# Creation of economical and robust large area MCPs by ALD method for photodetectors

Session Detector: R&D and Performance

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# Acknowledgements


- ALD group members
- HEP LAPPD Collaboration
- UCB (Prof. Oswald Siegmund) and UoC (Prof. Henry Frisch)
- Incom Inc. (Dr. Michael Minot and his Team)
- DOE for Funding, Contract No.“DE-AC02-06CH11357”
- Funding agencies

# Outline

- Overview: ALD-MCPs technology
- ALD Processes for MCPs creation
- ALD-MCPs Testing
- Summary

# Applications of MCPs

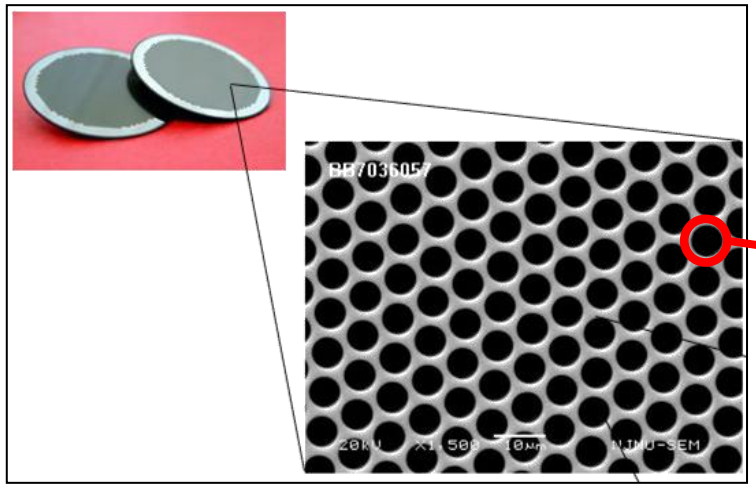
- Photodetectors, time-of-flight (ToF) mass spectrometry, molecular and atomic collision studies, electron microscopy , field emission displays, and night vision goggles and binoculars, medical imaging (PET scanners), homeland security (scanners for shipping containers and trucks), X-ray and Neutrons detection

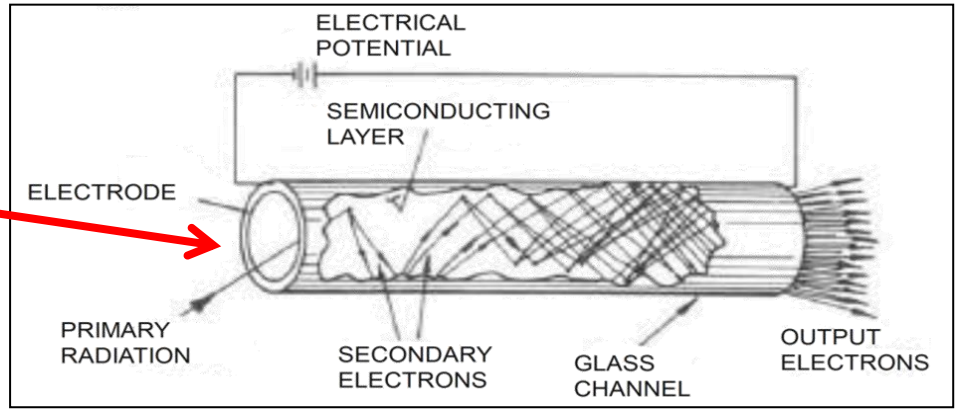
- **Large HEP experiments**

  LBNE/DUNE/μBooNE @Fermi Lab,
  Super-K RICH and BELLE II @Japan,
  LHC, ATLAS and CMS @CERN,
  Mark-I @SLAC

  PANDA @FAIR Germany,
  JUNO @China,
  CLAS12 @Jefferson Lab,
  NASA Space Mission

# Microchannel Plates (MCPs)






## Conventional Fabrication Method:

- Draw lead glass fiber bundle
- Slice and polish
- Chemical etch
- Hydrogen firing

## Issues:

- Expensive and need to import
- Resistance and secondary emission properties are linked
- Very long conditioning timing
- Contains lead
- Available in small form factor

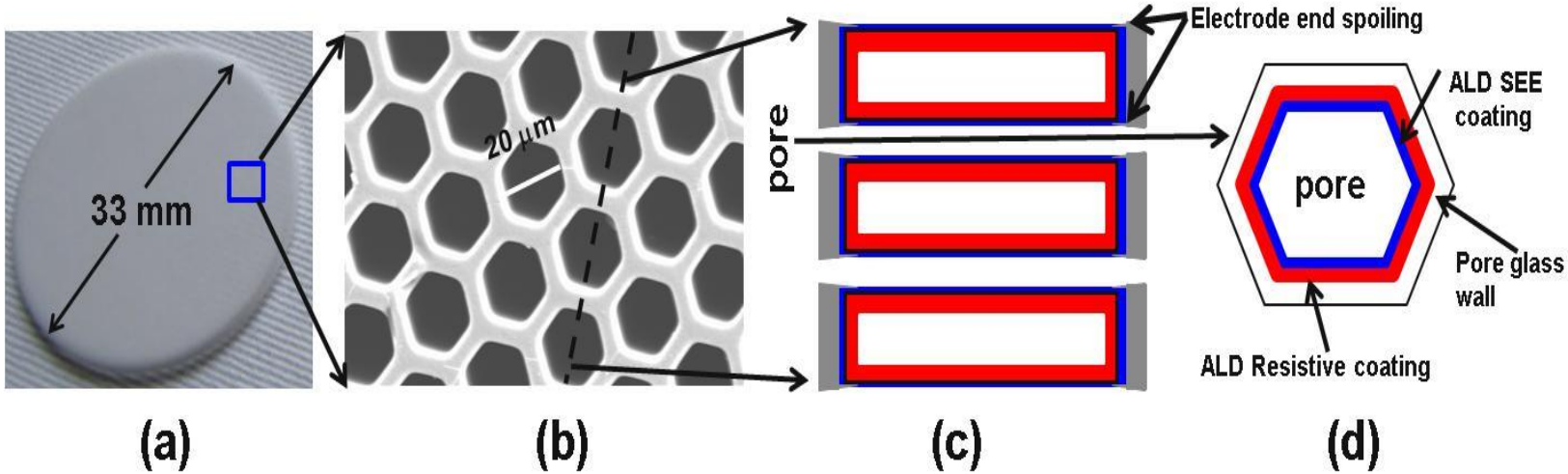
# Objective:

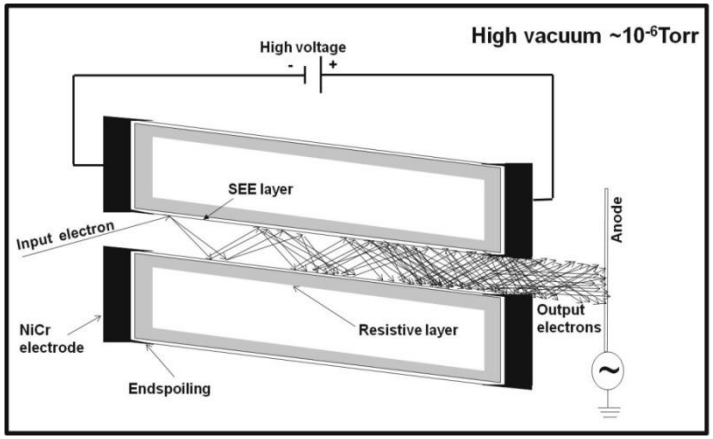
**Development of large area microchannel plate (MCP)-based photodetectors (DOE HEP LAPPD™ sponsored project)**

# Key Tasks:

**Creation of sturdy resistive (R) and secondary electron emission (SEE) coatings for porous substrates (e.g. Micro Capillary Array structures) to form desire MCPs**

# New Strategy – ALD Functionalization of Porous Glass

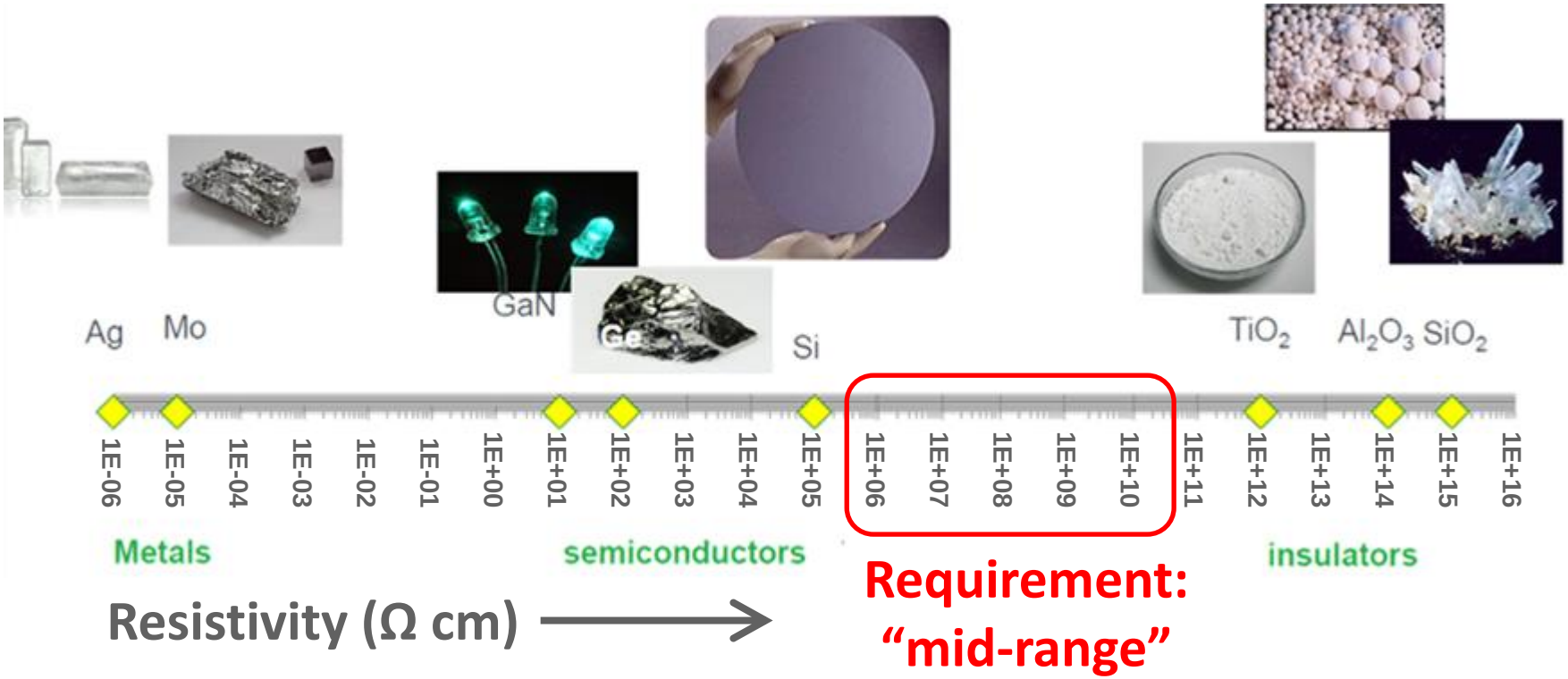



1) Resistive coating (ALD)
2) Emissive coating (ALD)
3) Contact electrode (PVD)

*A. Mane et. al., SPIE (2011)*
*D. Beaulieu, et. al., Nucl. Instr. Meth. Phys. A, 633, S59, (2011)*

# Resistivity Requirement for MCPs : “Mid-Range”



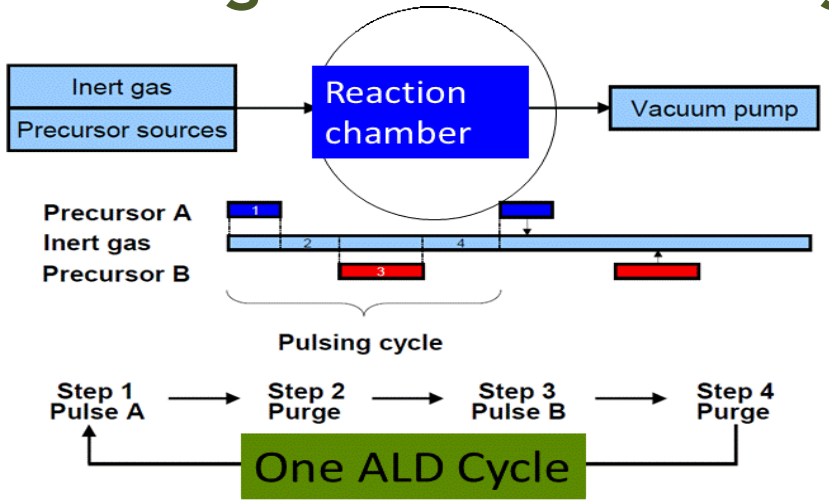

- Practically no naturally occurring materials with “mid-range” resistivity of $10^6$-$10^{10}$ Ωcm
- **Must be synthesized or engineered**

