EE 412 Final Presentation

Fabrication of 3D Current Collector for Microbattery

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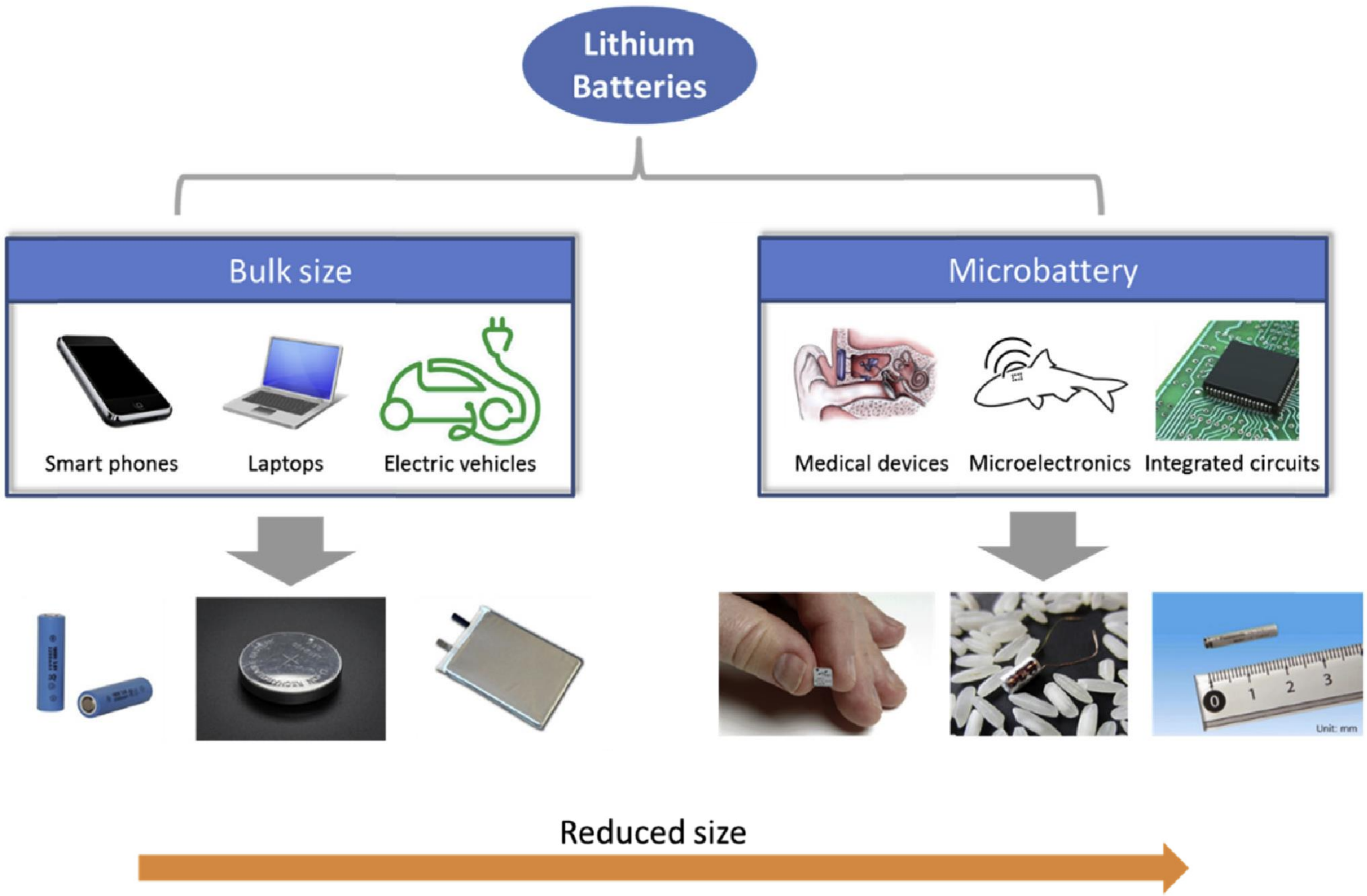
12/03/2015

From Batteries to Microbatteries



3D Batteries --- Advantages & Challenges

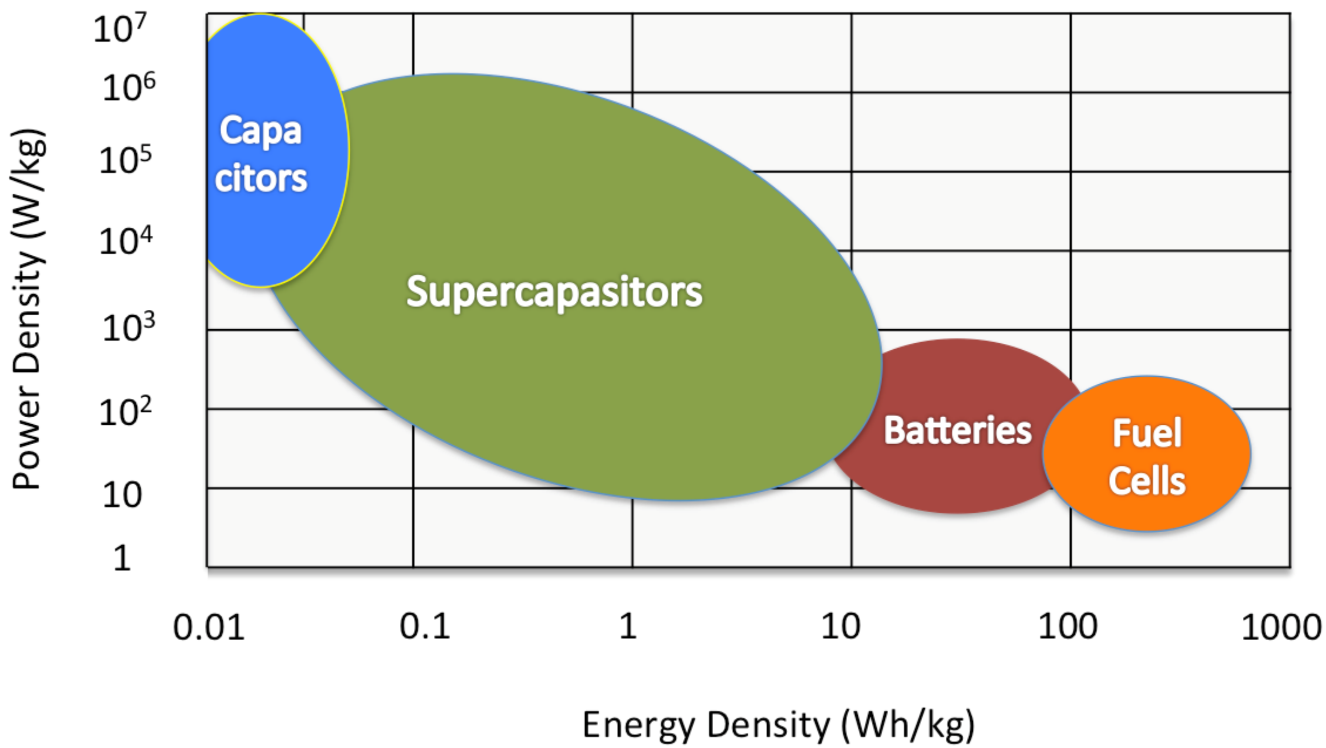
Advantages

- Small size
- Fast charging/discharging (High power density)

