IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

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Electrical Contact Resistance - The Key Parameter in Probe Card Performance

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Overview

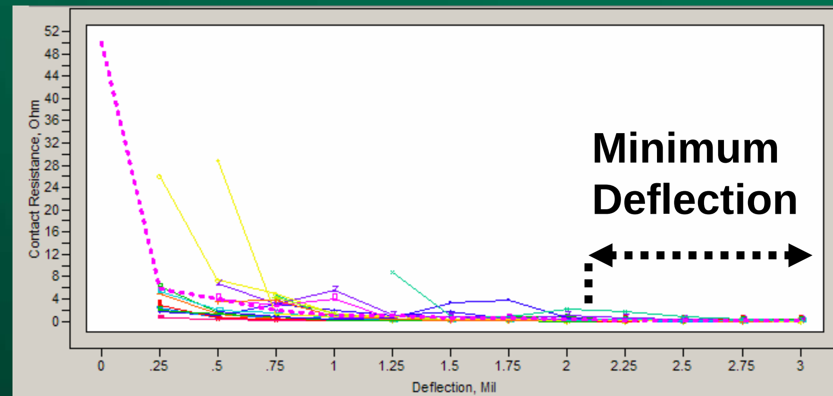
- Test cell & Contact Resistance measurement system
- Contact Resistance processes applied to probe cards
- Probe parameters related to Contact Resistance
- Contact Resistance stability
- Characteristic performance of selected probe designs on AL & Cu surfaces
- Summary
- Acknowledgements

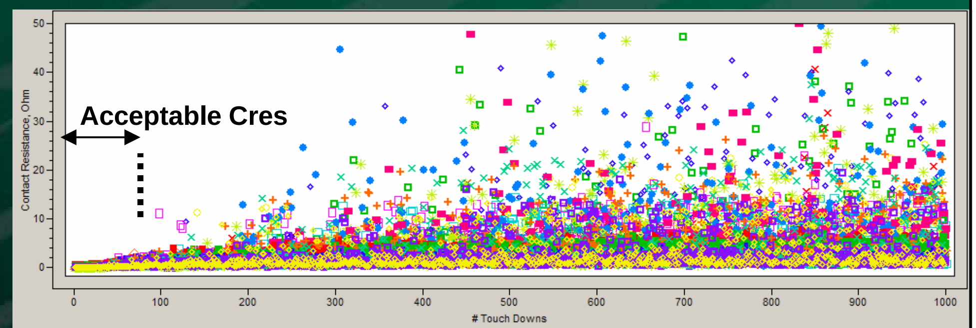
Test Cell & Contact Resistance Measurement System

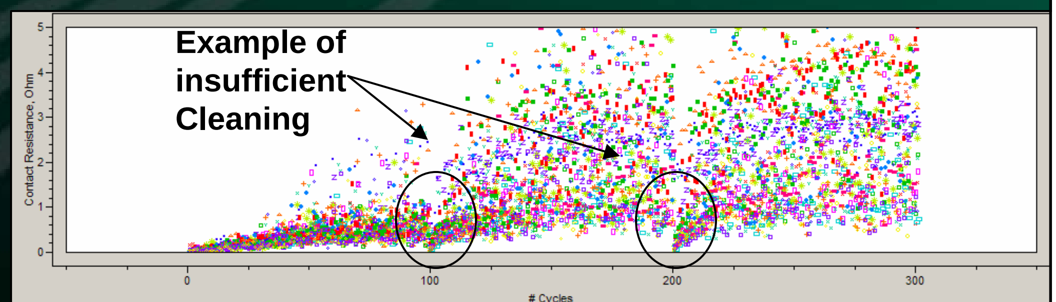
- TEL P12 & EG 2080 prober interfaced to Measurement system in Clean Room environment
- Keithley 2750 Multimeter/Switch/Data Acquisition System
- Agilent E3640A Programmable DC Power Supply
- Custom LabVIEW program for system control/data capture
  - GPIB Interface

Contact Resistance Processes Applied to Probe Cards

- Contact Resistance, Force/Deflection Relationship
  - Determine preliminary deflection to meet Cres objective
  - Add safety factor to compensate for process variation
  - Maximum allowable Mechanical stresses determine maximum deflection
- Contact Resistance, Repeatability
  - Multiple cycles with no cleaning
  - Observe cycle number at which cres exceeds specification
- Cleaning Method Effectiveness
  - Cleaning media
  - Cleaning frequency

