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Eliminating Dielectric Cracking of Cu/Low-k Devices During Cantilever Probing

D. Stillman and C.D Hartfield

Texas Instruments, Dallas, TX

SOUTHWEST TEST WORKSHOP

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Outline

- Objective
- Background
- Approach
- Needle Modification
- Test Results
- Summary

Objective

- Eliminate cracking of low-k dielectric material induced by cantilever probing
- Show the effects of cantilever needles on low-k material
- Review the features of the cantilever needle that effect low-k dielectric cracking
- Cantilever needle design alteration needed to eliminate dielectric cracking

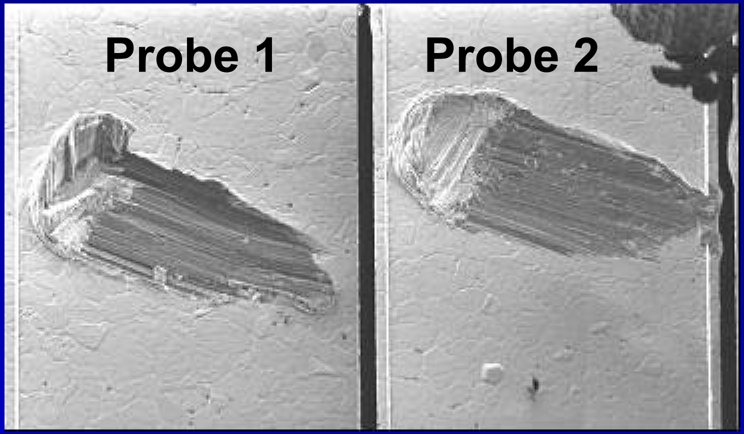
Background

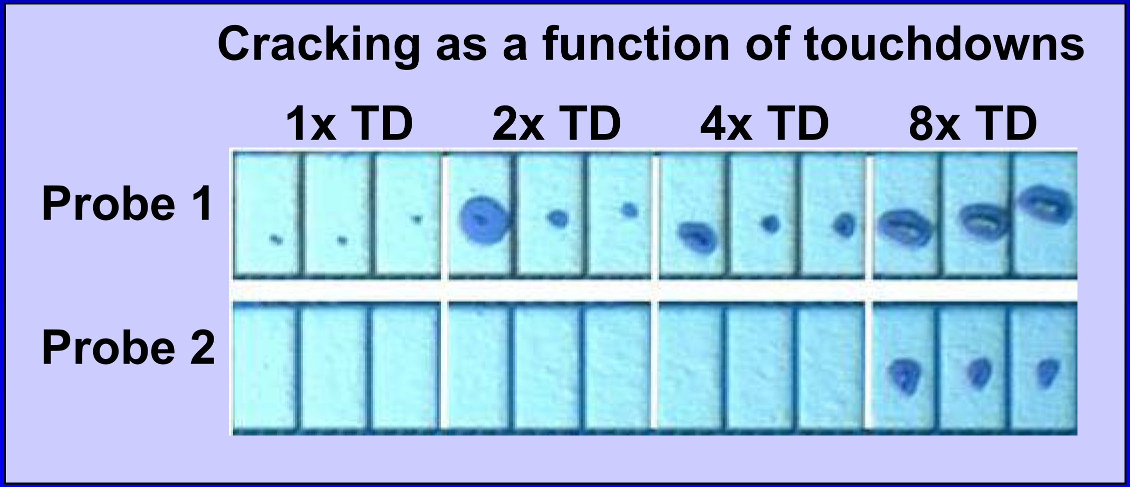
- Probe –induced cracking of devices is an ongoing test industry issue. Damage to Cu/Low-k devices during fabrication, probe, and assembly is a long-term reliability concern
  - **Low-k materials tend to have lower modulus and hardness**
  - **Fracture toughness reduced; difficult to measure**
- Low-k dielectrics are in a class of their own when it comes to fracture toughness and Youngs Modulus
  - **low modulus of elasticity and a extremely small fracture toughness equals a high probability of cracking.**
- TI: Metal structures changed and probing refined to eliminate probe cracks in look ahead builds, allowing successful qualification and ramp (unpublished information, ~1999).
  - **Chartered: Probe-induced IMD cracks cause infant mortality failures having high resistance (ISTFA 2003).**
- IBM: probe damage occurs with SiLKlow-k dielectric (ISTFA 2001)
  - **□□“The intrinsic inability to control tip contact forces with conventional tungsten tip probing techniques results in damage to the Cu interconnects and deformation of the underlying low k dielectric film.”**

Background

- Experiments show that probe force is not the only leading factor causing cracking.
  - Two needles
  - Identical force
  - Different scrubs and cracks results

Hartfield et al., SWTW 2003
Hartfield et al., ITSFA 2003
Hartfield et al., SWTW 2004

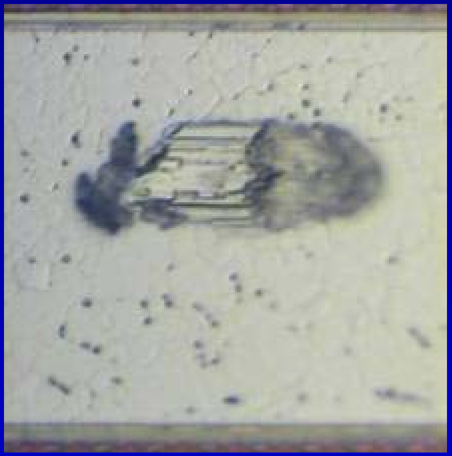




Background

- BCF was a key factor in cracking in past technology nodes.
- Different vendors showing different results in scrub marks and cracking.
- Scrub mark shape correlates to cracking of low-k dielectrics.
- Scrub shape correlates with probe tier.
  - **Majority of dielectric cracking is induced by needles on tiers one and three on a 6 tier quad site shelf probe card**

