SWTW

IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

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Transferable Fine-Pitch Probes

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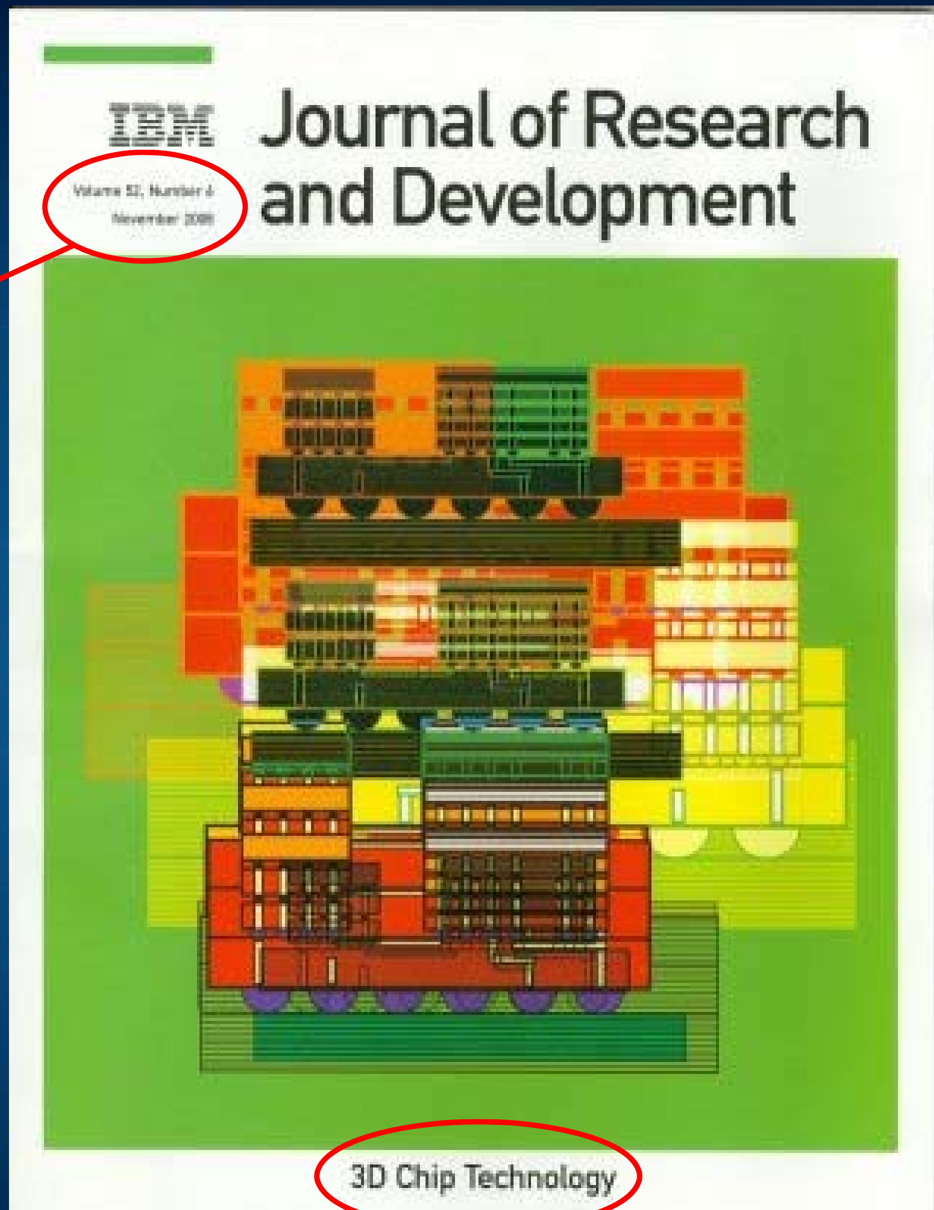
Overview

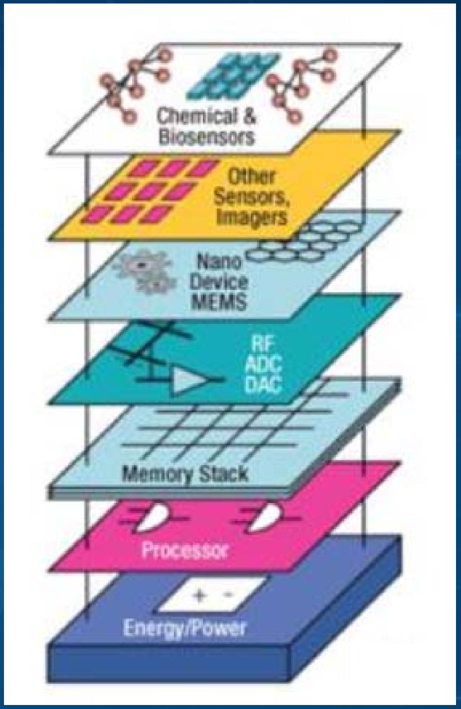
- Motivation (3D Si, “smart” probe)
- Transferrable probe tip process
- Issues
- Test vehicles, apparatus
- Contact resistance, force, max current
- Touchdown quality to date
- Probe stations in the future

2008


IBM
Journal of Research and Development
3D Chip Technology

3D Integration

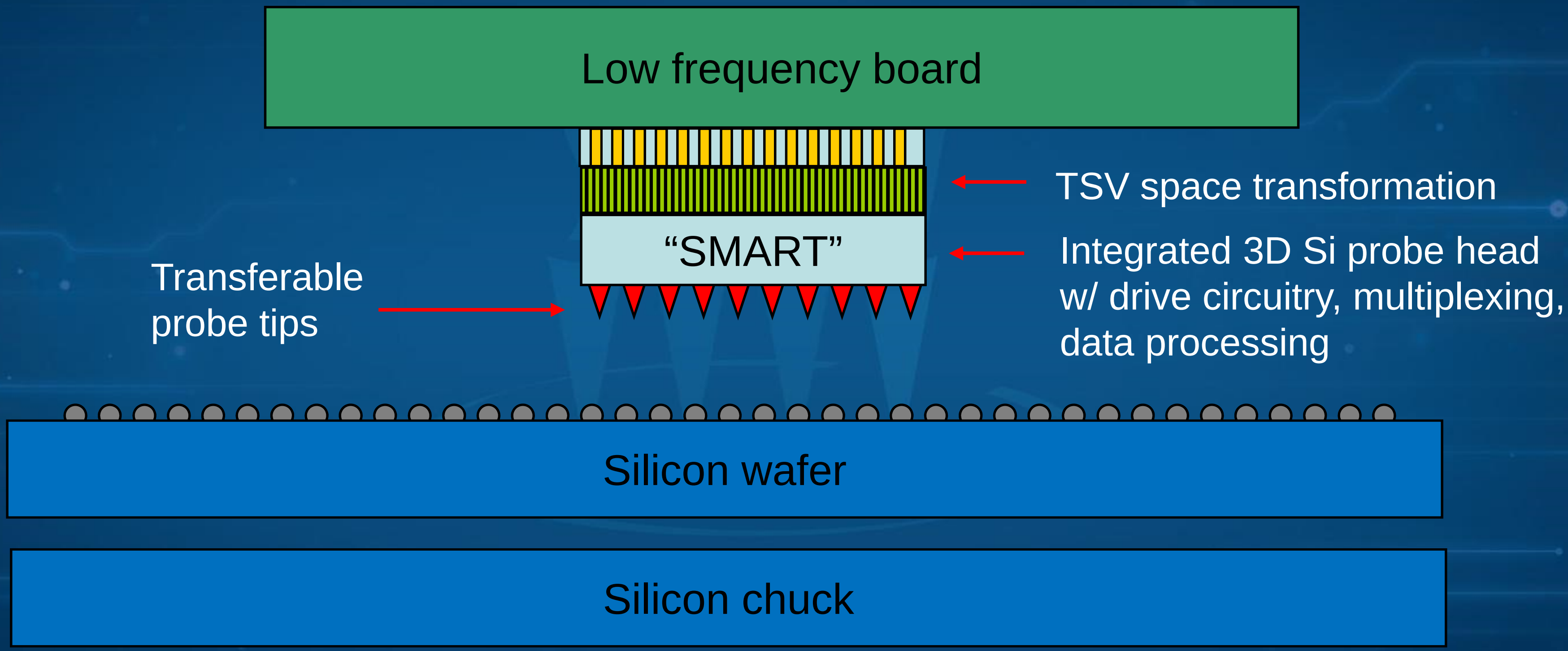
Benefits	Challenges
Reduced package thickness and area	Bond and assembly
Reduced package complexity	Cooling
Improved performance (fine pitch & short length interconnections)	Design methodology
Mixed chip technologies	Test for KGD, KGS
Reduced cost (holistic view)	Increased cost (Si processing viewpoint)



Future-fab.com

Fine Pitch / 3D Probing

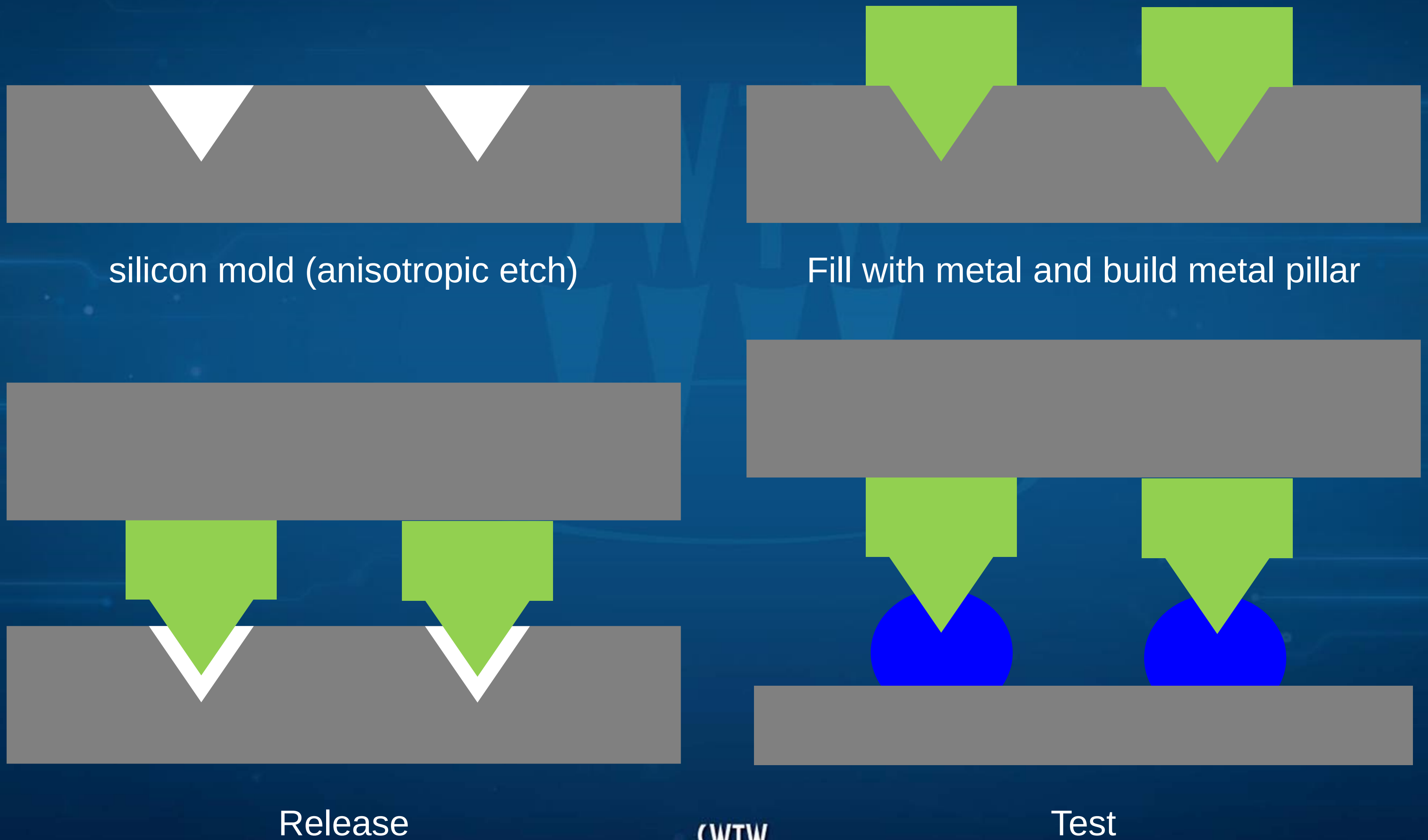
"Poll" the SMART probe for analyzed test results



