Novel microchannel plate device fabricated with atomic layer deposition

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Outline

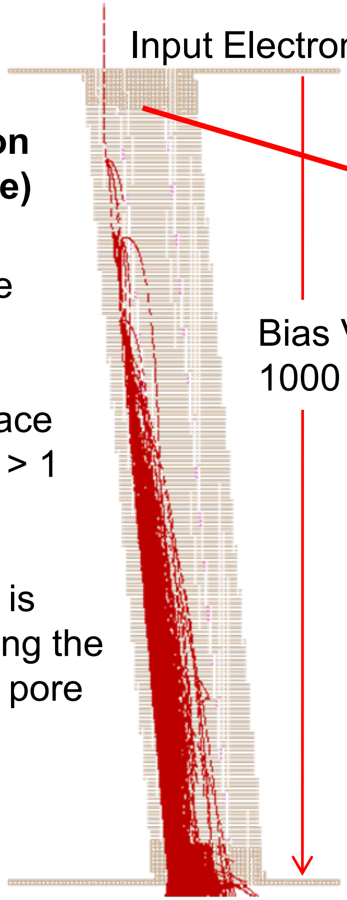
- Microchannel plate (MCP) background
- Key MCP film performance Metrics
- MCP functional thin film technology
  - Secondary electron emissive films
  - Conductive films
- Fast neutron detection application example
- Summary

What is a Micro Channel Amplifier?

Very Fast – Very Low Noise - Charged Particle Amplifier

Single Micro Channel Amplifier
(Pore ~ 0.002 mm in diameter)

Input Electron



Amplification
(SE Cascade)

Electrons are accelerated

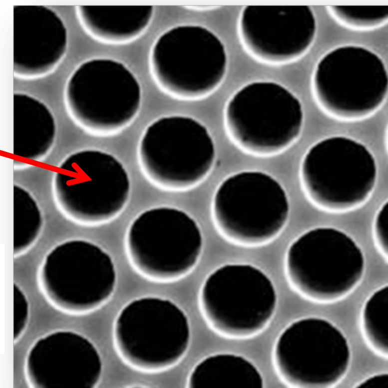
Strike a surface
This creates > 1 electron

The process is repeated along the length of the pore

Bias Voltage
1000 V

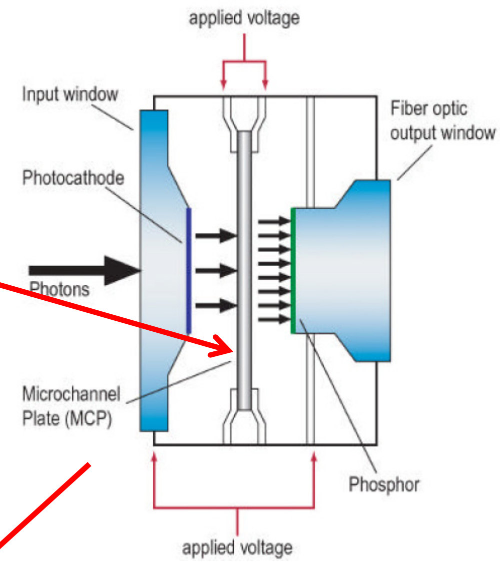
High Gain up to 1e6
Low noise – Very fast pico second response

Micro Channel Plate
(MCP -Array of pores)



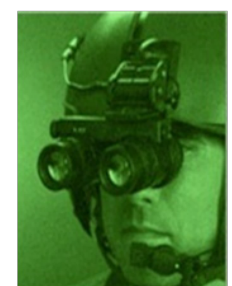
pore diameter ranges from 5-10 um in with an AR of >50:1

Micro Channel Plate
Used In Light Amplification



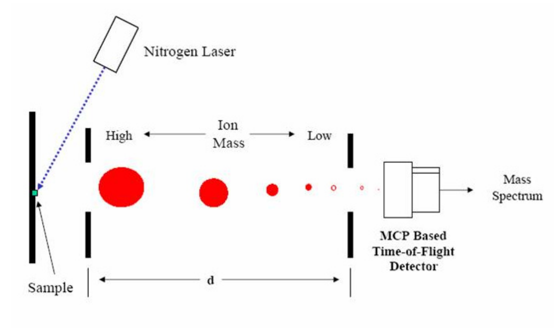
Finished NV Tube

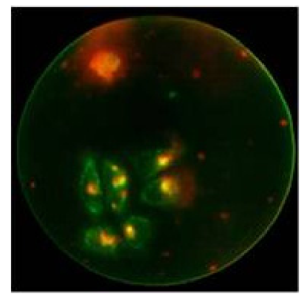
NV Application

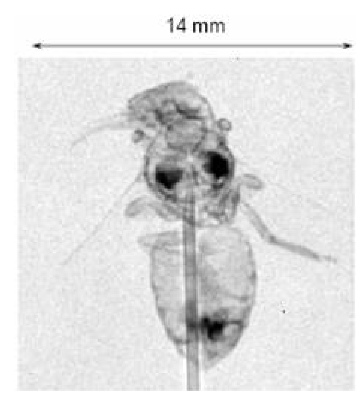


Areas of MCP detector applications

- Night vision goggles
- Mass spectroscopy
- Astrophysics
- Synchrotron instrumentation
- Biomedical research (FLIM, FRET,…)
- X-Ray and UV photon detection
- Neutron radiography and Bragg edge spectroscopy

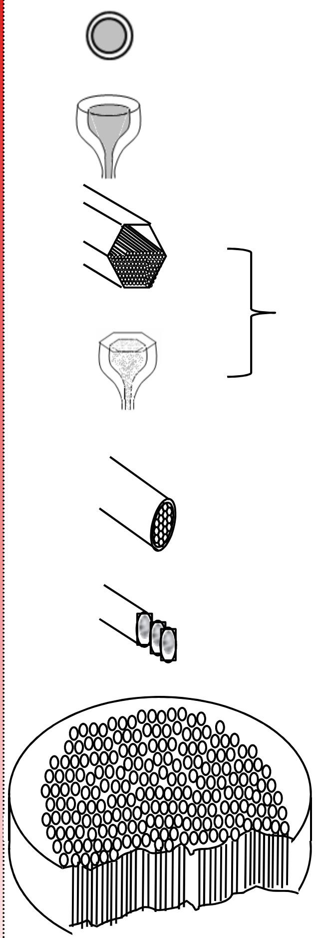






Critical MCP processing: Manufacture

Substrate Fabrication



1” Etch-able Core
Lead Glass Rod

Draw Tower

Stacked
Draw Tower
Repeated

Boule
5-100mm Dia

Diced
0.2-0.3 mm thick

Etched
Producing >5M
2-10 um pores

TABLE 2

Elemental composition of MCP glass[a].

