Navigating topography challenges in advanced e-beam lithography for implantable devices

BeaMeeting
05/27/2025

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LLNL-PRES-2006504
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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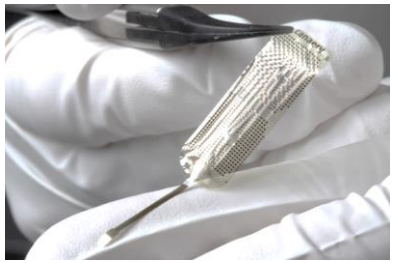
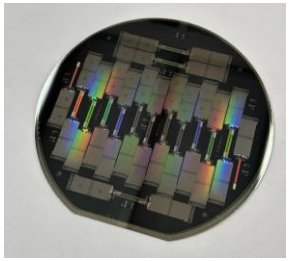
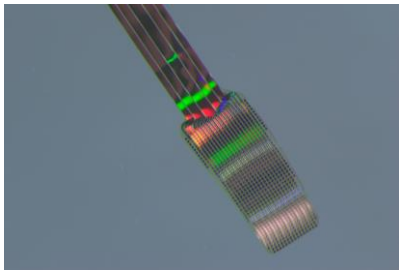
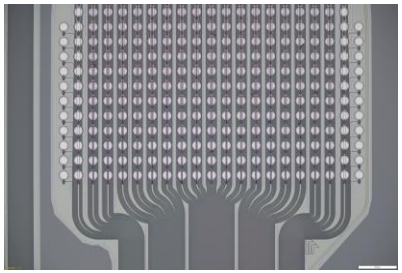
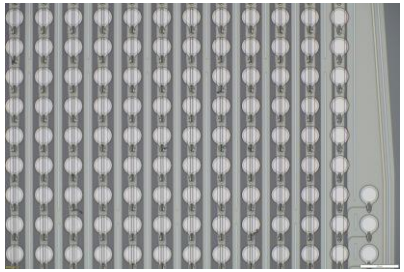
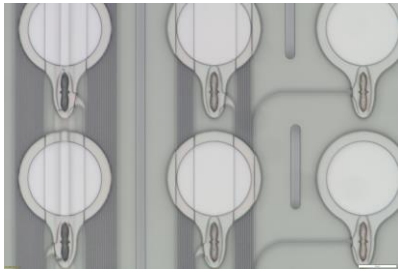
LLNL's first sets of EBL implantable devices fabricated in 2024

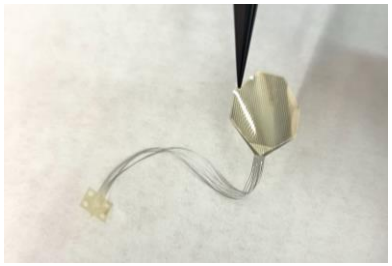
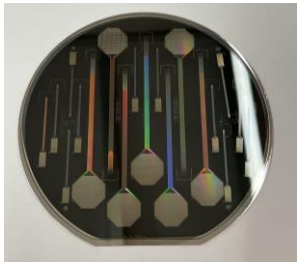
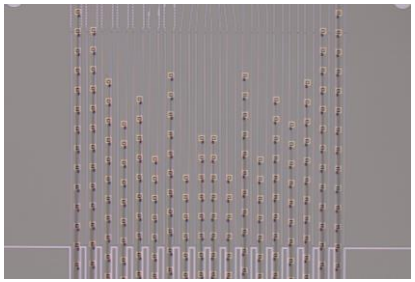
768-ch device

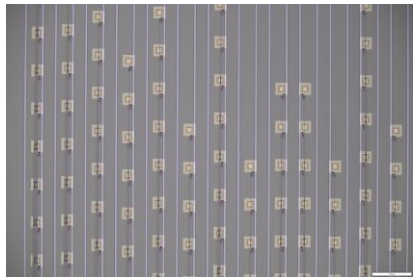
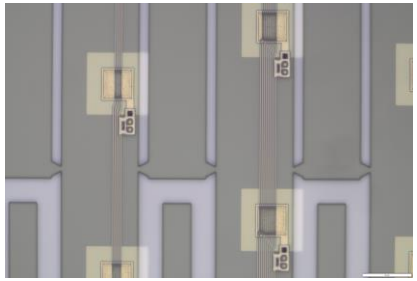
- 767 electrodes, 1 reference
- 40µm diameter electrodes
- 0.42µm trace width

1024-ch device

- 1024 electrodes
- 30µm-width electrodes
- 1µm trace width

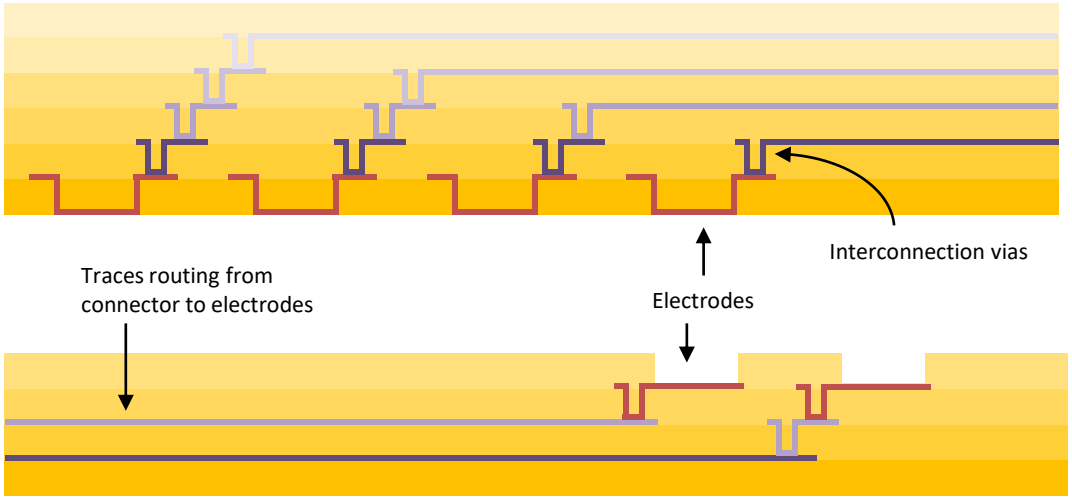
[LLNL and Canaery develop cutting-edge neural interface technology for scent detection | Lawrence Livermore National Laboratory]

canaery

Industry partner

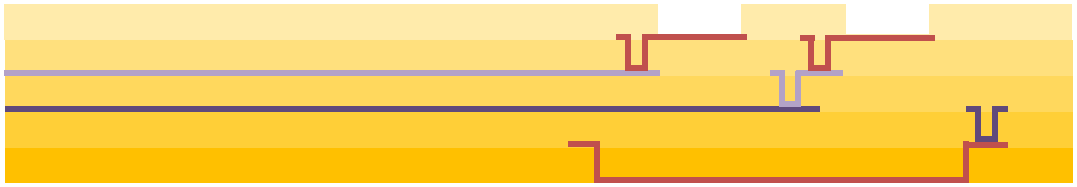
Cross-section of LLNL's implantable devices

4 trace metal
bottom-sided electrodes



2 trace metal
top-sided electrodes

2 trace metal
top & bottom-sided electrodes
(Less common)

