Effect of Multiple Discharges on Accumulated Damage to the DLC Anode Layer of a Resistive Well Electron Multiplier

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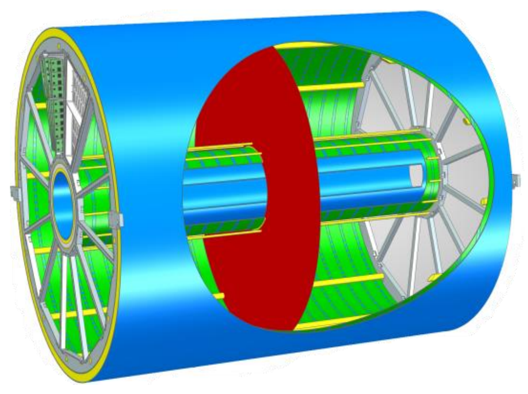
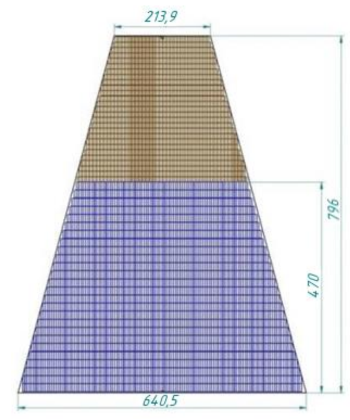
MPD TPC @ NICA

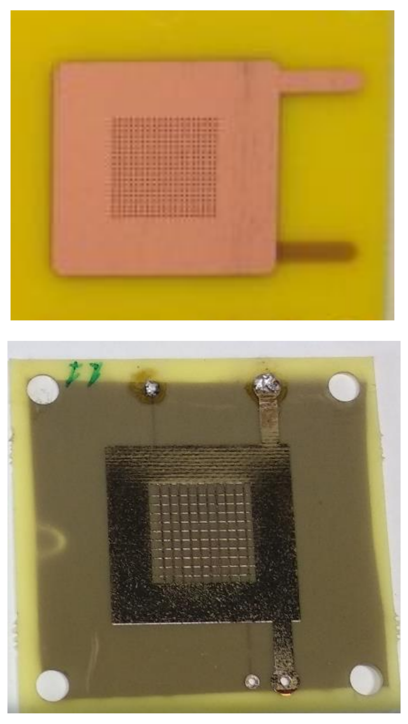


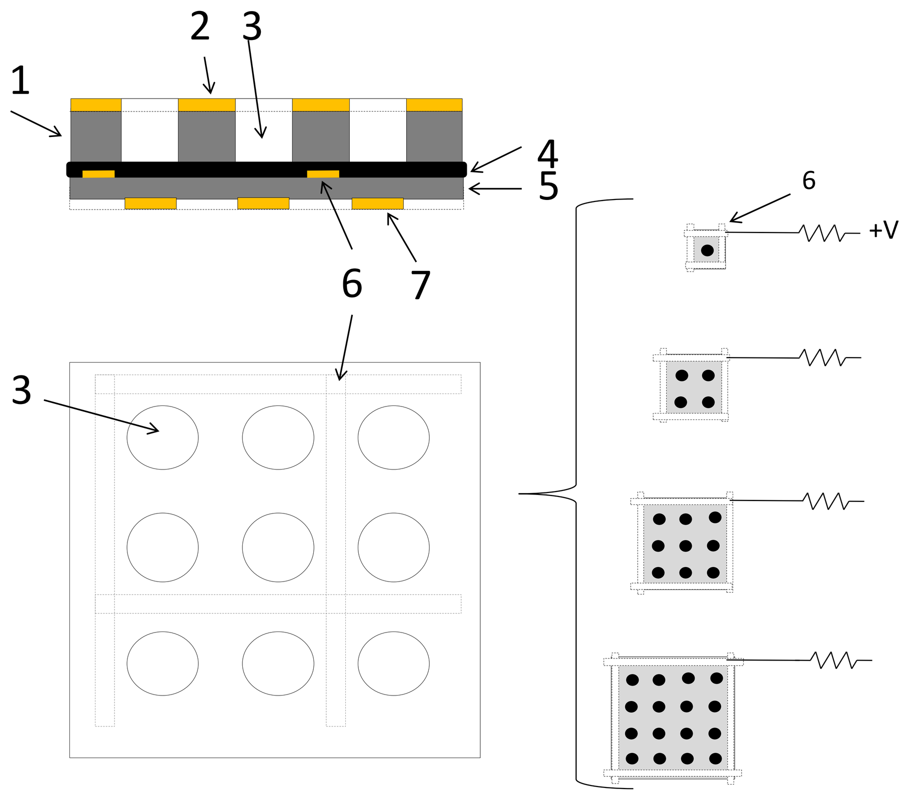
Current readout chamber design is based on MWPC. The expected rate of high ionization particles is about ~ 10^5 per cm^2 per year (about 0.3 ions/(cm^2*min)). For the planned future upgrade a detector with excellent robustness is needed. => R&D of detectors with resistive anode. Diamond Like Carbon (DLC) is a perspective resistive material to mitigate discharge damage. How it will be affected by accumulated damage from multiple discharges?



