Fabrication of low cost and robust large area microchannel plates (MCPs) for photodetection and imaging applications

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Energy System Division

ACCELERATOR SYSTEMS DIVISION SEMINAR
4/15/2015

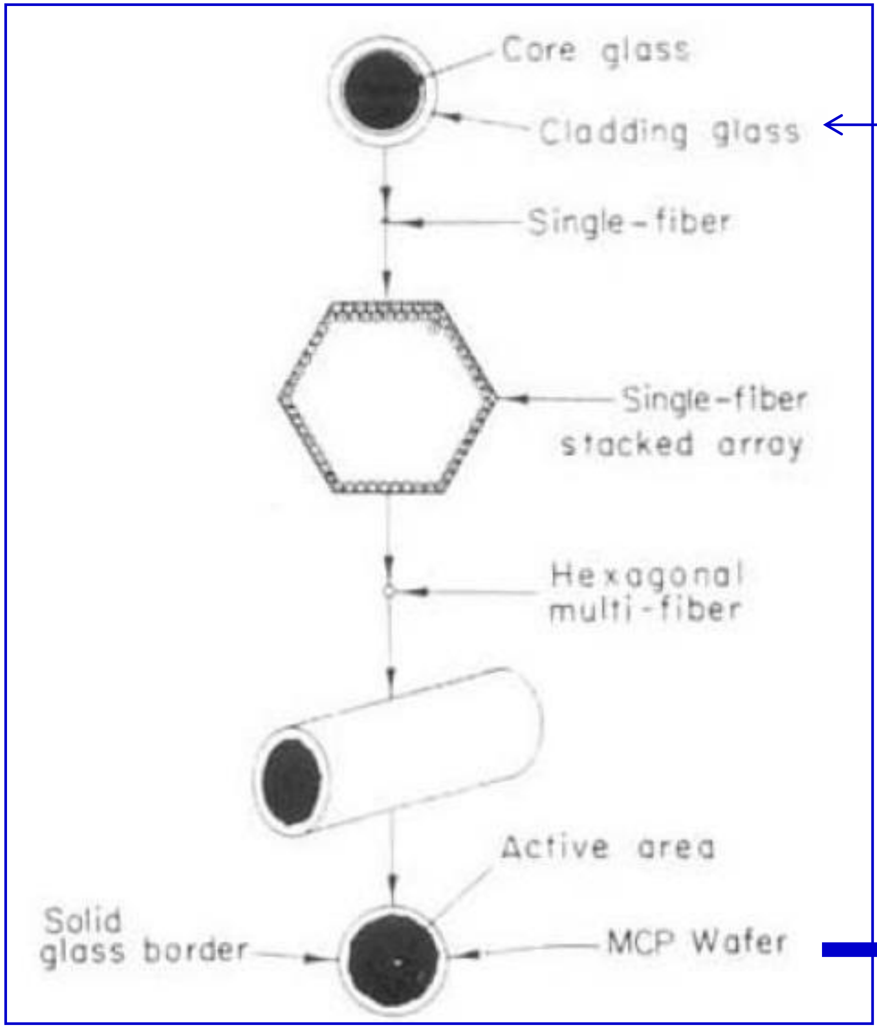
Outline

- Introduction
  - Microchannel plates
  - Atomic layer deposition method
  - ALD material development and characterizations
- ANL developed MCPs
  - MCPs testing results
  - Photodetector fabrication
- Can MCPs exploit for XBPM? : Few concepts
- Summary

Acknowledgements

- LAPPD Collaboration
- ES ALD group
- HEP detector group
- APS, EMC, CNM
- University of Chicago (Prof. Henry Frisch)
- University of California, Berkeley (Prof. Oswald Siegmund, Dr. Jason McPhate)
- Incom Inc, (Dr. Michael Minot and Dr. Aileen O'Mahony)
- DOE for Funding, Contract No."DE-AC02-06CH11357"

Conventional MCPs fabrication path

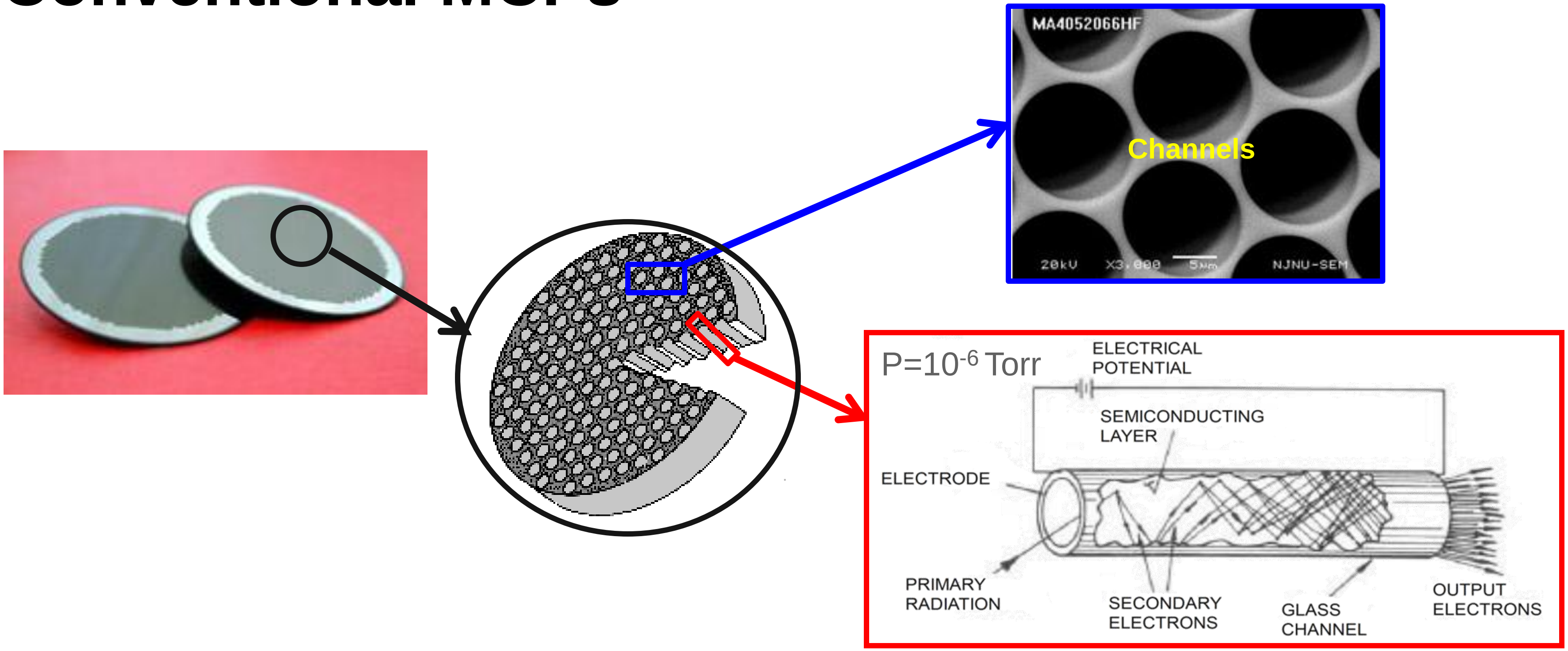


PbOx Glass

Hydrogen annealing
➔converts PbOx into semiconducting Pb and H_2O

J. L. Wiza, Nucl. Instrum. Methods **162, 587 1979.**

Conventional MCPs



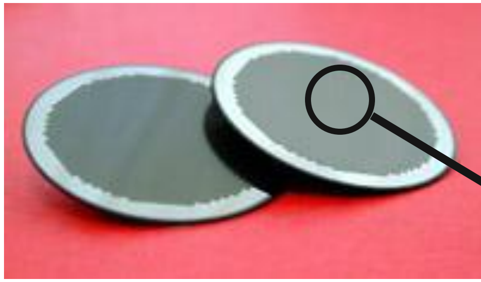
- **A pore resistance ~ 10^{12}-10^{15} Ω**
- **MCP resistance =10MΩ-1GΩ**
- **ΔV across a MCP $\leq$1200V**
- **Secondary electron emission (SEE) coefficient (δ) Pb <1.5**
- **Gain = 10^4-10^7**

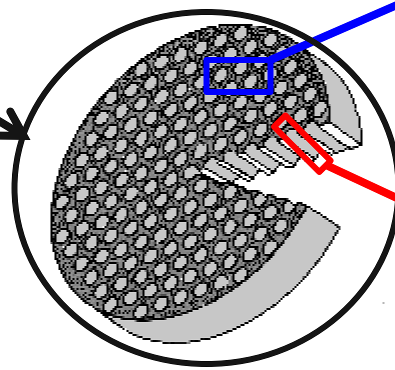
Source: Photonis and Hamamatsu

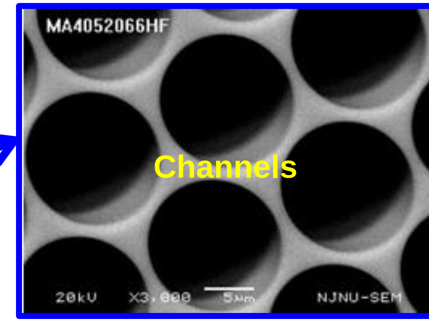
MCPs Applications

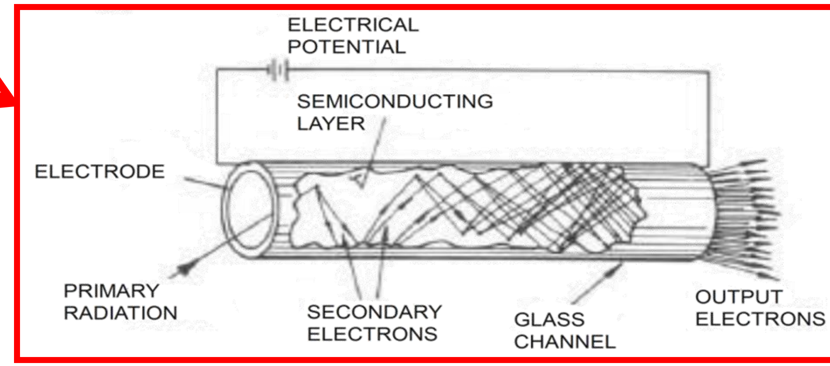
• Gas electron multipliers	• Photomultiplier tubes
• Electron microscopy	• High energy physics
• Field emission displays	• Nuclear physics
• Time-of-flight (ToF) • mass spectrometry	• Night Vision Devices
• Molecular and atomic • collision studies	• Medical imaging • (PET scanners)
• Security Scanners	• Astronomy
• Neutron detector	• High surface area template
• Gas sensors	• X-ray imaging

Conventional MCP detectors

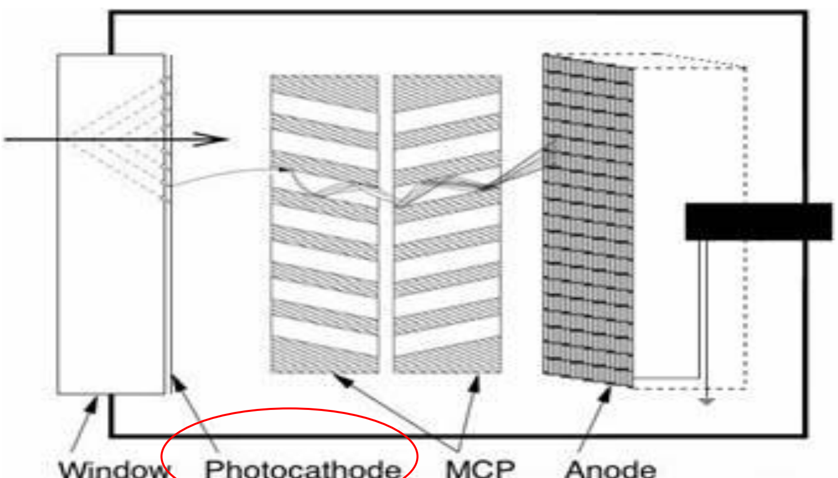




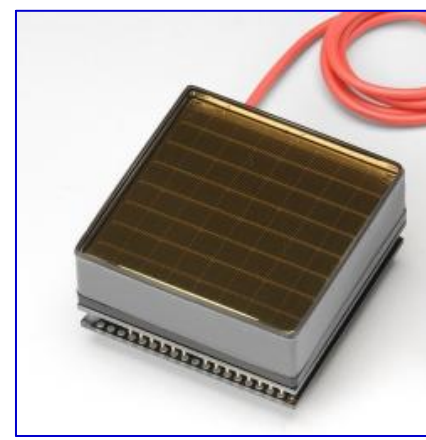




MCP Photomultiplier tube(PMT)

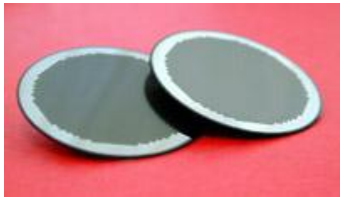


- **Continuous-dynode electron multiplier**



http://www.hamamatsu.com/

MCP fabrication methods and advantages/drawbacks

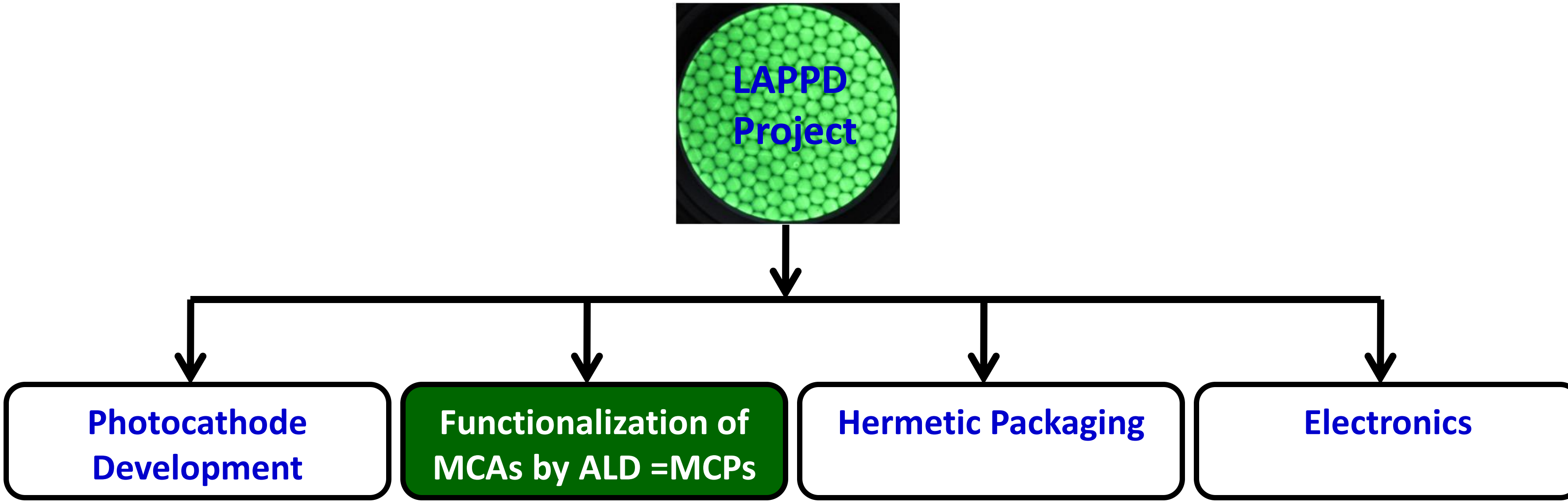
Conventional MCP Fabrication
➢Draw lead glass fiber bundle
➢Slice, polish, chemical etch
➢Heat in hydrogen
➢Top/Bottom electrode coating (NiCr)
Drawbacks
➢Expensive
➢MCP resistance and secondary emission properties are linked to semiconducting Pb
➢Limited optimize MCP performance for applications where lifetime, gain, substrate size, composition and thermal runaway are important


Overseas order, size and cost

MCPs development @ Argonne

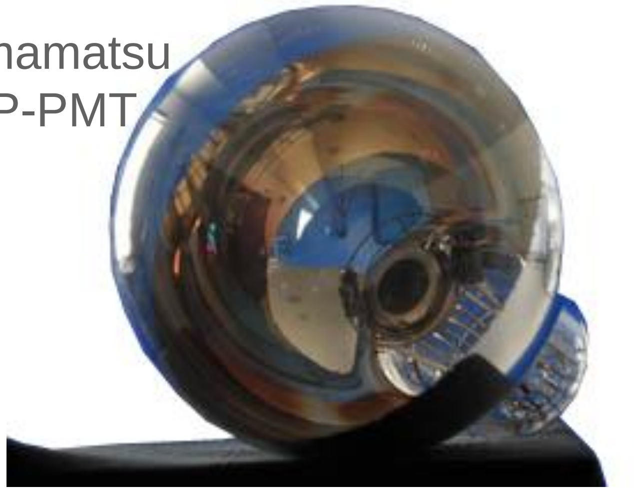
Background: DOE LAPPD project

- **Apply the basic concept of "micro-channel plate" (MCP) detectors to the development of large-area photo-detectors (LAPPDs) [8"x8" MCP] with quantum efficiencies and gains similar to those of photo-tubes.**
  - ***Higher or similar quantum efficiencies and gains to photomultipliers***
  - ***Use in wide range of applications***
- **To design and fabricate "economical" robust LAPPDs that can be tailored for a wide variety of applications that now use photomultipliers.**

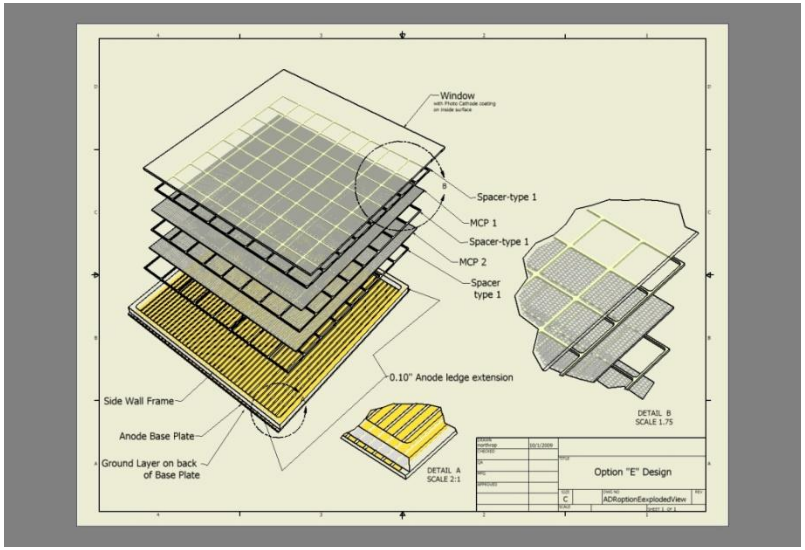


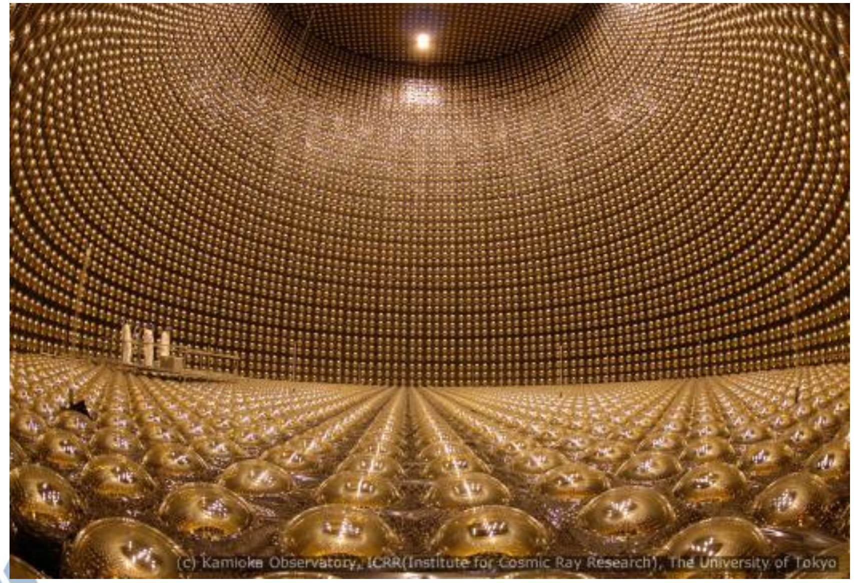
MCP PMT comparison (form factor=8”)

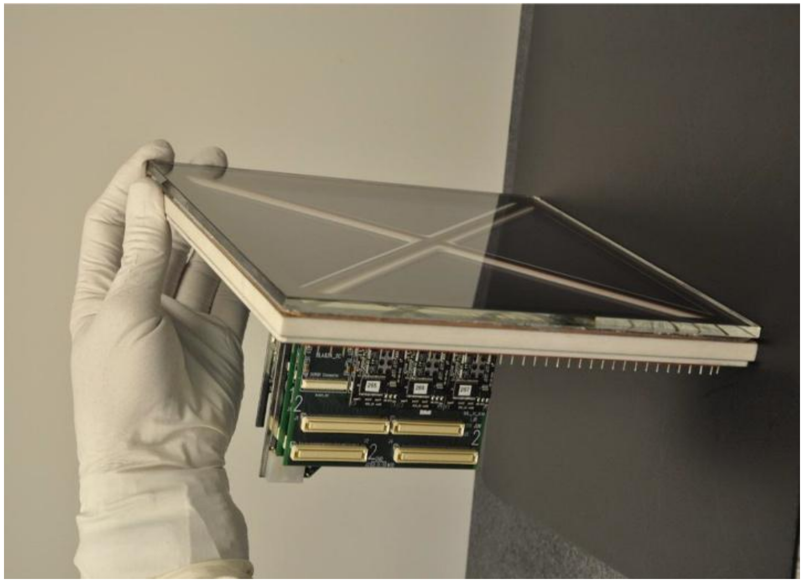
Hamamatsu
MCP-PMT



Argonne MCP LAPPD Approach



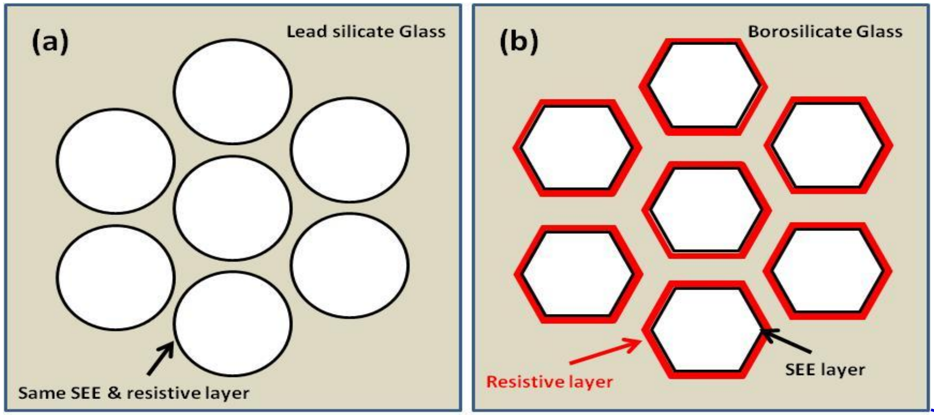




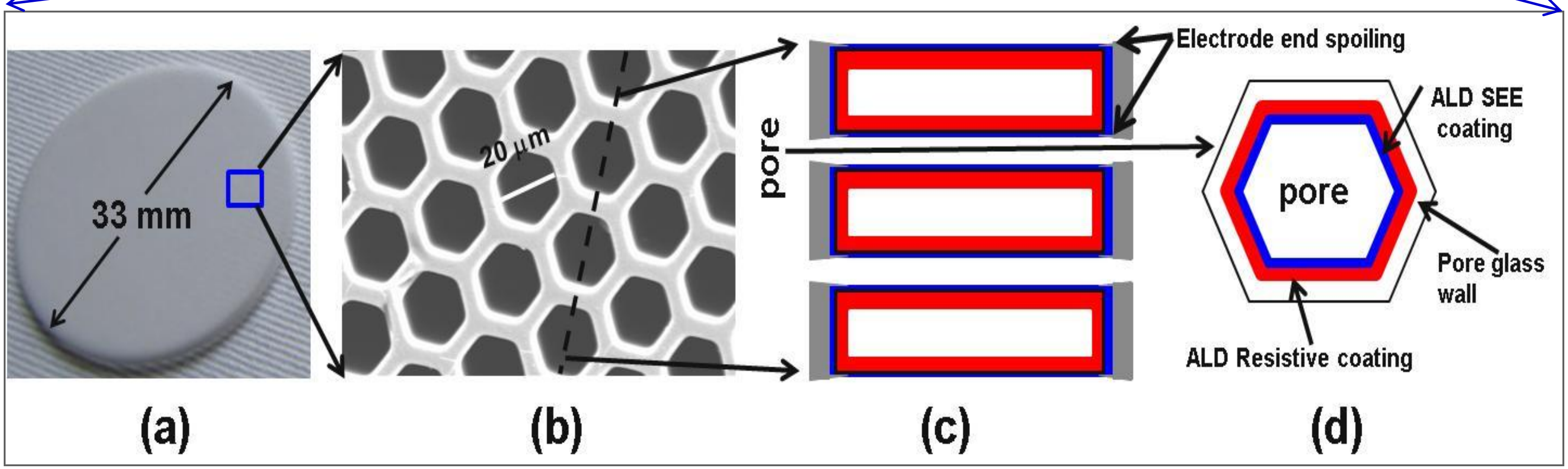
MCP functionalization comparisons:

Also we can fix or improve conventional MCPs by ALD route

Conventional Route

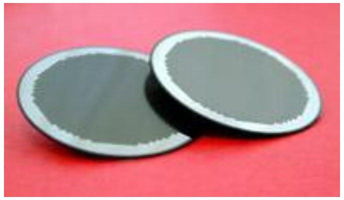
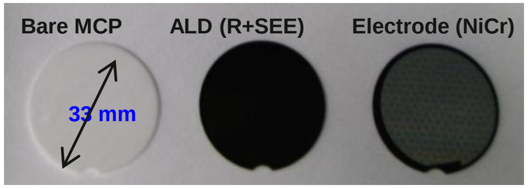


ALD Route



(a) As received capillary glass array (MCA) substrate (e.g. borosilicate glass, plastic, ceramics etc.…)
(b) Plan-view SEM of capillary array front surface,
(c) Schematic cross section of fully-functionalized MCP,
(d) Schematic cross section of individual MCP pore after ALD functionalization

MCPs fabrication methods distinction

Conventional MCP Fabrication	Argonne LAPPD Approach
➢Draw lead glass fiber bundle	➢Start with porous, non-lead substrate
➢Slice, polish, chemical etch	➢ALD (resistive + SEE layer) coating
➢Heat in hydrogen	➢Thermal treatment
➢Top/Bottom electrode coating (NiCr)	➢Top/Bottom Electrode coating (NiCr)
Drawbacks	**Advantages**
➢Expensive	➢Independent control over composition of Resistive and SEE coating
➢MCP resistance and secondary emission properties are linked to semiconducting Pb	➢Low thermal runaway
➢Limited optimize MCP performance for applications where lifetime, gain, substrate size, composition and thermal runaway are important	➢Applicable: Ceramics, SiO2, plastics, polymers MCPs
	➢Low cost (No major issue for scale-up with ALD)
	

Overseas order, size and cost

"Made in USA" capabilities
Economical

Starting Substrate for MCPs:
Borosilicate Glass Micro Capillary Array (MCA)

Micro Capillary Array (MCA) glass

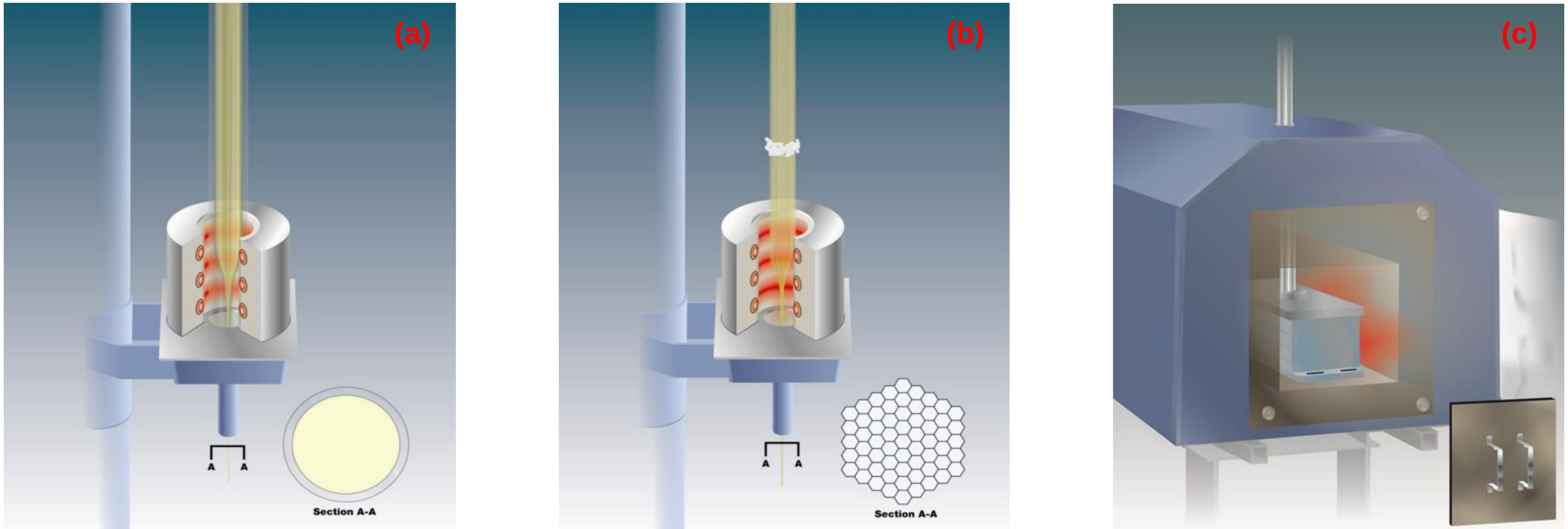
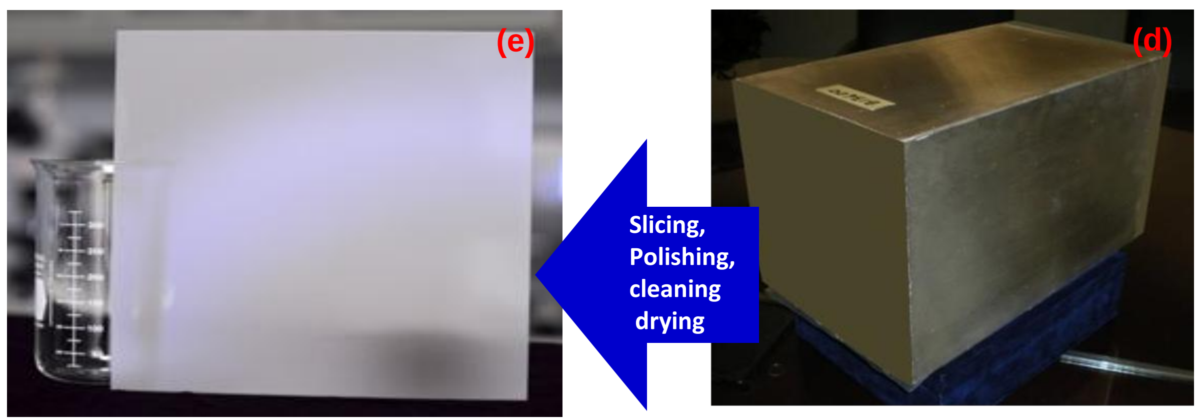
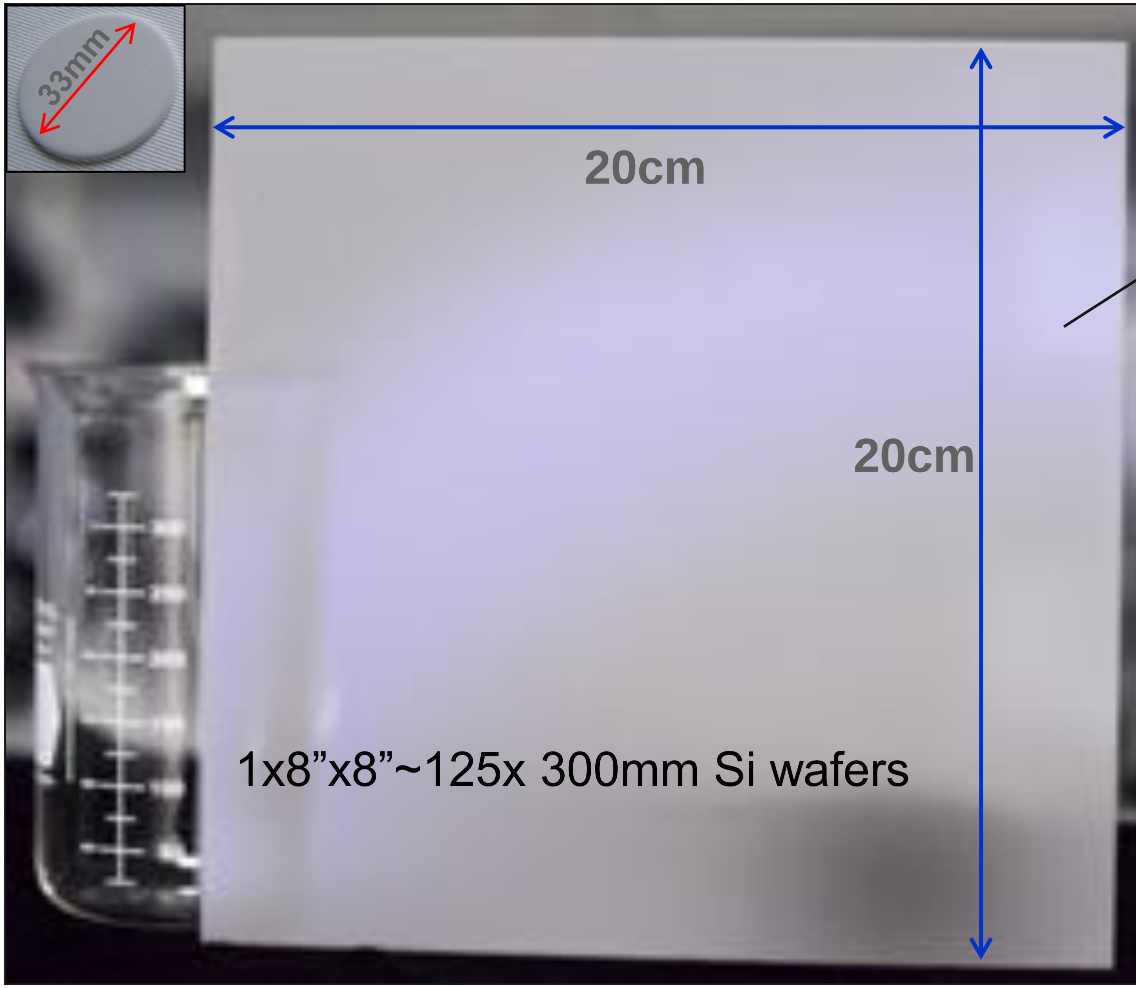


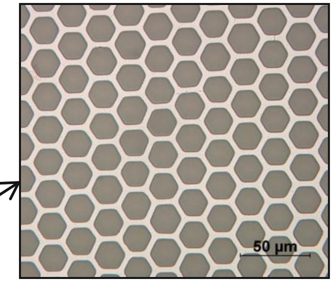
Figure 1: (a) Drawing of hollow glass tubes to form capillaries. (b) Bundles of capillaries re-drawn to from multis and multi-multis. (c) Pressing into block. (d) Block after fusion. (e) 200 x 200 mm MCA after slicing, grinding and polishing.



Size =9”x9”x18”

Large area Capillary Glass Array Substrates for MCPs





Complex Geometry

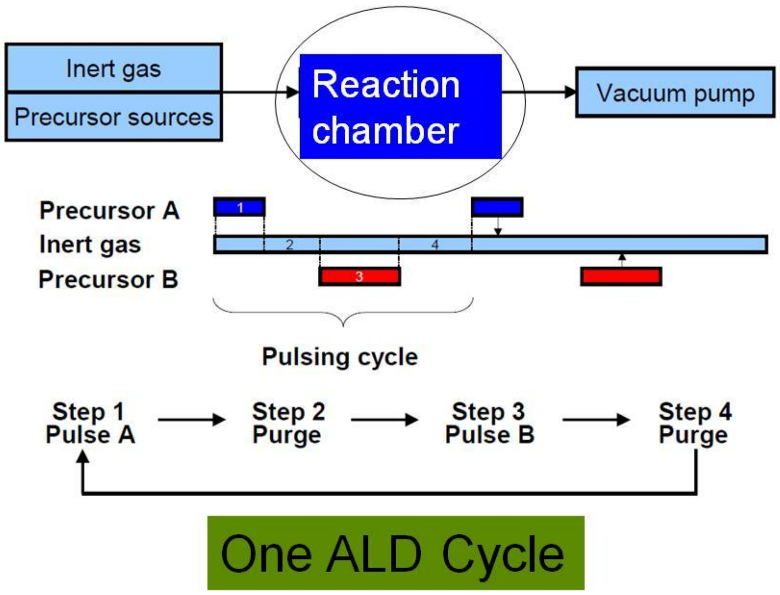
- **Surface area = 8.7 m^2**
- **Pore size = 20μm**
- **Thickness of plate=1.2mm**
- **Aspect Ratio = 60**
- **No. of Pores = ~80Millions**
- **Porosity = 65%**
- **Bias Angle = 8^o**
- **Sensitive Surface to OH**

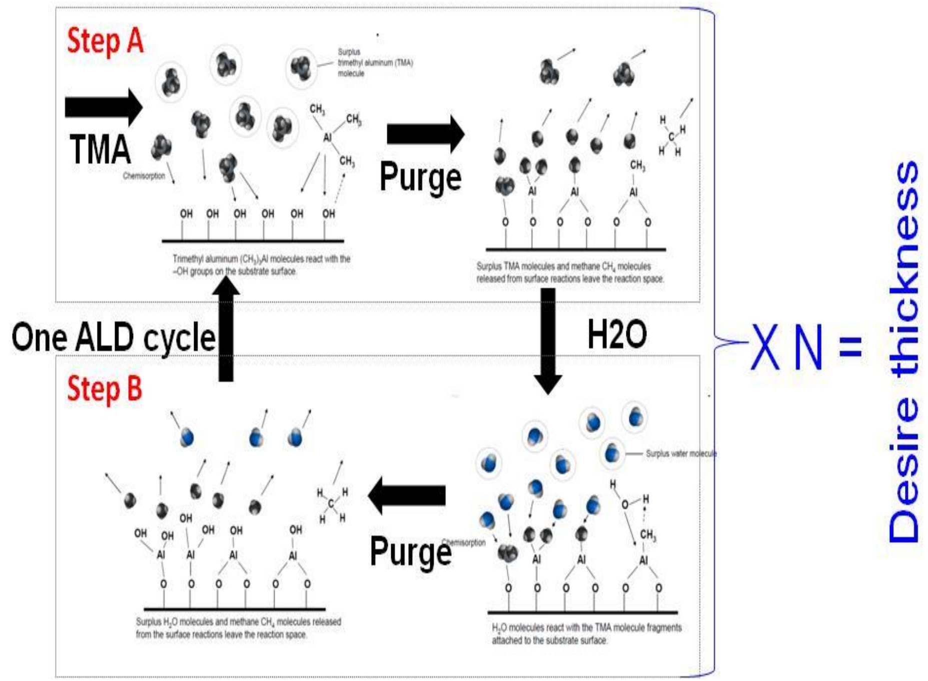
- **Very challenging substrate to coat for “any” thin film deposition method**
- **Atomic layer deposition method is ideal**

Atomic Layer Deposition Method

Atomic layer deposition:

Sequential precursors vapors introduction into reaction chamber

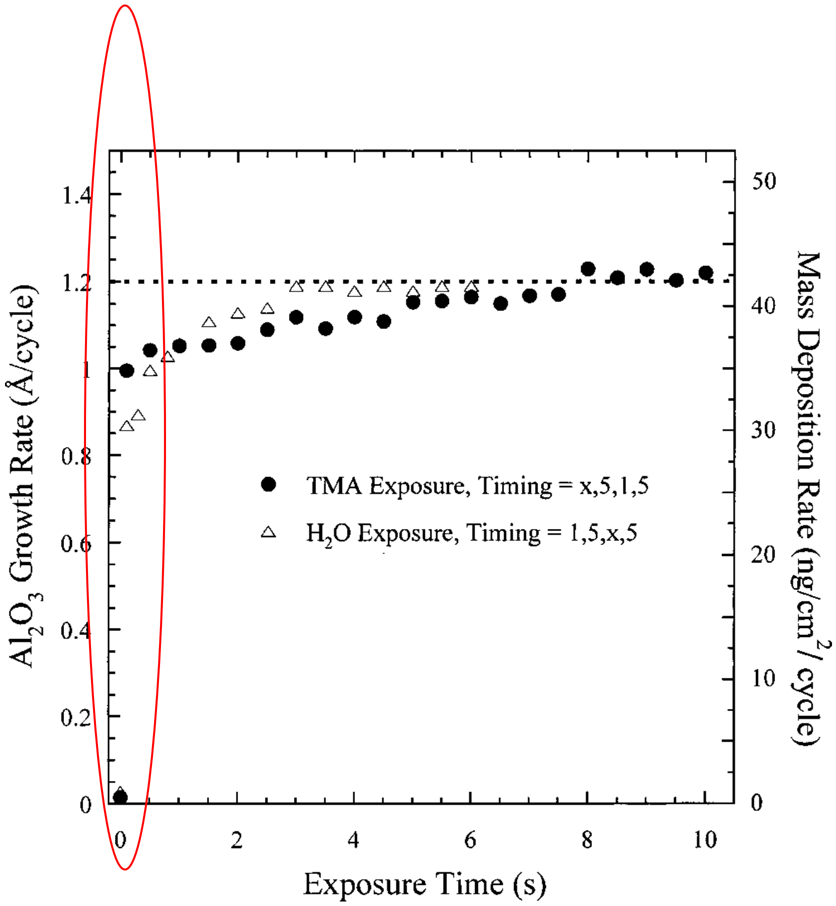


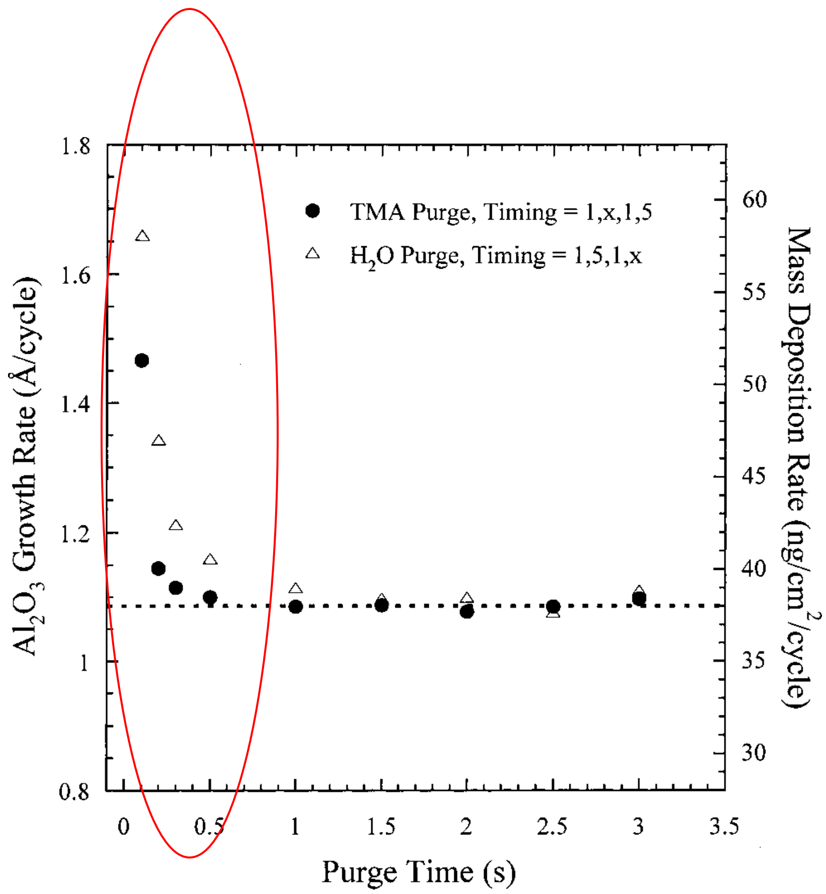


•Precursor introduce separately in time and space

•Involved <u>self-limiting</u> film growth via alternate saturated surface reactions

QCM study of ALD Al_2O_3





Evaluation of optimum dose / purge parameters

Elam *et al,* Rev. Sci. Instrum., Vol. 73, No. 8, August 2002

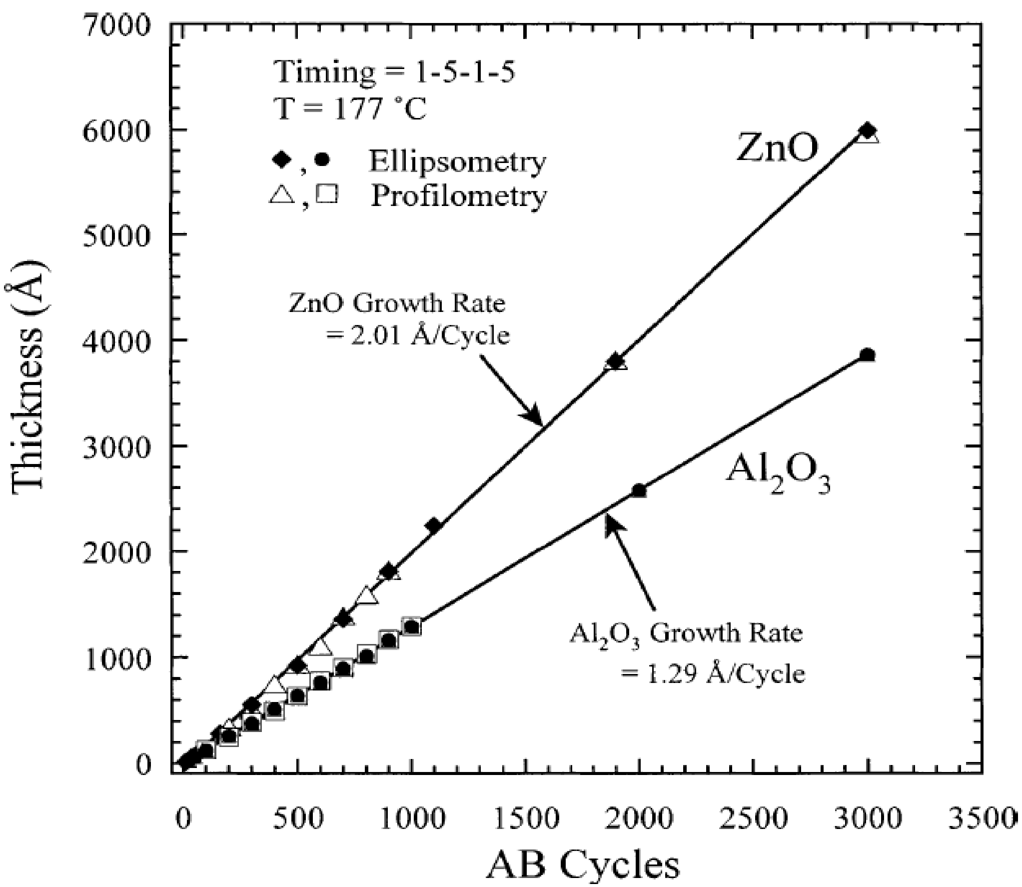
ALD precursors dependent

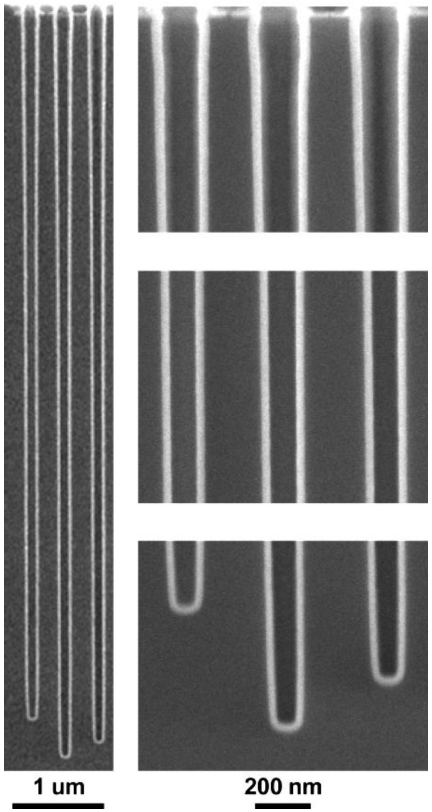
ALD Method Advantages
(due to self limiting growth mechanism)

- Extremely accurate thickness and composition control of mixed oxides, graded layer and nano-laminates
- Unique film step coverage compared to any other deposition technique
- Wide range of film materials available
- Lower deposition temperature can be used for sensitive substrates than in CVD
- Batch processing
- Low impurity level of the films enable excellent physical and chemical properties

Linear and conformal materials growth by ALD

e.g.
1)**ALD of Al_2O_3 by TMA and H_2O**
2) ALD of ZnO by DEZ and H_2O

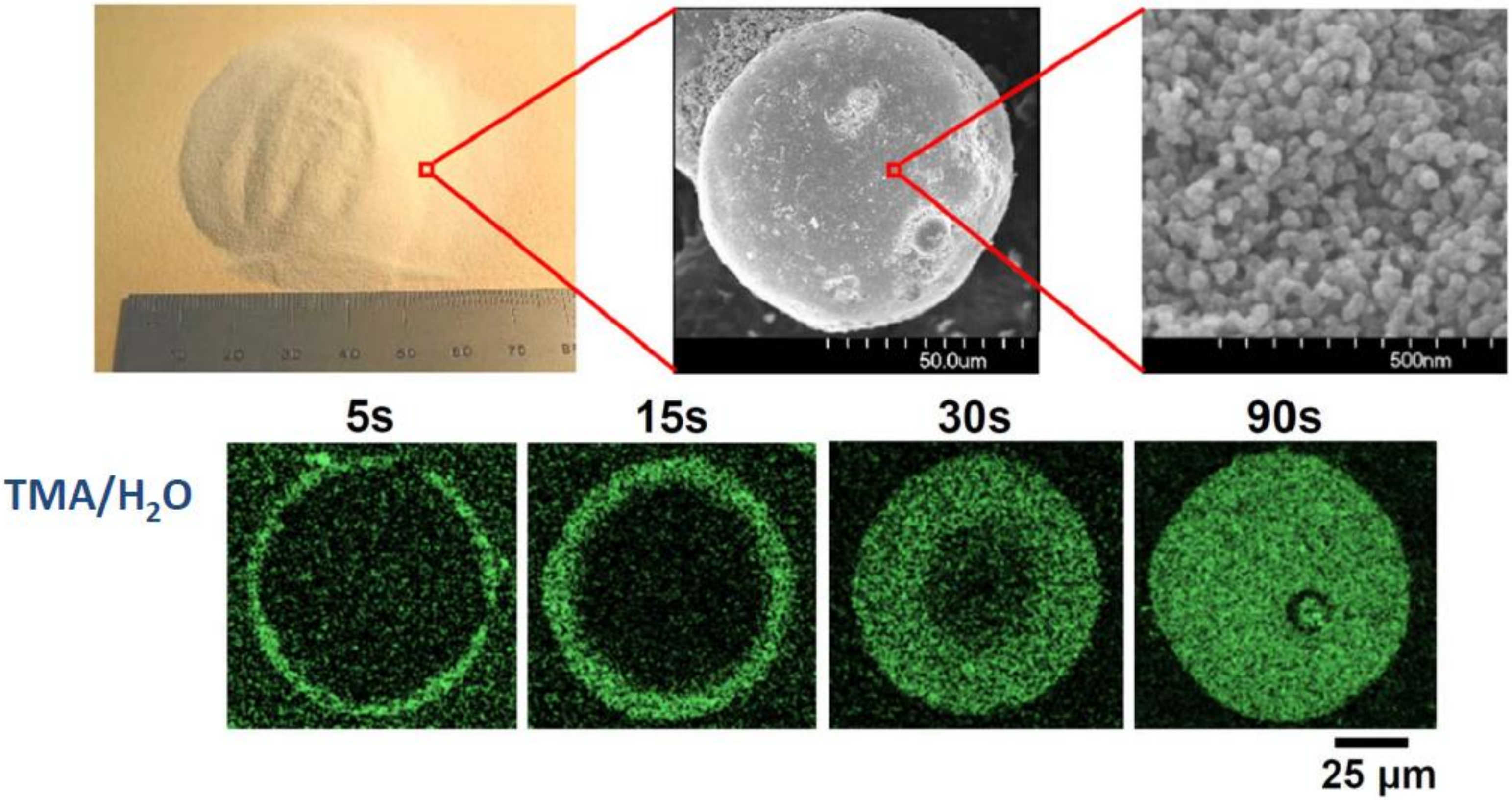




Elam et al, Chem. Mater., Vol. 15, No. 4, 2003

ALD on high surface area: E.g. Silica particles

- 100 micron particles, 30 nm pores
- Surface area = 100 m^2/g (=1400 300 mm wafers!)

