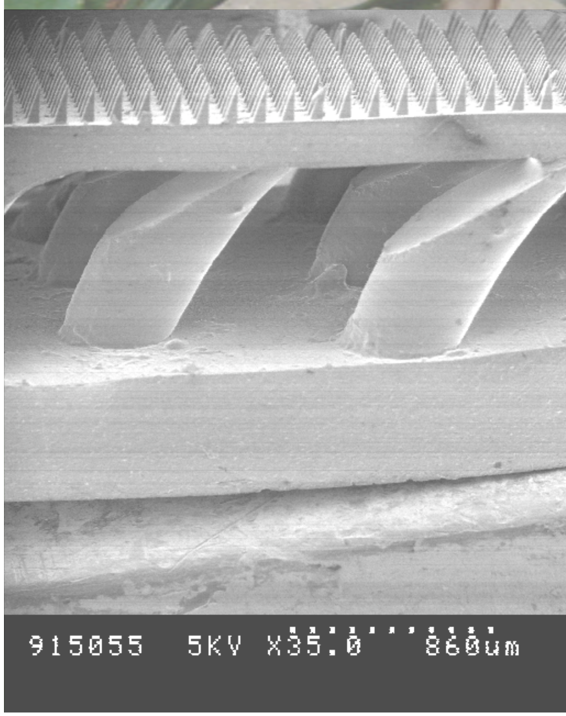
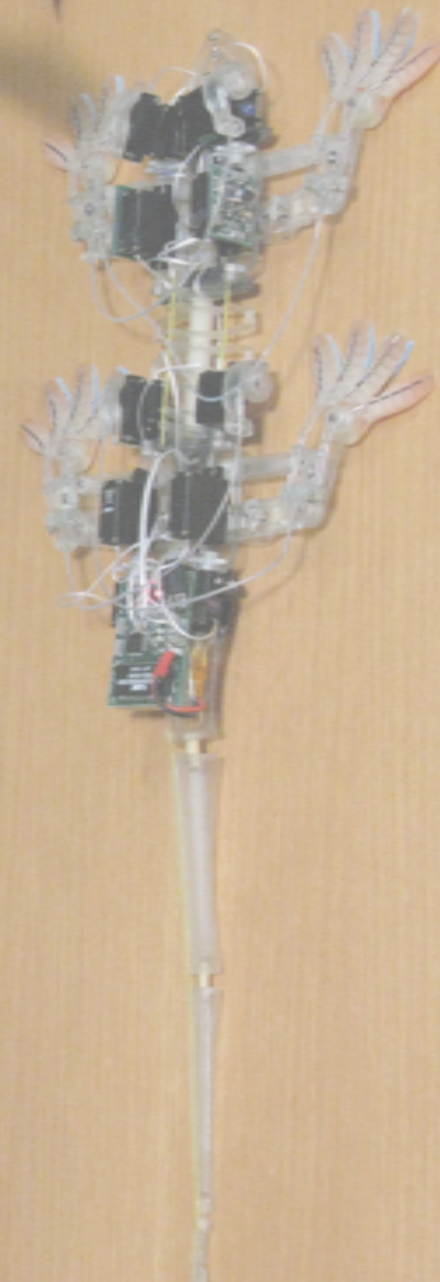
Aaron Parness

BS at MIT 2004

PhD at Stanford 2009





Early Projects in Mechanical Design

<u>MIT Undergrad Robotics Competition</u>

•2^{nd} place of 115 competitors

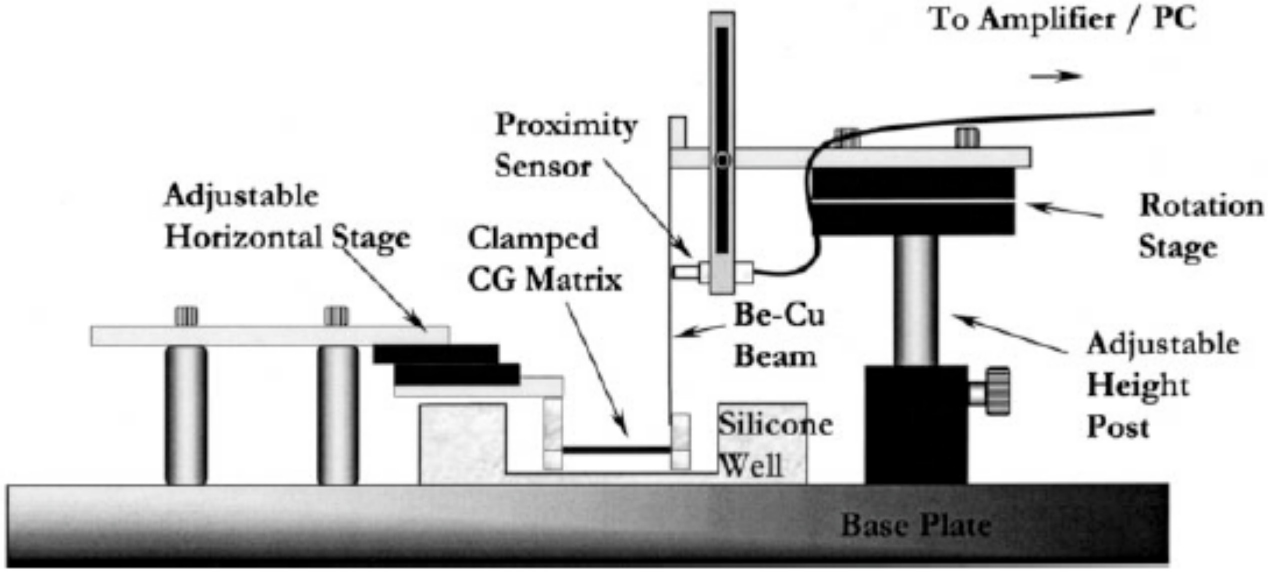
•Participation on MIT's team in the International Design Competition

<u>MIT Senior Project</u>

•Portable Panel Saw

•Adaptable fixture to fit common handheld circular saw designs

Undergraduate Research
MIT Biomaterials Laboratory

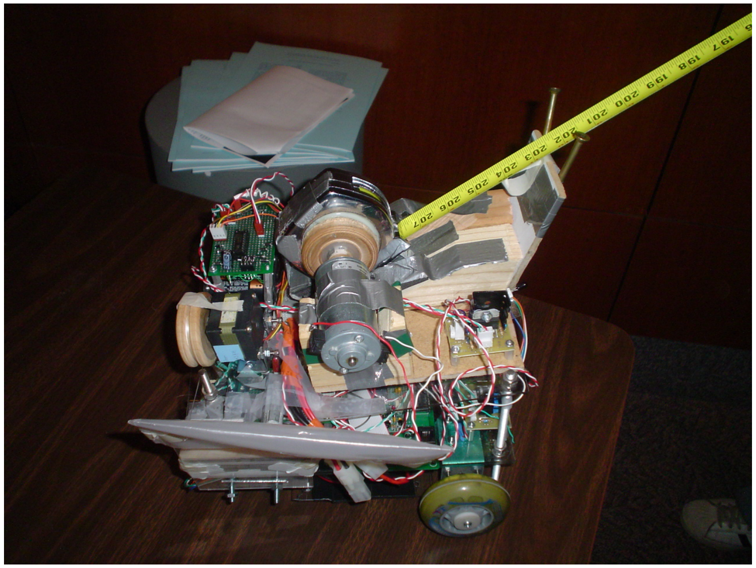


<u>Under Prof. Ioannis Yannas:</u>

Operated and maintained the Cell Force Monitor which used a cantilever beam to measure the contractile forces exerted on a porous collagen matrix by cells (dermal fibroblasts). Project focused on both in vivo and in vitro regeneration of injured nerves by blocking α-smooth muscle cell contraction.

Freyman, T. M., Yannas, I. V., Yokoo R., and Gibson L. J. (2002). Fibroblast contractile force is independent of the stiffness which resists the contraction. Exp. Cell Res. 272:153-162

MS Work

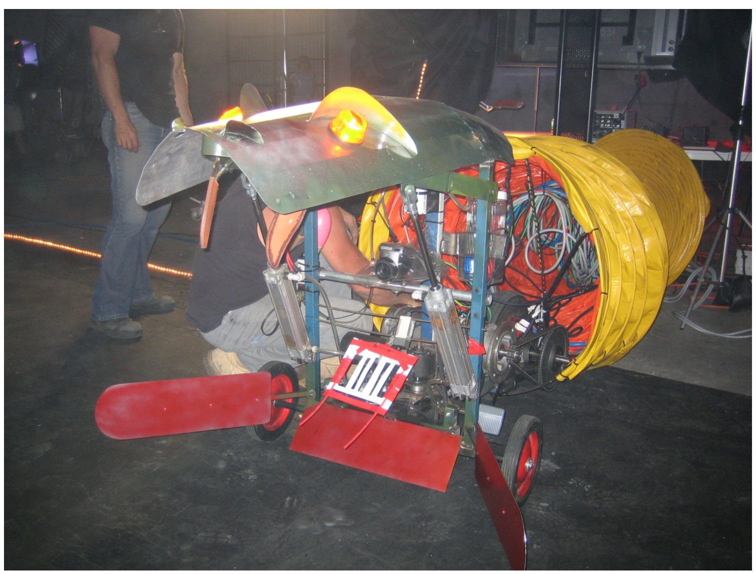


<u>Mechatronics coursework (ME218A-ME218D).</u>

Circuit Design, Microcontrollers, PCB Layout

2nd year project focusing on a remotely controlled birthing simulator for new obstetrical doctor crisis training:

Daniels, K. and Parness, A. Development and Use of Mechanical Devices for Simulation of Seizure and Hemorrhage in Obstetrical Team Training. *Simulation in Healthcare* [1559-2332] 2008 vol:3 iss:1 pg:42.



<u>Animal Planet Television Appearance</u>

Chasing Nature Episode 10, Rattle Snake

Designed and Built a biomimetic rattlesnake using infrared cameras for vision

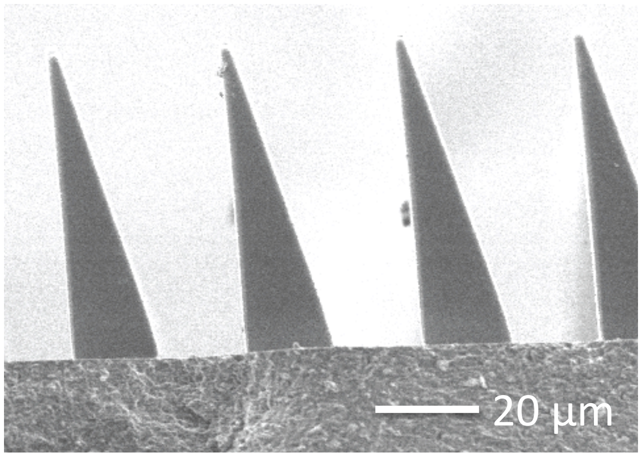
MS Research

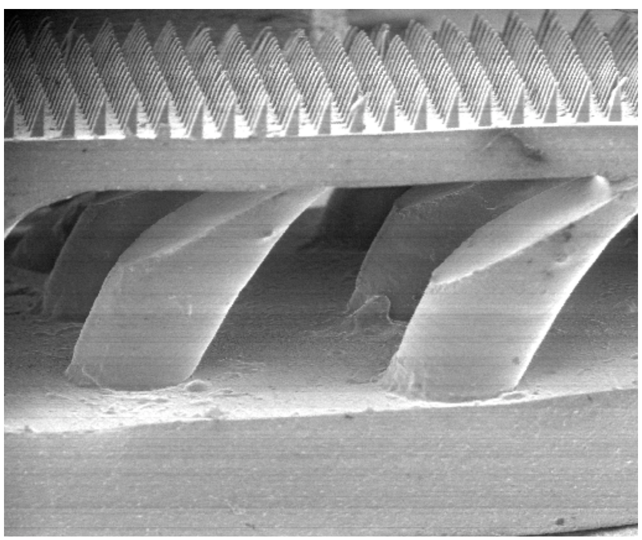
Shape Deposition Manufacturing techniques for microspine development.
Sponsored by the RiSE project.

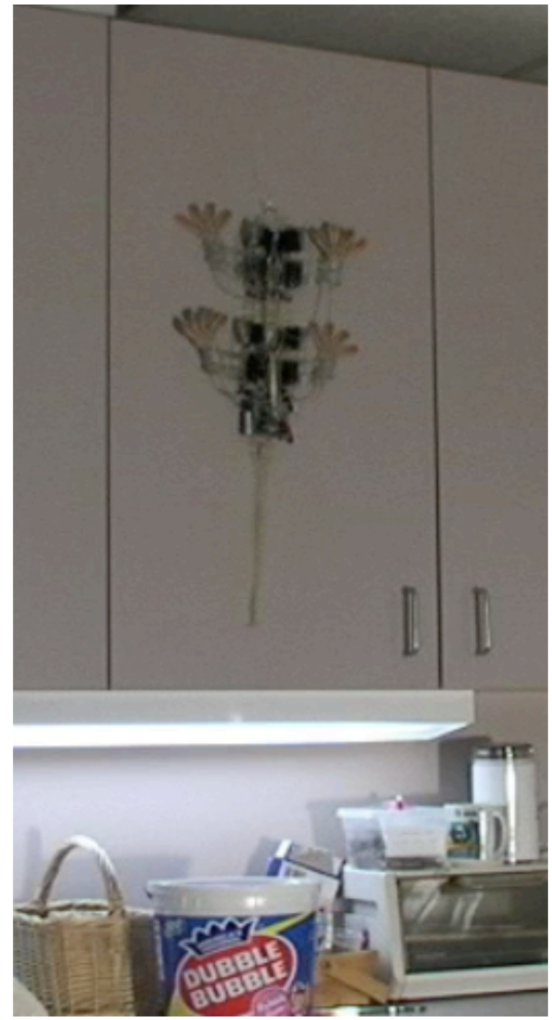
Alan T. Asbeck, Sangbae Kim, Arthur McClung, Aaron Parness, and Mark R. Cutkosky. Climbing walls with microspines. In Proc. of the 2006 IEEE Int. Conf. on Rob. and Aut., pages 4315{4317, Orlando, Florida, USA, May 2006.

