Electrohydrodynamic (EHD) Cleaning for C_{RES} Reduction in a High Volume Production Environment - An Engineering Evaluation

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Overview

- Cantilevered Probe Cleaning Problems to Address
- Commonly Used Cleaning Techniques
- Fine Pitch Cleaning Issues
- EHD Cleaning for Contact Resistance Reduction
- Mechanisms Behind EHD
- Benefits for High Volume Production
- Engineering Evaluation
- Summary

Cantilevered Probe Problems to Address

- **Probing is a “dirty business”**
  - Residues from wafer processing
  - Adherent particulates
  - Bond pad and probe needle surface oxides
  - Temperature effects, i.e. hot chuck testing, high current
  - High C_{RES} leads to yield fallout and reprobe

- **Maintenance of clean probe contact surface**
  - “Clean” probes provide low and stable C_{RES}
  - Quality of the intermetallic contact at conductive a-Spots
  - Short setup time and consistent prober/tester uptime

Commonly Used Cleaning Techniques

- **Burnishing on an abrasive surface**
  - 0.5, 1.0, 3.0, and 5.0-µm grit lapping film
  - 10-µinch finish tungsten-carbide cleaning plate
  - Ceramic cleaning chuck
  - Efficient for reducing C_{RES} at the cost of probe damage

- **“Non-destructive” techniques**
  - Manual brushing with or without IPA
  - Ultrasonic cleaning and DI-water rinse
  - Detergent and water immersion
  - CO_2 Snow
  - Variable effects on C_{RES} at the cost of P&A integrity

Fine Pitch Abrasive Cleaning Issues

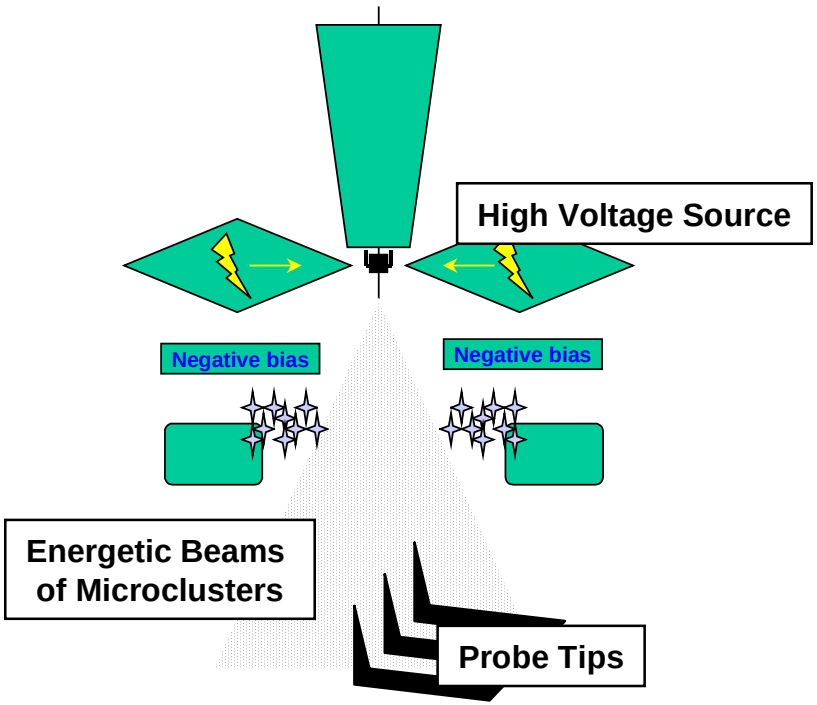
- **Current abrasive cleaning processes reduce C_{RES}**
  - Reduced pad sizes ⇨ sensitivity to non-planarity and misalignment
  - Smaller probe diameters ⇨ damage from frictional shear stresses
  - Smaller probe tips ⇨ coarse deformation of probe contact surface
  - Increased power requirements ⇨ oxidation and burnt probes
  - Excessive abrasive cleaning ⇨ reduced probe card life **($$$)**

