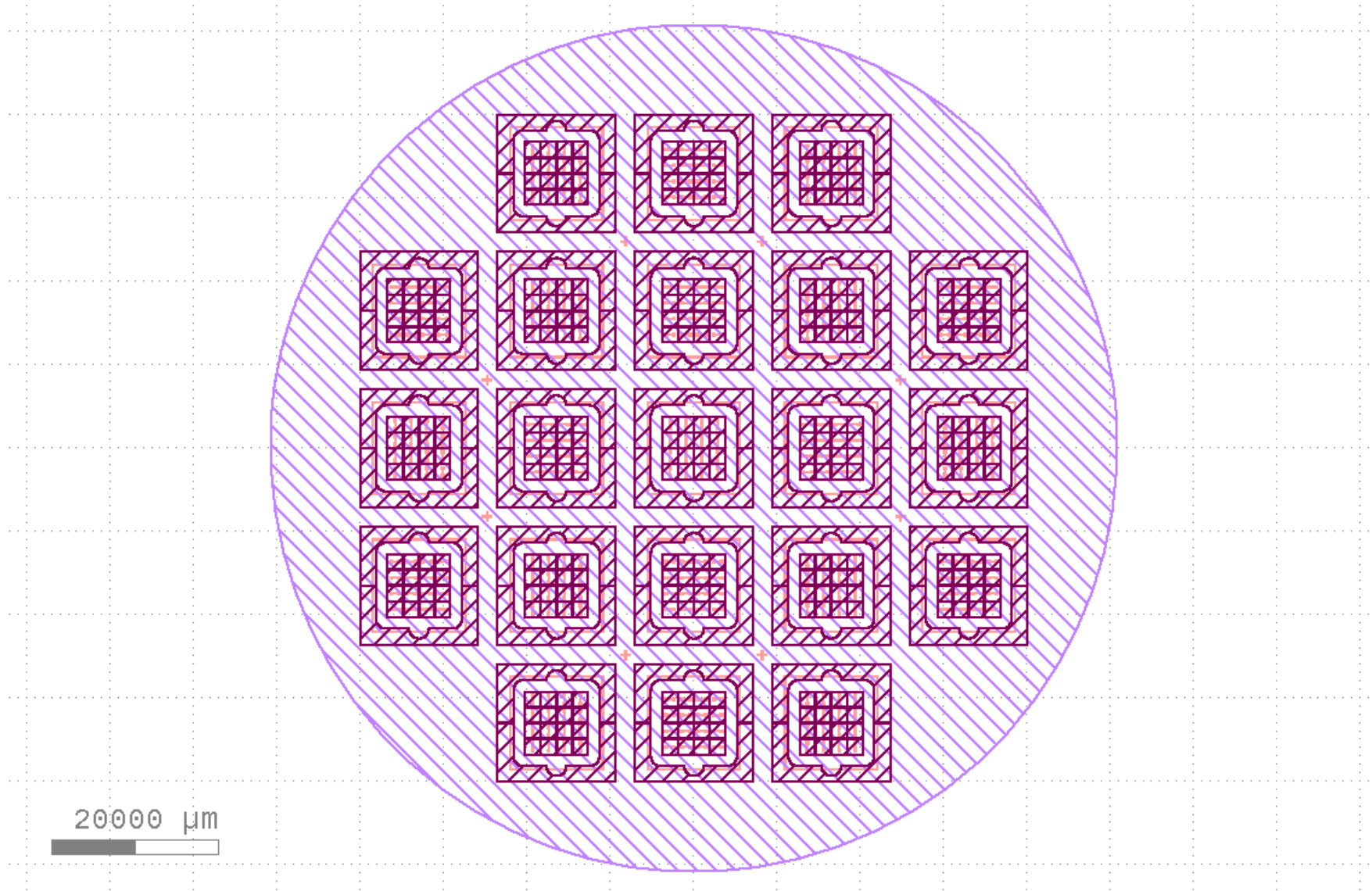


Growth and Characterization of Superconducting Josephson Junctions in Low-Temperature MBE

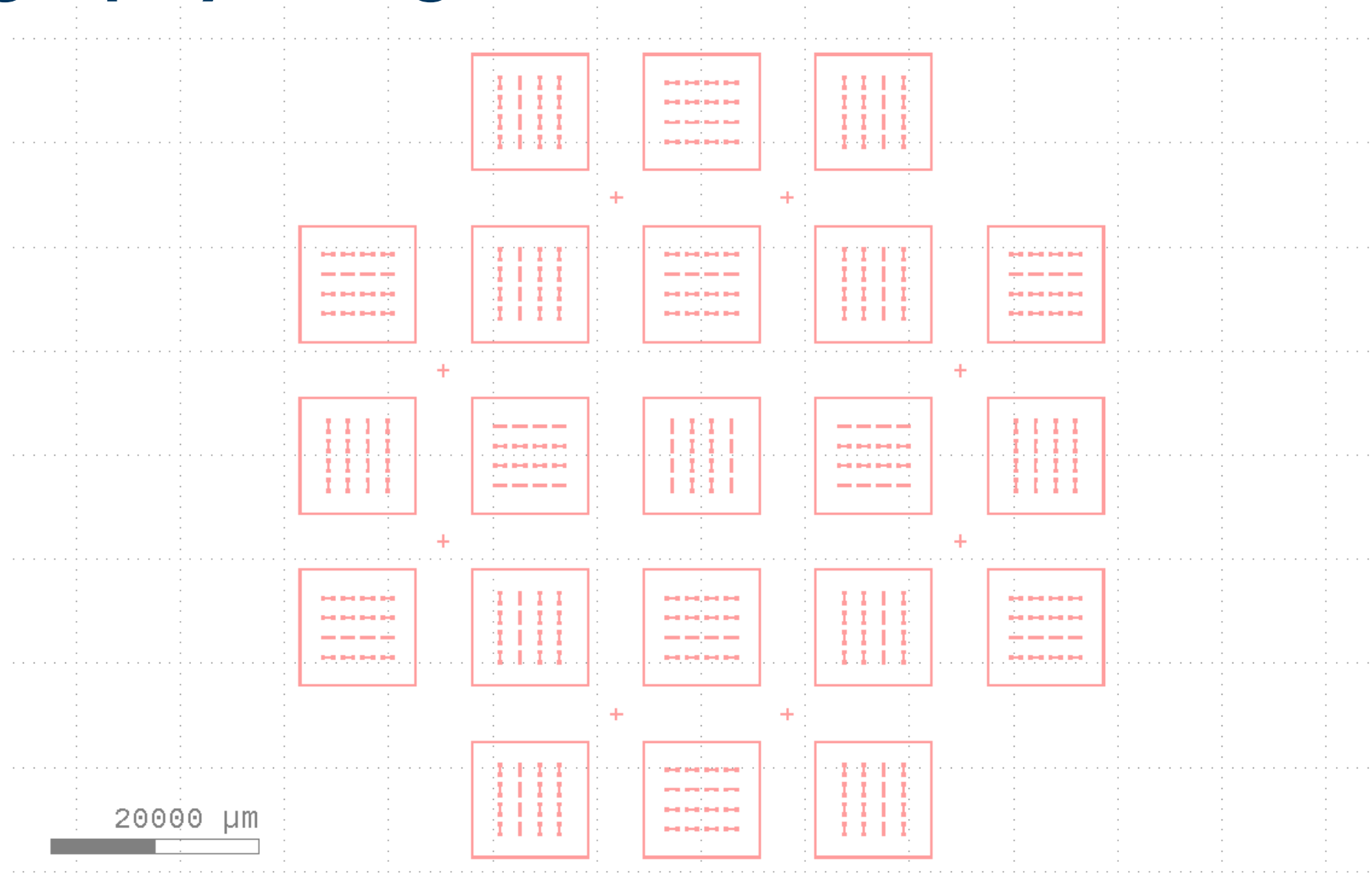
Shirshendu Chatterjee

Design of the Shadow Mask for the Josephson Junctions

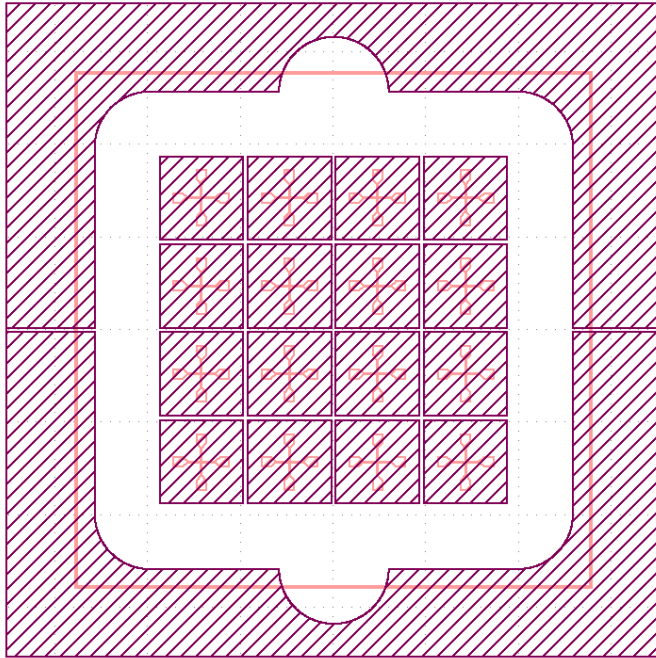
Shadow Mask – Design 1.



Lithography Design – 1.



