R&D on MCP ALD coating at Argonne

Anil Mane, Jeffrey Elam

Applied Materials Division

10/26/2022

Presentation for

LAPPD Workshop

Wednesday Oct 26, 2022, 12:00 PM → 5:45 PM US/Eastern

Description Organizers: Silvia Dalla Torre (INFN), Alexander Kiselev (BNL), Simona Malace (JLab), Deb Sankar Bhattacharya (INFN), Junqi Xie (ANL)

Hosted by CFNS: https://stonybrook.zoom.us/j/97182934798?pwd=TGJ2dkNwdUlqYS9Yc2owUVVTd05iUT09

Argonne NATIONAL LABORATORY · Brookhaven National Laboratory · INFN · Center for Frontiers in Nuclear Science · Jefferson Lab

Argonne NATIONAL LABORATORY

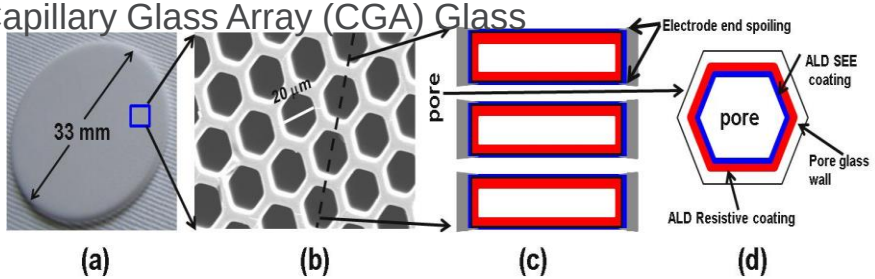
ALD coatings for MCPs

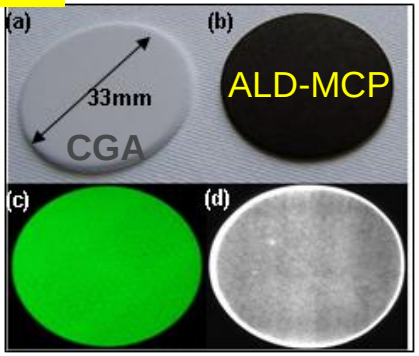
Microchannel plates (MCPs)

Elections and ion Multiplications, Photomultiplier tubes, Field emission displays, Night Vision Devices, high speed cameras Time-of-flight (ToF) mass spectrometry, Security Scanners, SNM (U, Pu) detection, Neutron detector, Medical imaging (PET scanners)

ALD functionalization of porous glass ➔➔➔➔ Microchannel Plates (MCPs)

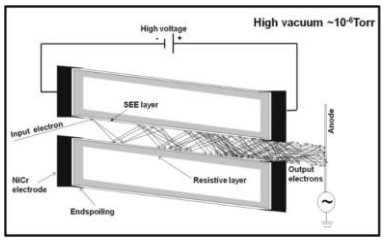
Capillary Glass Array (CGA) Glass





MCP gain map by Phosphor imaging

MCP gain map by X-delay line imaging

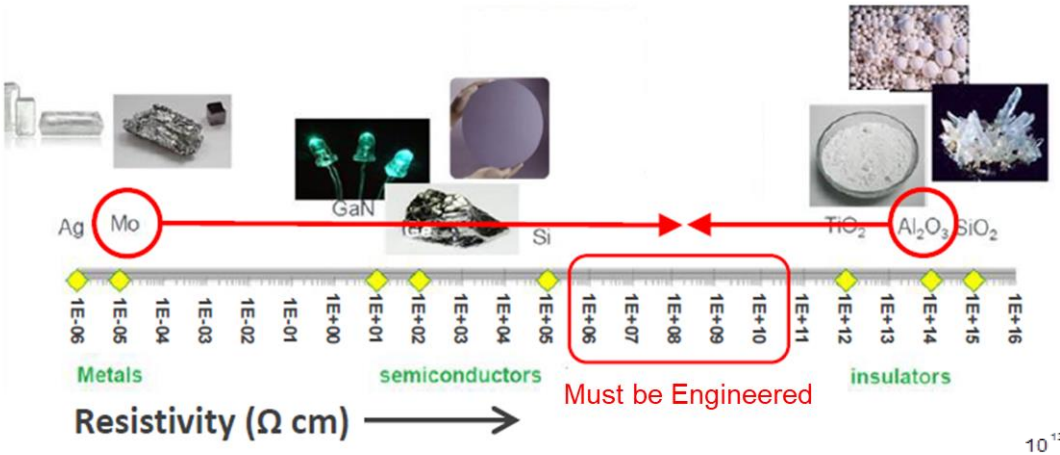


1) Resistive coating (ALD)
2) Emissive coating (ALD)
3) Contact electrode NiCr (PVD)

- **Independent R and SEE properties**
- **Low cost**
- **Pb-Free**
- **Excellent Stability**