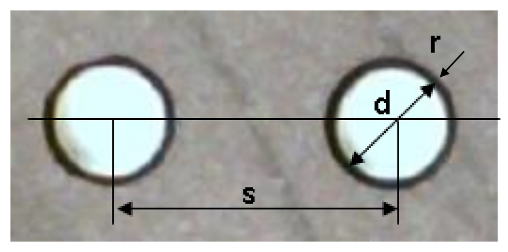
Resistive Well Electron Multiplier

One of the possible options for readout chamber upgrade is Resistive Well Electron Multiplier. The perforated structure of the RWEM detector used in the experiments was produced from a 500 μm thick FR4 with drilled holes of 200 μm in diameter and 500 μm in pitch. The resistive anode was made of 100 nm thick DLC layer with 30 MOhm/square sheet resistance.

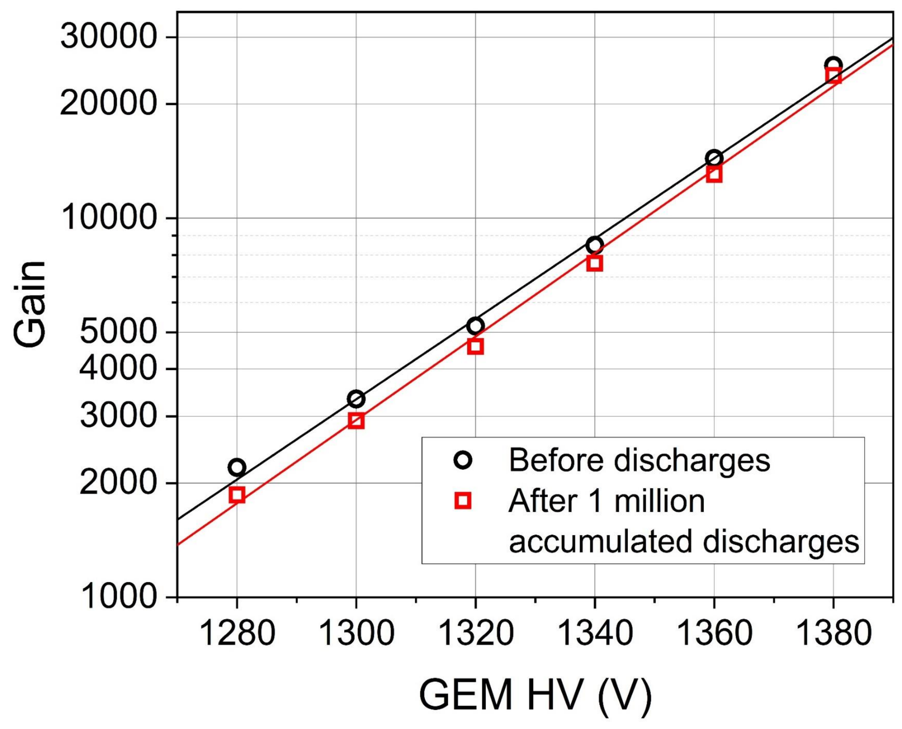




1. perforated dielectric plate with one side metallisation
2. top electrode
3. blind well-like hole
4. resistive DLC layer (anode)
5. dielectric plate with metallisation on both sides
6. Charge evacuation mesh surrounding either 1 hole (grid 1), or 4=2×2 (grid 2), 9=3×3 (grid 3), 16=4×4 (grid 4)
7. readout electrode (strip/pad/pixel readout elements)

