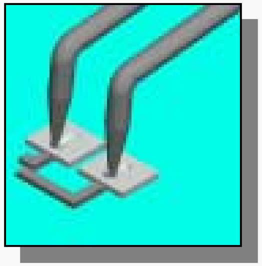
Vertical pad deformation during probe

Purpose

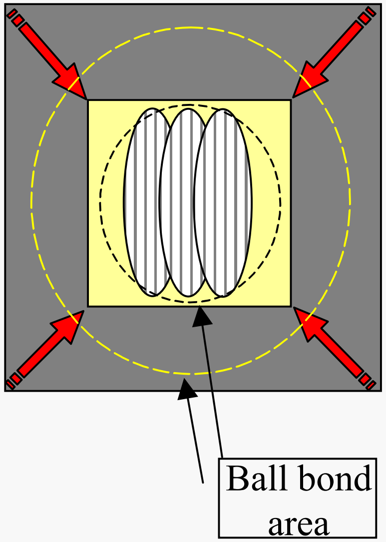
To quantify vertical penetration of aluminum pads as it relates to wire bonding using a cantilever probe card in a manufacturing environment



Agenda

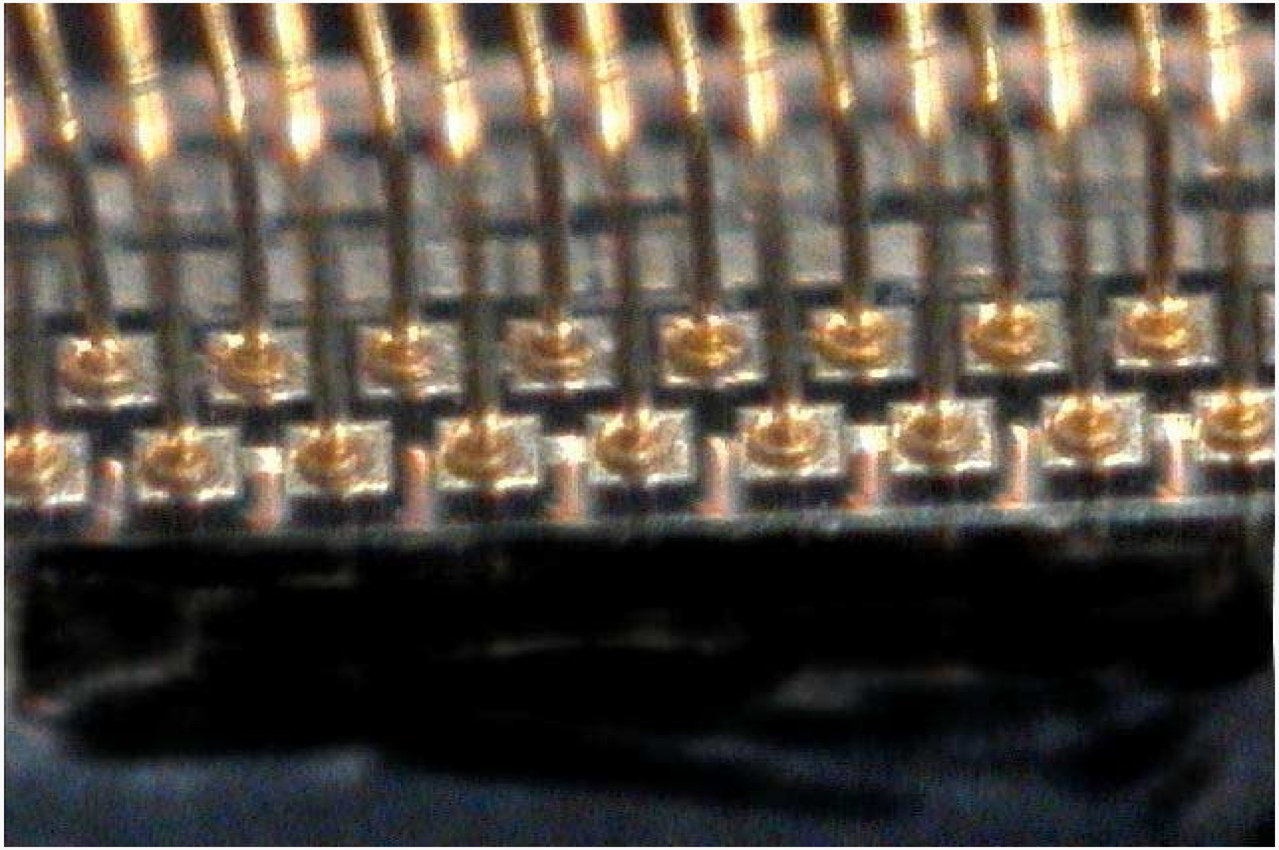
- Why we need it
- Surface profiler overview
- Probe recipes/setup
- 3D pad sample contour plots
- Initial results
- Challenges
- Future characterization
- Summary
- Acknowledgements

