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Performance studies of atomic layer deposited microchannel plate electron multipliers

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ABSTRACT

Microchannel plate (MCP) photon counting, event timing, imaging detectors have found wide use in astronomical, remote sensing, and biological imaging applications. Novel MCP technology using borosilicate glass microcapillary array substrates functionalized by the application of resistive and secondary emissive layers using atomic layer deposition (ALD) techniques has the potential to outperform traditional MCP technology. Using ALD techniques to functionalize the MCPs allow customization of parameters like gain and resistance independently from the glass substrate. Borosilicate substrates have many advantages over traditional micro-capillary arrays, including low radioactive content, higher open area ratios, low outgassing, and high operational stability. These ALD MCPs can be manufactured in large areas (400 cm^2) providing a unique solution for many timing/imaging applications. ALD MCPs can withstand the processing temperatures required for high temperature deposition of III–V materials, such as Gallium Nitride, for UV photocathodes with high quantum efficiencies (QE) in the Near-UV (∼100–380 nm). We present the effects of different ALD configurations on the gain (magnitude and uniformity), resistance, imaging, background and detection efficiency, and how these parameters change during lifetime testing. We also present the QE of ALD MCPs and various QE enhancement techniques.

1. Introduction

Microchannel plate (MCP) imaging photon counting detectors with event timing have found wide use in many applications, including astronomical [1], remote sensing [2], and biological imaging [3]. Combining high spatial resolution (∼10–100 μm in formats of up to 20 cm) with very high time resolution (sub-ns) can enhance the performance of such detectors in dynamic environments. This work uses a new class of borosilicate glass substrates with nano-engineered resistive and secondary emissive surfaces (Fig. 1) applied using atomic layer deposition (ALD) [4]. Significant enhancements in performance and lifetime can be achieved when incorporating these ALD MCPs in open face and sealed tube imaging photo-detectors.

2. ALD MCPs

Over the last several years, the quality of glass micro-capillary arrays used in ALD MCPs have undergone significant enhancements as the substrate quality and the processing techniques have improved. Measurements of the micro-capillary arrays show minimal pore deformations inside the hexagonal multifibers (Fig. 2). Pore deformations due to substrate fusing are limited to the hexagonal boundary resulting in greatly reduced modulations seen in images. The intensity of the image modulation has varied, but the latest MCPs show distortions on the order of ∼15% compared to ∼30% seen in older MCPs (Fig. 3). Better pore uniformity also contributes to improvements in the overall sensitivity variation of a detector.

Improvements in processing techniques have also enabled fabrication of the first 6 μm pore ALD MCPs. The 6 μm pore MCPs are Incom C14 glass, 13° pore bias angle, 63% open area ratio (OAR), and have 60:1 length to diameter ratio (L/D). Images and gain maps (Fig. 4) from these MCPs under Hg lamp UV illumination show good overall uniformity (<20%). The resistance of these MCPs (15 MΩ) was slightly too low at room temperature for stable use, Joule heating when a voltage is applied causes the MCP temperature to rise and the resistance to decrease. Even lower resistance causes more current draw and further heating eventually going into thermal runaway [5]. The 6 μm MCPs

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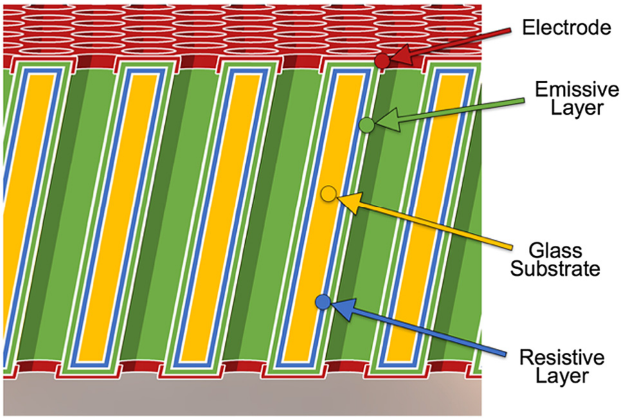

Fig. 1. Glass micro-capillary arrays are functionalized with atomic layer deposition. Resistances can be tailored to suit the application. Materials with high stable secondary emission (Al_2O_3 and MgO) can be used since they are decoupled from the substrate.

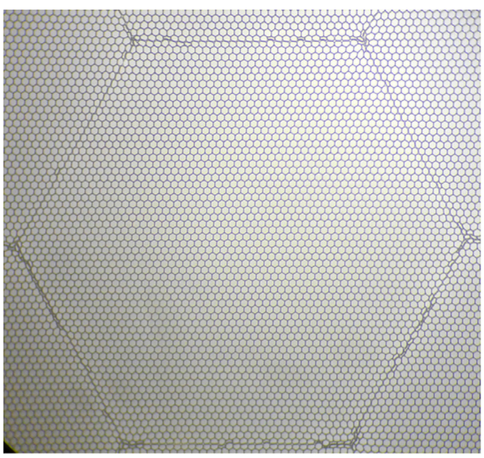

Fig. 2. Photo of 20 μm pore, 74% open area, 60:1 L/d, 2nd generation (Incom C14) micro-capillary arrays.

