

Extending 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 (and vertical) probe performance through probe tip shape.
- Characterize a methodology for extending probe card life.
- Demonstrate improvements in probe card performance as well as probe card service life.

Approach

- ...what it's all about: Contact Resistance
 - empirical model proposed by Babu, et. al (2001):

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

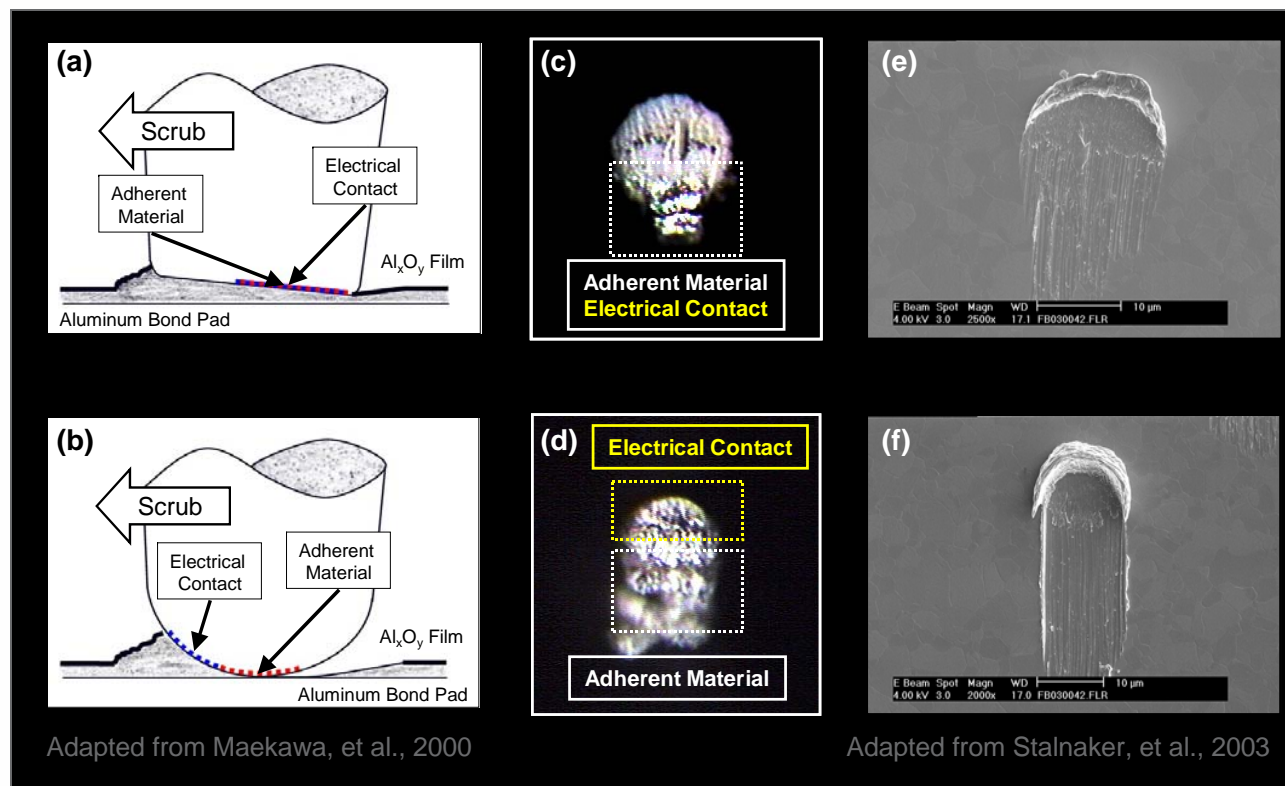
- ρ_{pad} , ρ_{probe} , ρ_{film} = resistivity values
 - σ_{YS} = material yield strength
 - P = contact pressure
 - a = average radius of contacting asperities, or *a-Spot* size
 - η = number density of *a-Spots* that are in real contact
- Contact pressure (P) is the applied force normalized by true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

Approach (cont.)