Josephson Junction - 1

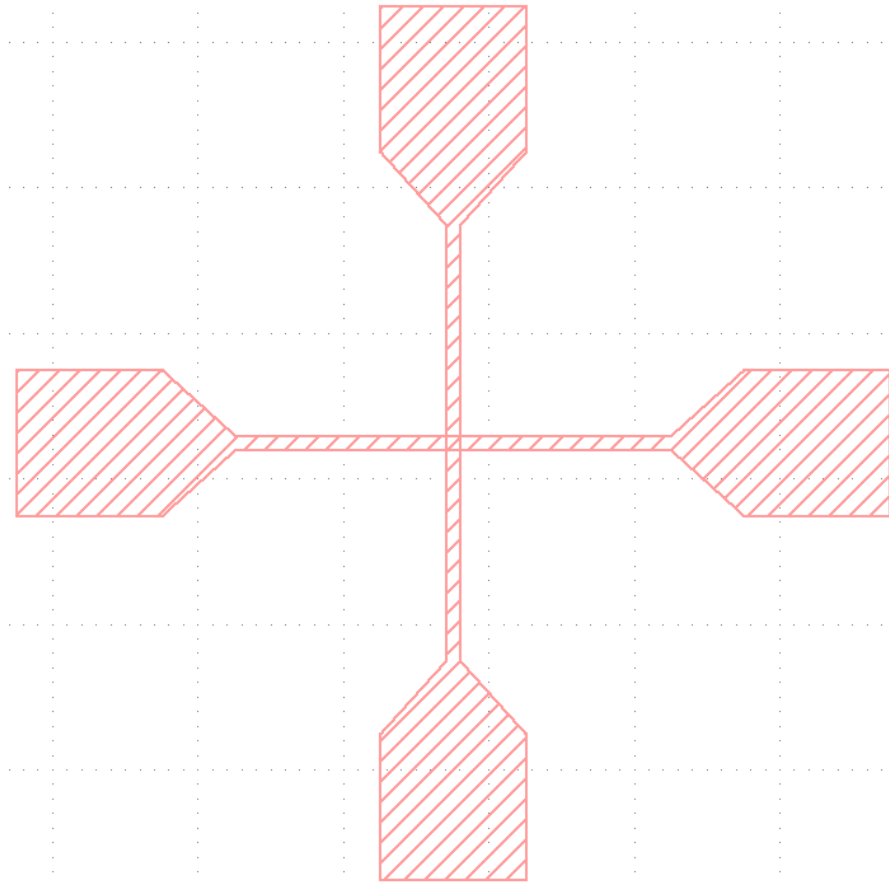


- The junction is $20\mu\text{m} \times 20\mu\text{m}$

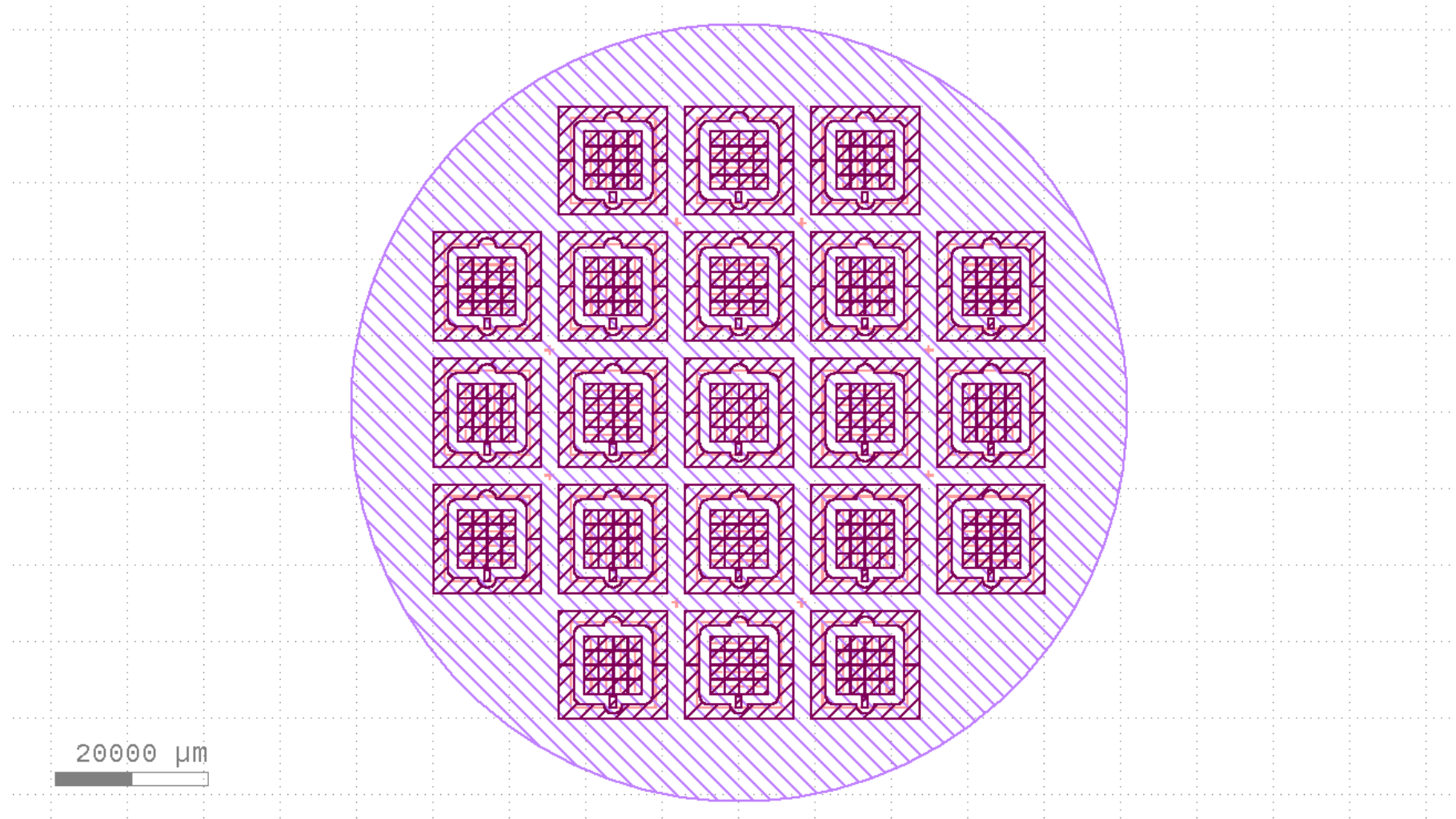
400 μm



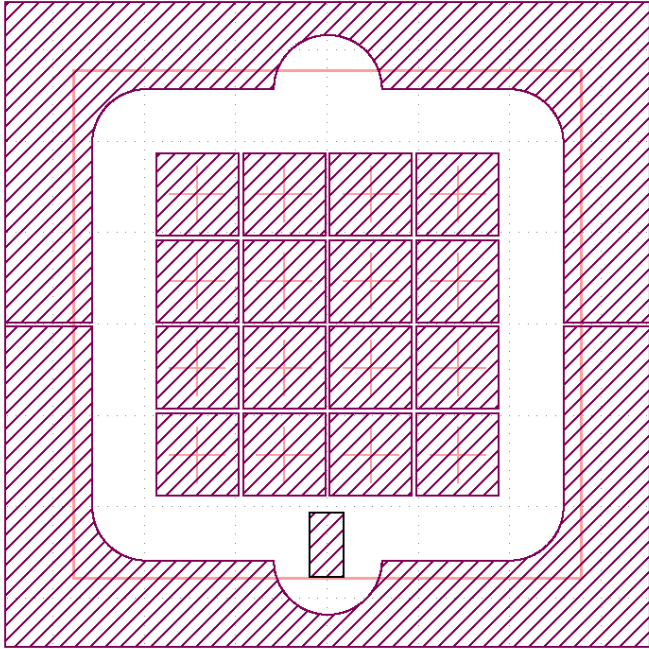
A scale bar indicating a length of 400 μm . The bar is a horizontal line with a black segment on the left and a white segment on the right, with the text "400 μm " centered above it.



Shadow Mask – Design 2.

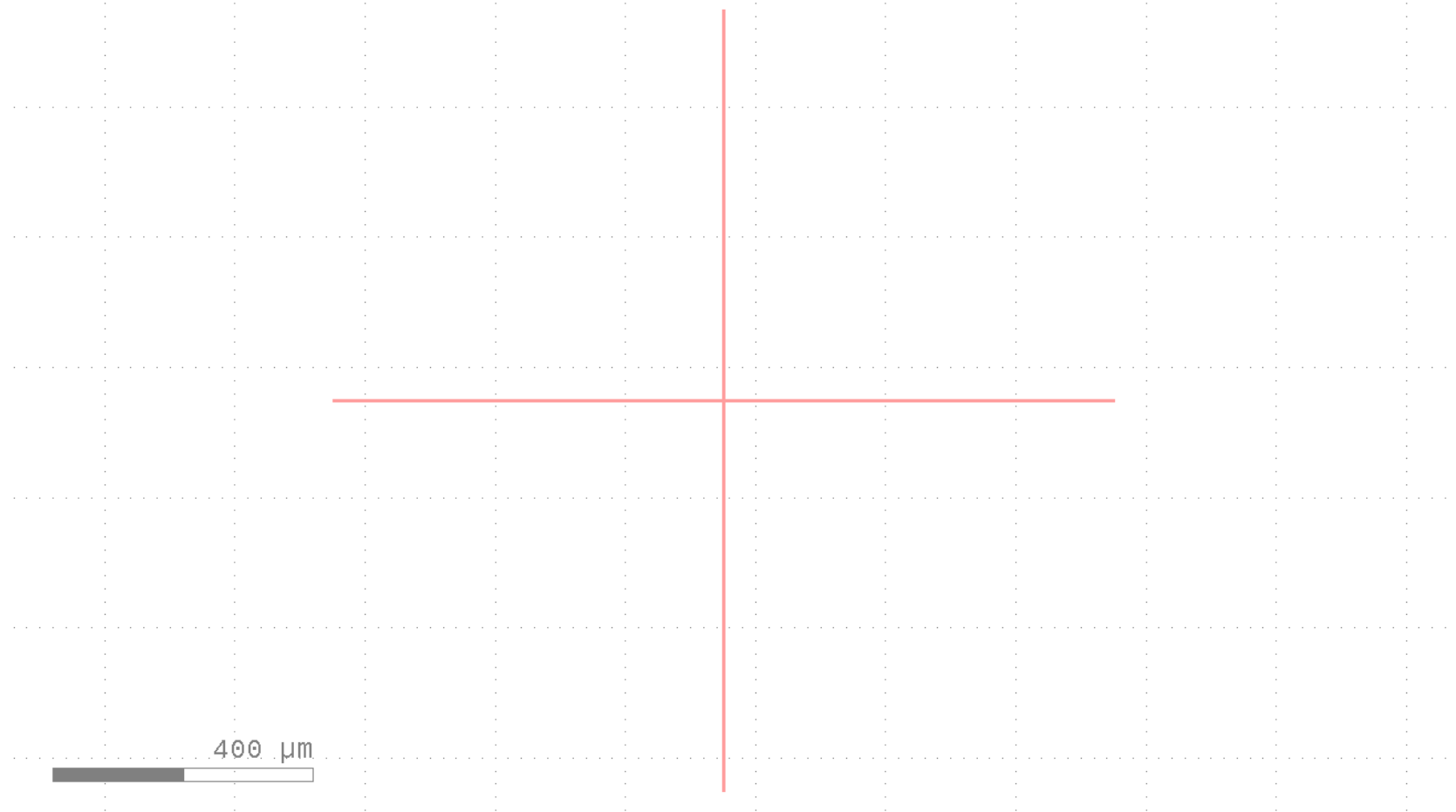


Josephson Junction - 2



Two junctions with different areas-

1. $1\mu\text{m} \times 1\mu\text{m}$
2. $2\mu\text{m} \times 2\mu\text{m}$

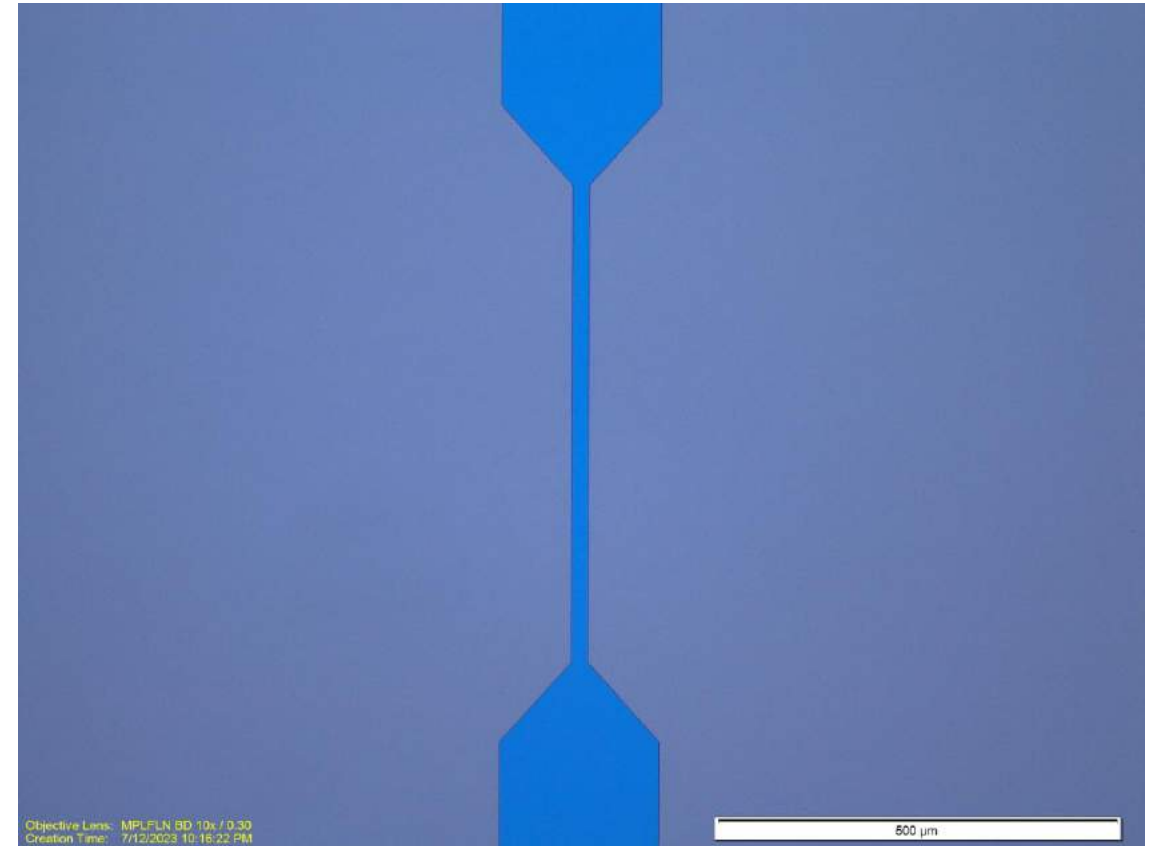
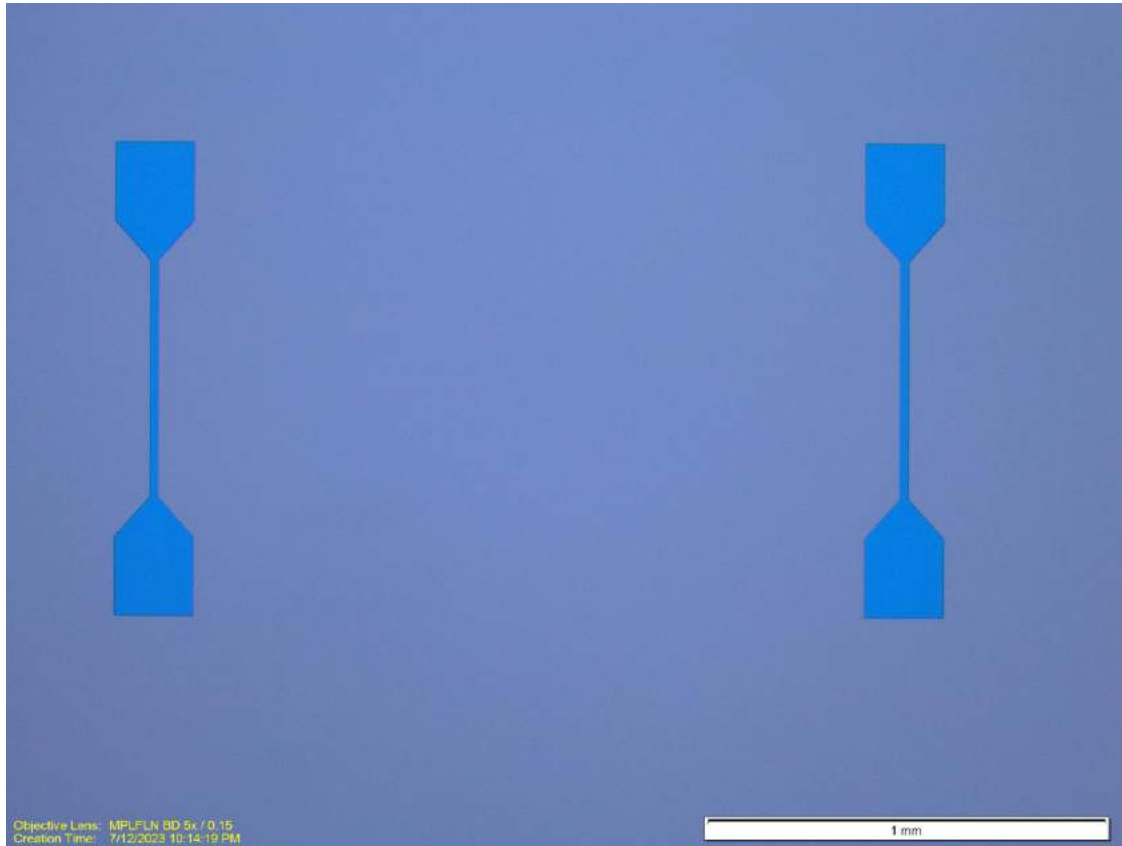


