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Modified Tool for Developmental Analysis and Real Time QRA Probe Card and Socket Results

Terence Q. Collier

CVInc – Richardson, Texas

TQCollier@covinc.com

The "Old Way" Test Analysis Limitations

- Sample & System Variability
- Surface Contamination
- Analytical Tool Cost
- Time between DOE design and data generation
- Real-time results

- Flexibility
- Surface Roughness
- Sample Grain Size
- Sample Preparation
- Probe Card Cost
- Unknowns including probe design, pad conditions, IMC, etc.

Why the MHT

Available and off the shelf! Fast and economical results!

No need for complete wafers (MHT has the capability to probe individual bumps and pads)

No need for a complete probe card (a single pin can be inserted into the tip)

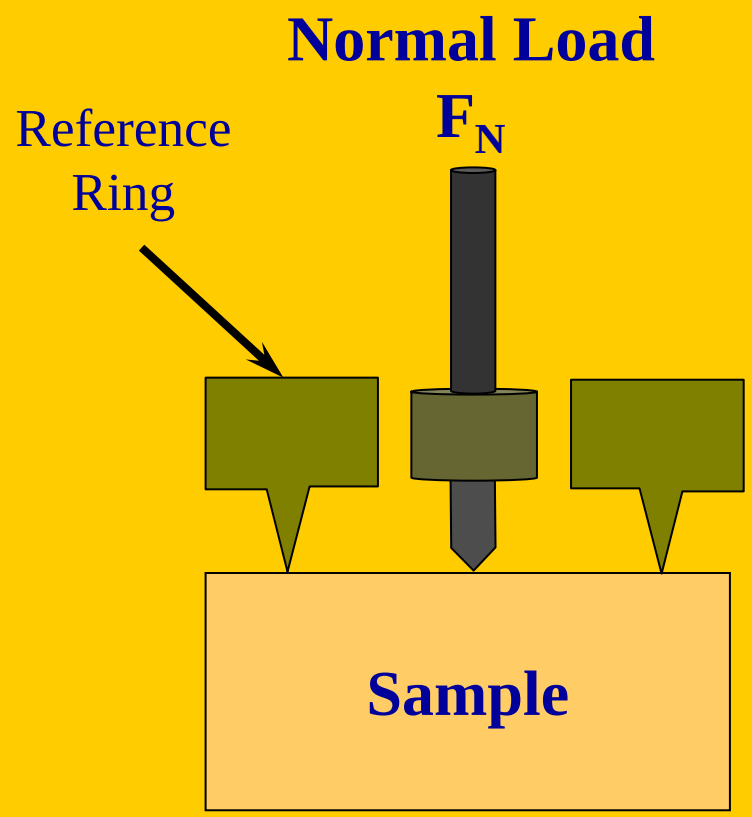
Eliminates the need to design and build mock test setups …… reducing the tolerance stack error in the Prober/Tester/Probe Card system:

Chuck Planarity	Wafer Planarity
Bond Pad Corrosion	Probe card
Die Performance	Electrical Contact Force

which can lead to invalid conclusion -and- result in REPEAT experiments.

Micro Hardness Tester

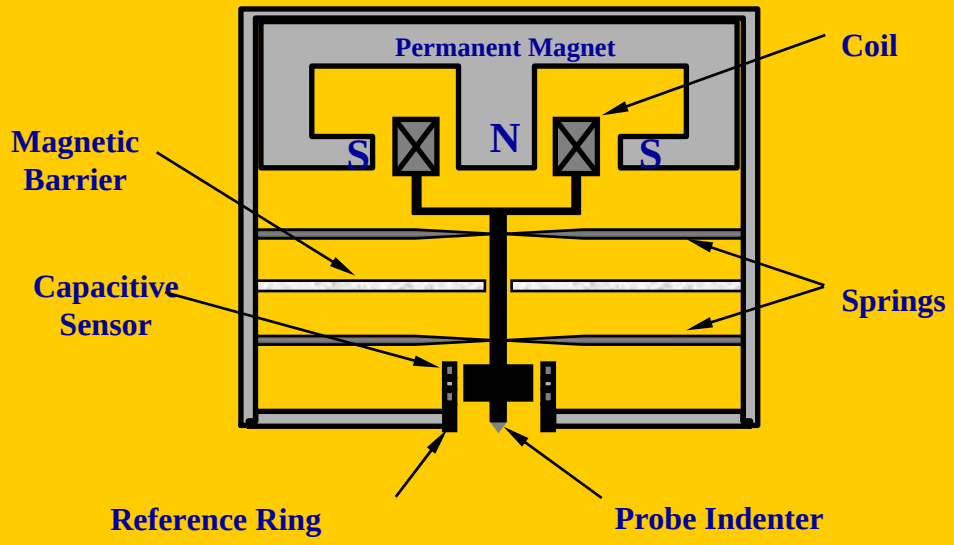
Maximum Force	**30 N**
Force Resolution	**10 N Scale = 0.3 mN** **30 N Scale = 1 mN**
Displacement Range	**500 μm**
Displacement Resolution	**0.3 nm**



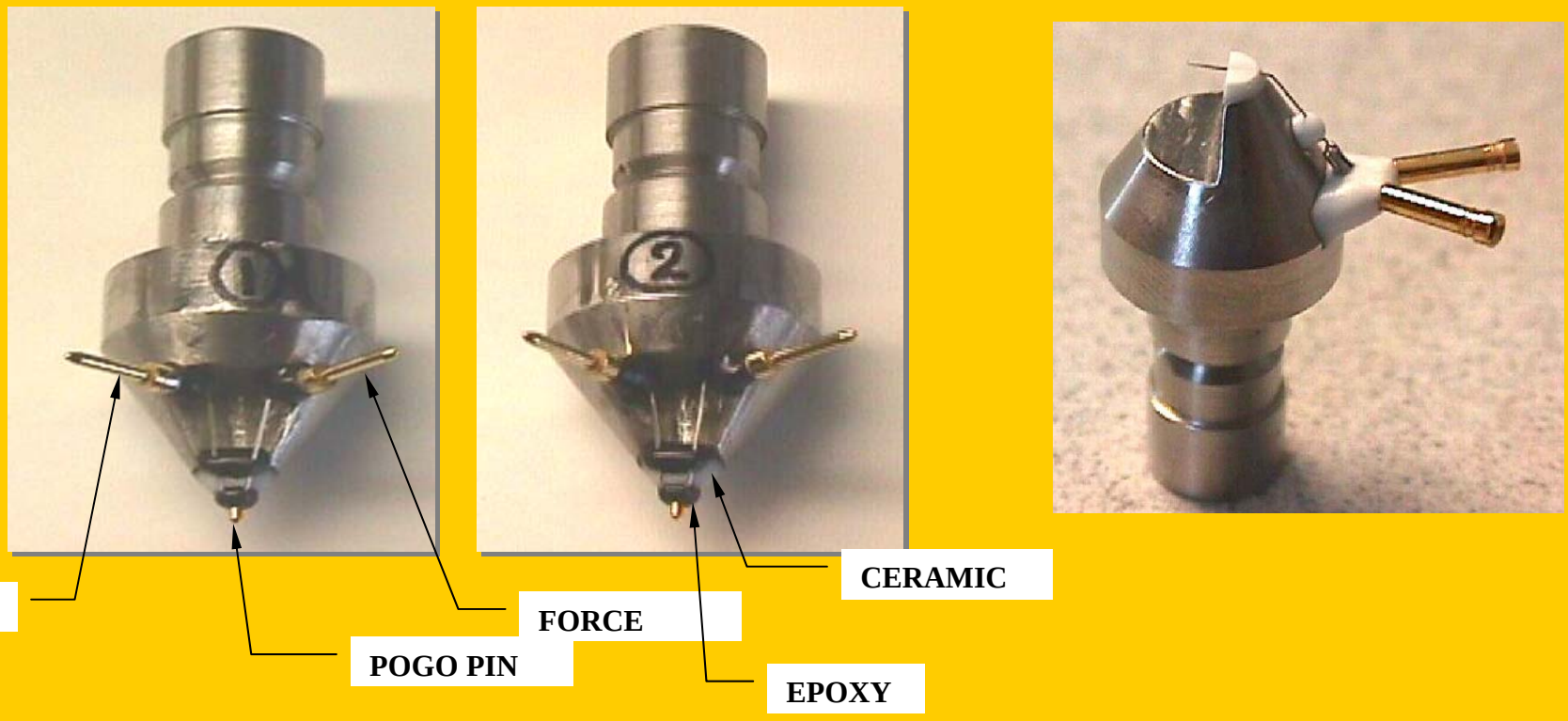
10mN~1gram Static and dynamic loading including a camera and video.