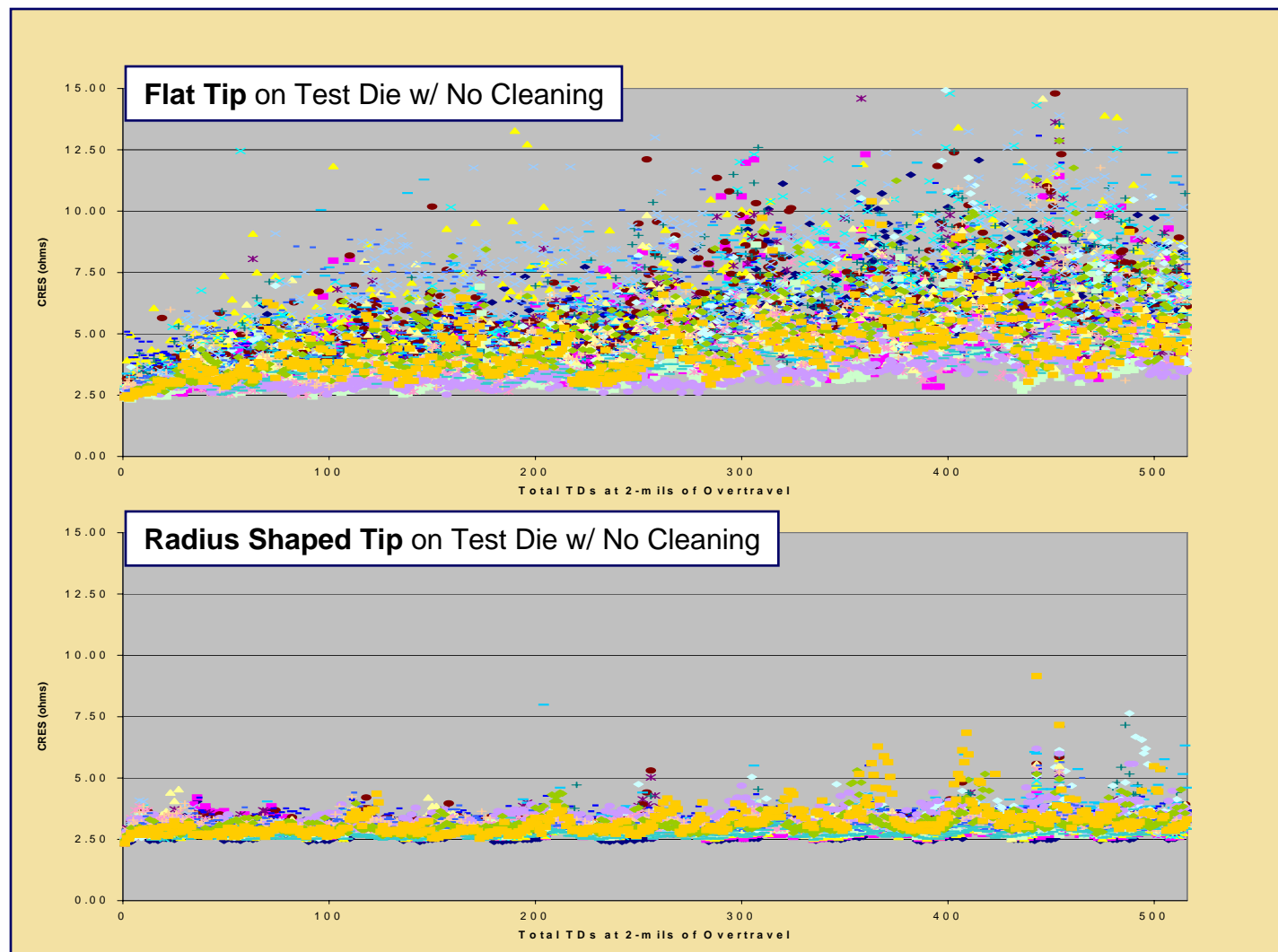
- Critical factors with applicability to wafer probes.
 - Presence of contamination, e.g. oxides, residues, etc.
 - Probe tip shape plays an important role in displacing the contaminants from the true contact area
 - On-line cleaning methods can be used to “control” adherent contaminants and remove debris
 - 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.



Tip Shape – CRES Stability



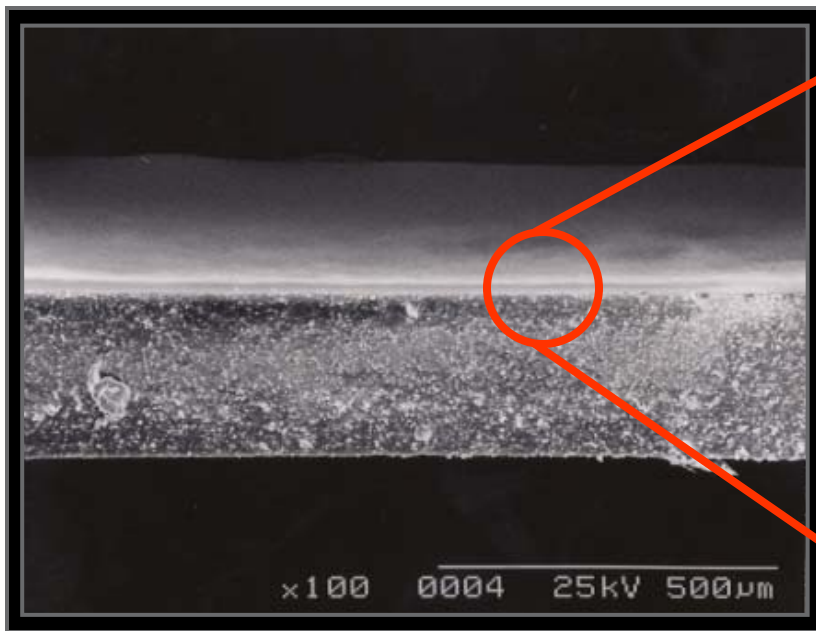
Probe Tip Shape Factors

- 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

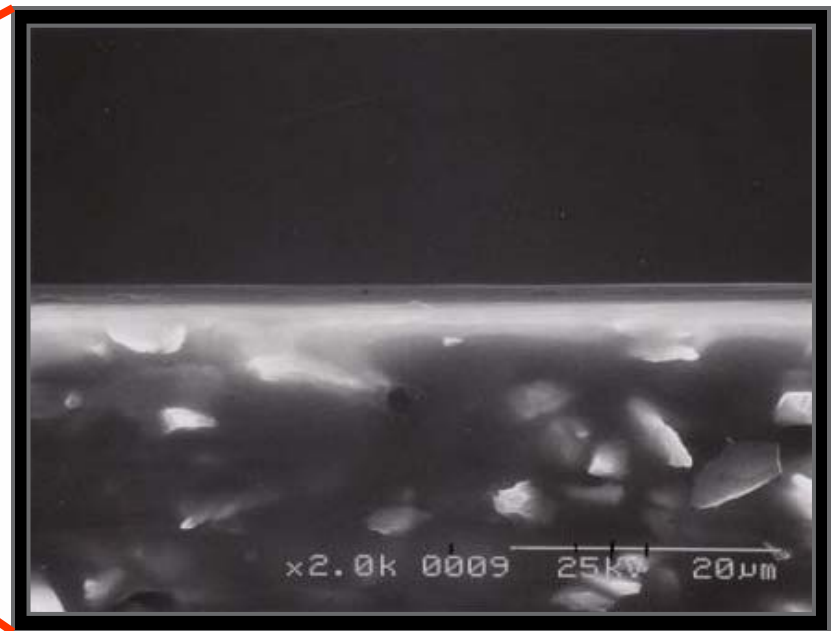
How to Make a Rounded Tip Shape ...?