PhD Research:

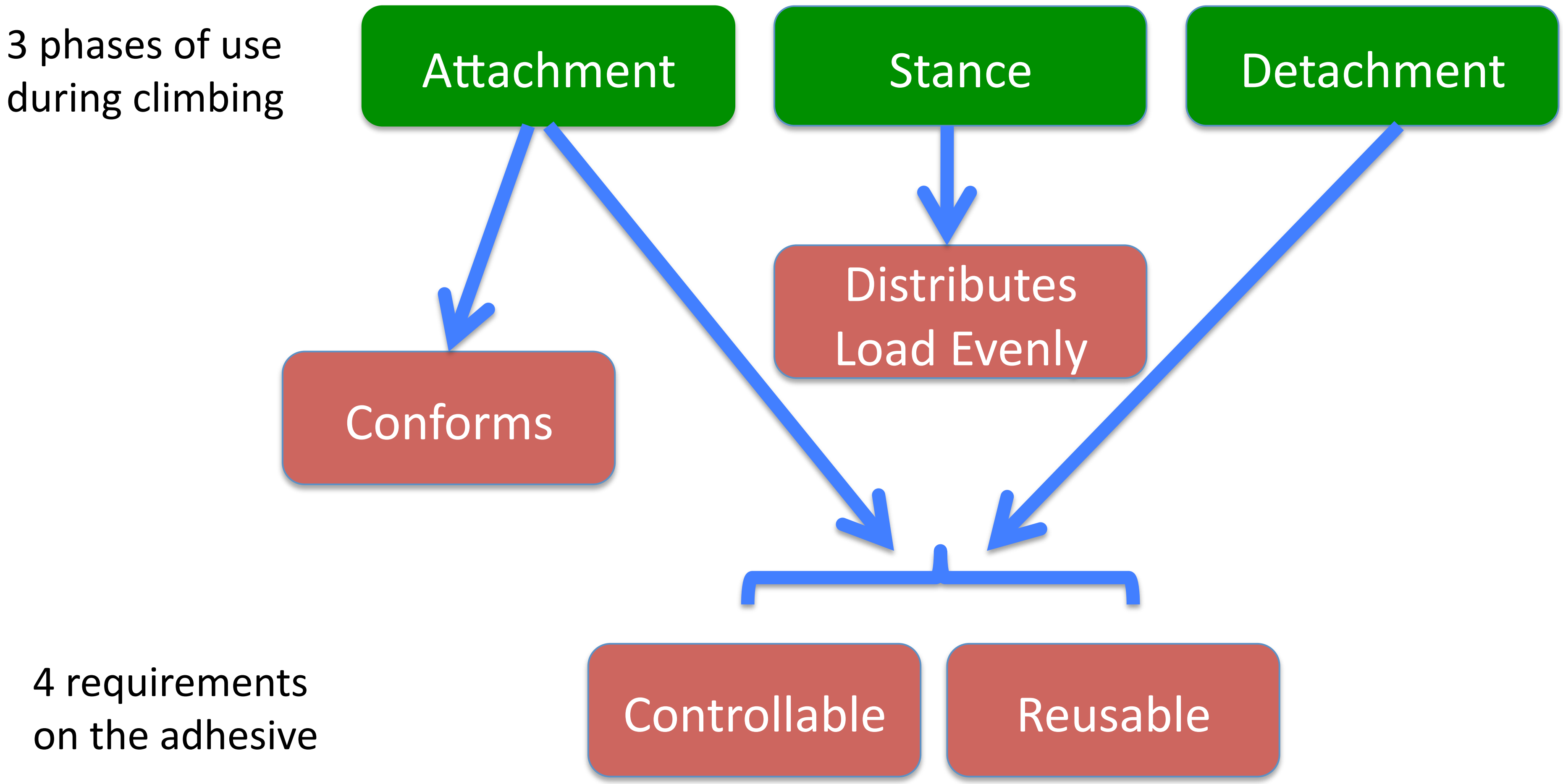
Microstructured Adhesives for Climbing Applications







A Framework for Climbing



Controllable

The primary challenge in climbing applications is not generating adhesion, but controlling that adhesion.

Efficiency benefits:

$$\eta = \frac{U_{gained}}{E_{attach} + E_{stance} + E_{detach}}$$

Stability benefits: vibrations caused by high detachment forces cause dynamic loading levels above the weight of the robot

Speed benefits: high force detachments take place over finite periods of time, reducing the ability to increase stride frequency

Reusability

Climbing applications require adhesives to go through many attach-stance-detach cycles to achieve useful mobility.

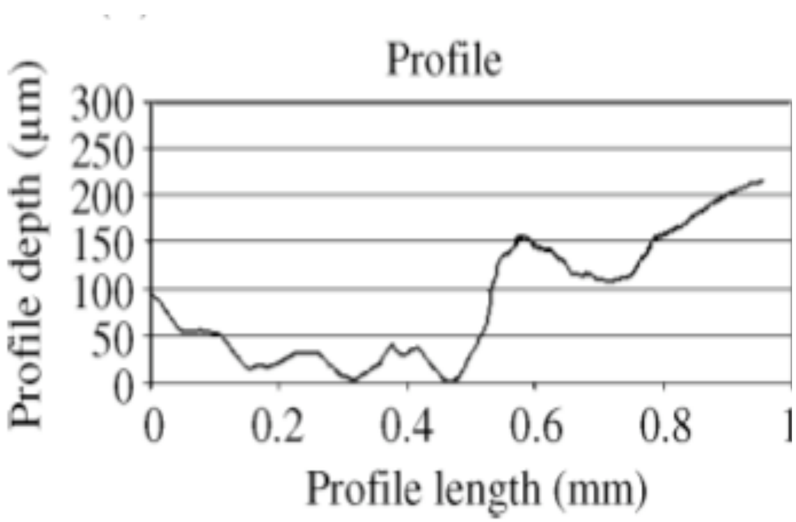
= 420 steps

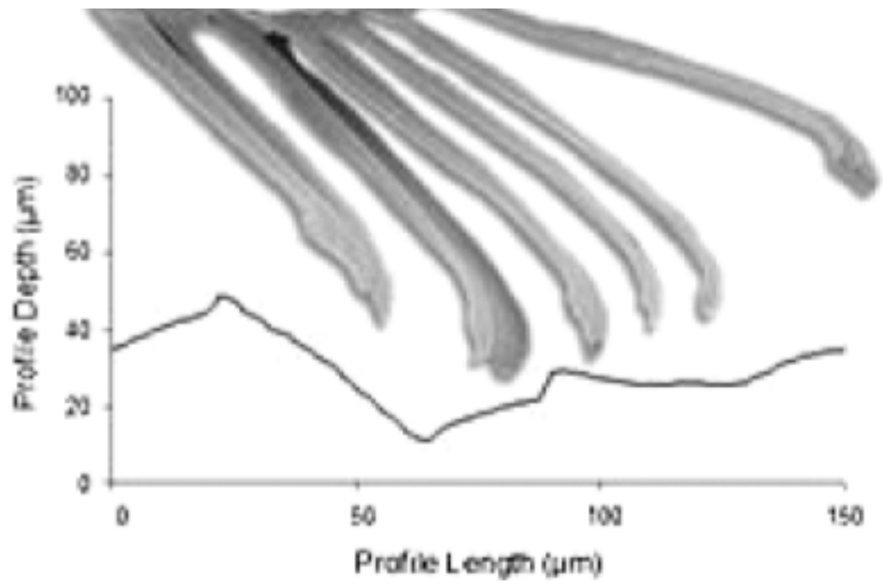
= 12, 660 steps

Conforms to Surfaces

Surfaces have roughness. Fibrillar adhesives must conform to this roughness on several length scales in order to engage a high percentage of terminal contacts.

Sandstone from gecko's natural habitat

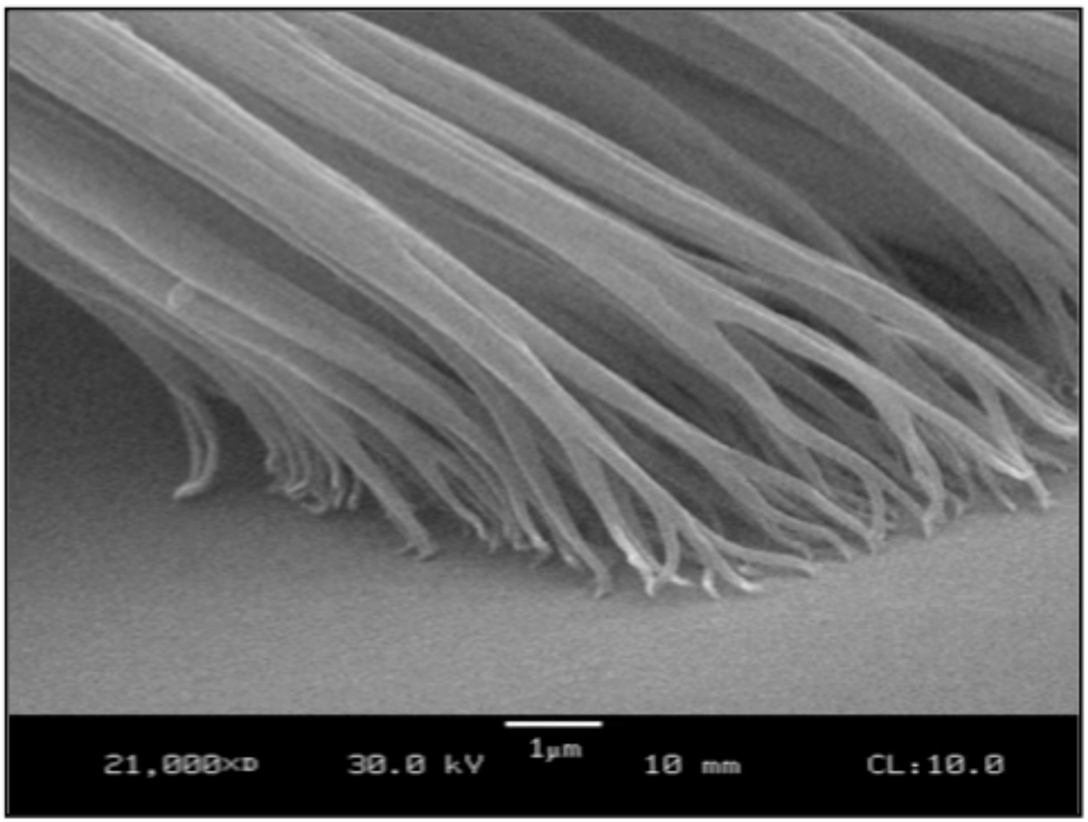




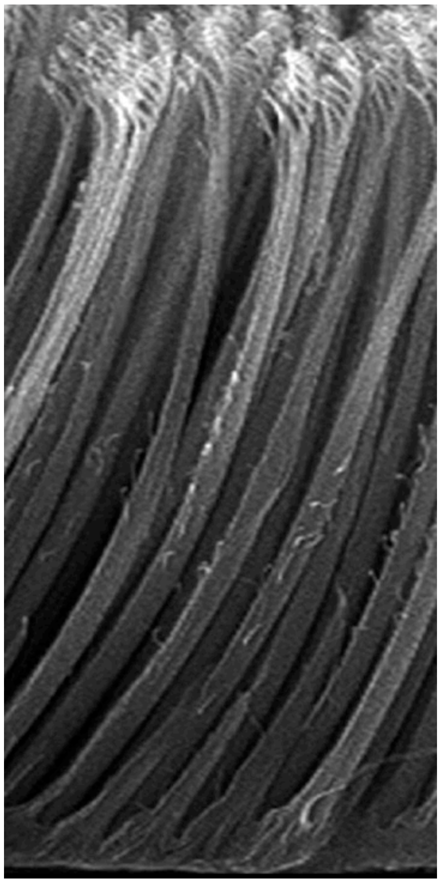
Russell, JAST, 2007

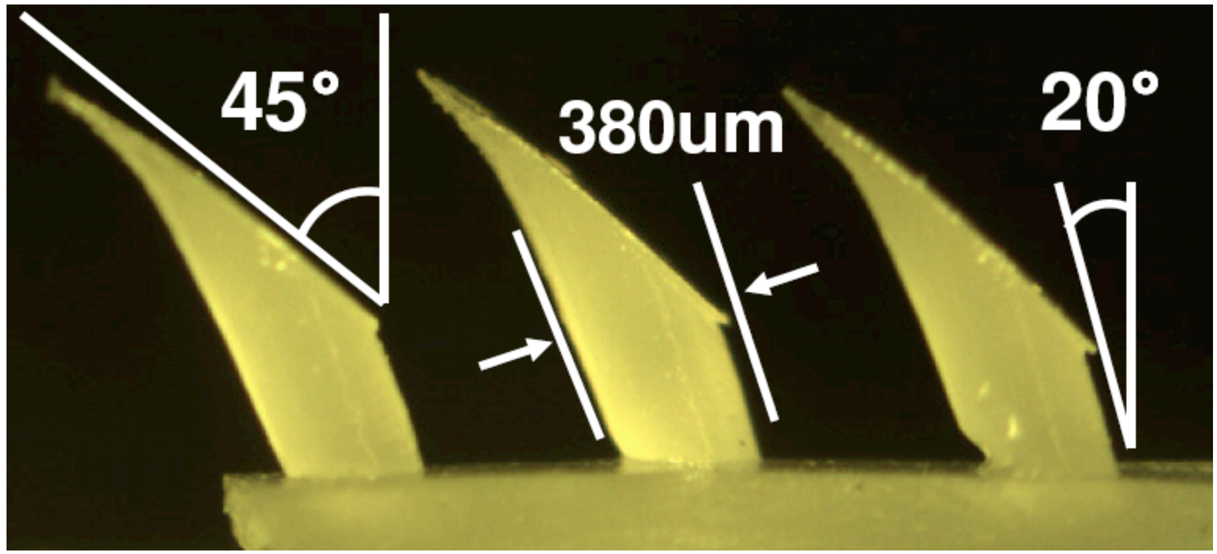
Distributes the Load

Because the van der Waals attraction for an individual stalk is weak, bulk loads must be evenly distributed to many contacts to prevent peeling/crack propagation.



