IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

Novel Method To Store Spring Energy in Probes

Salleh Ismail

Touchdown Technologies, Inc.

Overview

- Trends and Requirements
- Spring Energy Overview
  - Cantilever vs. Torsional
- Torsional Probe Results
- Core Technology Advantages

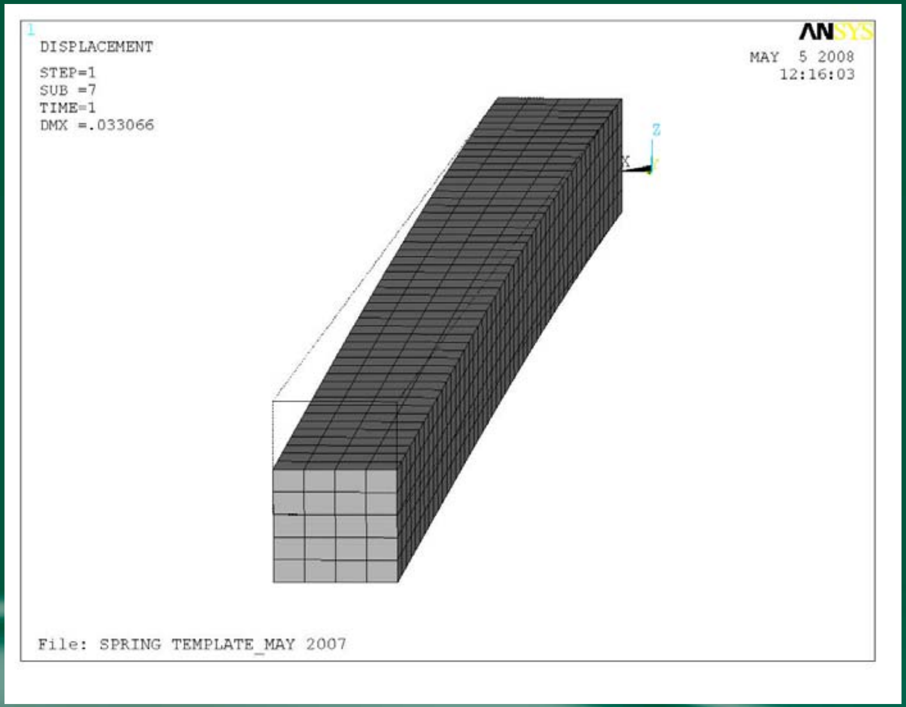
Trends and Technology Requirements

- Al pad trends:
  - Pitch shrinking
  - Pad size shrinking
  - Density increasing
  - Circuits under pads more common

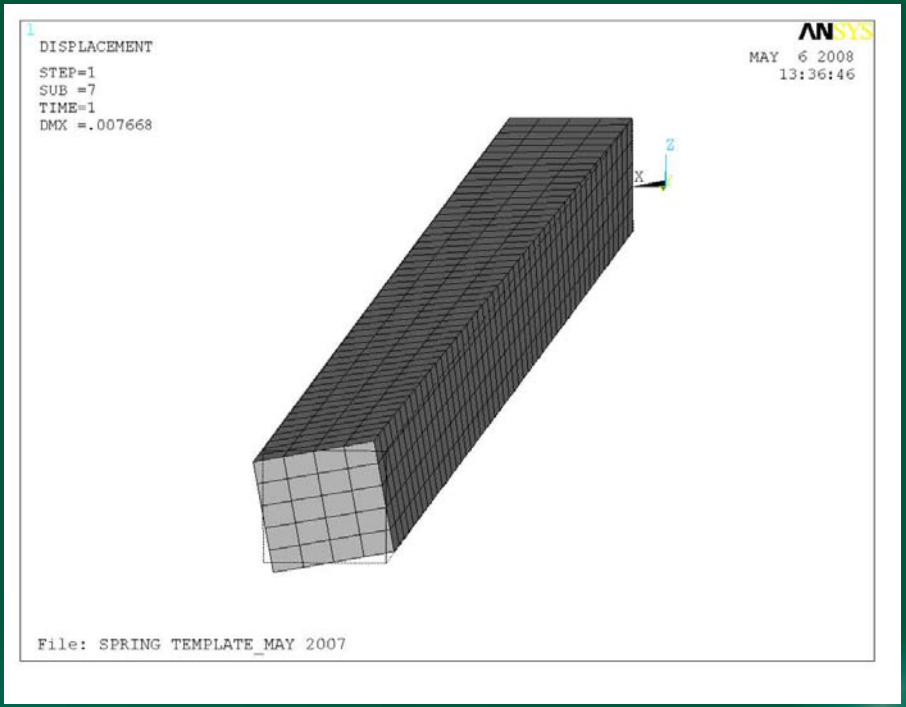
- Probe Card Technology Requirements:
  - Tighter pitch
  - Smaller scrub mark
  - Higher total pin counts (increase in parallelism)
  - Reduced and controlled probe force and scrub depth