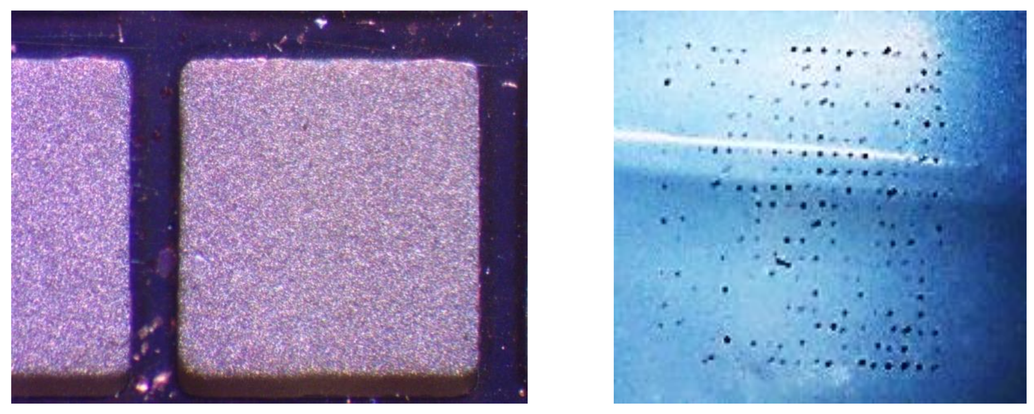


s=500 μm, d=200 μm, r~15 μm, thickness 500 μm (FR4)



DISCHARGE TESTS

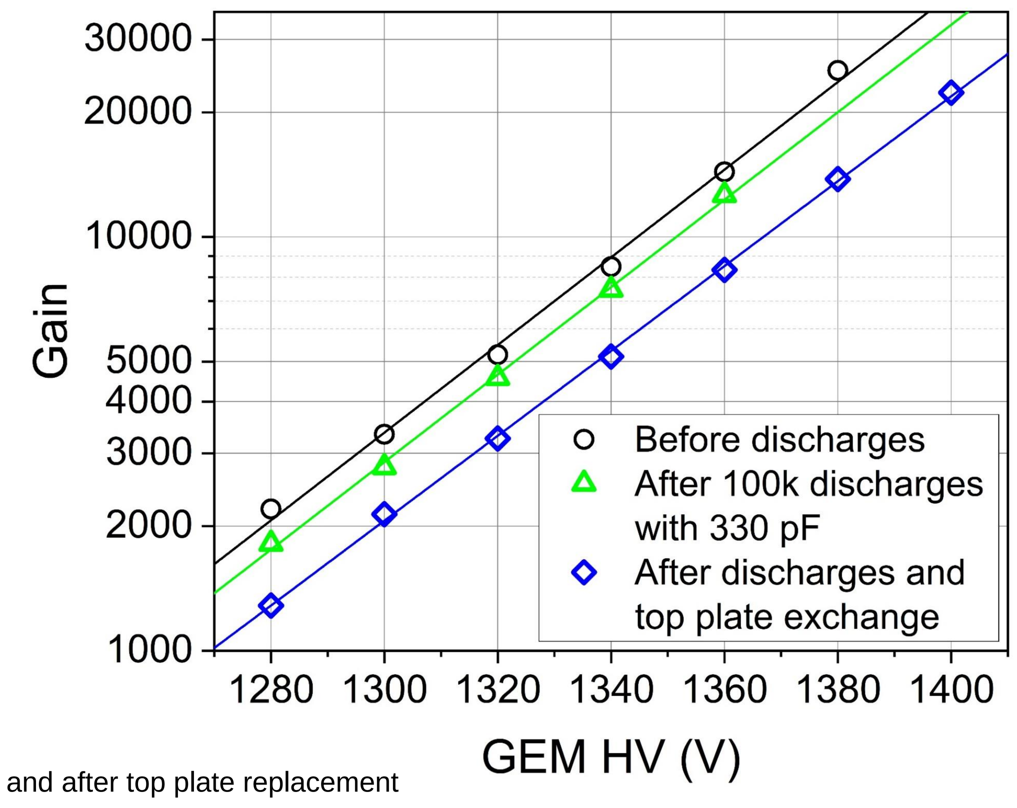
The detector was operated in Ar:CO_2 (90:10) gas mixture at gas gain of 3500. Discharge events were initiated by Am 241 alpha source placed in the drift gap. Discharge frequency was ~ 33 Hz. The RWEM detector with intrinsic capacitance of 34 pF did not show visible damage and changes in performance after **1 million** accumulated discharges. There were no changes in the performance and no visible damage to the detector.