Z	Element	Weight percent
82	Pb	47.8
8	O	25.8
14	Si	18.2
19	K	4.2
37	Rb	1.8
56	Ba	1.3
33	As	0.4
55	Cs	0.2
11	Na	0.1

[a] Density – 4.0 g./cm^3.

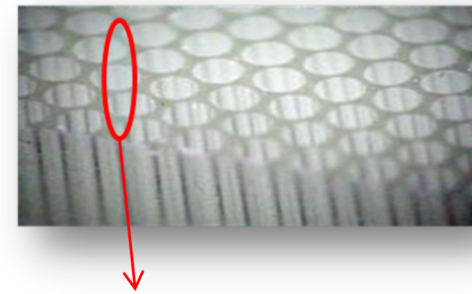
Wiza, Nuclear Inst. & Meth., Vol 162, 1979, 587

(approximate percentages)

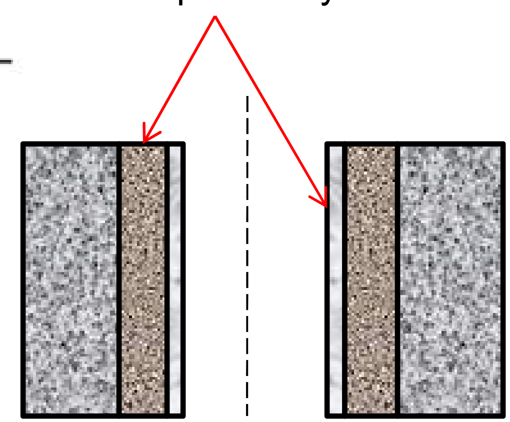
	Conventional 8161 cladding glass	Preferred cladding glass
SiO2	38%	37%
B2O3	0%	2.8%
Al2O3	0.24%	1.35%
Cs2O	0.29%	4.12%
Rb2O	3.7%	0.85%
MgO	0%	0.85%
CaO	0%	2.25%
BaO	2.05%	19.7%
PbO	50.5%	26.6%
Bi2O3	<0.04%	2.48%
As2O3	0%	0.65%
Sb2O3	0%	0.28%
K2O	5.44%	0% (trace)
Na2O	0.34%	0% (trace)
Fe2O3	0.02%	0%

US Pat 6271511

Substrate Functionalize



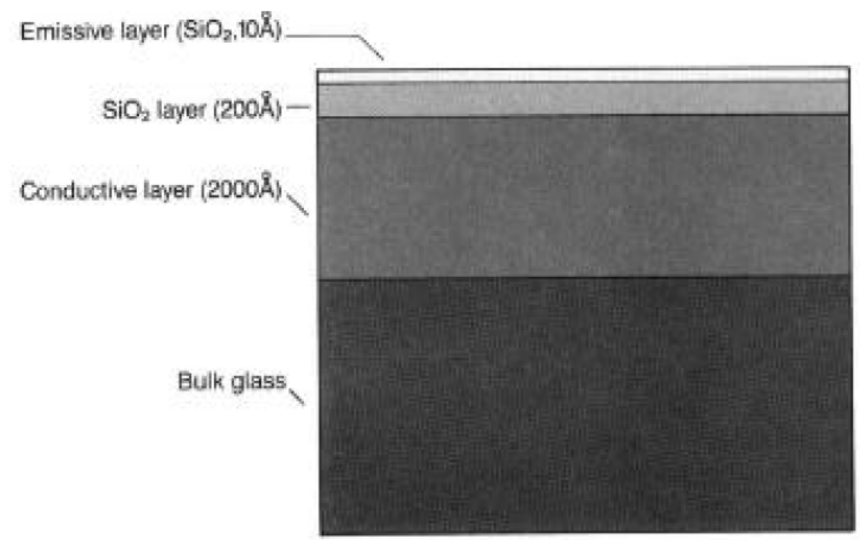
Furnace H_2 Firing
Both conduction and emission layer produced simultaneously and cannot be optimized independently



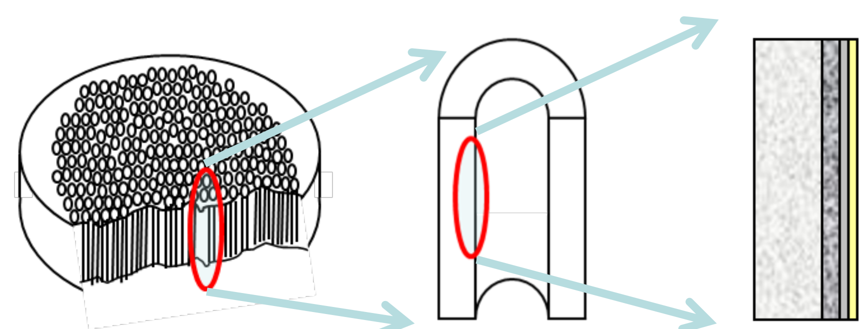
Alternative MCP Substrates: Key Findings

- Substrate
  - Mechanical structure
  - Electrically insulating
- Conductive layer
  - Conformal & uniform
  - ~10^{14} Ohms/Sq
  - Low field effect
- Emissive layer
  - Conformal & uniform
  - High secondary yield
- MCP Device
  - High Gain
  - Resistance stability and matching
  - Stable gain following "scrub"