- Electrochemical machining and polishing
 - **“Gang Process”** – the probe card is built with shaped tip probes
 - Probes must be “tweaked” into specification without lapping operations.
 - **“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.
- Material removal using “abrasive” methods
 - **“Sponge-like” material** impregnated with abrasive particles
 - Inconsistent and un-even material removal.
 - **Spatially distributed abrasive particles embedded into Polymer**
 - Polymer matrix provides uniform pressure distribution along tip length
 - Predictable material removal rates to attain semi-radius and fully radiused probe tips.

... how to make a Rounded Tip Shape ?...

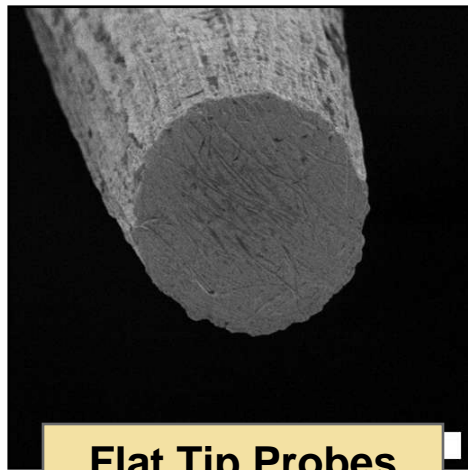


Highly cross-linked polymeric material
(Probe Form™)

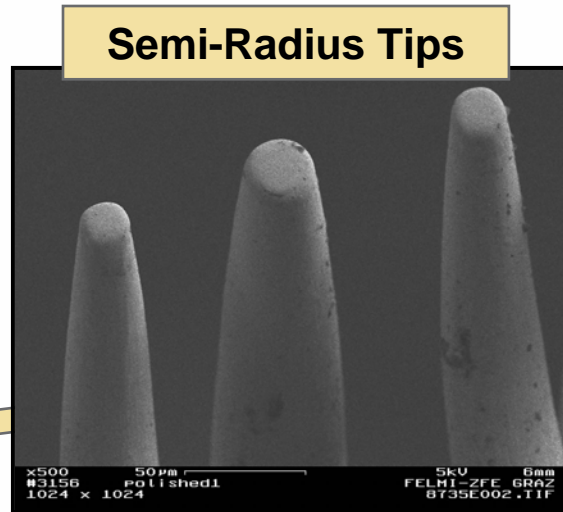


Spatially distributed abrasive particles

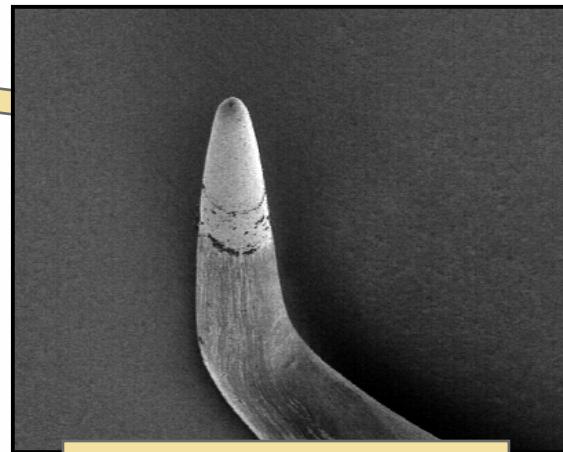
... how to make a Rounded Tip Shape ...



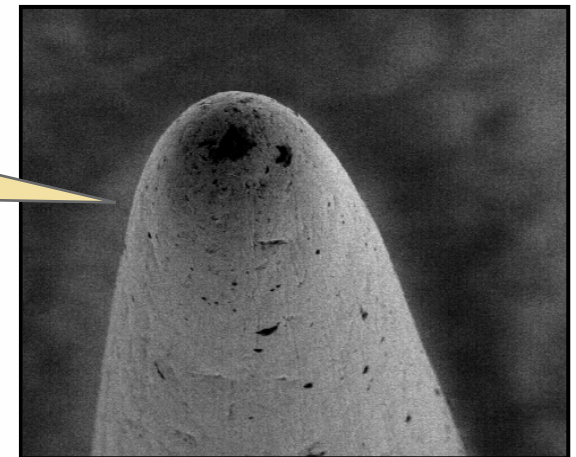
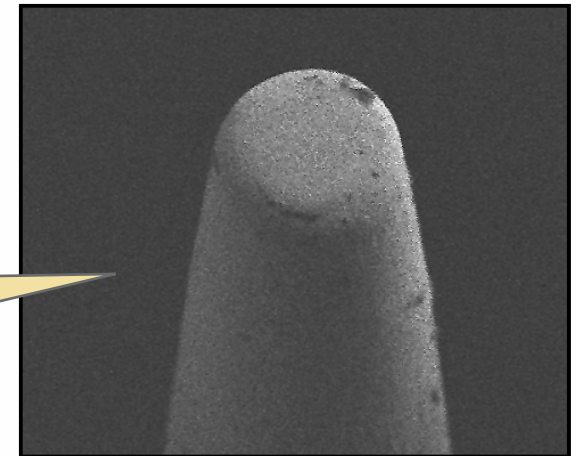
Flat Tip Probes