Two Spring Modes

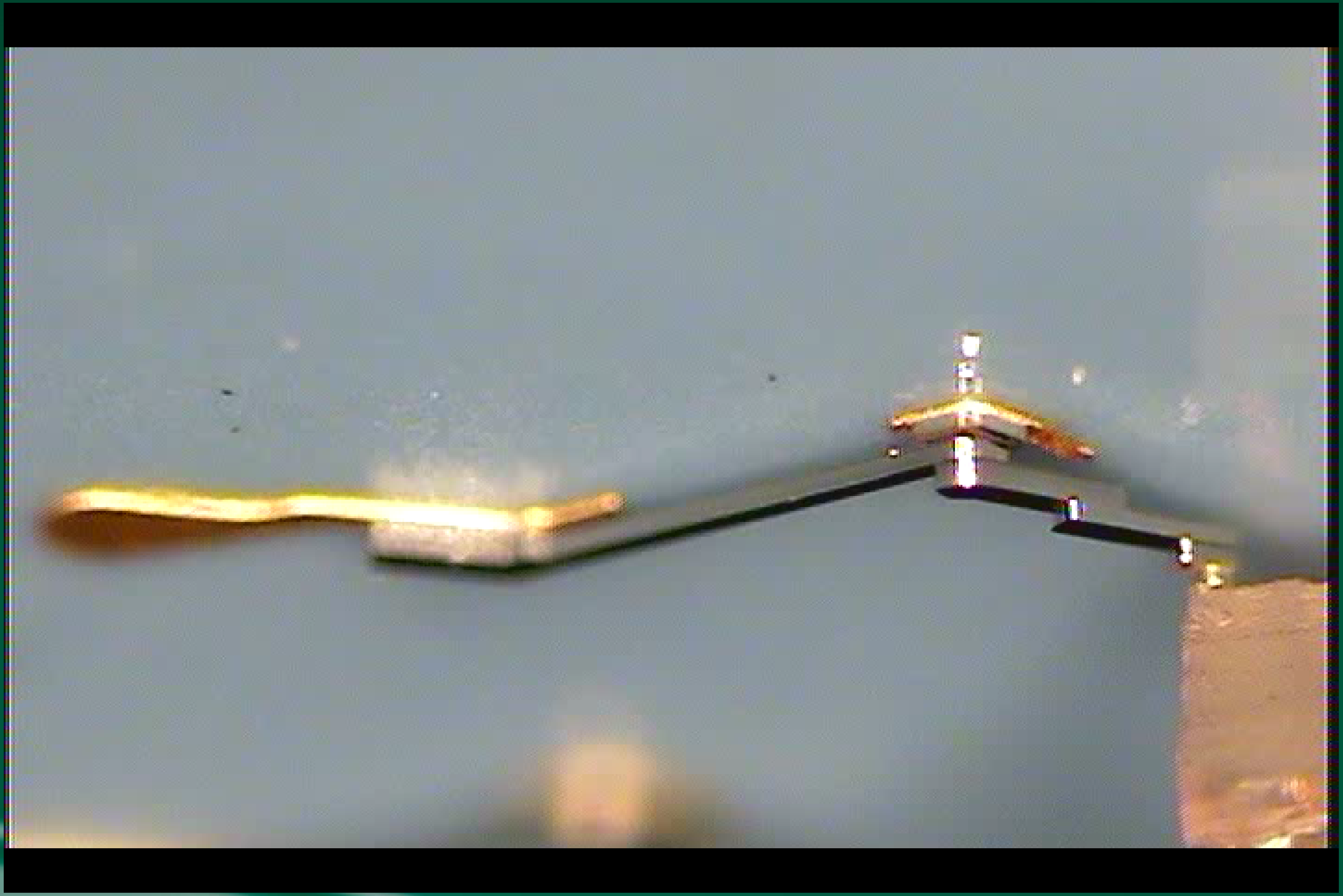
- Bending = Cantilever



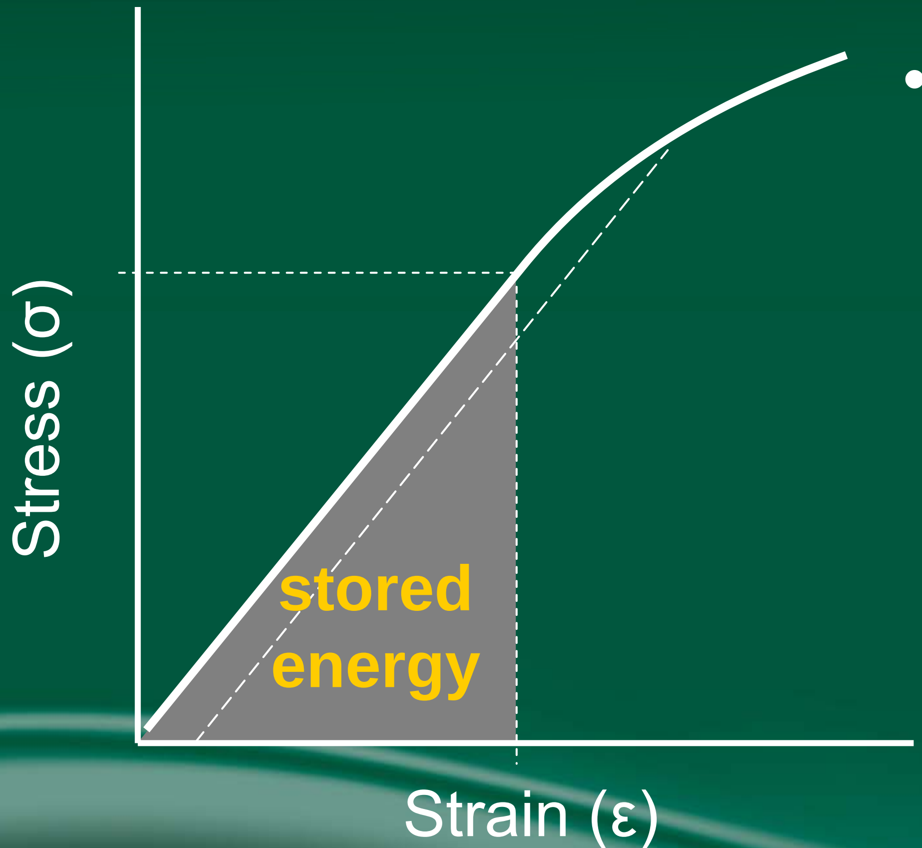
- Torsion



Torsional Probe Motion

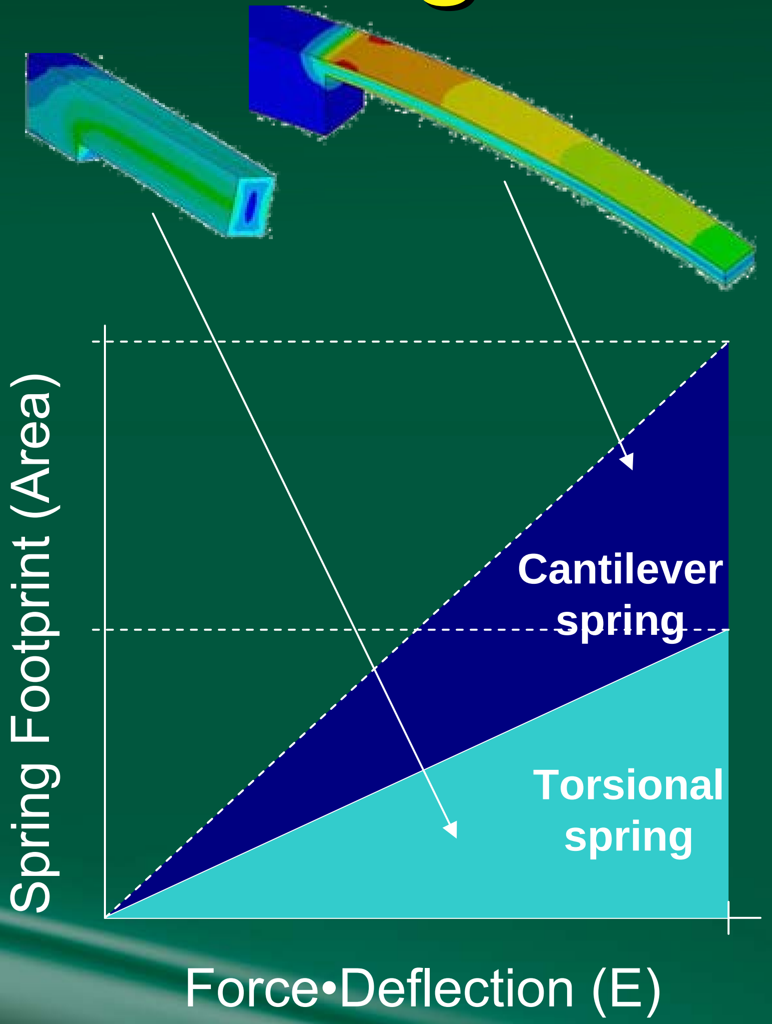


How spring energy is stored



- Spring Energy: Mechanical energy stored up in stressed material
  - Stress produced by external Force
    - Recoverable (if remains in resilient range)