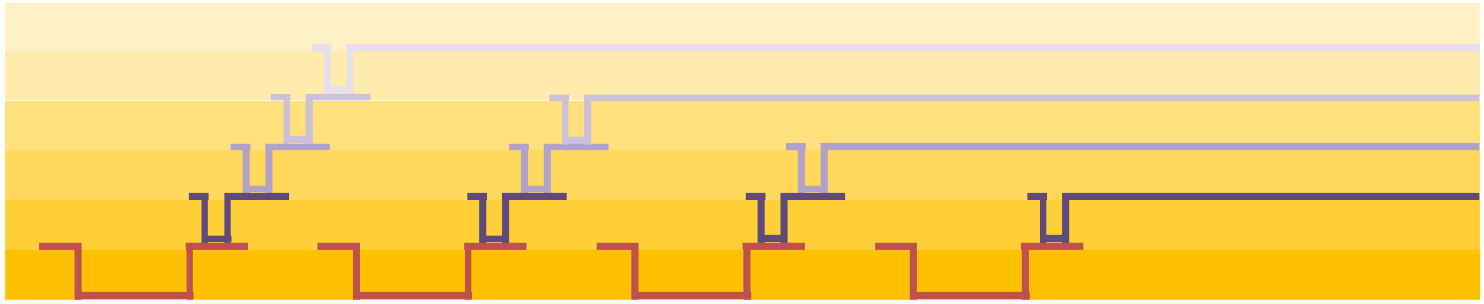


Polyimide | Trace Metal | Exposed Metal

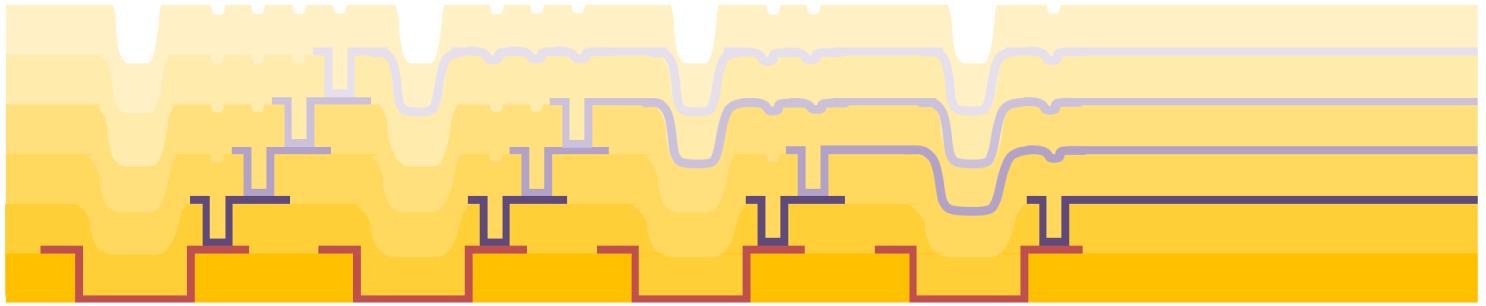
Topography introduced by vias

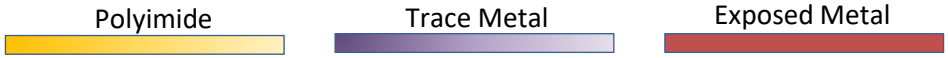
Previously shown:

4 trace metal
bottom-sided electrodes



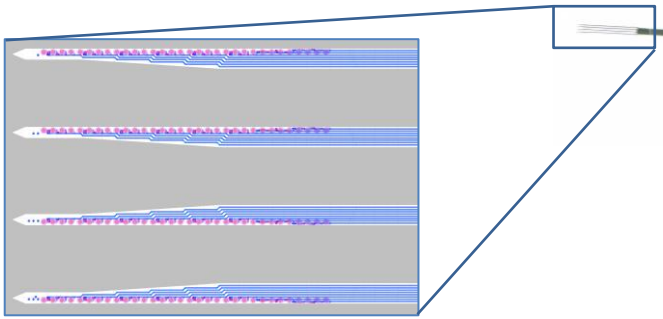
Realistically:

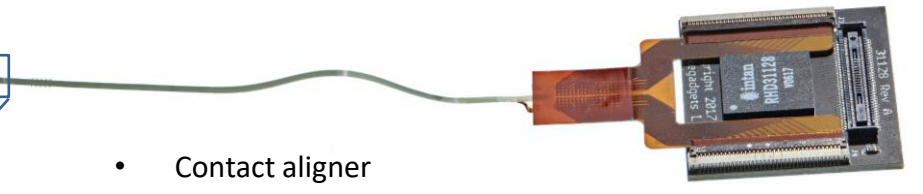




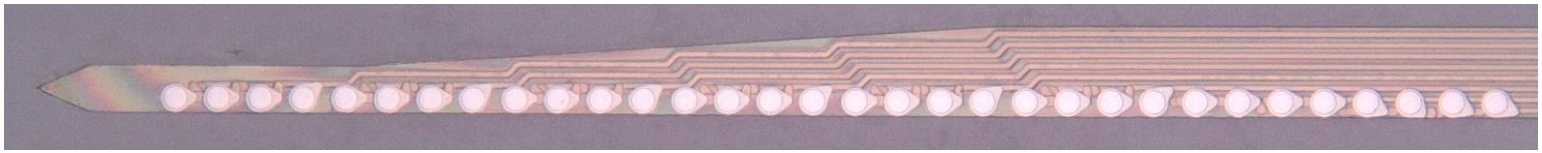
Example of LLNL's most fabricated device

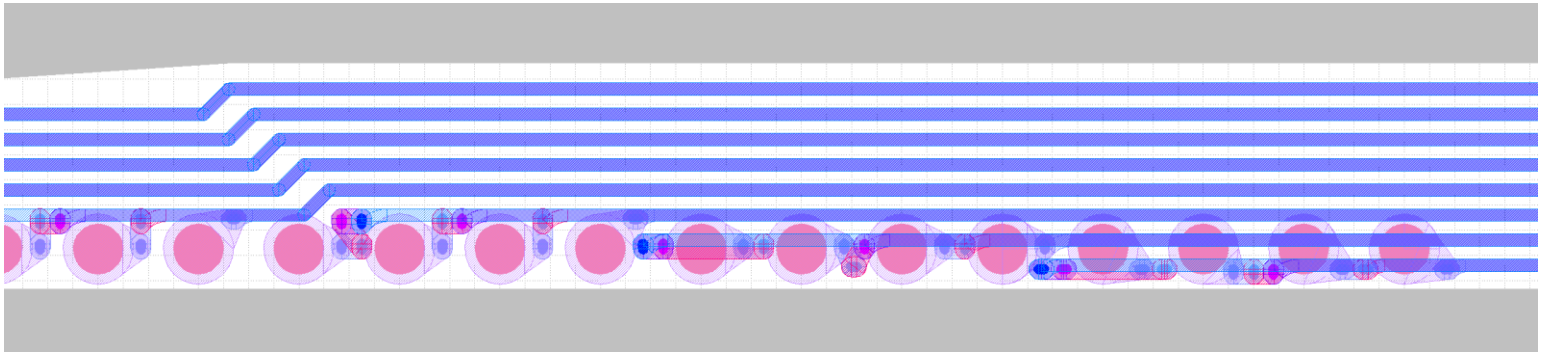
4 trace metal
bottom-sided electrodes





- Contact aligner
- 128 electrodes
- 20µm diameter electrodes
- 4-metal traces
- **5µm** trace width



