Constructing Complex 3-D Microstructures for Enhanced Adhesion

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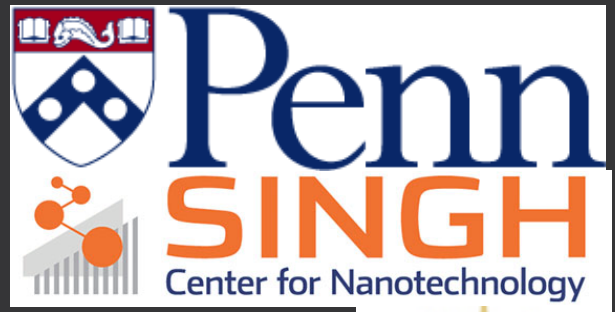
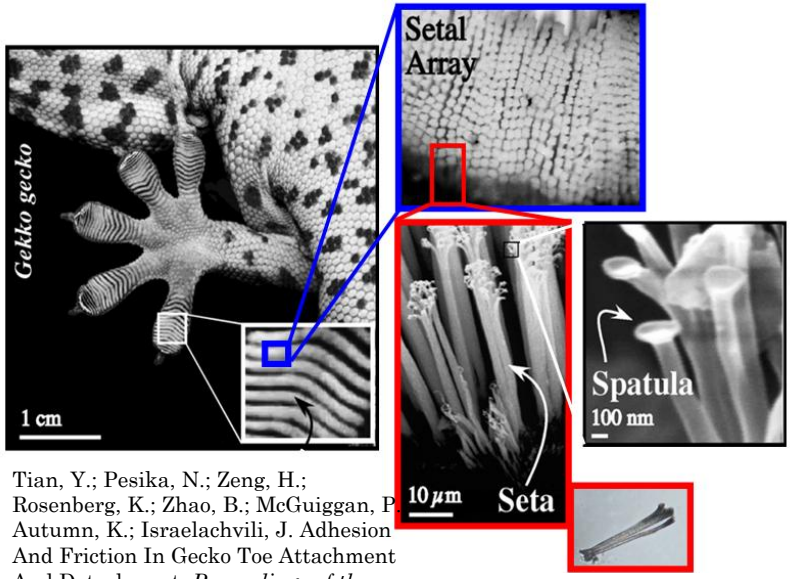
NNCI: Mid-Atlantic Nanotechnology Hub (MANTH) for Research, Education, & Innovation



Introduction

- Bio-inspired adhesives
- Geckos, lizards, spiders, and other insects
- Unique fibril geometry enable adhesive properties
- Difficulty in manufacturing complex structures
- Develop adhesives with complex geometries using two-photon lithography



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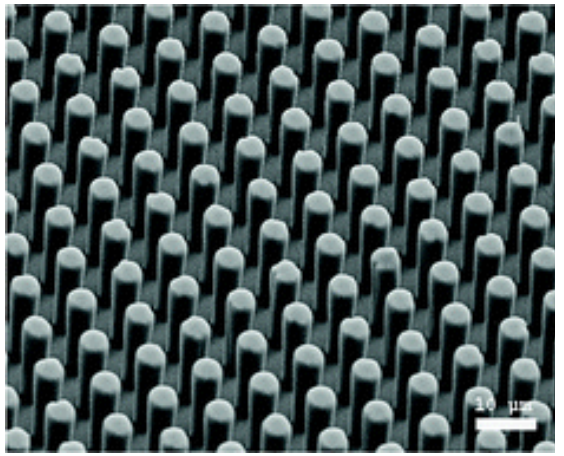

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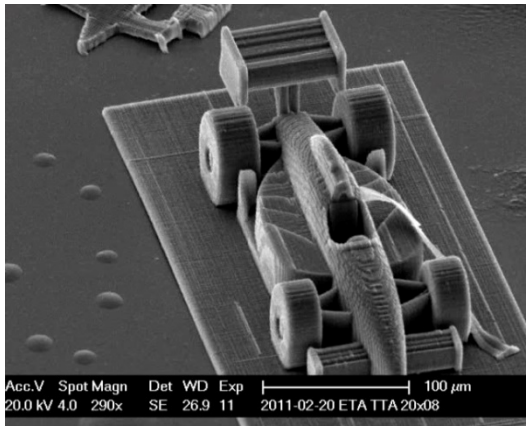
Two-Photon Lithography