# ALD of M-$Al_2O_3$ Composites (Where M = W or Mo)

- **Precursors used = $Al(CH_3)_3$, $H_2O$, $WF_6$, $MoF_6$, $Si_2H_6$**
- **Precursors properties: High vapor pressure, availability, and low cost**
- **ALD growth:**
  - **Growth of pure layers : W, Mo and $Al_2O_3$**
  - **Growth composite layers : W-$Al_2O_3$, and Mo-$Al_2O_3$**
- **Low temperature deposition processes (100-400$^oC$)**
- **Process scale up**


*Mane et.al., (US20130280546)*
*Mane et.al., (US20140220244)*
*Mane et.al., SPIE 2013*
*Mane et.al., CVD (2013) 186*
*Elam et.al., ECS 2013*
*W. Tong et.al., APL 102 (2013) 252901*
*Mane et.al., (Application #* 14/693,719*)*
*Mane et.al., ECS 2014*

# ALD thin film growth methodology



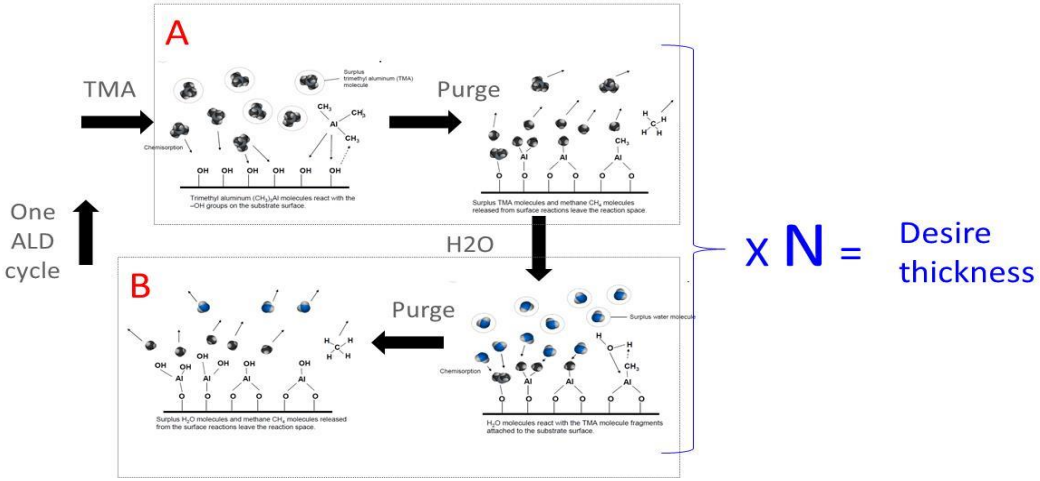

***e.g.***

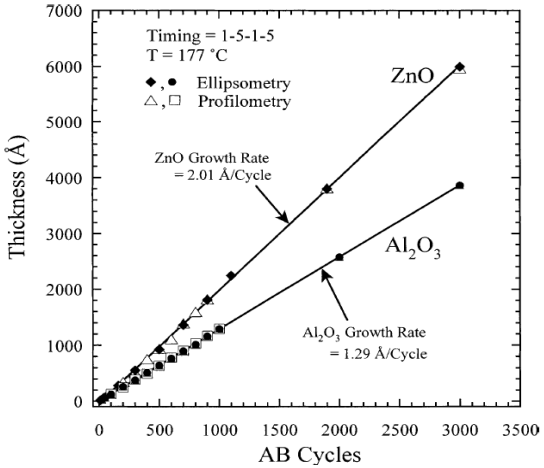
***1)*** **ALD of $Al_2O_3$ by TMA and $H_2O$**

**2) ALD of ZnO by DEZ and $H_2O$**

*Example (SEE layer) : ALD $Al_2O_3$ using TMA-$H_2O$*

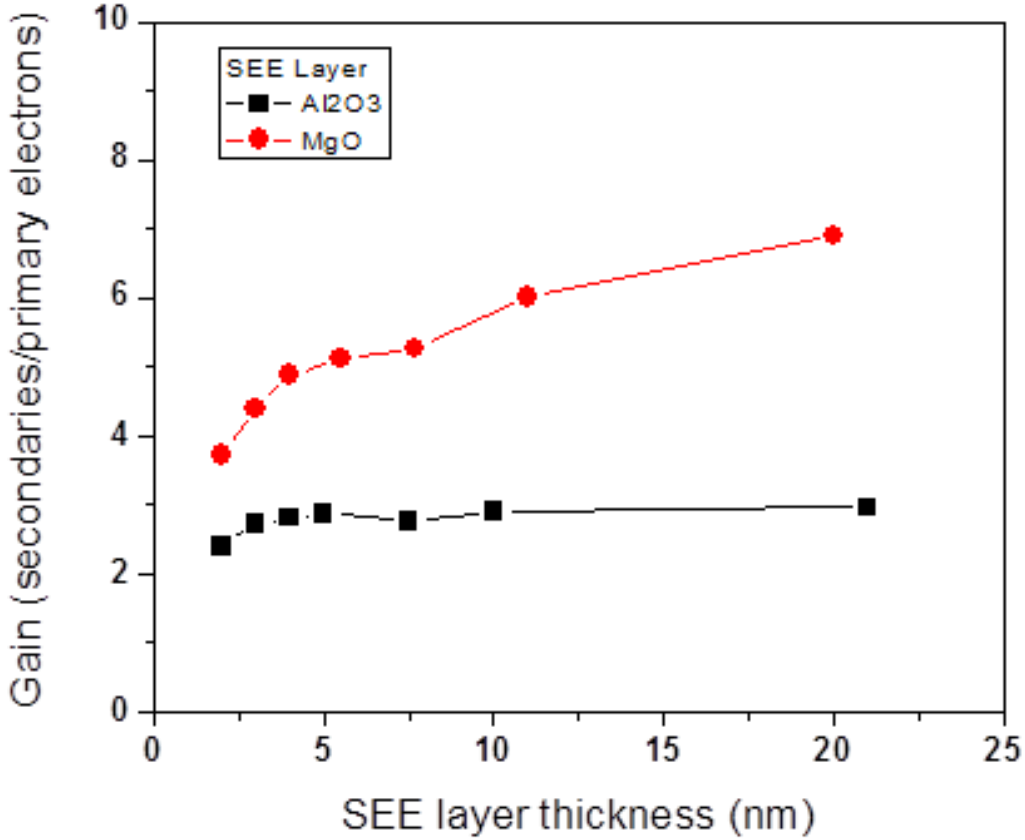
*Elam, Chem. Mater., Vol. 15, No. 4, 2003*




