THERMAL CONDUCTIVITY MEASUREMENT OF POLYMER FIBERS USING THE FOUR-PROBE METHOD

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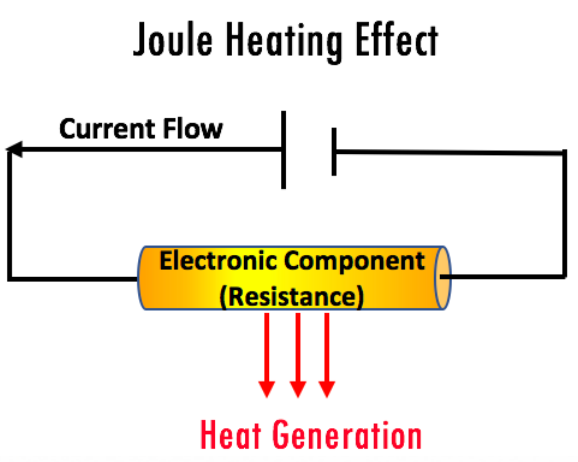
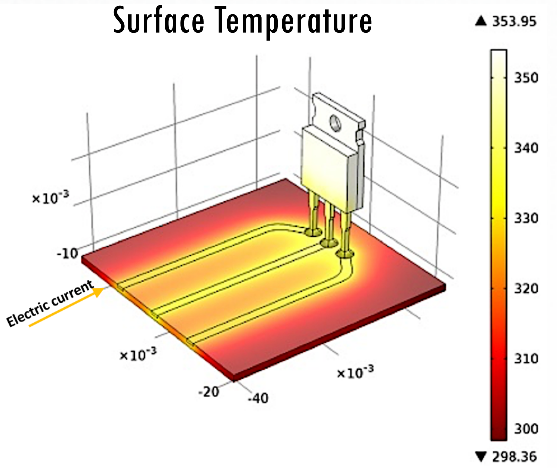
INTRODUCTION

Electronic components rely on the passage of current to operate. Since current flow through a resistance is accompanied by **heat generation**, these components become potential sites for excessive heating which can cause them to fail.

It's very desirable to develop devices made from materials that efficiently **control heat flow** to protect heat sensitive components.

Laptop or Desktop Overheating Service - Computer Fan Repair. (n.d.). Retrieved from http://icomputerdenver.com/computer-fan-overheating-and-power-down-problems/





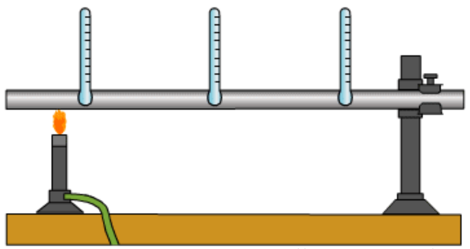
COMSOL Multiphysics©. (2017). *Power Transistors and Heat Transfer | COMSOL Blog*. [online] Available at: https://www.comsol.com/blogs/power-transistors-and-heat-transfer/.

INTRODUCTION: THERMAL CONDUCTIVITY

How do we know how much heat travels within a material?

$$q_x\hat{\imath} + q_y\hat{\jmath} + q_z\hat{k} = -\boldsymbol{k}\left(\frac{\partial T}{\partial x}\hat{\imath} + \frac{\partial T}{\partial y}\hat{\jmath} + \frac{\partial T}{\partial z}\hat{k}\right)$$

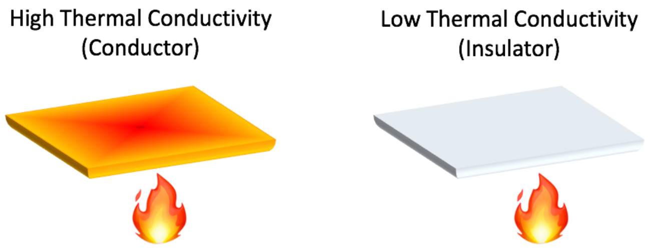
$$\boxed{\vec{q} = -\boldsymbol{k}\vec{\nabla}T}$$



Conduction. (n.d.). Retrieved June 28, 2017, from http://www.physicslovers.com/energy/conduction

Thermal conductivity measures the ability of a material to conduct heat.

Heat transfer occurs at a higher rate across materials of high thermal conductivity than those of low thermal conductivity.

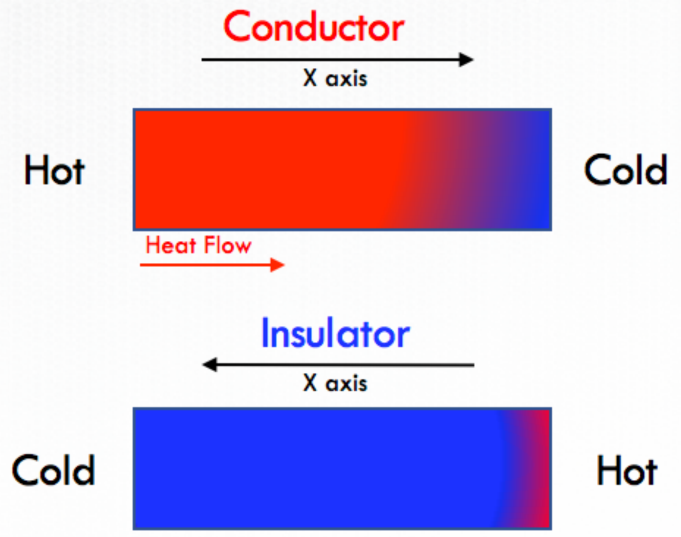


INTRODUCTION: THERMAL RECTIFICATION

Can you imagine a material that's able to control the heat flux along a specific axis, having a higher thermal conductivity value in one direction and at the same time insulate in the opposite direction?

Thermal rectifiers exhibit these properties.

Thermal rectification is a phenomenon in which heat flow along a specific axis is preferred in one direction than in the other.



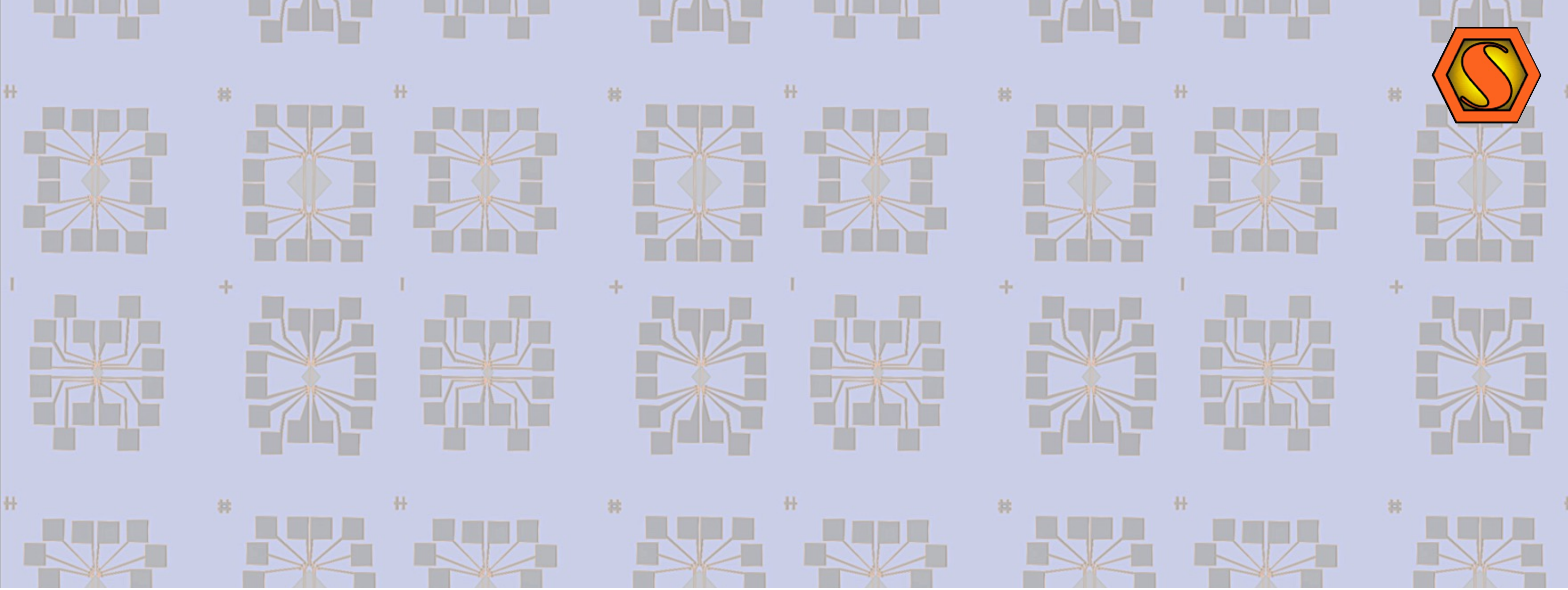
INTRODUCTION: OBJECTIVES

Main

Investigate if a polymer fiber synthesized by Prof. Wudl's group exhibits thermal rectification properties.

