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Novel large format sealed tube microchannel plate detectors for Cherenkov timing and imaging

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ABSTRACT

Large area (20×20 cm^2) sealed tube detectors using novel borosilicate glass microchannel plates, with bialkali photocathodes and strip-line readouts are being developed for Cherenkov light detection. Designs based on conventional sealed tubes with alumina brazed body construction and hot indium seals have been developed. Borosilicate glass substrates with 20 and 40 μm holes have been processed using atomic layer deposition to produce functional microchannel plates. Initial results for these in a 33 mm format show gain, imaging performance, pulse shape and lifetime characteristics that are similar to standard glass microchannel plates. Large area (20×20 cm^2) borosilicate glass substrates with 20 μm pores have also been made.

1. Introduction

Microchannel plate (MCP) devices are powerful devices for detection of Cherenkov light, with good imaging and timing characteristics. However, currently the largest format devices available are of the order of 5 cm, and these are expensive compared with photomultiplier tubes. Significant problems in covering large areas with such devices are both the cost, and the difficulty in fabricating large size MCPs. Other concerns include the packaging of a large sealed tube device, producing large area proximity focused photocathodes and the imaging/timing readout. As part of a collaborative program between University of California, Berkeley, the Argonne National Laboratory, the University of Chicago and several other partners, we are developing a 20 cm^2 sealed tube MCP detector sensor. One key to the new device is the incorporation of a novel implementation of MCPs. In collaboration with Incom, Inc. we are developing comparatively low cost MCPs using borosilicate glass substrates. The resistive and photo-emissive surfaces are applied by atomic layer deposition, eliminating most of the chemical processes and thermal reduction used for normal glass MCPs. The overall device will be 22 cm^2 and about 15 mm thick. The baseline is to use a bialkali photocathode to match the Cherenkov emission spectrum and to keep the overall background rate at an acceptable level. Strip-line anodes are also being developed, which will give modest (few mm) spatial resolution using novel timing electronics. Based on data from existing designs, this new electronics should provide timing accuracy of a few picoseconds.

2. Detector design scheme

The basic conceptual design for the sealed tube assembly is shown in Fig. 1. The scheme employs a borosilicate Schott Borofloat 33 [1] entrance window that transmits Cherenkov photons with wavelengths as short as 300 nm. A semi-transparent proximity focused bialkali photocathode converts the incoming photons to photoelectrons. The latter are amplified by a pair of MCPs and then detected on a strip-line readout anode. At Berkeley we have chosen a relatively conventional approach to the sealed tube construction. Meanwhile, the Argonne National Laboratory (ANL) is evaluating a different approach to promote ease of production and minimize costs [2]. Our scheme uses a hot indium seal for the tube (Fig. 1) and relies upon standard brazing techniques for the hermetic sealing of the main alumina ceramic tube body, indium well and strip-line anode substrate. All strip-line and high voltage connections are made using hermetically sealed brazed pins through the anode substrate. In common with most sealed tubes we have also incorporated non-evaporable getters inside the tube to maintain vacuum. The window to MCP gap is about 0.5 mm, and only two MCPs are needed to establish the few $\times10^6$ gain required for nominal detector operation. Given the large size of the detector we have taken steps to maintain spatial uniformity, including a biased

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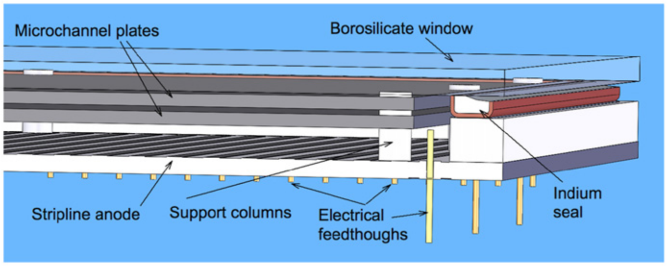

Fig. 1. Cross-sectional schematic of a 20 cm sealed tube detector. Light passes through a borosilicate window and interacts with a proximity focused semi-transparent bialkali photocathode producing photoelectrons. These are multiplied by a borosilicate substrate MCP pair that are functionalized using atomic layer deposition. The resulting electron clouds are then detected on a strip-line anode.

gap between the MCPs. There are also regularly spaced columns in the active area to maintain the internal spacings of components and to reduce the deformation of the window and anode under atmospheric pressure. These columns will be a combination of ceramic rods that fit through holes drilled in the MCPs, and spacer tubes. Gaps of ~0.5 mm between the MCPs and 6 mm between the MCPs and anode establish the appropriate event charge cloud size for the strip-line anode periodicity (~4 mm).