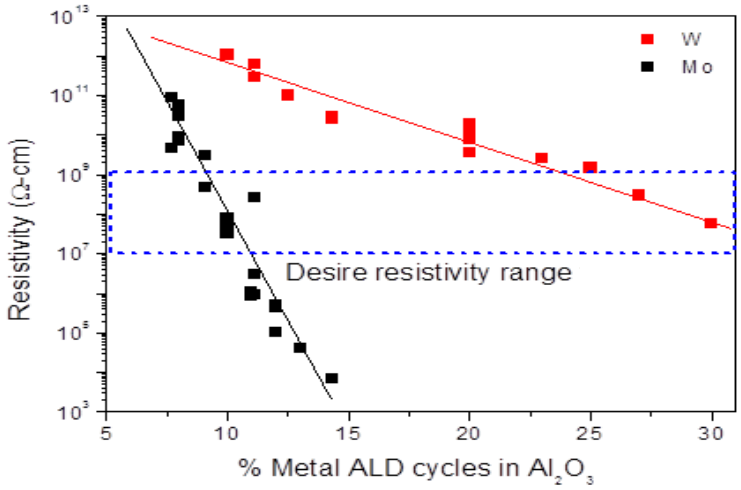
A. Mane et. al., SPIE (2011)
D. Beaulieu, et. al., Nucl. Instr. Meth. Phys. A, 633, S59, (2011)

Resistivity Range for MCPs



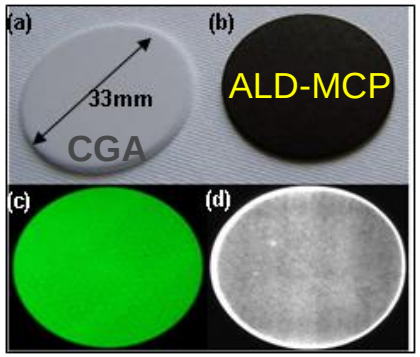
Nanocomposites :

Tunable resistive coatings



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

ALD coatings for MCPs



MCP gain map by Phosphor imaging

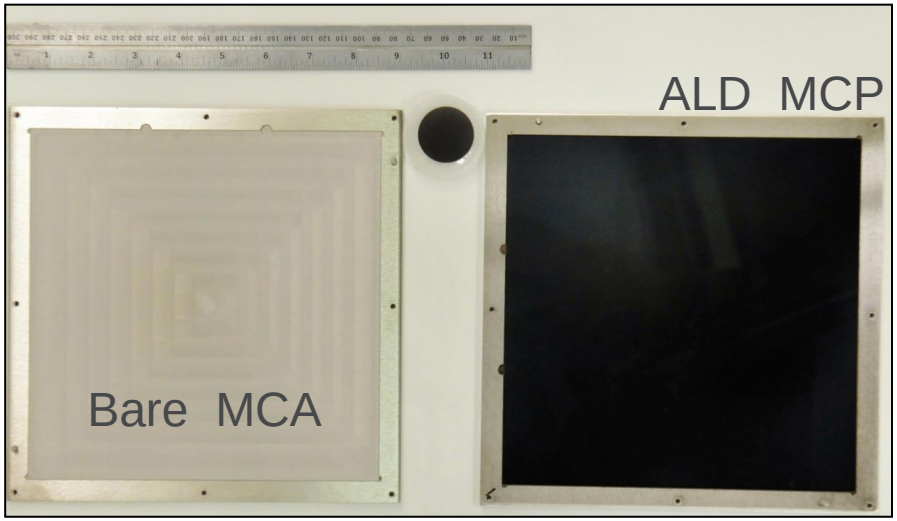
MCP gain map by X-delay line imaging

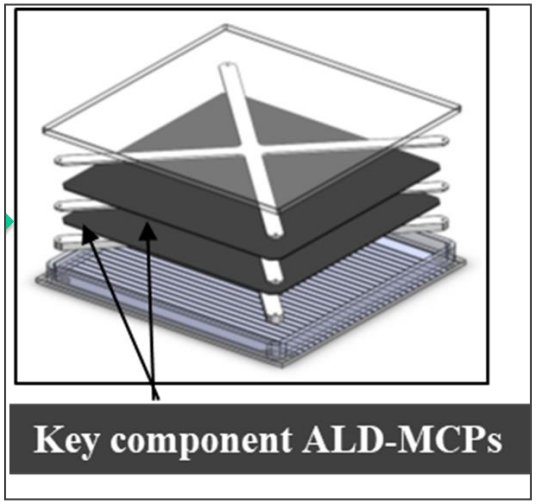
- **Independent R and SEE properties**
- **Pb-Free**
- **Robust coatings properties**
- **Excellent Stability**
- **Low-cost processing cost in batch production mode**
- **Possible to make MCPs (electron amplifications) structures in different forms**

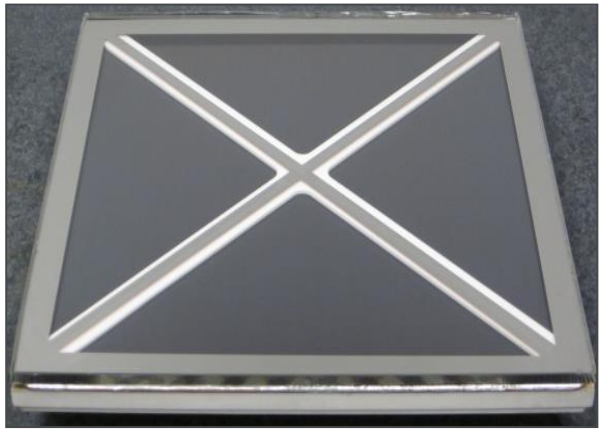
MCP properties:

- **High Gain**
- **Very Low Background (dark rate)**
- **Excellent long-term Stability**
- **10x *psec* time resolution**

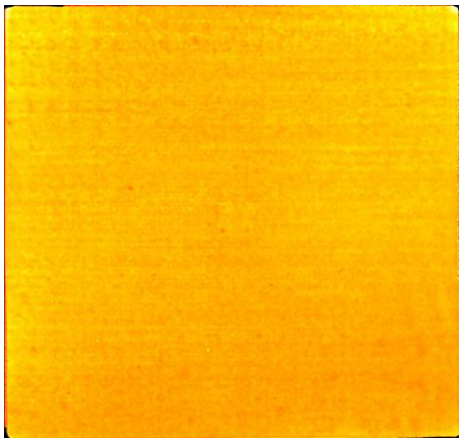
Part of LAPPD program from day 1 and it's a backbone of technology







ALD MCPs in Photodetector

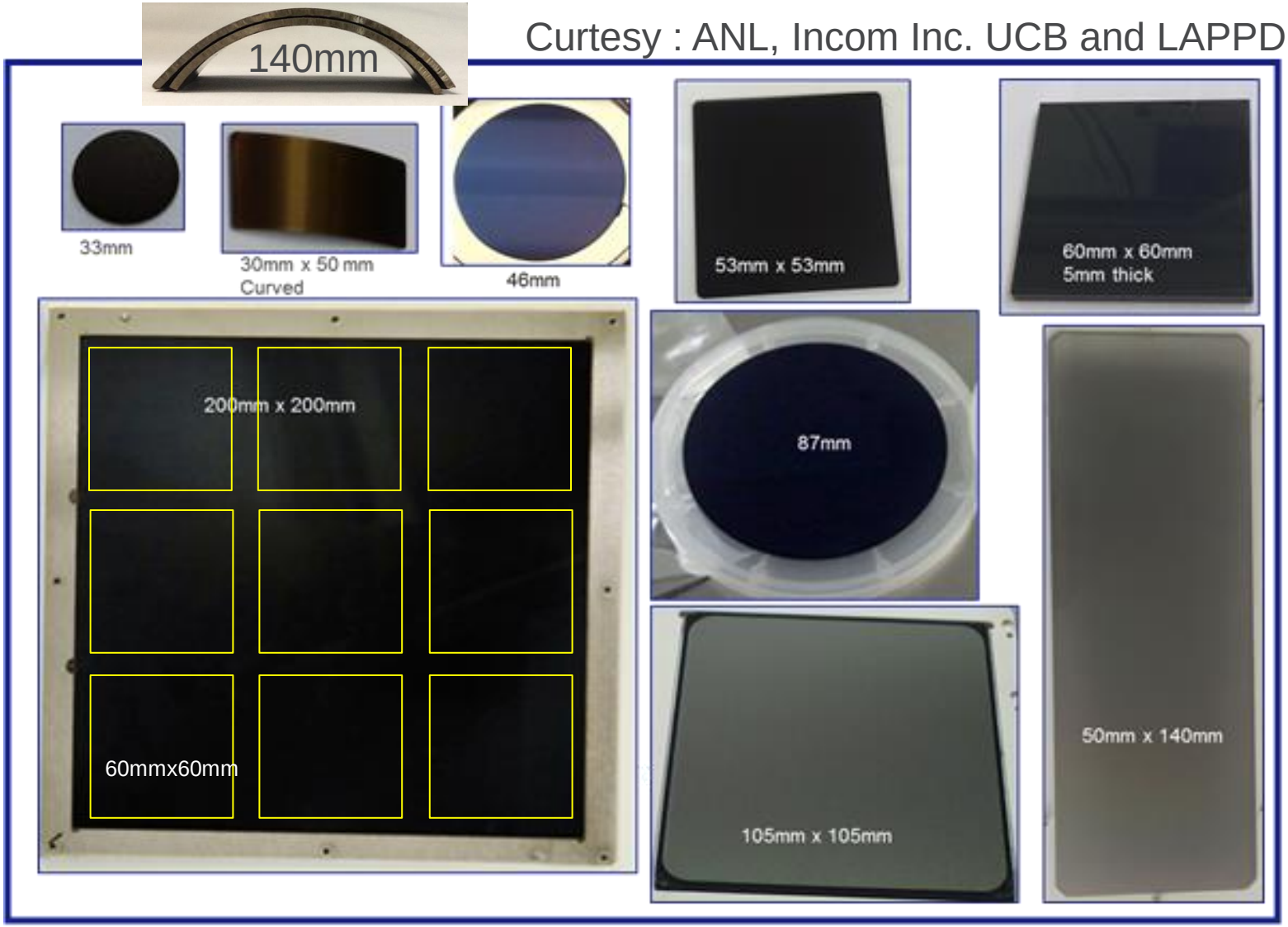


Working 20cm x20cm MCP in large area photodetector (Gain Map)