Patterning the Top Layers

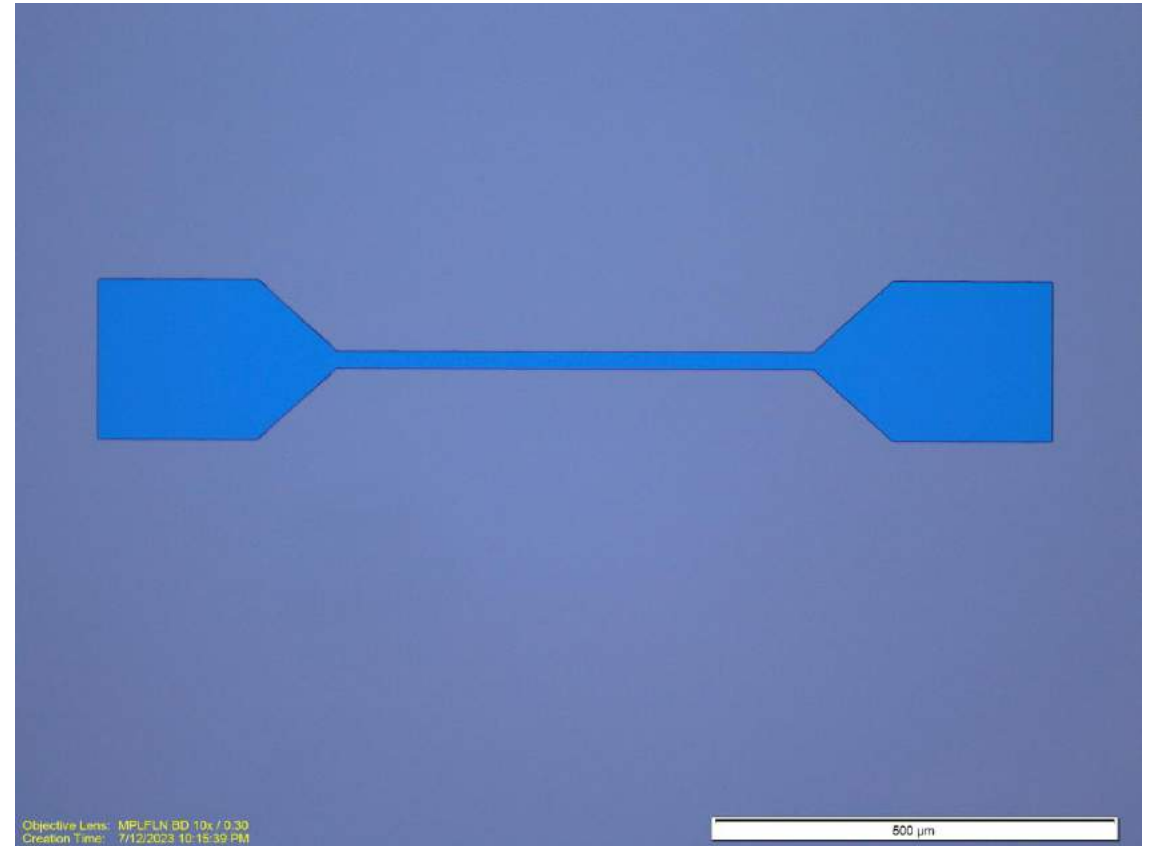
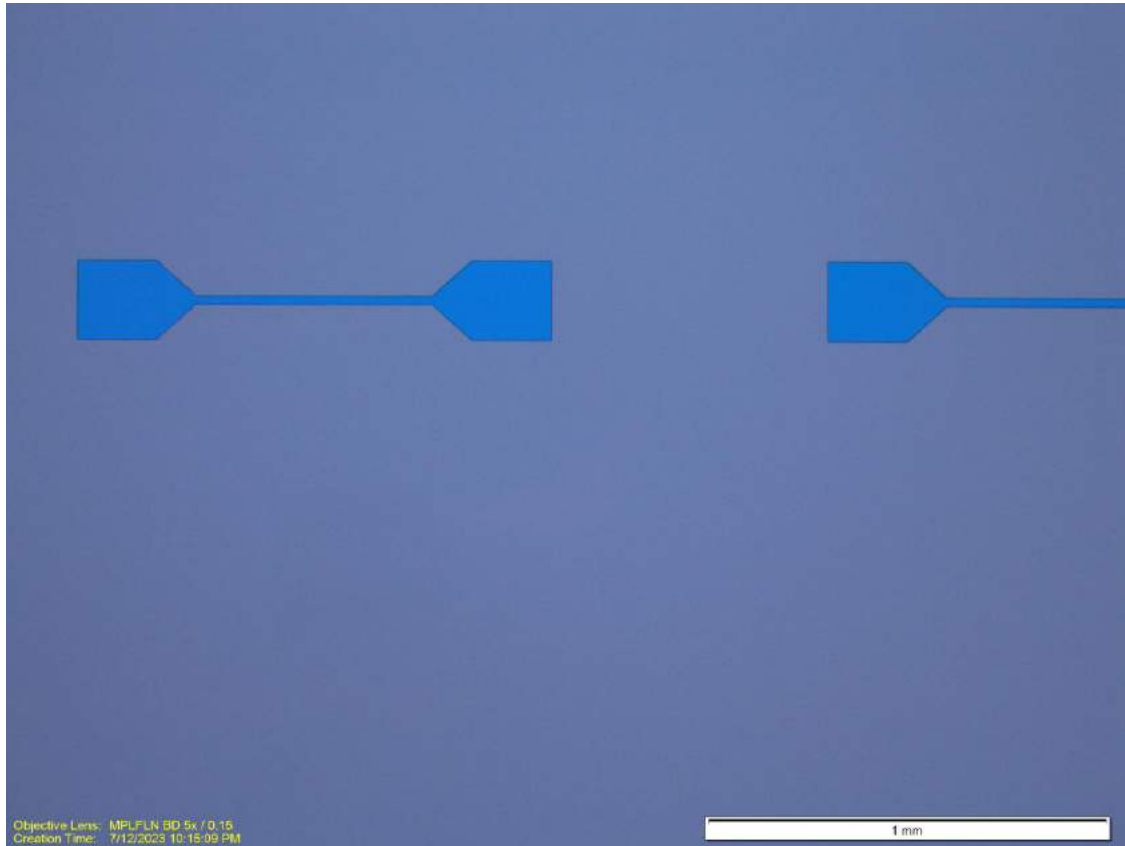
Recipe – 1st Lithography

1. 2 min Acetone in USW
2. 2 min Isopropanol in USW
3. PE II at 300mTorr and 100 Watts O₂ for 15 secs.
4. Spin resist AZ4110 at 4krpm for 30s ~ **1.2um thick**
5. Soft bake for 60 sec at 95C
6. MLA: **405nm** Laser, dose **300** mJ/cm² and defocus **4**
7. AZ400K 1:4 developer for 60 sec
8. DI for 60 sec

After 1st Lithography



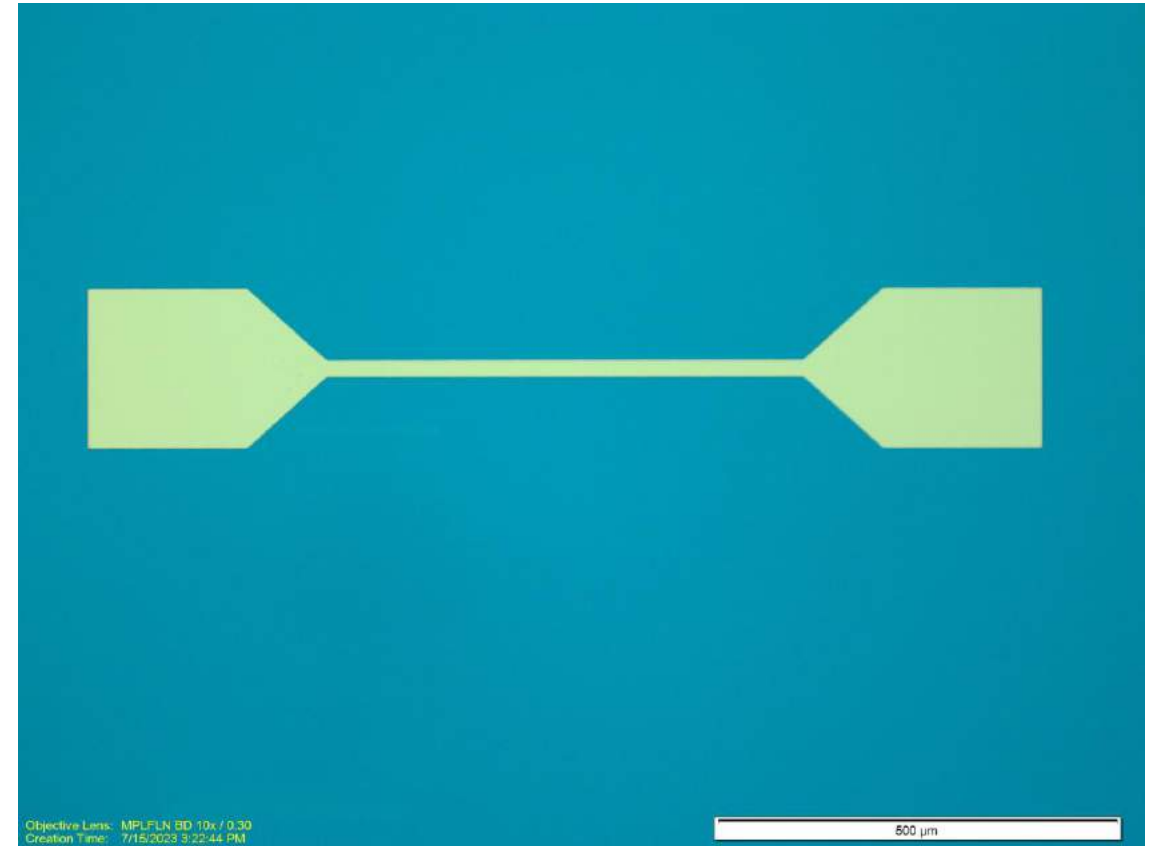
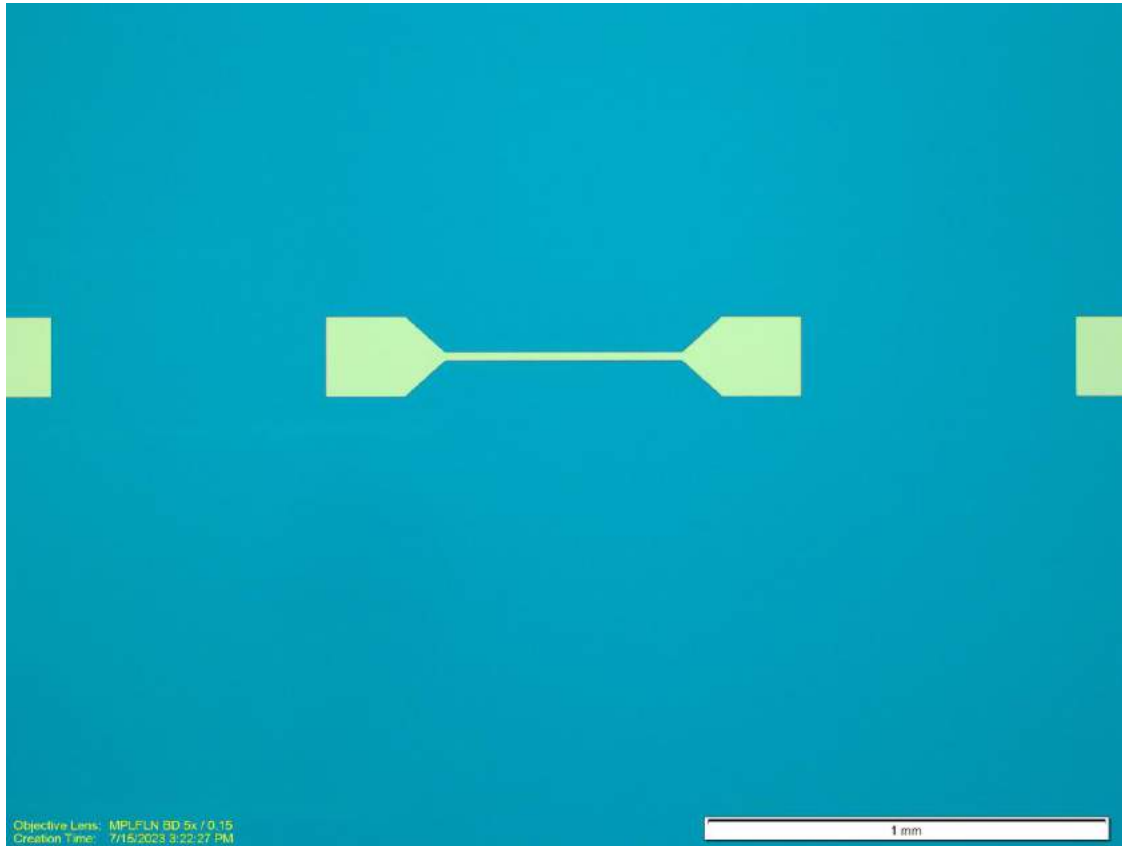
After 1st Lithography