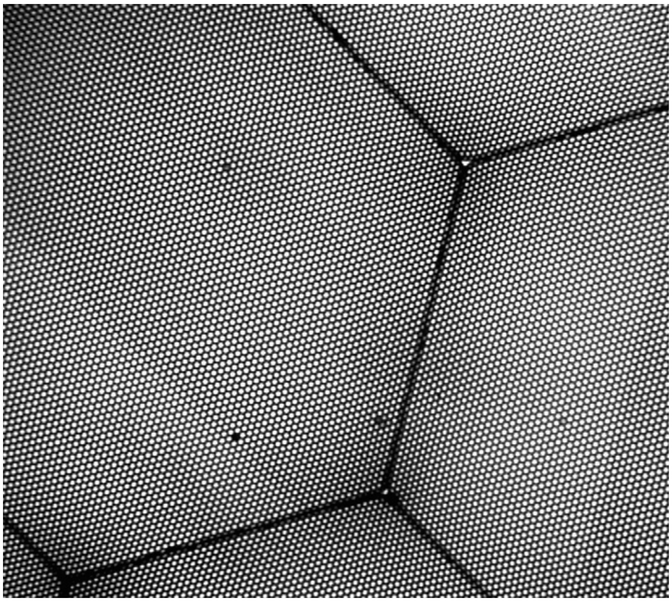

Fig. 2. Photograph of a 20 μm pore MCP made using borosilicate glass. Pore crushing at the multi-fiber hexagonal boundaries is evident, as are some blocked pores. Pore length to diameter ratio is 60:1, with a pore bias angle of 8°.

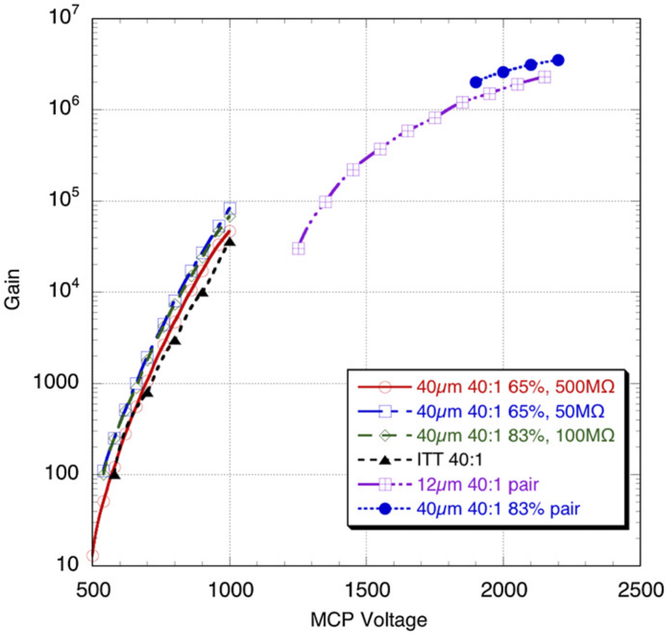

Fig. 3. Comparison of the gain/voltage curves for normal single and paired MCPs (ITT, 12 μm) [4] with the gain curves for single and paired ALD coated borosilicate MCPs with 40 μm pores, and 65% and 83% open area ratios.

3. Borosilicate microchannel plate development

One of the key issues in development of the 20 cm detector is obtaining MCPs. Currently it is not practical to make conventional glass MCPs with sizes of 20 cm^2 due to cost and processing constraints. A potential alternate option makes use of cheap borosilicate glass in the form of hollow tubes and then making MCP substrates in a typical drawing/stacking/fusing/slicing process, without extensive chemical processing. Incom, Inc. has constructed MCP substrates in this manner, with 40 μm (65% and 83% open area ratio, 40:1 channel length/diameter (*L*/*d*)) and 20 μm pores (65% open area ratio, 60:1*L*/*d*), beginning with 33 mm substrates (8° pore bias angle), and more recently 20 cm^2 substrates. On examination (Fig. 2), the substrates show some blocked holes, and distortions at the hexagonal multi-fiber boundaries, much like early conventional glass MCPs. Unlike standard MCPs, these borosilicate substrates are made into working MCPs by atomic layer deposition [3] of resistive layers and photo-emissive layers on the surfaces of the substrate. This process has been applied to the 33 mm Incom substrates by Arradiance, Inc. and also at ANL. The resistive layers have various compositions, but the photo-emissive layers applied are generally Al_2O_3. Resistances comparable with those of conventional glass MCPs have been achieved covering the range from ~50 to ~500 MΩ. Tests (Fig. 3) by Arradiance, and at Berkeley, show that the single and paired MCP gain characteristics are very similar to conventional MCP performance [4]. Pulse amplitude distributions (Fig. 4) are also in accord with standard glass MCPs. The lifetime characteristics of the MCPs are of great importance to their application in sealed tubes. MCPs with high temperature borosilicate glass, employing robust refractory coatings, should have positive effects on this issue. Our initial charge extraction (scrub) test on a borosilicate MCP which has not been previously vacuum baked, shows a rapid gain drop (gas desorption) followed by a slow decrease (Fig. 5). This result is compared with a conventional MCP tested under equivalent conditions. Scrubbing results can vary substantially, however this observation is encouraging and will be complemented by further studies. Imaging tests with UV illumination and using single MCPs with phosphor readout, or pairs of MCPs with a cross delay line photon counting readout have been done. The latter show (Fig. 6) evidence of gain depression at the hexagonal multi-fiber boundaries of both upper and lower MCPs, along with some Moiré modulation [5] at the edges of the image (due to non-optimal MCP rotational placement). Nevertheless, the response uniformity is reasonable, and the general gain uniformity is found to be good (±10%). In addition, the background rate for the new MCPs is quite uniform and less than 1 event $cm^{-2}\,s^{-1}$. Preliminary examination of the MCP pulse shape (Fig. 7) indicate that pulse rise times are of the order <1 ns for a 20 μm pore MCP pair, similar to a conventional MCP.

