IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

Probe Card Cleaning "A Short Tutorial"

Jerry Broz, Ph.D.
Gene Humphrey
Wayne Fitzgerald
International Test Solutions

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Tutorial Overview

- Part I – Fundamentals
  - Wafer Sort "A Very Basic Overview"
  - Probe Card Technologies
  - Contact Resistance (CRES)
  - Wafer Sort is a "Dirty Business"
  - Offline and Online Methods of Probe Cleaning
  - Survey of Available Materials
- Part II – Implementation
  - Probe Cleaning for HVM Wafer Sort
  - Online Materials Utilization
  - One Approach to "Recipe" Development
  - Cleaning Affects More than CRES
- Summary

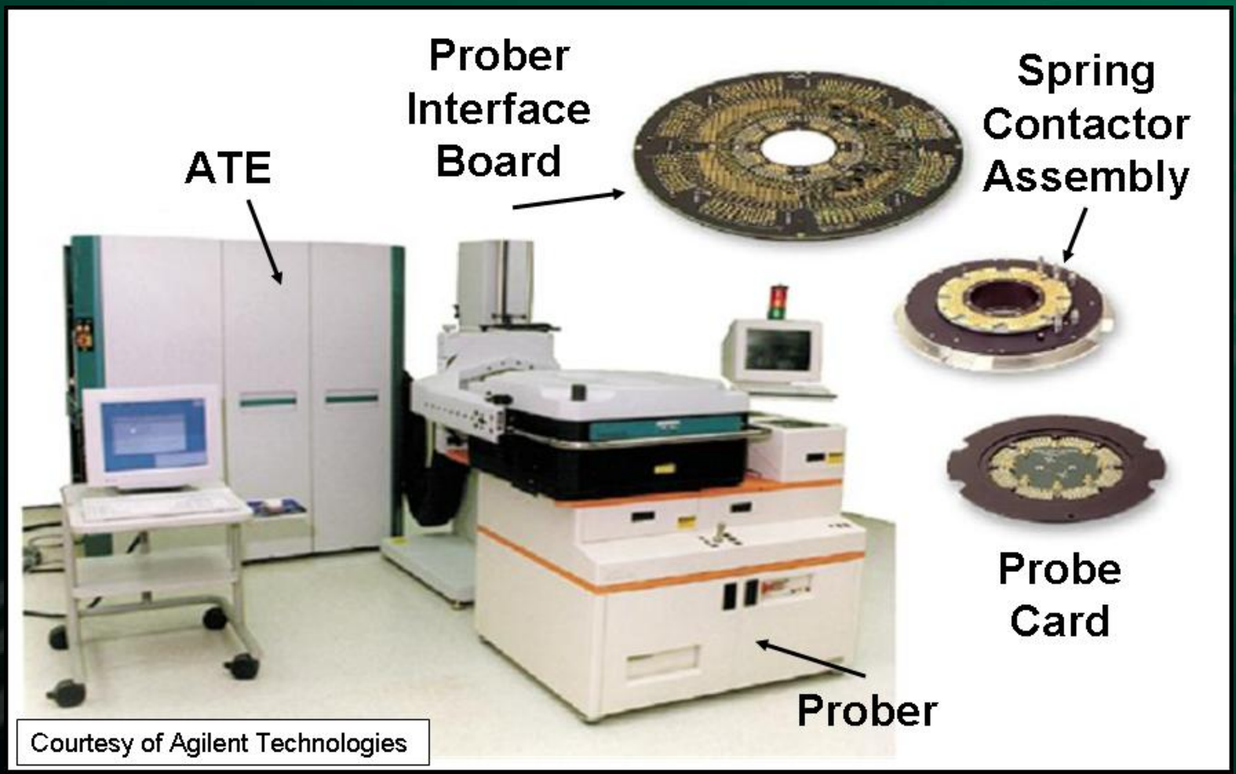
PART I – Fundamentals

Wafer Sort

"A Very Basic Overview"

How is Wafer Sort Performed ?

- Representative “Probe Test Cell” that is used during wafer level testing under various conditions

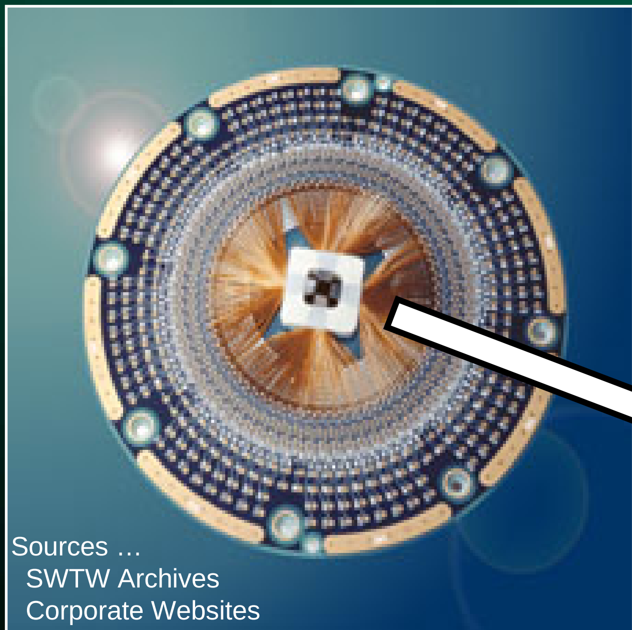


"Where the Rubber Hits the Road"

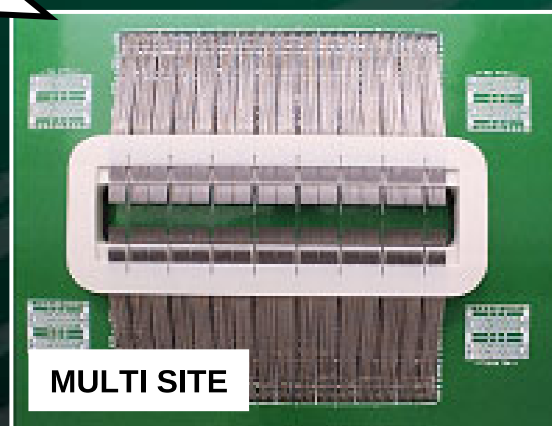
- The Probe Card provides a "real-world" interface between the DUT (device under test) and the test equipment (ATE)
  - Contactors are attached and configured to match DUT pad layout
- Contactors (a.k.a., probes, probe needles) are brought into physical contact with the bond or "probe" pads
- While the probes are in contact, a series of test programs are run to determine the pass / fail status of the DUT
  - Fundamental assumption of test engineering is "perfect" contact
- Upon test completion, contact between the probes and pads is broken, the die is binned, and the next die is positioned
  - Process leaves some sort of physical damage, a.k.a., "scrub mark" that can affect packaging, assembly, long term reliability, etc.

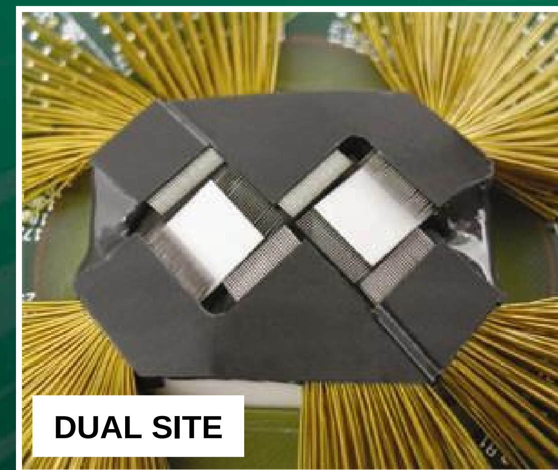
"Conventional" Contactor Technology

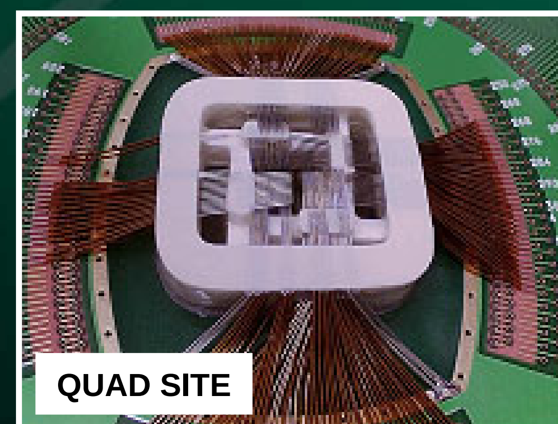
TEST TIME = $$$$$
Parallel Test is Economical



Epoxy Ring located
at the center of PCB

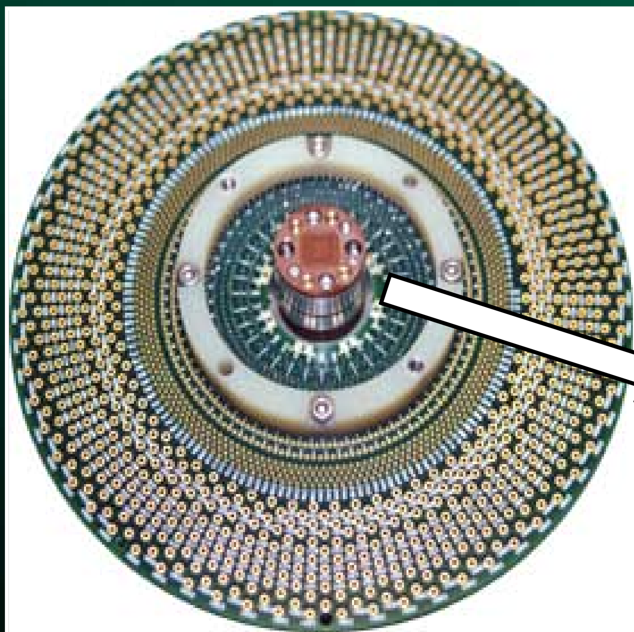




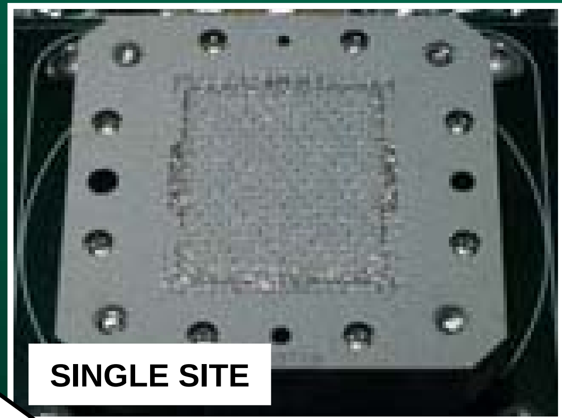


Constructed with small diameter
electrochemically machined wires

"Conventional" Contactor Technology



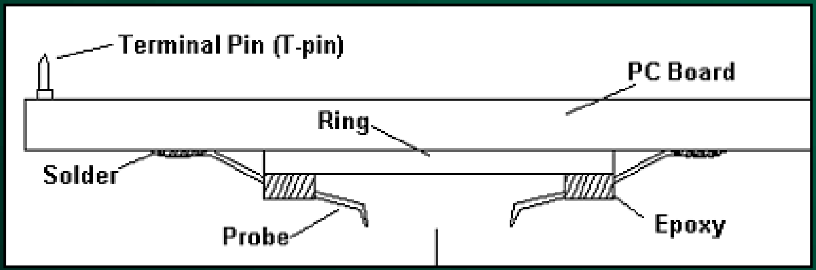
Probe Head installed at the center of PCB

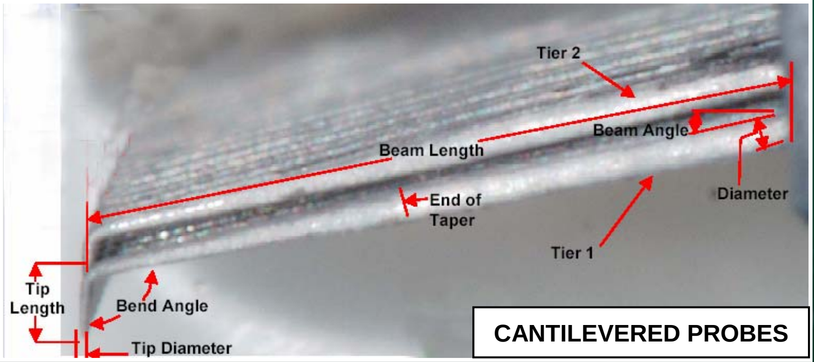


Sources …
SWTW Archives
Corporate Websites

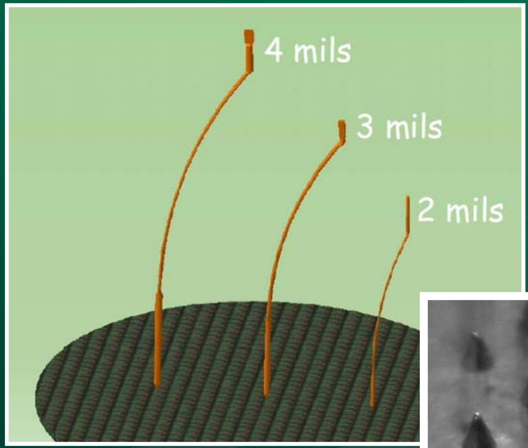
Constructed with small diameter formed wires (a.k.a., buckling beam) or miniature spring pins

"Conventional" Contactor Technology

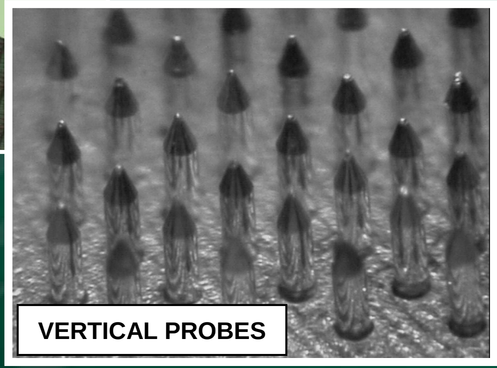




Stillman, et al., SWTW-2005

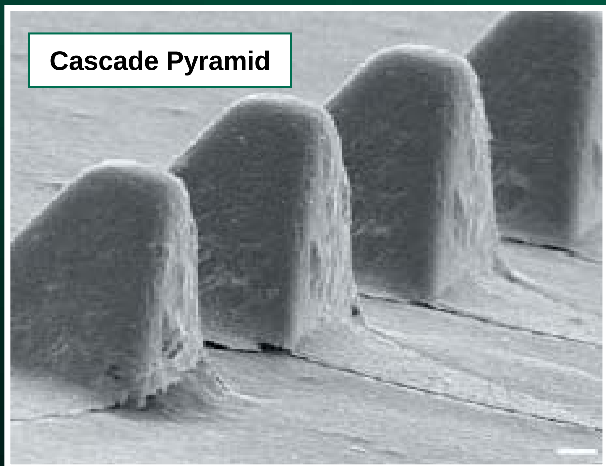


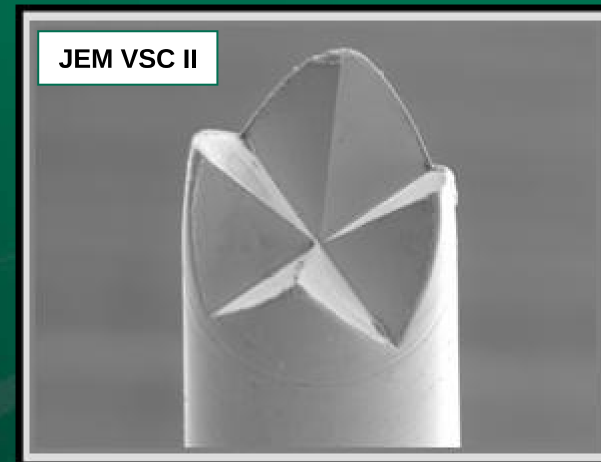
Miahle, et al., SWTW-2005

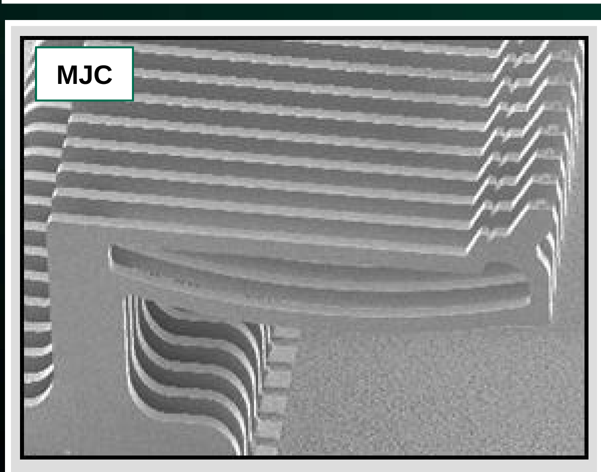


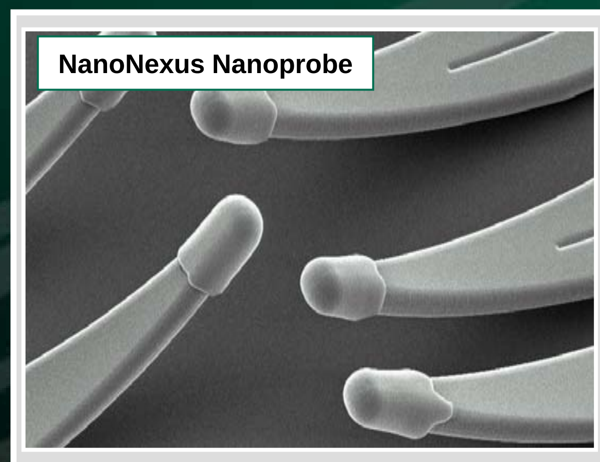
- Cantilever and buckling beam probe cards are manually assembled
- Assembly processes limit the probe pitch and number of pins
- In general, the probe card costs tends to be proportional to the number of contactors

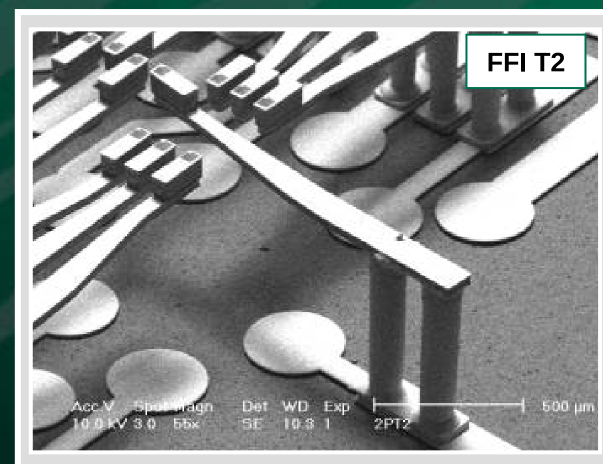
"Advanced" Technologies









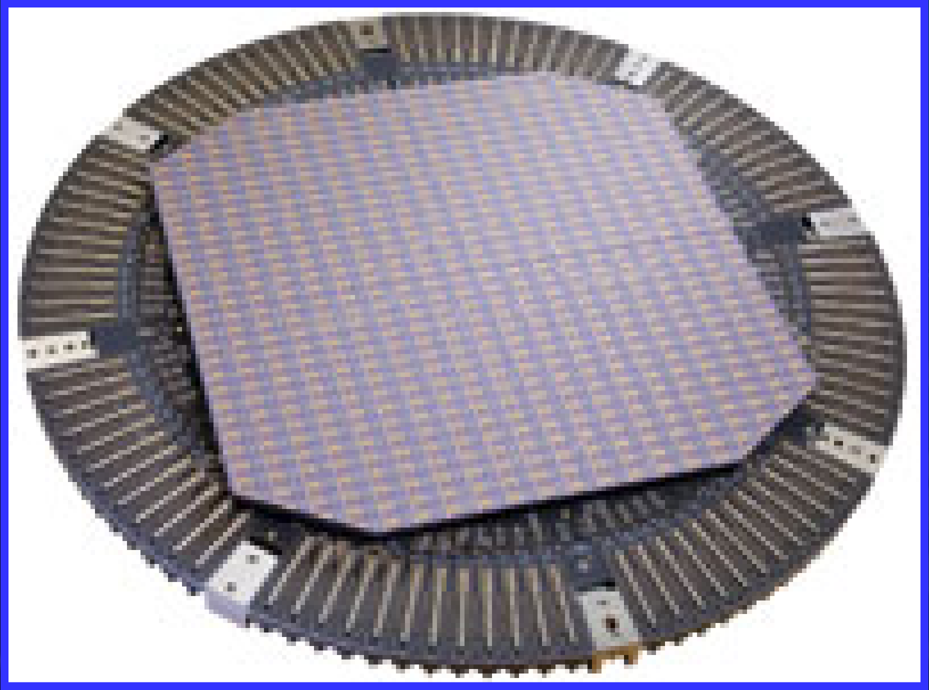


Source: SWTW Archives

Selection of "correct by construction" probe card technologies.

