AAO MCP Substrate Development at ANL

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Friday, June 11, 2010

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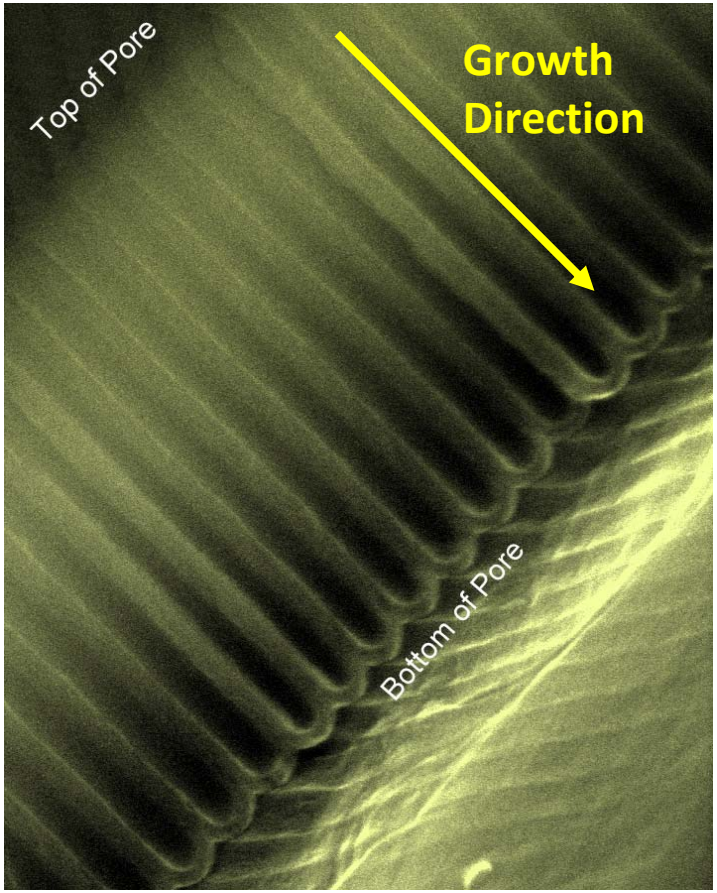
- Future Plan & Milestones

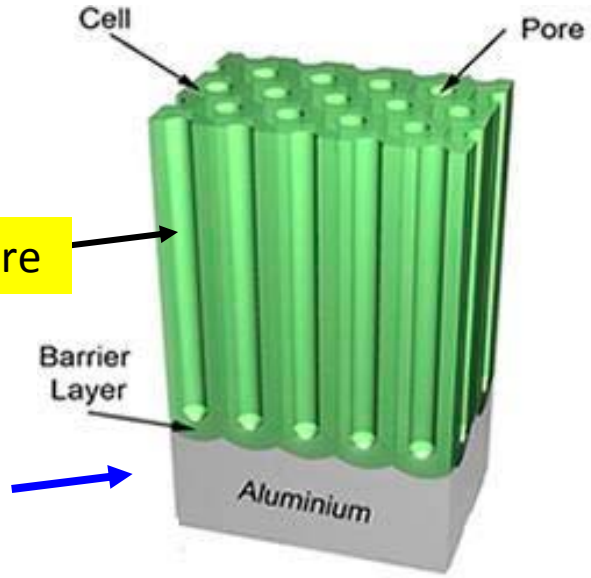
What is AAO(Anodic Aluminum Oxide)?

- Self-organized hexagonally closed packed nano-scale pores formed by anodizing aluminum in acidic electrolyte



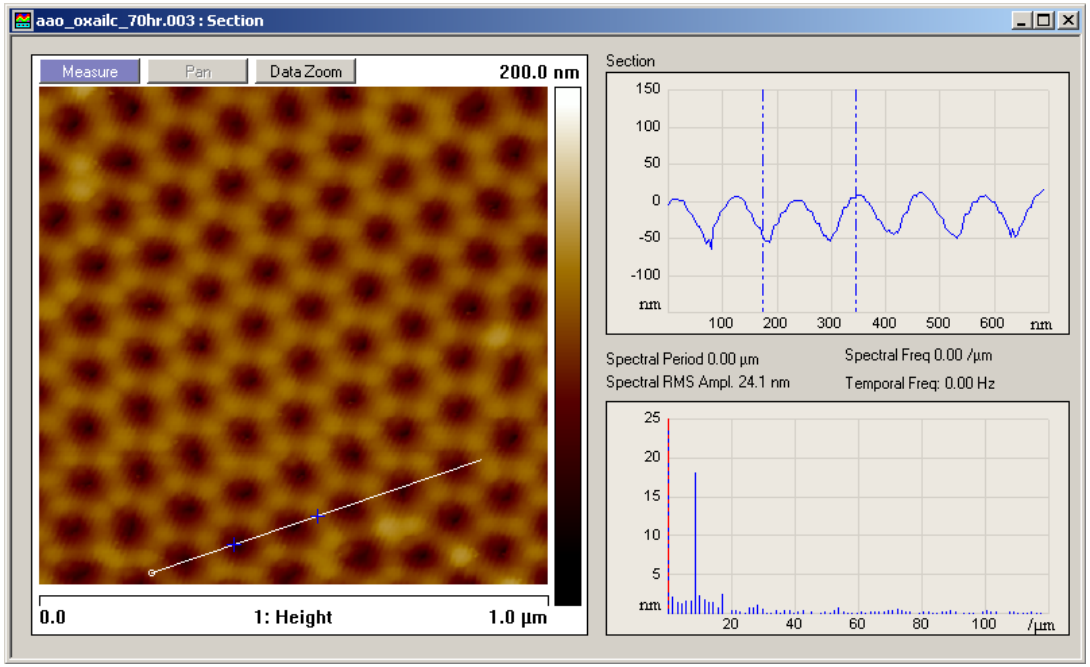
http://terpconnect.umd.edu/~pban/Research.htm

Cross-section of AAO



3-D model of AAO

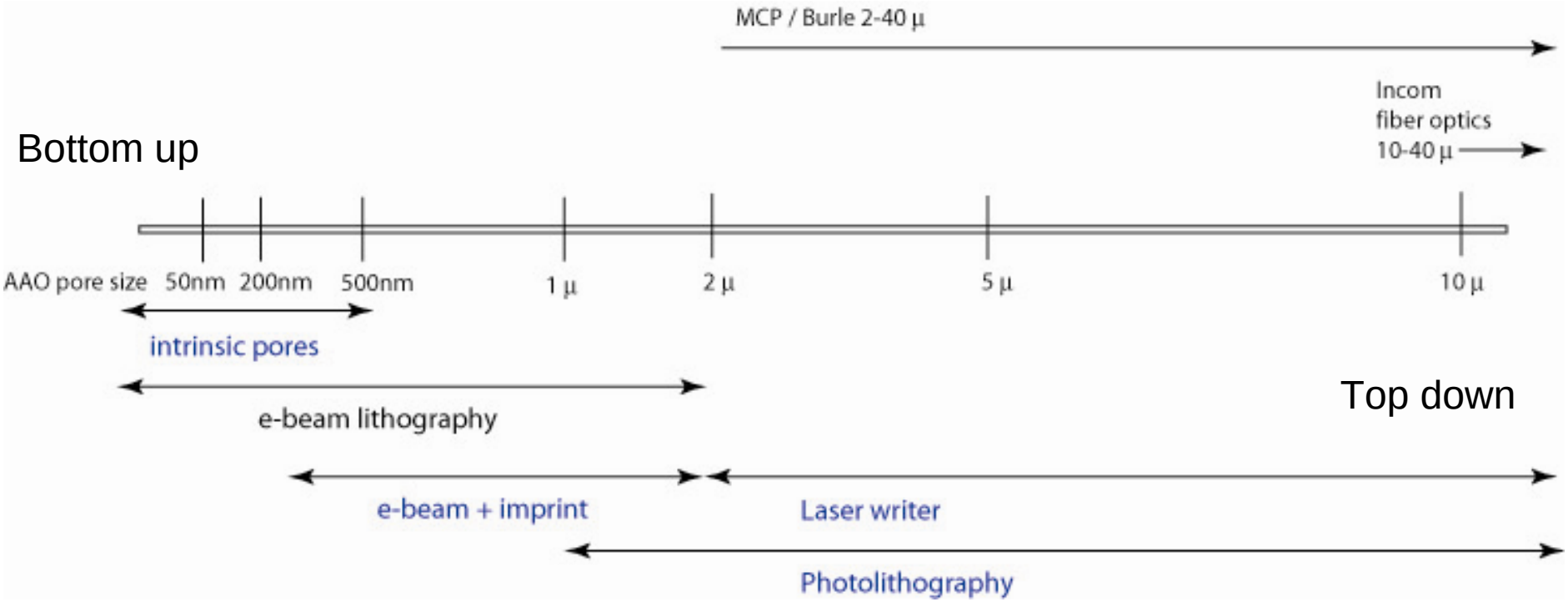
http://www2.chem.umd.edu/Groups/slee/new_site/research.html



Atomic Force Microscopy (AFM) image on top of AAO pores

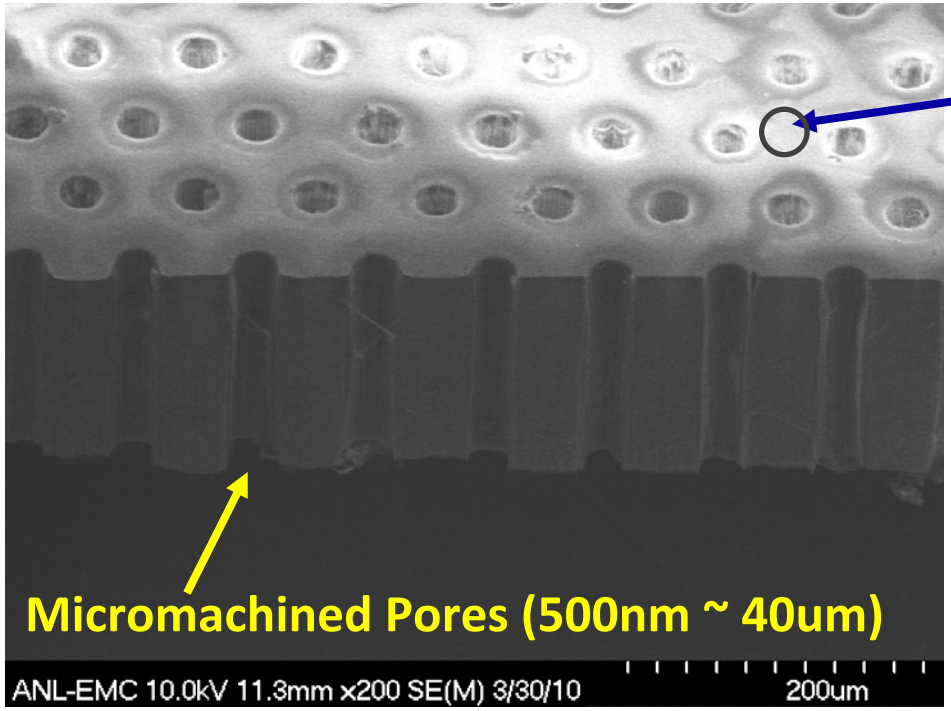
Advantage of AAO based MCP

1. **Al is inexpensive**
2. **Pore diameter can be varied in wide range :**
   - **20nm~500nm (intrinsic pores), >500nm (Micromachined pores by lithography and etching)**
   - **Laser Writer (32.8mm), 8''X8'' Large scale-> Photomask**