Designing a Microstructred Adhesive



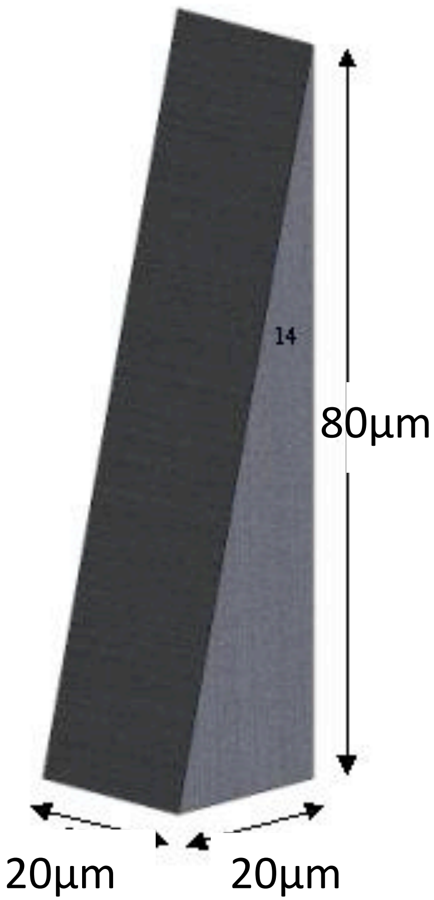


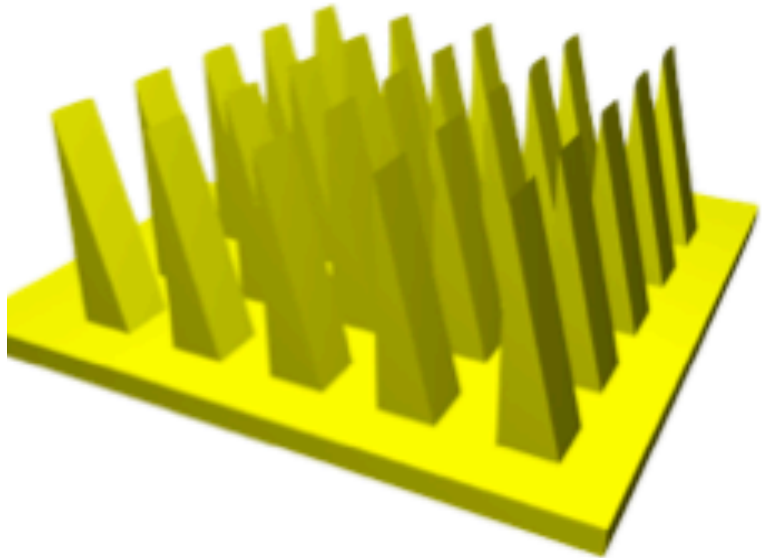
Emphasis:
- -Directional Features
- -Size
- -Tip Shape

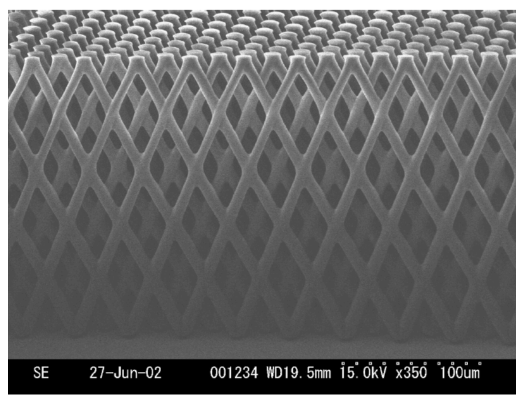
Limitations:
- -Fabrication Techniques
- -Materials

robotics.eecs.berkeley.edu
Santos et al. JAST 2007

MicroWedges



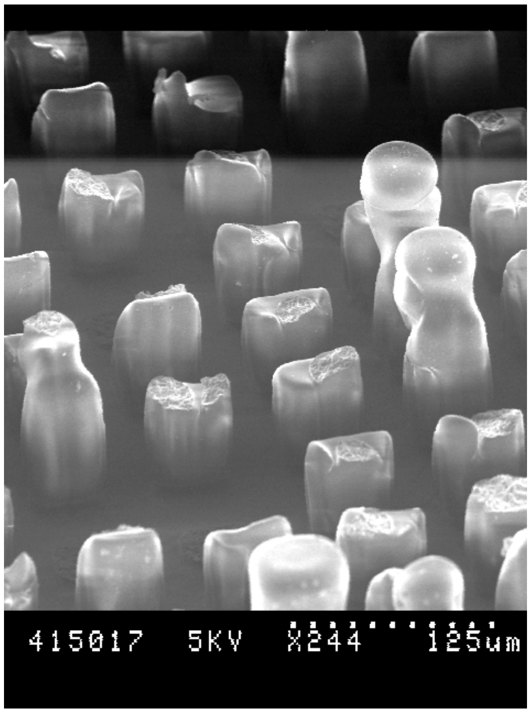


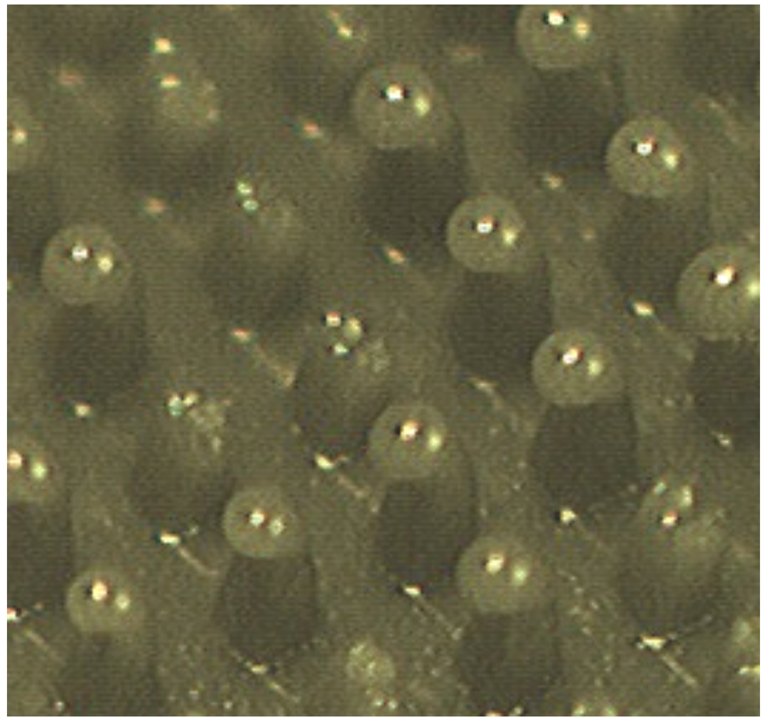


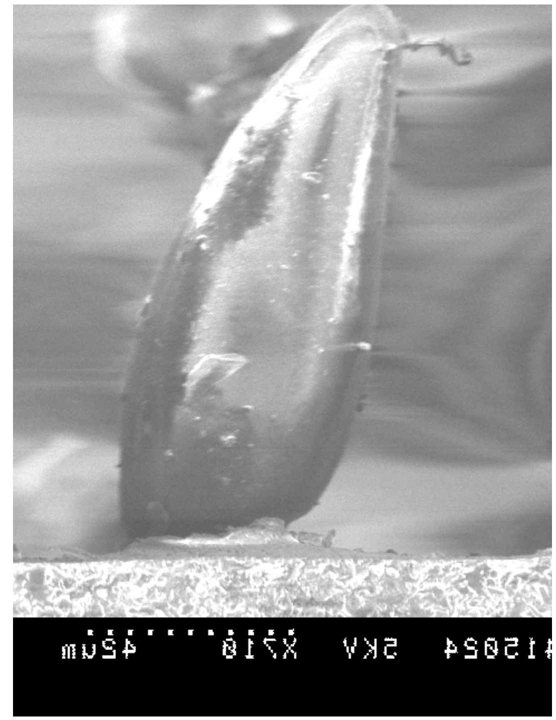
Inspired by work outside of synthetic adhesives:

Yoon et al, JMEMS, 2003 & 2006

Initial Failures

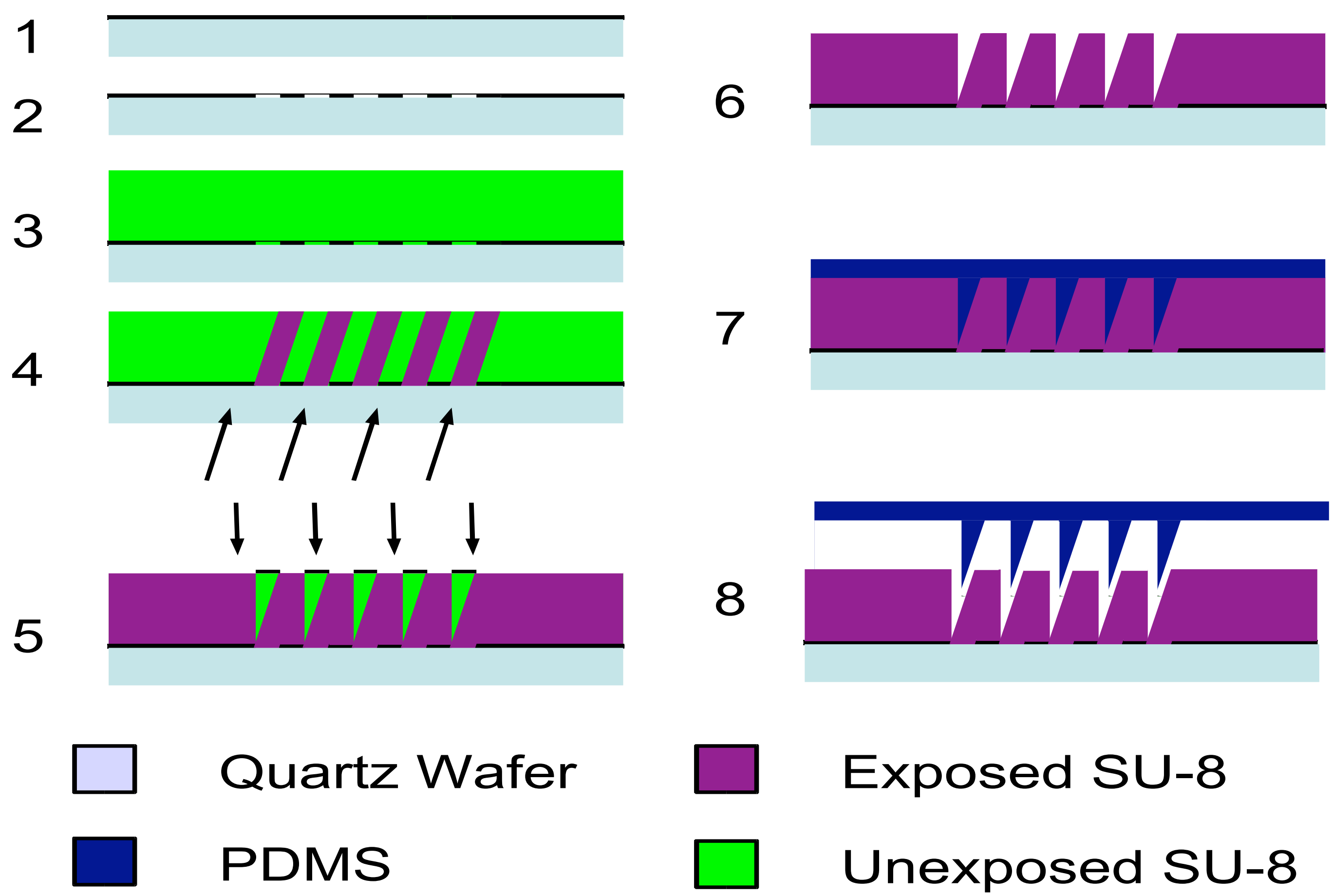




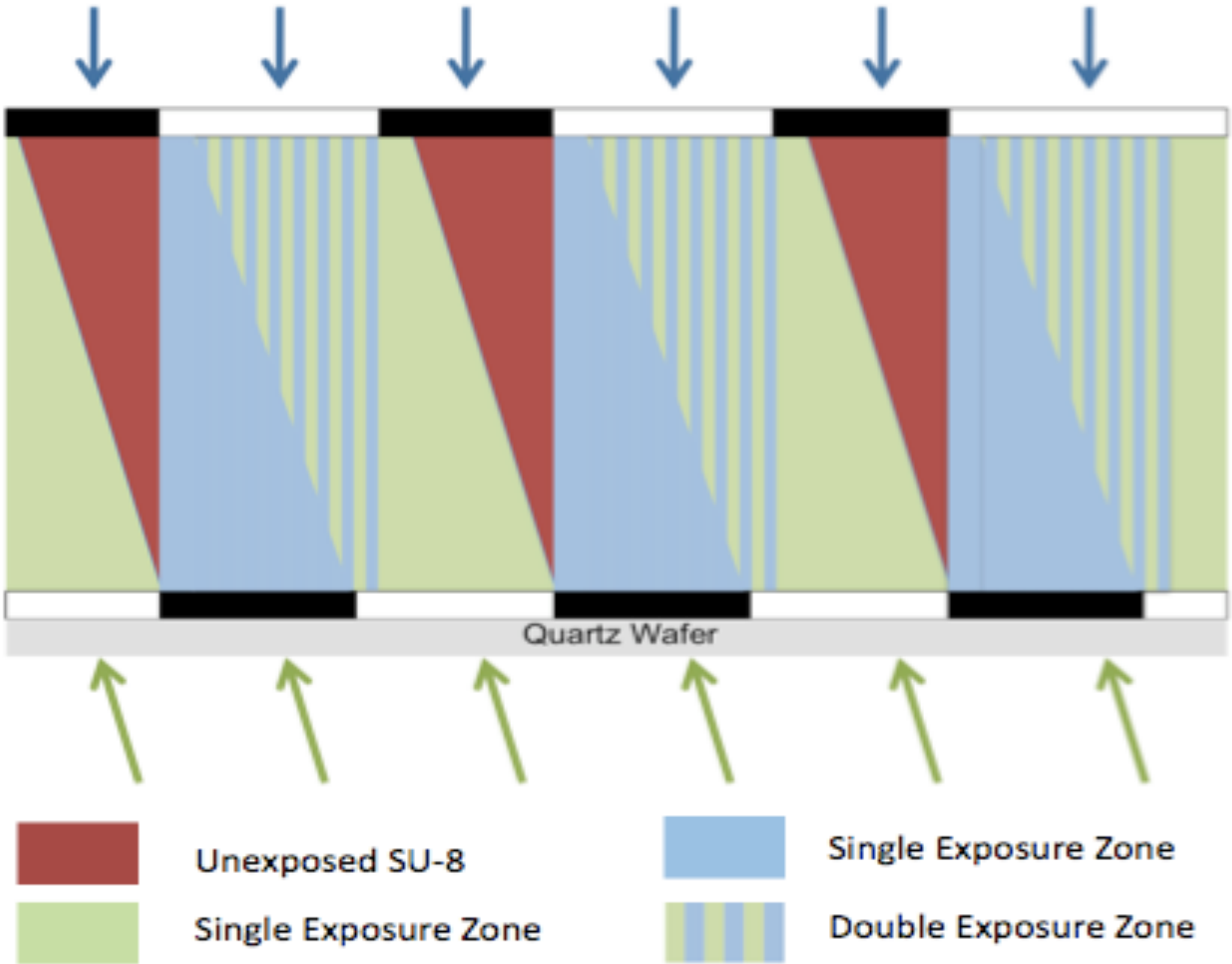


Primarily due to volumes of SU-8 being exposed to different amounts of UV during the two exposure periods.