Challenges

- Complicated fabrication procedures
- Limited material choices
- Poor cycle life

Power Density VS Energy Density

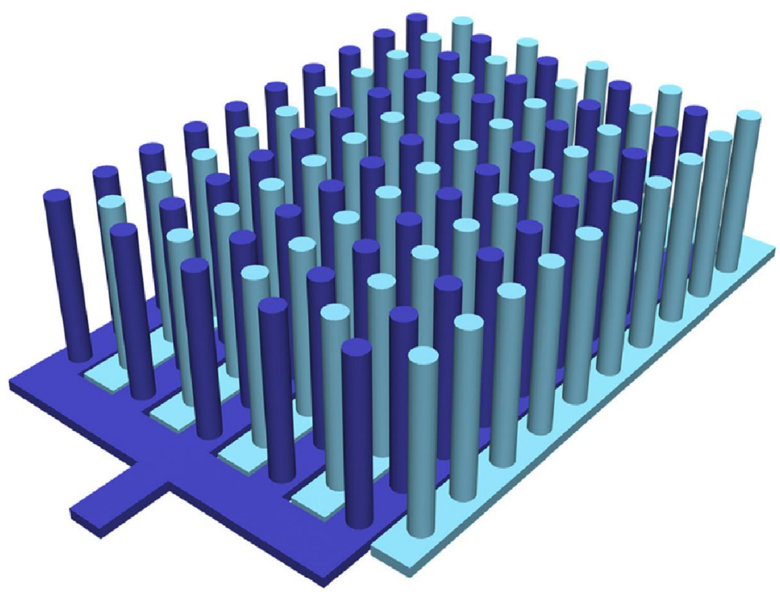


Chemical Reviews, 2004, 104, 10 4247

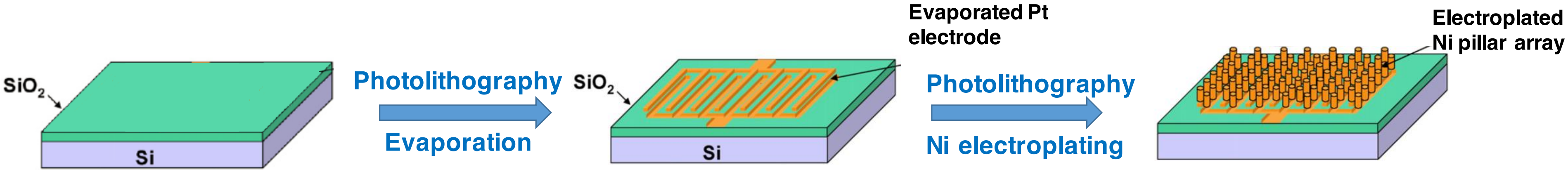
How to Increase Power Density

1) Small ion diffusion distance
2) High surface area

1) Nanostructure
2) 3D current collector



Proposed Fabrication Procedure

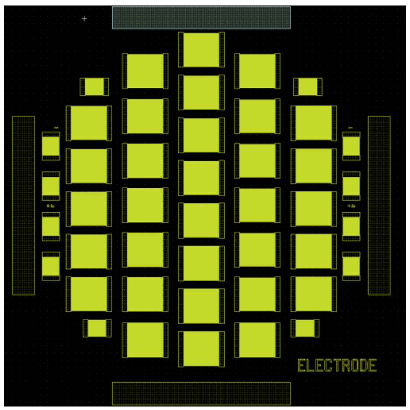


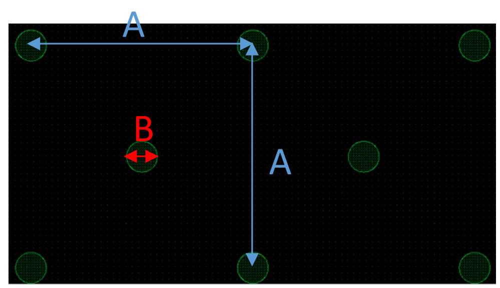
Finished until Here

1. Pattern the finger electrodes on thermally oxidized Si wafer
2. Pattern the template for nanopillar array on the finger electrode (thick photoresist!)
3. Using electroplating to deposit Ni nanopillar array
4. Using electroplating to deposit cathode and anode materials

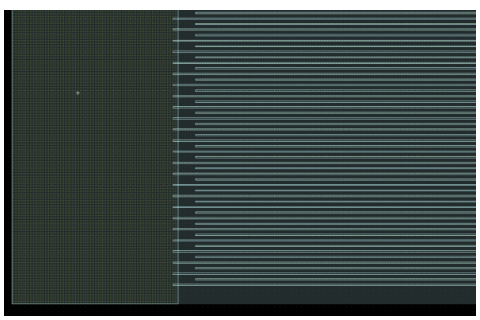
Step 1 --- Pt Finger Electrode

Transparency Mask with 10 μm Resolution (*CAD/Art Services, Inc.*)





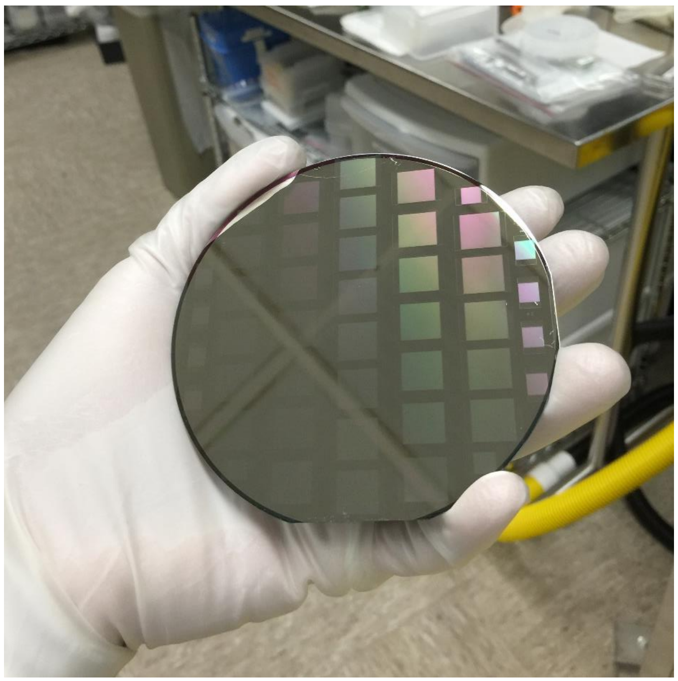
A= 72 um,	B= 10 um
A= 100 um,	B= 10 um
A= 120 um,	B= 15 um
A= 120 um,	B= 20 um
A= 180 um,	B= 30 um



