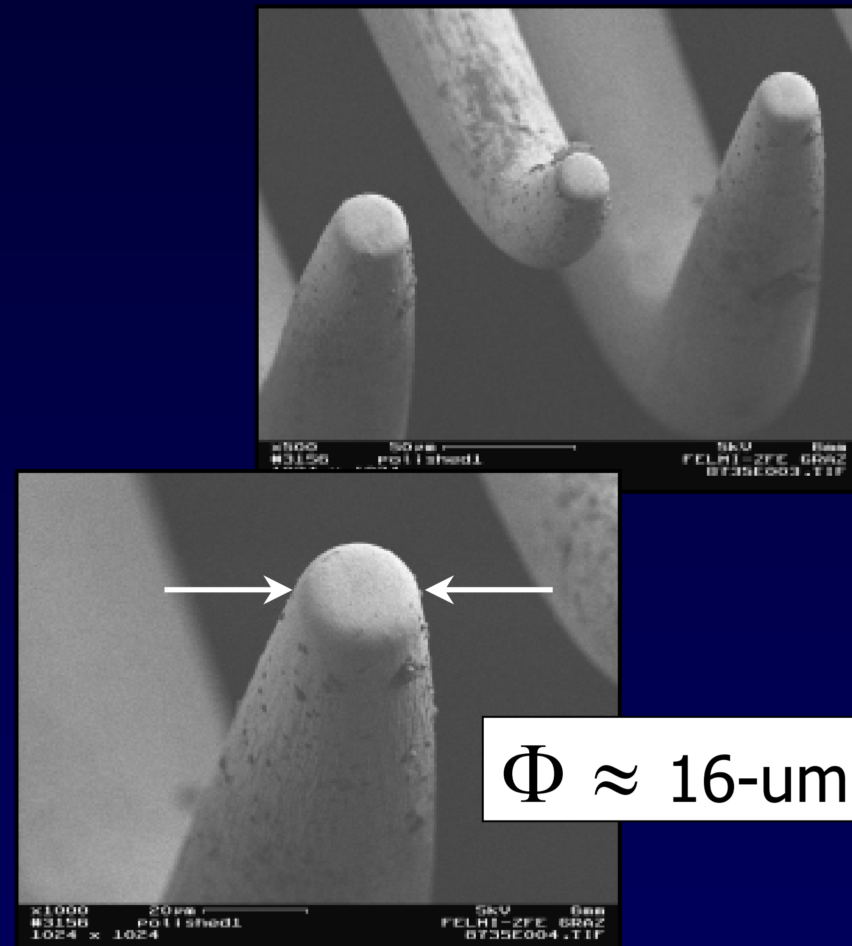


(no) Effect on Probe Alignment

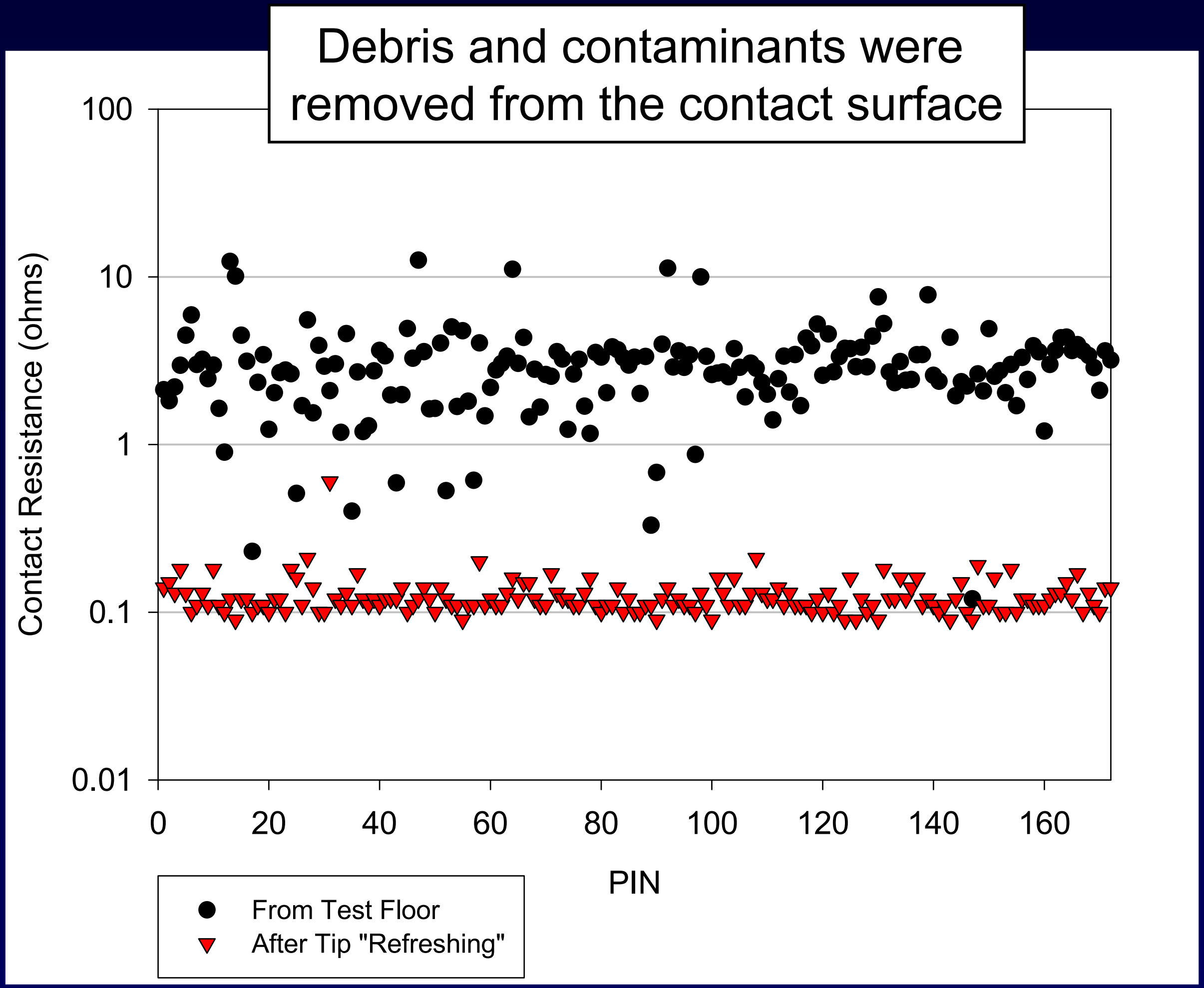