Advanced Large Area Array Probing

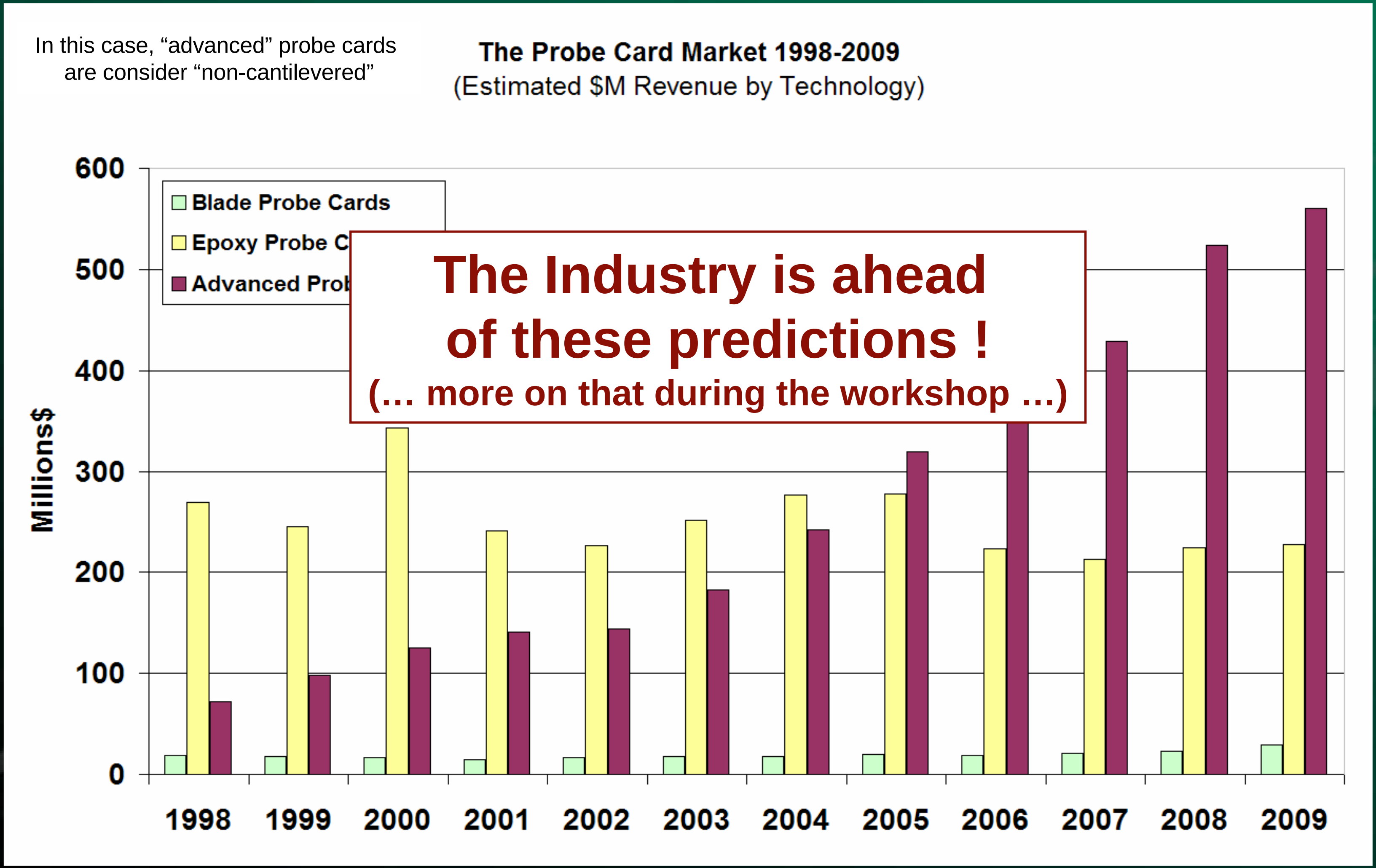
- FFI PH150XP™ Platform
  - 26,000 pin-count wafer-probe card



Test & Measurement World, April 2007

- Probe card manufacturers are pushing advanced wafer sort to a single "touch" 300-mm probe card (i.e., very large area array probing)
- Even with these advanced technologies, the probe tips must still "touch" the DUT during wafer sort

Trends of "Advanced" Probe Cards



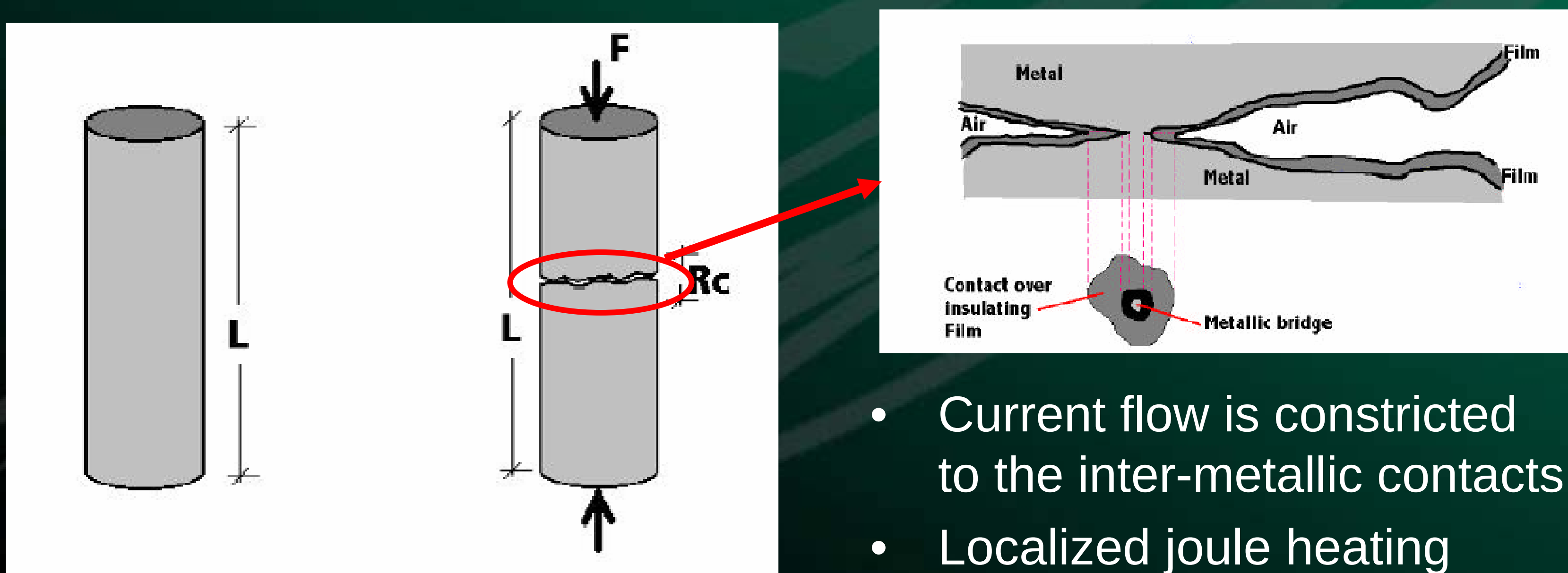
Source: VLSI Research, 2004

Contact Resistance

"a.k.a., CRES"

Contact Resistance (CRES)

- In the past few years, probe card technologies, construction materials, and manufacturing methods have advanced, but the mechanisms are the same
- CRES is probably one of the most CRITICAL parameters in wafer sort
- CRES Fundamentals …
  - CRES occurs between two bodies in contact
  - Creates losses in electrical and thermal systems



- Current flow is constricted to the inter-metallic contacts
- Localized joule heating

Contact Resistance (CRES)

- Contact Resistance is a combination two main parameters
  - Localized physical mechanisms … metallic contact
  - Non-conductive contribution … film resistance

- Empirical model for CRES

$$C_{RES} = \frac{(\rho_{probe} + \rho_{pad})}{4}\sqrt{\frac{\pi H}{P}} + \frac{\sigma_{film} H}{P}$$

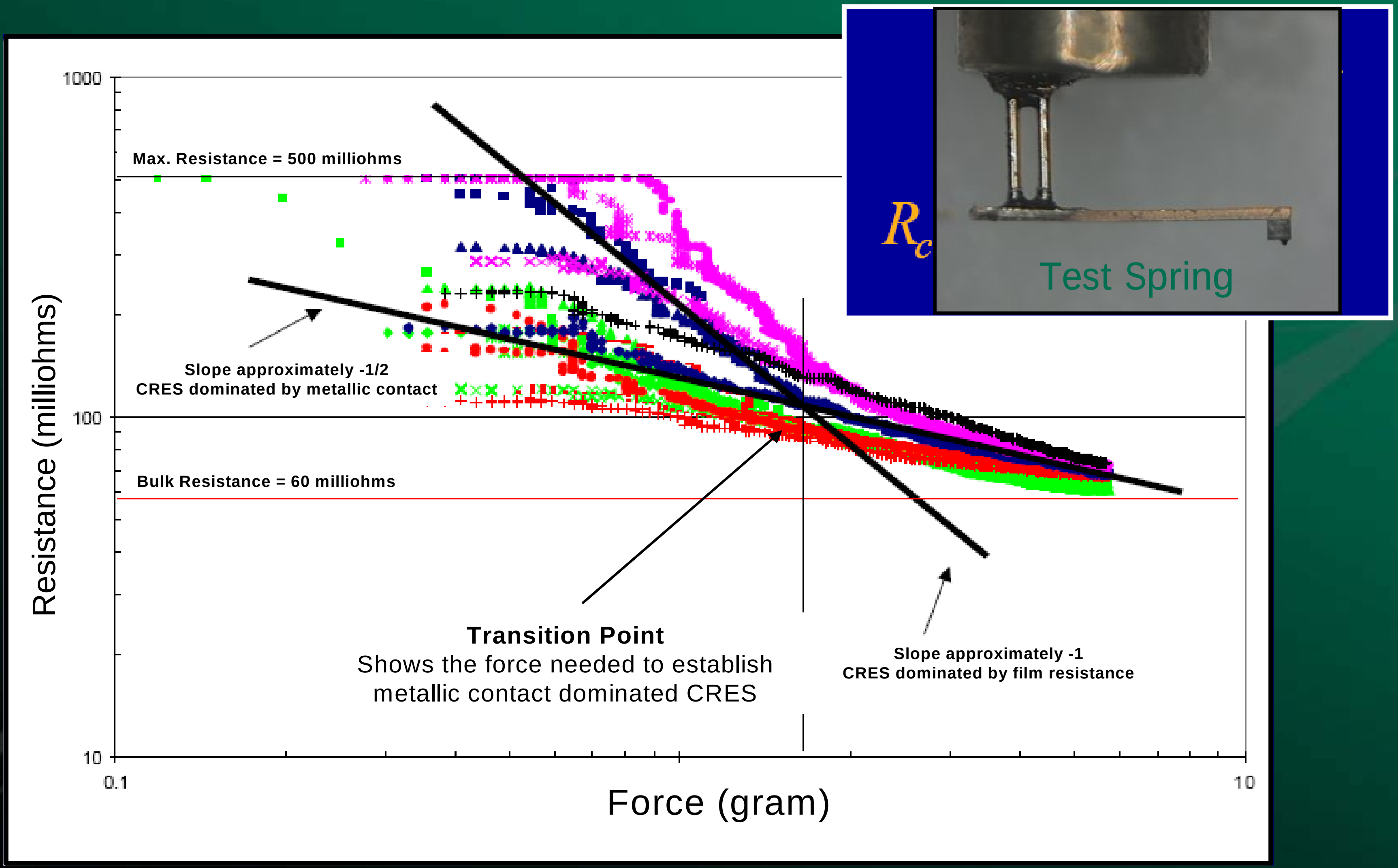
METALLIC CONTACT

FILM RESISTANCE

sistivity values
fter material
re
– applied force normalized by true con

- Unstable CRES is dominated by the film contribution (σ_{film}) due accumulation of non-conductive materials

Film Resistance Dominates CRES



Martens, et al., SWTW - 2002

Mechanisms of Contact Resistance

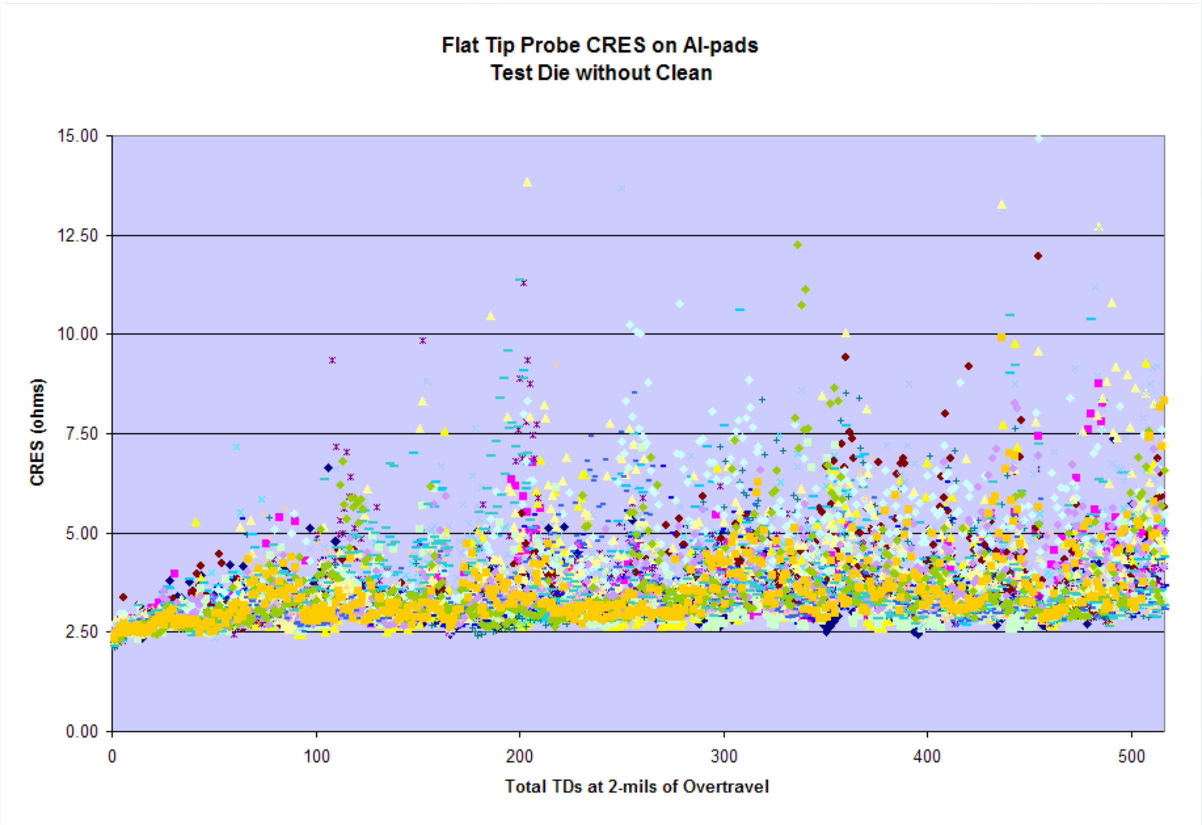
- Key Factors (among others) that affect CRES
  - Presence of contamination, e.g. debris, oxides, residues, etc.
    - Film resistance will eventually dominate the magnitude and stability of the CRES
  - Probe tip shape plays an important role in displacing the contaminants from the true contact area
    - *True* Contact Area = $\mathcal{F}$ (Tip Shape, Applied Force, Surface Finish)
      - *True* contact are is "large" ➔ applied pressure and *a-Spot* density are "low"
      - *True* contact area is "small" ➔ applied pressure and *a-Spot* density are "large"
  - Probe tip surface characteristics affect the "a-Spot" density
    - 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
  - Wafer sort temperature affects oxidation and debris formation

Plastic Deformation / Material Adhesion

- ALL probe technologies have a contact area that is substantially harder than the pads or solder bumps of the device
- Some sort of probe "contact and slide" is CRITICAL to the break surface oxide(s), but results in a localized plastic deformation, i.e., a probe mark
  - During sliding, material is displaced and transferred from the softer substrate to the harder substrate
  - Volume of material displaced and/or transferred is a complex function of metallic interactions, frictional effects, and other tribological properties

Wafer Sort is a "Dirty Business"

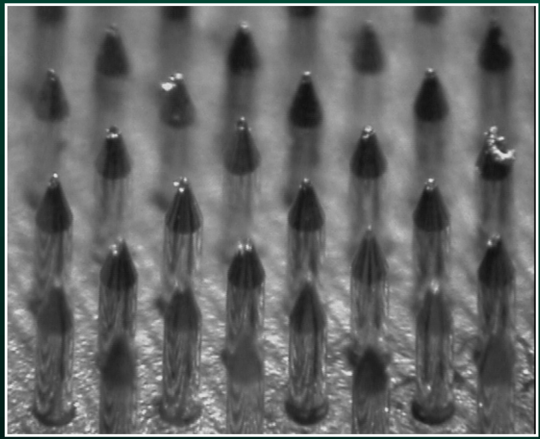
- Due to the mechanisms, all types of probes generate, accumulate, and pick up debris to some extent
  - Contact resistance increases (… a coincidence ?)



