Characterizing the Nanoscribe Photonic GT System for Fabricating MEMS Bistable Structures

Kevin Tobin[1,2], Dilan Ratnayake[2], Kevin Walsh[2]
[1]Mechanical Engineering, Lipscomb University
[2]Electrical and Computer Engineering, University of Louisville

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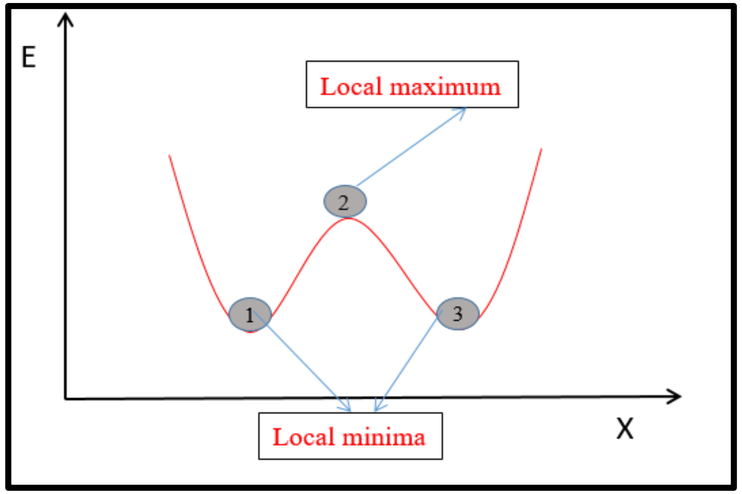
Outline

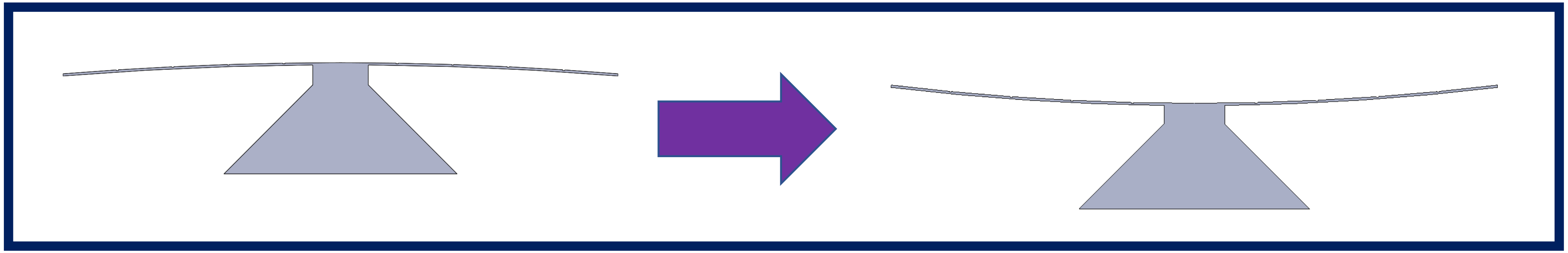
- Introduction
- Objective
- Fabrication Process and Materials
- Results
- Conclusions
- Recommendations

Introduction

- What is a "Bistable MEMS" device?
  - A MEMS device that is capable of transitioning into 2 distinct mechanical states
- Has the potential to be used in no electrical power (NEP) sensor and memory applications
- Previously required rather complex processing to fabricate, such as grayscale lithography, thermal reflow, or engineered stress in released micro-structures



Bistability => has two equilibrium states



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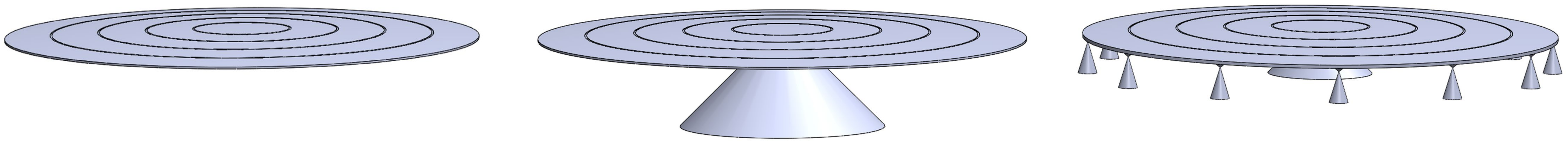
What if there was a faster and more flexible method for fabricating Bistable MEMS structures?