Nano Hardness Tester

Maximum Force	**300 mN**
Force Resolution	**1 μN**
Displacement Range	**20 μm**
Displacement Resolution	**0.04 nm**



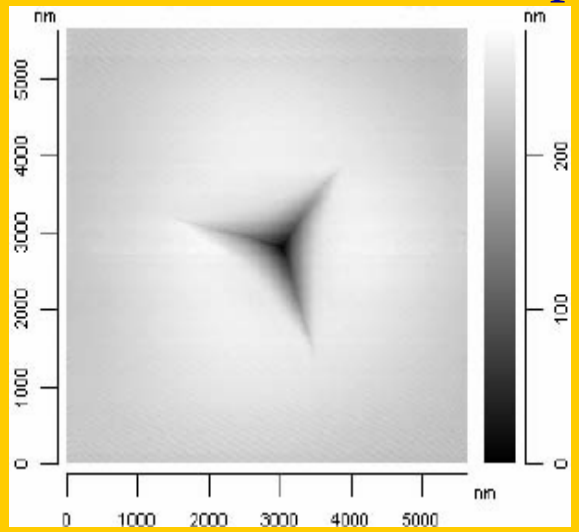
Sample Probe Tips for Pad, Bump and Socket Analysis

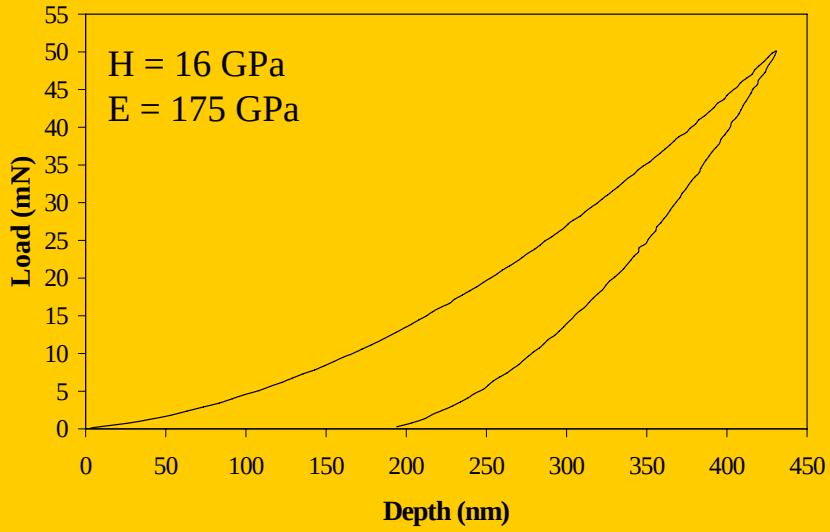


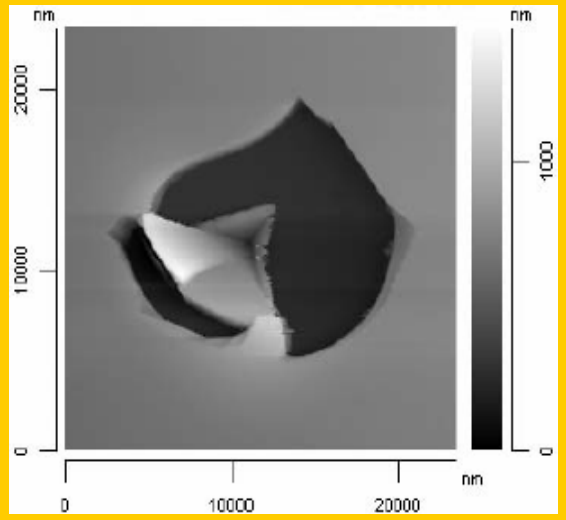
Probe tips are cheaper and more versatile than probe cards!
Traditional hardness tester tips are also available.