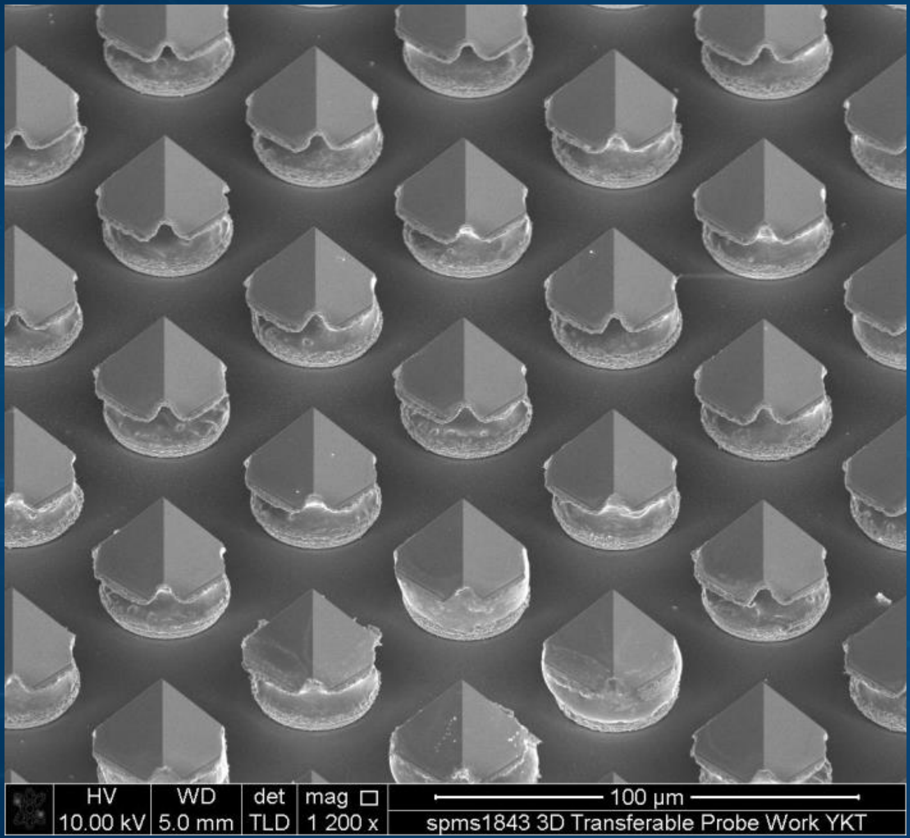
""CTE-matched"

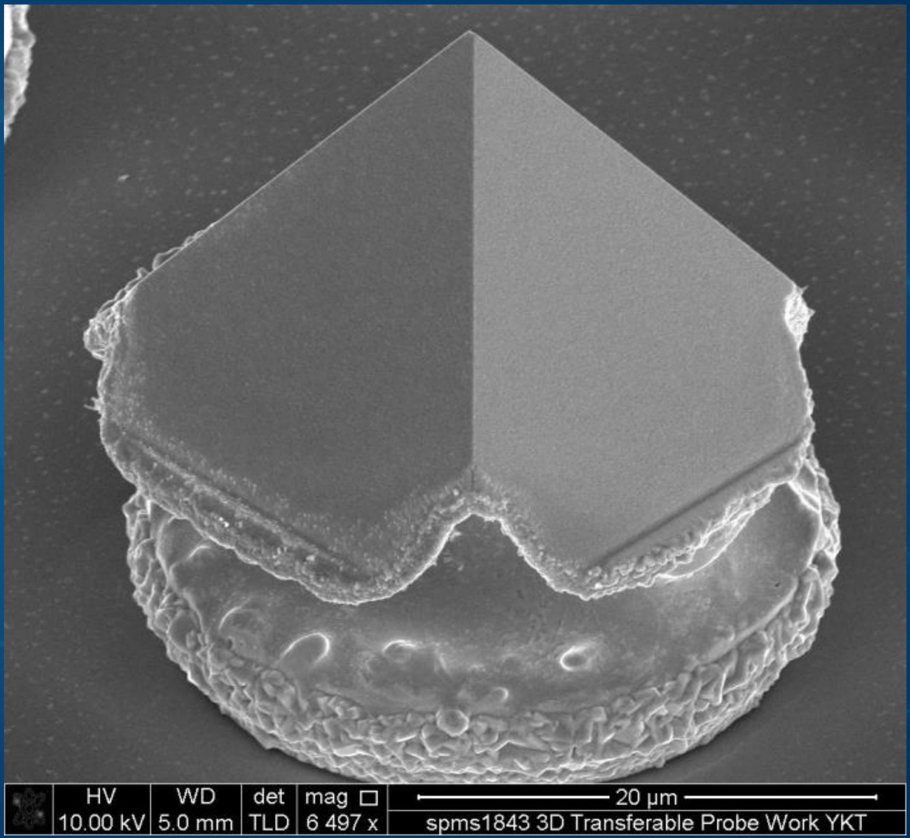
Example: L. Namburi, G. Maier SWTW 2013

Transferable Tips



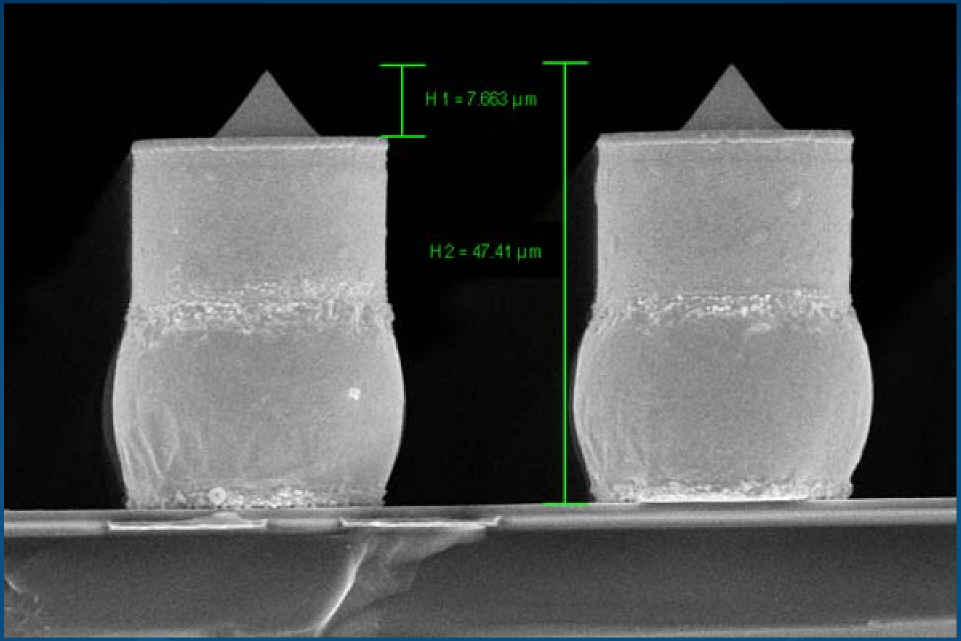
1st Generation

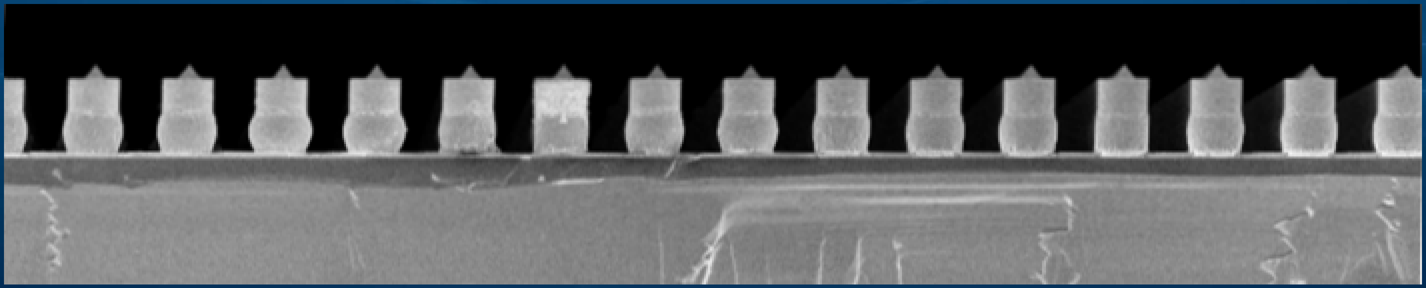


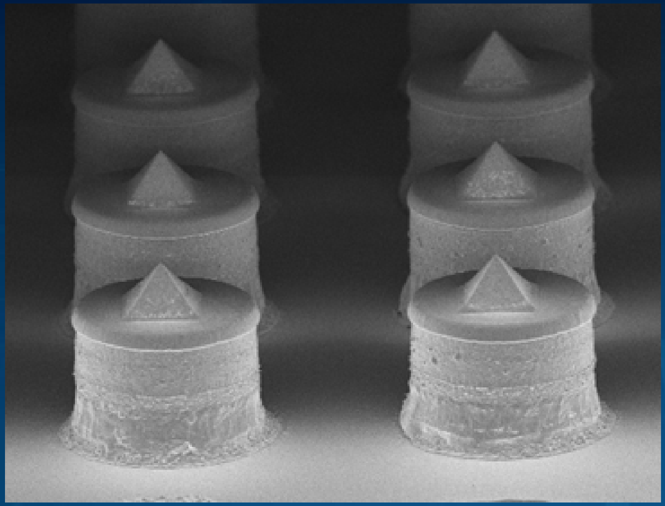


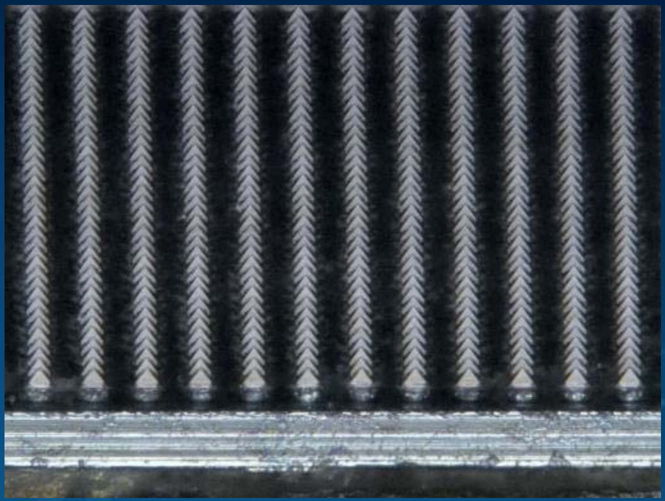
Tips are 4-sided pyramids with 70.5 degree cone angle.