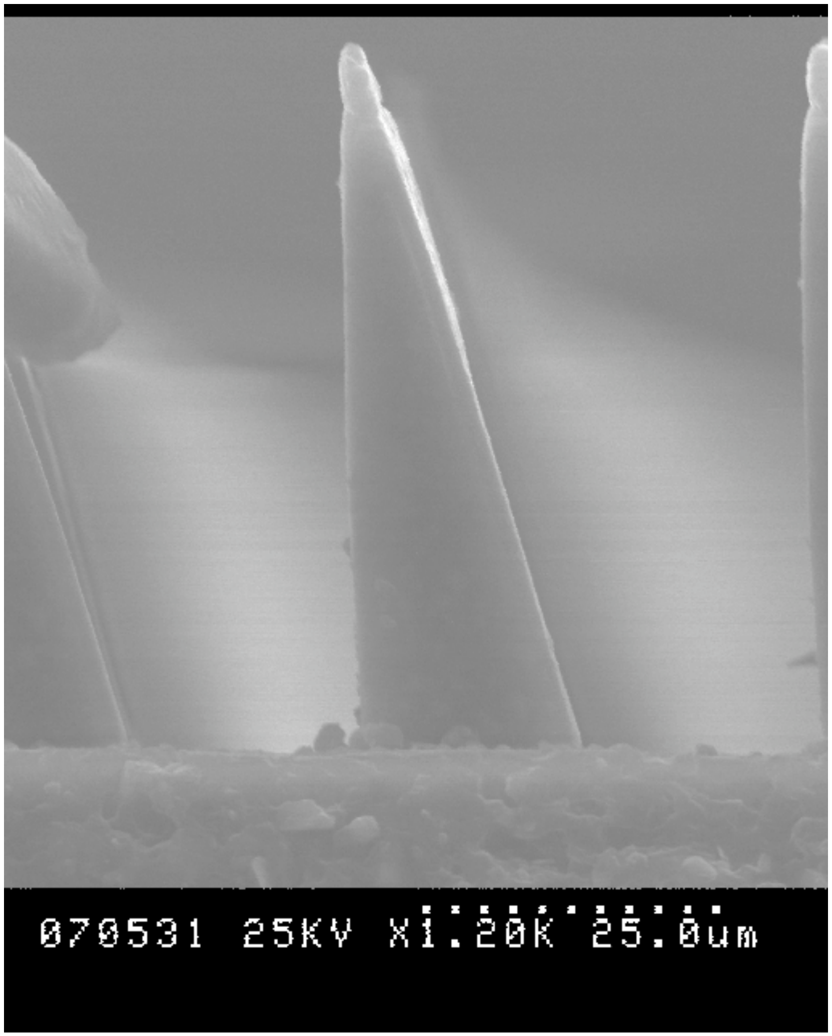
Improved Process
Two Mask Dual Angle Exposure with Alignment