Objective

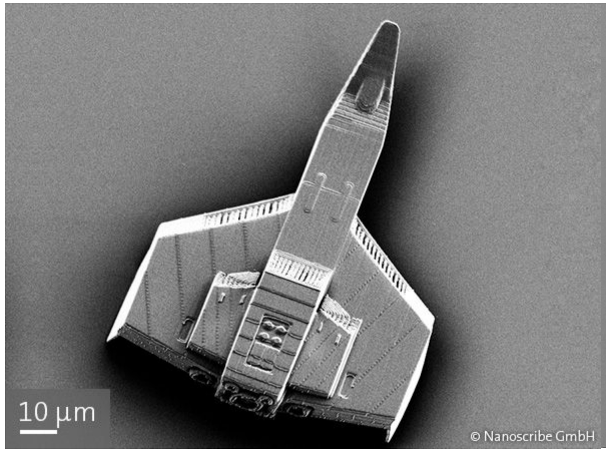
- The objective of this research is to determine the viability of fabricating bistable MEMS with the Nanoscribe Photonic GT system.
- If viable, this would be much faster and provide more flexibility.

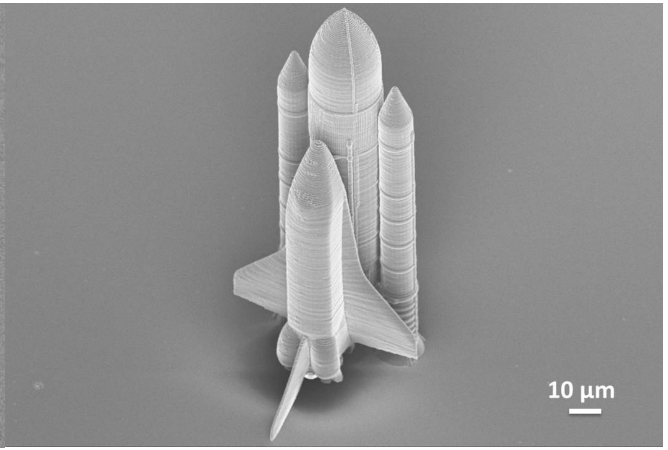


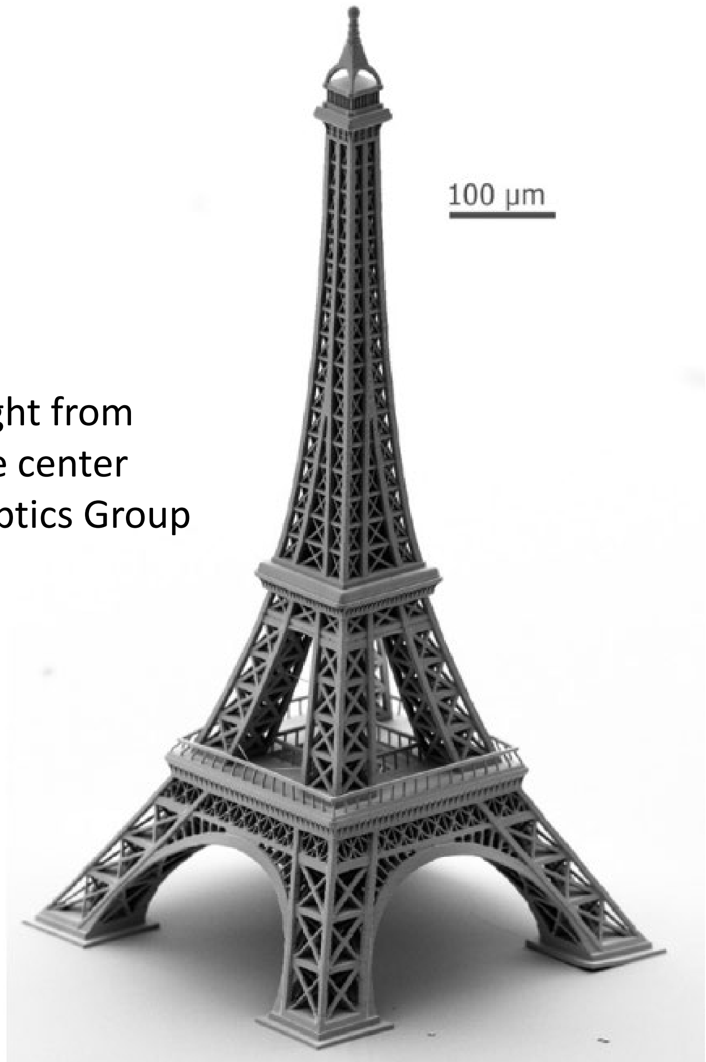
What is the Nanoscribe Tool?