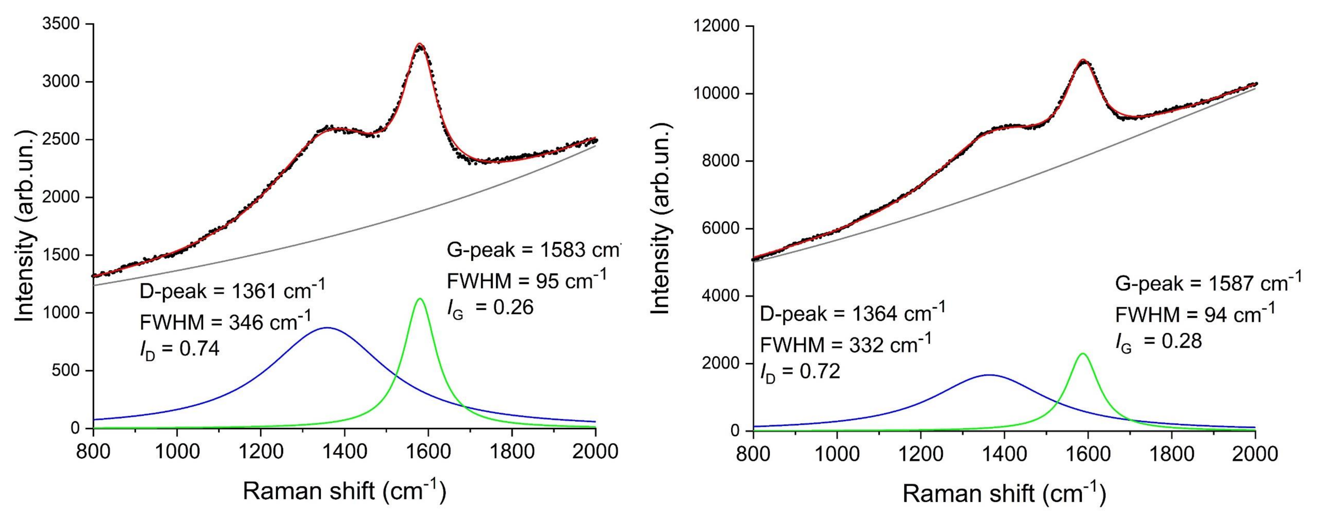


no visible damage to the DLC layer of RWEM after 1 million discharges. For comparison, damage to the resistive kapton after 1000 discharges

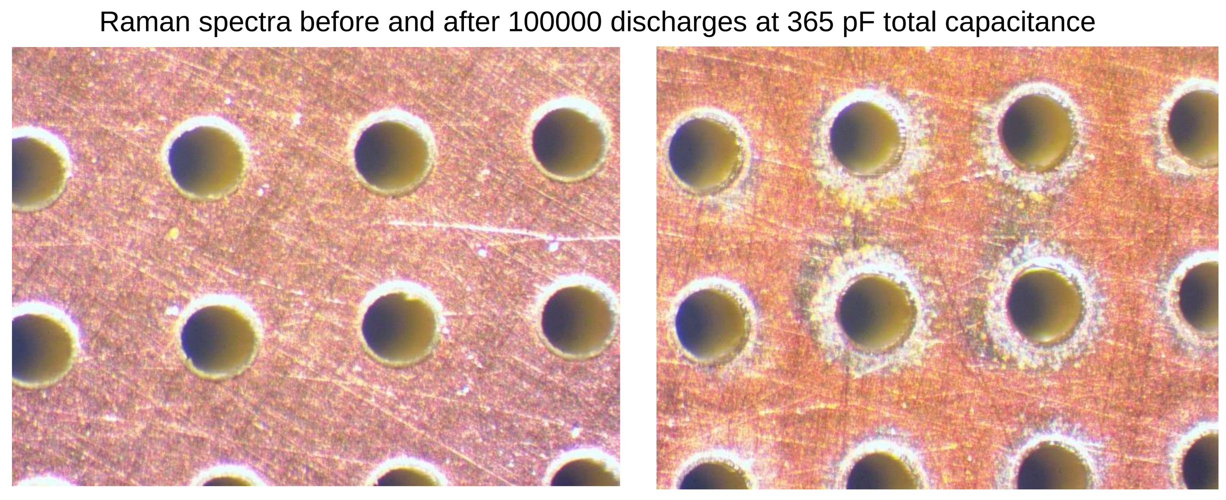
To simulate a large area detector, we added a capacitance in parallel with the test device. At a capacitance of **0.33 nF**, a slight damage of the RWEM perforated structure and DLC layer was observed after **100,000 discharges**. At the same time, Raman spectroscopy did not reveal any significant changes in the structure of the DLC layer.