- **Precursor introduce separately in time and space**

# ALD Grown Secondary Electron Emission Layers

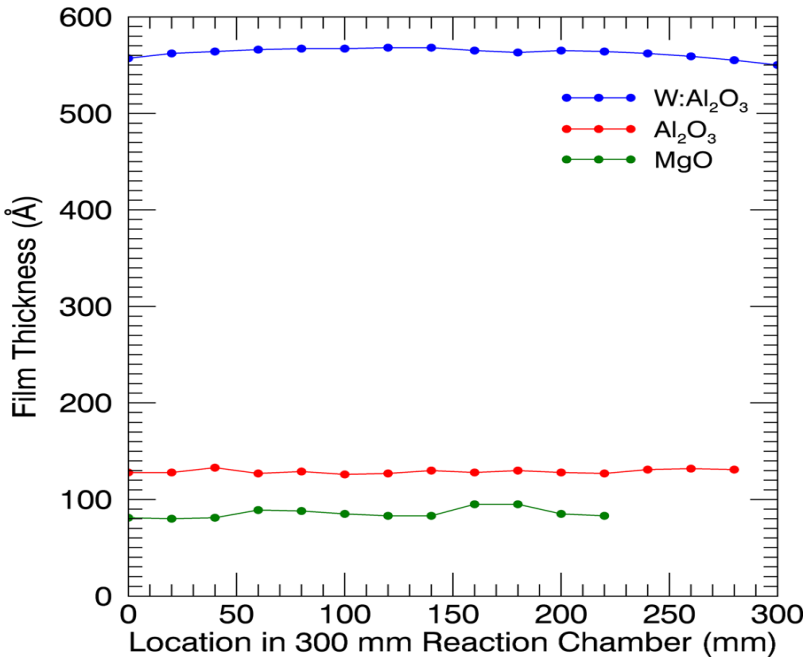



- Thickness and high gain

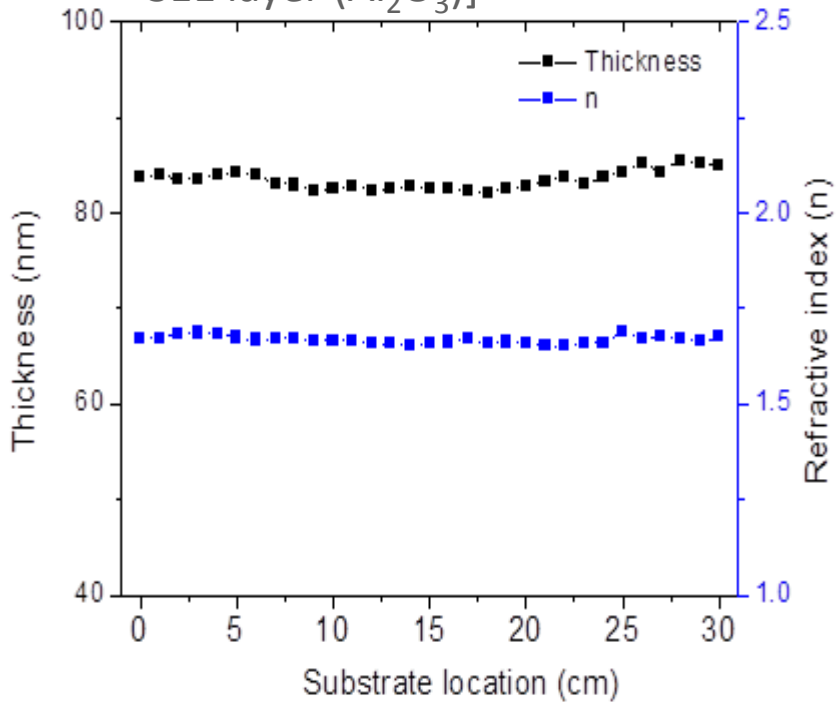
*Jokela et al. Aip Conf Proc, (2011) 1336, 208*