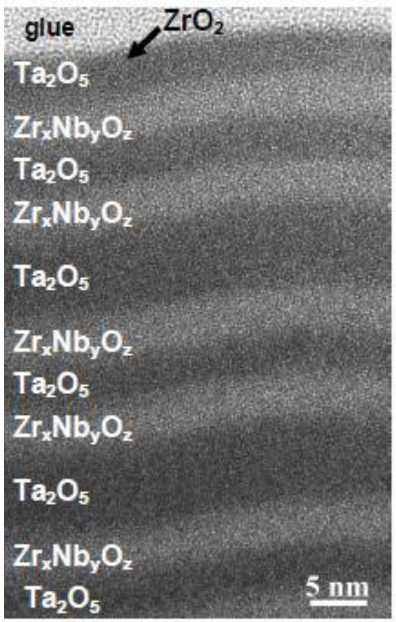


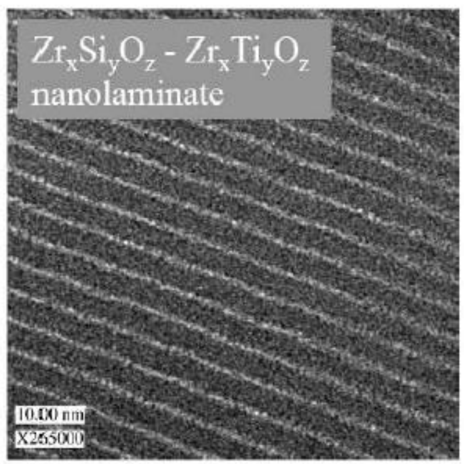
Thin Solid Films 516 (2008) 6158–6166

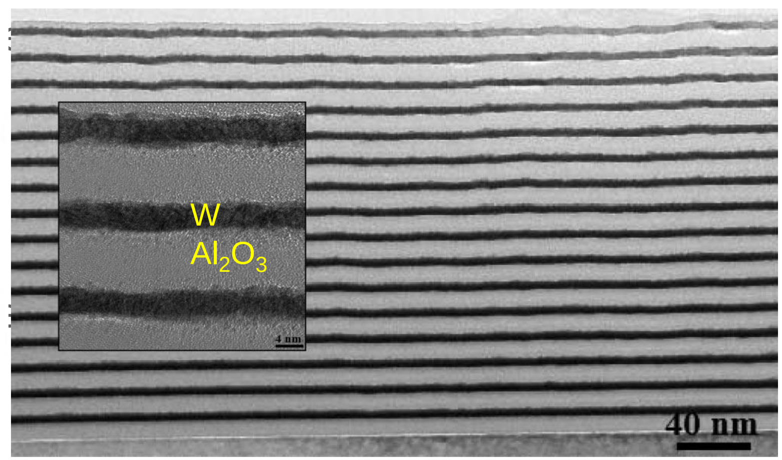
Uniform infiltration of nanoporous solids

Advantages (due to self limiting growth mechanism)

- Unique film step coverage compared to any other deposition technique
- Wide range of film materials available
- Extremely accurate composition control of mixed oxides, graded layer
- and nanolaminates
- ited films have less impurities than the films made by other iques at the same deposition temperature





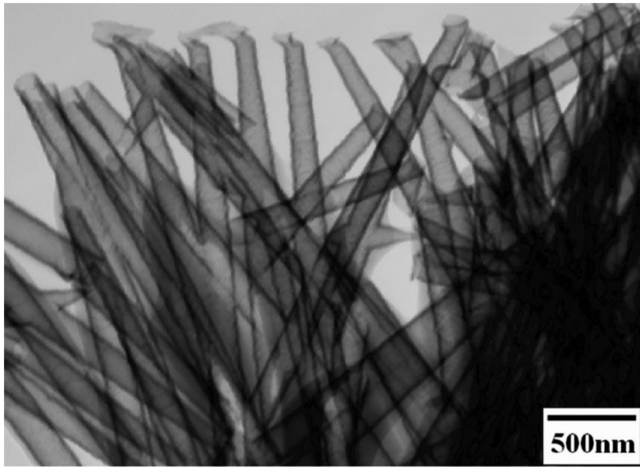


Materials Science and Engineering C 27 (2007) 1504–1508

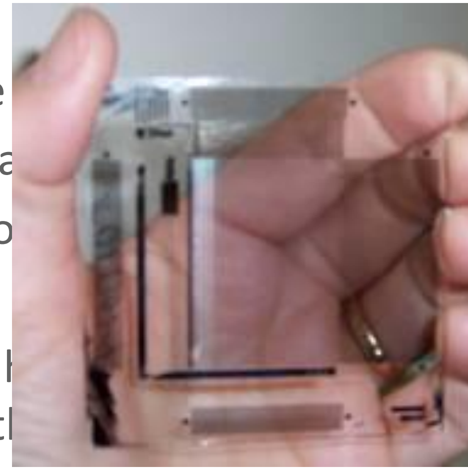
Appl. Phys. Lett. **2006, *88, 013116.***

Advantages (due to self limiting growth mechanism)

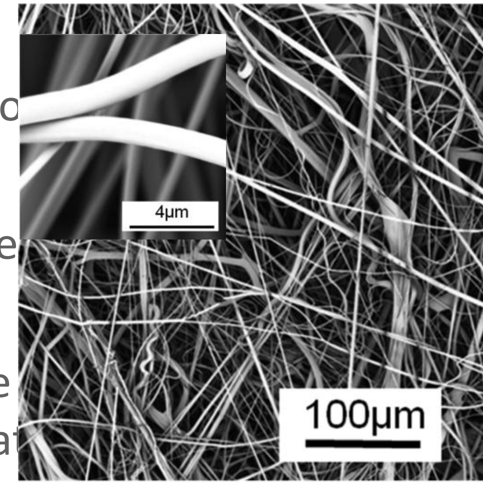
Chemical Reviews, 2010, Vol. 110, No. 1
TEM image of ZrO2 nanotubes fabricated in polycarbonate



Eastman Kodak Company, 2009



Langmuir 2010, 26(4), 2550–2558



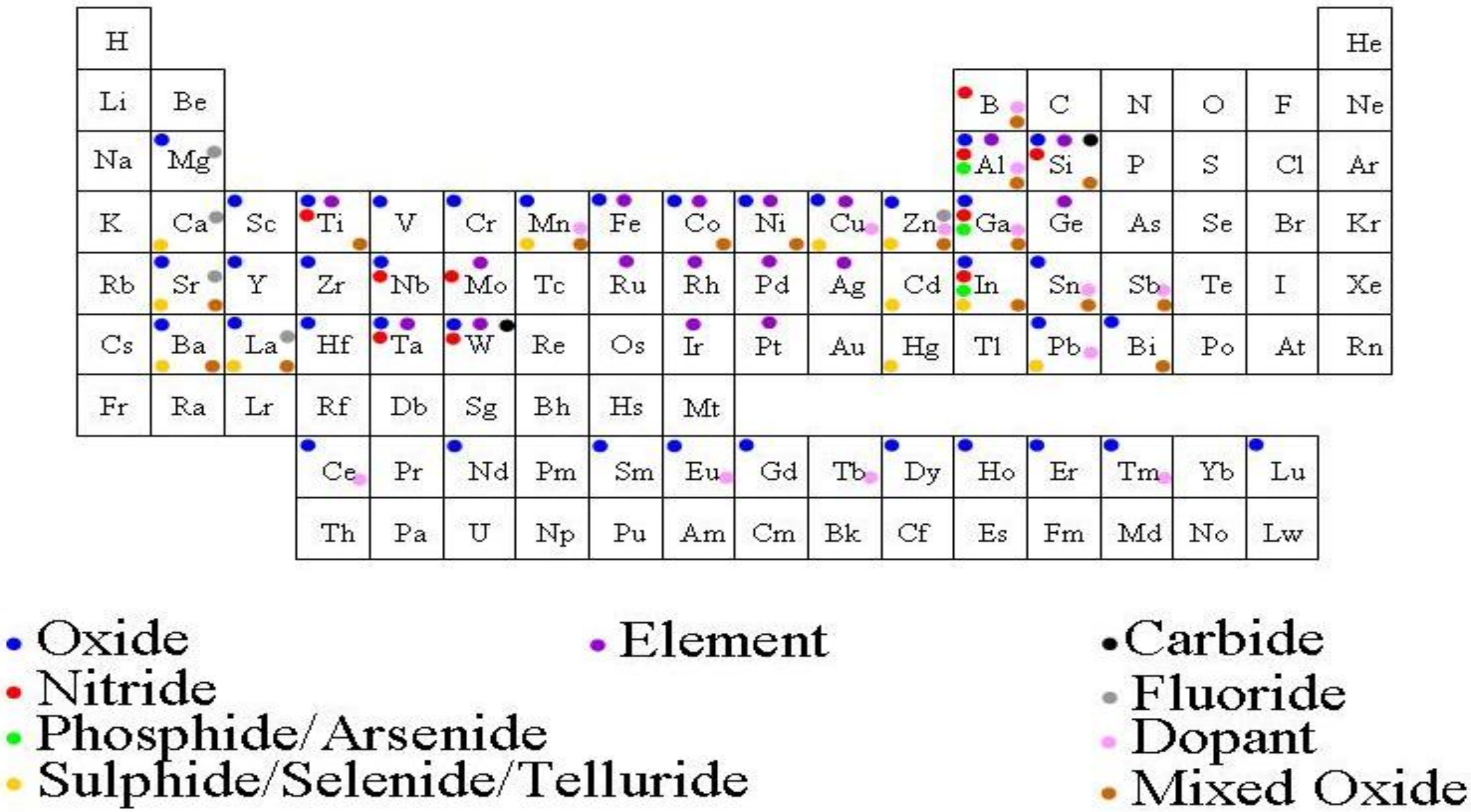
- Lower deposition temperature can be used for sensitive substrates than in CVD technique

For CVD = 100-900C
For ALD = Room temperature to 350C

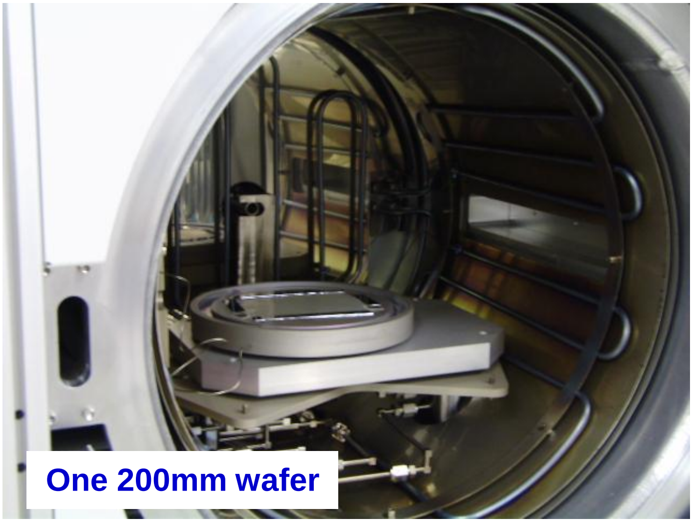
chemical properties

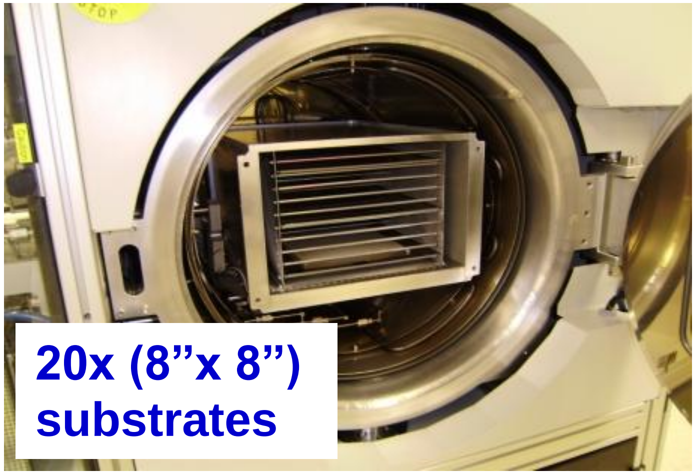
Advantages (due to self limiting growth mechanism)

- Unique film step coverage compared to any other deposition technique
- Wide range of film materials available



ALD method flexibility and advantages:





Materials requirements for MCPs

1. Dry and clean porous substrates (MCA)

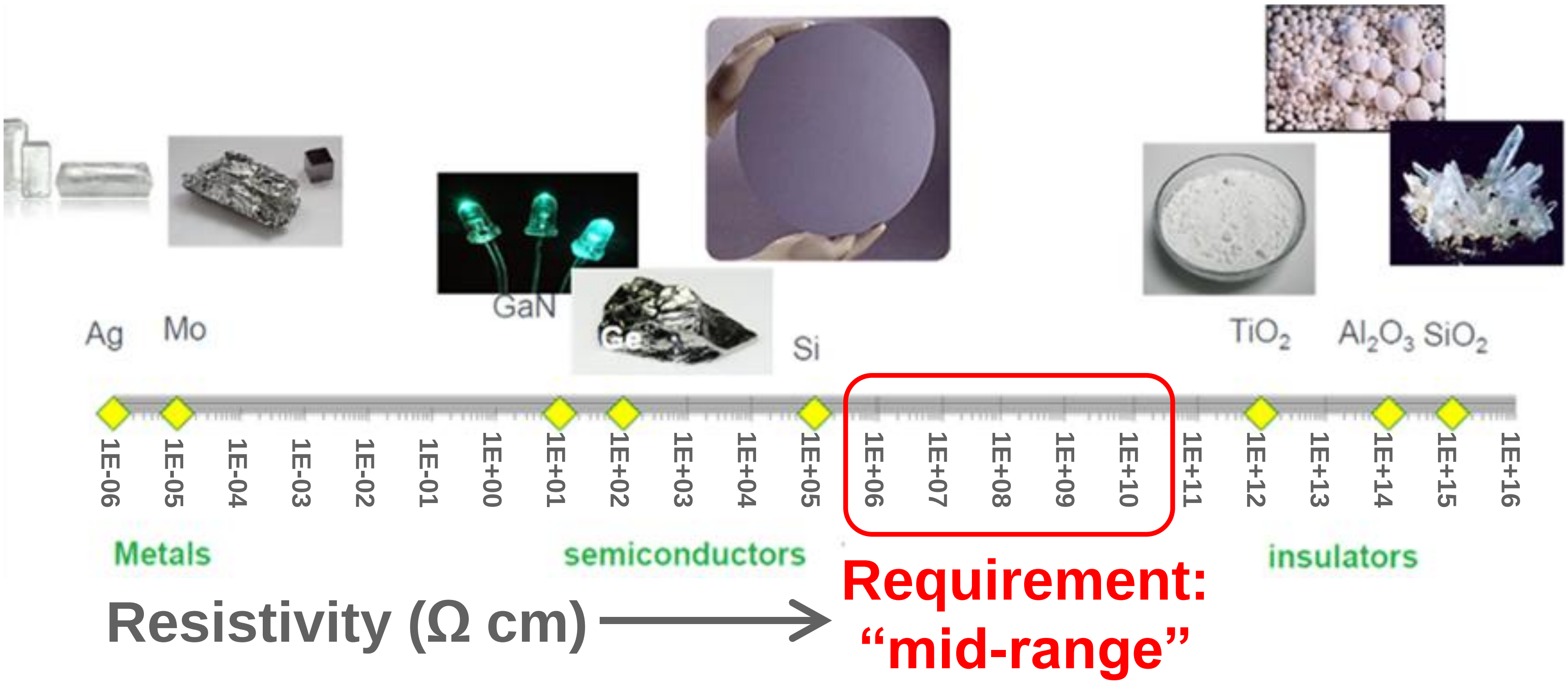
2. Uniform and conformal deposition of desire materials by ALD
   -Stable resistive material layer (to generate electrostatic field)
   - Material resistivity range =10^6-10^{10} Ω-cm

   -Stable secondary electron emission layer (signal amplification)

3. Stable Contact electrode (e.g NiCr, W, TiN, etc.) for electrical contact) especially by PVD electrode penetration normally a pore diameter)

***Mane et al*, SPIE 2011**

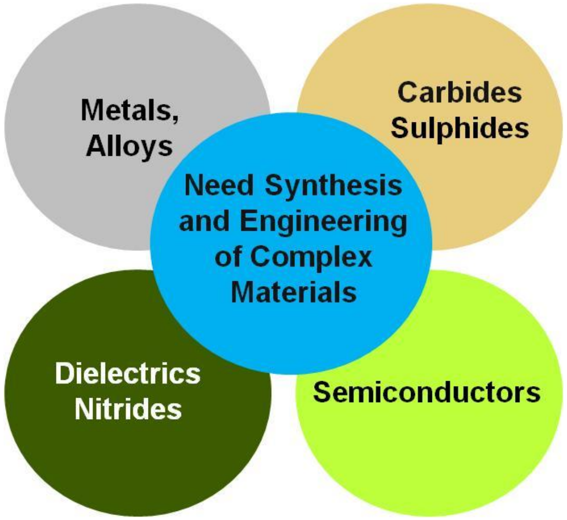
"Mid-Range" Resistivity Materials



- Practically no naturally occurring materials with "mid-range" resistivity of 10^6-10^{10} Ωcm
- **<u>Must be synthesized or engineered</u>**

Tunable Thin Film Resistive Coatings

"Mid-range" Tunable resistivity: 10^6-10^{10} Ω-cm



- **Mixing compatibility at nano scale**
- **Precisely control growth method for complex high surface area and aspect ratio structures? (ALD processing method is favorable)**
- **Practical use: Reliability, Stability, Manufacturable and Low cost**

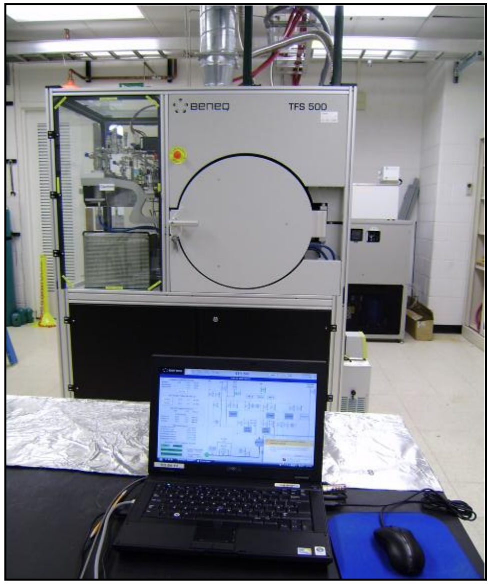
- **Few prior resistive materials by ALD:**
  -AlZnOx, NiAlOx, CuAlOx, TaZrOx, Pt-MgO, MgZnOx, SnAlOx, NbTaOx, etc.
- **Issues: Resistivity control, Stability, Precursors nature, Processing cost, etc.**

Argonne ALD Nanostructure M-Al_2O_3 Composite Films (Where M = W or Mo) Materials Engineering and Characterizations

Granted patents from this work for lab:
US 8969823
US 8921799
US 8604440

ALD capability at ES division (building 362)

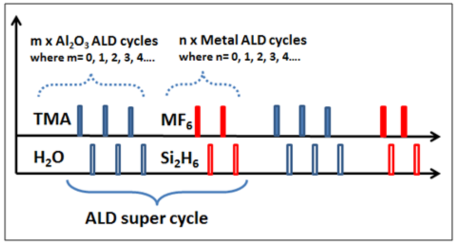
- 3 custom made ALD systems (10 precursors, up to 18x12” substrates)
- ALD powder coating system (up to 1 kg powder)
- Beneq TFS 500 ALD system (multiple 16” substrates)
- Oxford FlexAL ALD reactor (plasma assisted ALD)
- ALD systems equipped with in-situ FTIR, QCM, mass spec, resistivity



ALD Chemistries for Resistive Coatings

ALD of M-Al_2O_3 Composite Films

- Combine 2 ALD processes:
  - Oxide -- TMA/H_2O $\rightarrow$ Al_2O_3 : insulator, $\rho=10^{16}$ Ωcm
  - Metal -- MF_6/Si_2H_6 $\rightarrow$ M=W, Mo : conductor, $\rho=10^{-4}$ Ωcm



- Adjust resistivity with M/(M+Al_2O_3) cycle ratio
- Deposition Temperature
- Precursors types