"Refreshing" Fine Pitch Probe Tips

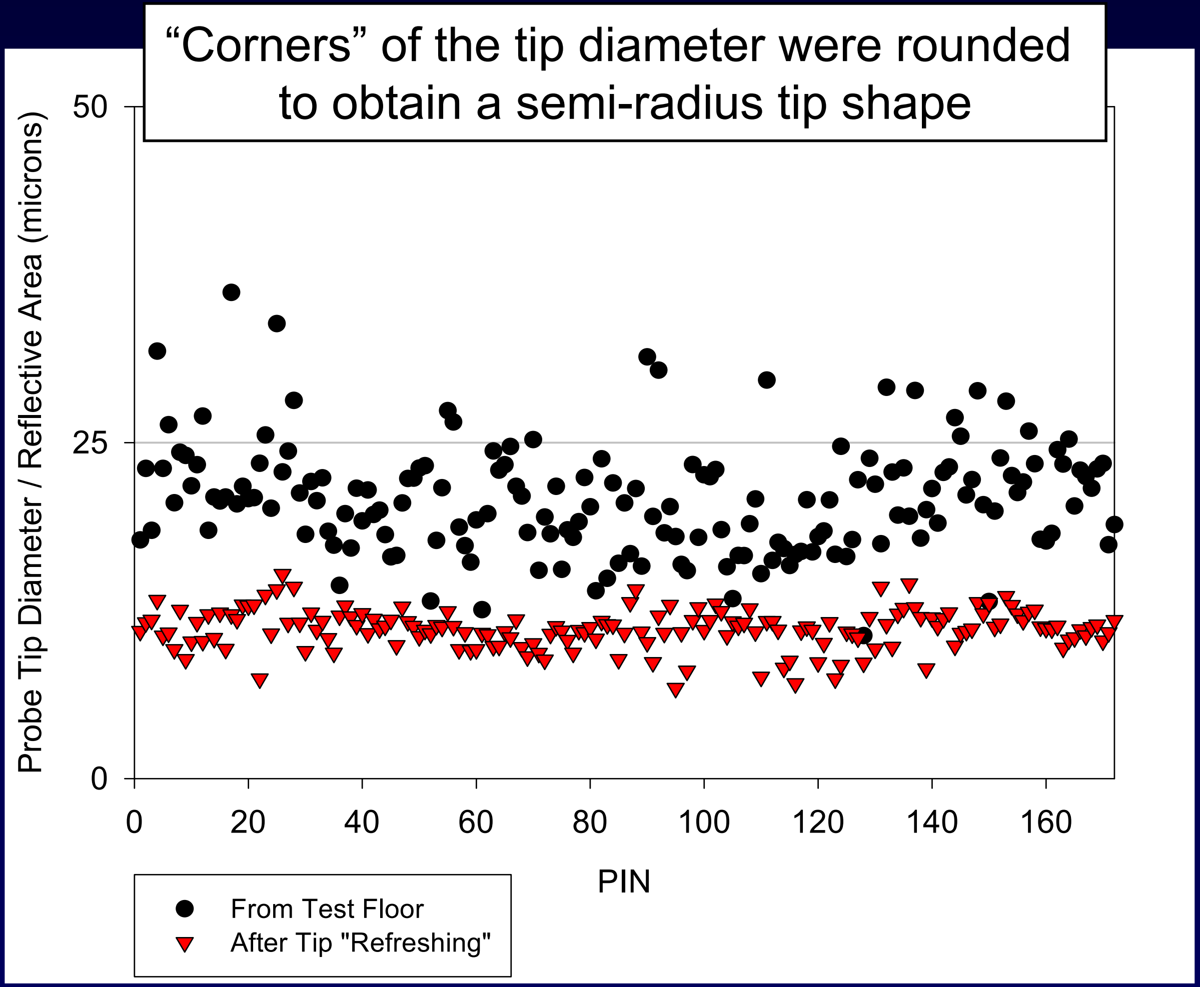