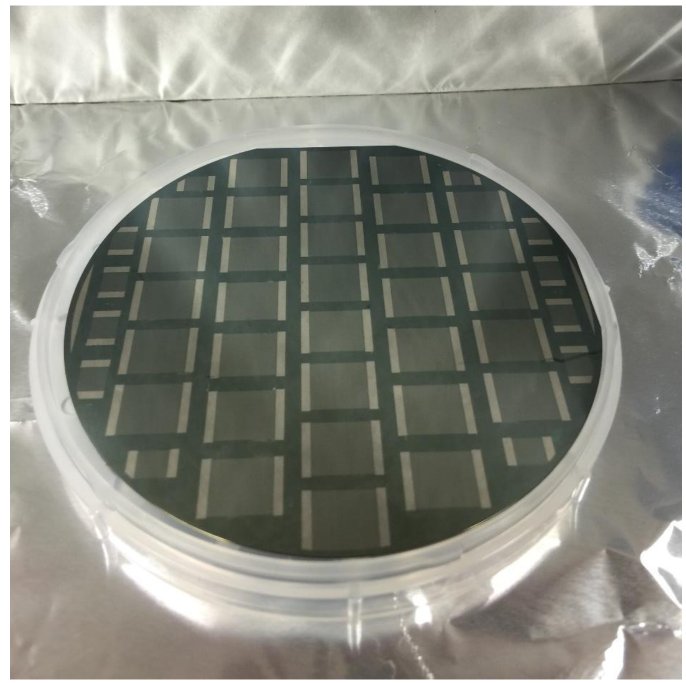
- SPR 3612, 1.5 μm
- Sputtering 20 nm Ti adhesive layer + 200 nm Pt

Step 1 --- Pt Finger Electrode

After Pt deposition

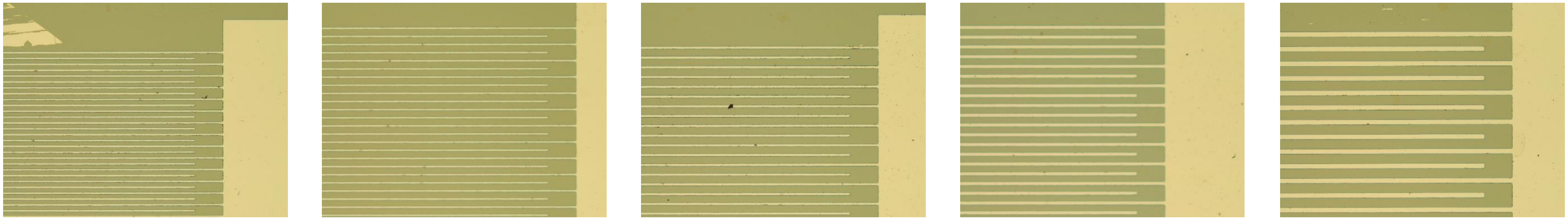


After photoresist removal

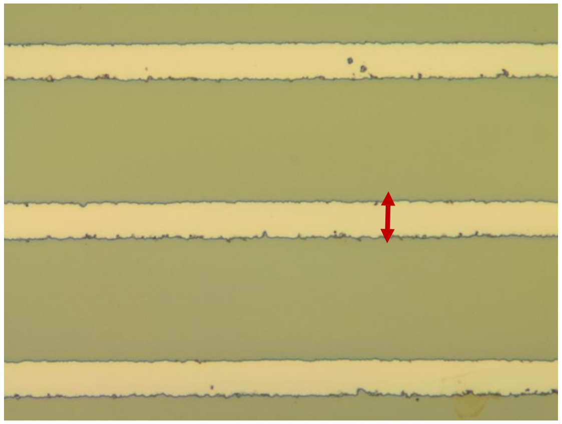


Step 1 --- Pt Finger Electrode

Different Feature Sizes



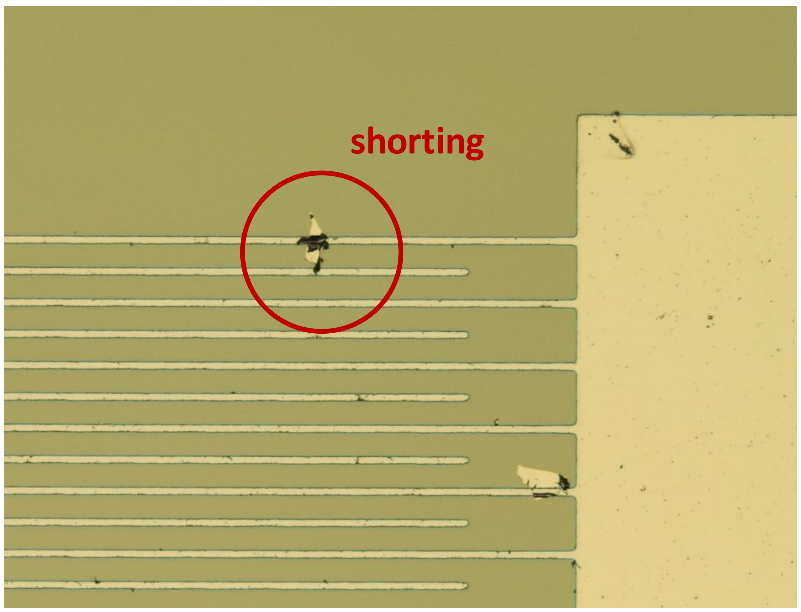
Transparency Mask Resolution

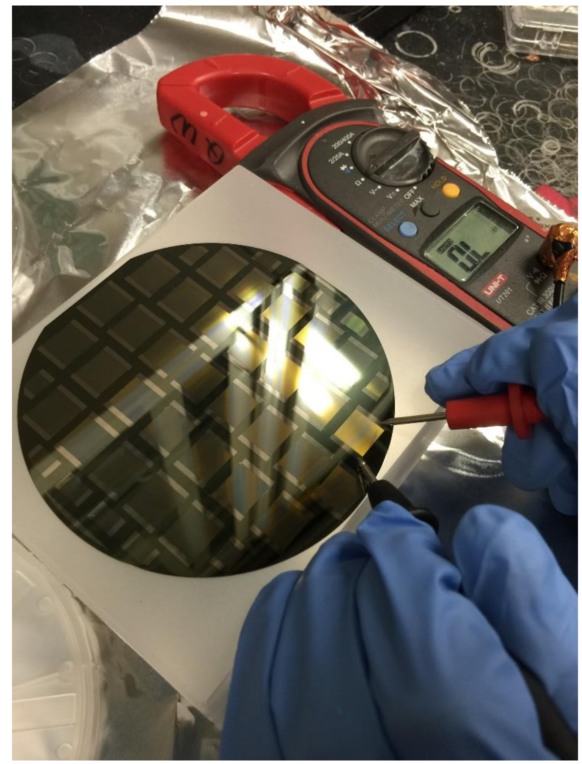


12 μm features

Step 1 --- Pt Finger Electrode

30s sonication during lift-off can effectively prevent shorting

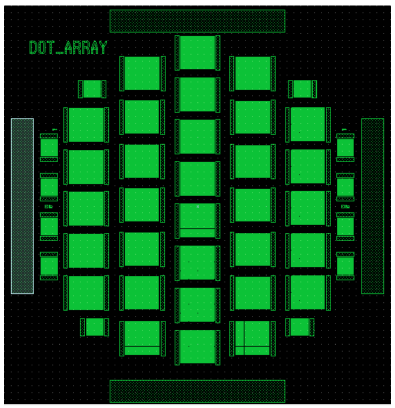




No shorting !