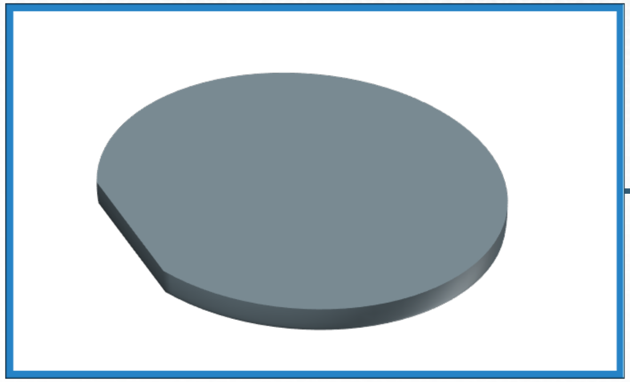
Specific

- Fabricate a thermal conductivity measuring device with four suspended heater lines.
- Measure the thermal conductivity a polymer fiber synthesized by Prof. Wudl's group.

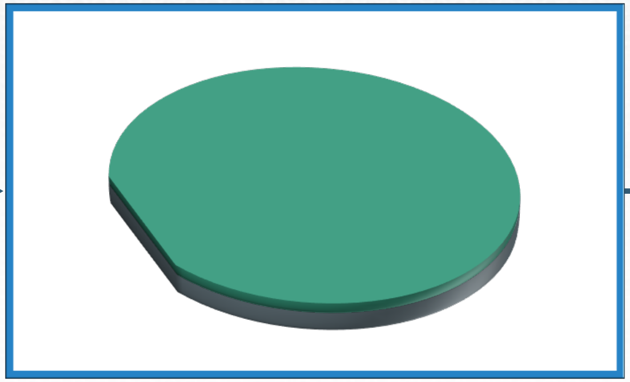


FABRICATION PROCESS OF OUR THERMAL CONDUCTIVITY MEASURING DEVICE

FABRICATION PROCESS: DEPOSITION STEPS

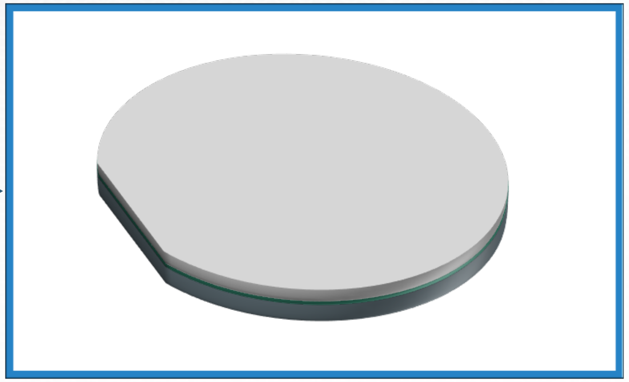


Silicon wafer



400nm Si_3N_4

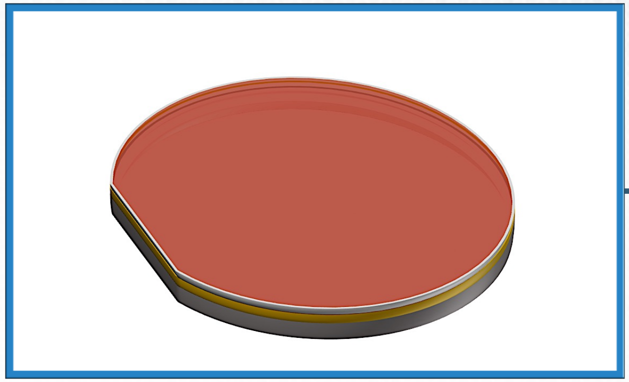
Tool: Nitride Furnace

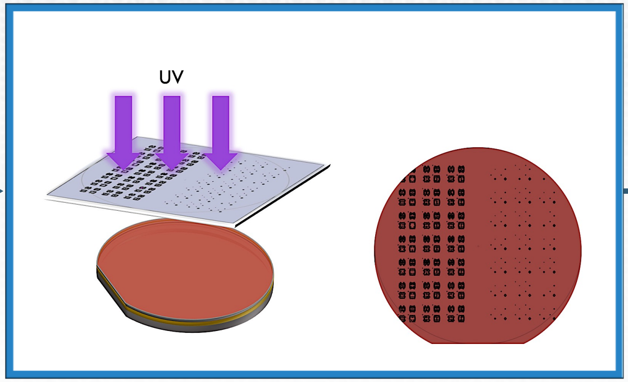


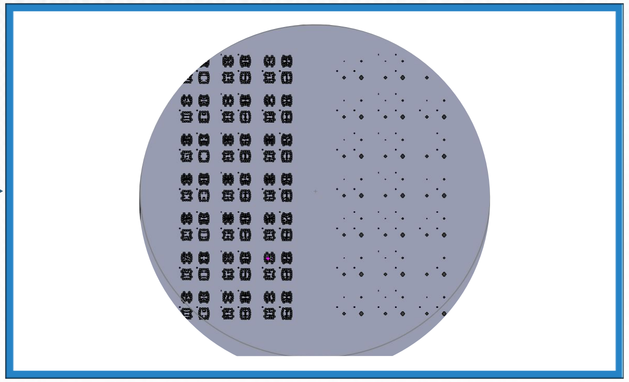
10nm Titanium and 60nm Platinum

Tool: Denton Explorer E-beam Evaporator

FABRICATION PROCESS: PHOTOLITHOGRAPHY







2 µm negative photoresist NR-1500 PY

Tool: SCS G3P8 Spin Coater 1

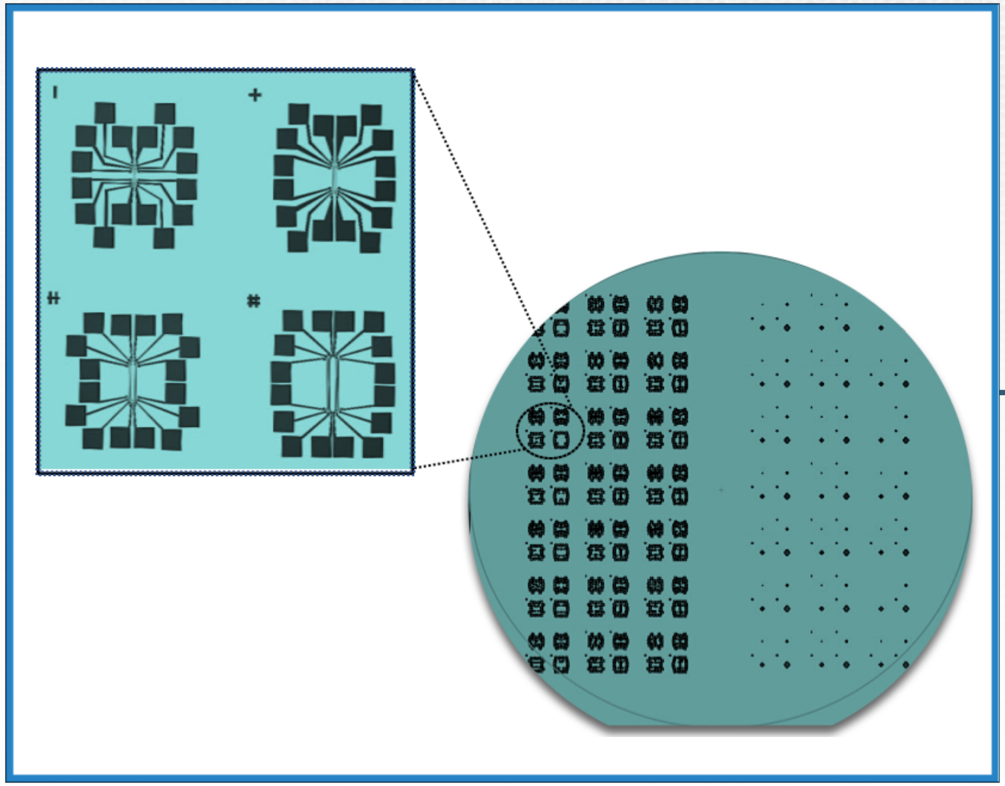
UV light shines on the sample

Tool: Karl Suss MA-6 Mask Aligner

Develop photoresist with RD-6

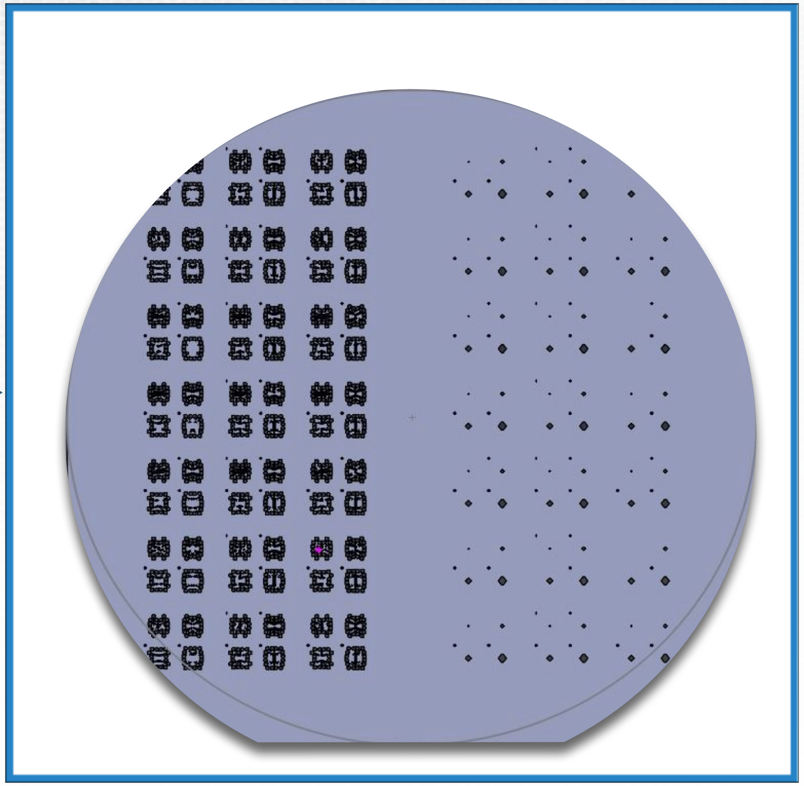
Picture provided by Dr. Yee's research group