MCP performance tied to glass composition

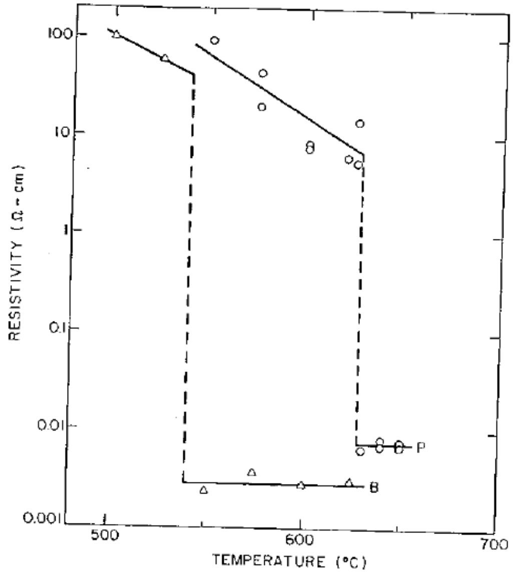


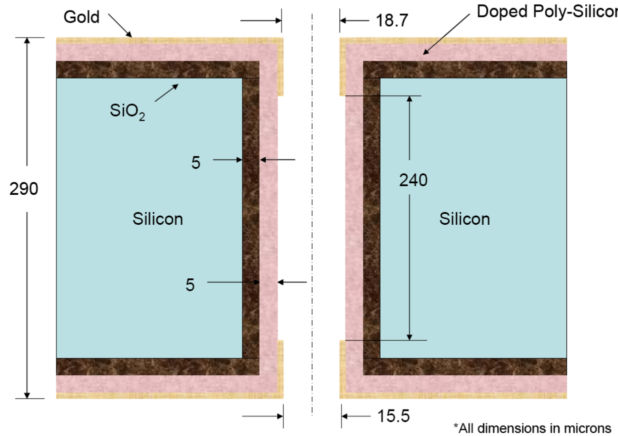
Channeltron electron multiplier handbook (Burle)

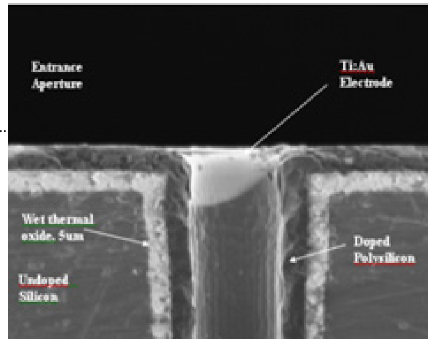


Silicon Pore architecture

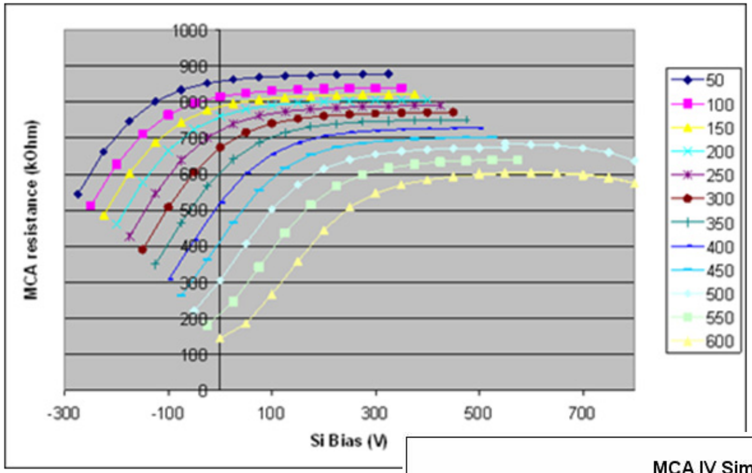
Conductivity Control

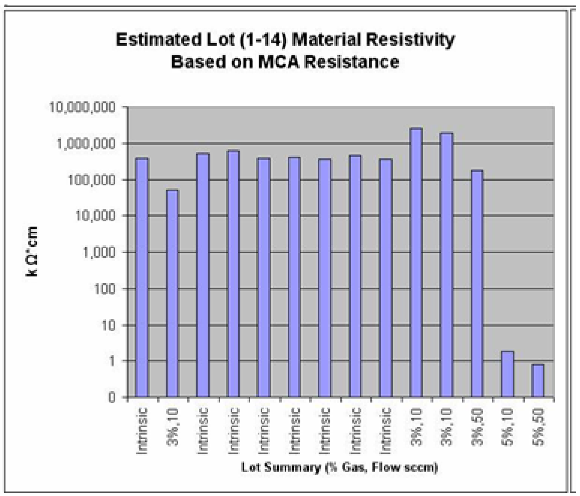


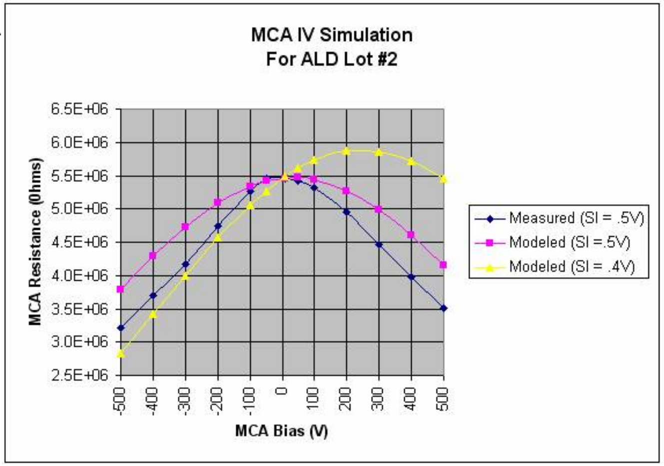




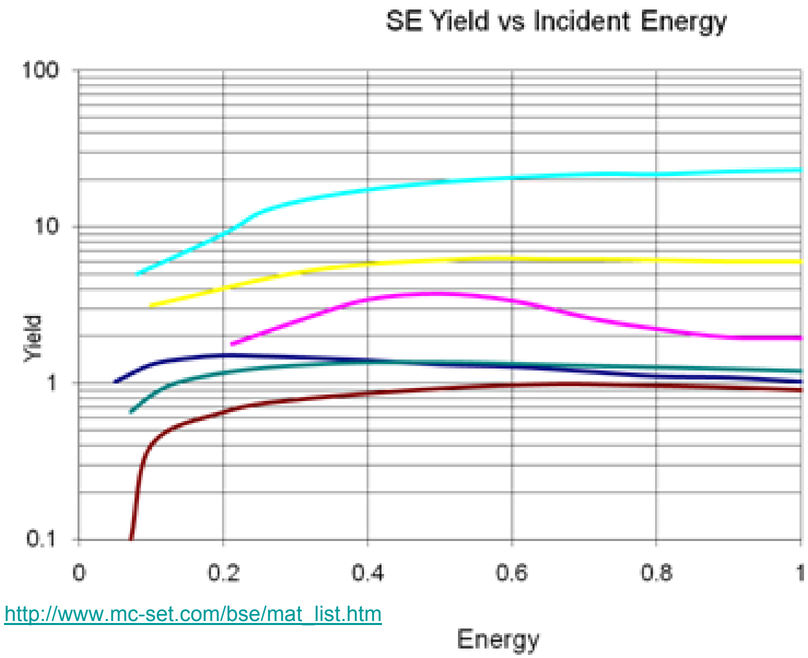
Resistance and transverse electric field