2^{nd} Generation

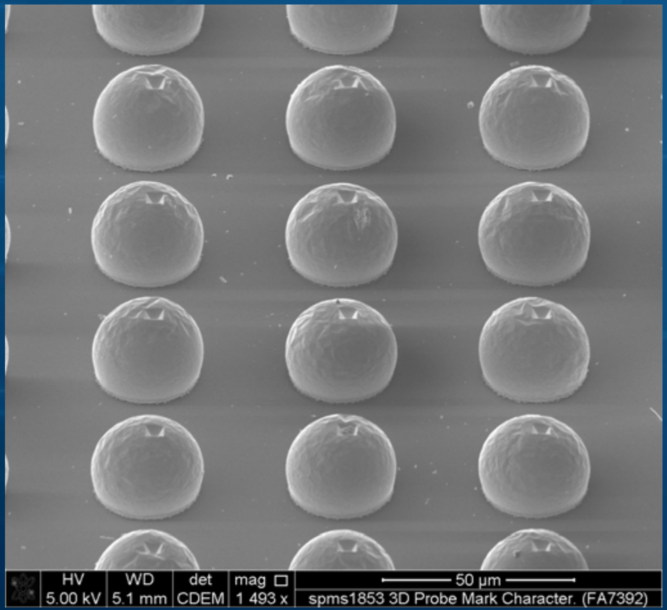




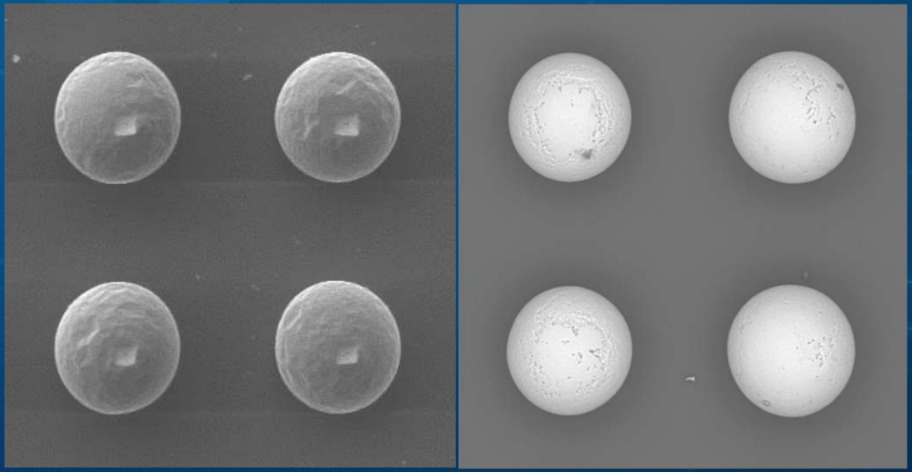




Transferable probe tips on 50 µm 3D silicon chip



Uniform probe marks



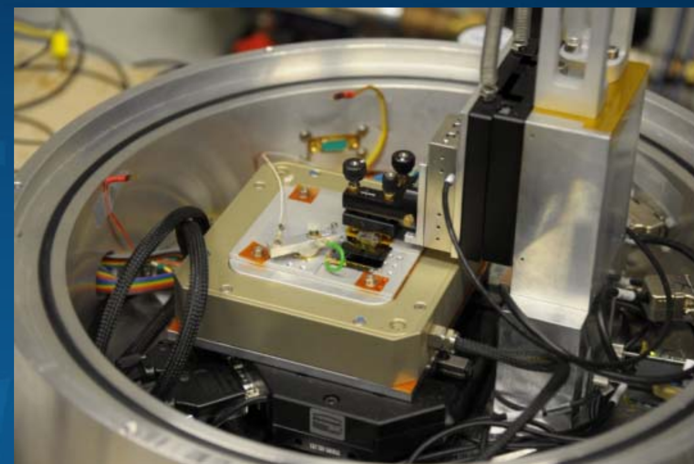
Solder recovery at 250° C in formic acid atmosphere.

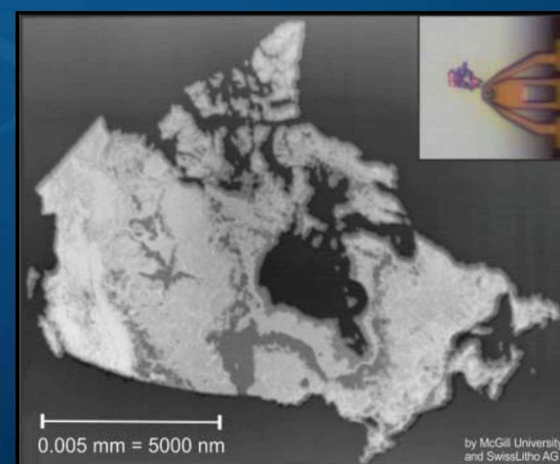
Transferable Tips

- **Low-temp process**
- **Variety of possible tip materials**
- **Variety of possible substrates**
  - Silicon, ceramic, glass, laminate, MEMs structure
- **Precise size, shape, location**
- **Precisely planar**
- **Non-compliant versions to-date**
  - Large compliance requires MEMs structure

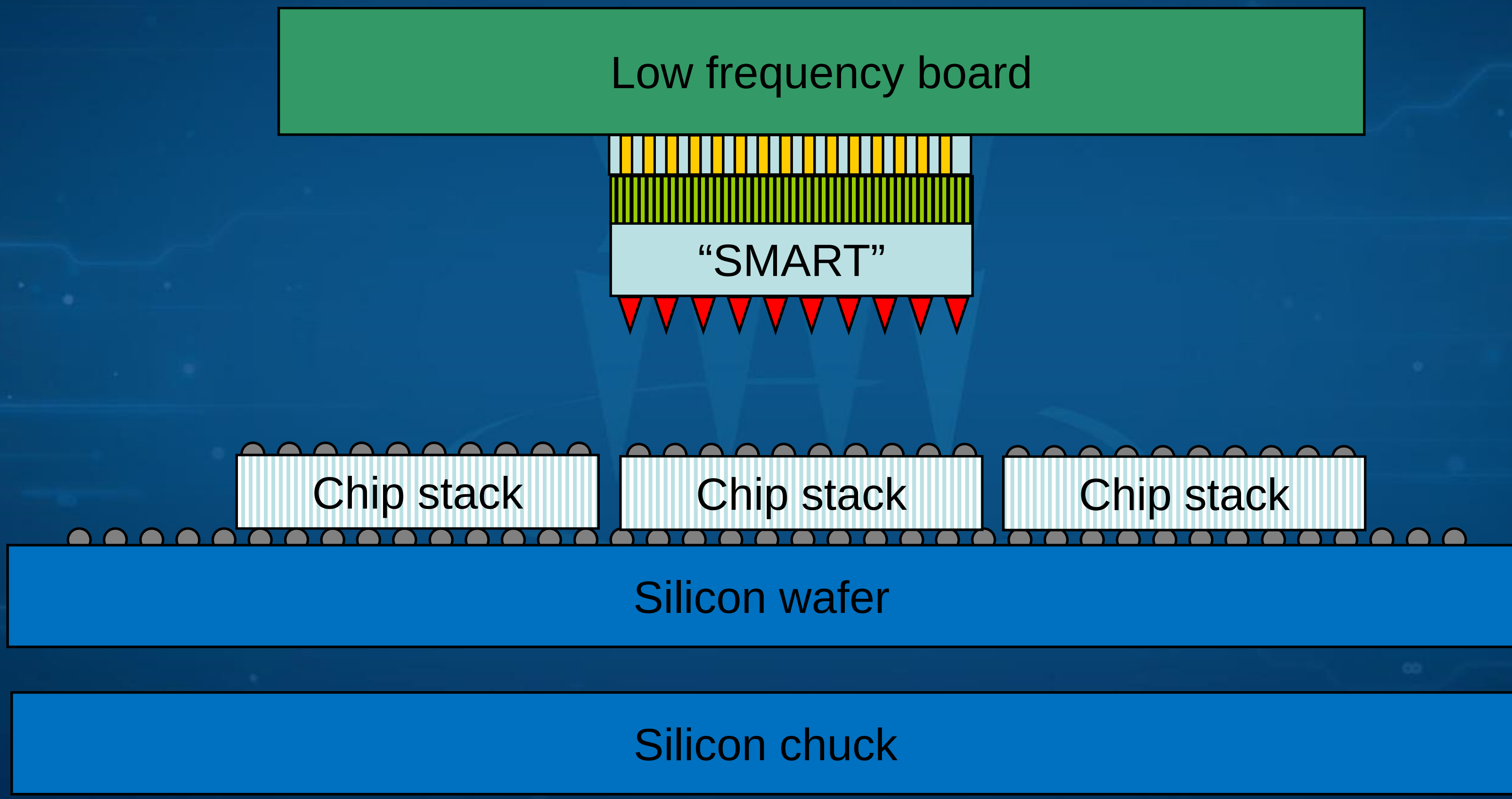
IBM Zurich Nanotip (2014)

- “nm-sized” tip, 1000 °C
- “chisel” into polymer
- 10 nm resolution
- ≤ 40nm penetration
- 11x14 µm Panda image in 11 minutes
- 30 µm wide Canada image, 1 Mpix in 1 min? (McGill Univ)
- Licensed to SwissLitho
  - “NanoFrazor”