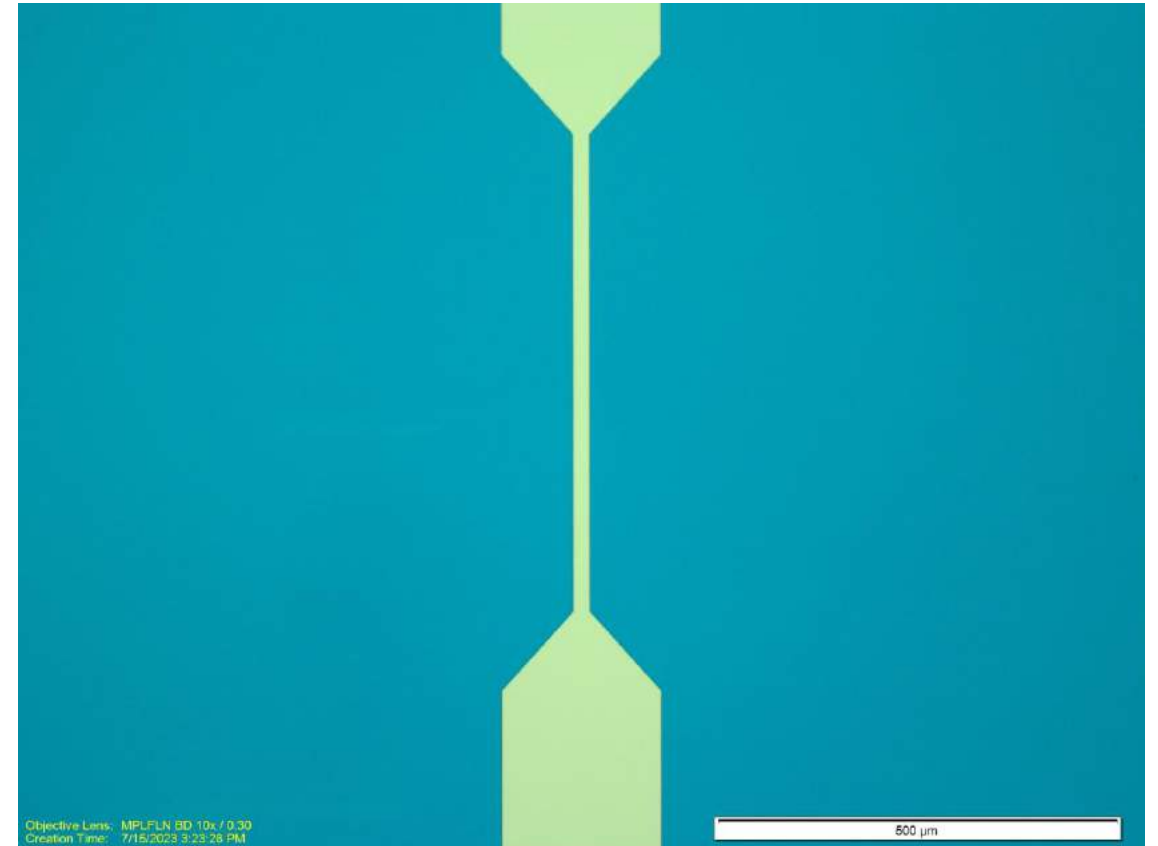
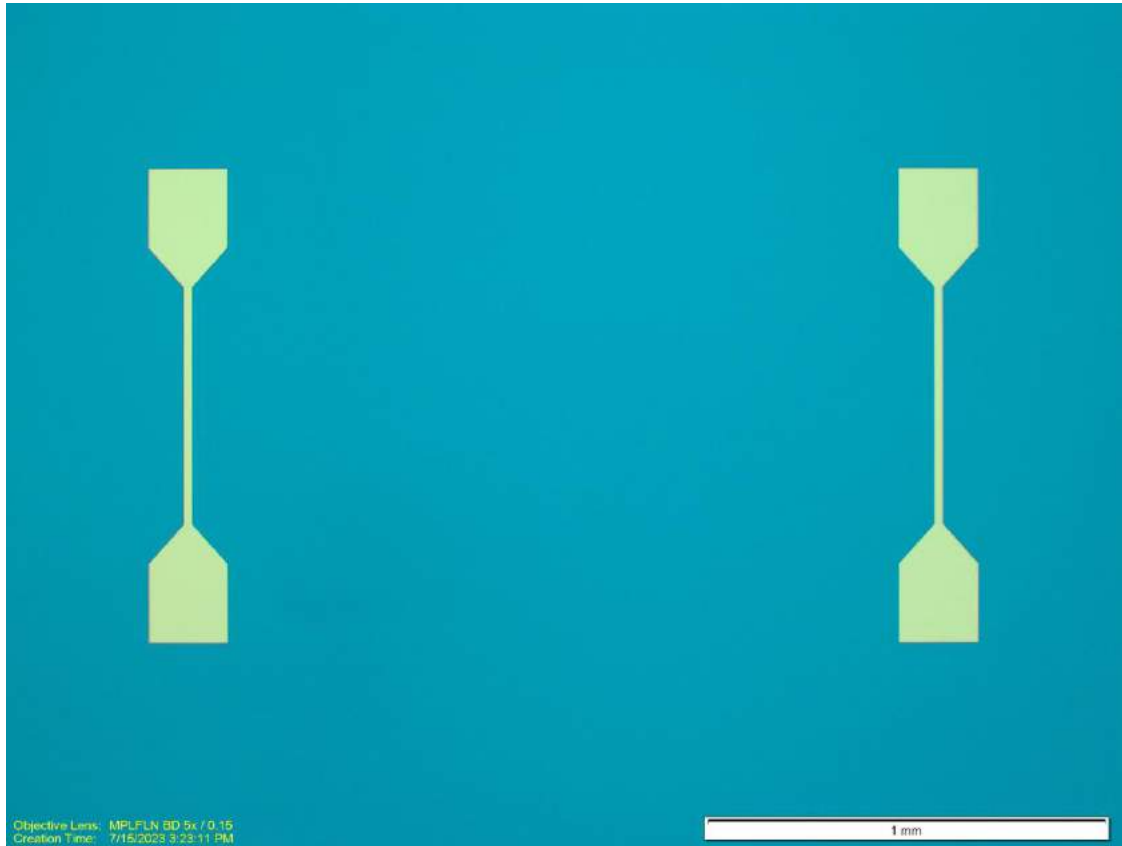
Recipe – Dry Etch and PECVD

1. PE II 300/100 O₂ for 15 sec
2. ICP #1 – O₂ clean for 5 min
 - CF₄/O₂ coat for 2 min
 - CF₄/O₂ etch for 4 min
 - O₂ clean for 5 min

After Dry Etch



After Dry Etch



PECVD and Capping Top Surface.

- PE II 300/100 O₂ for 120 sec.(goes on for 2 cycles along with solvent clean).
- PE II 300/100 O₂ for 15mins.
- PECVD LSNitride V3 for 10 mins.
- Spin HMDS, Bake for 60secs at 100C.
- Spin AZ41 10 to protect the Top surface.
- Bake at 100C for 60 secs.

Back Side Patterning

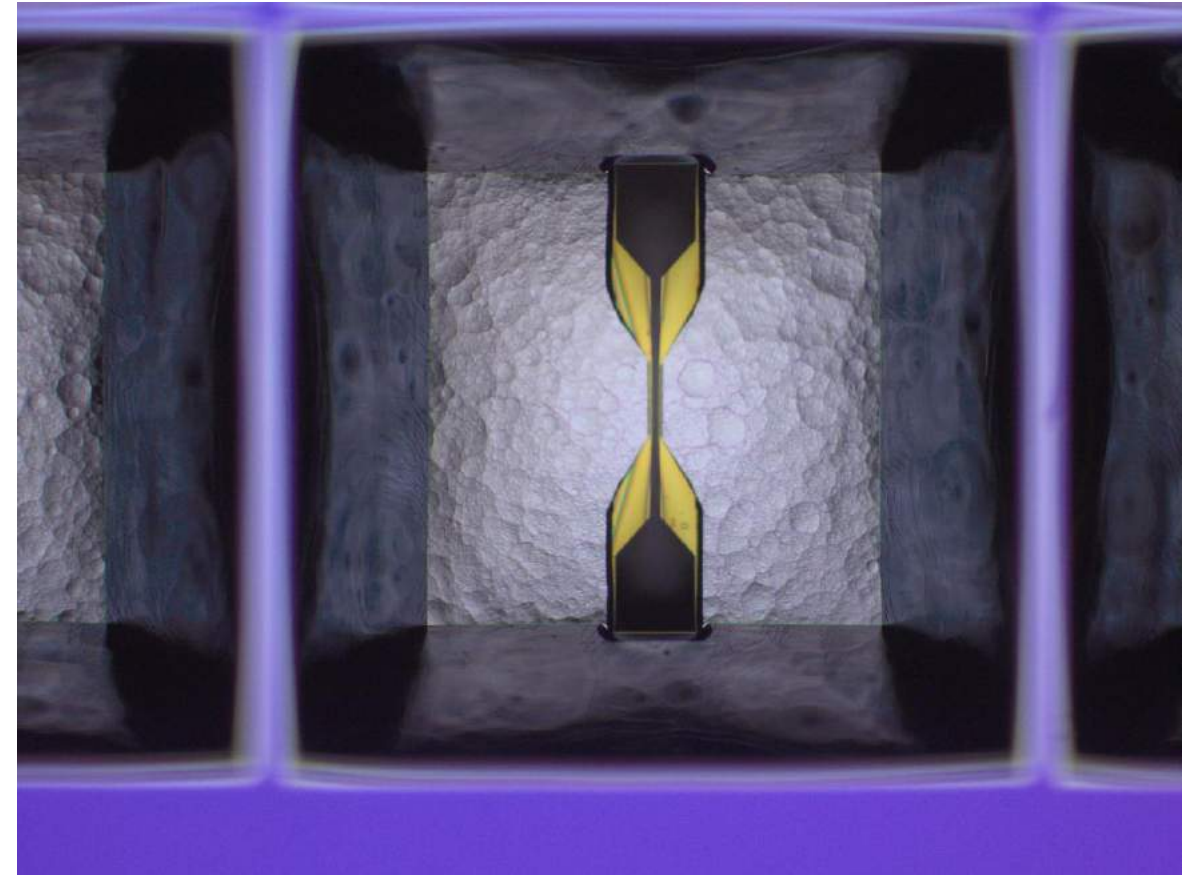
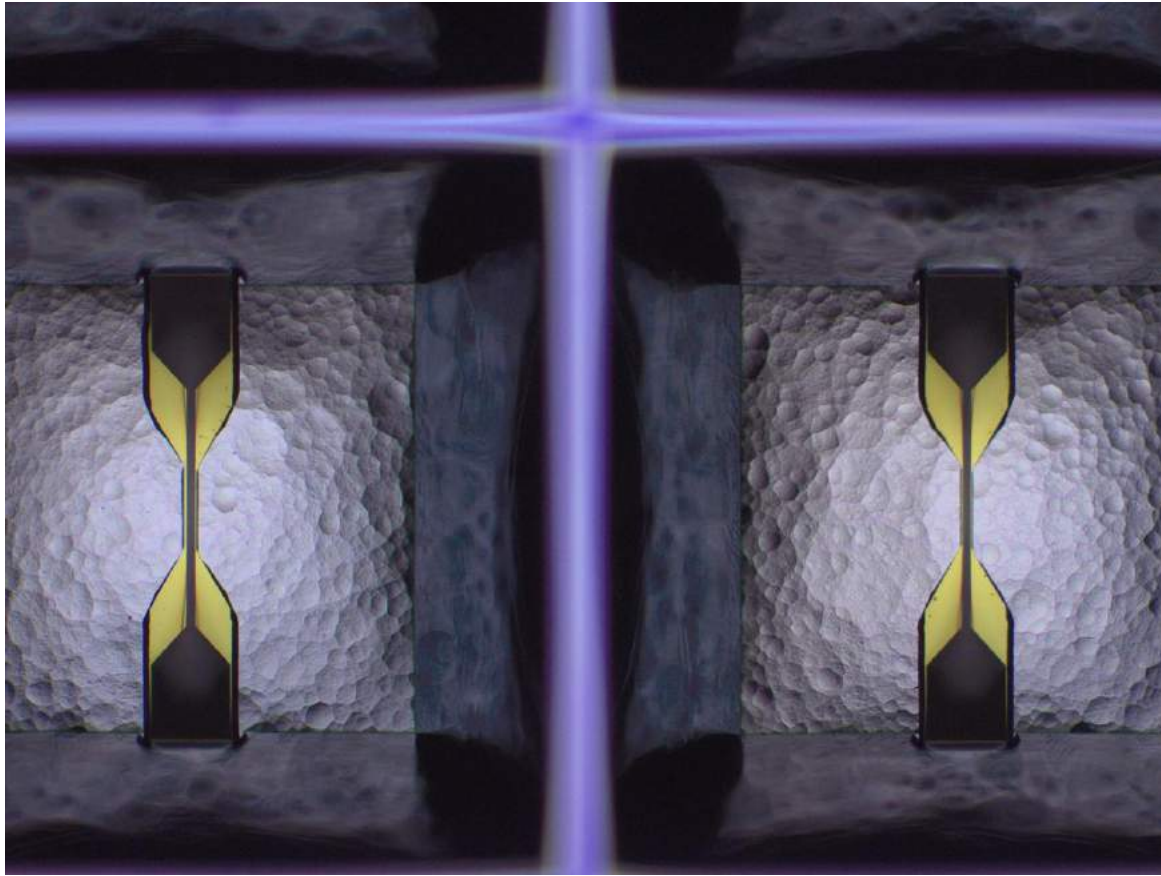
- Spin AZ4110 at 4krpm for 30secs.
- Bake for 95C for 60 secs.
- Align the backside with the front side with the MA6 Backside Aligner.
- Develop in AZ400K 1:4 developer for 60secs.
- Open up the patterns by doing a Plasma Etch in CF₄/O₂ at 300/100 pressure for 12 mins.
- To do 2 mins of O₂ Plasma Clean before putting in KOH.