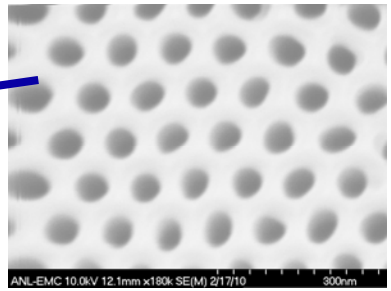


Advantage of AAO based MCP

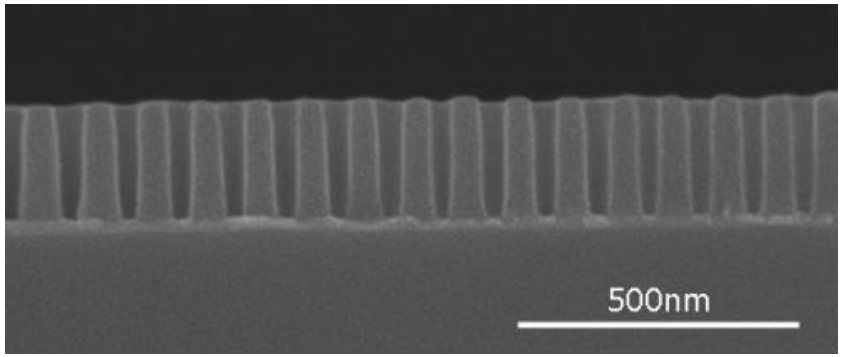
3. **Intrinsic pores are helpful to create vertically straight pores by wet etching**



Cross-section of Etched Pores

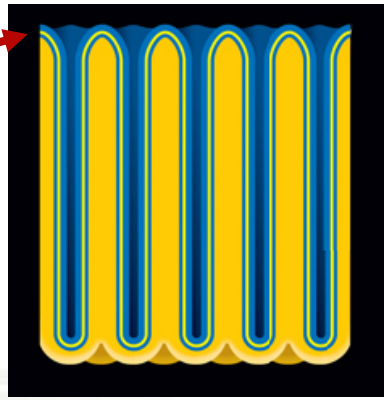


Intrinsic Pores 20~500nm



Si etching: not possible to etch deep trench with high aspect ratio

4. **Funnel entrance can be fabricated on one face**
   - **Intrinsic pores have naturally funnel shape entrance**
   - **To build funnel entrance**
     : By nanoimprint, apply varying voltage



mnemosyne.umd.edu/.../article3773.large.jpg

Roadmap for the development of AAO based MCP

Develop fabrication process
to create large scale micromachined pores

↓

Optimize for max. gain:
L/D by varying diameter of micromachined pores and thickness of AAO
Open area ratio

↓

Build funnel shape on channel entrance

↓

Scale up : 8'' X 8''

AAO MCP Fabrication Process

Self-ordered alumina by 2-step anodization
- experimental procedures

Electropolishing is carried out
HClO4/EtOH

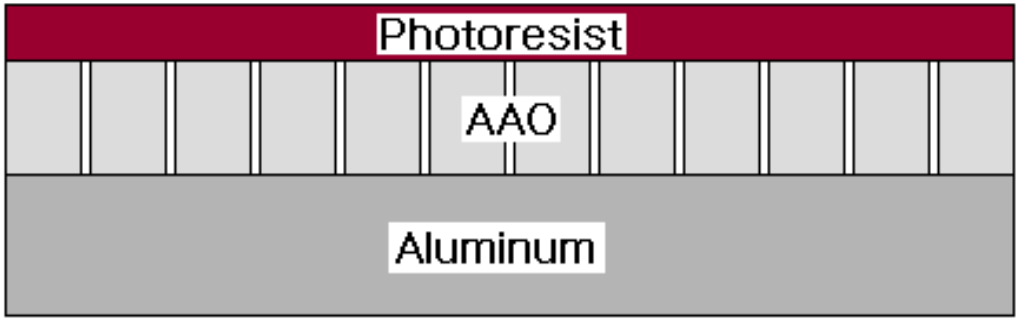
First anodization using
0.3 M sulfuric acid

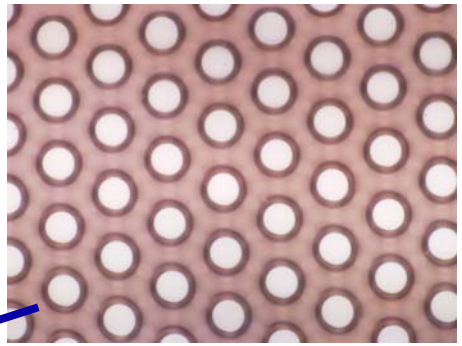
Selective dissolution
of the formed oxide layer
Chromic acid/phosphoric acid

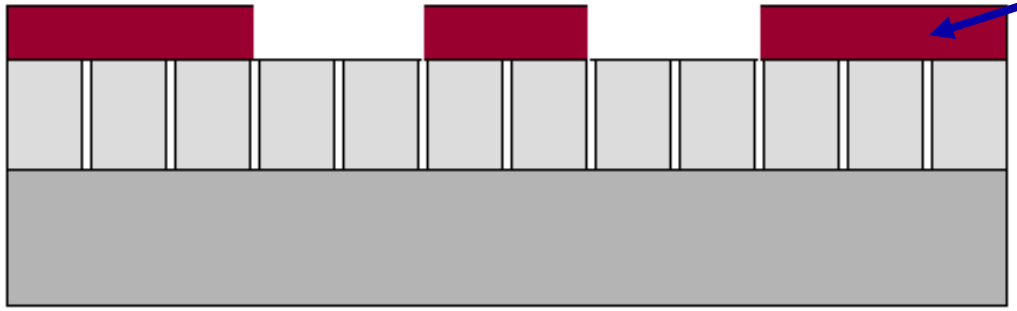
Second anodization
1~2 days

Pore widening
In phosphoric acid

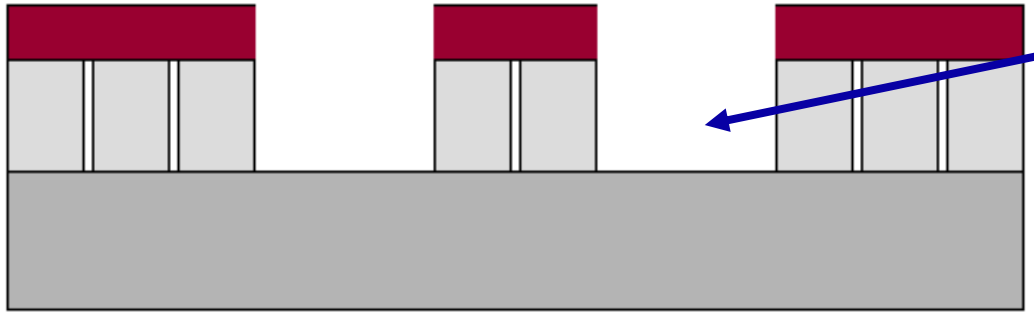
Photolithography on Aluminum anodic oxide (AAO) using laser (400nm) writer