Horse shoe crab scrub marks- no cracking



Comet scrub marks- cracking

Approach

Probe

Full flow wafer
+ Probe card

Probe multiple touchdown numbers

Inspection/Documentation

Photos

- Incoming scrub marks
- Post wafer saw
- Post wet etch

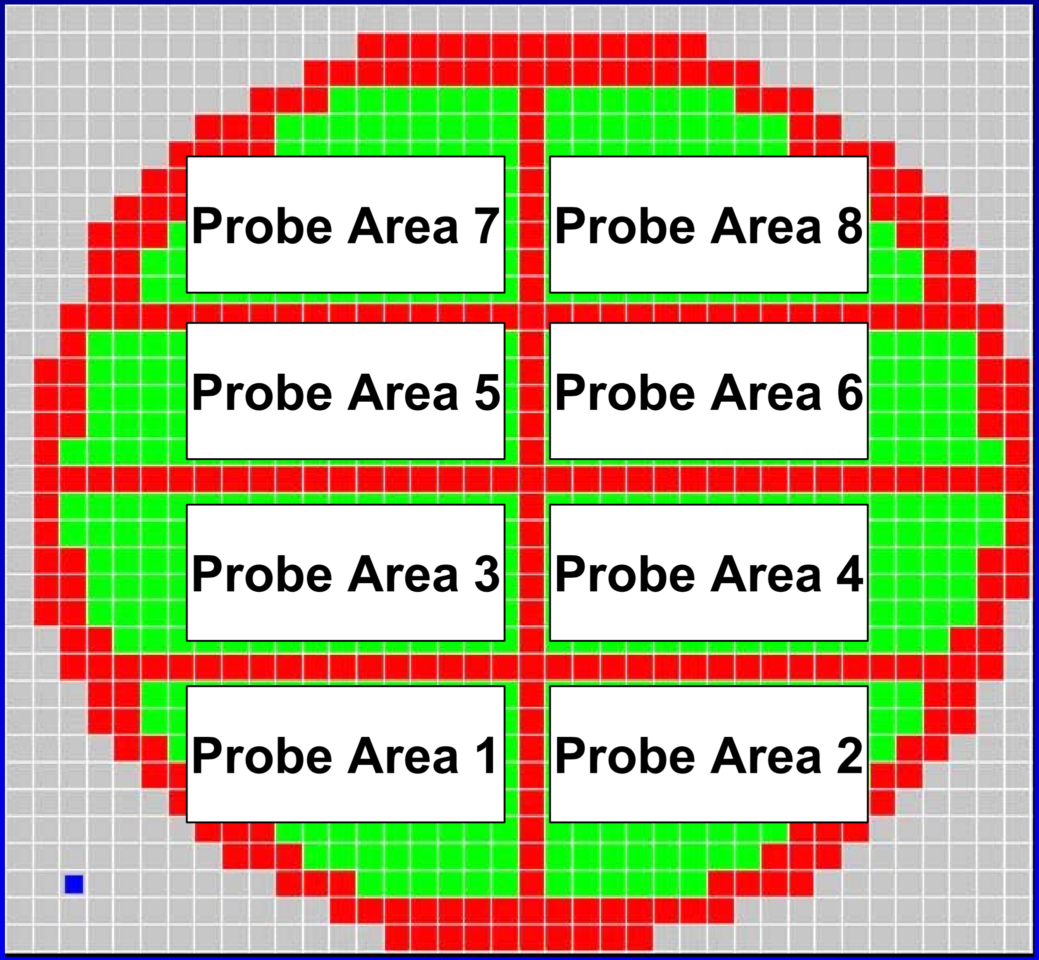
Counting

- Cracked pads
- Repeating pins
- Needle number, site and tier.