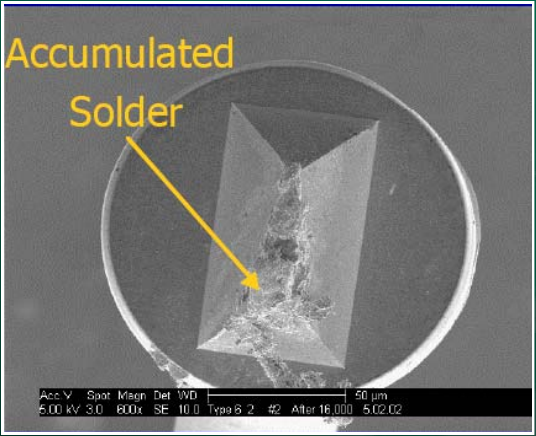
Stalnaker, et al., SWTW - 2003

Selection of "Dirty Probes"

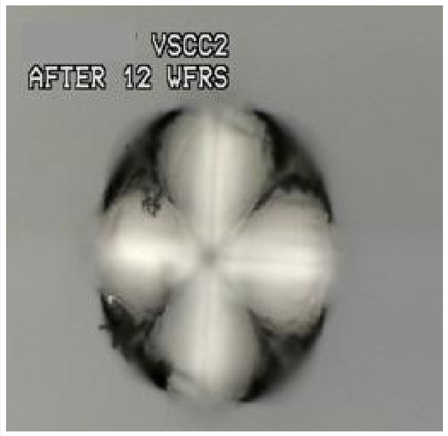
- Debris / Materials from solder balls …



Courtesy of WWL

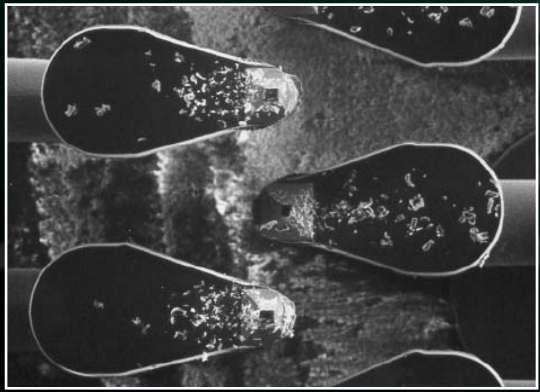


Martens, R., et al., SWTW-2002

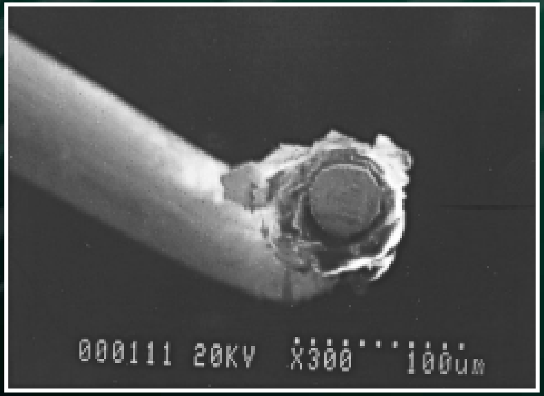


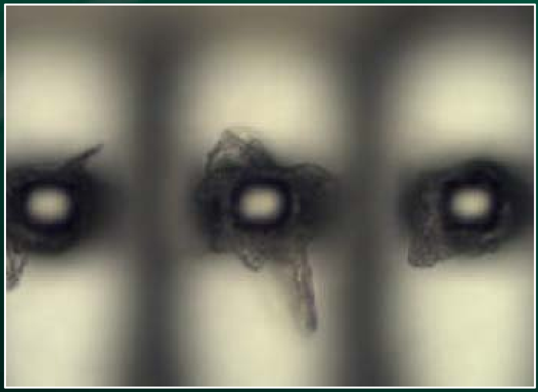
Forestal, J., et al., SWTW-2005

- Debris / Materials from bond pads …



Brandemuehl, et al., SWTW-1999



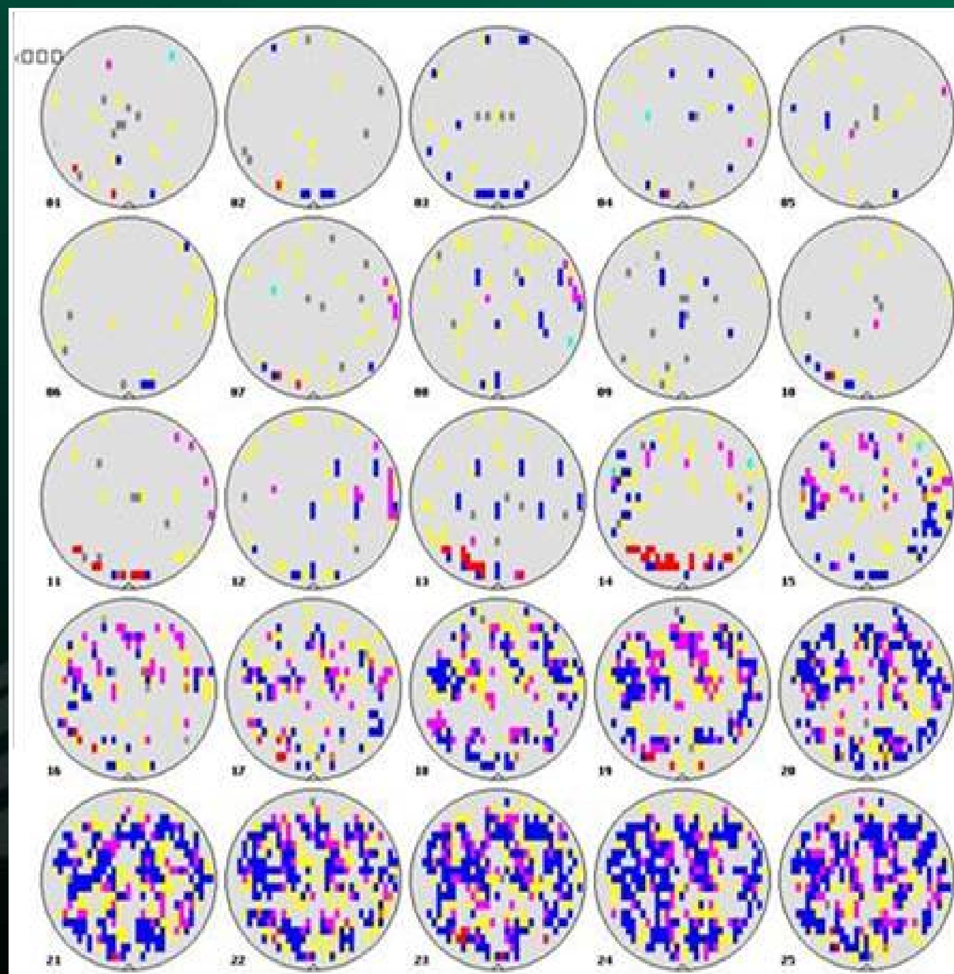


Cascade MicroTech 121-710-APP-0805

Unstable CRES Affects Wafer Yield

- Higher yield fallout can occurs with continuous probing

FIRST WAFER



LAST WAFER

Pietzschmann, et al., SWTW - 2005

Probe Cleaning
Is Needed !

Only reason probing _ever worked_ is the "self-cleaning effect" during contactor scrubbing

Offline and Online

- Off-line cleaning operations can be used during regular maintenance activities
  - Probe card is typically removed from the prober
  - Debris and adherent materials are removed
  - Contact surface shape and recovery is performed
- On-line cleaning operations control CRES and wafer yield during wafer sort
  - Probe card being used to perform wafer sort and test die remains docked within the prober
  - Excessive cleaning can reduce test throughput without yield benefits
  - Too little cleaning adversely affects test yields and affect uptime

Offline Probe Cleaning Methods

Offline Probe Cleaning Methods

- Probe Card Analyzers with media plates
  - Applied Precision (PRVX™ series)
  - Integrated Technology Corporation (ProBilt™ series)

http://www.api.com

http://www.inttechcorp.com

Offline Probe Cleaning Methods

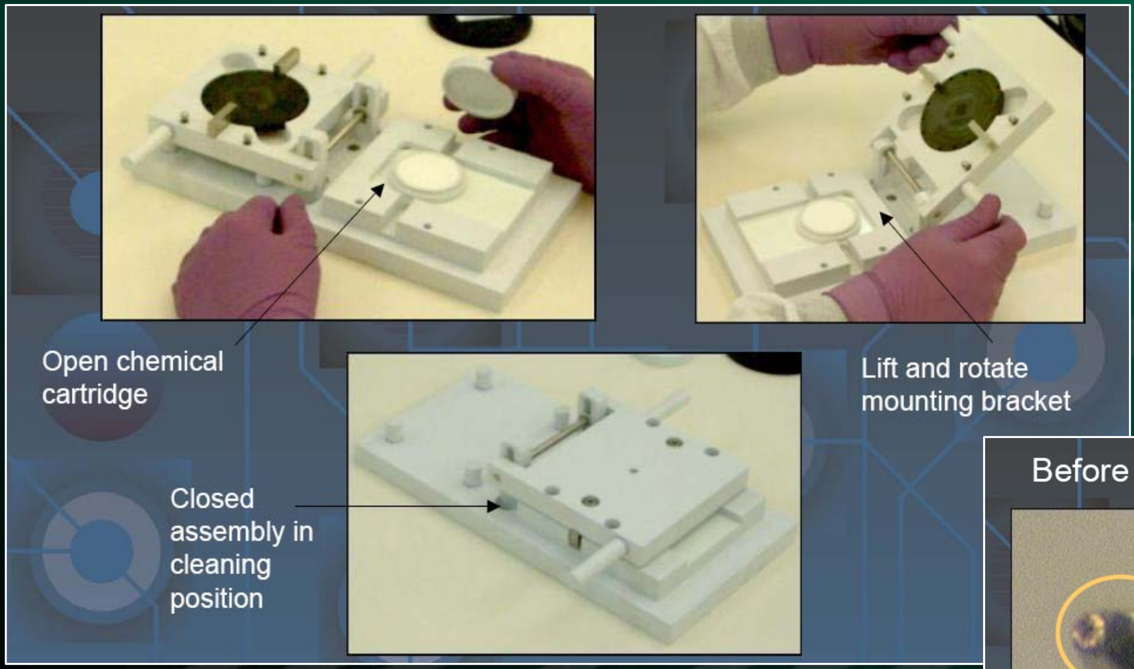
- Chemical probe cleaning tools
  - American Tech Manufacturing (PC-105™)
  - Nucent (CPCC- 350™, CPCC- 500™)

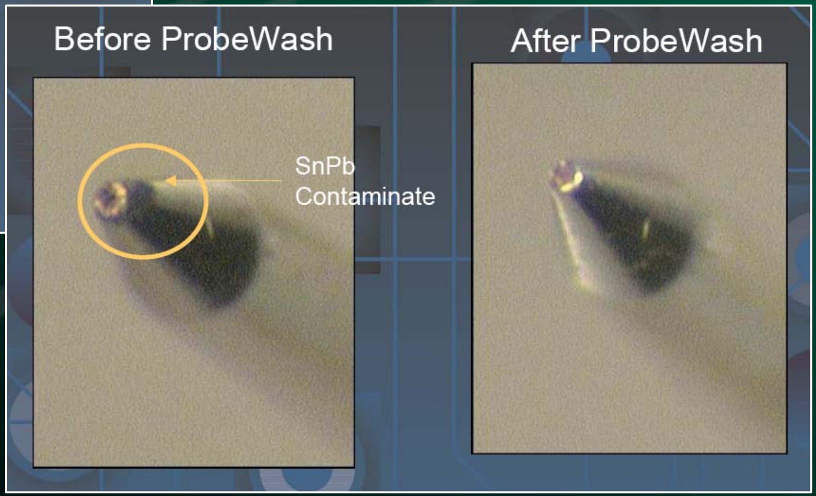
http://www.americantech.com

http://www.leftcoastinstruments.com

Offline Probe Cleaning Methods

- Wentworth ProbeWash™
  - Station with proprietary cleaning solutions

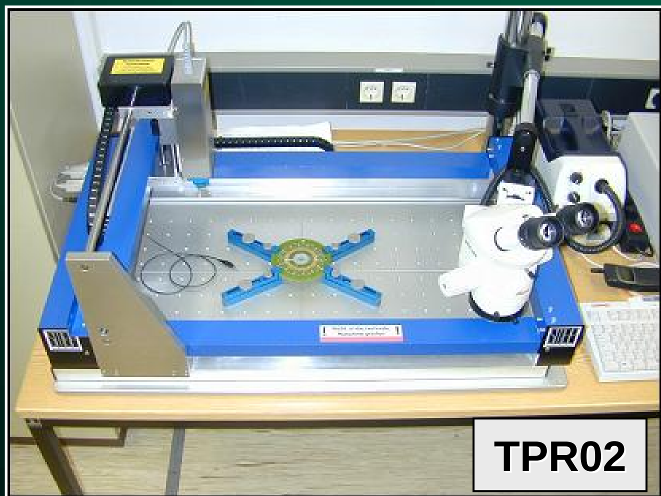


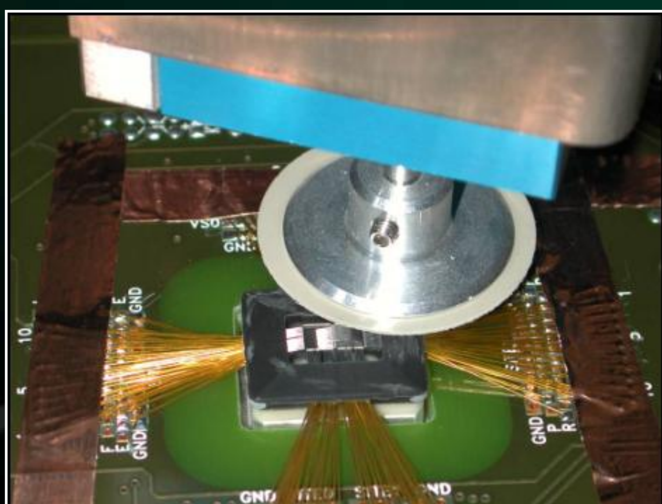


Fulton, et. al, SWTW-2003

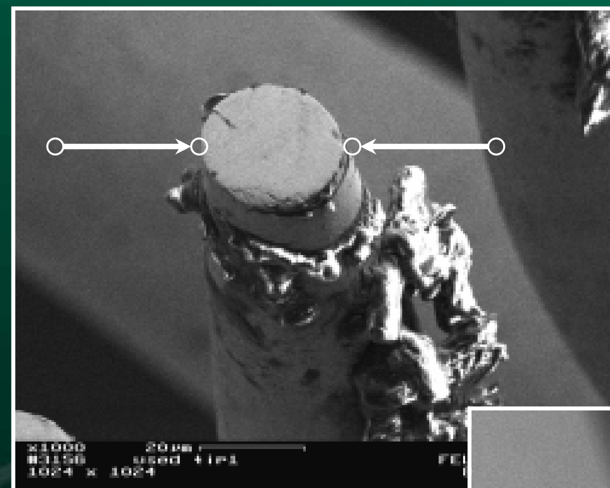
Offline Probe Cleaning Methods

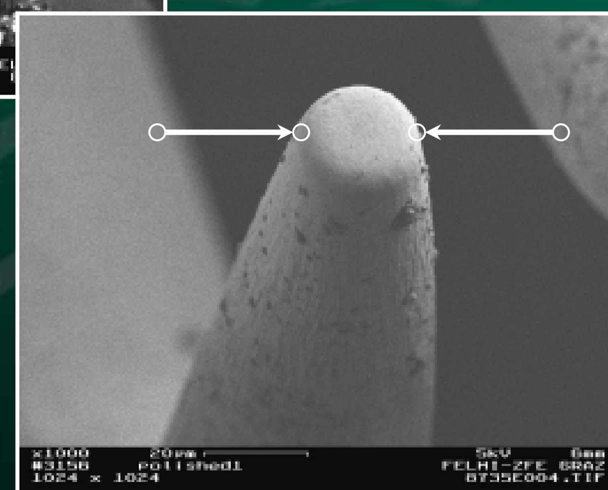
- T.I.P.S. Probe Refresher™





Gaggl et al., EMTC-2006





Humphrey and Gaggl, SWTW-2003

Offline Probe Cleaning Methods

- Other methods include …
  - Manual dry brushing with various fiber brushes
  - Manual IPA wet brushing
  - Ultrasonic immersion in various detergents followed by DI water
  - CO_2 snow (Cool Clean Technologies)
  - Laser ablation (New Wave Research)

Online Probe Cleaning Materials

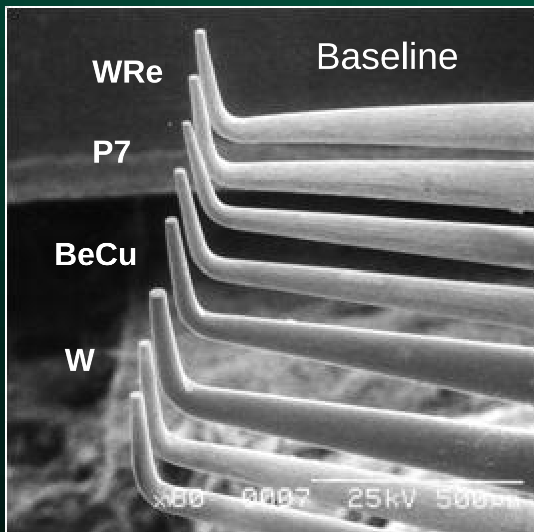
Destructive Probe Cleaning

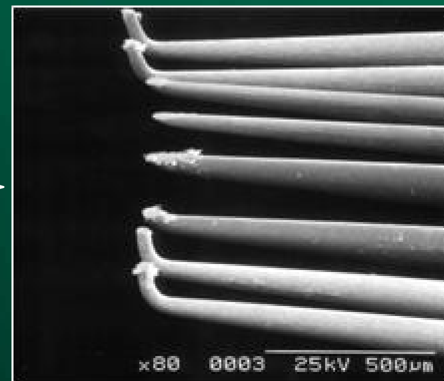
- "Low cost" abrasive cleaning of the probe contact area has been the primary method for years
  - Most of the "conventional" probe card technologies can withstand some level of abrasive cleaning
- Simply, the probes are "scrubbed" onto an abrasive medium which removes contaminant AND probe material
  - Cleaning with an abrasive medium is a destructive process that changes the shape of the probe tip
- Commonly used abrasive materials include …
  - Lapping films various grit materials and sizes
  - Tungsten Carbide disks and wafer
  - Ceramic Substrates

Abrasive Cleaning Works, But …

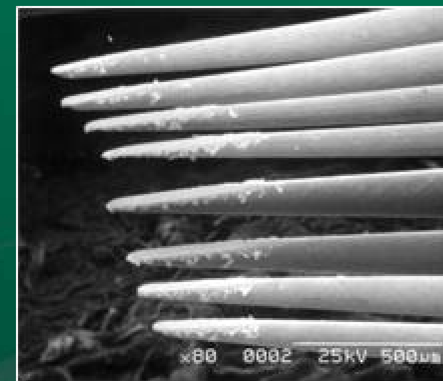
- Each time the probes are abrasively cleaned …
  - High frictional stresses are imparted
  - Material is removed and additional debris is generated
  - Contact surface is affected and can be damaged
  - Tip geometry is continually changed
- Cleaning residuals and can affect CRES as well as PTPA (e.g., operator intervention is needed)…
  - Particulates
  - Bond pad metal
  - Probe material
  - Airborne debris
- Eventually the probes are "worn" out of specification

Is Abrasive Cleaning Really "Low Cost"?