Step 2 --- Photoresist Mold for Ni Plating

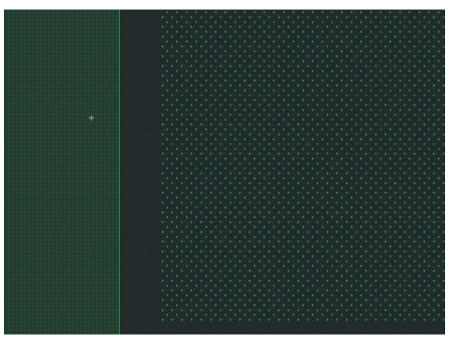
Thick Photoresist Mold for High Aspect Ratio Ni Nanopillars



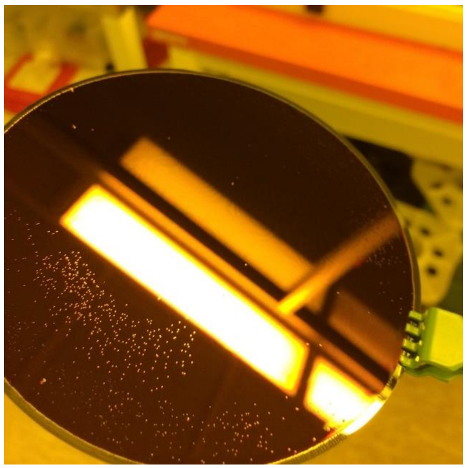
Transparency Mask with 10 μm Resolution

SPR 220-7 15μm/coat

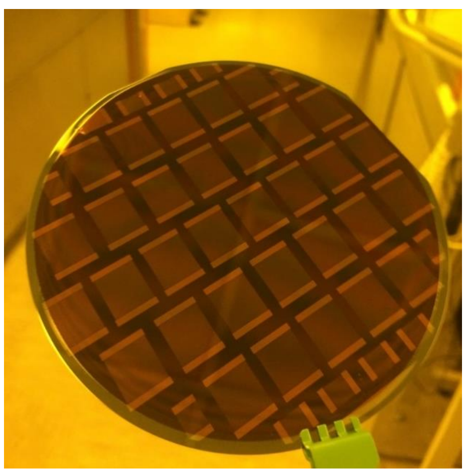
Post-bake 90 ^{o}C 200s



Step 2 --- Photoresist Mold for Ni Plating



Baking in 90 ^{o}C oven created bubbles due to solvent drying



Modified Procedure
200s hotplate baking on SVG coater
Rest for 1 day in the yellow area to allow the solvent to dry

Step 2 --- Photoresist Mold for Ni Plating

Exposure (Karlsuss)

○ Two Coats
Hard Contact
Gap: 60 μm
Multiple Exposure (300s): Expose 15s + Rest 15s
(20 cycles)

○ Three Coats
Hard Contact
Gap: 80 μm
Multiple Exposure (500s): Expose 15s + Rest 15s
(34 cycles)

Manual Development (Shipley MF-26A)

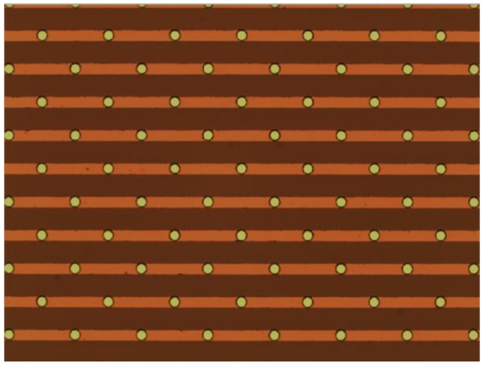
○ Two Coats
5 min development with manual shaking

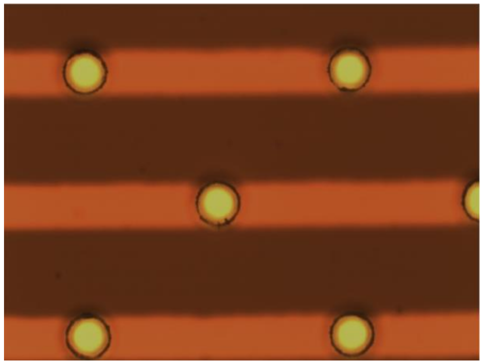
○ Three Coats
8 min development with manual shaking

Step 2 --- Photoresist Mold for Ni Plating

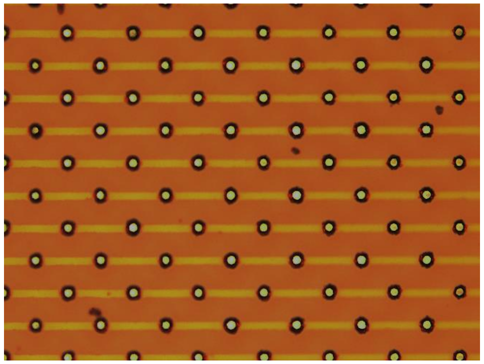
Managed to get feature size down to 15 μm !