- **Also, current cleaning processes are not "new" probe card technology friendly**

- **Clearly, there is a need to investigate an option for maintaining low C_{RES} without reducing the service life of these fine pitch probe cards**

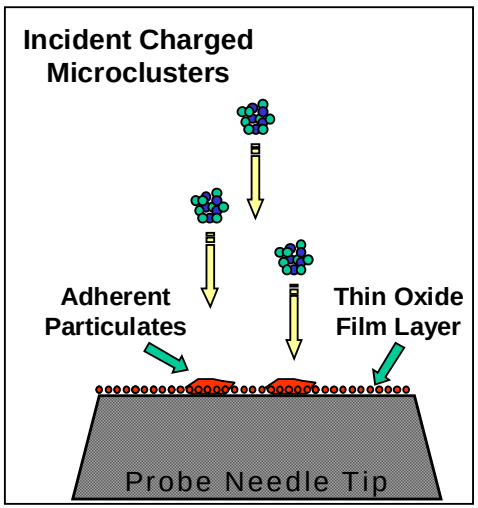
EHD Cleaning for C_{RES} Reduction

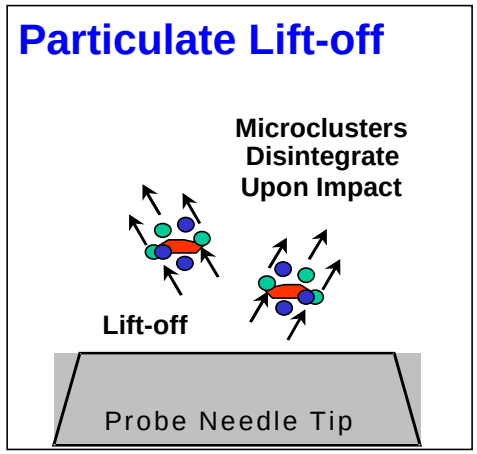
- **How does it work?**
  - Non-destructive
  - Fab-safe cleaning media
  - Requires a vacuum
  - Relatively fast compared to other methods

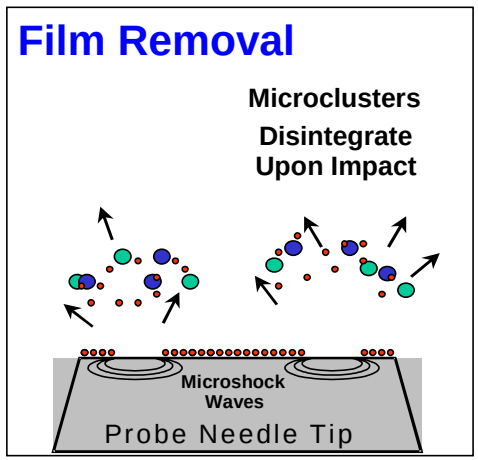


- **In a Production Environment**
  - Small footprint
  - Programmable recipes
  - Minimal operator training
  - Off-line cleaning only
  - Probe card PM schedule

Mechanisms Behind EHD







- **Particle lift-off**
  - "Massive" molecular clusters impact adherent particulates
  - Impulsive forces overcome van der Waal adhesion
  - Particulates are lifted off
- **Subsurface microshocks**
  - Molecular clusters travelling at hypervelocities
  - Microshock waves propagate along the probe surface
  - Material unloading due to passage of pressure waves

Benefits for High Volume Production

- **Effectively maintain low and stable probe C_{RES}**
  - Reduce “false fails” to increase yield
  - Minimize the need for reprobe
  - Decrease operator intervention
  - Extend probe card service life

- **Overall benefits to productivity and utilization**
  - Increased equipment up-time
  - Improved cycle-time and throughput
  - Improved cost of ownership (COO)

What we have been told…..
….. And what we really don't know…..