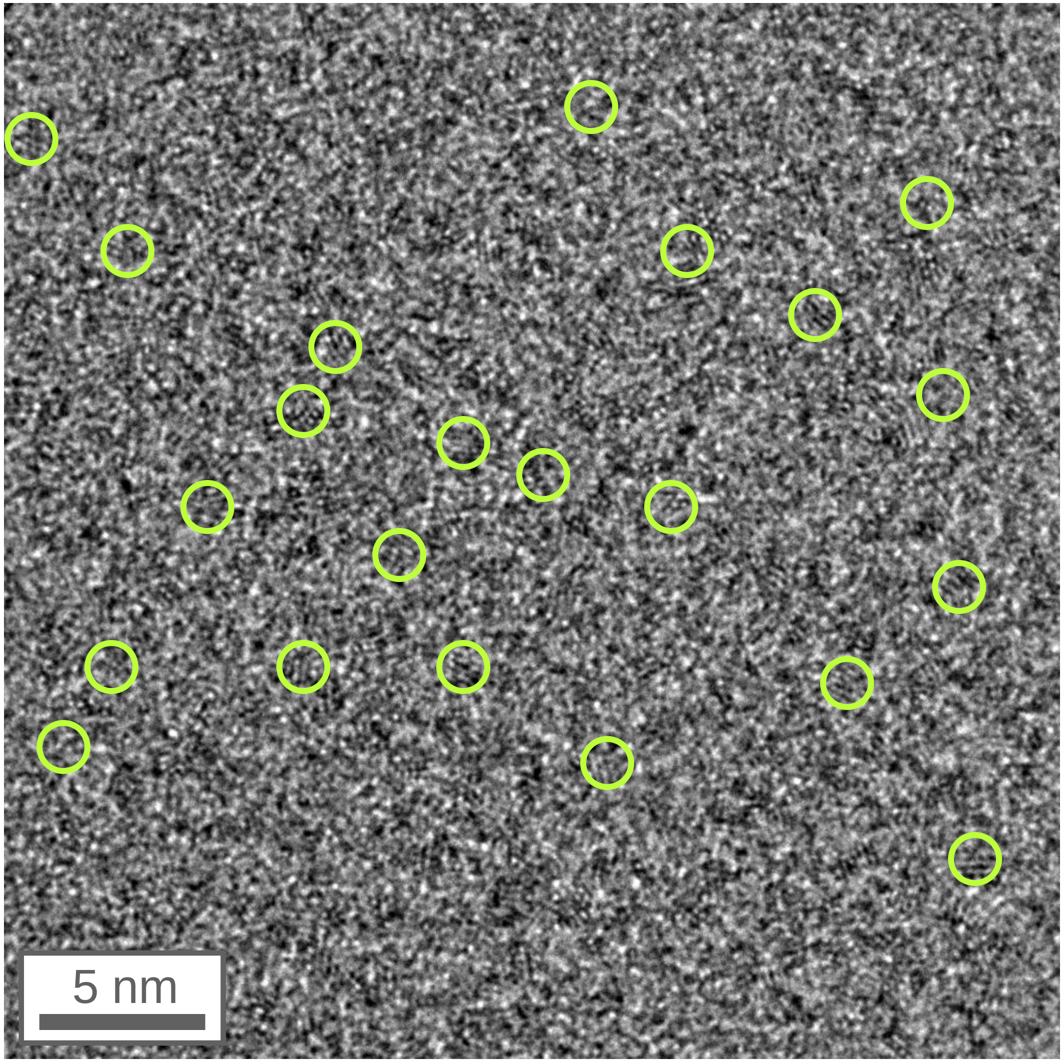
Publications:
Mane et.al., SPIE 2013
Elam et.al., ECS 2013
Mane et.al., CVD (2013) 186
Tong et.al., APL 102 (2013) 252901

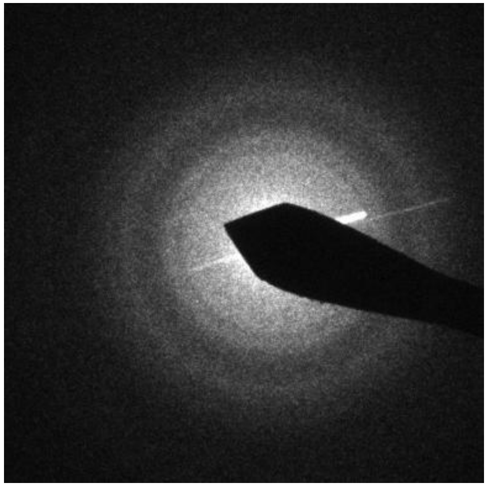
And more publication by collations work :
http://psec.uchicago.edu/library/doclib/

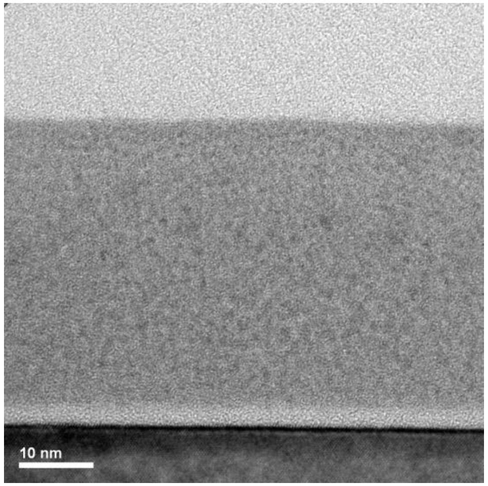
- **Precursors = $Al(CH_3)_3$, H_2O, WF_6, MoF_6, Si_2H_6**
- **Precursor : High vapor pressure, availability, cost**
- **Growth of pure layers : W, Mo and Al_2O_3**
- **Growth composite layers : W-Al_2O_3, and Mo-Al_2O_3**
- **Low temperature deposition processes (100-400^oC)**
- **Large area batch production**

TEM of $Mo:Al_2O_3$

$10\%(Mo:Al_2O3)$

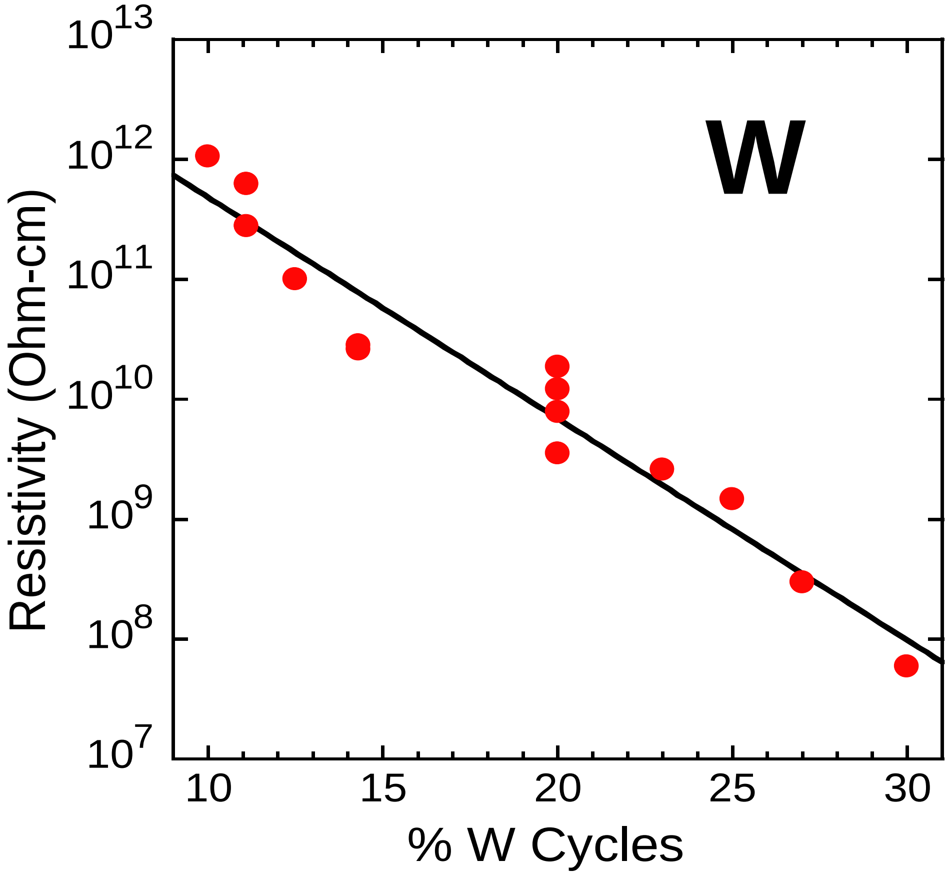


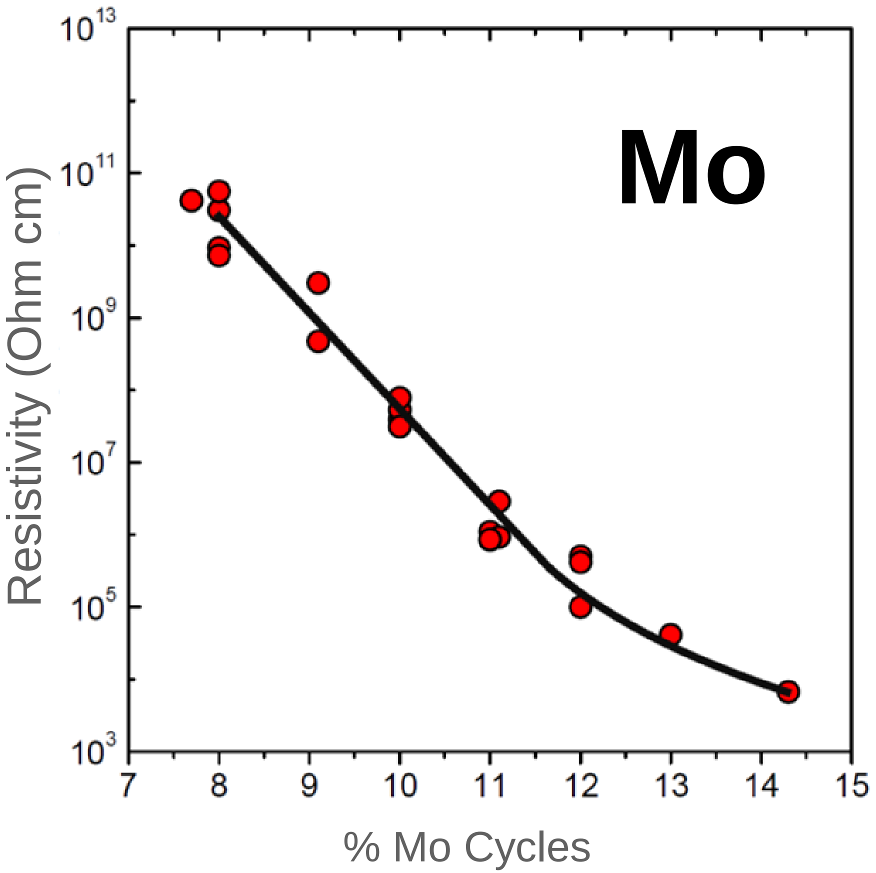




- 1-2 nm nanoparticles embedded in amorphous matrix

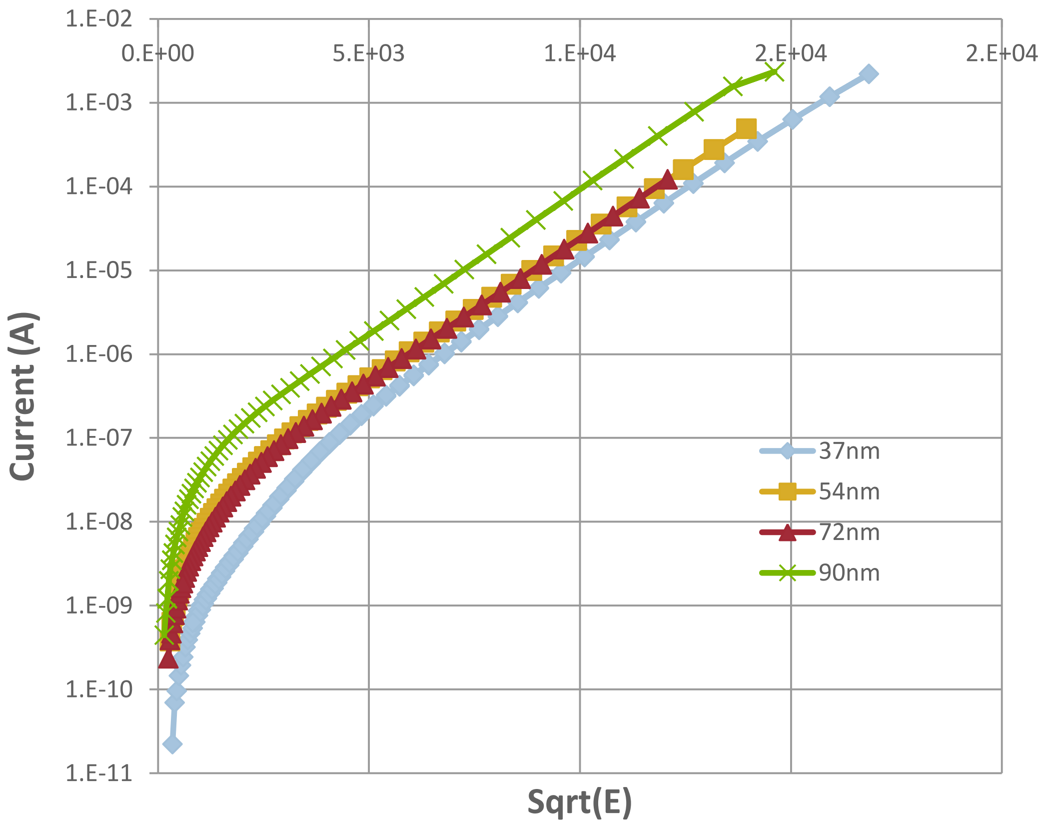
Resistivity of M-Al_2O_3 Composite Films





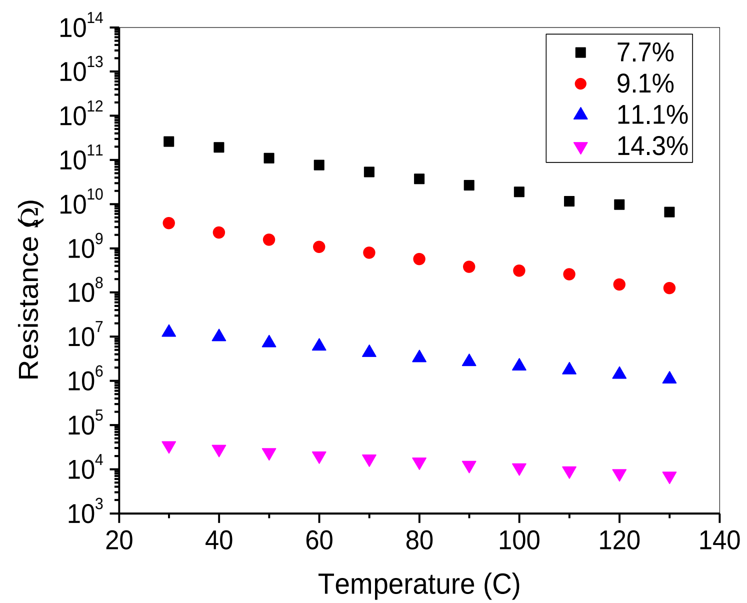
- Resistivity is tunable in the preferred "mid-range"

Electrical analysis



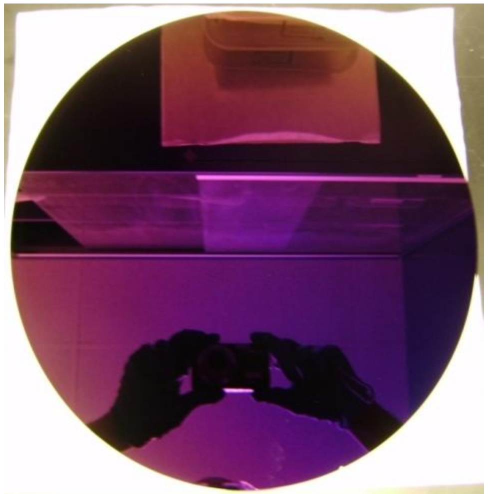
- Frenkel-Poole (FP) emission model fits well to IV data*
- R shows temperature dependence

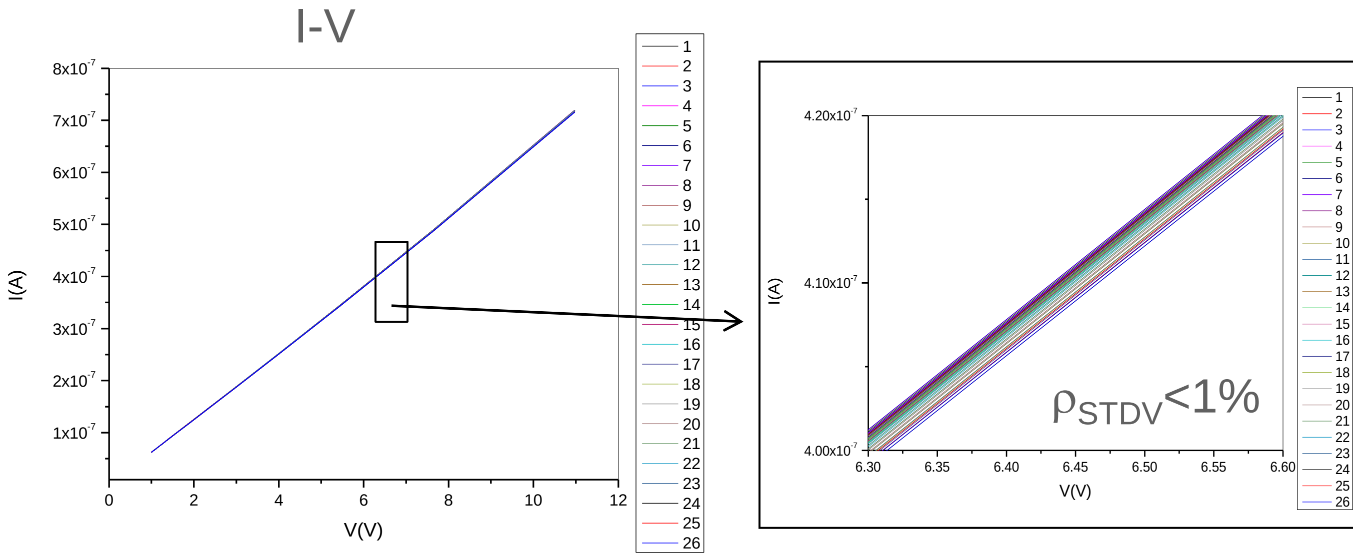
R vs. T for % of Mo cycles

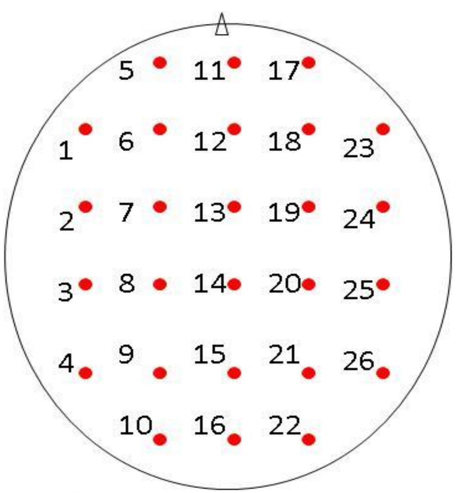


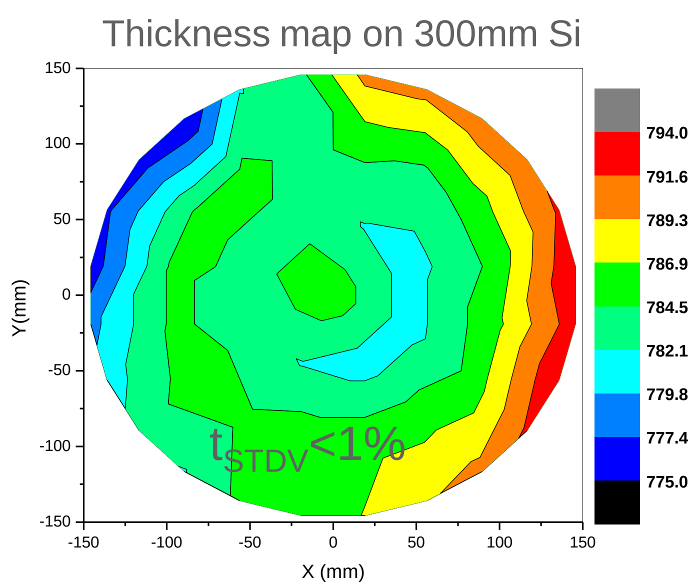
$$* \quad J \propto E \exp\left(\frac{-q\left(\phi_B - \sqrt{qE/\pi\epsilon}\right)}{k_B T}\right)$$

Process scale-up: ALD Mo:Al_2O_3 on 300mm Si wafer

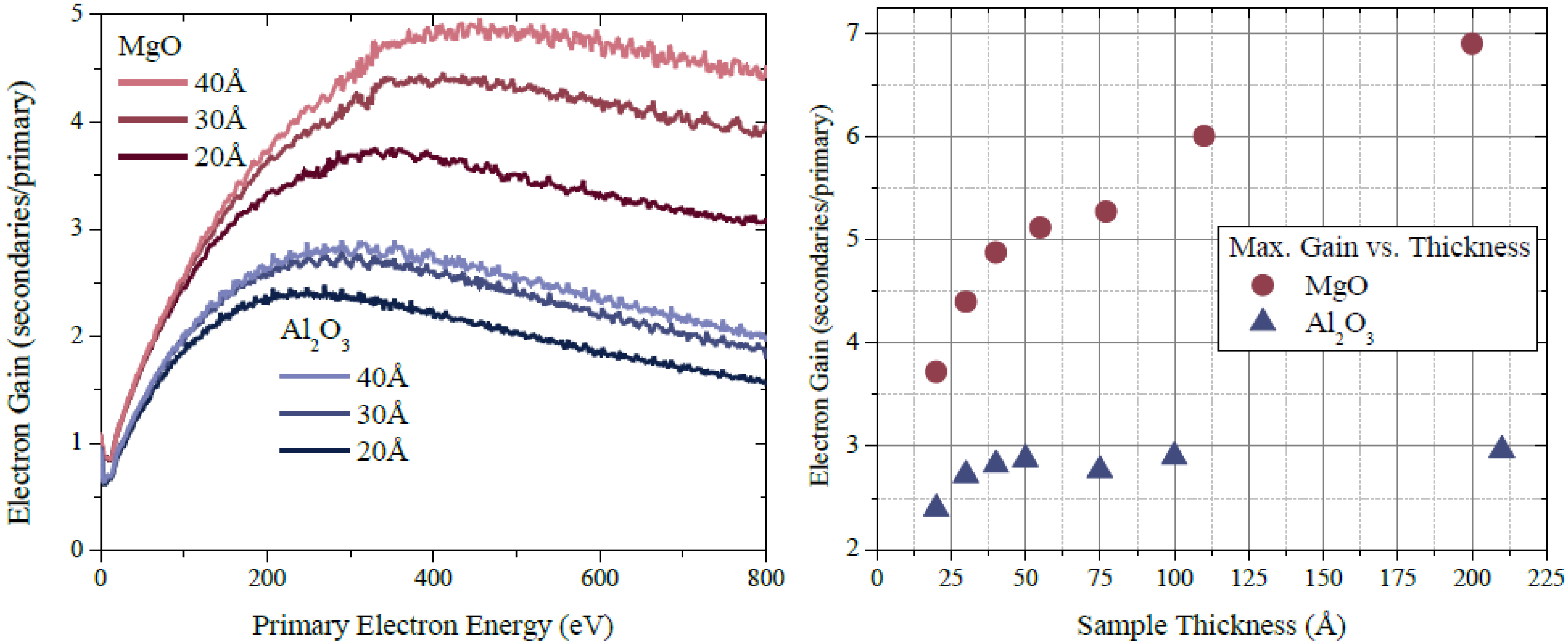








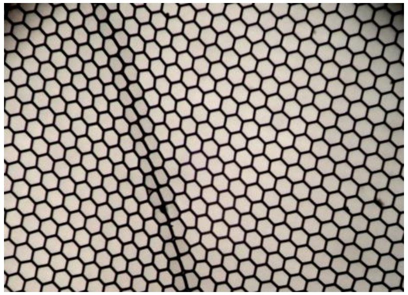
Secondary electron emission layers by ALD



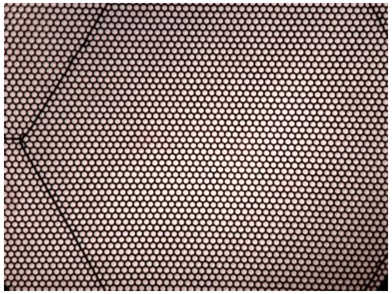
Jokela *et al*, Physics Procedia 37 (2012) 740 – 747

Present processes for MCPs

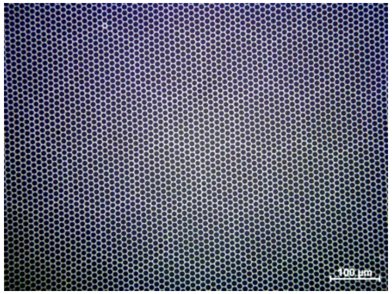
MCP substrates	ALD Resistive layer	ALD SEE layer	PVD Electrodes
Up to 8”x8”, Pore dia.=10, 20 and 40μm Bias angle=8º Aspect ratio =40, 60, 100	Al-ZnO Mg-ZnO $W\text{-}Al_2O_3$ $Mo\text{-}Al_2O_3$ Etc.	MgO Al_2O_3 Etc.	NiCr (1D end spoiling) Thermal evaporation



40μm pore borosilicate MCA with 83% open area



20μm pore borosilicate MCA with 65% open area



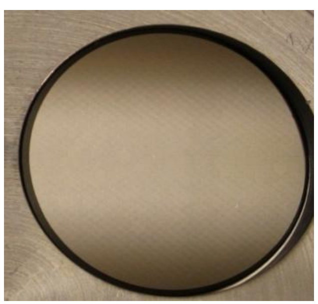
10μm pore borosilicate MCA with 60% open area