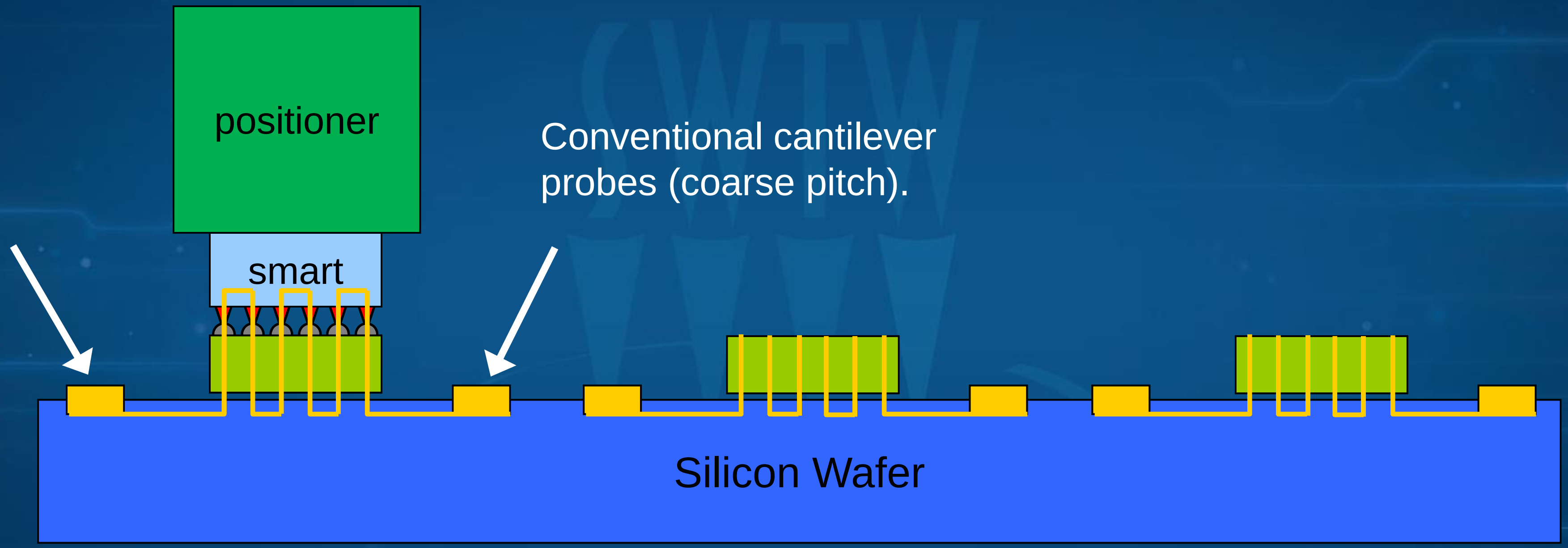




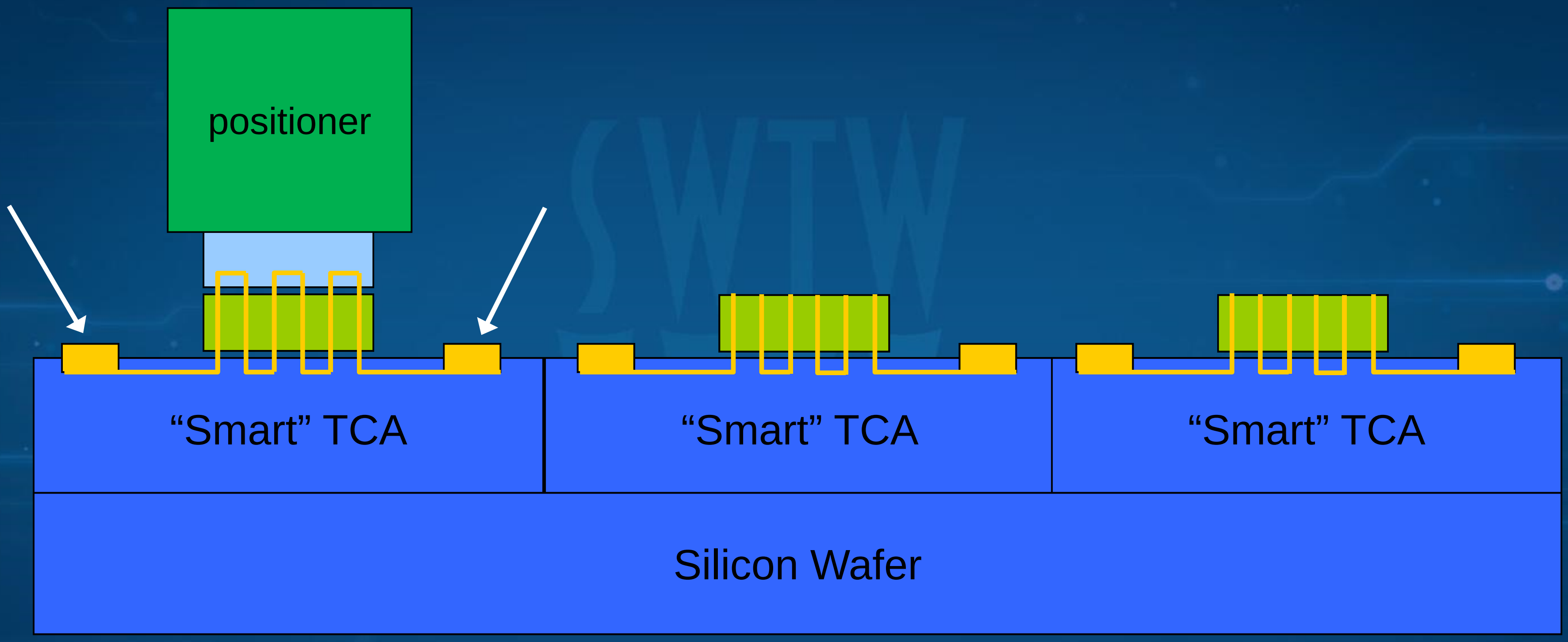
Fine Pitch / 3D Probing



Hybrid Probe Mode



Hybrid Probe Mode w/"Smart" Temporary Chip Attach (TCA) Wafer



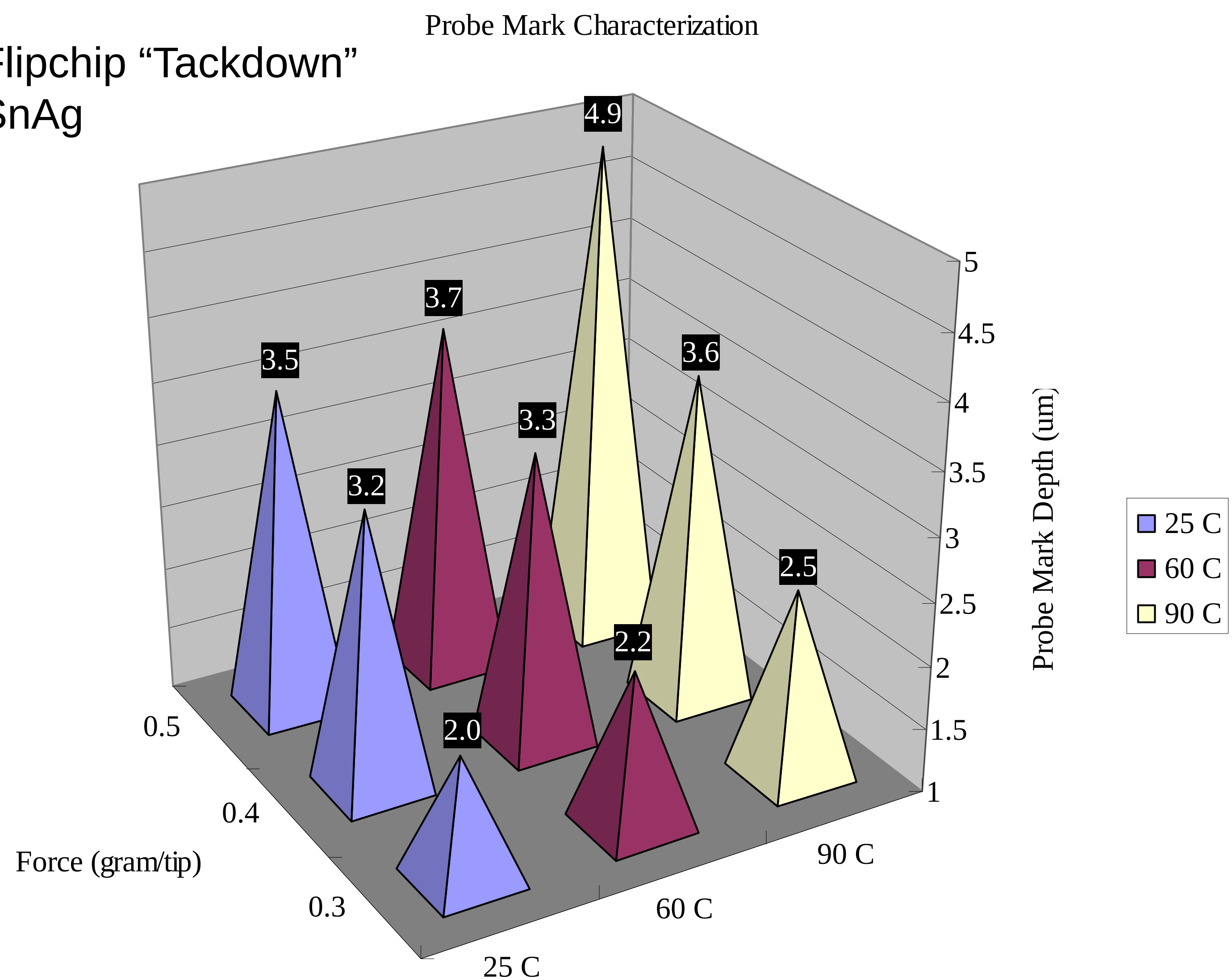
Issues

- **Convert processor chip into probe head**
  - Low-temp tip transfer process on thin die
- **Need 3D Si technology for space transformer**
- **Tip integrity and contact**
  - Vertical indent (no scrub) with small force
  - Thermal expansion issues with high-power test?
  - Compliance needed?
- **Damaged probe head?**
  - Throw it away!

Compliance / Planarity

- **High interconnection yield with flip-chip bond**
  - Routine lab yield 99.999 to 99.9999 % (50 µm pitch)
  - Pads/melted bumps → tips/bumps
- **Probe compliance issues**
  - Bump plating non-uniformity scales with thickness
    - 10% of 100 µm bump (200 µm pitch) is 10 µm
    - 10% of 15 µm bump (50 µm pitch) is 1.5 µm
  - Probe non-uniformity
    - Large over-drive required for many probe technologies
    - Not an issue with transferable tips.
  - Particle contamination
- **Do we need compliance?**

Flipchip “Tackdown”
SnAg



Probe Mark Depth vs Force and Temperature

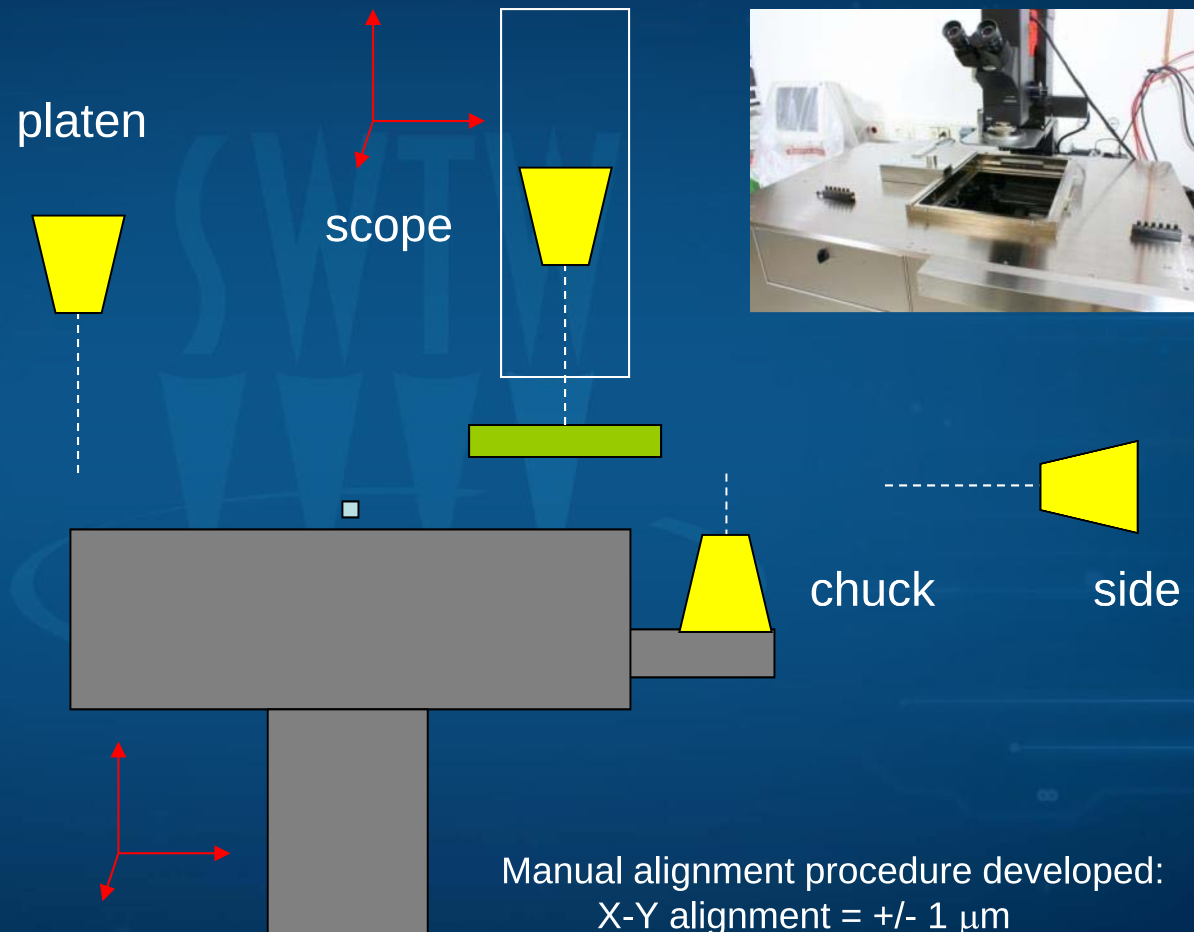
PA300 (Suss/Cascade)