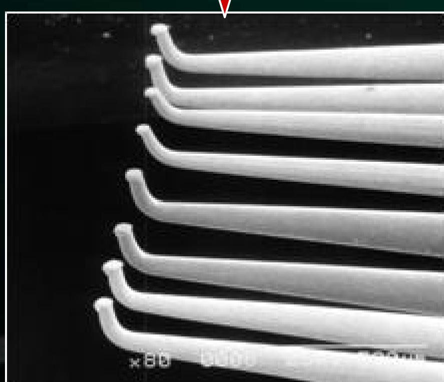




100k TDs
1-µm Lapping Film



100k TDs
3-µm Lapping Film



500k TDs
Tungsten-Carbide

500k TDs
Ceramic Disk

- On-line cleaning with "low cost" lapping films and other abrasive substrates do recover CRES
- Clearly, it is not as inexpensive as most people believe

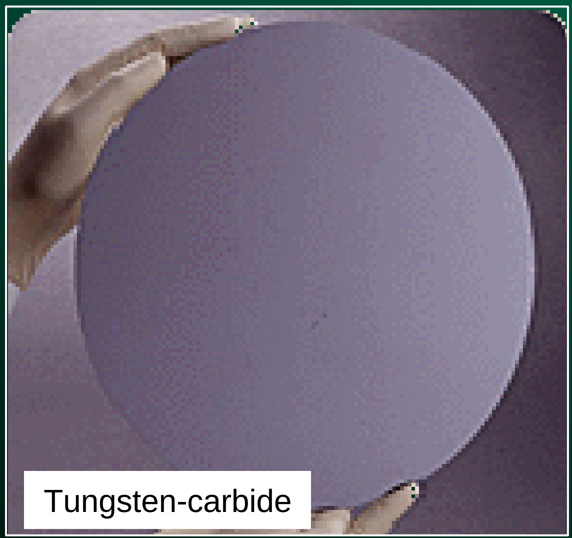
Non-Destructive Probe Cleaning

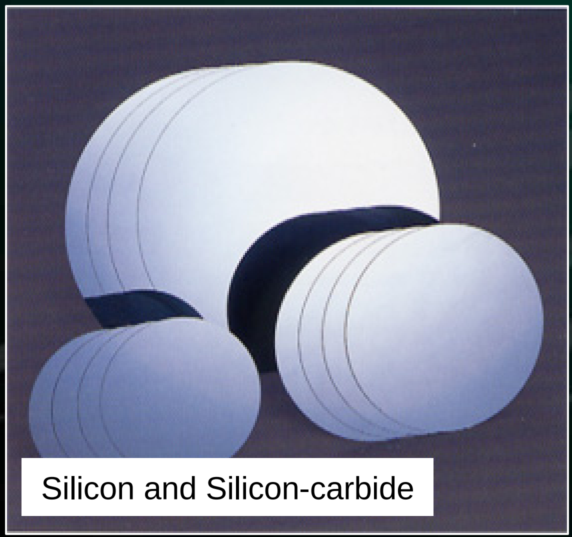
- Increasingly fewer probe technologies can withstand frequent abrasive cleaning
  - "Conventional" technologies with shaped tips are compromised
  - "Advanced" technologies cannot withstand frequent abrasive cleaning
  - Destructive cleaning can result in costly damage to the probe tips
- Semi-abrasive / non-abrasive / debris collecting on-line cleaning techniques.
  - Minimal shear loads
  - Effective debris collection
  - Probe contact surface maintenance
  - Facilitate frequent cleaning for optimal CRES control
  - "Preventative" cleaning to reduce resistive contamination build-up

Cleaning Materials Survey

- Rigid substrate materials
  - Tungsten carbide
  - Roughened silicon and silicon carbide
- Lapping films with various polymer backings
  - Various abrasive grit types
  - Various grit sizes
- Abrasively coated, polyurethane foam (sponge-like)
  - Various grit sizes
- Polymer based materials
  - Unfilled (debris collection only)
  - Abrasive particle filled (polishing or tip shaping)
- Hybrid materials constructed with multiple layers
  - Uniform abrasive coating across a polyurethane foam
  - Unfilled polymer across a lapping film

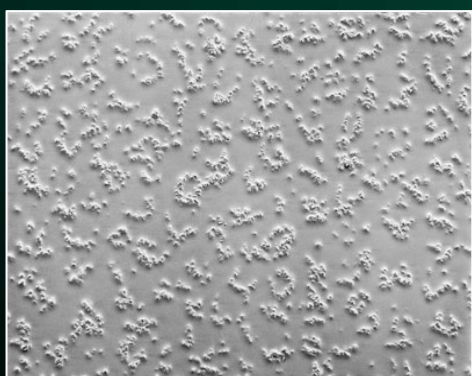
Rigid Substrates

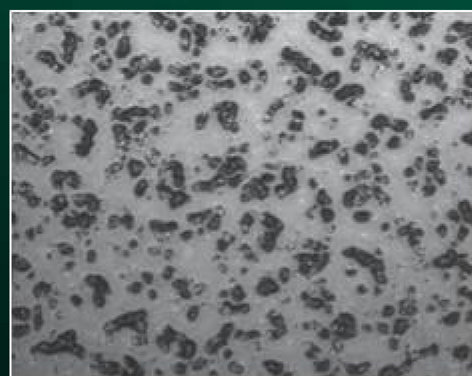

Tungsten-carbide

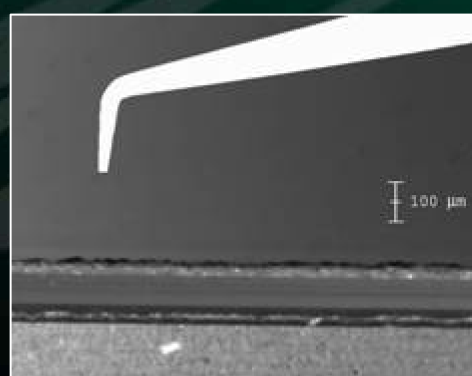

Silicon and Silicon-carbide

- Description
  - Non-compliant material
  - Ground surface with a controlled roughness profile
  - Abrasiveness is controlled by the surface finish and surface roughness
- Advantages
  - Extremely hard
  - Non-compliant
  - Consistent thickness and uniform surface texture
- Disadvantages
  - Abrasive surface that will damage probe tips during frequent usage
  - Weight of tungsten-carbide can be an issue
  - Frequent usage can plastically deform probe tips, i.e., “mushrooming”

Polyester Backed Lapping Films

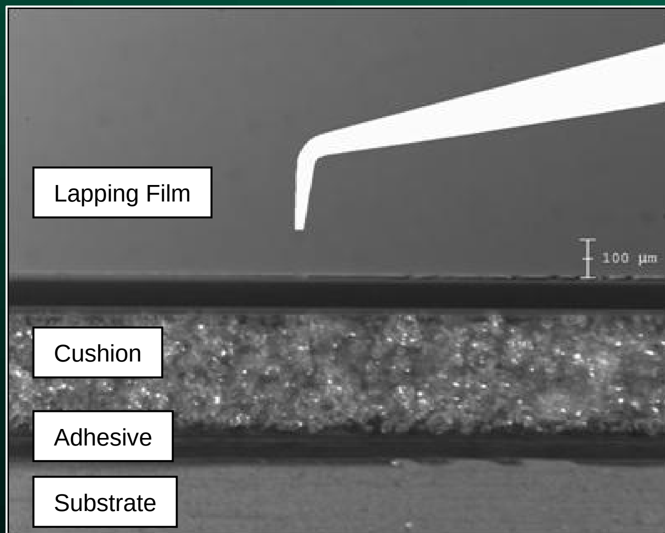


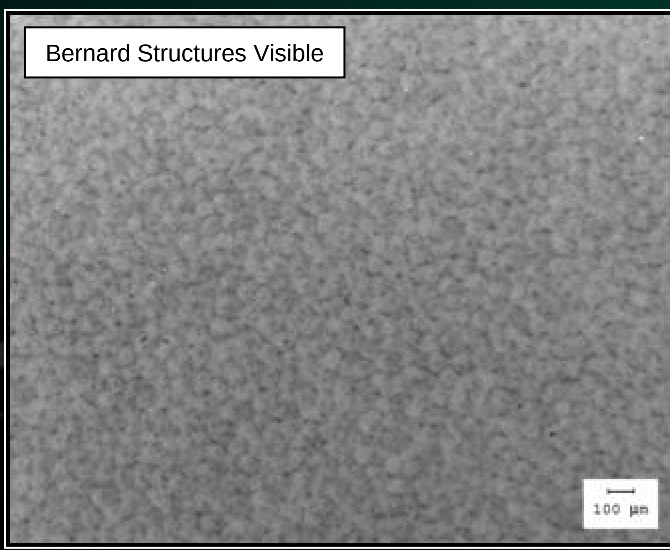




- Description
  - Abrasive particles applied in a slurry across a polyester film with a backside PSA
  - Abrasiveness is controlled by particle size
- Advantages
  - Least expensive option for probe cleaning
  - Removes adherent for a clean contact surface
- Disadvantages
  - Removes probe tip material.
  - Abrasive media adapted from other industries
  - Lot-to-lot and within-lot material thickness variations
  - Debris generation from dislodged particles and binder

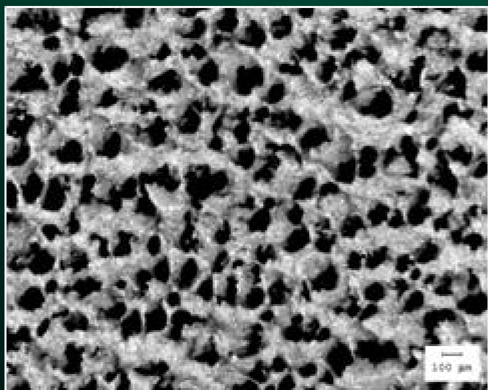
VHB™ Backed Lapping Films

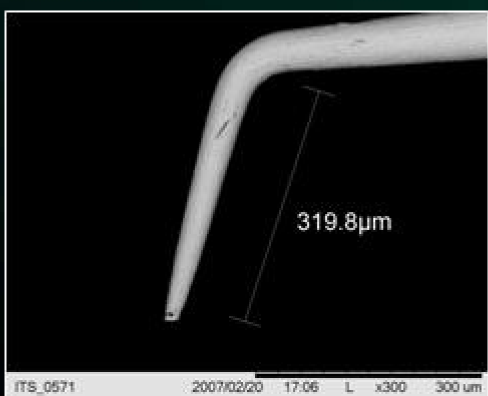




- Description
  - Abrasive particles applied in a slurry across a polyester film
  - Lapping film is installed onto a compliant VHB™ (“Very High Bond”) adhesive layer
  - Abrasiveness is controlled by particle size
- Advantages
  - Uniform surface morphology
  - Consistent thickness
  - Removes adherent material for a clean contact surface
- Disadvantages
  - Removes probe tip material
  - Compliance can affect the probe tip shape
  - Surface grit may polish a probe tip to a smooth finish instead of providing necessary texture
  - VHB™ (“Very High Bond”) adhesive layer makes the material difficult to remove

Polyurethane Foam Materials

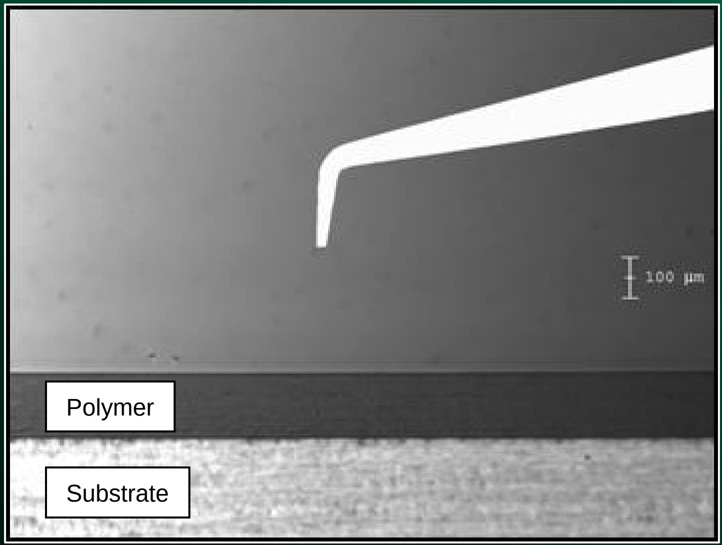


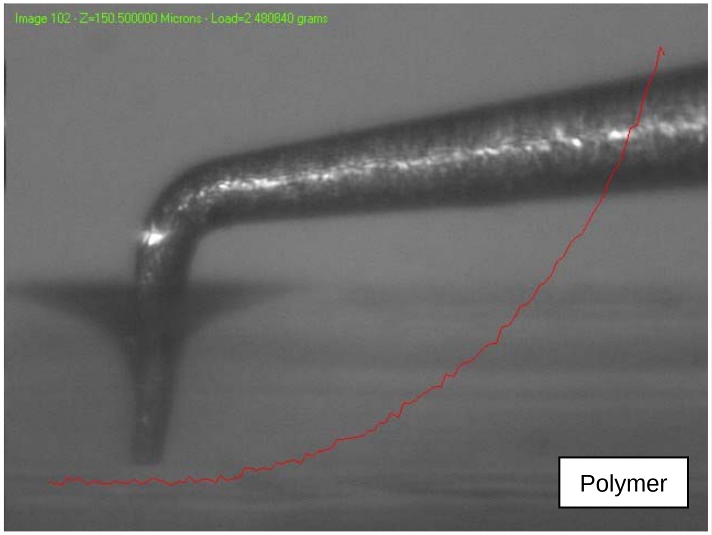


Cleaning affects tip shape.

- Description
  - Abrasive coating applied across a large cell porous polyurethane foam
  - Coating contains a dispersion of abrasive particles with various sizes
  - Abrasiveness of the material is controlled by the particle size
- Advantages
  - Removes adherent material from the contact surface and along the tip length
  - Used to maintain a radius shape to the probe tip
- Disadvantages
  - Variable surface height (> 200-μm)
  - Surface and sub-surface voids (> 200-μm)
  - Variable coating thickness
  - Extended usage “sharpens” the probe tip shape

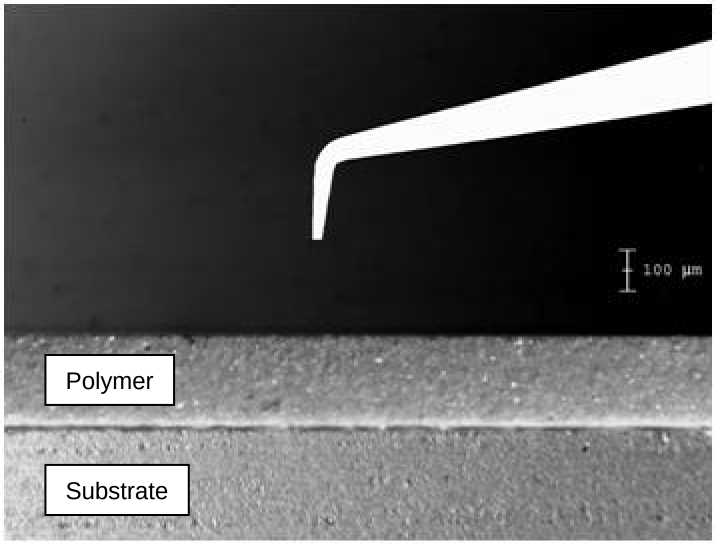
Unfilled Polymer Materials

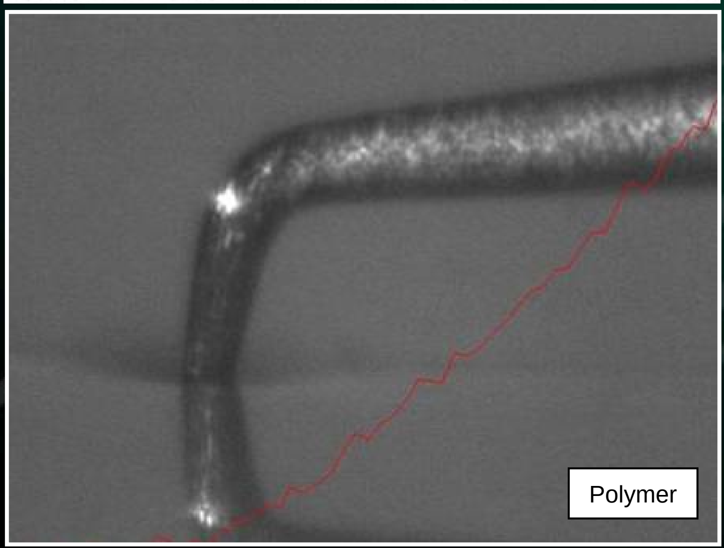




- Description
  - Unfilled, highly cross-linked compliant polymer material
  - Surface properties and bulk material properties are controlled for loose debris collection
- Advantages
  - Maintains probe card performance with no abrasive action
  - Key material properties can be modified
  - Removes adherent material from the contact surface, along the tip length, and other regions of the probe contact
  - Leaves no residue on probes or on DUT
  - -50C to 200C operating temperature
- Disadvantages
  - Lack of abrasiveness makes this material somewhat ineffective for tenaciously adherent materials