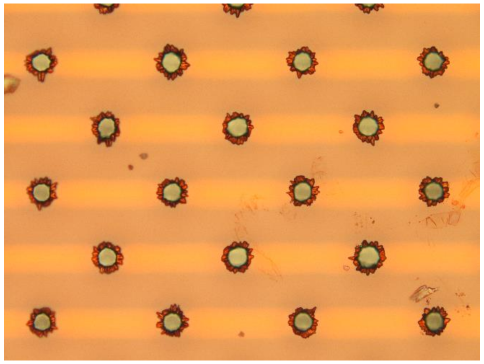
30 μm pore





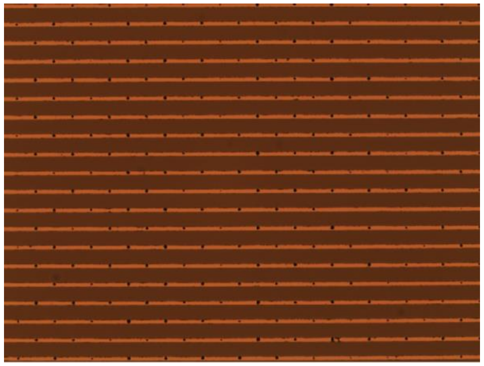
15 μm pore





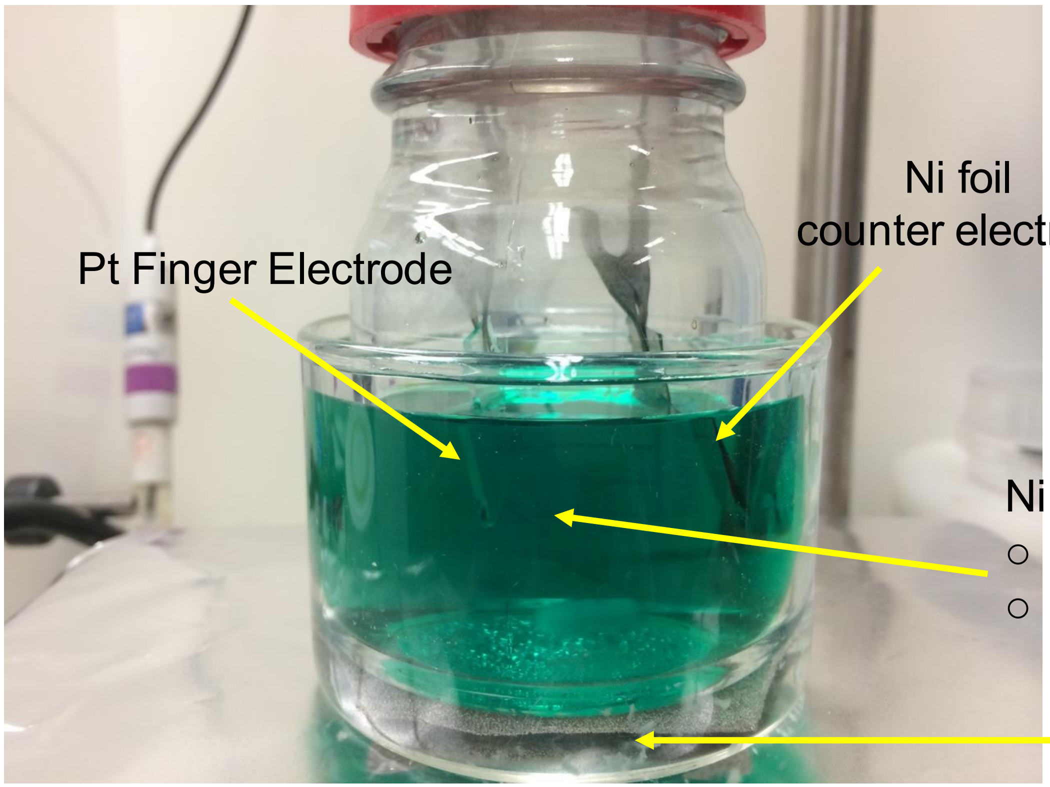
Failed to obtain 10 μm pore

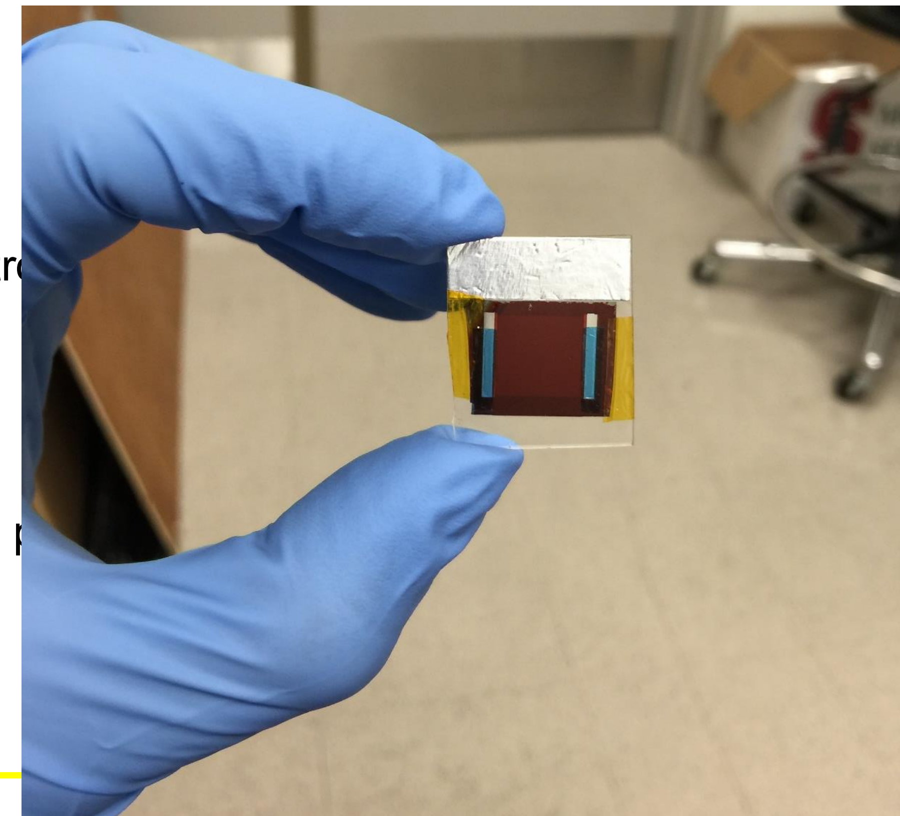
Limited resolution of transparency mask



Step 3 --- Electroplating of Ni Micropillars

Experimental Setup

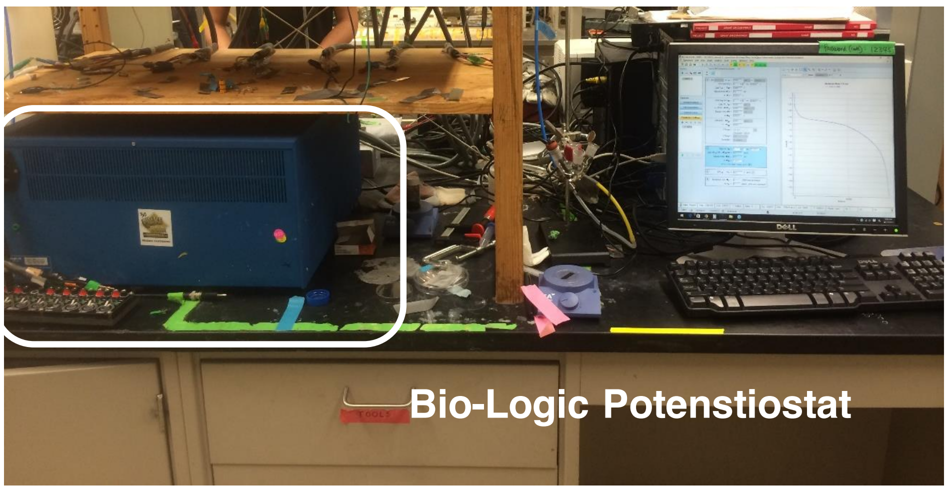




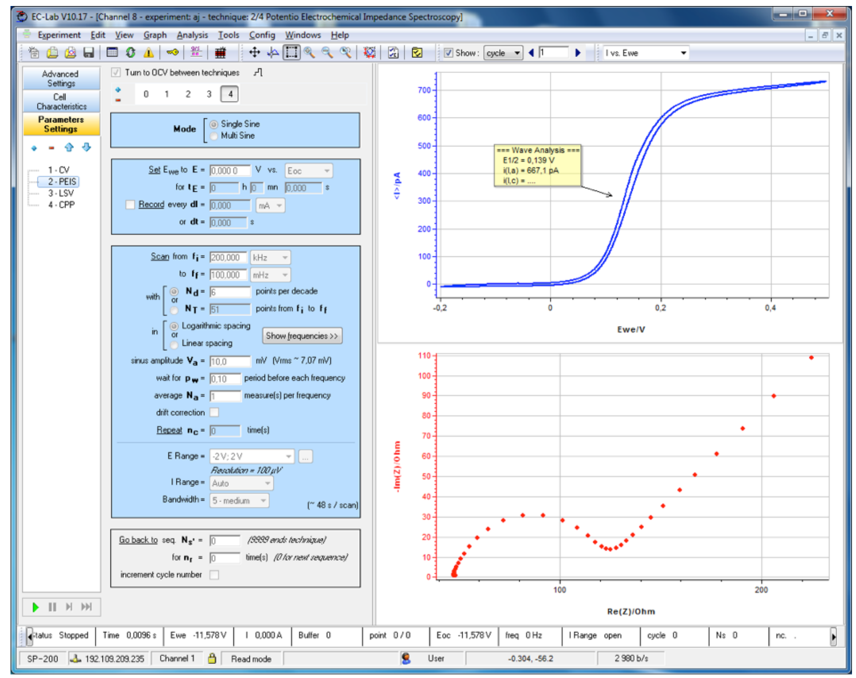