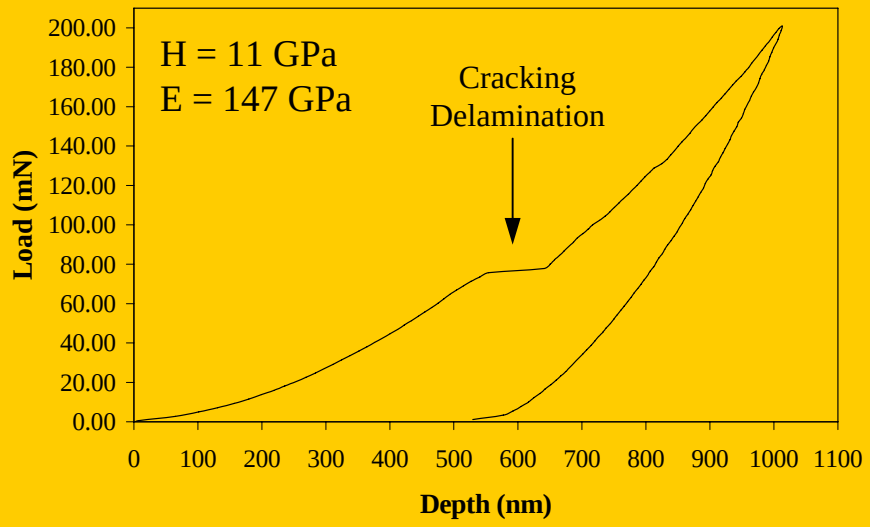
Micro-Hardness Test

Mechanical properties of thin films



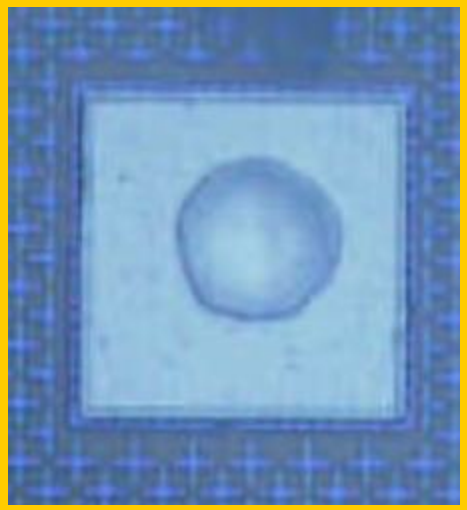




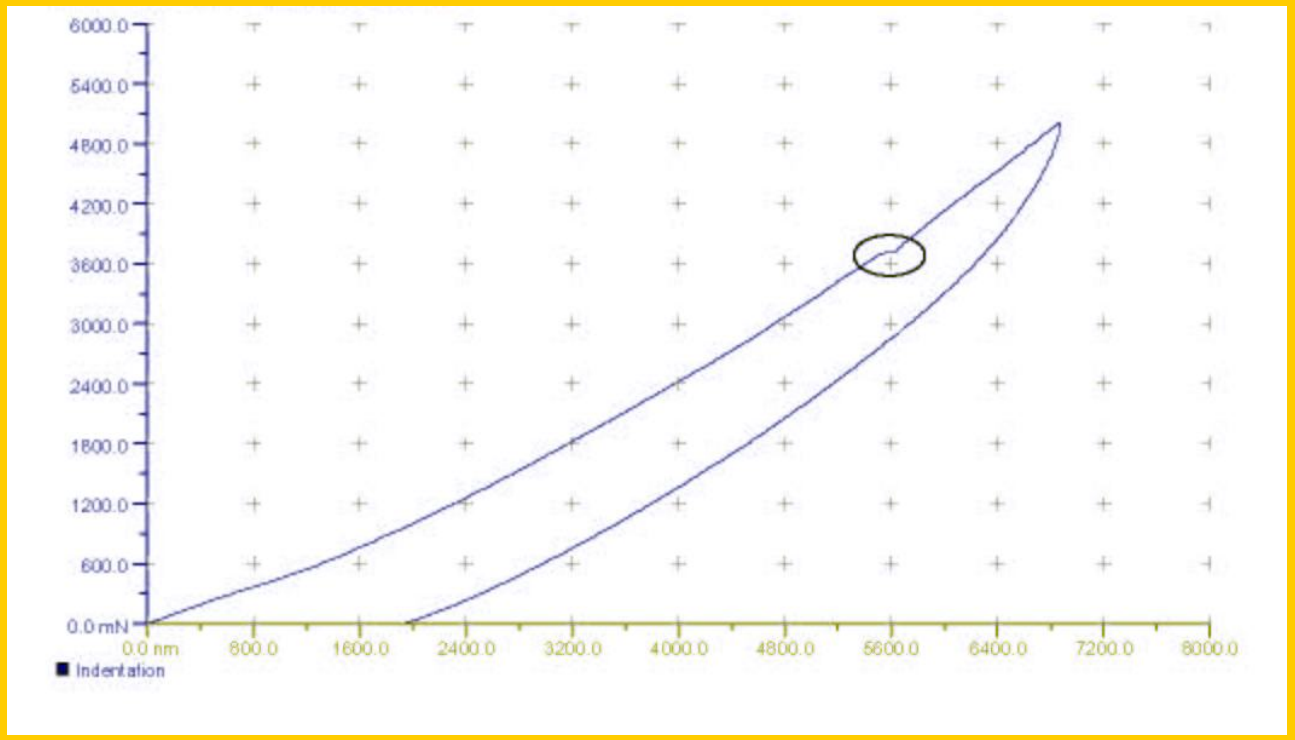


A Bond Pad is a Thin Film…….

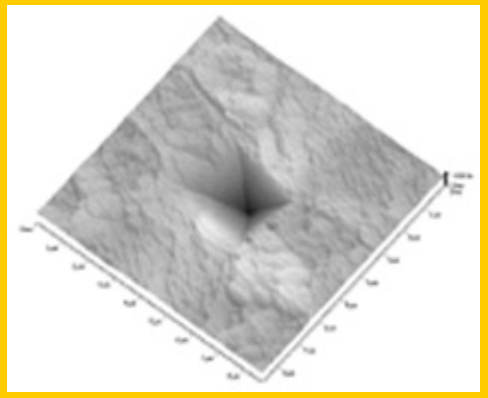
Regardless of technology, bond pads are a series of thin film stacks. Depending on the thickness, strength and brittleness, the inflection on the curve will be more or less pronounced but it is detectable. The data from the curve can be used to calculate hardness, modulus and friction.

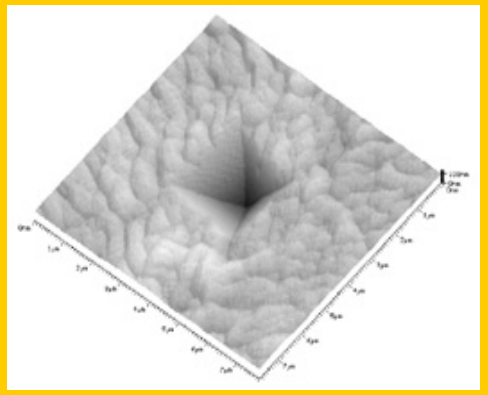


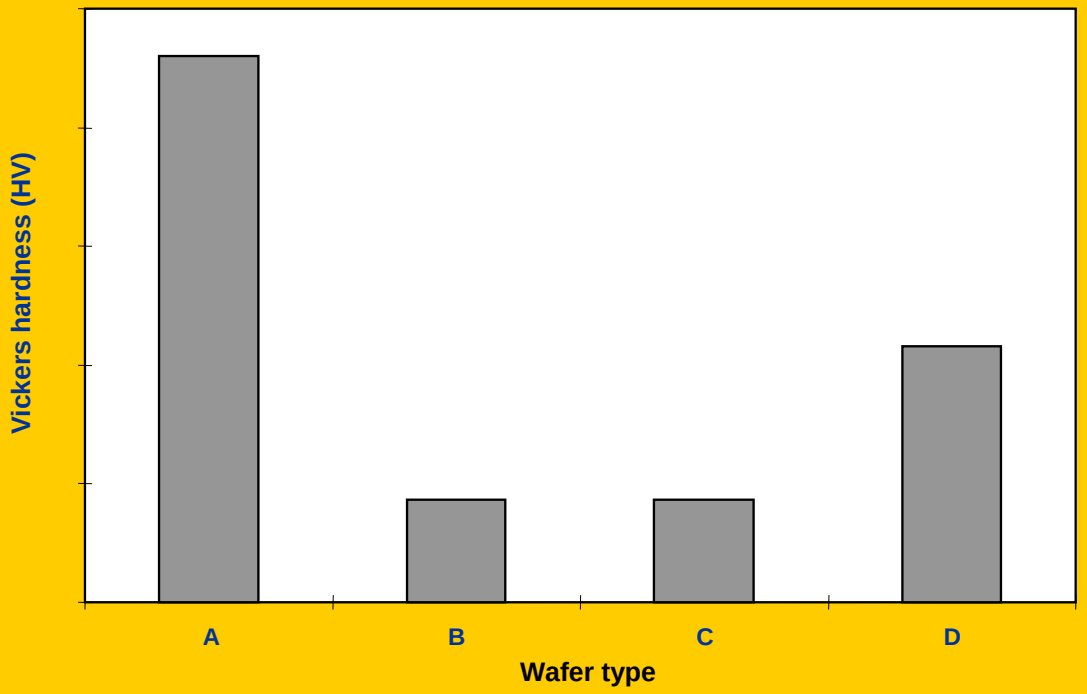
Sample probe run with 1st fracture point.



Integrated Circuit (IC) Bonding Pads

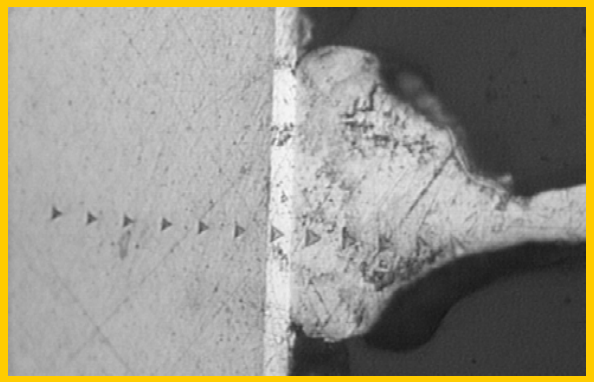


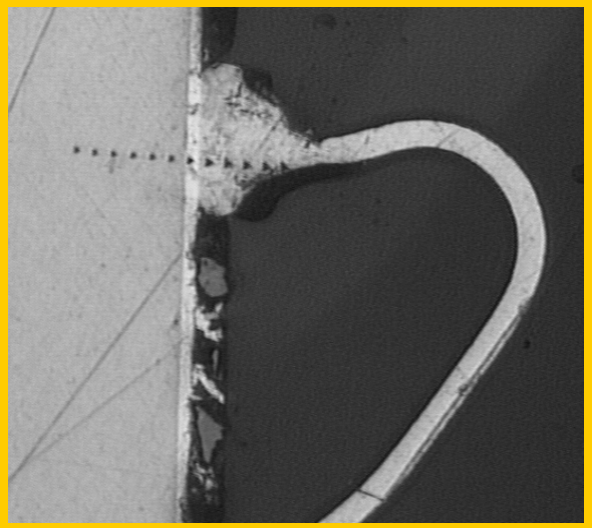


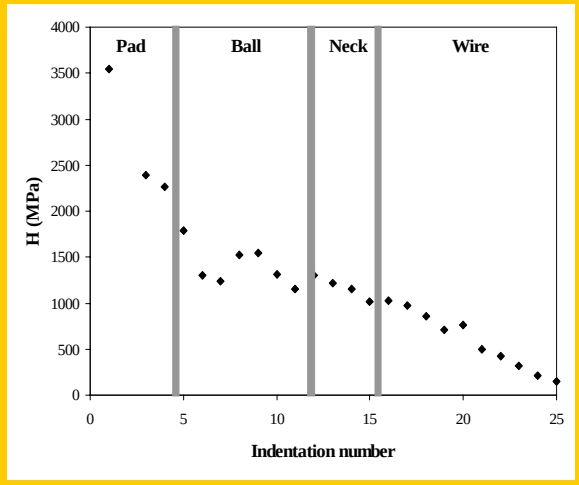


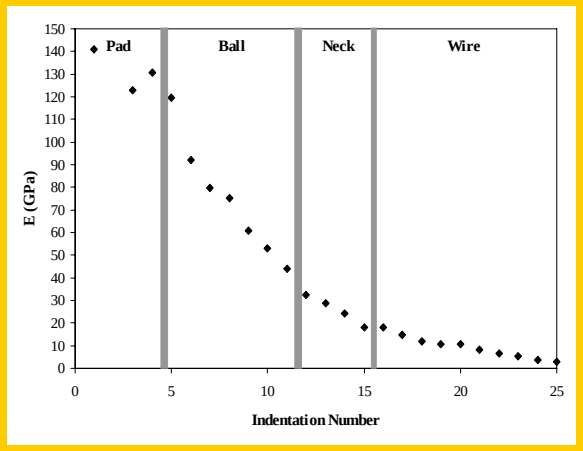
A quick evaluation of pad morphology can be used in-line to fab delivery.

