AAO Development at Argonne

H. Hau Wang, MSD
Seon W. Lee, HEP

LAPD Project
Microchannel Plate Godparent Review
HEP, Argonne, IL
March 25, 2010

AAO Basics

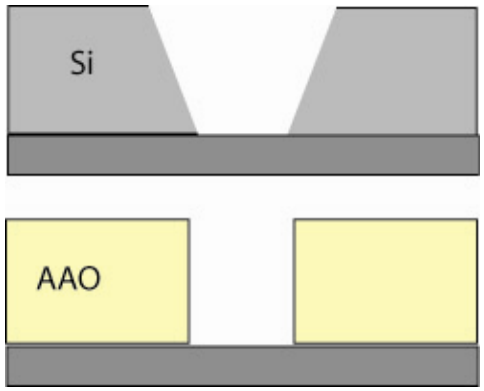
- Anodized Aluminum Oxide (AAO) contains intrinsic nanopores with pore diameters between 10 and ~350 nm formed through “self-assembly”.

- Al_2O_3 vs. SiO_x (B, Pb doped) – both robust and hard, can be functionalized through coating (ALD), can stand high temperature,…
- AAO advantages vs. silicate based MCP

  The intrinsic nanopores favor MCP applications that require small channel diameter (< 10 μm) and high spatial resolution;

  The intrinsic pores allow nearly vertical etching;

  Scale up is possible and cost effective



- Larger channel diameter (350 nm to 40 μm) in AAO is possible with lithographic tools.

Milestones

- Anodic Aluminum Oxide Plate Fabrication (AAO Group)

- Year 1

  (a) Achieve straight pores with diameter 0.7 micron (no-funnel option), 40 <L/D< 100, and open area ratio 60 %;

  (b) Demonstrate the feasibility of making AAO funnels suitable for photo-cathode deposition;

  (c) Produce blanks of 32.8 mm AAO plate for tests and MCP development.

- Year 2

  (a) Achieve straight pores with diameter 1 micron (no-funnel option), 40 <L/D< 100, and open-area ratio 80 %;

  (b) If funnels are feasible, achieve straight pores with diameter 1 micron, 40 <L/D< 100, and open area ratio 90 %;

  (c) Demonstrate gain > 1000, uniformity to < 15% in an AAO/ALD plate.

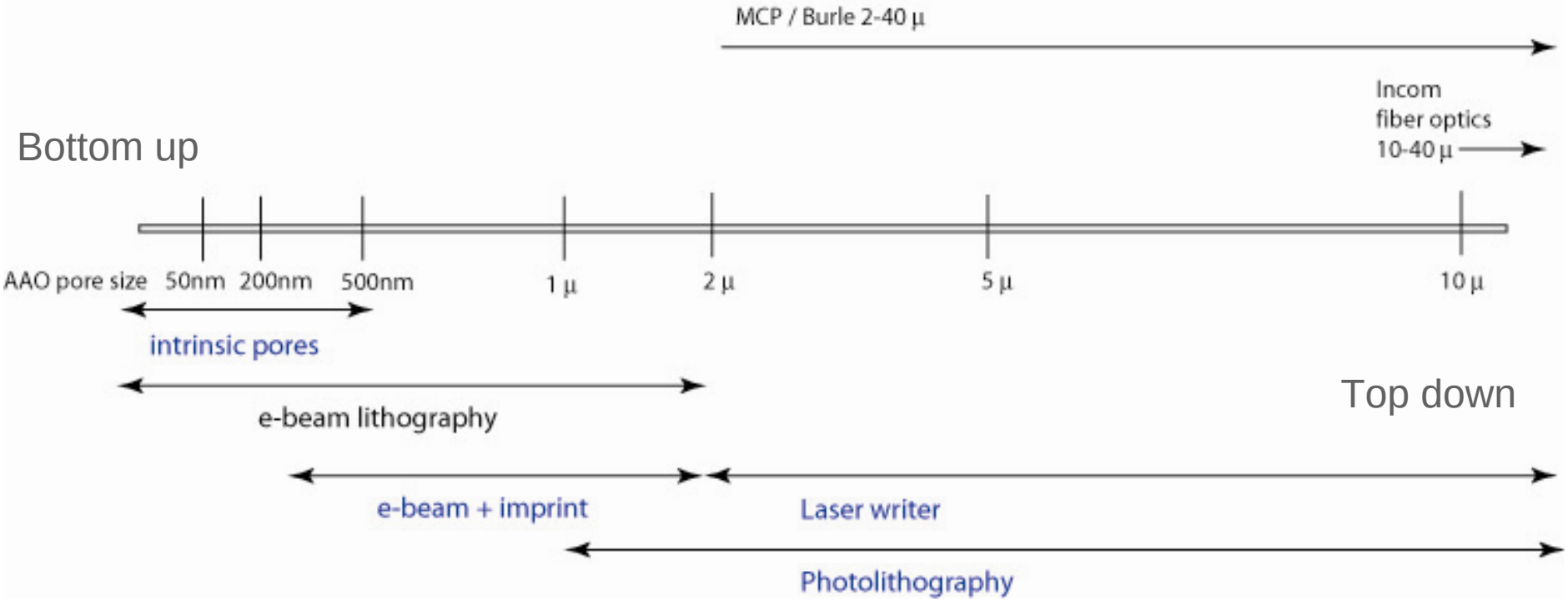
- Year 3

  (a) Fabrication of scaled substrates in quantities and sizes sufficient for 6 working proto-type modules;

  (b) Start program for industrialization: cost, facilities, throughput;

  (c) Continue exploring advanced processes and pore geometries for cheaper production and higher QE.

Approaches to address: Pore size, Pore distance, Aspect ratio, and Open area



- Photolithography, laser writer, e-beam and imprint tools are fast parallel processes that can be scaled up and reach any dimension from 20 nm to 40 microns. All these instruments are available to us in the ANL/CNM.

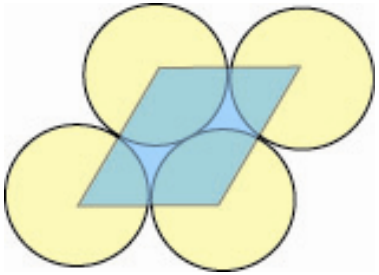
Aspect ratio

- Required AAO thickness (in μm) to meet the aspect ratio (L/D)
- White areas are straight forward

Aspect ratio L/D	Pore size D 0.5 μ	1 μ	2 μ	5 μ	10 μ	20 μ
40	20	40	80	200	400	800
60	30	60	120	300	600	1200
80	40	80	160	400	800	1600
100	50	100	200	500	1000	2000