Why we need it



- Pad damage (excavated area) linked to bonding success
  - Pad thickness decreasing below ≈ 1.0 - 1.2 microns
    - Punch through increases
    - Reduces bonding area on aluminum pad
    - Implies increase in bonding failure rates
  - Pad size shrinking
    - Ratio of pad deformation area to pad area increasing
  - Bonding parameters recipes becoming more critical - ball diameter/placement - power- temperature - duration
  - Dielectric material getting softer
  - Alternative contact metals characterization

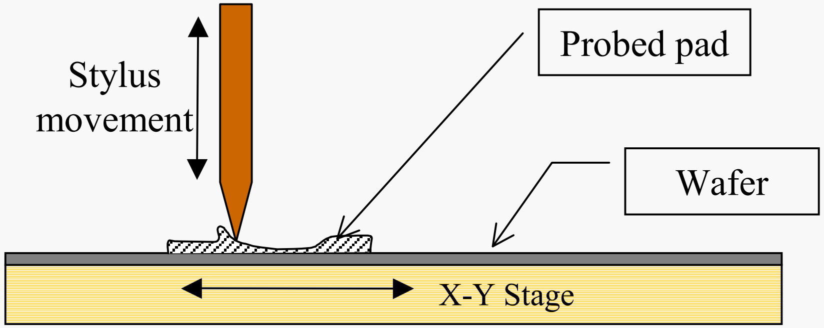
Typical gold wire ball bond



Profiler specifications

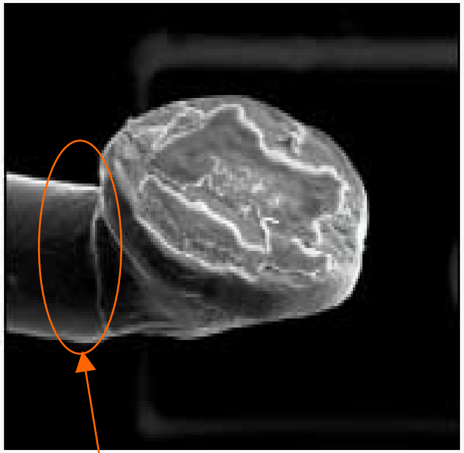
- Manufacturer - KLA-TENCORE
- Contact measurement (Stylus contact)
- Automated
- Non destructive - could be used as a monitor
- Vertical travel 130 microns
- Resolution ≈ 0.1 - 1 Å - depends on sample height
- Sampling rate 5 -1000 samples/sec
- Stylus force range 0.05 - 10mg
- Alignment - pattern recognition - comparable to a wafer prober
- Repeatability - ≈ 25Å @ 3σ
- Sample size of 60 X 60 microns test time ≈ 20 min

