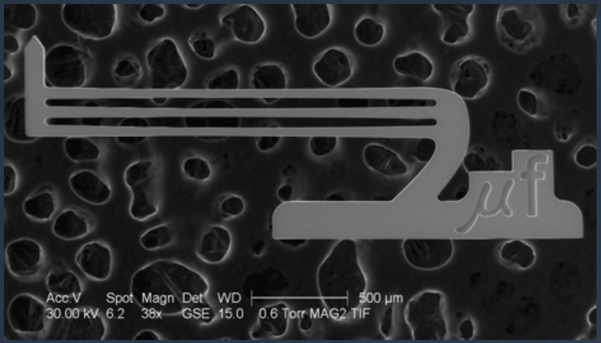
Mechanical Design of MEMS Probes for Wafer Test

Chris Folk



IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

Microfabrica™

Outline

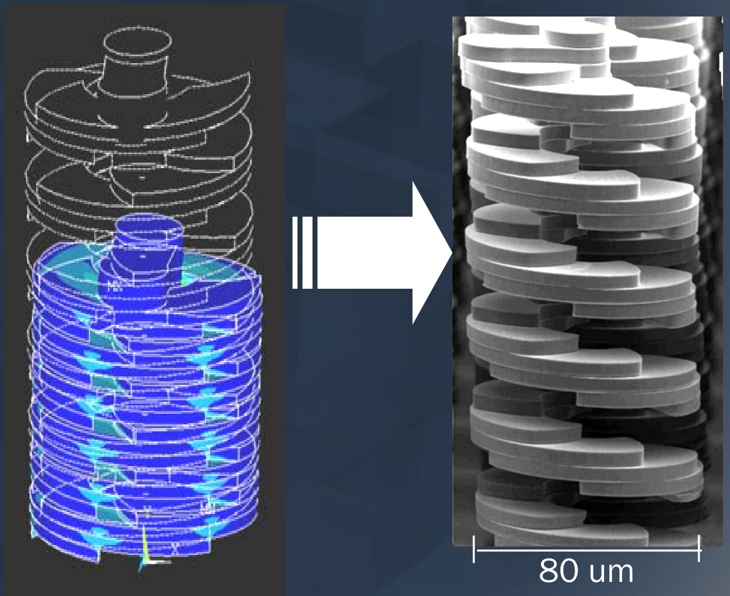
- Microfabrica’s EFAB® process
- EFAB process applied to Compliant Pins
- Design of a Compliant Pin
- EFAB process applied to a Vertical MEMS probe
- Design of Vertical MEMS probe
- Conclusions

EFAB® Technology Summary

- Multi-layer metal manufacturing technology for micro- to millimeter-scale devices
- Unlimited variety of complex 3-D shapes can be built
    - Designers are not constrained to standard shapes and processes
- Micron-precision features
    - Tolerances ~ 2 micron typical
- Utilizes wafer-scale batch process