FABRICATION PROCESS: ICP ETCHING



Platinum is etched

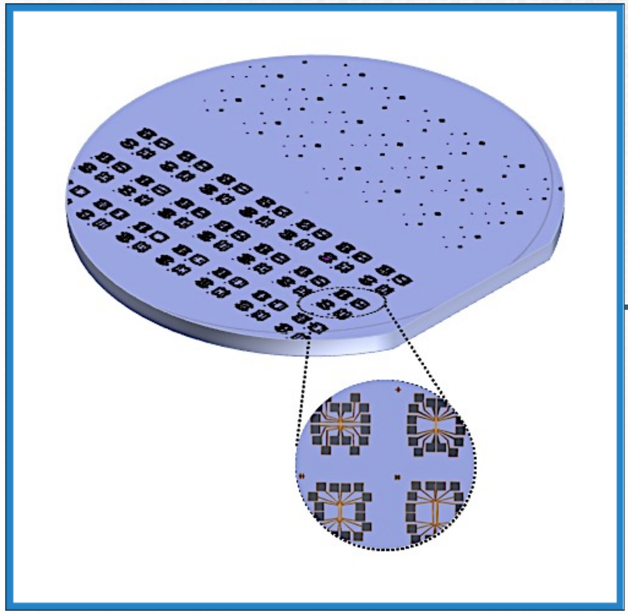
Tool: Plasma Therm ICP



Silicon Nitride is etched

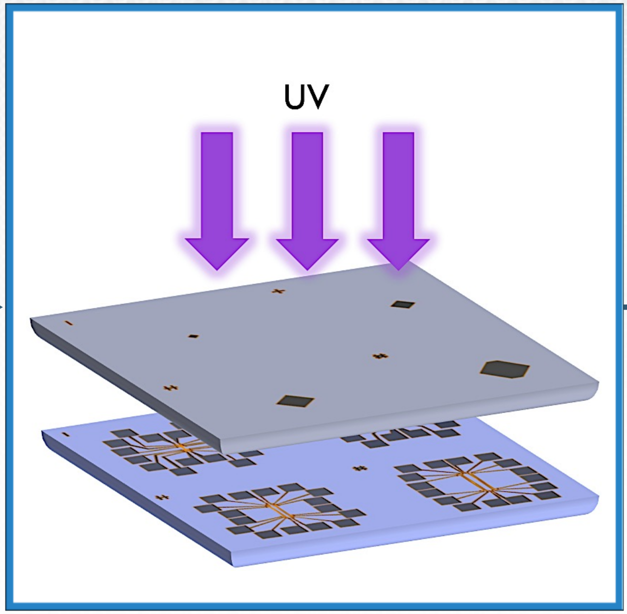
Photoresist is removed with acetone.