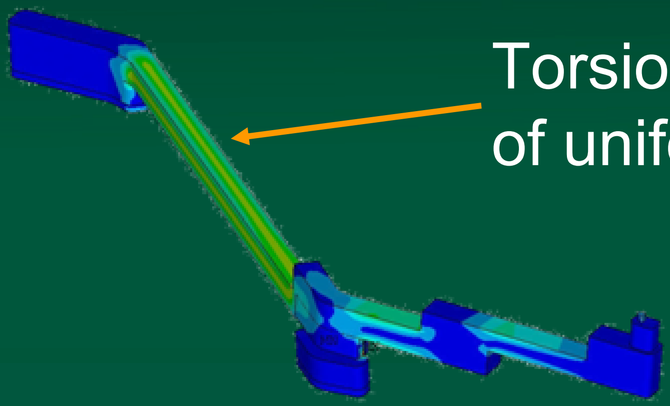
Spring Footprint for Energy Storage



Torsional Probe Energy Storage

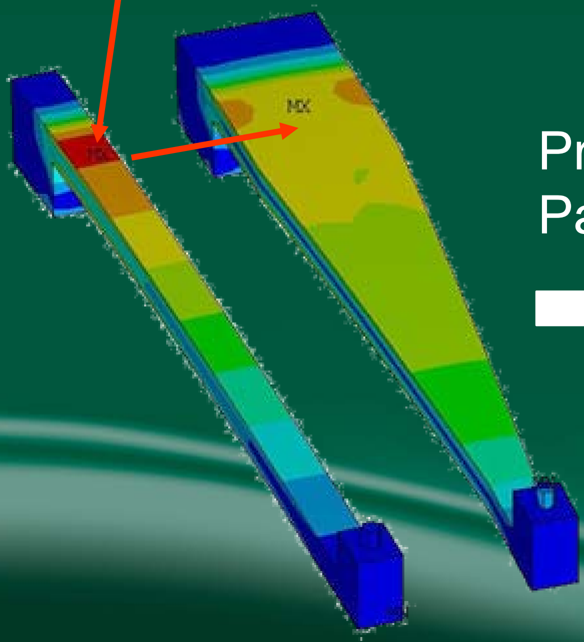
- Variables that affect the quantity of spring energy stored
  - Spring design (shape)
  - Lithography quality (dimensional consistency)
  - Material
  - Material treatment (anneal, quench, etc.)