Example Nano-Hardness Test









Sectioned IC bonded gold wires

Quick Probe Analysis Solutions
Science -vs- Myth

Science

Myths

The amount of art versus science can be very dependent on the topic. How much test technology is art depends on the area of focus. With probe cards, the net result might be a smidgen of science and a lot of art without the correct analysis tools.

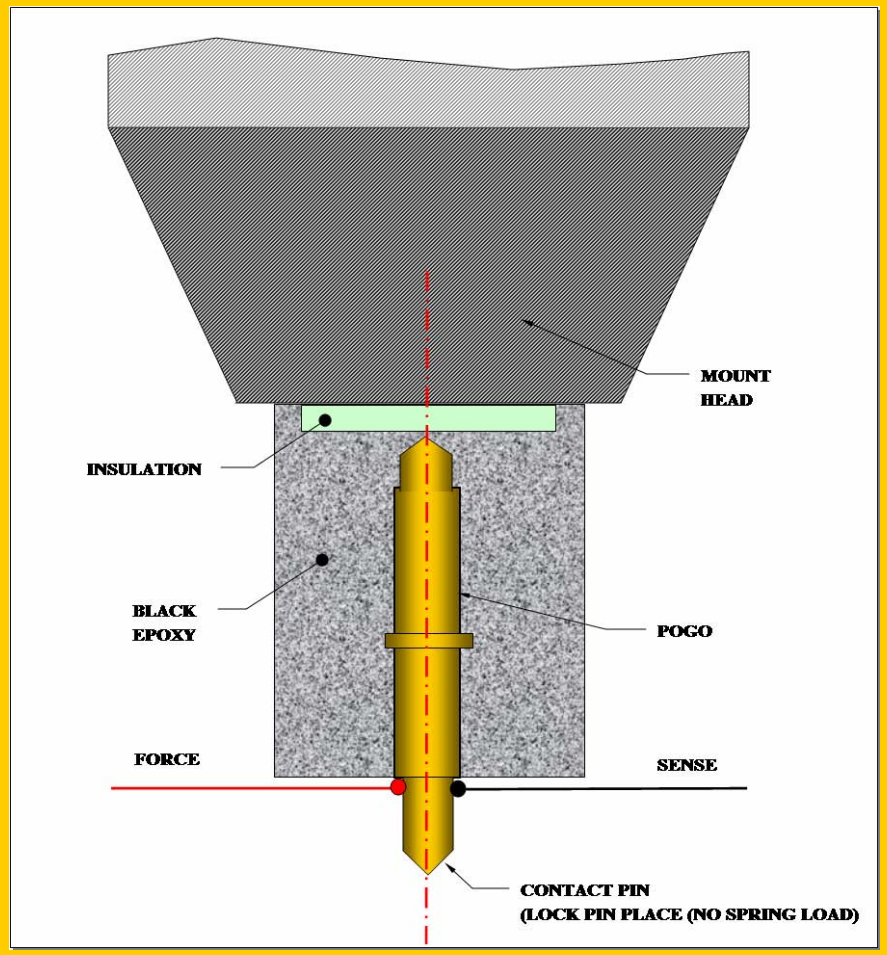
The Myths

- 1 million TDs
- No-clean/Non-reactive probes
- Sapphire/Scrub Analysis
- CRES

With every myth there is some truth. Each of these has a hocus pocus and some science as well. To fully understand, a product has to be constructed to baseline. Like blowing glass, the correct recipe, flame temperature and annealing must be sought prior to implementation.

1 million TDs

- Under the correct conditions most materials react.
- Low reaction rates mean it just takes time.
- Analysis of a gold pad (LGA) using a vertical probe demonstrates this task is difficult even on the macroscopic level.
- After 5k TD's a change in loading and resistance was noted.



No-clean/Non-Reactive Probes

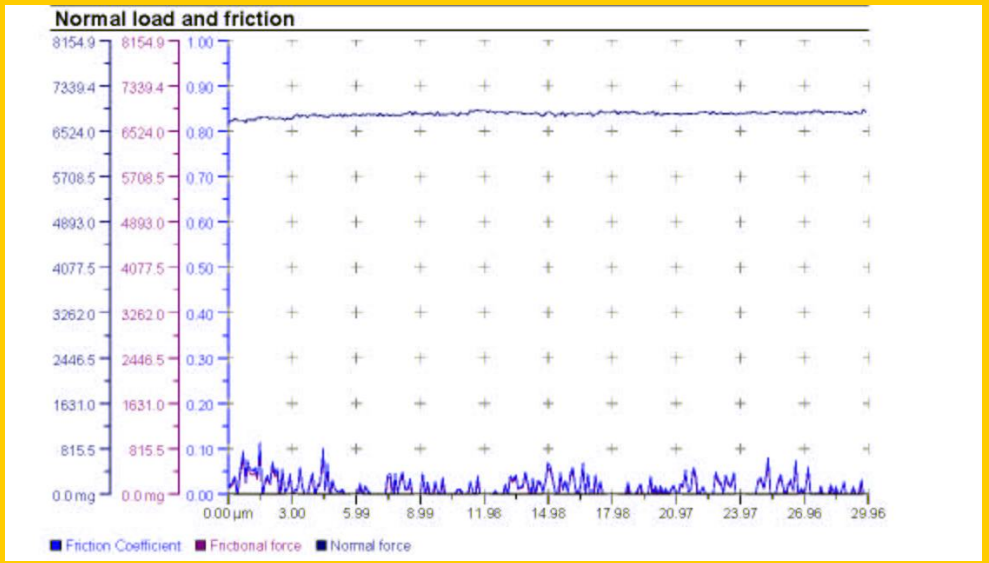
- A good concept but no such animal.
- Because of the fab there are molecules on the surface of the pad that would not exist naturally.
- Even an Au pad has halogens that would cause a reaction with various probe materials.
- A quick validation only requires running a single site probe on the pad or bump of opportunity. Its quick and easy to remove the probe and insert in a SEM, EDX, Auger, SIMMS, etc, without destroying the card.

Probe tip after only 5 TD's on a "clean" Al bond pad.