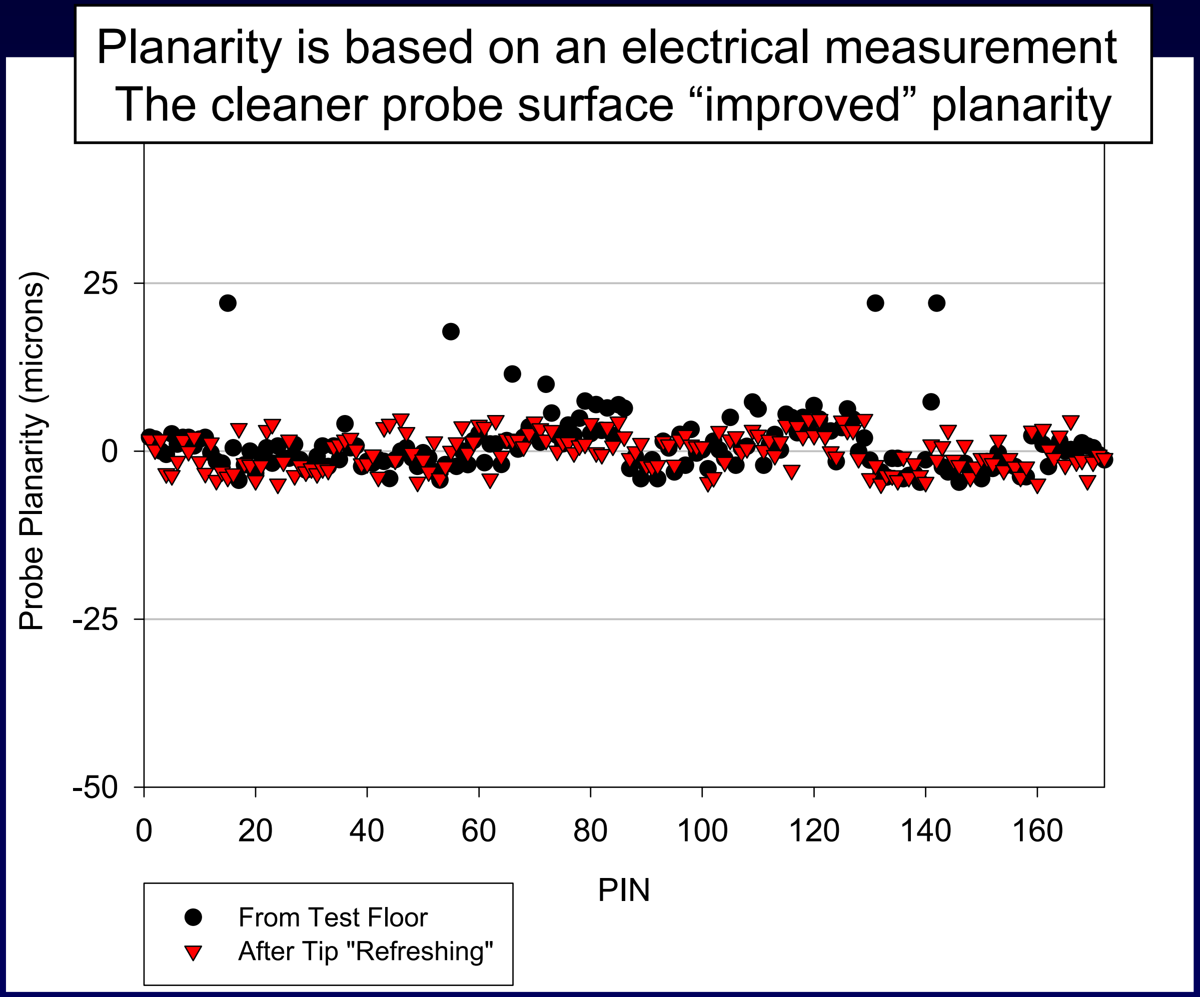
Effect on Contact Resistance



Tip Diameter (Reflective Area) "Reduction"

