MEMS Origami for Energy Harvesting at Soft Surfaces

REU Participant: Canisha Ternival

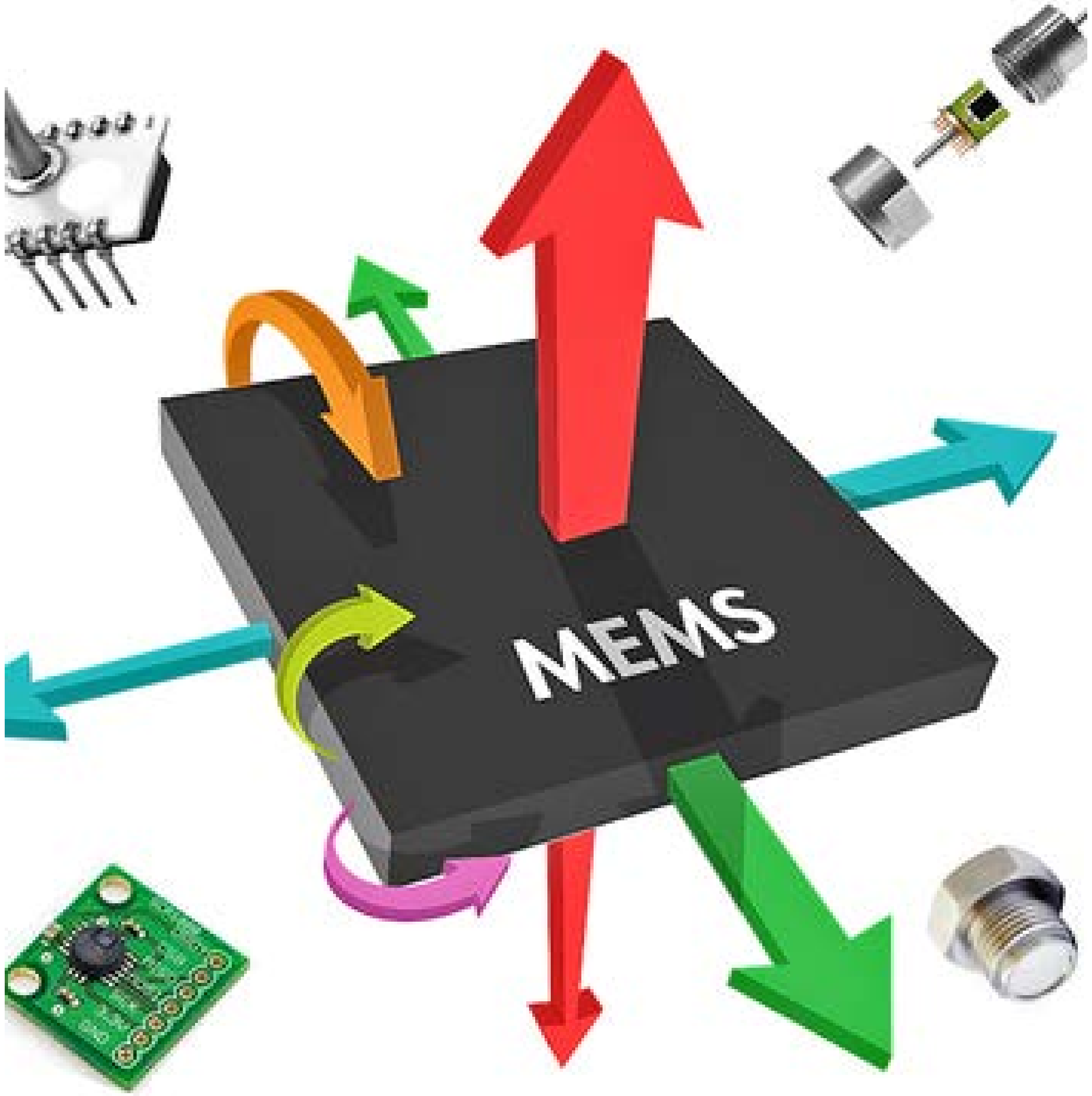
Home Institution: University of Florida

Major: Electrical Engineering

Mentor: Dr. Cindy K. Harnett

Background Motivation

- Microelectromechanical systems (MEMS)
  - Miniaturized mechanical and electro-mechanical elements that are made using the techniques of microfabrication

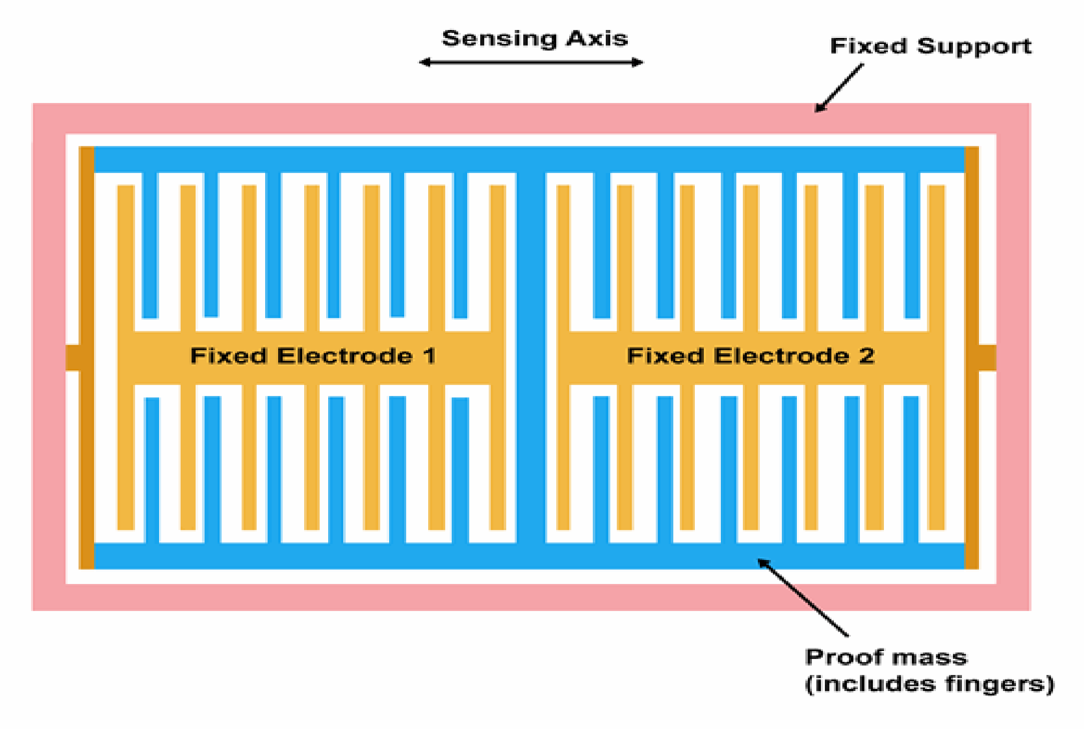


“Roger Grace Authors Eight-Part Series on Sensor/MEMS.” Sensorsmag, Mathew Dirjish. 8 Sept 2017.

Background Motivation

- MEMS can track human health and athletic performance in greater detail than ever before.
  - Smaller is better: Improved sensitivity, accuracy and reliability

“Versatile Accelerometer from STMicroelectronics Delivers Class-Leading Resolution and Low Power in Tiny Footprint.” STMicroelectronics, Geneva, 15 Feb 2017.



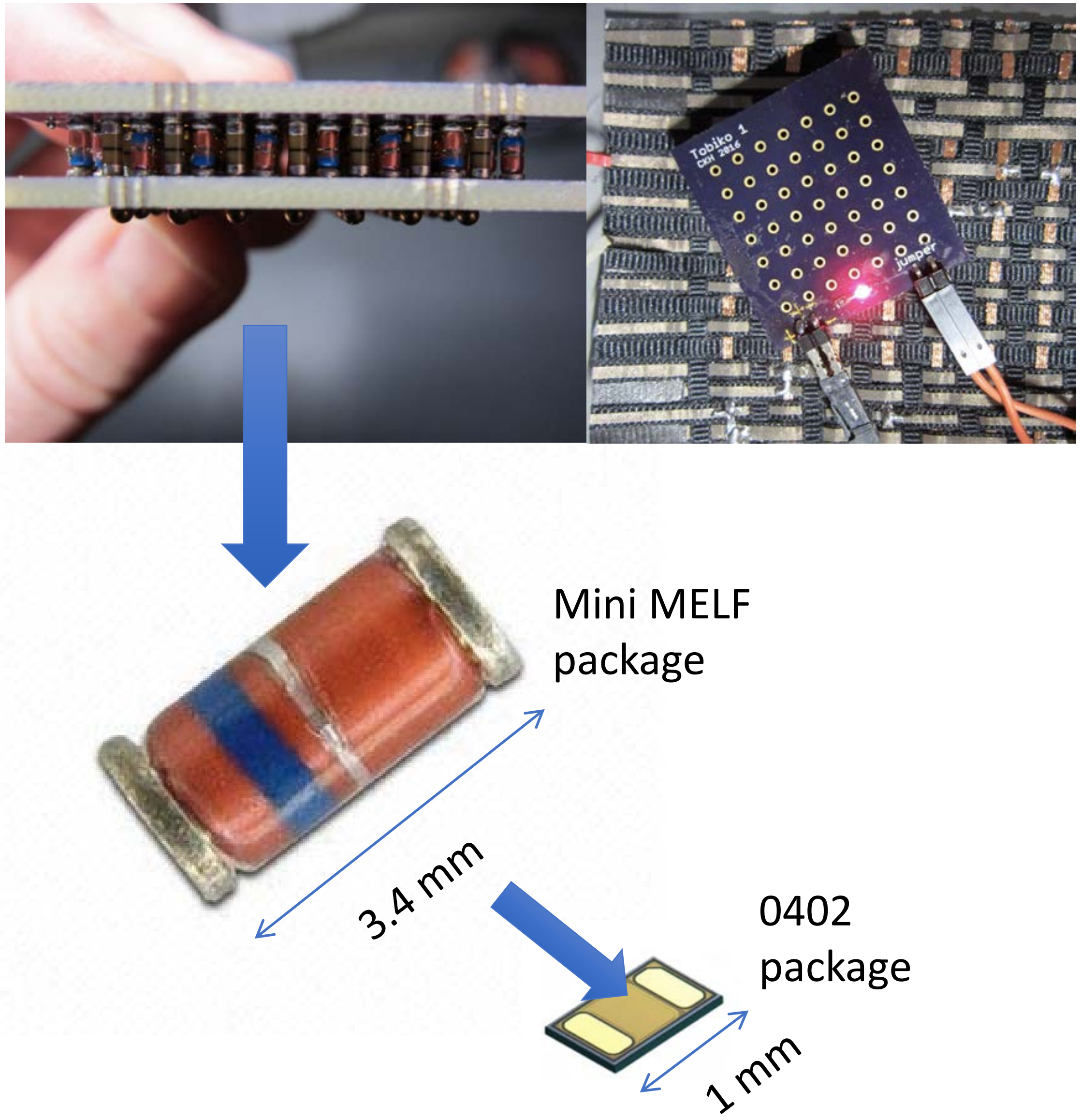
“MEMS Accelerometers.” SiliconSensing, Thinkology, 2017.

Developing a soft energy harvesting circuit

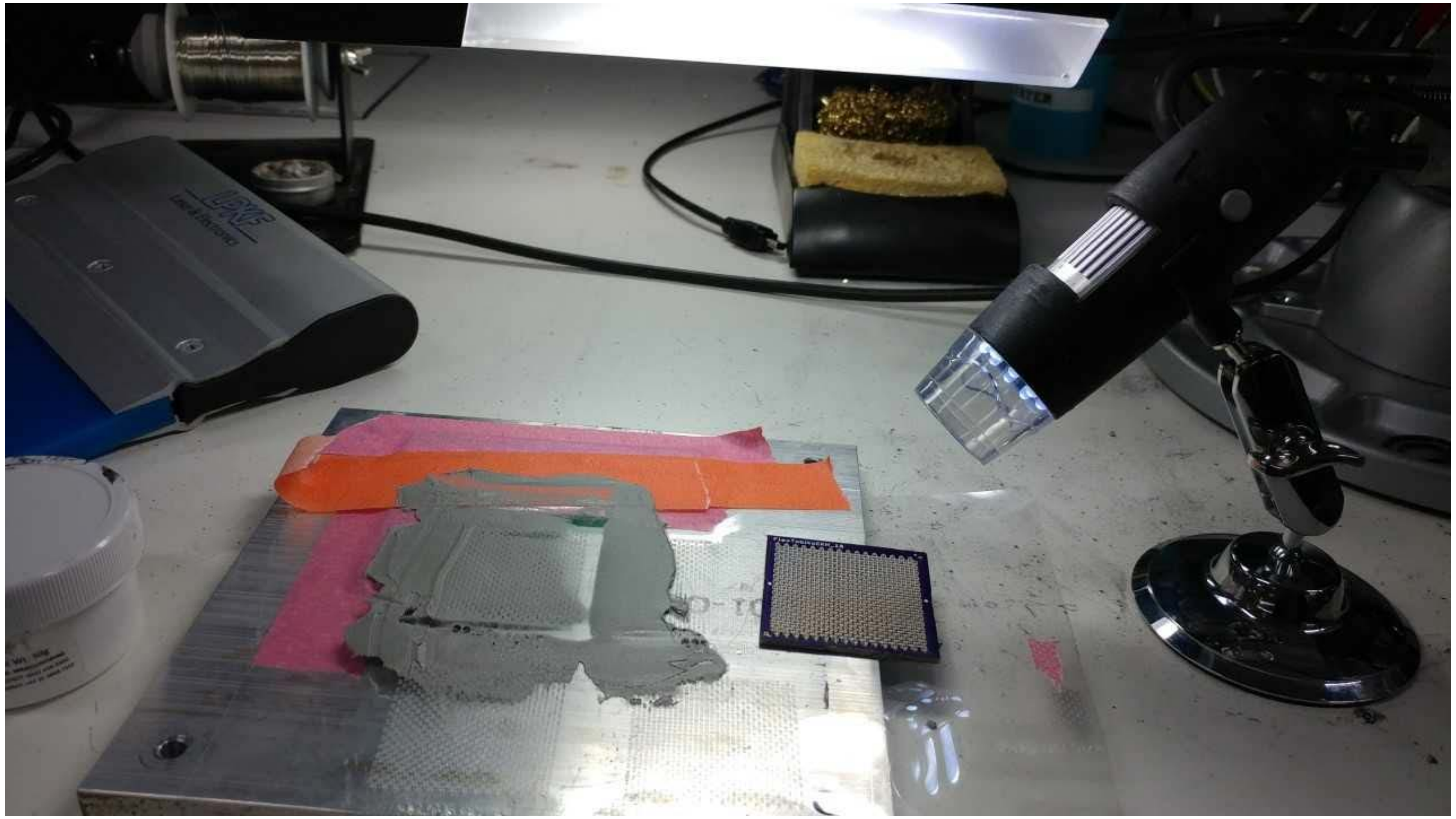
Previous work: An array of diodes on a printed circuit board (PCB) finds power and ground without alignment. The goal is a distortion-tolerant connection technology for soft electronics. But it’s not flexible.

Summer 2018: Miniaturize it with tiny diodes. And investigate MEMS origami to transfer tiny components to bendable, porous, stretchable fabrics.