Chuck camera:
Probe theta correction
Probe mark position
Parallelism

Platen camera:
Chuck theta
Die mark position
“blob” position

Side camera:
Height adjustment
“near contact” view
Rough parallelism

Scope camera:
Initial setup
Parallelism
Post-test inspection



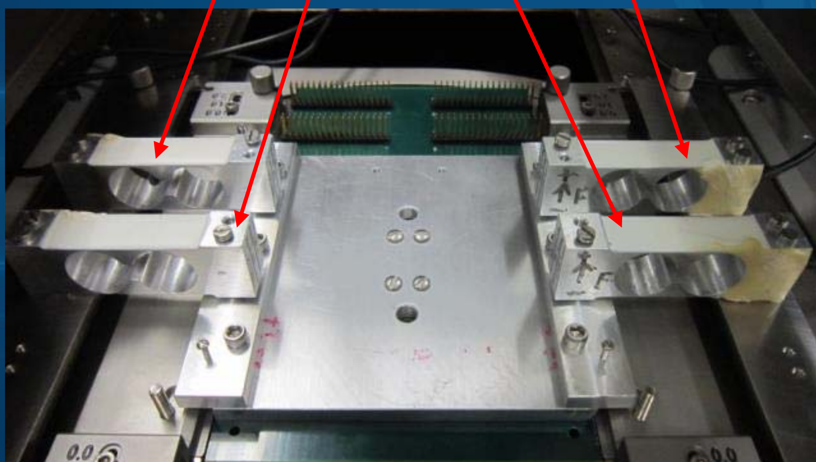
Manual alignment procedure developed:
X-Y alignment = +/- 1 μm
Z-parallelism ~ 2 μm at 10 mm (0.01 deg)

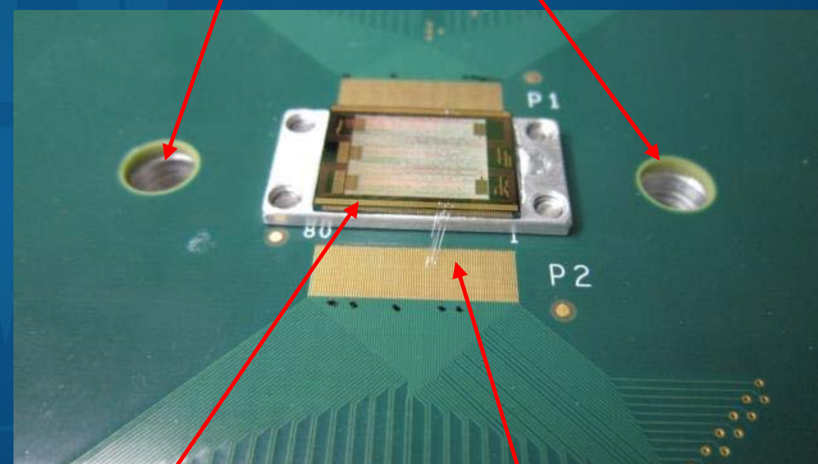
Note: none of the axes are perfectly aligned.