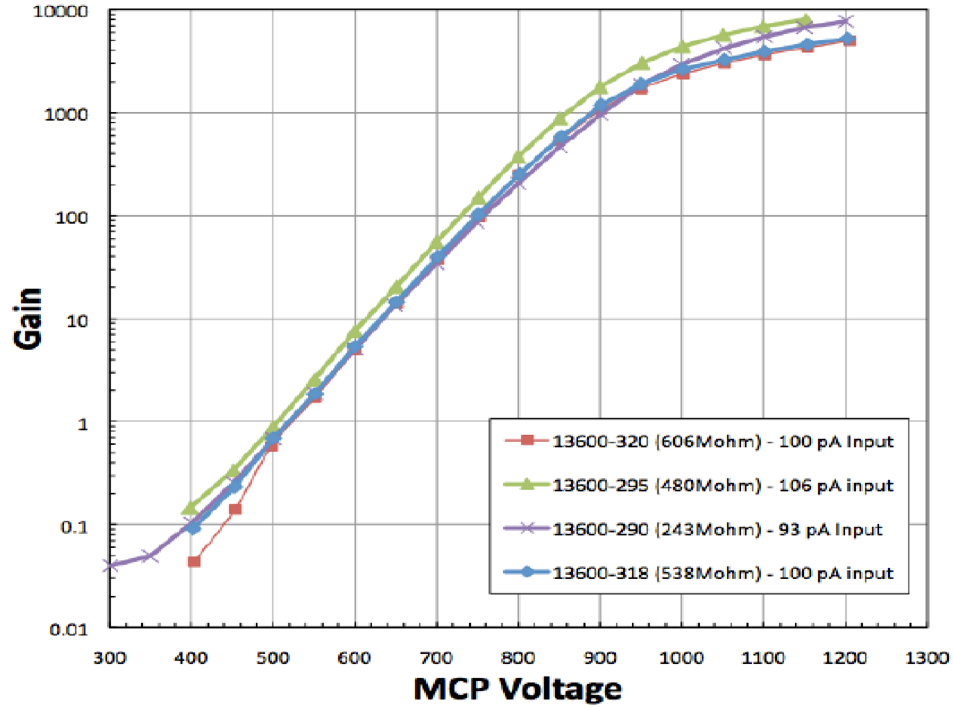
MCP Fabrication and Performance

33 mm capillary glass array (Incom)

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

With PVD NiCr electrode



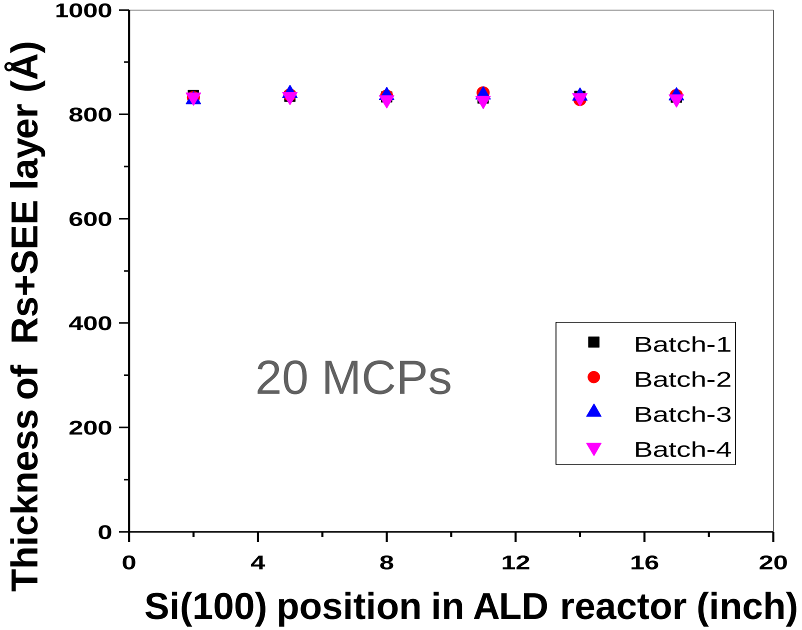


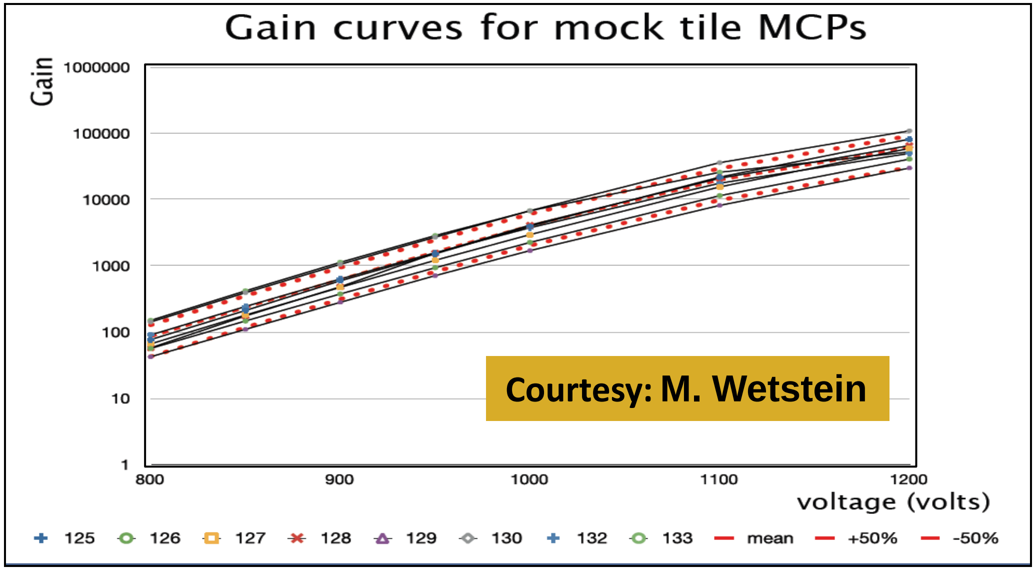
Easy to functionalized by ALD

- Gain is spatially uniform
- Gain of ~ 10^4, (comparable to commercial MCPs)
- Reproducible

1. *Mane et. al., Chem. Vap. Deposition, **19**, 186–193, (2013)*
2. *Mane et. al., Physics Procedia, **37**, 722-732 (2012)*
3. *Siegmund et. al. , Physics Procedia, **37**, 803-810 (2012)*

Reproducibility of BKM ALD process for MCPs

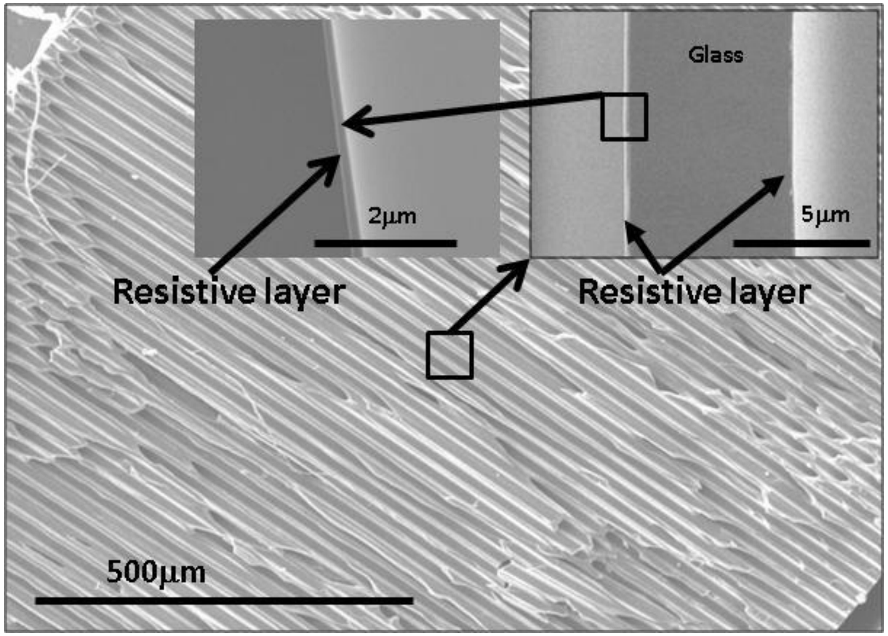


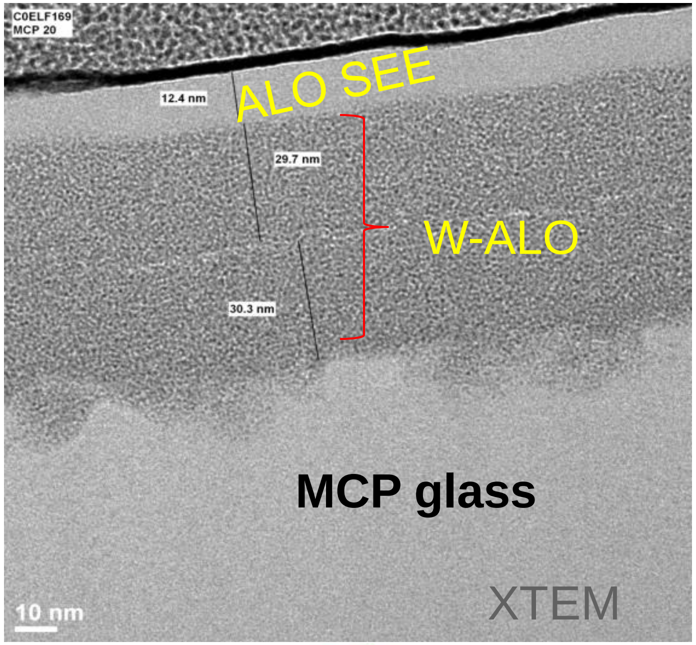


Average R of MCP's = 115 MOhms

- Within a batch and Batch-to-batch reproducibility

Microstructure of W:Al_2O_3 on MCP pore (AR=60)





- Conformal deposition on high AR=60 structure
- Uniform and atomically smooth film

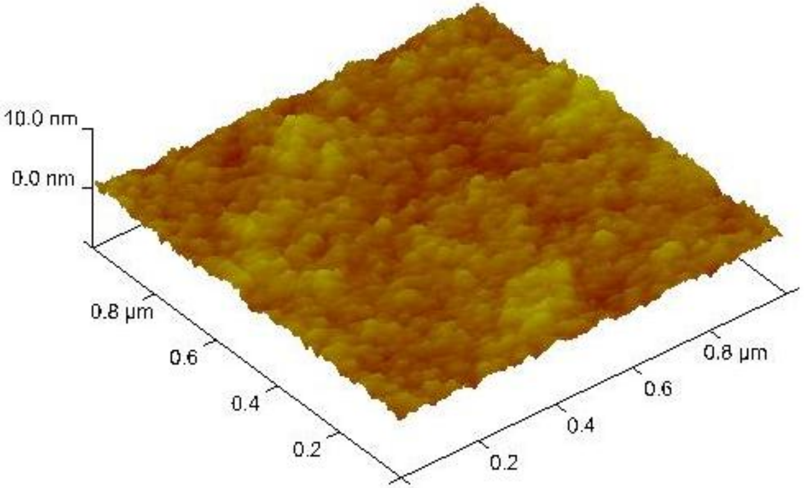
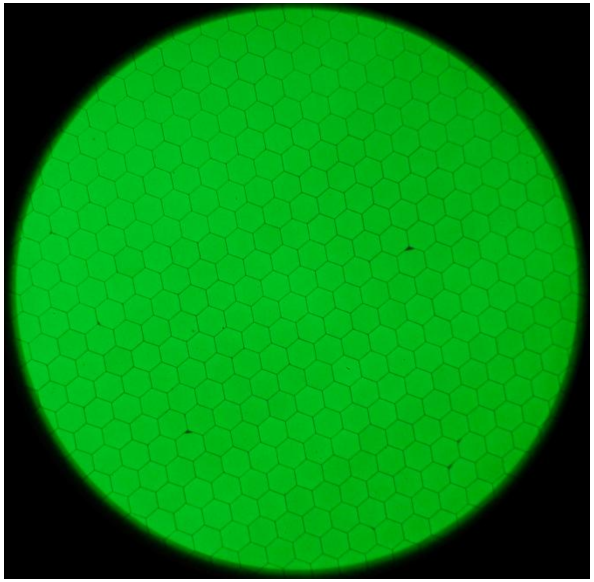


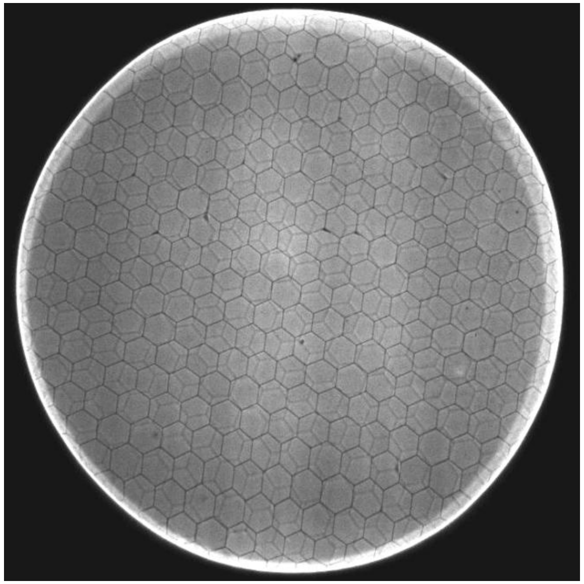
Image a roughness= 0.634 nm

MCP characterization details



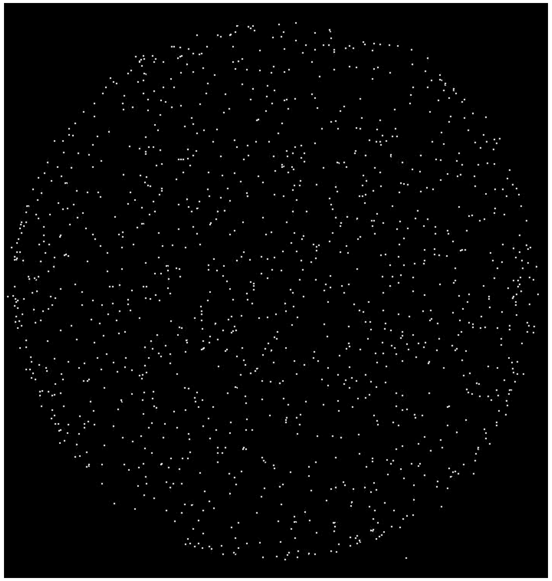
Phosphor image

Single MCP Image (Phosphor)



Gain map

Image of 185nm UV light, **ALD MCP pair, 20µm** pores, 8° bias, 60% OAR, shows top MCP hex modulation and faint MCP hexagonal modulation from bottom MCP

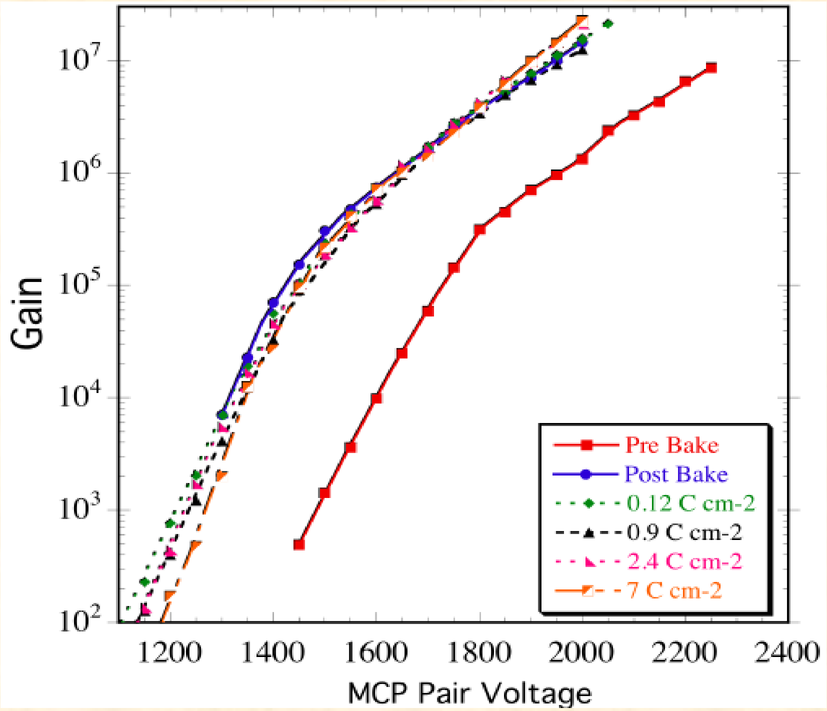


Background counts

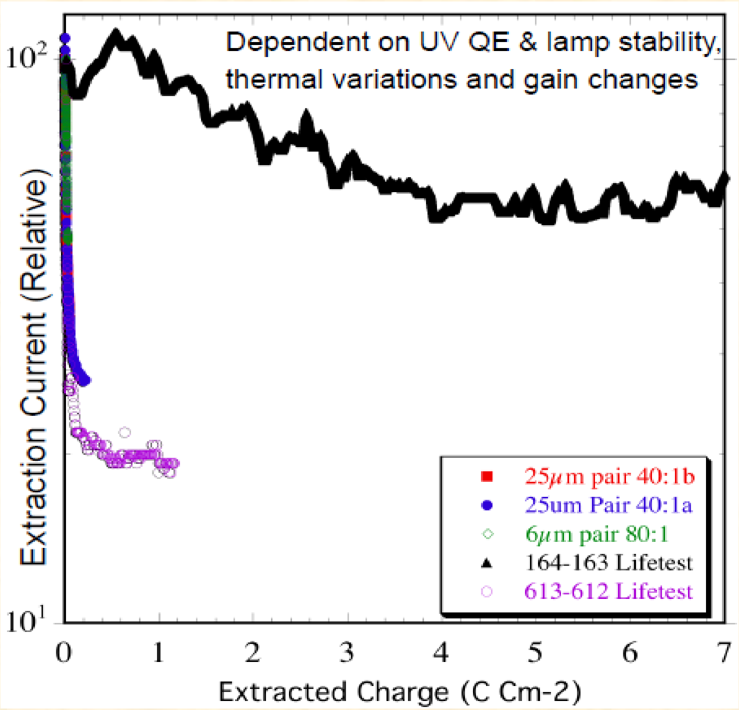
3000 sec background, 0.0845 events/cm^2/sec at 7 x 10^6 gain, 1050v bias each MCP

- Excellent gain uniformity and low background (1/4th of commercial MCPs)

MCPs gain, life test and stability



Gain curves of 164-163 ALD MgO MCP pair (20μm pore, 60:1 L/d, 8° bias) during conditioning.



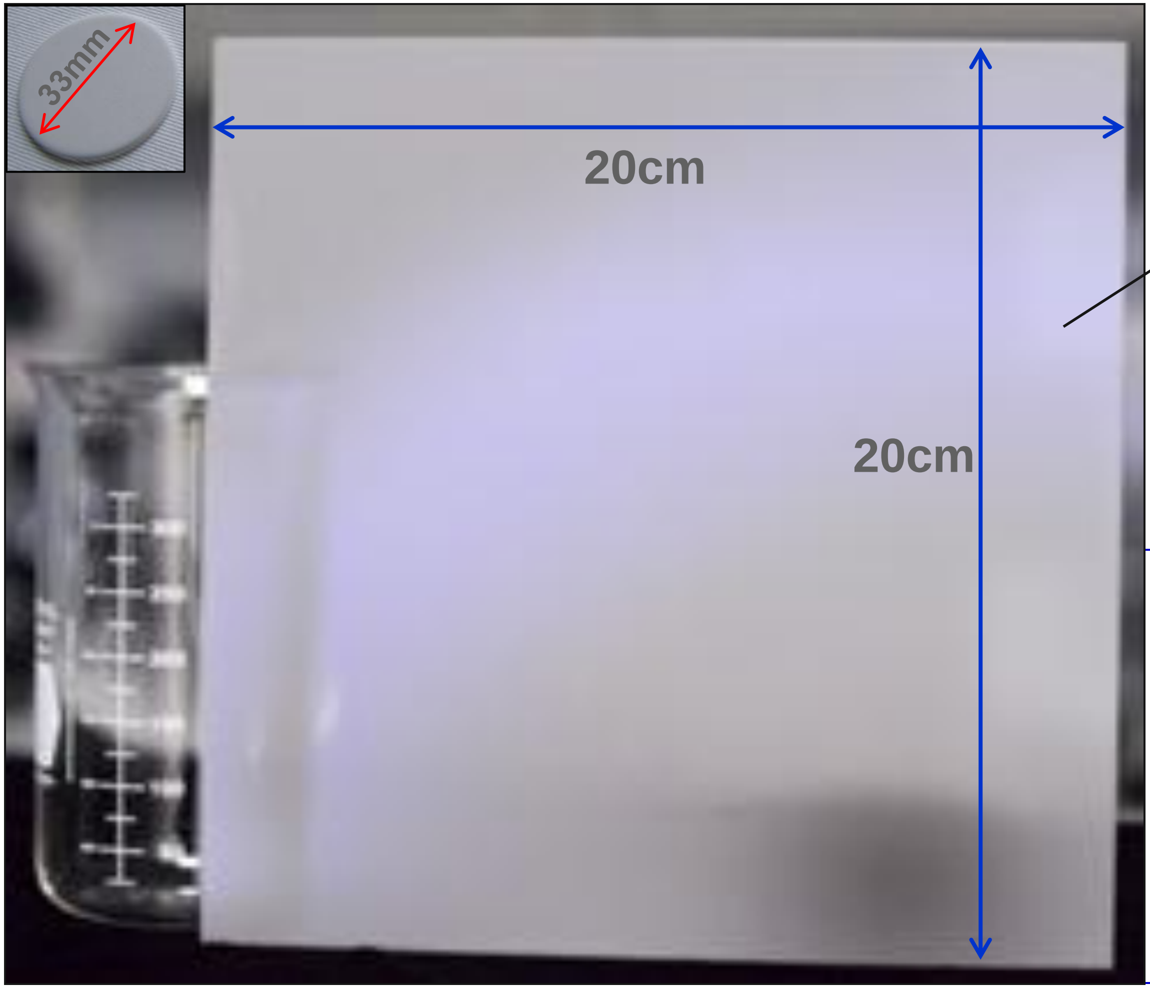
UV "burn-in" of ALD MCP pair 164-163 (20μm pore, MgO, 60:1 L/d, 8° bias) compared with conventional MCPs. Outgas during burn-in < 4 x 10^{-10} torr H_2 for the first 0.05 C cm^{-2}.

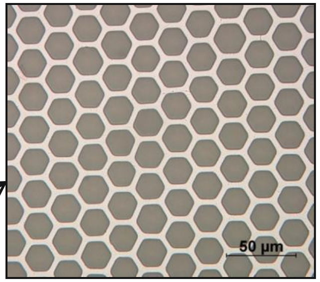
- Stable high gain and long life
- Few days scrubbing in comparison to several weeks for commercial MCPs

Small MCPs processing OK but large area MCPs processing is difficult and challenging

But resolved……..