- New 3D printer that utilizes 2 photon polymerization
- 3D feature size of 160nm possible
- Prints on nano, micro, and meso scales
- Compatible with dozens of photoresists

Images left and right from Nanoscribe. Image center from UCF Nano-Optics Group







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Materials

- Photoresists
  - IP-S – High viscosity, high strength, high surface quality, fast print rate
  - IP-Dip – Low viscosity, low strength, high level of detail
- Objectives
  - x25 – low level of detail, wide print field
  - x63 – high level of detail, small print field
- Substrates
  - Silicon
  - ITO Glass
  - Glass

Design Strategy

- Materials divided into 3 sets based on manufacturer's recommendations
- 3 Bistable Dome designs explored

	Photoresist	Objective	Substrate
Material set 1	IP-Dip	x63	Glass
Material set 2	IP-S	x25	ITO Glass
Material set 3	IP-S	x25	Silicon

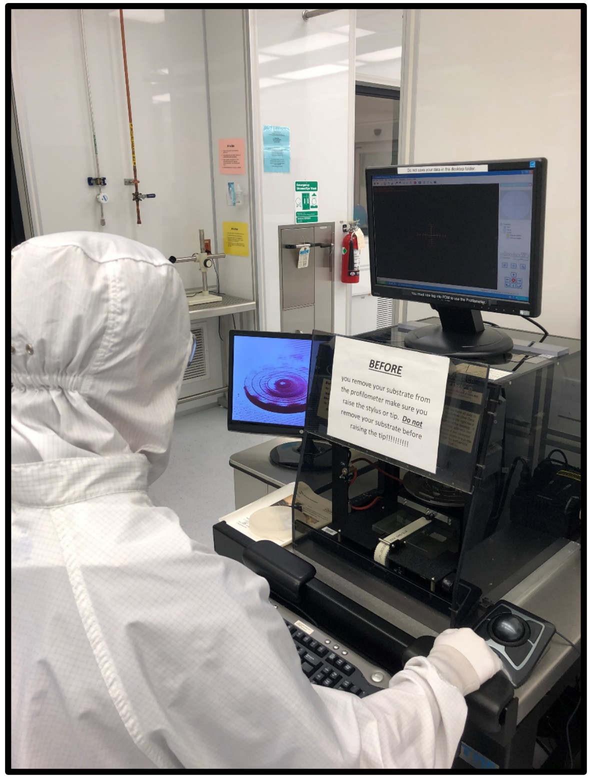
	Design 1	Design 2	Design 3
Material set 1	X		
Material set 2		X	X
Material set 3	X	X	X

Fabrication Process

- Designed in Solidworks
- Exported to DeScribe
- Parameters for print job set in DeScribe
    - Parameters such as slicing thickness, splitting, laser power and speed, etc.
- Printed
- Developed in PGMEA for 30 minutes, then IPA for 2 minutes

Characterization

- Each design was printed multiple times in multiple sizes
- Designs were modeled (Solidworks) and simulated (Ansys) to prove bistability
- Samples were imaged with optical and scanning electron microscopy
- Samples were characterized with a Dektak profilometer and Zygo image surface profile.



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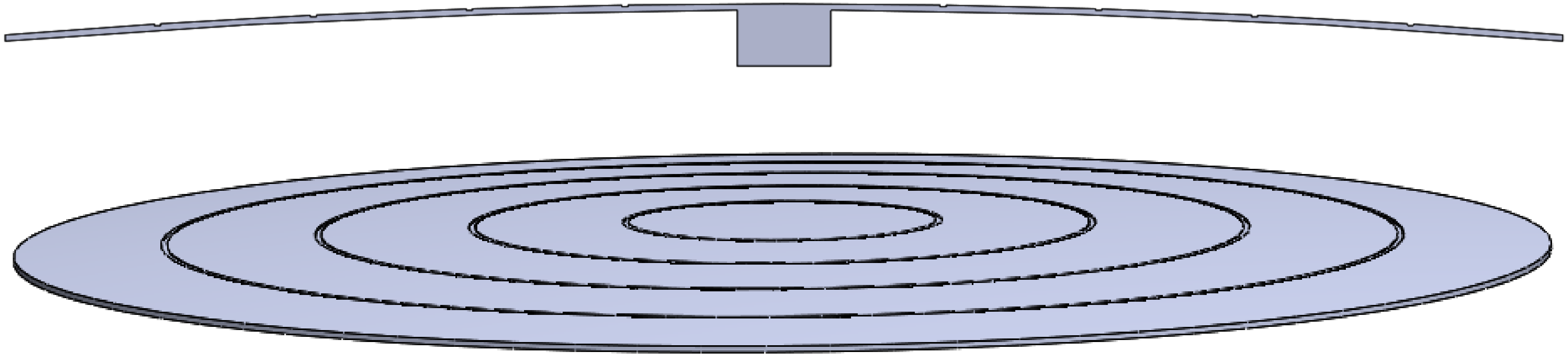
Dome Design 1