Step 3 --- Electroplating of Ni Micropillars

Experimental Setup --- Power Source

Constant Current Deposition



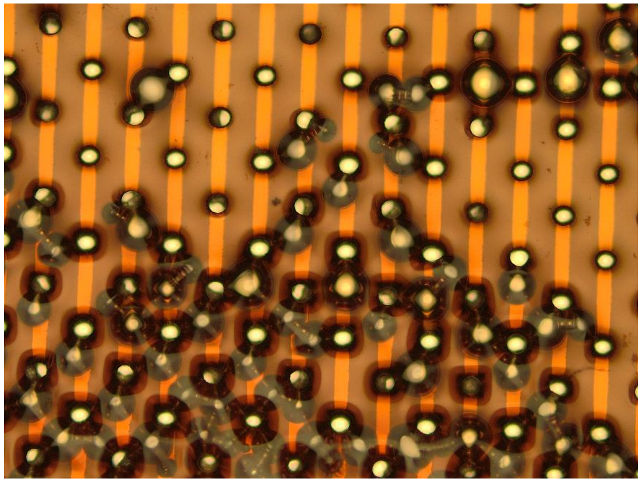
EC Lab Software



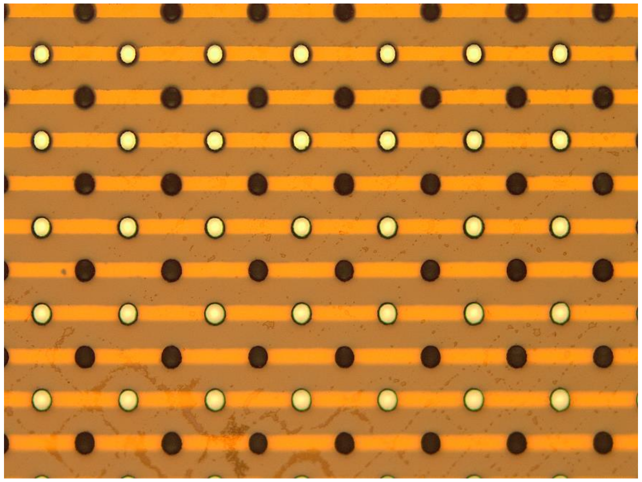
Step 3 --- Electroplating of Ni Micropillars

Oxygen plasma treatment (5 min) was found to improve electroplating quality

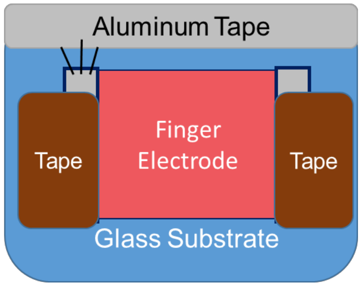
30 µm pore
No Plasma, 0.3 mA
voltage ramped to ~ 10 V