- **What have we been told about EHD cleaning?**
  - Reduces contact resistance
  - Removes aluminum and Al_2O_3 probe tips
  - Leaves no residuals on probes or bond pads
  - Non-destructive to probe contact surface

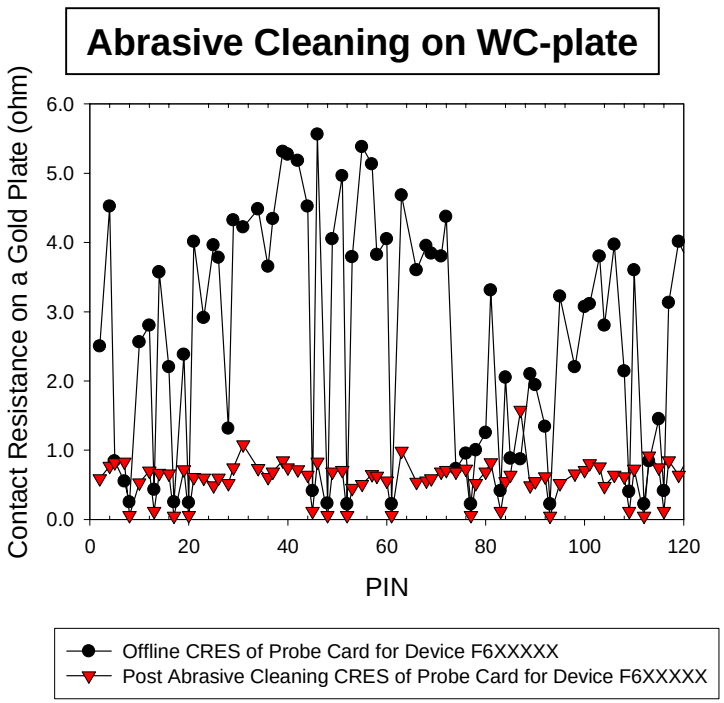
- **What do we need to learn?**
  - Damage to probe card materials
    - Epoxy ring
    - Ceramic guide plate
    - Printed circuit board
  - Long-term benefits on probe cards (if any)
  - Positive (or negative) effects on yield

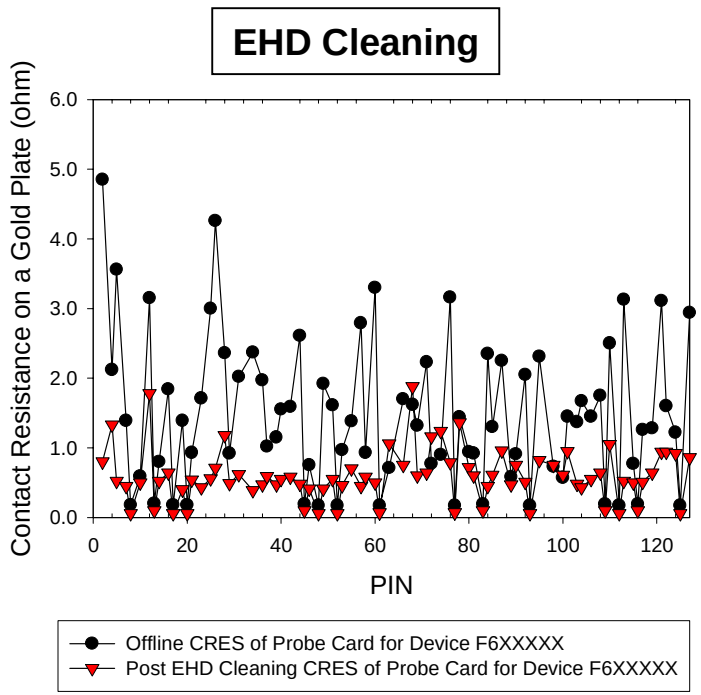
Engineering Evaluation - Part 1

“Technology Validation”

C_{RES} Reduction (EHD vs. Abrasive)?