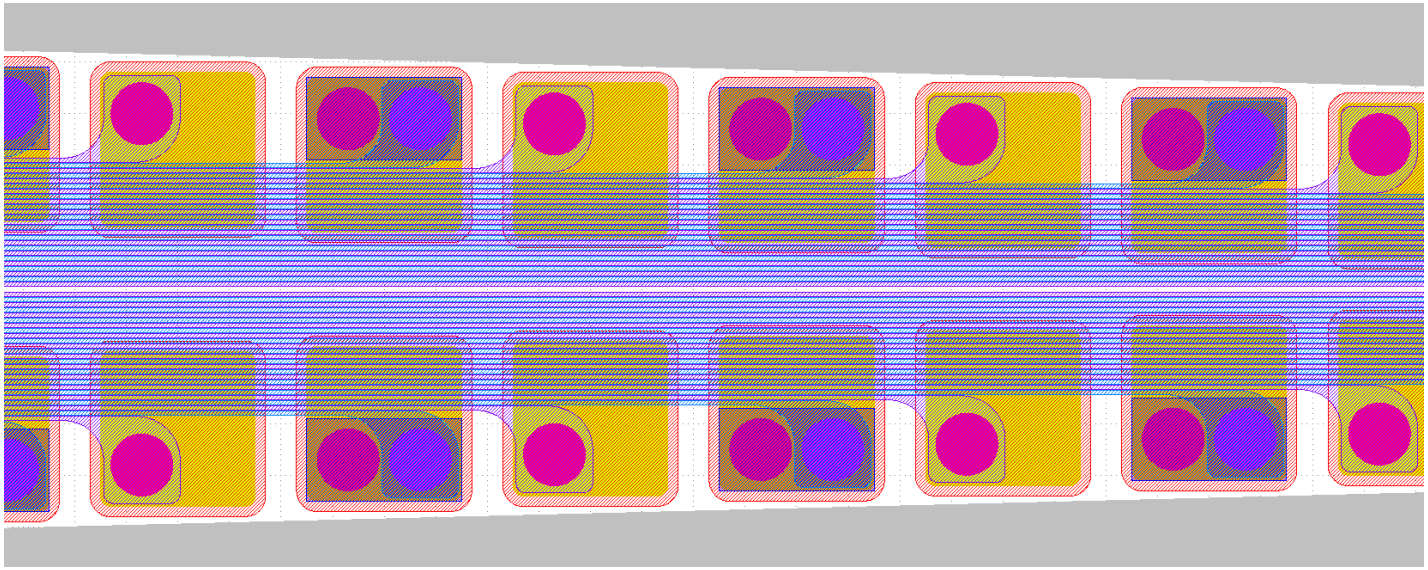


Initial dive into using EBL

Solid fill = interconnection vias

Diagonal stripes = patterned metal

- New design incorporating sub-micron features
- Traces positioned inside vias
- Need to study and test litho of sub-micron traces in vias (or wells) and reliability of resist mask for metal plasma etching

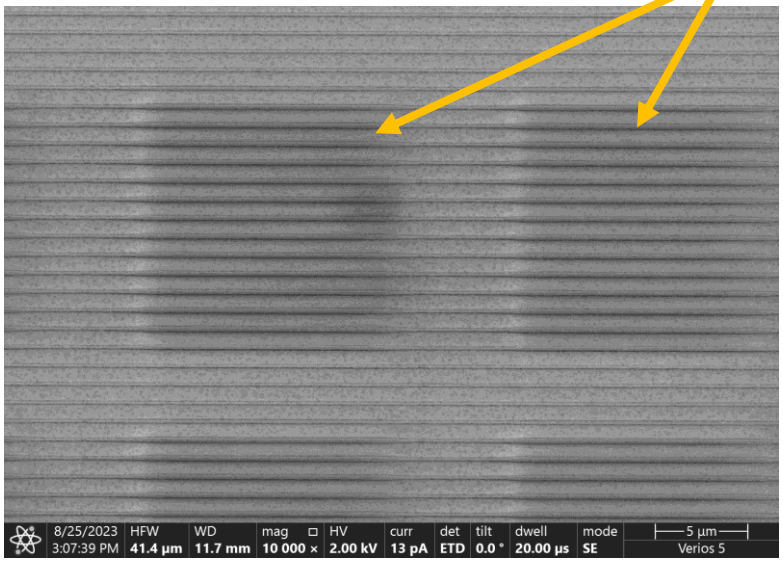


- Resist: 0.75µm AR-N 7520.17 new
- Dose: 105µC/cm^2

Patterned resist over wells

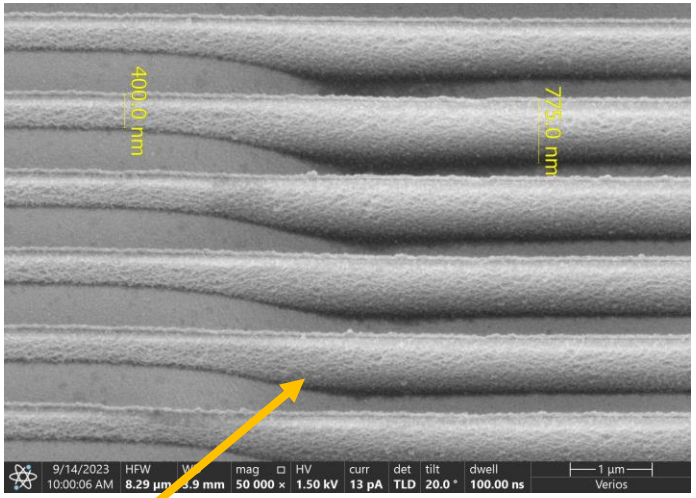
- Resist pools in wells leading to film thickness variations across a wafer.
- Important for patterned resist to be thick enough to survive as mask during metal plasma etching.

