Plastic Microchannel Plates with Nano-engineered Films

ARRADIANCE
www.arradiance.com

D. R. Beaulieu, D. Gorelikov, H. Klotzsch, P. de Rouffignac, K. Saadatmand, K. Stenton, N. Sullivan, A. S. Tremsin

Arradiance, Inc., 142 North Road, Suite F-150, Sudbury, MA 01776, USA

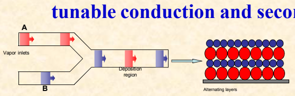
Abstract

Since their invention decades ago performance characteristics of microchannel plates (MCPs) rely on the properties of the substrate material, which defines both mechanical structure and electron amplification within the device. Specific glass compositions were developed to provide conduction and electron emission layer at the surface of the pores. The alternative technologies with quartz and alumina substrates have not matured enough to become a viable substitute to glass-based plates.

In this paper we report on the development of new MCP devices from plastic substrates. The plastic substrate serves only as a mechanical structure and electron amplification properties of this device are provided by nano-engineered conduction and emission layers. The film deposition procedures were optimized for low temperatures compatible with polymethyl methacrylate (PMMA) plastic.The gain of the PMMA MCP with aspect ratio of ~27:1 and pore diameter ~50 µm spaced on 70 µm hexagonal grid exceeded 200 at 470 V accelerating bias.

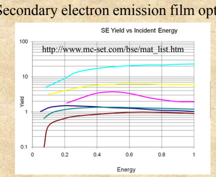
Development of hydrogen-rich plastic MCPs should enable direct detection of fast neutrons through proton recoil reaction. Recoil protons with escape ranges comparable to the wall thickness will initiate an electron avalanche upon collision with the pore walls. The electron signal is then amplified within the MCP pore allowing high spatial and temporal resolution for each detected fast neutron. We expect to achieve ~1% detection efficiency for 1-10 MeV neutrons with temporal resolution <10 ns and spatial resolution of <200 µm and very low background noise. These plastic MCPs may become very attractive alternative in special nuclear material monitoring applications as well as in fast neutron radiography and tomography enabling non-destructive testing of thick samples due to high penetration depth of fast neutrons.

Nano- engineered films for microchannel plates: tunable conduction and secondary electron emission films

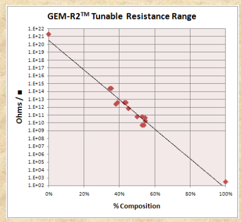


- High conformality (>500:1)
- Scalable to large areas
- Digital thickness control
- Pure films
- Control over film composition
- Low deposition temperatures (50-300°C)

Secondary electron emission film options



MCP conduction film – tunable resistance

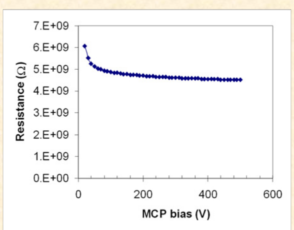


- Controllable conductivity range over more than 7 orders of magnitude
- Ohmic conduction
- Stable resistance in the presence of applied field
- TCR < 1% - comparable to Pb-glass MCP values

Performance characteristics

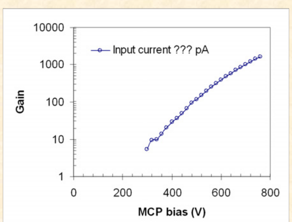
PMMA MCP: pores ~50 µm, center to center spacing ~70 µm, L/D ratio ~27:1

Resistance as a function of MCP bias



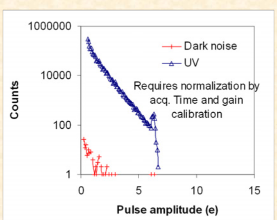
Current amplification mode

Full field electron illumination

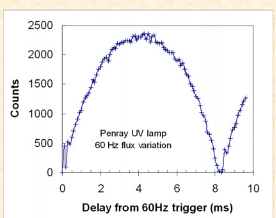


Single event counting

UV penray lamp full field illumination
Standard glass MCP installed behind the PMMA MCP



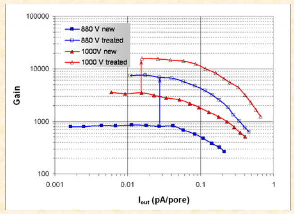
Pulse height distributions: UV counts and dark noise counts
Dark noise ~1 event/s/cm²



Timing histogram of events detected under 60Hz-modulated UV illumination

Emission film applied over commercial glass MCPs:

50:1 L/D, 4.8 µm pores, ~250 MΩ resistance

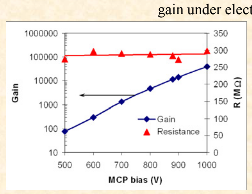


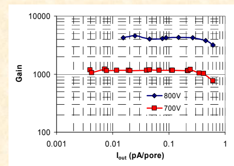
5x-10x gain increase

Full field illumination image. Photograph of the phosphor screen.

Emission and conduction films. NO LEAD glass substrate

10 µm pore NO LEAD glass substrate, 40:1 L/D, R~280 MΩ
gain under electron bombardment

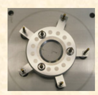


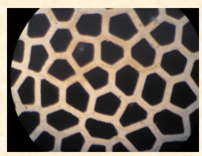


- Stable resistance
- Typical exponential gain increase with bias (~ 40000 at 1000V)
- Good TCR (comparable to glass MCP values)

Plastic MCP: PMMA substrate, ALD resistive and conductive films

Pores ~50 µm, center to center spacing ~70 µm, L/D ratio ~20:1 and ~27:1





Substrate produced by Paradigm Optics, Inc. Resistive and conductive films were developed by Arradiance for compatibility with low temperature ALD deposition process.

Experimental setup: current amplification and pulse counting modes

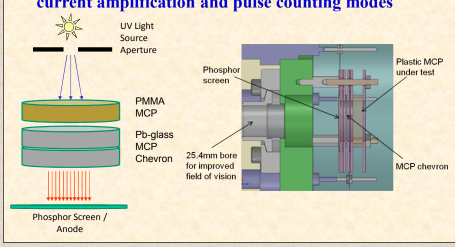
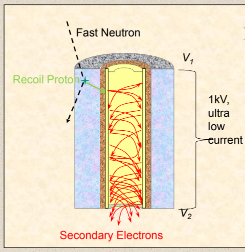


Photo of the phosphor screen with detector under UV illumination. No noise spots or artifacts from PMMA MCP are observed. The defects on the image are due to phosphor internal features.

Fast neutron detection principle



- Hydrogen-rich plastic microchannel structure
- Arradiance functional thin films: Conductive film, Emissive film
- Neutron-proton recoil reaction within plastic
- Proton initiated secondary electron cascade
- Output pulse $10^3 – 10^6$ electrons
- Standard readout electronics
- Detection efficiency ~1% for 2-10 MeV neutrons

References:

1. N. Sullivan, D. Gorelikov, H. Klotzsch, P. de Rouffignac, K.Saadatmand, K. Stenton, D. R. Beaulieu, A. S. Tremsin, "*Novel Fast Neutron Counting Technolgy for Efficient Detection of Special Nuclear Materials*", 2009 IEEE International Conference on Technologies for Homeland Security, HST 2009, Waltham MA, May 11 - 12, 2009.
2. D. R. Beaulieu, D. Gorelikov, P. de Rouffignac, K. Saadatmand, K. Stenton, N. Sullivan, A. S. Tremsin, "*Nano-engineered Ultra High Gain Microchannel Plates*", Nucl. Instr. Meth. A (2009) DOI information: 10.1016/j.nima.2009.03.134