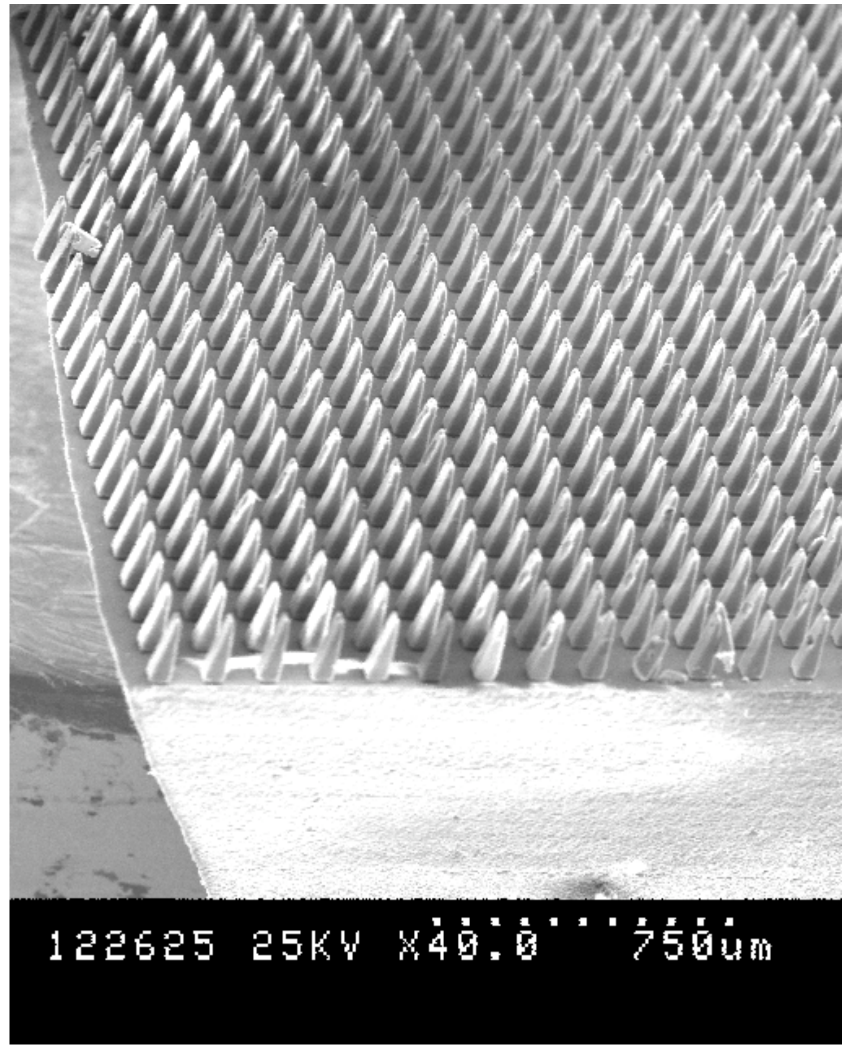


Overmask Design

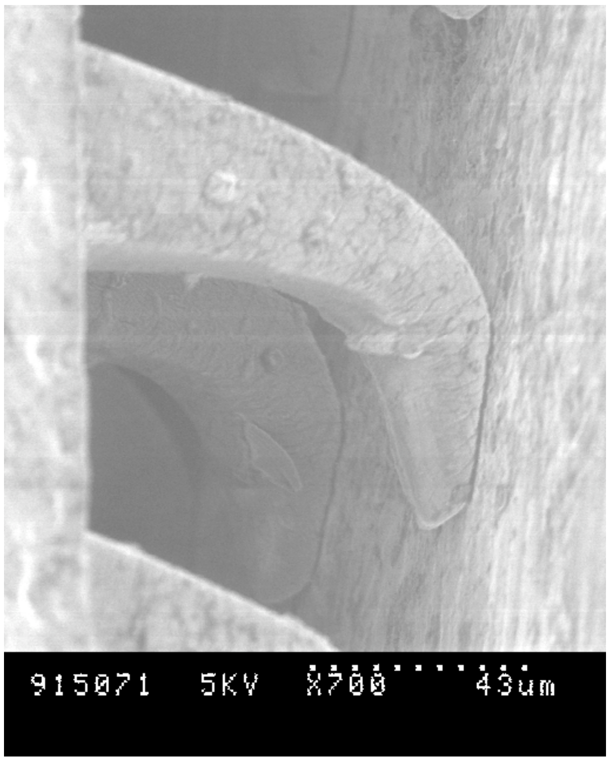


Improved Shape and Yield

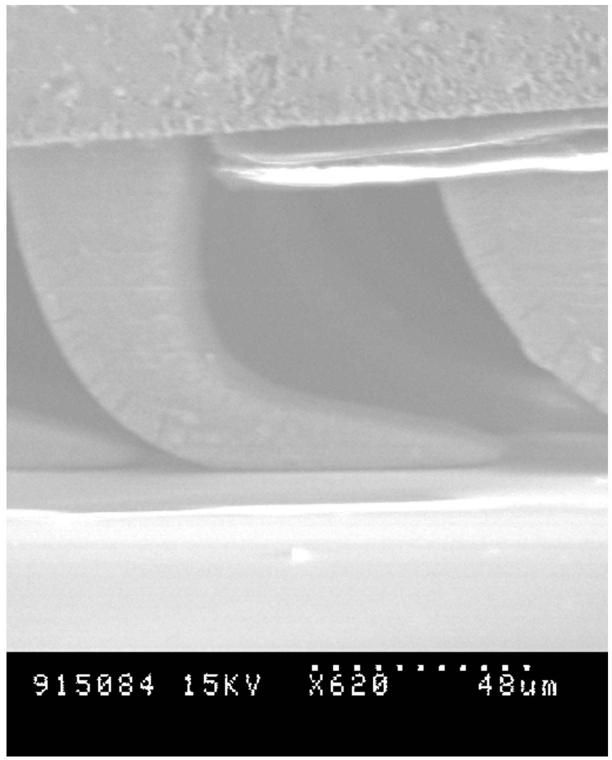




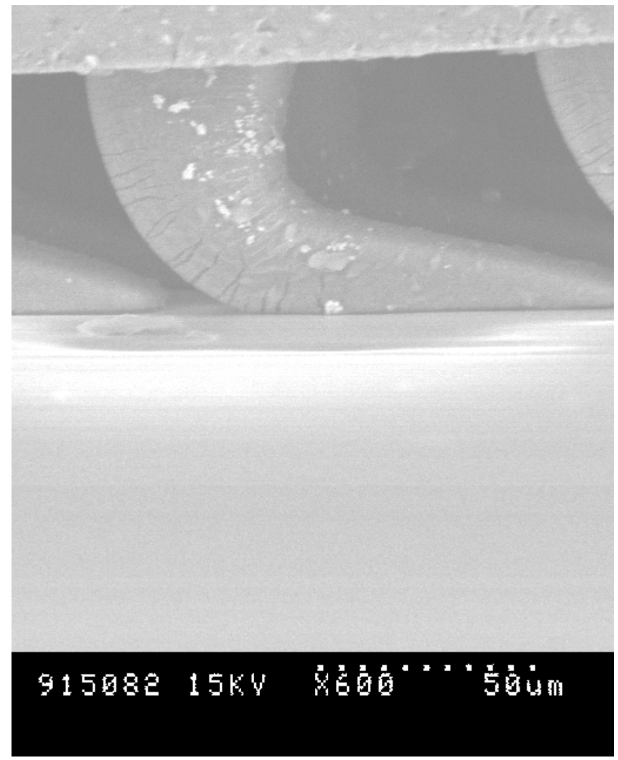
Loaded Wedges



Slightly Loaded



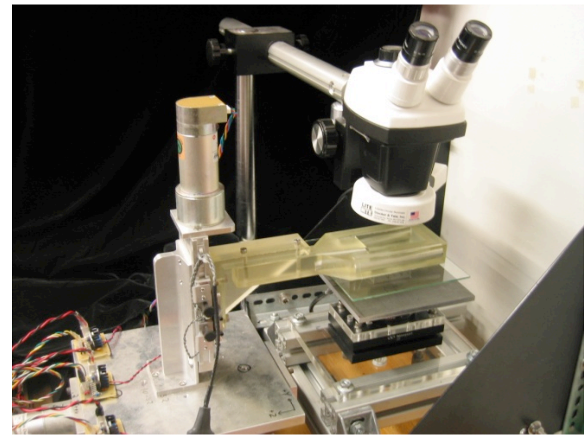
Moderately Loaded

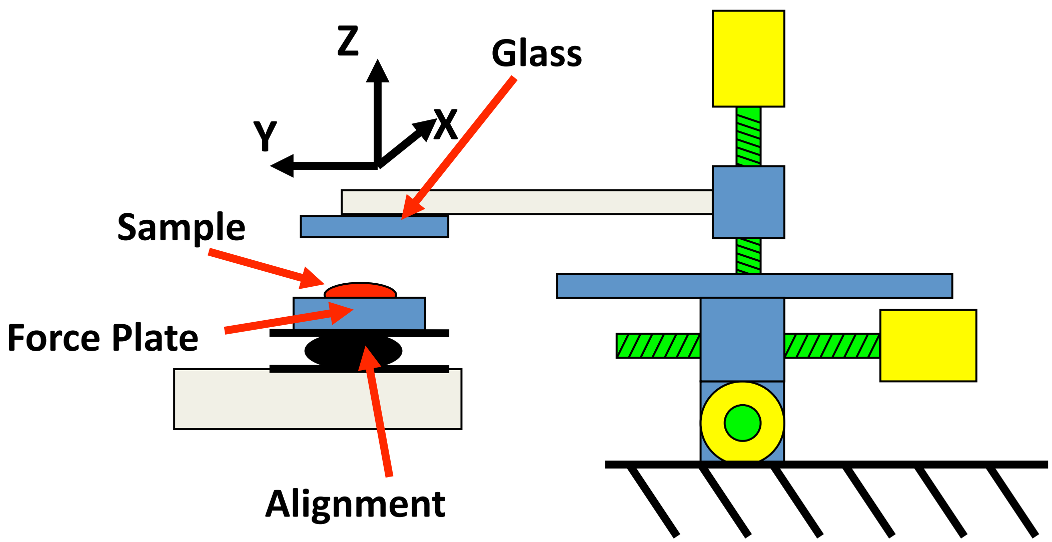


Heavily Loaded

Experimental Test Setup

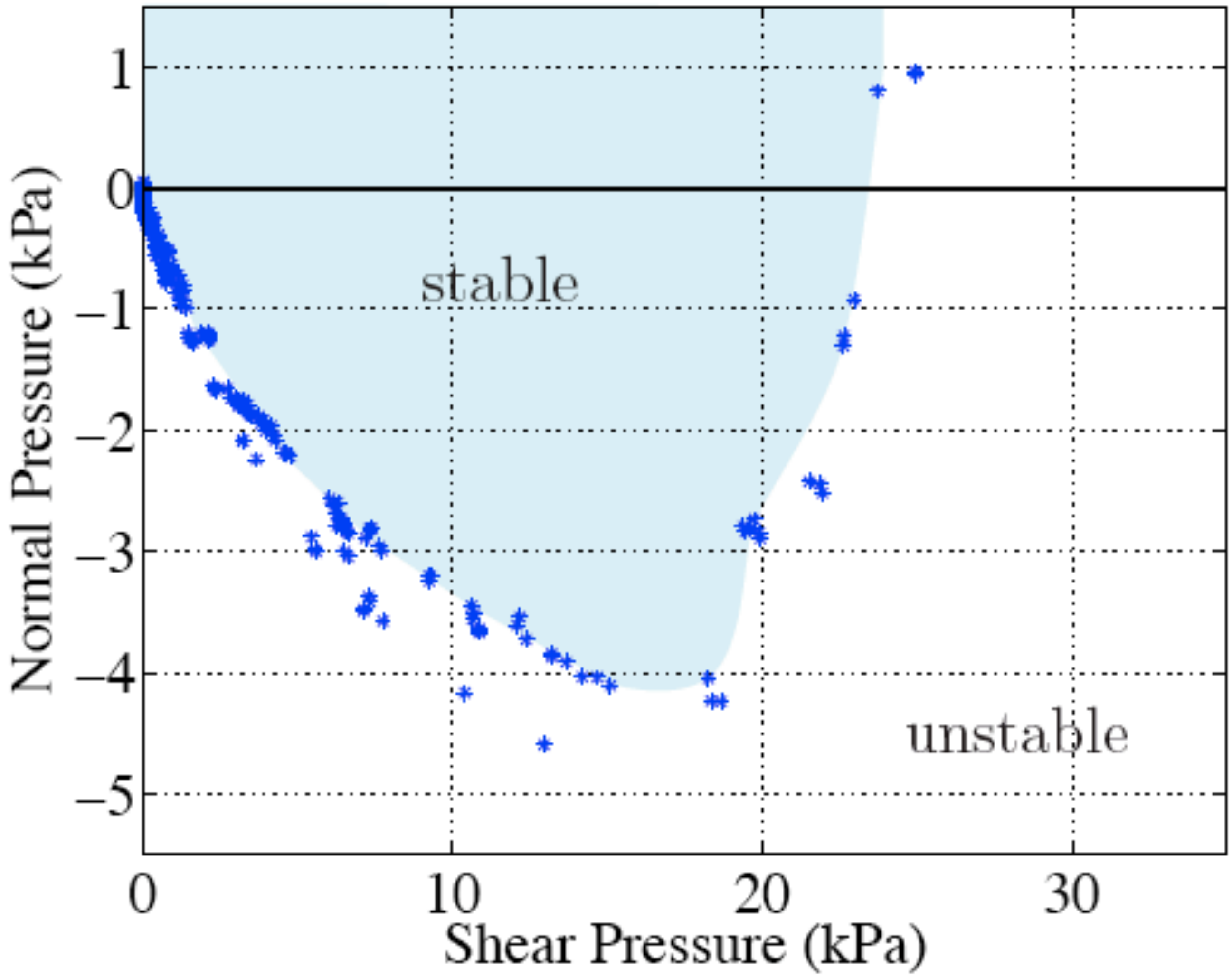
- 3 Motor-Driven Lead Screws
  - X/Y – 0.2” per Revolution; 1.7um per Tick
  - Z – 0.05” per Revolution; 0.4um per Tick
- 6-axis Force/Torque Sensor
  - +/-25mN Noise
- 2-axis Alignment Stage





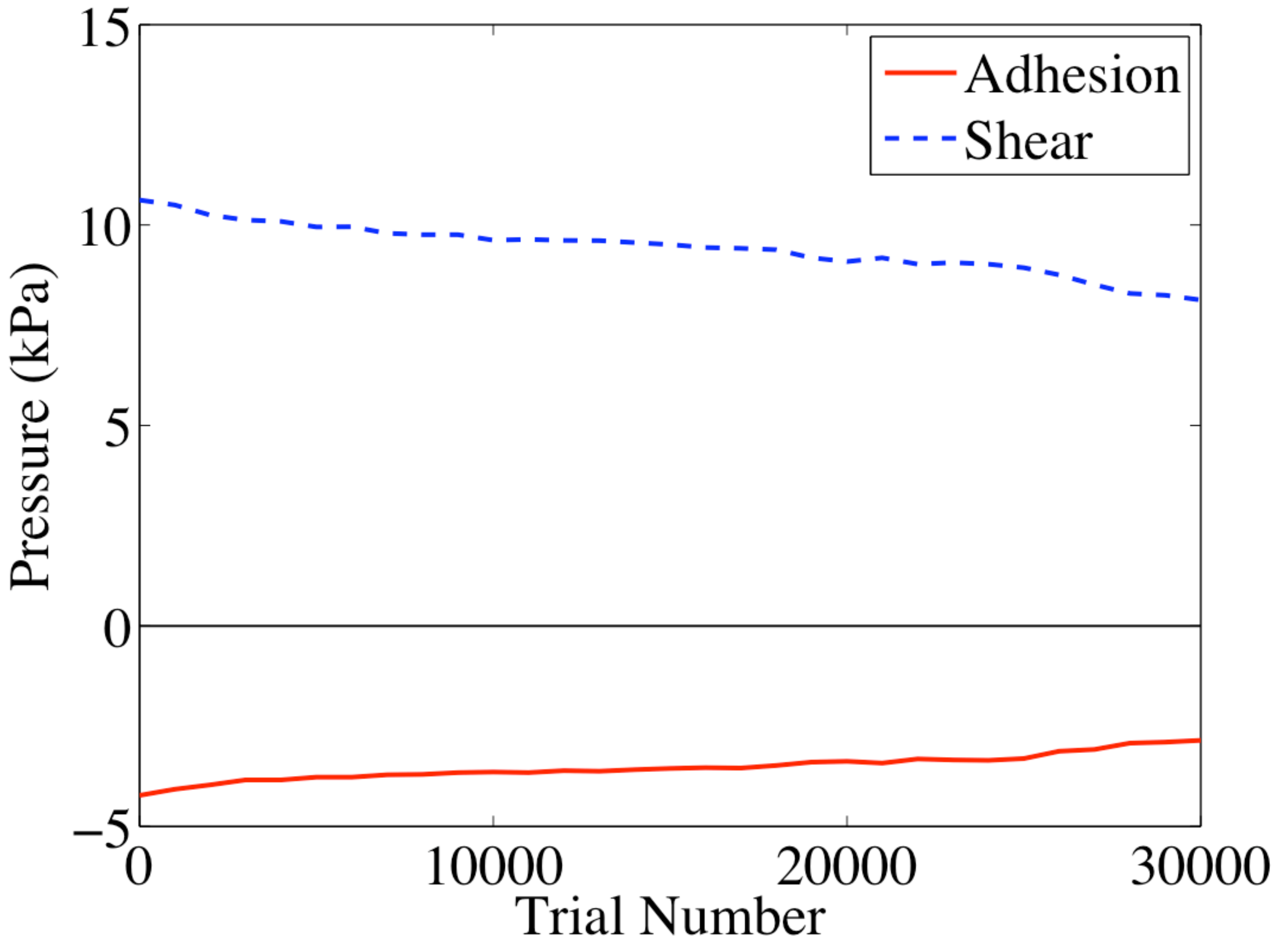
Performance: Controllable

GOOD



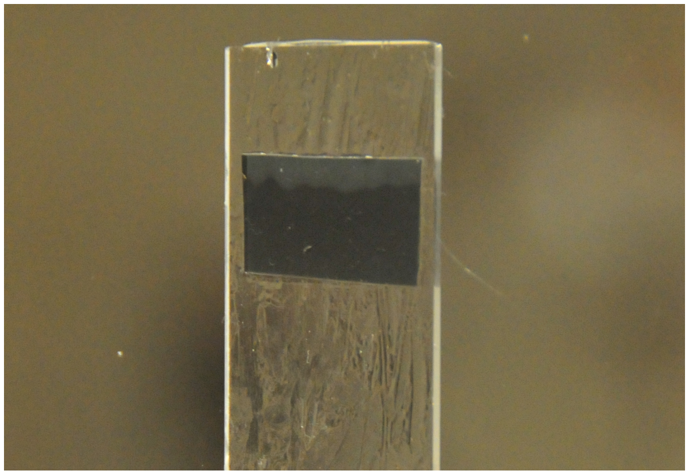
Performance: Reusability

GOOD



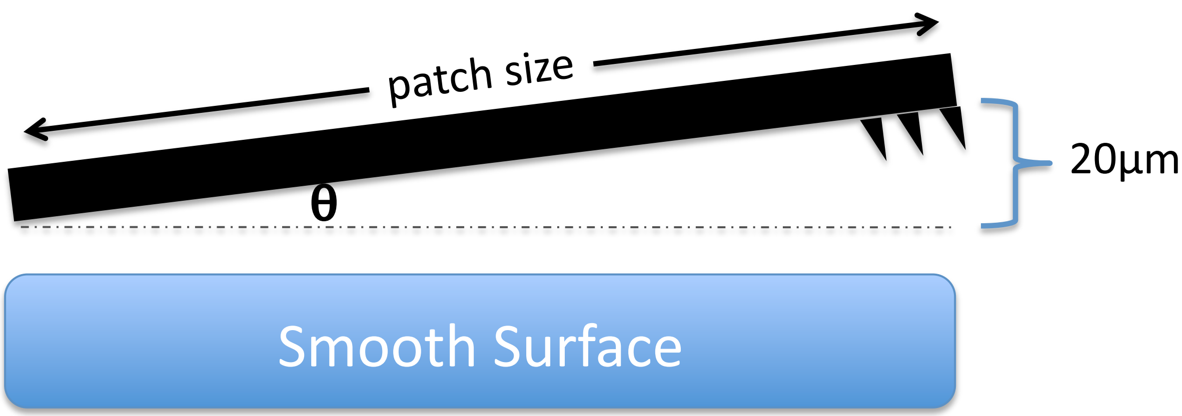
Performance: Conformation

POOR



Challenges with Conformation

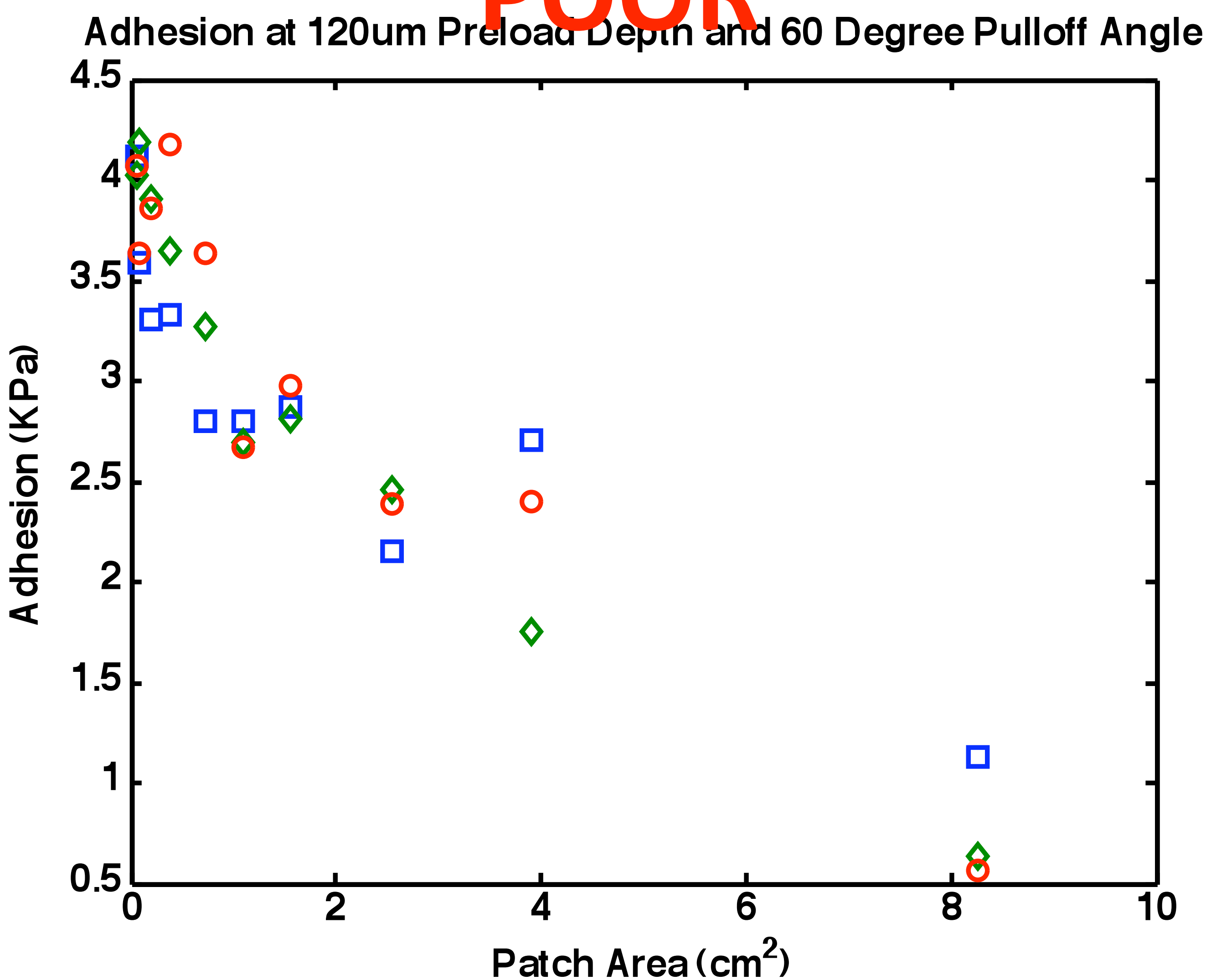
- Local
  - Irregularities in backing layer
  - Surface roughness
- Global
  - Alignment
  - Part tolerances of robot toes