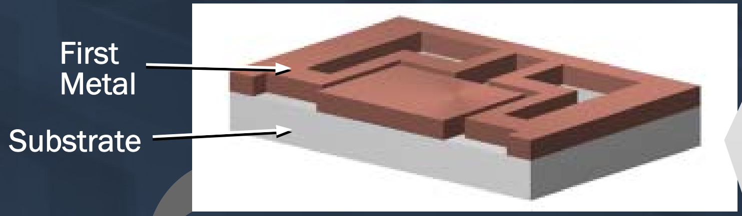
From 3-D CAD Design and Simulations

to Microdevice

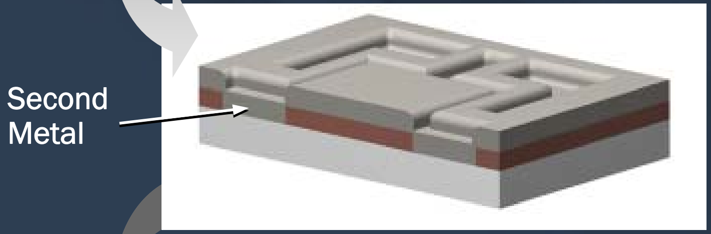


EFAB Process Flow

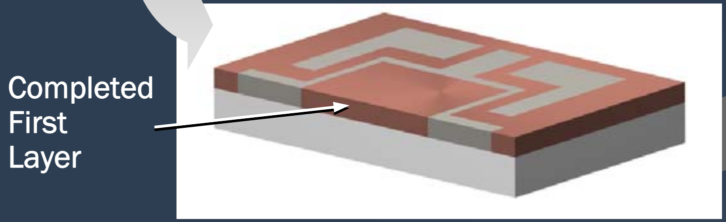
Pattern Deposition



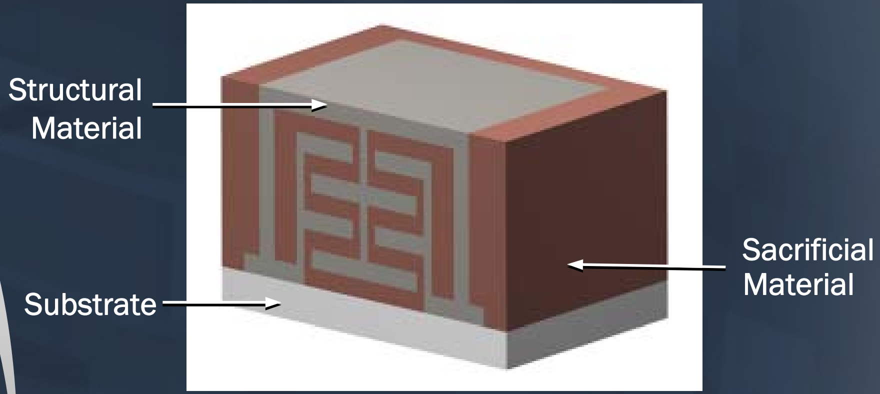
Blanket Deposition



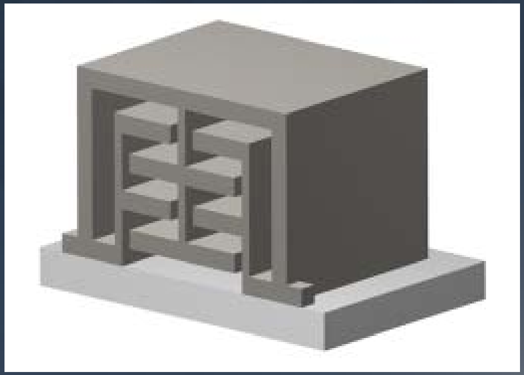
Planarization



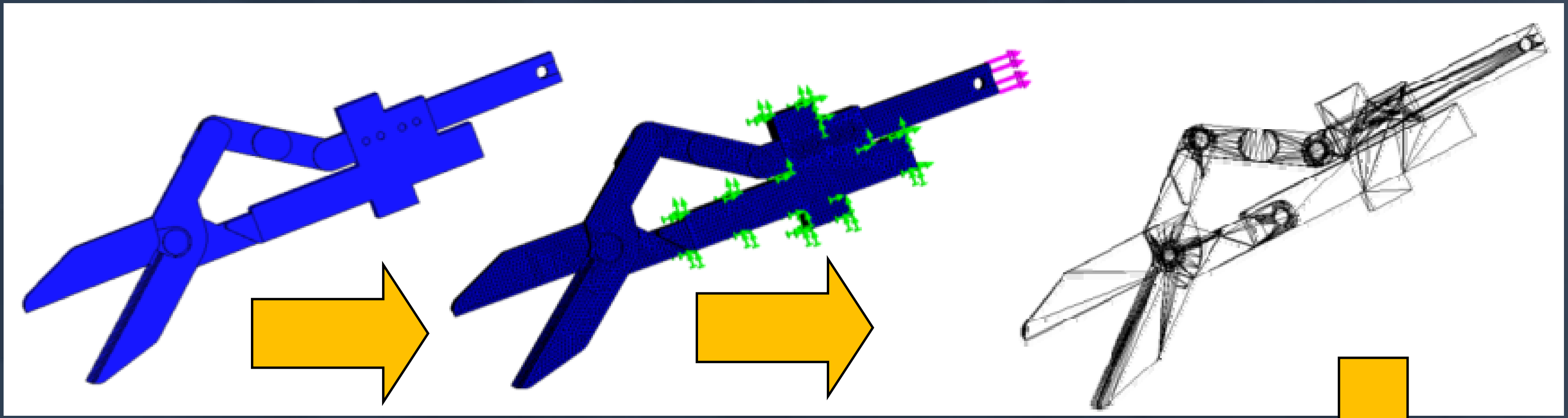
After *n* Layers



Final Structure
After Etching Sacrificial Material



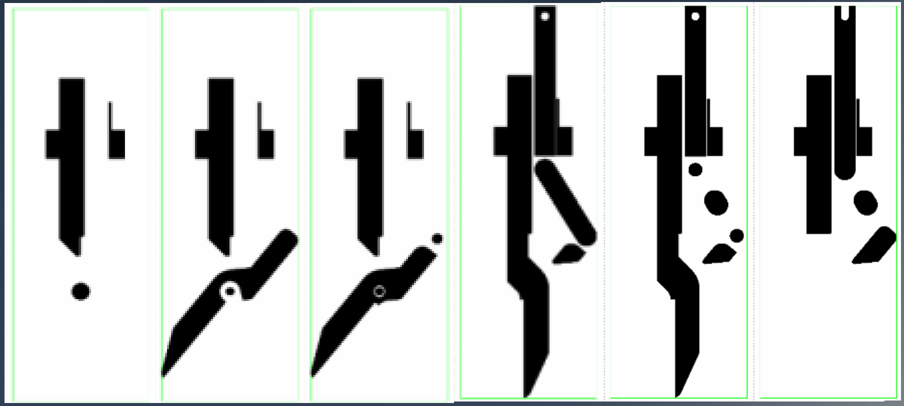
EFAB Design Flow



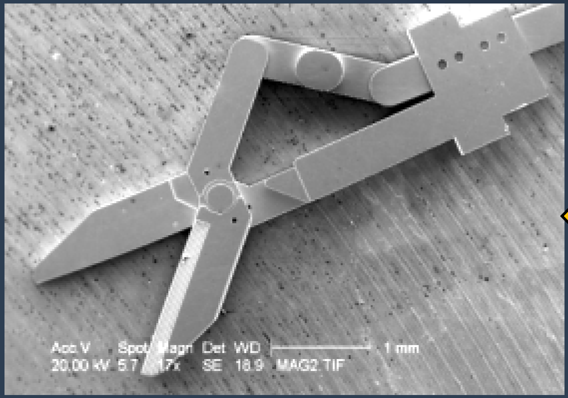
Solid Model

Simulation

STL File Export



LayerView^{TM} Cross-sectioning



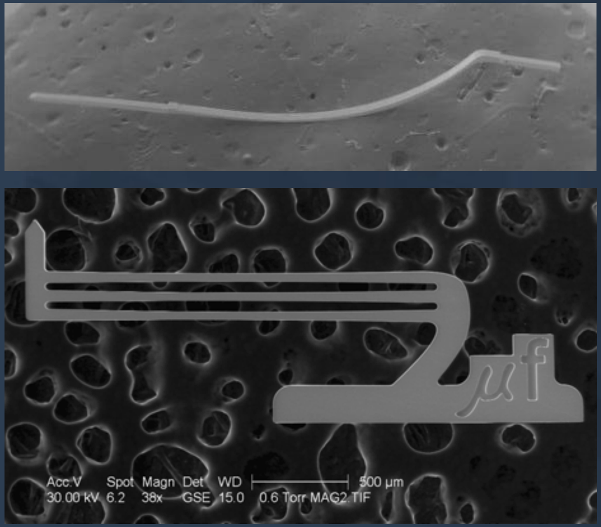
Fabricated Device

Advantages of EFAB Technology for Wafer Probes

- Lithography-based batch manufacturing
  - Precise and very uniform pin dimensions
  - Arbitrary complex geometries = design flexibility

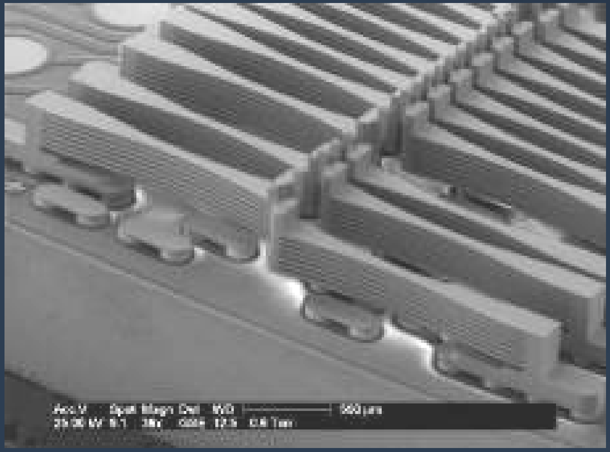
- Two-metal structure for optimum performance
  - Nickel-cobalt alloy Valloy^{TM}-120 body for best spring behavior
  - Rhodium-based Edura^{TM}-180 tips for low wear & excellent contact resistance

Wafer Probe Products Using EFAB



Compliant Pins

- Custom-made precision individual springs and spring pins for wafer probing and fine-pitch socket applications