Large area Capillary Glass Array Substrates for MCPs



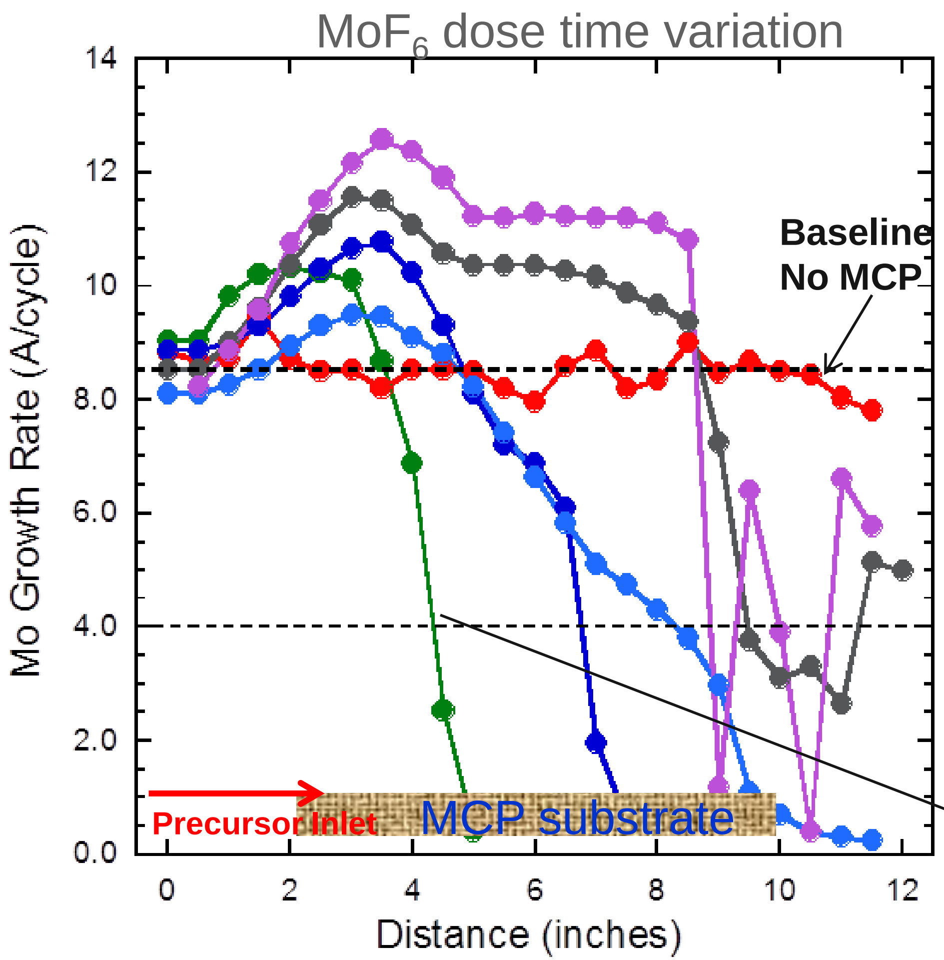


Complex Geometry

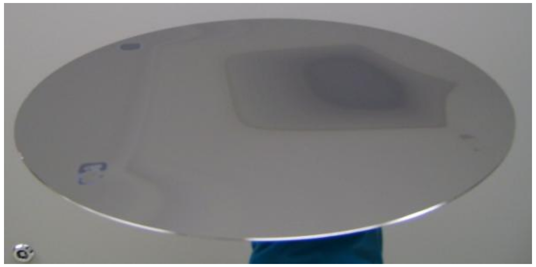
- Surface area = 8.7 m^2
- Pore size = 20μm
- Thickness of plate=1.2mm
- Aspect Ratio = 60
- No. of Pores = ~80Millions
- Porosity = 65%
- Bias Angle = 8°
- Sensitive Surface to OH

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

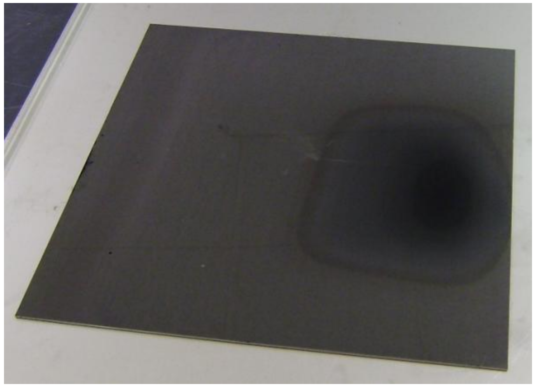
ALD of Mo on Large Area MCPs in conventional cross-flow ALD reactor



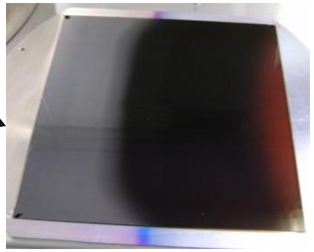
Underneath 300mm Si wafer



MCP substrate after Mo



MCP substrate after Mo



- Very high thickness non-uniformity for Mo

Finally we learned how to coat large area MCP substrates by ALD method

US 20140220244A1

(19) **United States**

(12) **Patent Application Publication**

Mane et al.

(10) **Pub. No.: US 2014/0220244 A1**

(43) **Pub. Date: Aug. 7, 2014**

(54) **ALD REACTOR FOR COATING POROUS SUBSTRATES**

(71) Applicant: **UChicago Argonne LLC**, Argonne, IL (US)

(72) Inventors: **Anil U. Mane**, Downers Grove, IL (US); **Joseph Libera**, Clarendon Hills, IL (US); **Jeffrey W. Elam**, Elmhurst, IL (US)

(73) Assignee: **UChicago Argonne LLC**, Argonne, IL (US)

(21) Appl. No.: **14/175,396**

(22) Filed: **Feb. 7, 2014**

Related U.S. Application Data

(60) Provisional application No. 61/761,988, filed on Feb. 7, 2013.

Publication Classification

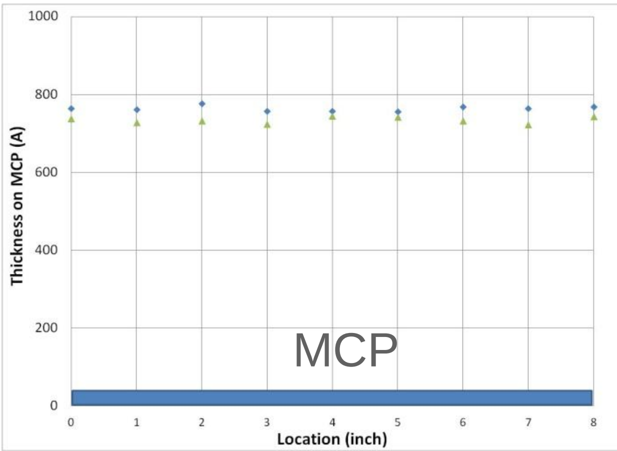
(51) **Int. Cl.**
C23C 16/455 (2006.01)

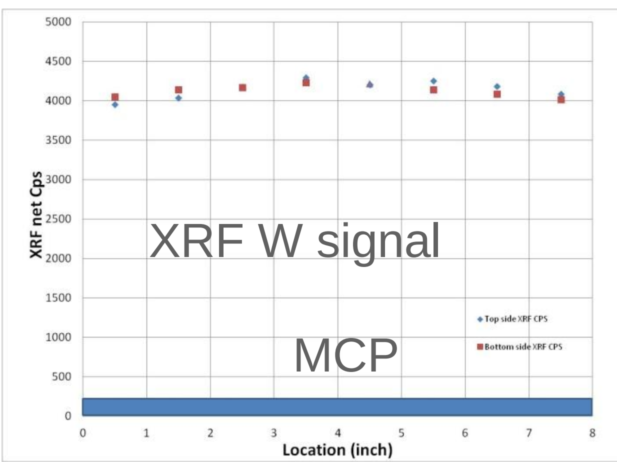
(52) **U.S. Cl.**
CPC ***C23C 16/45565*** (2013.01)
USPC **427/209**; 118/728; 118/715

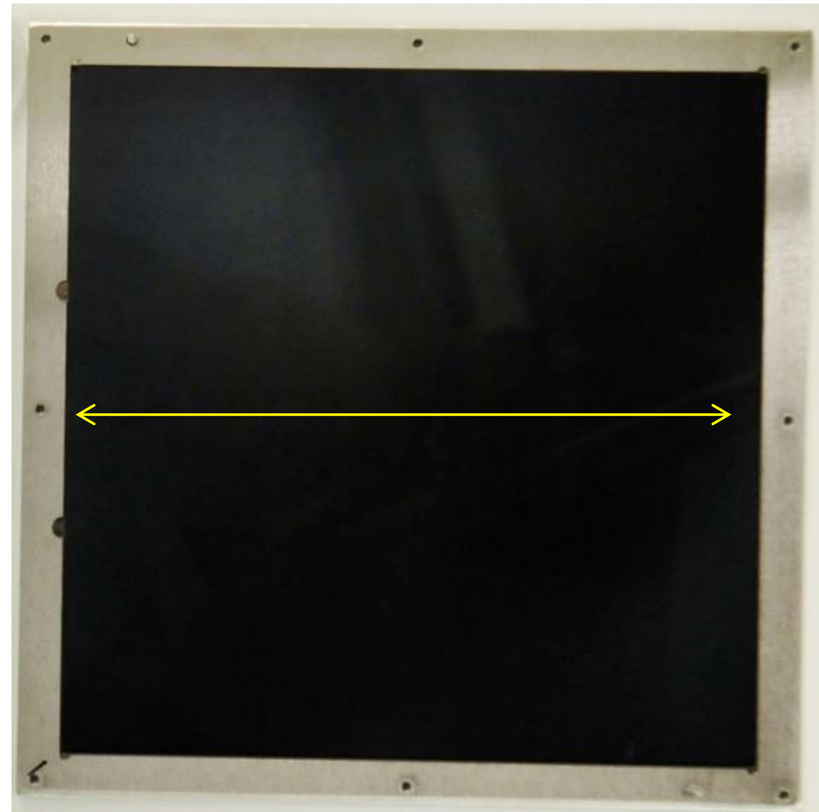
(57) **ABSTRACT**

A system and method for improved atomic layer deposition. The system includes a top showerhead plate, a substrate and a bottom showerhead plate. The substrate includes a porous microchannel plate and a substrate holder is positioned in the system to insure flow-through of the gas precursor.

ALD of composite W:Al_2O_3 on Large Area MCA







- Uniform thickness and composition

Uniformly coated ~80millions 20 micron pores with aspect ratio = 60 by ALD with complex materials

R&D Magazine

2012

R&D 100 Winners

50th ANNIVERSARY

Press release: *R&D* Editors Announce 2012 R&D 100 Awards

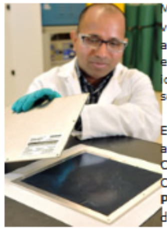
Award Winners

Larger microchannel plates at less cost

Wed, 08/22/2012 - 8:11am

Get today's R&D headlines and news - Sign up now!

2012 R&D 100 Winner



IM725_ANL_MicrochannelPlate

Microchannel plate (MCP) detectors are a key supporting technology for a variety of imaging and sensing applications in medicine, physics, and safety and security applications. Built from a 2D array of microscopic channel electron multipliers on thin, flat plates, MCPs identify low levels of electrons, ions, photons, or neutrons, and provide an amplified response via gain from secondary electron emissions that occur within the channels of the MCP.

Existing manufacturing processes are expensive, limiting widespread adoption. **Argonne National Laboratory**, Argonne, Ill., **Incom Inc.**, Charlton, Mass., and **Berkeley Space Sciences Laboratory**, Berkeley, Calif., have introduced a new invention, the **Large-Area Microchannel Plates** (MCP), which represents a cost-effective route for producing MCP detectors. Two new technologies have been combined to achieve the cost reduction: large-area capillary glass array plates developed by Incom using a novel hollow-core strategy; and atomic layer deposition (ALD) coatings developed at Argonne.

Unlike conventional multifiber glass manufacturing, which does not allow adjustment of electron emission properties, Incom's hollow capillaries dispense with the need to remove core material by chemical etching. Instead of leaded glass, the new process uses environmentally friendly borosilicate glass. The addition of ALD coating functionalizes the capillary array wafers to impart the necessary conductivity and secondary emission properties. When used for high-volume manufacturing, this fabrication technology, the developers predict, will reduce cost by a factor of three to five.

Technology
Microchannel plate detector

Developers
Argonne National Laboratory
Berkeley Space Sciences Laboratory
Incom Inc.

Development Team

IM725_ANL_Micro_Team

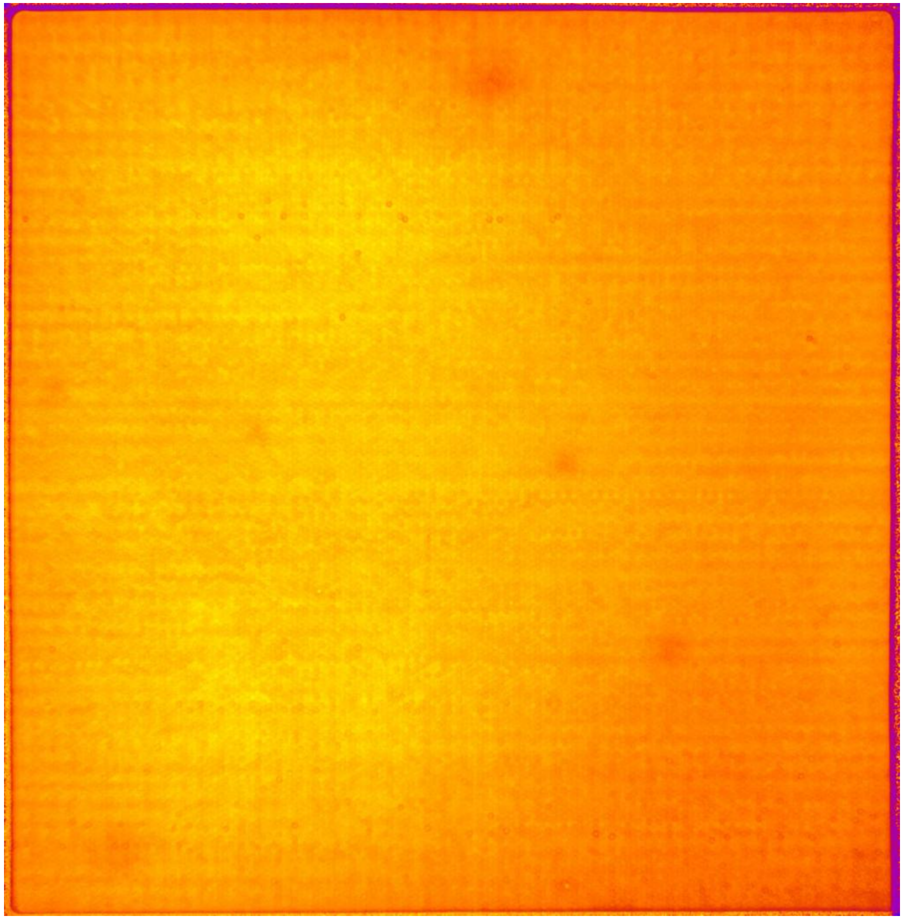
Argonne: Jeffrey Elam, Anil Mane, Henry Frisch, Robert Wagner Berkeley Space Sciences Laboratory: Oswald Siegmund, Jason McPhate Incom: Michael Detarando, Michael Minot

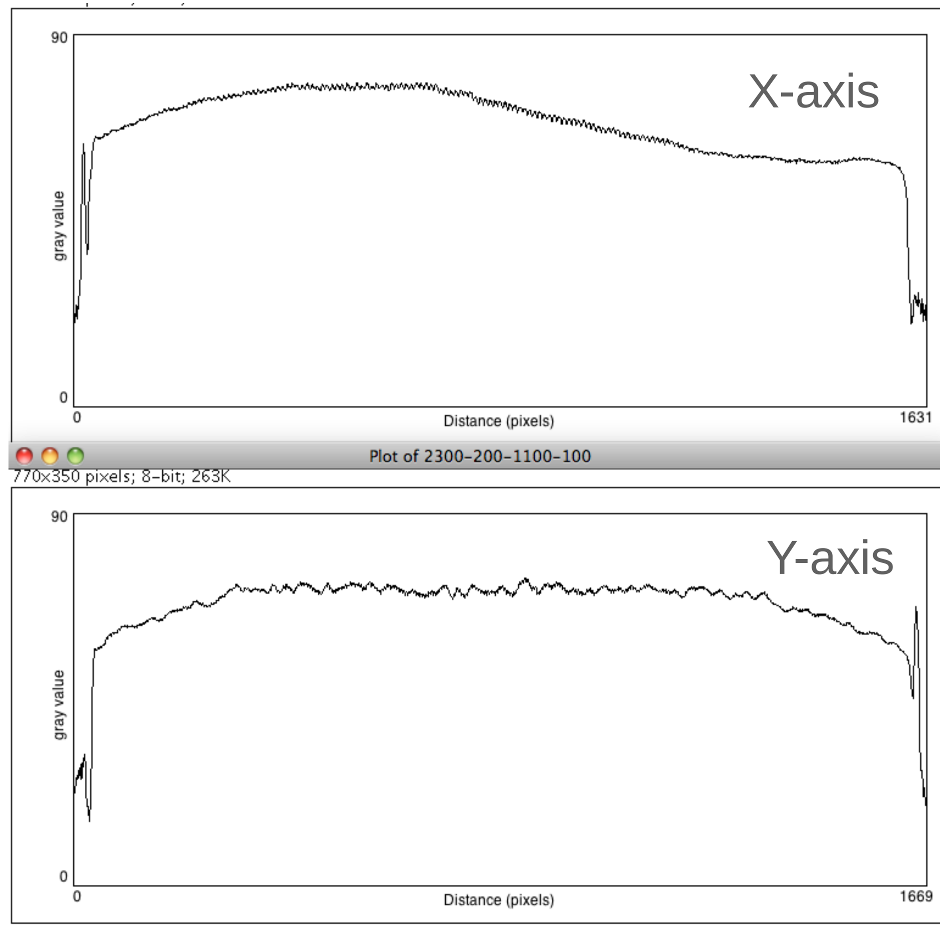
Large area MCPs testing……

UC Berkeley, UoC, APS and ANL HEP

Gain uniformity

Mean gain ~7 x 106

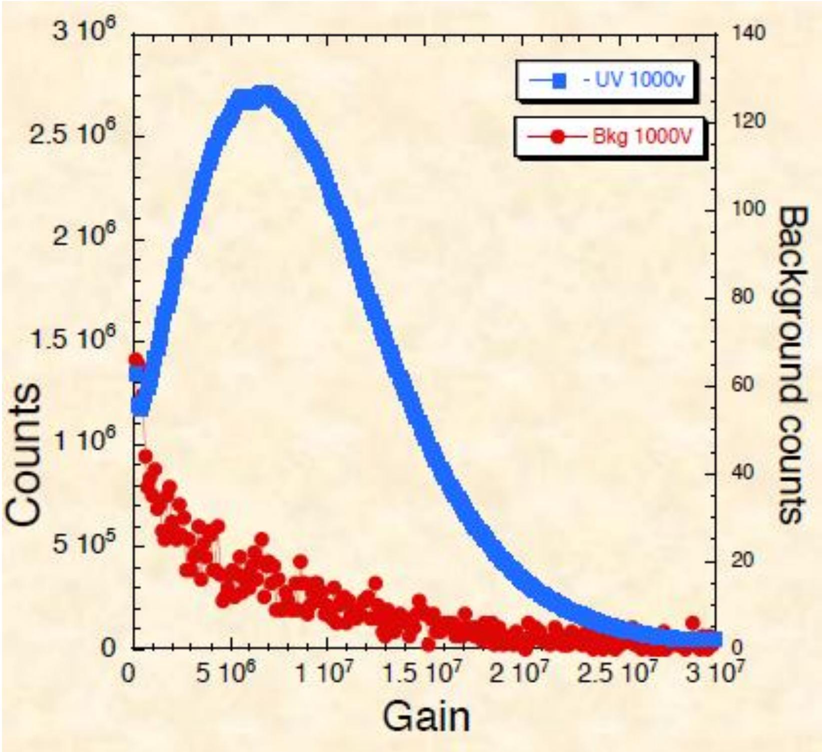




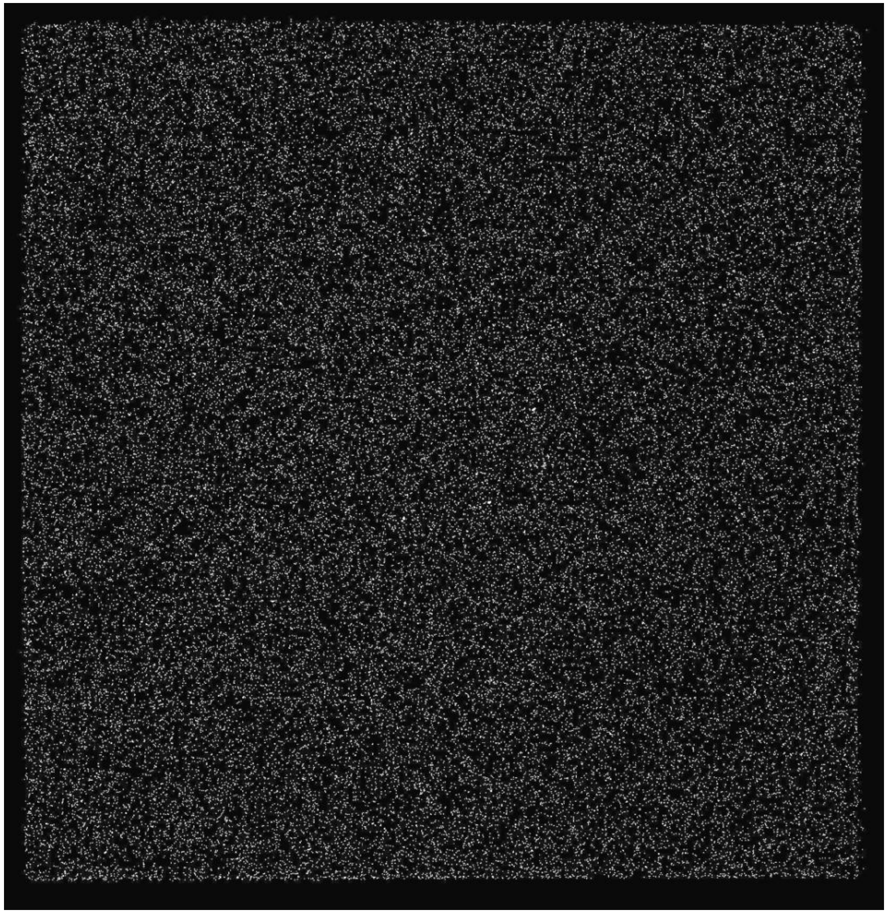
Worlds largest working 20cm x20cm MCP (Gain Map)

Received 2012 R&D 100 Award

Gain map and background

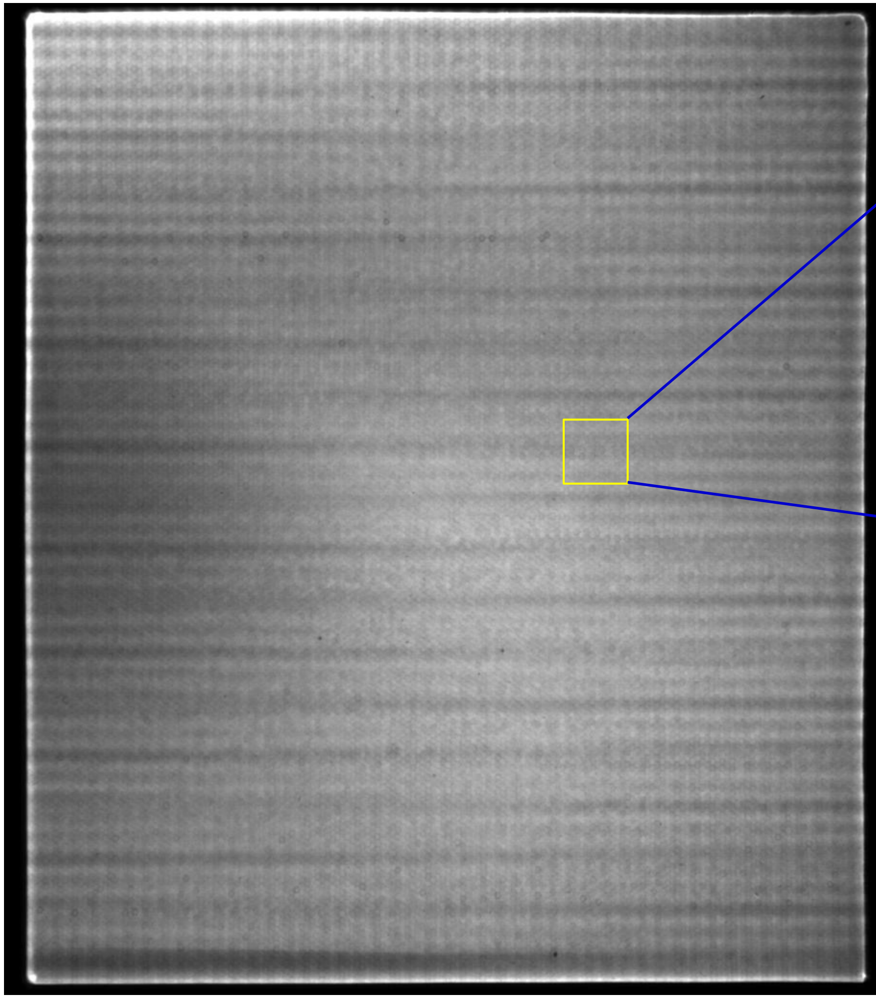


Pulse height distributions for UV and background

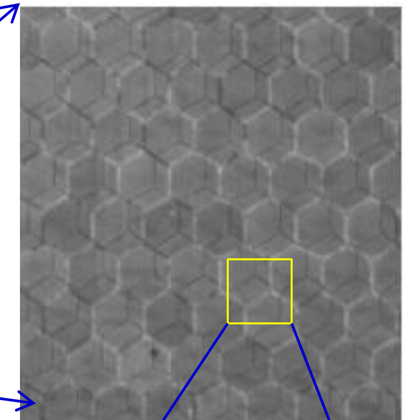


Background very low !! 0.068 counts sec-1 cm-2 is a factor of 4 lower than normal glass MCPs. 20cm MCP pair background, 2000sec,2k x 2k pixel imaging

Gain map cross-delay line readout



Expanded area view showing the multifiber edge effects.