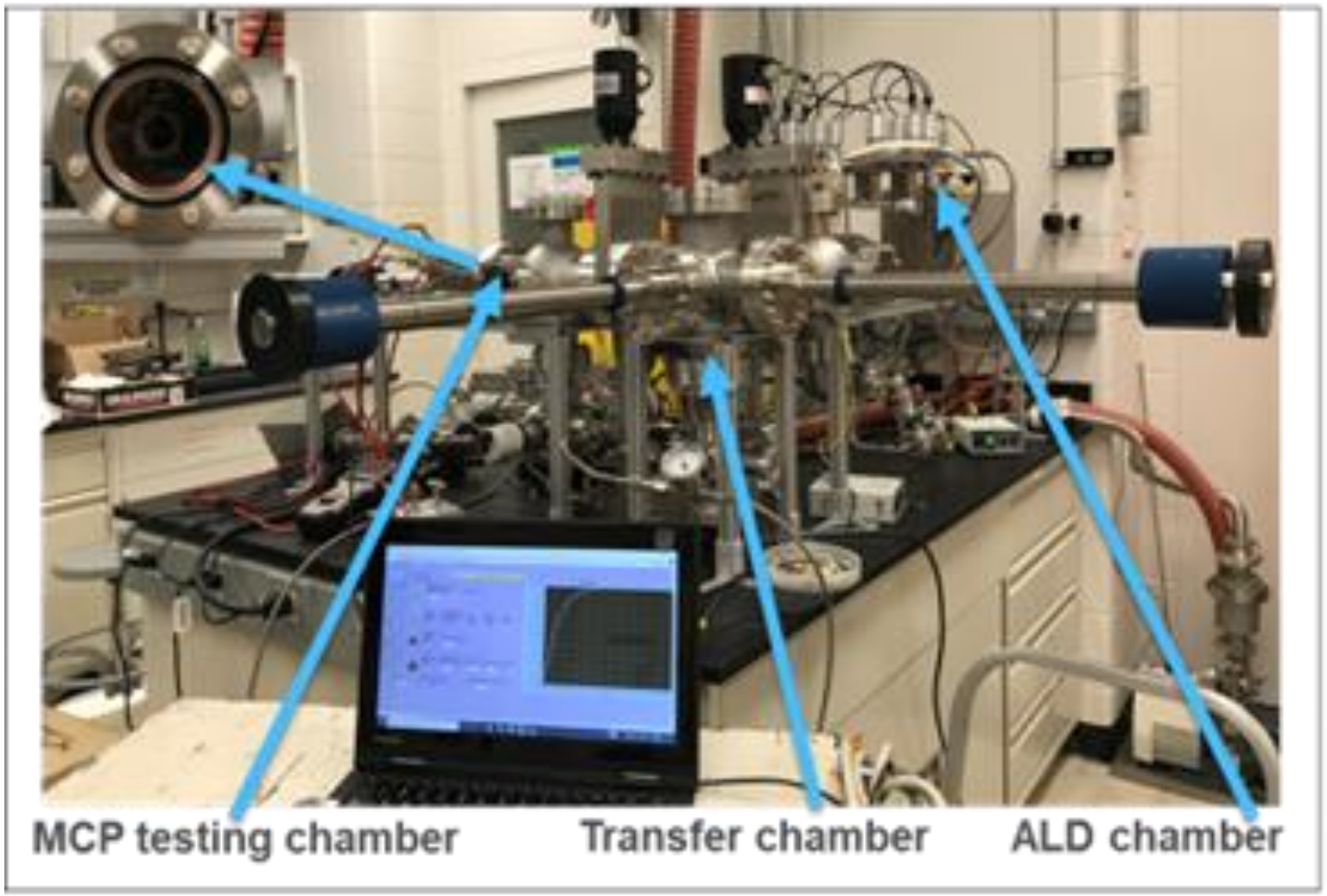
- **High Gain**
- **Very Low Background (dark rate)**
- **Excellent long-term Stability**
- **10x *psec* time resolution**