Top-down Image

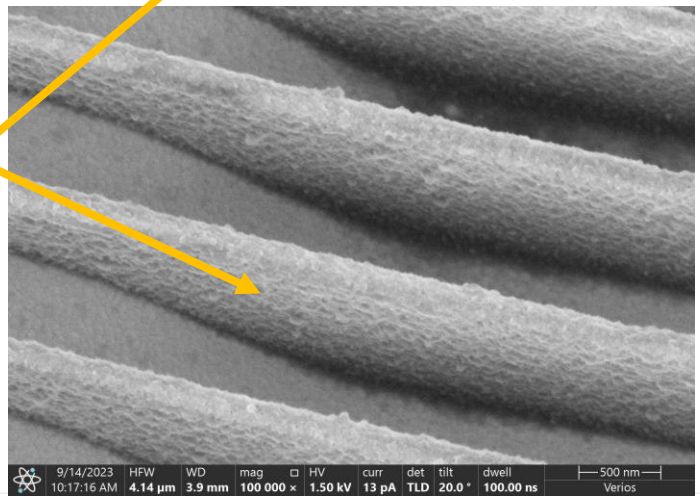


Square wells with patterned resist traces to mimic new design

Angled Images

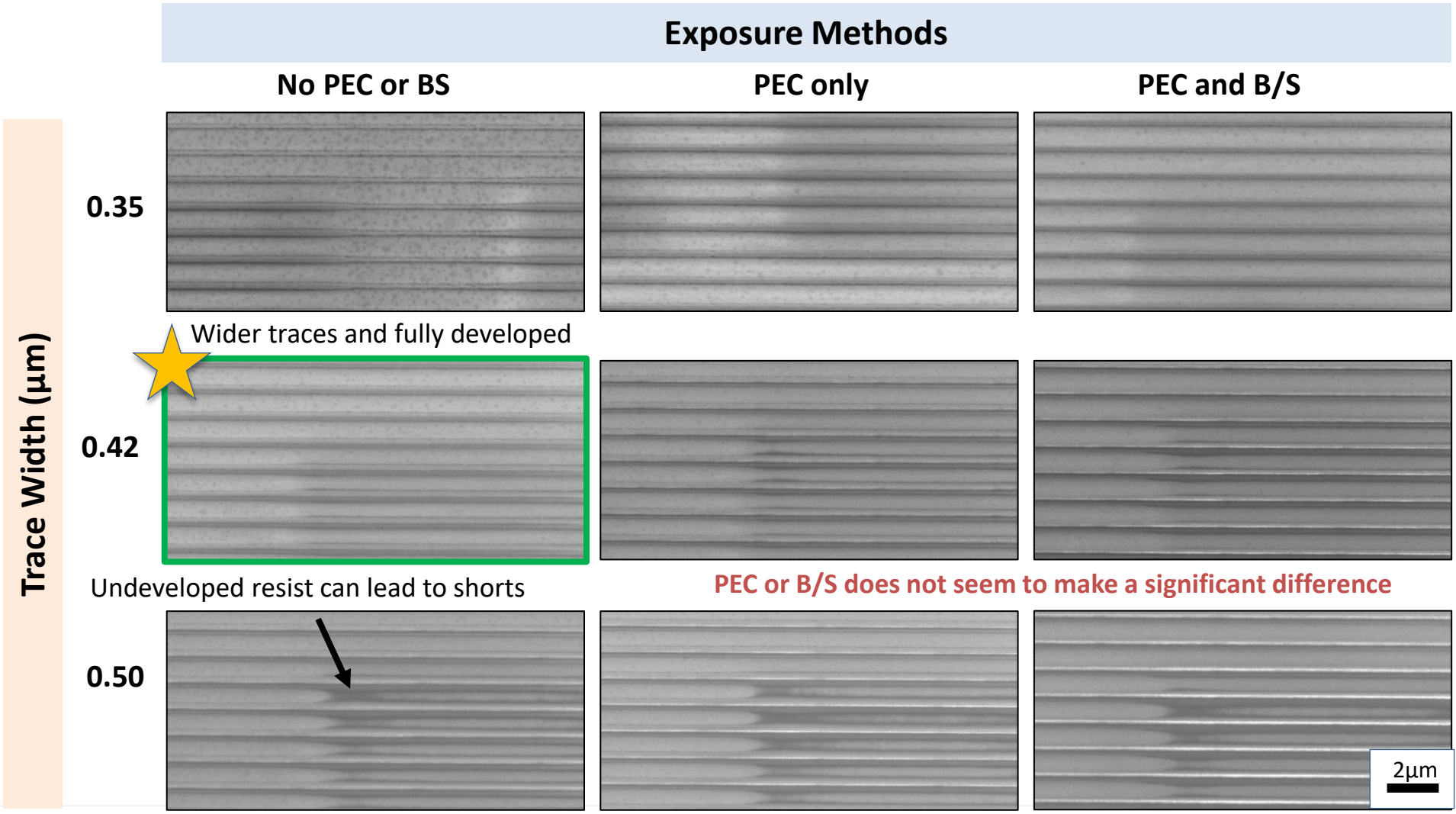


Thicker resist in wells

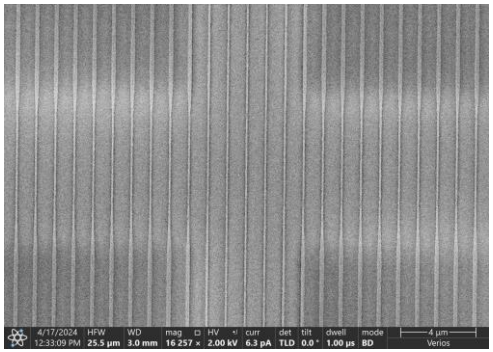
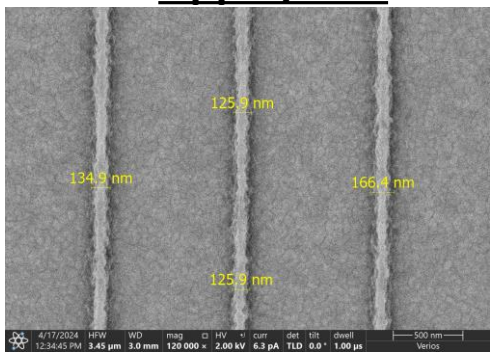
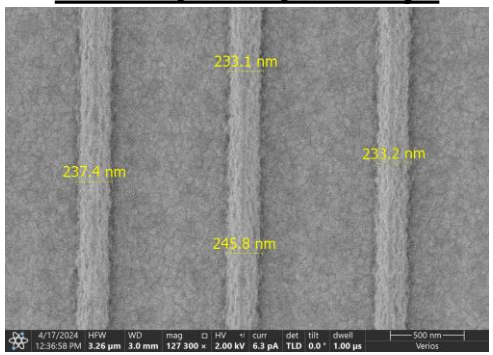
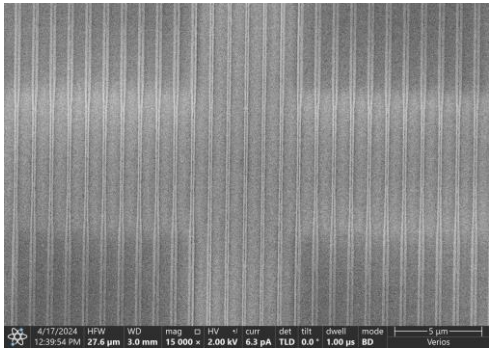
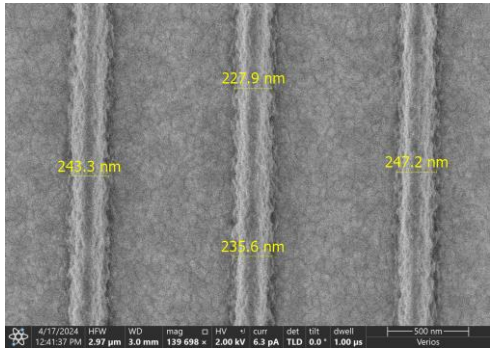
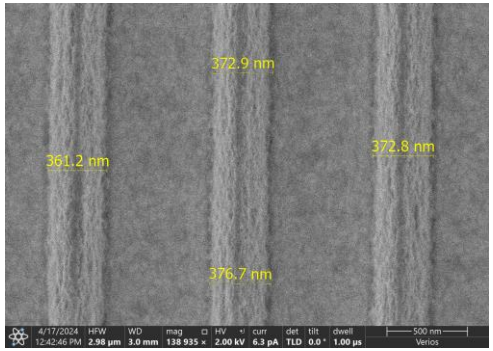
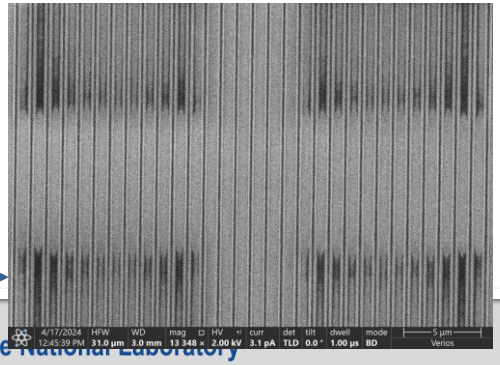
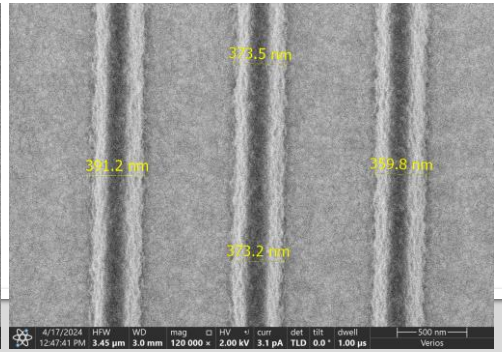
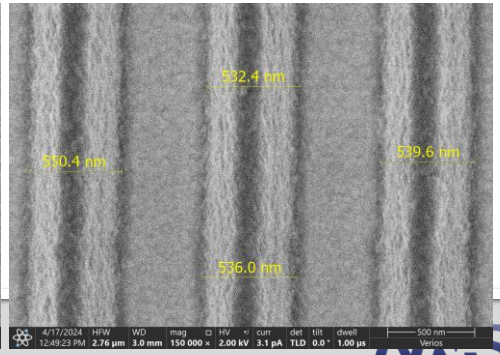