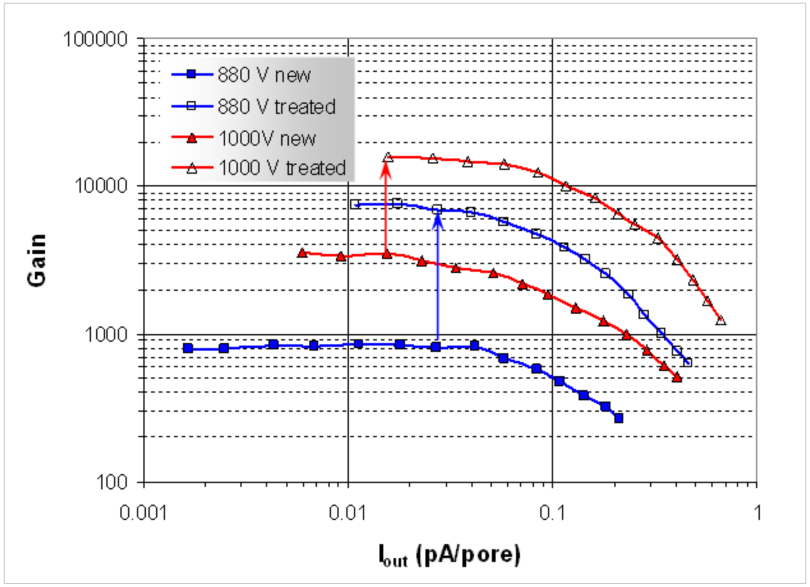
Secondary electron (SE) emissive layer materials



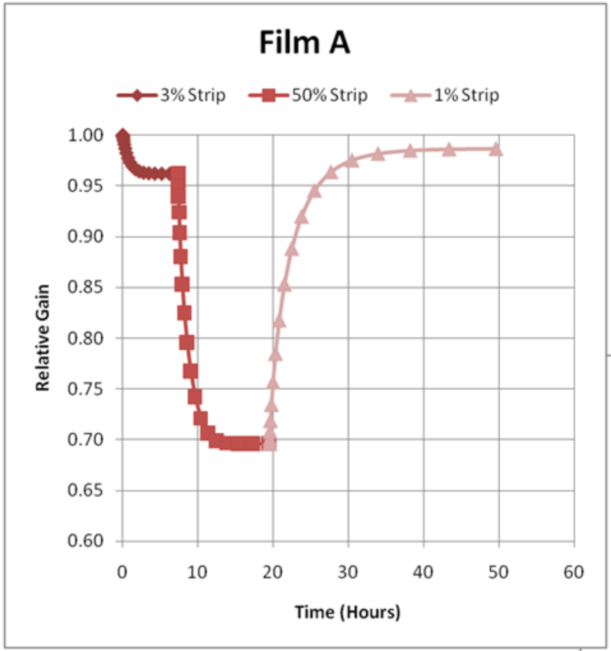
http://www.mc-set.com/bse/mat_list.htm

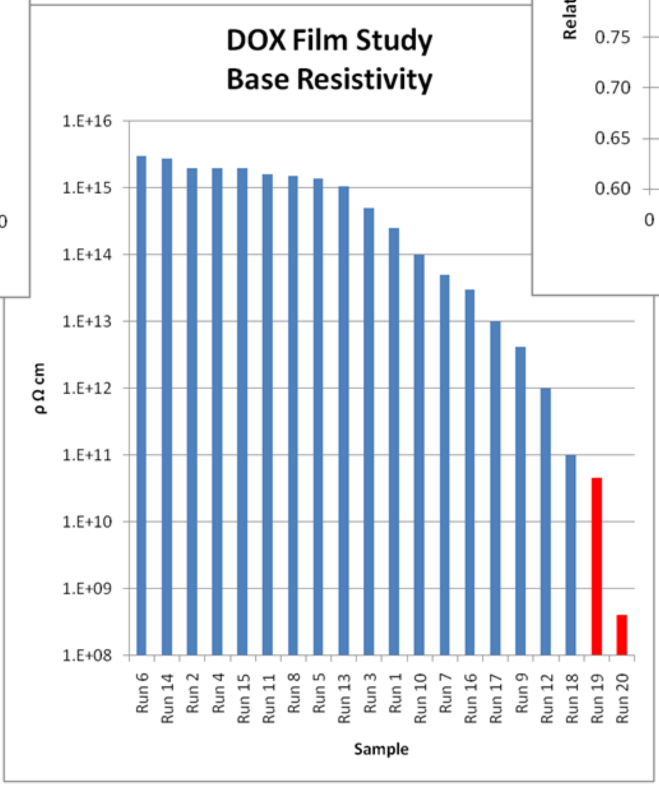
- ALD enables wide range of material selection
- SE yields range from ~1 to ~ 5 in energy region of interest
- MCP Pb-glass SE yield ~1-2

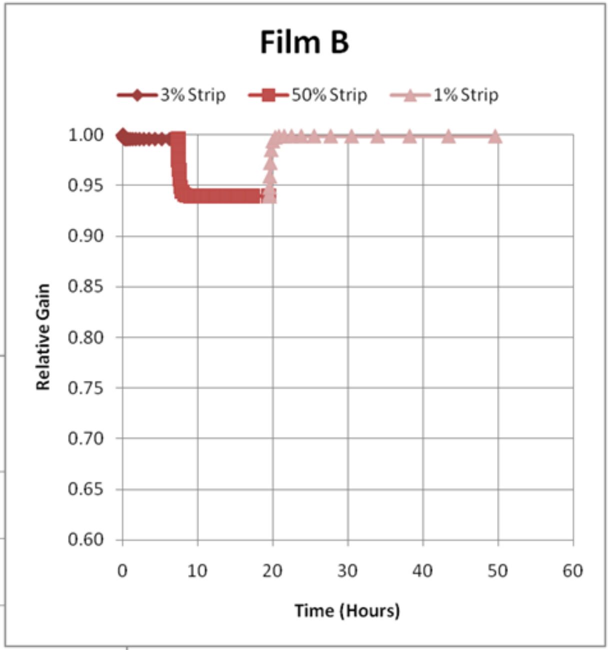
- Applied over commercial glass MCPs:
- 50:1 L/D, 4.8 mm pores, ~250 MW resistance
- 5x-10x gain increase