30 µm pore
5 min Plasma, 0.3 mA, 0.1 mAh
voltage ~ 1 V

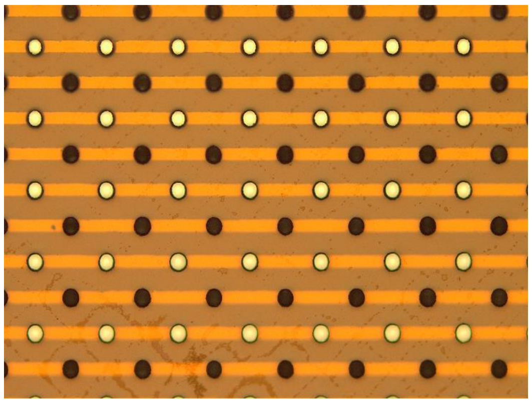


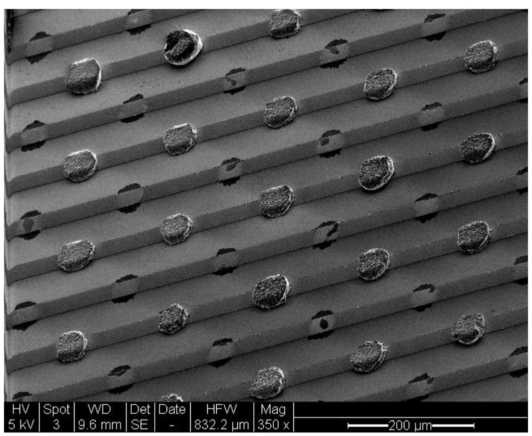
Singe Electrode Plating



Step 3 --- Electroplating of Ni Micropillars

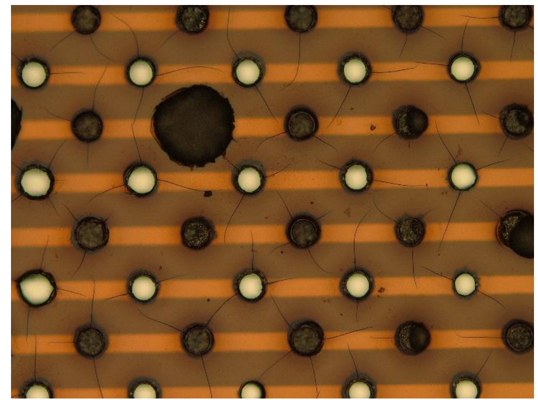
30 µm pore
0.3 mA, 1.5 mAh

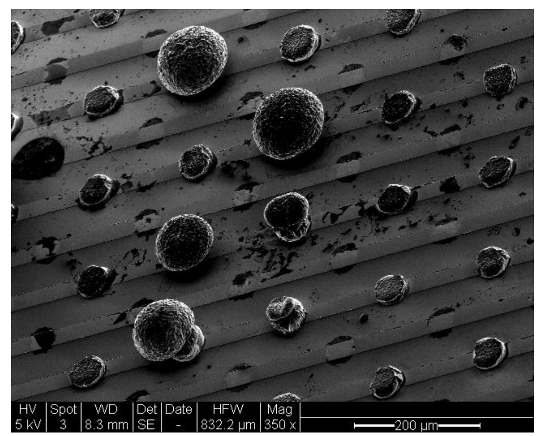




Increase time →

30 µm pore
0.3 mA, 3 mAh

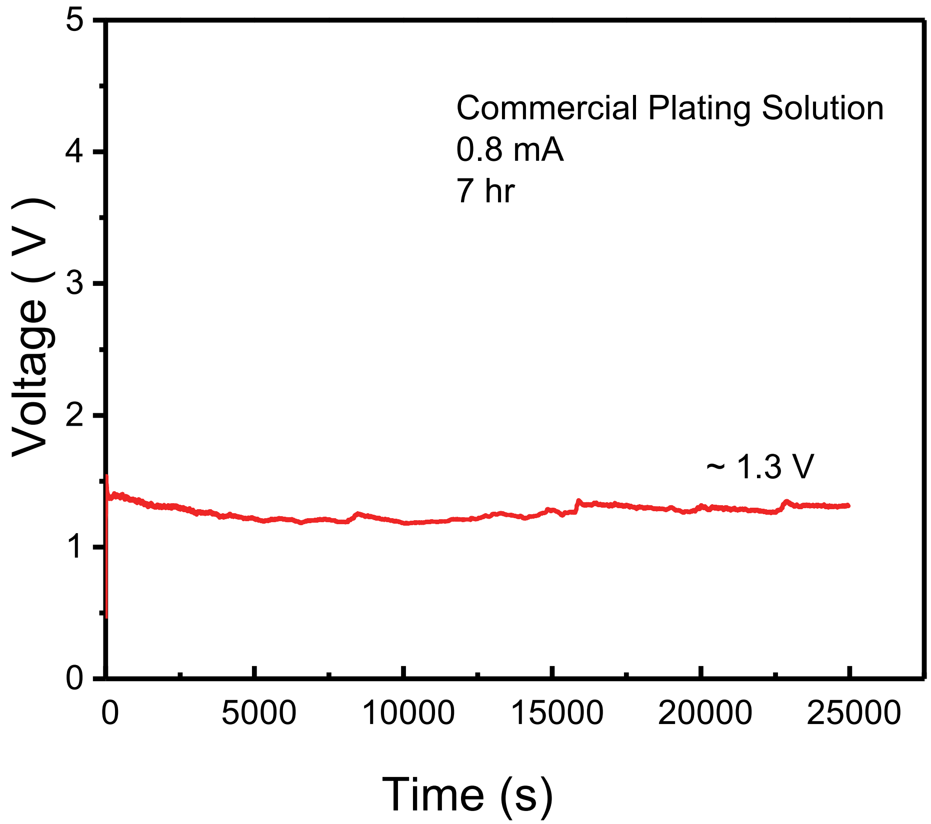




Step 3 --- Electroplating of Ni Micropillars

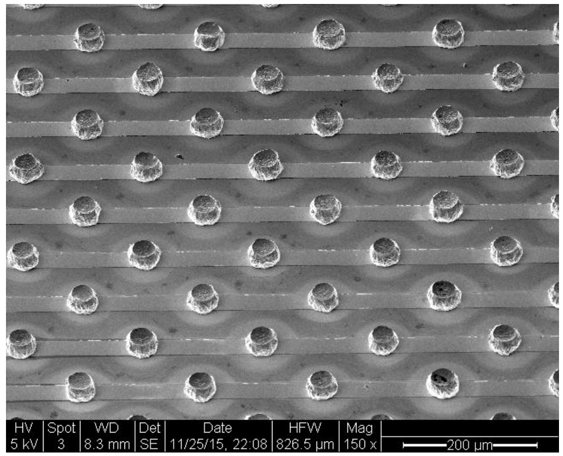
Commercial Ni plating solution gives more uniform morphology

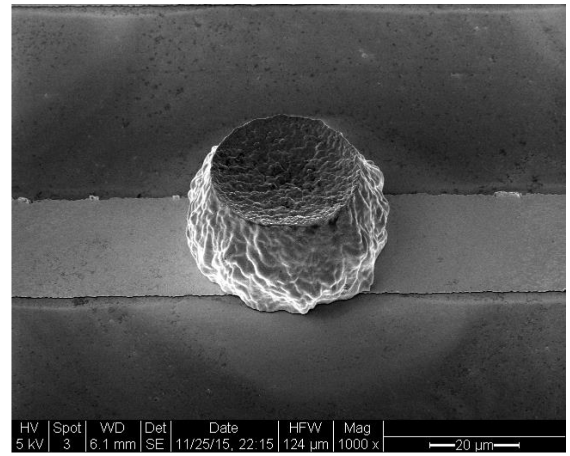
KROHN
Bright Nickel Electroplating Solution



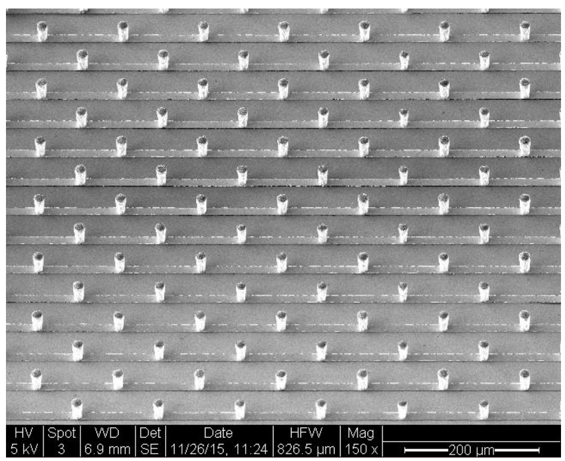
Step 3 --- Electroplating of Ni Micropillars