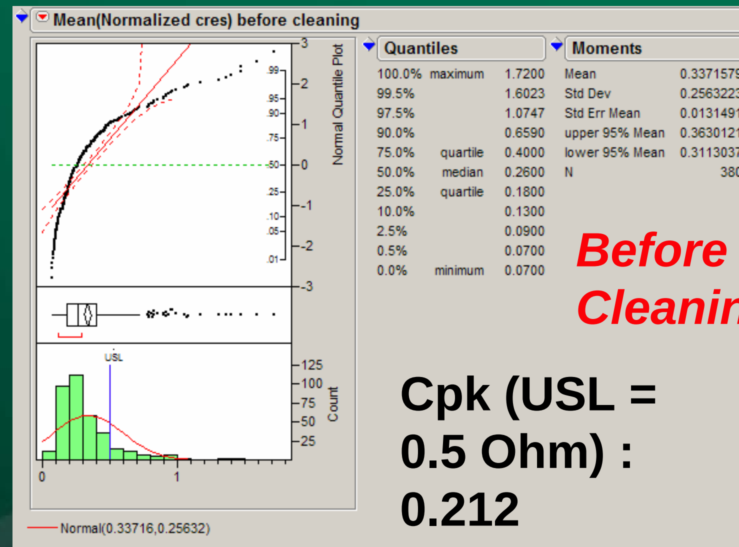


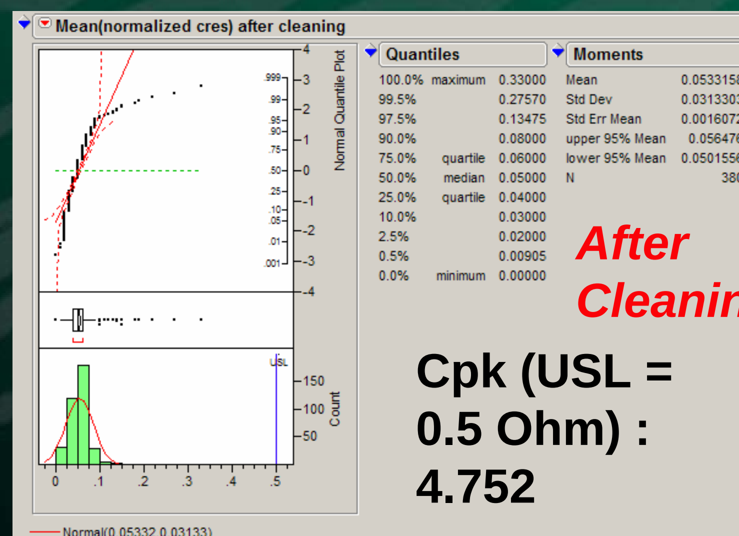




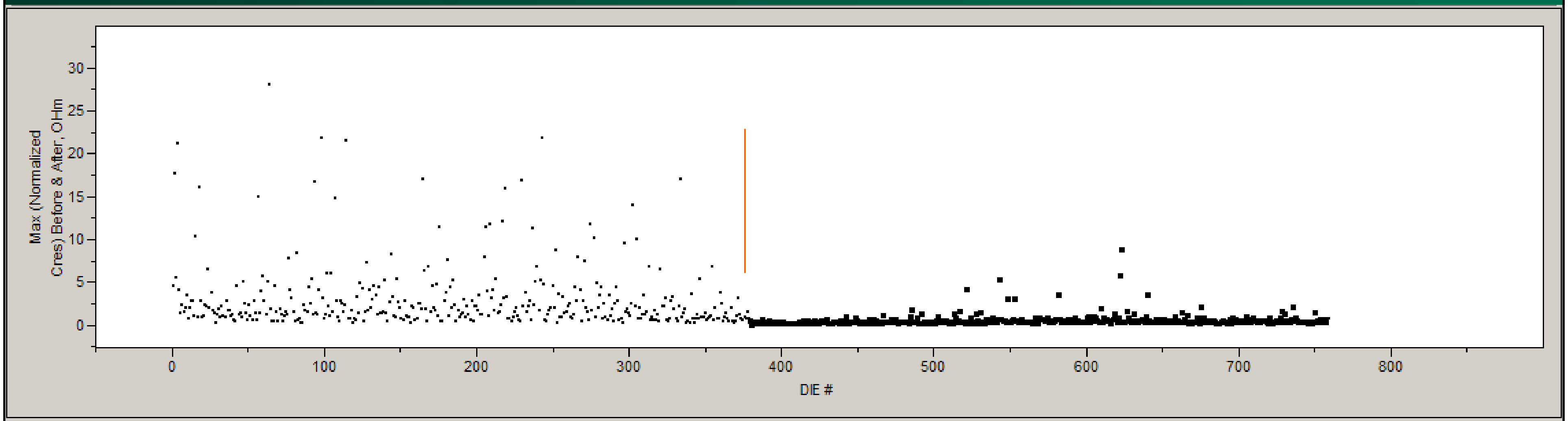
Contact Resistance Process Capability

- Statistics in determining Cres capability
  - Performance Parameters:
    - Max allowable cres as upper specification limit (e.g. 0.5 Ohm)
    - Mean Cres specification
    - Std Dev Cres specification
    - % quantile Cres specification
  - Cpk Value determines process control capability (Cpk>1.3 desired)
- Statistics used in determining cleaning capability
  - Compare Cres Statistics Before-After Cleaning





Cleaning Method Effectiveness



Before Cleaning

The 99.5 quantile:1.6023, Cpk (USL = 0.5 Ohm) : 0.212

Mean (Normalized_Cres):0.3371

Std Dev (Normalized_Cres): 0.2563

After Cleaning

The 99.5 quantile: 0.275, Cpk (USL = 0.5 Ohm) : 4.752

Mean (Normalized_Cres):0.0533

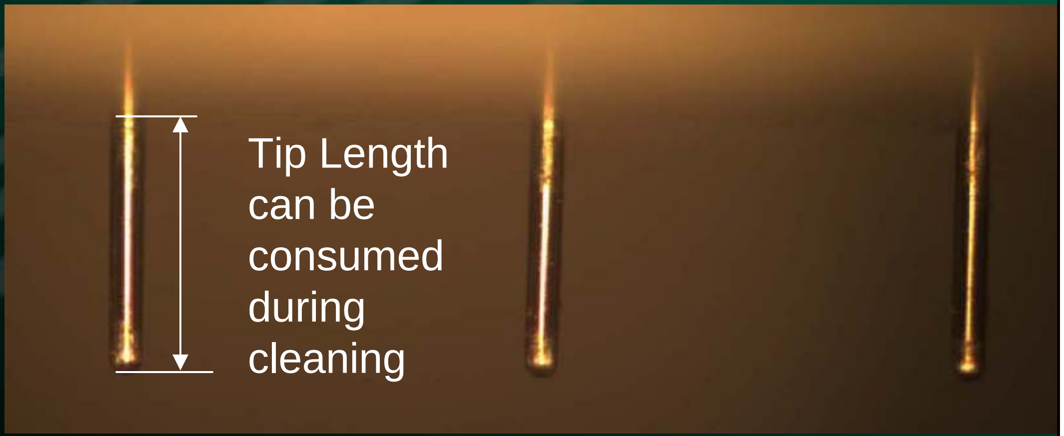
Std Dev (Normalized_Cres): 0.0313

Probe Parameters Related to Contact Resistance/Cleaning

- Tip diameter/size change as fn of cleaning cycles
  - Affects alignment to pad
  - Ultimately detrimental to Cres
- Tip length change as fn of cleaning cycles
  - Minimum clearance between wafer and lowest probe card component
- Tip's plating wear

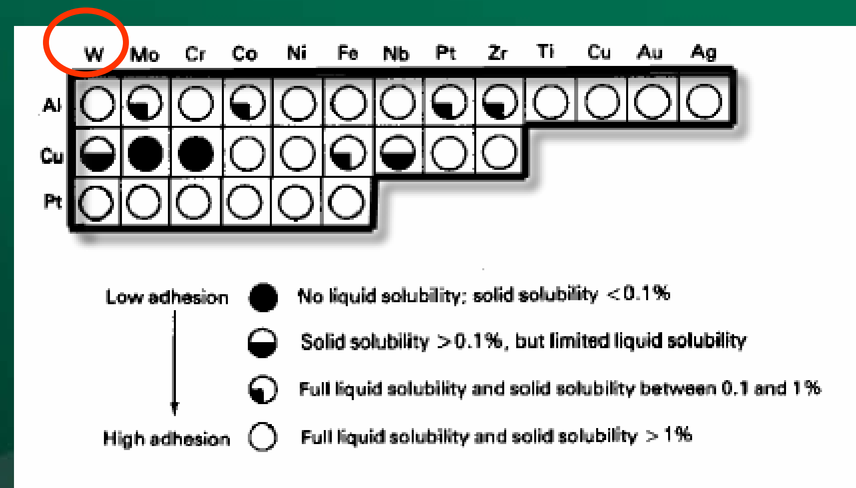
MEMS-Vertex™ Probe Tips

Fine Pitch Vertical Probe Tips



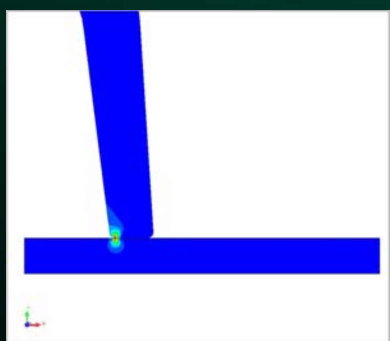
Contact Resistance Stability - Key Components

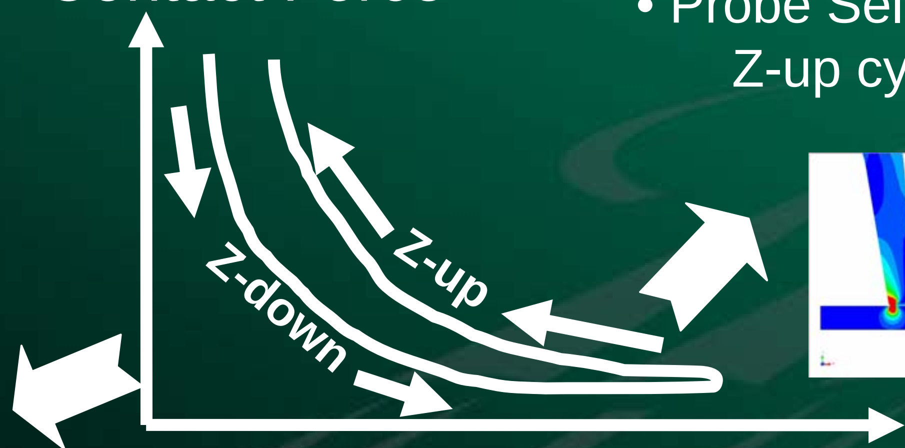
- Contact metallurgy
  - Formation of non-conductive films on probe's contact surface
  - Probe-Pad (bump) metallurgical interaction. Adhesion of pad & tip materials
  - Formation of polymers on surfaces under friction
- Contact micromechanics
  - Penetration of non-conductive films in the Z-down cycle
    - Aggressive penetration not allowed when probing ACUP, Low_K pads
  - Probe self-cleaning in the Z-up cycle
    - Probe's designed motion wipes off the tip's critical contact section in the Z-up cycle
    - Removal of adhered, adsorbed particulates
- External cleaning
  - Compensates imperfections in the listed above