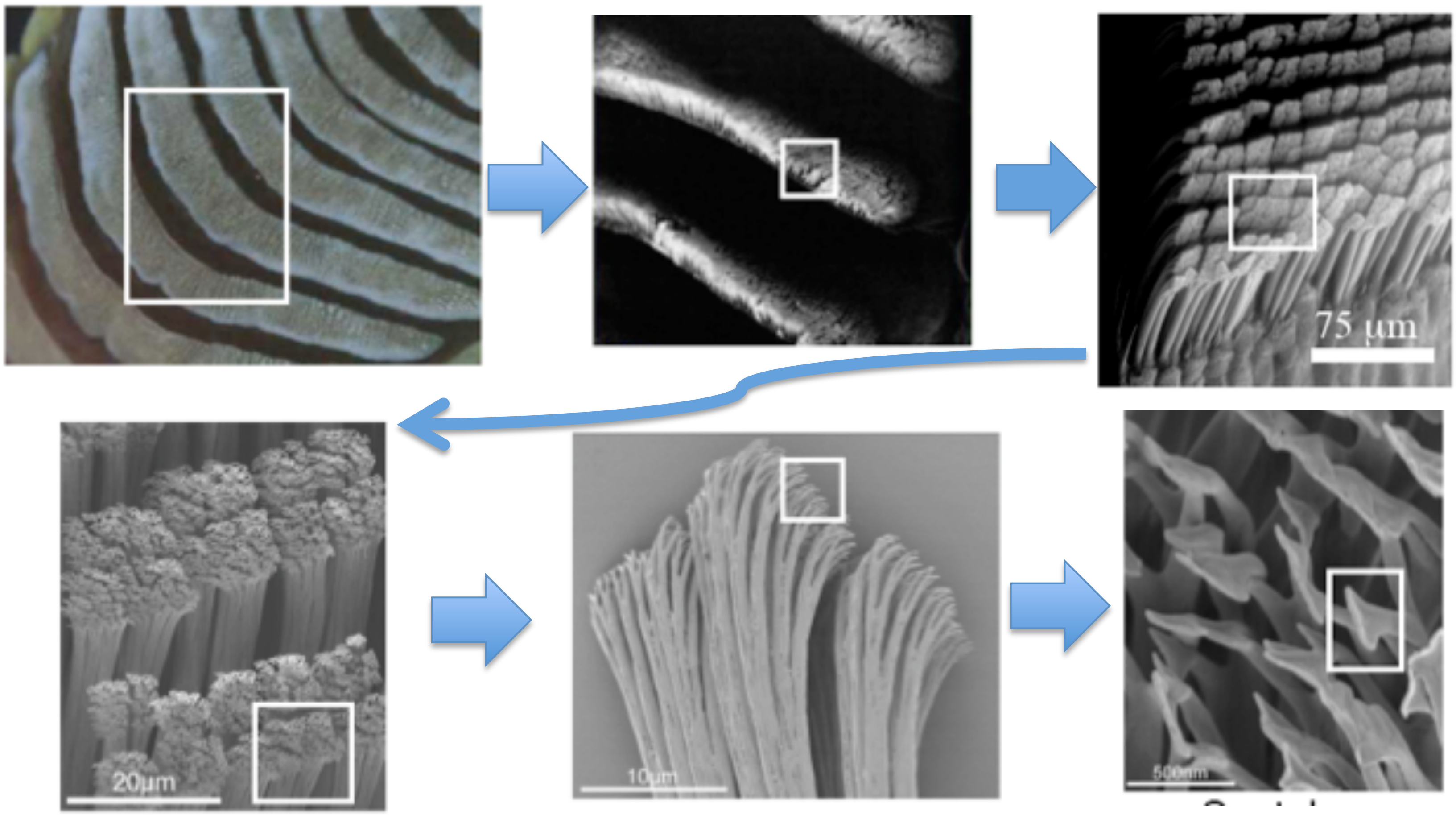
patch size	θ
200µm	5.7
1mm	1.15
4cm	0.029

Performance: Load Sharing

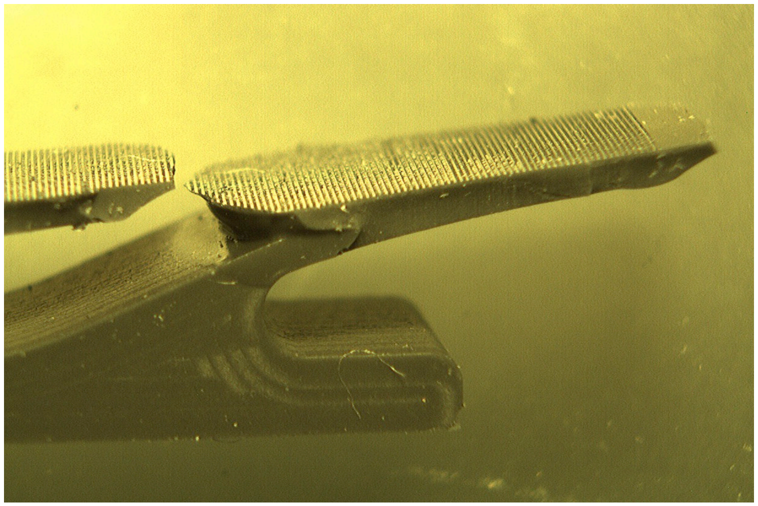
POOR



Gecko Hierarchical Design

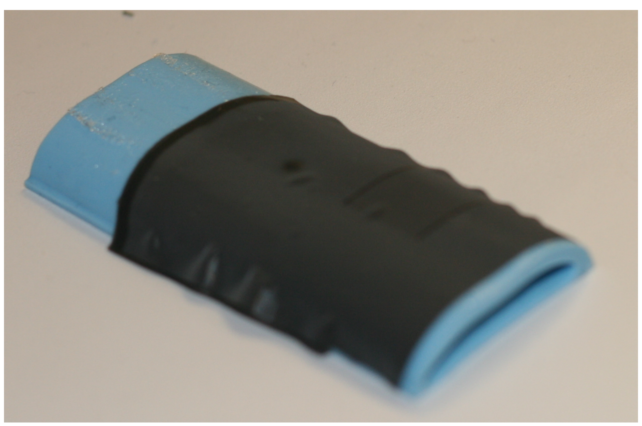


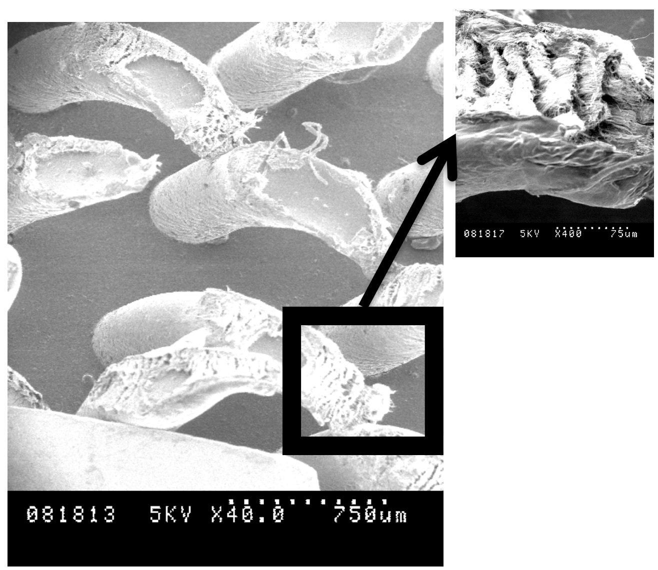
Failed Hierarchies

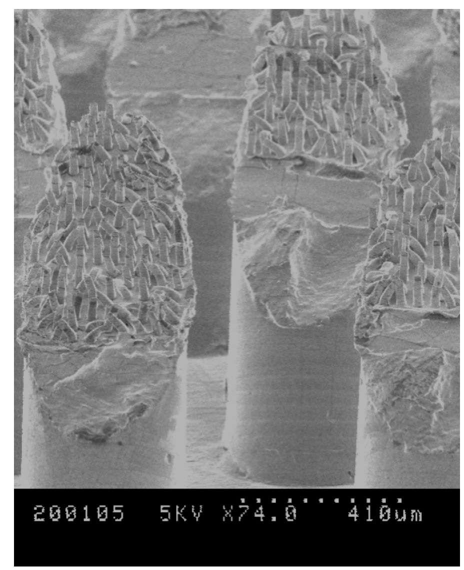


Lessons Learned

- Must prevent stress concentrations from stretching or uneven loading that will cause peeling moments
- Must maintain a high ‘real area’ of contact