FABRICATION PROCESS: SECOND PHOTOLITHOGRAPHY



2 µm positive photoresist SC 1813

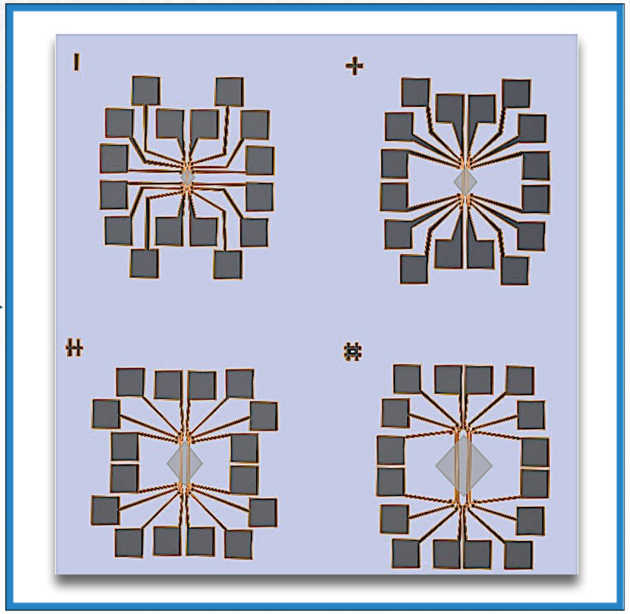
Tool: SCS G3P8 Spin Coater 1



Mask and wafer alignment

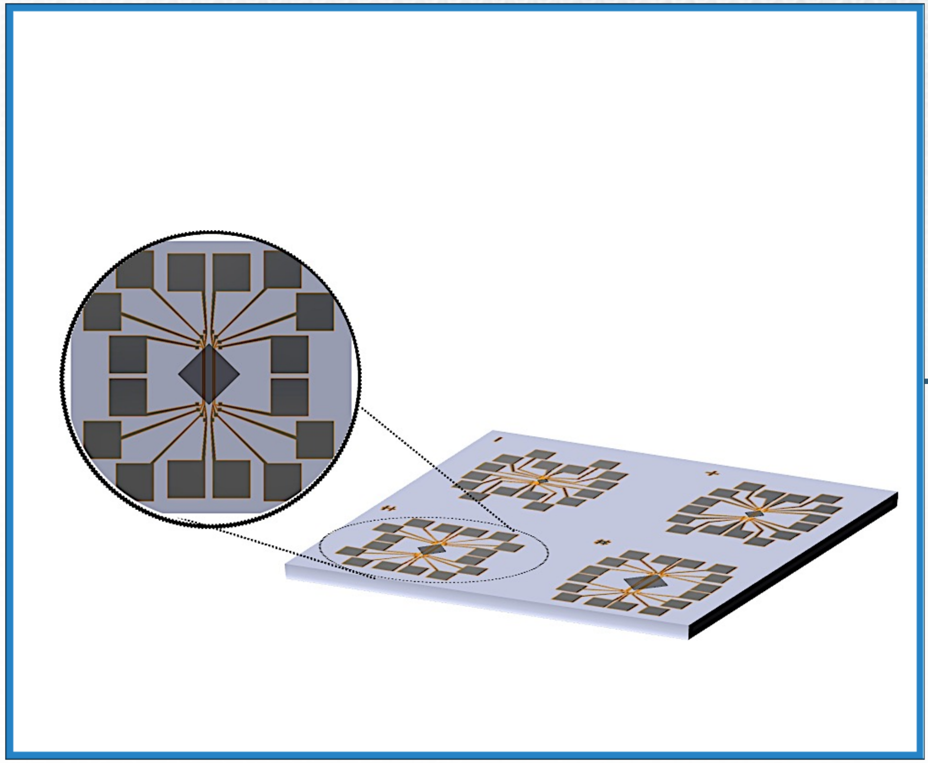
UV light shines on the sample

Tool: Karl Suss MA-6 Mask Aligner



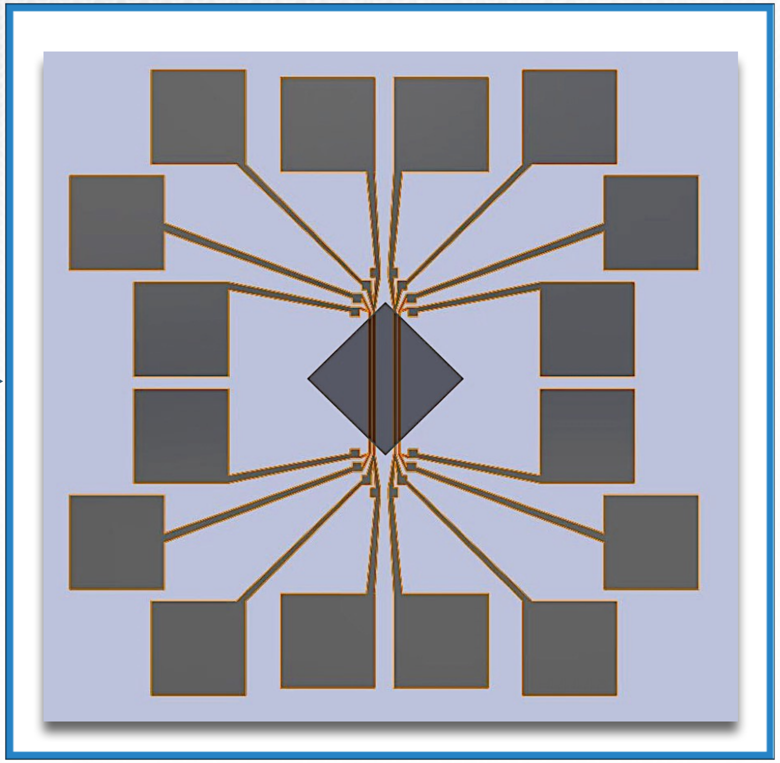
Develop photoresist with MF-319

FABRICATION PROCESS: XENON DIFLUORIDE ETCH



Silicon is etched

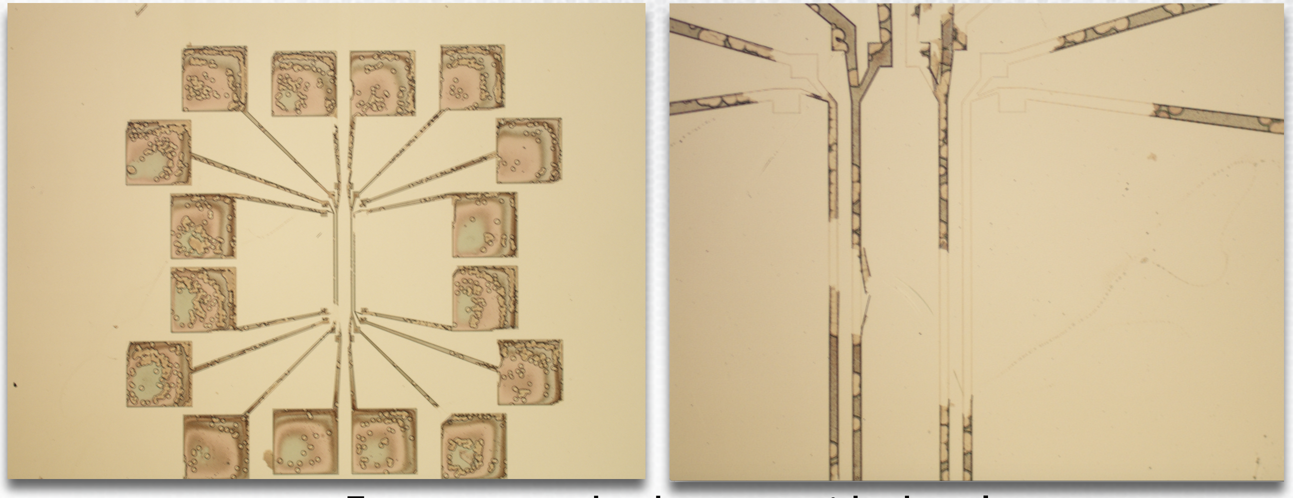
Tool: Xactix Xenon Difluoride Etcher



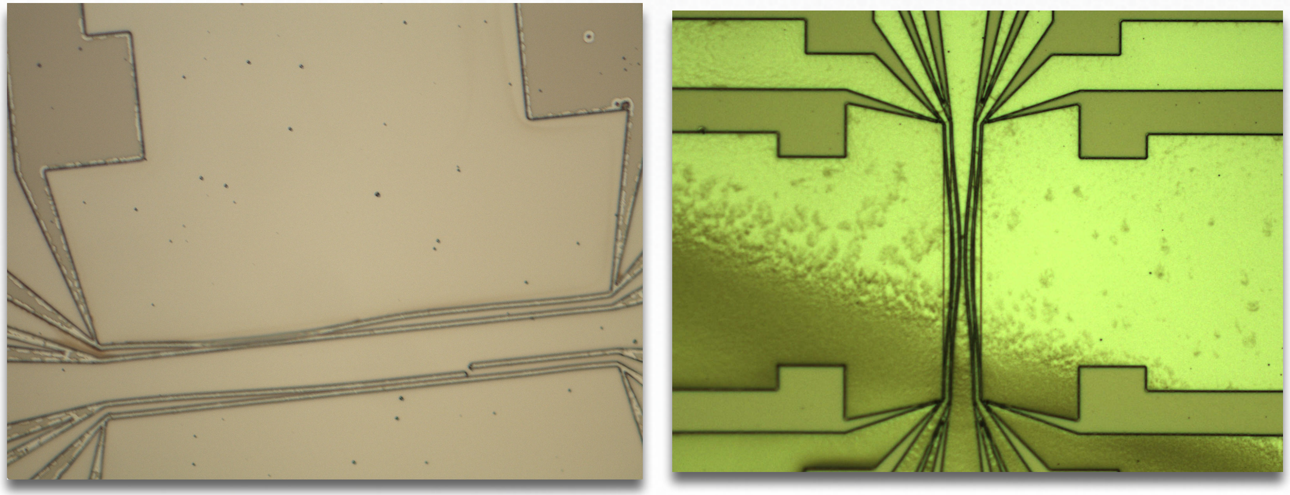
Remaining photoresist is removed with Acetone.

RESULTS

PROBLEMS DURING THE FABRICATION PROCESS



Features washed away with developer



Bent and broken heater lines

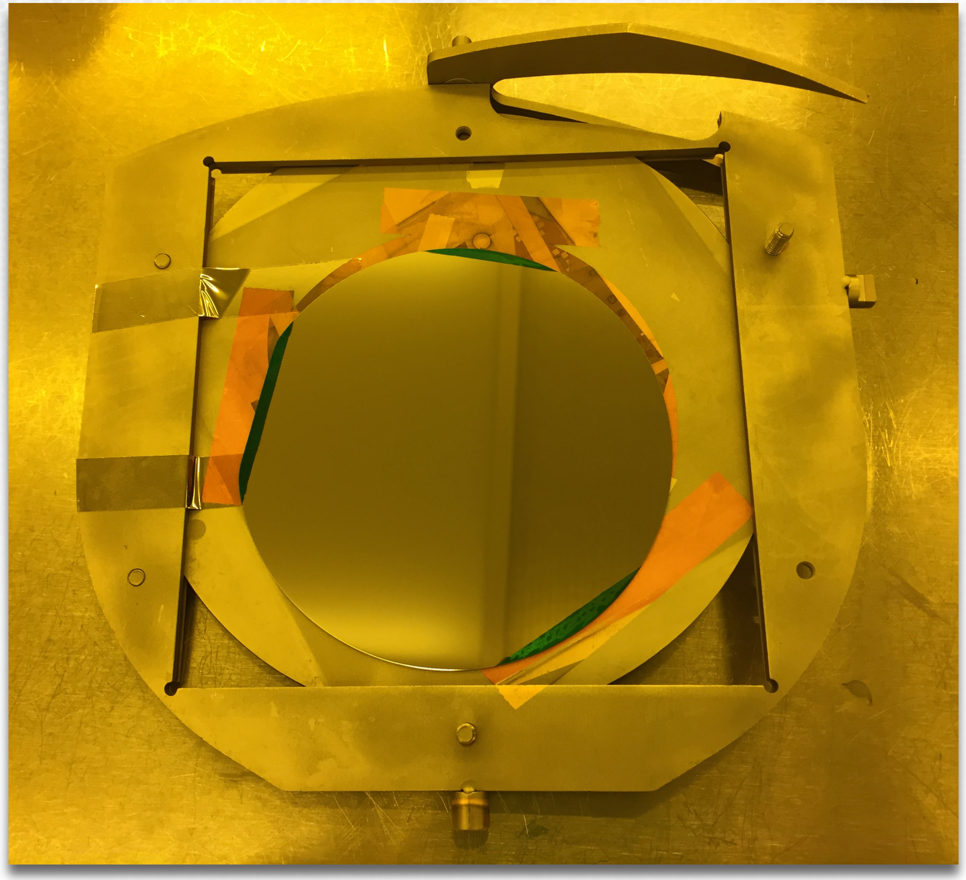
Some of the **problems** that we faced during the fabrication process were:

- Features being washed away with the developer
- Broken and bent heater lines.

After evaluating the **main parameters** involved in the process, we found the solution to these problems as you will notice in the following slides