Pink area is a challenge for AAO fabrication

Open area

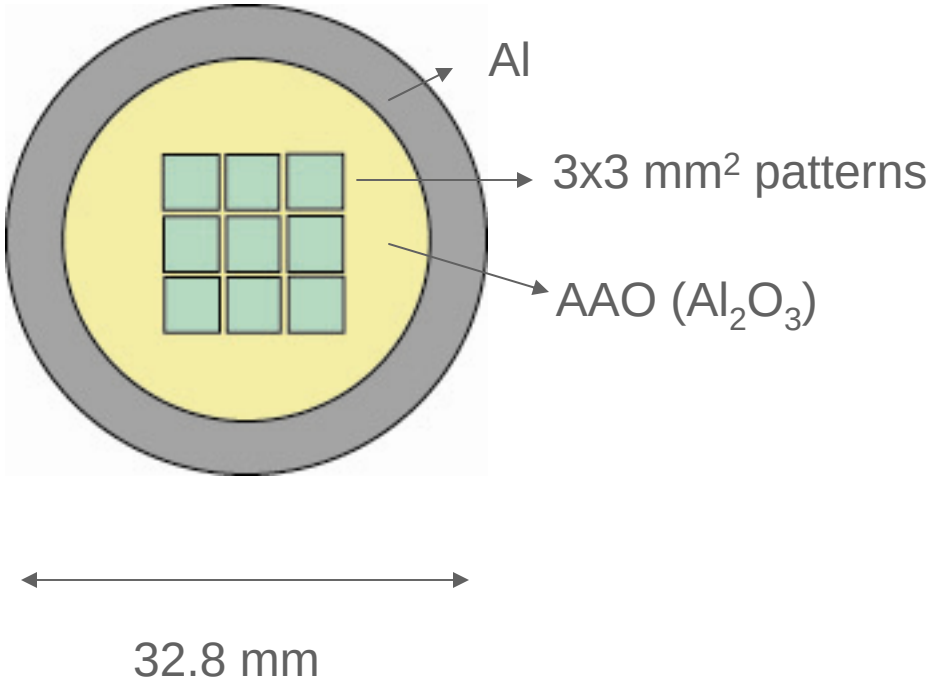


Pore size hcp structure a -pore diameter	Pore-to-pore distance	Calculated open ratio	Accomplishment
a	2 a	22.7 %	Accomplished
a	1.5 a	40 %	
a	1.25 a	58 %	Possible, end of 1st year
a	1.10 a	78.7 %	Possible, end of 2nd year
a	a	90.7%	Not possible

- Open area up to 80% is feasible.
- 90% open area is only possible if funnel shaped entrance can be prepared.

Pattern prepared with laser writer update

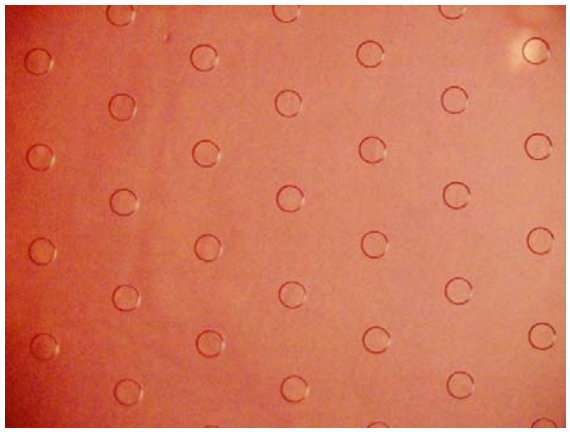
- AAO membrane with 60, 40, 20, 15, 10, 8, 6, and 4 micron diameter pores have been successfully prepared.



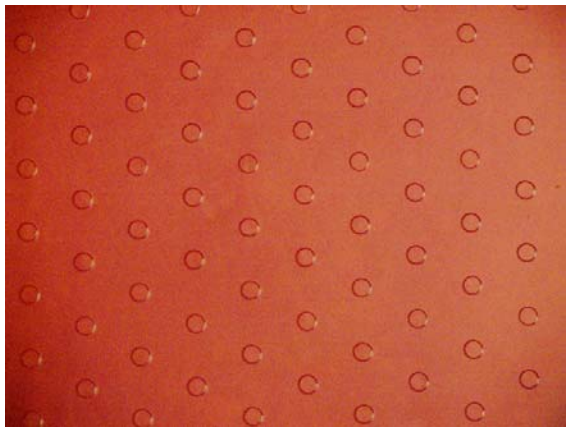
AAO with photo-resist after laser writer patterning and developing