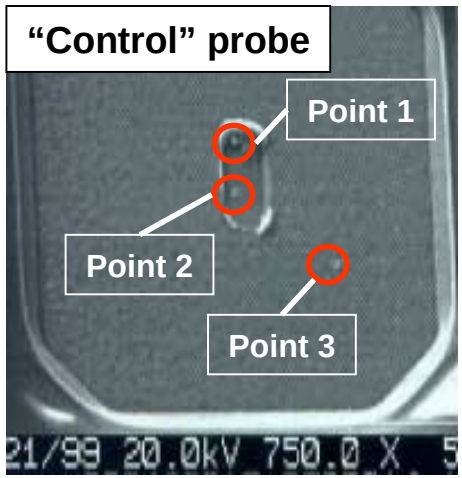
- **Representative Production Probe Cards**
  - All cards had been regularly used to probe Al-bond pads
- **For typical cards, EHD cleaning reduced the C_{RES} to a level comparable to that attained with off-line abrasive cleaning**

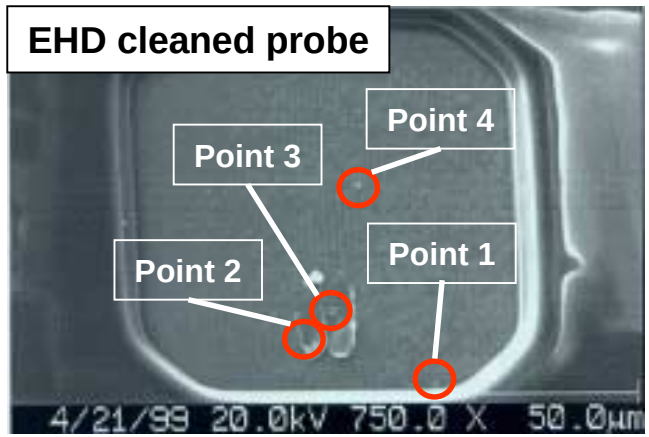


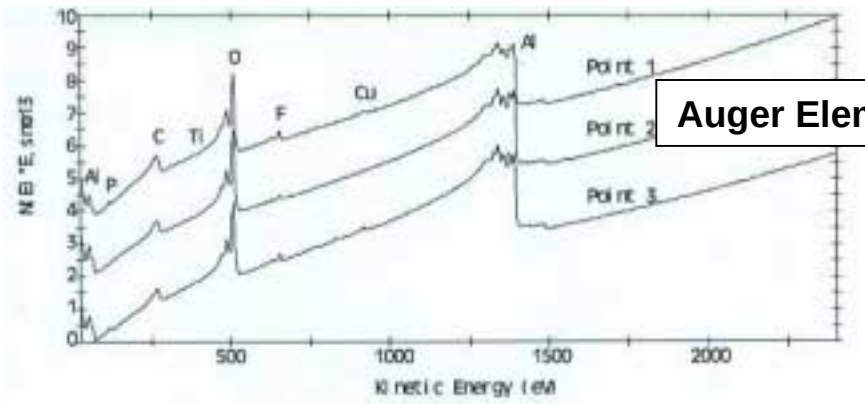


Residuals on Bond Pads?

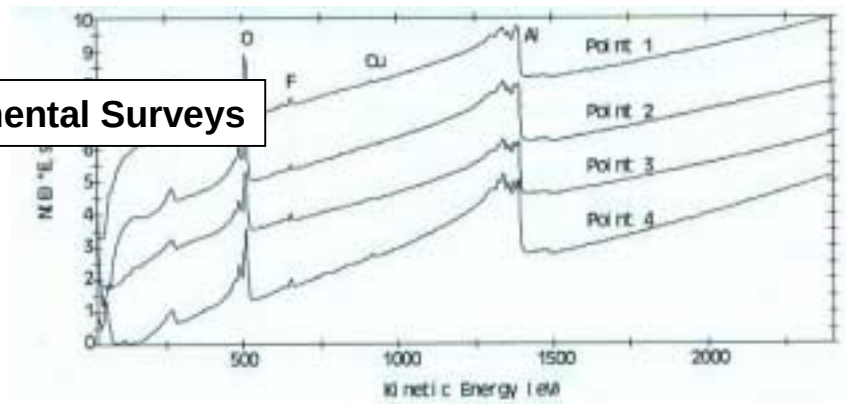
- No residue from the EHD cleaned probes was observed on the bond pad or in the scrub marks