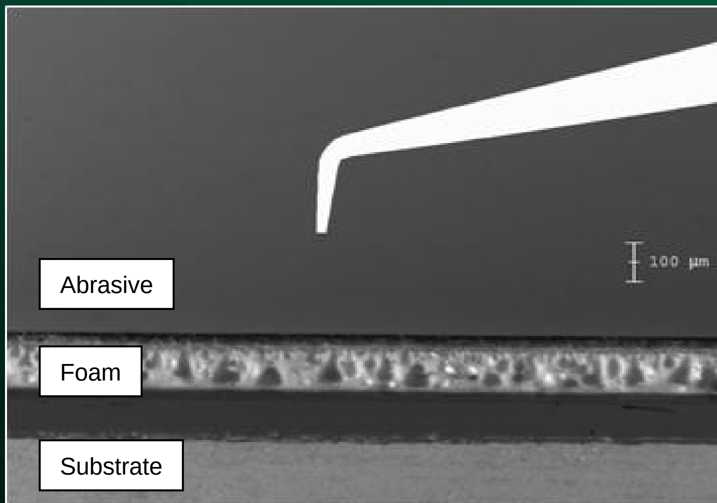
Filled Polymer Materials

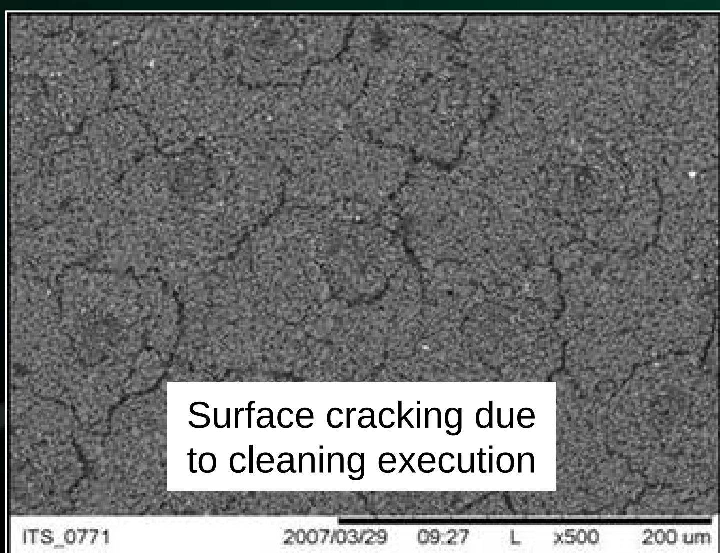




- Description
  - Highly cross-linked compliant polymer material with abrasive particles uniformly distributed across the entire cross-section
  - Hardness and surface tack used to for loose debris collection
  - Abrasive particle loading and size are used to control the polishing / forming properties
- Advantages
  - Maintains probe card performance with light polishing action
  - Key material properties can be modified
  - Removes adherent material from the contact surface and along the tip length
  - Leaves no residue on probes or on DUT
  - -50C to 200C operating temperature
- Disadvantages
  - Effectiveness for flat-tipped vertical and cantilevered probes process dependent
  - Additional cleaning insertions may be needed

Hybrid Materials

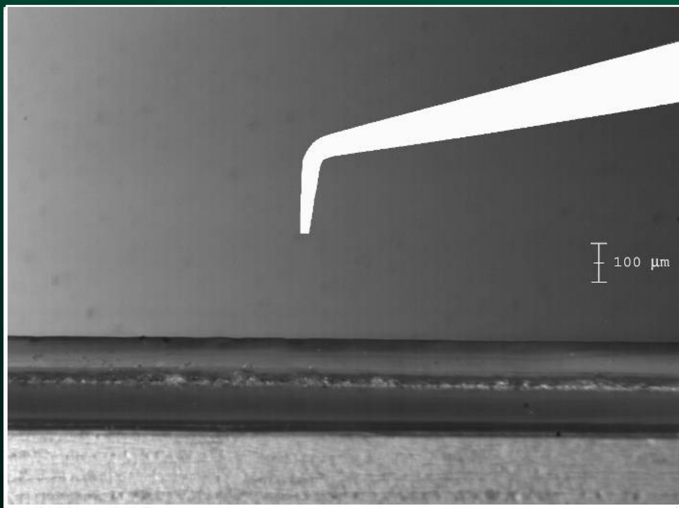


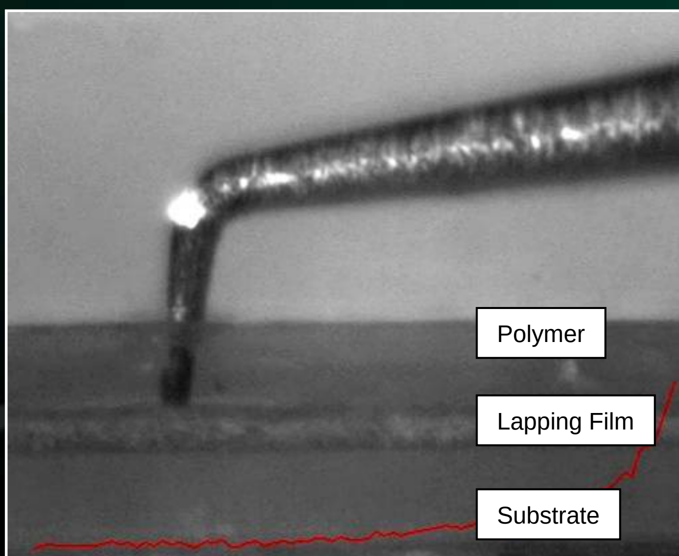


Surface cracking due to cleaning execution

- Description
  - Thin, solid abrasive coating applied across small cell porous foam material
  - Coating can contain abrasive particles with various sizes
  - Abrasiveness of the material is controlled by the particle size
- Advantages
  - Uniform thickness and surface morphology
  - Cushioned polyurethane base allows “soft and gentle” cleaning of the needles
  - Heat resistance up to 130C
- Disadvantages
  - Removes probe tip material
  - Internal variations below the layer of abrasive particles
  - “Witness Mark” during cleaning show surface cracks extend through abrasive coating

Hybrid Materials





- Description
  - Unfilled, highly cross-linked compliant polymer material applied across a lapping film
  - Abrasiveness of the lapping material is controlled by the particle size
- Advantages
  - Unfilled polymer collects debris from the tip length and other part of the probe
  - Key material properties of polymer can be modified to suit application
  - Precision lapping film removes “weld nugget” build-up on contact surface
  - Heat resistance up to 125C
- Disadvantages
  - The polymer layer must be fully penetrated before the probe tip can contact (and scrub against) the surface of the lapping film
  - Excessive utilization can cause delaminating between polymer layer and lapping surface

Discussion

- Rigid Substrate and Lapping Film Materials
  - Two wear primary mechanisms
    - Probe tip length reduction
    - Symmetric probe tip diameter increase
  - Smaller surface roughness and grit sizes have less effect on the tip shape; however, differences in the material removal rates due to the surface morphology were observed
  - Due abrasiveness of these materials, they are generally not suitable for fragile probe geometries and could cause significant damage to the contactors

Discussion

- Foam Materials
  - Non-uniform surface could pose problems during installation
  - Two wear mechanisms
    1. Probe tip length reduction
    2. Asymmetric probe tip “sharpening” as well as tip diameter reduction
  - Smaller grit sizes have less effect on the tip shape; however, the sharpened probe tips could damage the bond pad and the underlying structures
  - Material does not provide debris collection from the contact surface and tip shapes
  - Due abrasiveness and non-uniform surface morphology of this material, it is not suitable for fragile probe geometries and could cause significant damage to the contactors

Discussion

- Polymer Materials
  - Unfilled polymers have no abrasive qualities and are primarily designed for debris collection
    - Completely a non-destructive cleaning operation
  - Ineffective for tenaciously adherent materials
  - Filled polymers provide light abrasive action to remove tenaciously adherent contamination from the contact surface
    - Minimal effects on the tip geometries
  - Due to the mechanics of the tip / polymer contact interaction, the materials may not be effective for flat tip geometries
  - A large number of cleaning insertions (relative to the fully abrasive materials) may be required to completely remove contaminants

Discussion

- Hybrid Materials
  - Two wear mechanisms identified
    1. Probe tip length reduction
    2. Symmetric probe tip diameter increase
  - Smaller grit sizes had less effect on the tip shape; however, differences in the material removal rates due to the surface morphology were observed
  - Abrade “weld nuggets” from the contact surface of the probe tip and provide some debris collection

Other Considerations

- Consistent geometrical, morphological, and mechanical properties for consistent probe / cleaning material interaction
  - Uniform cross section and surface morphology
  - Repeatable and reproducible mechanical behavior
- Sufficient polishing / cleaning action to control and maintain CRES performance
- Thermal stability with minimal property variations
  - -50C to 185C (and higher)
- Applicability to probe card technologies (conventional and advanced)
  - Cantilevered probes with flat, radius, semi-radius tips
  - Vertical with flat, wedge, radius, and pointed tips
  - Photo-lithographically based
  - MEMs based technologies
  - Others ?

Selection Matrix "Eye Chart"

	Morphology		Mech.	Cantilevered Probe Tip Wear			Debris	Temp	Cantilevered			Vertical - Cobra			Advanced
Description	Surface	X-Sect.	Perform	Length	Diam.	Shape	Collect	Range	Flat	Radius	Semi	Flat	Wedge	Point	Contacts
Rigid Substrate					increase	flat	N	-50C to 125C	Lapping			Contact Supplier			Contact Supplier
Polyester Backed Lapping Film					increase	flat	N	-50C to 125C	Lapping						
Lapping Film on VHB Foam					increase	flat	N	?	Lapping						Contact Supplier
Large Cell Foam					sharpen	pointed	N	-30C to 130C				Contact Supplier			Contact Supplier
Unfilled Polymer					no change	no change	Y	-50C to 200C	Debris Only	Debris Only	Debris Only				Contact Supplier
Filled Polymer					no change	little change	Y	-50C to 200C	Debris Polish	Debris Polish	Debris Polish				Contact Supplier
Abrasive Layer Small Cell Foam					increase	flat	N	-??C to 130C							Contact Supplier
Polymer Layer on Lapping Film					increase	flat	Y	-50C to 125C	Debris Nugget						Contact Supplier

- Optimal on-line cleaning materials selection during wafer sort is a critical element of integrated chip manufacturing process
- Industry is requesting probe technology + cleaning solution
- Economic benefits of "educated" cleaning are best realized with high value devices and probe card technologies
  - Throughput and uptime improvements
  - Increased wafer yields
  - Extended probe card service life and performance

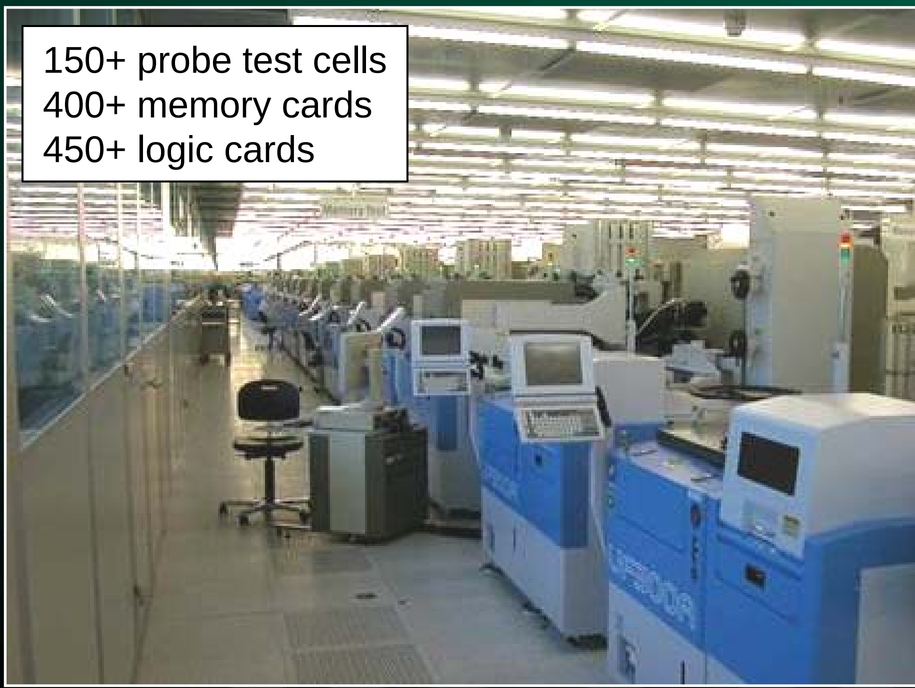
PART II – Implementation

Probe Cleaning for HVM Wafer Sort

Examples of HVM Sort-floors

Qimonda

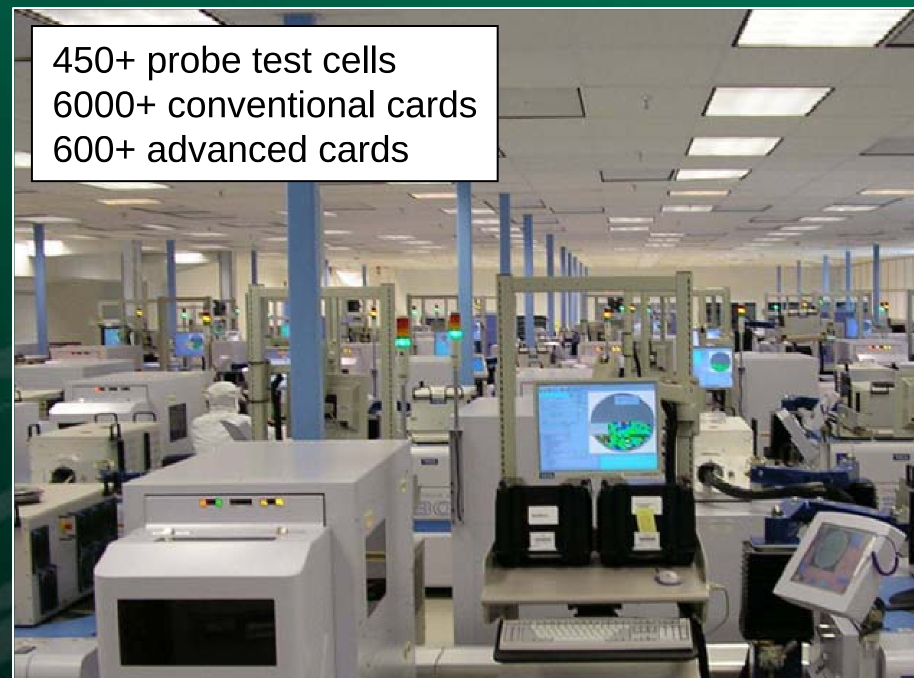
150+ probe test cells
400+ memory cards
450+ logic cards



Pietzschmann, et al., SWTW-2005
Pietzschmann, SWTW-2006

Texas Instruments

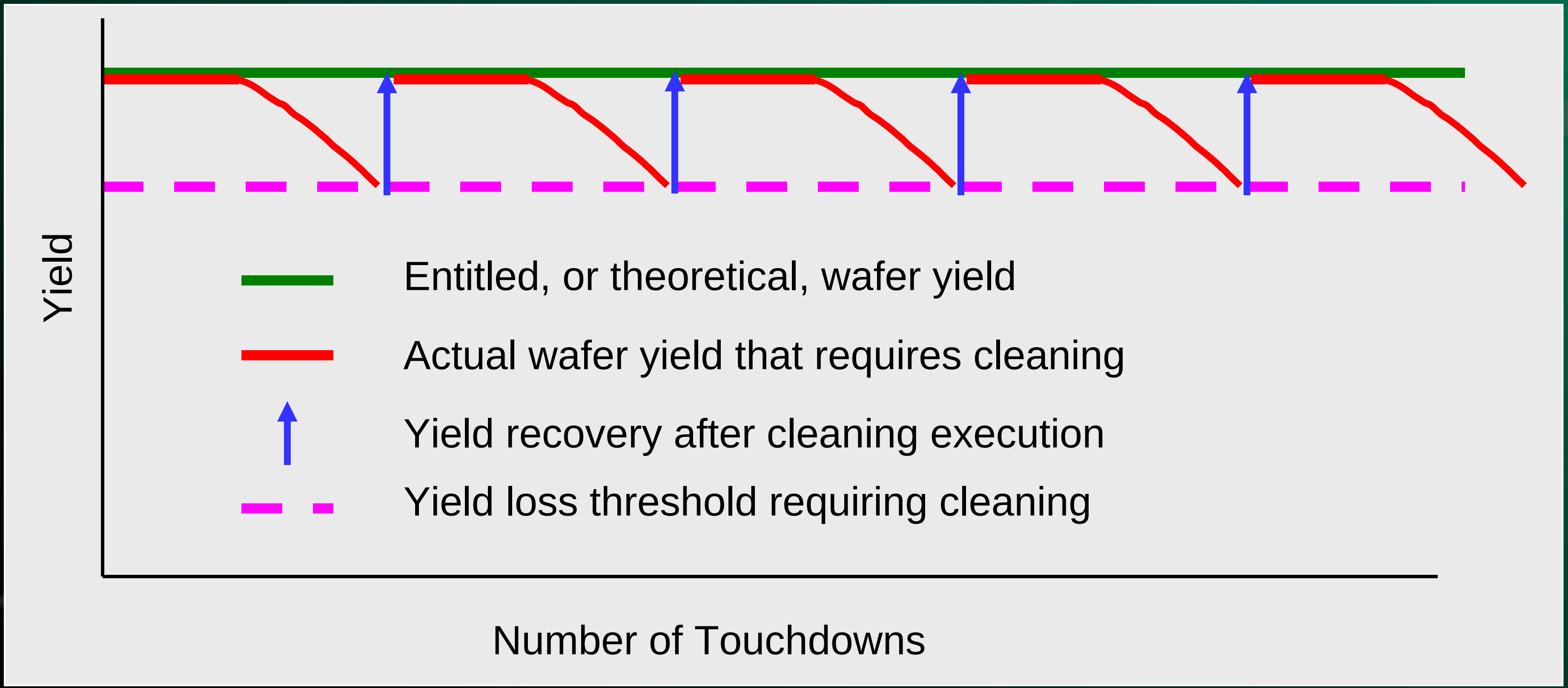
450+ probe test cells
6000+ conventional cards
600+ advanced cards