Semi-Radius Tips



Full Radius Tips



Radius tip images courtesy of AMI Semiconductor



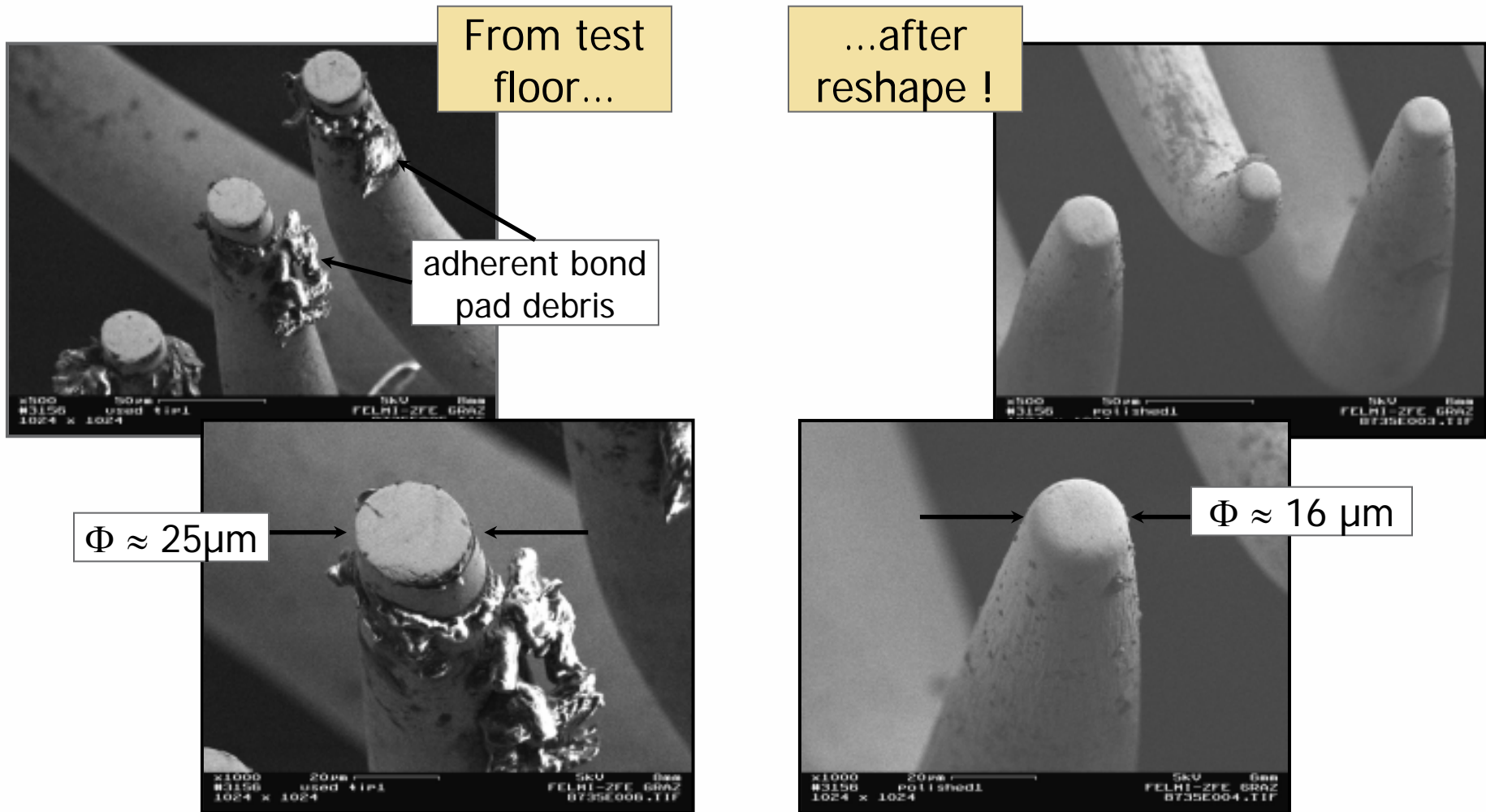
... how to make a Rounded Tip Shape !

Reshaping a Flat Tip Probe

How to Maintain a Round Tip Shape ?

- **Online Cleaning on Prober** with non-destructive cleaning pads
 - advantage: "On-Line" process, no docking process with probe card
 - disadvantage: sometimes not efficient enough to remove hard sticking contamination e.g. in power probing– "agressive" needle polish on prober required, prober is too slow for efficient "reshaping"
- Use of dedicated **Probe Card "Refreshing" equipment**
 - advantages: fast process, more aggressive needle polish on prober can be used, tip shape is maintained by performing off-line preventive maintenance of probe card
 - disadvantage: "off-line" process (so far)