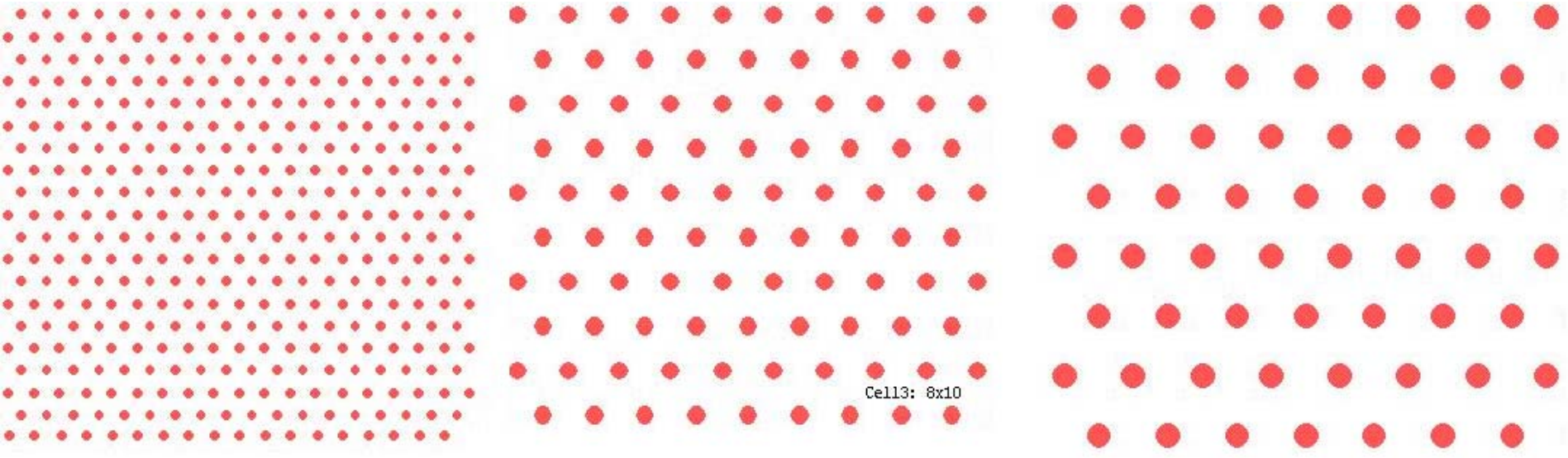


- Mask design : L-Edit



Micromachined Pore

2um, 5um, 10um hcp (hexagonal closed packed) pores patterns

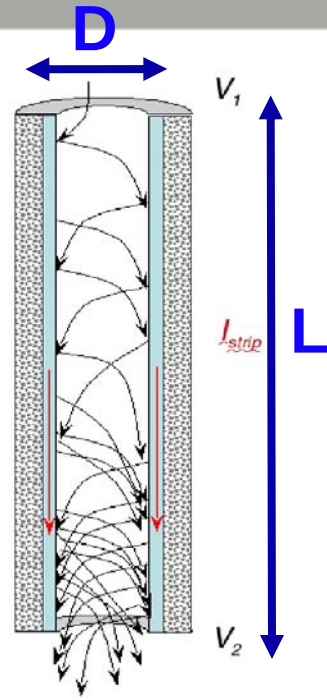


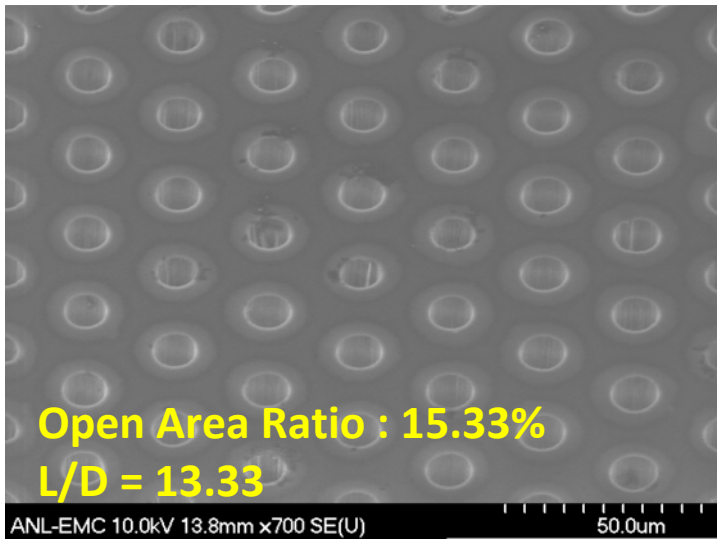
- Diameters of pores and pore-to-pore distance can be varied by drawing pattern

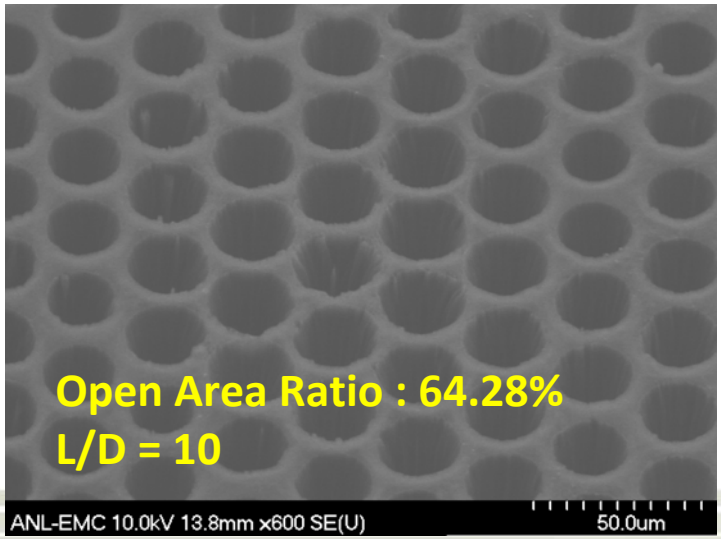
Optimize to maximize gain

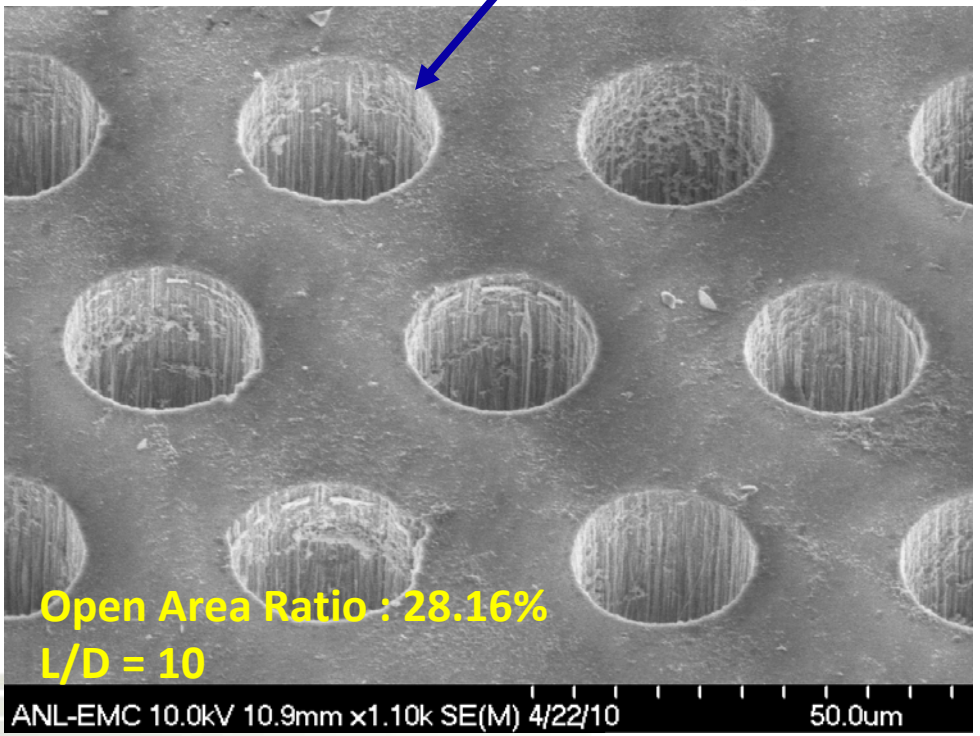
Electron multiplication is determined by a channel aspect ratio (L/D).

- **Channel aspect ratio: the ratio of Length to Diameter**
- **L/D should be adjusted to maximize the electron amplification**
  - **Maximize open area ratio**