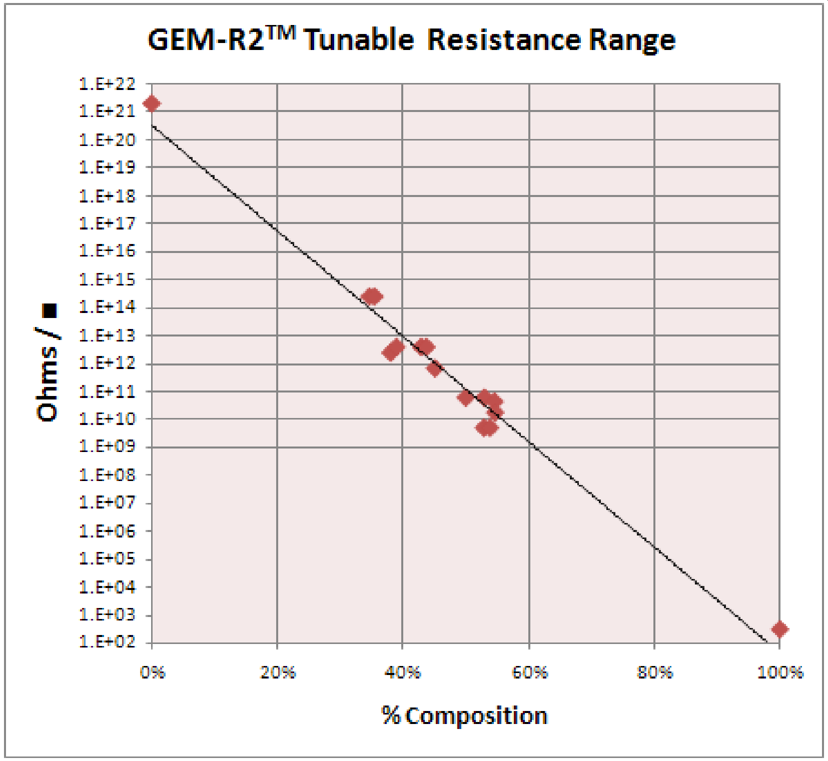
High Flux Stress induced charging



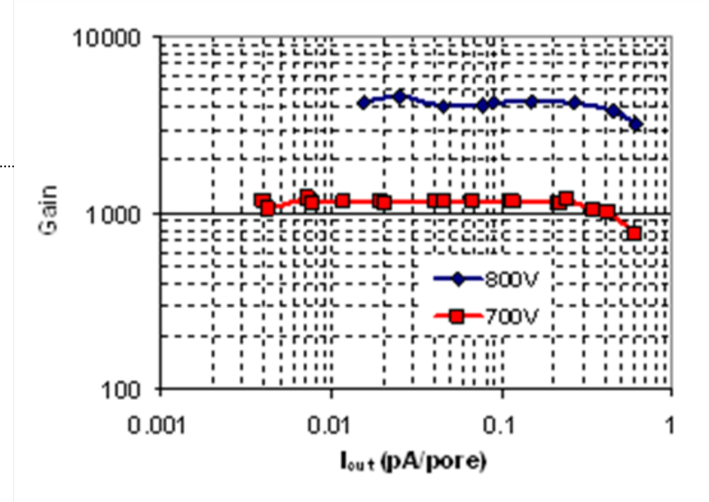




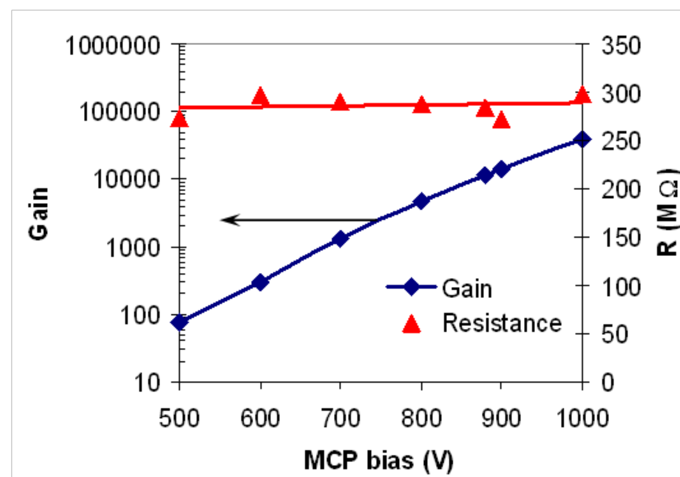
Conductive layer materials



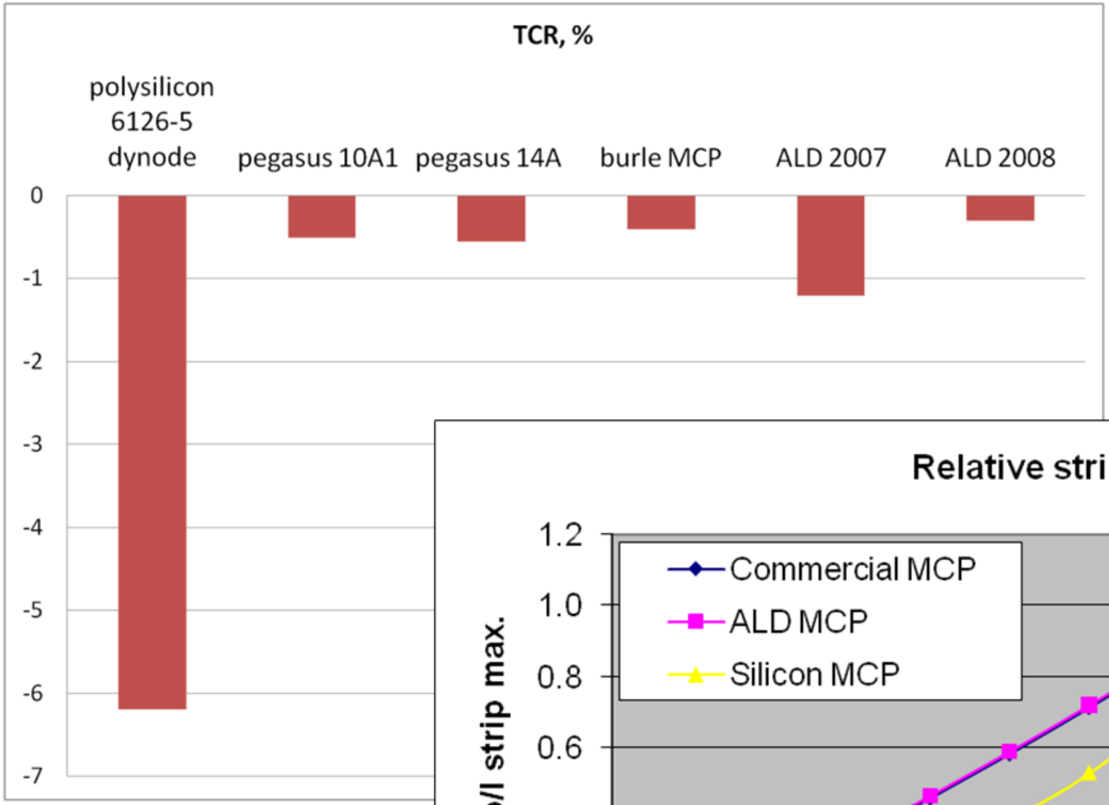
- Controllable conductivity range over more than 7 orders of magnitude
- Ohmic conduction
- Stable resistance in the presence of applied field
- TCR < 1% - comparable to Pb-glass MCP values