# Uniformity of the functional ALD coatings on MCPs

Individual ALD layers

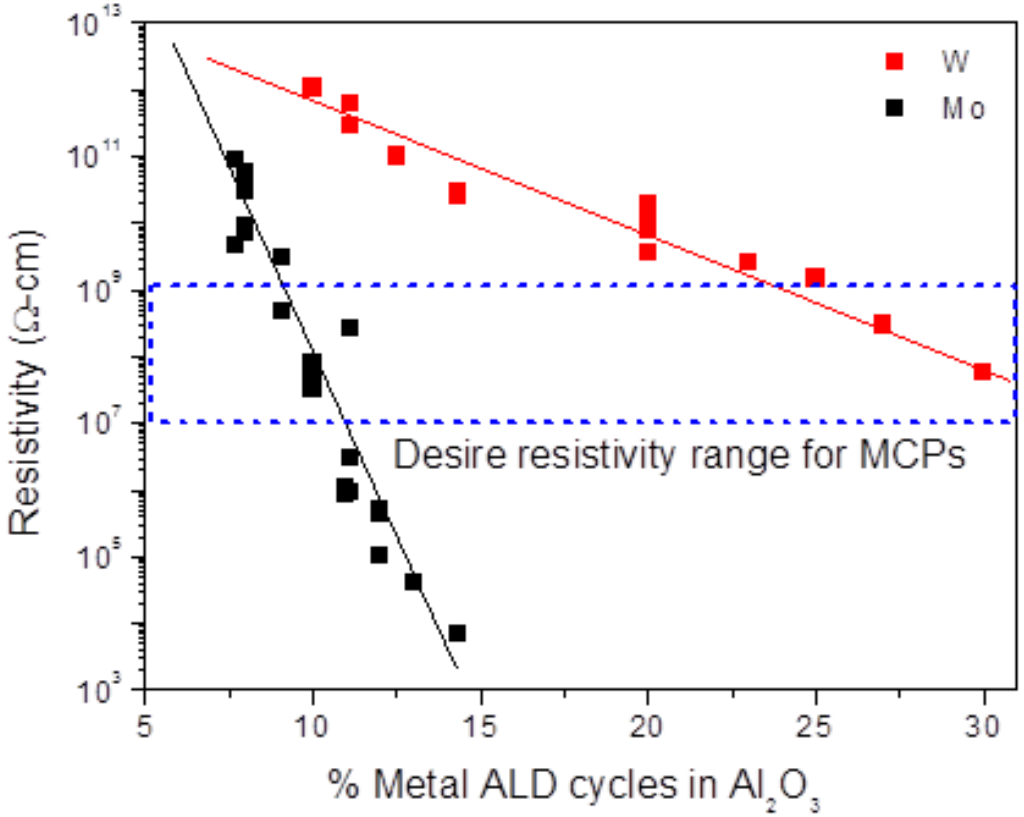


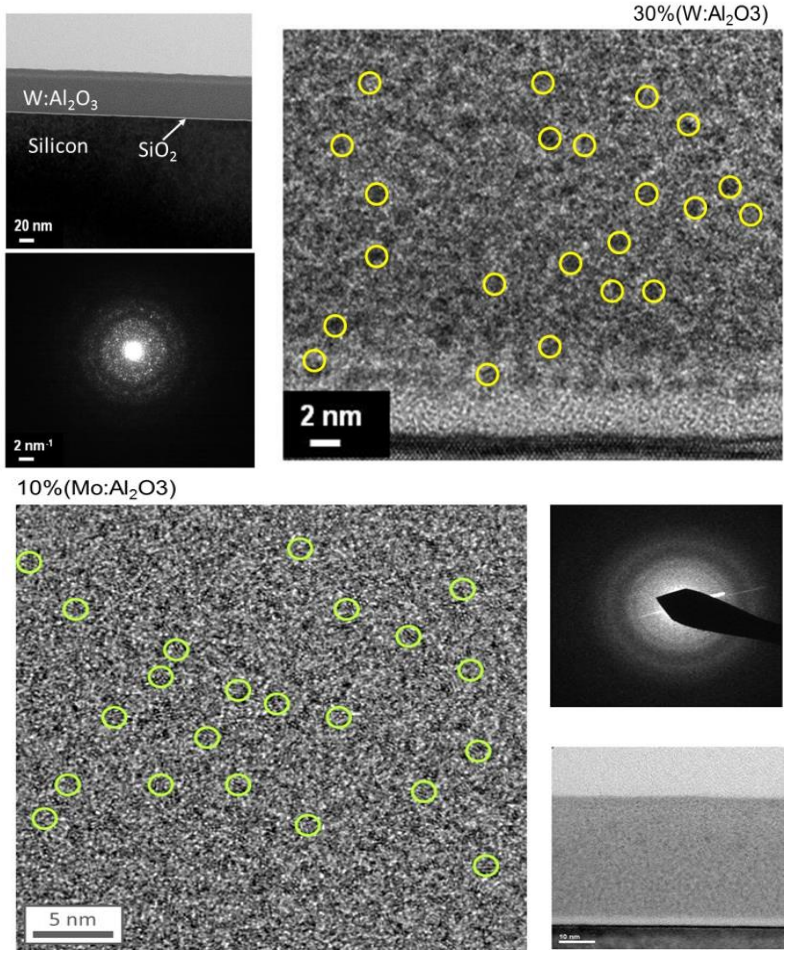

Stack of [Resistive layer ($W:Al_2O_3$) + SEE layer ($Al_2O_3$)]




*O'Mahony et. al. JVST A **34**, 01A128 (2016)*

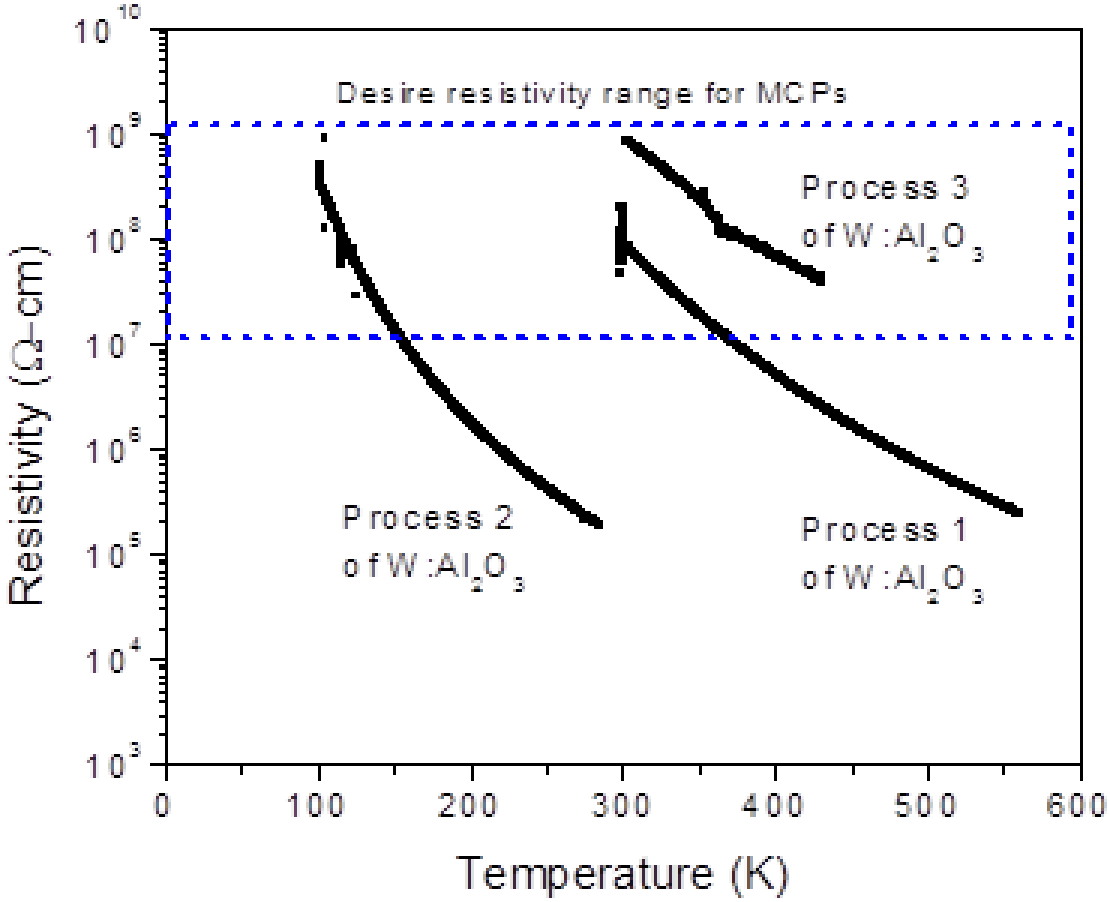
# ALD of ($M:Al_2O_3$; where M=Mo or W) Nanocomposites