KOH Etch

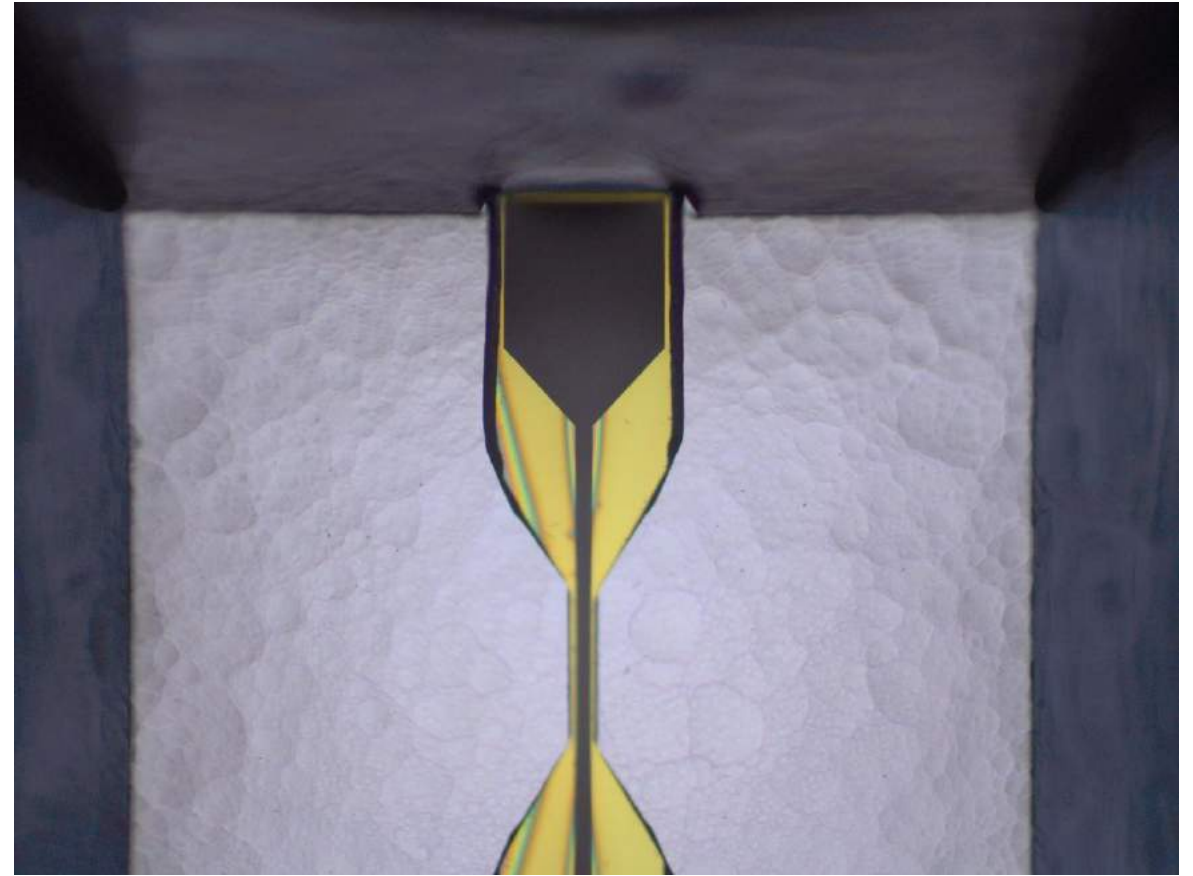
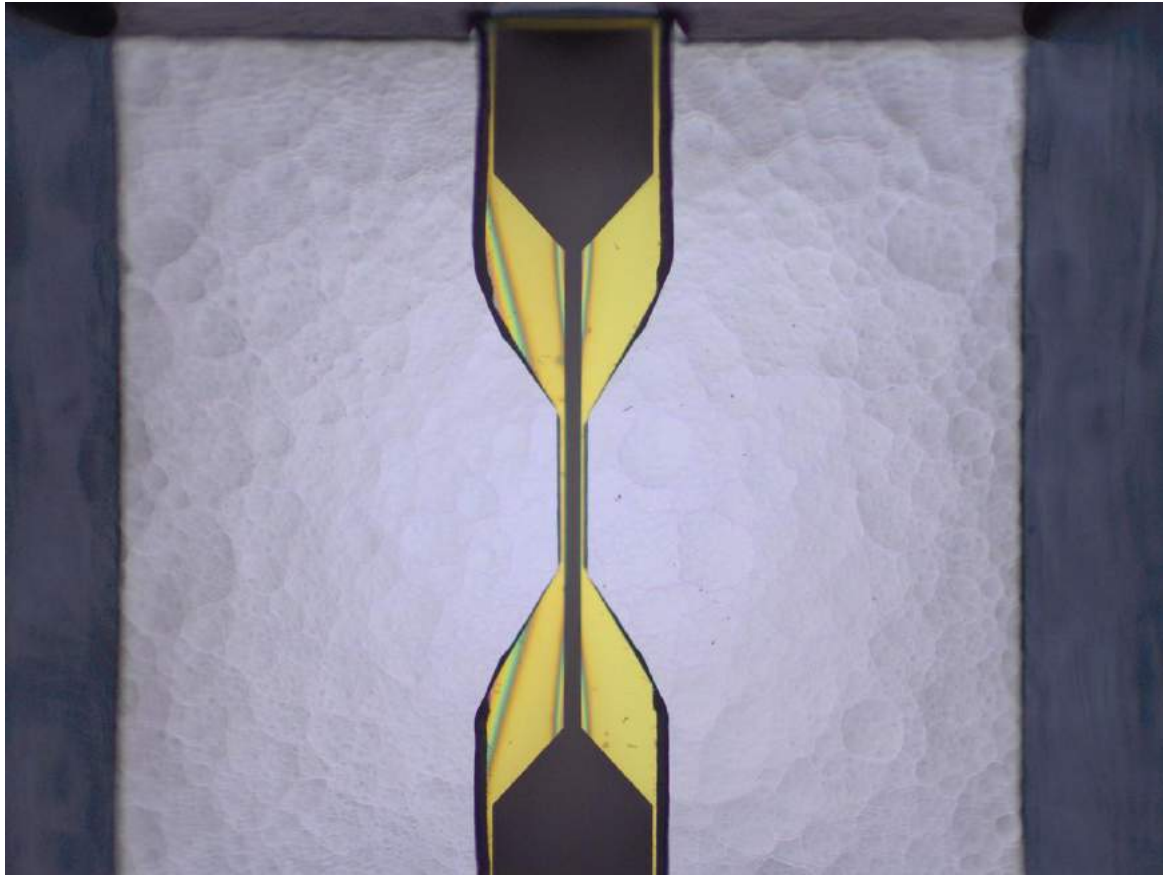
- The sample is put in KOH bath at 87C for 8 hours.
- The first large area is seen coming through.
- HF etch of 3mins and 30secs is done.
- The sample is put in KOH till the patterns start coming out properly.
- The etch is stopped as soon as the pattern is opened up(not wait for all the silicon to be etched).

The remaining silicon makes the mask more stable during the evaporation in MBE.

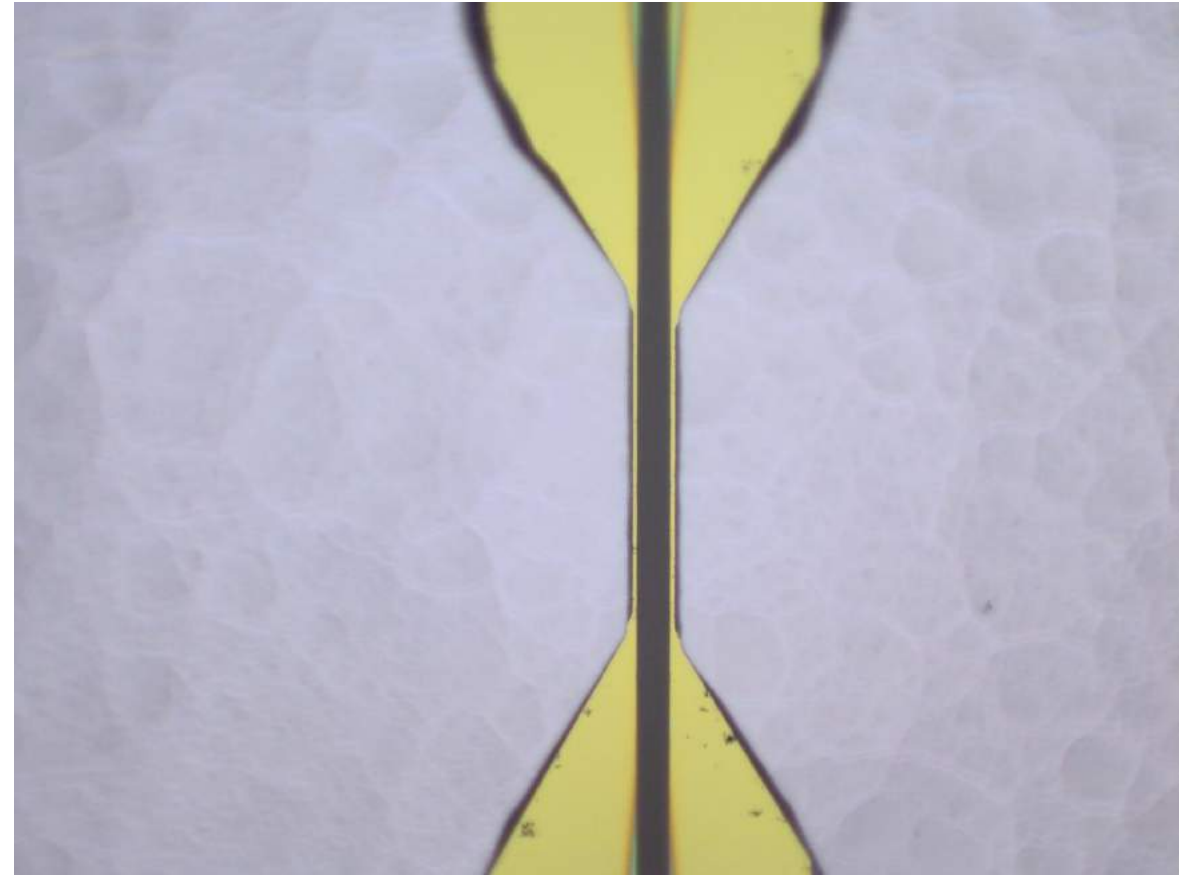
After Final KOH etch



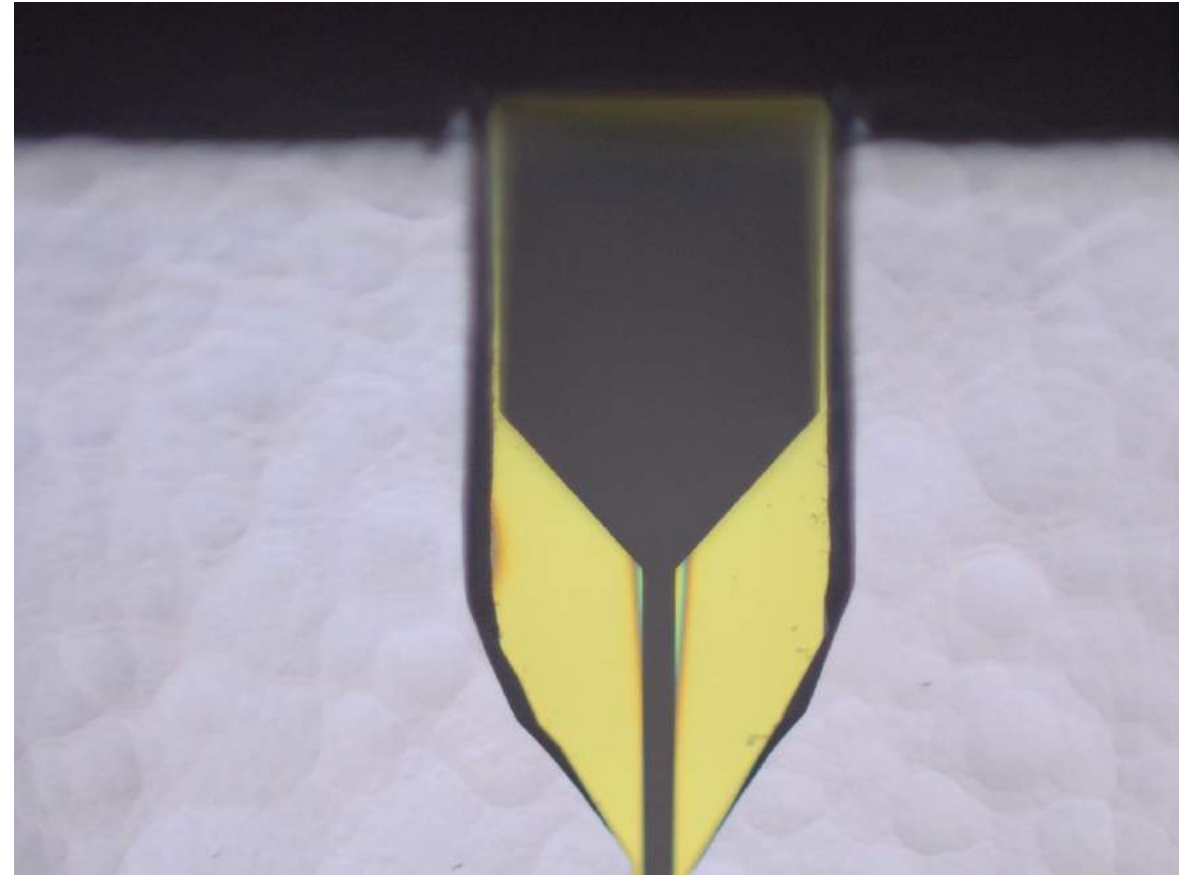
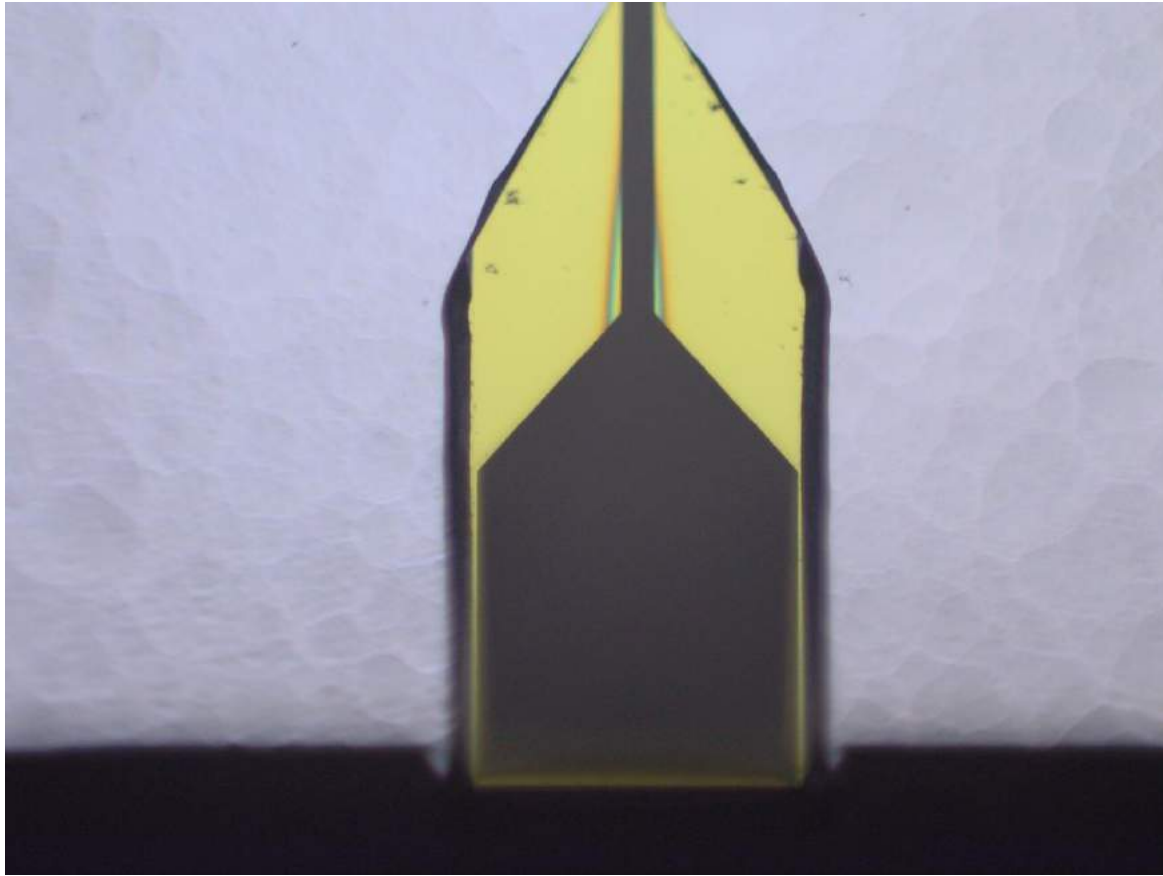
After Final KOH etch