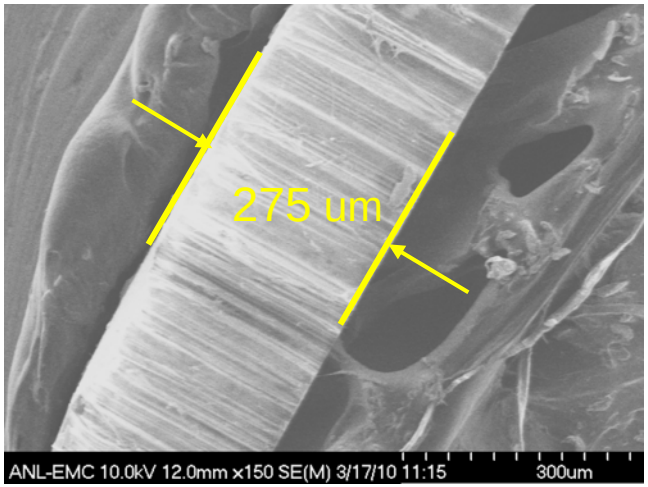


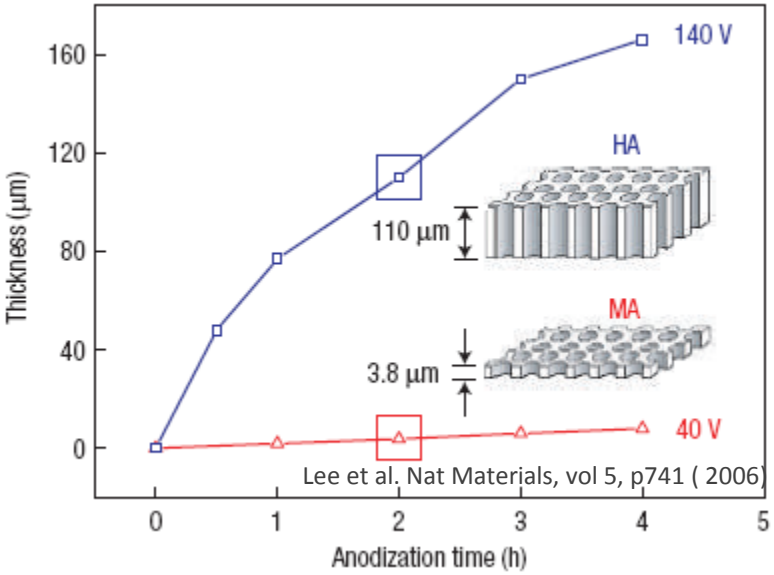


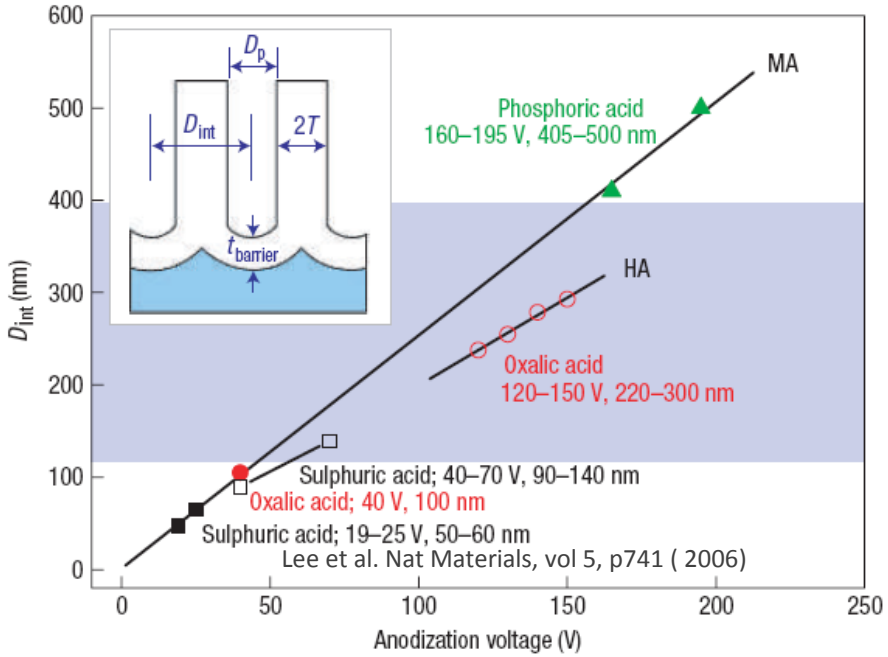


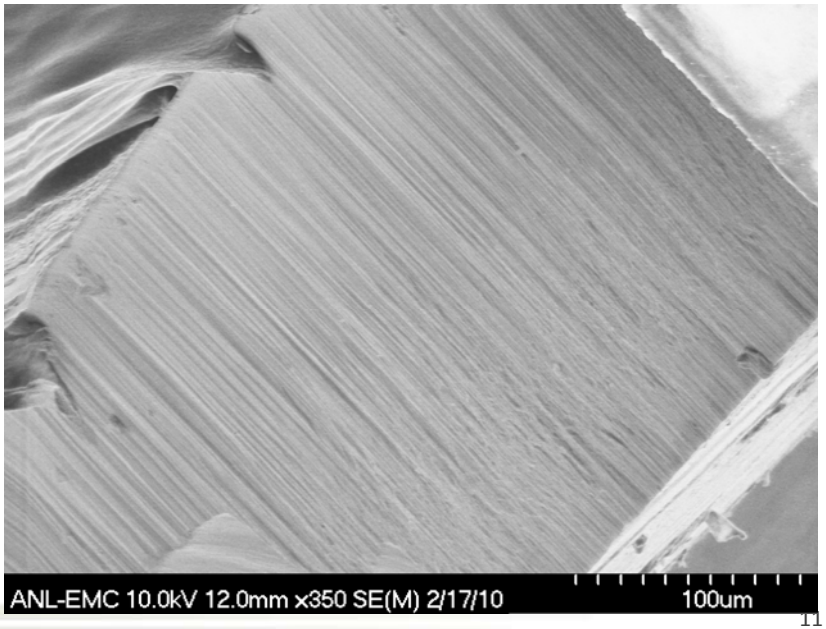


Diameter of pores, pore-to-pore distance, thickness of AAO









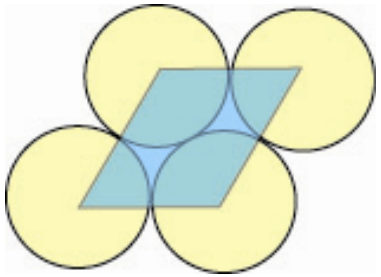
Aspect ratio

- 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 um	40 um	80 um	200 um	400 um	800 um
60	30 um	60 um	120 um	300 um	600 um	1200 um
80	40 um	80 um	160 um	400 um	800 um	1600 um
100	50 um	100 um	200 um	500 um	1000 um	2000 um

Green area is considered possible range for AAO MCP

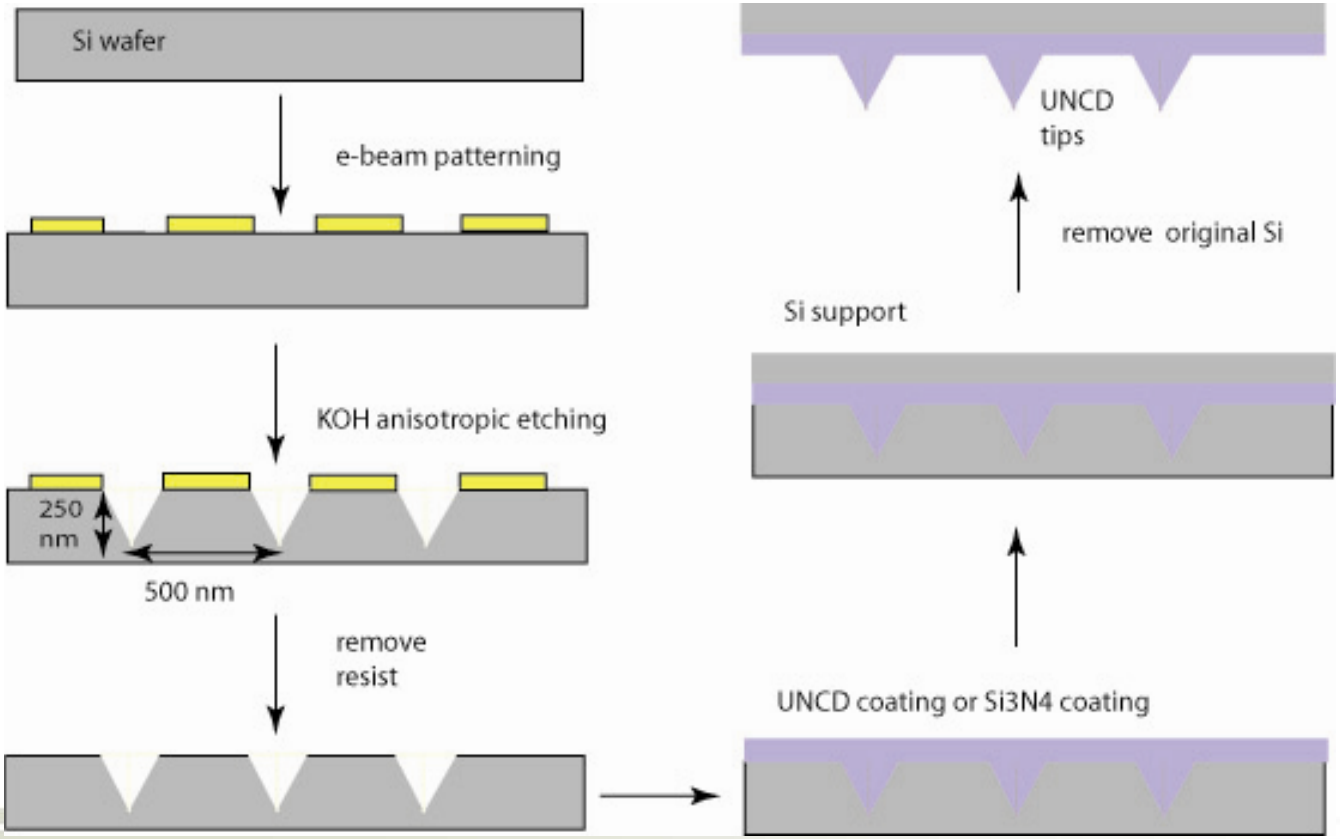
Open area



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 %	Accomlished for small area test sample
a	1.25 a	58 %	Accomlished for small area test sample
a	1.10 a	78.7 %	Possible, end of 2nd year
a	a	90.7%	Possible only with funnel

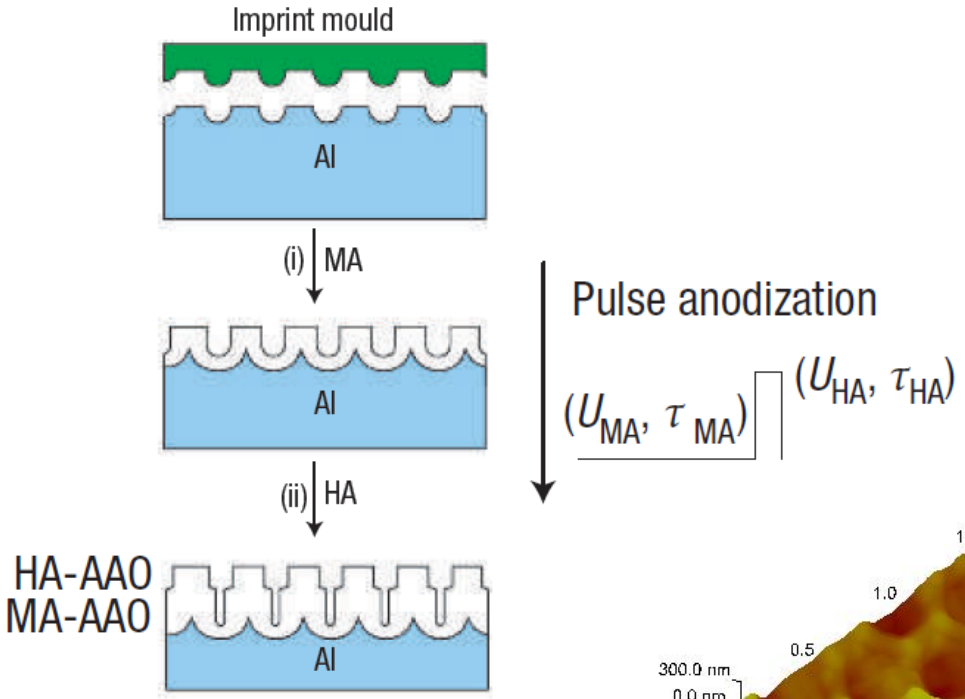
- Open area up to 80% is feasible.
- 90% open area is only possible if funnel shaped entrance can be prepared.

Funnel Shape Entrance – For intrinsic pores



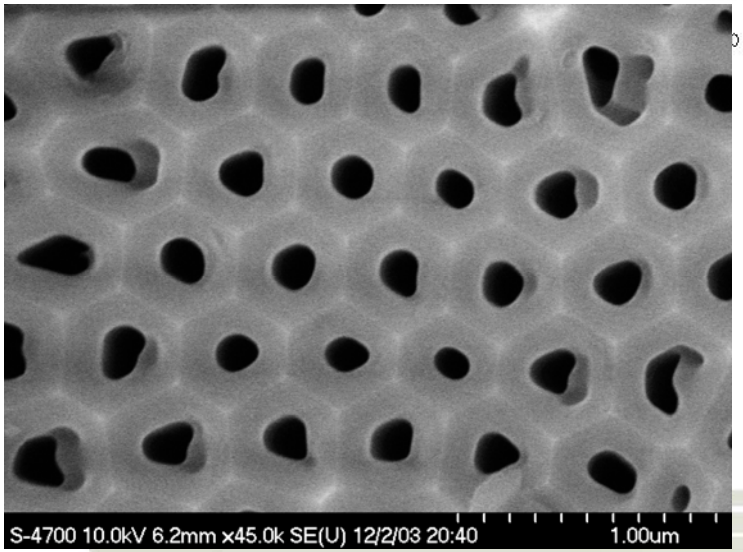
Funnel Shape entrance for intrinsic pore

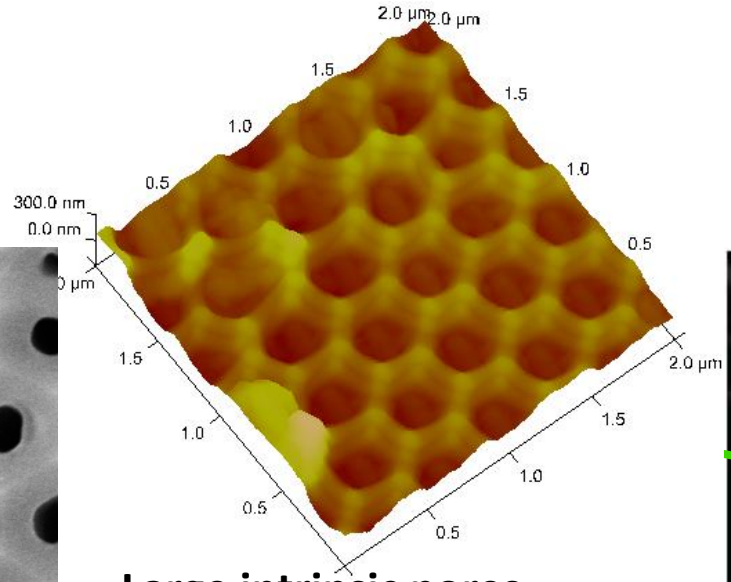
- Nanoimprint technique & Varying voltage