Sapphire/Scrub Analysis

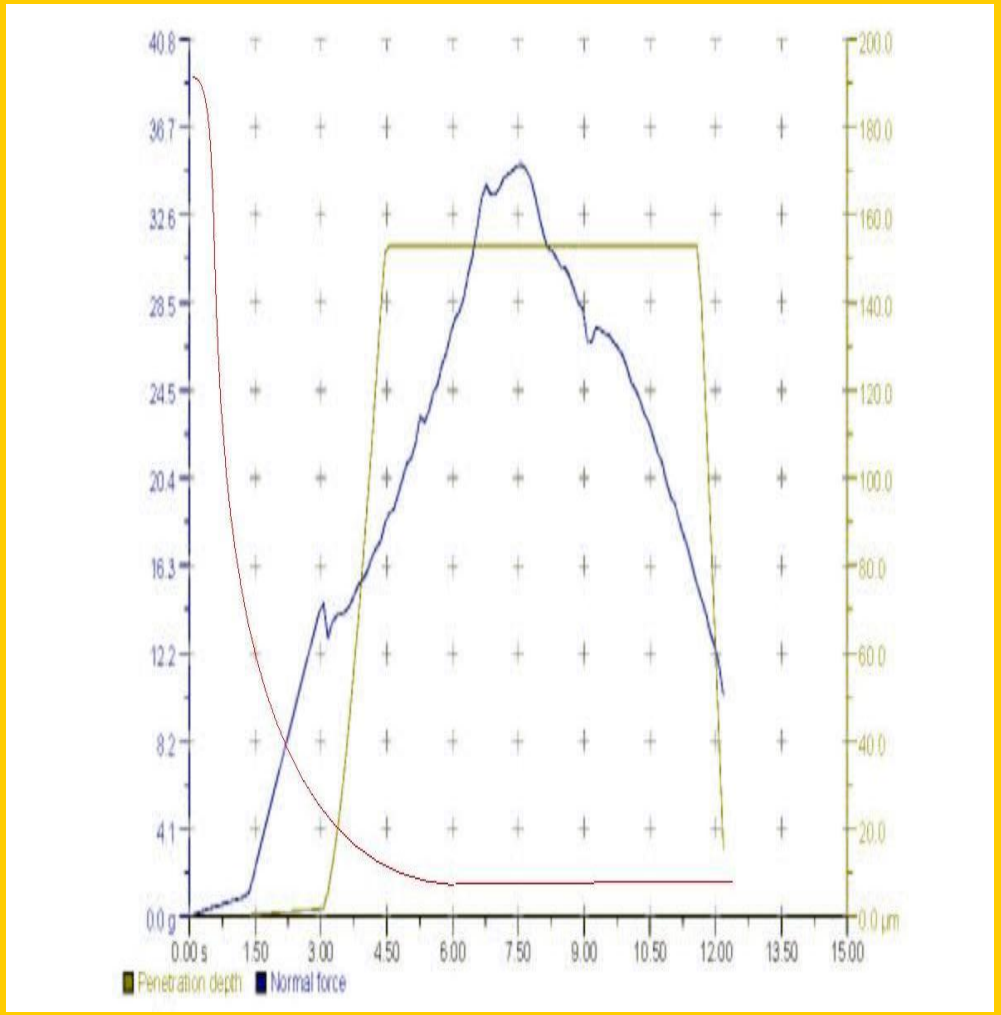
- Probe card analysis using sapphire is an urban myth.
- The sapphire, crystalline Al2O3 with Cr impurities, would be better cut and mounted into a ring for your wife!
- Frictional results show that measurements on sapphire have unrealistic values and don't truly simulate probe mechanics.

Sapphire is a clean and polished surface unlike a bond pad. Even when roughened the friction would be different.



CRES

- CRES was measured at time zero and after 500 and 5k TD's.
- Even a gold pad probed with a PdCo needle shows changes in resistance.
- Root cause – don't know (pin was not analyzed); likely debris burned onto the tip



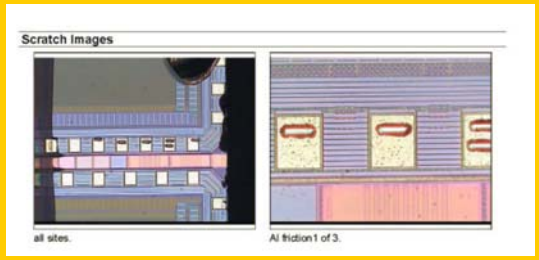
The Science

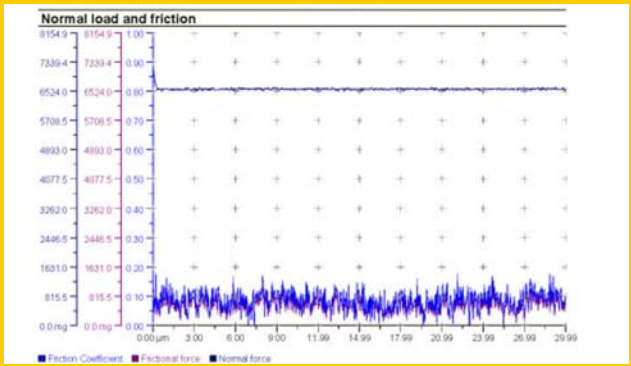
- AlO-OH (not Al2O3)
- Lowk damage
- High temp probing
- Intermetallics
- Cleaning
- Probe needle cycling

AlO-OH (not Al2O3)

- Bond pads are not aluminum oxide (Al2O3) but a soup of materials primarily composed of hydroxides.
- Depending on the processing, the pad can take up various morphs all changing the “durability” of the pad-probe tip interface.
- Probe needle tip geometry and beam has a direct influence on performance.

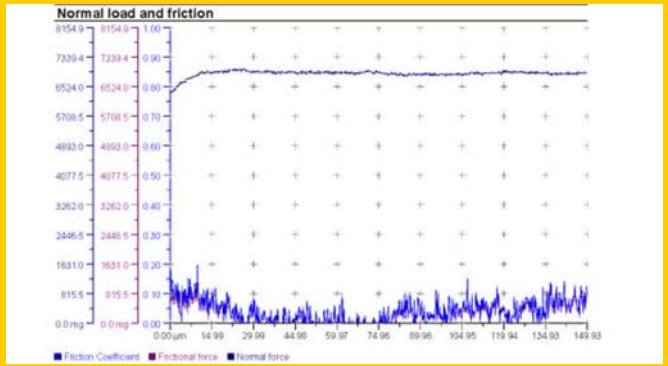
Friction: Al Pad -vs- Al2O3



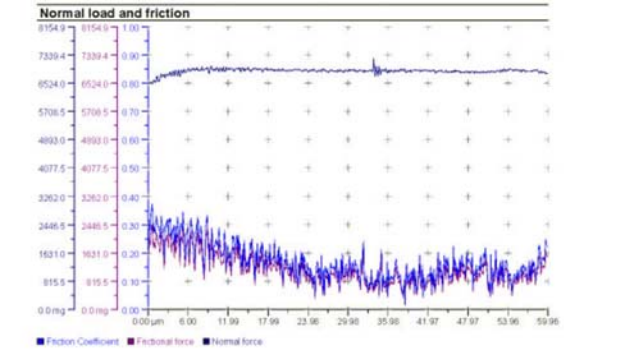


Cobra on Pad

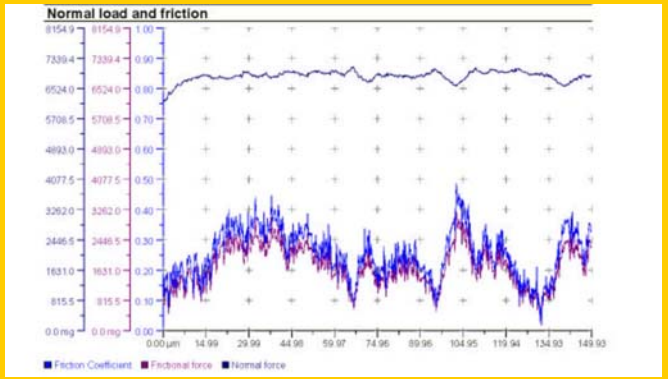
What about a cantilever probe on sapphire



Canti on polished Al2O3



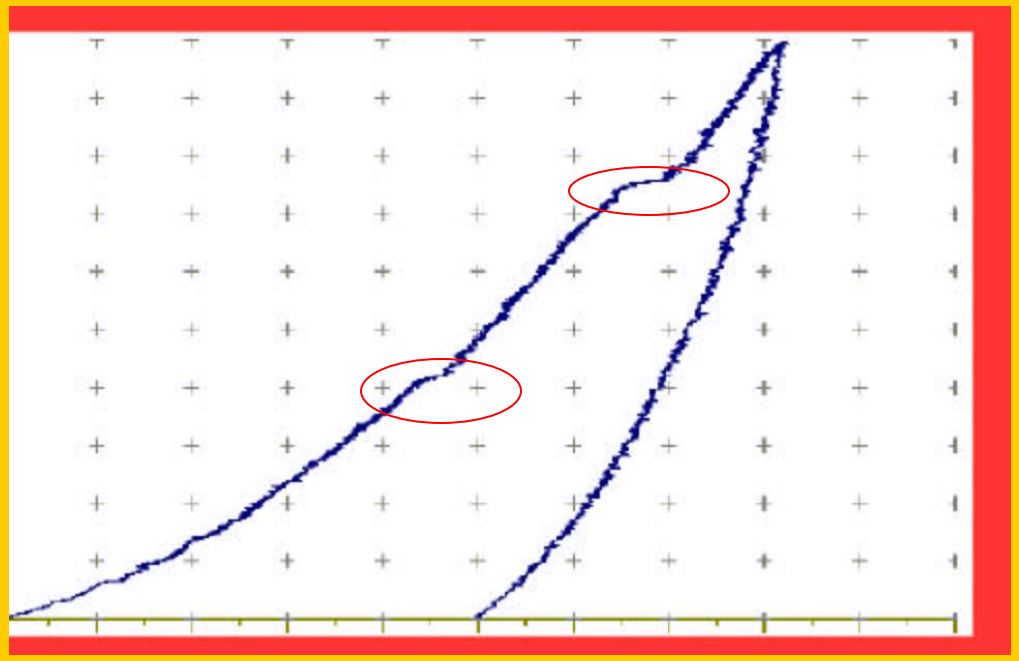
Cantilever on Pad



Cantilever on Al2O3

Low-k Damage

- Lowk damage occurs due to mechanical loading.
- Both brittle and non-brittle materials can fail under varying load conditions typically tensile.
- Analysis using the incorrect probe geometry and load conditions can lead to incorrect conclusion.