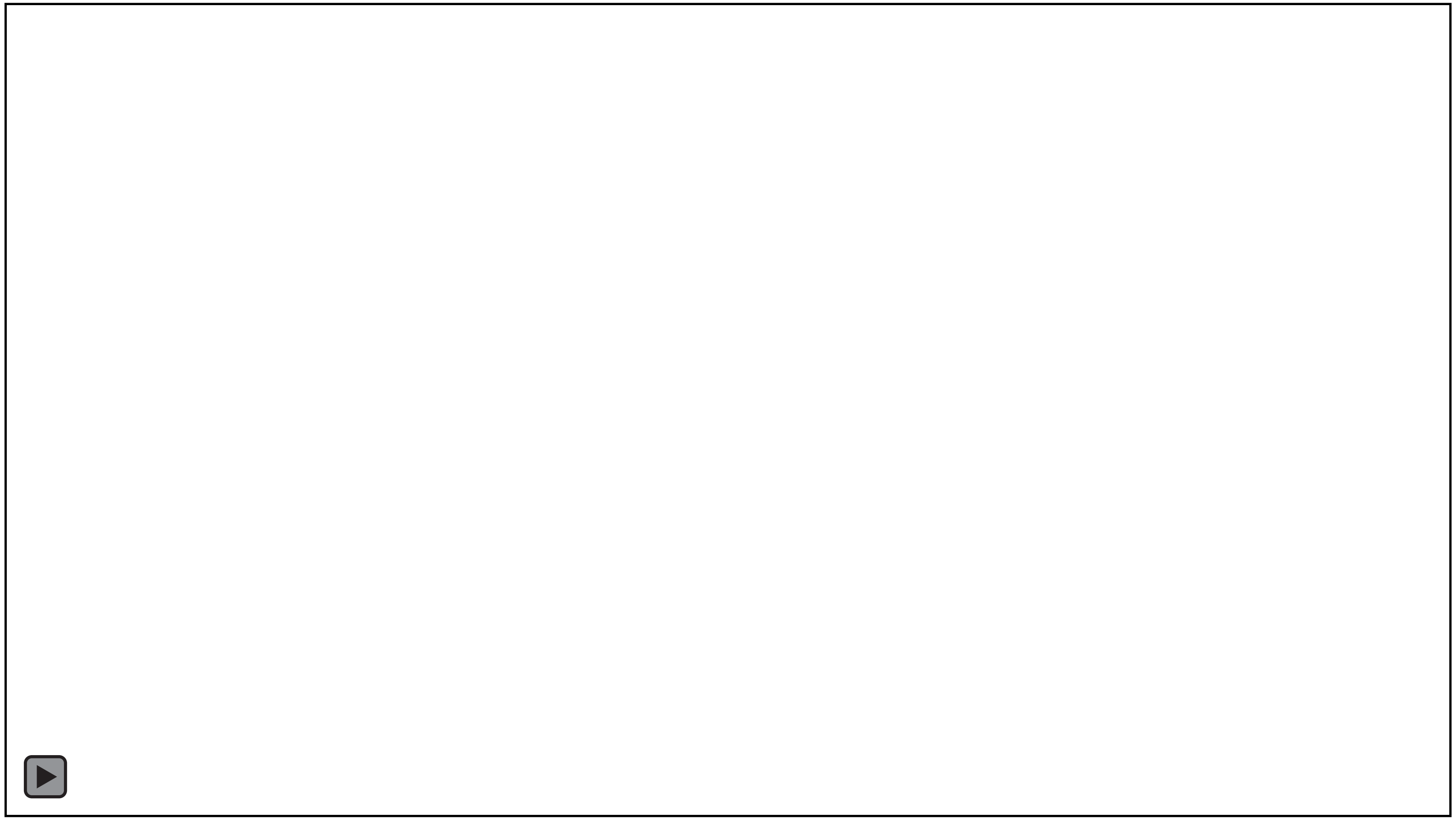
Future: Build the entire energy harvesting circuit as a monolithic thin-film device that can transfer to a soft material.



Testing the tiny diodes on a conventional printed circuit board

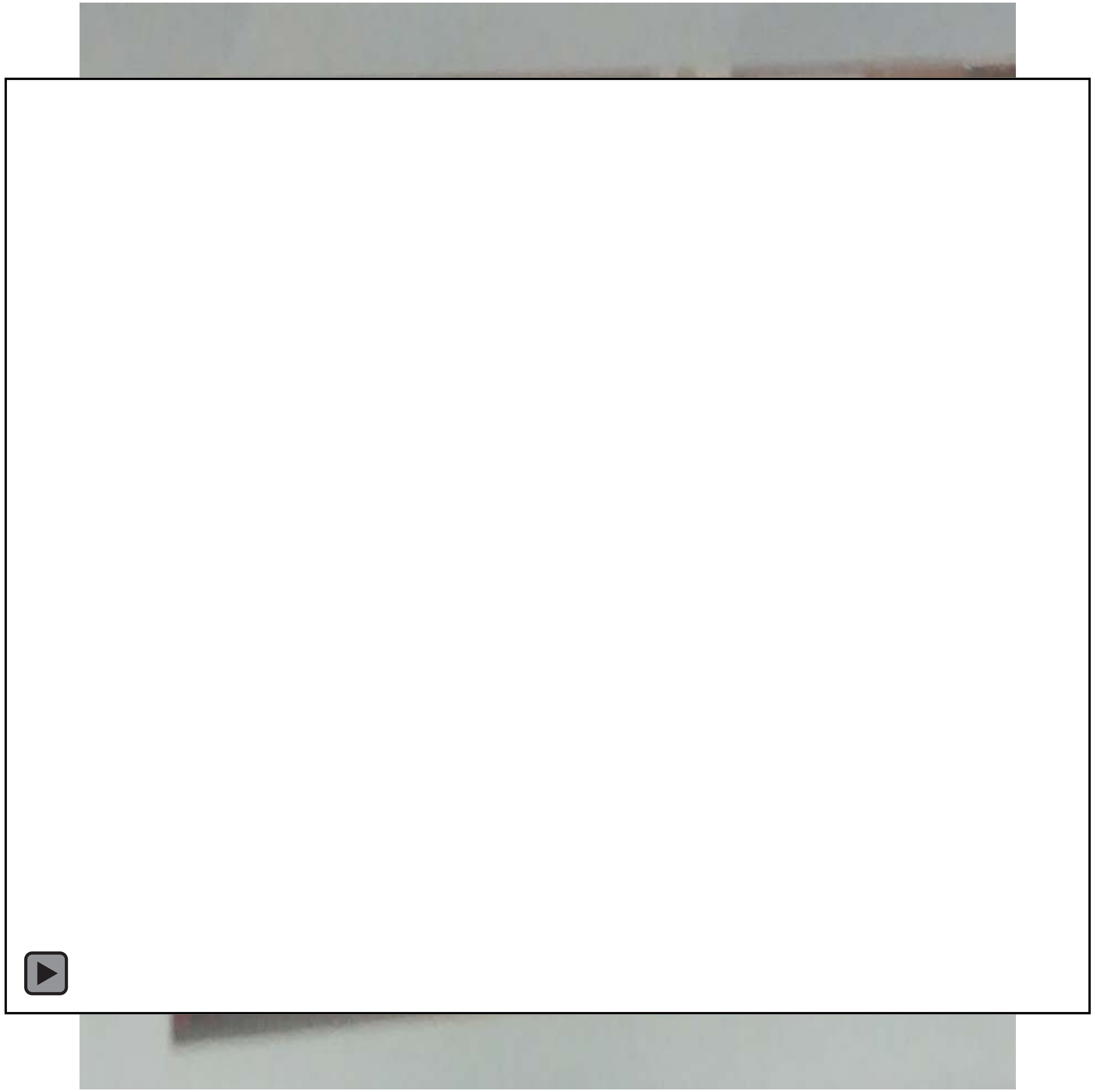


- **Step 1: Solder Paste Stenciling**



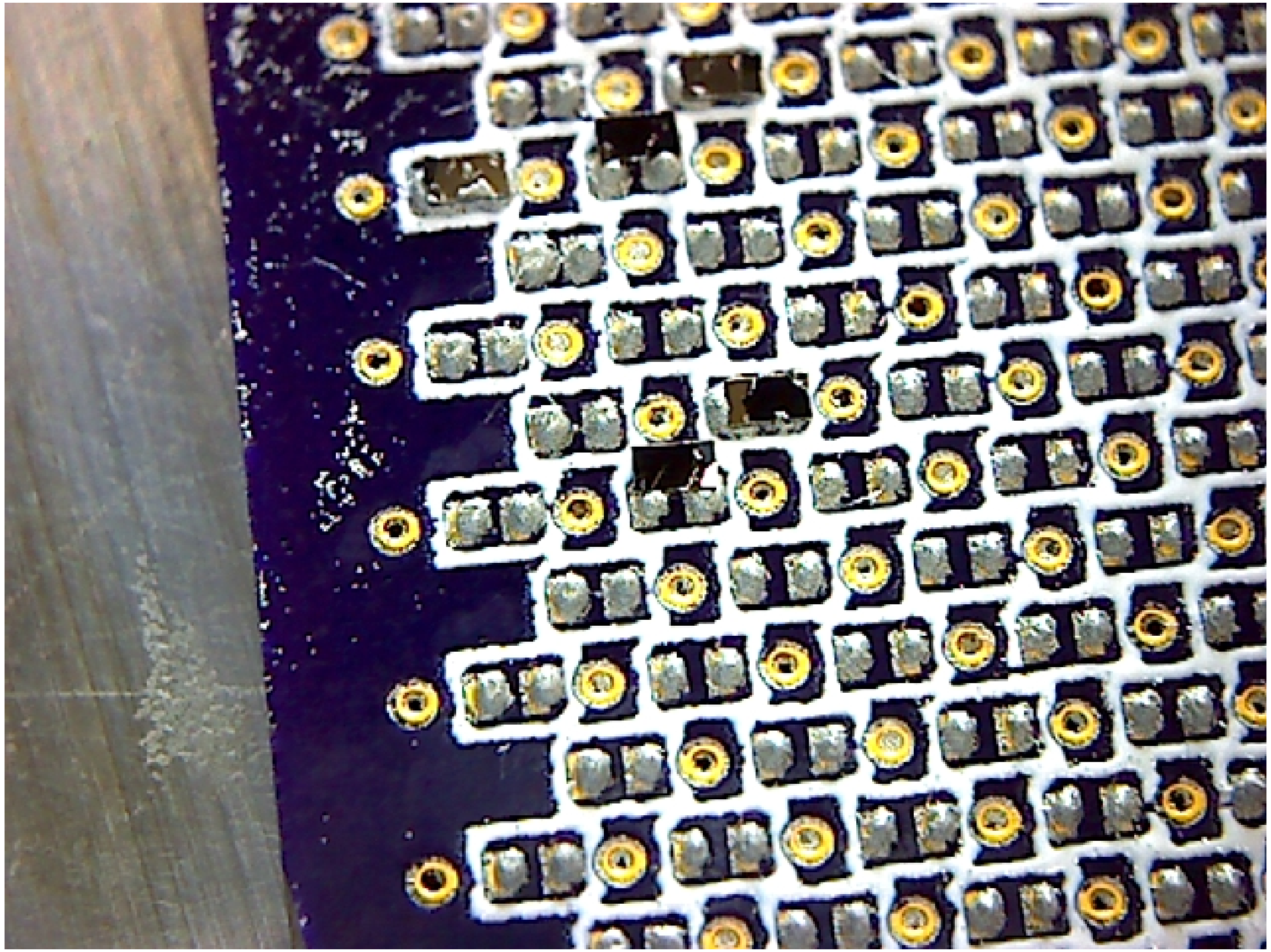
PCB Assembly

- **Step 2: Pick and Place**



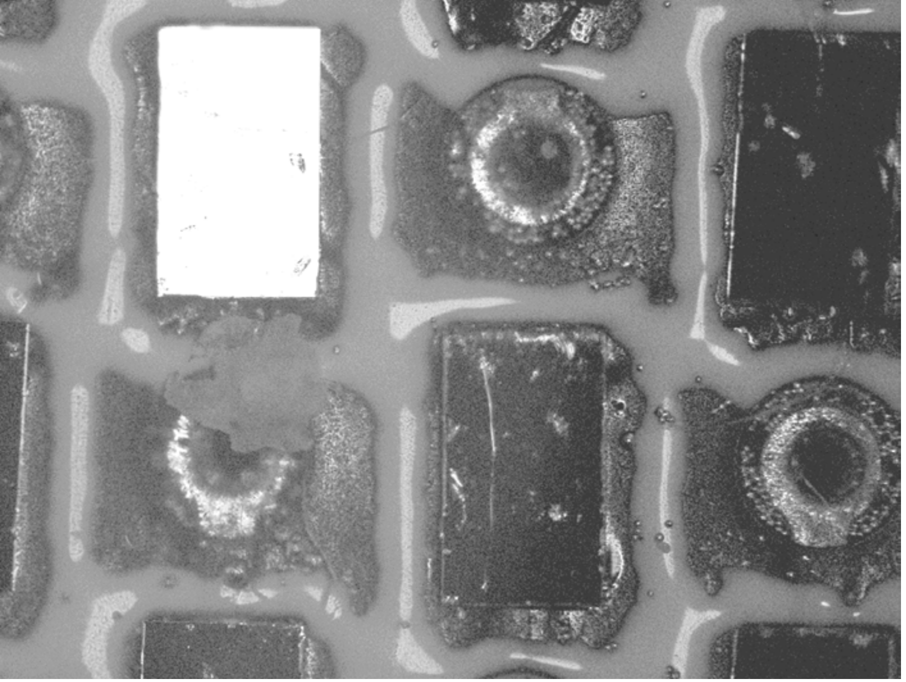
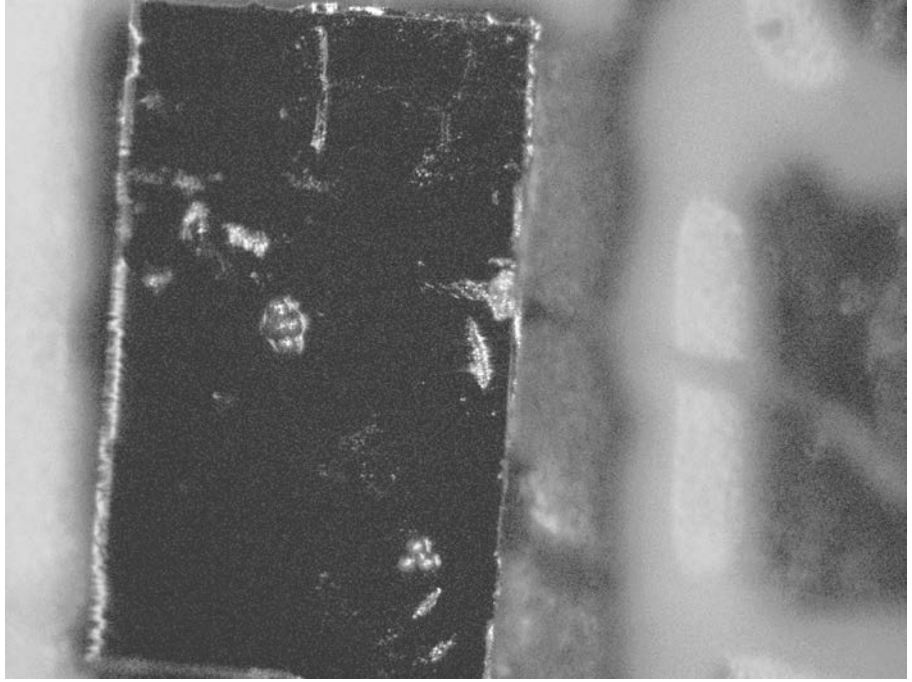
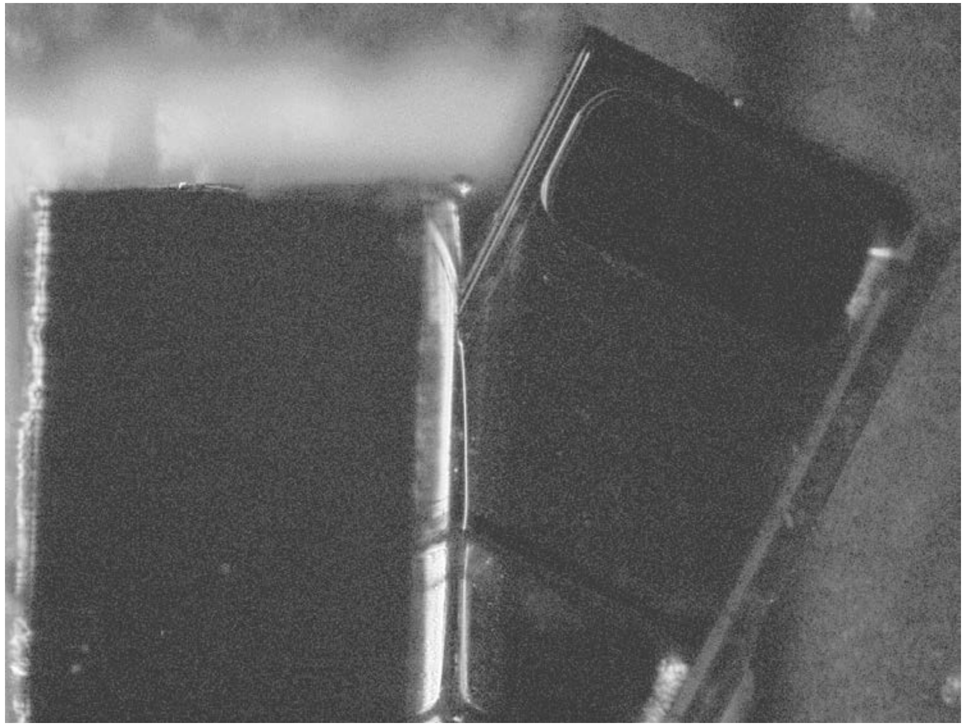
PCB Assembly