Test matrix

1µm pitch traces
1.2µm deep vias with 2µm PI coverage
PEC: Proximity effect correction
B/S: Bulk-sleeve



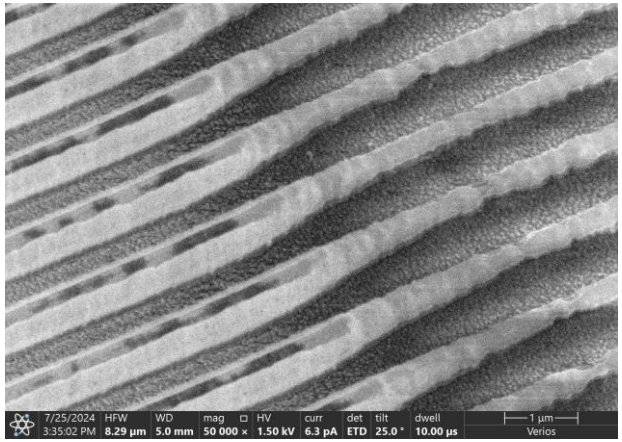
Close-up of resist features
(no PEC or Bulk/Sleeve)

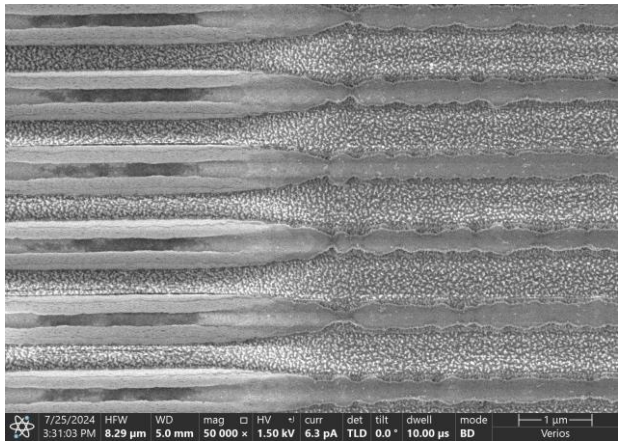
Trace Width	Overview	Upper/Hills	Lower/Vias/Valleys
350nm			
420nm Best trace width based on previous results.			
500nm Undeveloped resist →			

After metal etching
(no PEC or Bulk/Sleeve)

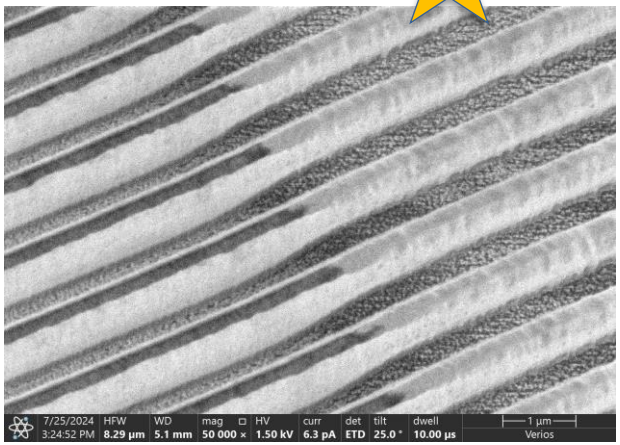
Trace width:

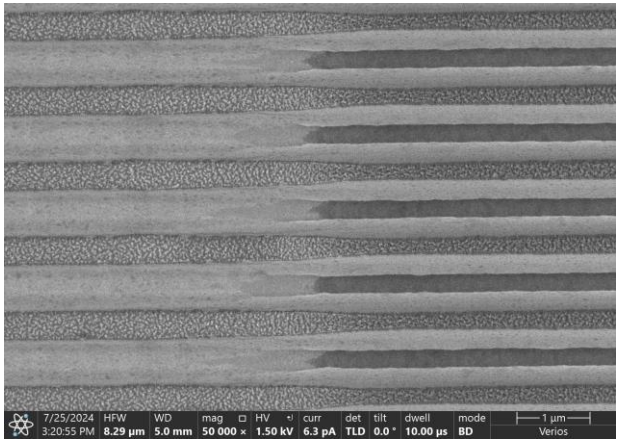
350nm



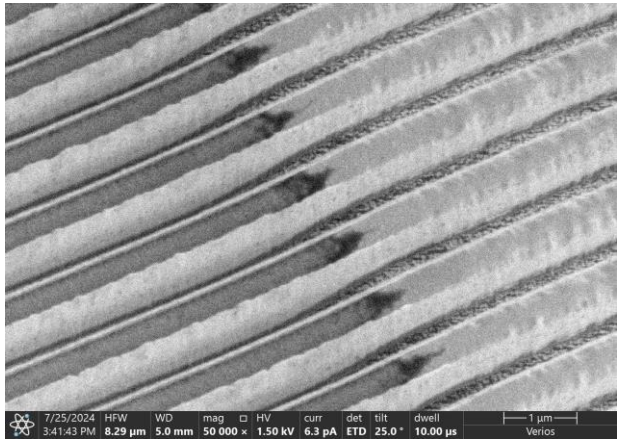


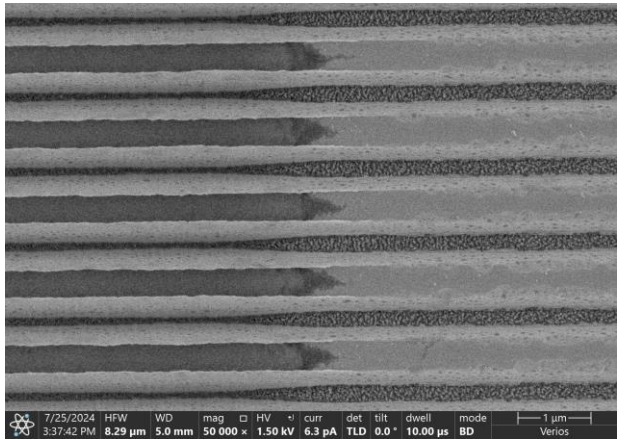
420nm





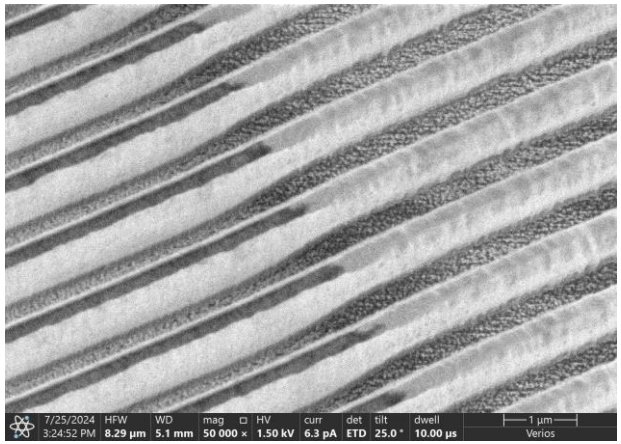
500nm

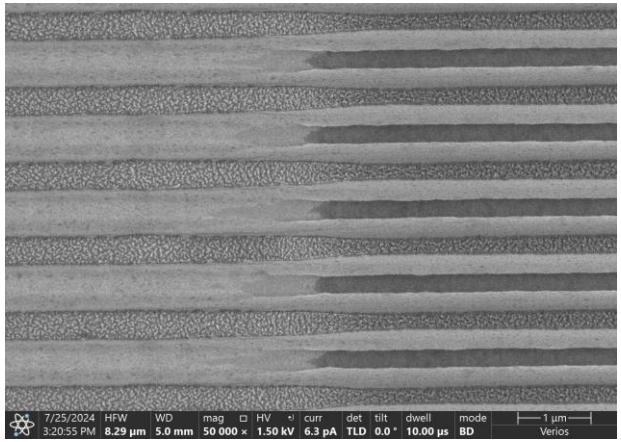




Previous test wafers were insufficient

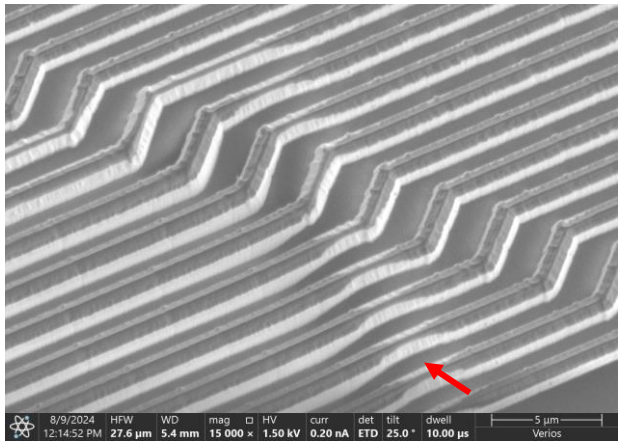
No patterned metal between polyimide layers