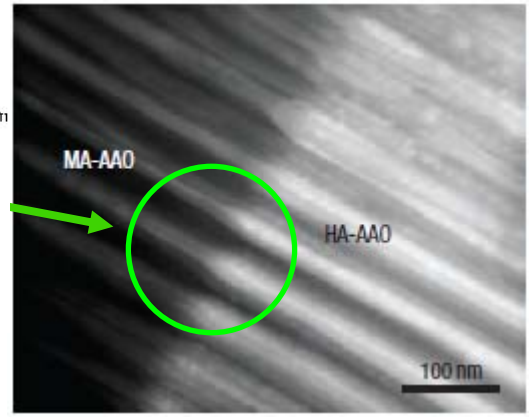


Lee et al. Nat Materials, vol 5, p741 (2006)

Lee et al. Nat Nanos, vol 3, p234 (2008)

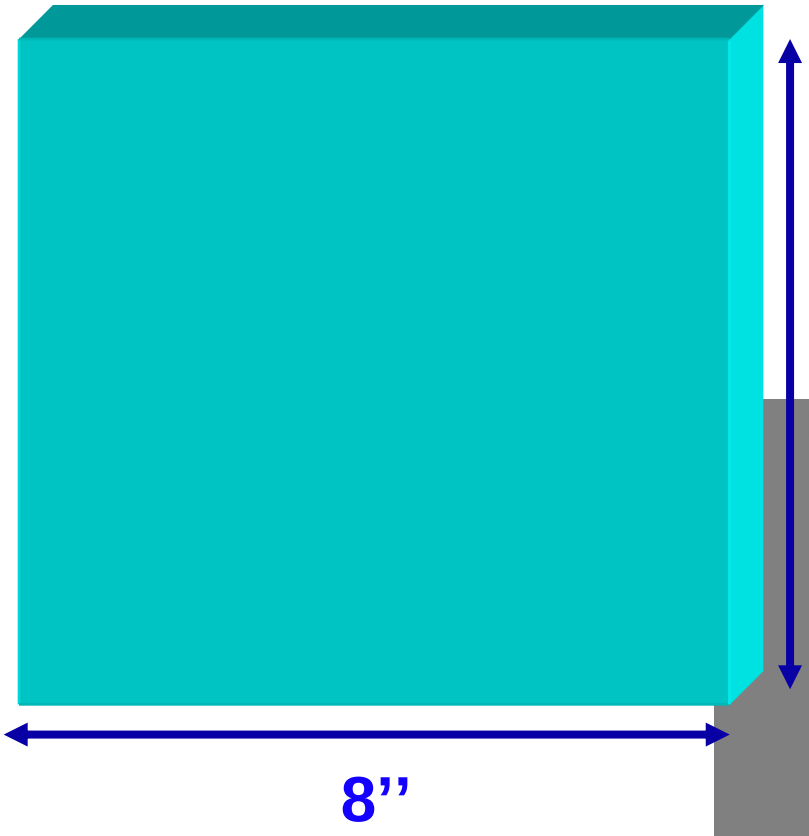




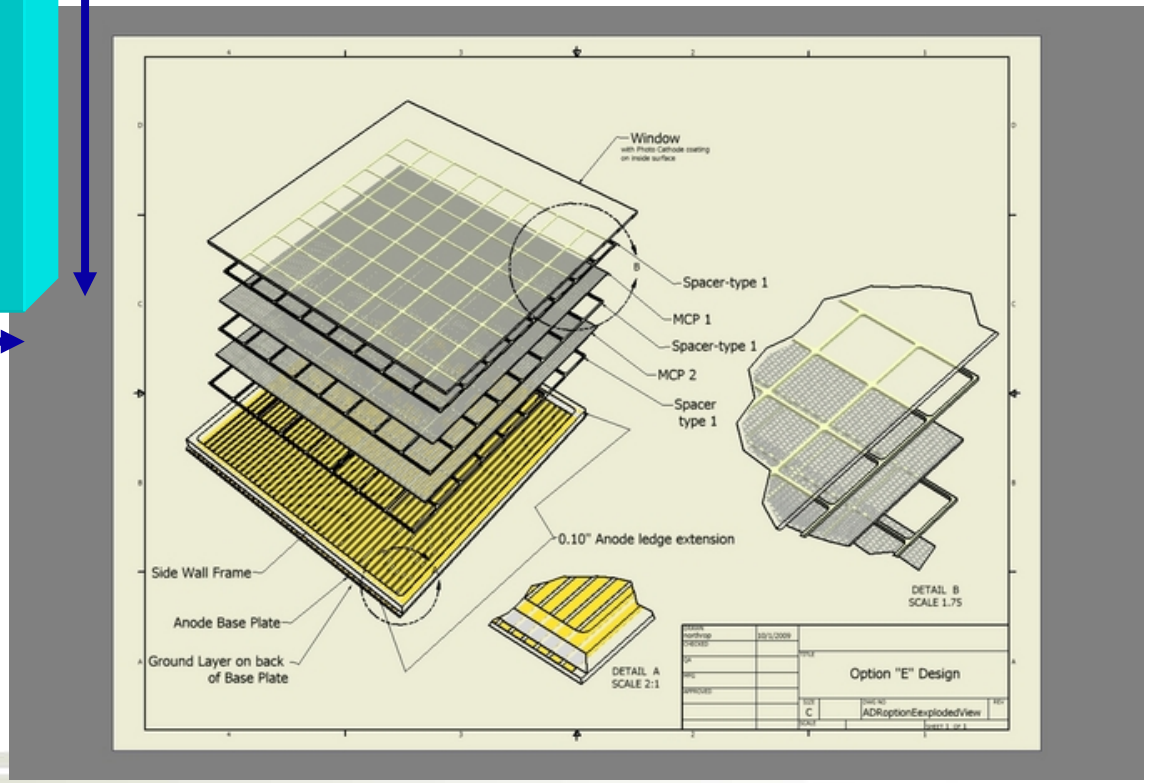


Large intrinsic pores
-hard anodization
-pore to pore distance 440nm
-pore diameter 300nm

Scale up : 8’’X8’’