After top FR4 plate was replaced by a fresh one, the detector performance was partially recovered.



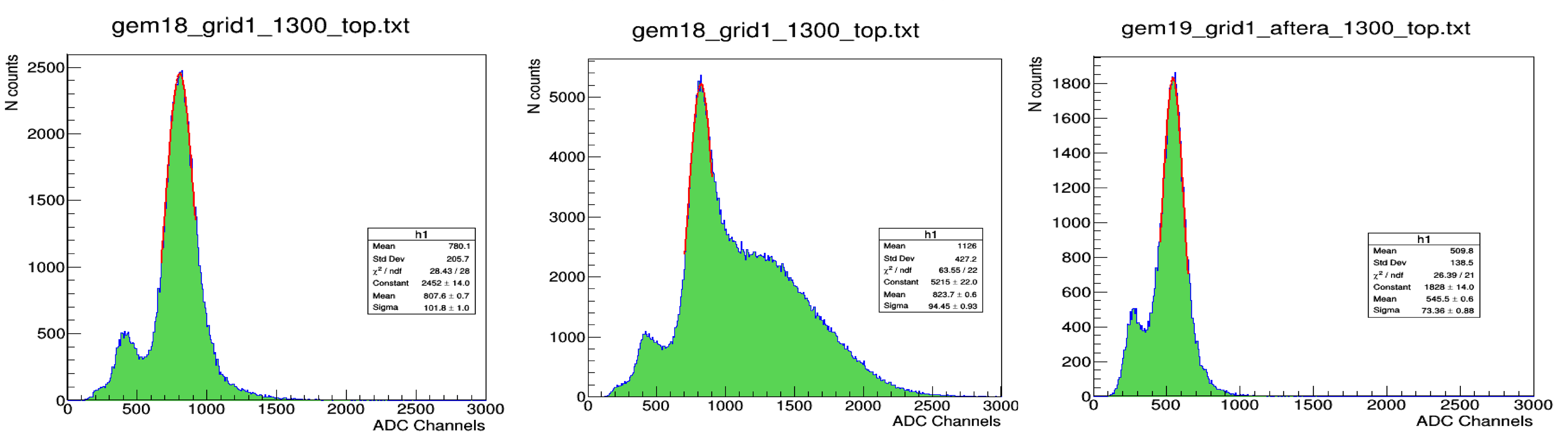


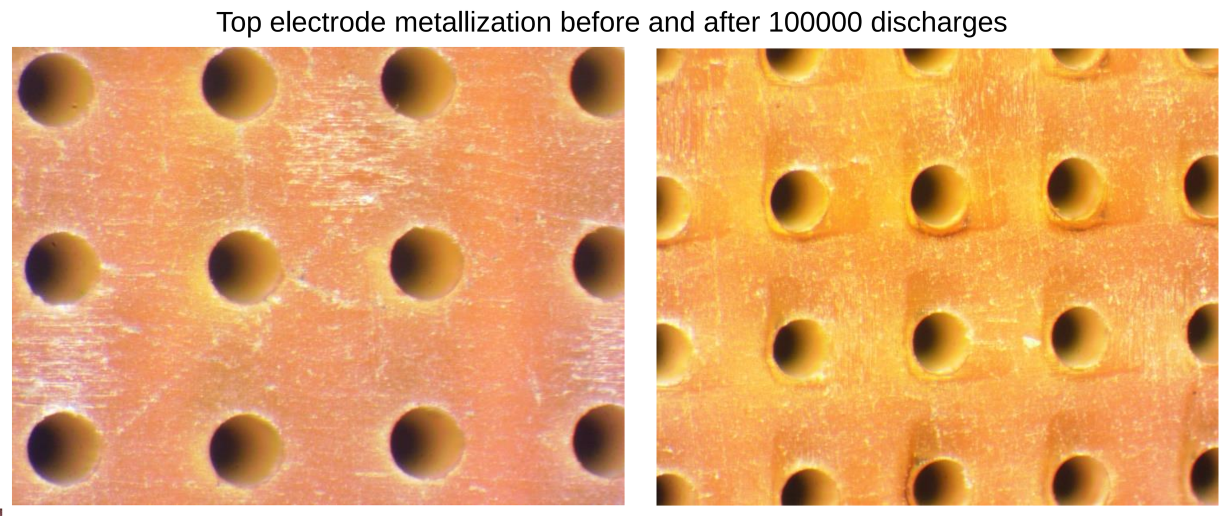
Raman spectra before and after 100000 discharges at 365 pF total capacitance