- 3-D Direct Laser Writing
- Non-linear absorption process and femtosecond laser
- Alternative to traditional stereo-lithography
- Two-Photon Lithography via Nanoscribe Photonic Professional GT in QNF

Nanoscribe



High resolution structure

Geometries Explored

Size/Characteristics					Spacing (µm)
5 µm height, 5 µm diameter	No Cap	10 µm cap diameter	10 µm cap diameter	10 µm cap diameter	5
10 µm height, 10 µm diameter	No Cap	20 µm cap diameter	20 µm cap diameter	20 µm cap diameter	10
15 µm height, 15 µm diameter	No Cap	30 µm cap diameter	30 µm cap diameter	30 µm cap diameter	15
20 µm height, 20 µm diameter	No Cap	40 µm cap diameter	40 µm cap diameter	40 µm cap diameter	20

Geometries Explored

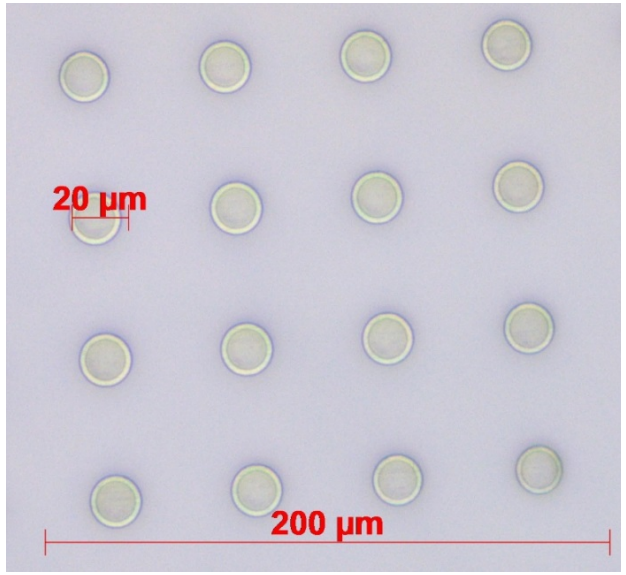
Structure A:
Pillar

Structure B:
Mushroom
Cap

Structure C:
Small Fillet

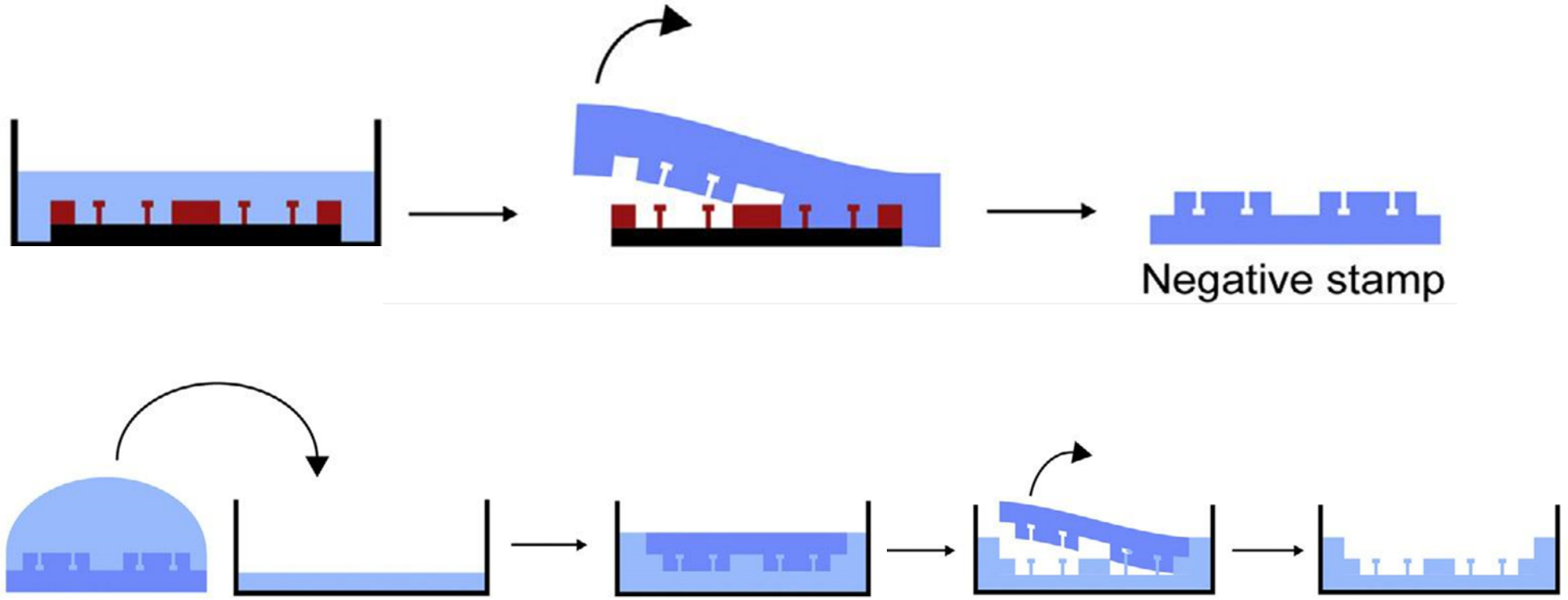
Structure D:
Large Fillet

Side-View Profiles



Top-View Profile

PDMS Molding



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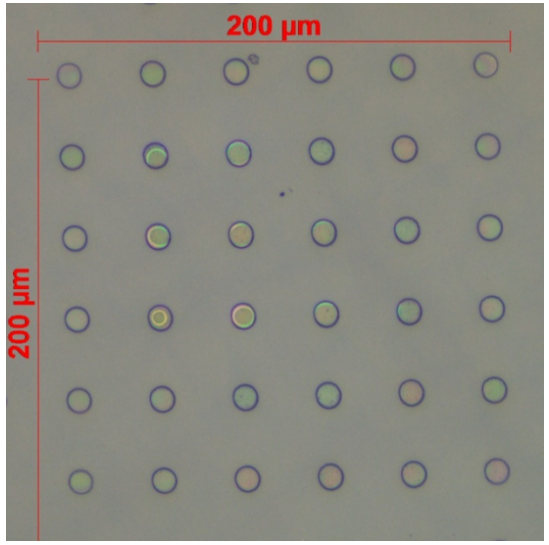
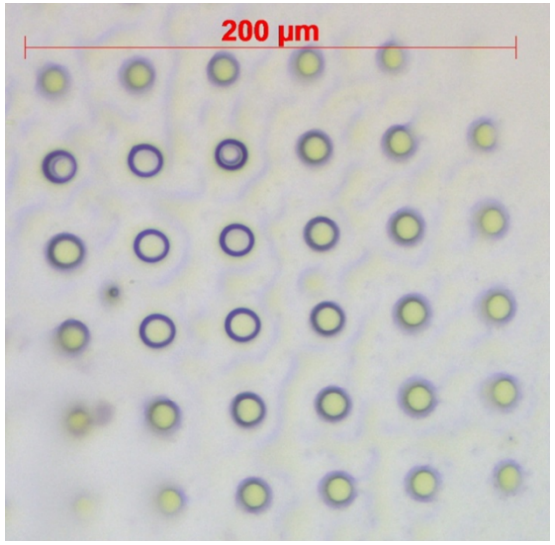
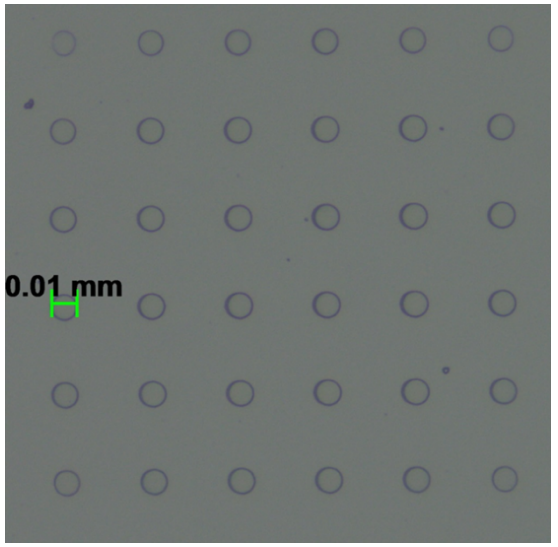
Optical Imaging