- **Step 3: Reflow Soldering**



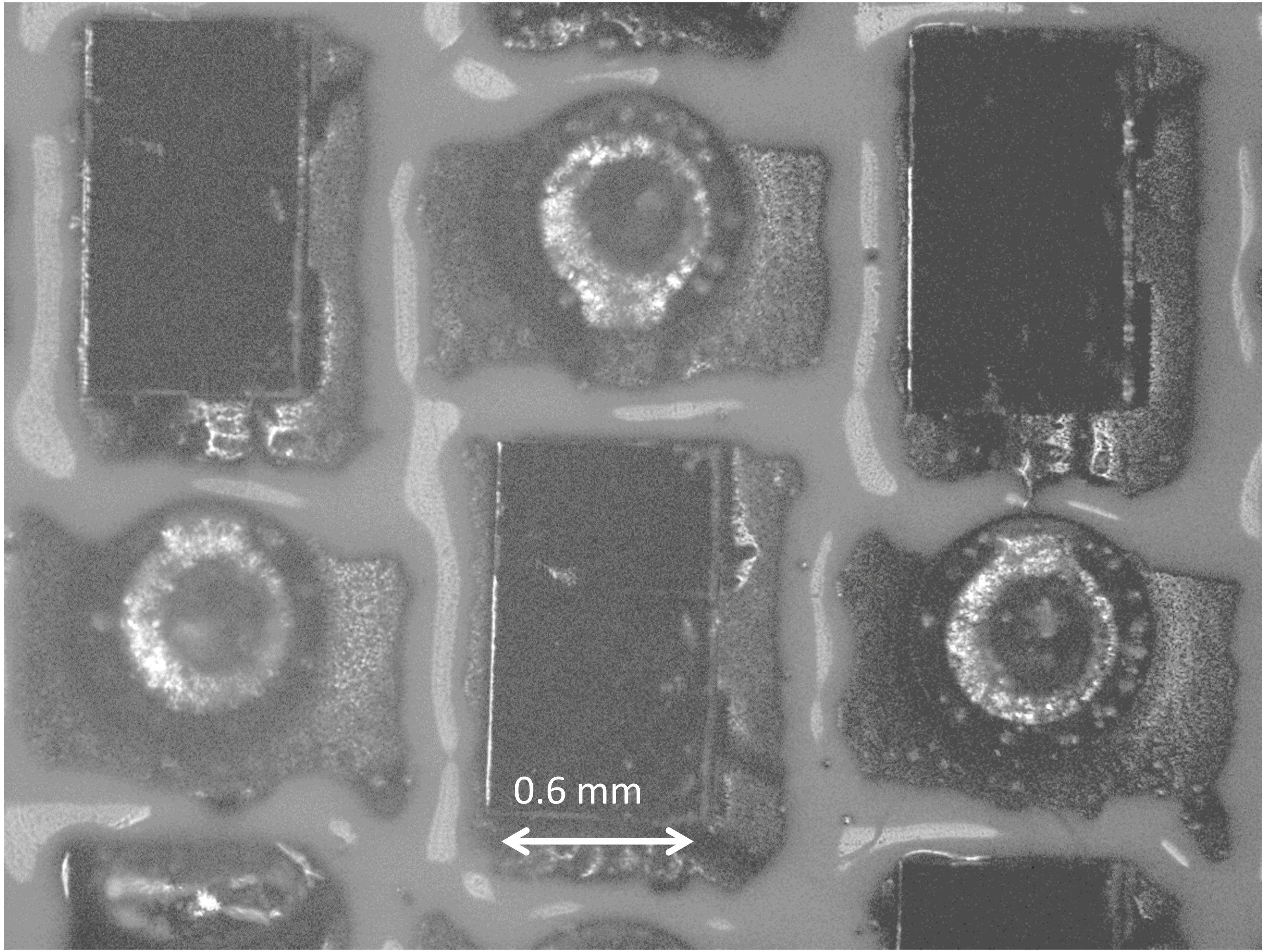
PCB Assembly

- **Step 4: USB Scope Inspection**

PCB Assembly

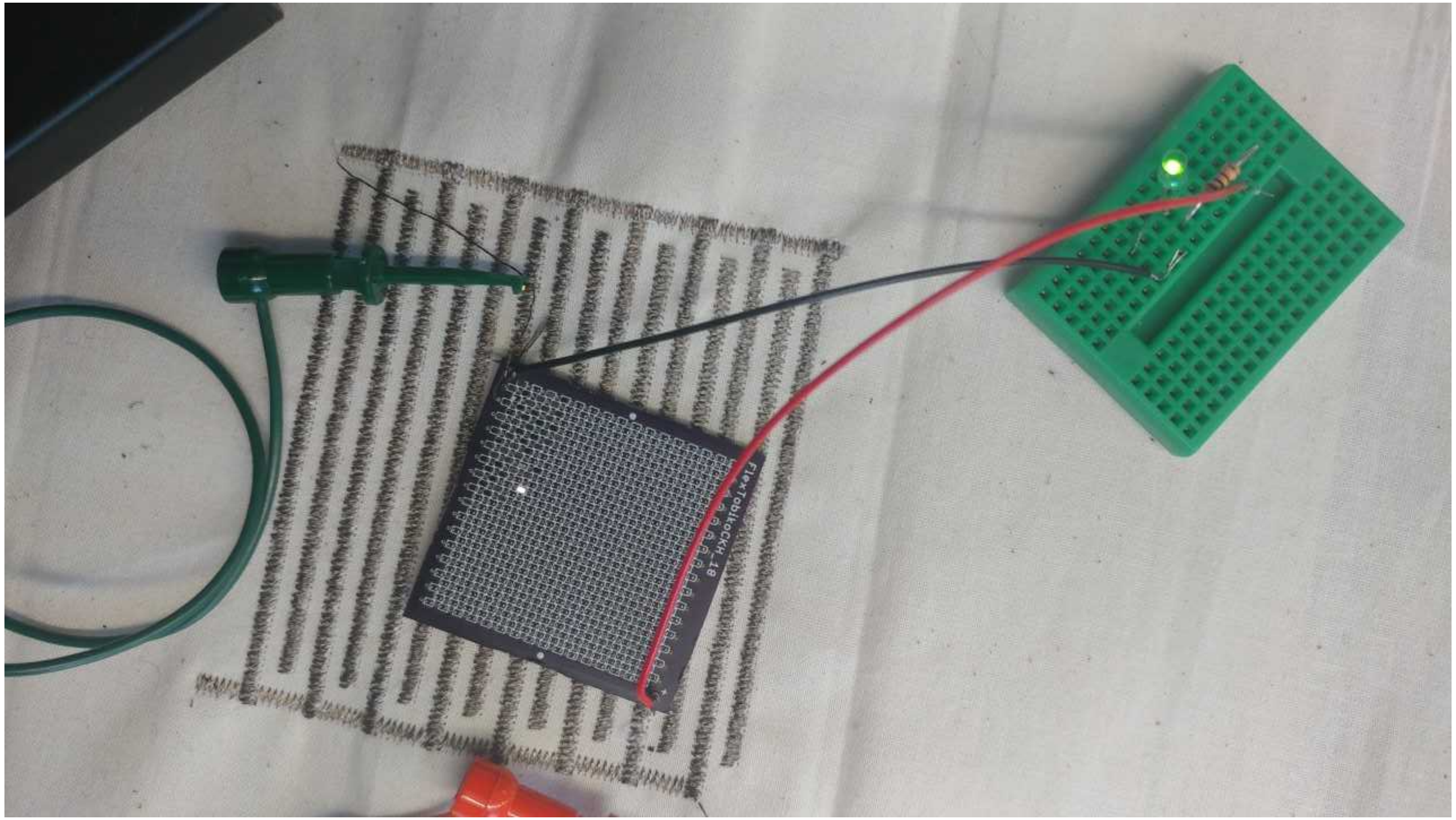
- **Step 4: Microscope Inspection**
- **Bad News!**
- **The 100 micron thick diodes are getting damaged**
- **Slow down!**



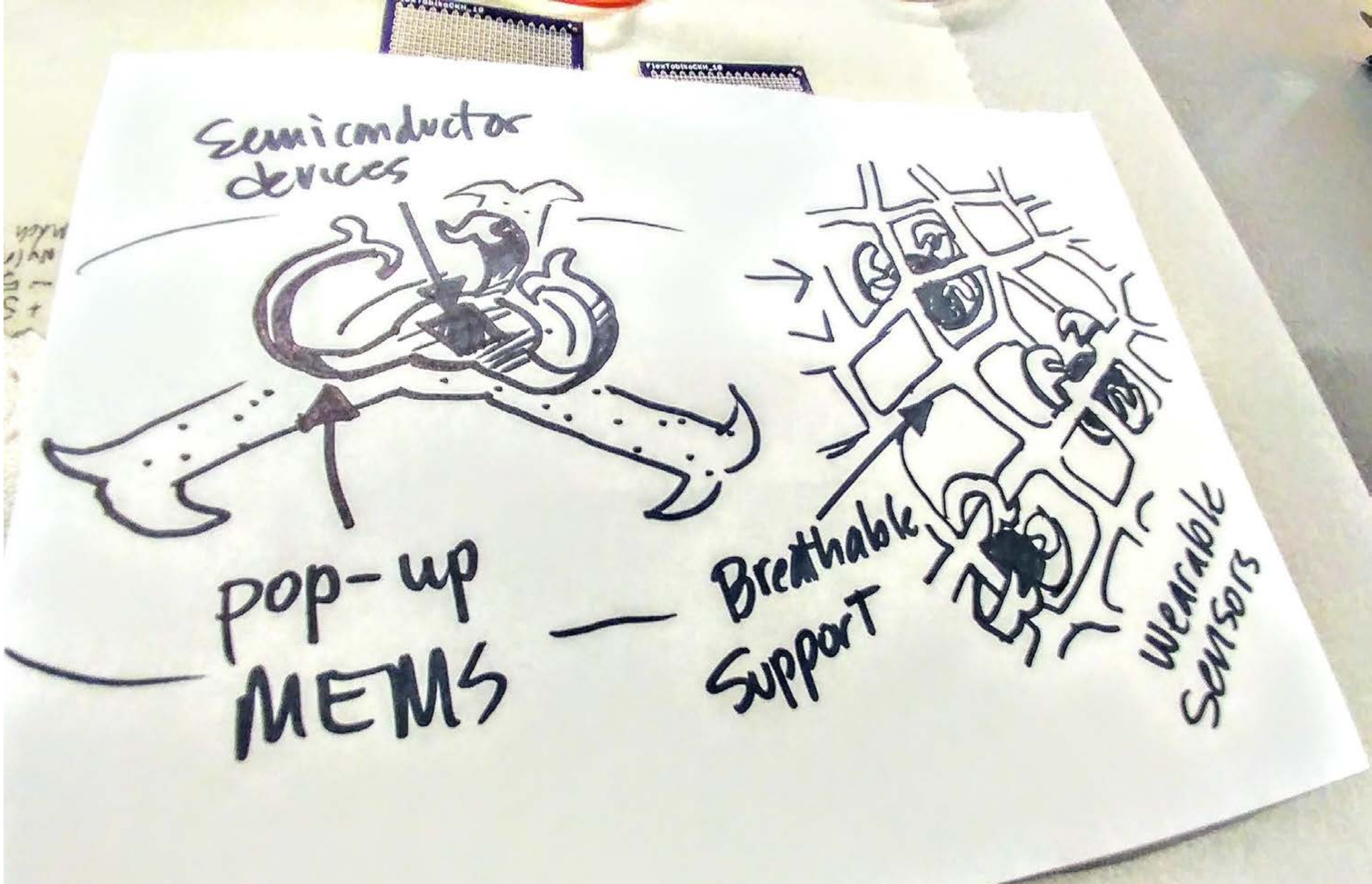
PCB Assembly

- **Step 4: Microscope Inspection**
- **Good News!**
- **Microscale components were transferred to the PCB.**

Result: functional circuit with diode arrays



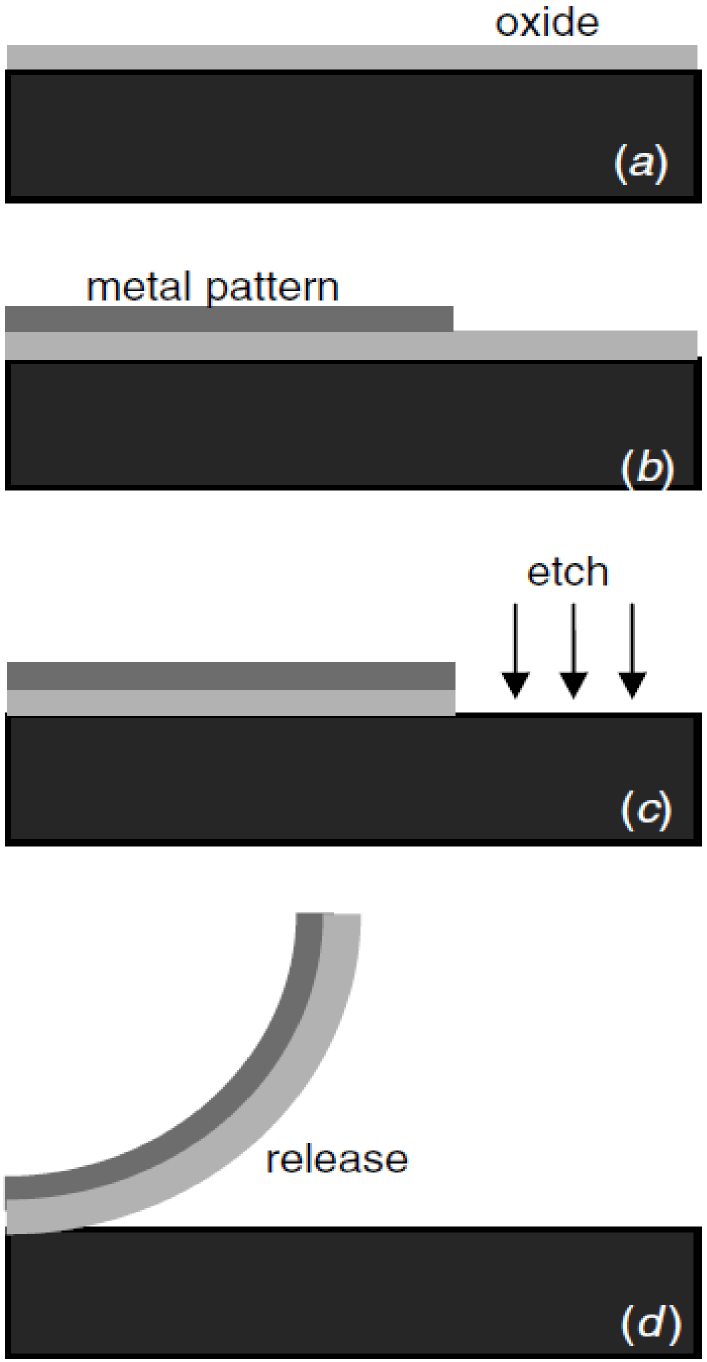
Ultimate Goal:



Use pop-up MEMS to put diode arrays that can detect power in any orientation on flexible surfaces

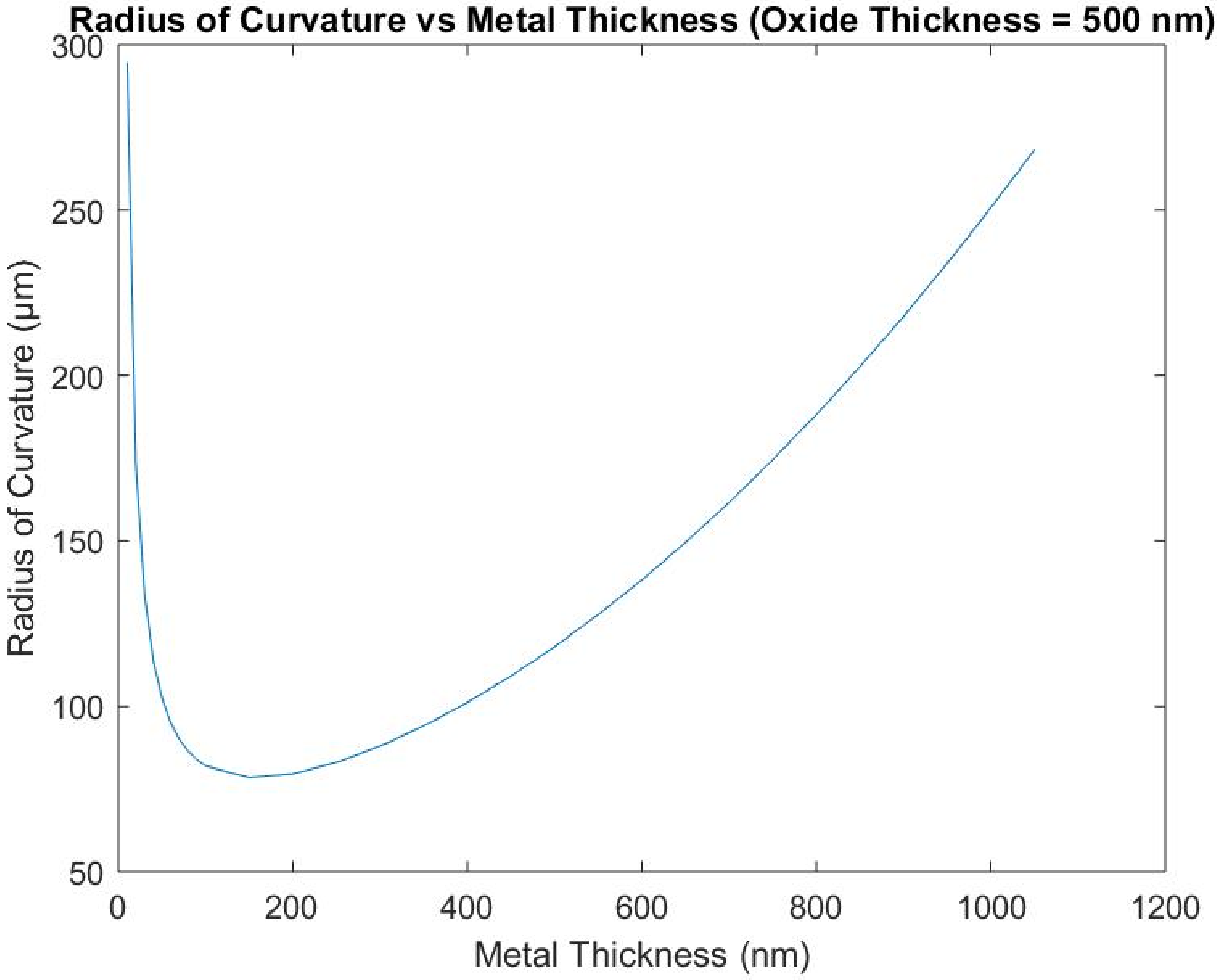
Investigate the “Pop-Up” effect to make grippers that transfer micro-components onto fabric

- (a) Silicon wafer with 400–500 nm thermal oxide.
- (b) A 200–300 nm thick metal pattern is applied using photoresist liftoff.
- (c) The metal acts as an etch mask to pattern the oxide in a CF_4/H_2 plasma etch
- (d) The metal-oxide bimorph is released by etching the silicon in XeF_2 gas. The oxide’s compressive stress is released by curling the bimorph out of the plane.

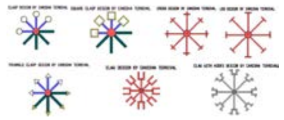


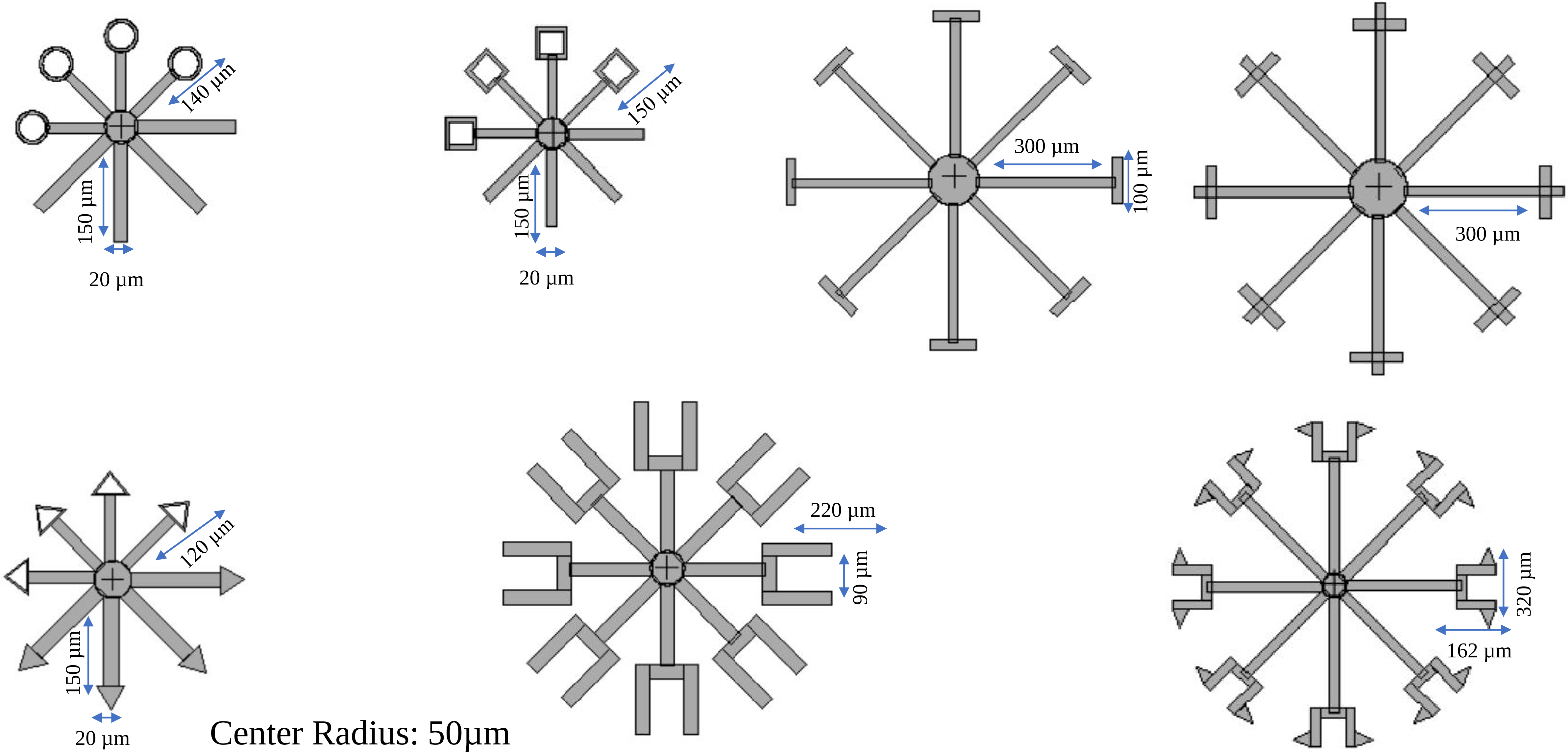
Moiseeva, E., Y. M. Senousy, S. McNamara, and C. K. Harnett. "Single-mask microfabrication of three-dimensional objects from strained bimorphs." Journal of Micromechanics and Microengineering 17, no. 9 (2007): N63.

Radius of curvature depends on the materials' modulus and thickness



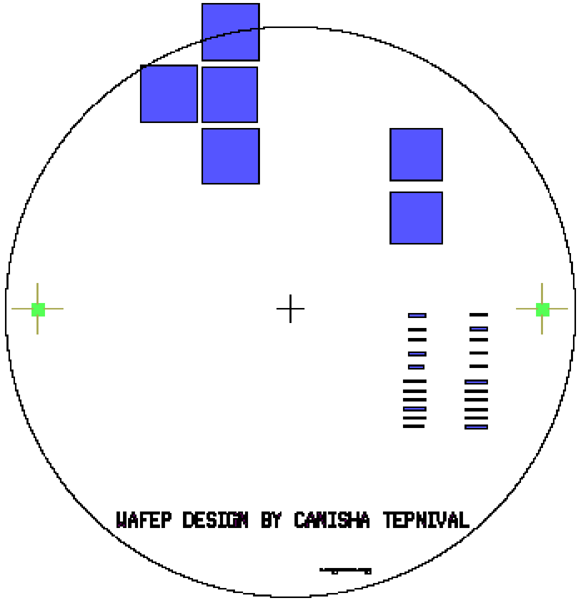
Seven designs via L-Edit, a layout editor