1.0 micron = 10,000 Å

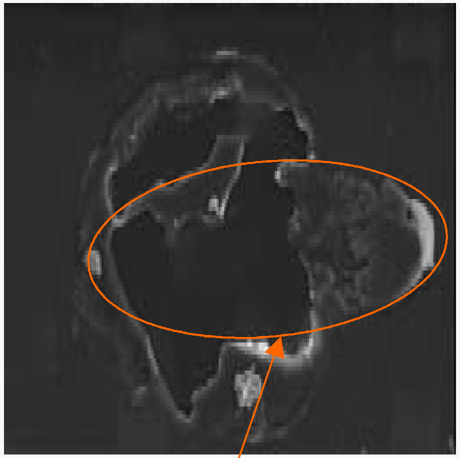


Basic principle

Bonding fail

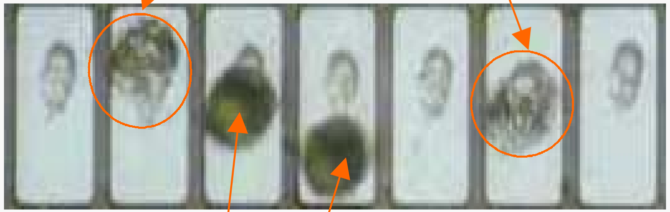


Normal failure area



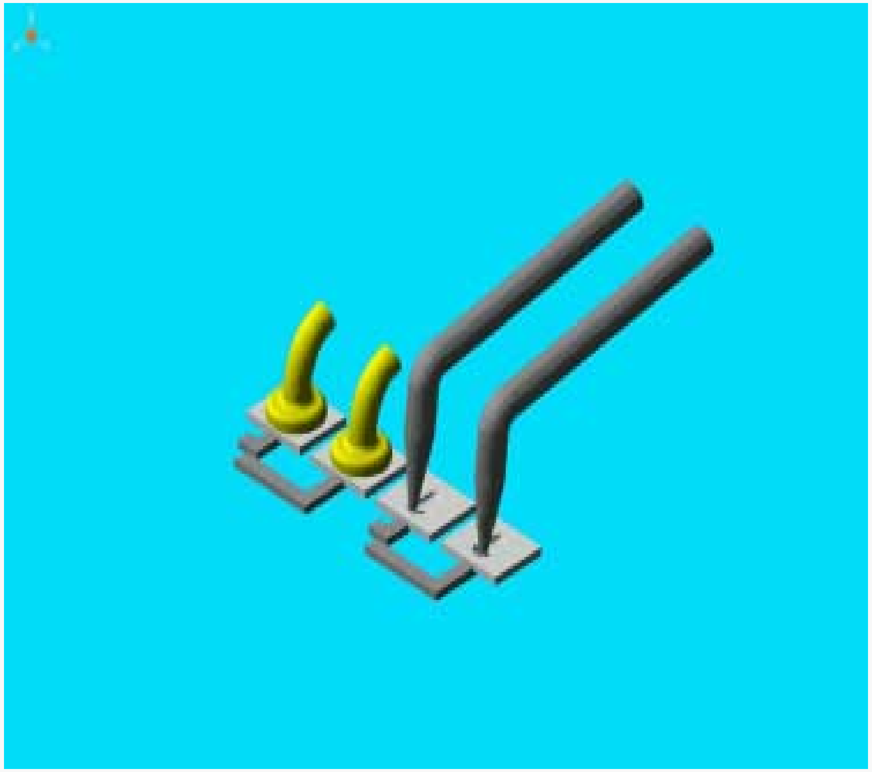
Probe mark

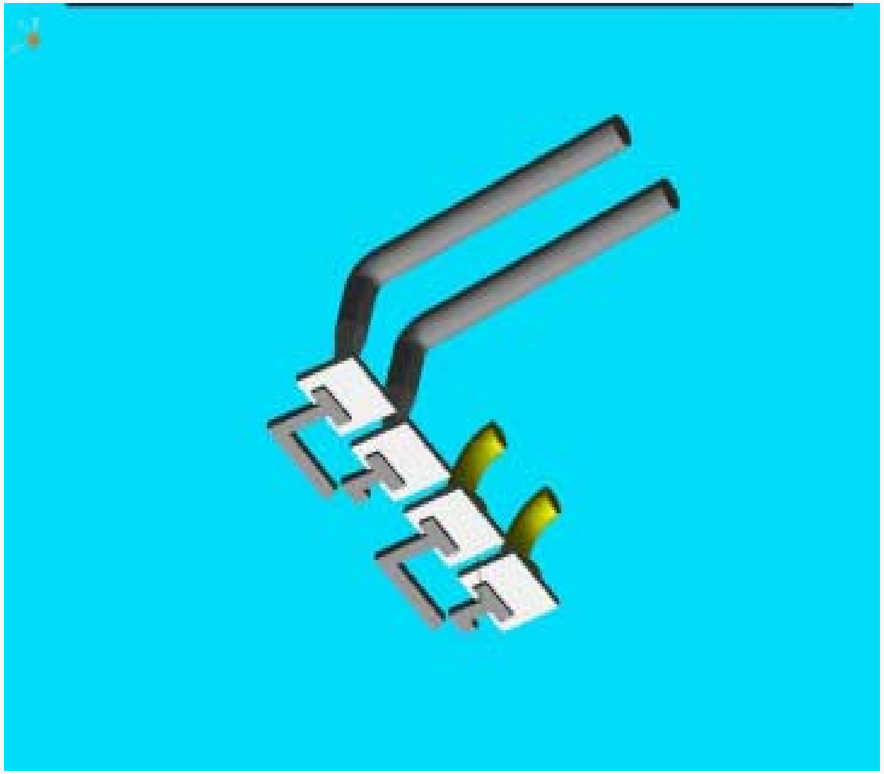
Bond tear outs



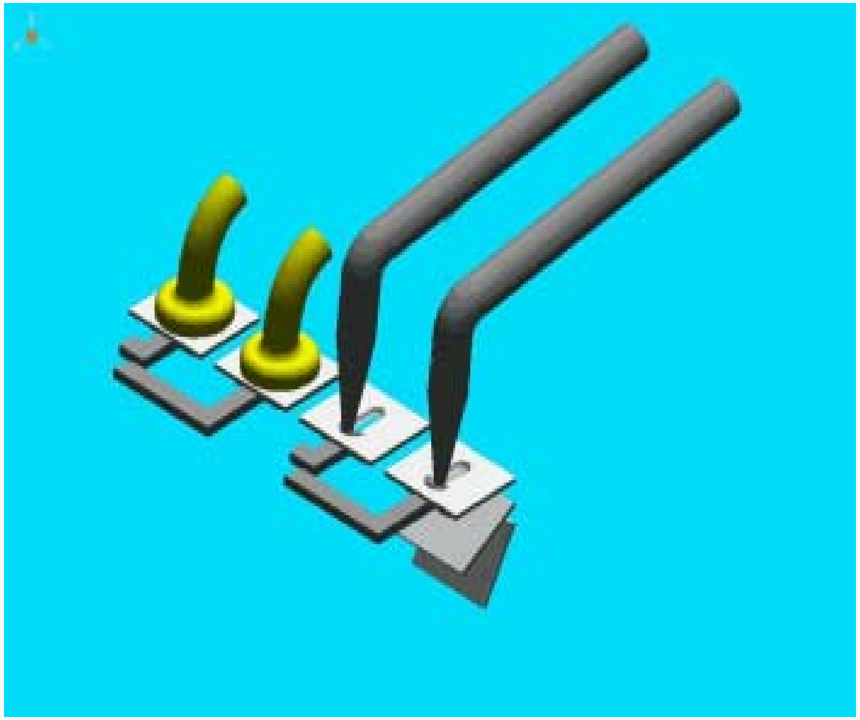
Normal bonds

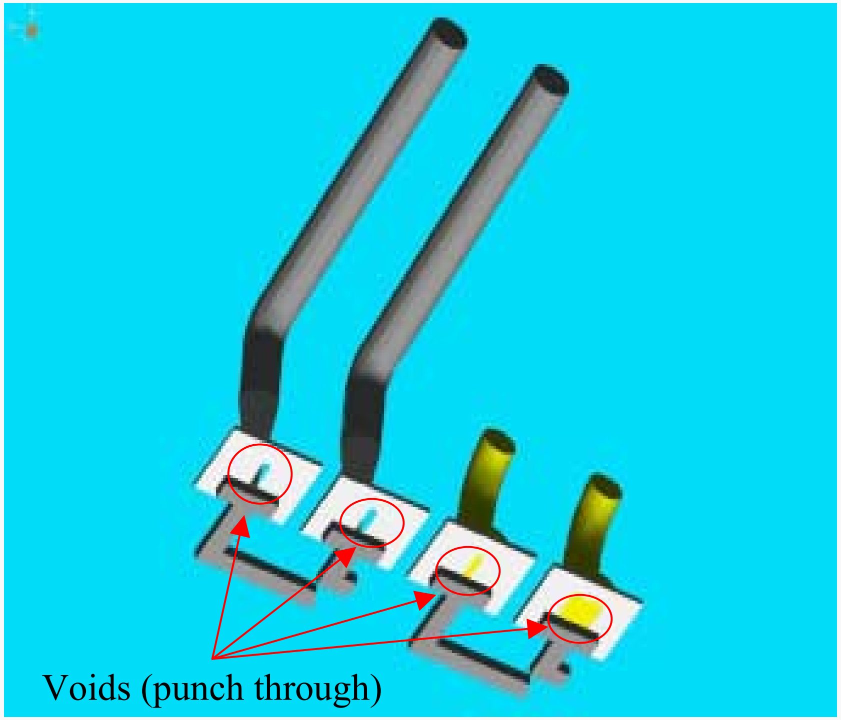
Typical “thick pad” ≈ >1.0 microns





“Thin Pad” below ≈ 1.0 micron

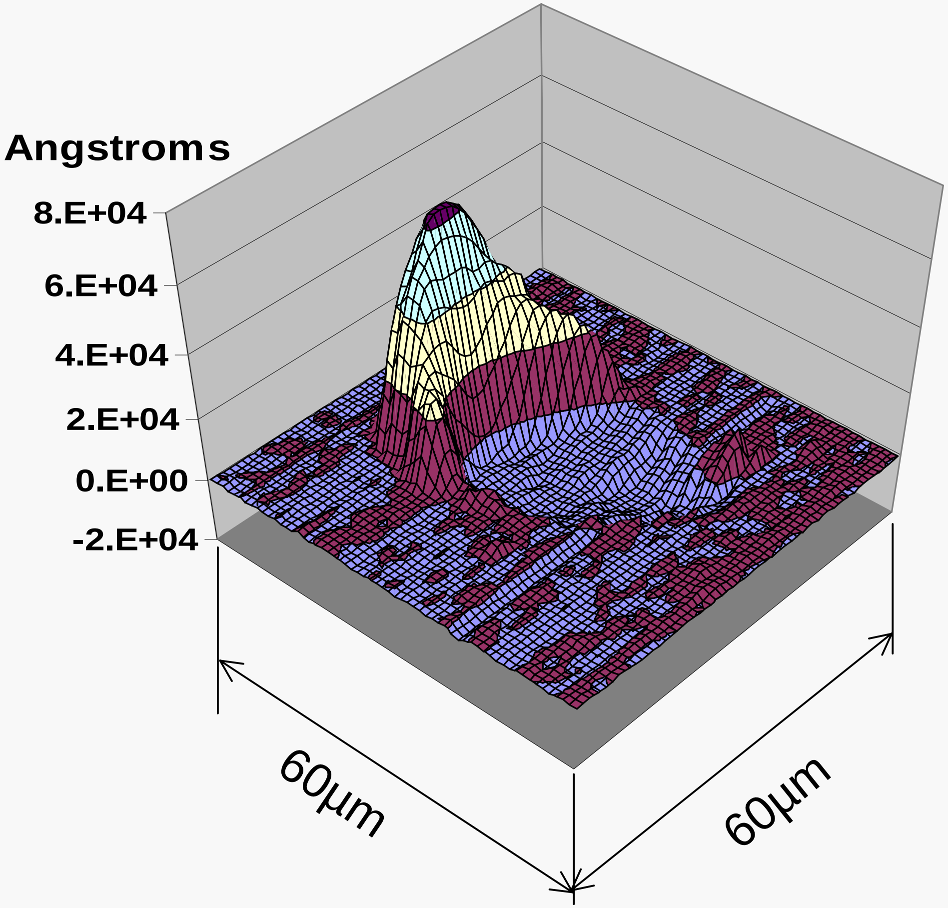




Setup

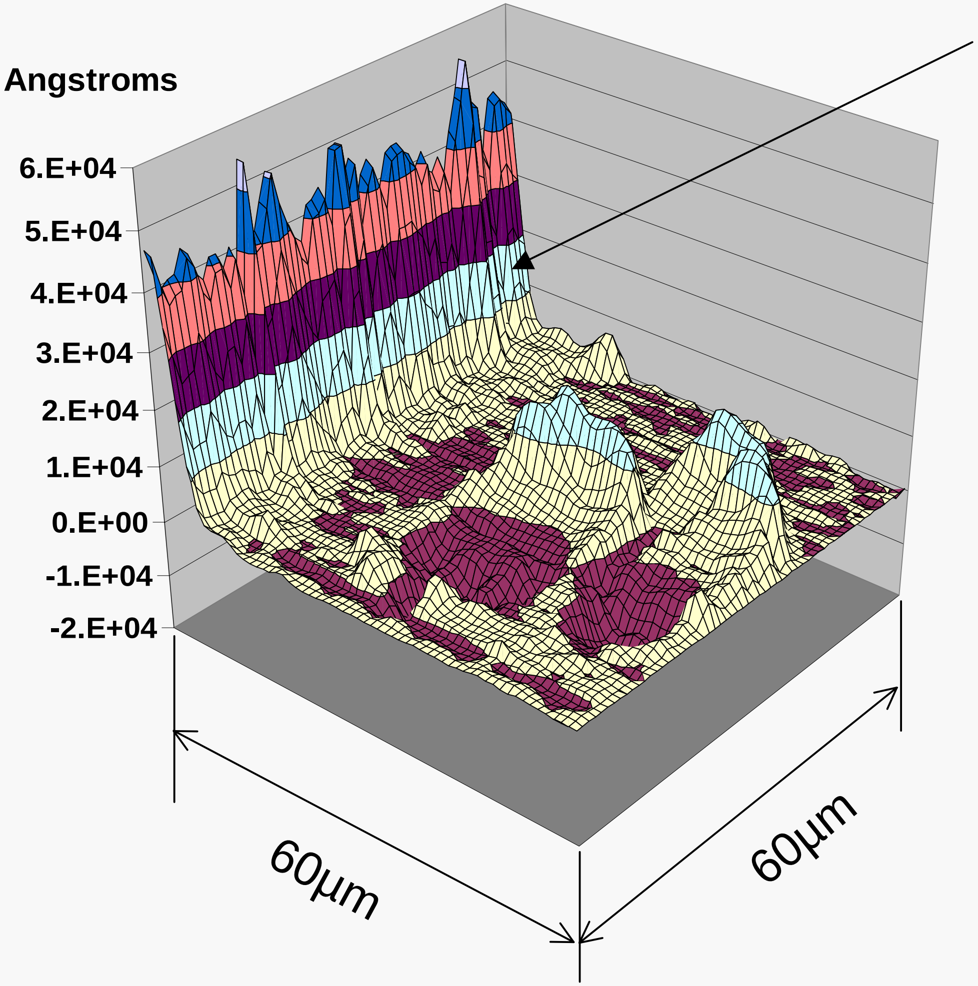
- 1X25 probe card - 125 micron pitch
- 5 mil OD from first touch (worst case)
- 4X double Z stroke for all pads (worst case)
- All recipes abrasive cleaned with 3 micron aluminum oxide film