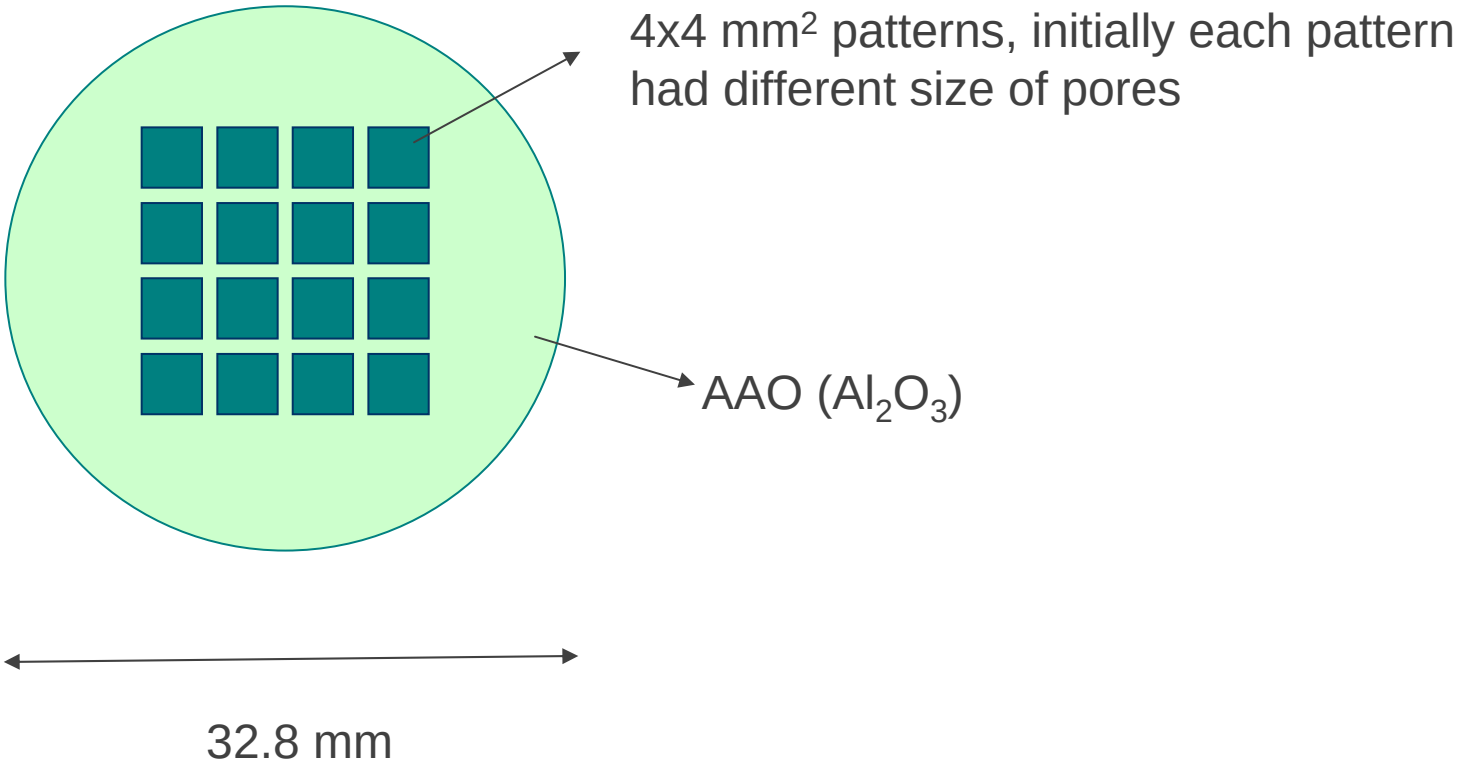


- 8’’ X 8’’ AAO MCP :
- Need to design teflon cell to grow large scale AAO

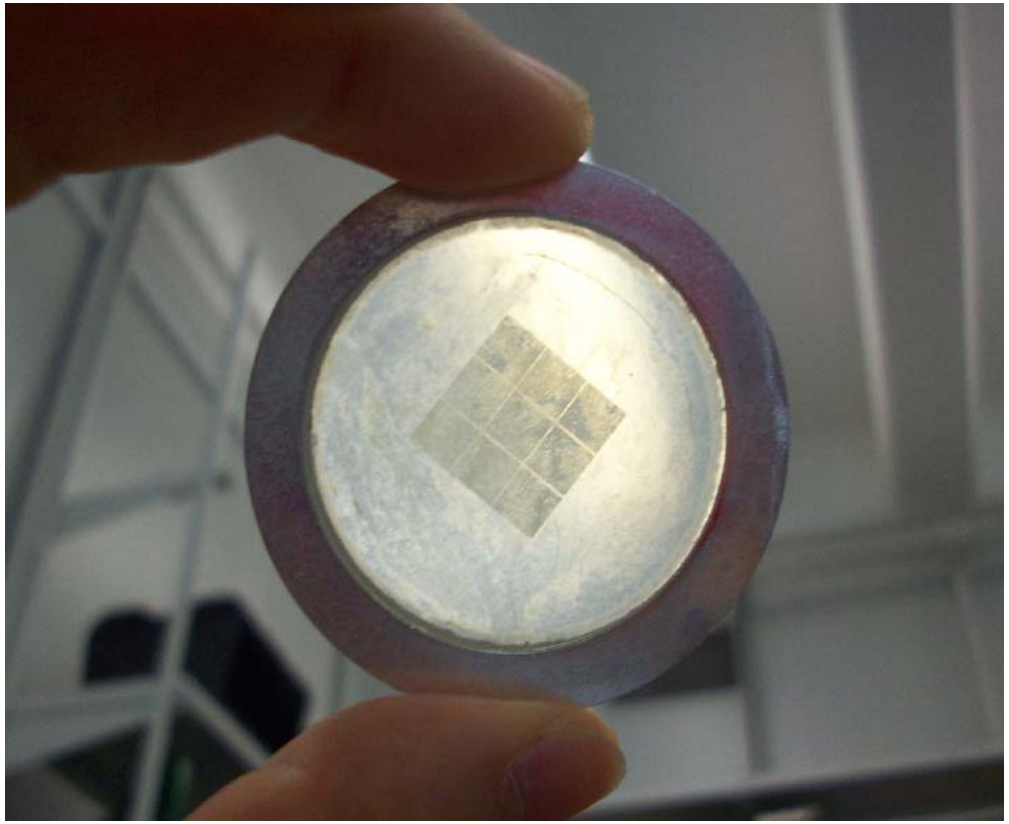


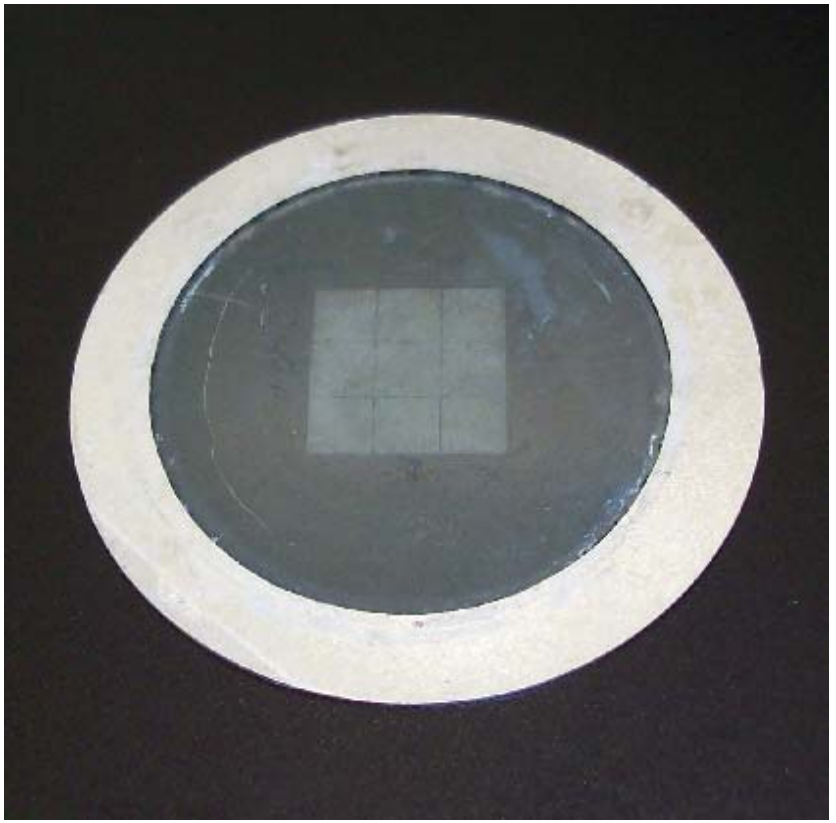
Current status of AAO MCP development at ANL

- 32.8 mm free standing AAO is being prepared .



Status of testable AAO based MCP at Argonne



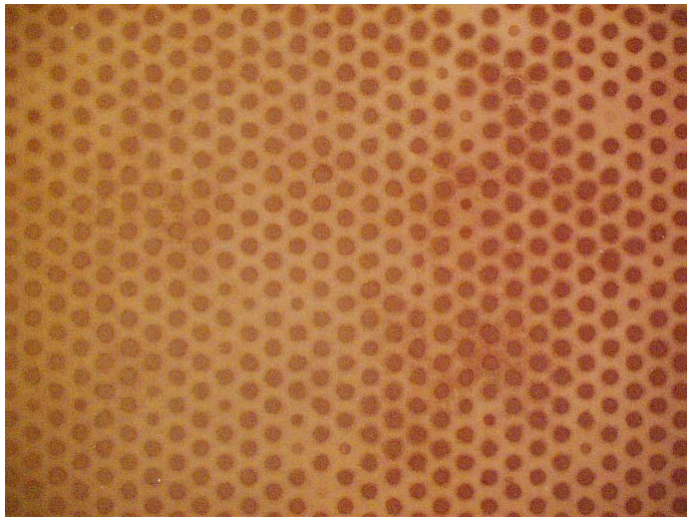


- 32.8 mm free standing AAO
- Pore size : 20 um
- Open area ratio : 22.66%
- L/D : 10

1st testable AAO based MCP at Argonne – Optical Image

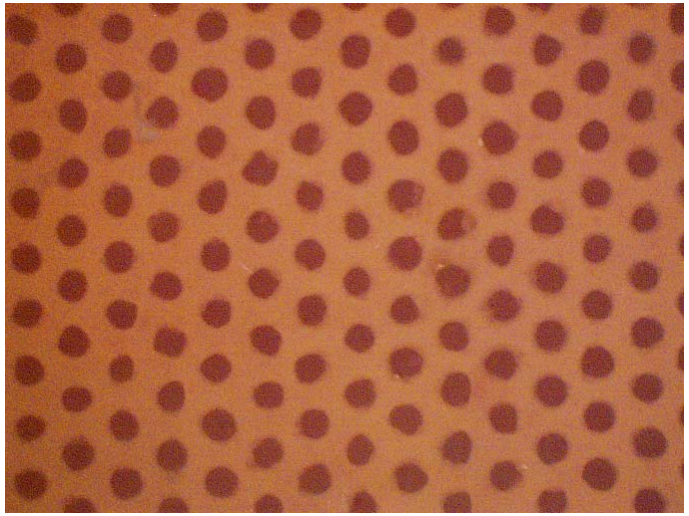
- 32.8 mm free standing AAO is ready
- Pore size : 20 um
- Open area ratio : 22.66%
- D/L : ~ 10

Front



X10

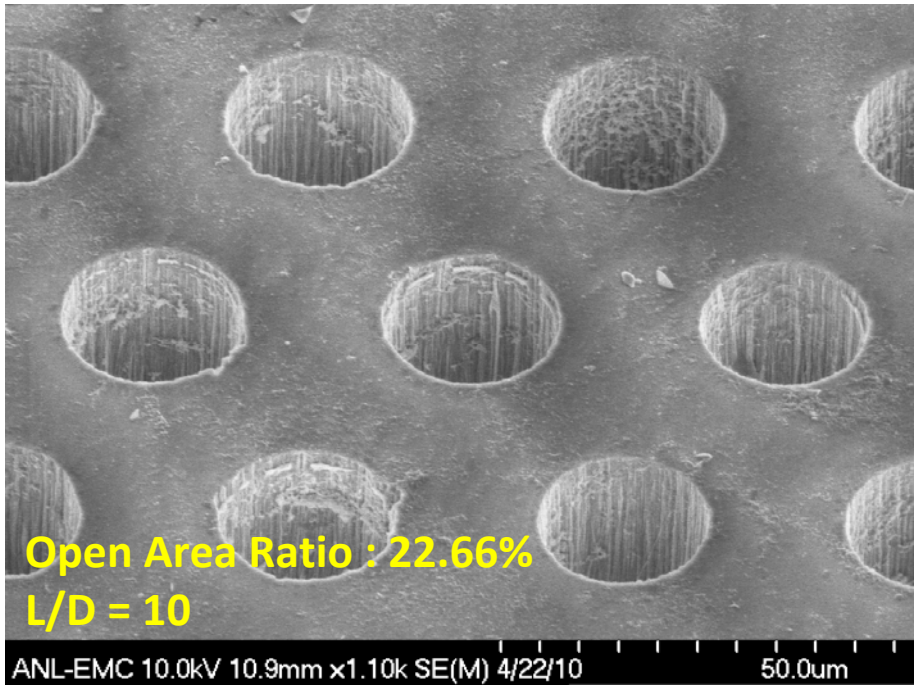
Back



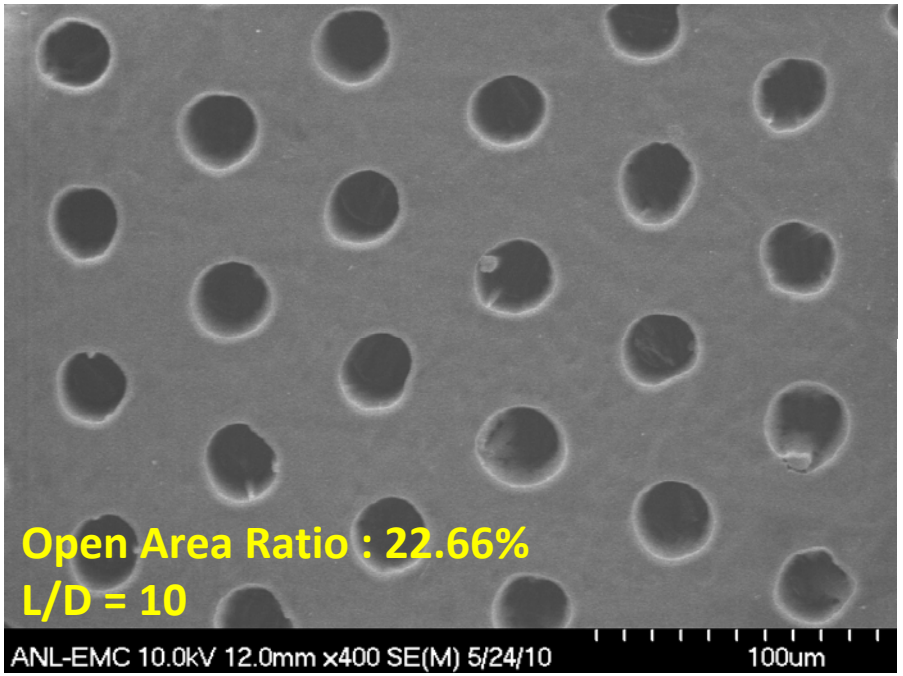
X20

Current status of AAO MCP development at ANL

- **SEM(Scanning Electron Microscopy) Images of etched 20 um pores, open area ratio 22.66%**