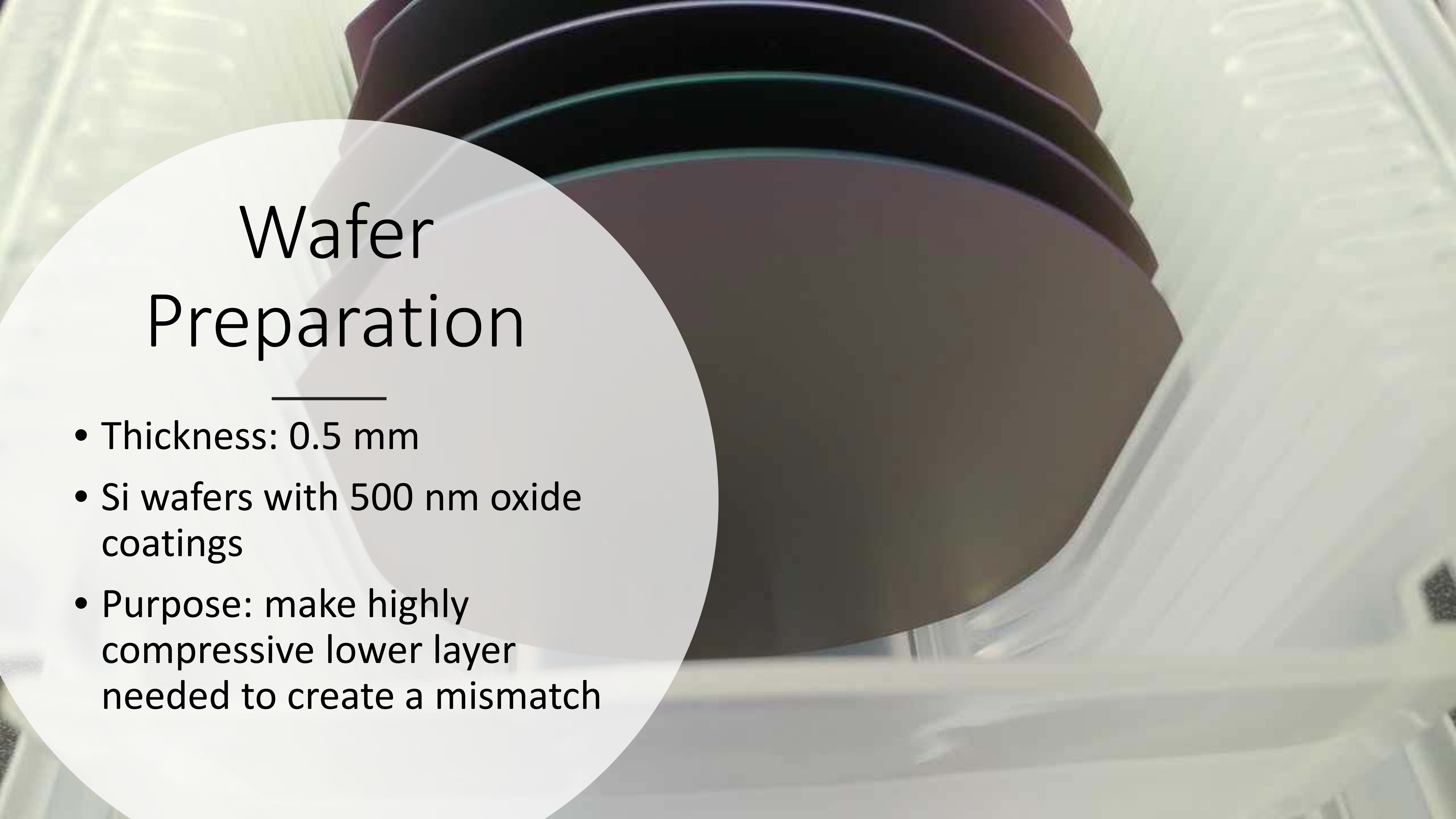


I designed several gripper structures and made a photomask

Before and After

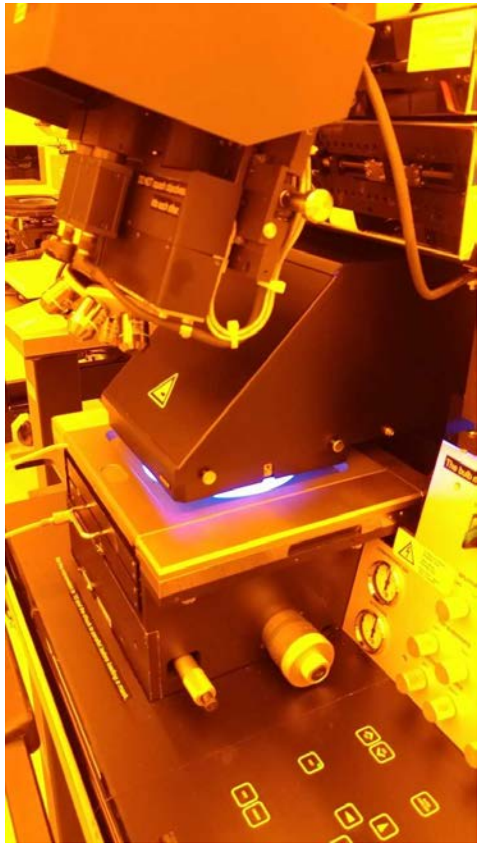


Purpose: master copy for patterning the wafers



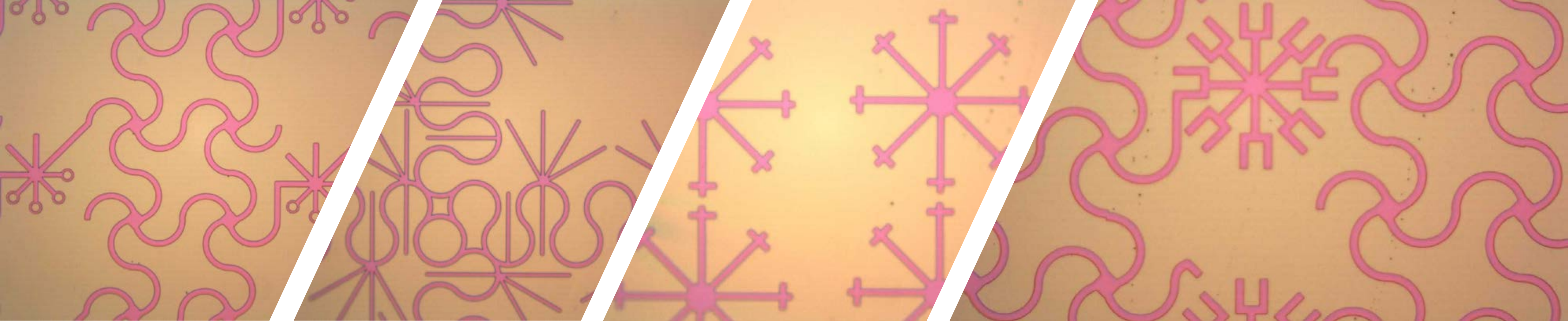
Wafer Preparation

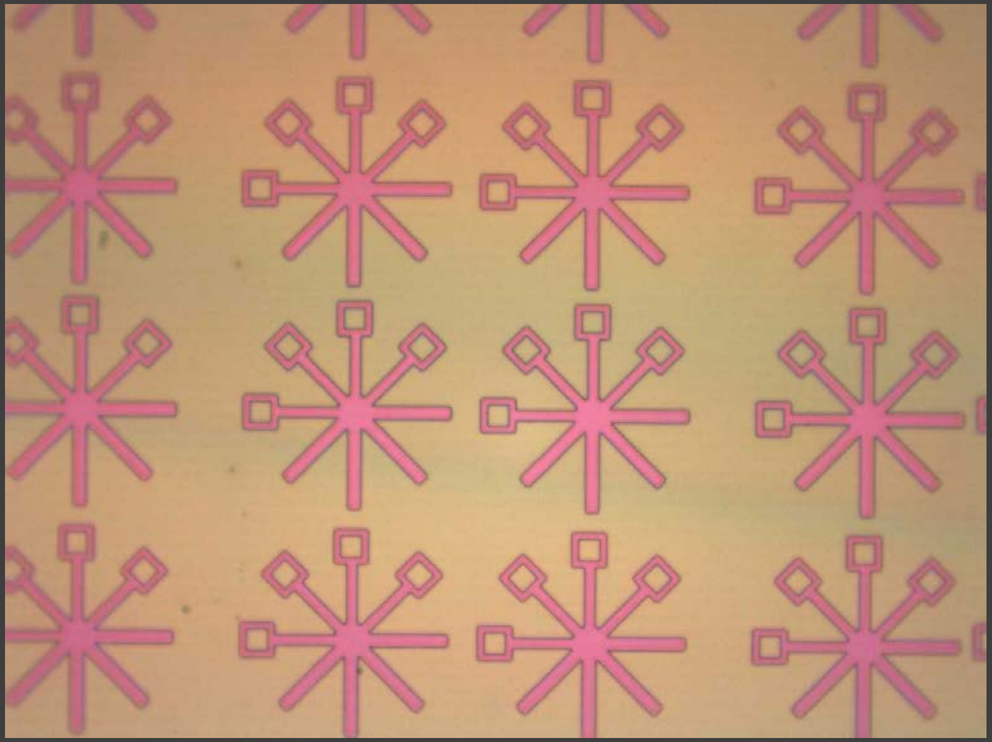
- Thickness: 0.5 mm
- Si wafers with 500 nm oxide coatings
- Purpose: make highly compressive lower layer needed to create a mismatch



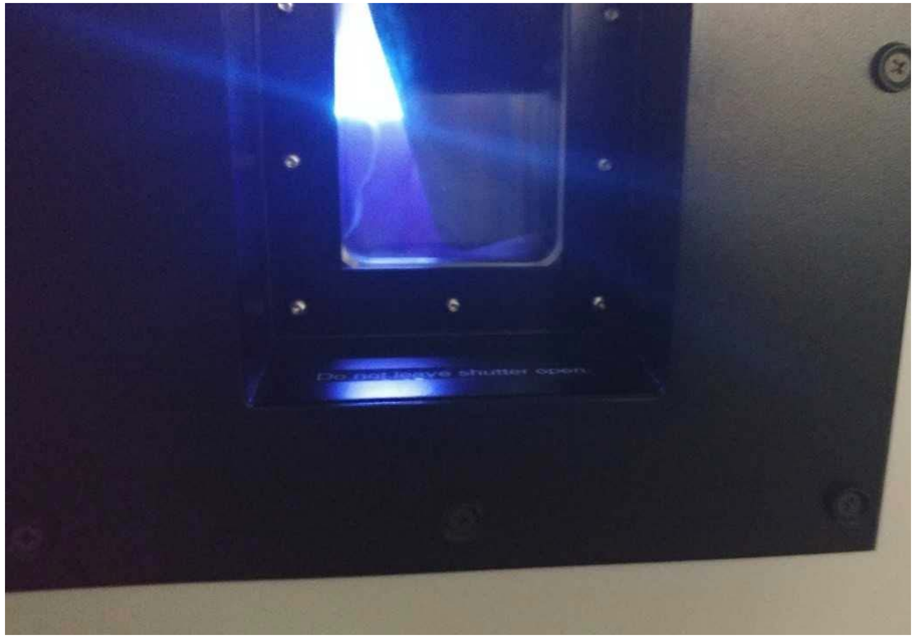
Photolithography

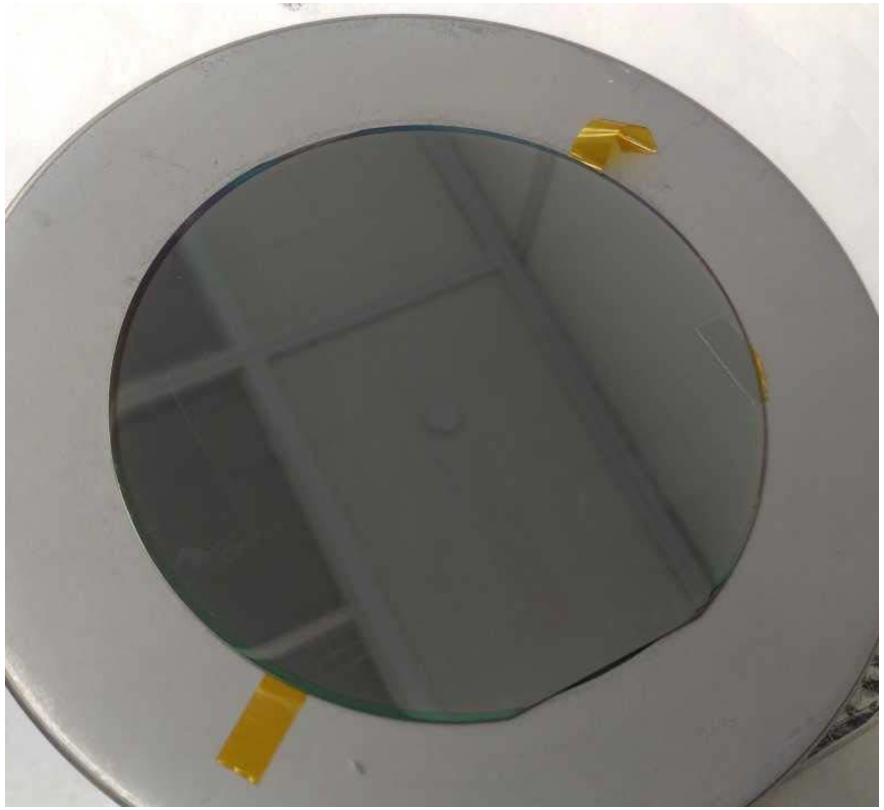
Purpose: pattern wafers





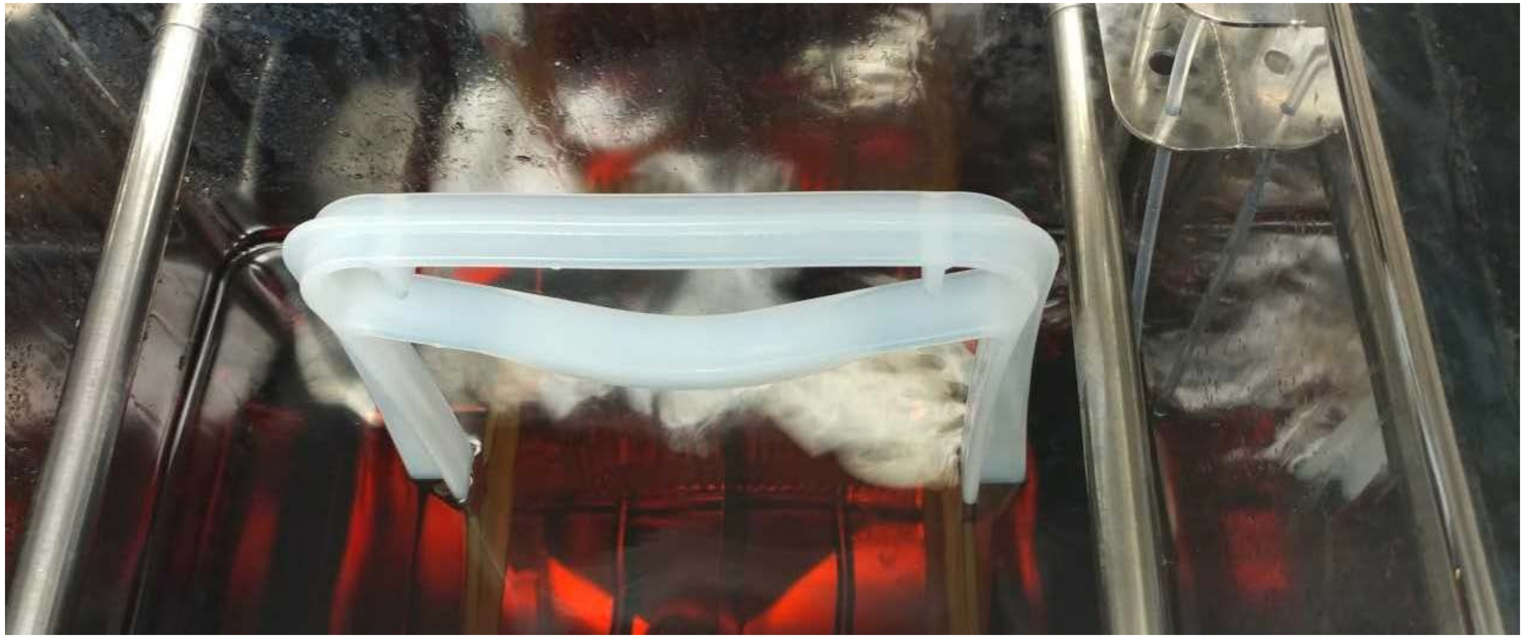
Inspection



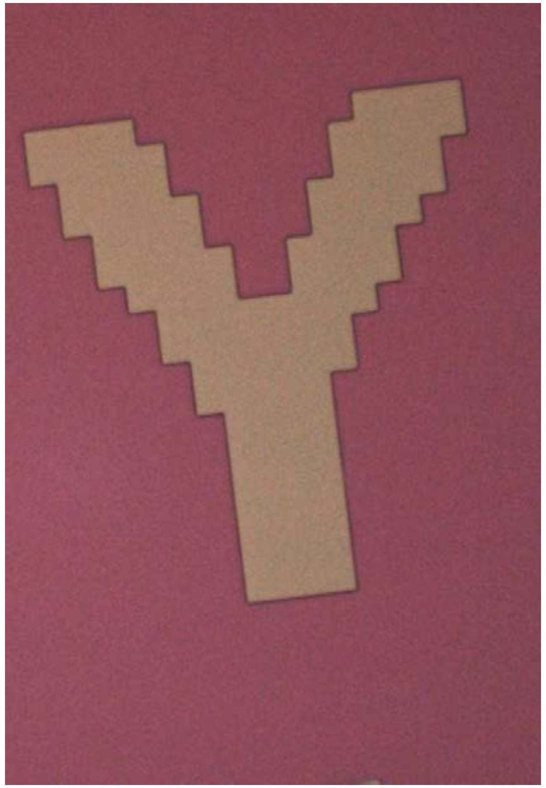


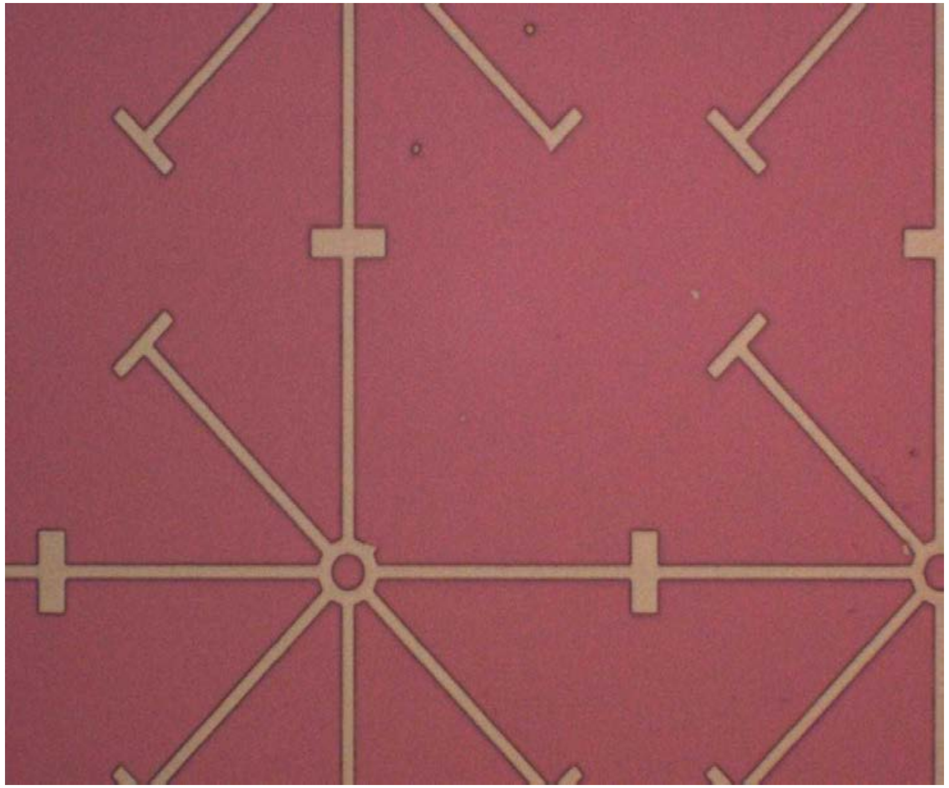
Metal Deposition (Lesker PVD75)