Layout Constraints Due to Stress Concentration: Cantilever vs. Torsion

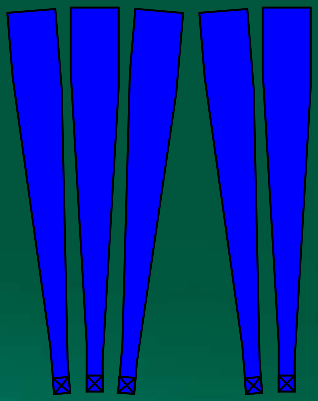


Torsional Bar is of uniform size

Cantilever beam tapered to reduce high stress area

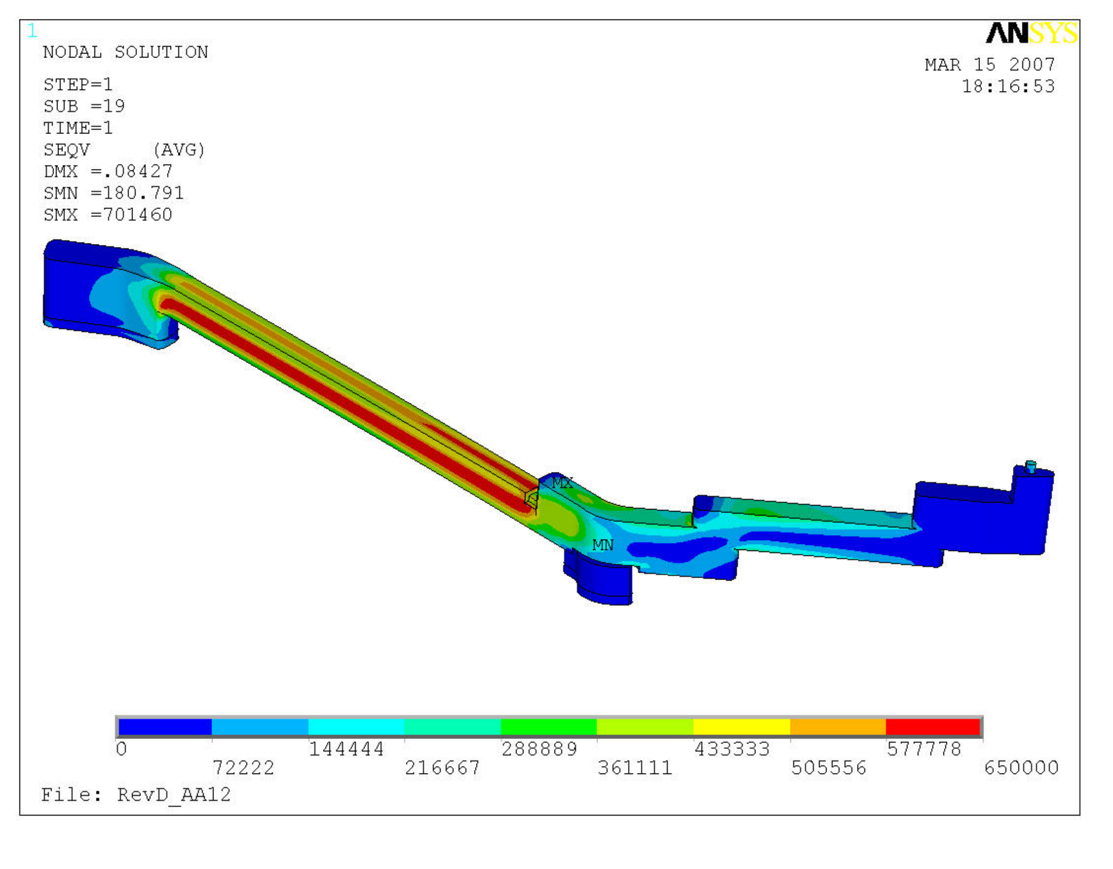


Probe Packing



Challenging in scaling to finer Pitch

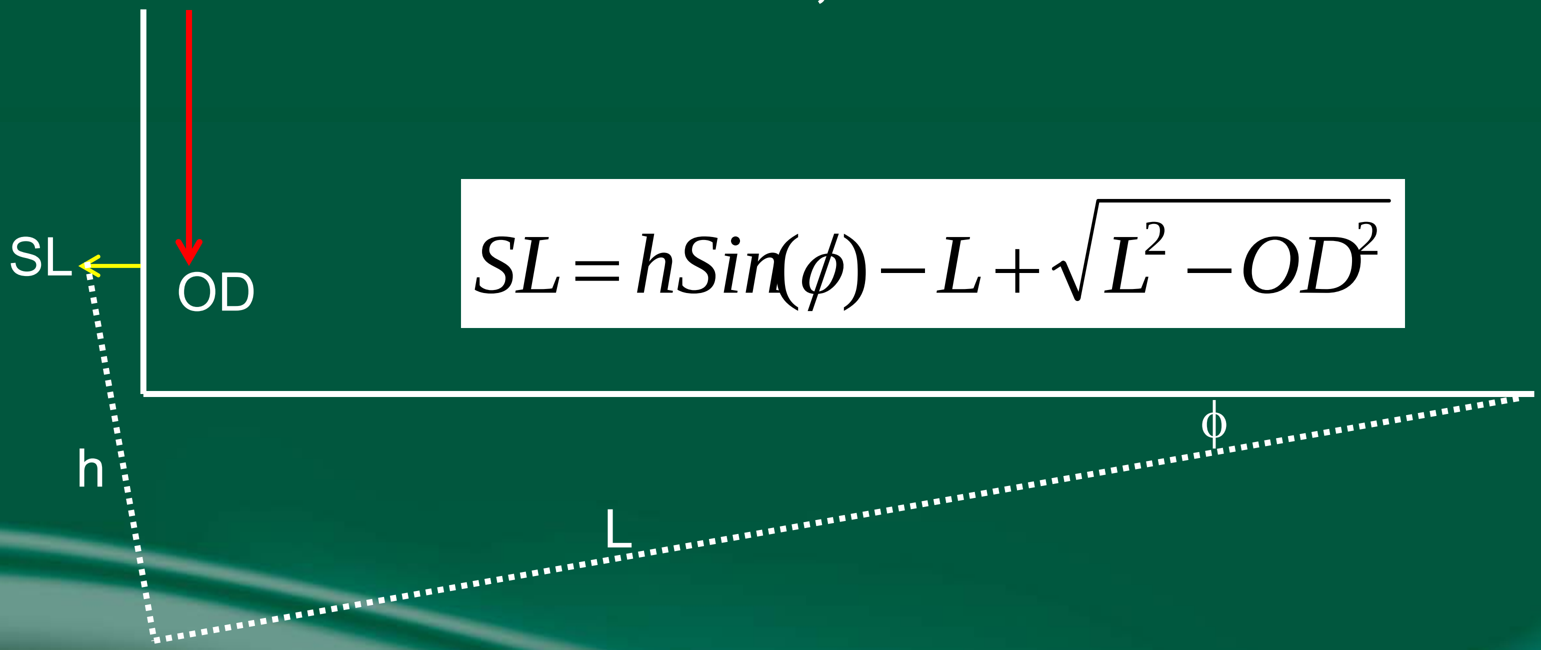
Stress Distribution



Scrub Length

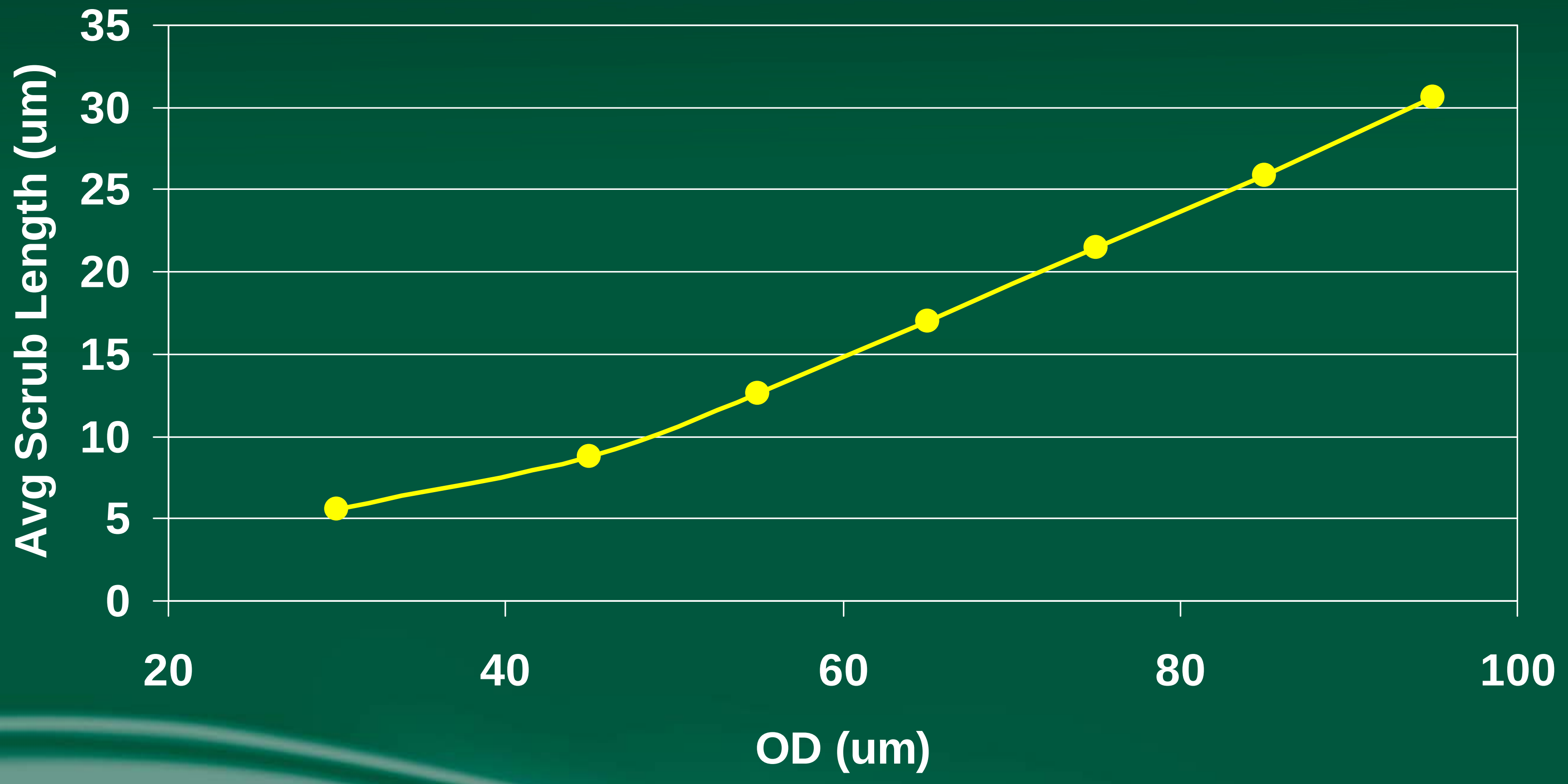
Scrub Length parameters

- Height of Tip to Beam, h
- Length of the Beam, L
- Over Drive, OD



$$SL = hSin(\phi) - L + \sqrt{L^2 - OD^2}$$

Scrub Length vs. OD



Probe Force

(Spring Stiffness)

Cantilever

$$k_c \propto E\frac{a^3 \cdot b}{L^3}$$

- a is the Thickness
- b is the width of Bar
- L is the Bar Length

- Parameter most sensitive to Stiffness is Bar Thickness a
  - Control Metric: Planarization