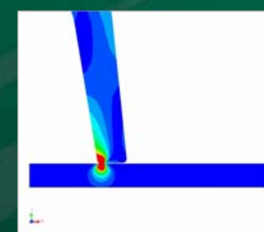
Degree of expected adhesion between metal combinations. *Source: E. Rabinowicz, Determination of Compatibility of Metals… V14, 1971, p.198-205*

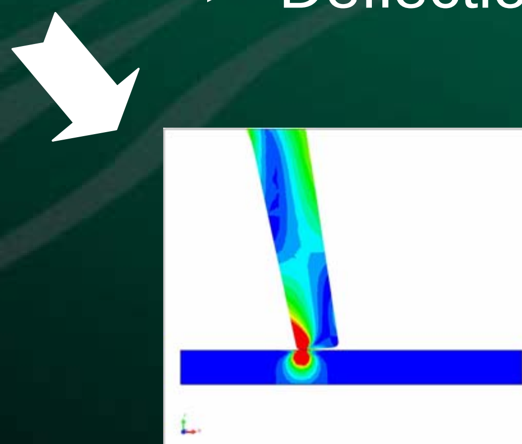
Contact Resistance Stability
- Probe Contact Micromechanics





- Probe Self-cleaning in the Z-up cycle

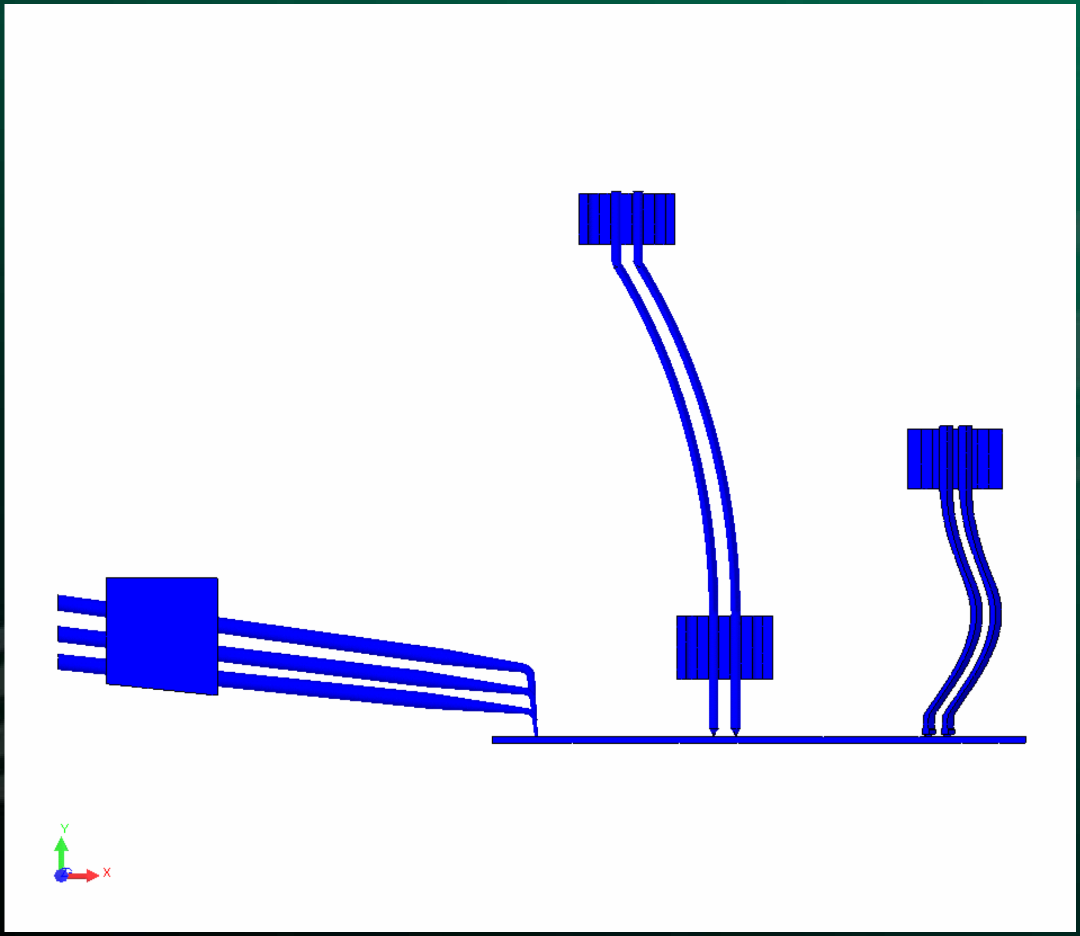




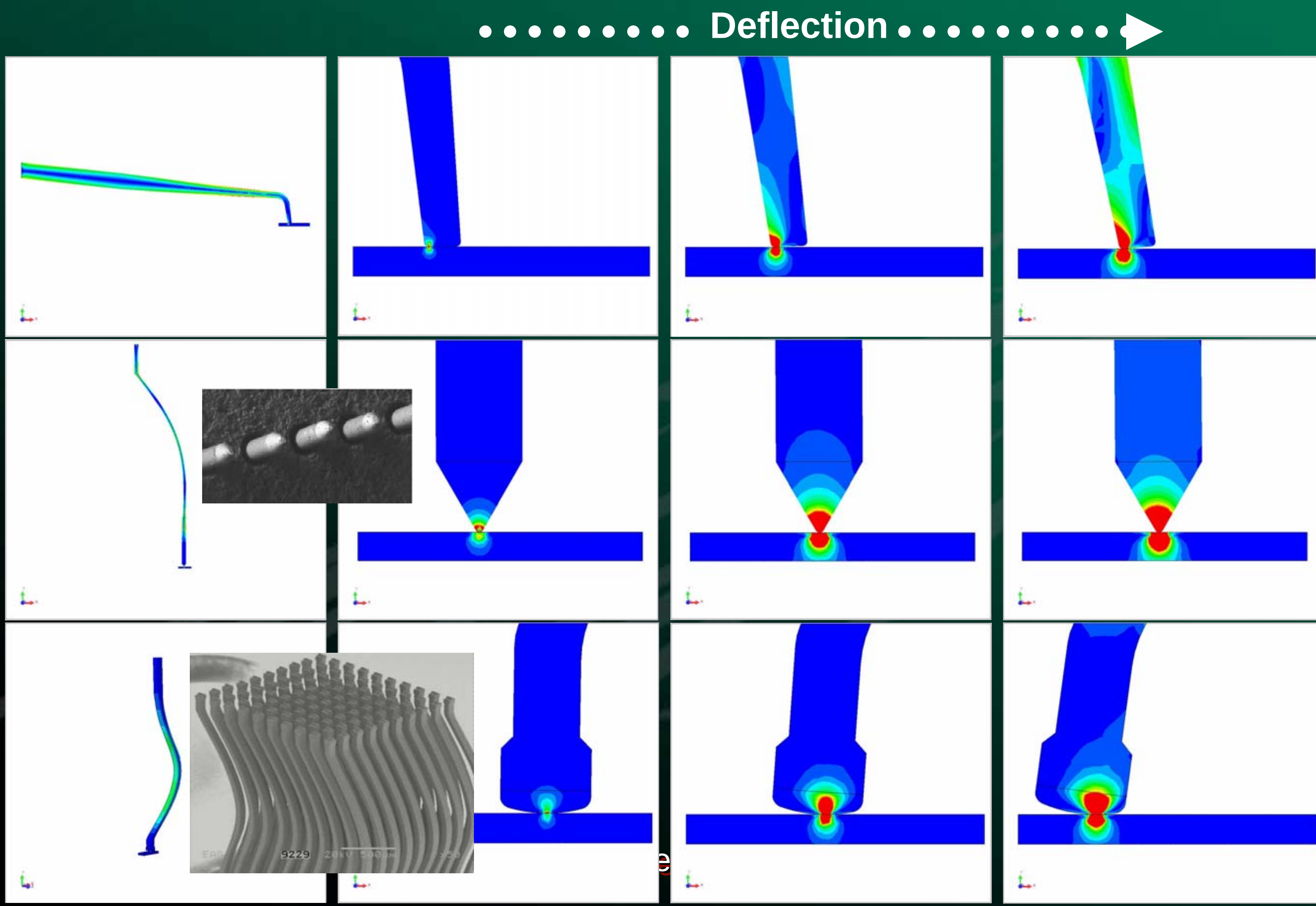
- Penetration of non-conductive films in the Z-down cycle
- Aggressive penetration not allowed when ACUP, Low_K pads