Master Mold: Mushroom Cap, 10 µm height, 10 µm diameter

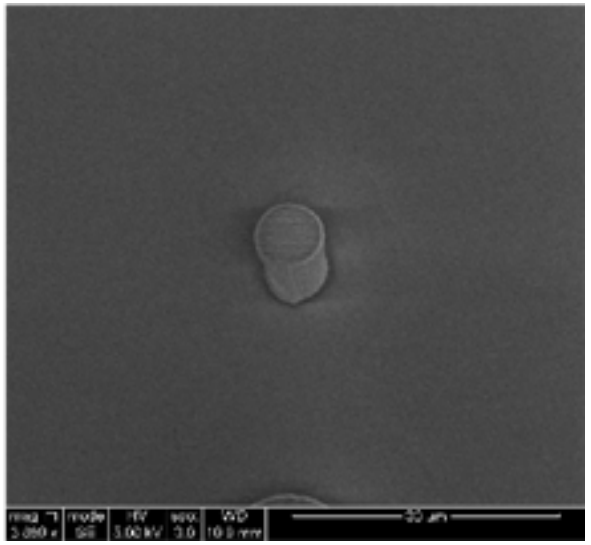


Negative Mold: Mushroom Cap, 10 µm height, 10 µm diameter

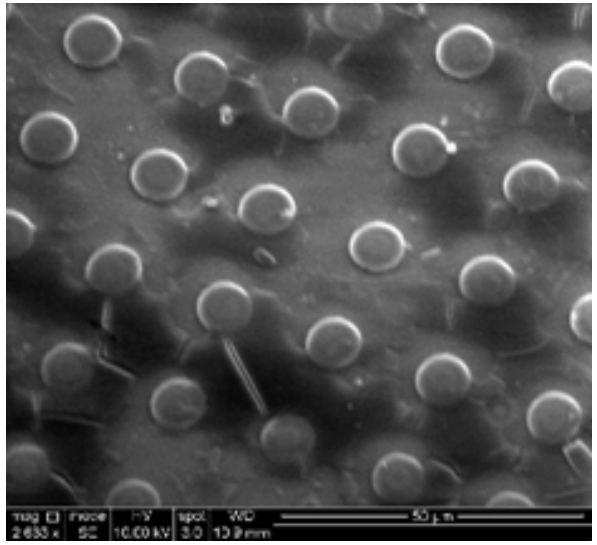


Final PDMS Structures: Mushroom Cap, 10 µm height, 10 µm diameter

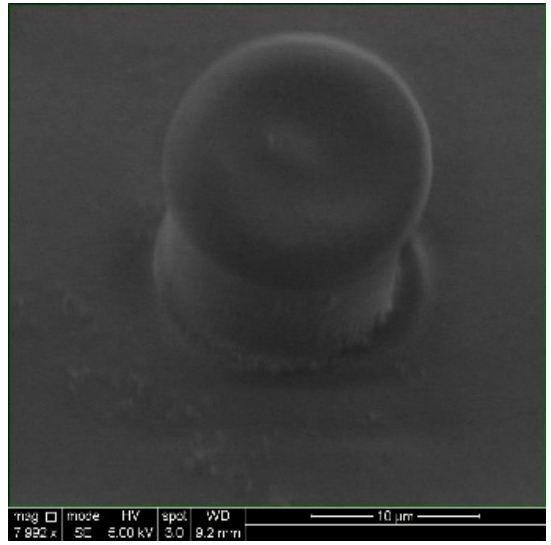
SEM Imaging



Master Mold:
Mushroom Cap, 5 µm height, 5 µm diameter

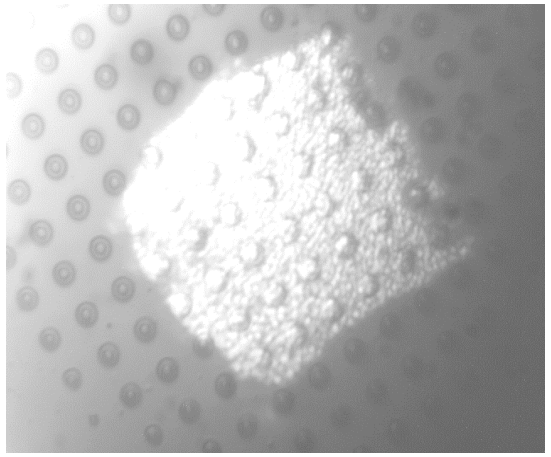


Negative Mold:
Mushroom Cap, 5 µm height, 5 µm diameter

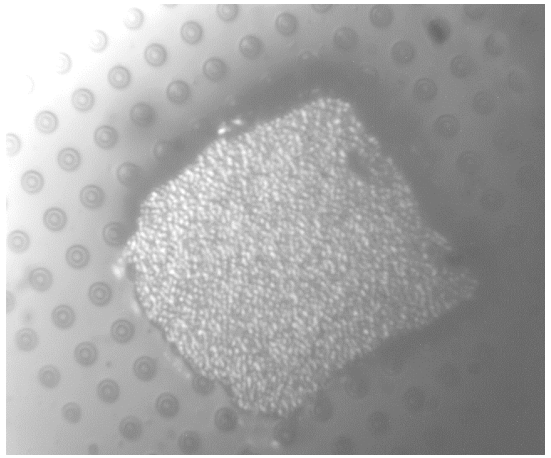