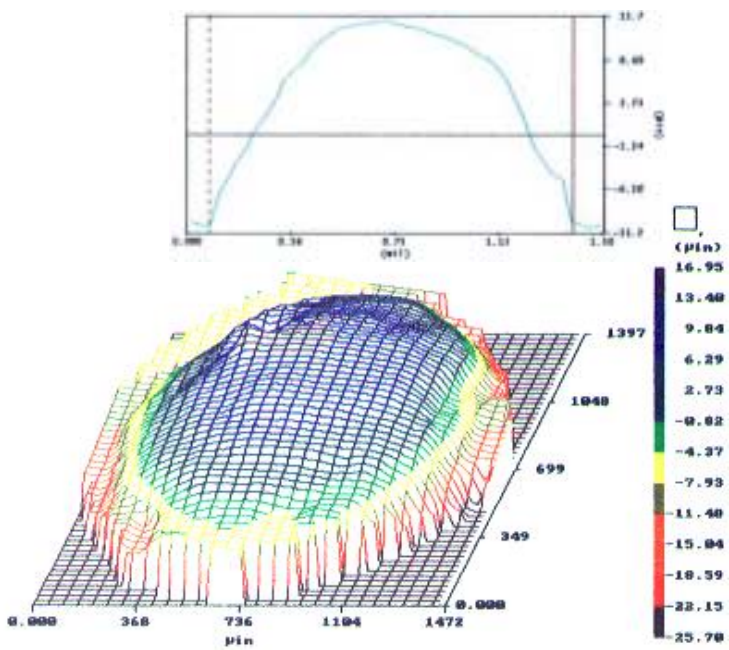


Auger Elemental Surveys



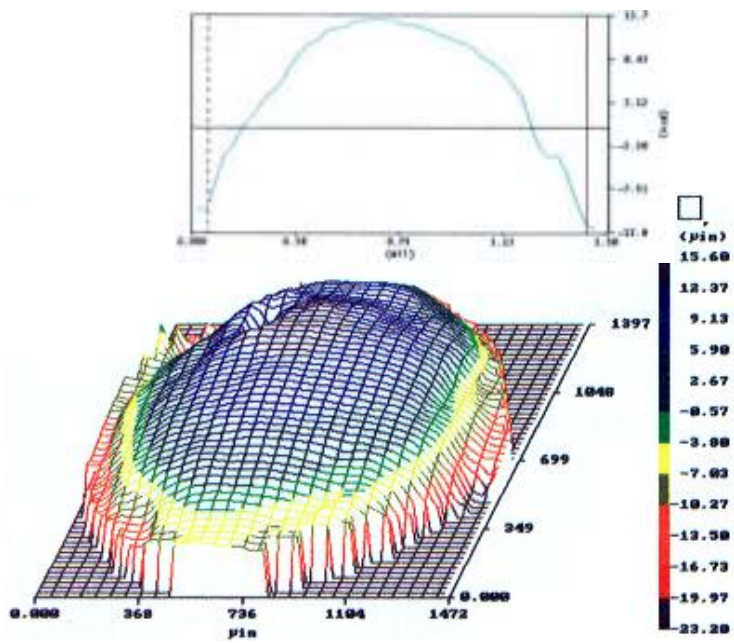
Non-destructive to probe contact surface?