Probe Card

Force sensors

Observation holes





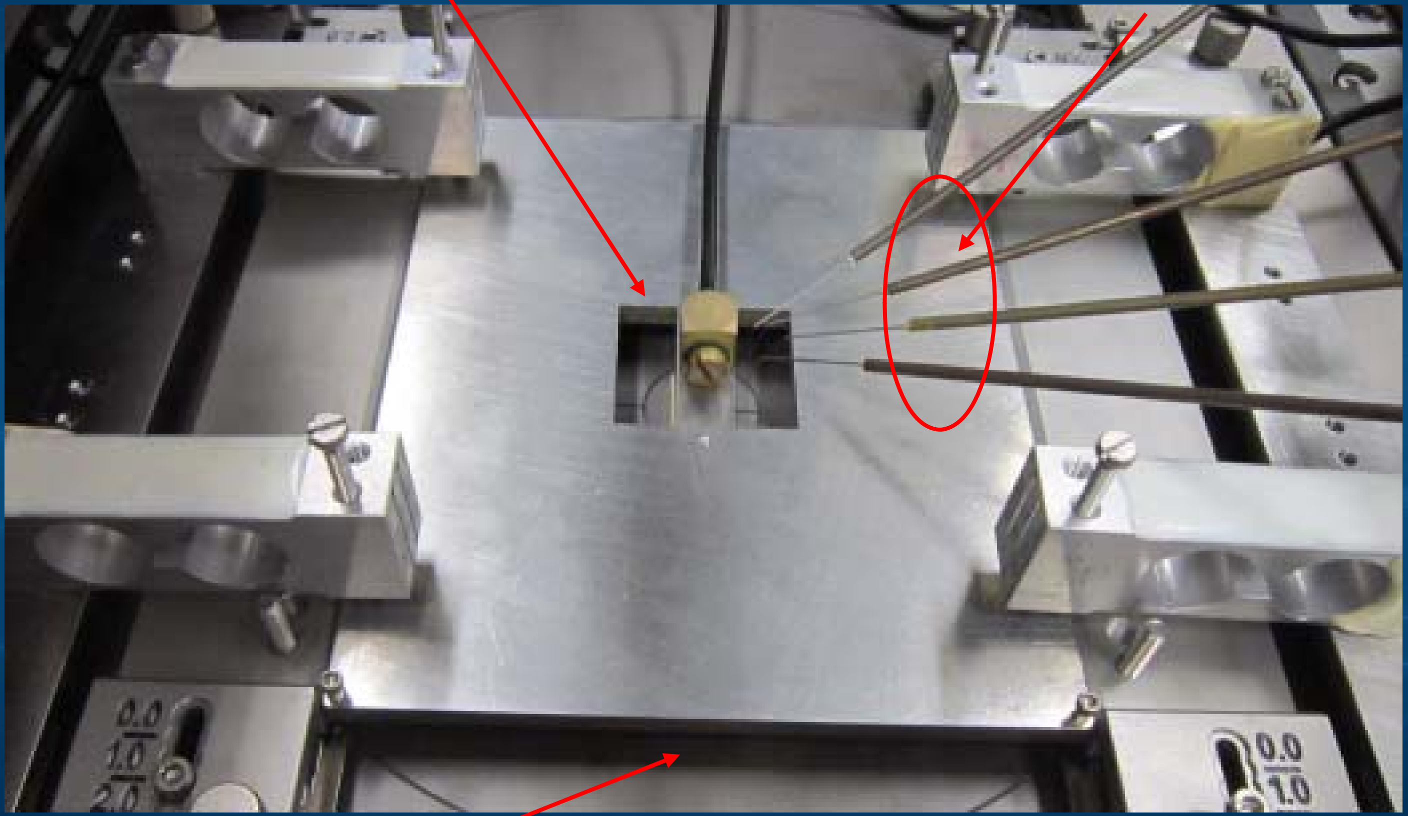
Probe die with tips

wirebonds

Hybrid Mode

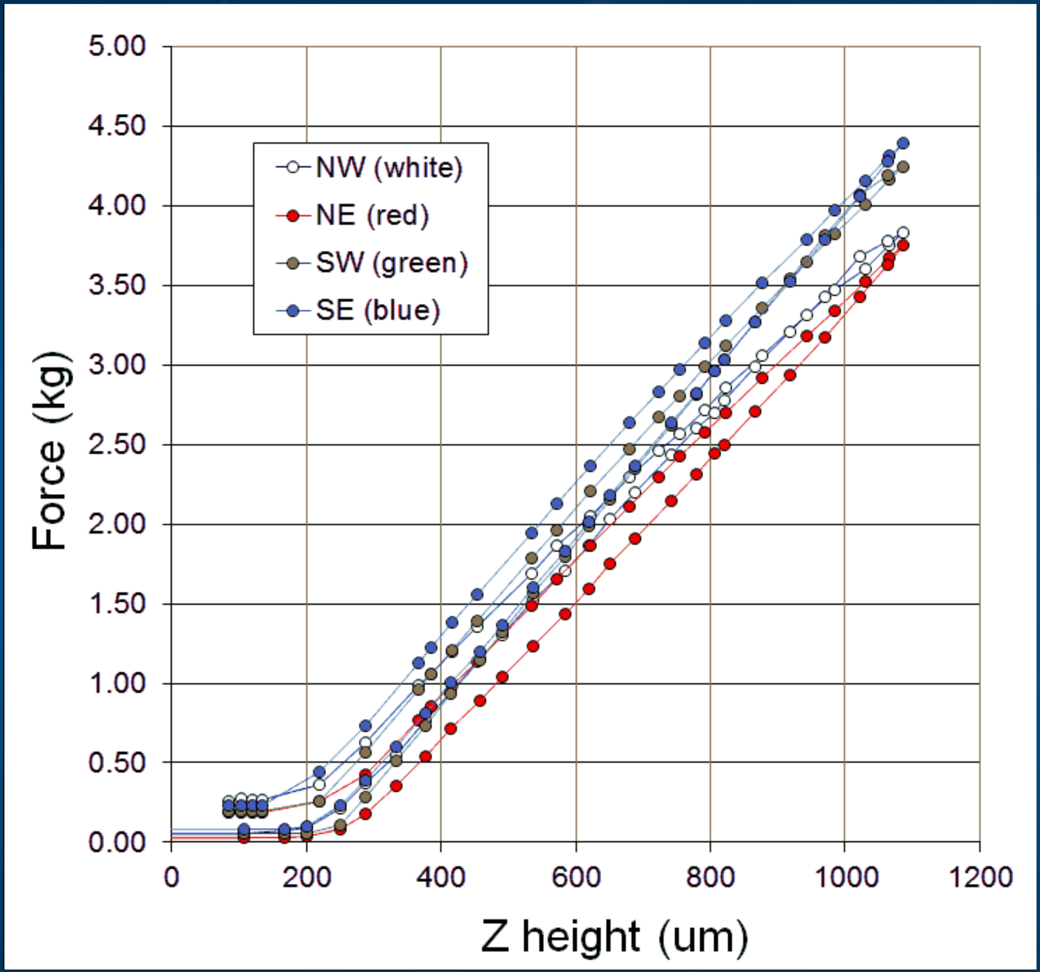
Top vacuum chuck w/bumped die

Manual probes



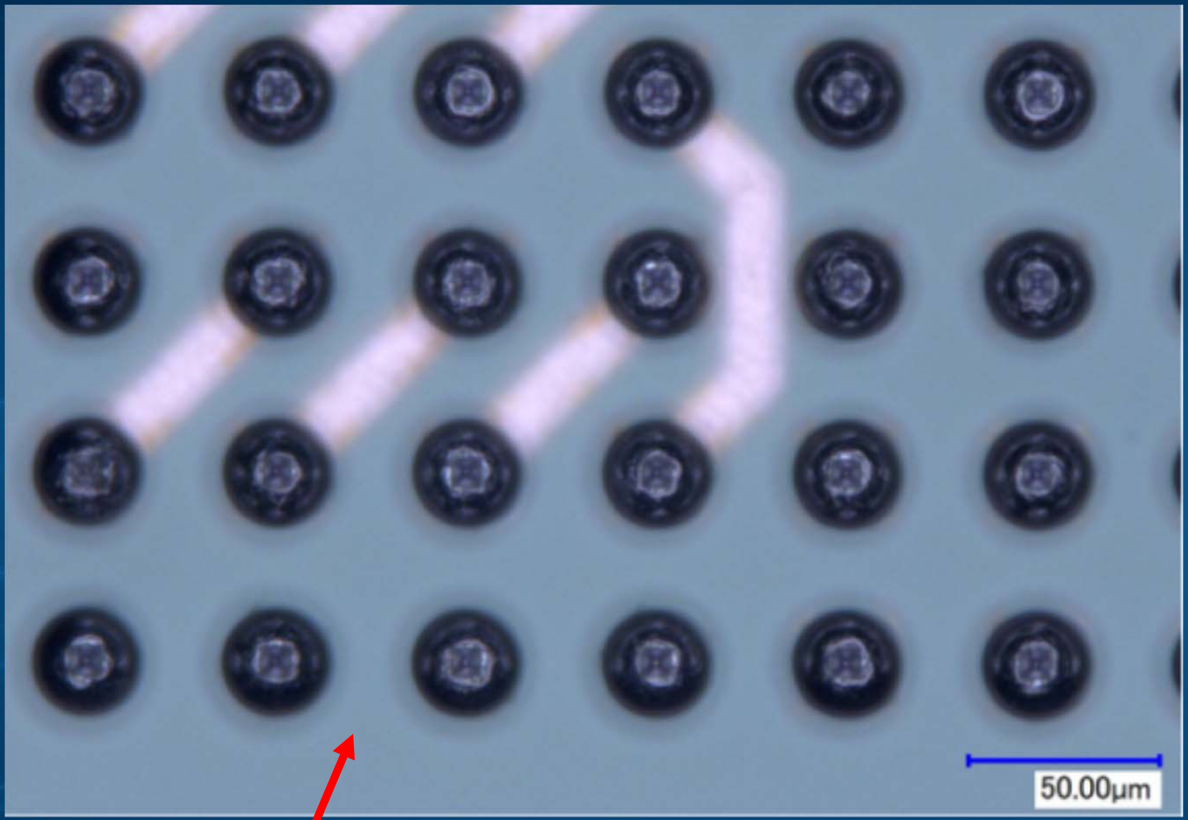
Bottom chuck w/probe tip die

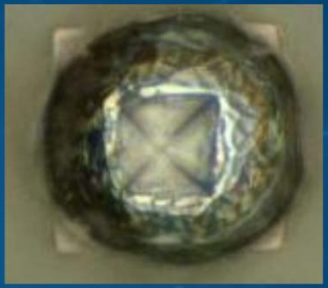
Force Plot



Touchdown has "stabilized" when all four forces increase at the same rate.

Probe Marks

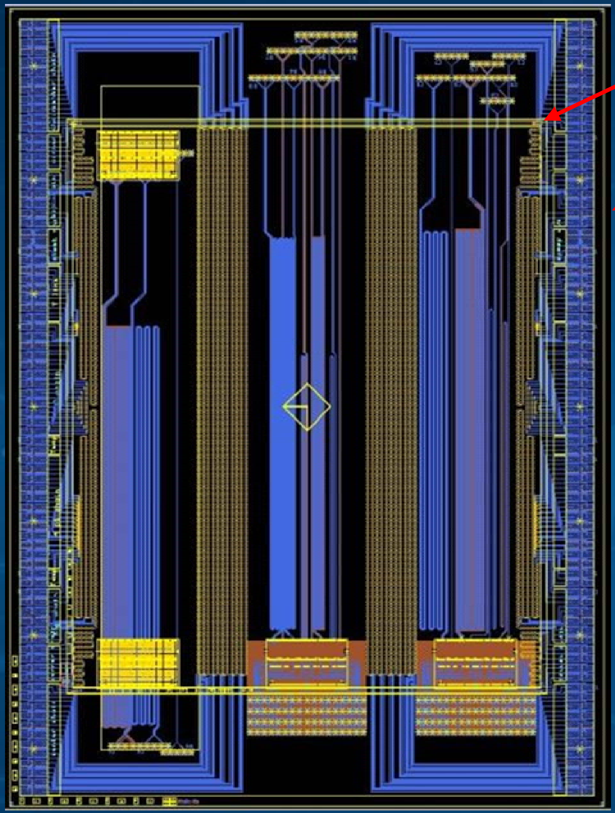




"max" indent

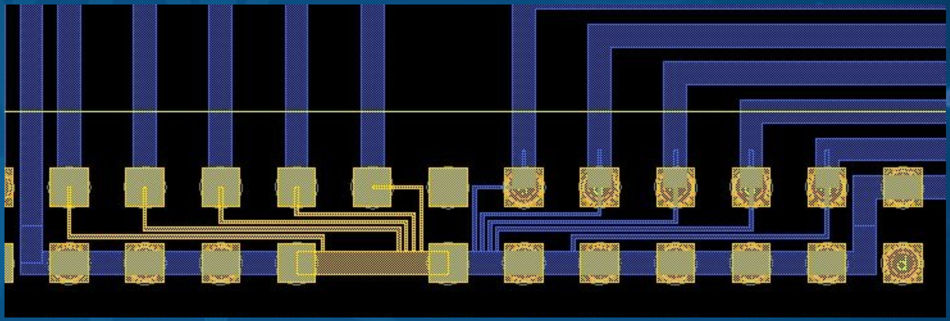
8x8 µm pyramid indent = 5.6 µm indent tip depth

Test Vehicle



Top die (bumped)

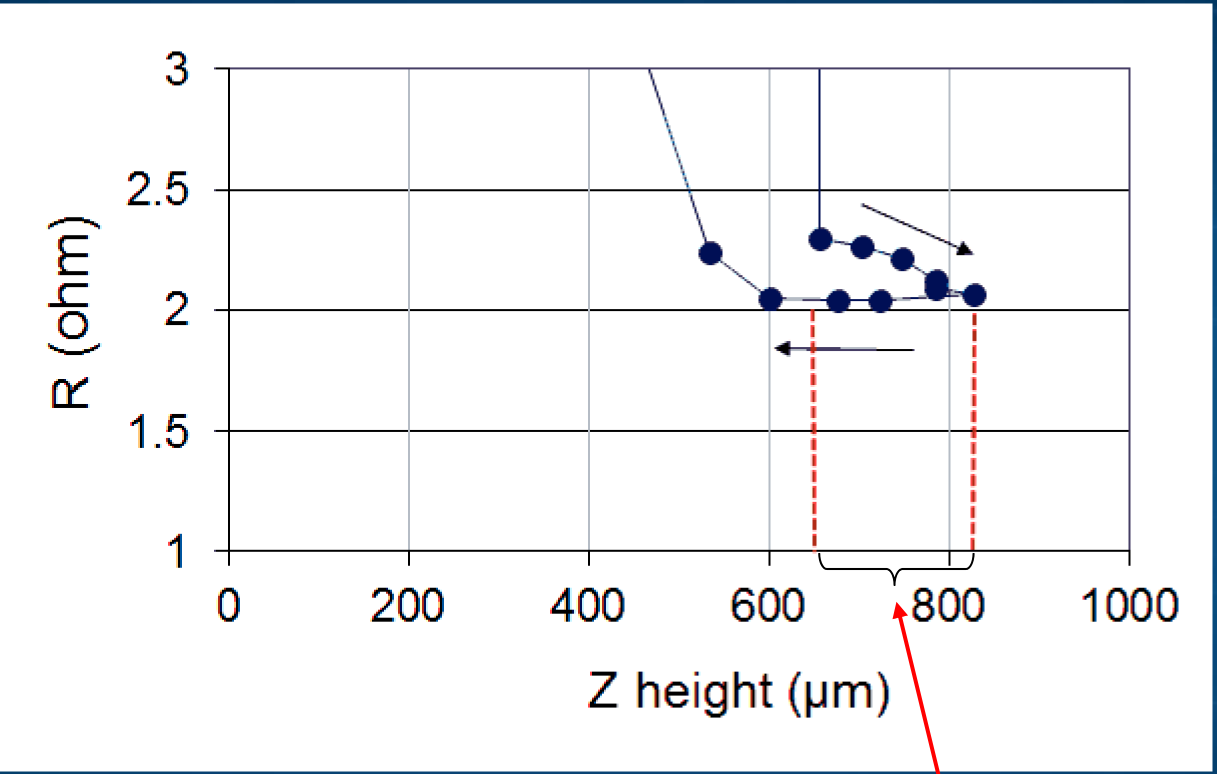
Bottom die (tip transfer)



Contact resistance sites (4-pt)

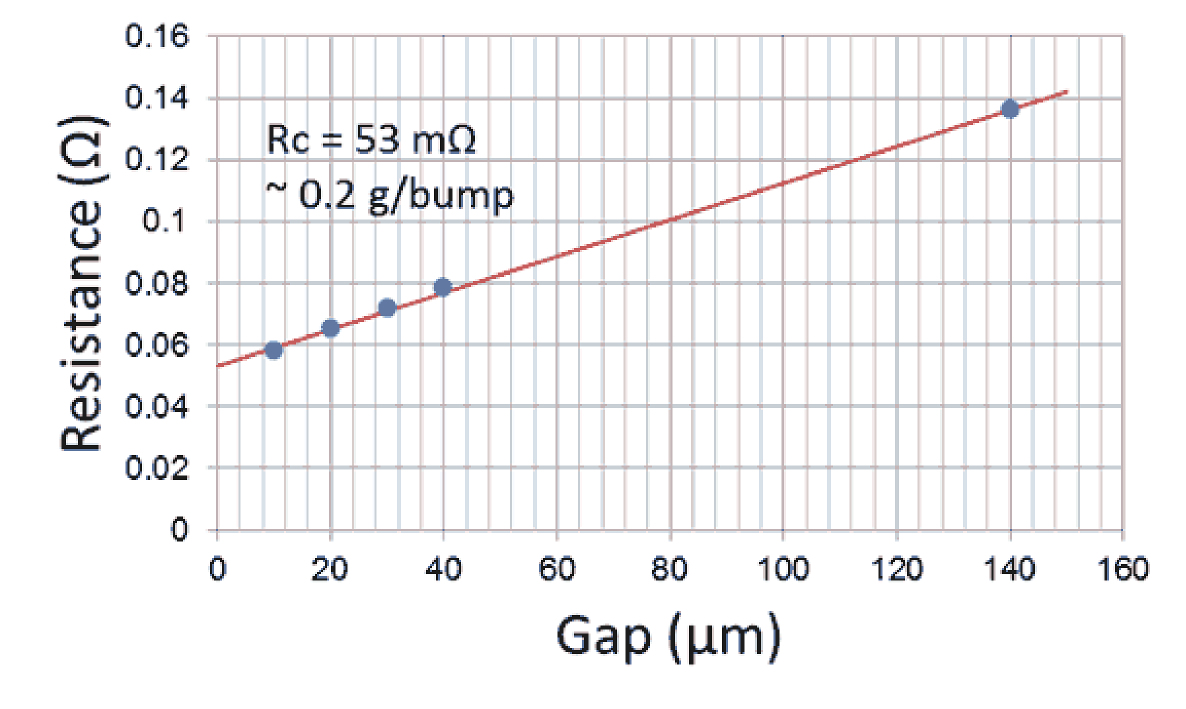
50 μm pitch
45,406 bumps (total)
12,644 electrically-testable bumps
Chain lengths from 1 to 230 links