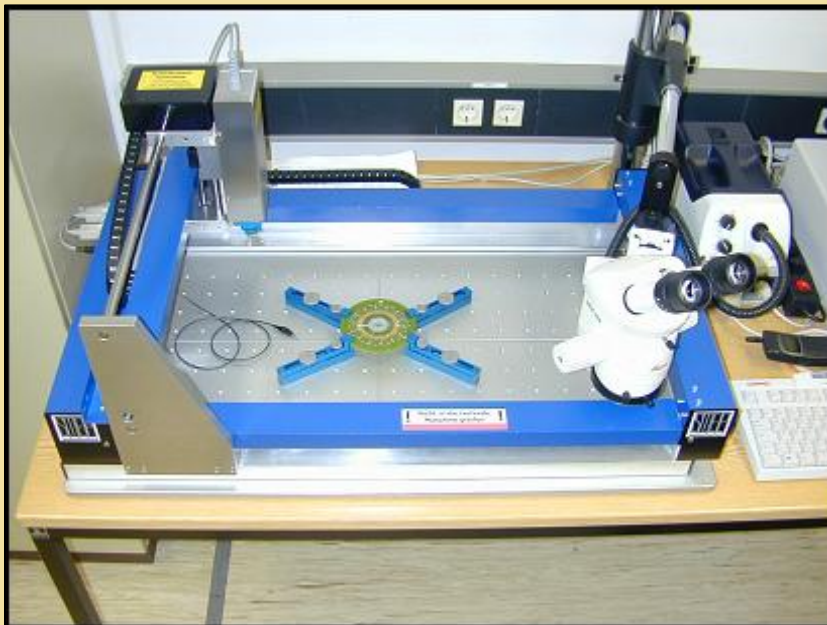
“Refreshing” Fine Pitch Probe Tips



Probe Tip Shaping and “Refreshing” ...Off-line Equipment

- 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

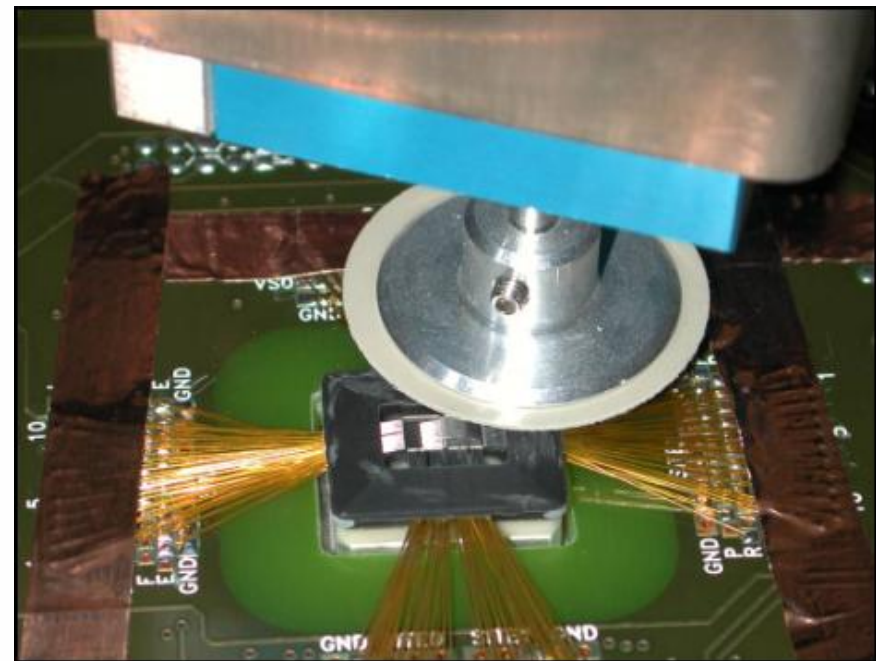


Fine Pitch Probe Card during Machining

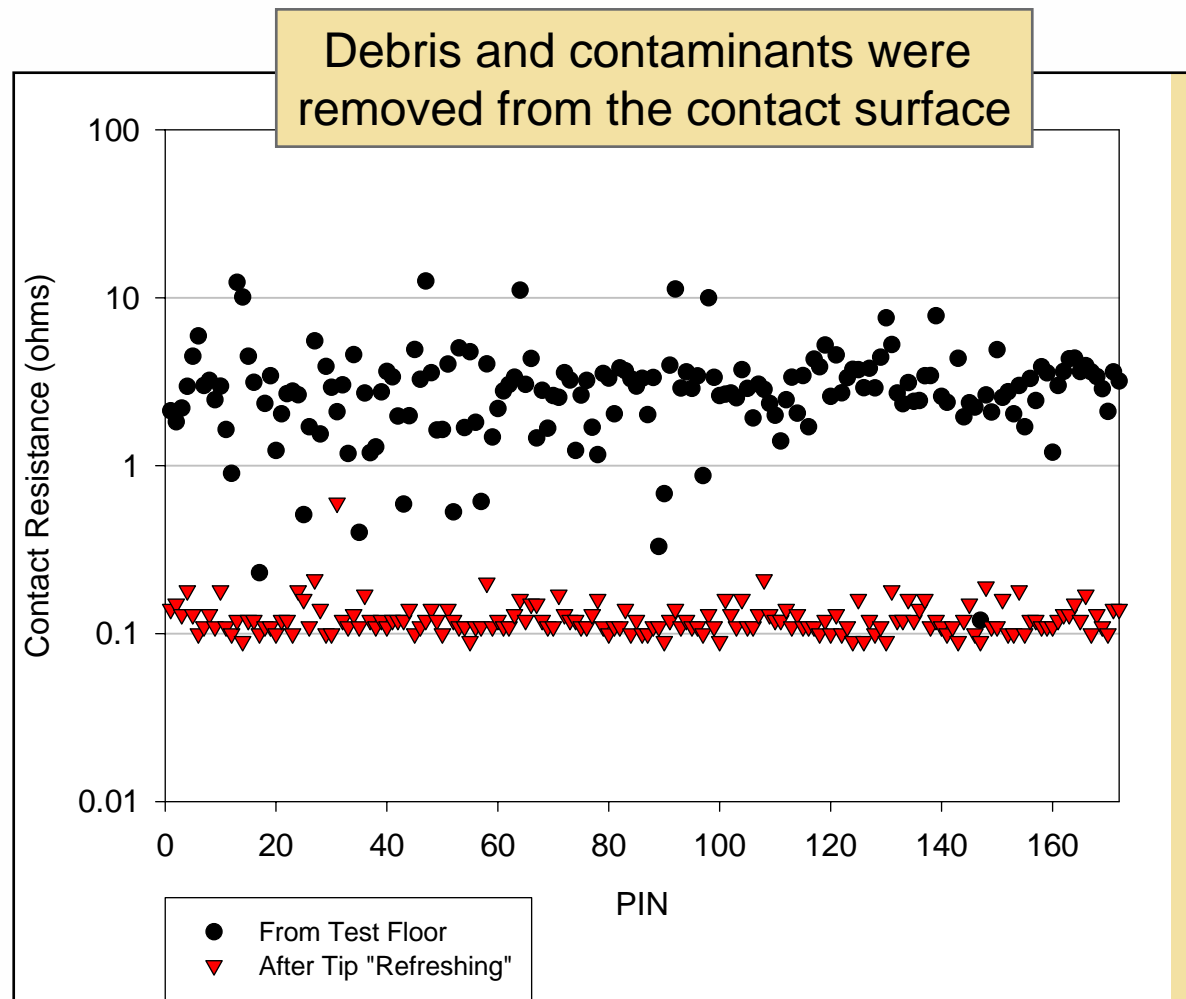