Tip Surface 2D Profile



Probe as received from vendor

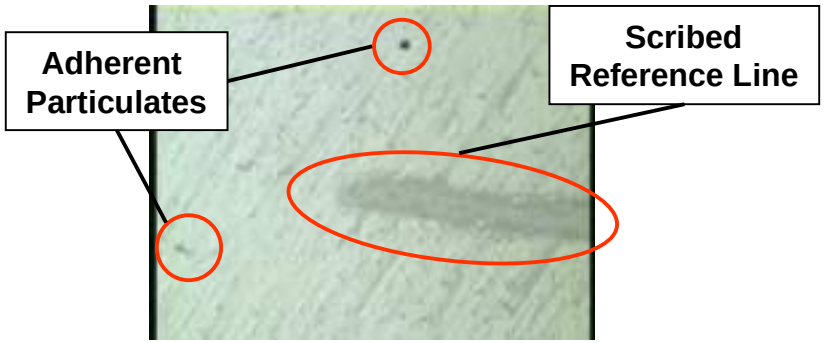
Tip Surface 2D Profile

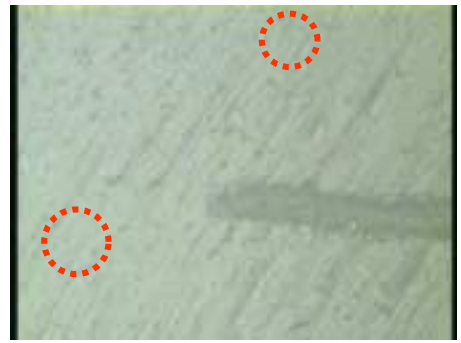


EHD Cleaned Probe Tip

- Probe surface topography was unchanged by EHD cleaning
- No discernable changes in probe planarity and alignment

Damage to Card Materials - Epoxy?





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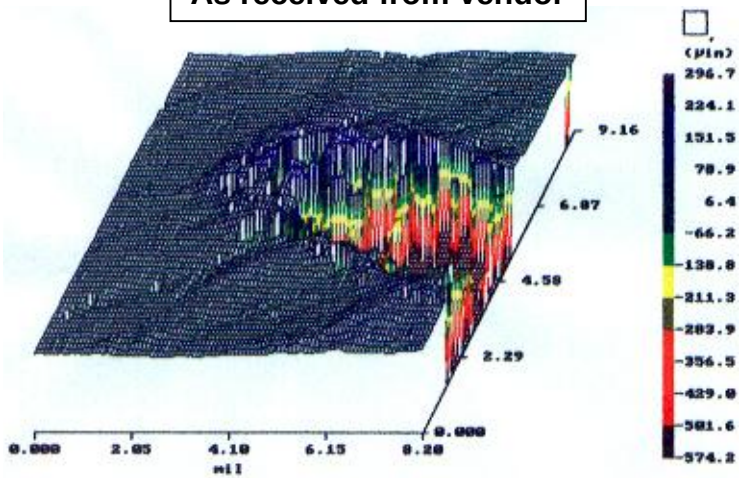
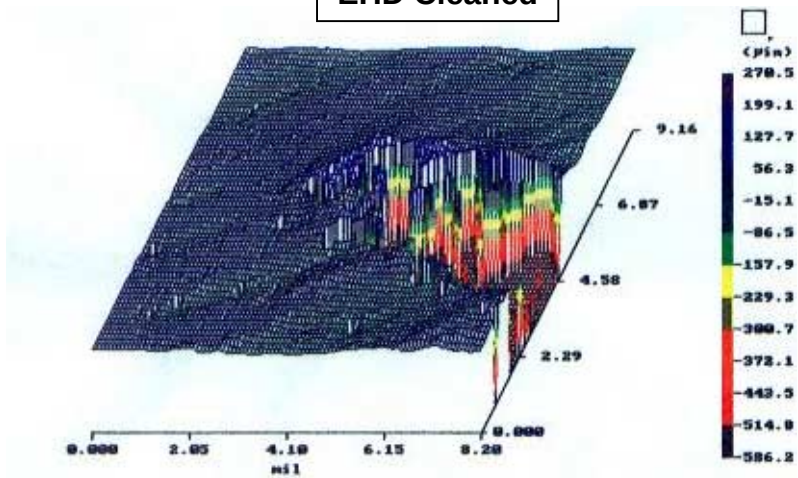