Pore diameter a μm and pore-to-pore distance 4a μm

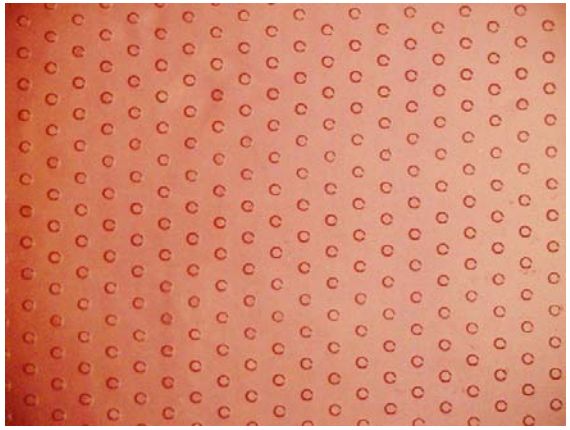
Optical Images 10x lens



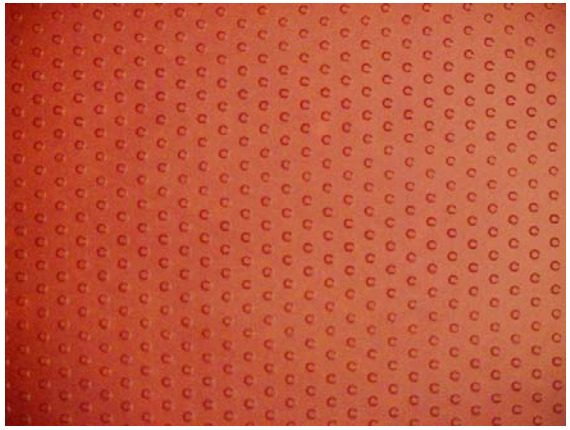
60 μm



40



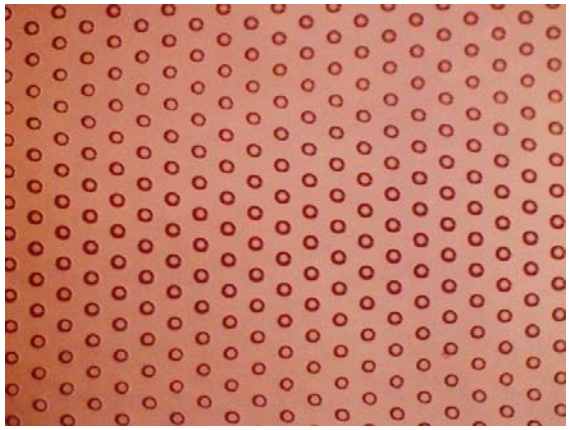
20



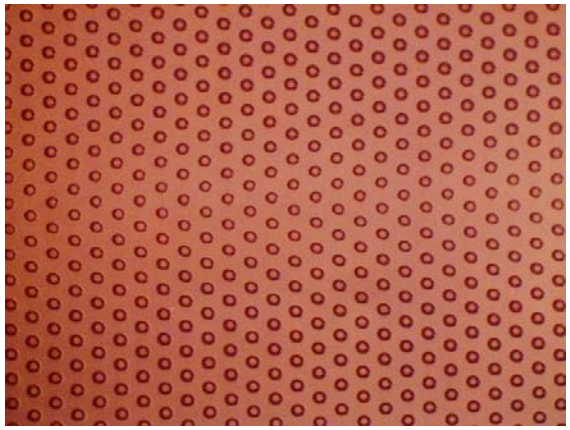
15

Pores from 10 to 4 μm

20x lens

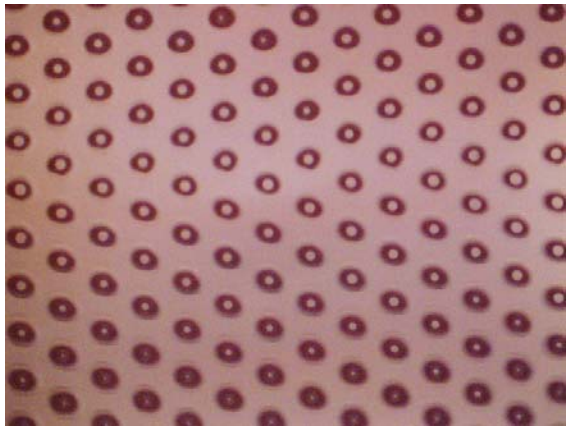


10 μm

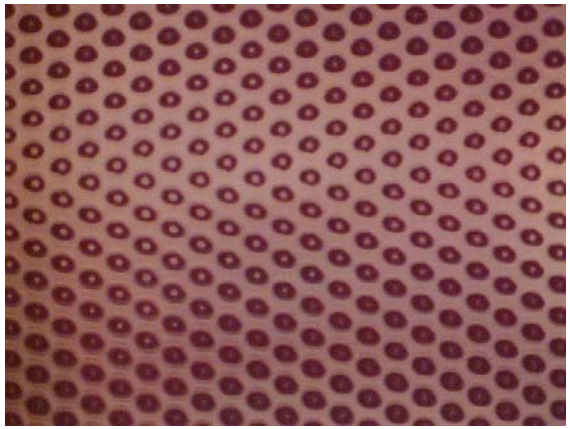


8

50x lens



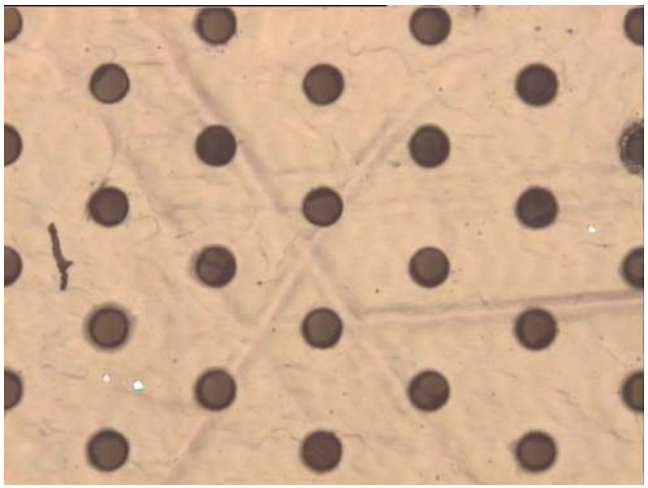
6 μm