Probe Deflection
Cantilever, Vertical Buckling & MEMS-Vertex™

- Three technologies with different modes of contacting wafer resulting in different scrub motions

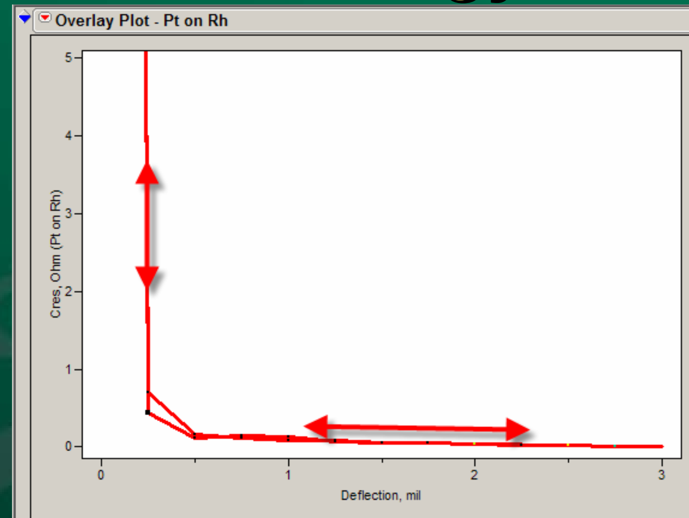


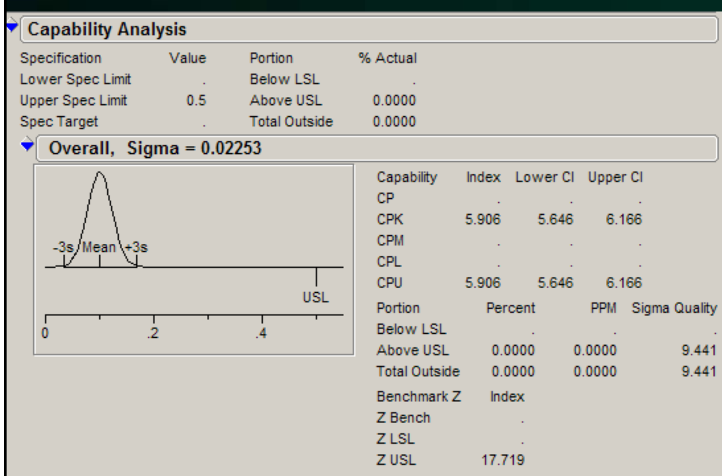
Probe Micromechanics – Location of Contact Stresses



Contact Resistance Stability – A Case of “good” Contact Metallurgy

- Near ideal probe-pad contact behavior
  - Platinum probe tip/Rhodium Pad data shown
  - Cres approaches steady state within short OT
  - Long, Flat working range of Cres
  - Cres loop “reversible”





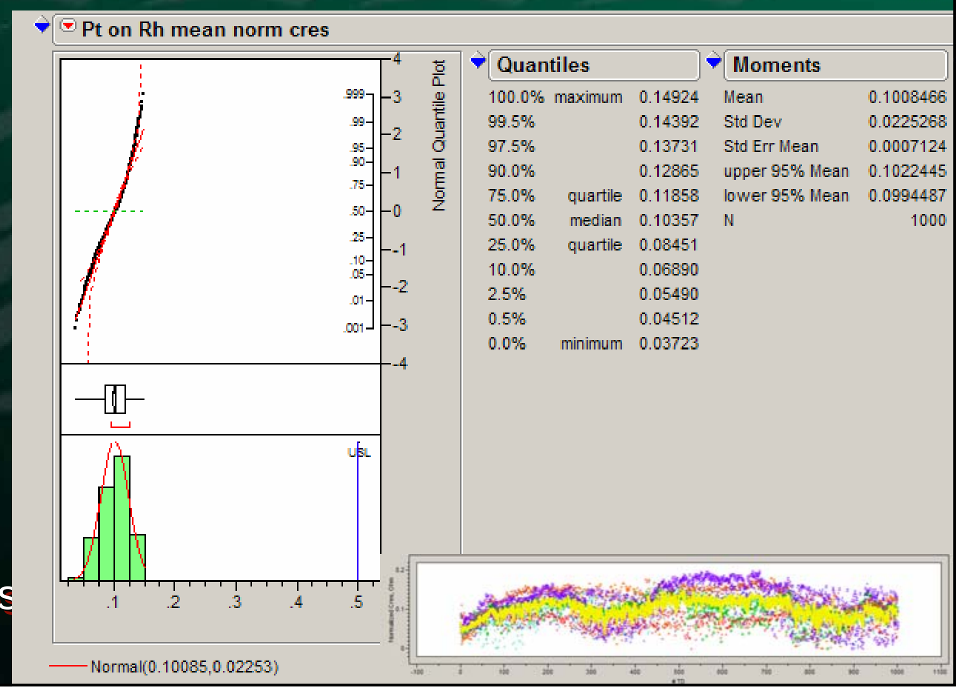
Specification	Value	Portion	% Actual
Lower Spec Limit	.	Below LSL	.
Upper Spec Limit	0.5	Above USL	0.0000
Spec Target	.	Total Outside	0.0000

Capability	Index	Lower CI	Upper CI
CP	.	.	.
CPK	5.906	5.646	6.166
CPM	.	.	.
CPL	.	.	.
CPU	5.906	5.646	6.166

Portion	Percent	PPM	Sigma Quality
Below LSL	.	.	.
Above USL	0.0000	0.0000	9.441
Total Outside	0.0000	0.0000	9.441