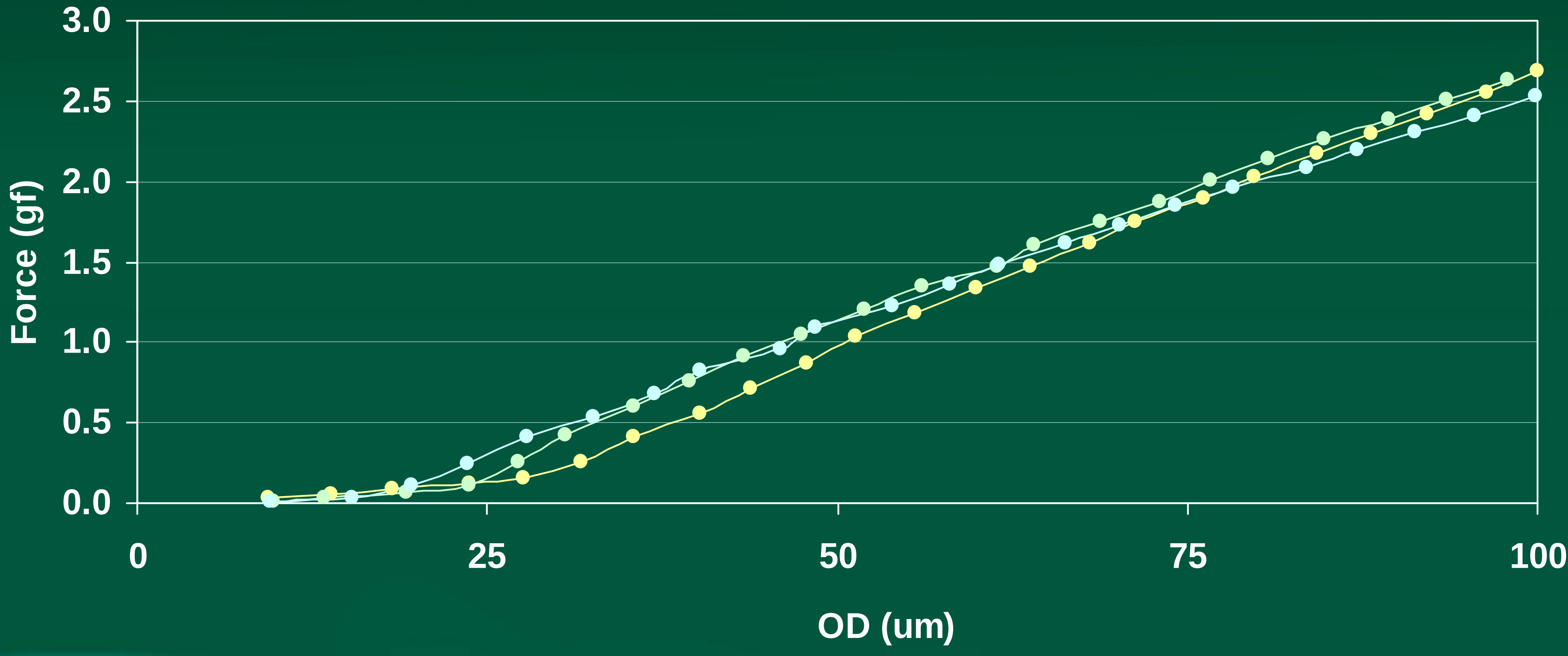
Torsion

$$k_t \propto E\frac{a \cdot b^3}{L \cdot D^2}$$

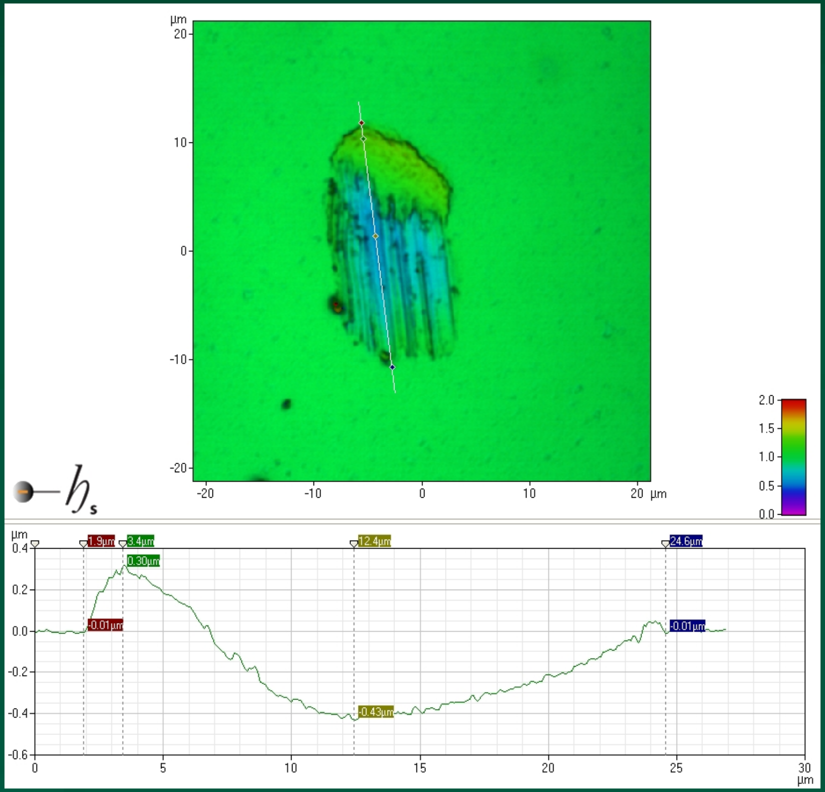
- a is the Thickness
- b is the width of Bar
  - where a>b
- L is the Bar Length

- Parameter most sensitive to Stiffness is Bar Width b
  - Control Metric: Lithography