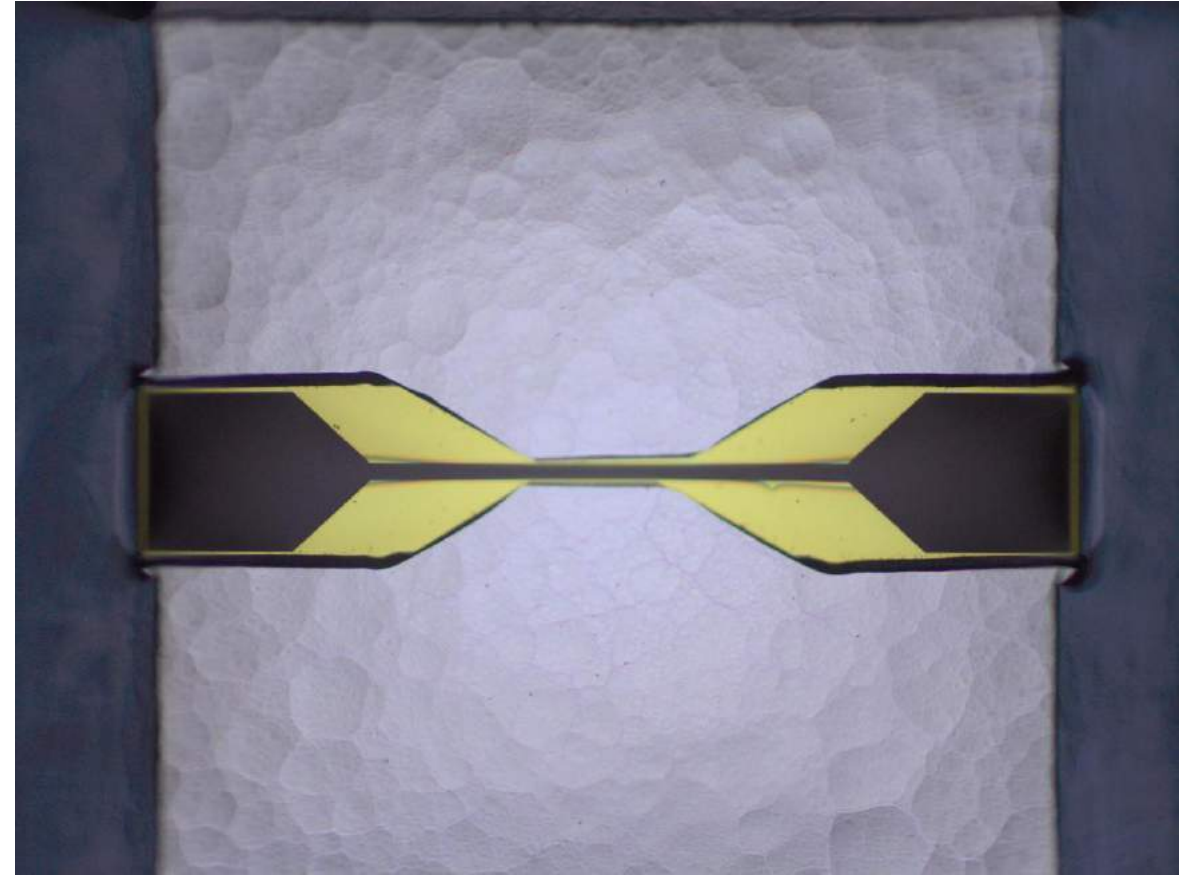
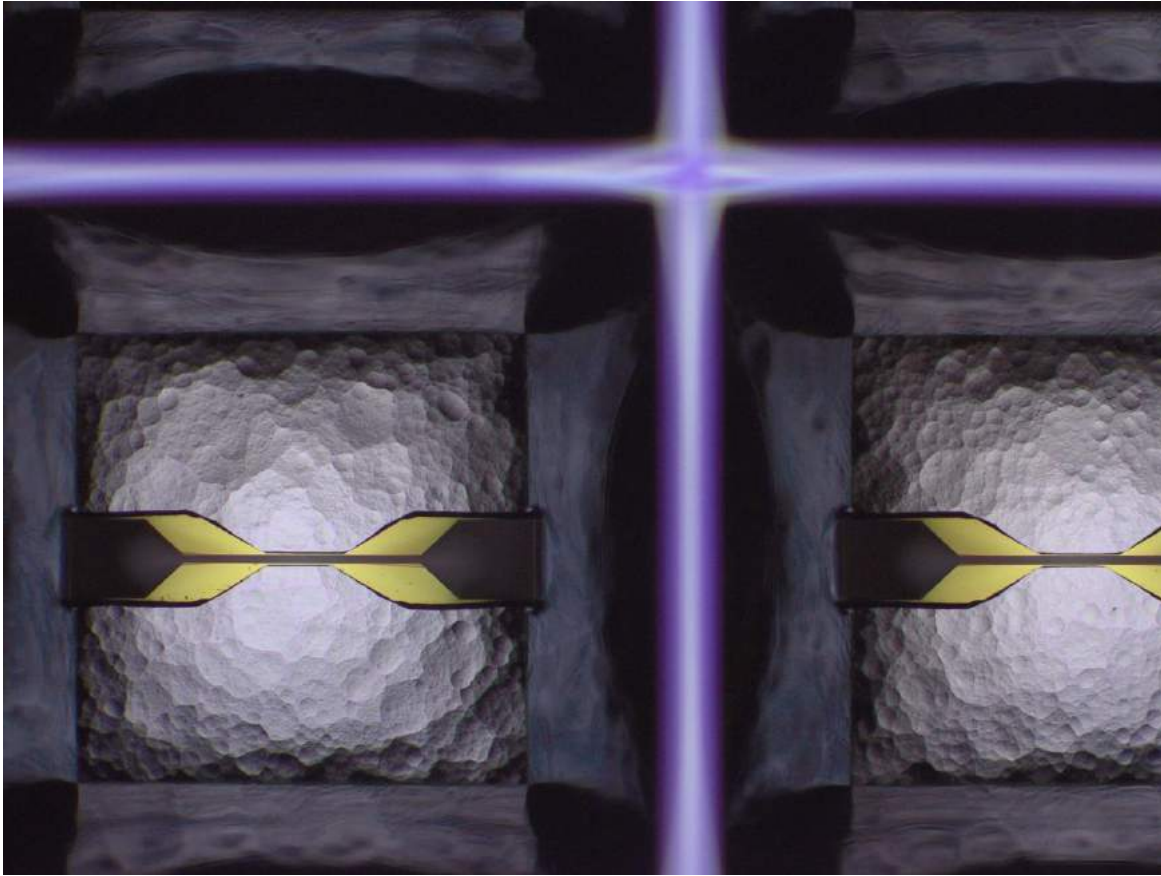
After Final KOH etch



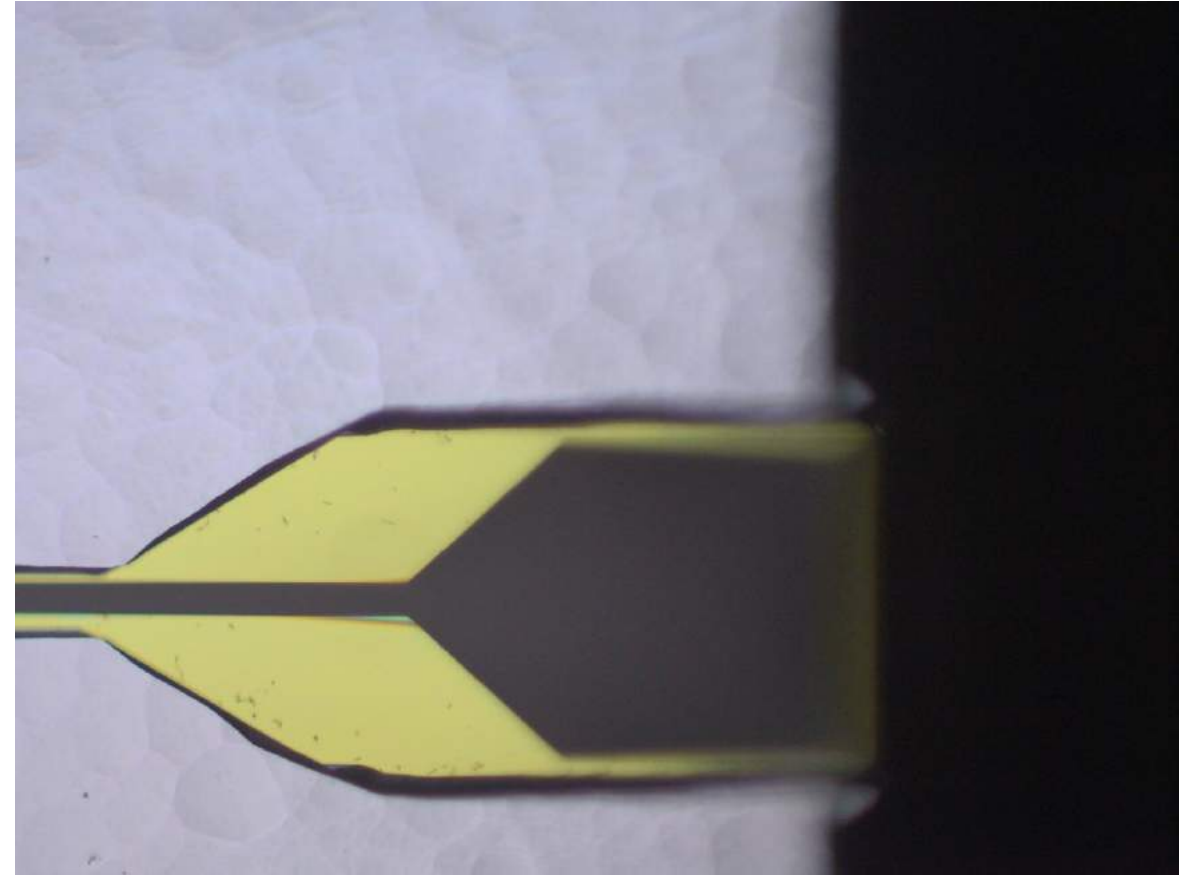
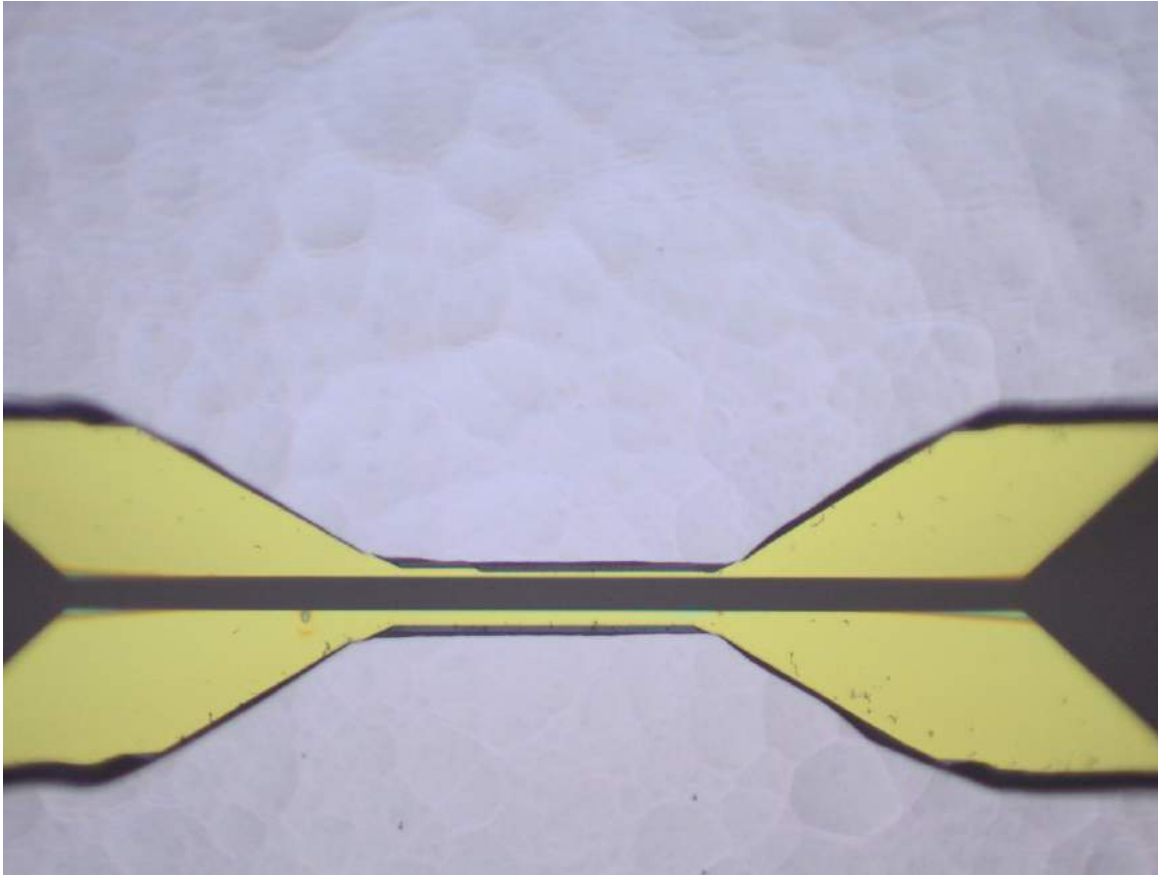
After Final KOH etch