Principle of Operation

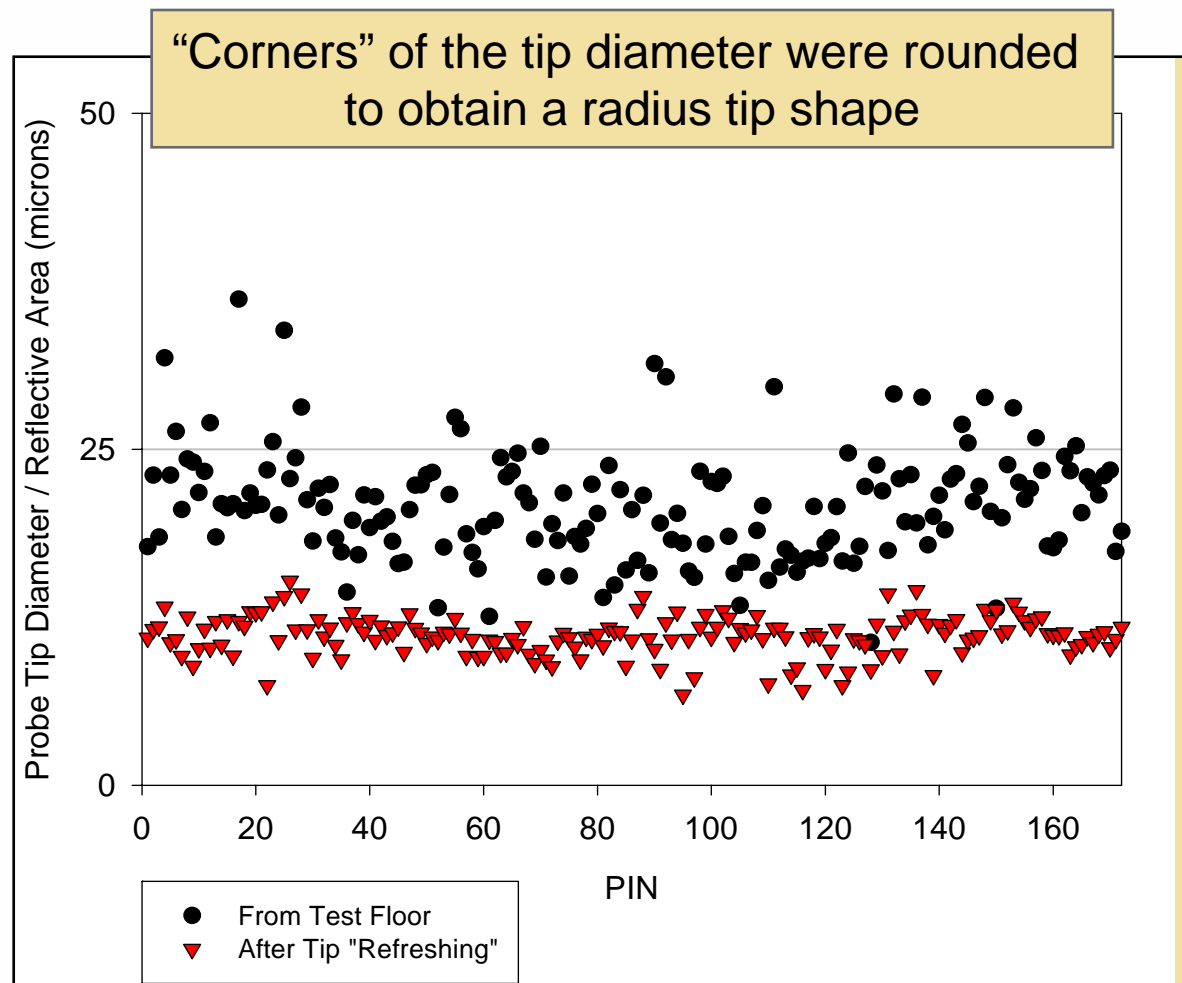
- Grinding head equipped with ITS Polish Pad
 - Probe tips repeatedly inserted into the abrasive polymer material.
 - Embedded aluminium and adherent debris from wafer is removed.
 - Probe tips are quickly shaped (or reshaped) and polished.