Results

Cracks found during the counting process result in a failed probe card

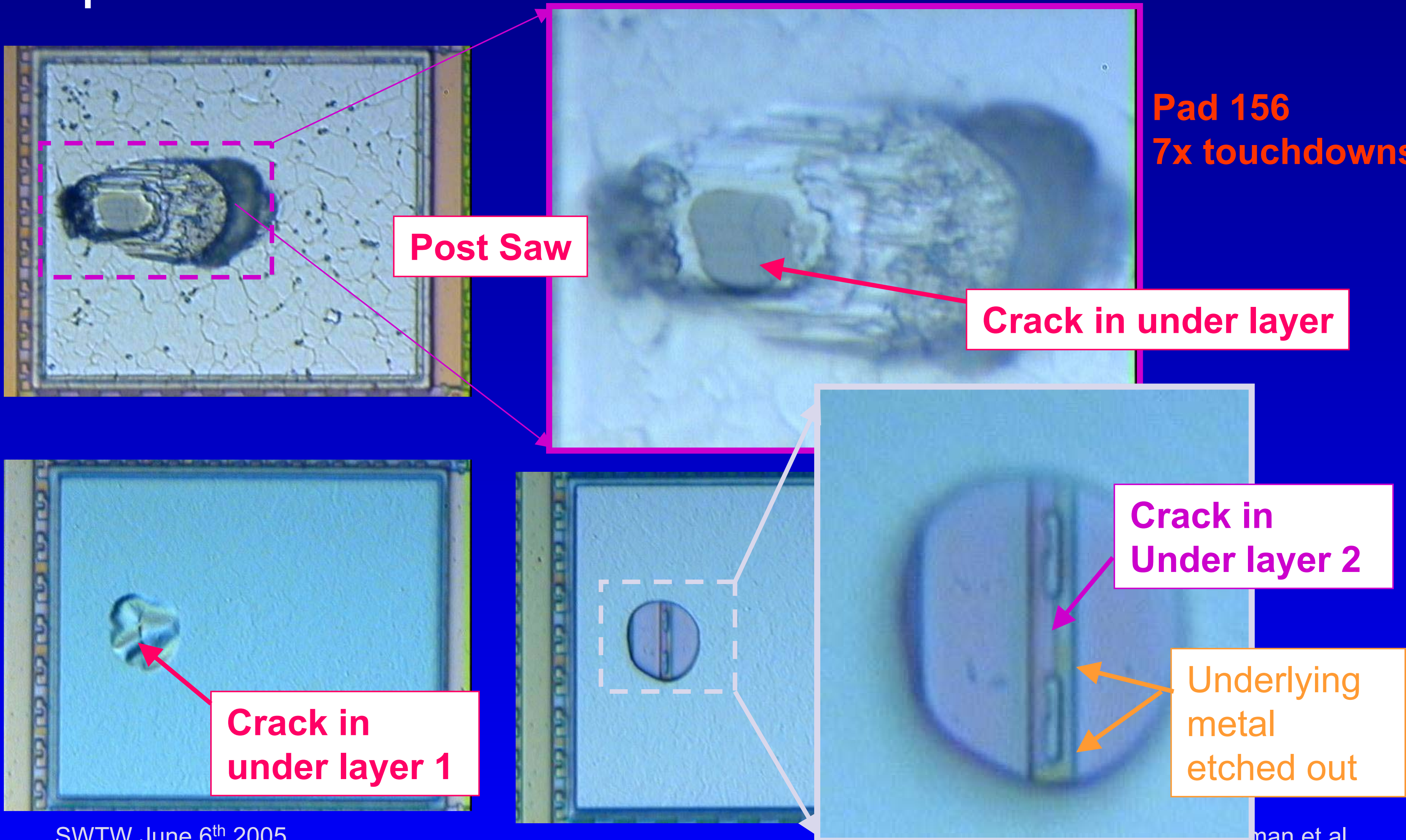
Approach
Probing



Probing Settings

- Full production over-travel
- Cleaning of the probe needles at the beginning of the wafer only