Benchmark Z	Index
Z Bench	.
Z LSL	.
Z USL	17.719

Cpk=5.9



Quantiles

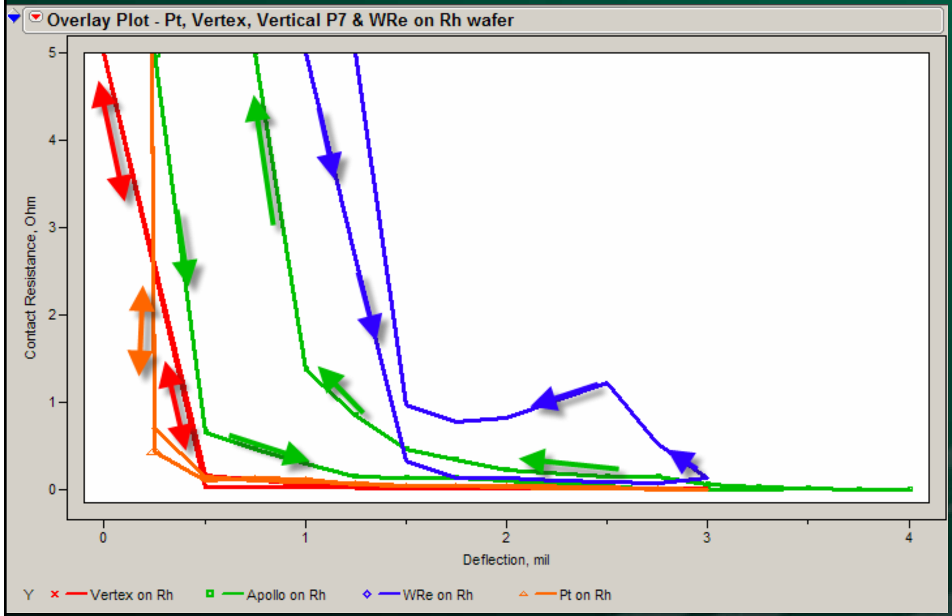
100.0%	maximum	0.14924
99.5%		0.14392
97.5%		0.13731
90.0%		0.12865
75.0%	quartile	0.11858
50.0%	median	0.10357
25.0%	quartile	0.08451
10.0%		0.06890
2.5%		0.05490
0.5%		0.04512
0.0%	minimum	0.03723

Moments

Mean	0.1008466
Std Dev	0.0225268
Std Err Mean	0.0007124
upper 95% Mean	0.1022445
lower 95% Mean	0.0994487
N	1000

Contact Resistance Stability Study

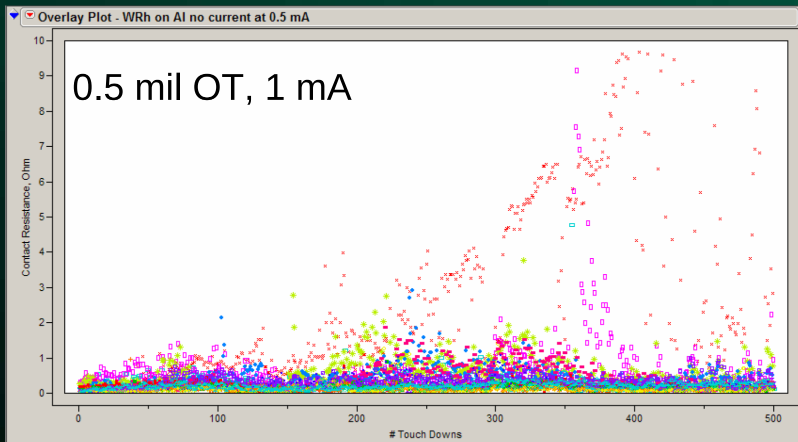
- Pt, Vertical P7, WRe Cantilever & MEMS-Vertex™ on Rhodium Wafer

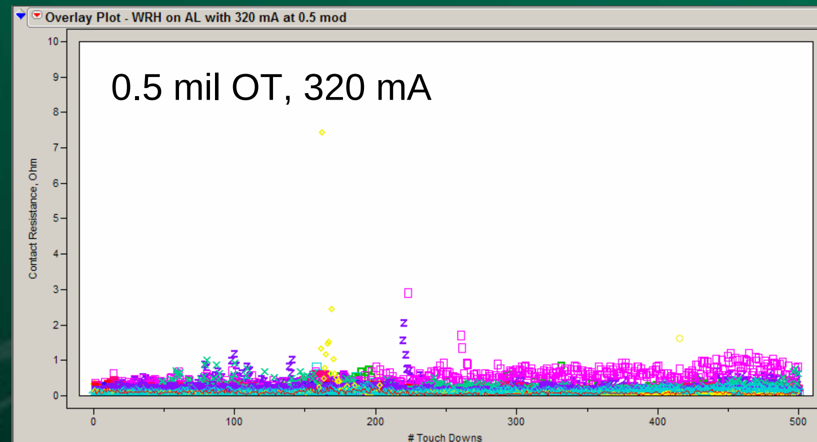


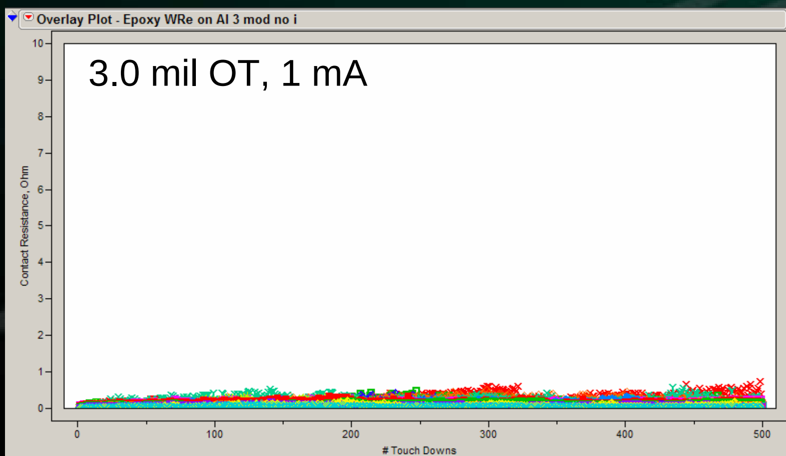
- Characteristic cres loops per probe type on Rh Wafer
- "Reversible" cres loop for ideal metallurgy vs. real probe metallurgy/micromechanics
- Applied as a method for quick evaluation of probe design performance

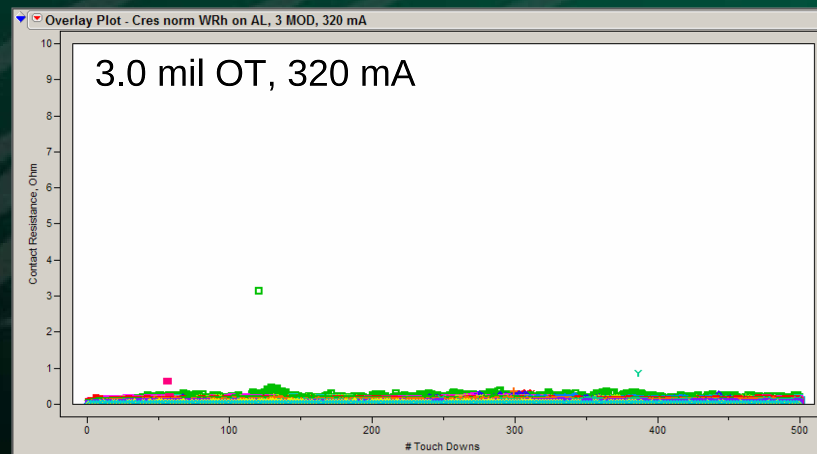
Contact Resistance Stability – Current Effects, WRe on AL