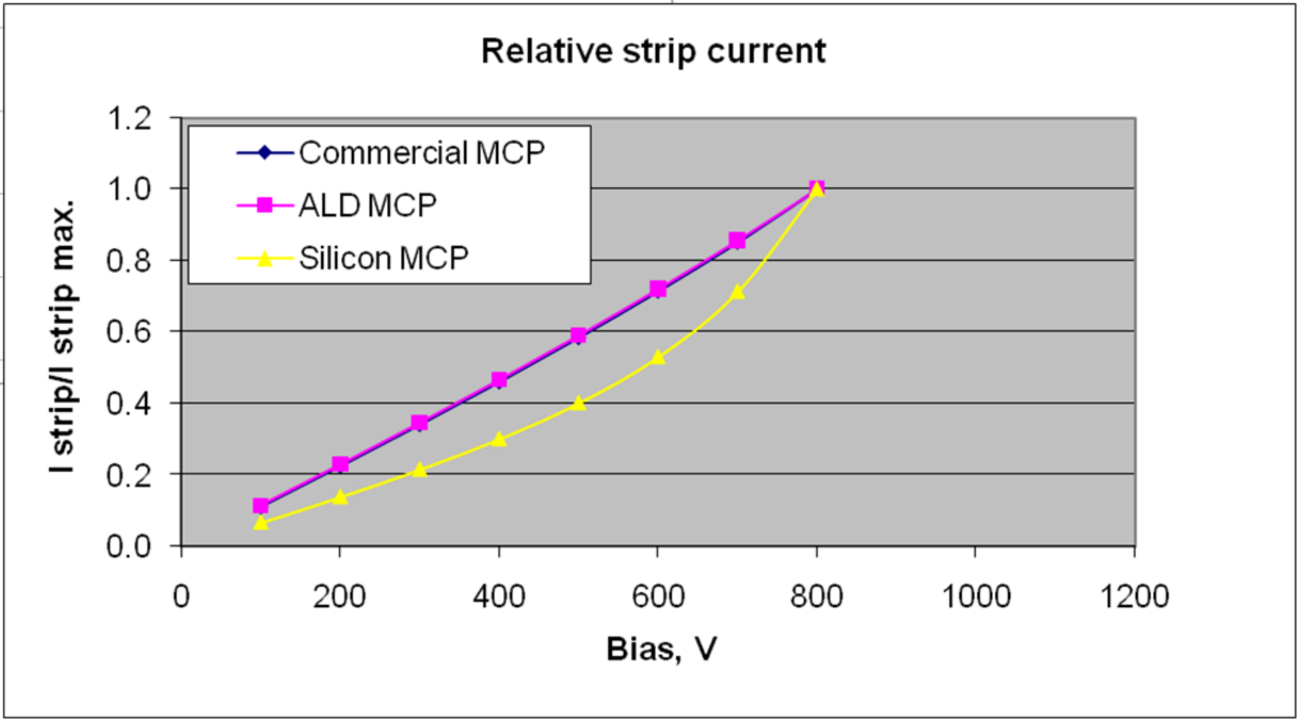


- 10 um pore, Soda Lime glass substrate, 40:1 L/D, R~280 MW,
- Stable resistance
- Typical exponential gain increase with bias
- Good gain ~ 40000 at 1000V bias
- Good TCR (comparable to glass MCP values)