- “Mushroom” dome
- Very short anchor
- Simplistic



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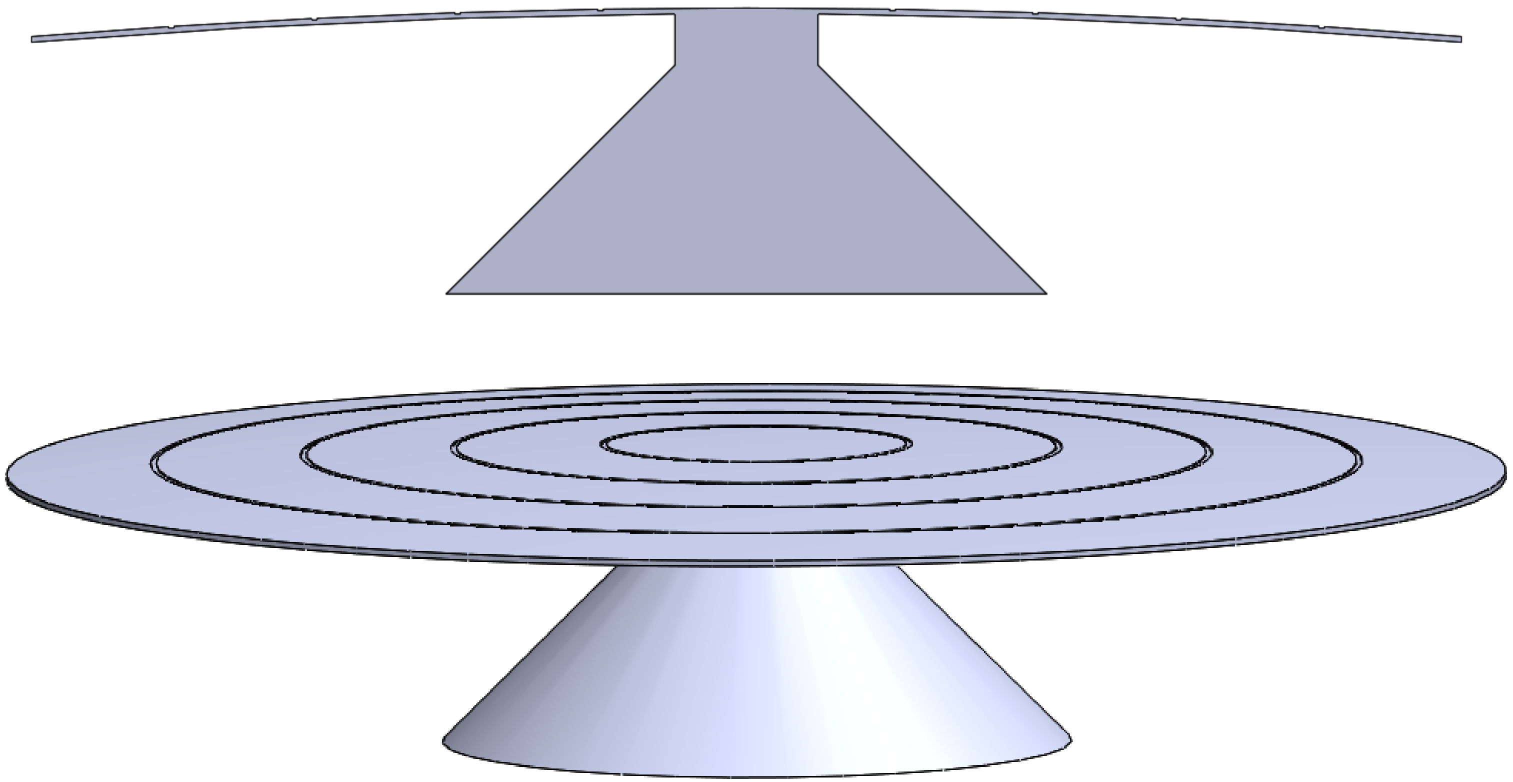
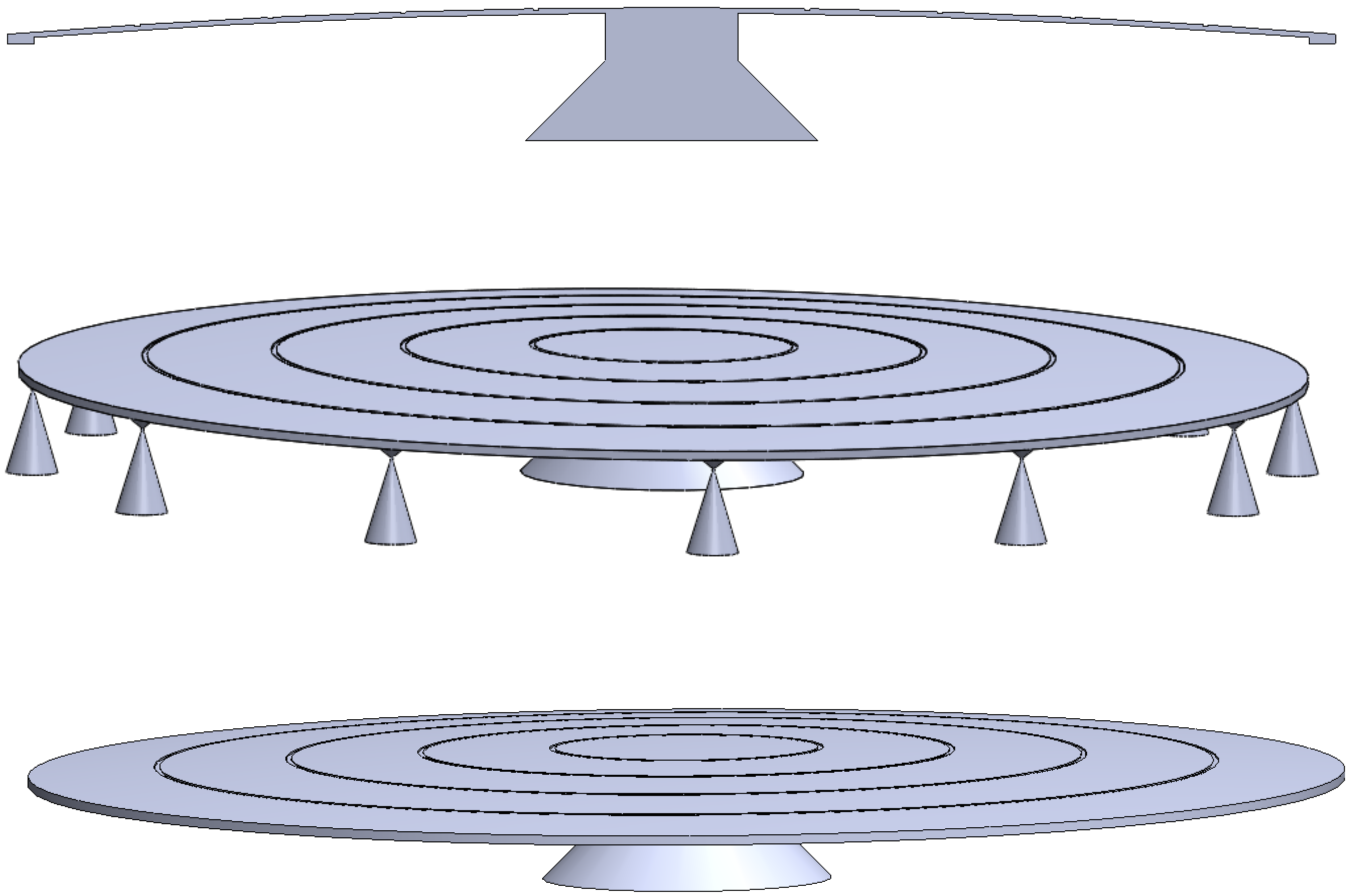
Dome Design 2