- Stability of Cres improves at low range of deflection at 320 mA



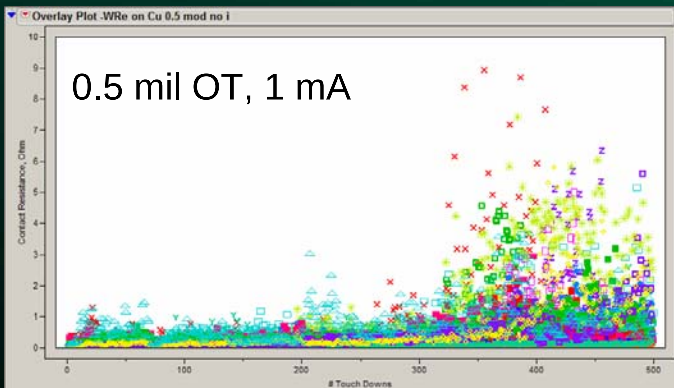


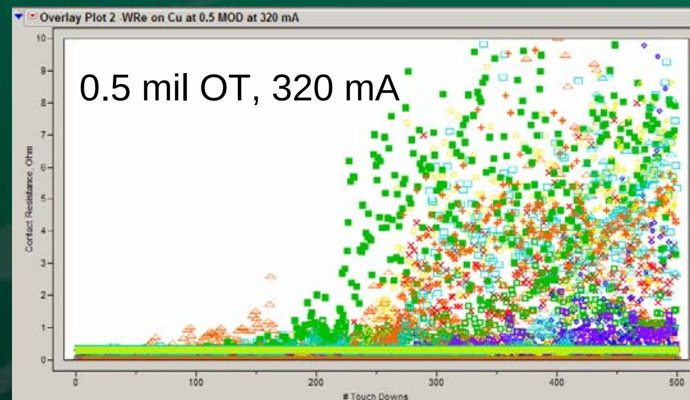


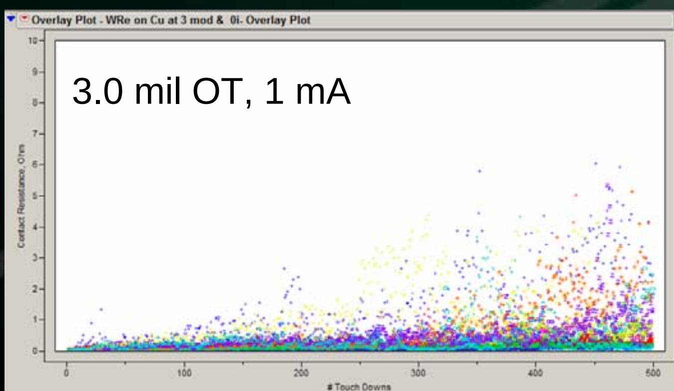


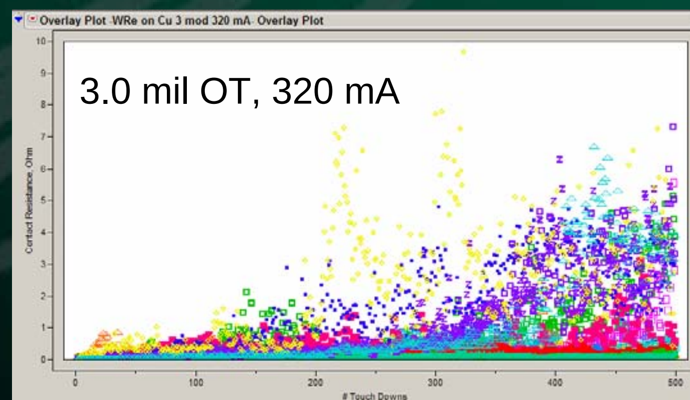
Contact Resistance Stability – Current Effects, WRe on Cu