Approach
Inspection/Documentation

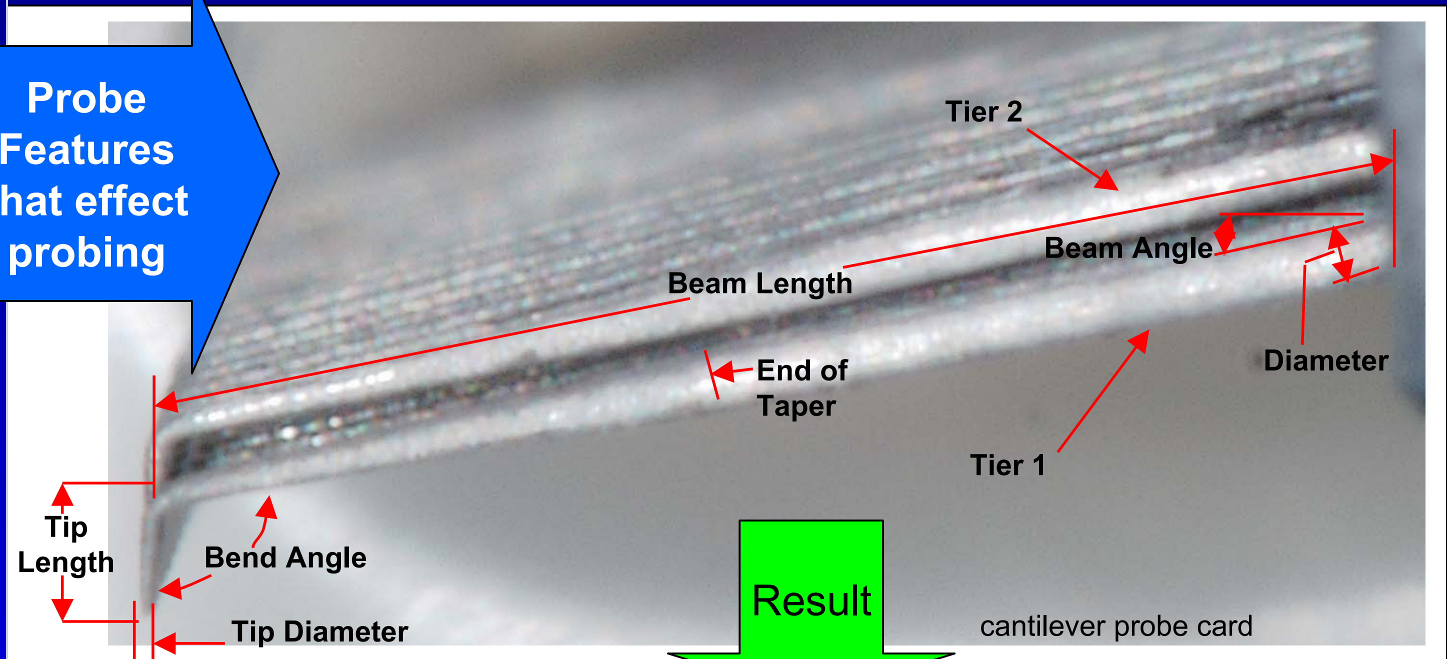


Needle Modification

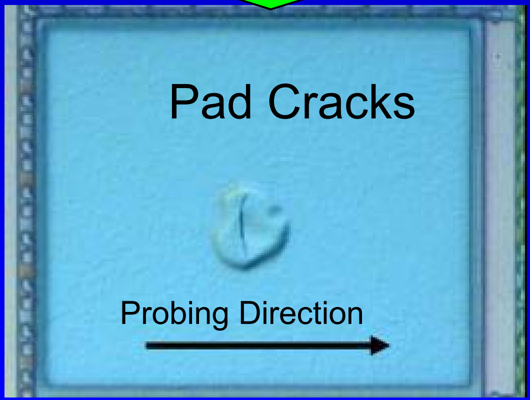
Probing Features

- ~~Tip Shape~~
- ~~Tip Diameter~~
- Approach Angle
- ~~Beam Angle~~
- ~~Wire Diameter~~
- ~~Under Layer Roughness~~
- Beam Length
- ~~Taper Method~~
- Tip Length
- Knee Diameter
- ~~Difference in vendors~~
- ~~Wire Material~~
- ~~Probe Force~~
- ~~Probe Chuck Impact~~
- Taper Length

Probe Features that effect probing



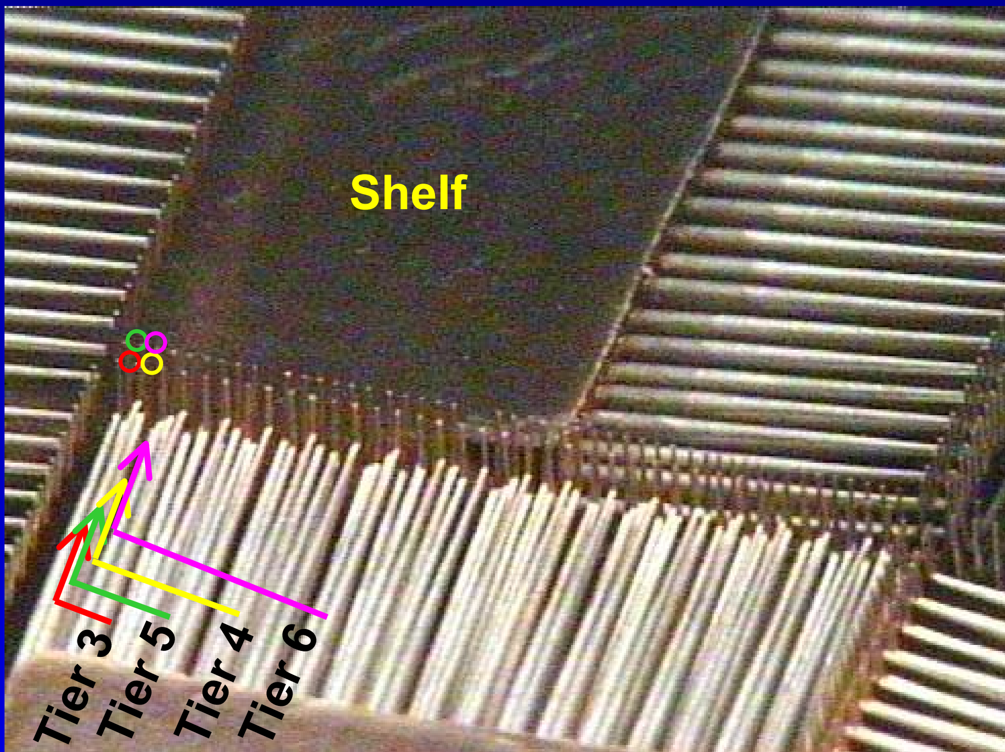
Result



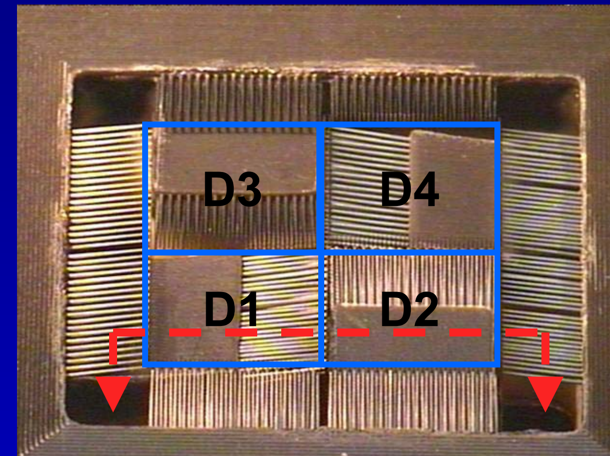
Stillman et al.