- Thicker tapered anchor
- Taller anchor



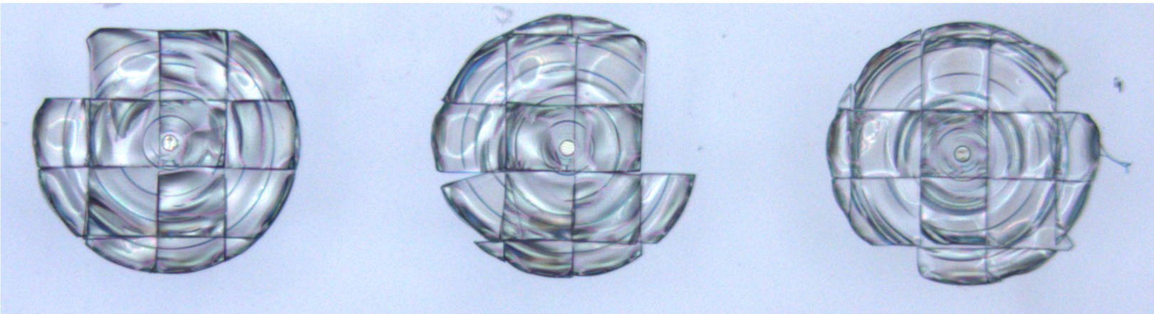
Dome Design 3

- Slightly shorter anchor
- Thicker perimeter
- 2 versions
  - One with periodic supports along the edge of dome (designed to release)
  - One without supports

