Development of economical and large area microchannel plates for photon detectors

Anil U. Mane*[a], Jeffrey W. Elam[a], Jason McPhate[b], Oswald H. W. Siegmund[b], Matthew J. Wetstein[a,c], Robert G. Wagner[a], Michael J. Minot[d], and Henry J. Frisch[a, c]

[a]Argonne National Laboratory, Argonne, Illinois 60439
[b]Space Sciences Laboratory, University of California, Berkeley, California 94720
[c]Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637
[d] Incom, Inc., Charlton, Massachusetts 01507

Abstract

The development of large area microchannel plate (MCP) - based photodetectors with high performance has advantages for many potential applications including low-level signal detection, photo-detection, astronomy, electron microscopy, time-of-flight mass spectrometry, molecular and atomic collision studies, fluorescence imaging applications in biotechnology, field emission displays, medical imaging, and cluster physics. MCPs are also used to make visible light image intensifiers for night vision goggles and binoculars. The performance of MCP-based photodetectors depends not only on the microchannel plates themselves, but also on their configuration (e.g. single, double; chevron-type or triple; z-stack), as well as on the photocathode, the anode structure, and the signal readout. The Large Area Picosecond Photodetector (LAPPD) Project is a US Department of Energy (DOE) funded collaborative project [1] that addresses each of these critical components of the photodetector with the goal of developing low cost, large area (20cm x 20cm) MCP-based photodetectors.

The requirement of low cost poses a severe challenge to fabricating the large area MCP component of the large area photodetector and rules out conventional methods. Our approach to this problem combines two recent technical advances. The first is the capability to produce large micro-capillary array blocks developed by Incom Inc. (Charlton, MA). The Incom process uses hollow, multifiber borosilicate (non-leaded) capillaries, eliminating the need to remove the core material by chemical etching. The capillary arrays are fabricated as large blocks that are sliced to form large area wafers, without regard to the conventional limits of L/d (capillary length / pore diameter), and subsequently polished. The second technological advance is the development of coating technology based on atomic layer deposition (ALD) for functionalizing the capillary

array plates to impart the desired electrical resistance and secondary emissive properties. Atomic layer deposition is a powerful and precise thin film deposition technique, which utilizes self-limiting chemical reactions between precursor vapors and a solid surface to deposit material in a layer-by-layer fashion. Gaseous diffusion of the precursors, coupled with the self-saturating surface reactions generates extremely uniform and conformal coatings on the high aspect ratio capillary glass arrays. ALD provides atomic level control over the thickness and composition of the films, and allows the properties of the resistive and secondary electron emission (SEE) layers to be tuned independently.

Figure 1 shows the photograph of the 33mm MCP processed at various steps. We have developed several robust and reliable ALD processes for the resistive coatings and SEE layers to provide precise control over the resistance in the target range for MCPs (10^6-$10^9\Omega$) and SEE coefficient (up to 8) [2, 3]. The MCPs are tested in stacks of one or two plates and exhibit gains as high as ~10^7 for a pair of MCPs. This approach allows the functionalization of microporous, insulating substrates to produce MCPs with high gain and low noise. These capabilities allow separation of the substrate material properties from the amplification properties. We studied the various MCP parameters such as gain, background counts, and resistance as a function of the ALD process parameters. Figure 2 shows the performance of the ALD functionalized 33mm MCPs. These MCPs shows the high gain (Figure 2a), long life test (Figure 2b), high spatial resolution, high timing resolution, and very low background rate. Following our initial development on the 33mm substrates, we scaled up the ALD process to functionalize the large area 20cmx20cm MCPs (Figure 3) and similar performance was achieved [3,4]. Here we will discuss the complete process flow to produce fully functionalized working large area MCPs and illustrate their performance.

References:

[1] http://hep.uchicago.edu/psec/
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[4] O.H.W. Siegmund, J.B. McPhate, S.R. Jelinsky, J.V. Vallerga, A.S. Tremsin, R. Hemphill, H.J. Frisch, R.G. Wagner, J. Elam, A. Mane and the LAPPD Collaboration, 2011 IEEE Nuclear Science Symposium Conference Record N45-1

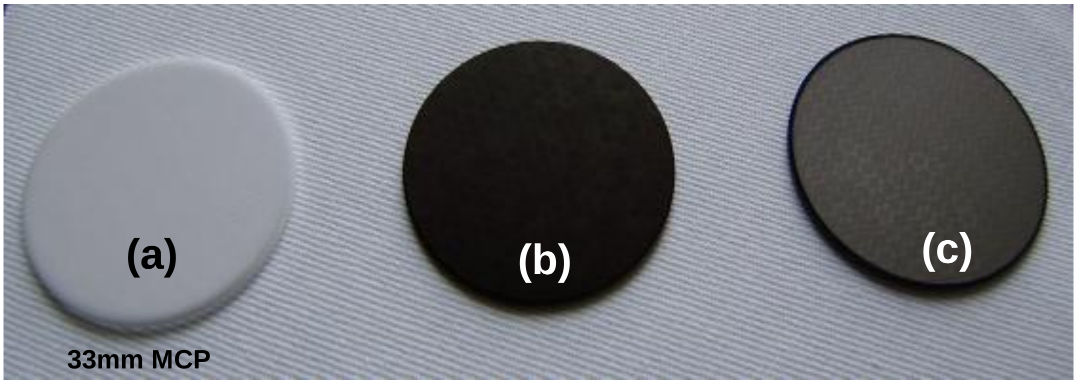

Fig. 1. Photographs of (a) as received bare 33mm MCP from Incom Inc, (b) after ALD resistive + SEE layers, and (c) after 200nm NiCr thermal evaporated coating .

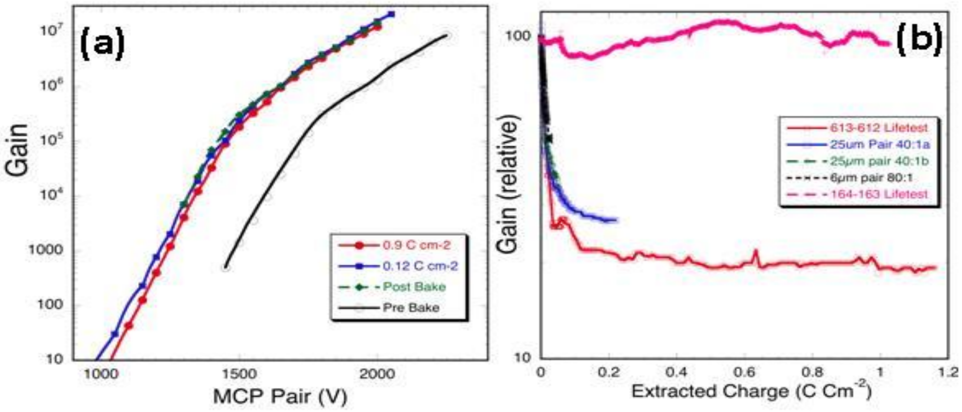

Fig. 2. (a) Gain as a function of voltage for an ALD borosilicate MCP pair (20 µm pore, 60:1 L/d, 8° bias) at several stages of preconditioning. (b) Relative gain versus extracted charge for 33 mm ALD MCP pairs #613-613 and #164-163, (20µm pore, 60:1 L/d, 8° bias) compared with conventional MCPs.

Fig. 3. Photograph of a fully functionalized 20 cm x 20cm MCP with 20 µm pores and 8° bias angle