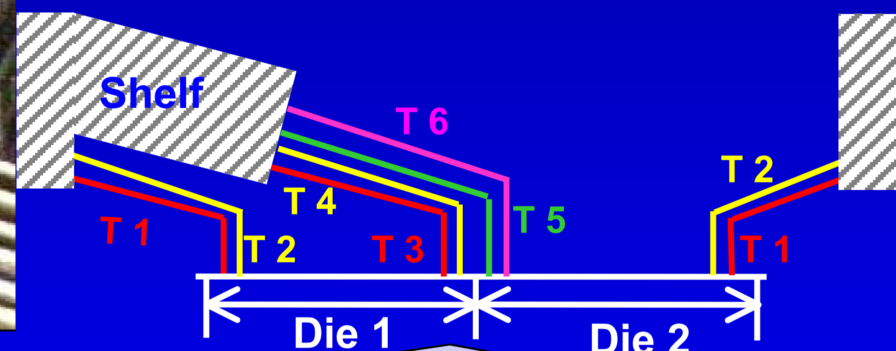
Needle Modification

Tier and Shelf Design



Bottom View of probe card





Rigid needles = Short beam length + Short tip lengths + Short taper lengths = Cracking

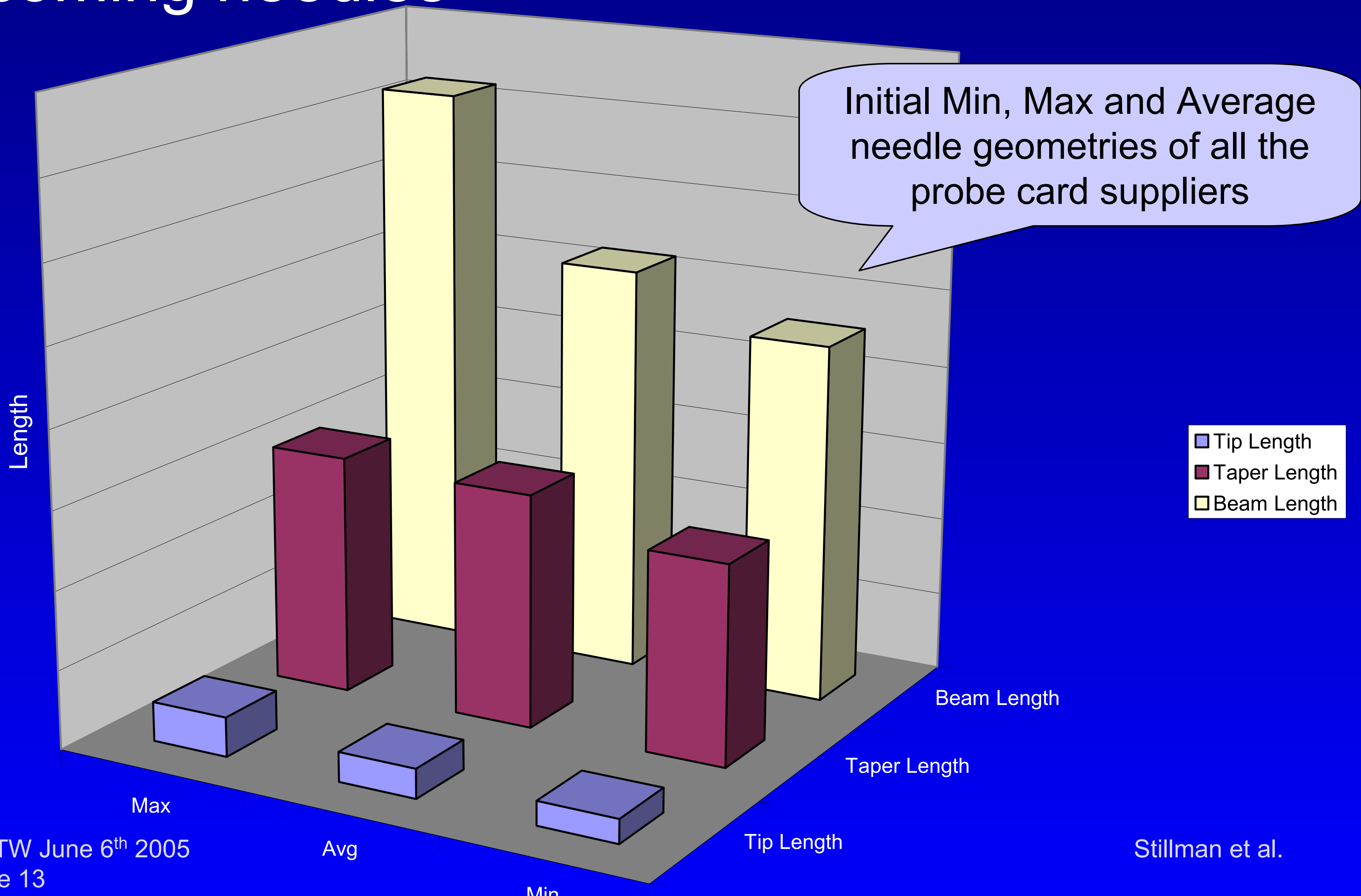
Tier 1 = Tier 3 = Short beam length + Short tip lengths + Short taper lengths = Rigid needles = Cracking

Needle Modification

- Worked with different probe card suppliers
- All suppliers have different:
  - Needle geometries
  - Build practices
  - Cracking results