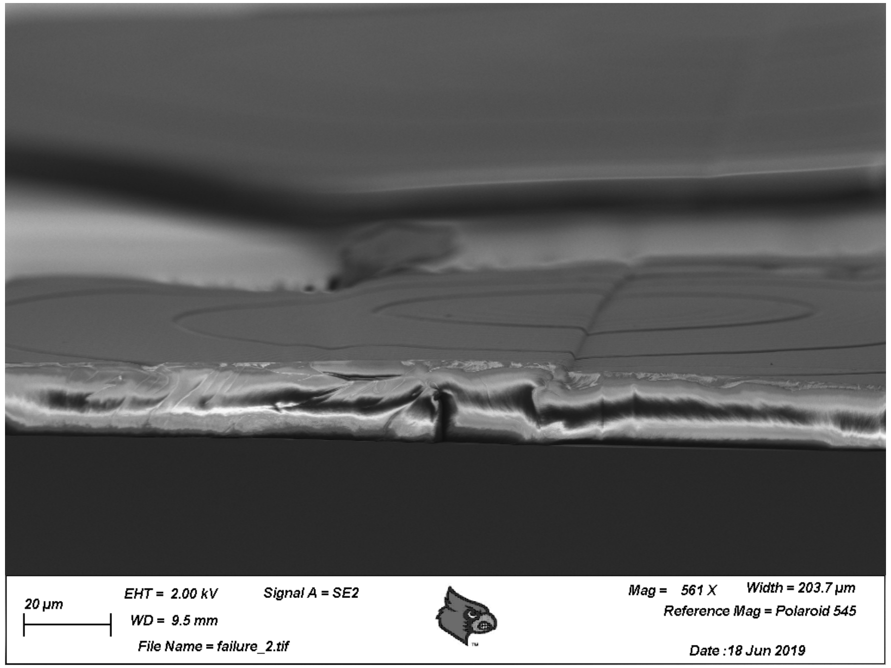


Results

- Design 1
  - Structures made with Material Set 1 warped and collapsed on themselves
    - Material Set 1, with IP-Dip, deemed unsuitable
  - Structures made with Material Set 3 had unpolymerized resist trapped under dome



Above- Structures fabricated using Material Set 1
Below- Cross section of structure fabricated using Material Set 3



1. **Neither Material Set resulted in a successful dome structure.**
2. **Material Set 1 had severe stitching problems and was ruled out.**
3. **Material Set 3 remained a possibility if the anchor height is increased.**