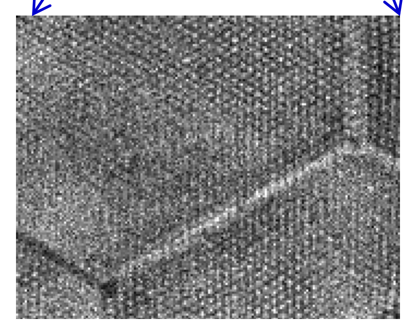
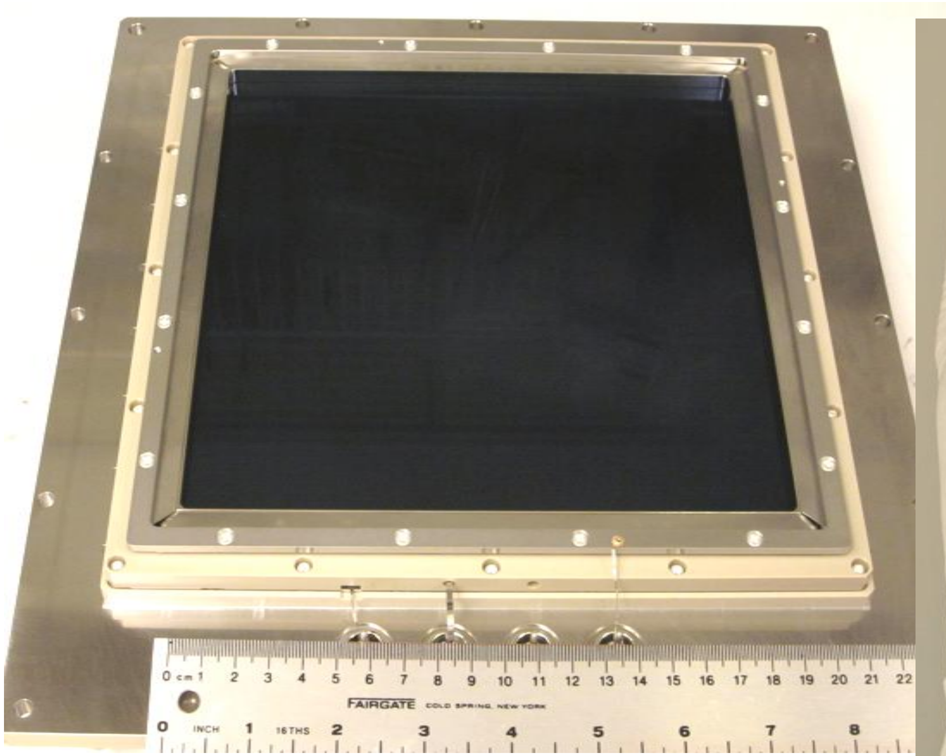
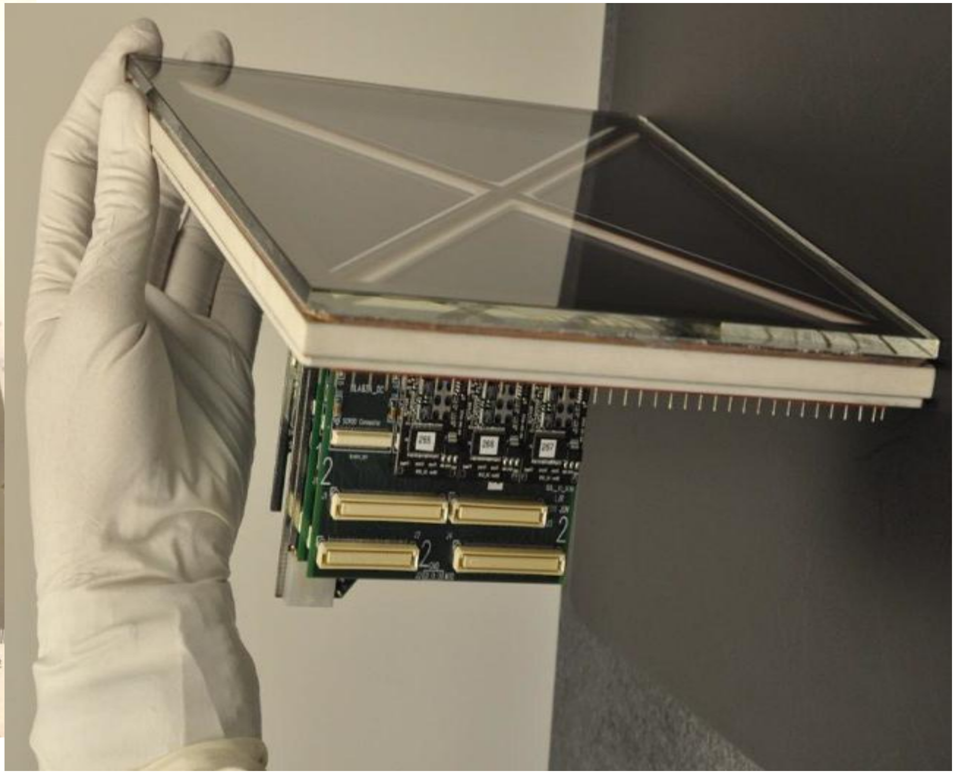


Image striping is due to the anode period modulation as the charge cloud sizes are too small for the anode. 20cm, 20µm pore, Al2O3 SEE, MCP pair image with 185nm non-uniform UV illumination

Large Area photodetector

Courtesy : Prof Ossy



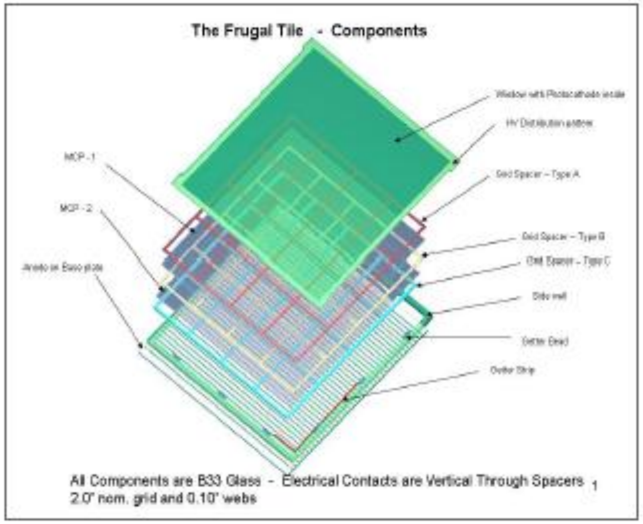


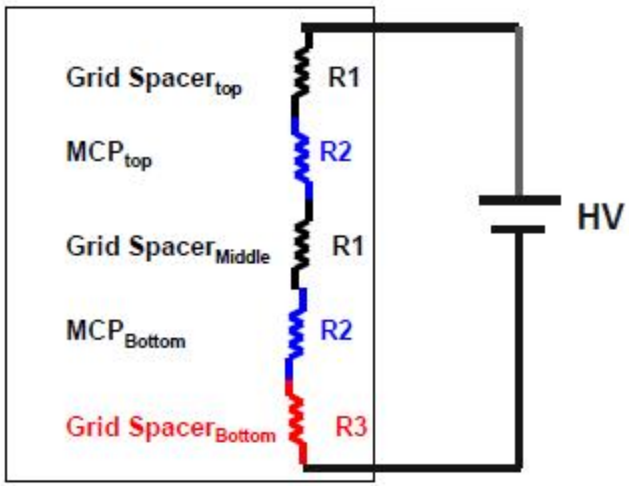
- High Gain (10^5-10^7)
- Very Low Background
- Excellent Stability
- 10x *psec* time resolution
- 100μm spatial resolution
- Less scrubbing timings

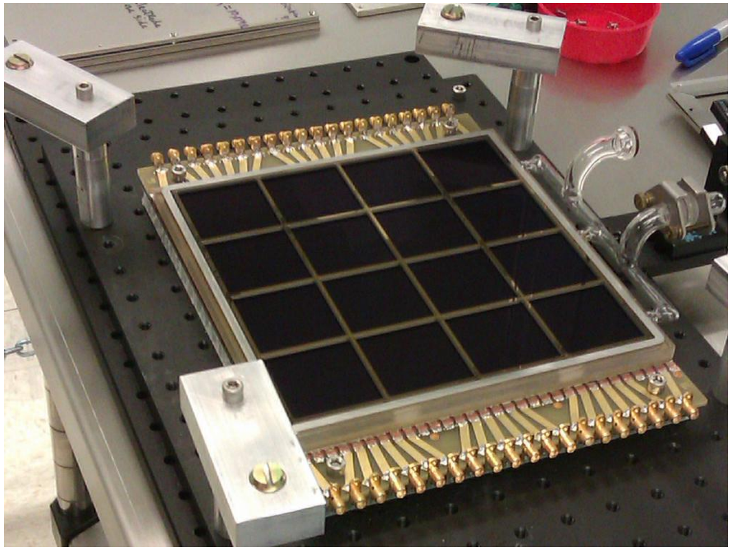
LAPPD concept

Seal device concept

Equivalent circuit diagram



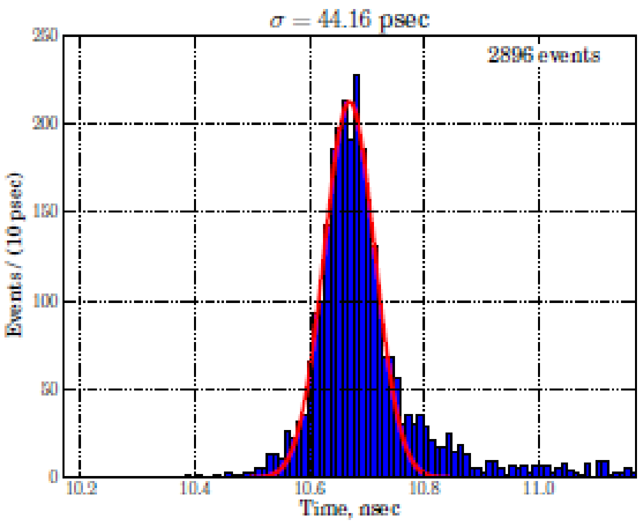


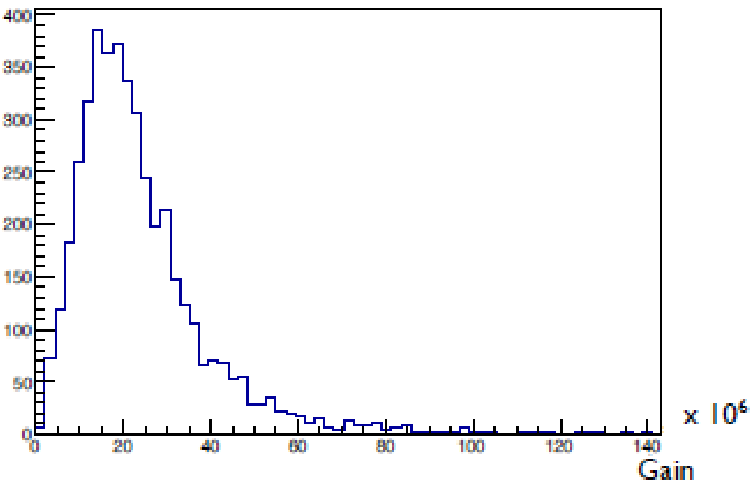


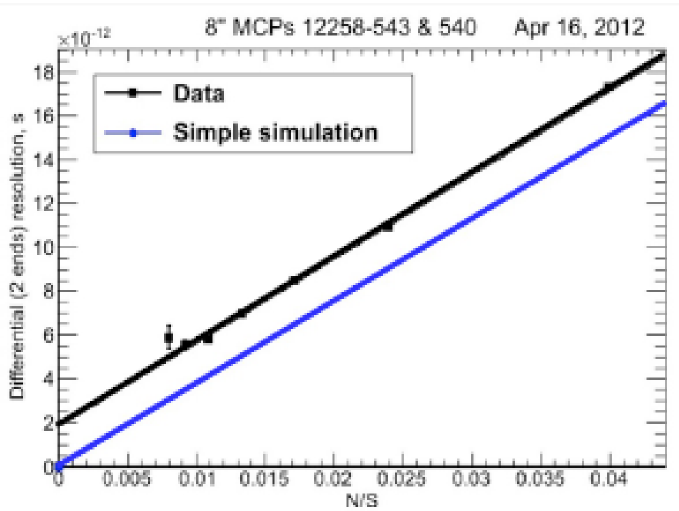
•Makes simple electrical contact
(If all parts are optimized)
•Option for individual component contacts

Courtesy: APS team

we can measure single PE timing and gain characteristics

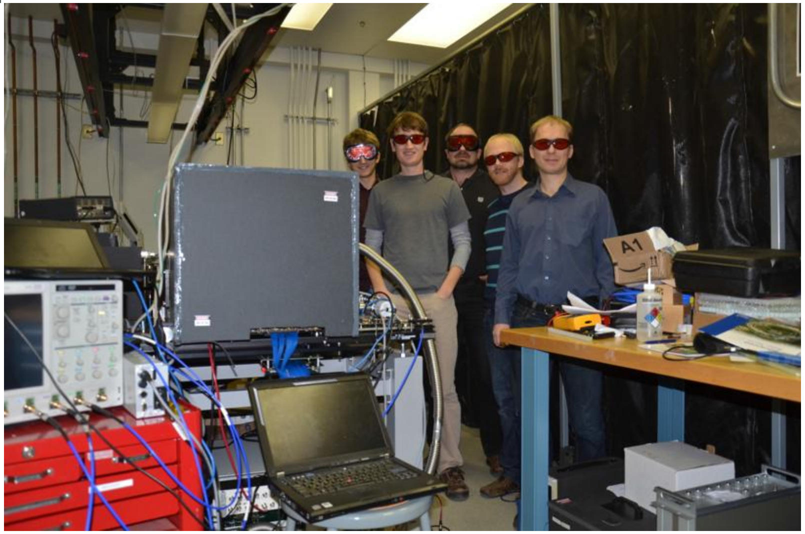






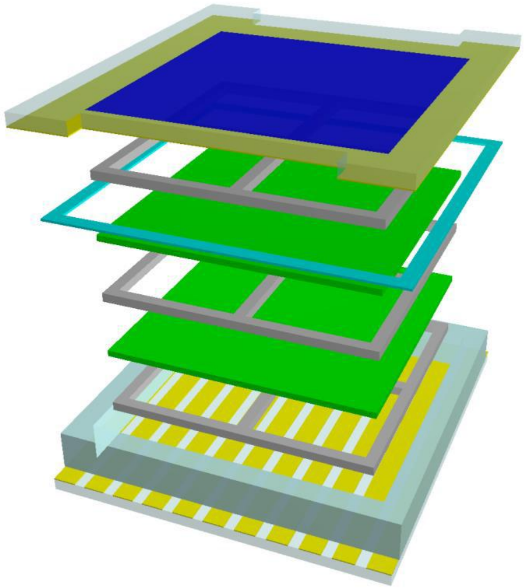
With large signals from many photoelectrons (approaching those expected in collider applications), differential timing approaches few picosecond levels.

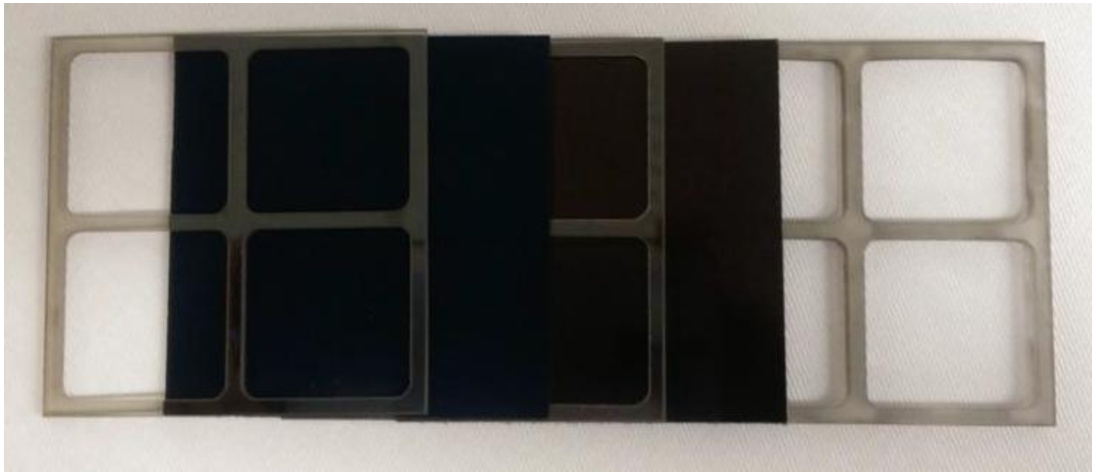
MCP Performance Testing Team
APS, UoC, HEP

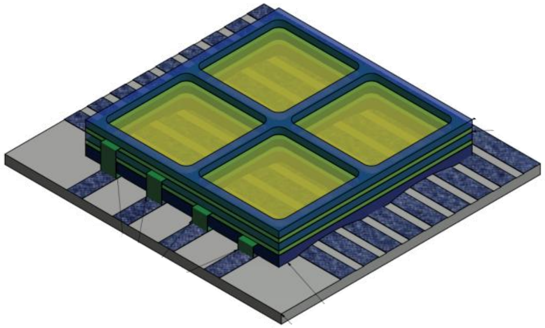


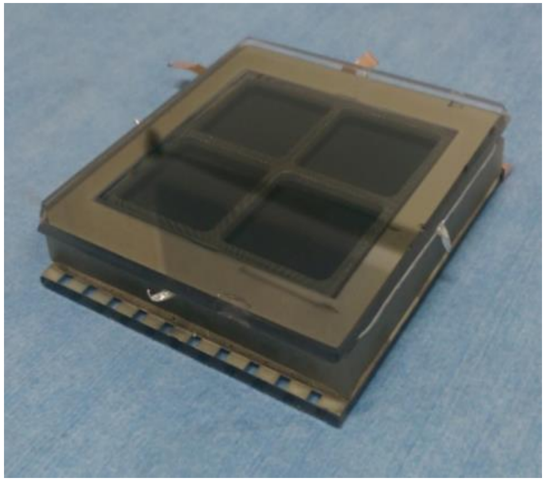
Current R&D on MCPs and photodetector fabrication at ES and HEP

6cm Photodetectors Development









Bi-alkali photocathode (K2CsSb)

Bialkali photocathode deposition facility at HEP

Quantum efficiency for **K2CsSb** achieved ~22%

Standard data sheet for ANL 6cm photodetector

Argonne NATIONAL LABORATORY

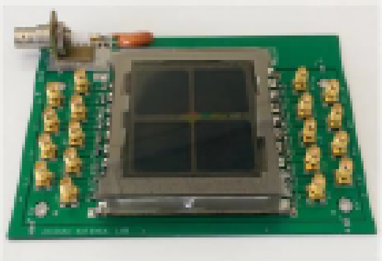
High Energy Physics Division

6cm x 6cm Photodetector Data Sheet

Photodetector Tube No.: # 32
Mfg Date: Oct. 15, 2014

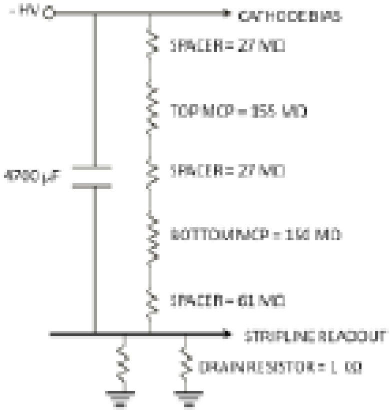
SECTION 1: DESCRIPTION

Window material	Borosilicate glass
Window mask	NiCr
Photocathode type	Bialkali
Multiplier structure	MCP chevron (2), 20 μm pore, 60:1 L:D ratio
Stack structure	Resistor chain design
Anode structure	0.47 cm silver strip line, 0.23 cm space
Active area	6 cm x 6 cm
Package open-area-ratio	65 %



SECTION 2: CHARACTERISTICS

Photocathode Characteristic	
Spectra response range	300 nm ~ 600 nm
Quantum efficiency	Max 20%
Timing Characteristic	
Operation voltage	2100 V - 2600 V
Transition speed	1.8 mm/ns
Gain	1e6 - 1e7
Single Photoelectron	
Time resolution	57 ps
Position resolution	/
Multi Photoelectron	
Time resolution	16 ps
Position resolution	<0.5 mm



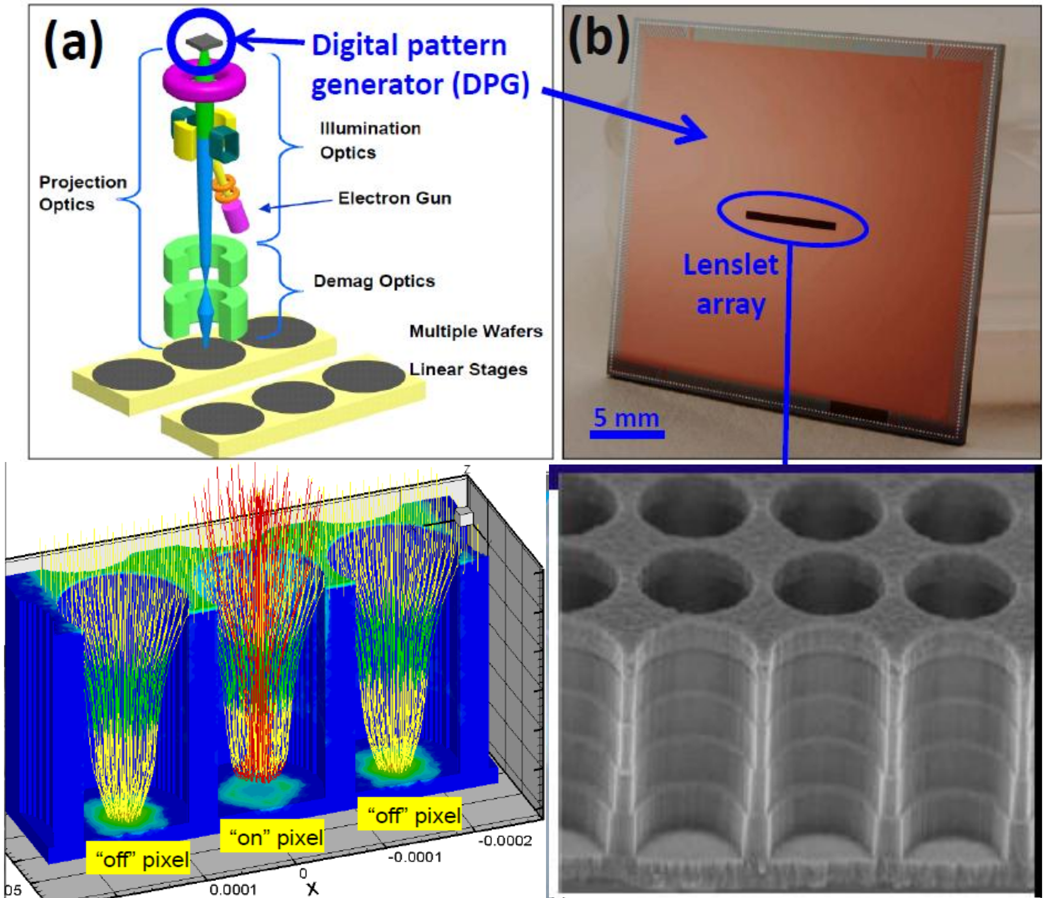
Charge dissipation coatings for electron optics

Resistive coating (Mo:Al_2O_3) application to MEMS devices

KLA-Tencor: "Reflective Electron Beam Lithography (REBL)" tool

-REBL is a maskless nanowriter system writes device patterns directly on the wafer via electrons

-Targeting high-volume (100 wph) 10 nm logic node performance for competitive cost of ownership.