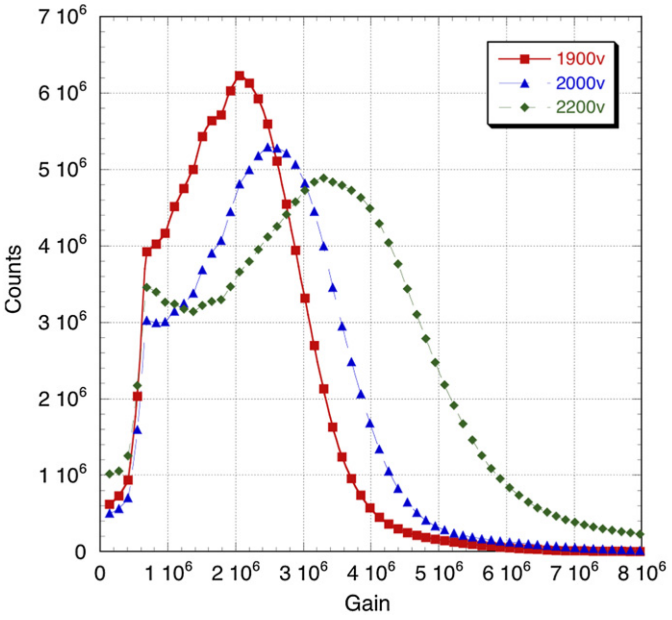

Fig. 4. Pulse height distributions at several gains for a pair of 40 μm pore ALD coated borosilicate MCPs. Pore length to diameter ratio is 40:1, and pore bias angle is 8°. An electronic threshold of 5×10^5 has been applied, which rejects amplifier noise for the imaging tests while allowing most of the photon events to be accepted.

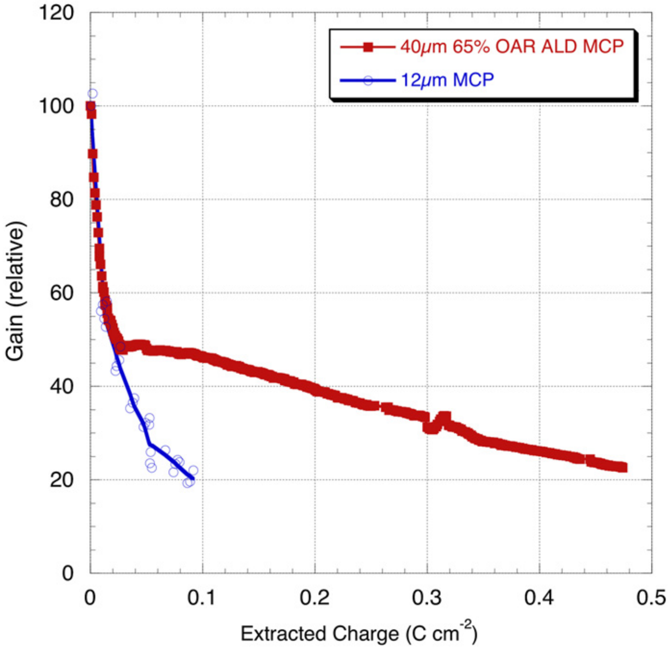

Fig. 5. Gain as a function of extracted charge for an ALD coated borosilicate MCP with 40 μm pores, $L/d=40{:}1$, pore bias 8°, compared with a conventional glass MCP.