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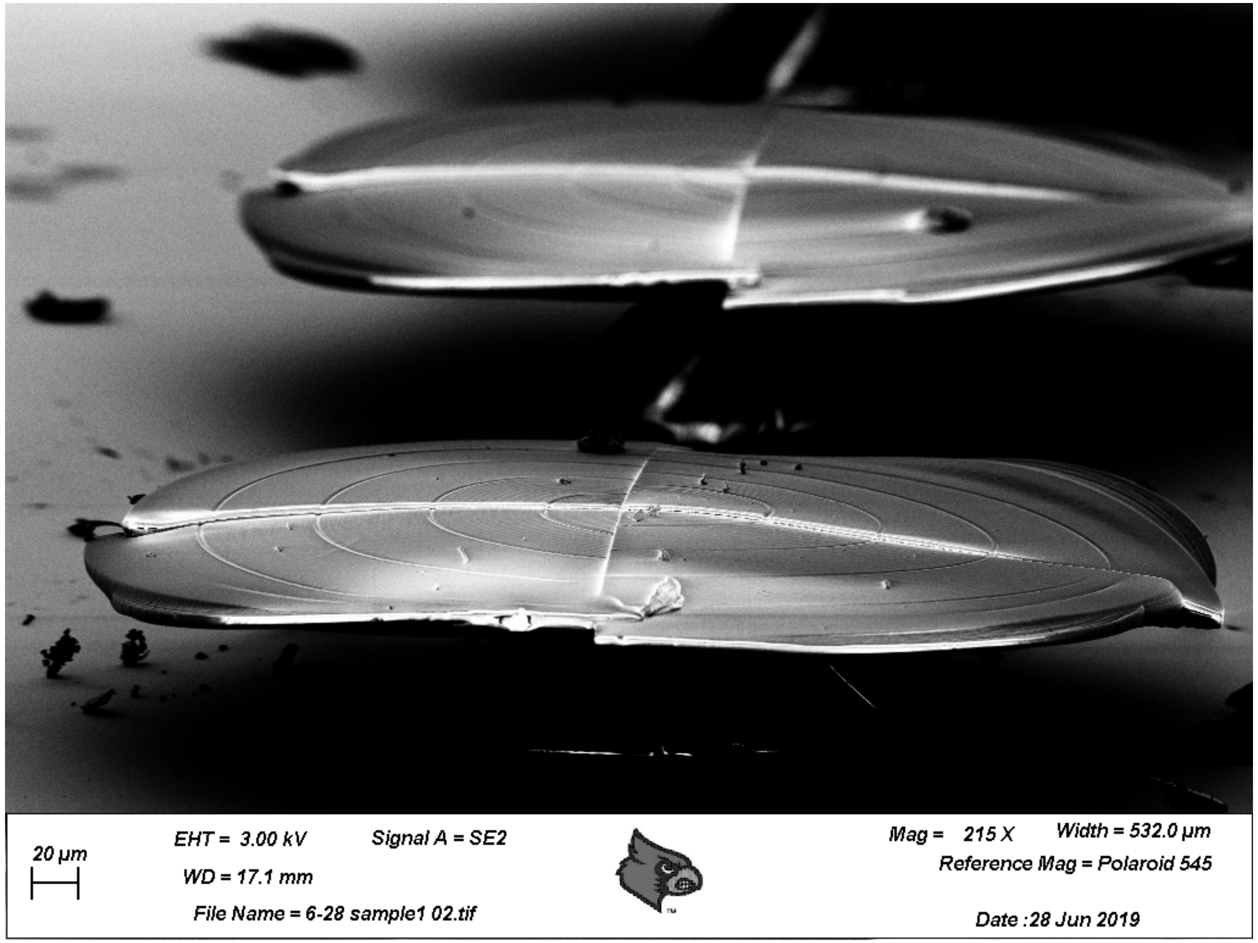
Results

- Design 2
  - Structures made with Material Sets 2 and 3 both warped and did not align well at the stitching lines
    - Material Set 2 required a lower laser power, which may lead to a weaker structure



1. **Increasing the anchor height resolved the undeveloped resist issue.**
2. **Both Material Sets produced warped domes.**
3. **The fabrication of unsupported structures is challenging with the Nanoscribe!**

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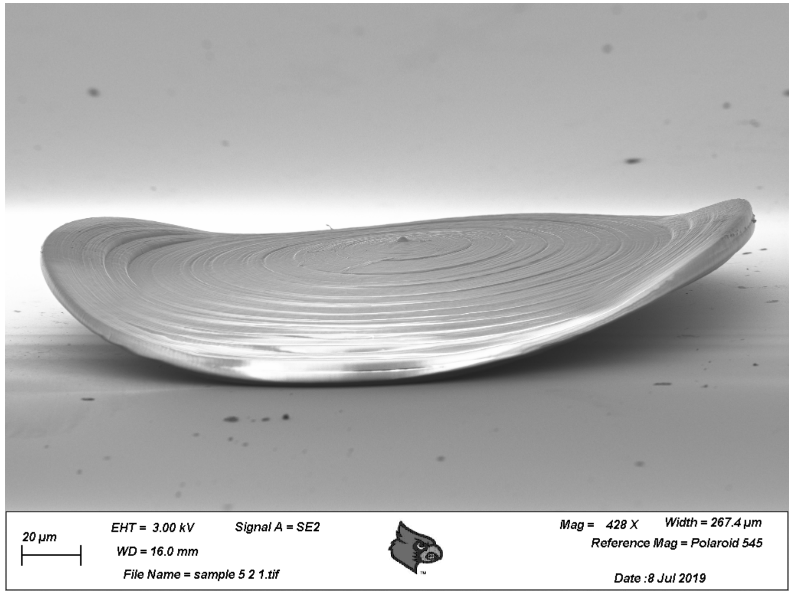
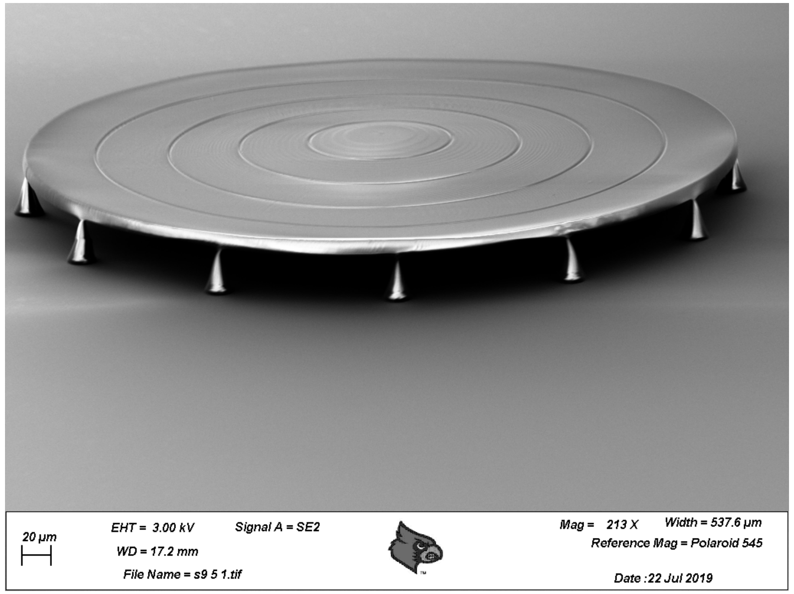
Results