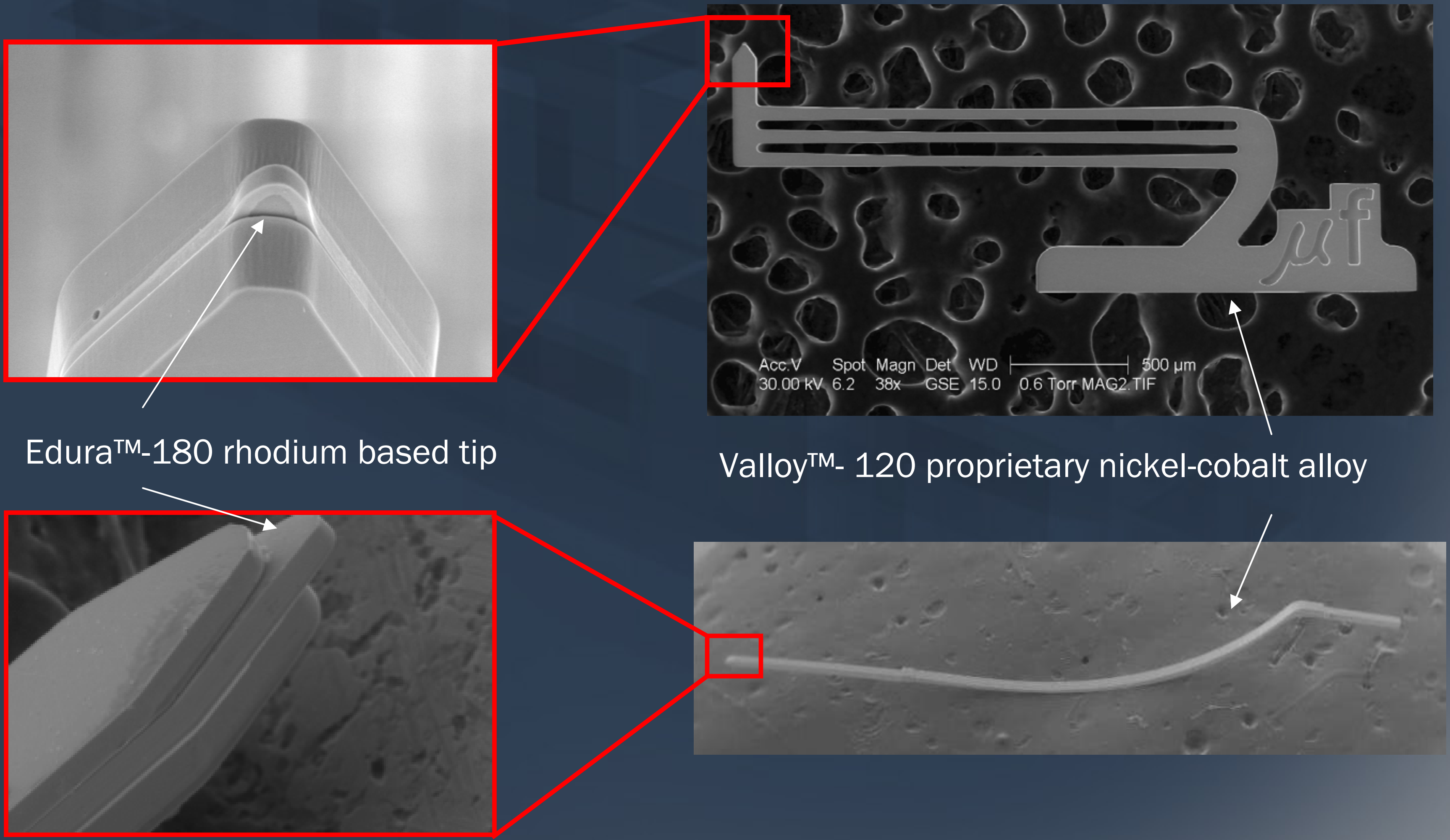


Vertical MEMS (VMEMS) Probes

- Cantilevered structures for memory test
- 50 µm pad pitch demonstrated
- Enables high parallelism multi-site applications

Compliant Pins

- Different probe styles (cantilever, buckling beam) and arbitrary tip shape can be designed to meet desired specifications.



Edura™-180 rhodium based tip

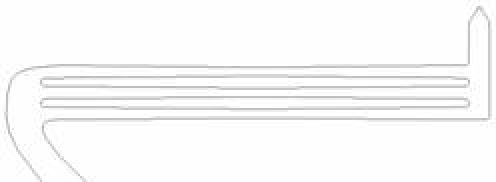
Valloy™- 120 proprietary nickel-cobalt alloy

How to Design a Compliant Pin

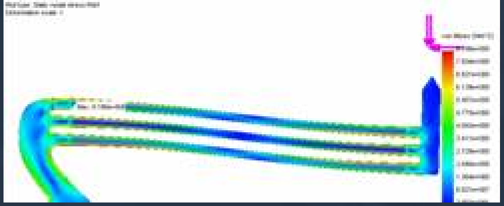
- Review prober and probe card requirements
- Determine range of probe card flexure, probe tip planarity
- Determine force and scrub. When designing pins with EFAB, force and scrub are decoupled. Therefore, good Cres is achieved by tuning these parameters.
- Usable overtravel for an individual pin is determined by:

  first pin: minimize fatigue, creep, pad damage

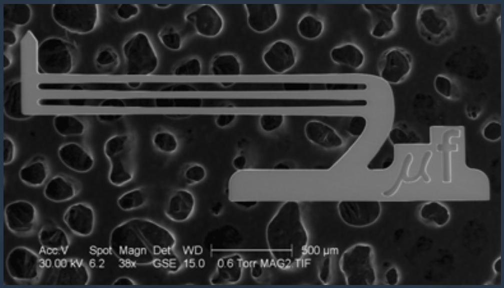
  last pin: have sufficient force and scrub to achieve good Cres
- Testing validates choices, or back to the drawing board!



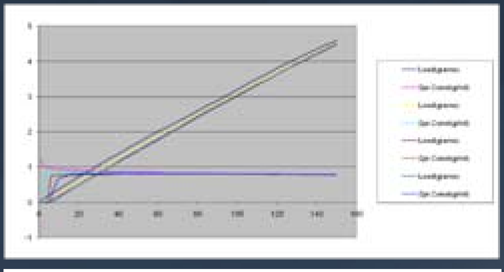
CAD



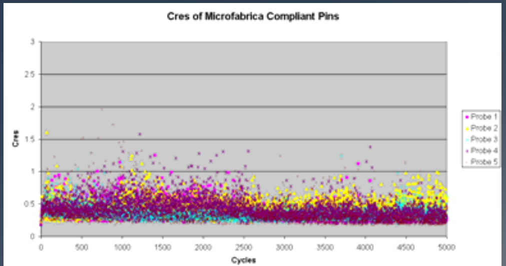
FEA



Fabricate



Mechanical test



Electrical test

Simple Cantilever

For a point load applied at the end of a beam:

Maximum deflection

$d=PL^3/(3EI)$

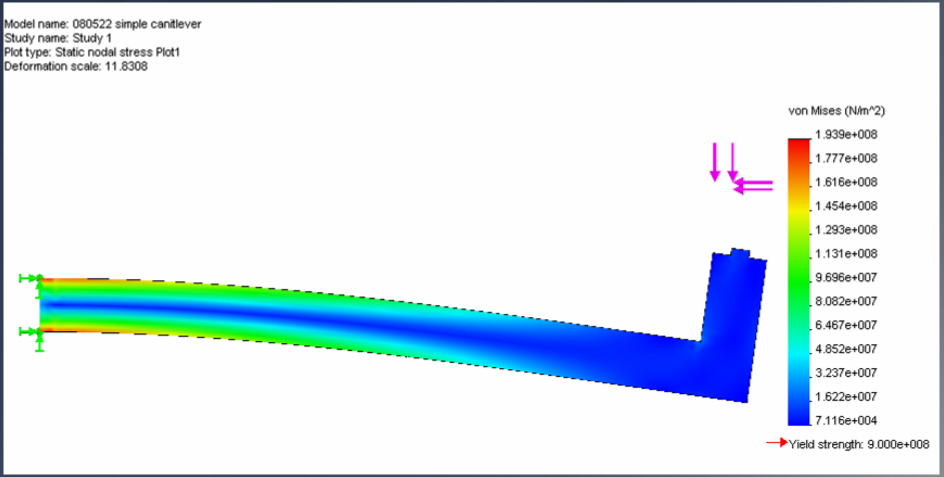
Equation of elastic curve

$y=P(x^3-3Lx^2)/6EI$

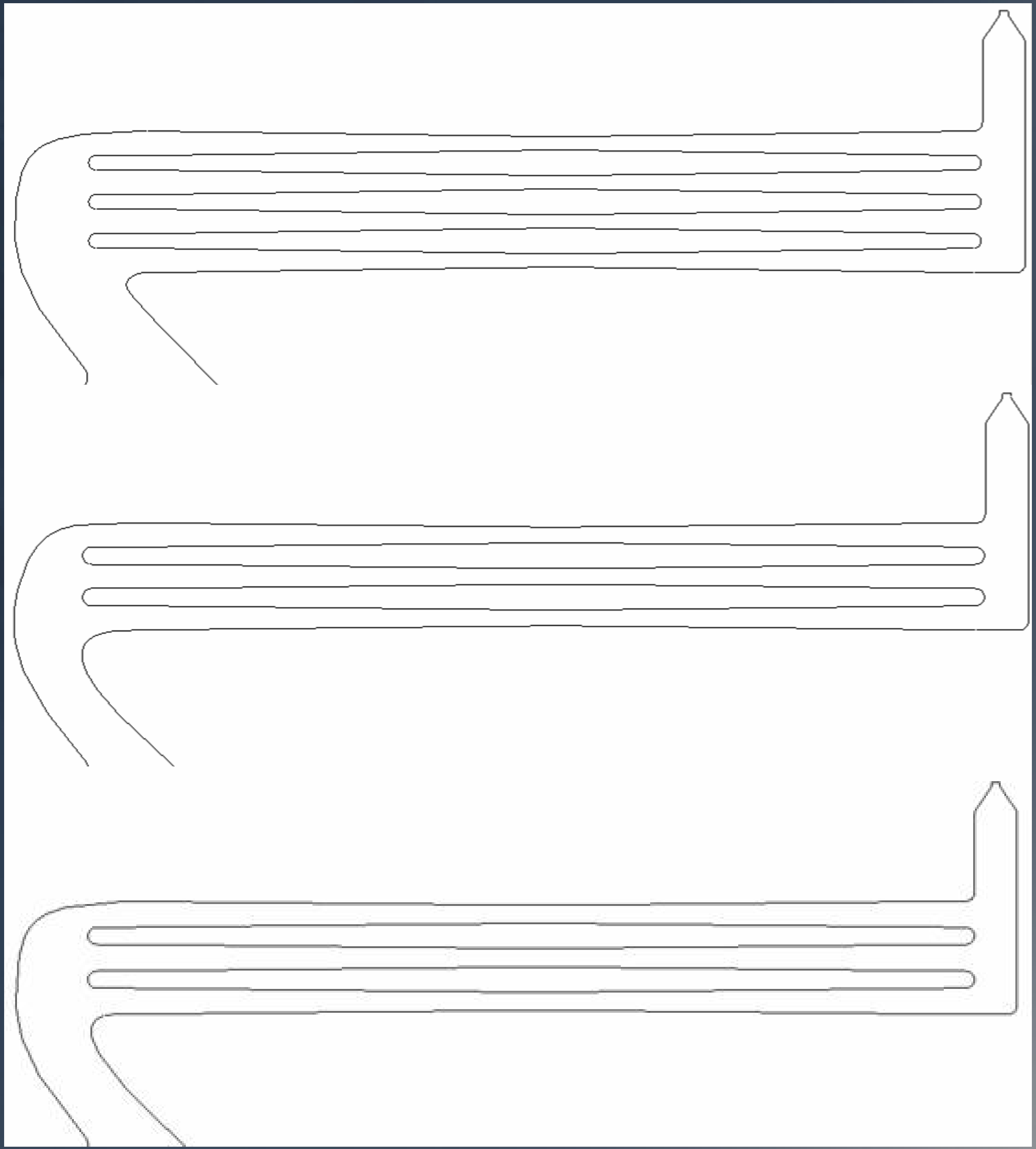
I=moment of inertia

Add friction and probe neck

Stress concentrated at root of cantilever. Probe scrub coupled to stiffness of probe.



Why multi-beam cantilevers?