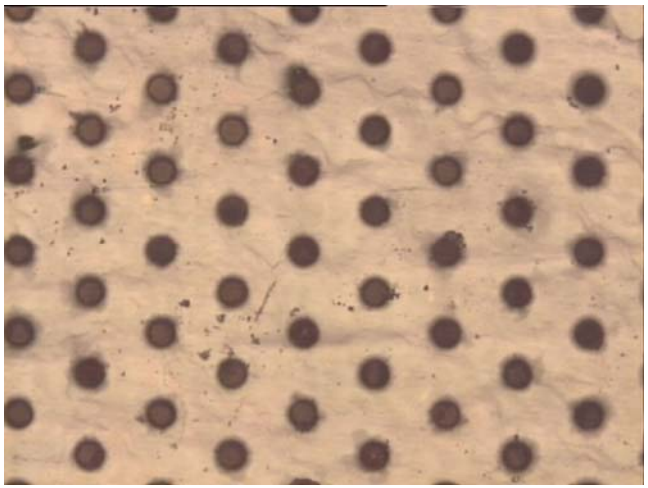


4

AAO after chemical etching
Optical images

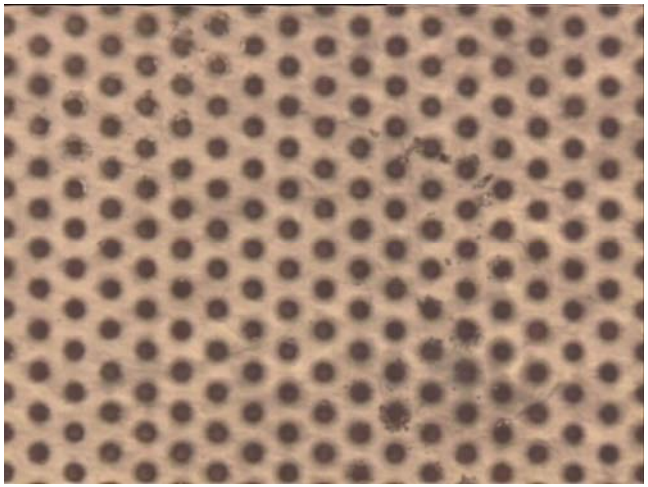
5 x lens
60 μm
pore
diameter

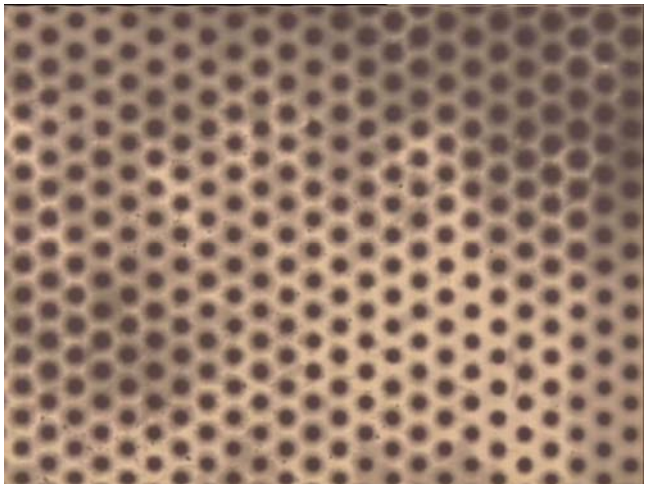




40 μm

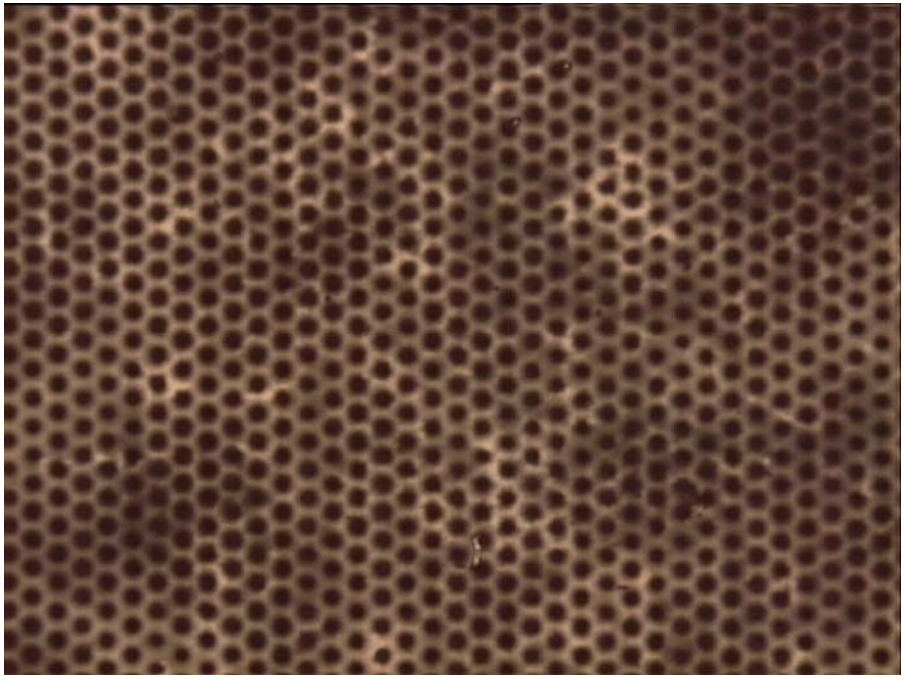
20 μm



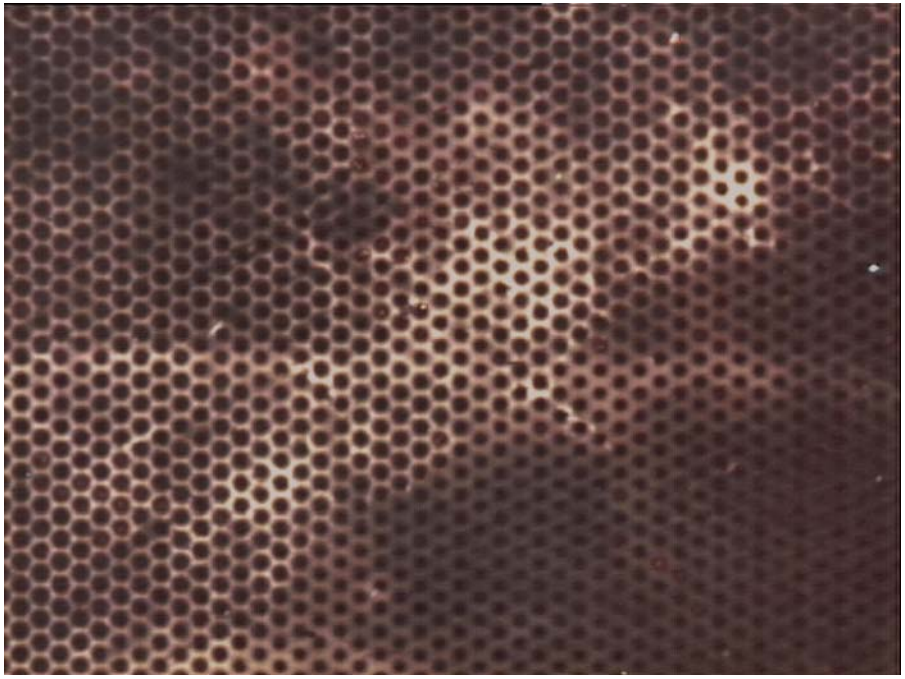


15 μm

AAO with 10 and 8 micron pores after etching
Optical images



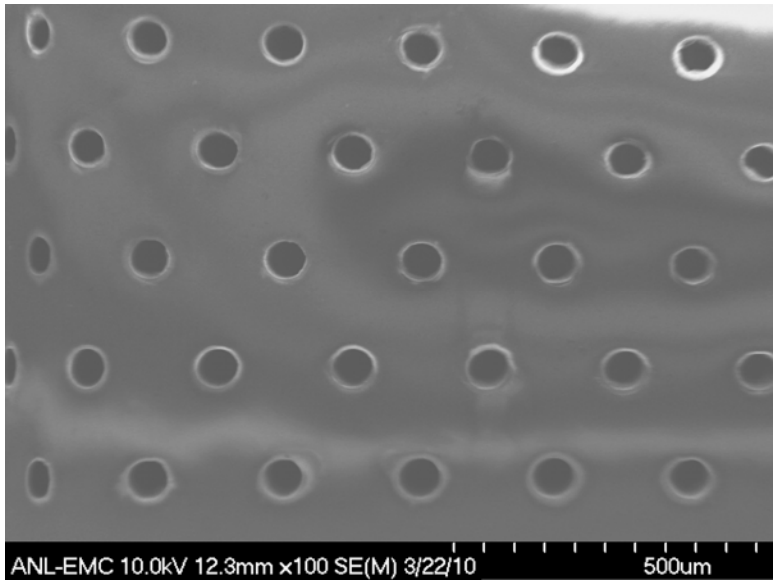
10 μm pore diameter
Pore-to-pore 40 μm
Photo area ~1.2 x1.6 mm^2