- No improvement in stability of Cres due to current



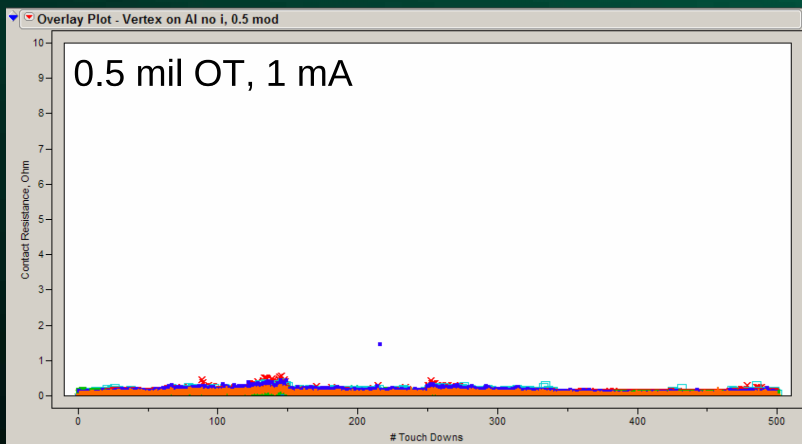


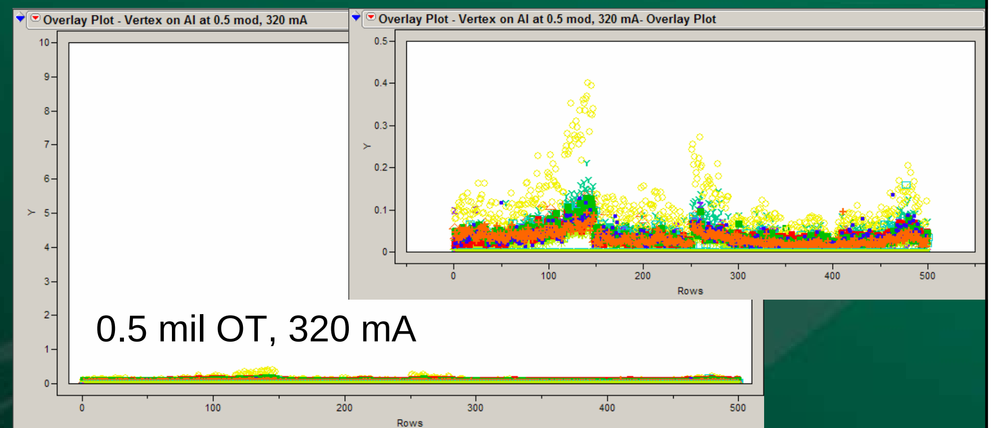


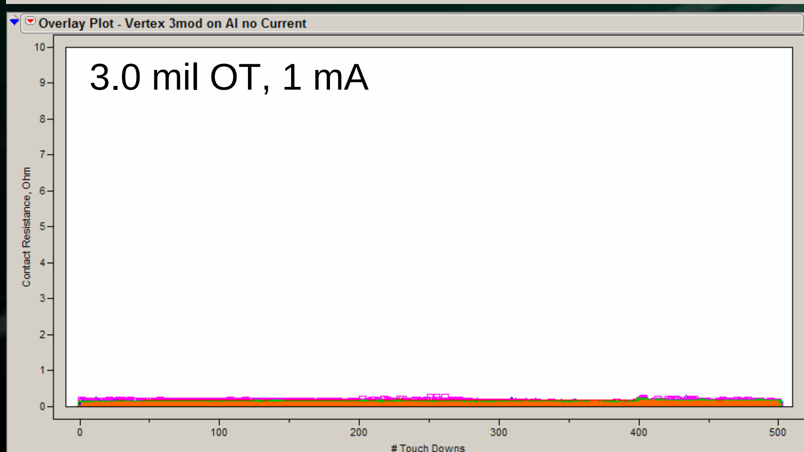


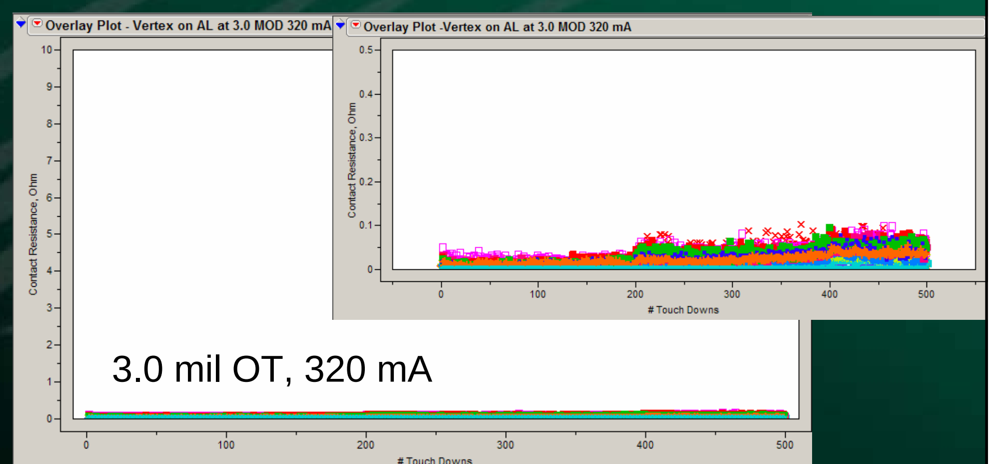
Contact Resistance Stability – Current Effects, MEMS-Vertex™ on AL

- No major improvement in stability of Cres at 320 mA



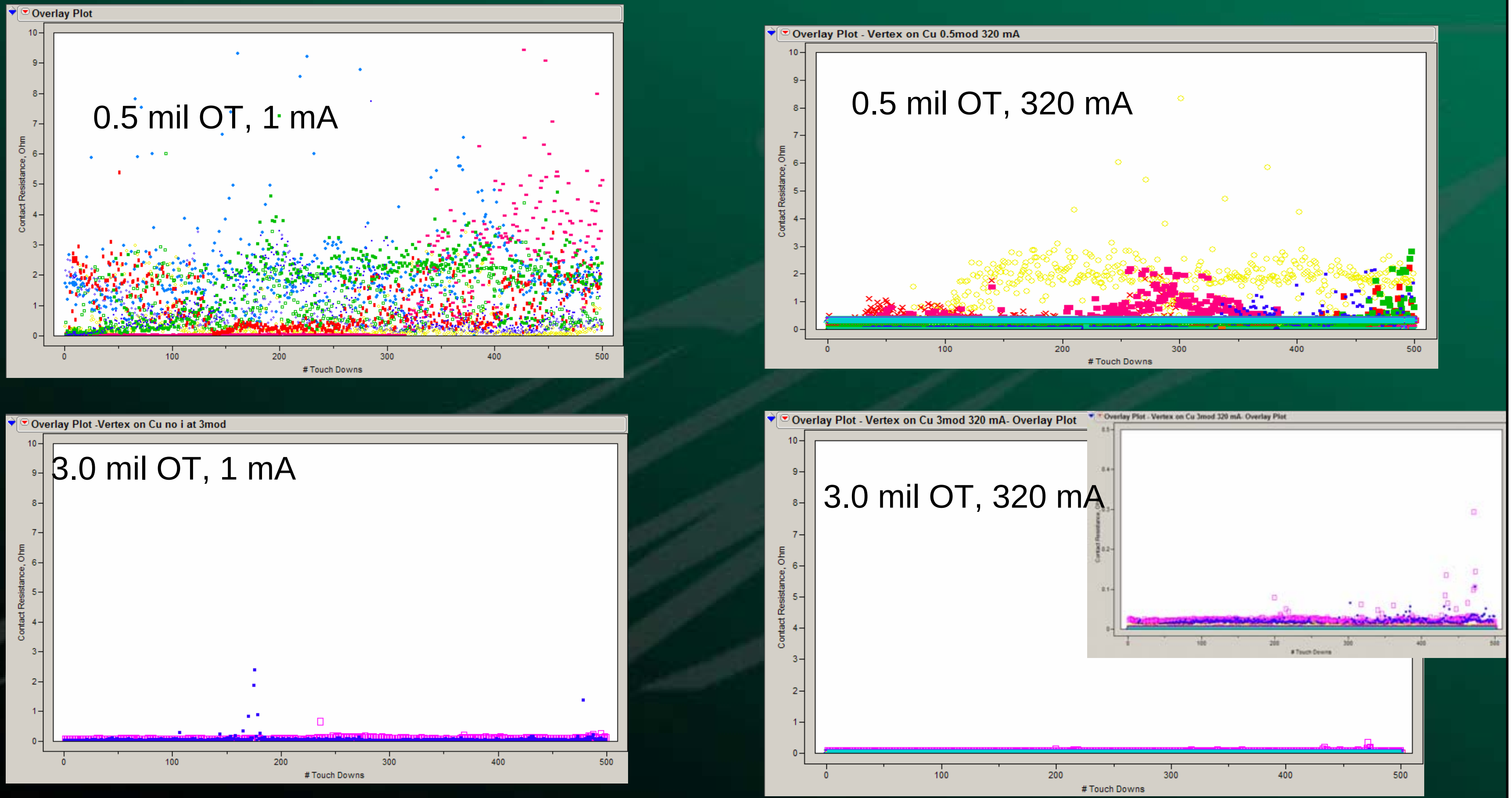






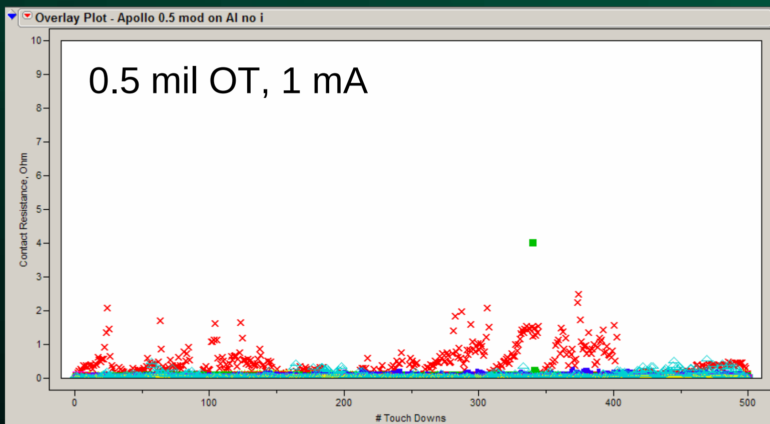
Contact Resistance Stability – Current Effects, MEMS-Vertex™ on Cu

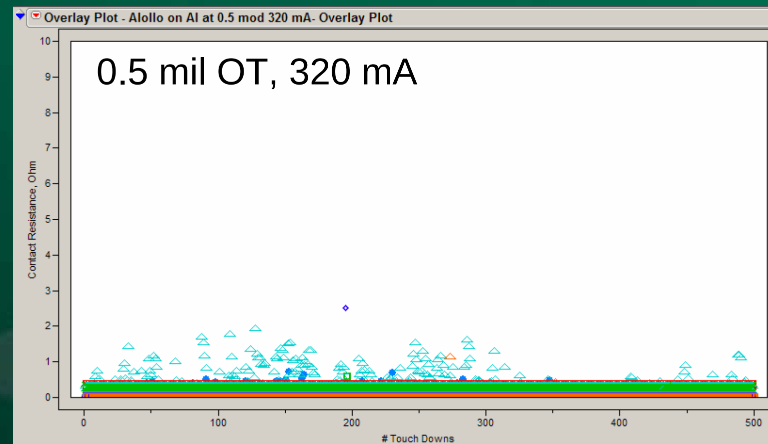
- Current improves stability of Cres at low deflection