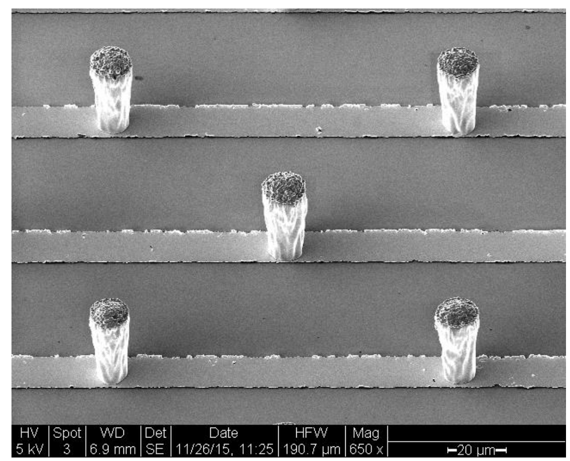
2 coats
30 μm pore
0.8 mA, 5.5 mAh





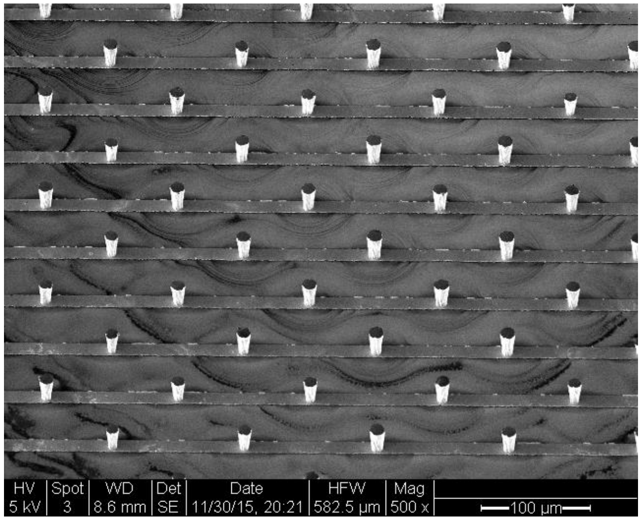
2 coats
15 μm pore
0.8 mA, 5.5 mAh

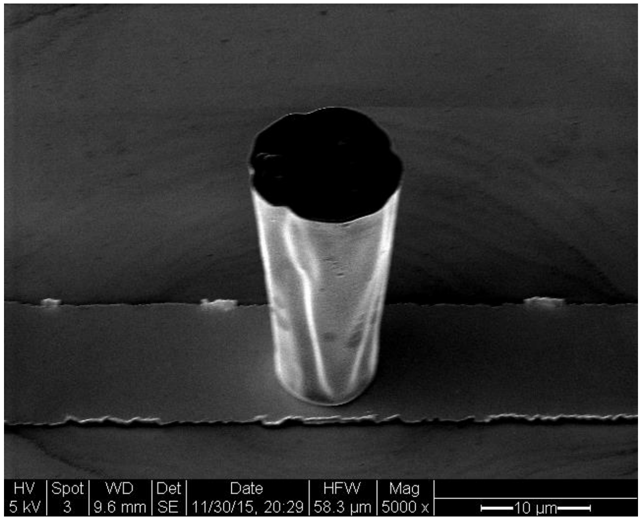




Step 3 --- Electroplating of Ni Micropillars

3 coats
15 μm pore
0.8 mA, 8.5 mAh

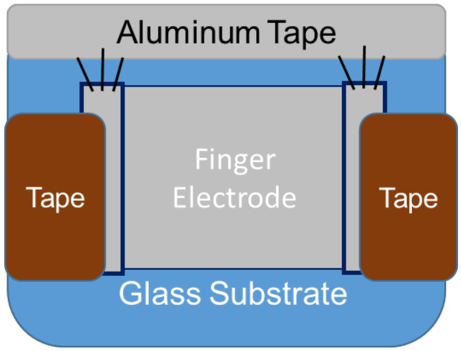




Pillar height did not increase very significantly

Tape covering the two side Pt bars got loose in acidic plating solution with time

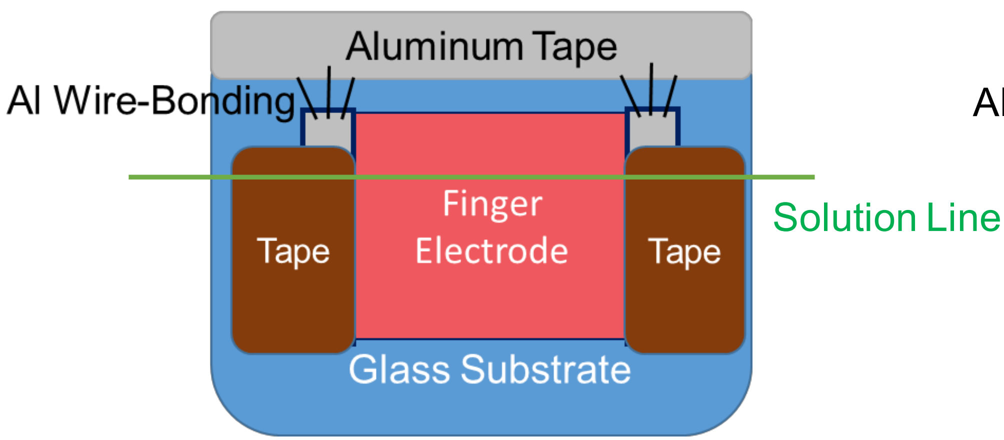
Ni being plated onto the Pt bars instead of into the pores



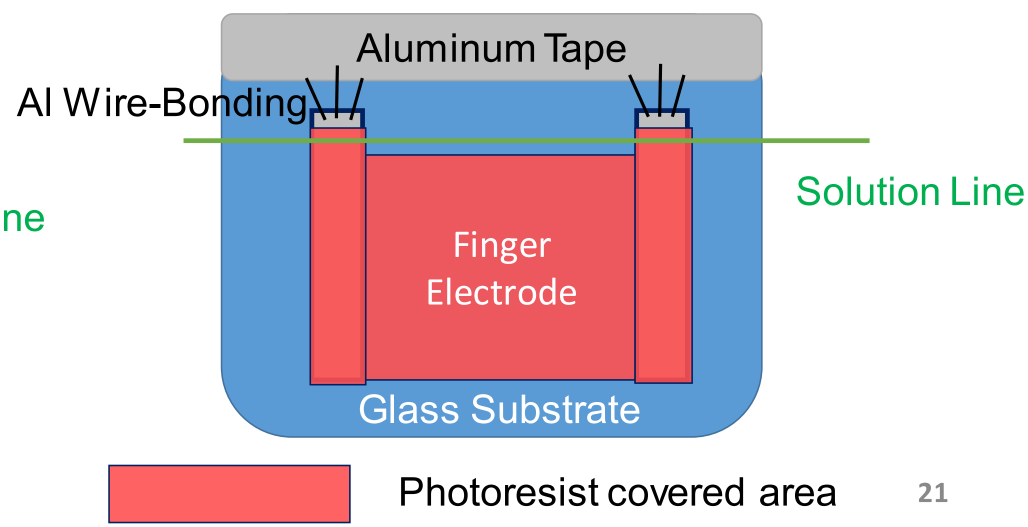
Step 3 --- Electroplating of Ni Micropillars

Lessons Learned/ Future Improvements

- Ni tends to be plated onto the two side bars (more favorable than into the pores)
- Al wires can get corroded/disconnected easily in contact with the acidic plating solution
- Ni tends to be plated at the air/solution interface which can cause shorting



Improved Device Design



Conclusions

- Successfully fabricated Pt finger electrode
- Achieved thick photoresist mold for Ni electroplating (SPR220-7) up to 45 μm thickness and a feature size of 15 μm
- Obtained promising preliminary results on electroplating Ni micropillar arrays
- Gained valuable experiences on electroplating and device design

Acknowledgement

We thank Prof. Howe for the great support from the class

We thank Robert and Michelle for tremendous help and helpful discussion

We thank Mahnaz, Uli, Maurice, Mary, Usha and all the other SNF members for trainings, helps and supports!


THANK YOU