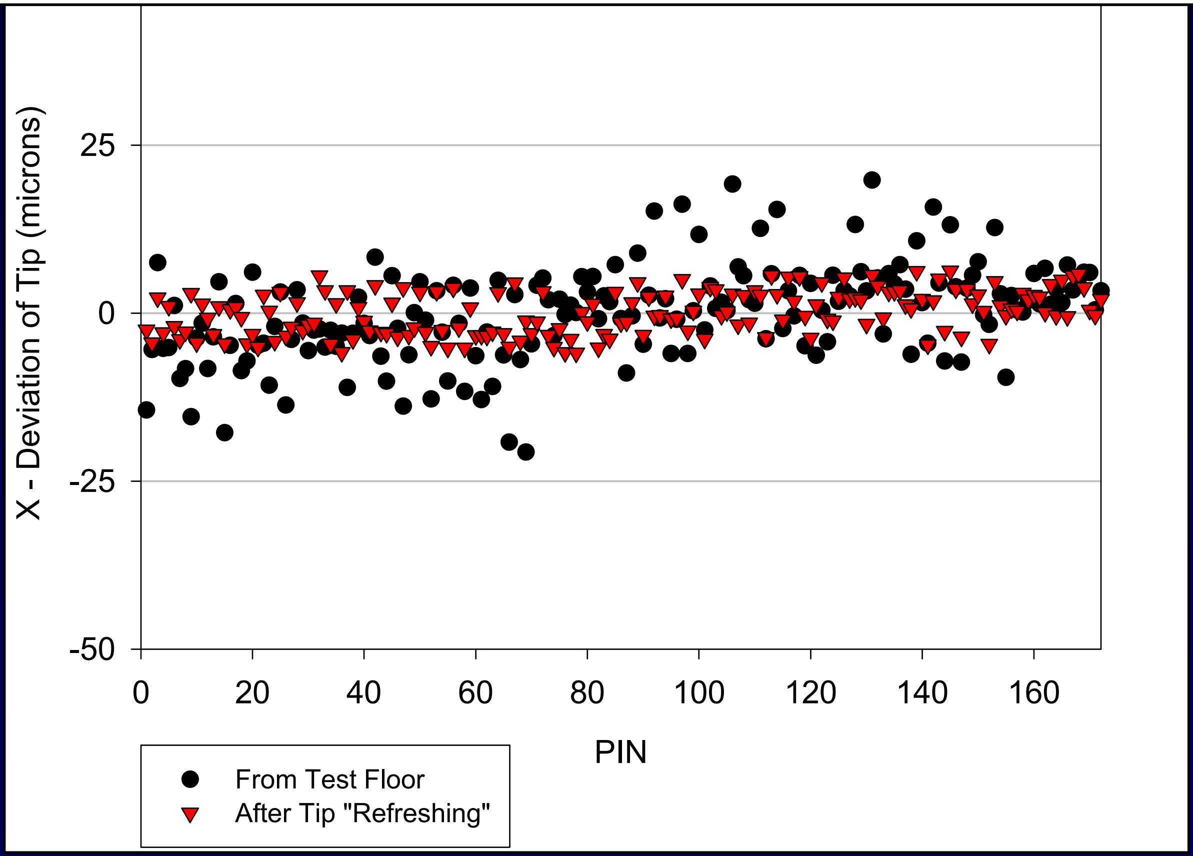


(some) Effect on Planarity



(some) Effect on Alignment

Alignment is based on optical measurements
Removal of adherent pad materials “improved” alignment

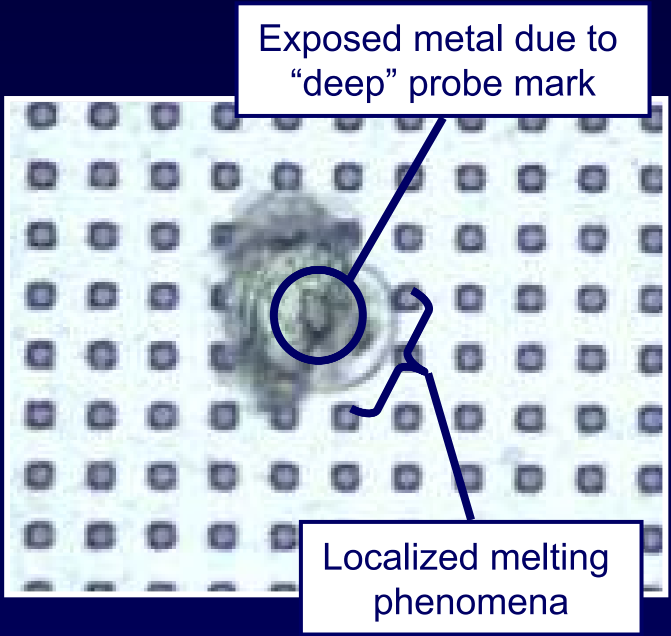


Design Considerations / Limitations

- Bearing stresses (force / unit area) exerted by shaped probes are substantially greater than those of flat tip probes.
  - Estimate as much as 35X greater applied bearing stress.
  - Probe force can be reduced without affecting performance
- Shaped probes could “dig too deep” into the bond pad.
  - Shear forces and stress distribution imparted to the bond pad during the “scrubbing action” may cause damage to the underlying structures.
  - Barrier metal or bare silicon could be exposed; thereby, resulting in assembly and reliability issues.
- Structural characteristics and load bearing capacity of the IC device must be considered.
  - Pads over active area (POAA), e.g., power semiconductor testing.
  - Low-k dielectric layers are more fragile and could be damaged.
  - High current applications can have higher contact temperatures due to localized Joule heating phenomena

End-User Customer Application

- High current automotive wafer test
  - Flat-tipped probe geometry
    - Contact quality degraded quickly requiring frequent cleaning and maintenance
  - Radius-tipped probe geometry
    - High current densities and localized Joule heating observed
    - Damage to underlying structures
  - Semi-radius tipped probe geometry
    - Consistent electrical contact
    - Maintained off-line with the TPR02
    - Non-destructive on-line cleaning to collect debris and adherent material



Summary

- A systematic approach was utilized to further understand cantilevered probe tip contact mechanisms and electrical performance characteristics.
- Improvements in probe card performance and service life were realized through off-line probe tip shape forming and "refreshing" practices.
- Design considerations for probe bearing stress, resultant probe mark depth, and user application are needed to avoid damage to the underlying structures.
- Appropriate on-line cleaning solutions are required to properly maintain a tip shape for optimal electrical performance.

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- End-user customers that must remain anonymous

Thank you for your attention

Questions ???