4. Detector system development

The initial results on ALD processed borosilicate MCPs are very supportive of their use in the development of the 20 cm sealed tubes. Since high spatial resolution is not required, the current shortcomings of these MCPs may not be a significant impediment. Implementation of the full size 20 cm detector is well underway at Berkeley. Test bialkali photocathodes are currently being made on borosilicate windows, and the components of the detector are under construction as well as a full size ultra-high vacuum processing tank for the processing of tubes (vacuum bake, MCP scrubbing, large area photocathode deposition and cathode transfer/hot indium sealing of the window). While tests and optimization of the borosilicate/ALD MCP technique are still ongoing using the 33 mm format, 20×20 cm^2 substrates with 20 μm pores, $60{:}1L/d$, 8° bias and ~60% open area ratio have been made. These will be functionalized and tested in a full size detector mockup. Contemporaneously, development of high-speed electronics for position encoding and time stamping of events to a few

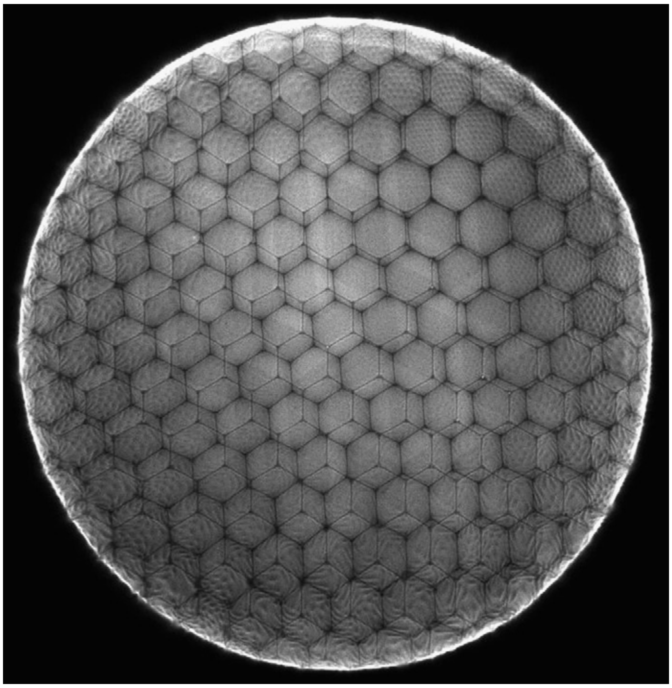

Fig. 6. Image with 254 nm light using a pair of ALD coated borosilicate MCPs with 20 μm pores, $L/d=60{:}1$, pore bias 8° and a cross delay line readout anode. The hexagonal multi-fiber packing structure is clearly visible, as are moiré patterns around the edges of the image due to non-optimal MCP rotational orientation [5].

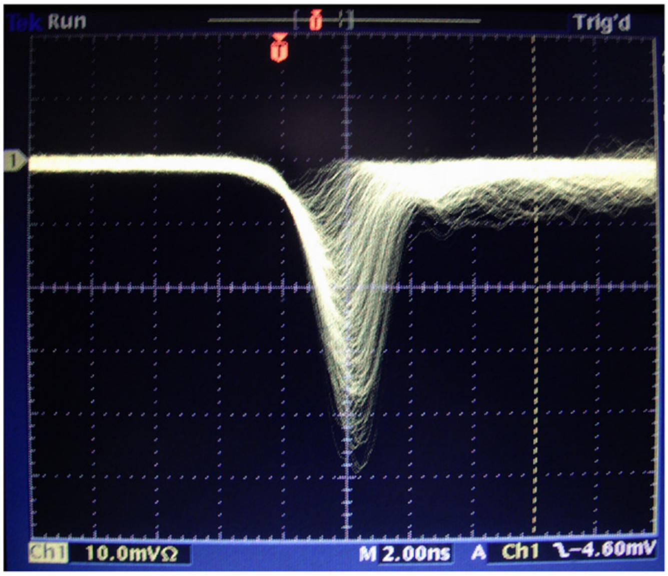

Fig. 7. MCP signal pulse shapes recorded using a 500 MHz oscilloscope for a pair of ALD coated borosilicate MCPs with 20 μm pores, $L/d=60{:}1$, pore bias 8°.

picoseconds is underway at the University of Chicago and the University of Hawaii [6].

Acknowledgements

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References

[1] 〈www.schott.com/borofloat〉.
[2] M. Wetstein, et al., in this Proceedings.
[3] M. Ritala, M. Leskelä, Nanotechnology 10 (1) (1999) 19.
[4] O.H.W. Siegmund, in: J.A.R. Samson, D.L. Ederer (Eds.), Methods of Vacuum Ultraviolet Physics, Chapter III, second ed., Academic Press, 1998.
[5] A.S. Tremsin, O.H.W. Siegmund, M.A. Gummin, P.N. Jelinsky, J.M. Stock, Appl. Opt. 38 (1999) 2240.
[6] J.-F. Genat, G. Varner, F. Tang, H.J. Frisch, Nucl. Instr. and Meth. A 607 (2009) 387.