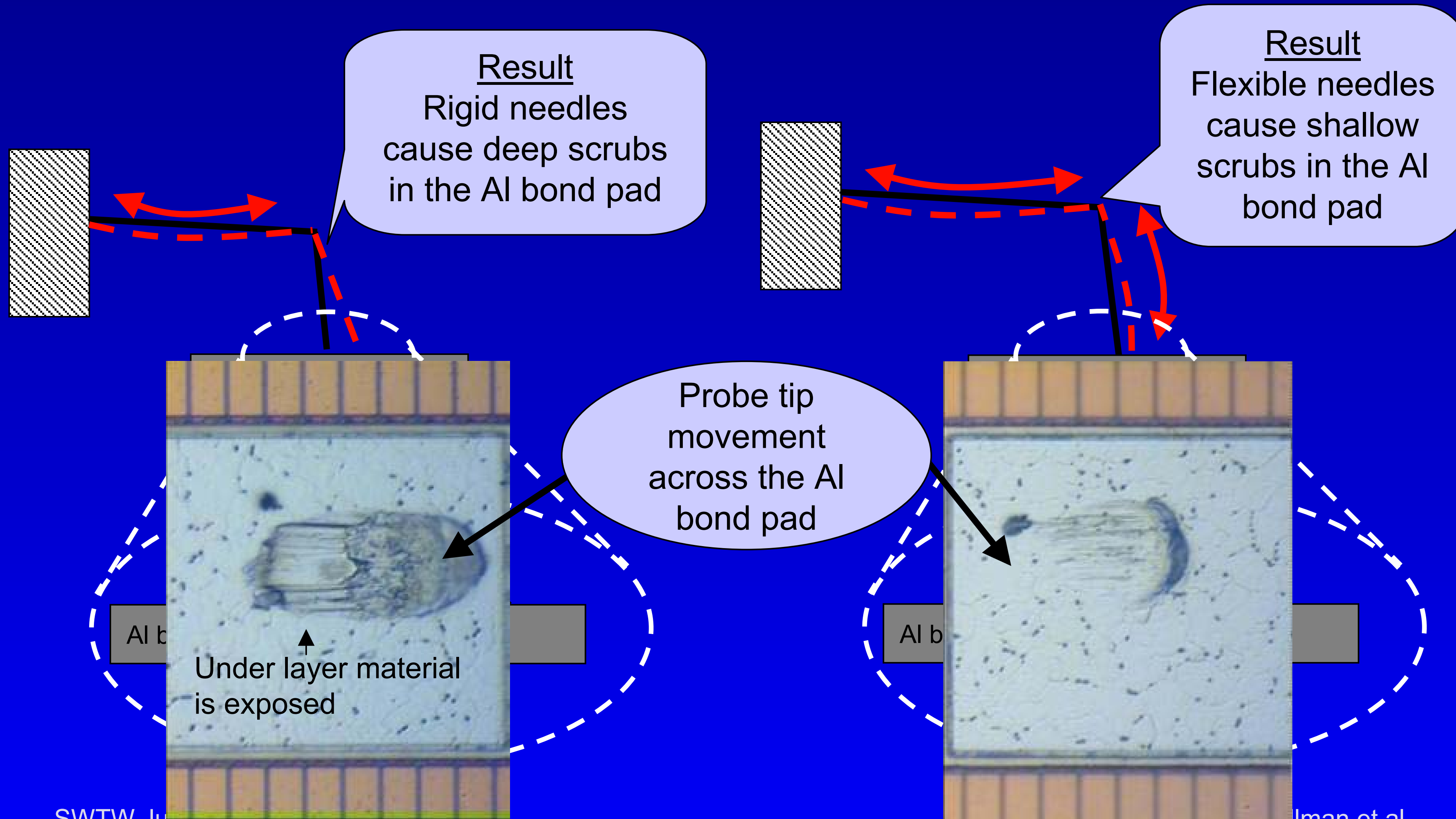
Needle Modification

Incoming needles

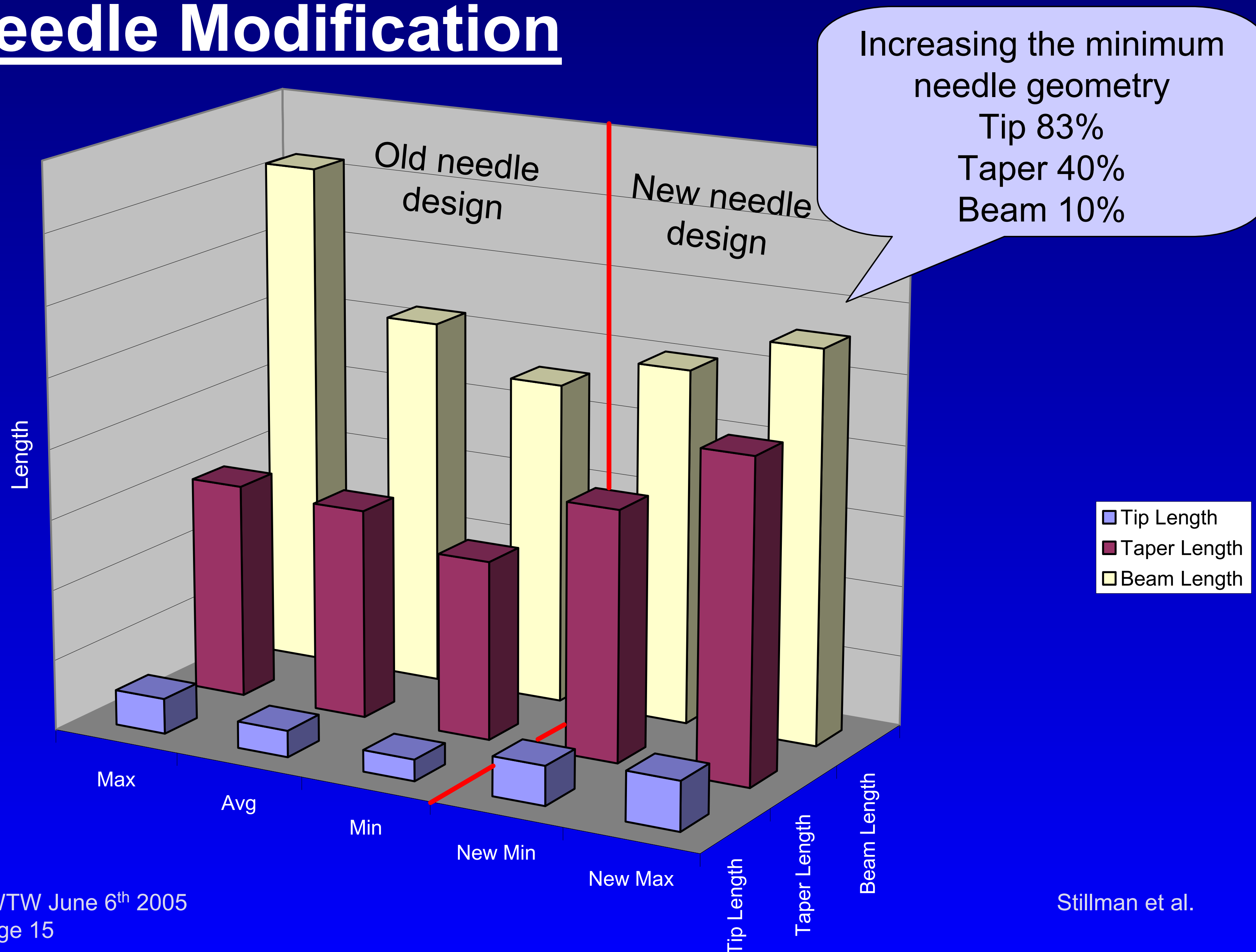


Needle Modification

Rigid Needles vs. Flexible Needles



Needle Modification



Test Results

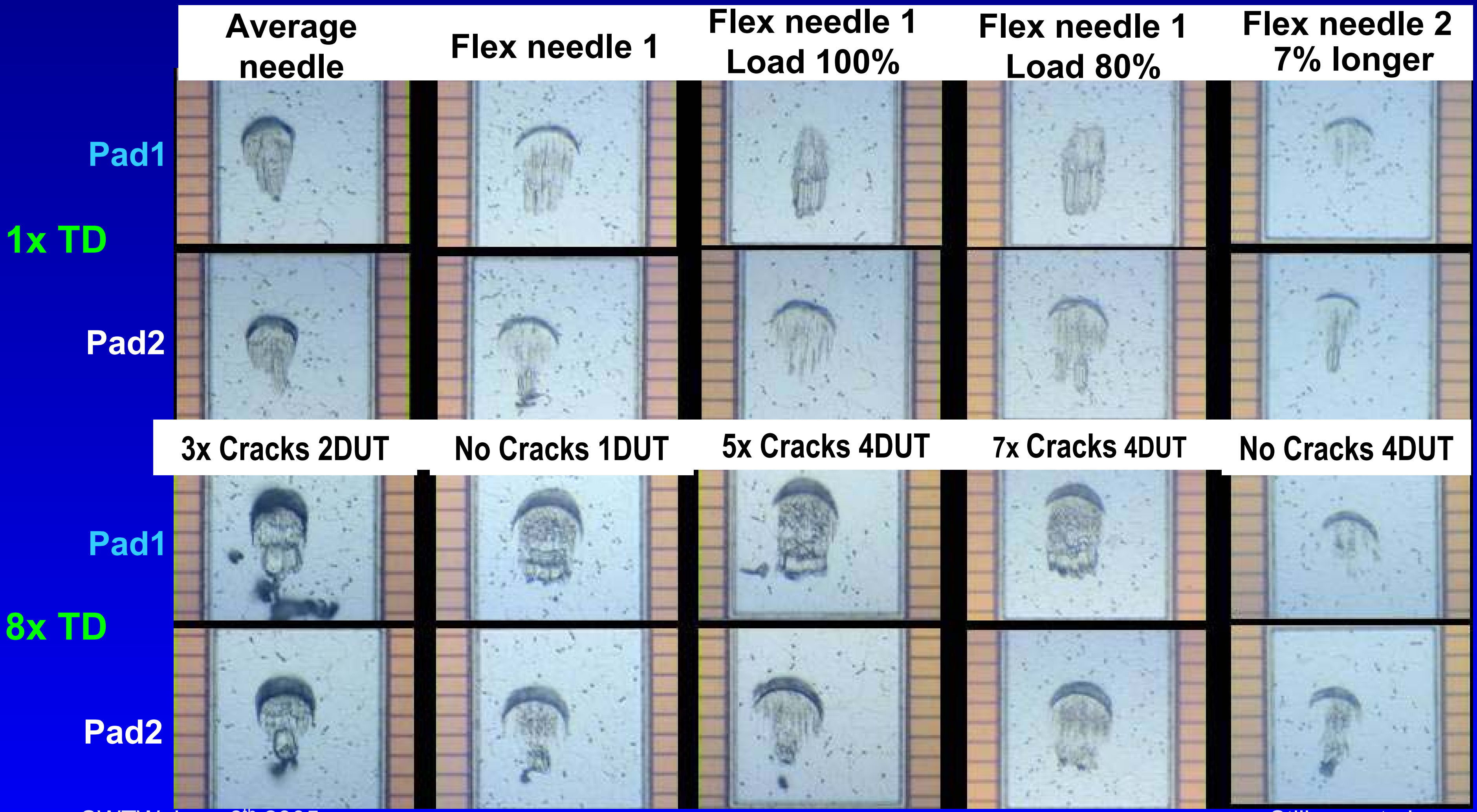
- Chart of improvement

	Old Needle Design		Low Force Needle		New Needle Design	
Vendor	Percent Load	Cracking (TD)	Percent Load	Cracking (TD)	Percent Load	Cracking (TD)
A	100	6x	57	6x	62	7x
B	100	6x			68	7x
C	100	3x	57	3x	80	8x
D	100	5x			80	8x
E	100	4x			80	7x
F	100	4x			62	8x