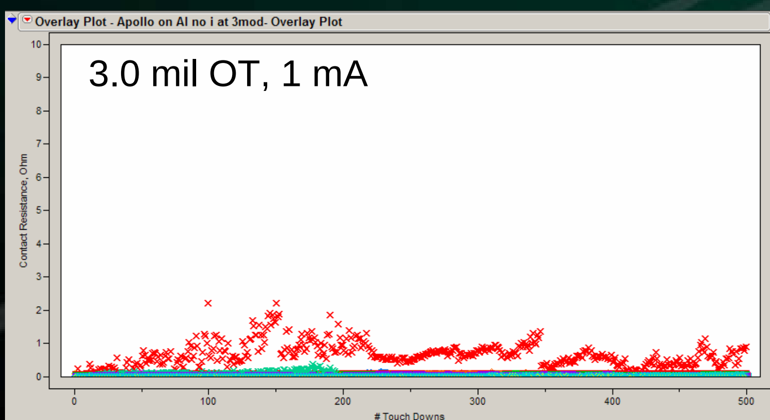


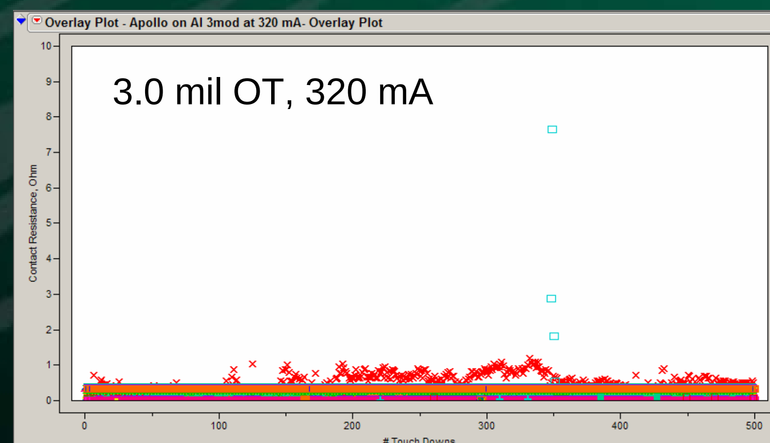
Contact Resistance Stability – Current Effects, Vertical P7 on AL

- No major Improvement of Cres stability at 320 mA



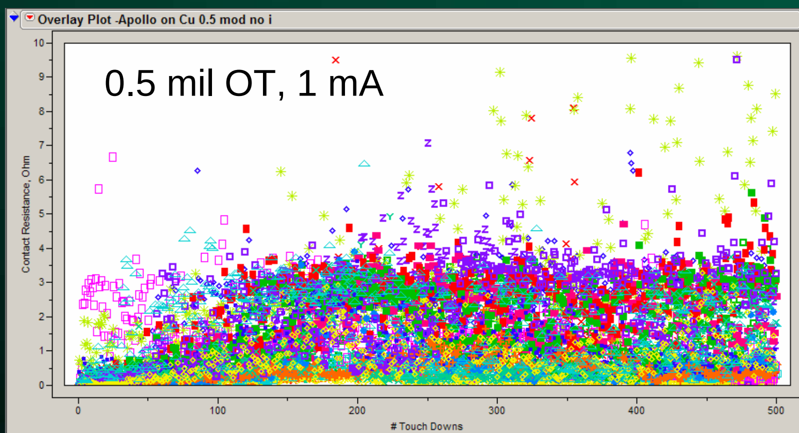


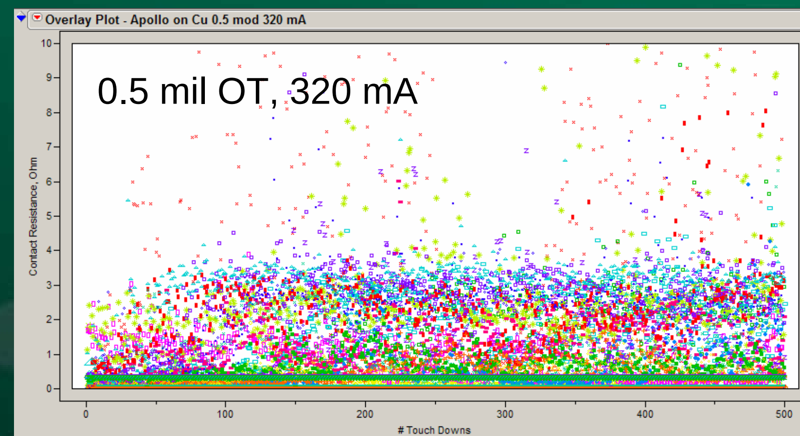


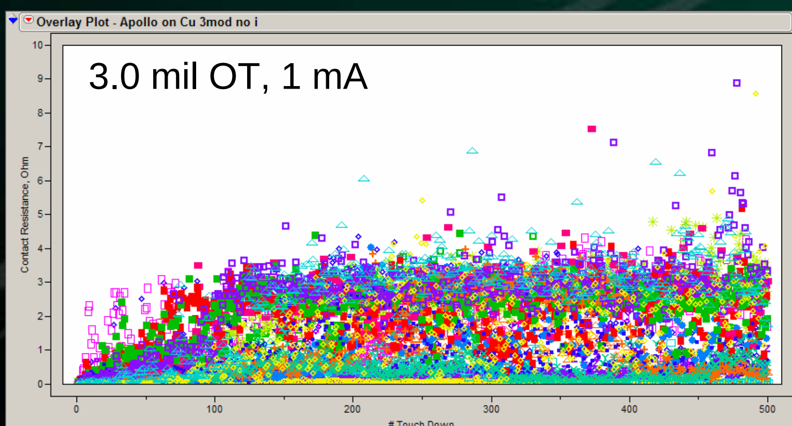


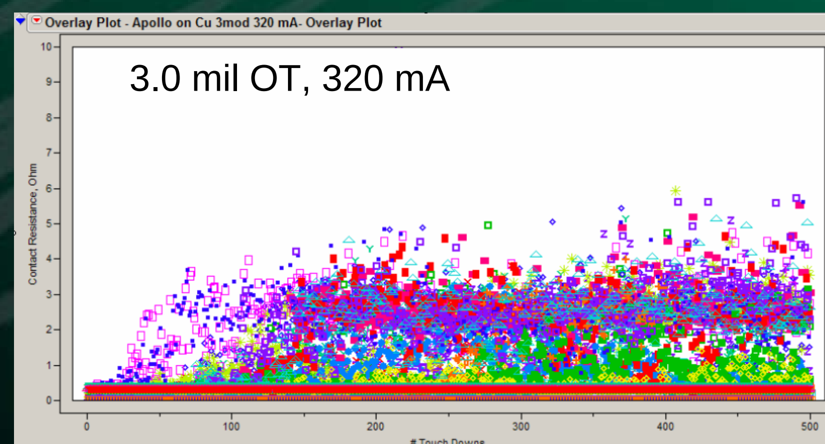
Contact Resistance Stability – Current Effects, Vertical P7 on Cu

- No improvement in stability of Cres at 320 mA, marginal OT setting









Summary/Next Steps

- The presented three probe technologies: Cantilever, Vertical and Mems-Vertex interact with wafer surface in different mechanical mode producing different Cres levels
- At marginal deflection levels on Al, cantilever WRe probe shows cres stabilization with higher current levels. Probe Cres at adequate overdrive levels is not affected by 320 mA current level (within 500 touch downs range)
- Mems technology allows for use of specific metallurgy for the probe body (perfect spring) and a different metallurgy for the tip (perfect contactor) providing best cres performance on Al and Cu
- Presented Cres results are representative of specific wafer/probe tip metallurgies used in this study. Wafers were provided by MicroProbe's customers
- Next Step: additional tests with wider range of current levels/deflections

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