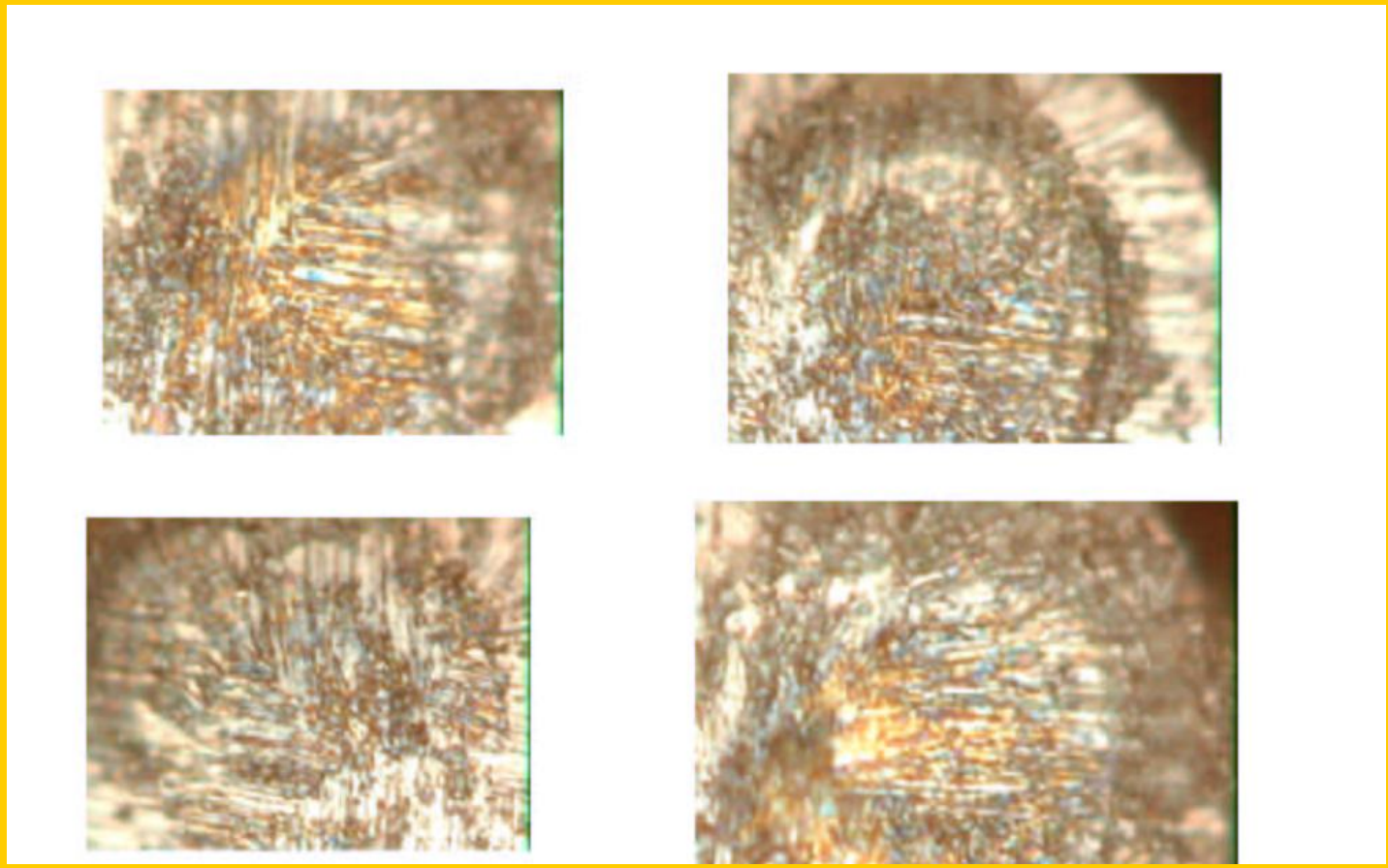
Using the MHT one can approximate both the low-k fracture as well as a secondary fracture.

Using the NHT the exact loading parameters can be determined

High temp probing

- High temp probing is tough on a wafer. Its difficult to know if the region under analysis is at the correct **and** stable temperature conditions.
- CRES, Icc, load force, alloy type and internal probe resistance all contribute additional variables that cannot be measured with typical setups.
- Either of these variables can be the critical parameter under given set of conditions.
- For example…….. P7 on SnPb introduces intermetallics at the interface that can “burn” into the probe needle. The same WRe needle might see slightly higher resistance at time zero but little additional impact over the same number of touchdowns.

Southern Fried Probe

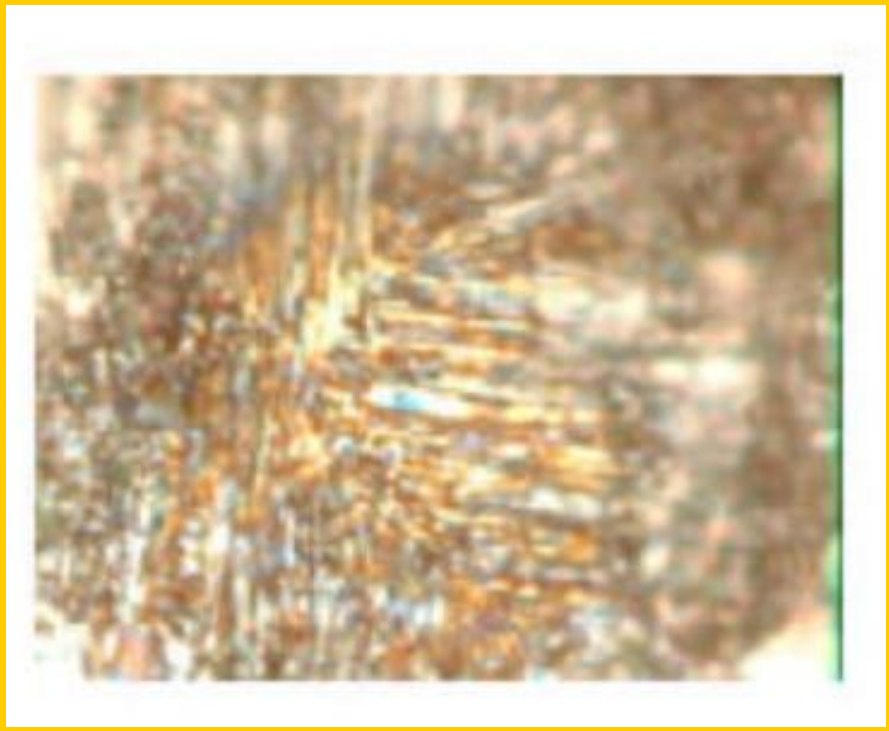


A combination of burned probe and intermetallics. These probes have to be removed and replaces. A costly event.

Intermetallics

- SnPb and SAC don't mix well with Au or Pd or Pt
- SnPb and SAC don't mix well with Cu
- W/WRe does not like flux residue
- W/WRe does not like oxygen
- AuSn does not like high current (reflows at 275C).
- AuSn, PdSn intermetallics (IMC) form a .25um to .4um layer on initial contact with very little load and current. The rate of IMC formation can be changed by changing either of the two parameters

IMC formation on the bump. Image shows a probed bump with needle debris, and intermetallic formation.