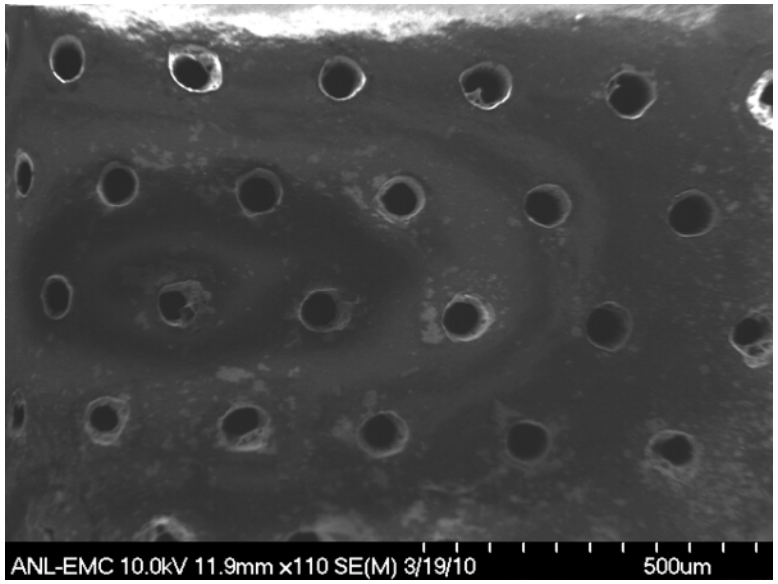


8 μm pore diameter
Pore-to-pore 32 μm

SEM images after etching

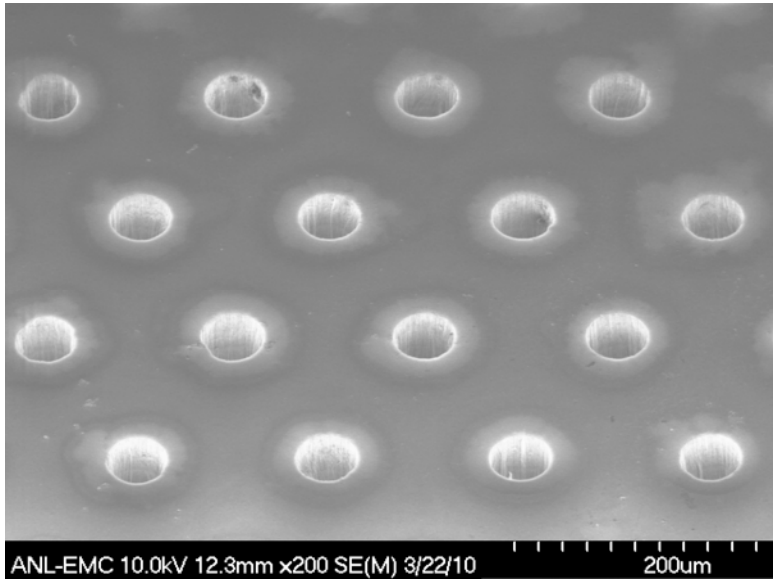
60 μm front

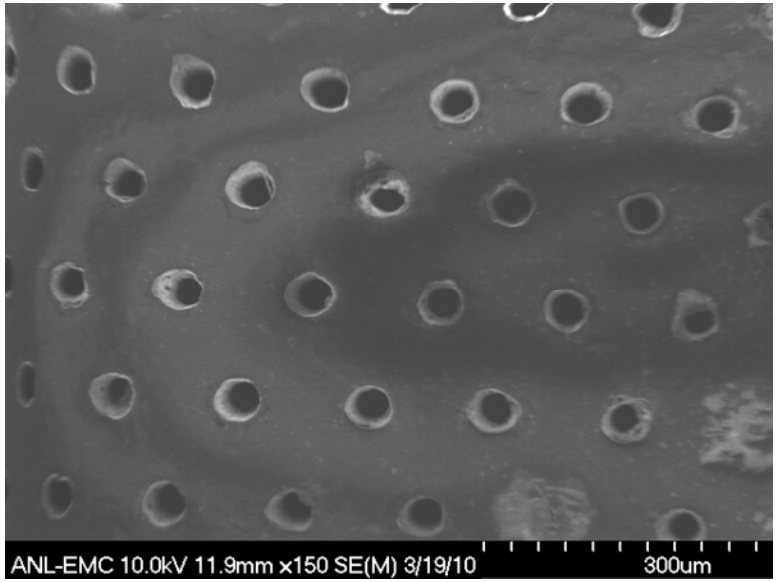




60 μm back

40 μm front

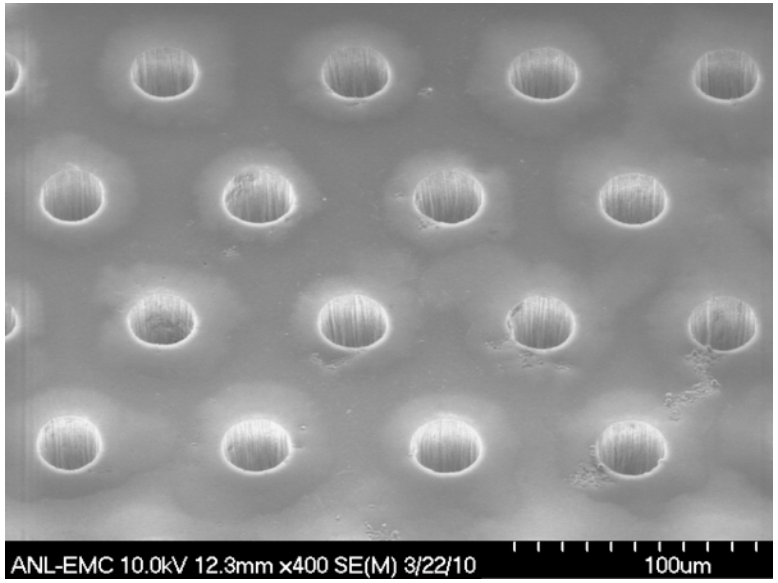


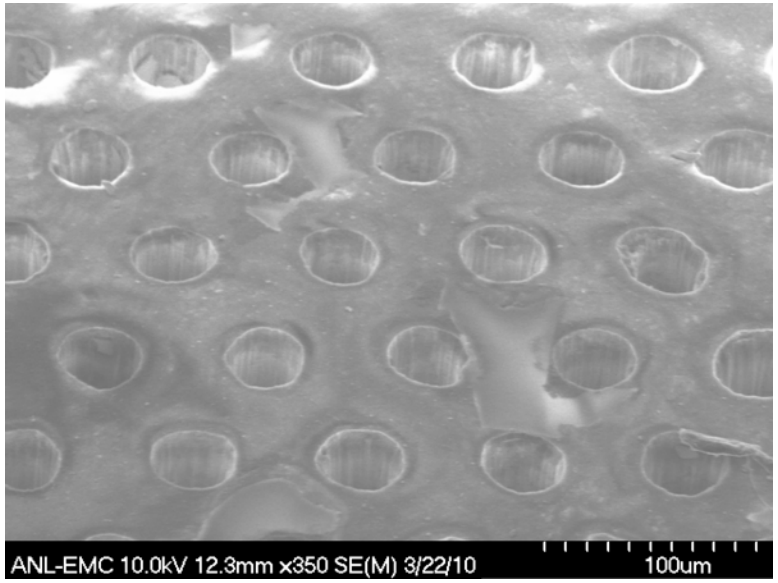


40 μm back

SEM images – AAO with etched pores

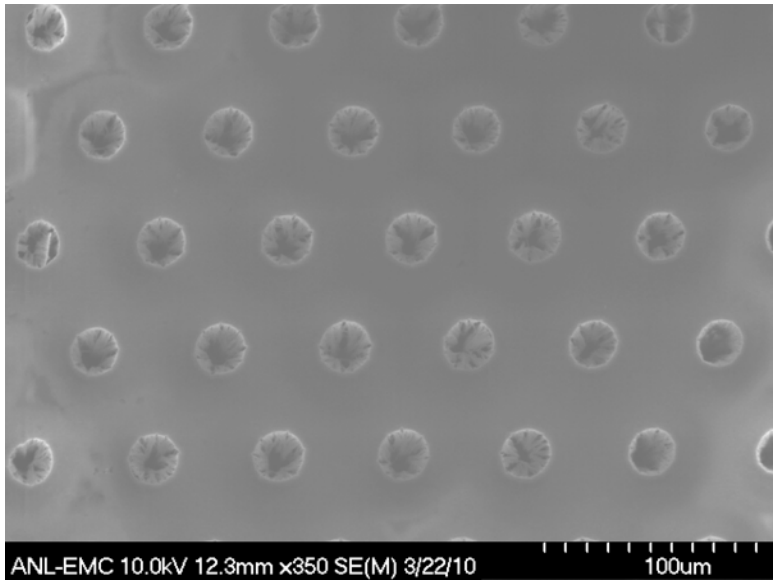
20 μm front

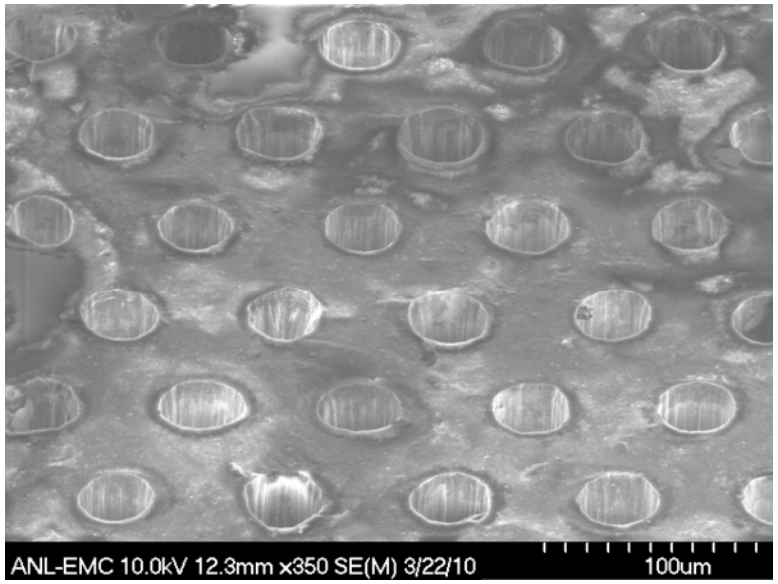




20 μm back

15 μm front

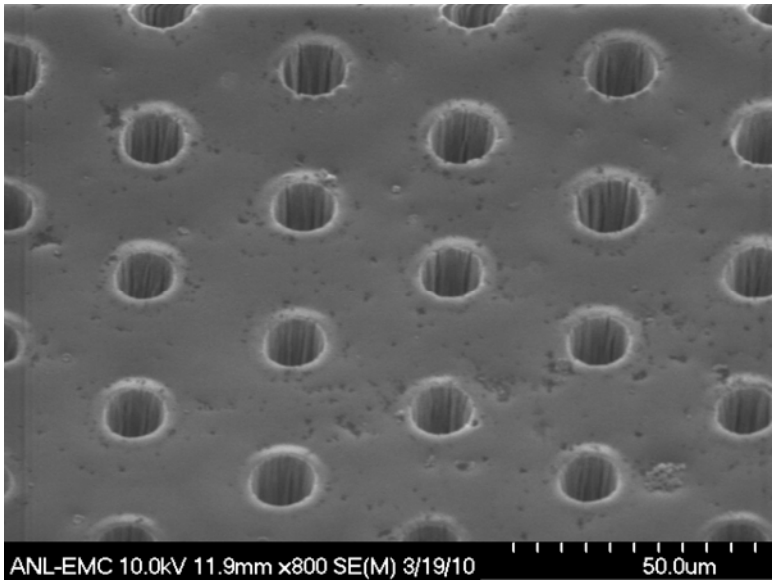


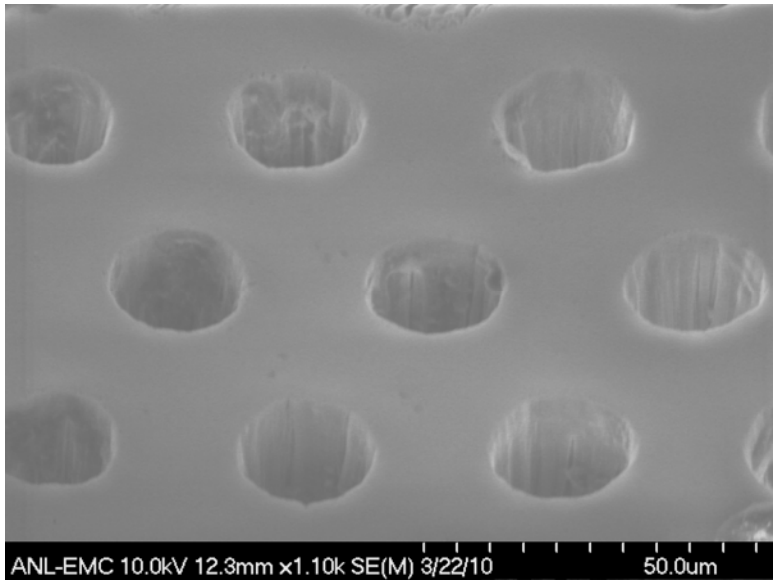


15 μm back

SEM images

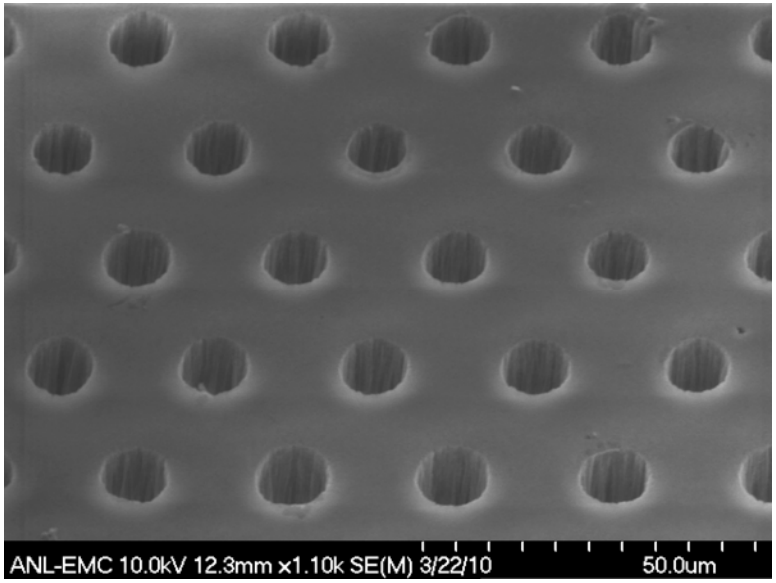
10 μm front