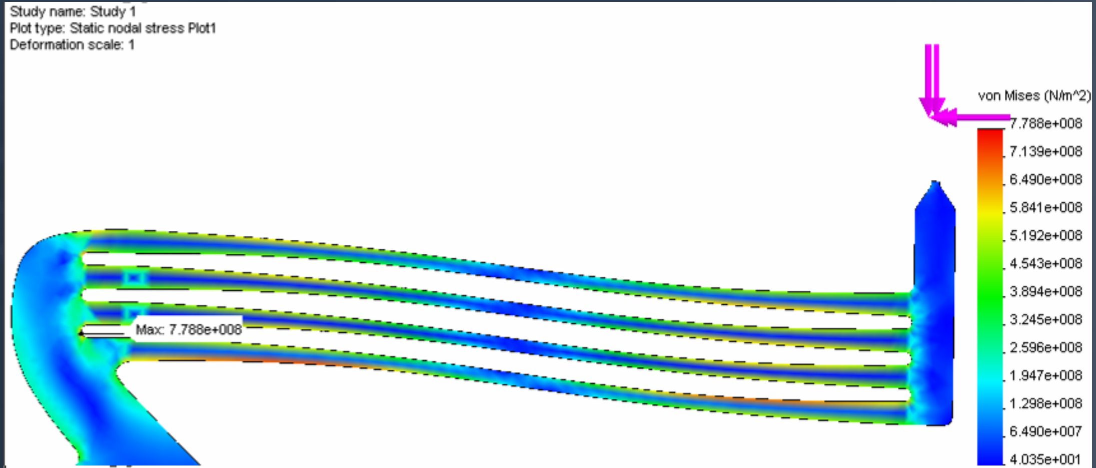
Short scrub, 0.75 g/mil

Long scrub, 0.5 g/mil

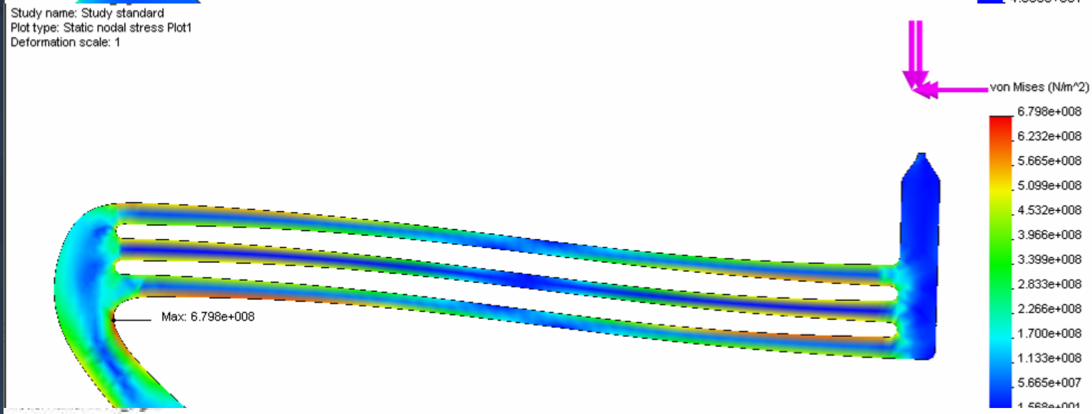
Long scrub, 0.75 g/mil

FEA used to determine Von Mises stress

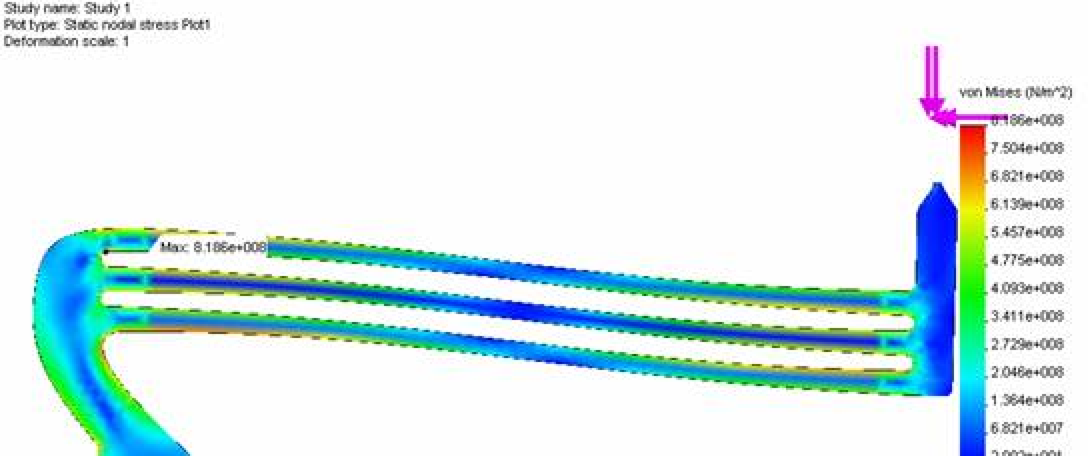
Short scrub, 0.75 g/mil



Long scrub, 0.5 g/mil



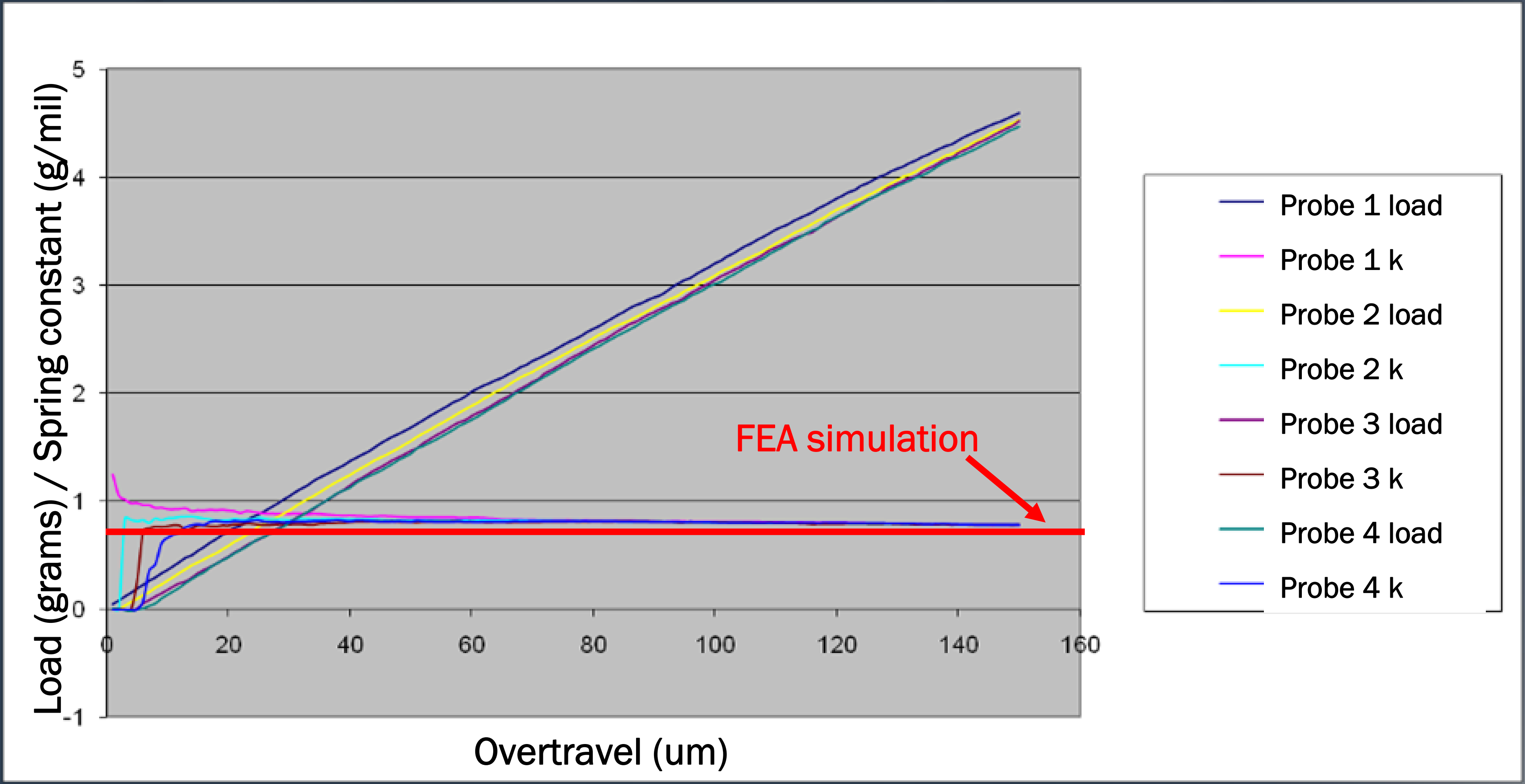
Long scrub, 0.75 g/mil



Design Tradeoffs Impact Pin Performance

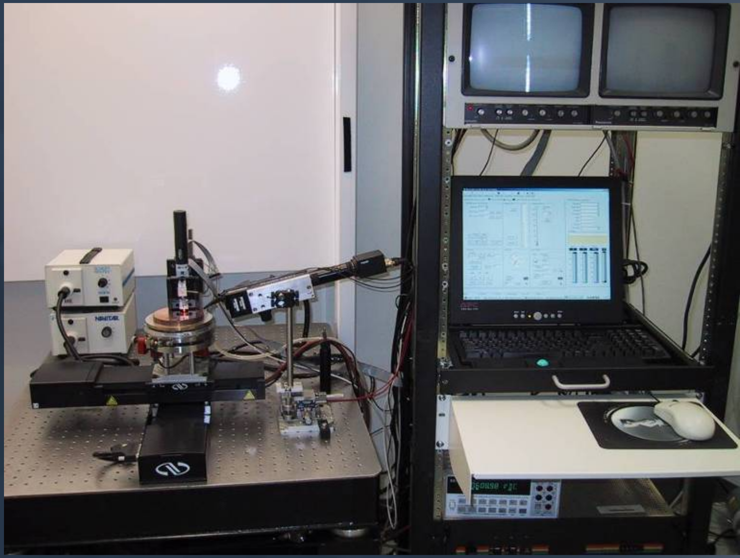
Probe Name	Short scrub, 0.75 g/mil	Long scrub, 0.5 g/mil	Long scrub, 0.75 g/mil