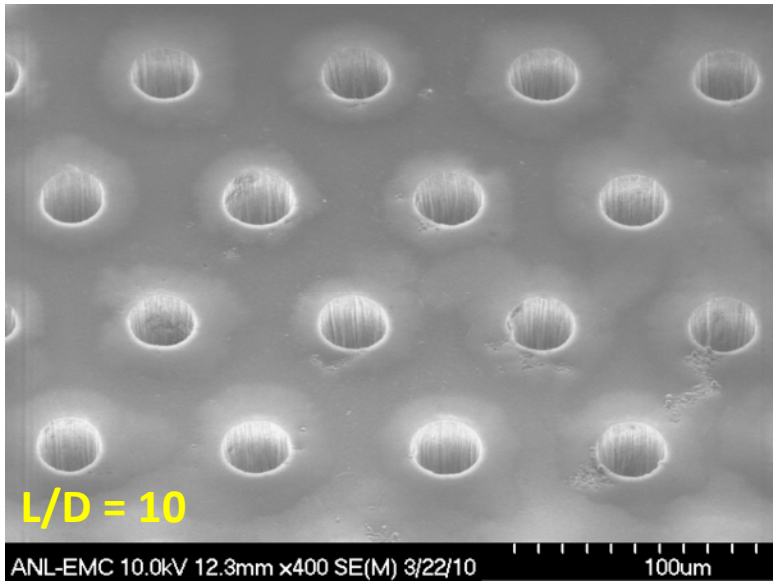
Front

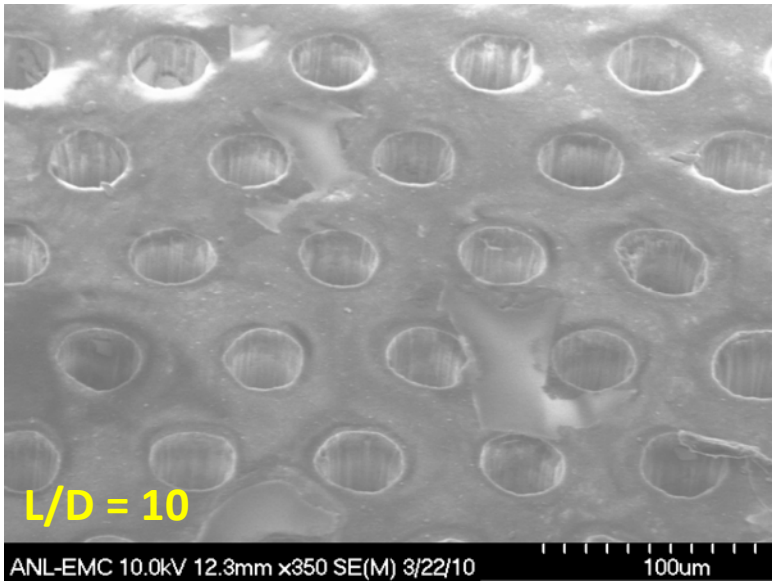


Back

SEM images – AAO with etched pores

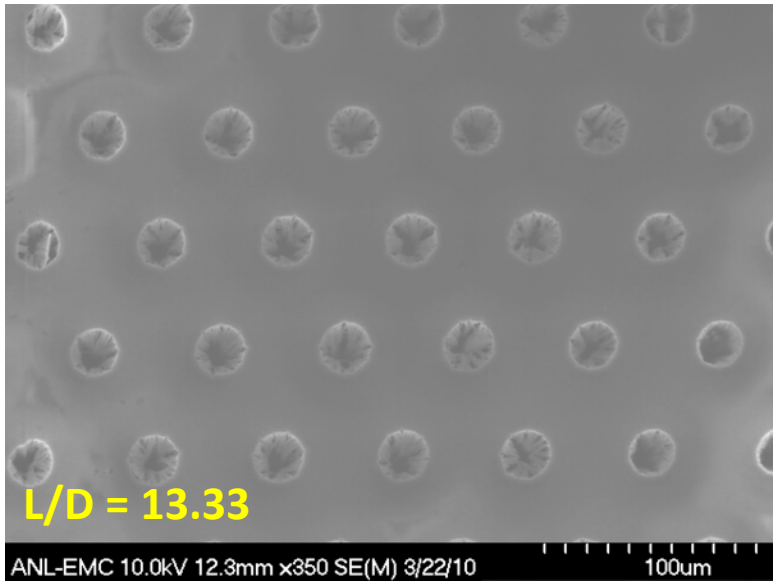
20 μm front

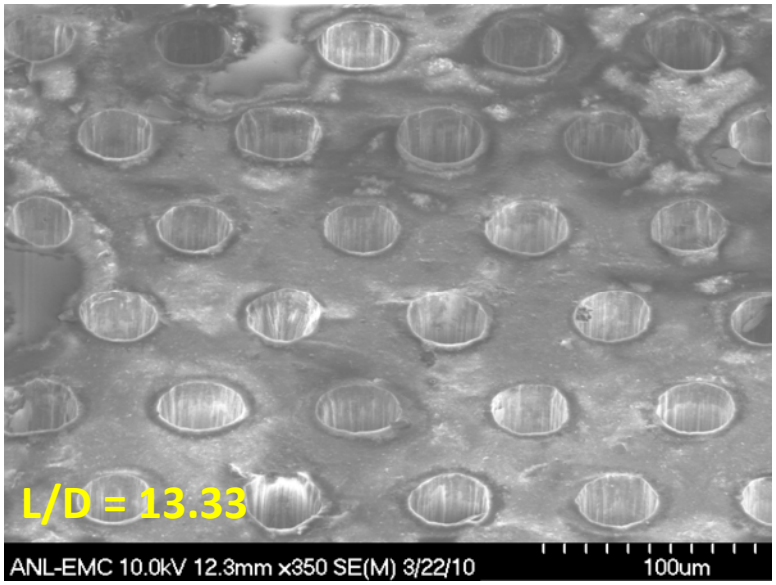




20 μm back

15 μm front

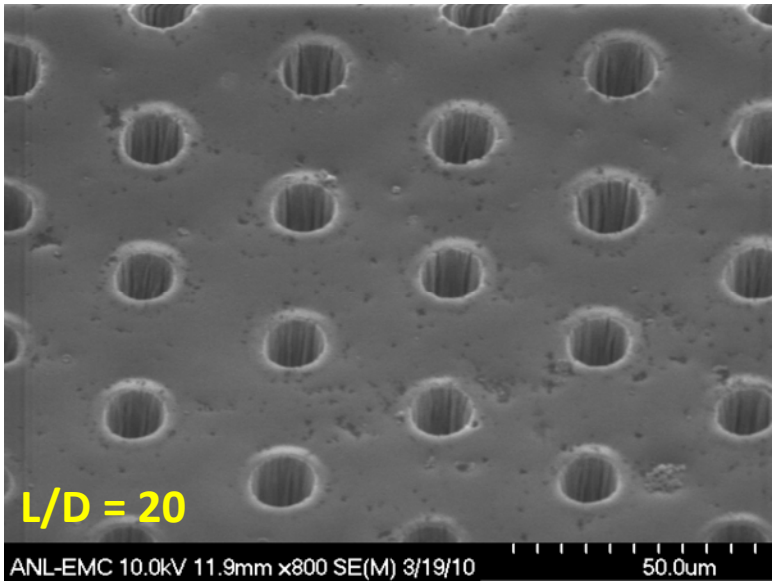


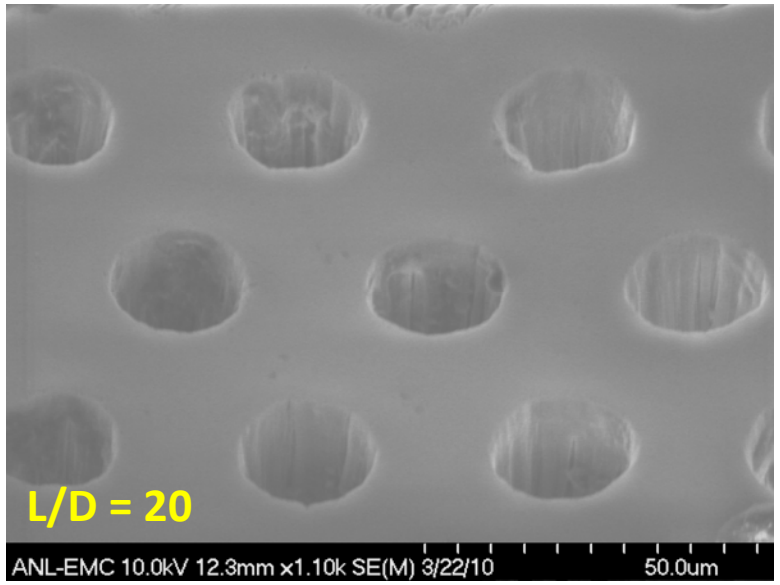


15 μm back

SEM images

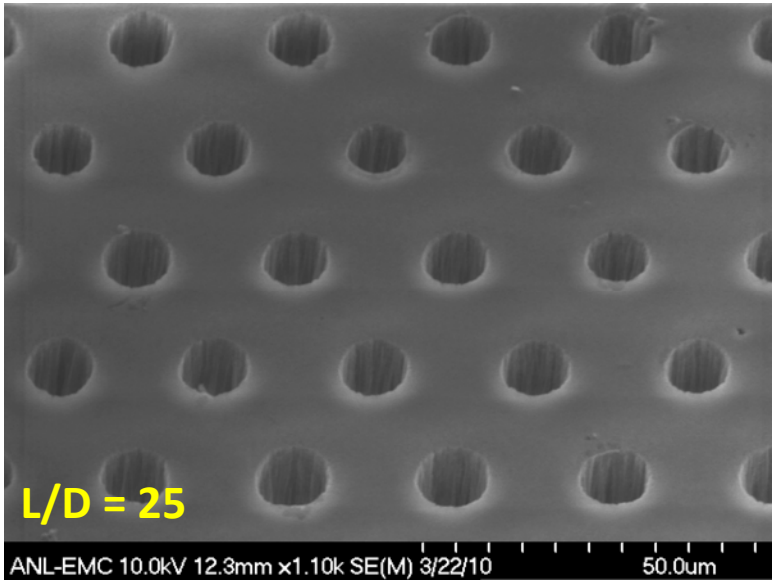
10 μm front

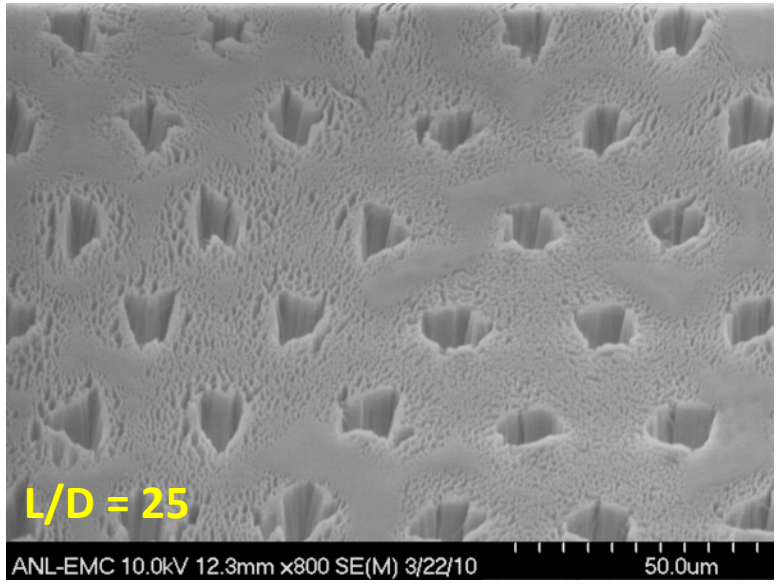




10 μm back

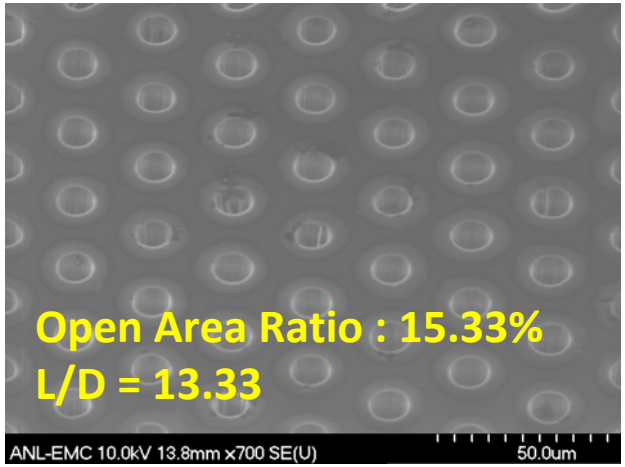
8 μm front

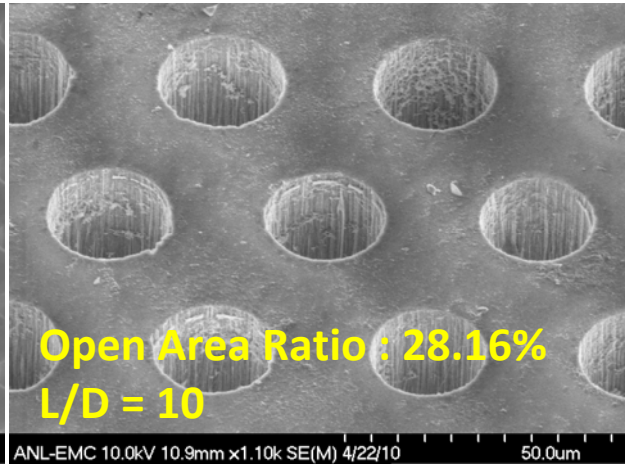


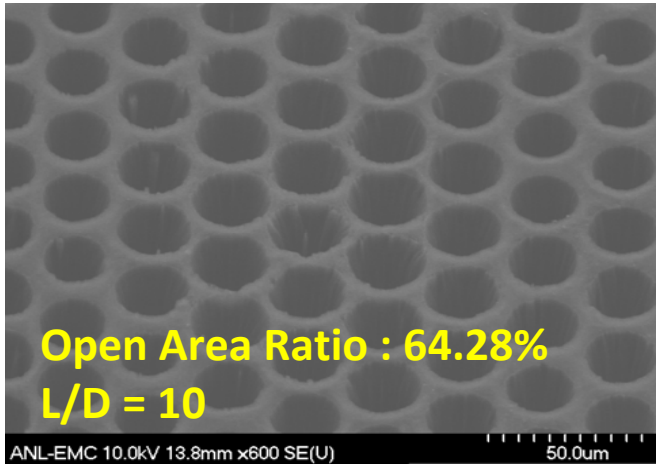


8 μm back

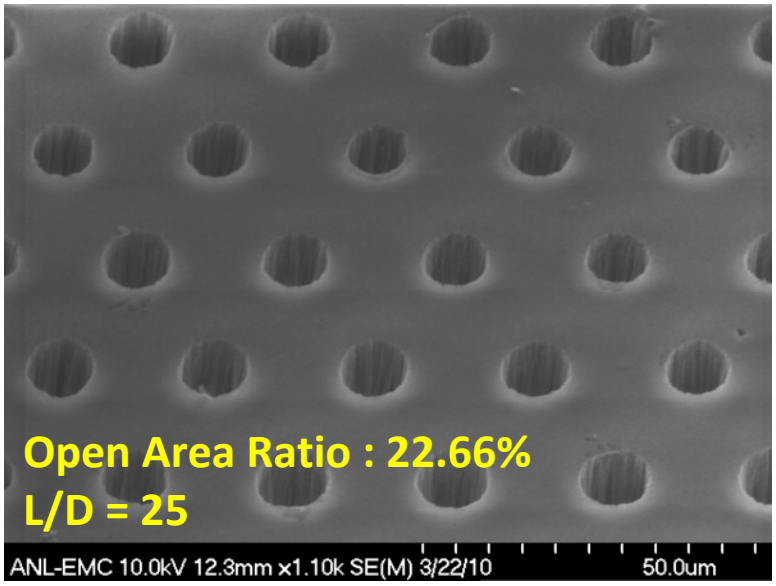
Open area ratio achieved: 64.28%
Aspect ratio L/D=25 achieved

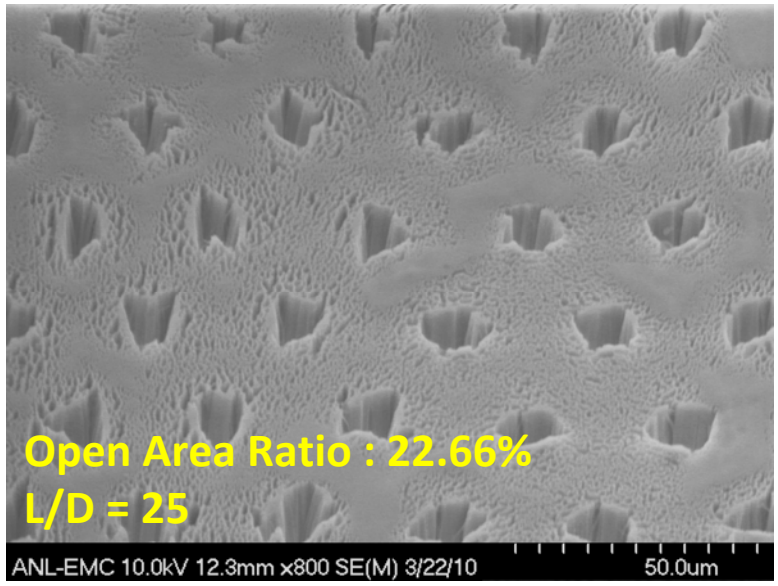






8 μm front





8 μm back

Milestones

- Year 1

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

  -> Toward large pore to pore distance, we are developing both intrinsic pore etching and nanoimprint techniques