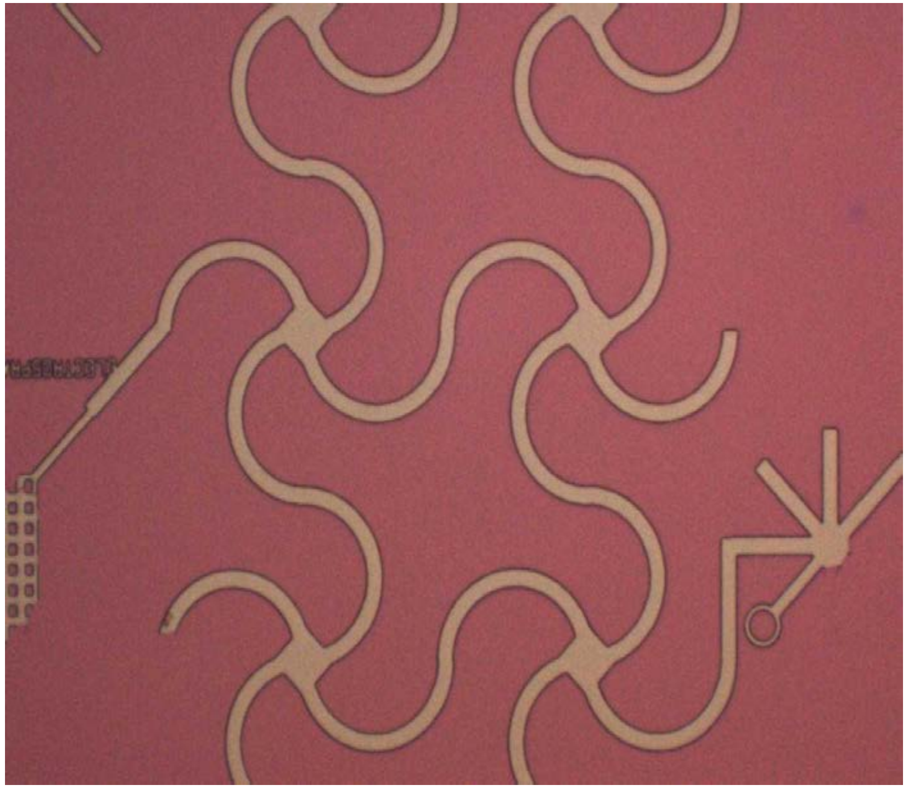
Purpose: make tensile/neutral second layer needed to create a mismatch for release