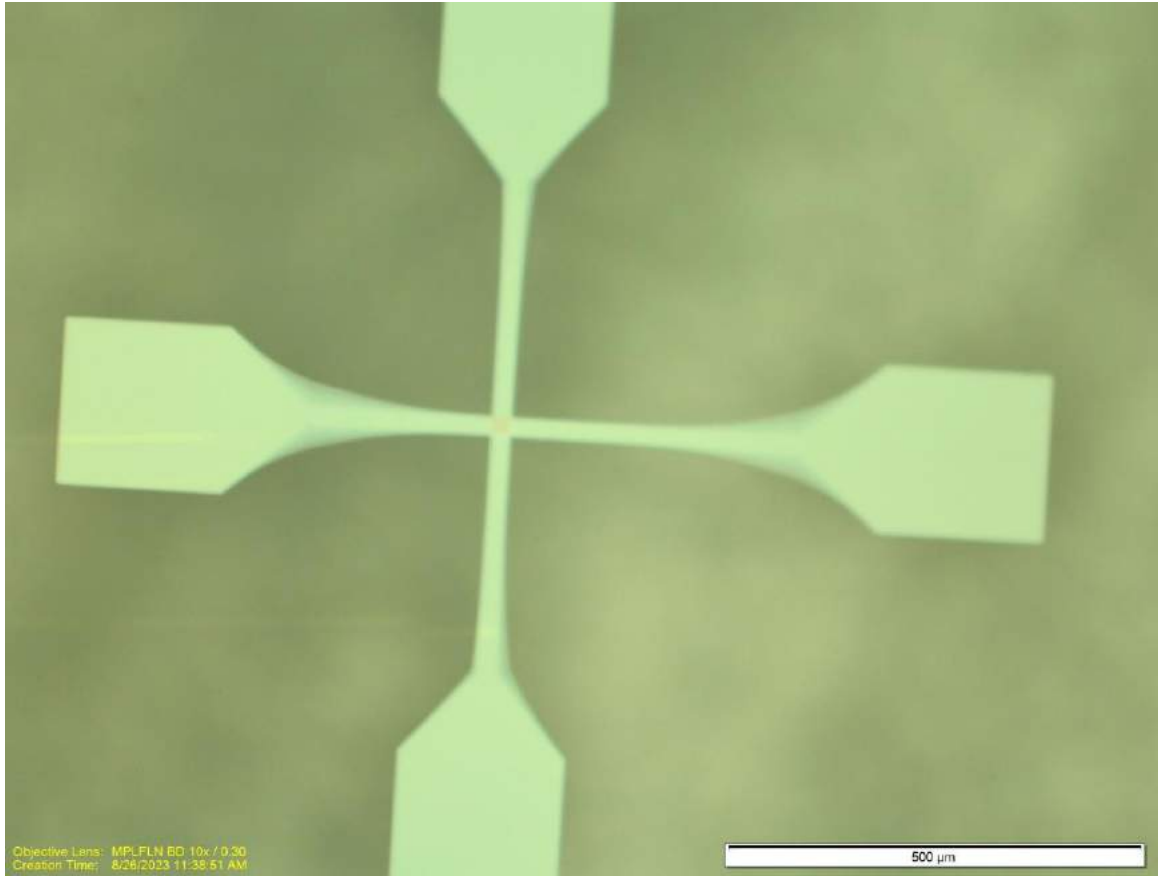
After Final KOH etch



After Final KOH etch



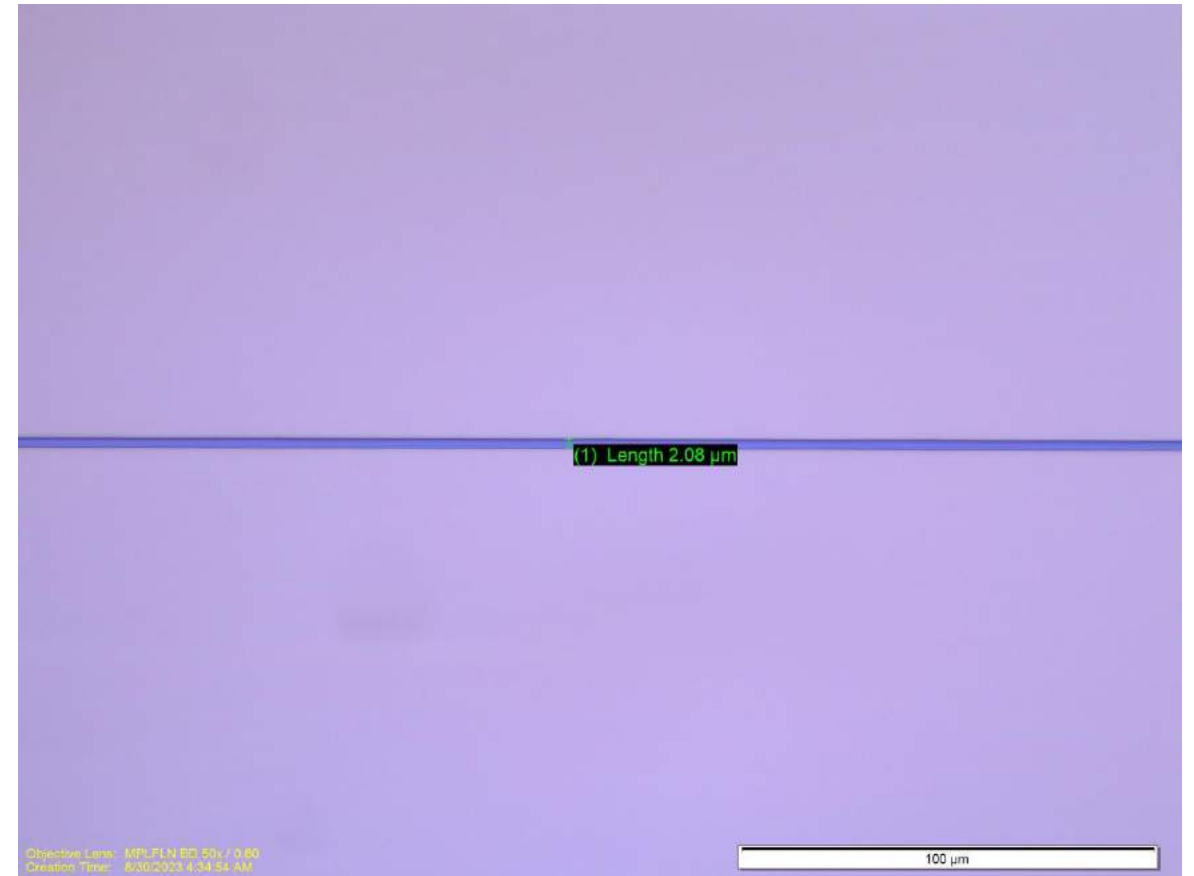
Growth of Ta/Ta₂O₅/Ta Josephson Junctions



Growth of Ta/Ta₂O₅/Ta Josephson Junctions



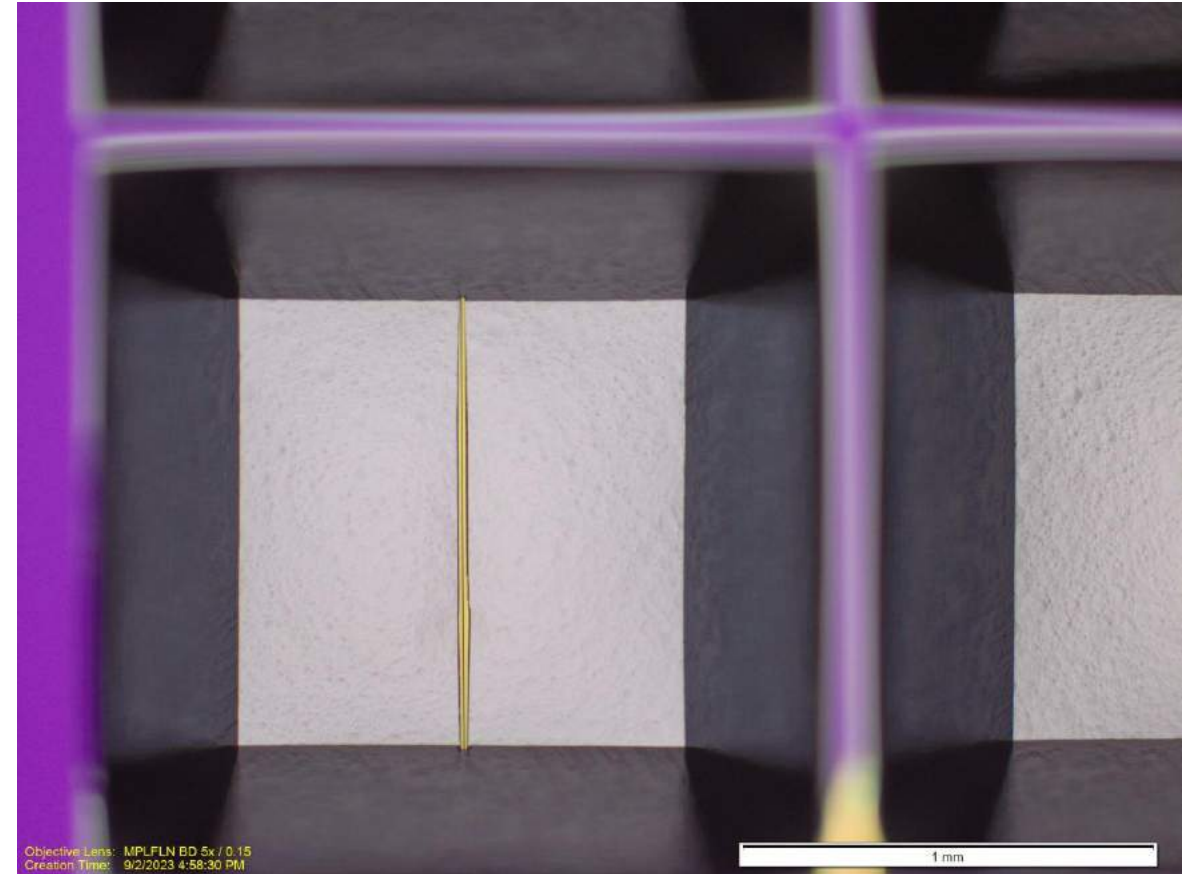
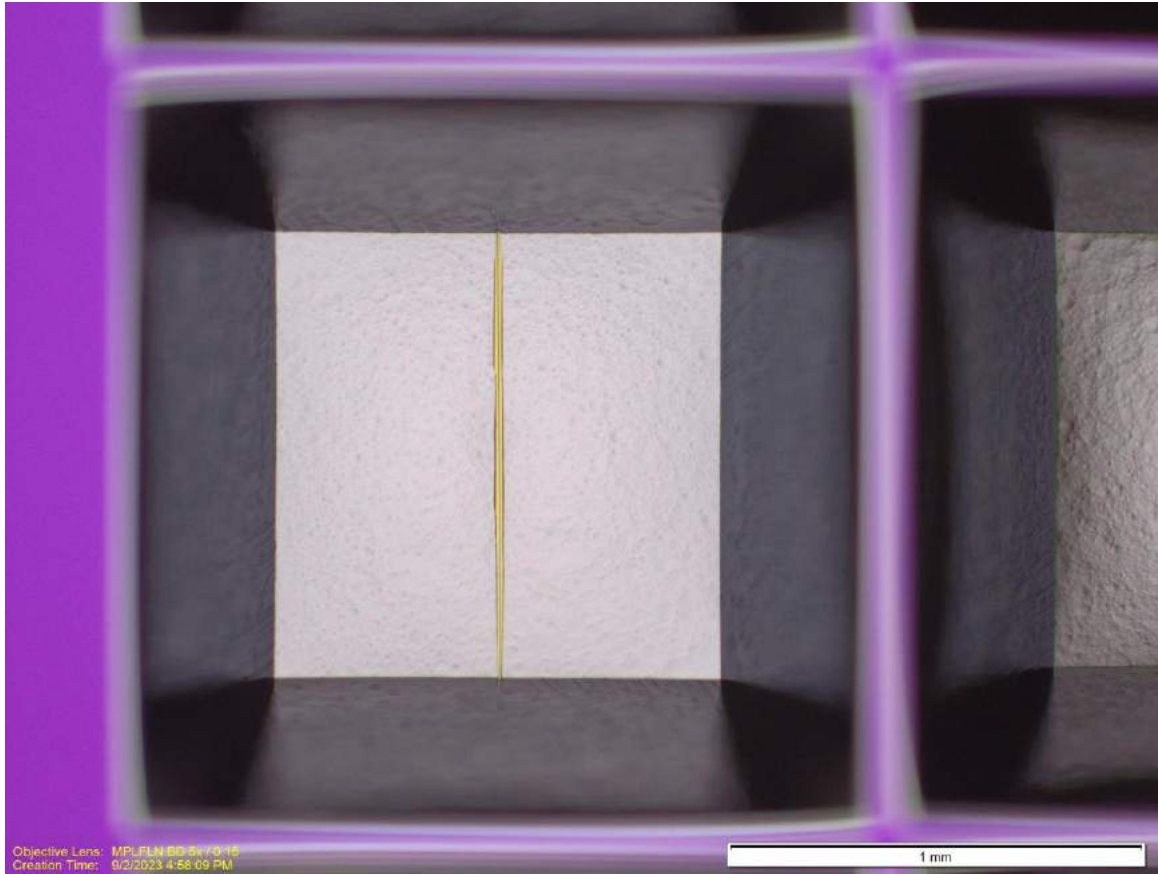
First Lithography-Pattern 2