Computed spring constant	0.75 g/mil	0.5 g/mil	0.75 g/mil
FEA Applied force (g)	5.00	3.30	5.00
Computed overtravel (um)	167	170	168
Computed scrub motion (um)	8	16	16
Max Von Mises σ (MPa)	780	680	820
OT required for 2g force (um)	68	101	68
σ VM required for 2g force (MPa)	310	400	330

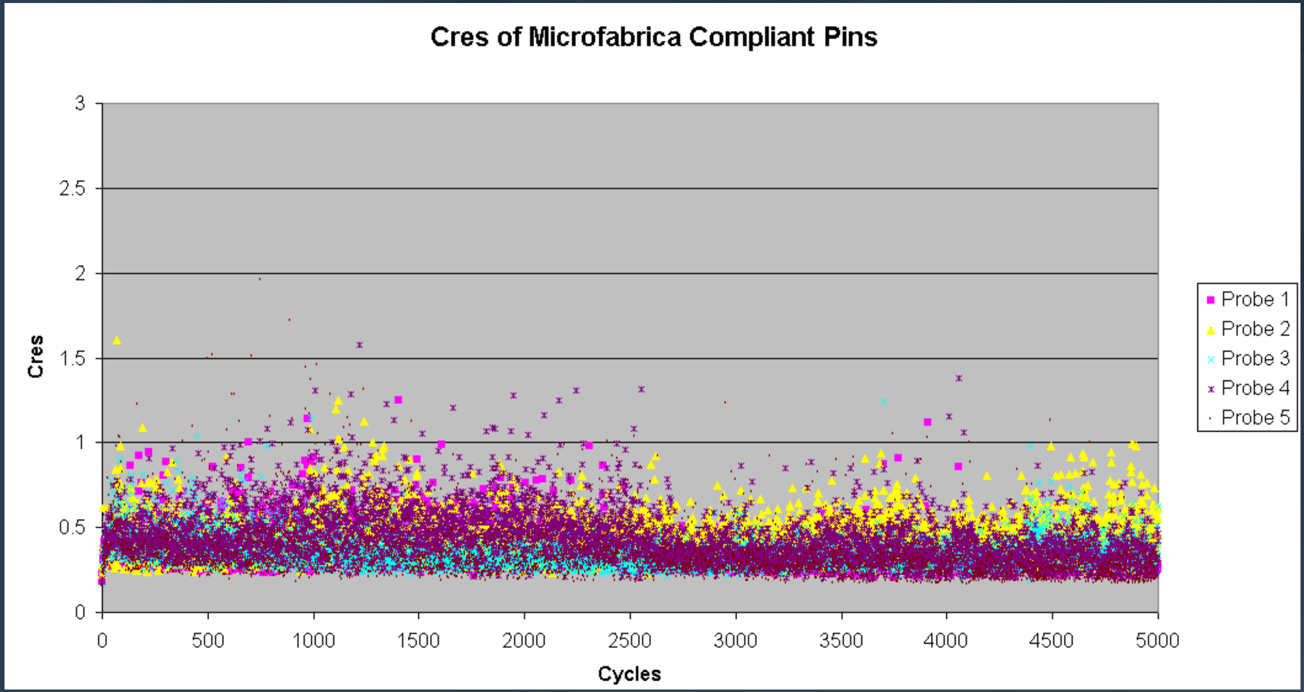
Spring Constant Matches Simulation



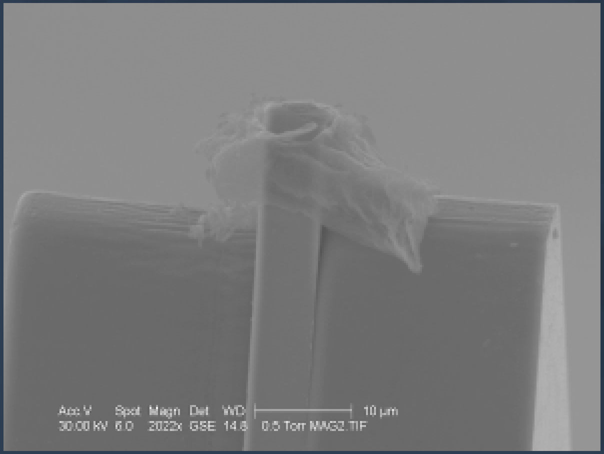
Cres Testing

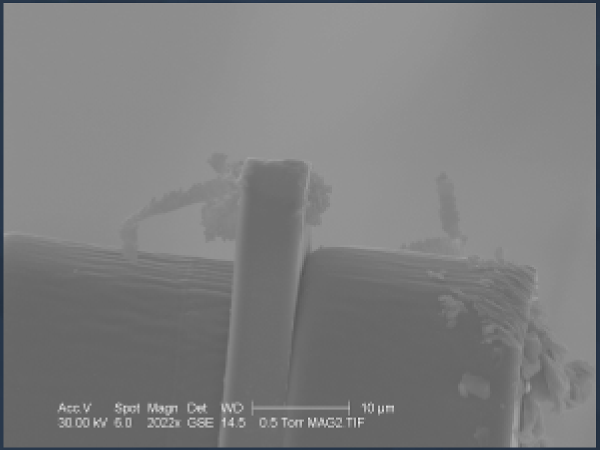
0.75g/mil, long scrub probe
100 µm over travel
100^0C
5000 cycles
Al on Si wafer
Without cleaning