- Pad thickness - ≈ 1.2 - 1.4 micron aluminum
- ≈ 80 microns square
- 30° C (ambient) test temperature

Sample plot - probed in same general area



Number of samples <1.2 microns	4
Number of samples <1.0 microns	60
Number of samples <0.8 microns	189
Number of samples <0.6 microns	340
Number of samples <0.4 microns	420
Number of samples <0.2 microns	496

Sample plot - probed in several areas



Number of samples <1.2 microns	0
Number of samples <1.0 microns	1
Number of samples <0.8 microns	37
Number of samples <0.6 microns	93
Number of samples <0.4 microns	187
Number of samples <0.2 microns	315

Penetration results summary (in mils)

Contact material - aluminum

		Recipe A	Recipe B	Recipe C	Recipe D	Recipe E	Recipe F
Parameter	All recipes	1.2dia @ 1.5g/mil	0.8dia @ 1.5g/mil	1.2dia @ 1.0g/mil	0.8dia @ 1.0g/mil	1.2dia @ 0.8g/mil	0.8dia @ 0.8g/mil
Minimum =	0.69	0.80	1.00	1.00	0.69	0.80	0.96
Maximum =	1.37	1.37	1.30	1.14	1.12	1.06	1.12
Average =	1.03	1.11	1.07	1.08	0.92	0.96	1.04

Challenges for pads under 1.0 micron thick

- Reduce pad damage
  - Reduce pad penetration
  - Reduce delta force between probes
  - Reprobe limit reductions
  - Probe tip “conditioning” refinements - grit size/frequency
  - Eliminate pad “shaving” - removal of pad material
- Geometry under pads - design ground rules
- Probe/prober variation reductions - XYZ alignment/force/tip diameter
- Metrology to test floor emulation refinements - I.e. first to full contact window - make the same

Future characterization

- Elevated temperature effects
- Correlation to bonding failures with additional probe recipes
- Pad excavation volume - both above and below pad surface

Summary

- Pad analysis can be used to monitor/correlate bonding failure mechanisms
- Currently a process development tool
  - Can be used as a manufacturing monitor
- Penetration dependent on several factors:
  - Contact force (@ overdrive)
  - Probe tip geometry - diameter/shape
  - Cleaning technique and frequency
  - Scrub characteristics
  - Number of probings
  - Probing repeatability (same location ≈ maximum penetration)

Acknowledgements

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