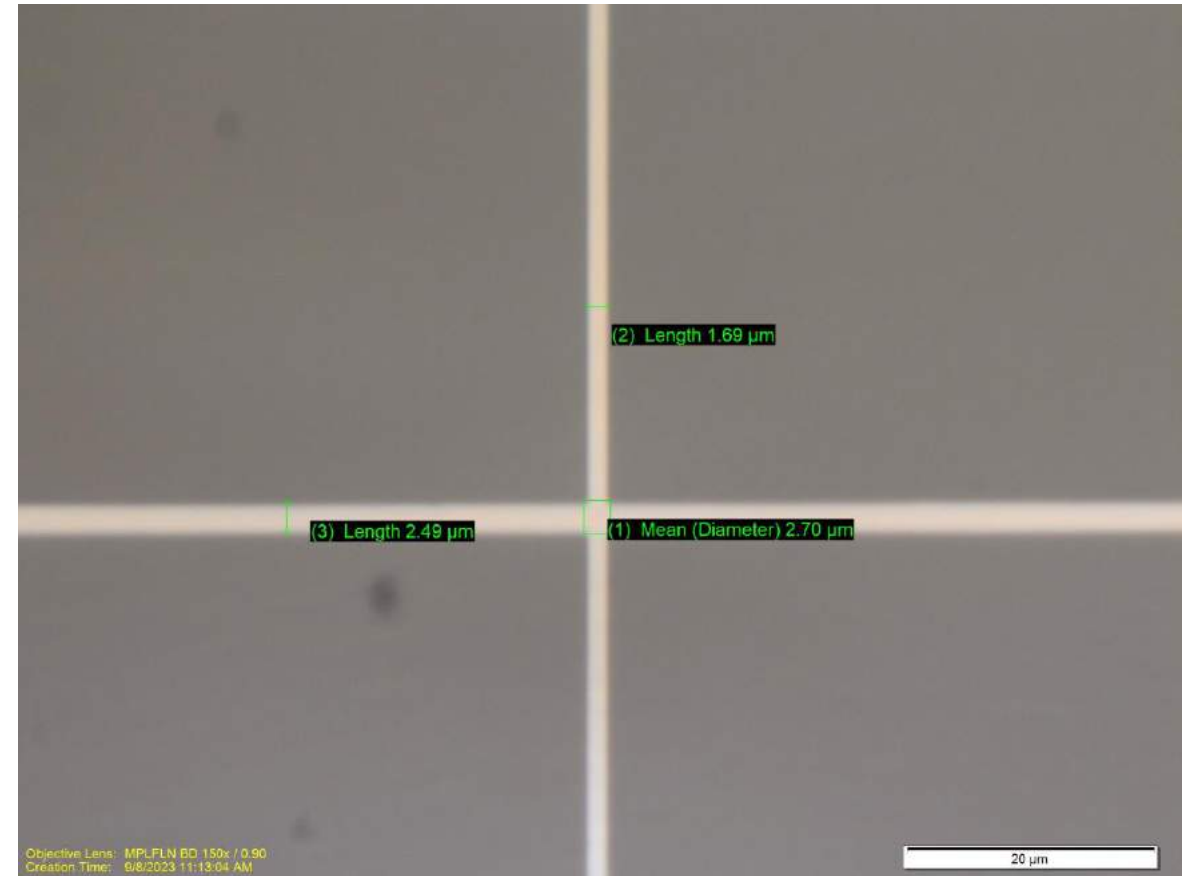
First Lithography-Pattern 2



After KOH Etch- Pattern 2



After Growth - Pattern 2

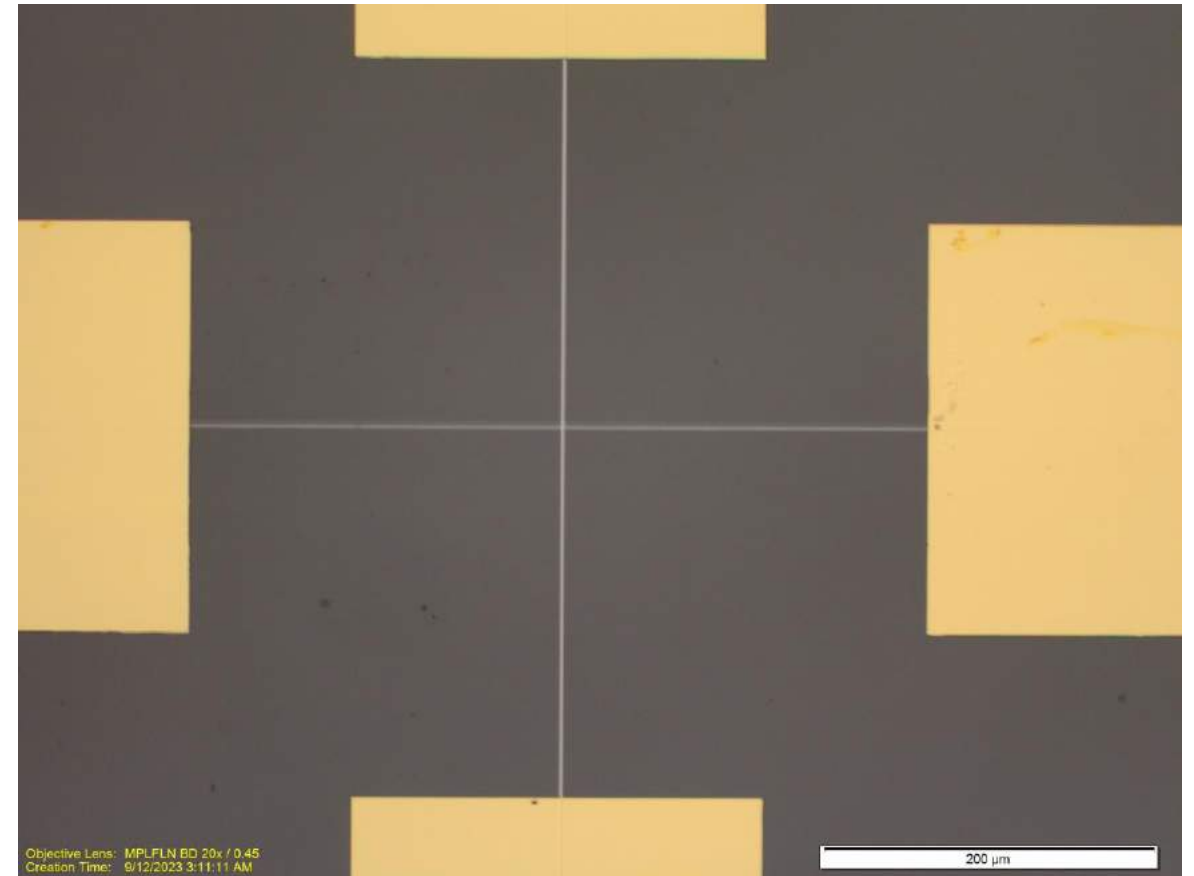
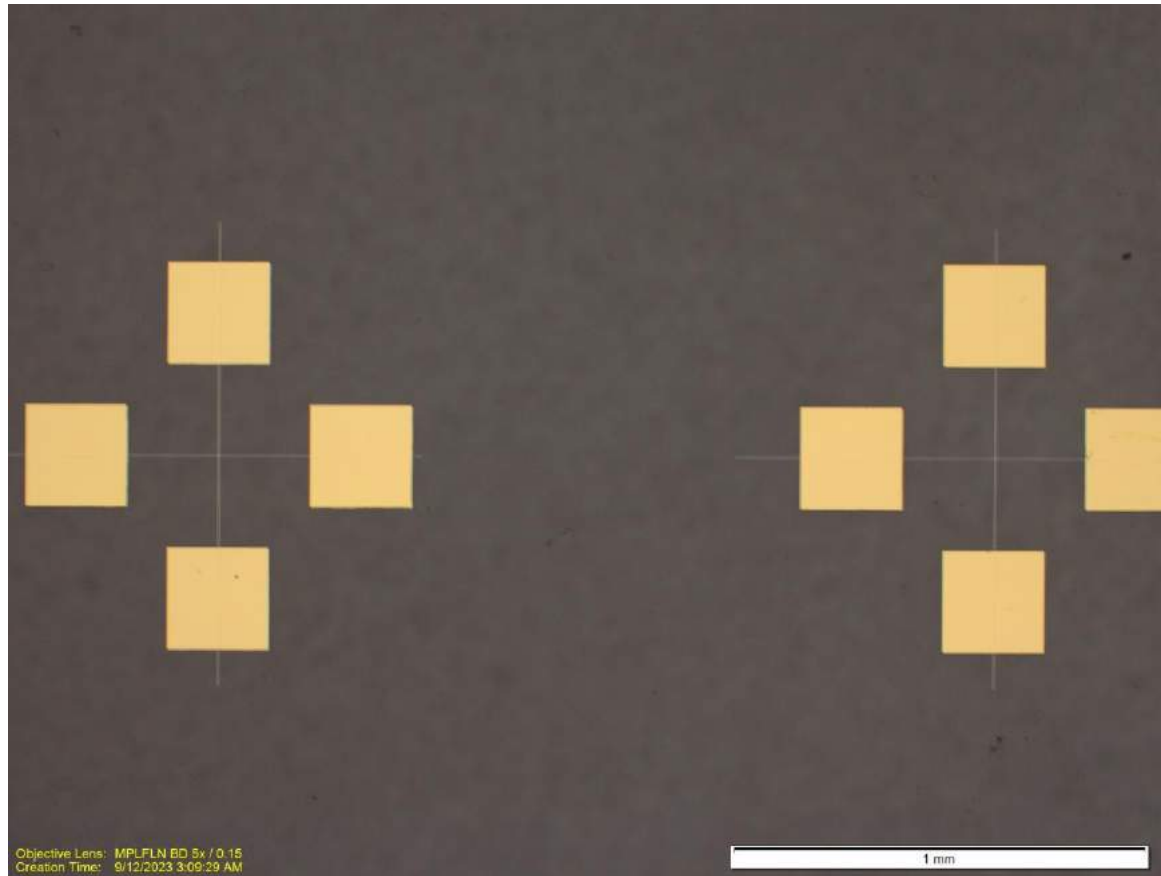


Fabrication of Contact Pads

- Clean the wafer with Acetone and IPA for 2 mins each without sonication.
- Spin AZ4110 at 4krpm for 30secs
- Bake at 95C for 60 secs.
- MLA **405nm** with **dose – 200 mJ/cm²** and **defocus -0.**
- Develop in AZ400K 1:4 for 60secs
- O₂ plasma 300/100 for 1 min.
- HF etch for 2 mins.
- E-beam evaporation of **Ti/Au** in **10nm/100nm**.

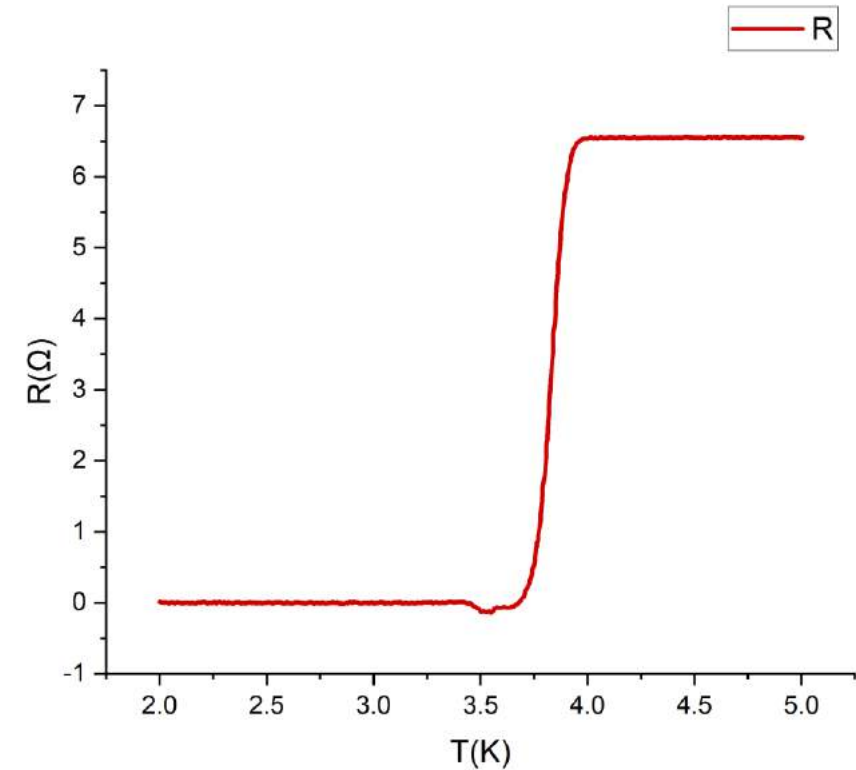
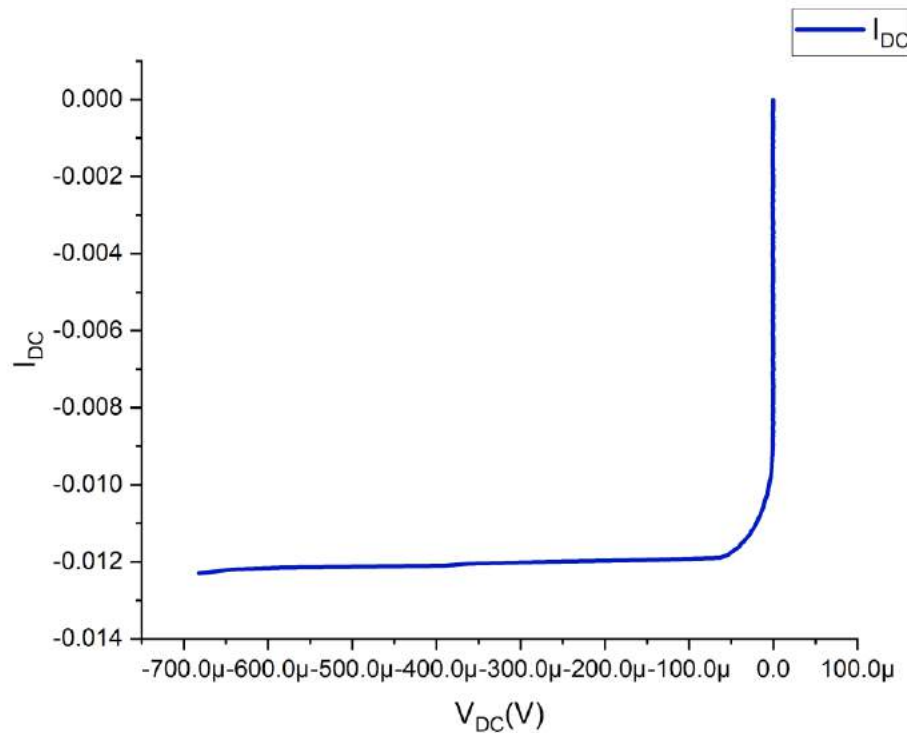
Note- Fabrication was tried without HF etch, but the contact resistance came out very high~**10kohms**.

Final Device



Transport Measurements- Pattern 1

- The first device(20 μm x 20 μm) showed superconductivity.
- The transition temperature was seen at 2.06K.



UC SANTA BARBARA