RESULTS: TITANIUM AND PLATINUM DEPOSITION

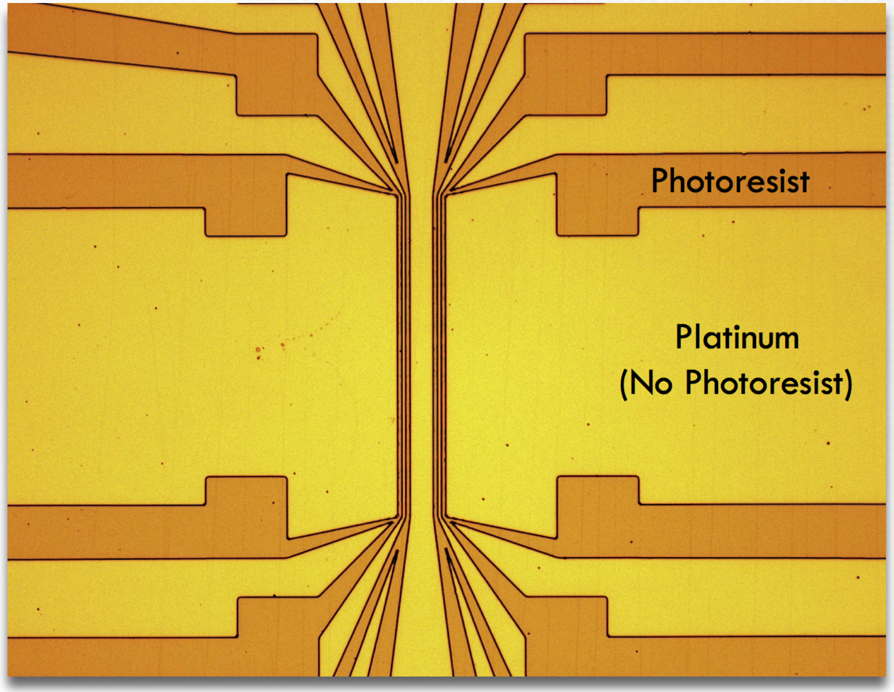
Denton Explorer E-beam Evaporator



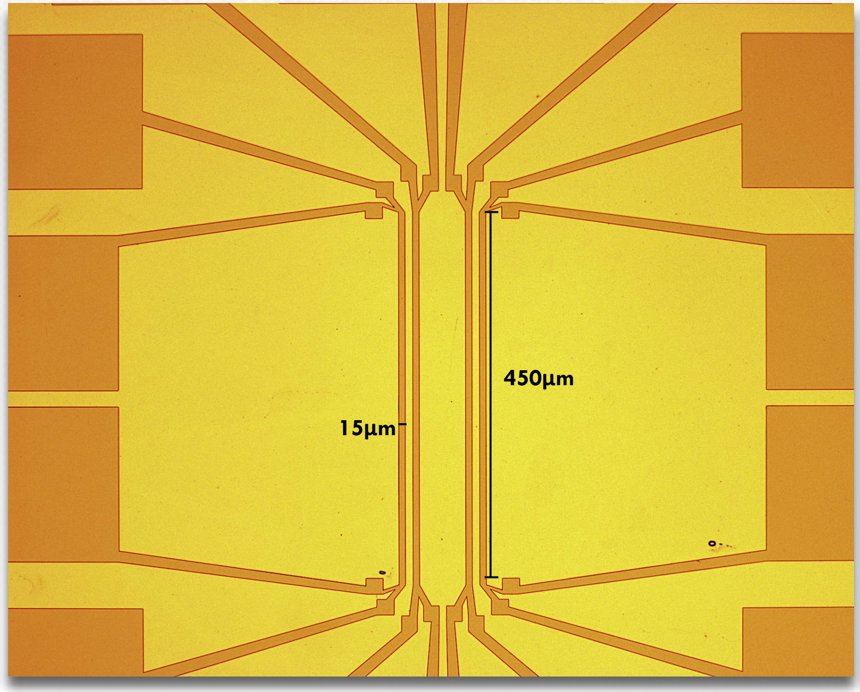
10nm Titanium and 60nm Platinum

RESULTS: FIRST PHOTOLITHOGRAPHY

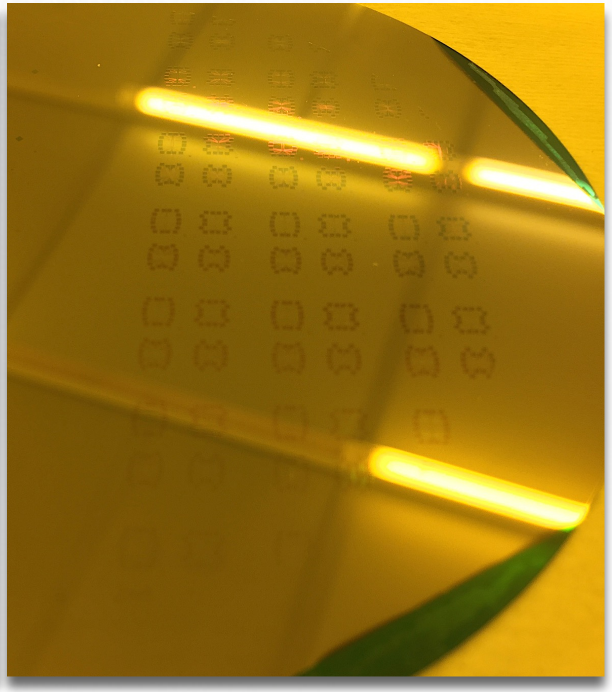
After negative photoresist is spin coated into the wafer we expose it to UV light using a mask to create features in the wafer. Negative photoresist hardens when exposed to UV light, the rest will get washed away with the developer.