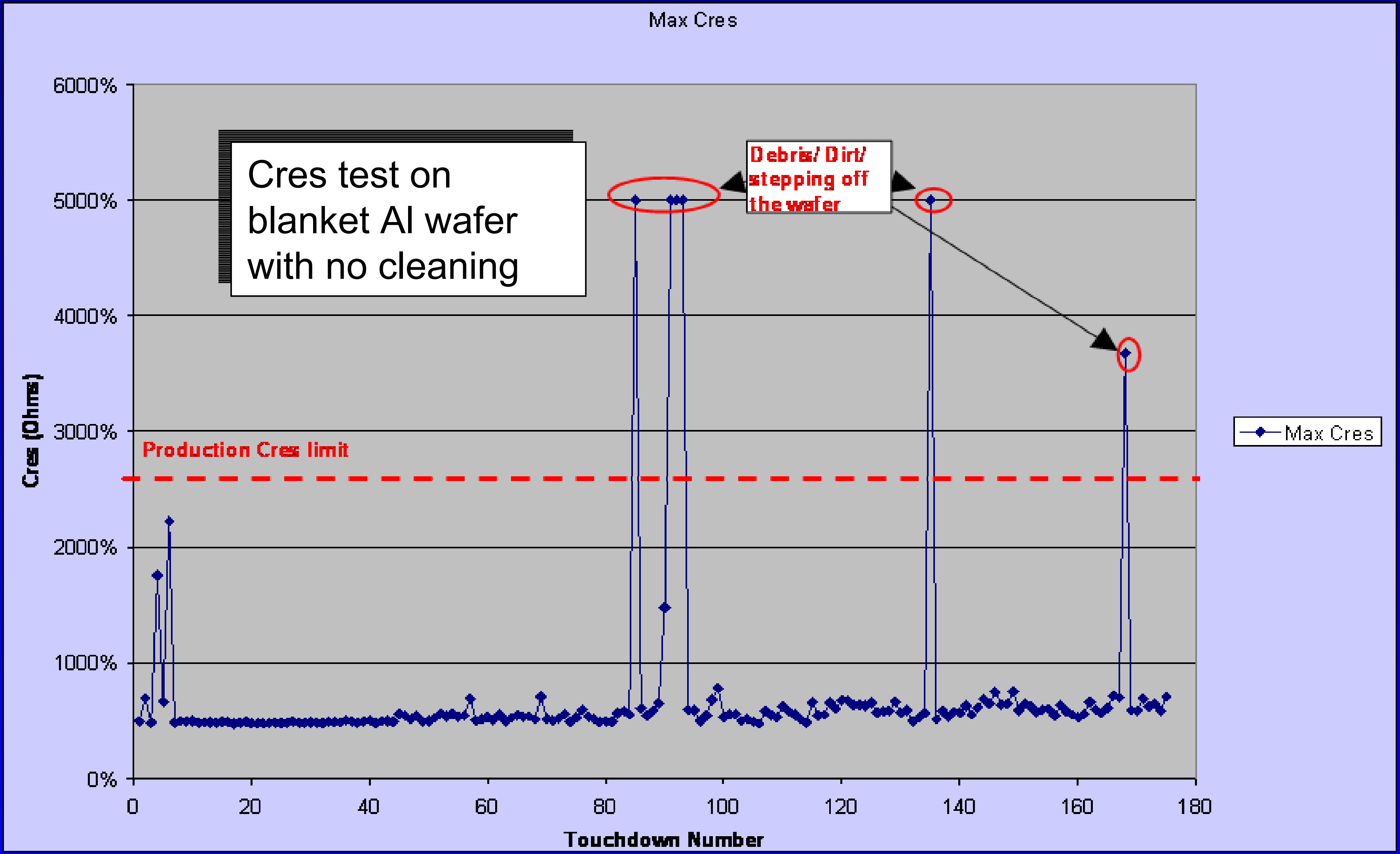
The new needle design causes a 20% - 40% reduction in the needle force

Test Results

Vendor E result



Test Results
Contact Resistance



Summary

- Rigidity of the probe needles cause deep scrub marks and cracking of low-k dielectrics
- Tier 1 and tier 3 are the most rigid needles in a 6 tier quad site design
- Increasing the Beam, Tip and Taper length of the probe needles reduces the severity of scrub damage and ultimately eliminates cracking of the low-k dielectrics

Acknowledgments

- All of the probe card suppliers
  - For working extremely hard with Texas Instruments
- TI Management
  - For Providing the support and resources to isolate the root cause of probe induced cracking
- Neal Okerblom (TI)
  - For prober support
- Nancy Ota (TI)
  - For de-processing support

References

Hartfield et al., “A Novel In-Situ Methodology to Characterize Bond Pad Dielectric Mechanical Behavior During Wafer Level Test”, Southwest Test Workshop, 2003.

Hartfield et al., “Evaluation of Cantilever Probe-Induced Dielectric Cracks in Cu/Low-k Devices”, Southwest Test Workshop, 2004.