3-pt Contact Resistance



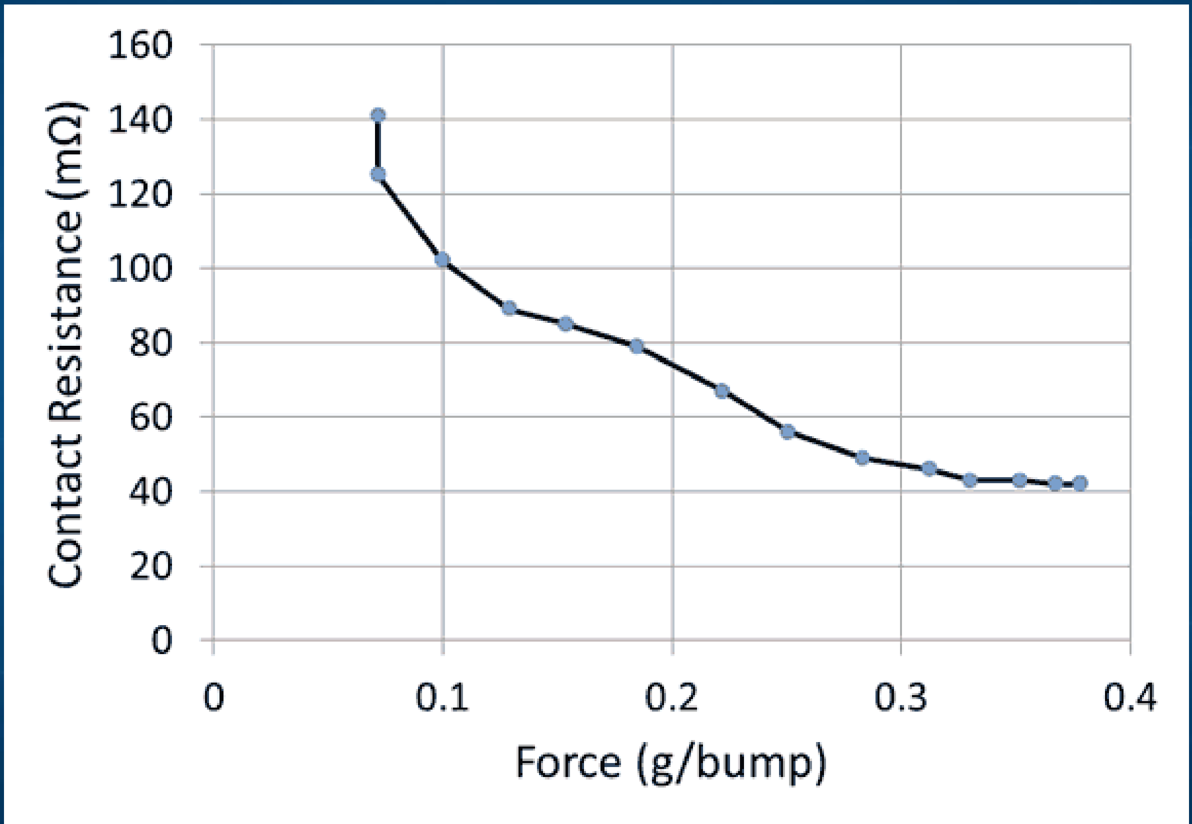
Additional force of ~ 0.01 gm/bump
reduced contact resistance by ~ 40 mΩ.

4-pt Contact Resistance

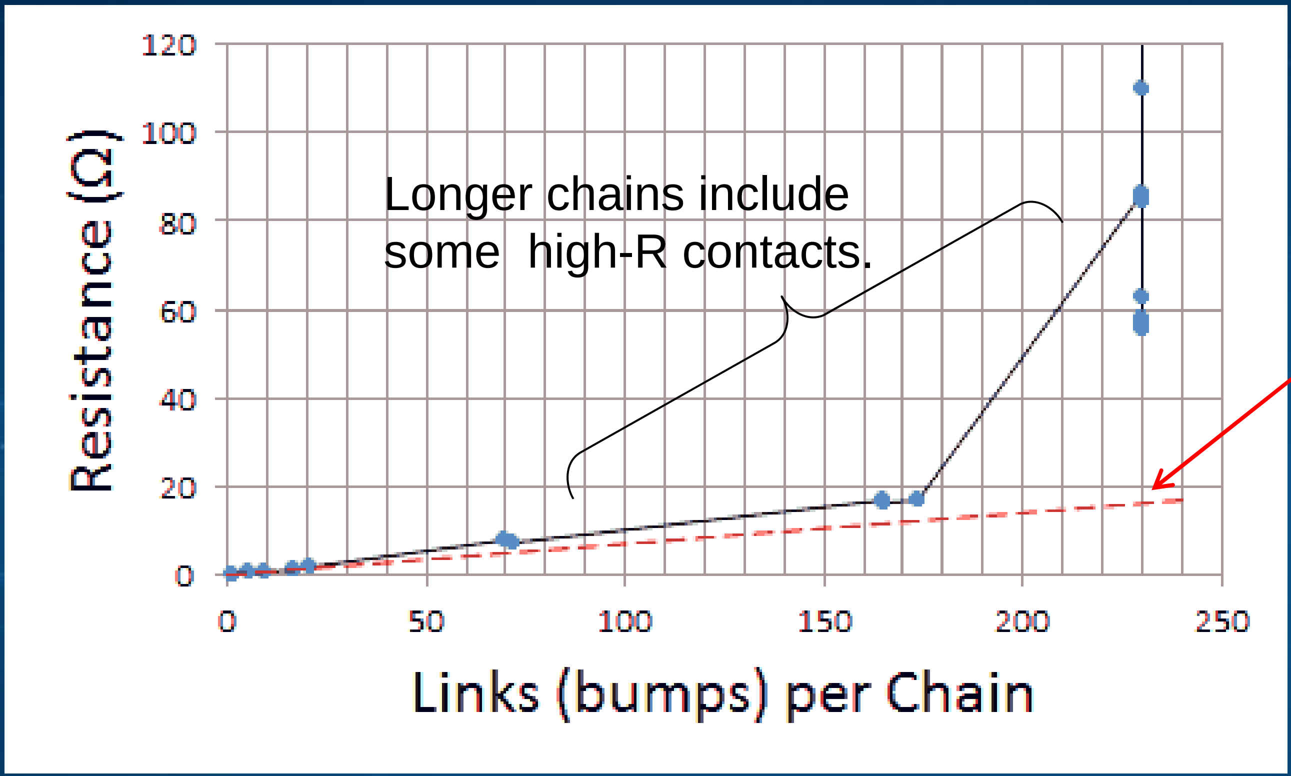


Rc depends upon probe force, “good” contact at 0.05 - 0.5 g/bump.
Lowest Rc measured thus far ~ 30 mΩ
Typical Rc = 10-30 mΩ in joined parts (melted bump/pad)

Contact Resistance and Force



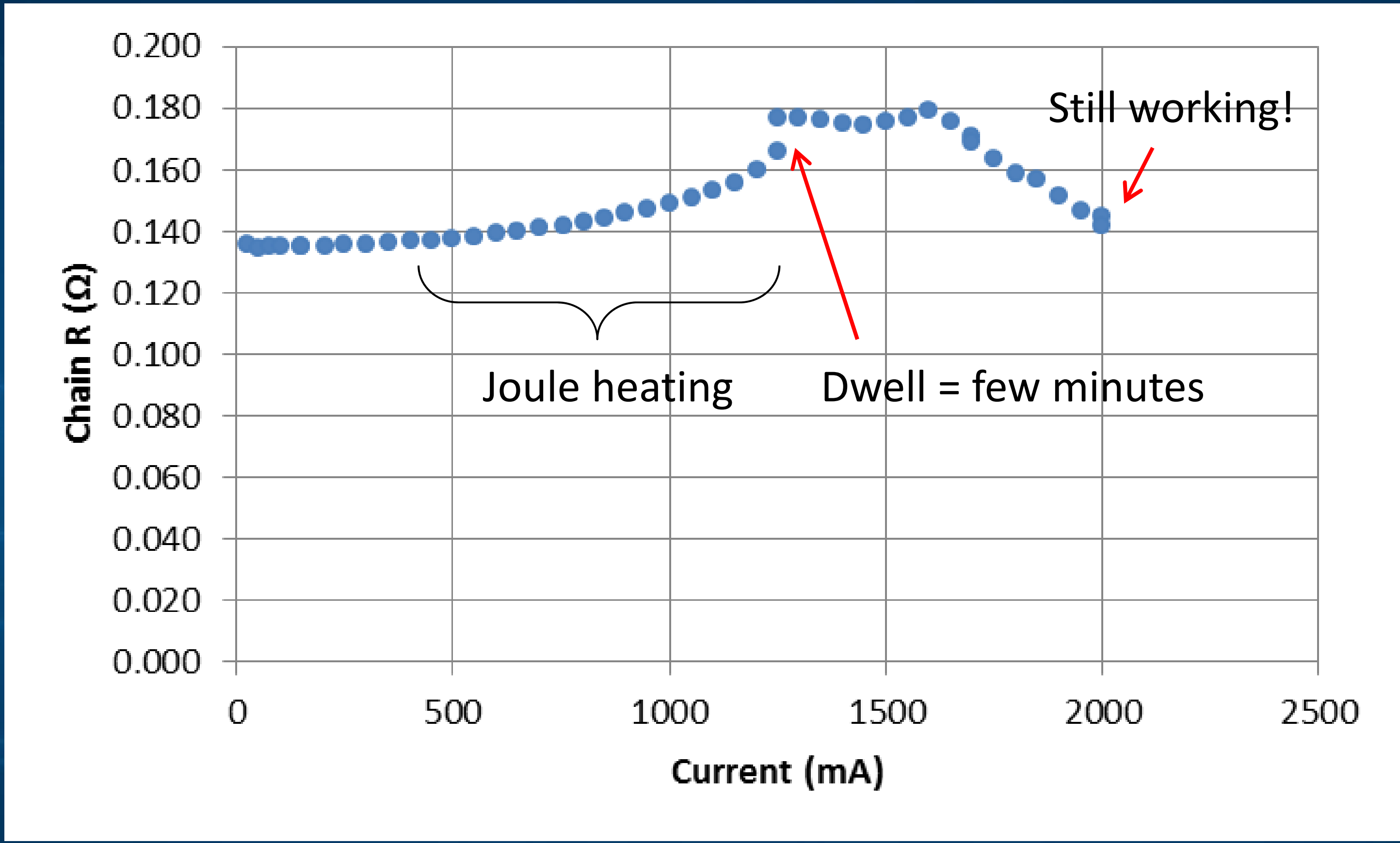
Chain Resistance



Linear fit to data
up to 21 links.