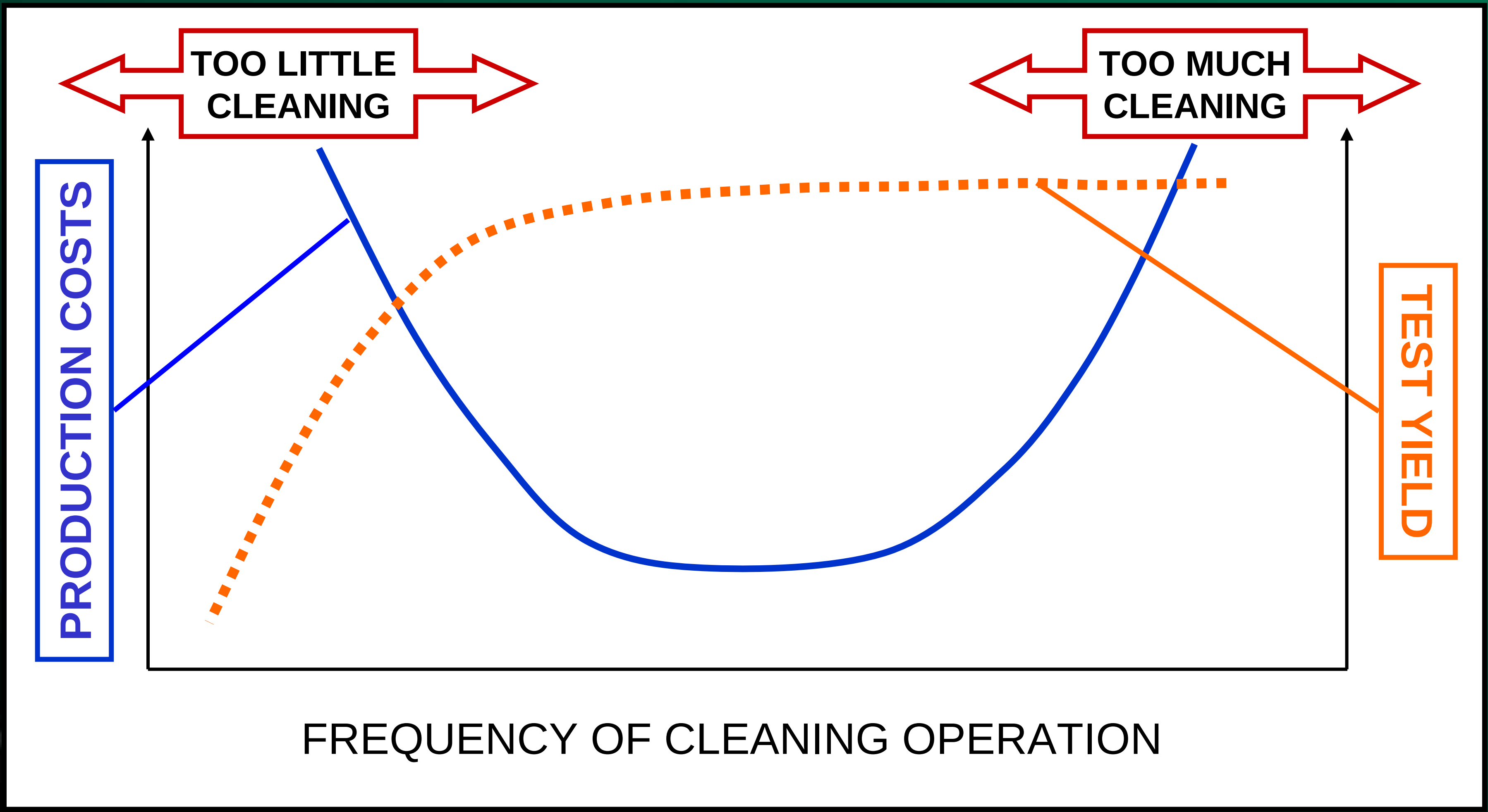
Wegleitner, et al., SWTW-2005
Harris, SWTW-2006

Probe Cleaning for HVM Wafer Sort

- Excessive cleaning reduces test throughput without yield benefits.
- Too little cleaning adversely affects test yields and affects uptime.



Generalized "Costs of Cleaning"



Goals of Online Cleaning

- Increased manufacturing revenue
  - Increase test yield
  - Extend contactor life and maintain tip shape
  - Reduce CRES and site-to-site dependant failures
  - Reduce spare probe card inventories
  - Reduce potential damage from handling
- Increased and maximized throughput
  - Optimize Overall Equipment Effectiveness
  - Eliminate the need for off-Line cleaning
  - Reduce operator intervention
- Improved environmental Health & Safety
  - Trap airborne particulates
  - Reduce debris accumulation

How Do I Choose ?

Probe Card Type
- "Conventional"
- "Proprietary"

Device Metallization
- Aluminum
- Aluminum-capped
- Tin / Lead Bumps
- Lead-Free Bumps
- Bare copper

Cleaning Materials
- Debris collection
- Abrasive
- Semi-abrasive

Temperature
- -40C (or lower)
- Ambient
- +155C (or higher)

What's the Best Combination !!

Electrical
- High Current
- CRES Sensitivity

Prober Settings
- Test Cell "Integrity"
- Cleaning Overdrive
- Number of Touchdowns
- Cleaning Frequency
- Stage Performance

Probe Tip Shape
- Cantilevered Tips
- Vertical Tips
- Pyramid Probe
- MEMs Defined
- Proprietary Geometries

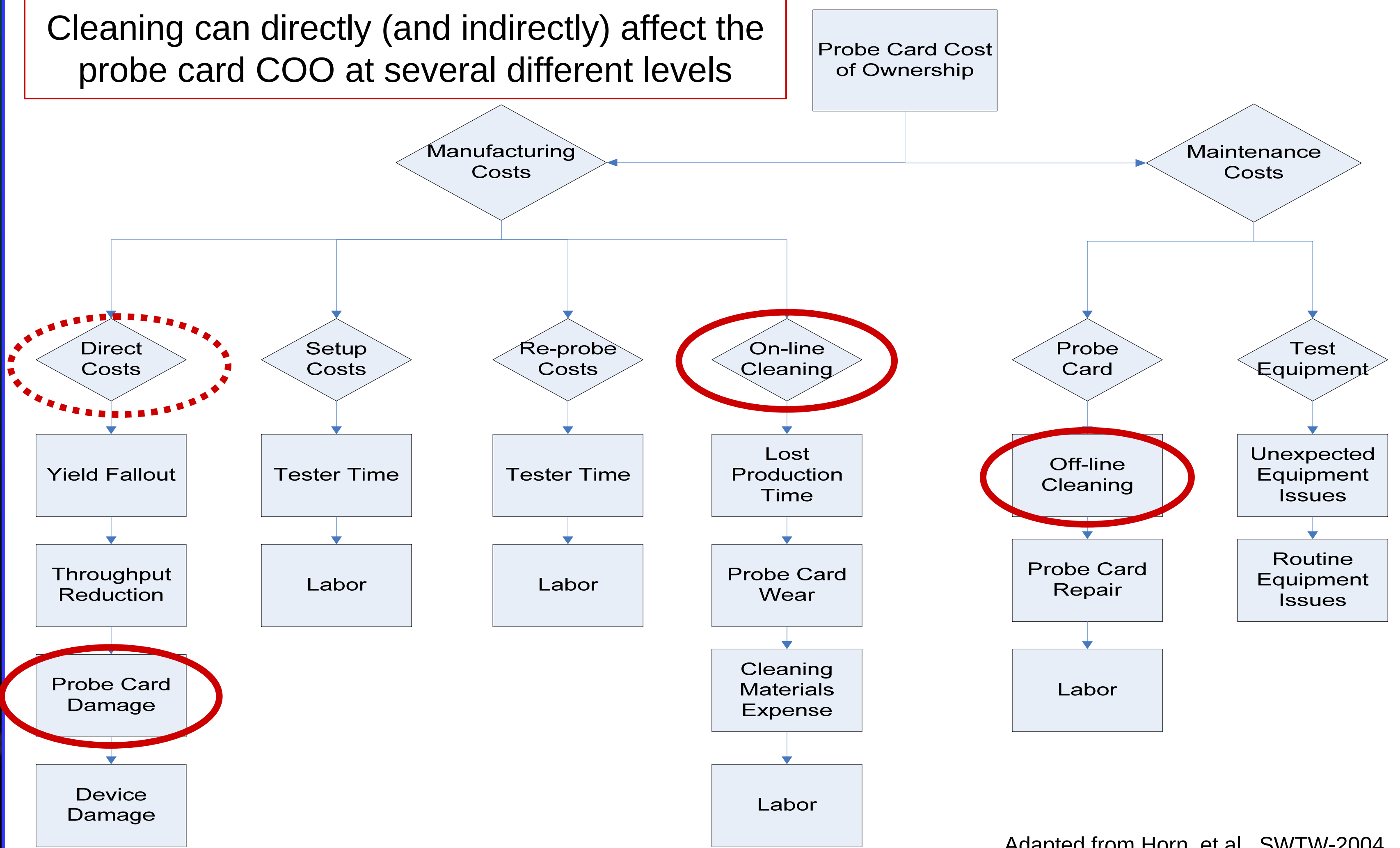
Probe Materials
- "Conventional"
- "Proprietary"

Cleaning Material Selection Criteria

- Applicability to probe card technologies being used for sort.
  – Probe tip shape and tip material
- Overall cleaning performance
  – Uniform surface and cross-sectional morphology for prober setup
  – Consistent performance during repeated insertions
- Process Requirements
  – DUT probe pad or bump metallurgy
  – Probe tip size and shape limits
- Temperature range during each sort operation.
- Economics
  – Total Cost of Ownership should be assessed; often <u>ONLY</u> the "initial costs" are considered.

Probe Card COO in an HVM

Cleaning can directly (and indirectly) affect the probe card COO at several different levels



Adapted from Horn, et al., SWTW-2004

Revisit Selection Matrix "Eye Chart"

	Morphology		Mech.	Cantilevered Probe Tip Wear			Debris	Temp	Cantilevered			Vertical - Cobra			Advanced
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- End-users with multiple probe-card technologies and demanding device requirements may have several different cleaning materials and recipes
- Often a sound "best guess" from past experience is implemented
- Probe card technology + cleaning solution are defined by the probe card manufacturer

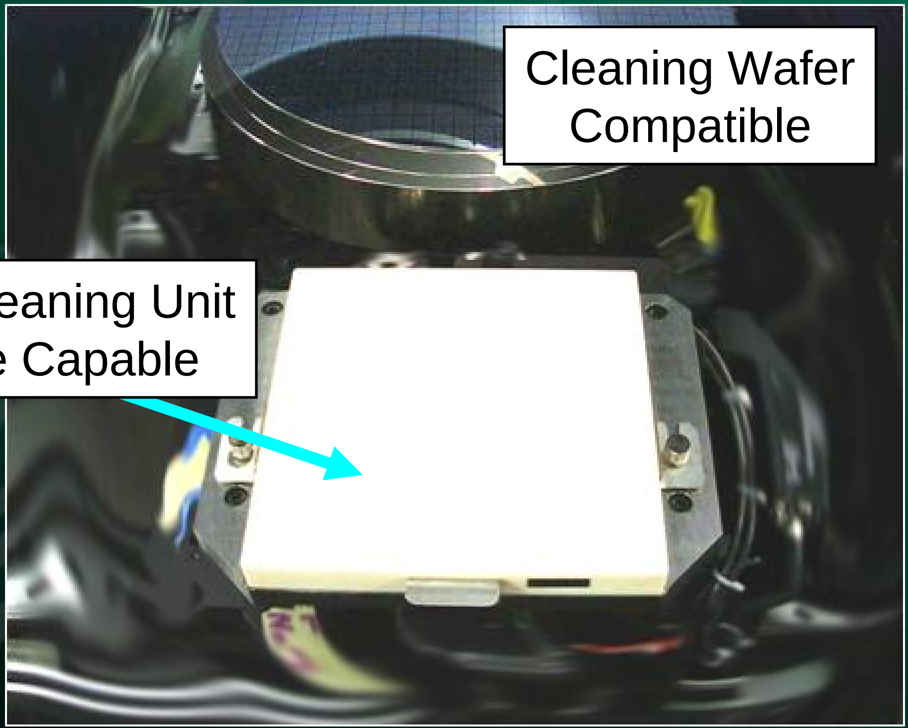
Utilization Overview

- Online utilization methods
  - Materials are applied to cleaning blocks that reside within the wafer.
    - Small blocks range in size from rounds and rectangles
    - Large area units facilitate cleaning recipe optimization
  - 150, 200, and 300-mm cleaning wafers
- Advances in cleaning execution performance
  - Profiling for surface recognition and consistent cleaning overtravel
  - Multi-zonal cleaning for abrasive + debris collection cleaning optimization
  - Efficient stepping patterns and stage translation during cleaning execution

Cleaning Material Utilization

- Accretech UF™ series wafer prober
  - 200-mm and 300-mm cleaning wafer handling
  - Capable of one to three zones on cleaning unit
  - Multiple brush cleaning zones with various natural and synthetic fibers

http://www.accretechusa.com

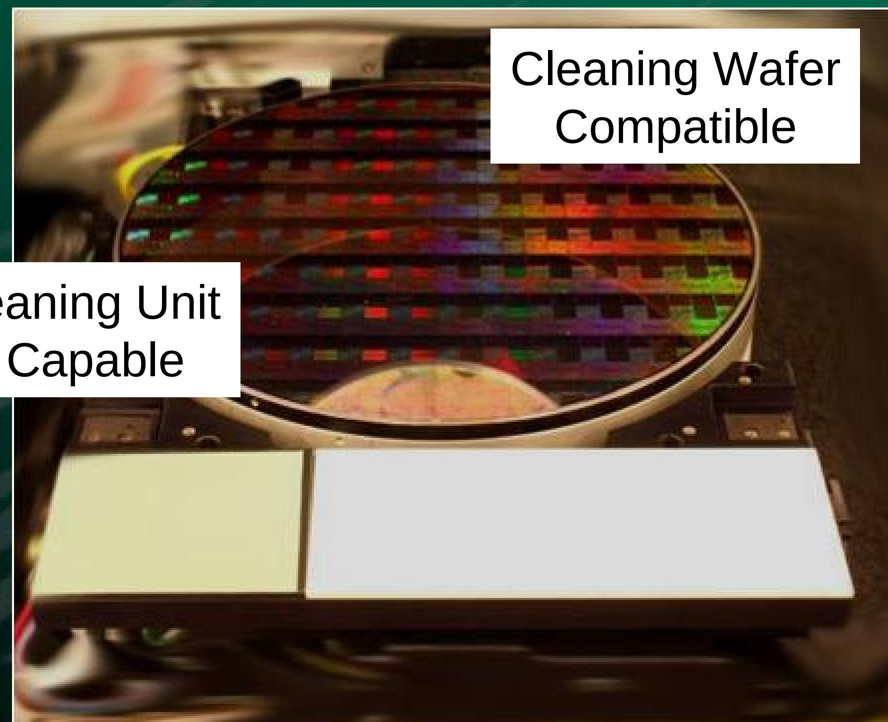


Courtesy of Accretech

Cleaning Material Utilization

- Electroglas EG6000™ series wafer prober
  - 200-mm and 300-mm cleaning wafer handling
  - Capable of one to three zones on main abrasion plate
  - Up to seven cleaning zones are available
  - Multiple brush cleaning zones with various natural and synthetic fibers

Large Area Cleaning Unit
Multiple Zone Capable



http://www.electroglas.com

Courtesy of Electroglas

Cleaning Material Utilization

- Tokyo Electron Limited (TEL) P12XL™ series wafer prober
  - 200-mm and 300-mm cleaning wafer handling
  - Capable of multiple zones on main polishing plate
  - Brush cleaning zones with various natural and synthetic fibers

http://www.tel.com

Courtesy of Tokyo Electron Limited

Online Cleaning Operational Considerations

Cleaning Block

- Cleaning block (or unit) …
  - Advantages
    - Cleaning execution can be performed frequently and quickly with small reductions in throughput
    - Multi-zone capable and compatible with hot and cold probing operations
  - Disadvantages
    - Potential for deflection issues on older probers
    - Some probers do not profile the cleaning surface
    - Contact height of the cleaning area is manually defined
      - Compliant materials (polymer and foams) need more care when mechanically detecting the surface of the material
    - Size limitation when cleaning large area array probe cards
    - Manual installation of cleaning materials (bubbles, defects, contaminants)

Cleaning Wafer

- Cleaning wafer …
  - Advantages
    - Compatible with large area probe cards
    - Accepts very large probing forces
    - Cleaning surface is well defined during the wafer loading operation for consistent overtravel.
  - Disadvantages
    - Long cleaning cycle times due to loading, profiling, unloading, and reloading operations.
    - Not multi-zone capable
    - Stored within the prober and potentially exposed to airborne contamination.
    - Some size limitations when cleaning 2-touch and 1-touch large area array probe cards

Multi-Zone Cleaning

- Advantages
  - Enables the prober to handle many varieties of cleaning materials for multiple probe card technologies
  - Prevents potential cross-contamination issues when probing different metallizations with the same prober
  - Facilitates combinations and execution sequences for maintaining tip shape and extending probe card life.
- Disadvantage
  - Probe card technology + cleaning material tracking is critical to prevent catastrophic damage.
  - Reduces the available cleaning area and could affect usage for large card arrays.
  - One area may be fully utilized before the other.