*Mane et.al., CVD (2013) 186*
*Mane et.al., ECS 2014*

# Adjusting Resistivity of MCPs for various operations



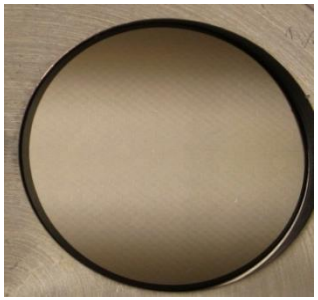

- Process -1 for Around Room Temperature MCP operation
- Process -2 for Low Temperature MCP operation (Liquid Ar)
- Process -3 for High Temperature MCP operation

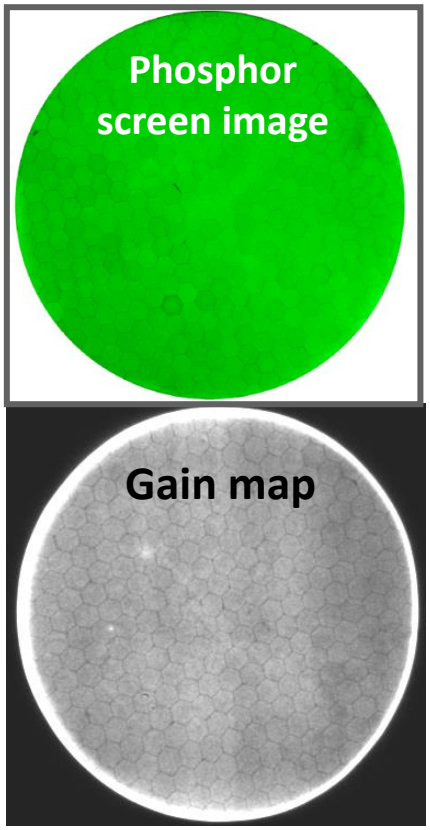
# Small ALD MCP Fabrication and Performance

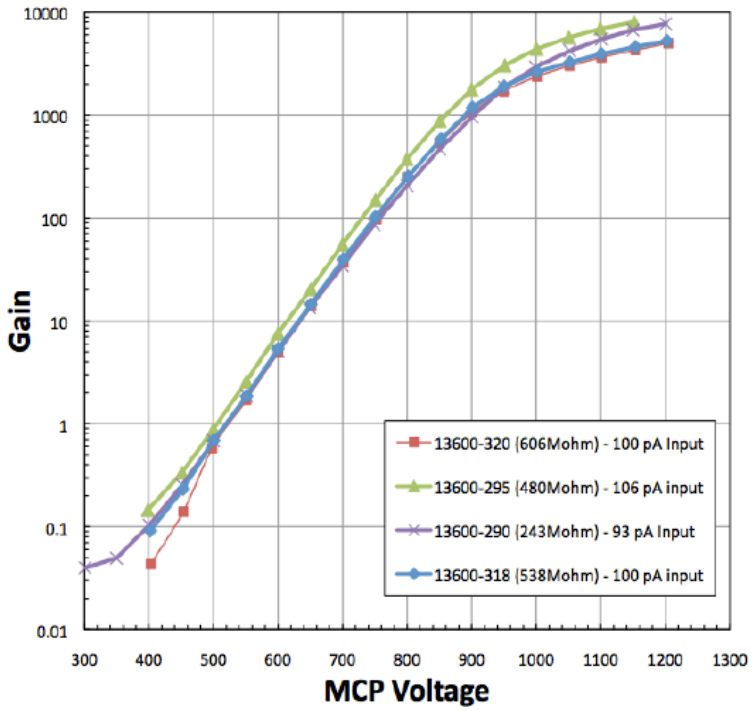
33 mm capillary glass array (Incom)