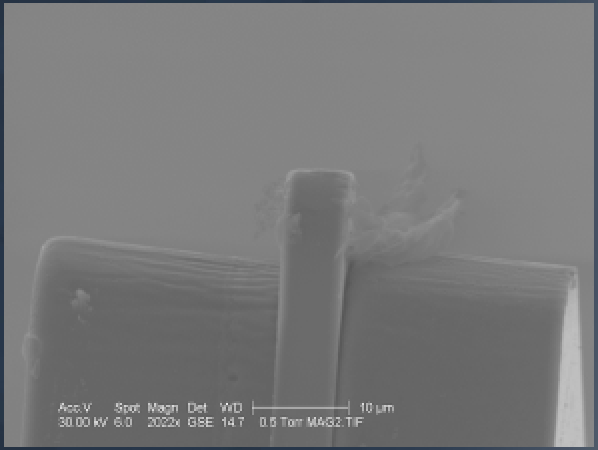




Minimal Debris 5K – No Clean



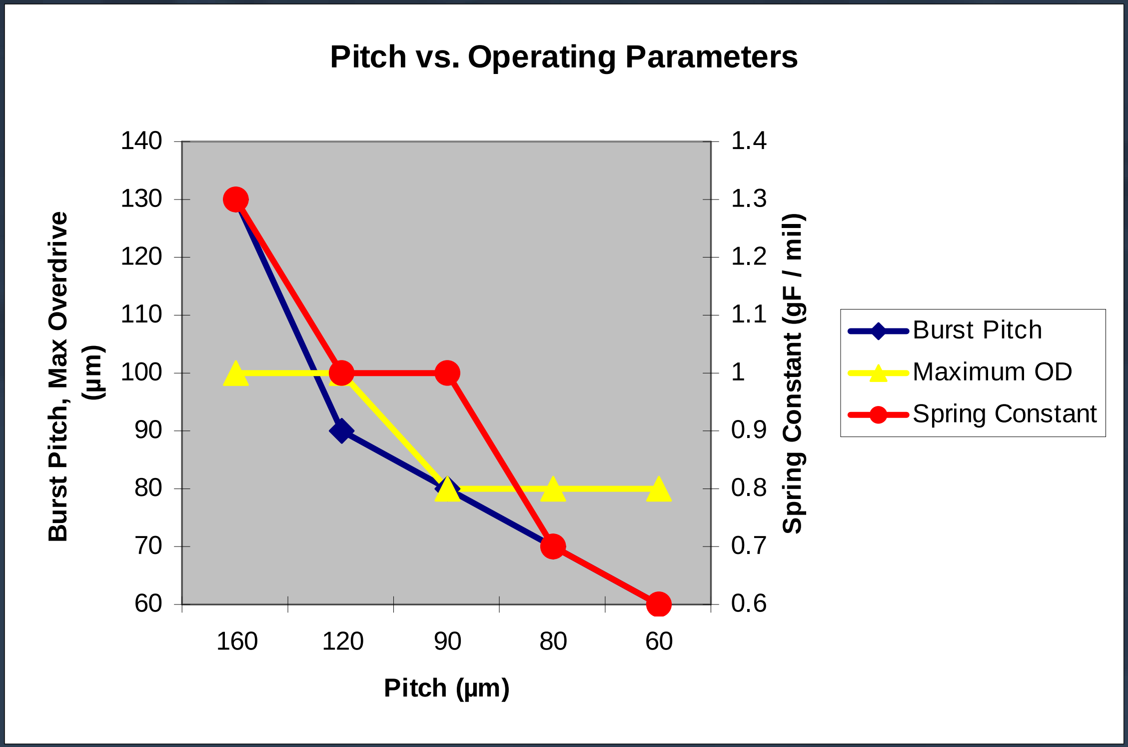




Vertical MEMS (VMEMS) Probes

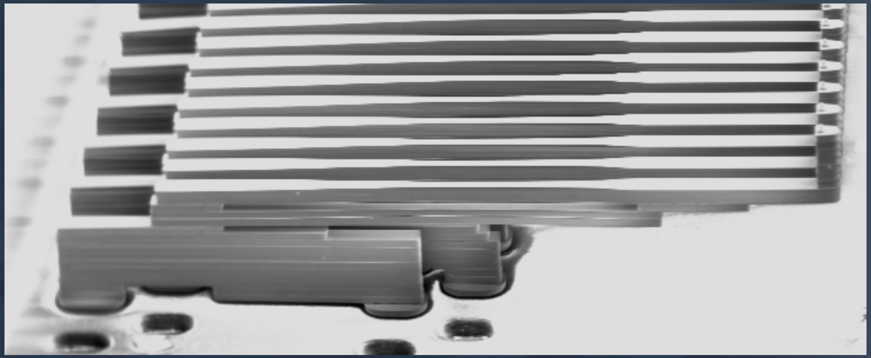
- Custom-designed to meet specific force, compliance, height, footprint and scrub requirements
- Extremely tight linear pad pitches are possible