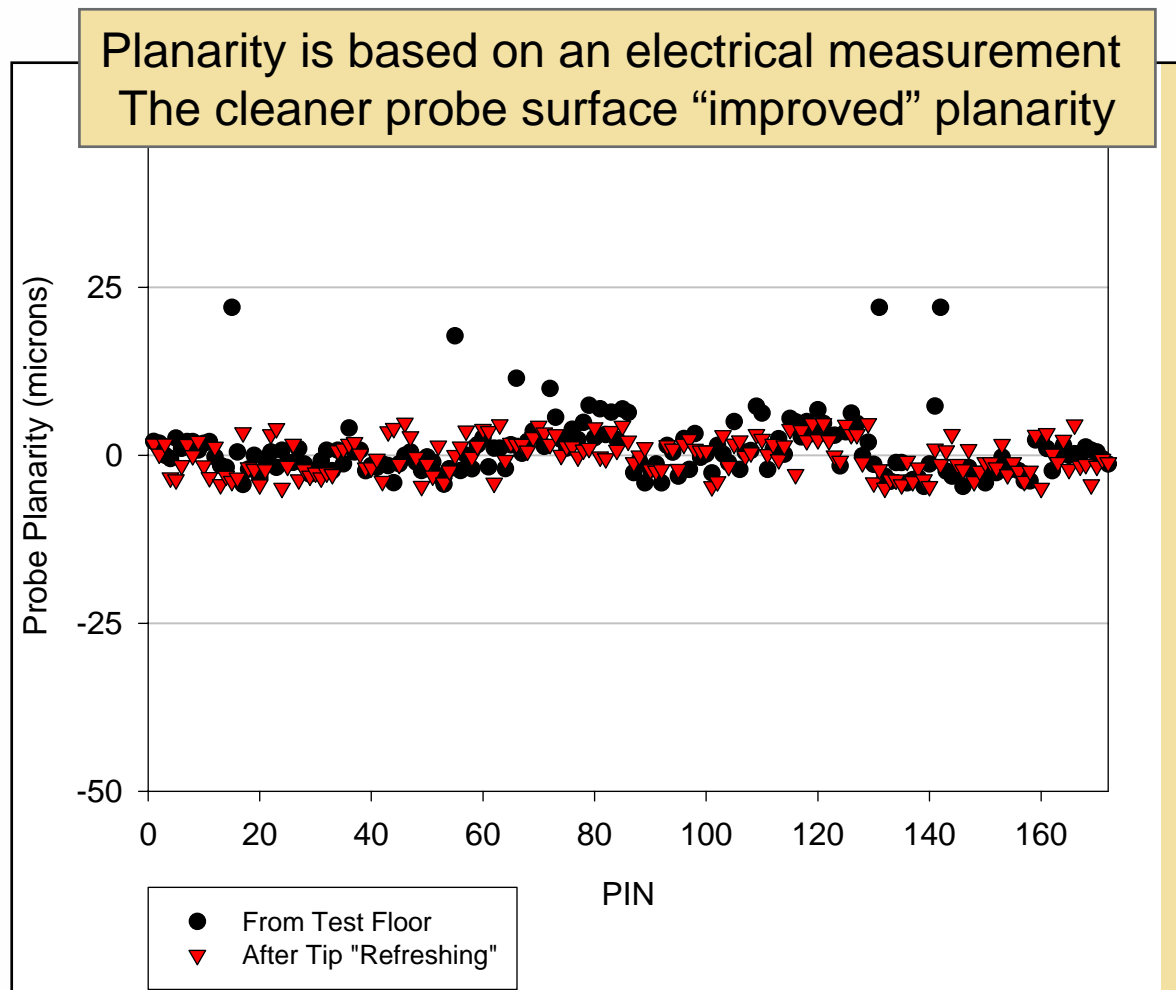
Effect on Contact Resistance



Tip Diameter Reduction

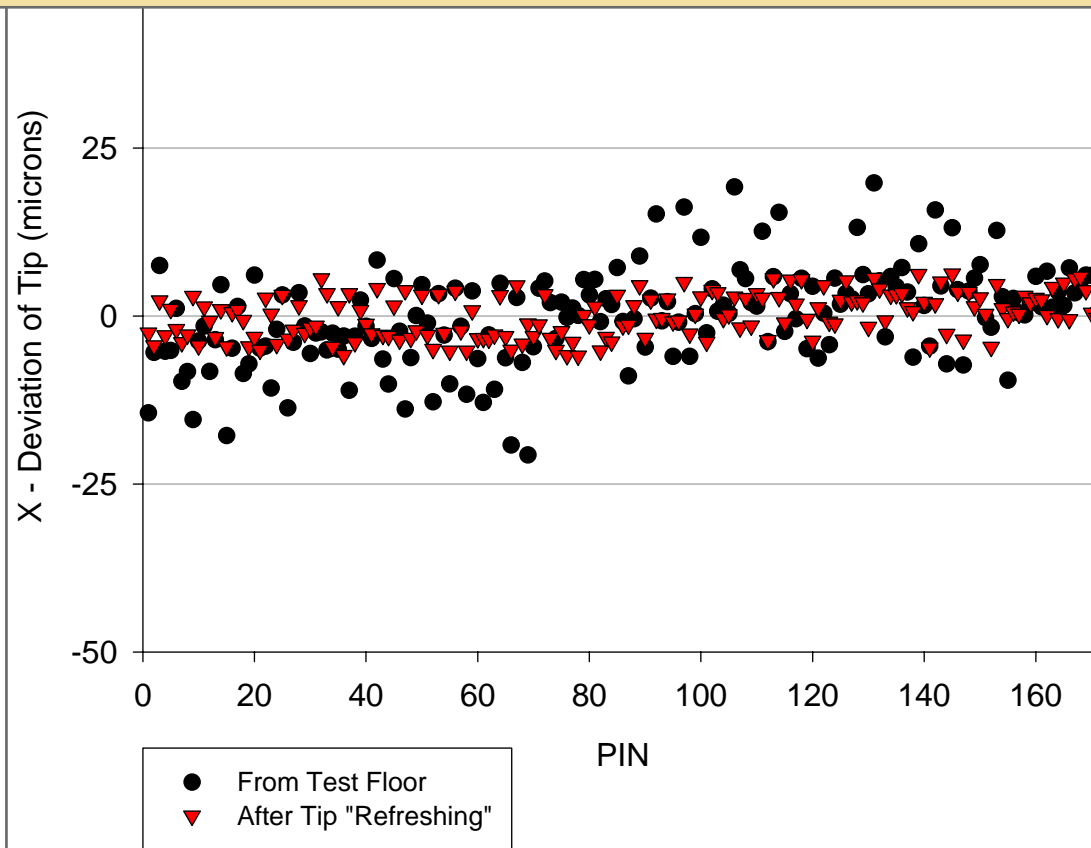


(some) Effect on Planarity

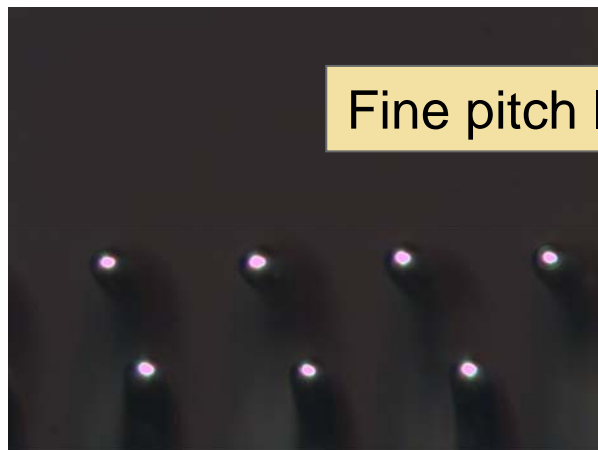


(some) Effect on Alignment

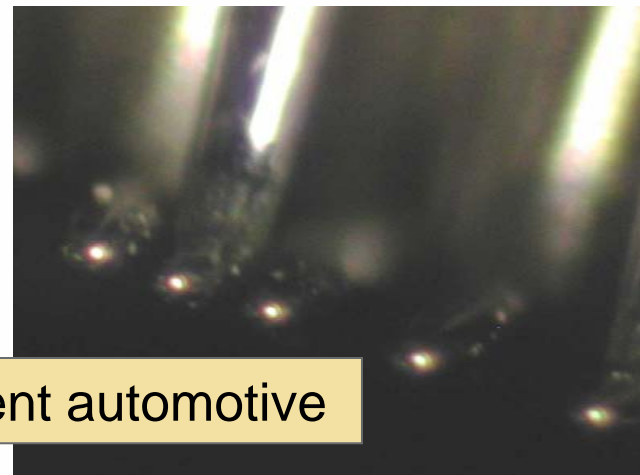
Alignment is based on optical measurements
Removal of adherent pad materials "improved" alignment



Tip Reshaping - Applications



Fine pitch logic

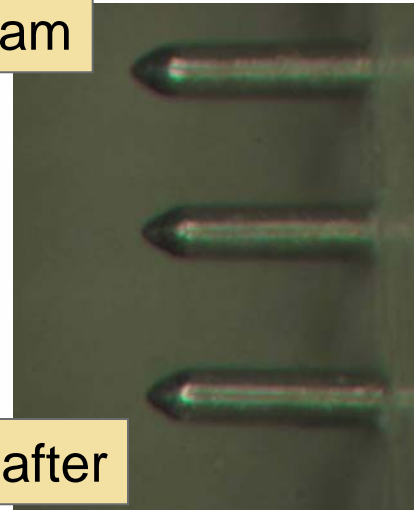


High current automotive



Vertical Cobra & Buckling Beam

before

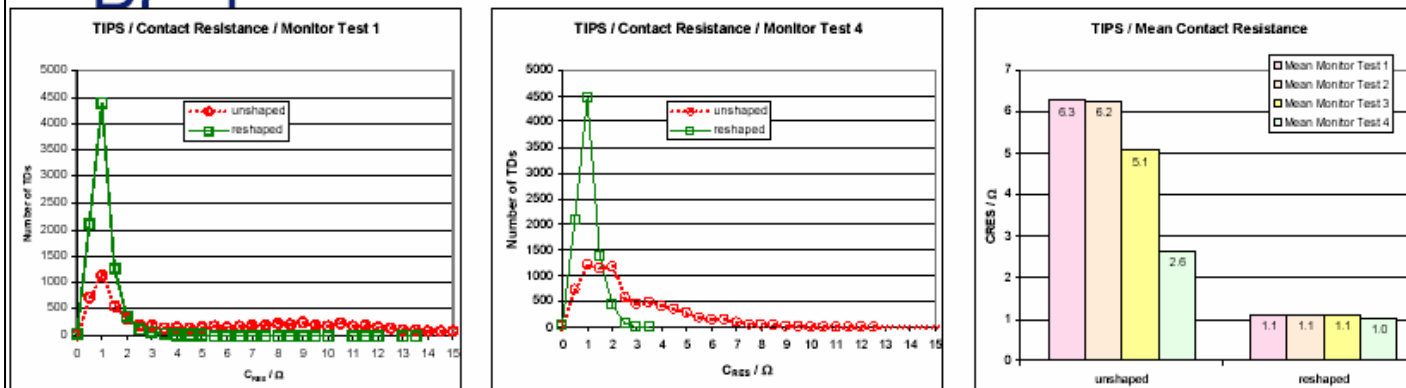


after

...some "real" test floor data – 32 site vertical buckling beam probe card

PHILIPS

TIPS efficiency – C_{RES} measurement – DC 1



- TIPS reduced C_{RES} from av. 6Ω to 1Ω .
- TIPS reduced the fritting ratio Φ to almost 0% → only stable contacts.
- Yield gain 3.5% (4020, 88% → 91.5%)

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.
- Appropriate on- and offline cleaning solutions are required to properly maintain a tip shape for optimal electrical performance and can lead ultimately to better test yields and longer probe card life.

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