- Design 3
  - Unsupported version
    - Severe warping
  - Supported Version
    - Printed as designed without major defect

1. **The unsupported dome design failed as expected, but the supported design was successful, illustrating that edge supports are necessary.**
2. **More importantly, it proved that these concave-down dome structures could be printed successfully.**





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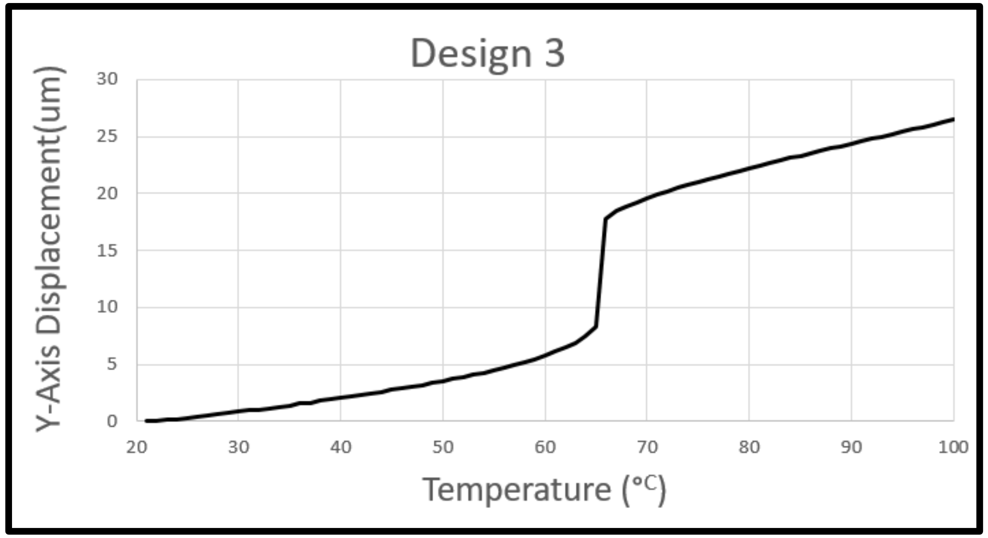
Simulation

- Design 3 was simulated with a 1um layer of Aluminum (TCE = 23 ppm/K) covering the top surface of the 2um thick polymer dome (TCE = 70 ppm/K). The simulation shows that as temperature increases, the bilayer concave-down dome abruptly changes states due to the mismatch in the materials' coefficient of thermal expansion, proving bistability.



Conclusions

- The Nanoscribe tool has extreme difficulty fabricating "unsupported thin structures".
- This can be overcome with strategically-placed support elements.
- The combination of IP-S (the thicker resist), the x25 objective, and a silicon substrate was most suitable for this application.
- Ansys was used to demonstrate that a bilayer dome of polymer-aluminum can exhibit mechanical bistability.
- The Nanoscribe is potentially a viable means of fabricating bistable MEMS structures.

Recommendations

- Continue with the experimentation by coating the successful MEMS domes with aluminum and test for mechanical bistability.

Acknowledgements

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