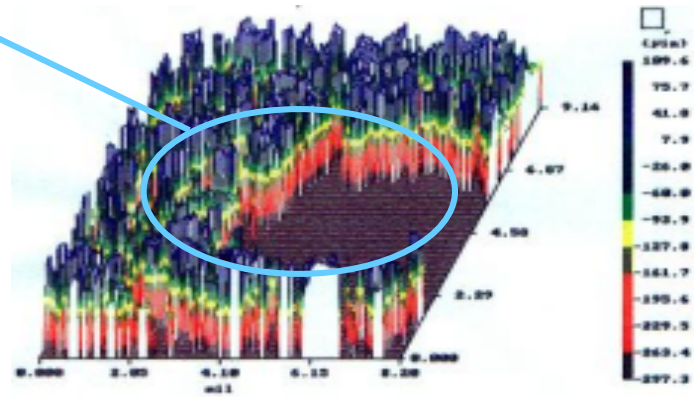
EHD Cleaned



- Adherent particulates were removed from the surface
- Sharp corners of a scribed reference line were unaffected
- The contours of the surface were unchanged

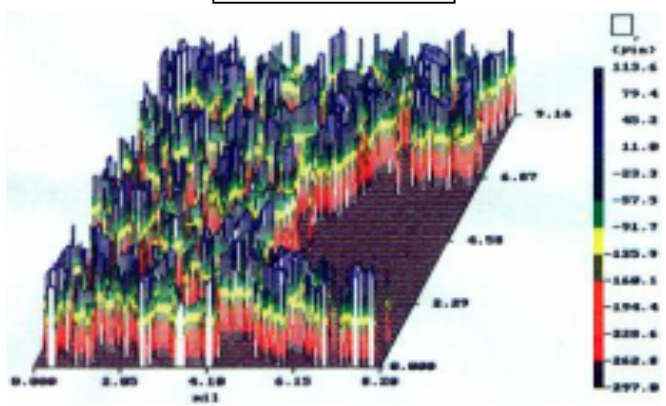
Damage to Card Materials - Ceramic?

As received from vendor



- **Ceramic lower die (guide plate)**
  - Adherent contaminants associated with probing were removed from the surface
  - Overall surface texture was not discernibly changed

