Extended lifetime MCP-PMTs

Characterisation and Lifetime measurements of ALD coated Microchannel Plates, in a sealed photomultiplier tube

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With an increasing trend towards higher luminosity and bunch crossing rate for particle physics, the lifetime limitations of MCP based photon detectors has become of particular interest. For example the proposed LHCb upgrade TORCH will require an accumulated anode charge of 5 C/cm^2 for the lifetime of the detector, while a standard model does well to reach 0.1 C/cm^2.

Atomic Layer Deposition (ALD) is a chemical process used to deposit atomic mono-layers on a substrate. A process has been developed to deposit a surface with improved secondary emission yield on to a MCP substrate. The principal advantage of a higher SEY is the ability to achieve significantly higher gain at the same operating voltage across a single MCP. Further to this, it is suspected the atomic mono-layers deposited by ALD coating prevents desorption of gaseous contaminants in the MCP glass. The ions produced during desorption are widely believed to be a direct cause of photocathode aging in MCP-PMTs, leading to the hope that ALD coating can improve MCP-PMT lifetime.

Gain Characterisation

Two MCP-PMTs were manufactured, each a 10 mm active diameter and two chevron stacked MCPs with 10 µm pores. One tube was ALD coated with a high secondary electron yield material, whilst the other was left uncoated.

Figure 1 shows the gain calibration for each tube, using a calibrated DC light source and ammeter to monitor photocurrent. The ALD coated MCP-PMT shows significantly improved gain, requiring a MCP bias approximately 500 V less than the uncoated MCP-PMT to achieve equivalent gain.

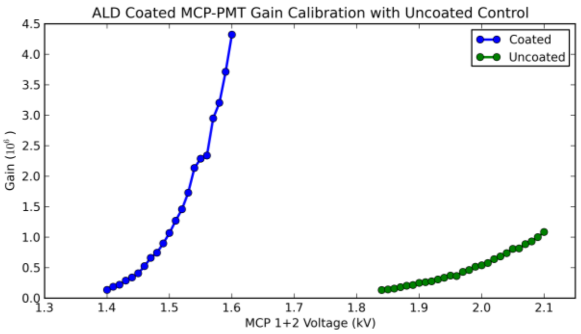

Figure 1

Timing Properties

Each MCP-PMTs timing performance was characterised using a pulsed 650nm laser diode with a 40ps FWHM pulse duration (Photek LPG-650) and 3ps RMS jitter attenuated to single photon levels. The delay of the detector's signal from the laser trigger was then measured using a LeCroy 5GHz oscilloscope. Each MCP-PMT's voltage was set to operate at a gain of 1×10^6. The mean delay gives the detector's transit time and the distribution's FWHM gives the transit time spread. The transit time is shown in Figure 2, the ALD coated MCP-PMT has a slightly longer transit time, due to the reduced field inside the MCP pores. Each tube's transit time spread was approximately the same, as shown in Figure 3.

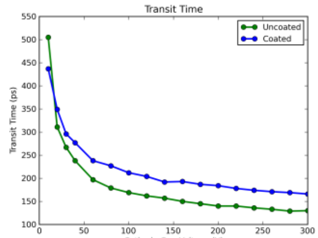

Figure 2

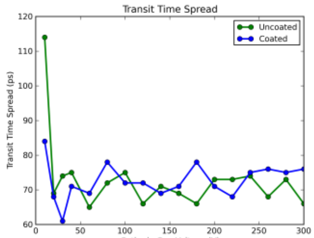

Figure 3

Lifetime Results

Following characterisation each MCP-PMT underwent accelerated life testing, where a 0.25 cm^2 area was illuminated using a DC light source, and the MCP-PMTs photocurrent monitored. The initial gain of the MCP-PMT detectors were set to be 1×10^6, and the operating voltage was fixed for the duration of the life test.

Figure 4 shows the change in photocurrent during the life test for both MCP-PMTs, with the ALD coated MCPs significantly outperforming the uncoated MCPs. After extracting a total charge of 5.1 C cm^{-2} the ALD coated MCP-PMT photocurrent fell by 30%, this fall in photocurrent is down to aging of the MCPs, as the photocathode's quantum efficiency, shown if Figure 5, has not changed (within measurement errors). The uncoated MCP-PMT's photocathode degraded significantly, with the peak QE at 504nm being reduced by approximately 80%.

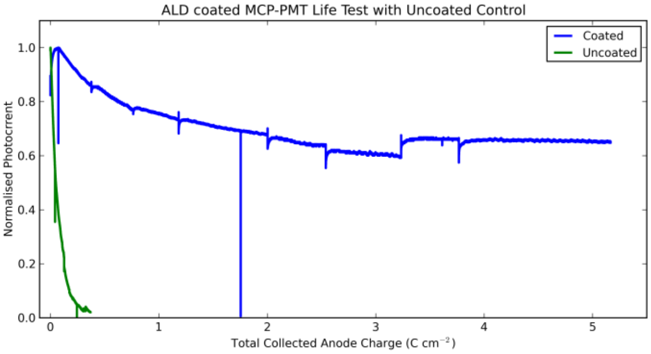

Figure 4

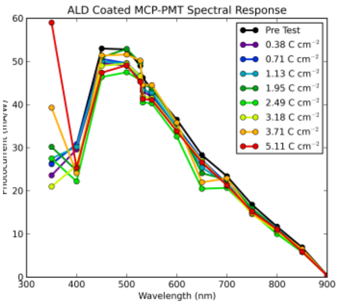

Figure 5

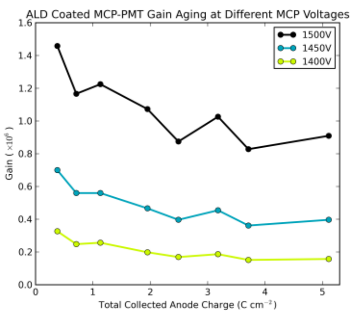

Figure 6

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