Photographs of various types of ALD MCPs

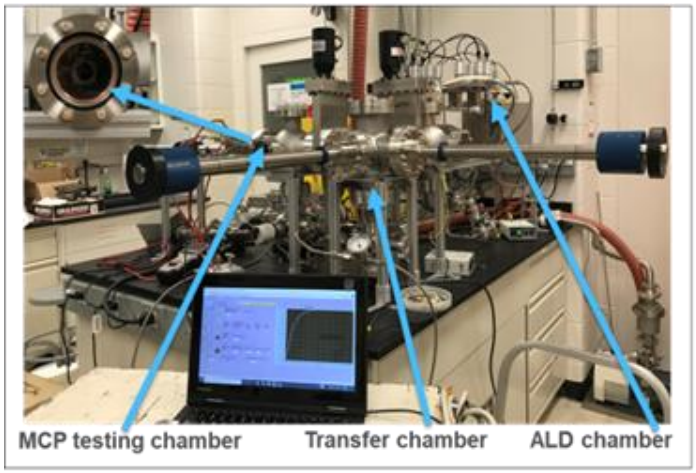
Curtesy : ANL, Incom Inc. UCB and LAPPD

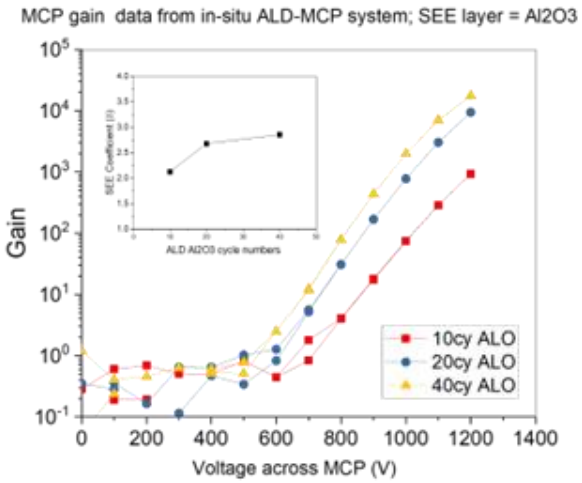


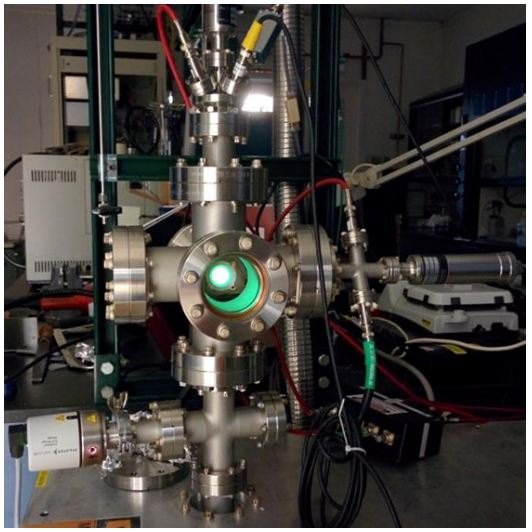
ALD coatings screening for advanced MCPs

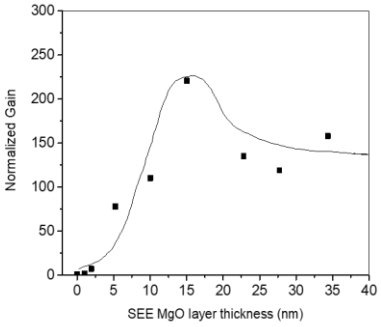


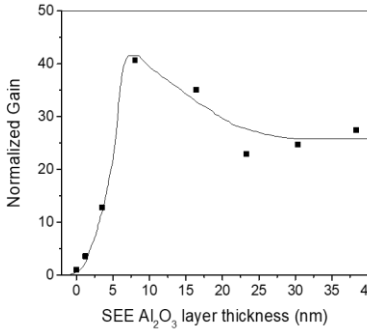
ALD coatings screening for advanced MCPs