Liftoff

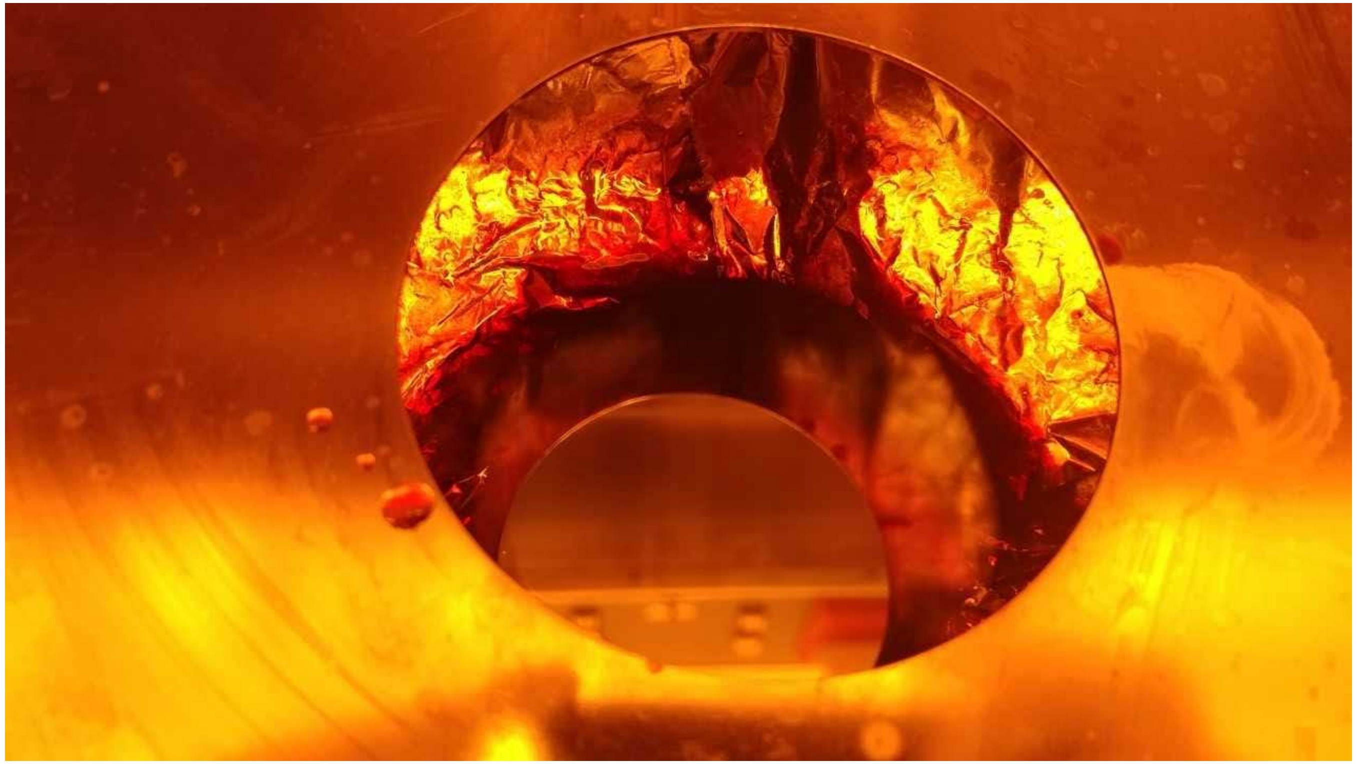


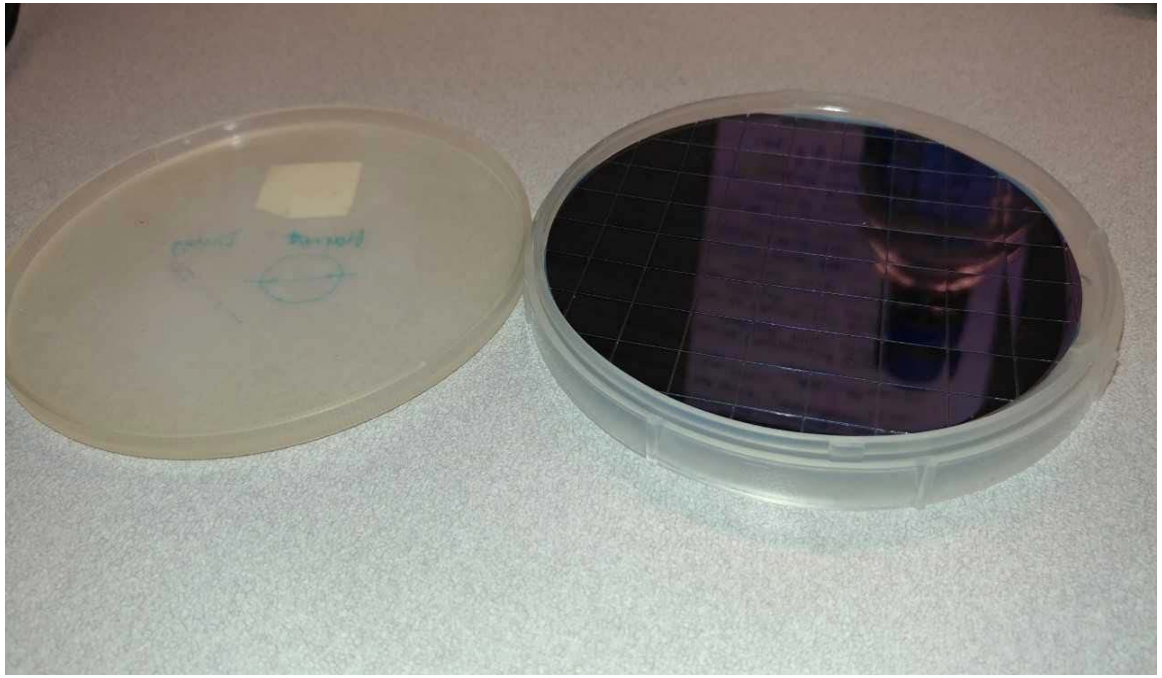


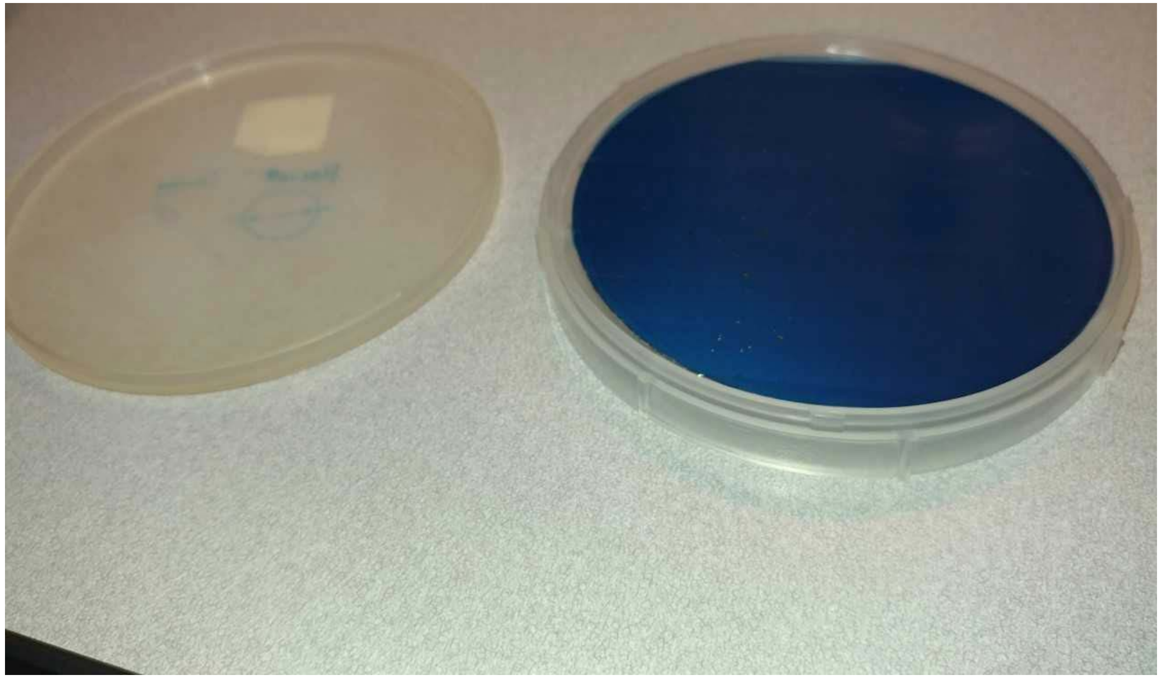


Inspection

Protective Coating of Photoresist





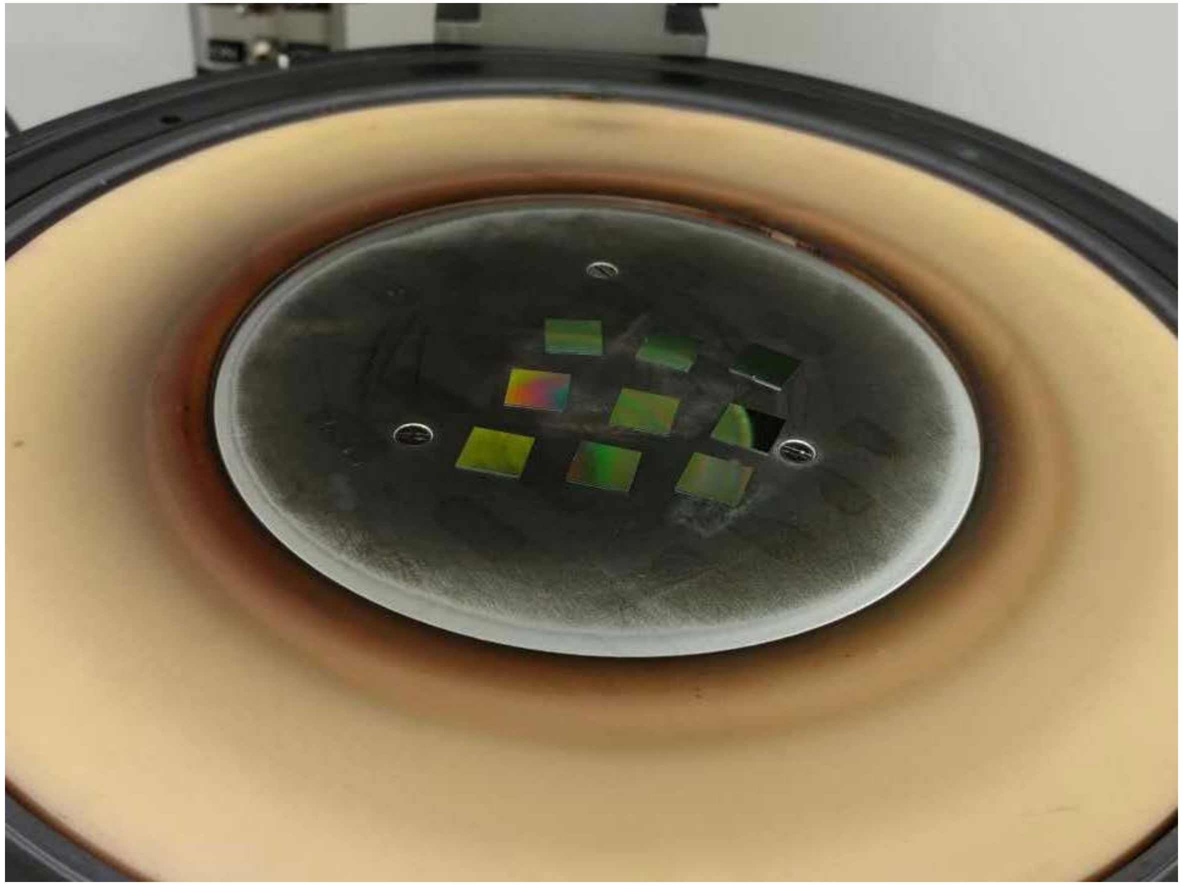


Dicing

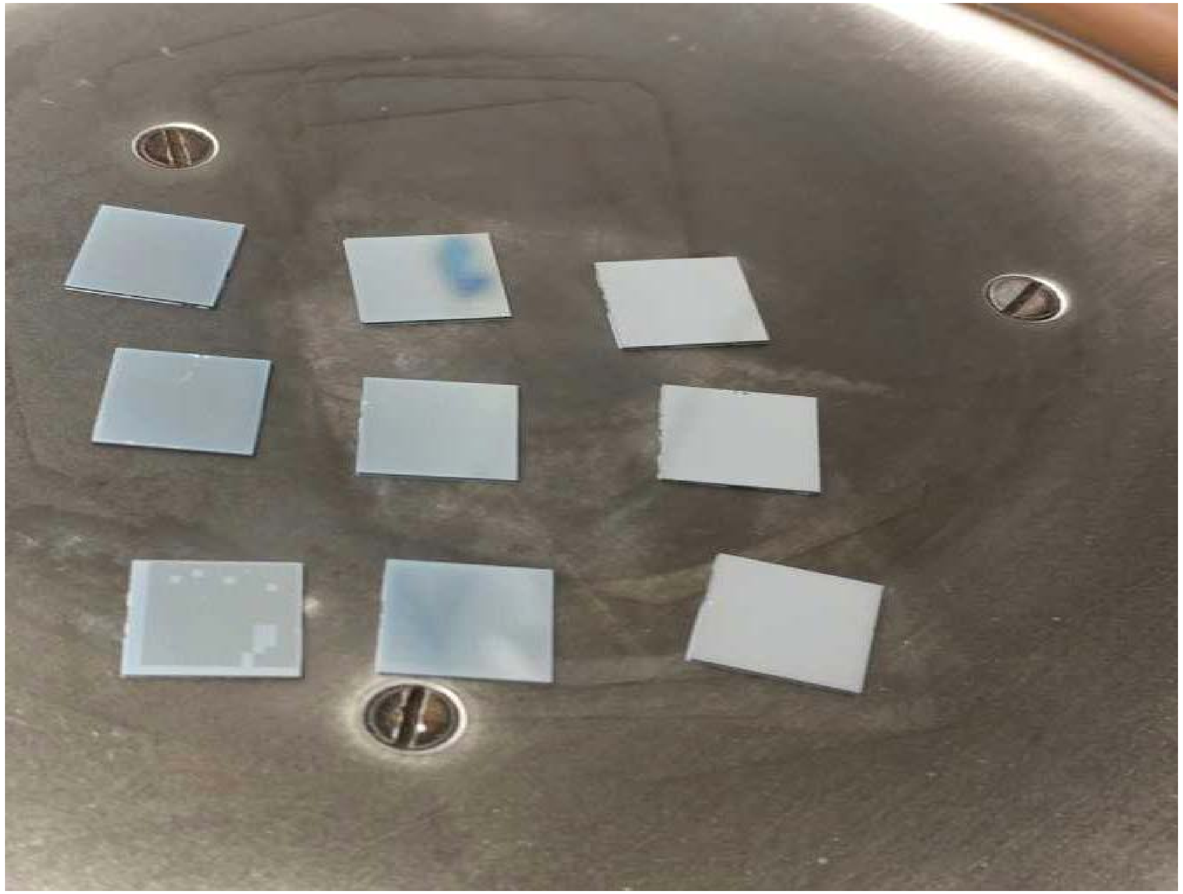
Photoresist Removal

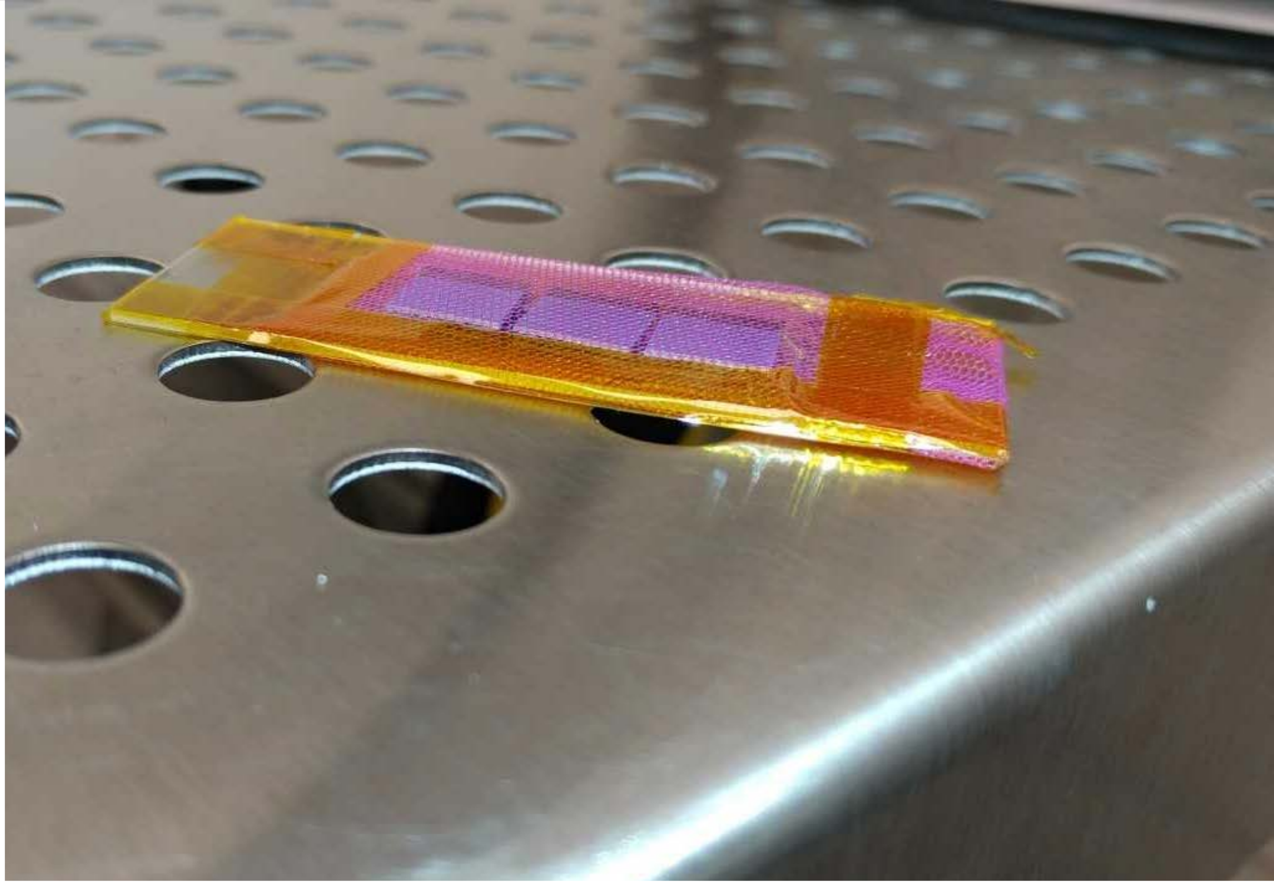
Expose underlying silicon through an oxide etch

Before



After



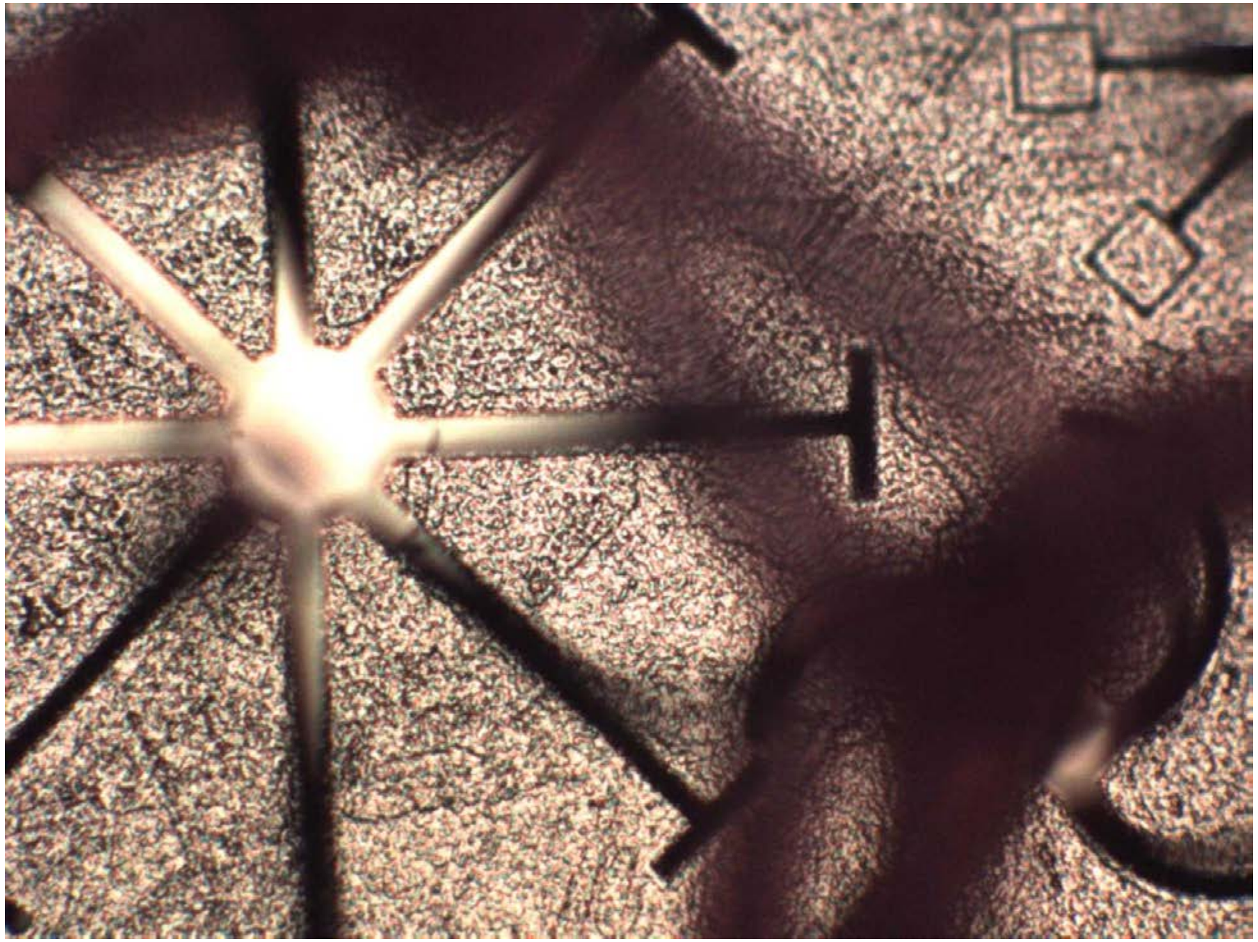


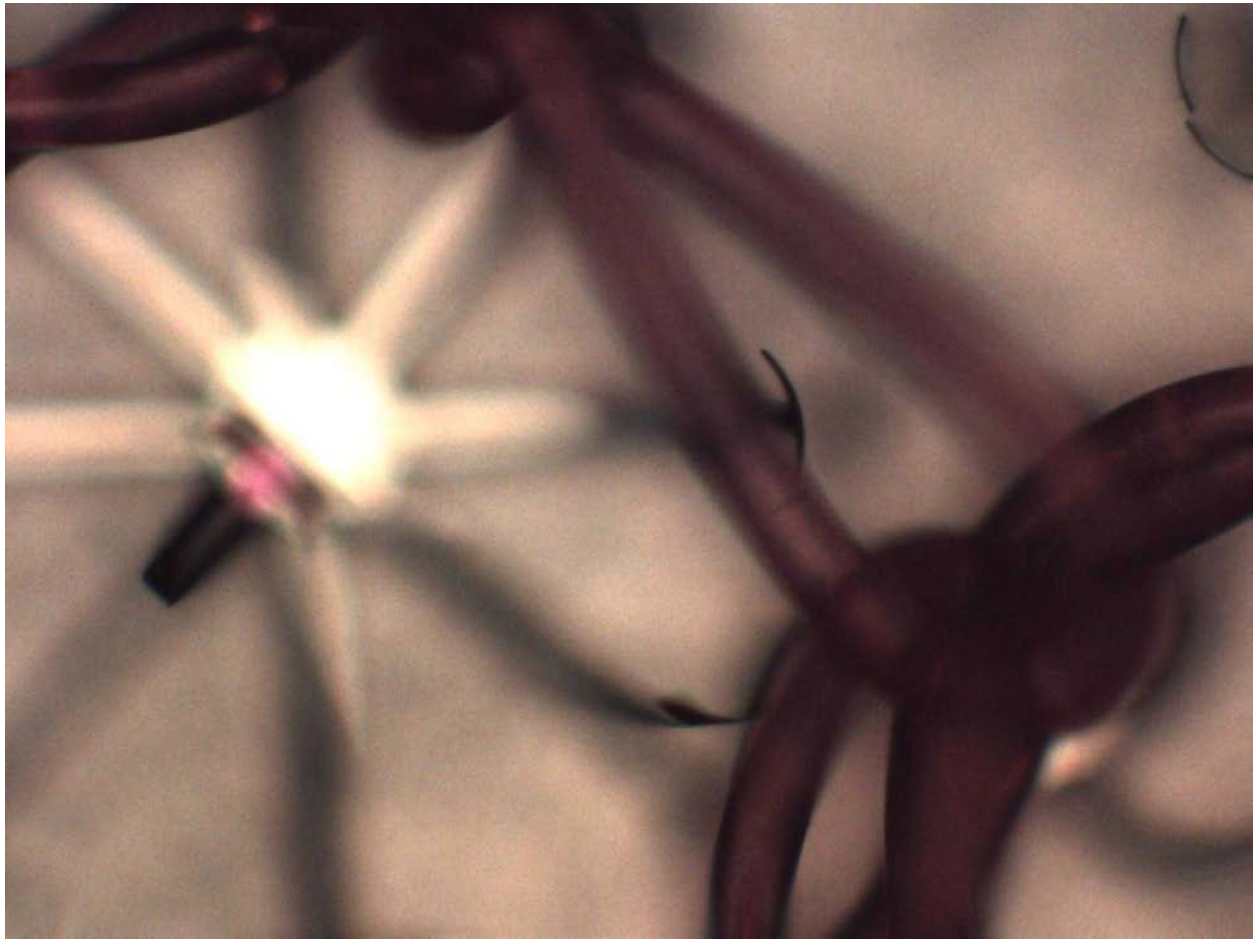
XeF2 Etching Preparation: mesh fabric is stretched over the unreleased devices

XeF2 etching under fabric (Xactix Machine)

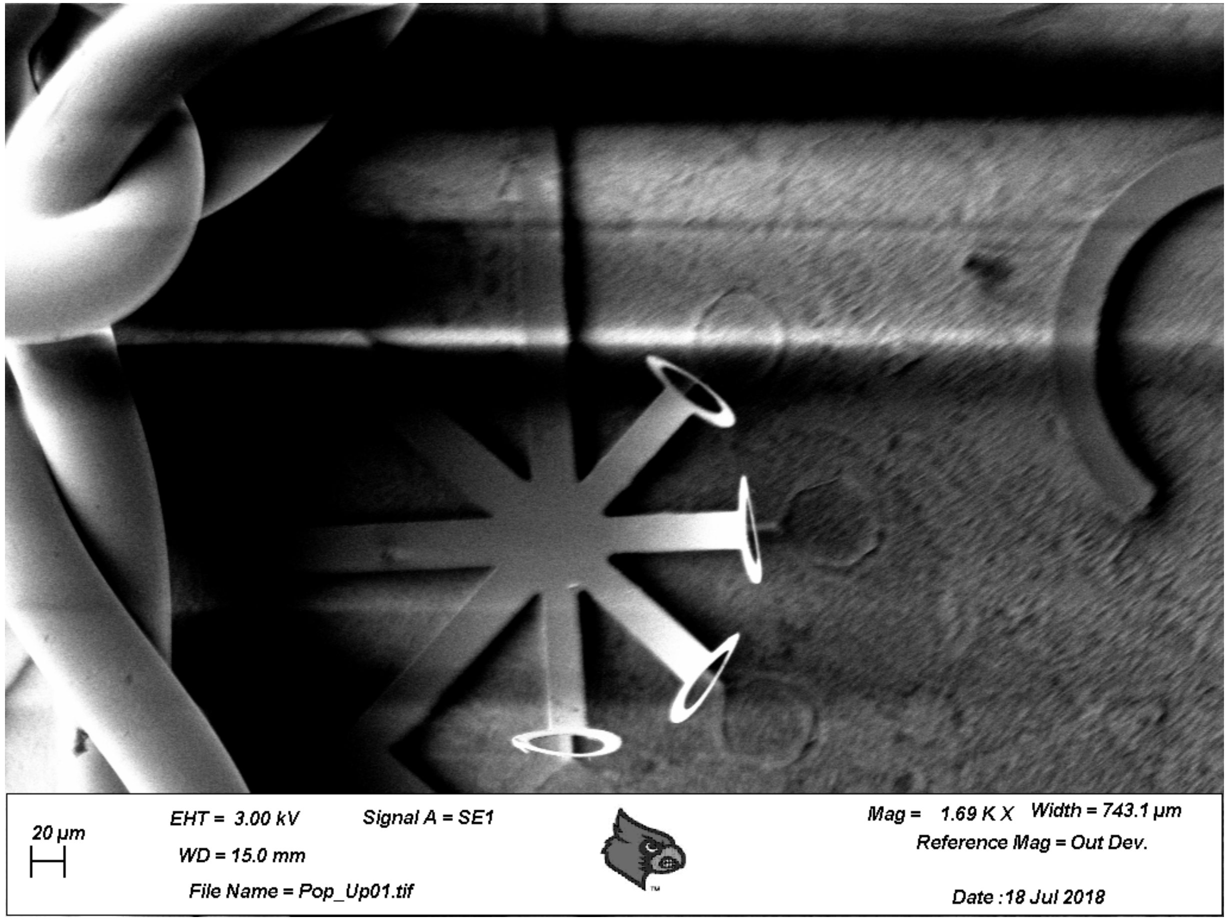
Purpose: release bimorphs by relieving the compressive stress in the oxide