MEMS device:

- **CMOS controlled (248 x 4096) electron-optical mirror array (lenslets) at 1.6 µm pitch)**
- **Pixel On/Off switch by modulation of bottom potential**

1.Gubiott et al., Proc. of SPIE Vol. 8680 86800H-1

2.Tong et al, Appl. Phys. Lett. 102, 252901 (2013)

MEMS Lenslets structure:

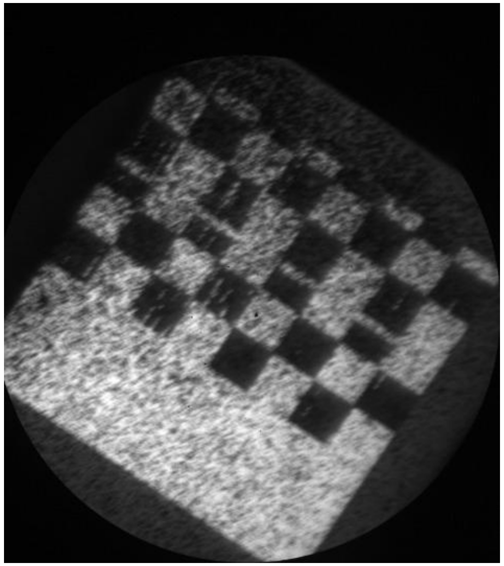
- Oxide and metal electrode planes
- Reflection of electron by adjusting ΔV on electrodes

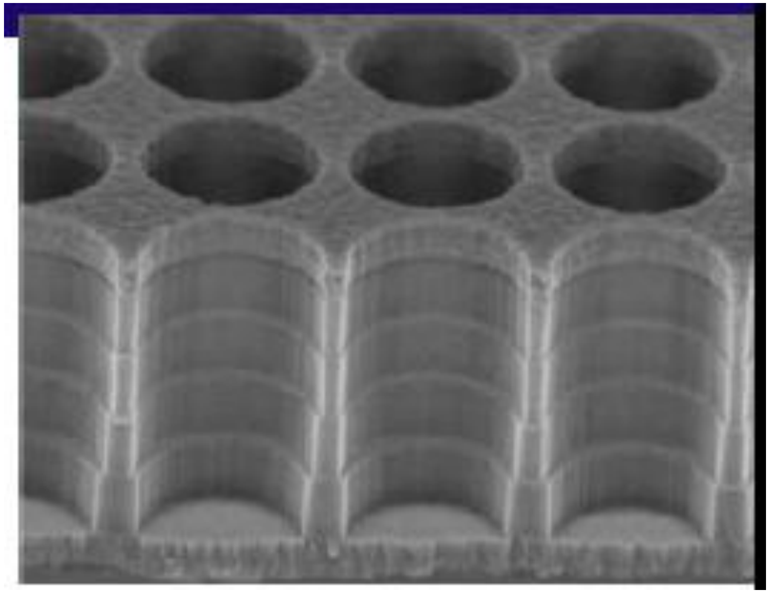
Charge drain coating ($Mo:Al_2O_3$) application to MEMS devices

Major Issues:

- MEMS device charging
- Electrical breakdown
- Shorter life (stability)

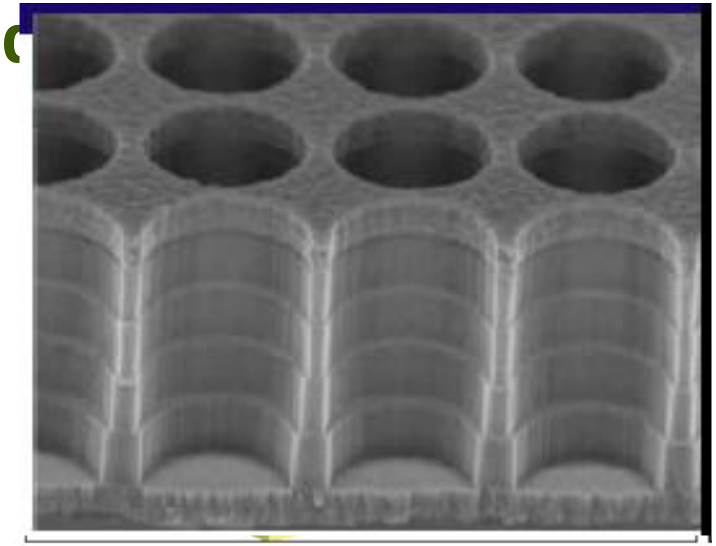
1.Gubiott et al., Proc. of SPIE Vol. 8680 86800H-1
2.Tong et al, Appl. Phys. Lett. 102, 252901 (2013)

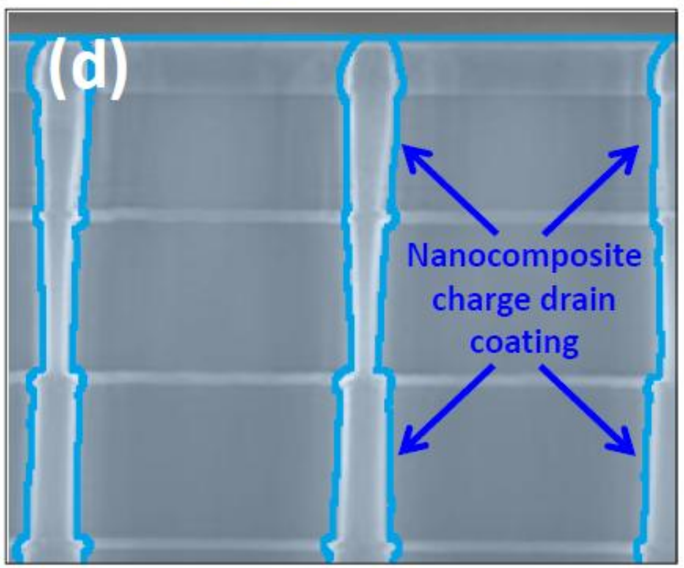




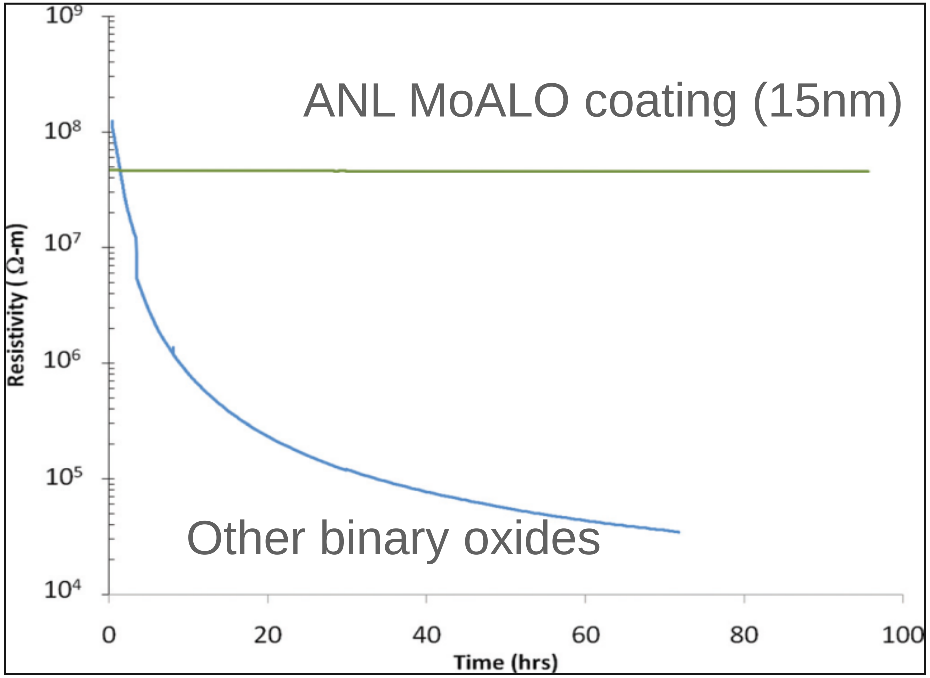
- Non-performing segments of the MEMS lenslets caused by charge accumulation

Resistive coating ($Mo:Al_2O_3$) application to MEMS





Coating stability



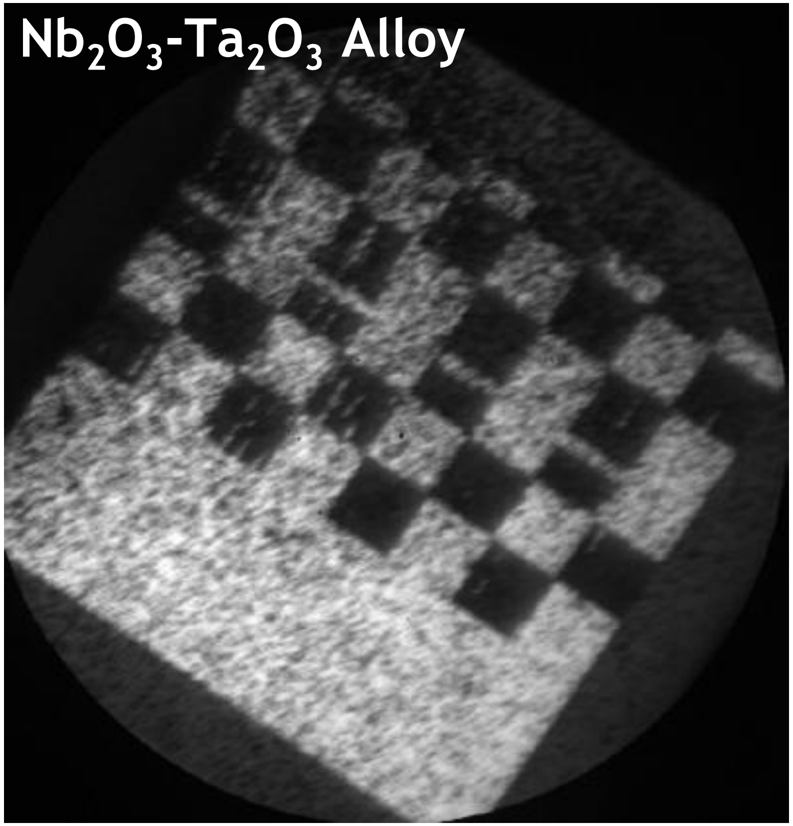
- **Stable materials**
- **Sustains high electric fields (25MV/cm)**

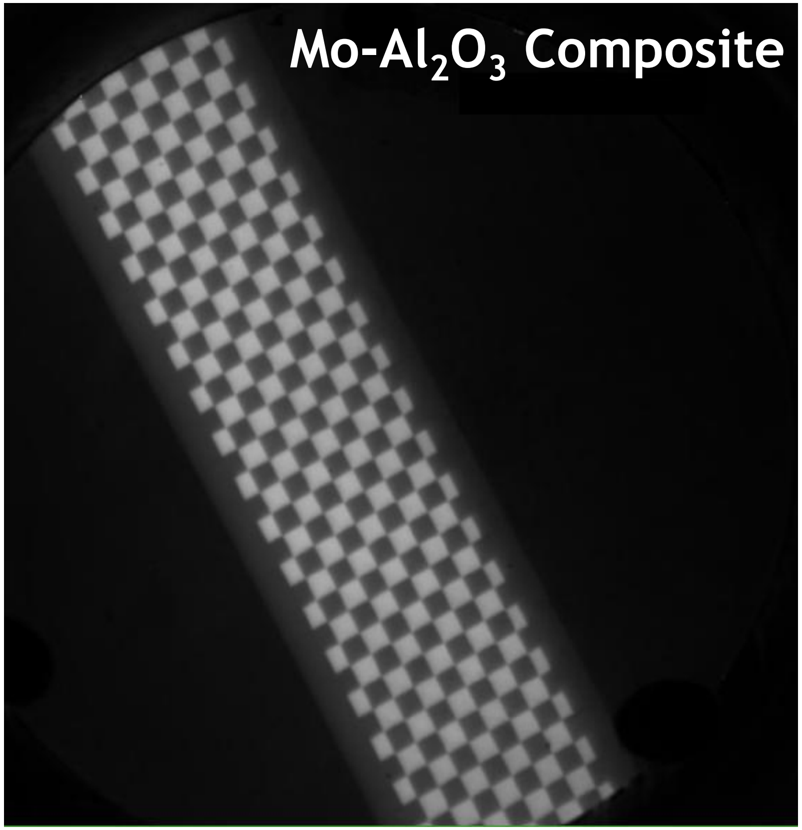
Lenslets structure:

- Oxide and metal electrode planes
- Reflection of electron by adjusting ΔV on electrodes

Performance of ALD Mo-Al_2O_3 Composite Film on DPG

Images of DPG test pattern on phosphor screen:

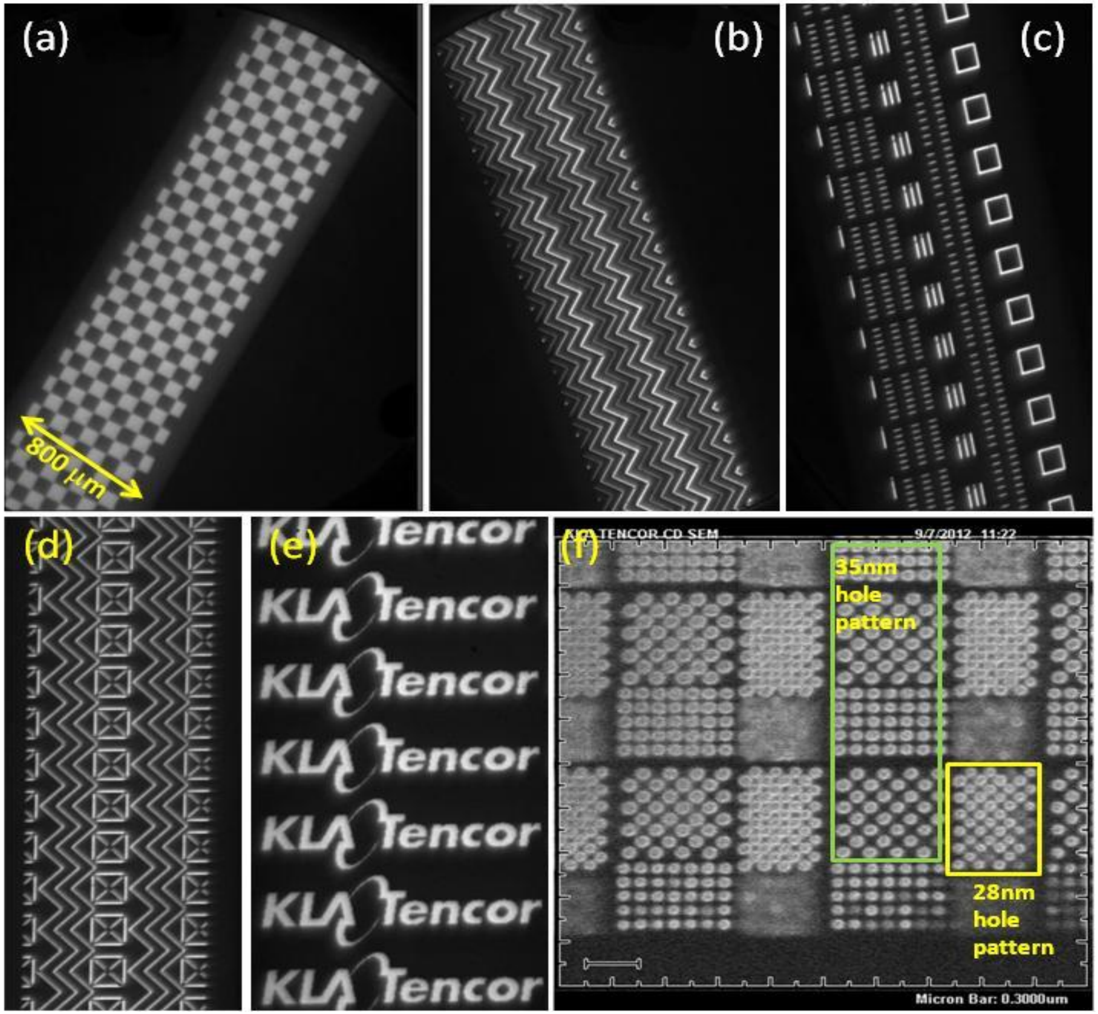




- Improved resolution and contrast using Mo-Al_2O_3 composite film

Charge drain coating ($Mo:Al_2O_3$) application to MEMS devices

Test patterns of functional CMOS DPG chips imaged coated with 15nm ALD $Mo:Al_2O$



1.Gubiott et al., Proc. of SPIE Vol. 8680 86800H-1
2.Tong et al, Appl. Phys. Lett. 102, 252901 (2013)

R&D Magazine

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Award Winners

Coatings Quash Harmful Charges

Thu, 08/29/2013 - 1:23pm

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2013 R&D 100 Winner

ANL Nanocomposite Charge Drain Coatings

Electrostatic charging can be an annoyance at the macroscale; but in development of ion- and electron-optical devices, as well as microelectromechanical systems, this phenomenon can be severely detrimental to performance. In response, **Argonne National Laboratory** and **KLA-Tencor Corp.** have designed thin films that can prevent electrostatic charge from accumulating on virtually any surface. These **Nanocomposite Charge Drain Coatings** can be deposited over complex 3-D surfaces, offer excellent stability over a wide range of operating conditions and high electric fields. Fabricated using atomic layer deposition, thehe coatings seamlessly blend both conducting and insulating materials. By controlling the ratio of these components, the resistivity of the charge drain materials can be adjusted over a wide range to suit a particular application.

Technology

Nanocomposite coatings

Developers

Argonne National Laboratory
KLA-Tencor Corp.

Development Team

Nanocomposite Charge Drain Coatings

How we can use MCP-based detectors for “X-ray Beam Position Monitoring” ?

Some thoughts and discussion with Dr. Kamlesh Suthar

Objectives:

- **Focus on simple scheme**
- **Economical (especially when quantity needed)**
- **How to achieve fine resolution for x-ray beam position monitoring**
- **Each sector detector can talk to each other (optional)**

Concept # 1: For X-ray beam

•Use of only MCPs and gas particles

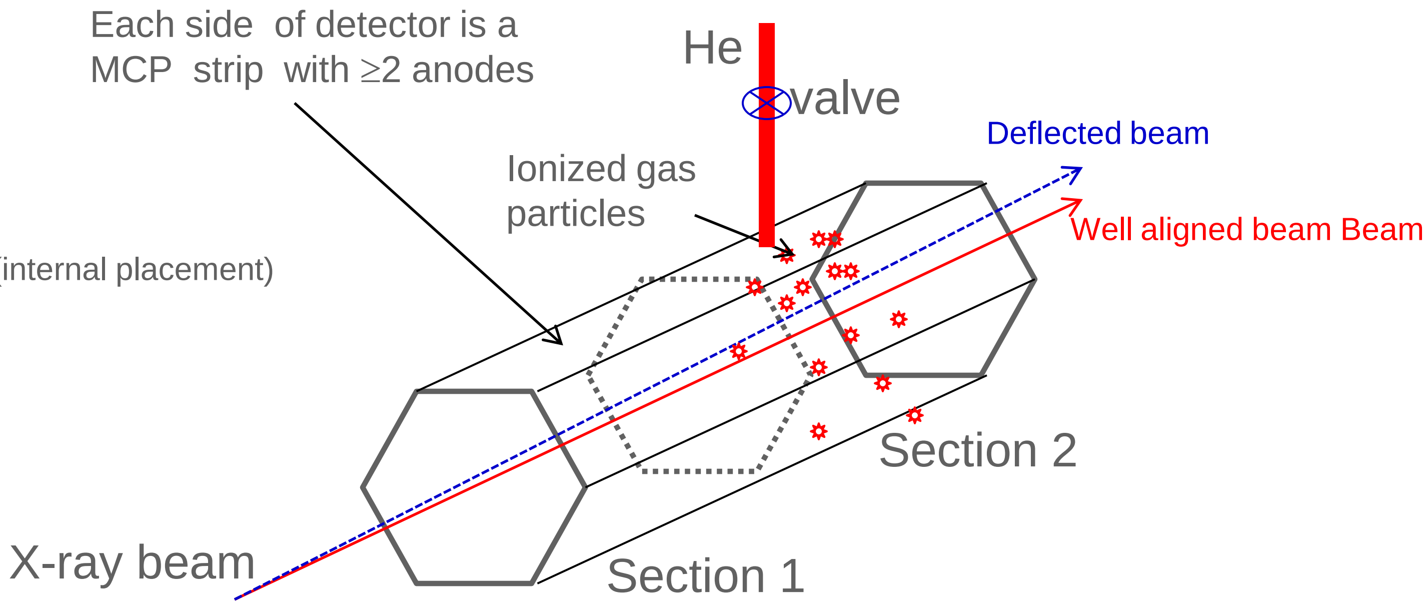
-Similar to GEM detector concept but use of MCPs

-X-ray beam will ionize gas particles and produce electrons in a cascade manner

-These electrons will get amplify by different sections of MCPs but maximum signal will be on one of the section of this detector

•No photocathode

•Use of existing vacuum (internal placement)

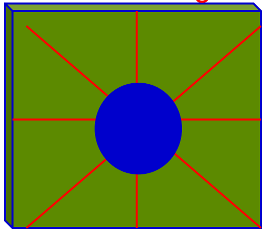


Depend on the signal strength from various anodes and their position, we can adjust the beam position in a feedback loop with alignment magnets

Concept # 2: For X-ray beam

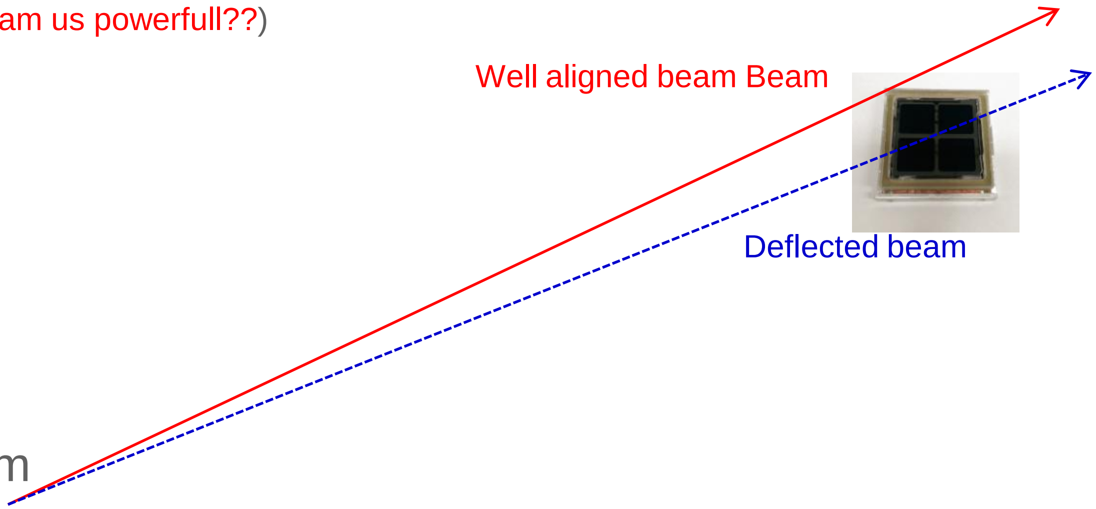
- Use of ANL developed low cost desire size photodetector tubes with ≥4 anodes structures
- X-ray beam will generate electrons form photocathode
- Detector will work as conventional photomultiplier tube

MCP and anode designed stacked



- External placement
- Photocathode needed

(Quality may not matter cause x-ray beam us powerfull??)

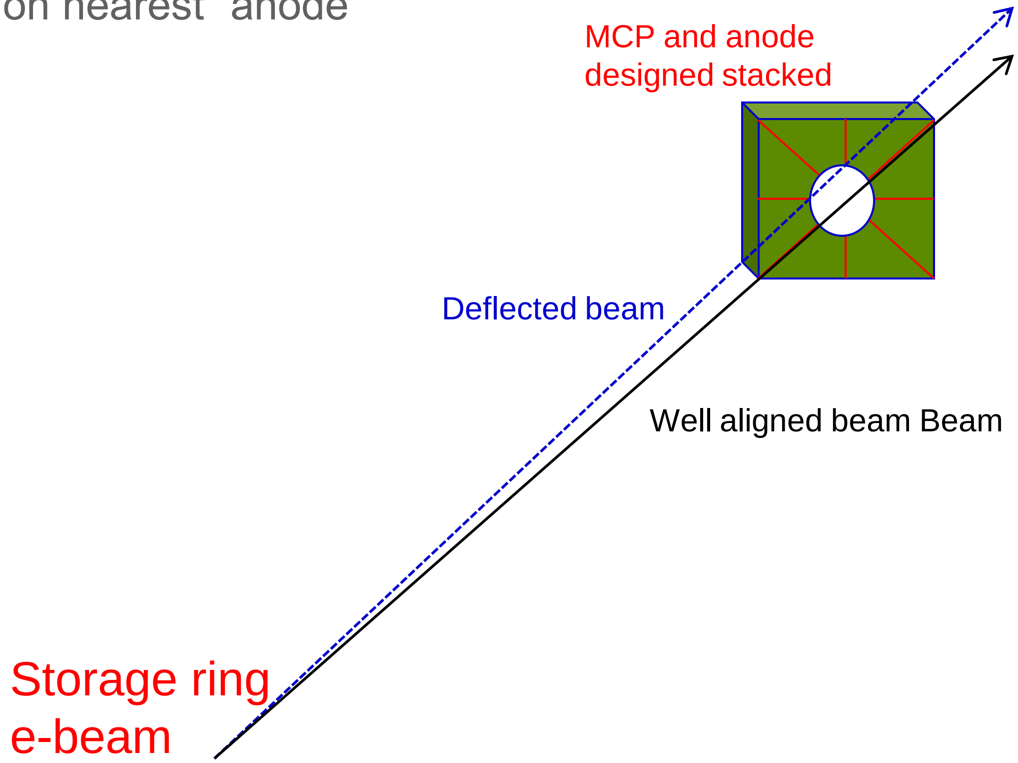


Depend on the signal strength from various anodes and their position, we can adjust the beam position in a feedback loop with alignment magnets

Concept # 3: For e-beam storage ring

•Use of only MCP(s) with ≥4 anodes structures
•Internal placement placement
•Distorted e-beam will fall on active MCP area and will produce current pulse due to electron multiplication on nearest “anode”

•No photocathode
•Use of existing vacuum (internal placement)



Depend on the signal strength from various anodes and their position, we can adjust the beam position in a feedback loop with alignment magnets

Summary

Tried to present flavors of

- **ANL ALD materials synthesis capabilities at ES**
- **Basics of ALD for novel material engineering**
- **MCPs fabrication method and charaterisations**
- **In-house MCP based detector development @ HEP**
- **Applications of ALD coatings**
- **Various achievements**
- **Propose few concepts on MCP-based detectors for “XBPM”**

Thank you!!!

License and technology commercialization

APRIL 16, 2012 CHARLTON, MA. - INCOM Inc, headquartered in Charlton, Massachusetts and The Argonne National Laboratory (ANL), Lemont, Illinois jointly announced today that INCOM Inc. will develop and commercialize cost-effective and robust large-area microchannel plate (MCP) detectors under a license agreement finalized by ANL earlier this month.

Microchannel plate (MCP) detectors are used for detection of particles (electrons or ions) and impinging radiation (ultraviolet radiation and X-rays). This is a critical technology for a wide variety of imaging applications ranging from medicine and physics to national security.