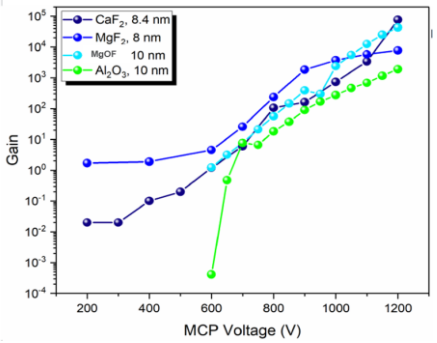




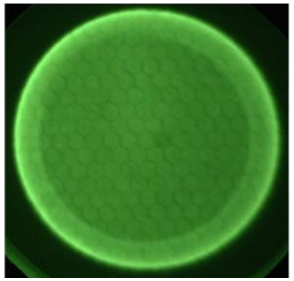




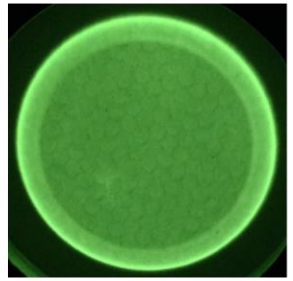




MCP with (15nm) MgO SEE layer

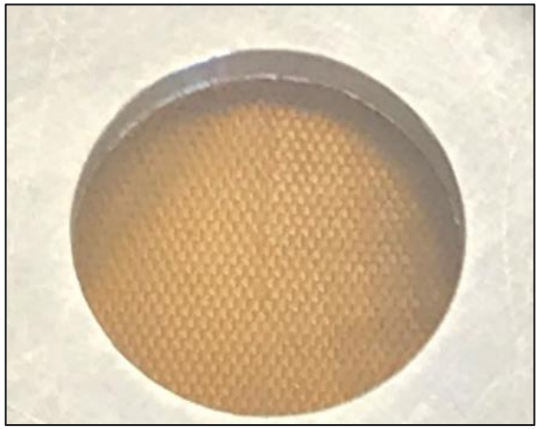


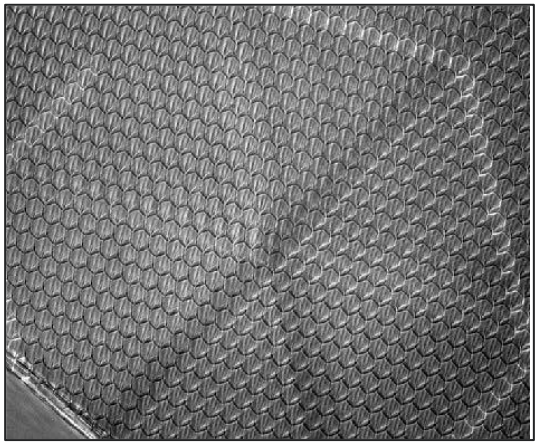
MCP with (8nm) Al_2O_3 SEE layer



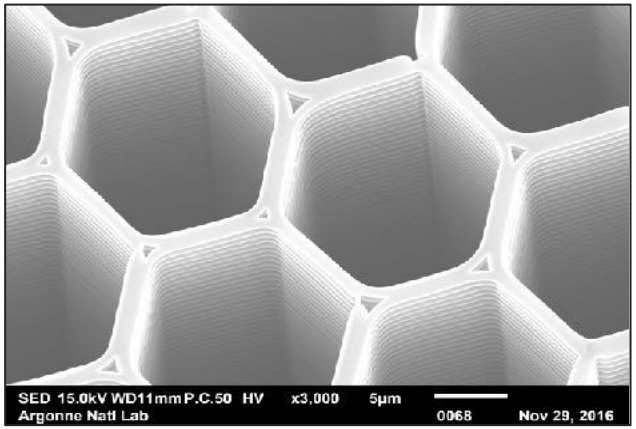
Quick optimization of SEE layers and coating uniformity quality

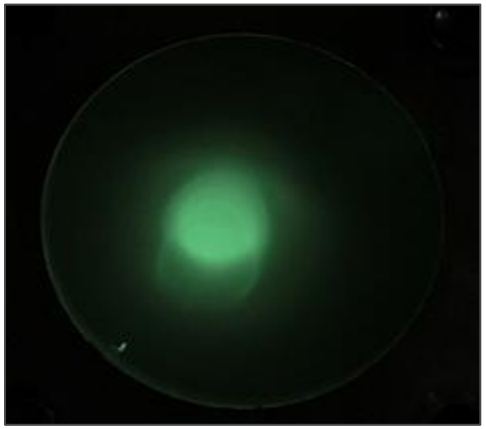
MCP ALD coatings for 3D printed capillary array





ALD coatings (R+ SEE)



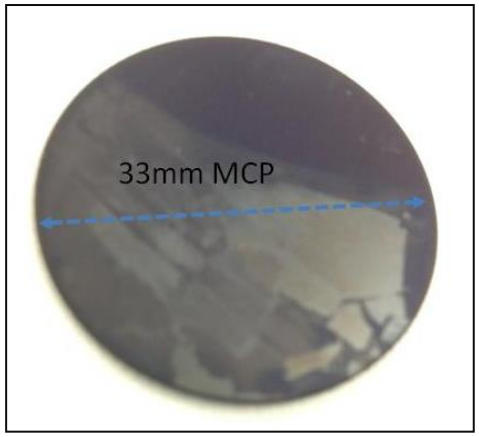


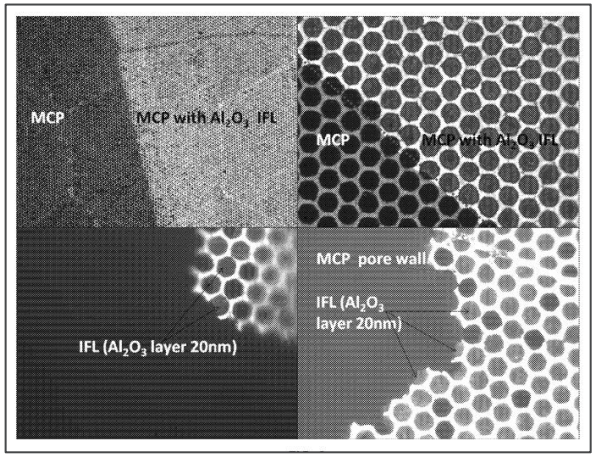
Wagner etal, US Patent 10,403,464

ALD materials for MCP Detectors

Membrane MCP

- Barriers for ion feedback
- Define electron emission layer @ input (first strike)
- Neutron sensitive membranes for neutrons detection