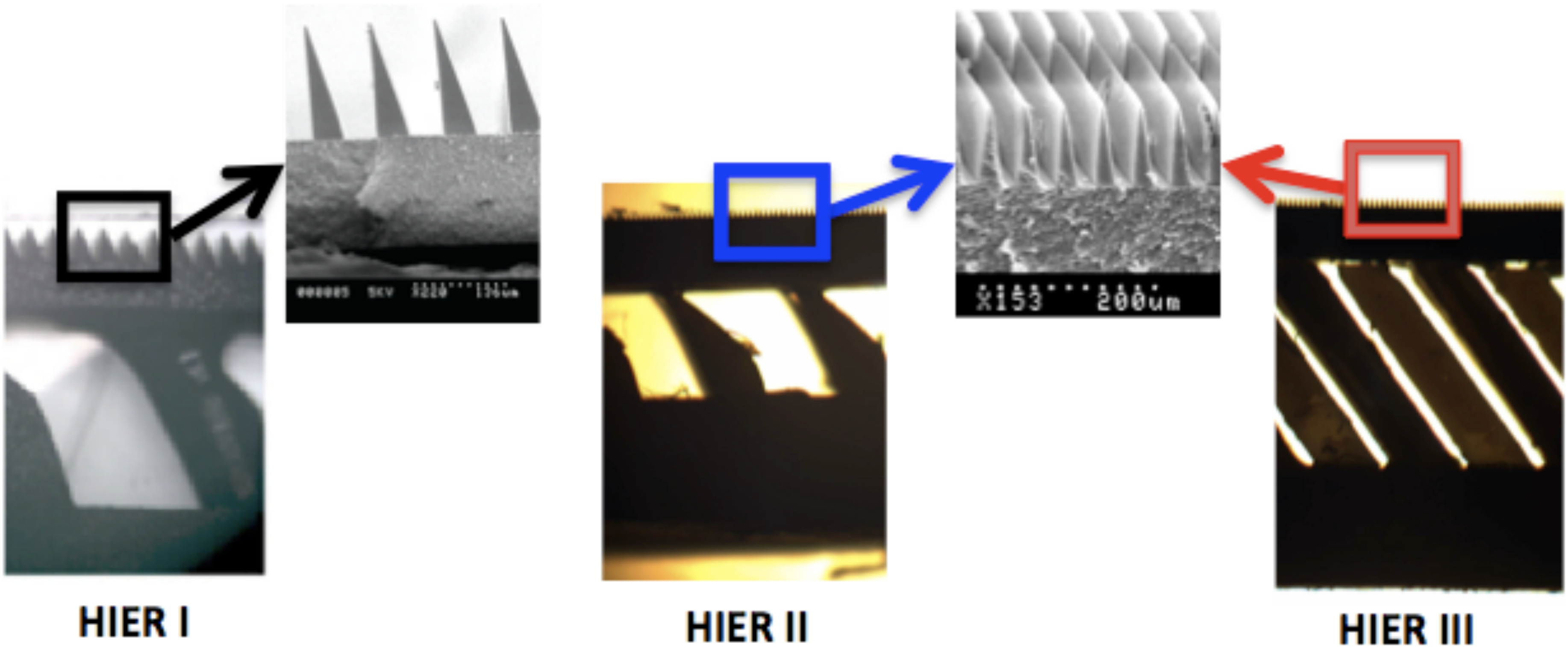




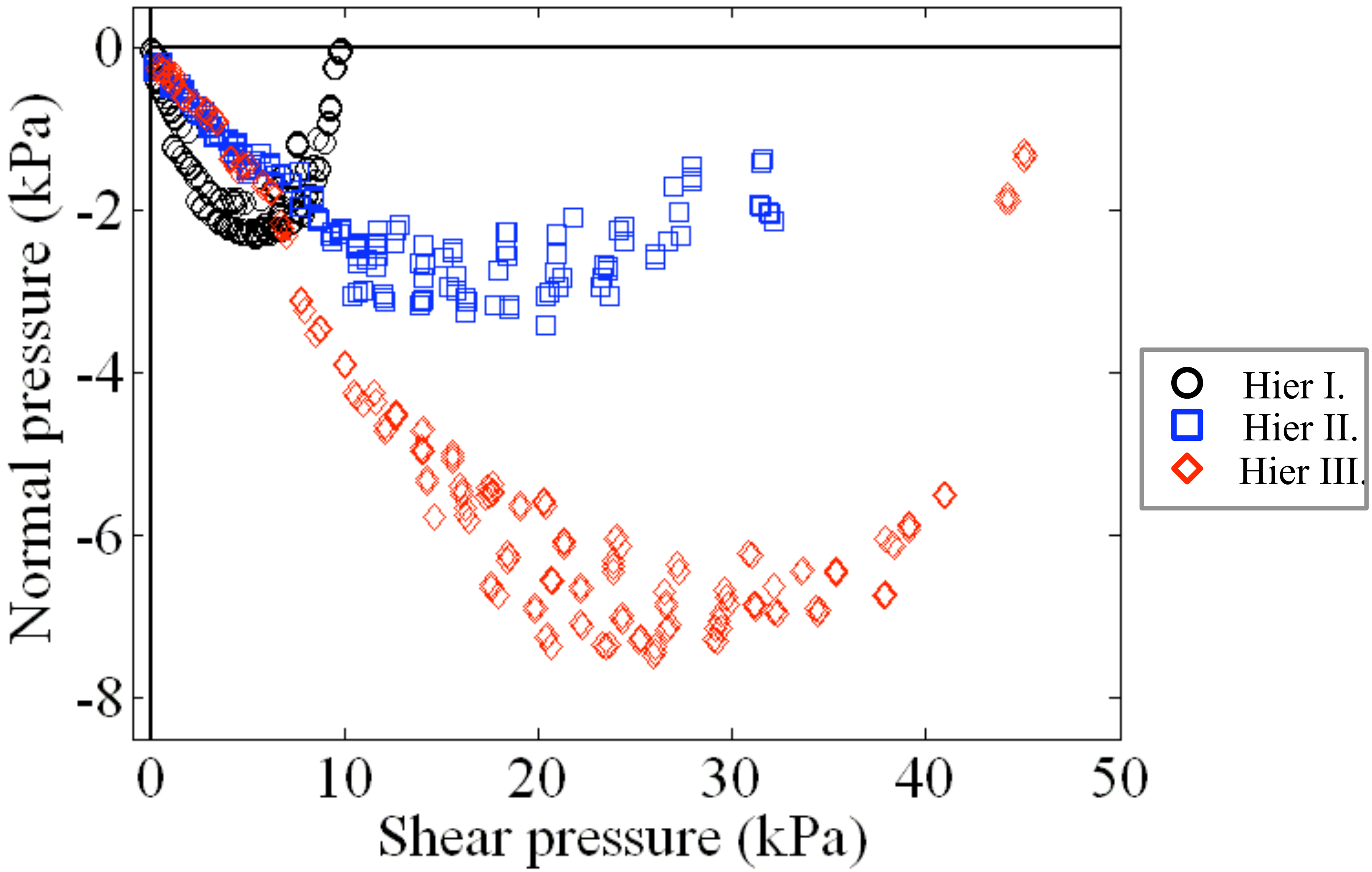
Film Buckling Issues:

limiting 'real area' of contact

Iterated Hierarchical Designs

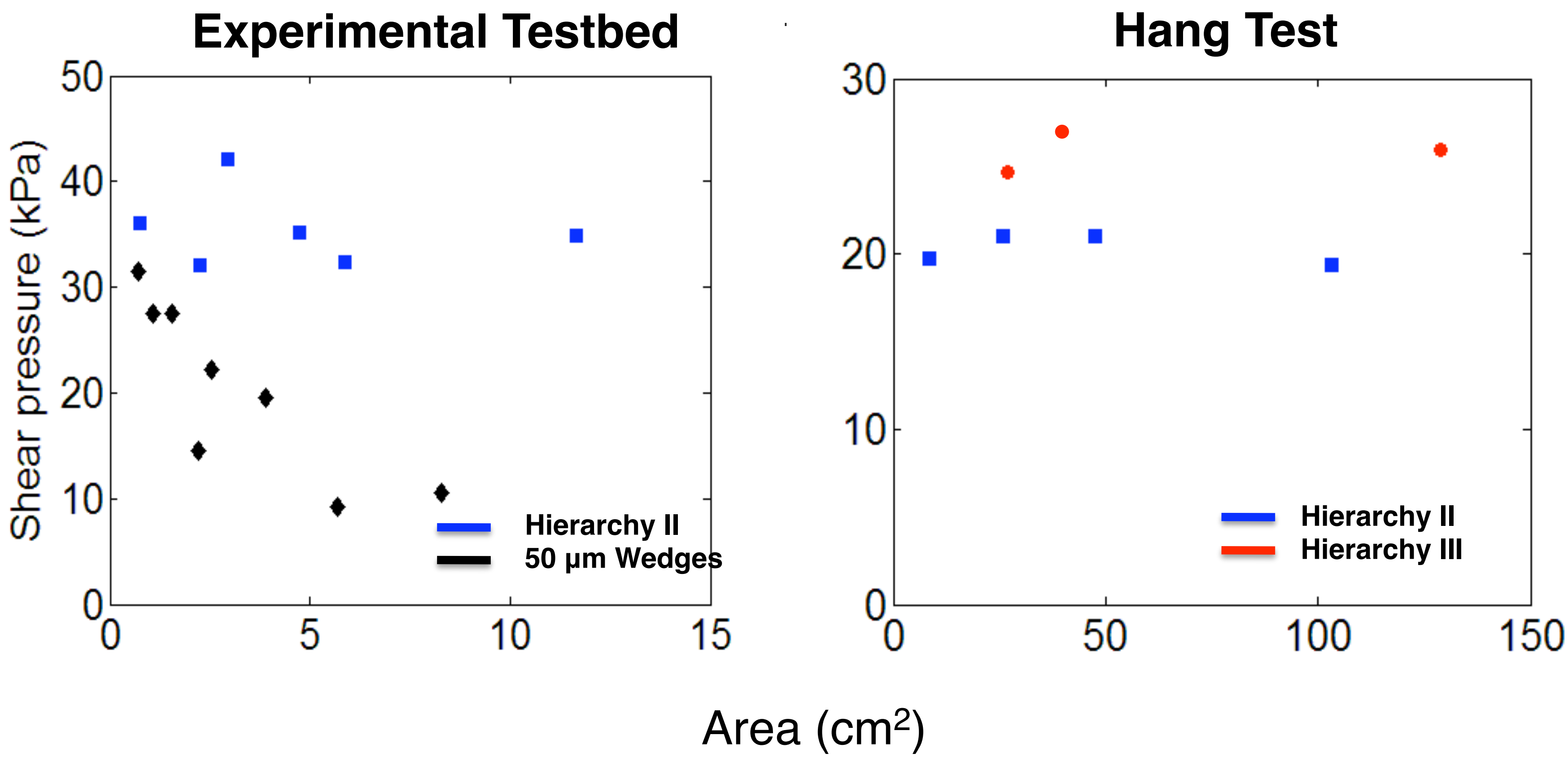


Hierarchy Limit Curves: Still Directional

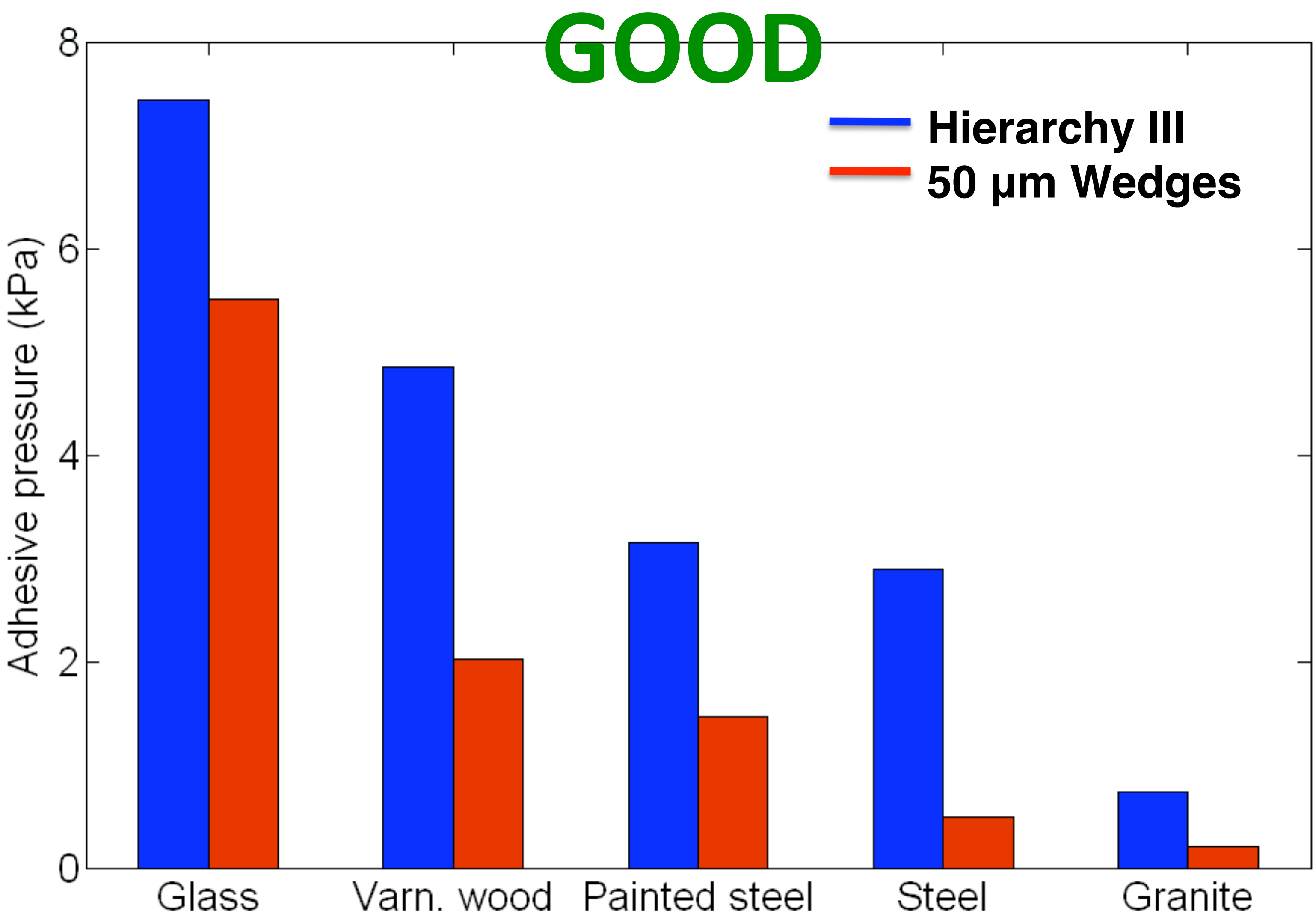


Scaling: Equal Load Distribution

GOOD

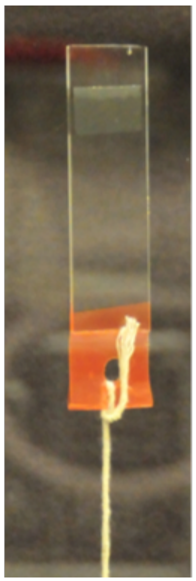


Rough Surface: Conformation



Rough Surfaces: Conformation

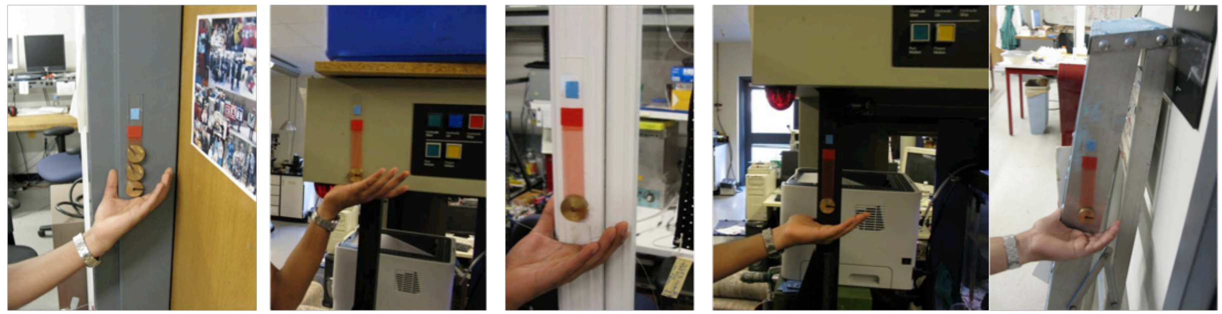
Wedges



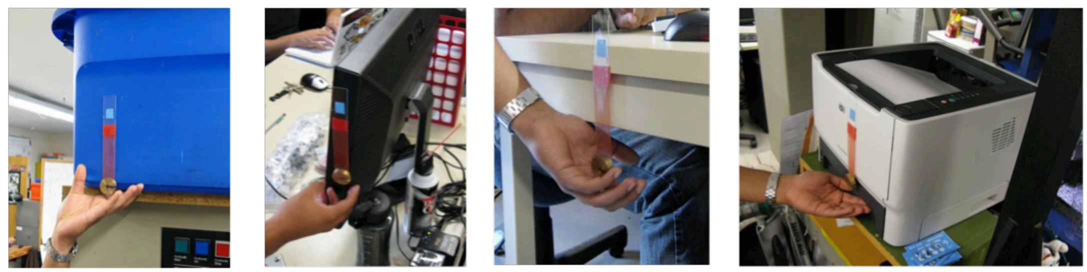
Glass

Hierarchy I

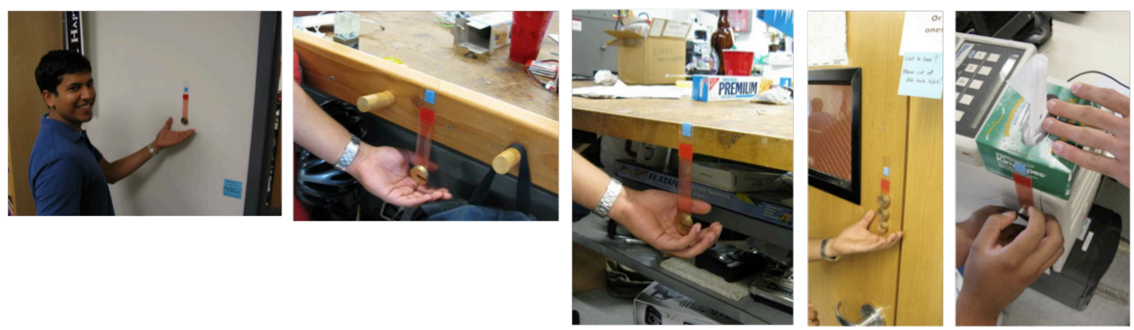
Varnished wood and metal



Plastics



Wood, drywall, cardboard

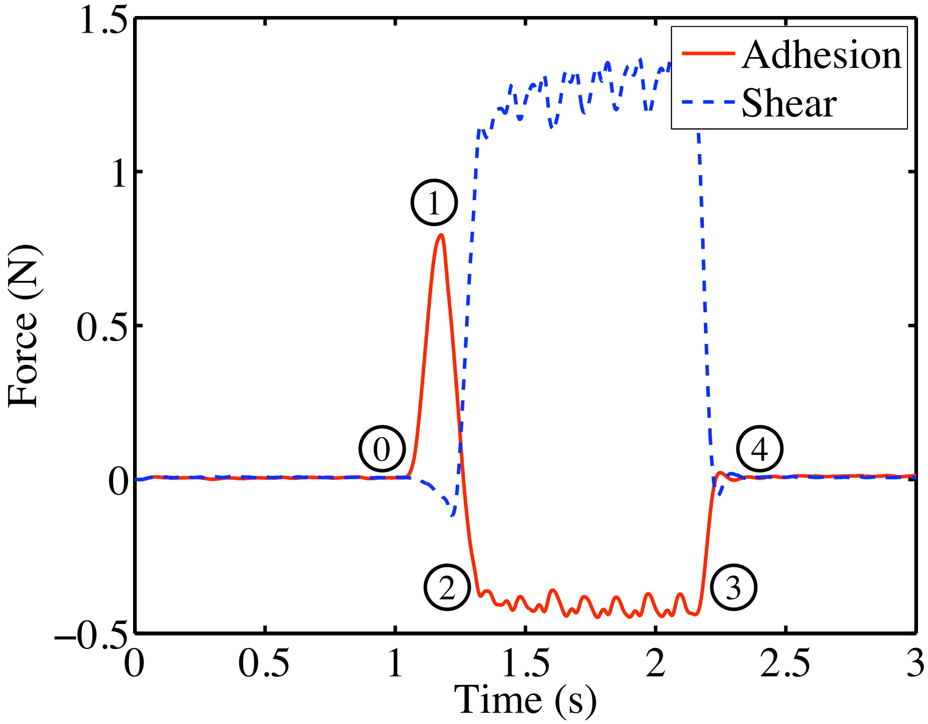


Large Patch Demonstration

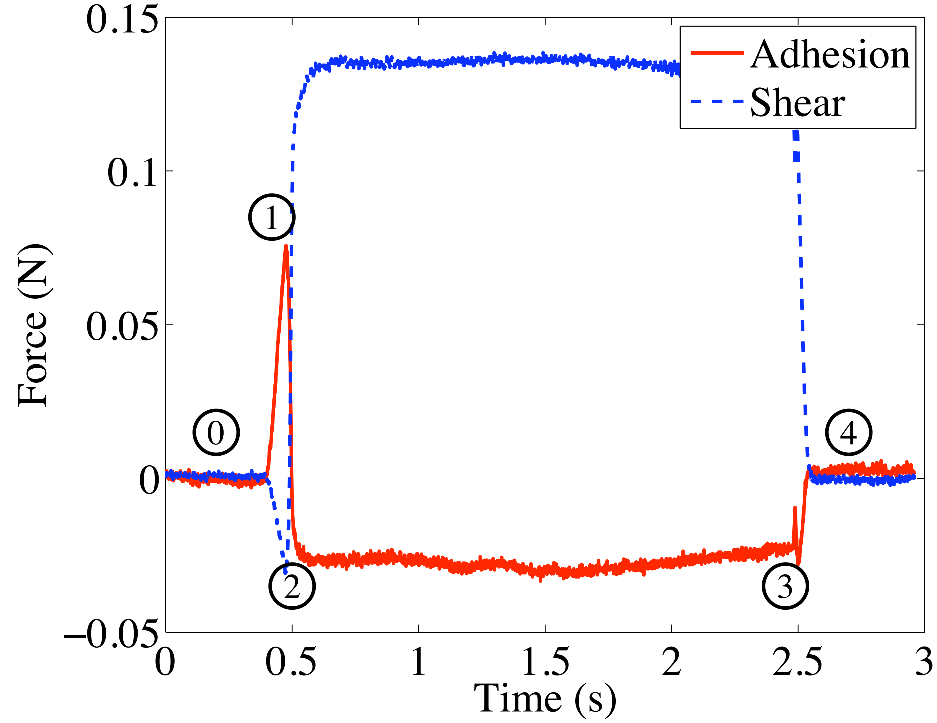
Dynamic Adhesion

The ability to maintain adhesion while failing in shear.

Microstructured adhesive



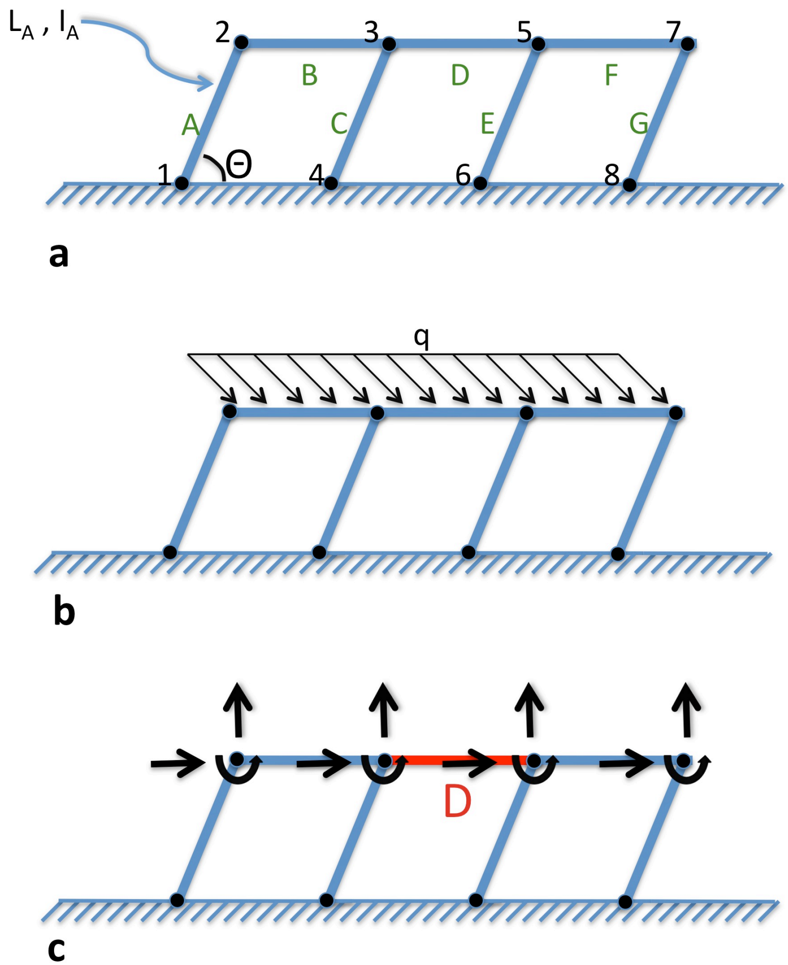
Gecko setal array



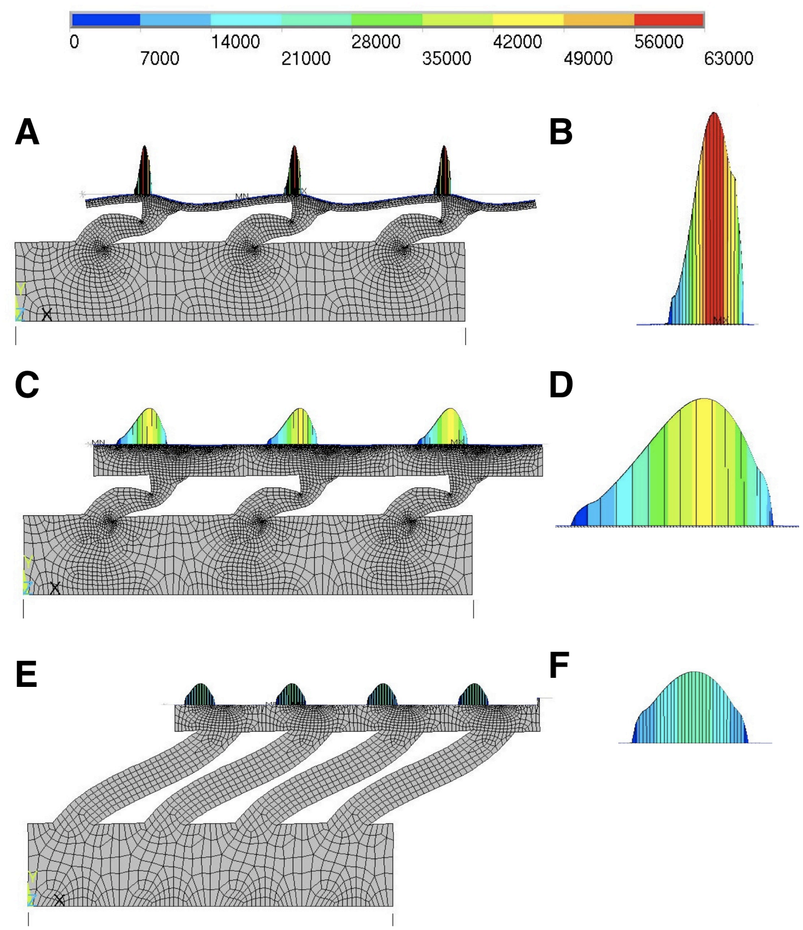
Dynamic Adhesion

Iterating Forward: Optimized Suspensions

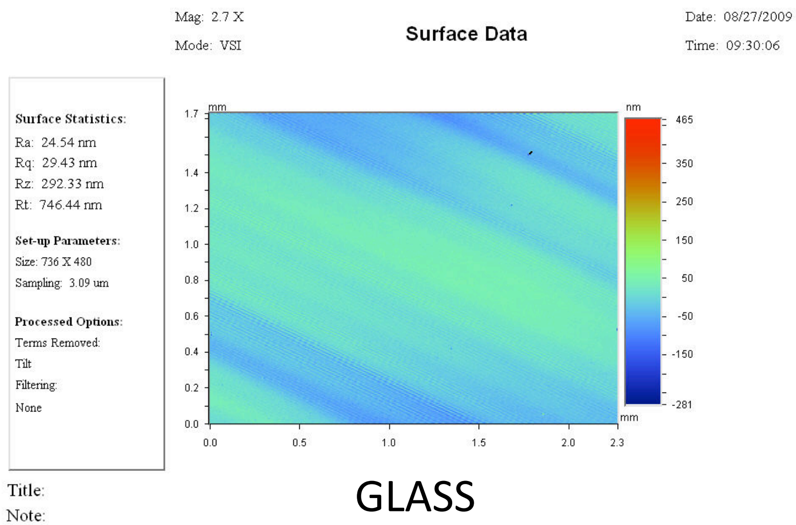
Matrix Analysis of Framed Structure



ANSYS and Molecular Modeling

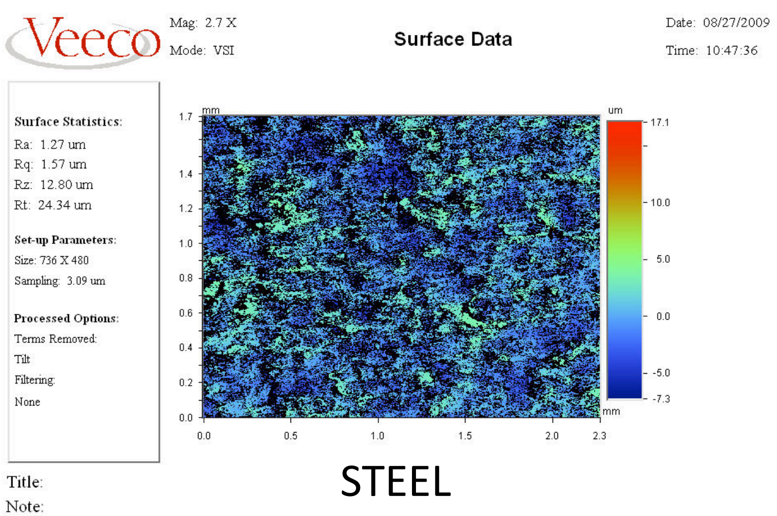


More Surfaces

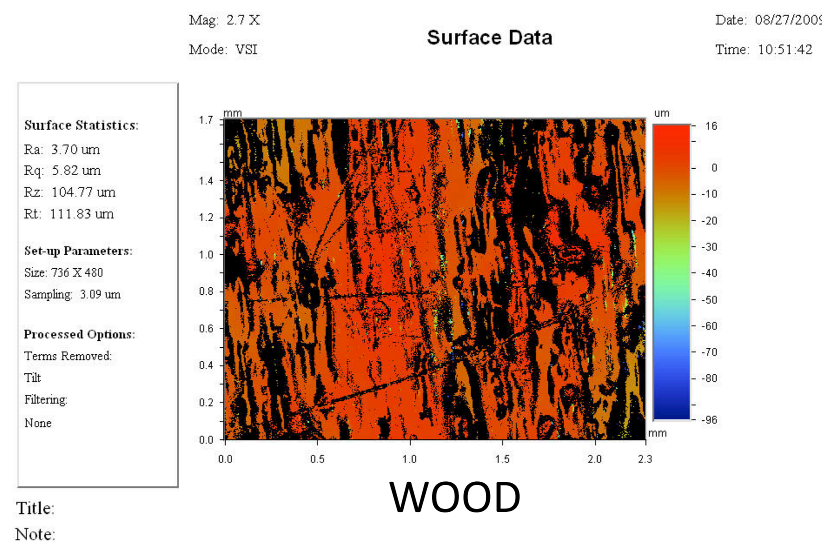


GLASS

Requires a 3rd, smaller level of features in the hierarchy



STEEL



WOOD


QUESTIONS?