Feature 1

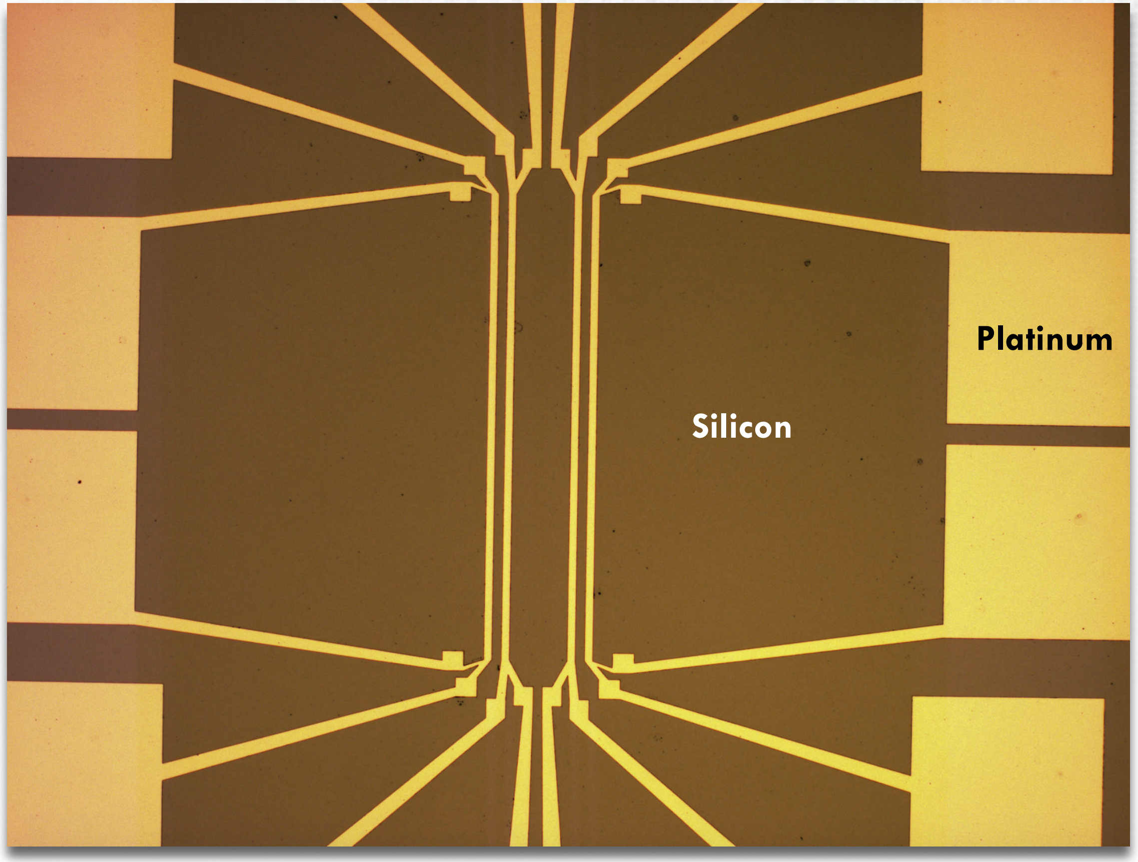


Feature 4

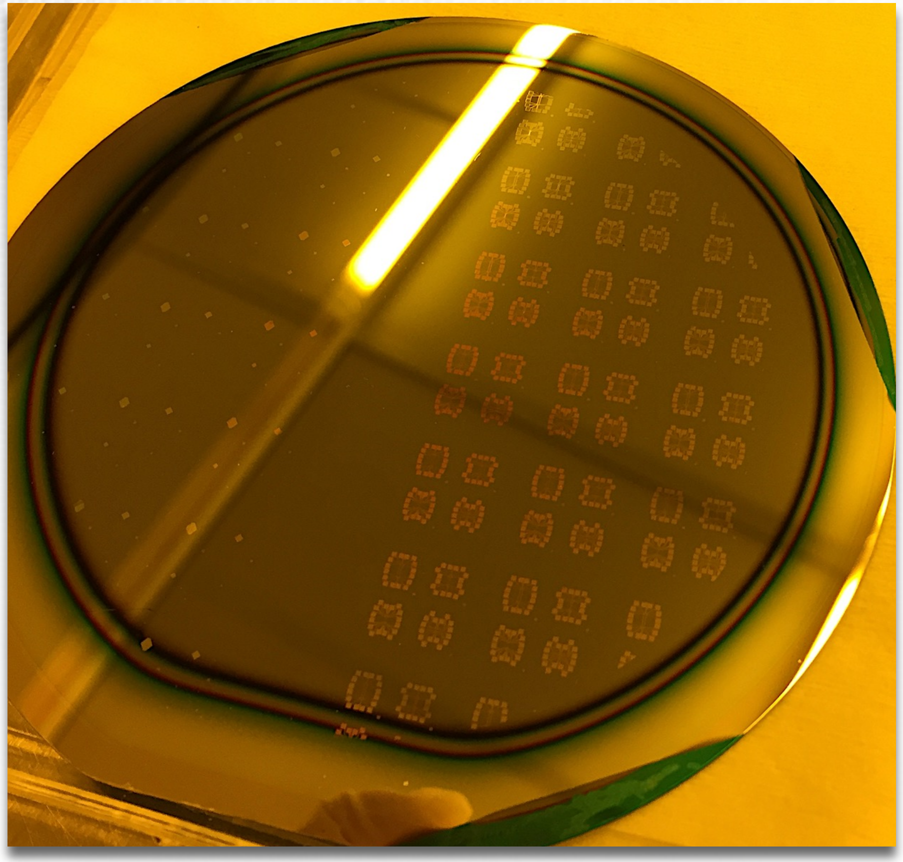


RESULTS: ICP ETCHING

Platinum and silicon nitride are etched

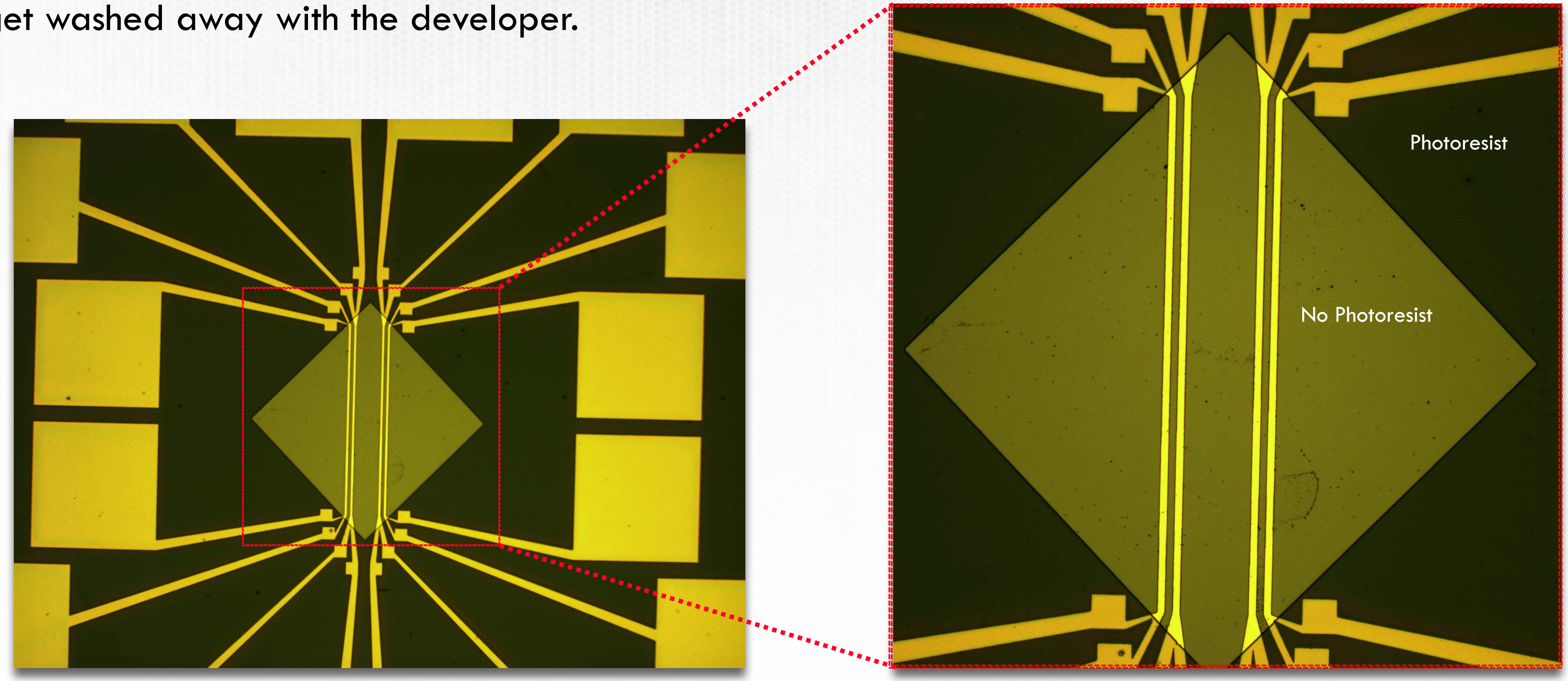


Feature 4



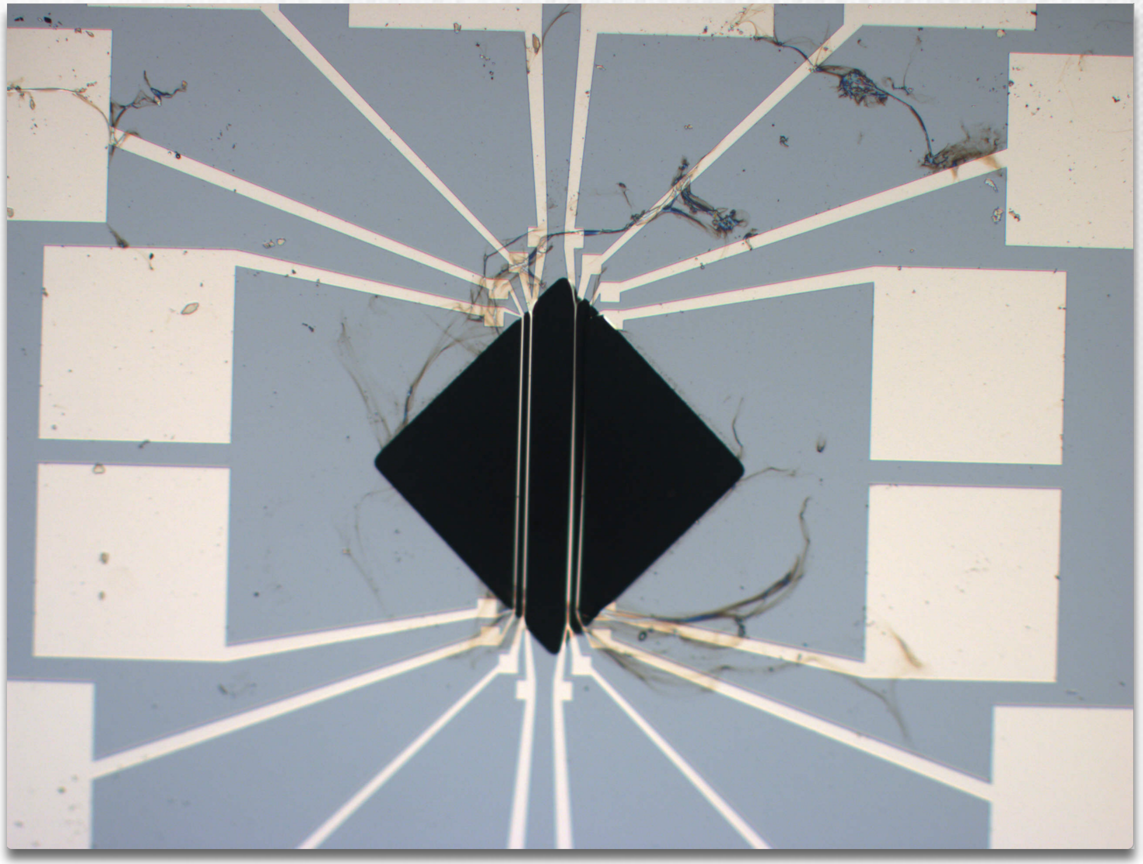
RESULTS: SECOND PHOTOLITHOGRAPHY

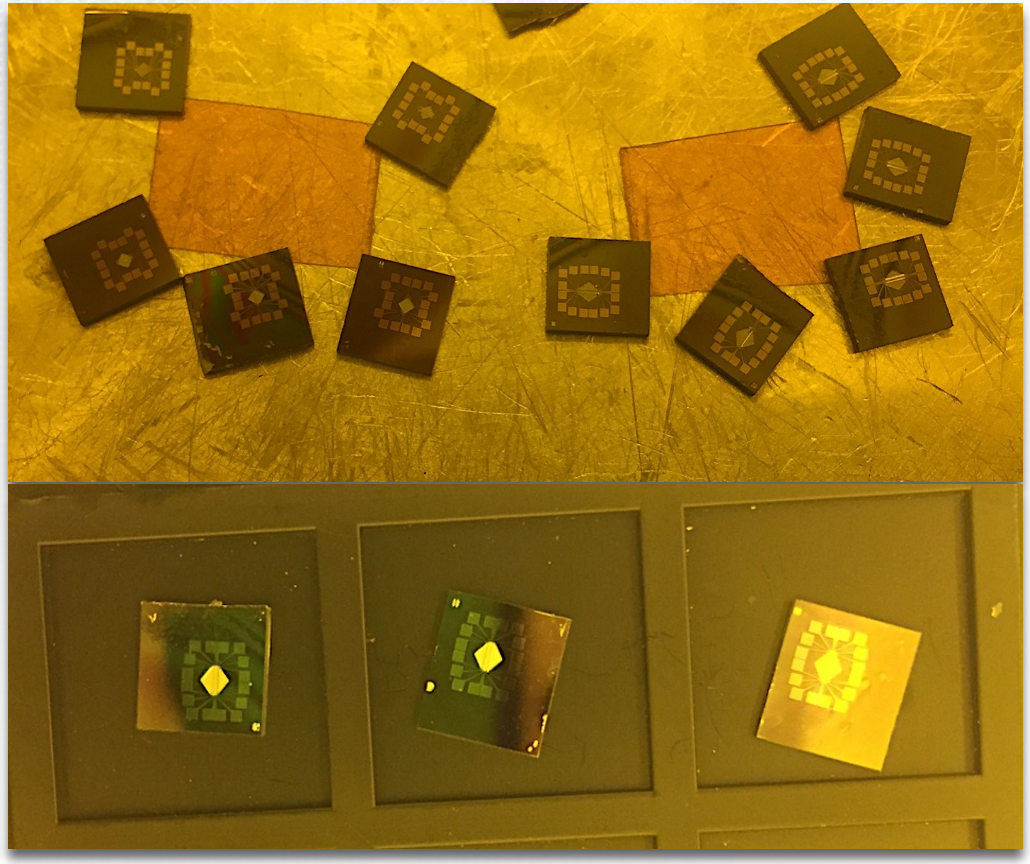
After positive photoresist is spin coated into the wafer we expose it to UV light using a mask to create features in the heater lines. Positive photoresist softens when exposed to UV light and will get washed away with the developer.