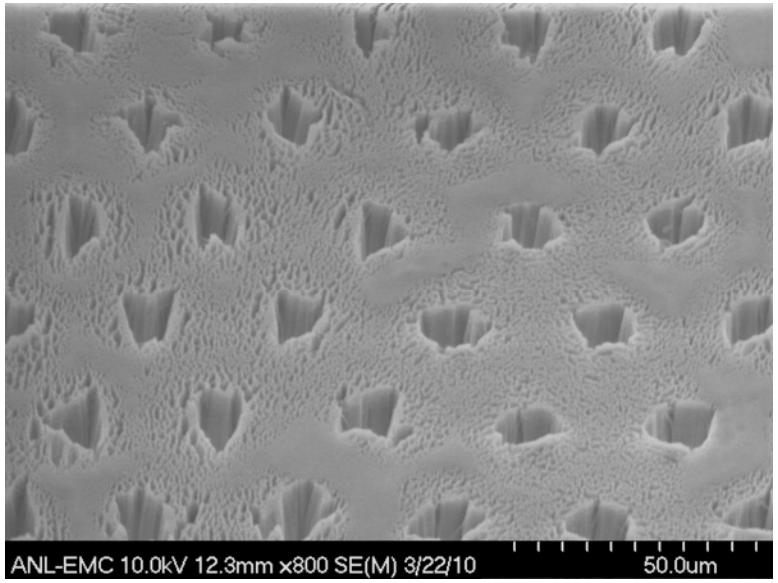




10 μm back

8 μm front

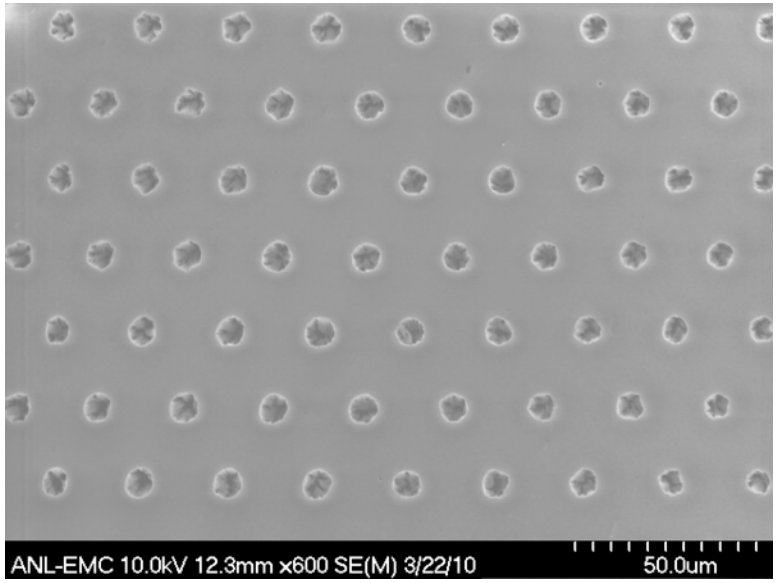


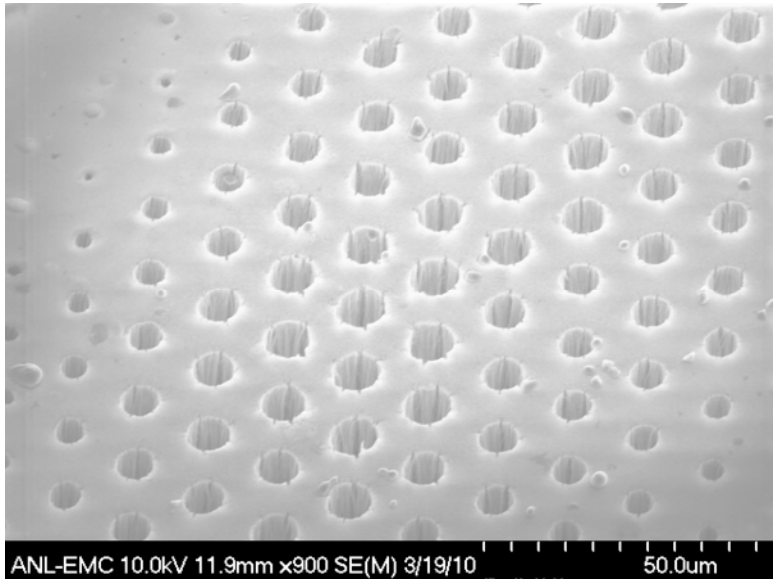


8 μm back

SEM images – 6 and 4 μm diameters

6 μm front

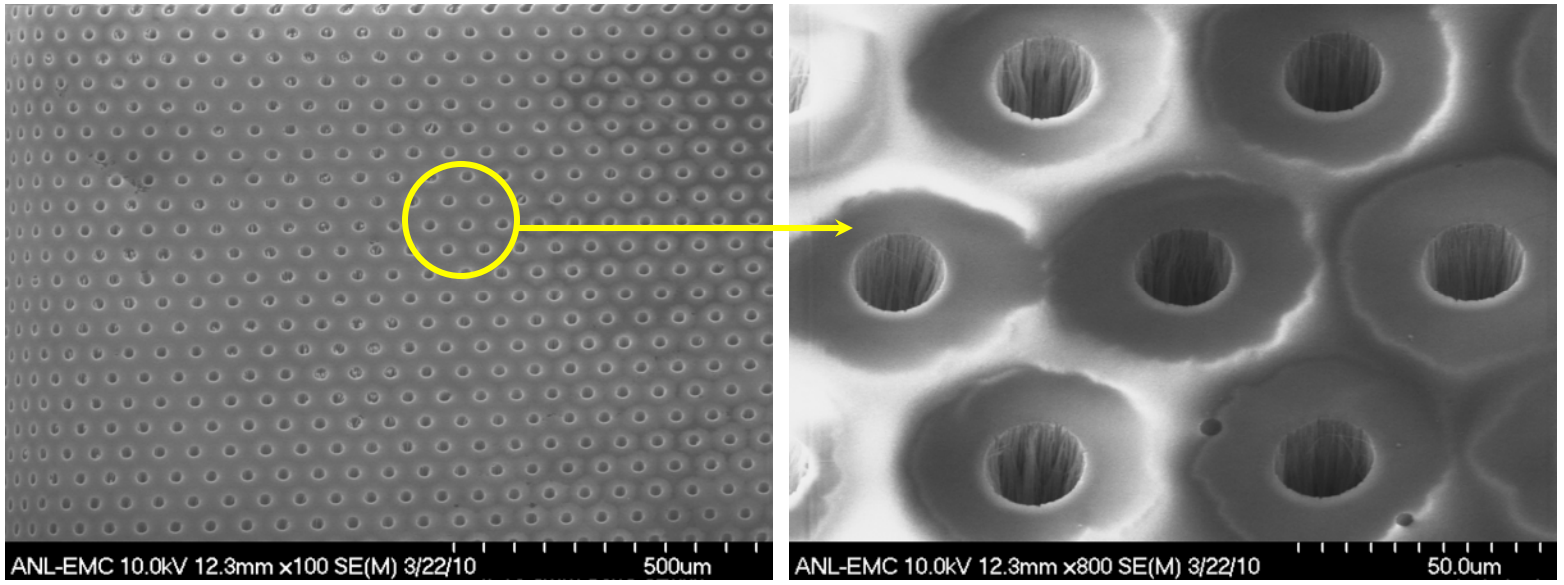




4 μm front

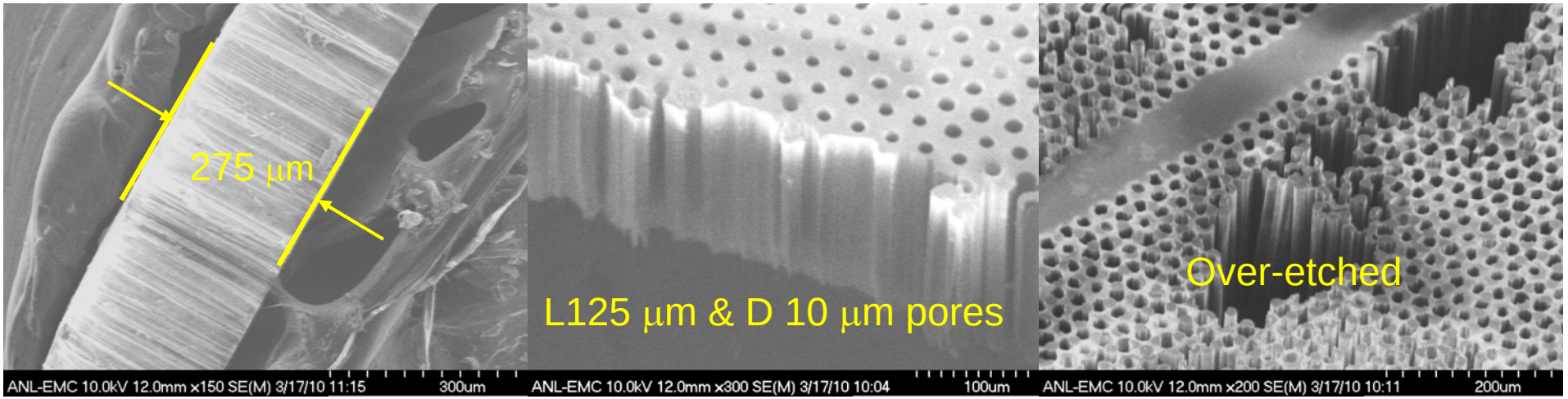
- 60 to 8 microns pores have been prepared successfully.
- Chemical etching for pores 8 microns and below is more difficult.
- Photoresist, etching concentration, temperature, and timing require more studies.

Possible route to create Funnel Shape entrances



- 15 μm pores with zoom in view (Front side)
- Over etching around the pore provides a possible route to control the "funnel shaped" entrances.