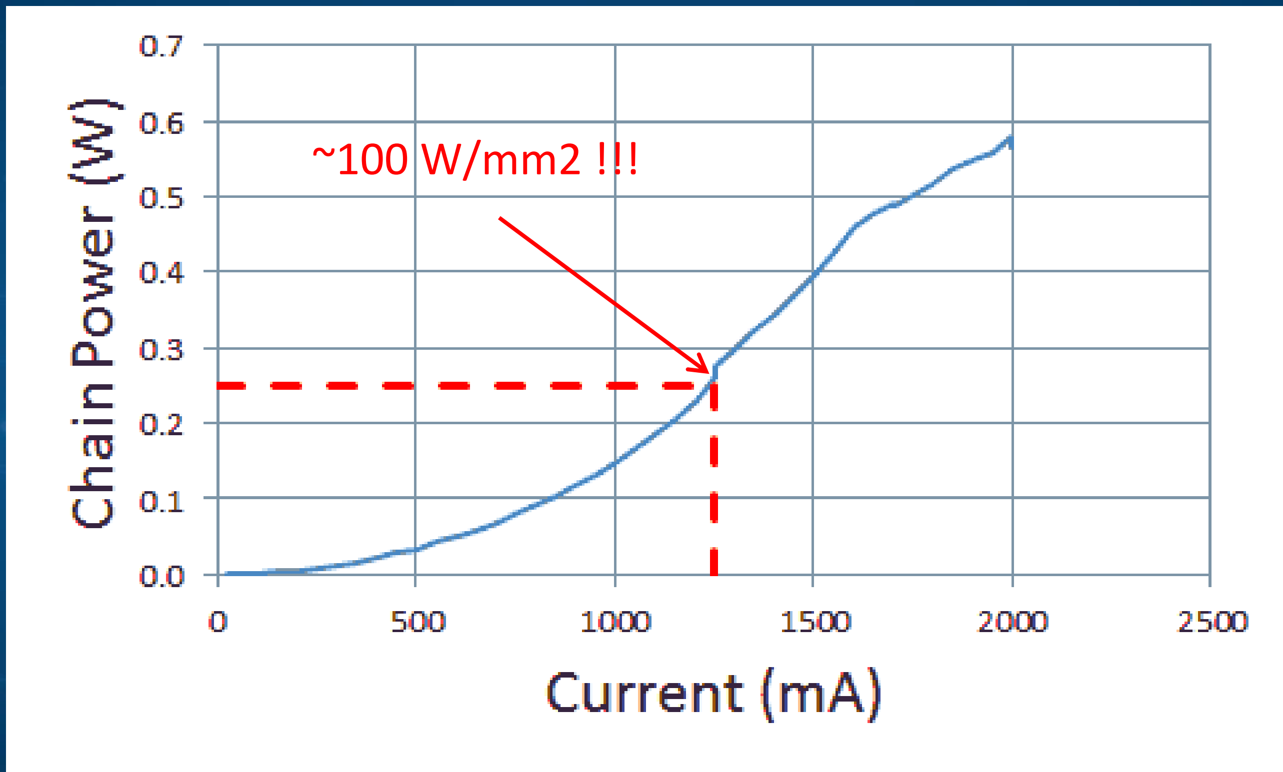
Touchdown contact yield of 99.9% demonstrated thus far.
-Limited by test parameters, not test vehicle.

DC Current Stress: 2-bump chain



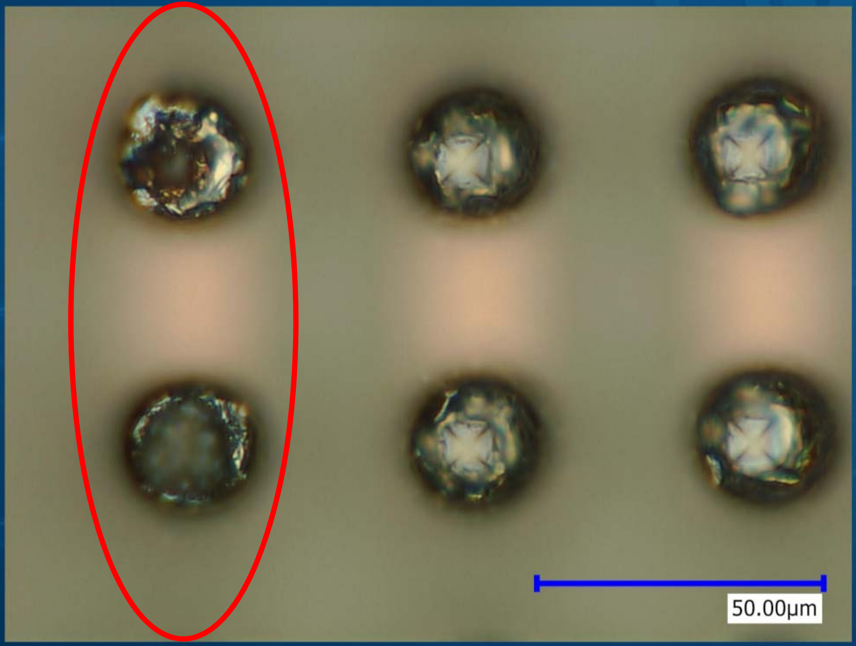
Joule heating apparent at ~ 500 mA……
1A short-duration current should be acceptable.

Power Dissipation in 2-bump Chain

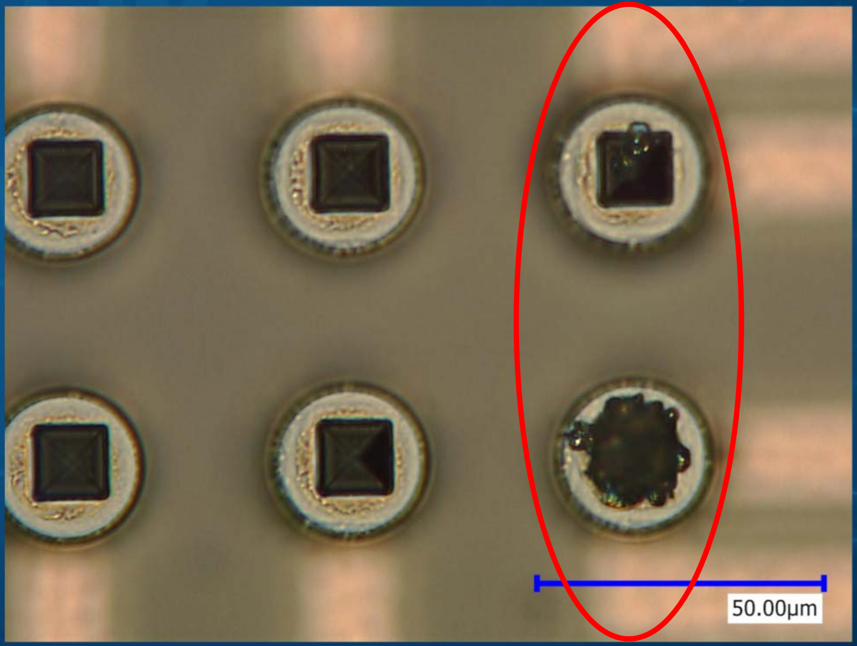


Post-Mortem

Current = 2A



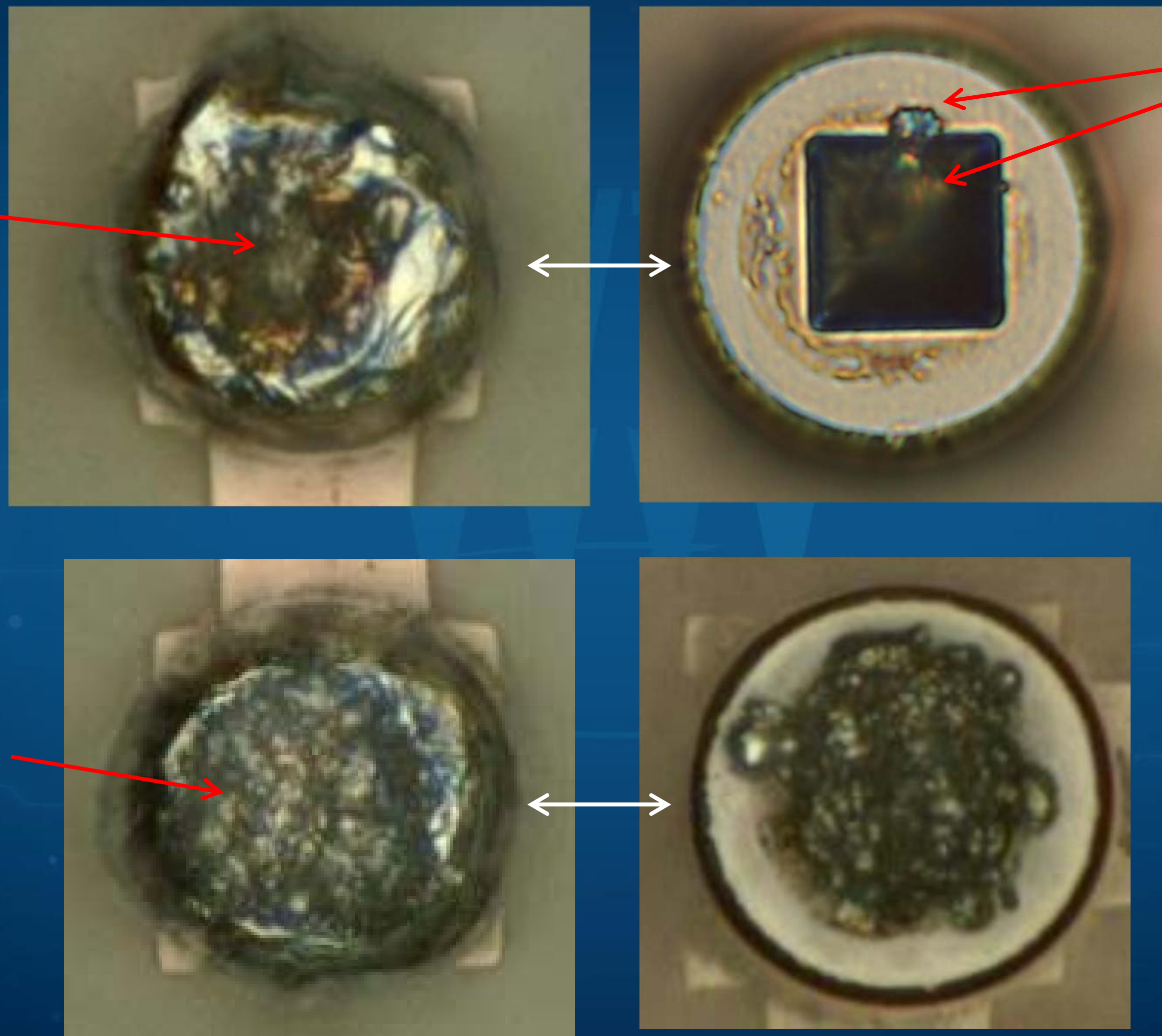
Current = 2A



Post-Mortem (cont'd)

Tip indent w/oxidation

Solder residue



Pull-out on bump side

Touchdown Alignment

- **Stage movement accuracy ~ ± 1 µm (x,y,z)**
- **Homemade "semi-automatic" alignment procedure**
  - X,Y,ϴ → Δx, Δy ~ ± 1 µm
- **Parallelism is biggest challenge**
  - No auto-leveling capability in prober (co-parallelism)
  - Have not yet found conditions for "gimbal-ing"
  - Δz ~ ± 2 µm over 12 mm die (0.01 deg tilt)
- **No probe damage or debris seen thus far**
  - < 100 touchdowns

Future Probe Stations

- **Area-array probing at pitches < 50 µm**
  - > 100,000 connections
- **Clean tool environment**
- **Flip-chip bonder capabilities**
  - Soften or melt solder
  - Controlled ambient
    - Vacuum , plasma, formic acid ….
- **Inexpensive, high-performance “smart” probe heads**

Transferrable Probe Tip (TPT) technology

- **Fine-pitch capability**
  - < 50 μm
- **Active-device probe head ("smart probe")**
  - Low cost, high-speed test
- **Vertical probe without compliance**
  - Minimal damage and debris
  - High current capability
  - Disposable probe head

300 mm wafer capability…..