IMC formation on the probe tip. AuSn, carbon residue as well as oxides are all present due to excess current and temp.

Cleaning

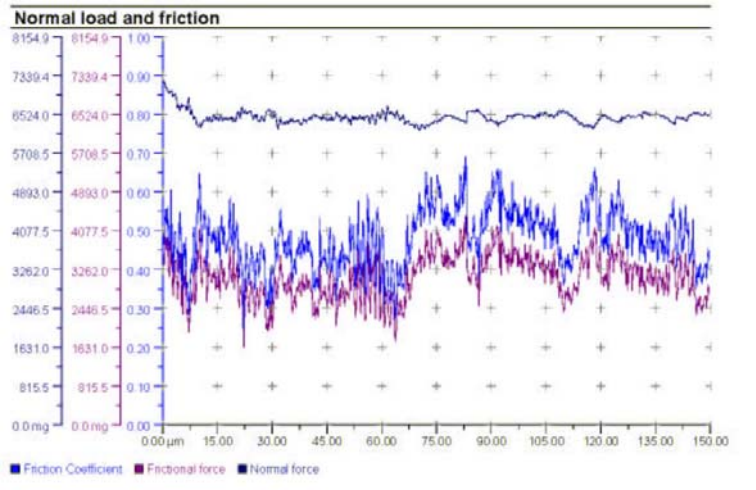
- Cleaning without the proper cleaning media is like not cleaning at all.
- Cleaning with the wrong cleaning media is the equivalent of allowing my 3 year old to play with the card.
- Cleaning depends highly on the media type and probe needle. Soft materials do not work well with cantilever needles.

WC demonstrates a better solution when compared to lapping paper. Surprising is that the friction force on a vertical needle is less than that of the cantilever needle.

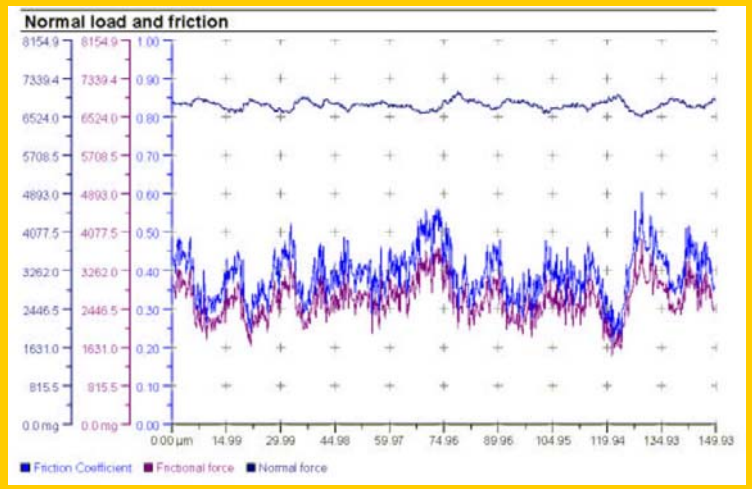
Friction is typically .3 with a load on the cantilever contact point of 2.5 grams.

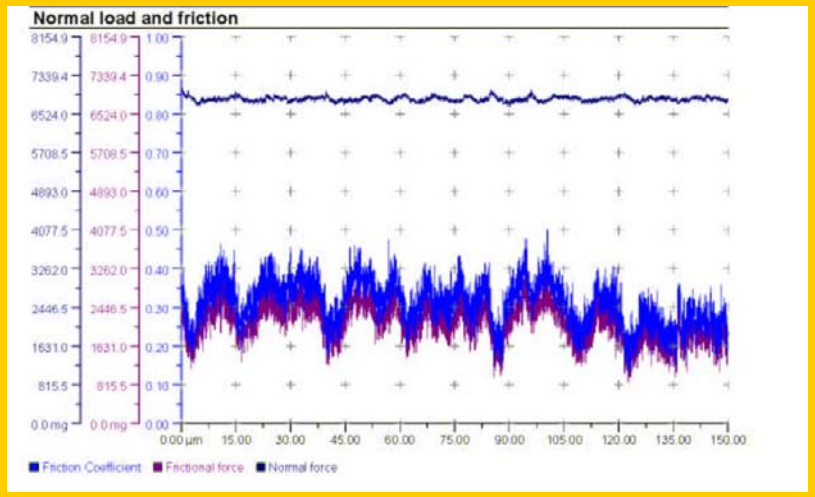
The WC interface has a needle that flexes but skims the surface. There is some stubbing but then the needle moves freely when compared to lapping media or tacky surfaces.

Cleaning Examples



Frictional studies confirm the need for cleaning prior to production test. The first cleans show higher friction that stabilizes after a set cleaning regiment.



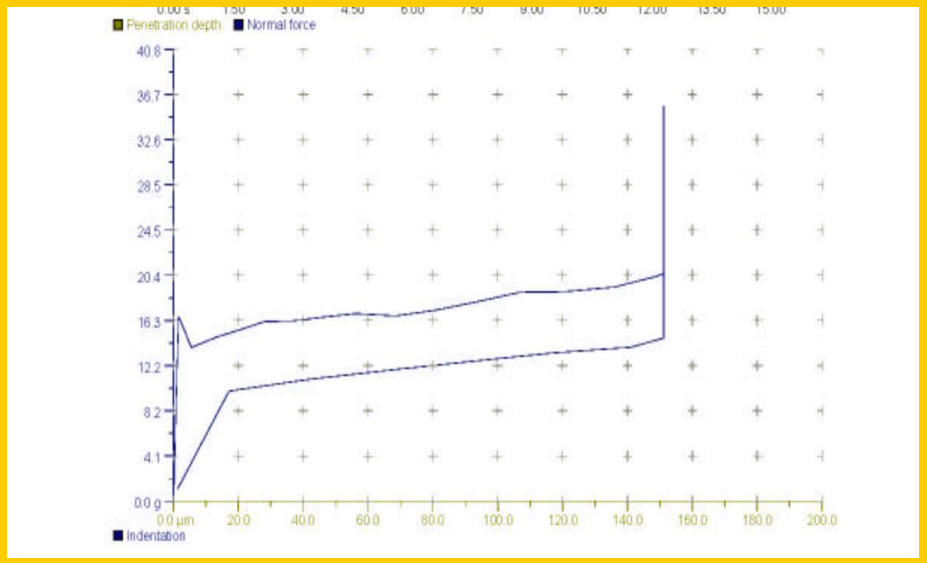


Probe Needle Cycling

What can be said, there are tools out there to run this test. Its also easy to build a bench set-up system to fixture the probe card into place and cycle:

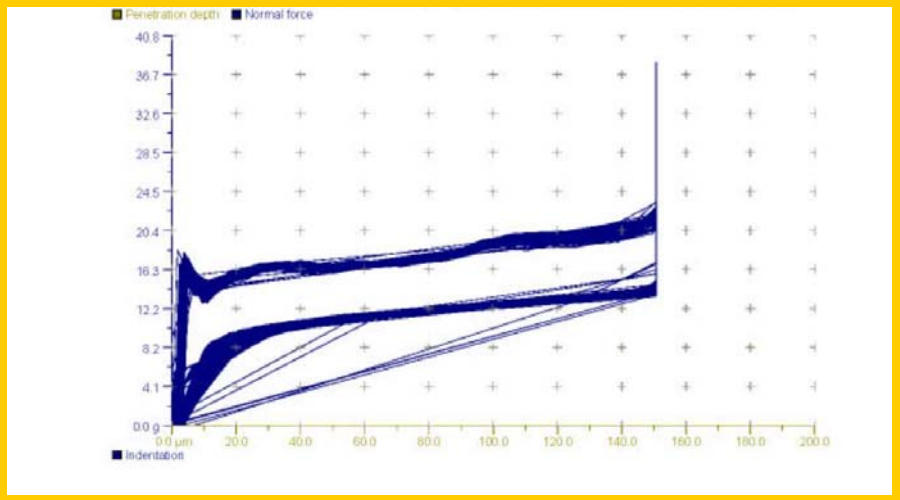
- **The difference the MHT/NHT makes is that the coordinates of the card can be loaded and each individual pin can be cycled at whatever rate, deflection and life desired.**
- **The variability of a pin over the life of the card can be analyzed to show deltas in single or multi-site, position or tier.**
- **In addition to the ease of use the tool will calculate the spring constant, simulated modulus and mechanical durability at ambient, hot or cold temperature**
- **Maintaining a constant load and changing current demonstrates how the force on the pad changes during probing.**