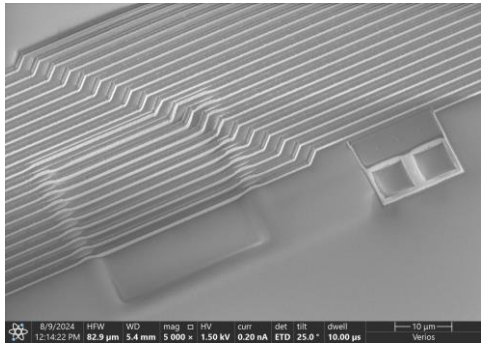


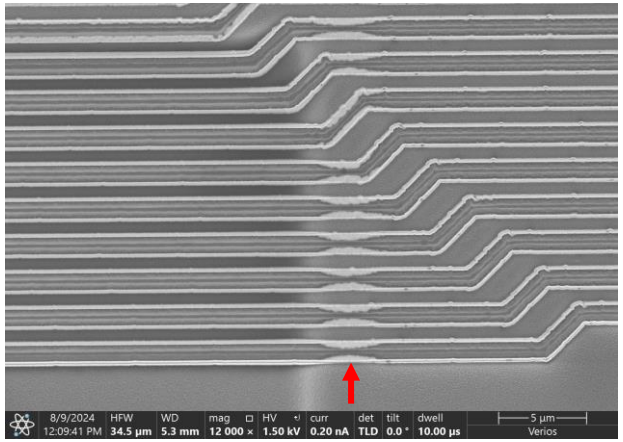


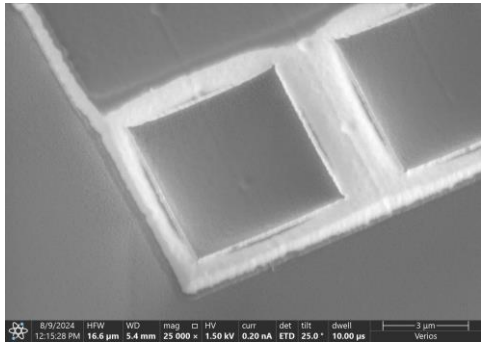
Si/ 1.1µm PI/ 2µm PI/ 0.3µm metal

with Patterned metal between polyimide layers



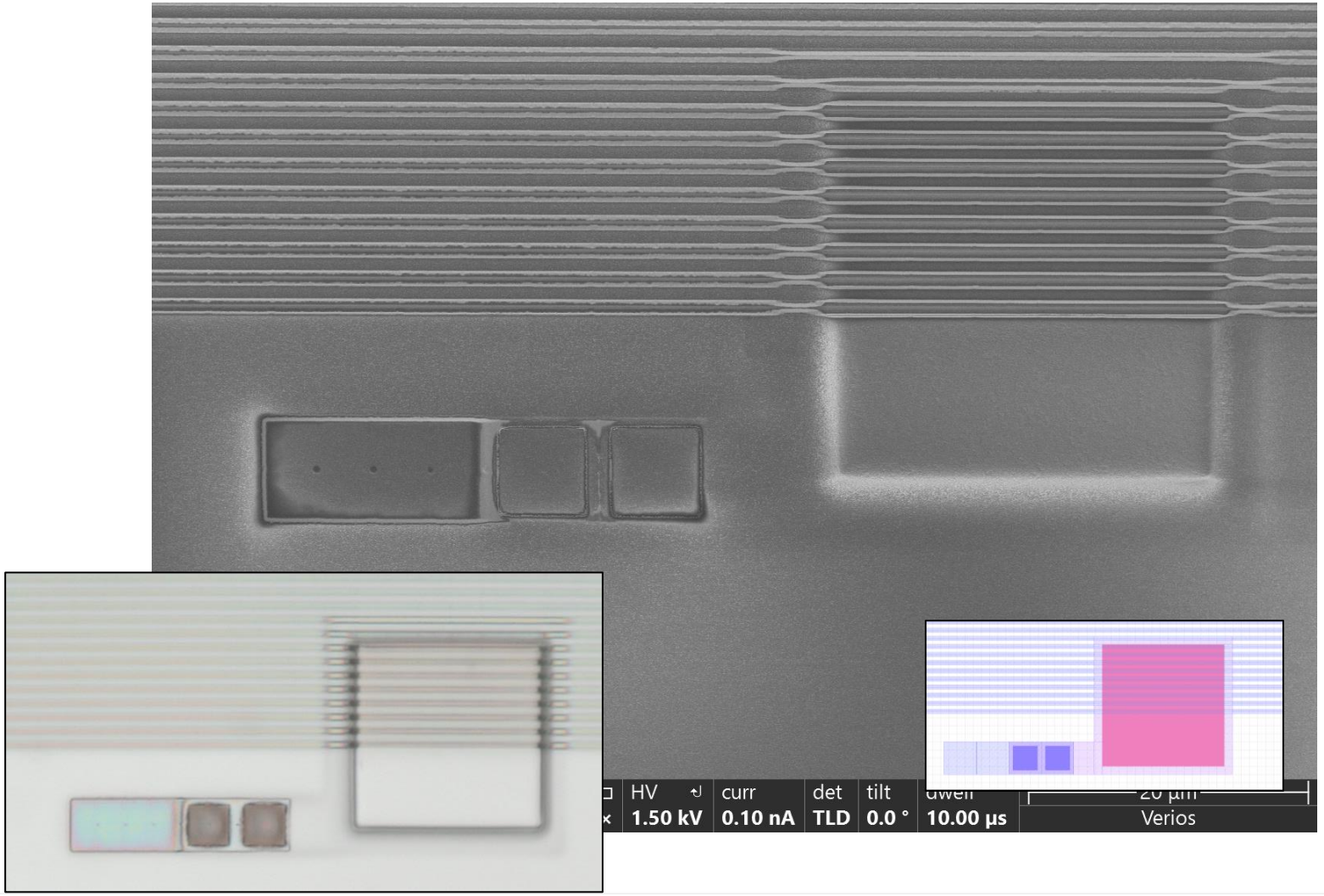




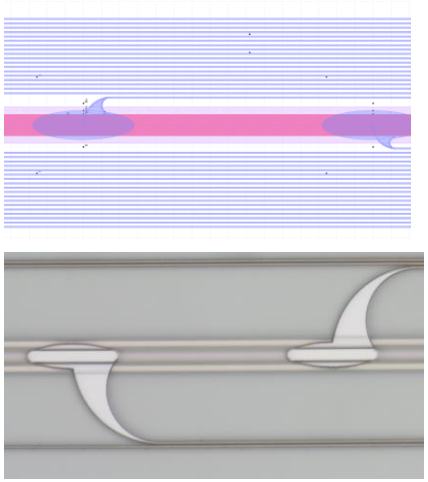


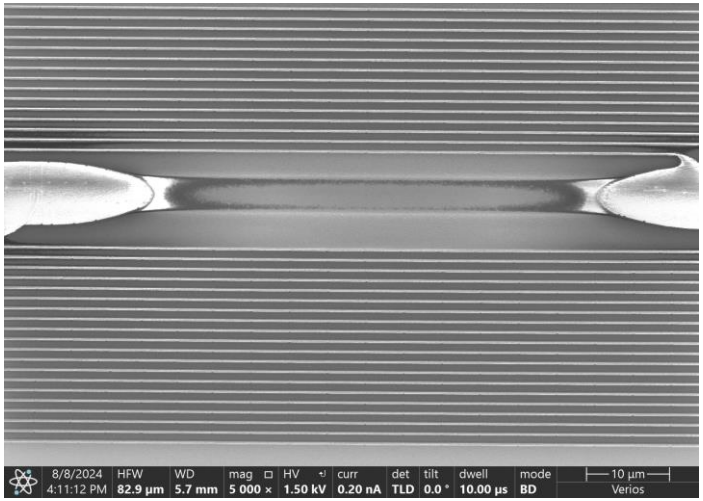
Si/ 1.1µm PI/ 0.3µm metal/ 2µm PI/ 0.3µm metal

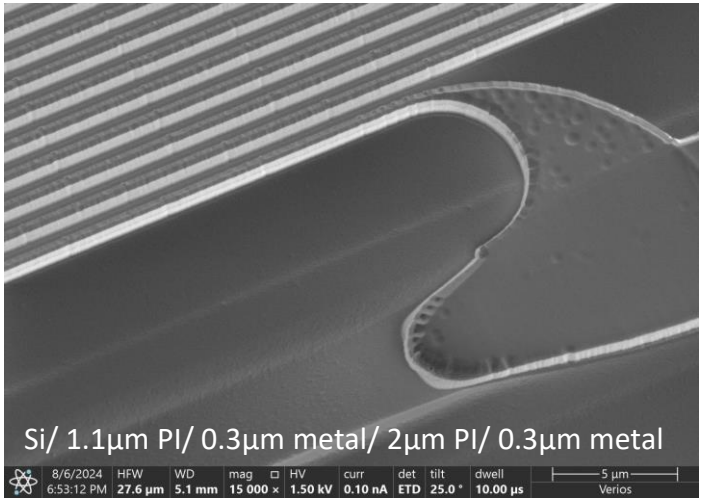
Example 1: bottom-side electrode devices

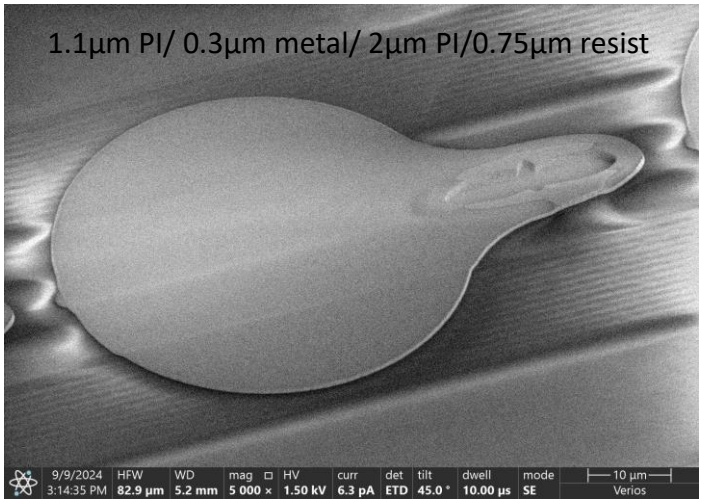


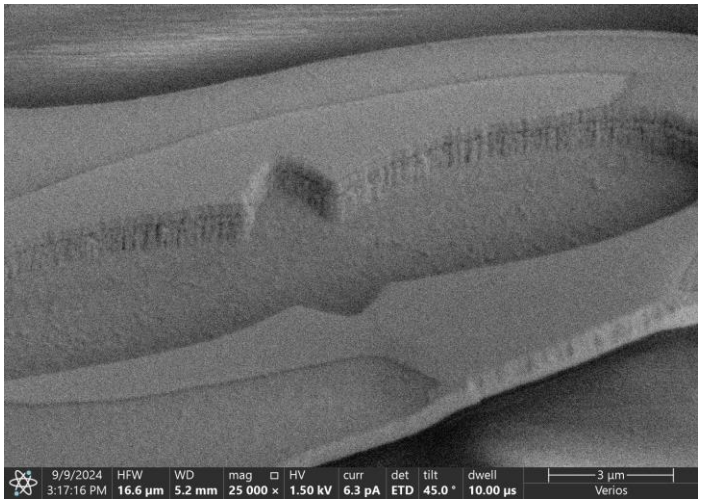
Example 2: top & bottom-sided electrode devices