EHD Cleaned



Engineering Evaluation - Part 2

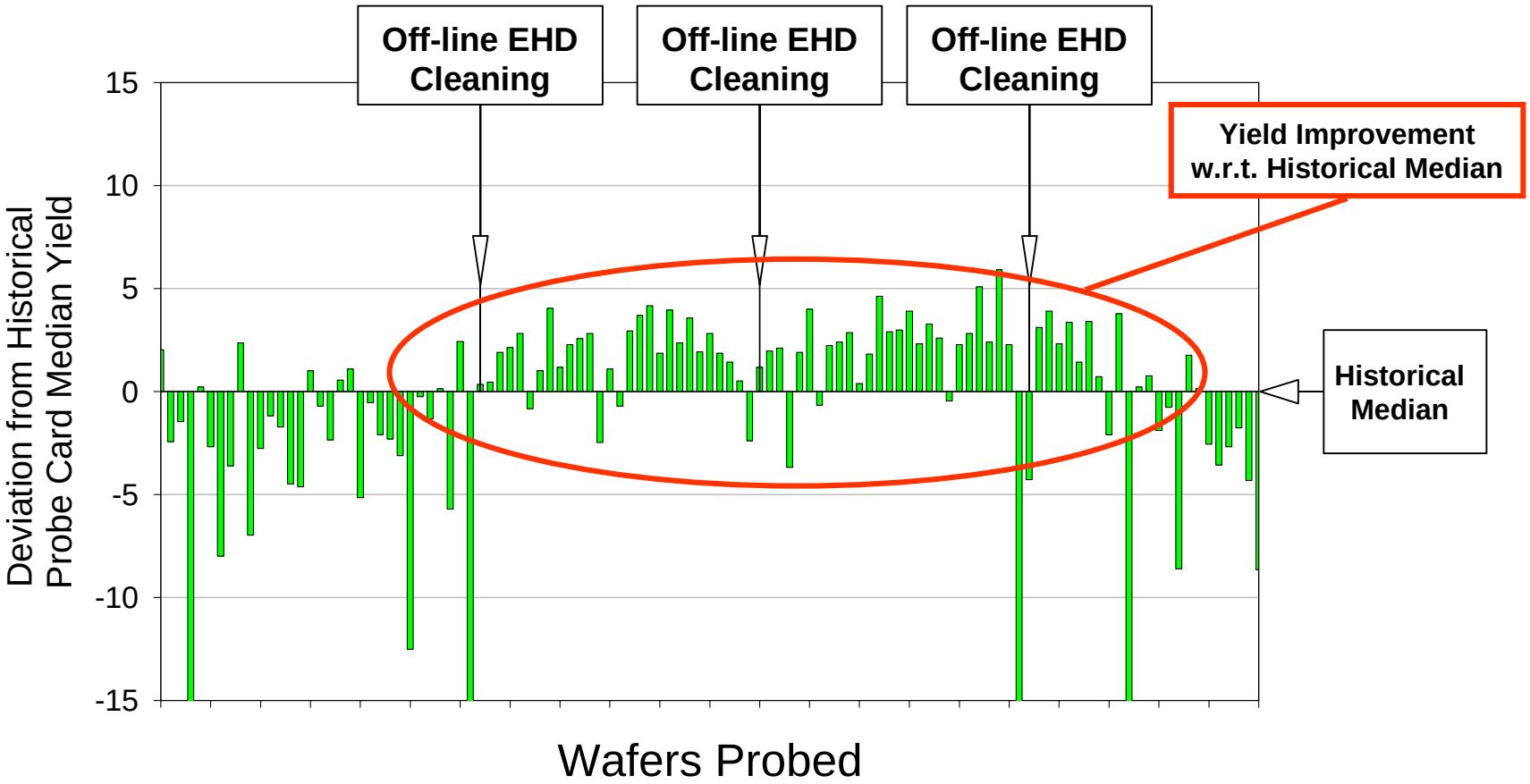
“We still have lot to learn...”

On the Probe Floor - Long Term Evaluation

- **High volume devices sensitive to C_{RES} stability and variation**
  - Fine pitch, dual-site cantilevered probe cards
  - Probe cards with production track records (historical)
- **Probe card metrology and cleaning procedures**
  - Baseline C_{RES}, leakage, BCF, and P&A
  - Off-line cleaning procedures
    - 10-µinch, WC-abrasive plate
    - EHD cleaning
  - Re-evaluation of C_{RES}, leakage, BCF, and P&A
- **Monitoring of wafer yield and reprobe rates**
  - Within lot pre- and post cleaning yield assessments
    - Deviations from historical values assessed
  - Lots split across several probers (planned)
    - Parent lot (standard card); child lot (EHD cleaned card)

Preliminary Production Floor Results

- Observed yield fallout (i.e., poor probe card performance)
- Yield recovery exhibited after off-line EHD cleaning



EHD Evaluation Summary

- **Off-line Fine Pitch Probe Card Cleaning**
  - Effective for reducing C_{RES}
  - Viable alternative to abrasive cleaning
  - Non-destructive to probes, epoxy, and ceramic
  - No detectable residues observed within (or outside) of scrub marks
- **Long term evaluations in a production environment**
  - Yield fallout and reprobe
  - Equipment utilization
  - Probe card life
  - Ongoing and long-term benefits
- **Difficulties**
  - “Onions, onions, and more onions”…….