Cleaning Parameters

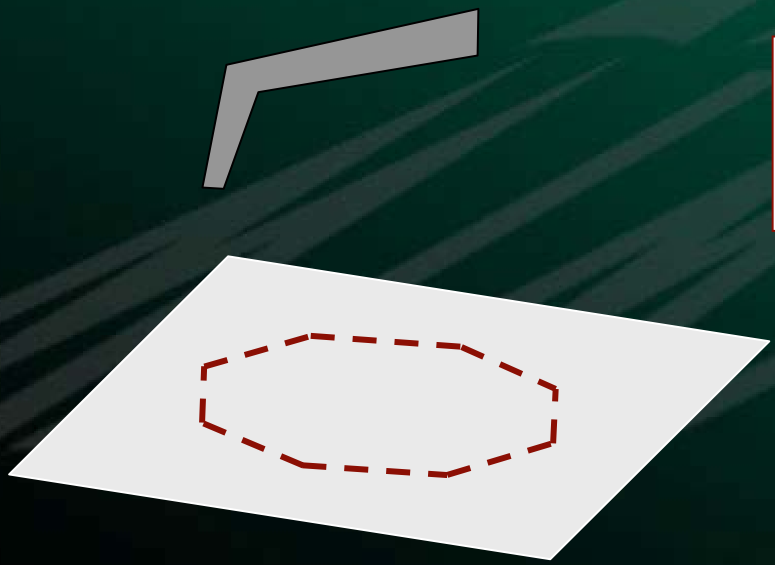
- Cleaning before "Lot Start"
  - Probe cleaning cycle is executed before sort begins
    - Purpose – remove particles, oxides, or other contaminants that may be present on the probe tips since the probe card was last used
- Cleaning after "Lot End"
  - Probe cleaning cycle is executed after sort ends prior to storing the probe card or at the lot change.
    - Purpose – to insure that a clean probe card is put into storage or that materials are not carried over

Cleaning Parameters

- Cleaning overtravel (or overdrive)
  - Overtravel used during each insertion during a cleaning cycle
    - Often the cleaning overtravel is set to equal probing overtravel
    - Cleaning overtravel can be adjusted to reduce wear rate or improve cleaning
- Stepping (or index)
  - Most wafer probers have optimized stepping patterns
    - Algorithms are based on the needle array or device pad layout for maximum utilization of the cleaning area
  - "Fresh" clean material with each insertion for greatest cleaning efficiency
    - Rule of Thumb: Step offset ~ 2.5x probe tip surface diameter

Cleaning Parameters

- XY translation at overtravel during cleaning (scrubbing)
  - Some flat tip probes need some type of XY scrubbing motions
    - X-only, Y-only, L-shape, squares, octagon, orbital
  - Not all cleaning media can withstand or support this type motion
    - Translation motion can damage the cleaning material surface
    - Mechanical stresses on the probe in all directions during this cleaning action could overstress, damage, or misaligned needles



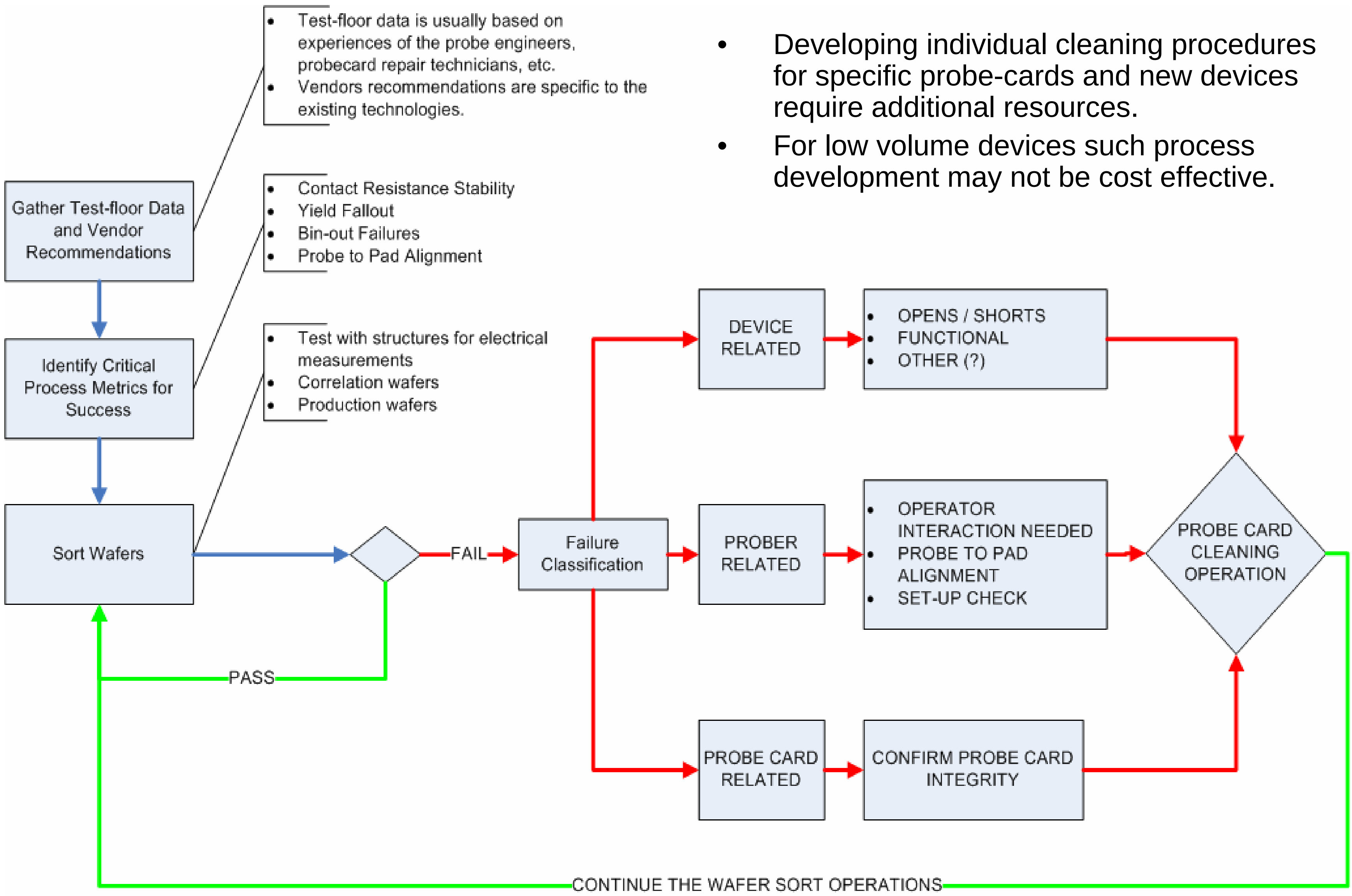
Example of octagonal cleaning motion for Illustrative purposes

Cantilevered probes are generally cleaned with a z-only motion

One Approach to Cleaning Recipe Development

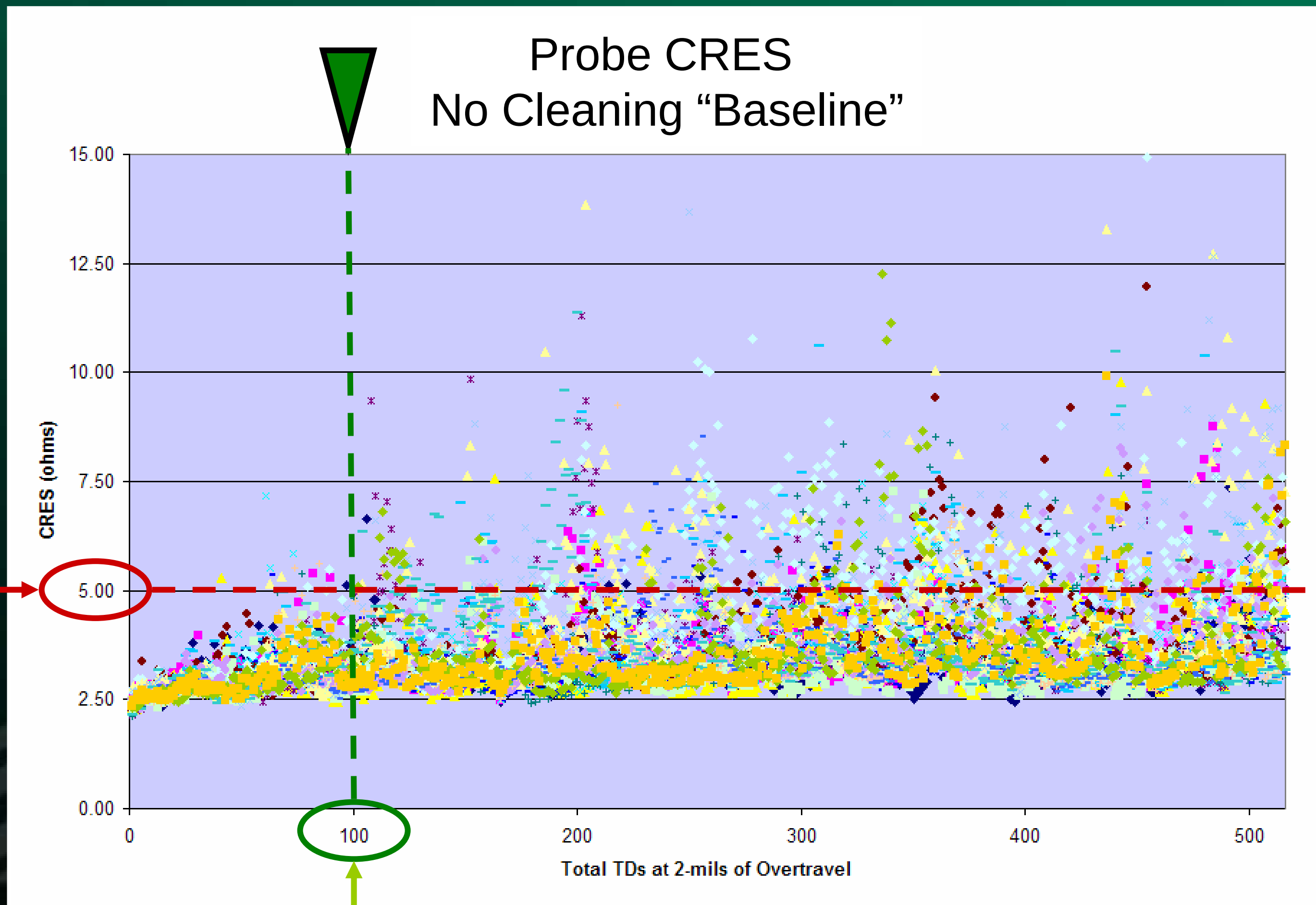
General Procedure

- Developing individual cleaning procedures for specific probe-cards and new devices require additional resources.
- For low volume devices such process development may not be cost effective.



Defining a Cleaning Recipe

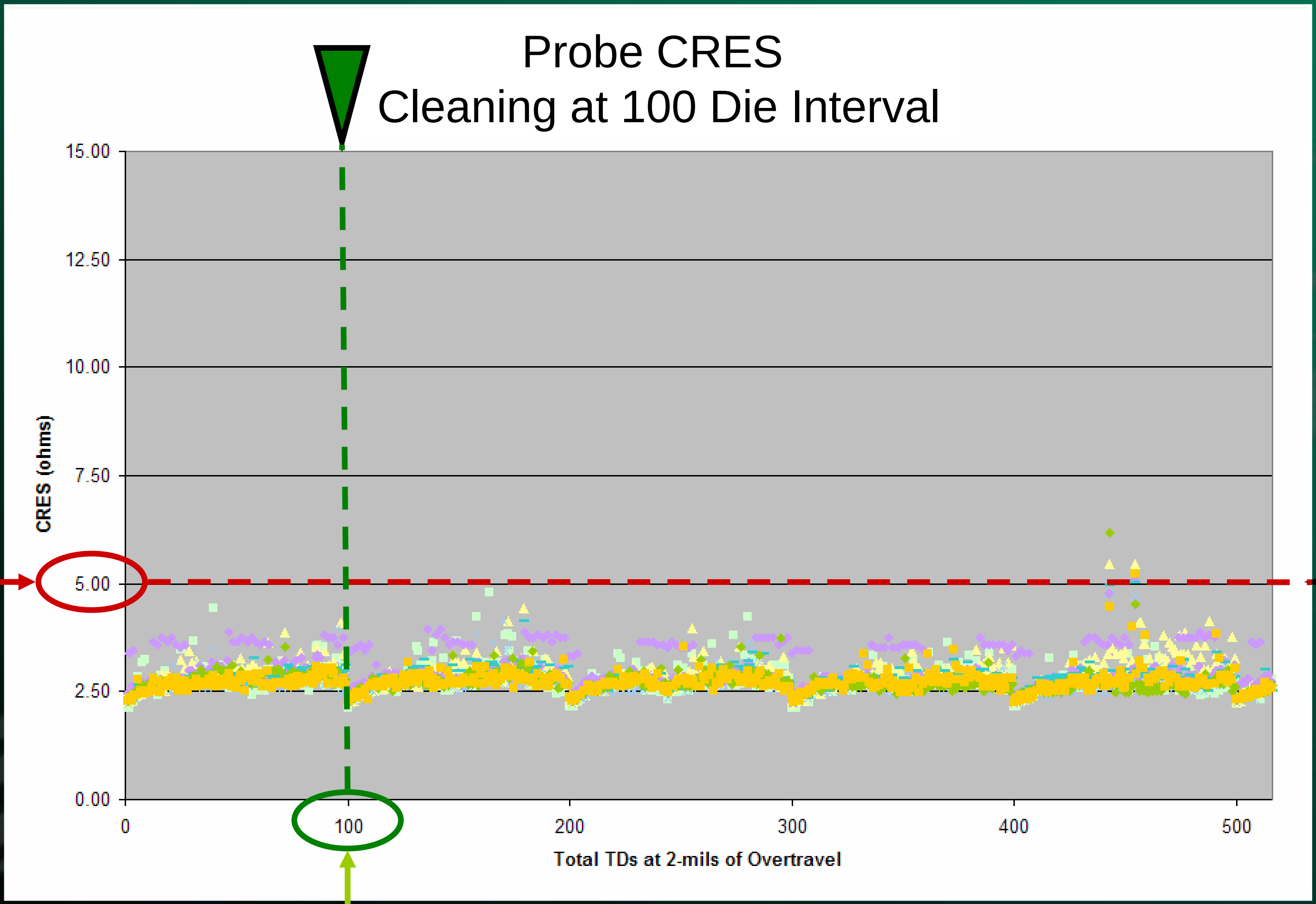
CRES = 5-ohm Specification Limit for Yield Fallout



To maintain yield a cleaning Frequency at 100 Die Interval

Broz, et al., SWTW-2005

Defining a Cleaning Recipe



CRES = 5-ohm Specification Limit for Yield Fallout

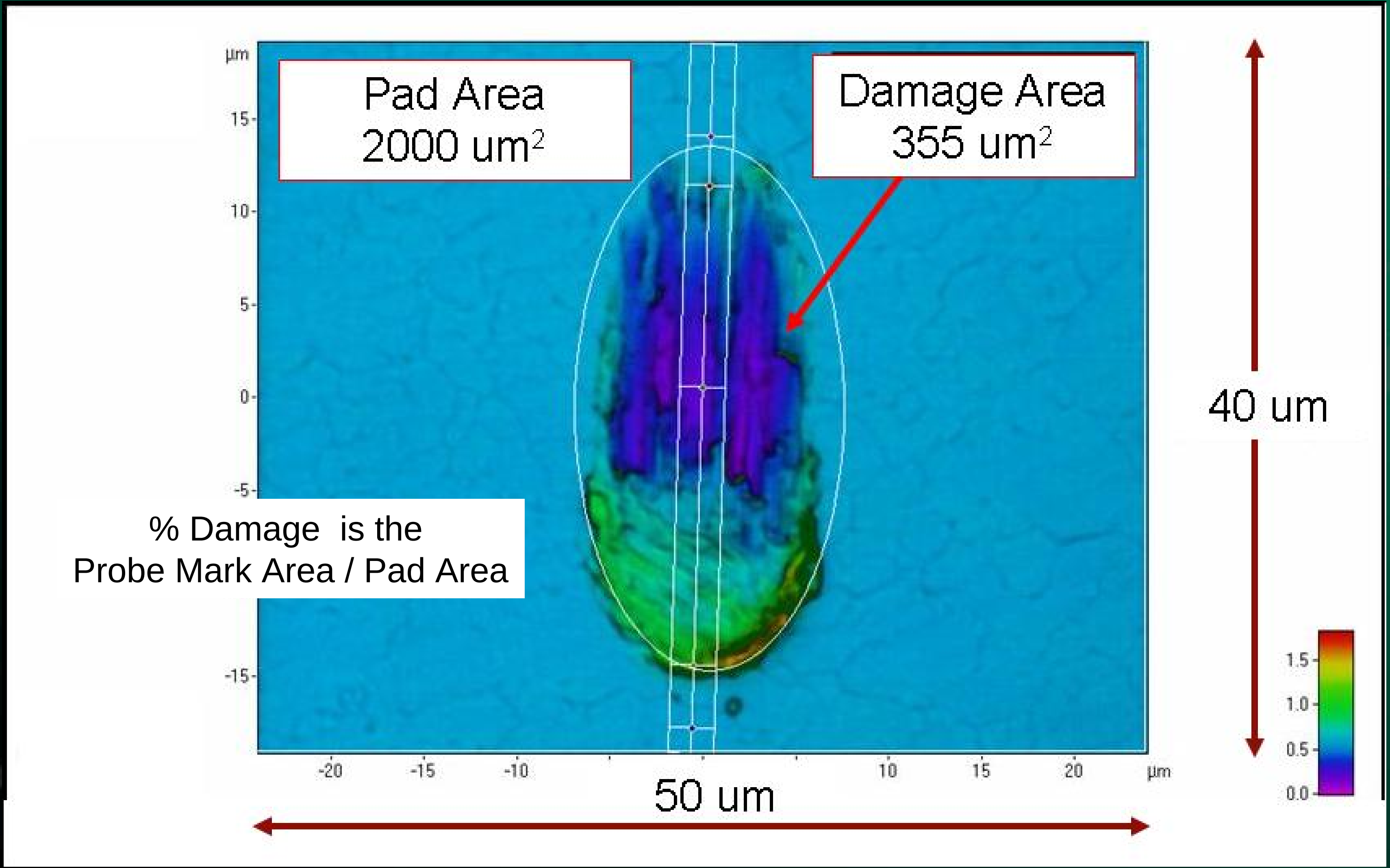
To maintain yield a cleaning Frequency at 100 Die Interval