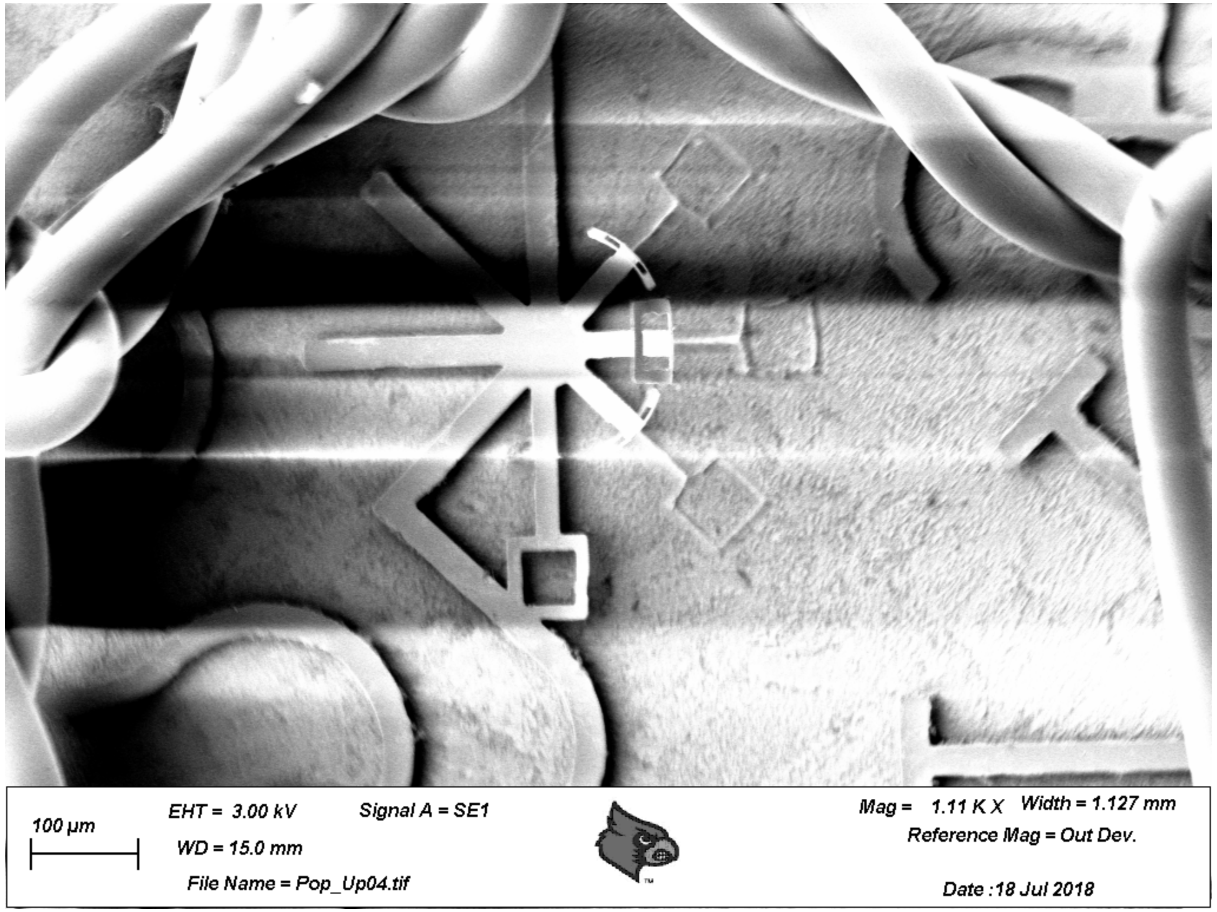
Post-20 Cycles





Post-20 Cycles

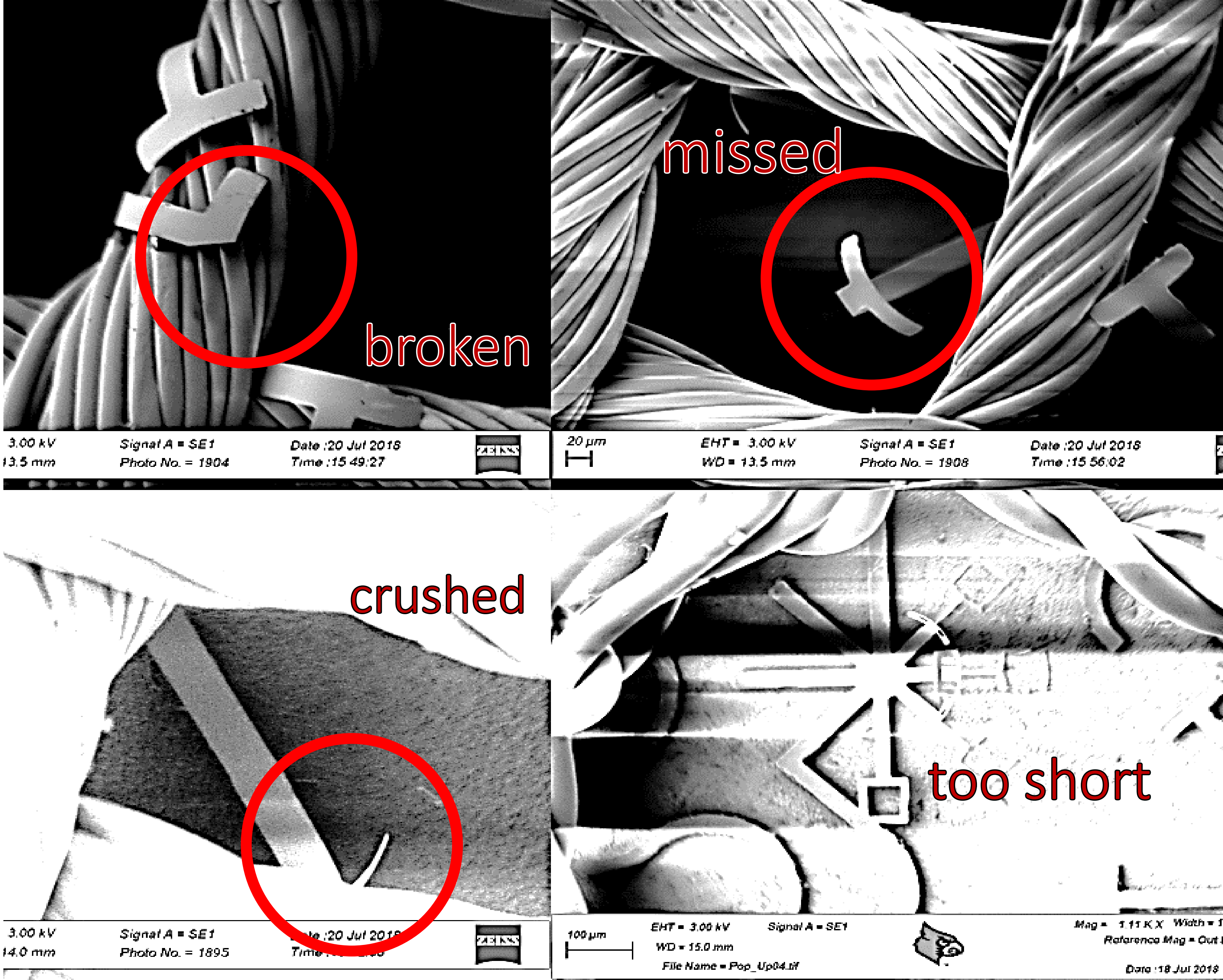




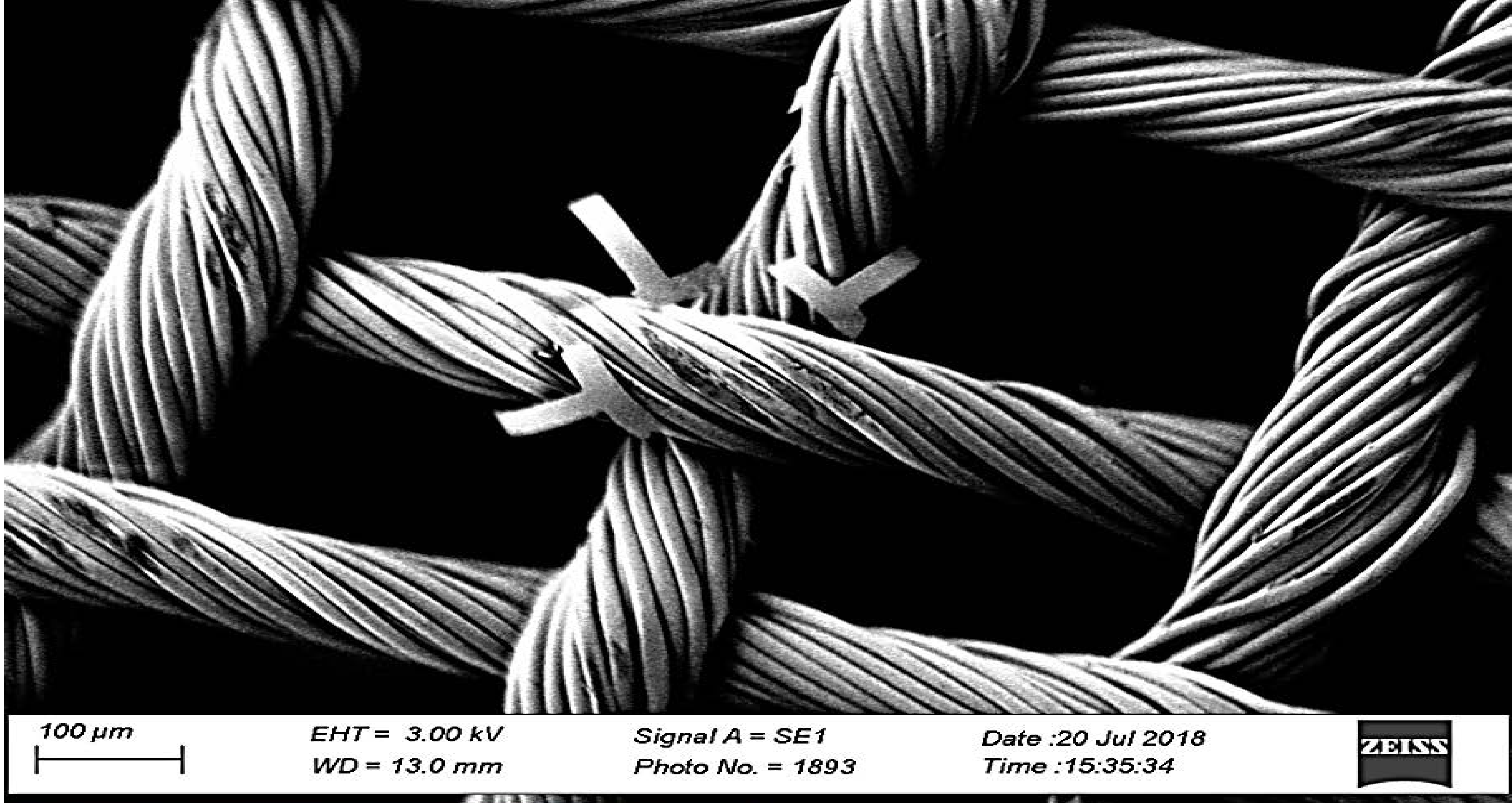
Calculated radius of curvature: 81.96 µm

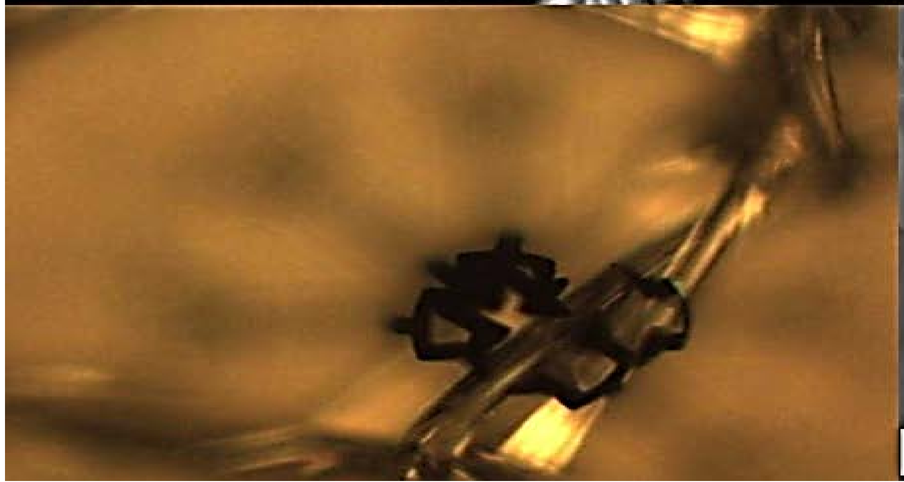
Measured radius of curvature: 86.67 µm

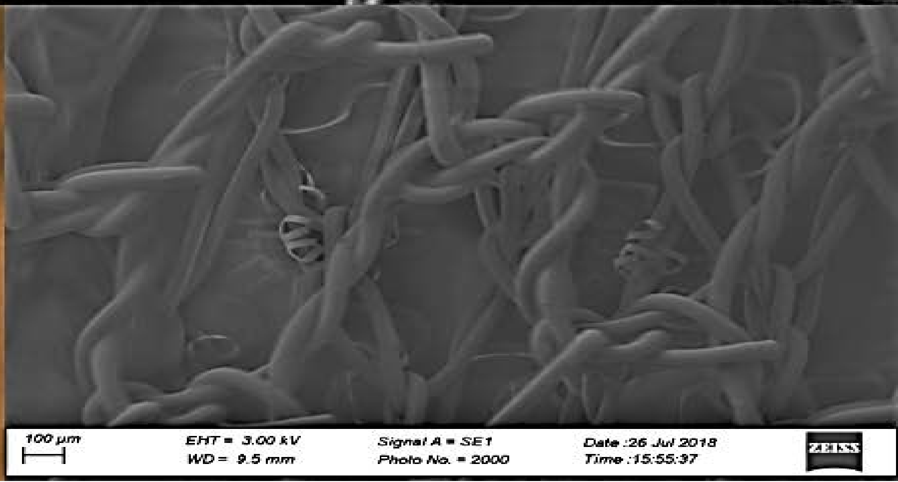
Post-40 Cycles Issues



Post-40 Cycles Successes







Acknowledgements

- We thank the National Science Foundation (award number 1560235) for funding our work.
- We thank FirstBuild's Senior Electronic Design Engineer Tim Gillespie for help with PCB assembly, and the staff in the University of Louisville cleanroom, Julia W. Aebersold, Curtis P. McKenna, Evgeniya Moiseeva, and Jasmin Beharic, for microfabrication support.

Q & A