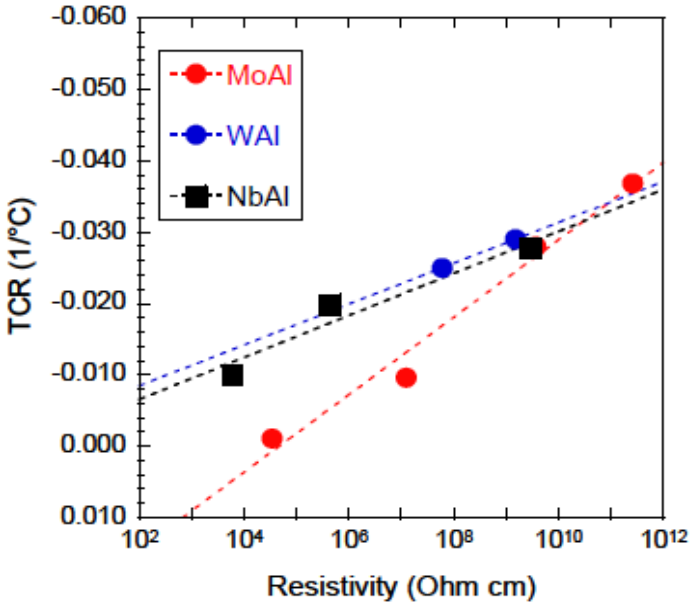




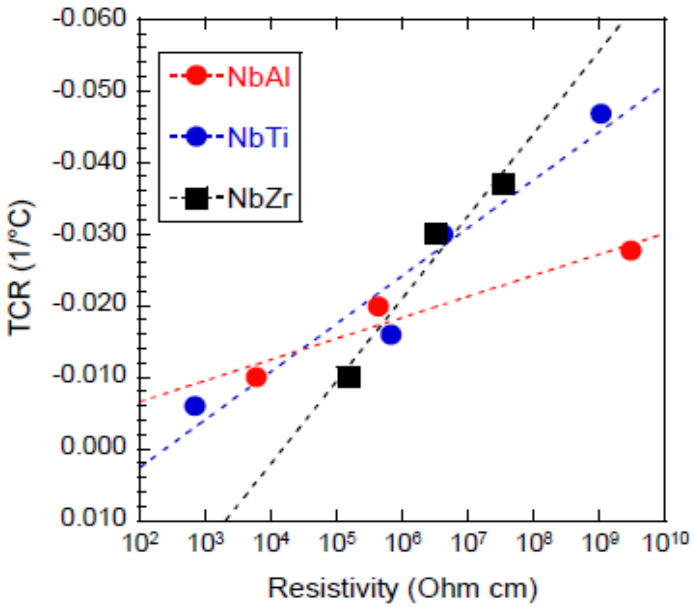
- Mane etal, US Patent 10,867,768
- ANL-IN-22-133 and ANL-IN-22-131 (Membrane/Grid types electron amplification structures)

ALD coating for MCPs

Adjusting MCPs TCR for various operations



- TCR can be controlled through metal



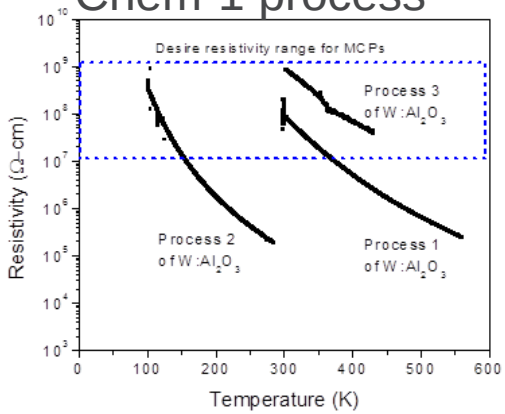
- TCR can be controlled through dielectric

Mane et. al, ALD 2017 Conference

ALD coating for MCPs

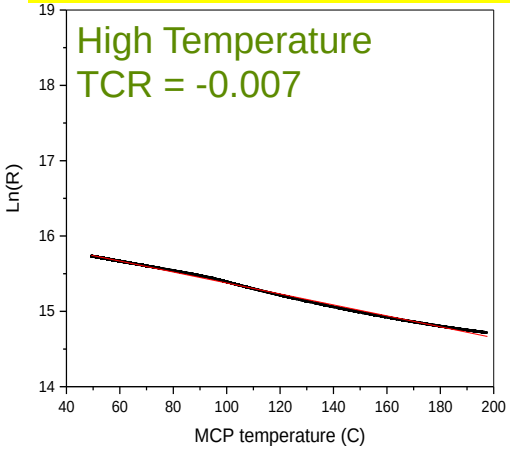
Adjusting resistivity of MCPs for various operations

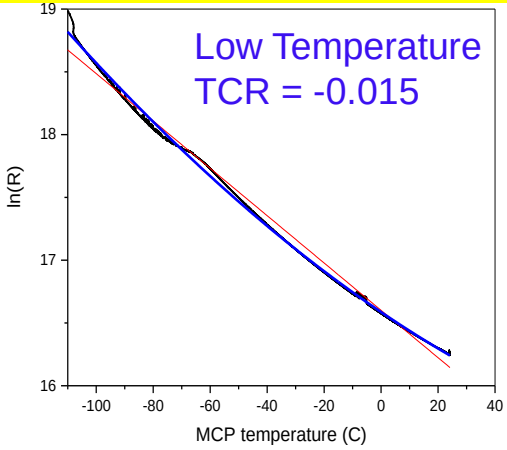
Chem-1 process

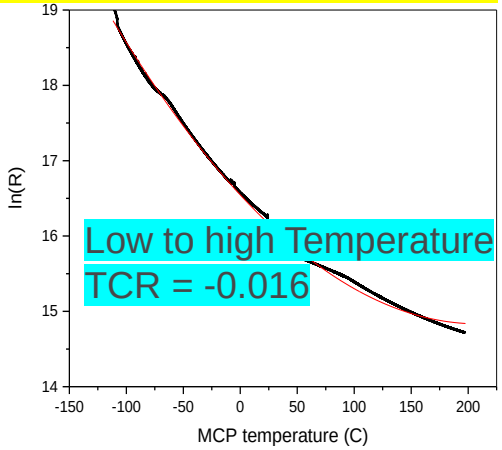


- Process -1 for Around Room Temperature MCP operation
- Process -2 for Low Temperature MCP operation (Liquid Ar, Xe)
- Process -3 for High Temperature MCP operation

Chem-2 process





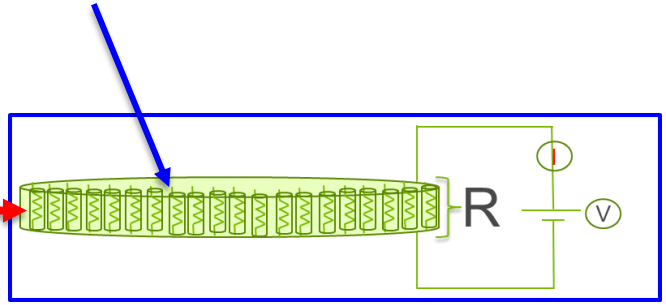


In-situ Resistance –ALD: Concept and Hardware

MCP parameters:

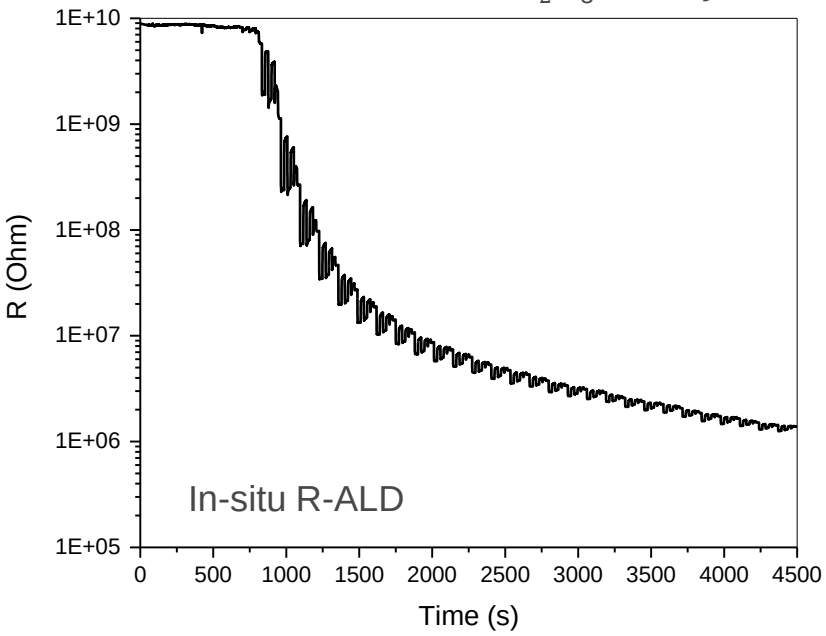
- **MCP size = 33mm**
- **Pore size = 20μm**

Number of pores = ~1.8 millions means ~1.8 millions resistors will be created during nanocomposite ALD coating

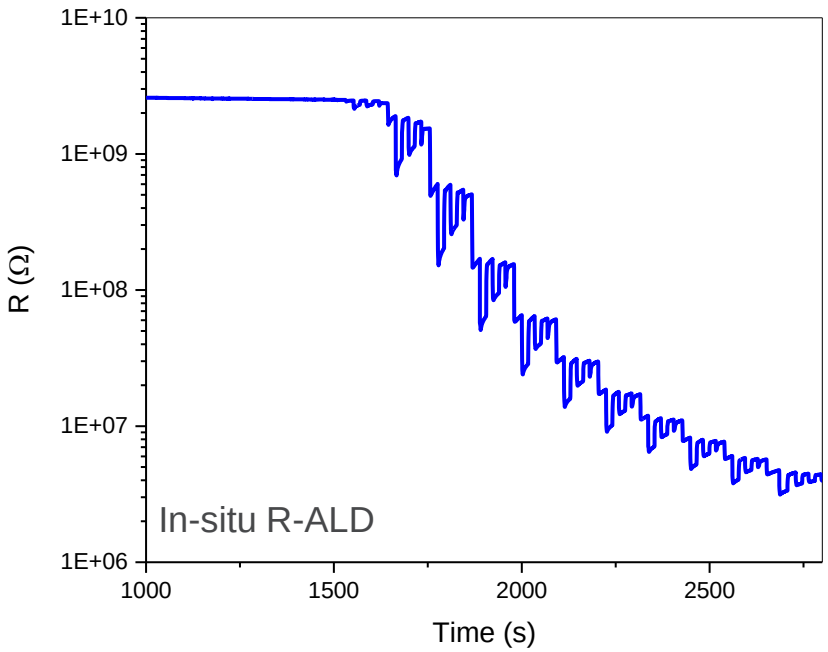


In-situ R measurement for ALD of resistive Nanocomposite

ALD @ 200C for W:Al_2O_3= 1:2 cycles



ALD @ 300C for W:Al_2O_3= 1:2 cycles



We can dial resistance of MCPs very precisely

ANL Invention/patent ANL IN-21-105

WHAT IS ARGONNE ROLE

- Understanding current ALD-MCP baseline process issues
- Developing processes and understanding chemistries
- Exploring ALD precursors for same materials
- Developing efficient hardware for processing MCPs faster
- Effect of contamination, ambient
- New ways of making electron amplifying structures

Transferring best learning knowledge to Incom Inc

Take away messages

- ALD-MCPs are backbone of LAPPDs and other MCP detectors
- ALD materials research is very essential for current and advanced MCPs
- ALD materials for magnetic field application is needed to explore

Near term we are working on:

- ALD coating for fast timing MCPs (selective ALD coatings)
- Low-TCR MCPs via developing resistive layers
- High gain MCPs via high SEE coefficient materials
- ALD-MCPs sensitivity under different ambient (open end detectors)

Acknowledgements

U.S. DEPARTMENT OF ENERGY
Office of Science

National Nuclear Security Administration

INCOM 40 YEARS OF INNOVATION