With ALD Mo-$Al_2O_3$ resistive coating and ALD MgO emissive layer

With PVD NiCr electrode





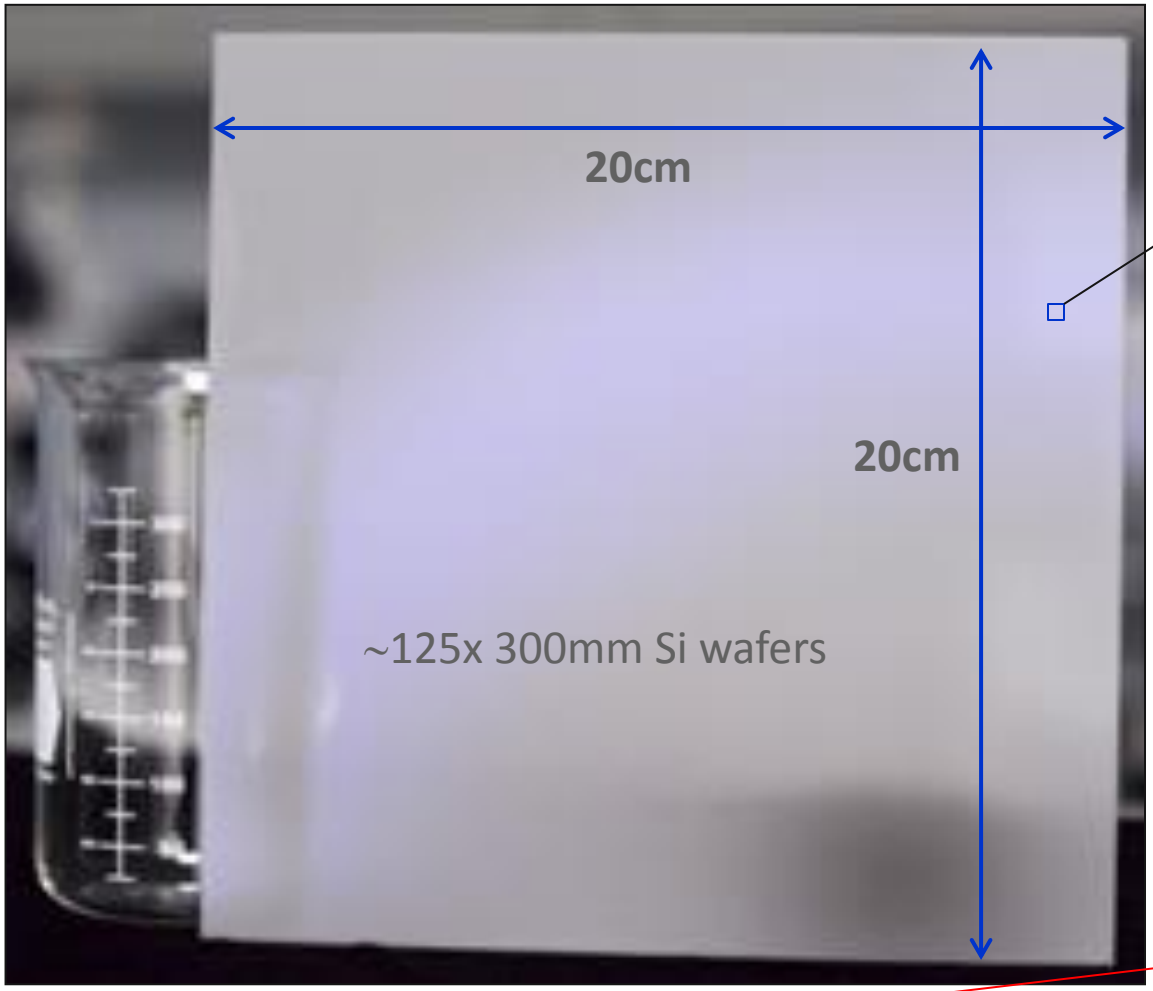



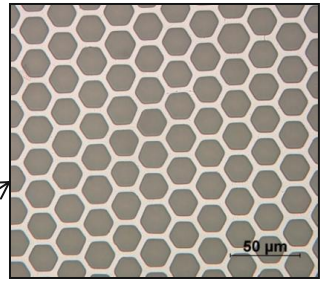

**Easy to functionalized by ALD**

- Gain is spatially uniform
- Gain of ~ $10^4$, (comparable to commercial MCPs)
- Very low background

A. U. Mane et. al., Chem. Vap. Deposition, **19**, 186–193, (2013)
A. U. Mane et. al., Physics Procedia, **37**, 722-732 (2012)
O. H. W. Siegmund et. al. , Physics Procedia, **37**, 803-810 (2012)

# Capillary Glass Array Substrates for MCPs



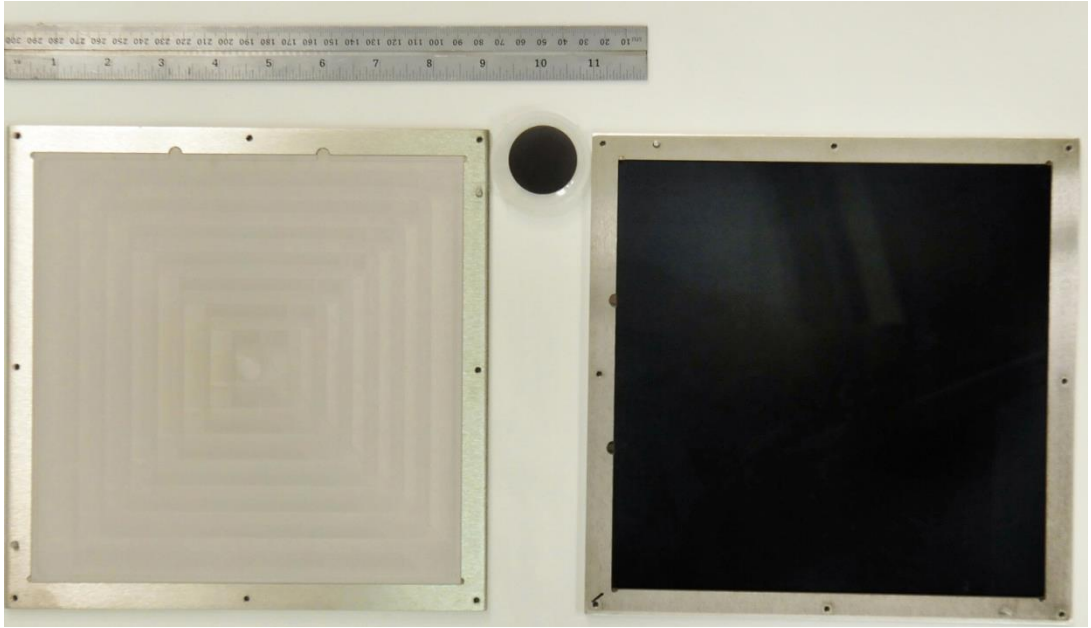




- Surface area = 8.7 $m^2$
- Aspect Ratio = 60
- No. of Pores = ~80Millions
- Porosity = 65%
- Bias Angle = 8°
- Pore size = 20µm
- Thickness of plate=1.2mm
- Sensitive Surface to OH
- Complex Geometry

- **Very challenging substrate to coat for any thin film deposition method**

*Mane et.al., (US Patent # US20140220244)*

# Large Area ALD MCPs



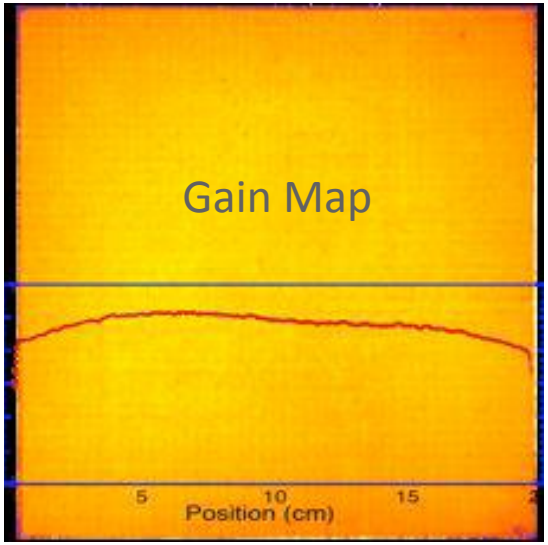
Bare MCA ALD MCP

- **High Gain (>$10^5$)/mcp**
- **Very Low Background**
- **10x *psec* time resolution**
- **100μm spatial resolution**
- **Excellent Stability**
- **Short (2-3days) scrubbing time**