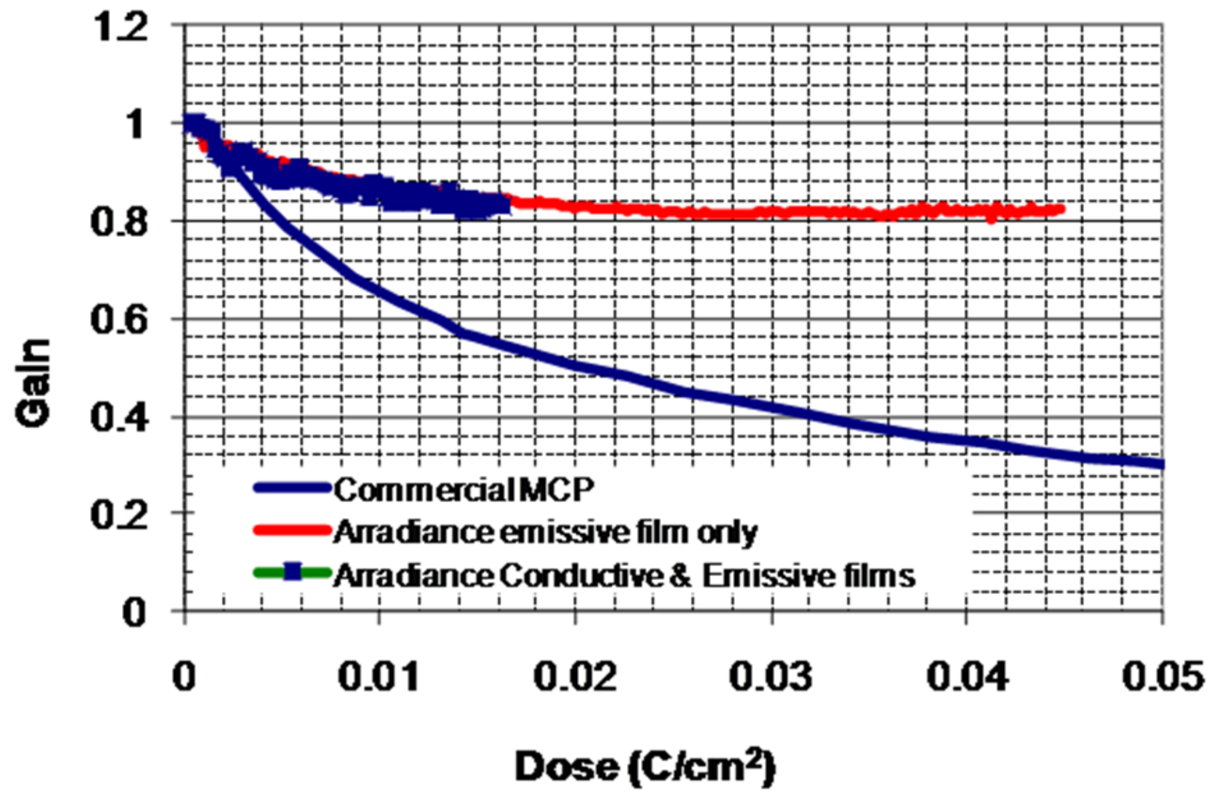
Conductive layer materials





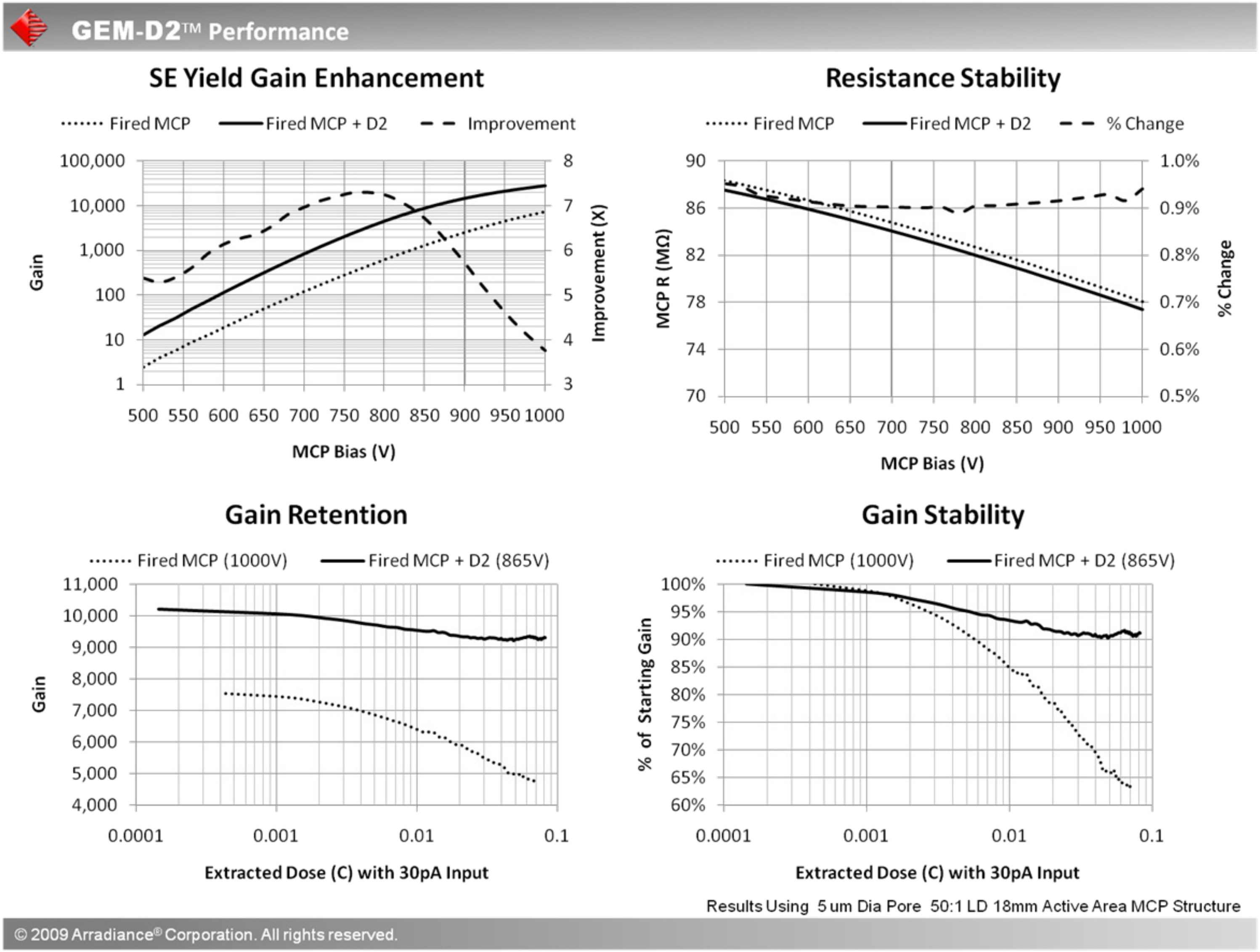
MCPs with conduction and emission films

10 μm pore NO LEAD glass substrate, 40:1 L/D, Bias = 880V, I_{out}~0.4 pA/pore, gain under electron bombardment