Pitch & Performance Tradeoffs

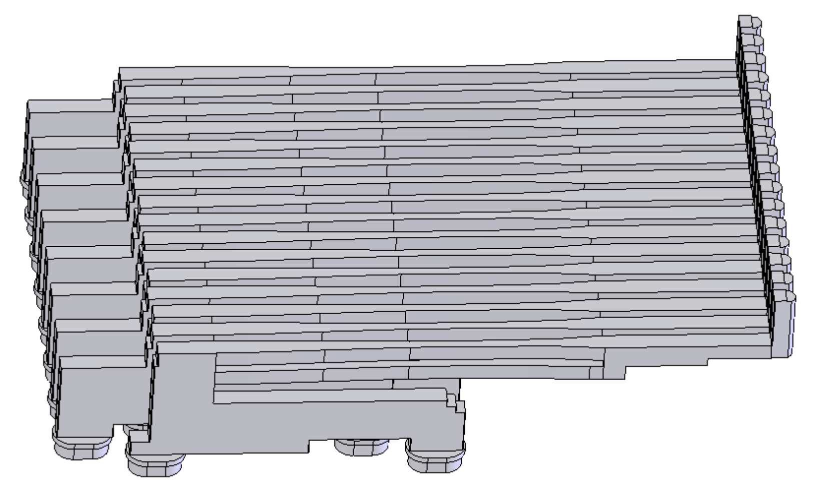


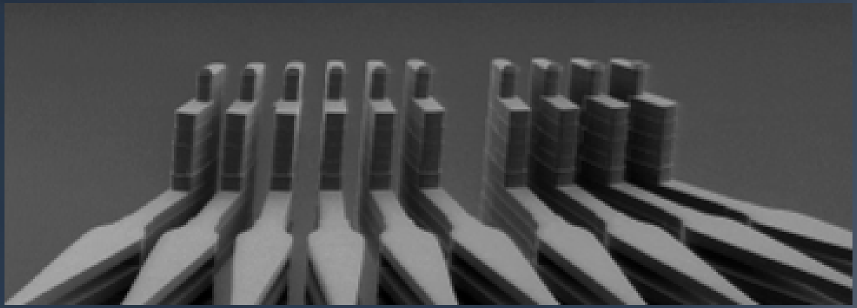
MF900 – 90 µm pitch

- Pitch:
  - True – 90 um
  - Burst – 80 um
- Over Drive: 80 um
- Spring Constant: 1.0 g/mil



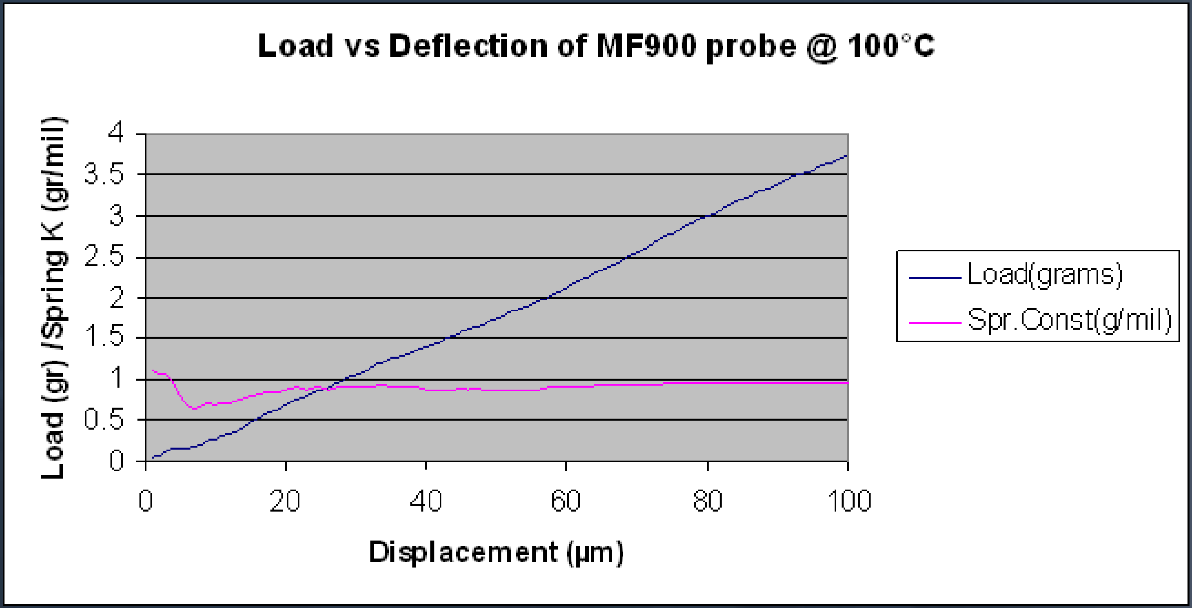
True



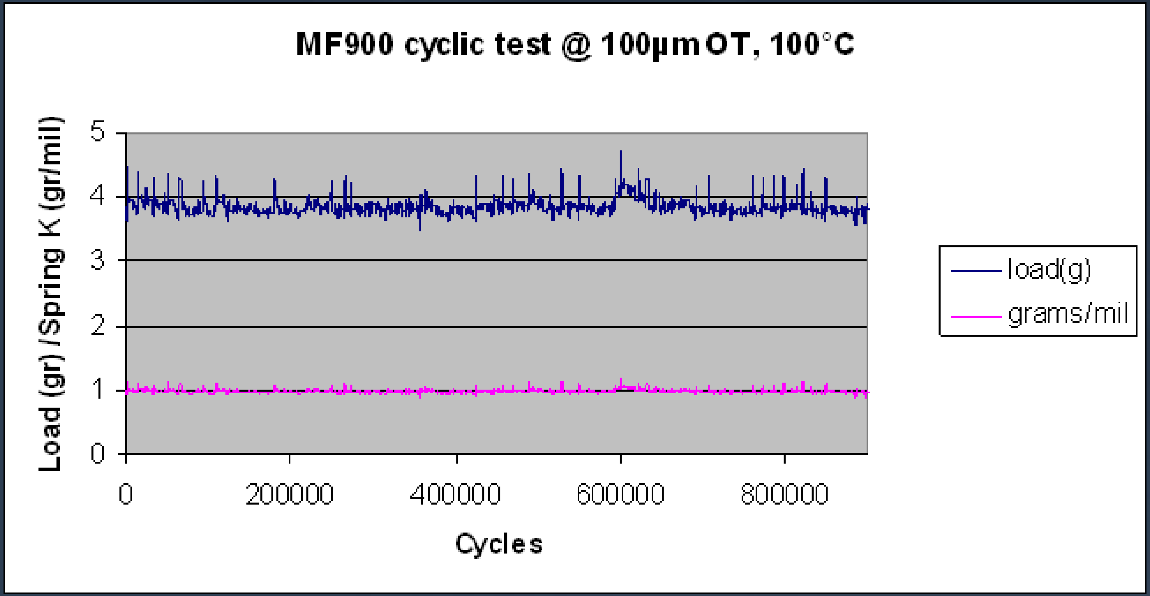


Burst

Mechanical Testing



- Designed spring constant =1 gF/mil



- Maintains consistent load >900k cycles

Conclusions

- EFAB process enables unique designs for building both Compliant Pins and VMEMS probes
  - Valloy^{TM}-120 high performance spring material
  - Edura^{TM}-180 excellent tip contact material

- Multi-beam cantilevers allow spring constant and scrub to be decoupled

- Well characterized materials and process enables closed loop of design -> simulation -> fabrication -> test
  - Measured performance of pins closely matches FEA
  - Sub-ohm Cres achieved
  - Tip design yields minimal debris