Probe Force vs. OD



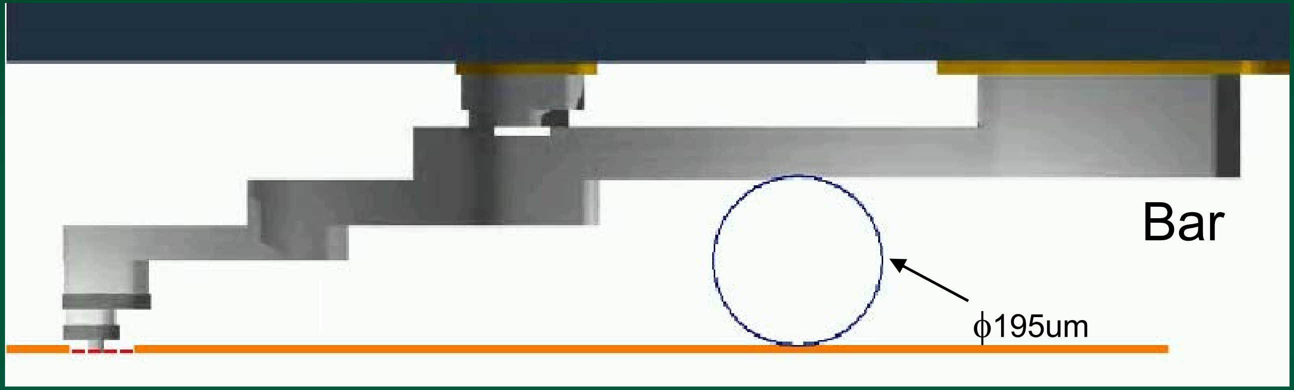
Typical Scrubmark Depth Profile

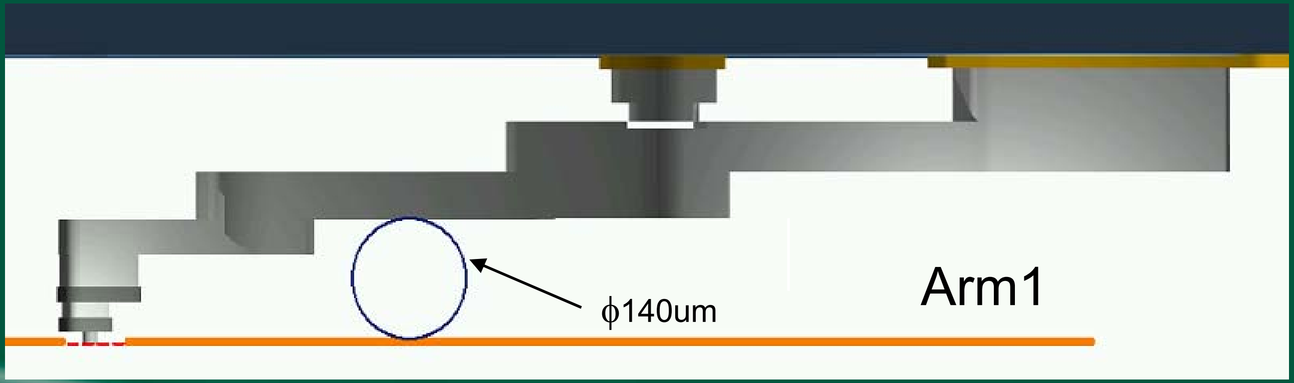


Scrub Profile @ 90C, 65um OD

Pad damage ≤ 2% by volume, pileup not included

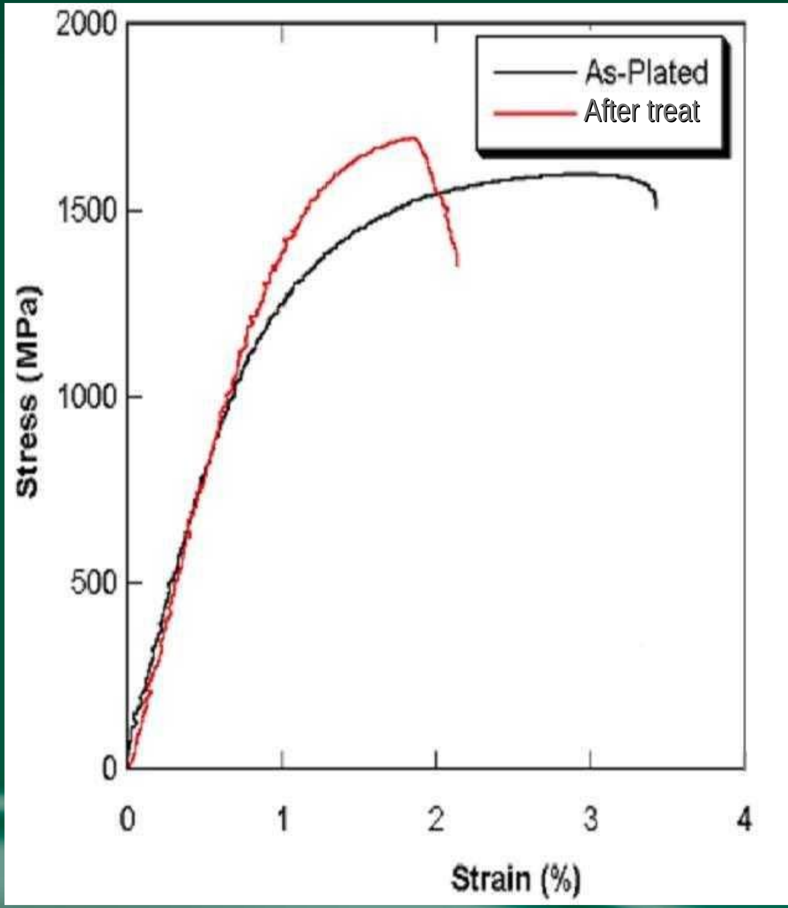
Robustness: Particles & Debris





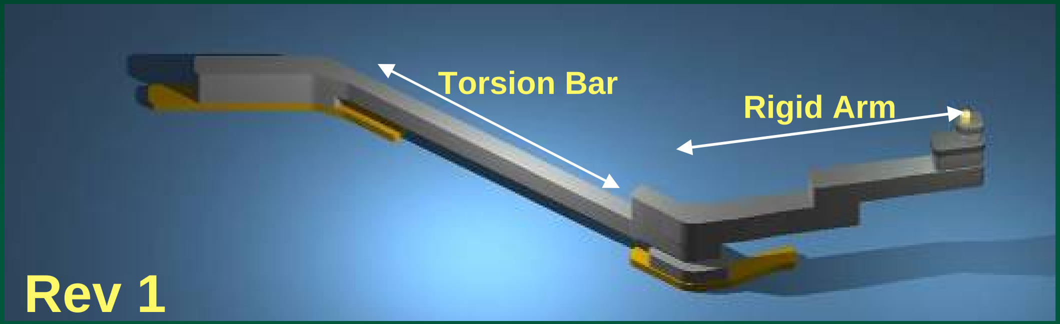
Resilient to particles and debris.