**>200 publications using ALD MCPs, from LAPPD collaboration (**http://psec.uchicago.edu/**)**

8”x8” MCP-photodetector tile

ALD MCPs in Photodetector




**Working 20cm x20cm MCP in large area photodetector**

# Photographs of various types of ALD MCPs


Curtesy : Incom Inc. UCB and LAPPD

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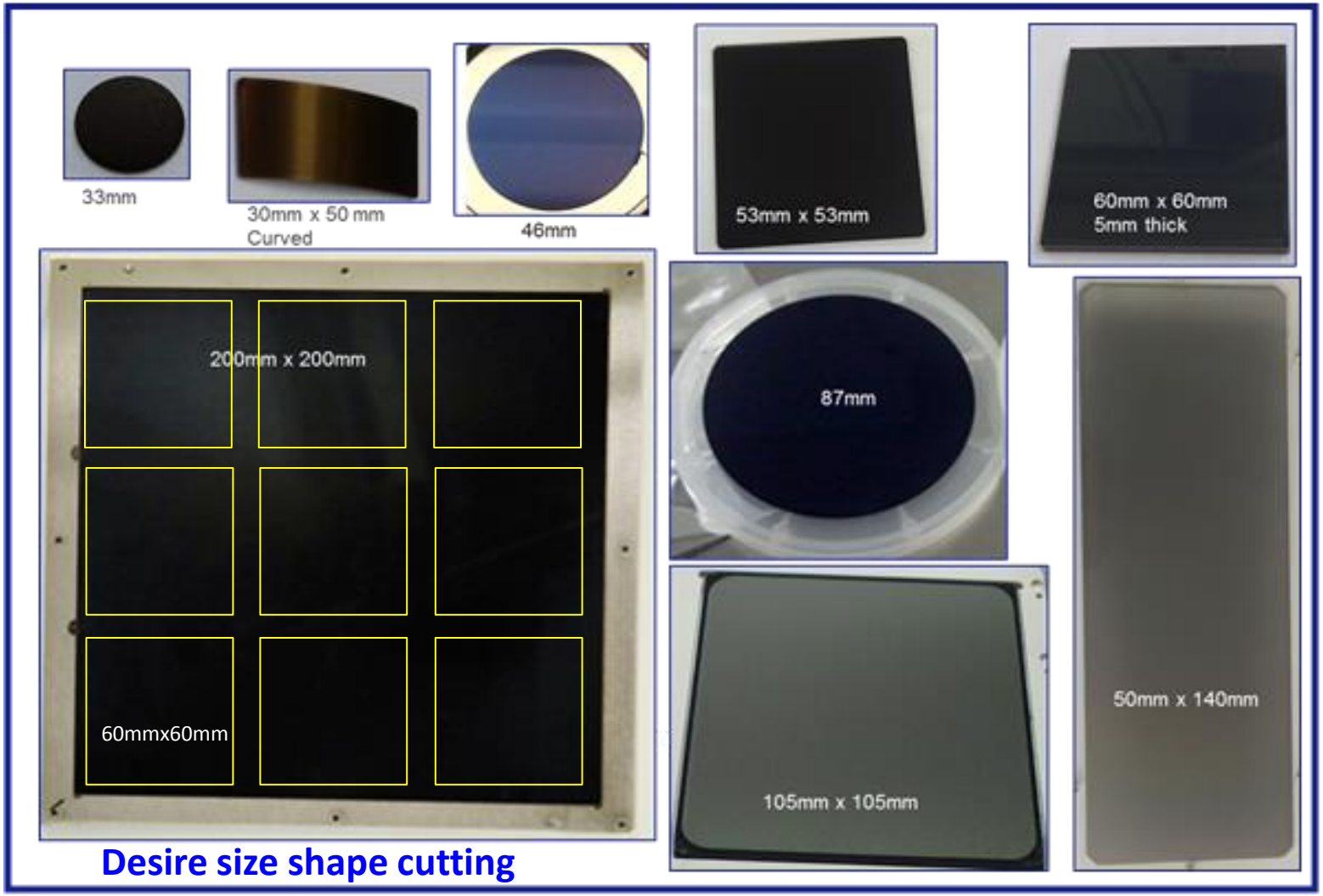
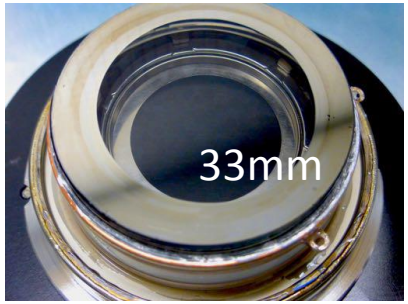
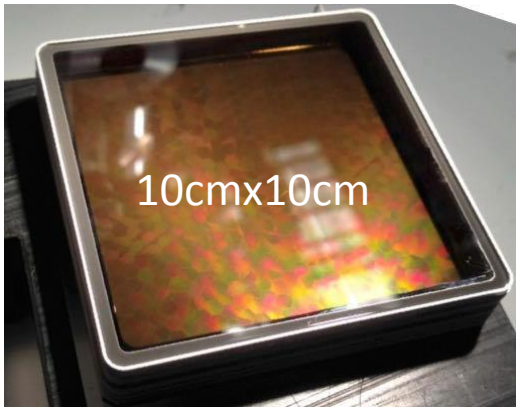



Curtesy : Incom Inc. UCB and LAPPD

# Photodetectors made with ALD MCPs









Great cost saving!!!


**2 x 3 Super-Module Mockup**

# Summary

- Demonstrated ALD nanostructure materials functionalization path to create economical large area high performance MCPs

- Various type photodetectors are made with ALD-MCP and displays long life sturdy performance

- Commercialization of ALD-MCPs and LAPPD™ technology is in progress (with Incom Inc, MA) and will have impact on near/long terms MCP-based detectors applications in various areas such as HEP, Nuclear, Biology, Materials, Medical, Transportation, Space programs, etc.

Thank you !!!