RESULTS: XENON DIFLUORIDE ETCHING

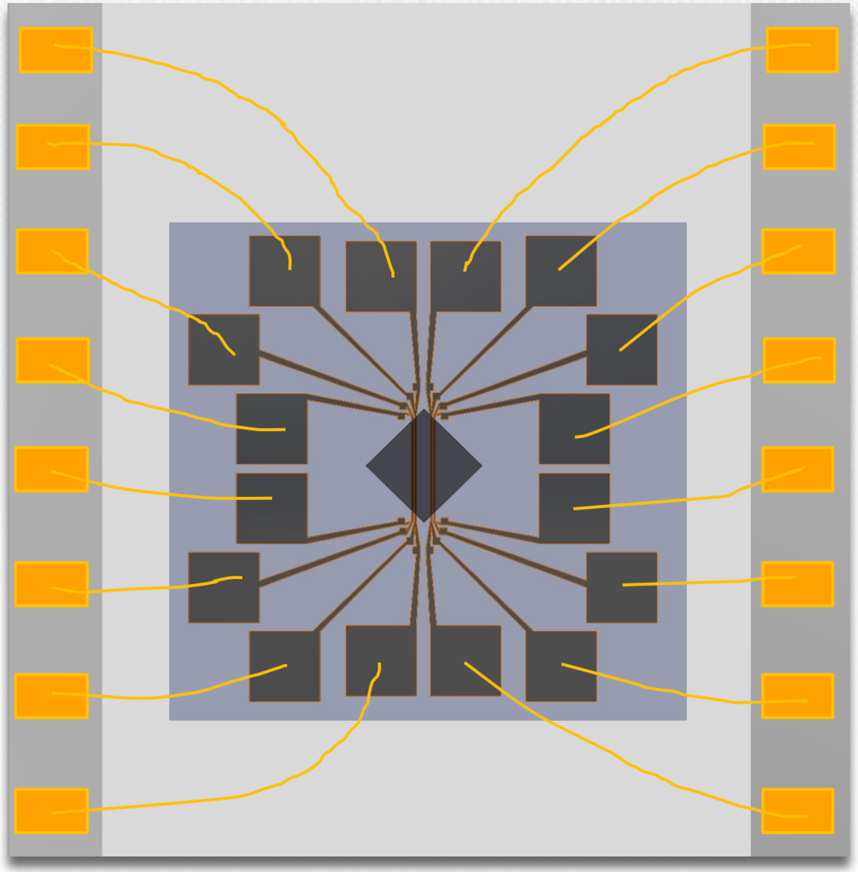
One micrometer of silicon is etched. The result is 4 suspended heater lines.

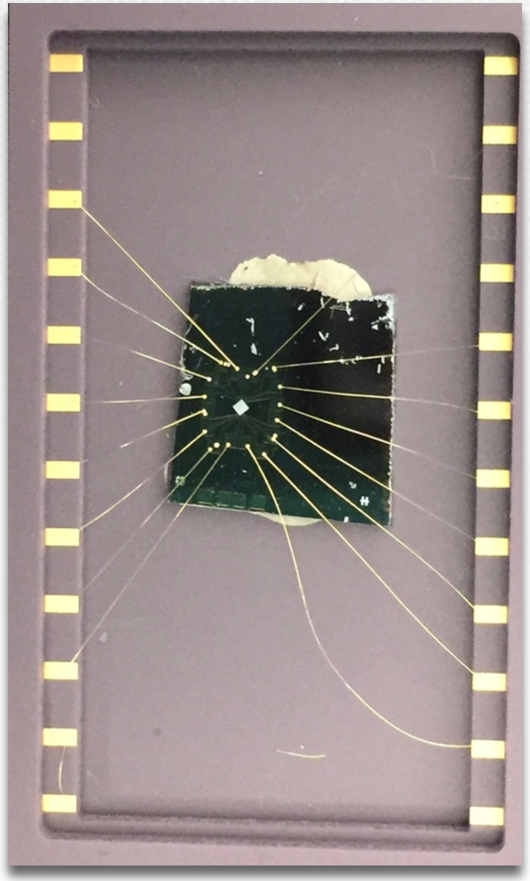




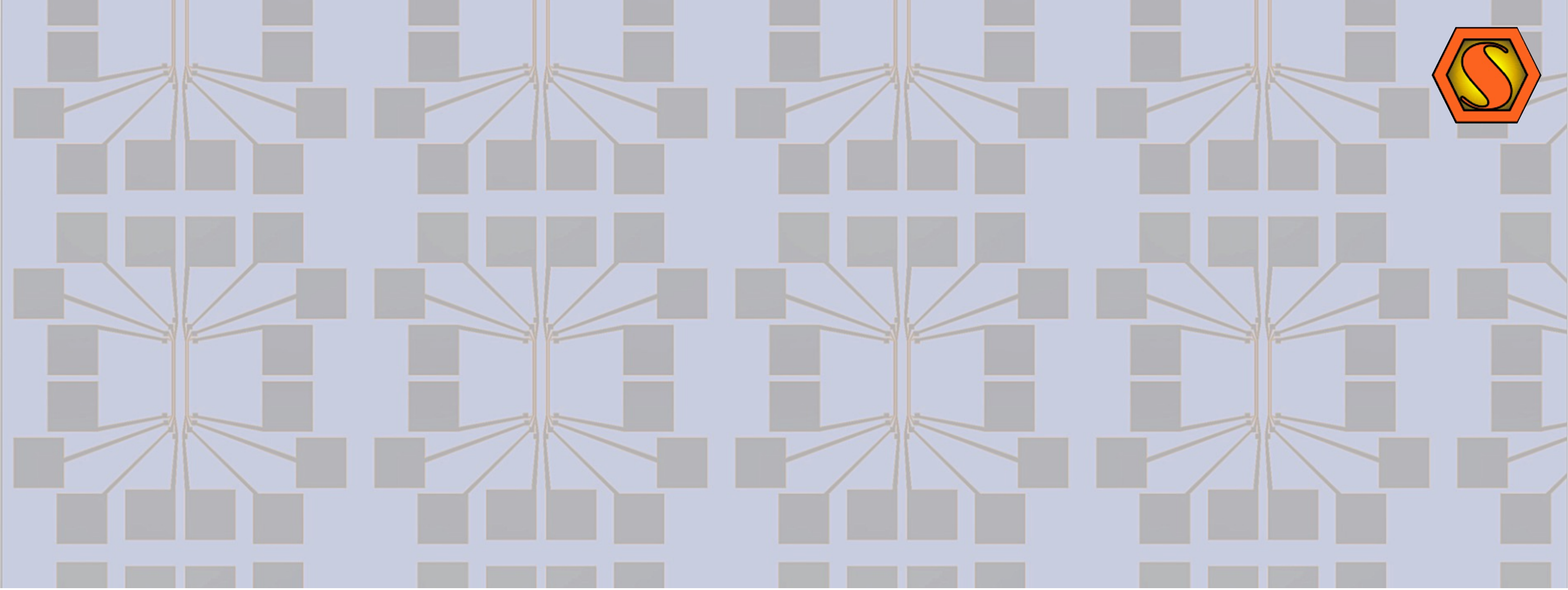
Picture taken by Aravindh Rajan

RESULTS: FOUR-PROBE THERMAL MEASURING DEVICE





We succeeded in fabricating a thermal conductivity measurement device.



CONCLUSIONS AND RECOMMENDATIONS

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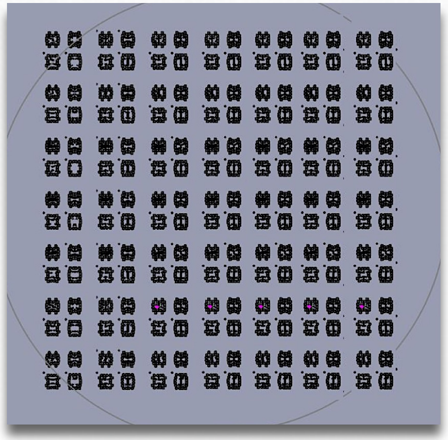
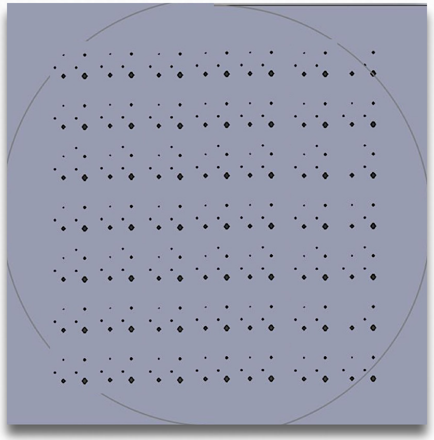
Our four-probe thermal conductivity measuring device was fabricated in a reproducible way and with the desired specifications.