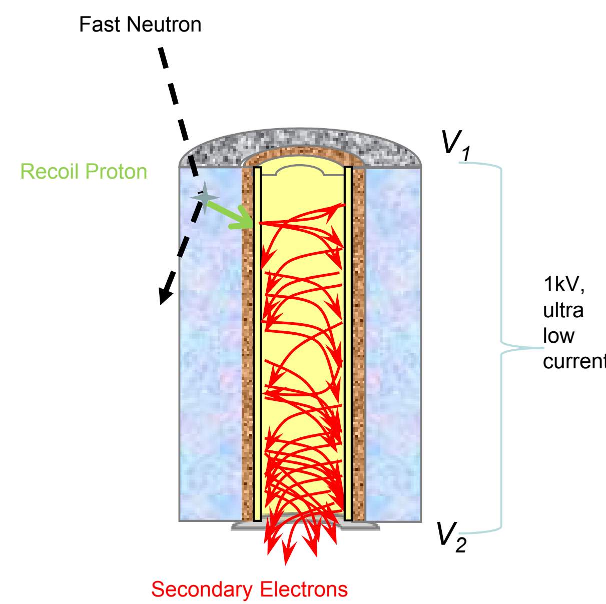
Quickly reaches stable gain

Arradiance D2TM Film Technology
Typical MCP Performance Enhancement

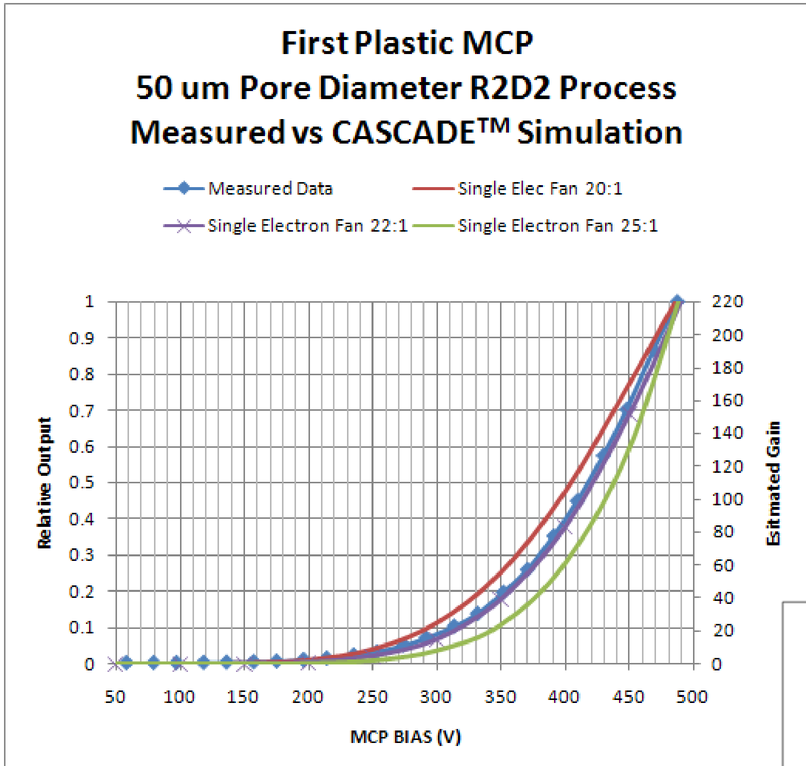


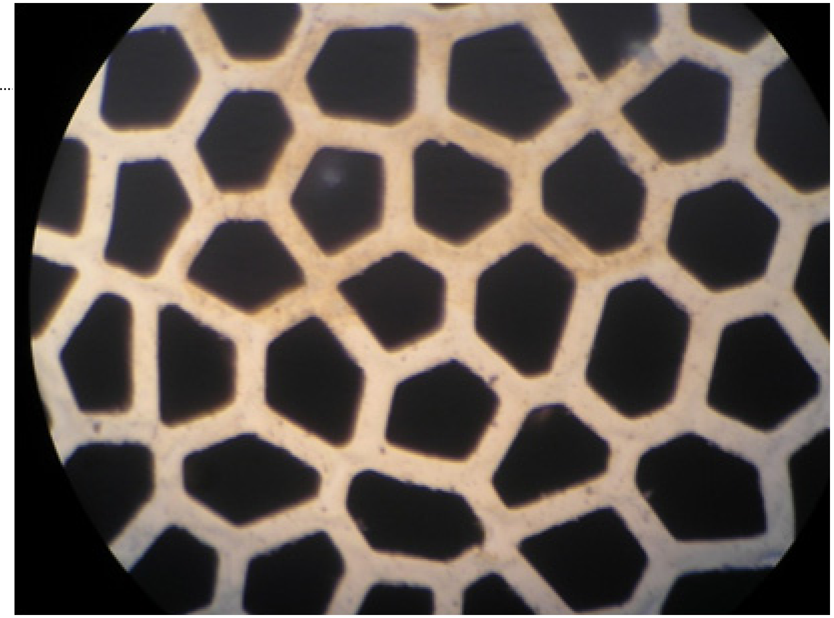
SNM detection technology overview

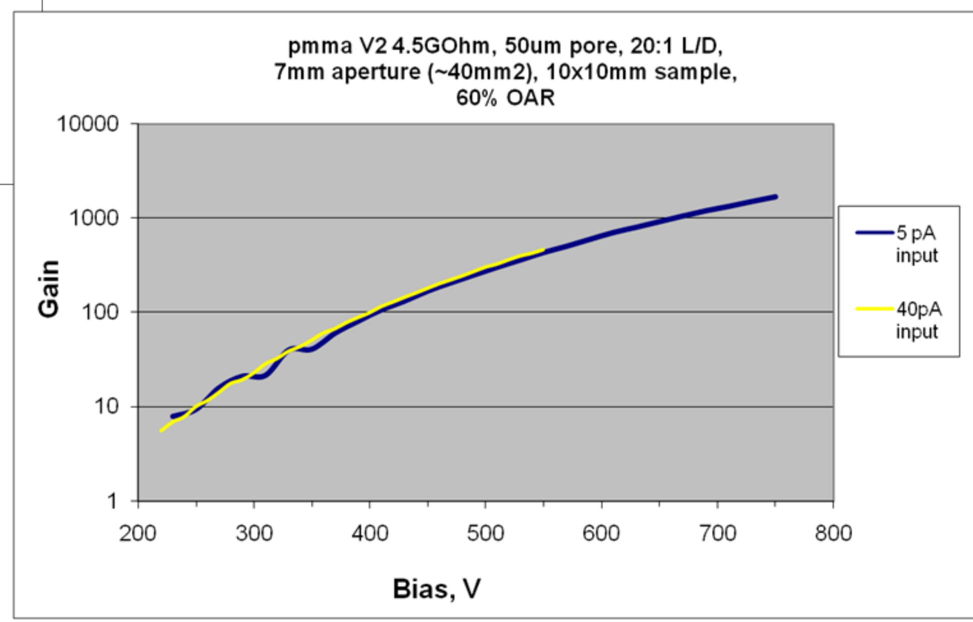
- Hydrogen-rich PMMA microchannel structure
- Graded Temperature ALD deposition
  - Active films deposition at 140C
- Neutron-proton recoil reaction within plastic at better than 1% efficiency
- Proton initiated secondary electron cascade
- Output pulse 10^3 – 10^6 electrons
- Standard readout electronics
- Technology is scalable to large format



Plastic substrate MCP







- First attempt on 50 μm pores
- Reasonable gain for electron amplification, Limited by L:D
- Uniform response
- Stable operation

Summary

- Emission and conduction layers for MCP technology have been developed
- Emission layer improves the performance of glass MCPs
  - High gain
  - Longer lifetime
  - Reduced outgassing / ion feedback
- Substrate independent conduction and emission films open new possibilities
  - Large area micromachined and plastic substrates
  - Temperature compatibility over a wide range
  - Novel photocathode materials/configurations
  - Low noise – no radioactive traces
  - Better uniformity / reproducibility / spatial resolution