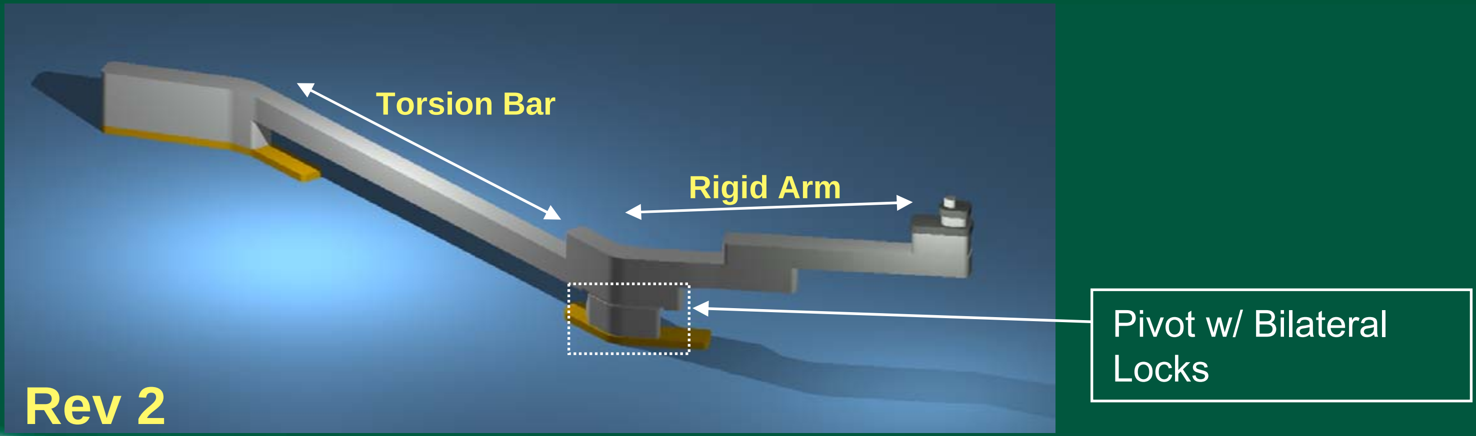
Spring Material



- This Ni Alloy delivers industry-leading strain limit / specific energy limit at elevated temperatures
  - Ni Alloy Stress-Strain Curve
  - (from tensile tests → E=201GPa)

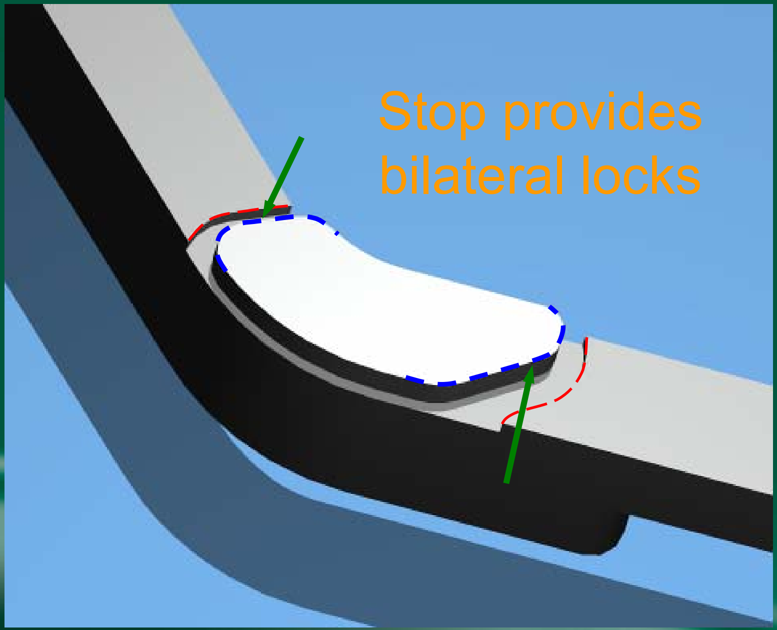
Probe Design Evolution

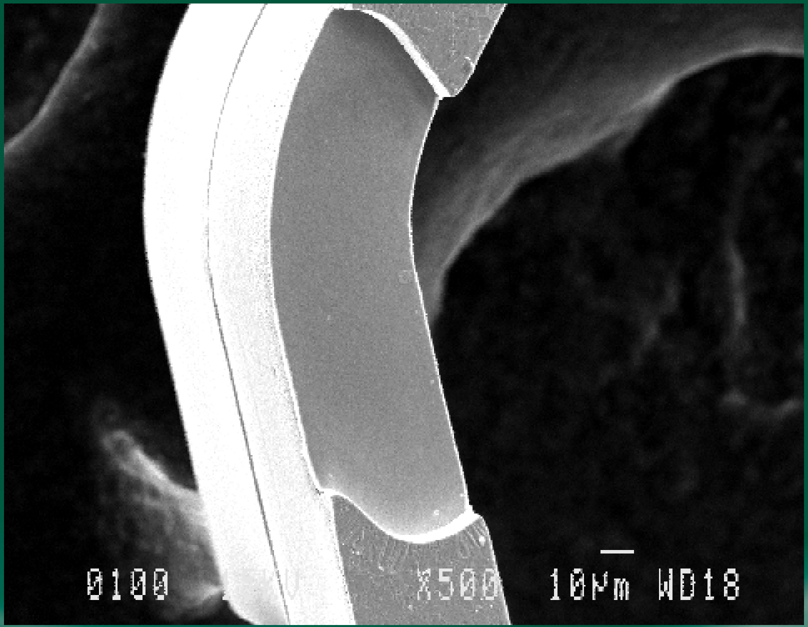




Improved Pivot-Stop

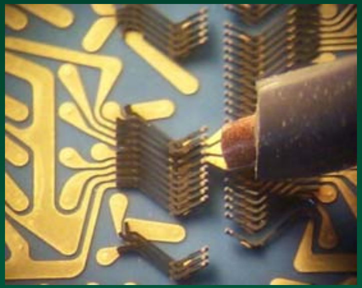
- Pad pitch reduction enabler
  - Improved lateral probe constraint
    - Pivot stop completely under bar
    - Probe designed to "lock" onto stop during OD



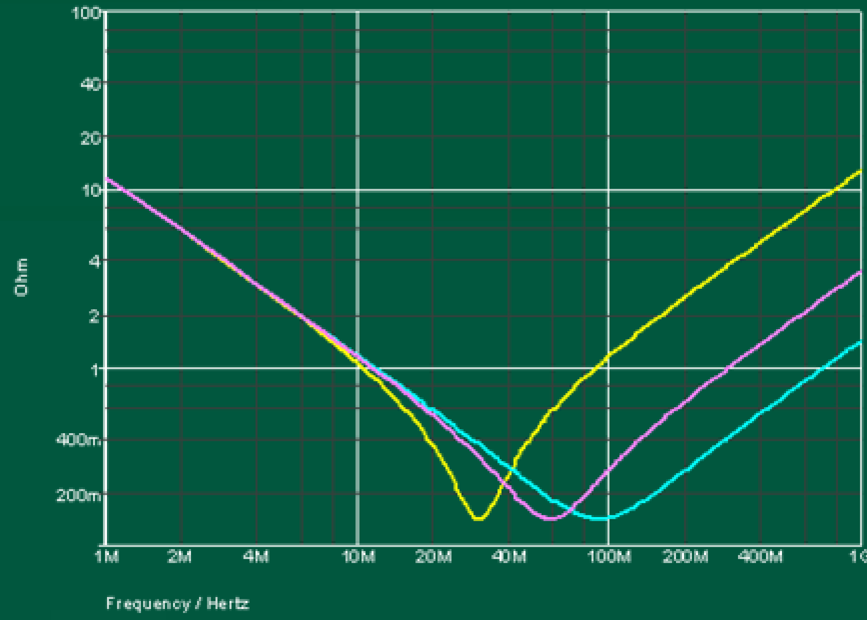


Probe Characterizations

Electrical Measurement



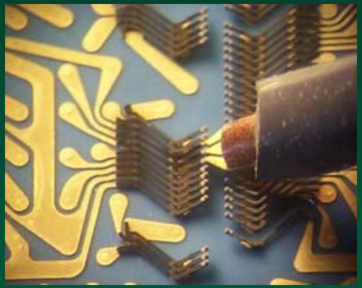
Z of Power Delivery (DRAM Design)