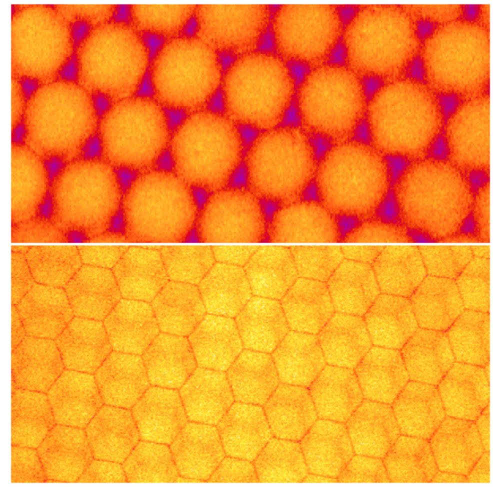

Fig. 3. Gain modulation has improved from ∼30% in older substrates to ∼15% in the latest batch.

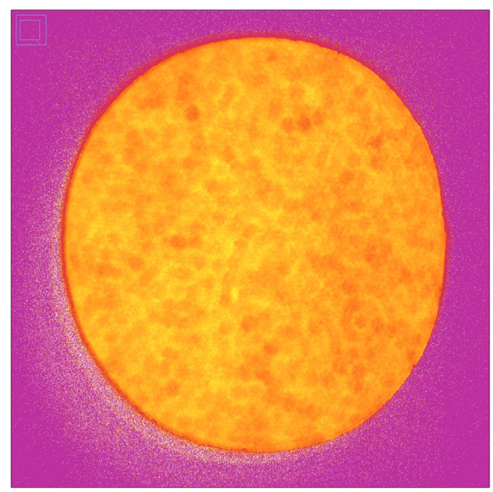

Fig. 4. Gain map image of 6 μm pore 33 mm diameter ALD MCP (Incom C14 glass, 13° bias, 63% OAR, L/D 60:1).

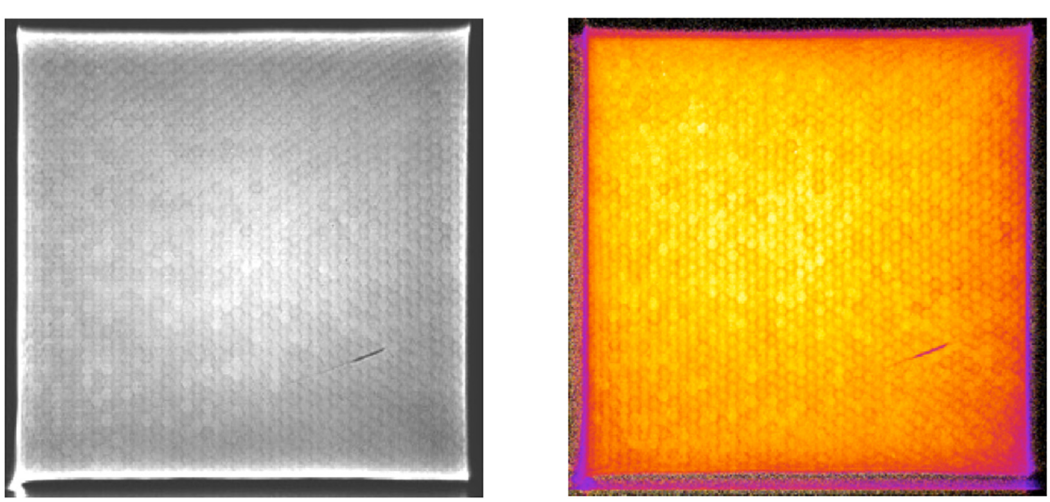

Fig. 5. Image (left) and gain map image (right) of a chevron pair of 10 μm pore 53 × 53 mm^2 ALD MCP (Incom C14 glass, 13° bias, 63% OAR, L/D 60:1).