Broz, et al., SWTW-2005

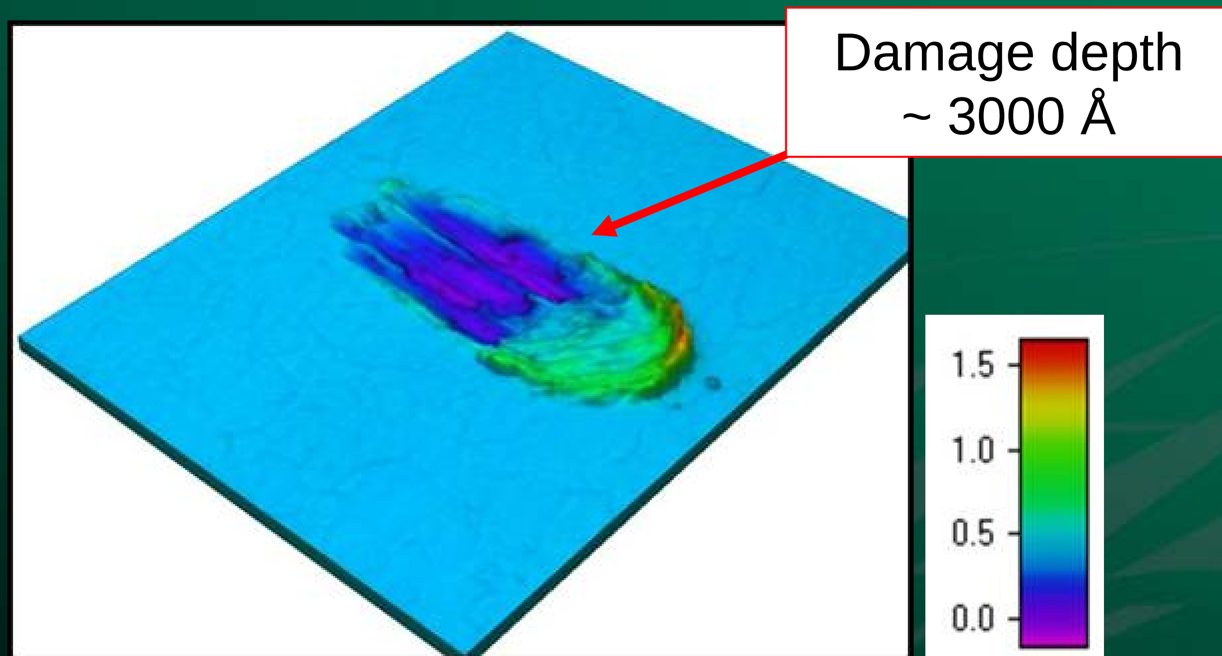
Cleaning Affects More Than CRES

- Controlled probing is critical for high dollar devices
  - Excess pad damage due to probe has been positively correlated to bondability and long term reliability defects
  - Excessively deep probe marks damage and crack low-k dielectrics, circuitry under bond pads, and aluminum caps
- Probe tip geometry changes from abrasive cleaning can have detrimental and long term affects for the device
  - Increased tip diameter due to abrasive cleaning materials
    - Reduced contact stresses for CRES instability
    - Higher area damage across the bondable area
  - Reduced or sharpened tip diameter due to shaping materials
    - Substantially increased contact pressure at the probe tip
    - Deeper probe marks and barrier metal cracking
    - Probe to pad alignment issues

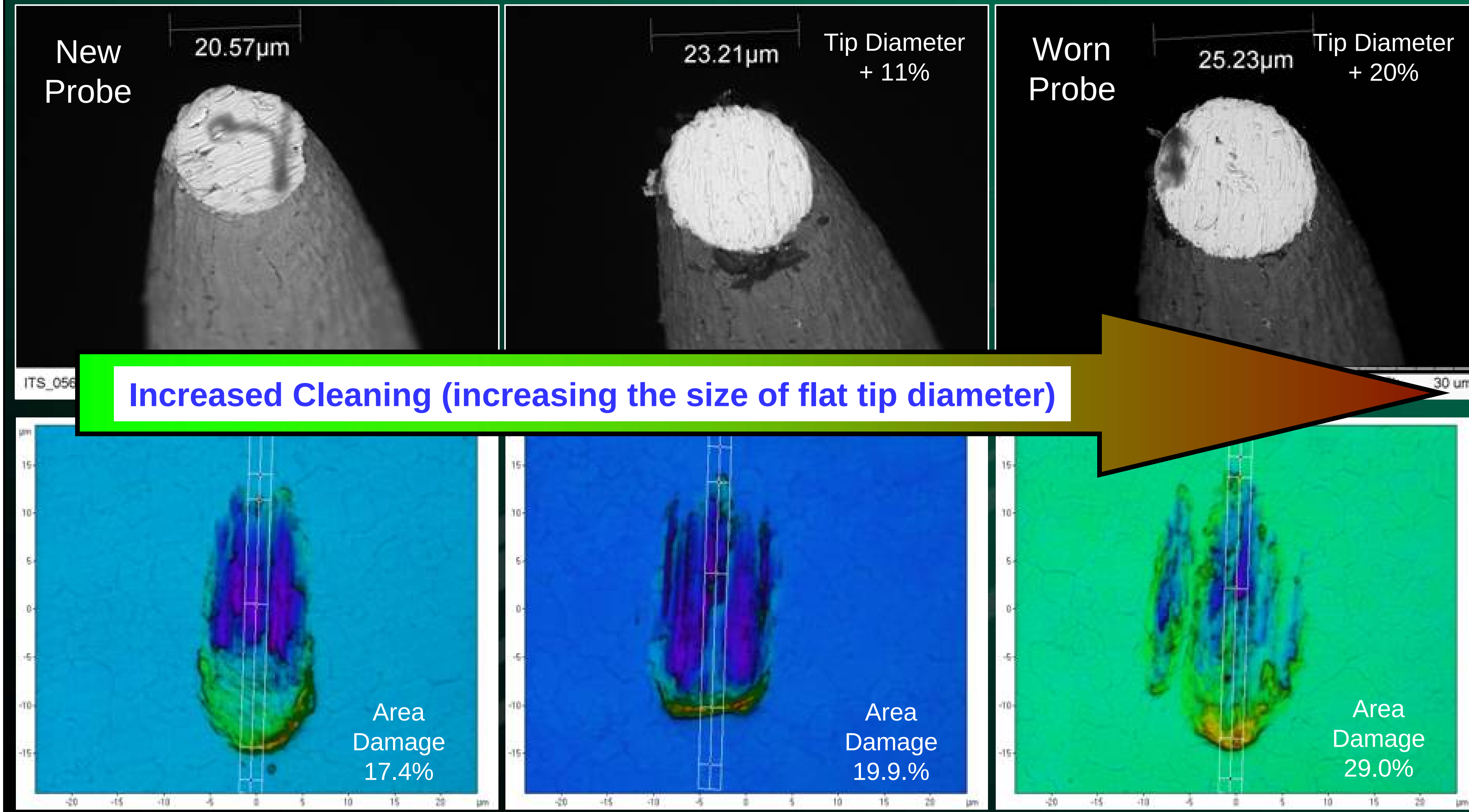
Virtual Pad for Probe Damage



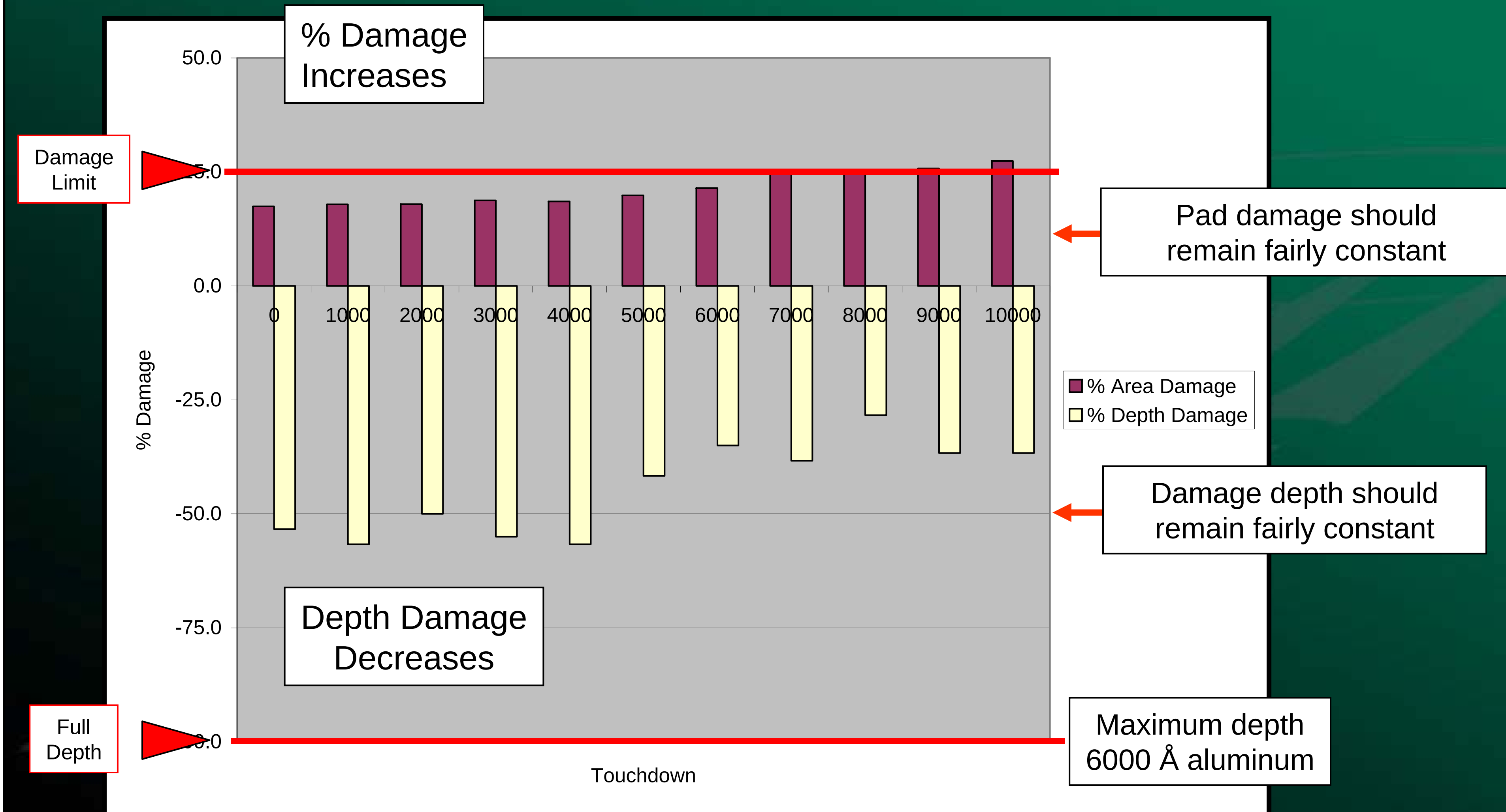
Virtual Pad for Depth Damage



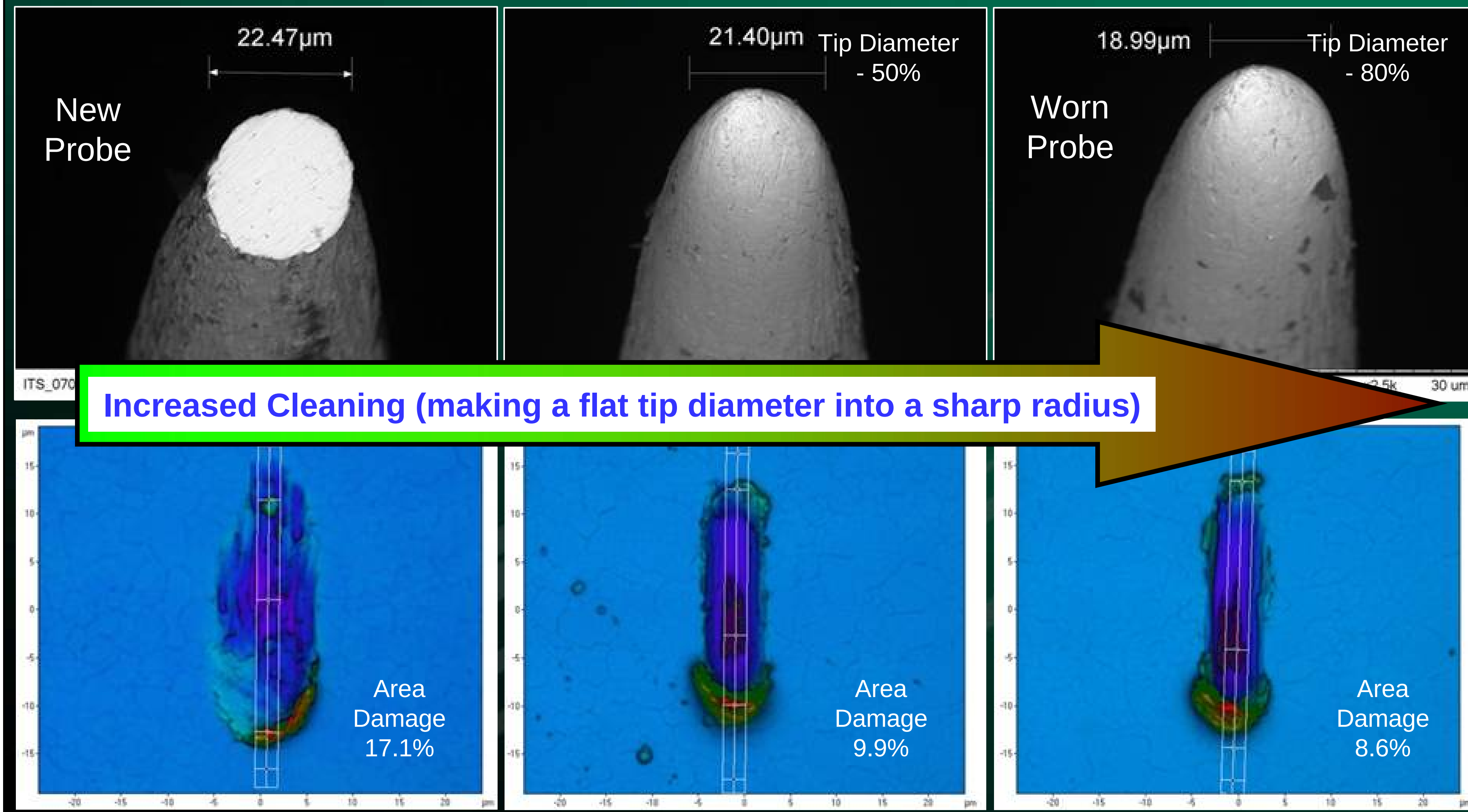
Increasing Tip Diameter



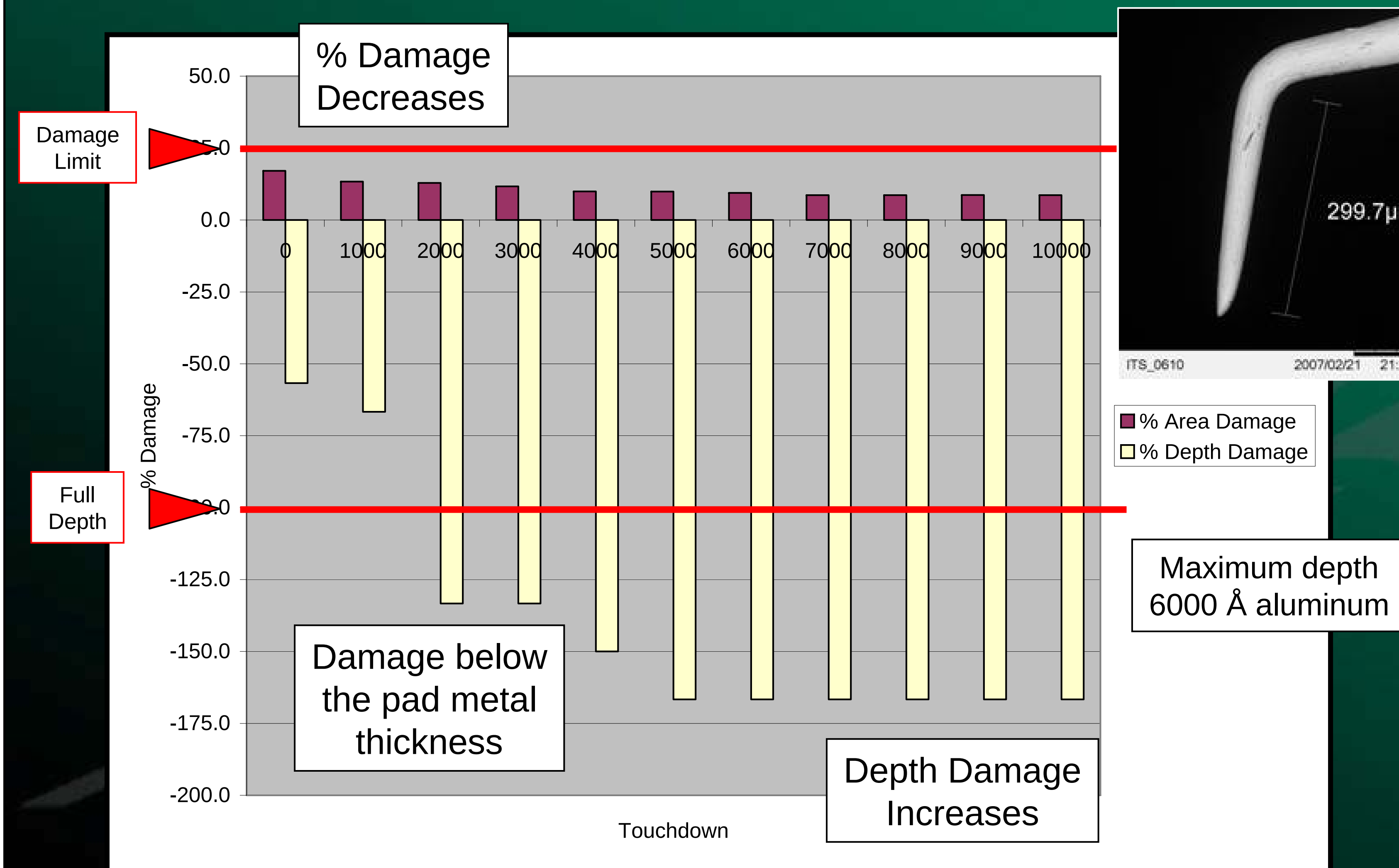
Pad Damage Assessment



Decreasing Tip Diameter



Pad Damage Assessment



Summary

- For all technologies, some level of probe cleaning IS needed
- High yield fallout can occur with continuous probing due to CRES instability
  - Probes generate, accumulate, and pick up debris during sort that affects CRES
  - Abrasive cleaning (considered a "low cost" solution) has been used to control the CRES of many probe card technologies for years
  - "Advanced" probe card technologies are sophisticated and can be VERY high dollar; however, "low tech" practices and "low dollar" materials are frequently used on the sort-floor
- Online and offline probe cleaning practices are utilized to reduce CRES and stabilize yields
  - Proper cleaning can have a direct and measurable impact on the net revenue generated by a sort-floor
  - Probe cleaning affects all aspects of Overall Equipment Effectiveness
- Optimal on-line cleaning materials and processes are a critical element of wafer level test.
  - Probe technology + optimal cleaning solution = HIGH YIELD
- Individual cleaning procedures for specific probe-cards and new devices are being developed

Thanks for Attending …

Questions ???

Please enjoy San Diego and the SW-Test Workshop !