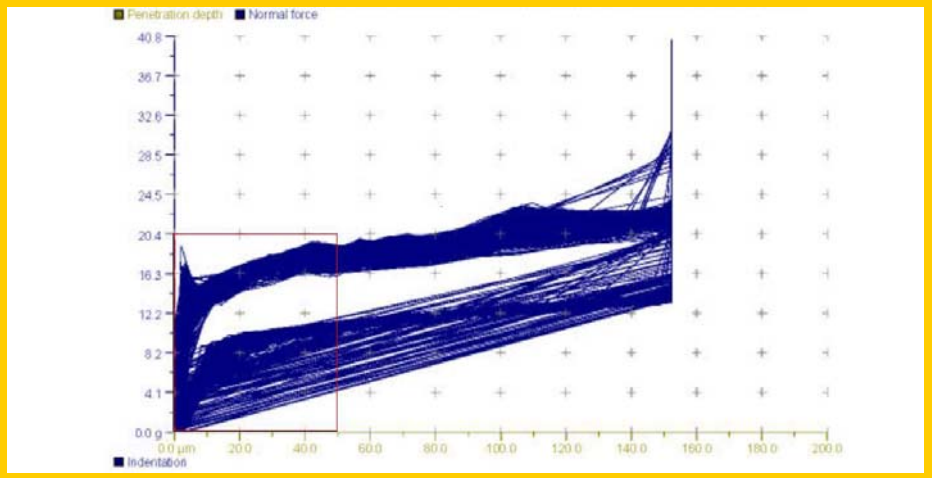
Cycles on a Cobra-Style Card



Counterclockwise starting at the left:

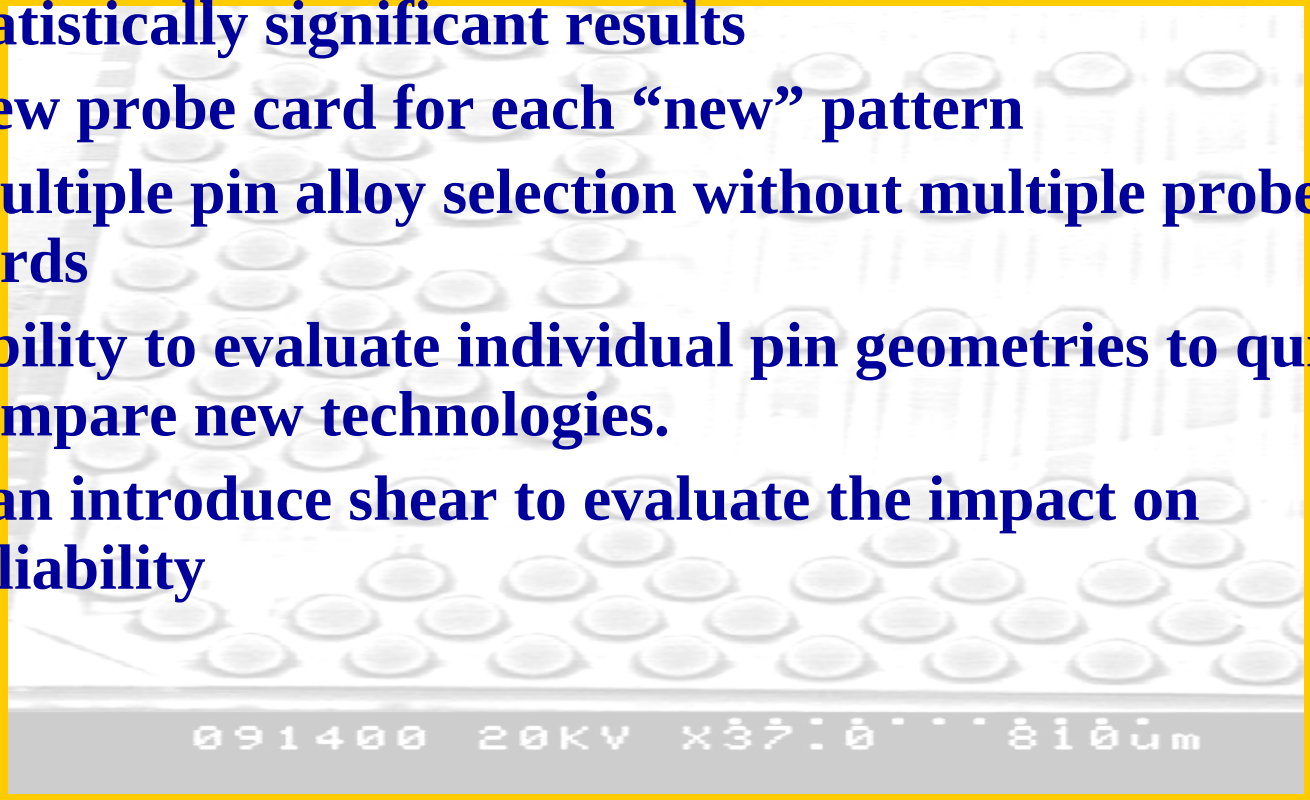
Single site load/unload highlights the spring constant. Cycles of 500 and 5000 demonstrate consistency but a change in the k-value. With a change of almost 5 grams, this 1000 pin card would see a 5kg delta for stable electrical contact.



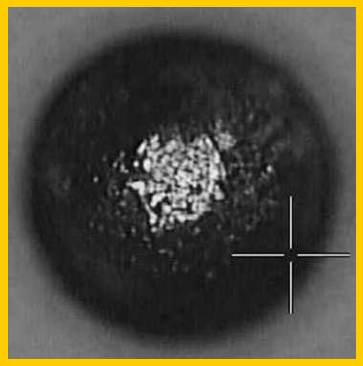


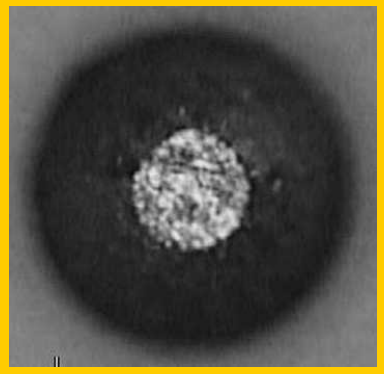
Flip Chip Determination

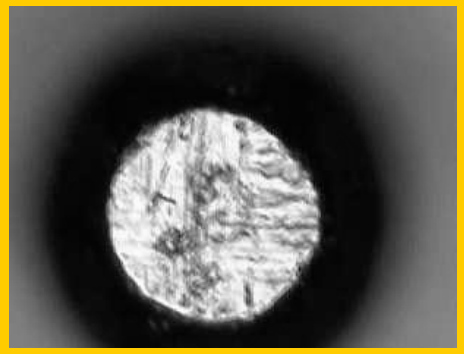
- Typical probe cards requires large number of die for statistically significant results
- New probe card for each “new” pattern
- Multiple pin alloy selection without multiple probe cards
- Ability to evaluate individual pin geometries to quickly compare new technologies.
- Can introduce shear to evaluate the impact on reliability



Pb-free Flip Chip Analysis







- Left to right SnPb under constant load
- SAC at 74% higher load to achieve similar spot size
- SnPb at same loading as SCA
- Total time to determine new load setting and BCF for SAC was 10 minutes

Pb-free

SnPb

Open Platform Configuration

Summary of MHT/NHT Benefits

ISSUE	MHT
Calibration	Highly accurate and reproducible Load and Depth calibration to ASTM standard references
Positioning Accuracy	Positioning to nearest 0.1 µm
Contact Conditions	MHT uses loads and indenter geometries which correspond exactly to probe testing conditions. Actual probe tips can be mounted on the MHT for accurate simulation testing.
Data Analysis	Instrumented indentation data can provide Hardness, Elastic Modulus, Stress-Strain, Fracture Toughness, etc….
Ease of Use	Completely automated in Open Platform configuration. Accepts wafers.

Thank you for sharing your time. Please feel free to contact us if there are any additional questions at info@covinc.com

Enjoy San Diego.