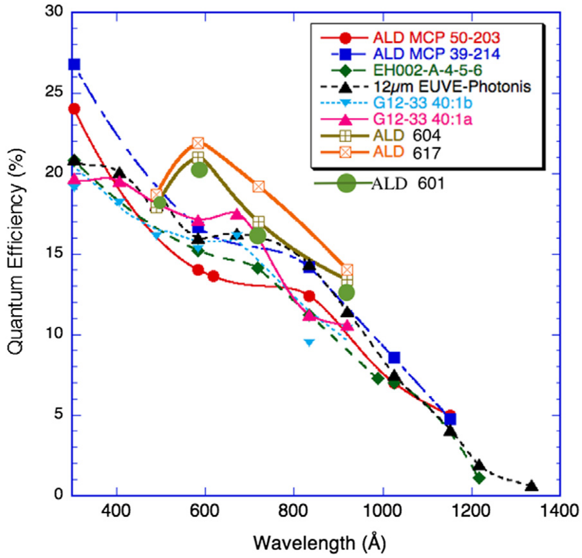

Fig. 6. Bare MCP quantum efficiency for ALD MCPs with ~74% open area compared with best case conventional MCPs (~60% open area).

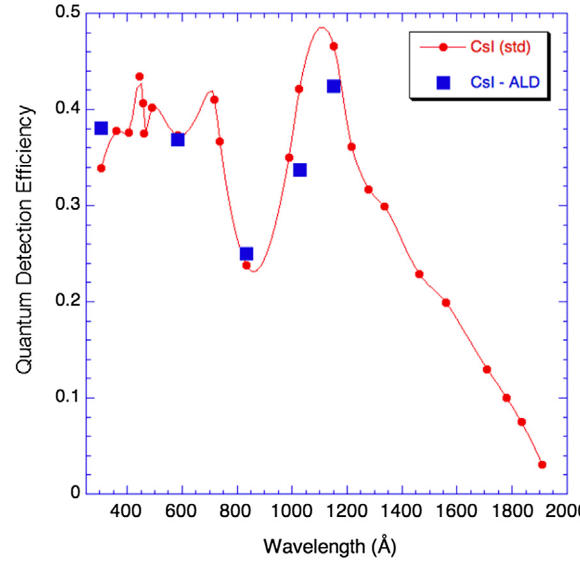

Fig. 7. Opaque CsI quantum efficiency for good traditional MCPs, and for initial batch of C14 ALD MCPs (bias angle only 8°) is very similar.

were cooled to −50 °C, effectively increasing their resistance enough for stable use. The ability to tailor the resistance ALD MCPs to a wide range of values (Ω s to GΩ s) makes them an attractive solution for photo detectors in extreme environments.

Much work has been done on improving the 10 μm ALD MCPs for inclusion into Planacon detectors [6]. Tests of 53 × 53 mm^2 ALD MCPs (Fig. 5) show good images, uniform gain maps, and low backgrounds (<0.1 cts s^{-1} cm^{-2}). Ions, from outgassing in the sealed tube, are accelerated towards the window will damage the semi-transparent photocathode over time. The low outgassing of the borosilicate substrates after processing has improved the life of photocathodes in sealed tubes [7].

3. UV photocathodes

ALD MCPs have consistently shown higher quantum detection efficiencies (QE) than traditional MCPs after coating the front surface with a standard NiCr electrode [8]. The most recent batch of Incom C14 substrates (ALD 6xx in Fig. 6) have shown the highest bare MCP QEs ever measured. To date, the opaque Alkali photocathodes used on ALD MCPs have resulted in similar QE to the best results with traditional MCPs (Fig. 7). Further optimization of the ALD MCPs, such as larger bias angles, should result in better QEs.

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References

[1] J. Vallerga, J. Zaninovich, B. Welsh, et al., The FUV detector for the cosmic origins spectrograph on the hubble space telescope, Nucl. Instrum. Methods Phys. Res. Sect. A 477 (2002) 551–555.
[2] W. Priedhorsky, J. Bloch, Optical detection of rapidly moving objects in space, Appl. Opt. 44 (3) (2005) 423–433.
[3] X. Michalet, R. Colyer, G. Scalia, et al., New photon-counting detectors for single-molecule fluorescence spectroscopy and imaging, Proc. SPIE 8033 (2011) 803316.
[4] S. George, Atomic layer deposition: an overview, Chem. Rev. 110 (2010) 111–131.
[5] M. Popecki, B. Adams, C. Craven, et al., Microchannel plate fabrication using glass capillary arrays with atomic layer deposition films for resistance and gain, J. Geophys. Res. A 121 (8) (2016) 7449–7460.
[6] PLANACON™ Photodetector. URL www.photonis.com (Accessed: 30 September 2017).
[7] C. Ertley, O. Siegmund, A. Tremsin, et al., Microchannel plate imaging detectors for high dynamic range applications, IEEE Trans. Nucl. Sci. 64 (7) (2017) 1774–1780.
[8] C. Ertley, O. Siegmund, J. Hull, et al., High dynamic range photon counting imagers using nano-engineered microchannel plates, in: IEEE Nucl. Sci. Conf. R, 2015, pp. 1–6.