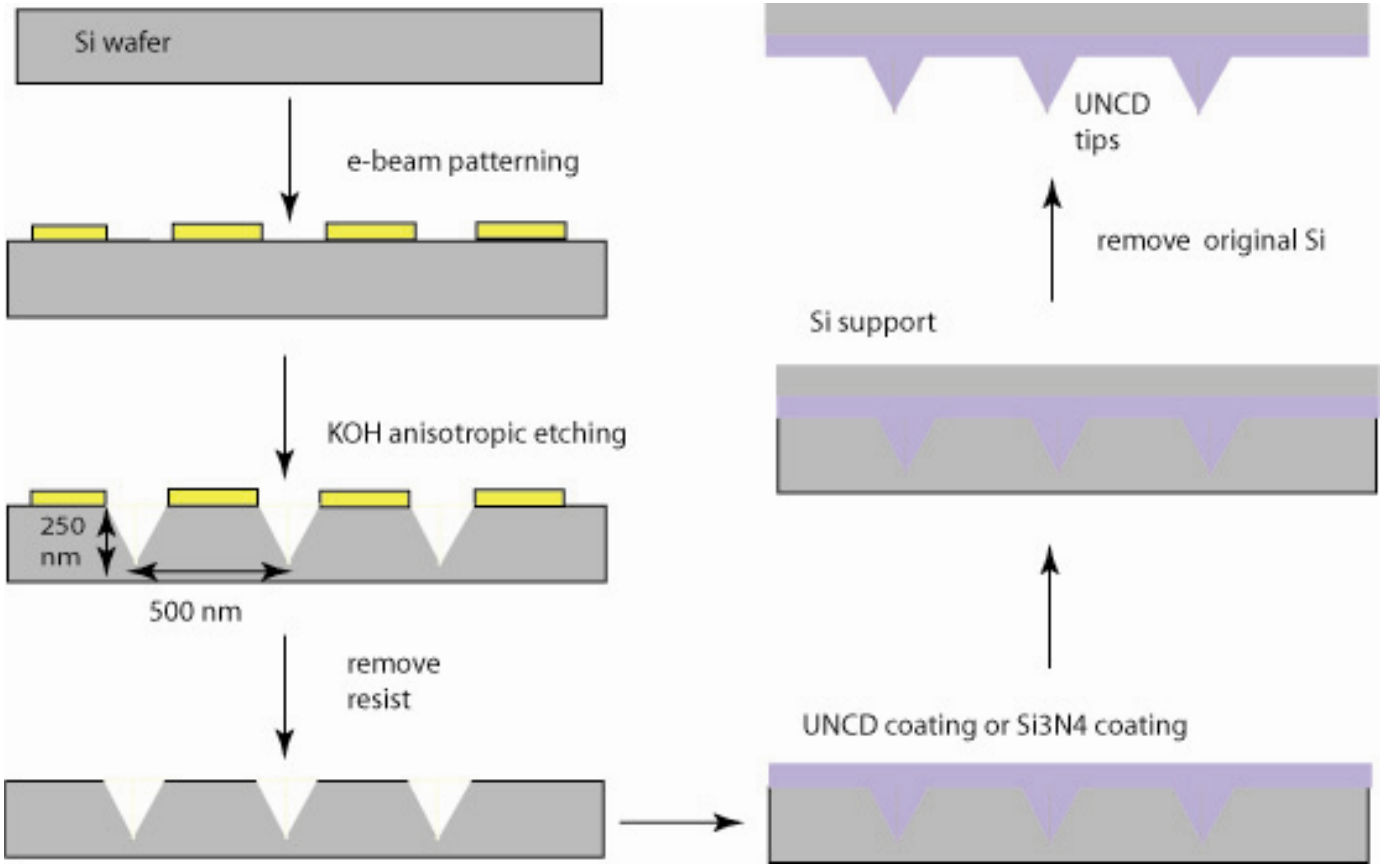
Challenges to overcome



- AAO thickness larger than 500 μm remains challenging
  (Approaches – hard anodization, longer time,..?)
- Etching concentration, temperature, and timing optimization is challenging (Very time consuming, need more small equipments, high quality control, …)
- Higher open area (>70%) reduces mechanical strength and causes potential defects and fractures

Plans to develop intrinsic pores less than 2 microns

1. Create patterns with 0.5 to 2 microns pore-to-pore distance with e-beam tool;
2. Anisotropic etching to prepare pyramidal holes;
3. Fill the holes with nano-diamond (or other materials) to make imprint stamps;
4. Stamping to prepare patterned Al surface for anodization.



Summary and Future Plans

- 60 to 8 micron pores have been prepared with laser writer
- Pores below 8 microns need further development

- AAO with larger (60%) open area will be developed
- Intrinsic pores with pore-to-pore distance between 0.4 and 2 microns will be developed

- A few AAO samples for ALD coating and further testing will be prepared
- Secondary electron emission testing… (MSD)
- Photocurrent amplification testing… (APS/HEP)
- Plan to demonstrate working AAO based MCPs with the ALD and testing groups.

Acknowledgments – DOE/HEP