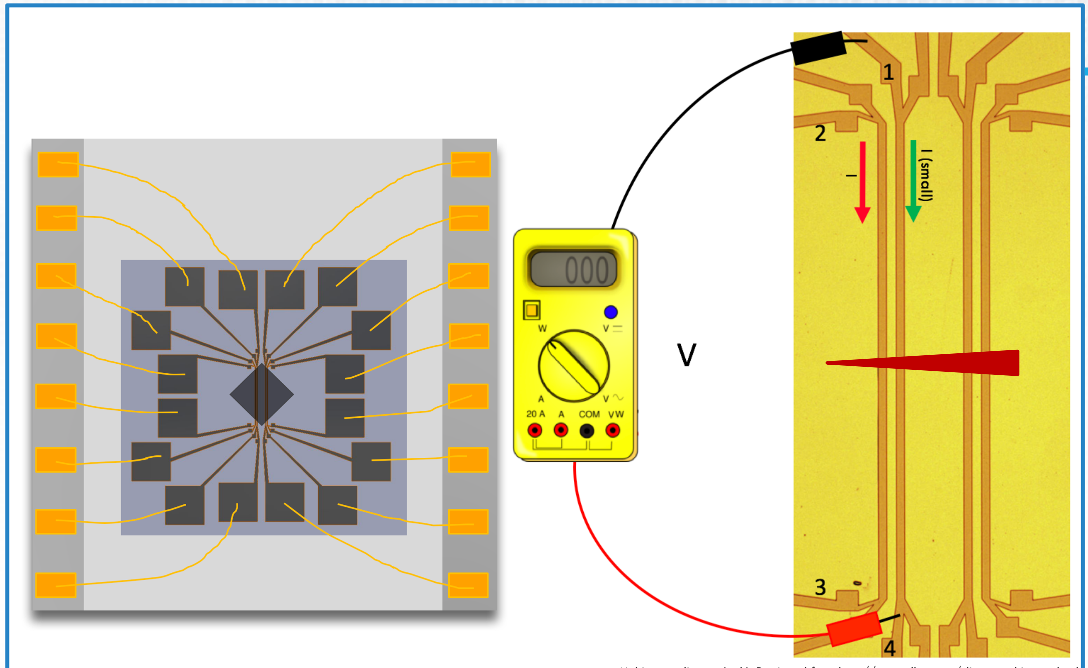
The process takes a long time to complete and modifications are suggested to save time and speed up the production.

One of these is to make two separate masks with different features on each. By doing this, more features can be obtained from one wafer.



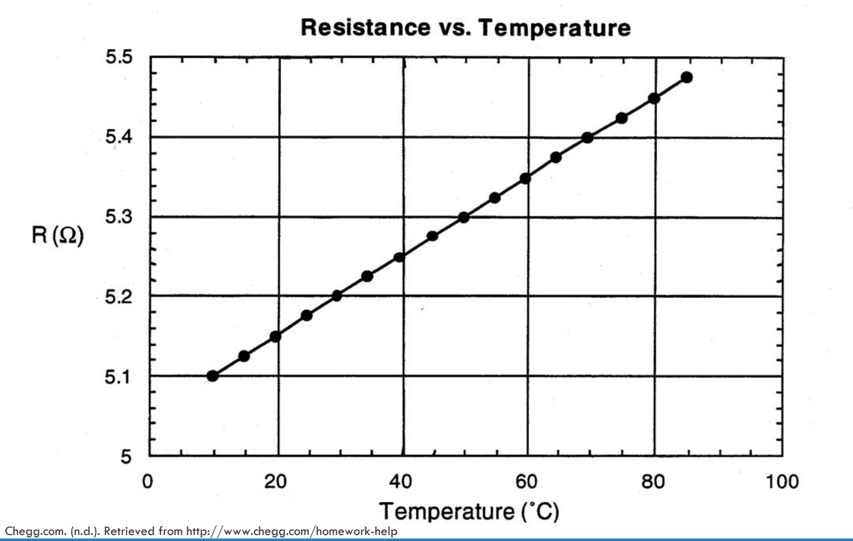


FUTURE WORK



Multimeter clip art. (n.d.). Retrieved from http://www.clker.com/clipart-multimeter.html

We apply a known current (I) through 2, to heat the polymer. Through 1 we send a small current, we measure the voltage (V) drop and using Ohm's Law we calculate the Resistance (R).



Chegg.com. (n.d.). Retrieved from http://www.chegg.com/homework-help

Thermal conductivity (K)

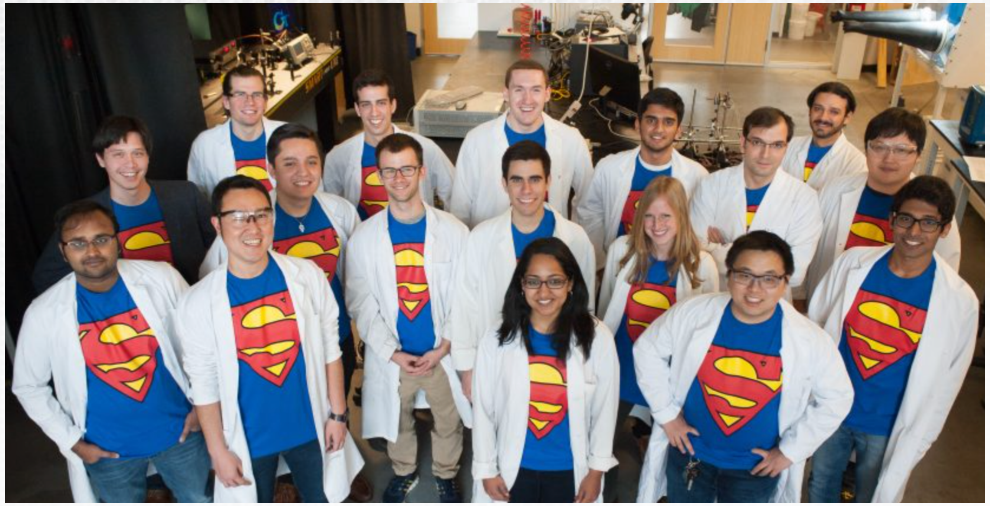
Level of Rectification

$$\varepsilon = \frac{k^{+} - k^{-}}{k^{+} + k^{-}}$$

ACKNOWLEDGEMENT

- Dr. Shannon Yee
- Patrick Creamer
- Aravindh Rajan
- Sampath Kommandur
- SUIN Program
- Dr. Nancy Healy
- Leslie O'Neill
- Cleanroom staff

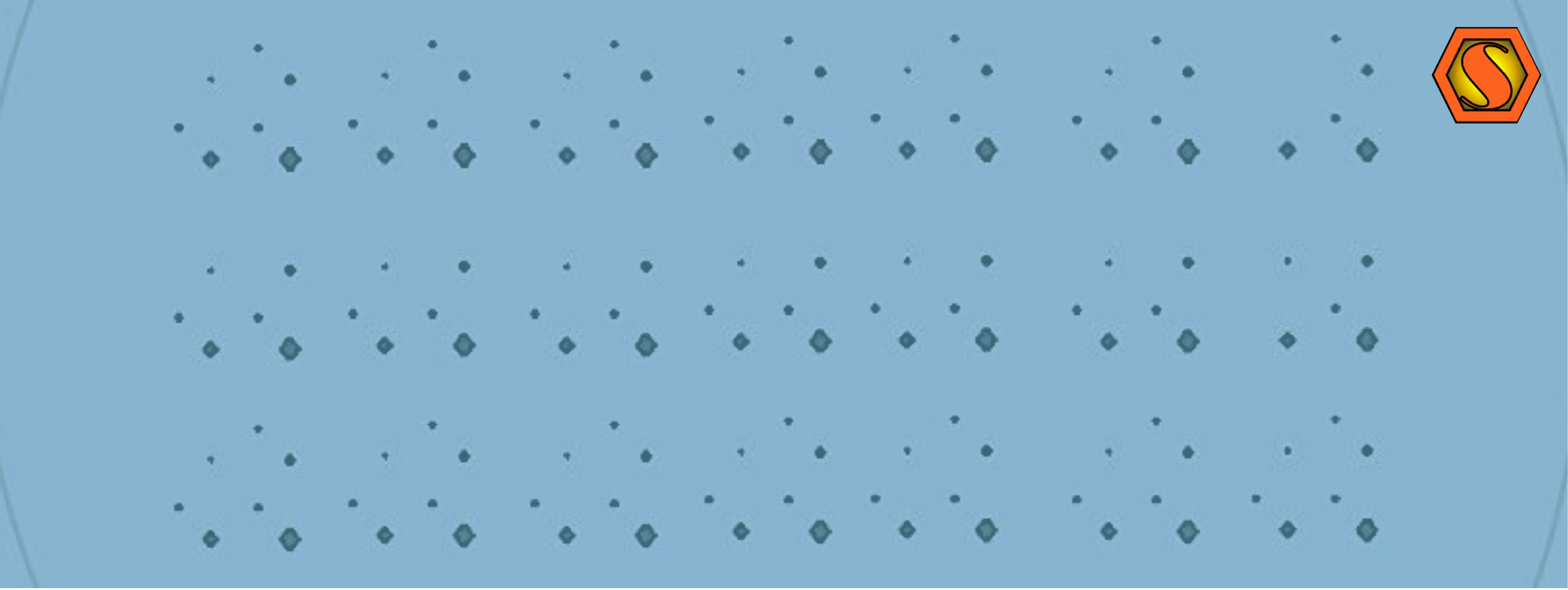
STEEL



SENIC Southeastern Nanotechnology Infrastructure Corridor

NSF

National Nanotechnology Coordinated Infrastructure



QUESTIONS?