  -> intrinsic pore: any aspect ratio, micromachined pore

  -> open area ratio 60% was achieved for small area test sample.

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

  -> intrinsic pores naturally come with funnel shape

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

  -> 20 um pores AAO MCP samples delivered to the ALD group

- 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.

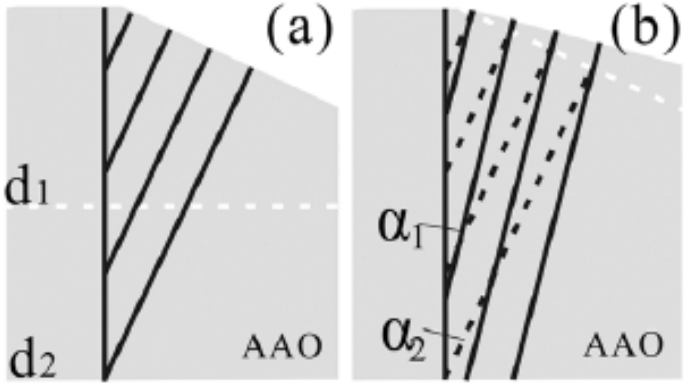
Plans for testable AAO based MCP in near future

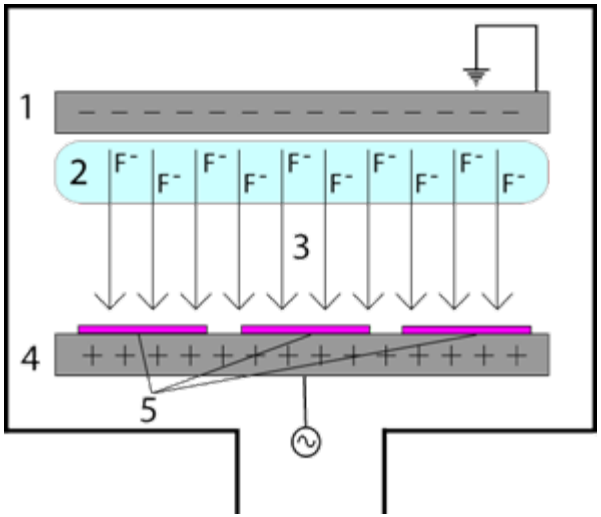
- **We started to provide testable AAO based MCP**
- **Currently making samples**
  - **To increase open area ratio**
  - **To increase aspect ratio**
- **ALD – Qing, Anil**
- **Test at APS – measure amplification gain**

Acknowledgments – DOE/HEP

The First Strike Problem

- Curved pores



Nanotechnology 18 (2007) 035304

- RIE (Reactive Ion Etching) – large scale pores