Final PDMS Structures: Mushroom Cap, 10 µm height, 10 µm diameter

Micro-Indenter Set-Up



Before Adhesion Testing

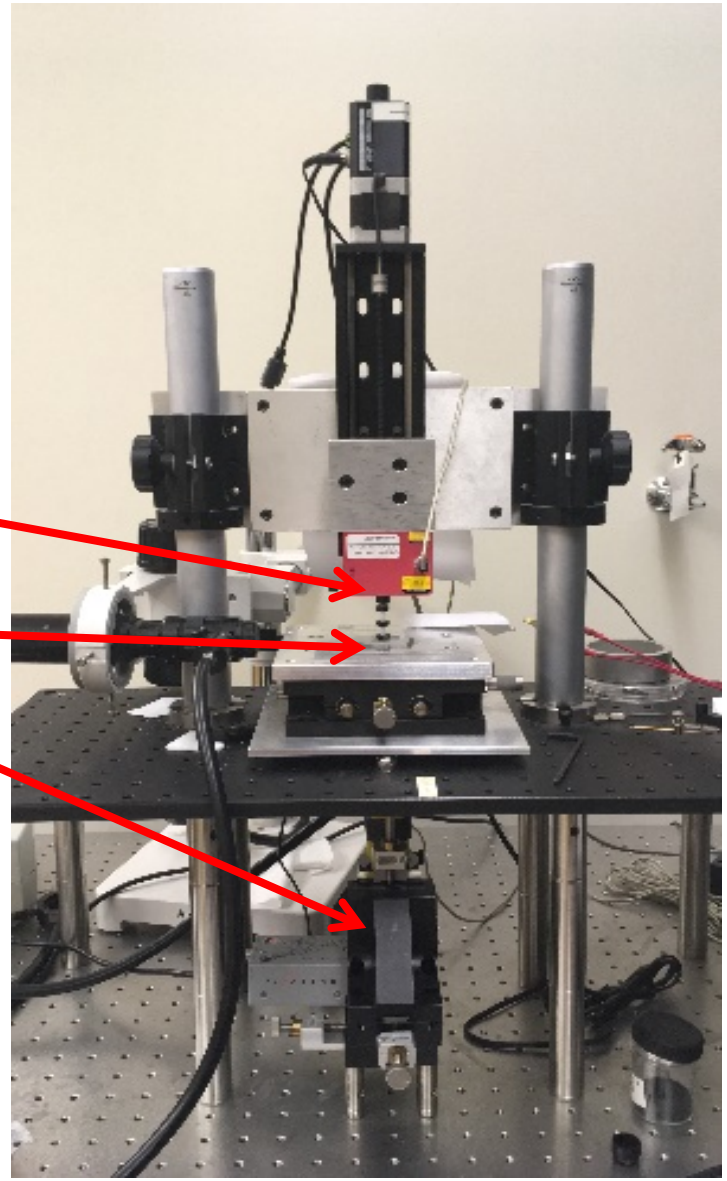


During Adhesion Testing

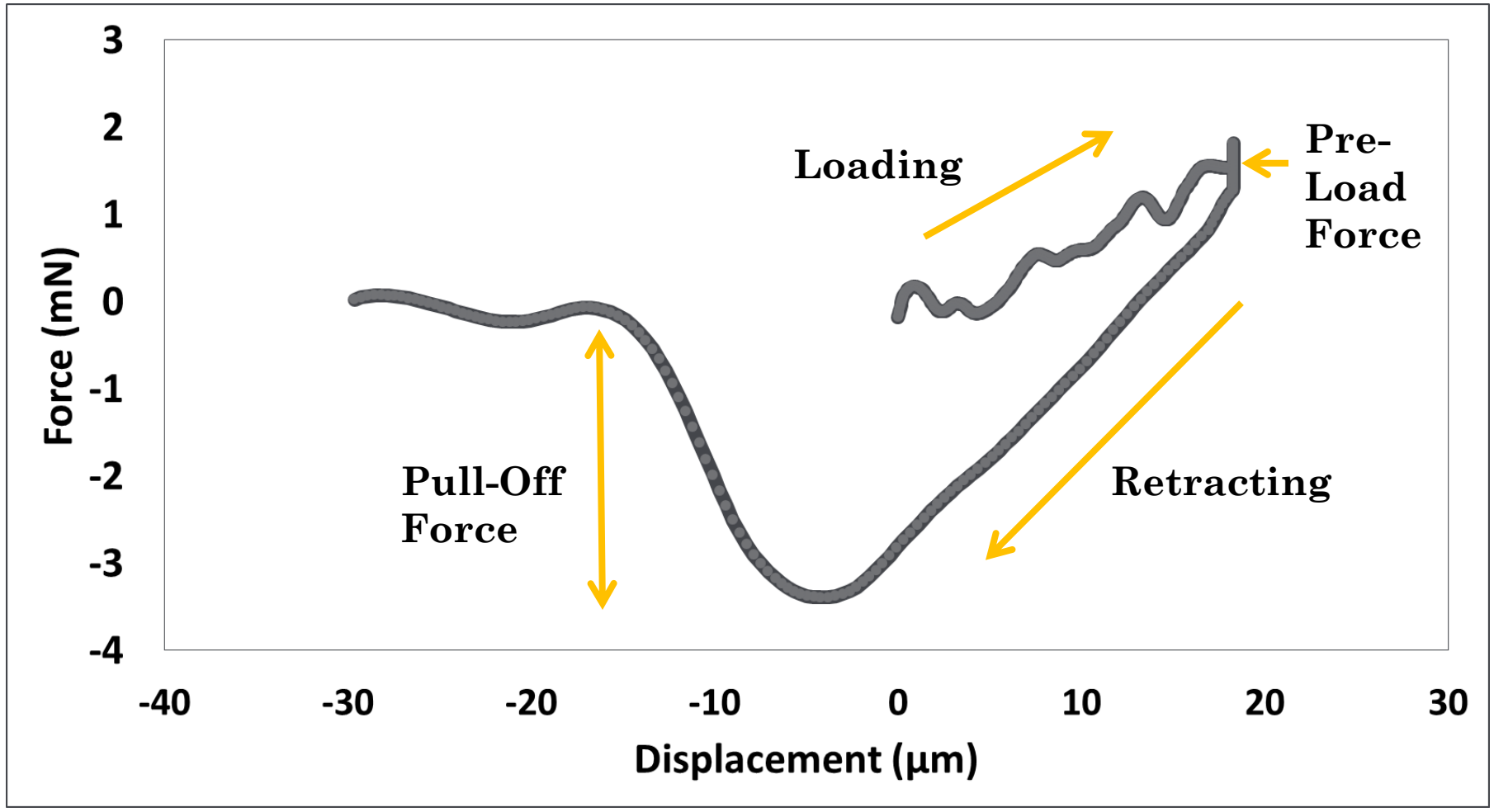
Force load cell and silicon substrate

PDMS Microstructures

Microscope



Micro-Indentation Results: Force v. Displacement



Adhesion Properties

Size/Characteristics				
Description	Pillar	Mushroom Cap	Small Fillet	Large Fillet
5 µm height, 5 µm diameter	0.47 mN	0.87 mN	0.86 mN	1.03 mN
10 µm height, 10 µm diameter	0.76 mN	0.82 mN	0.82 mN	0.92 mN
15 µm height, 15 µm diameter	0.72 mN	0.79 mN	0.80 mN	0.88 mN
20 µm height, 20 µm diameter	0.67 mN	0.75 mN	0.77 mN	0.84 mN

Conclusion

- Designed and Fabricated complex microstructures using two-photon lithography and PDMS molding
- Characterization with Optical and Scanning Electron Microscopy
- Adhesion Testing using Micro-Indentation Set-Up
- Successful in demonstrating differences in adhesion properties as a result of small-scale changes to architecture of adhesive devices

Acknowledgements

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