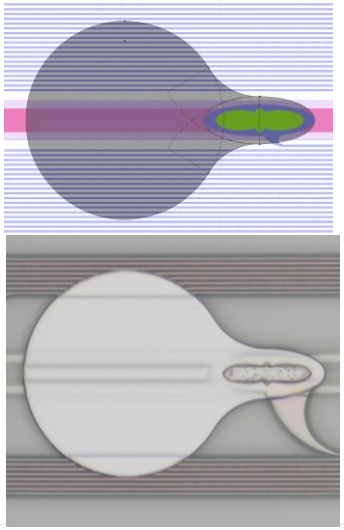






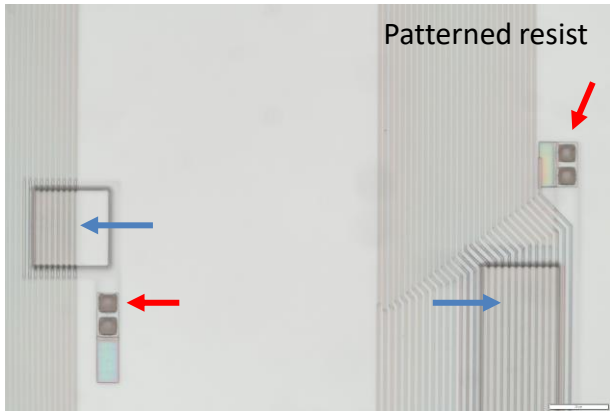


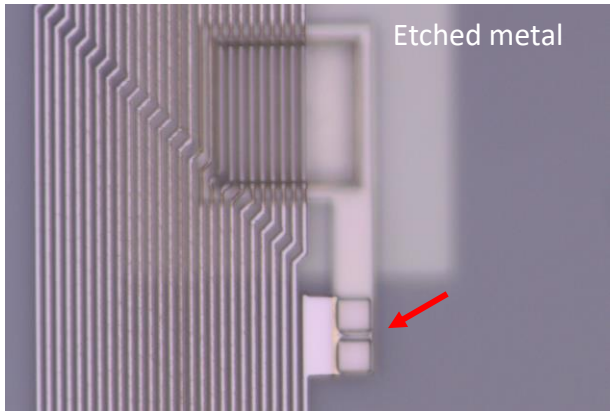




Topography effects from vias and patterned metal

Issue: Over developing to clear resist in **valleys**, led to thinned resist in **high points**. Resulting in etched metal during metal patterning step and ultimately disconnected electrodes.



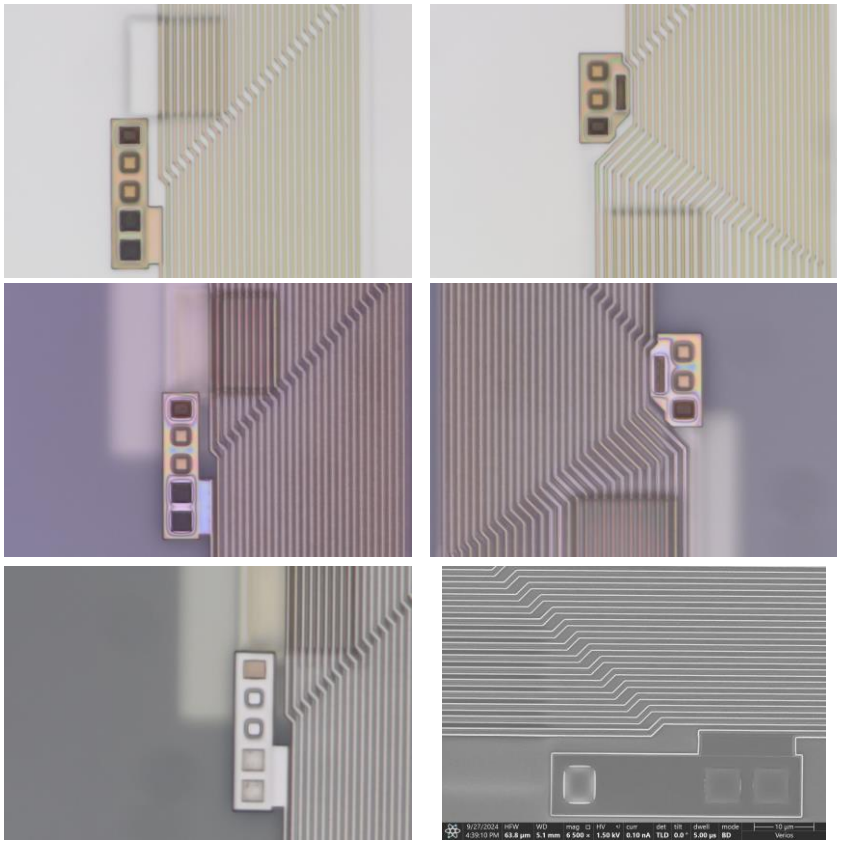


Temporary fix: Over-expose resist in high points to survive long develop time → split design into datatypes to allow overexposure in specific regions.

- However, overexposing large features would impact adjacent small features. Not a problem for this particular design

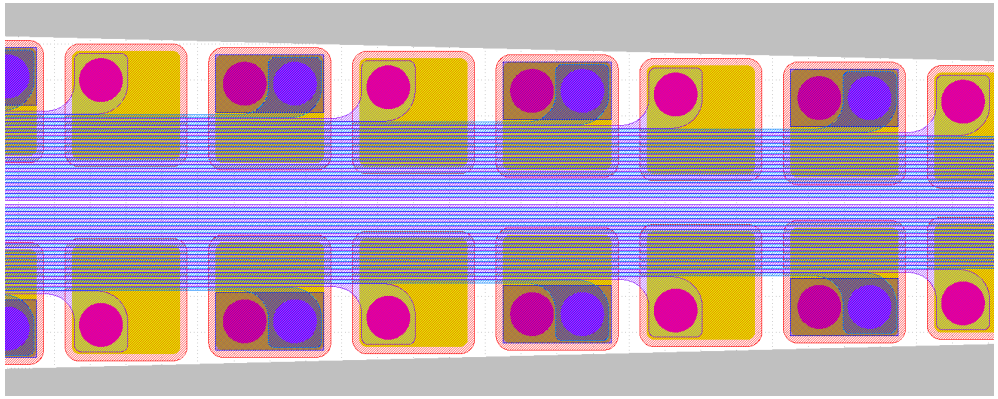
Patterned resist

Etched metal



Moving forward

1. Contrast curves
   - Improve our baseline for required dosage
2. Dose by region
   - To account for topography changes and resulting resist thickness
3. Minimize topography influence where possible
   - Route traces away from topographical regions
   - Thicker polyimide to planarize



Thank you! Any questions?

Special thanks to **Erin Graf** for initial investigation into e-beam lithography for LLNL's implantable devices.

Facilities/Support:

Center for MICRO & NANO TECHNOLOGY

ENGINEERING
LAWRENCE LIVERMORE NATIONAL LABORATORY

GenISys
Advancing the Standard

Funding:

Work funded under NIH BRAIN Initiative (L21582) and Strategic Partnership Project (L23564) and Cooperative Research and Development Agreement (TC02420) with Canaery.

UCSF
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NIH


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