- Low Impedance Power Delivery Capable
  - Required of higher di/dt DUTs
  - Power/GND probes can be bussed together at stop
  - Ability to place capacitors on the wafer side

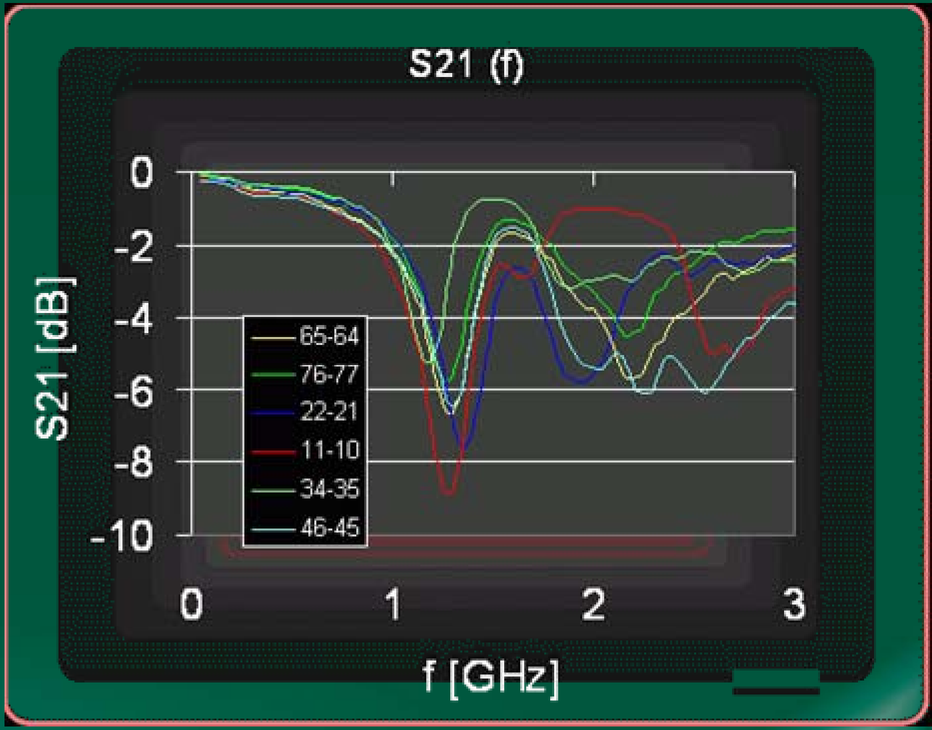
Probe Characterizations

Electrical Measurement



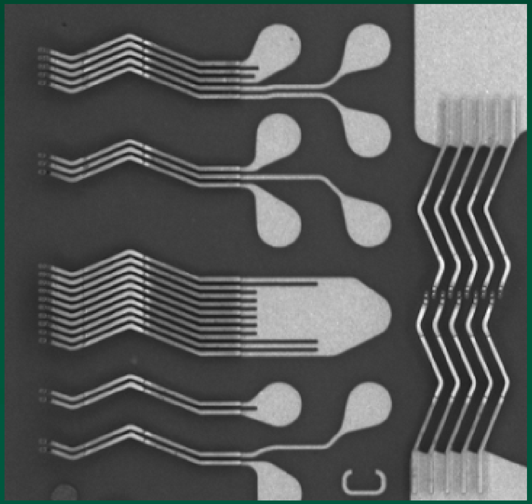
Insertion Loss (S21) Typical Result

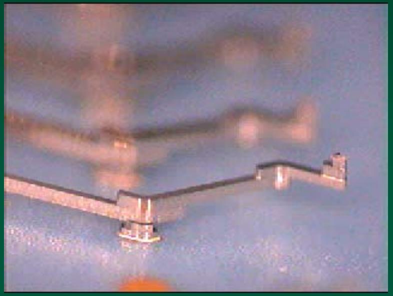
- SI Performance
  - Physical line length of probe very short
  - All gold interconnect in Space Transformer
  - SI design rules and Z=50ohms capable in Space Transformer traces

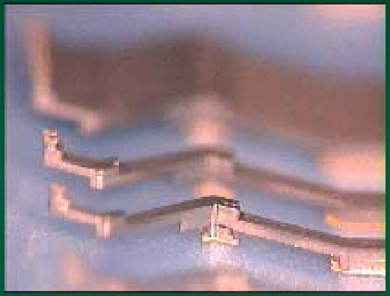


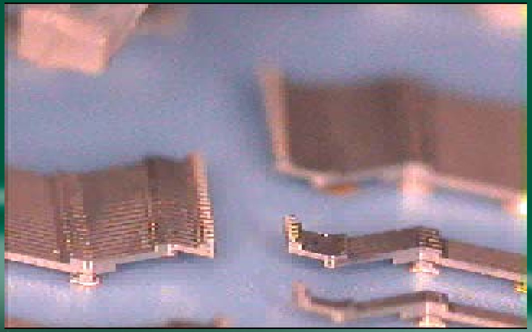
Probe Photographs

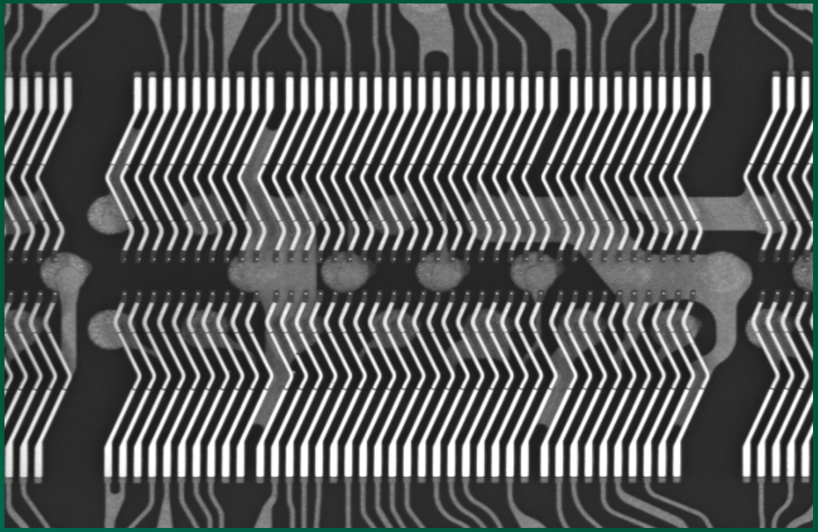
Pitch Shown: 70um sustained / 65um interlaced











Technology Advantages

- Torsional Probe Advantages
  - Efficient mechanical energy storage in smaller spring volume - Superior packing density
  - Low force at recommended OD
  - Unique scrub motion causes very little pad damage
  - Design robust to process sensitivity
  - Scrub mark control
  - High margin stress management
  - Effective SI / Power Delivery

Thank You

- Any Questions?