Top electrode metallization before and after 100000 discharges

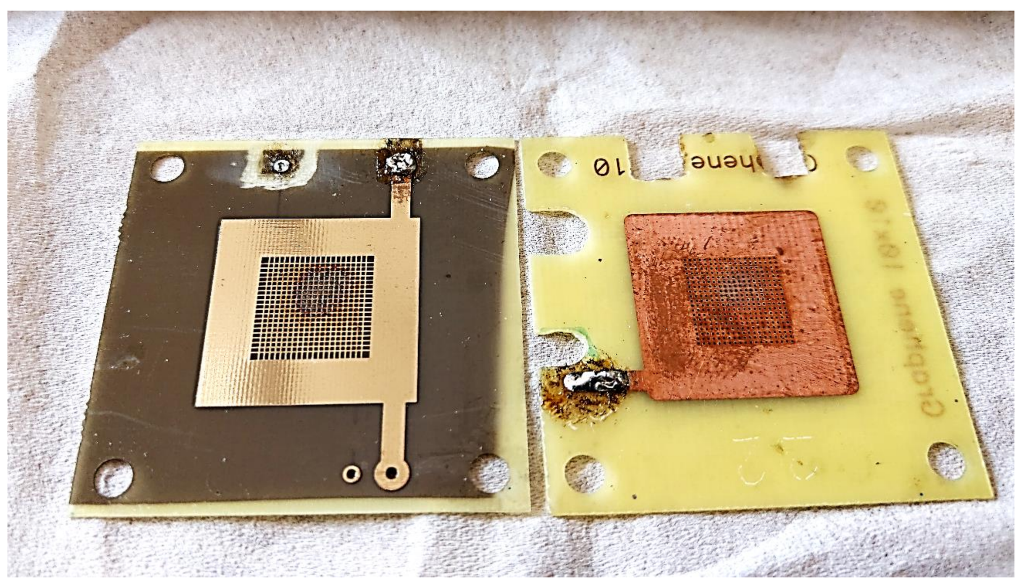
Fe-55 spectra before and after 100000 discharges at 365 pF total capacitance, and after top plate replacement

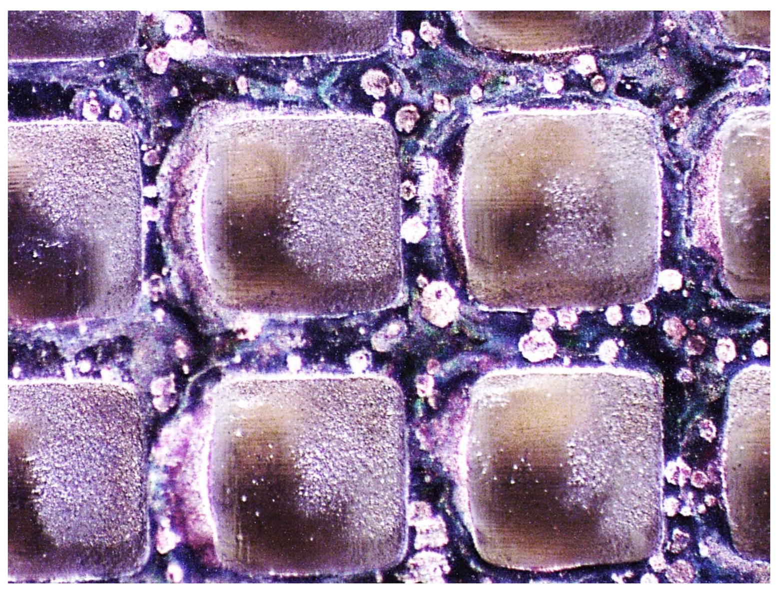


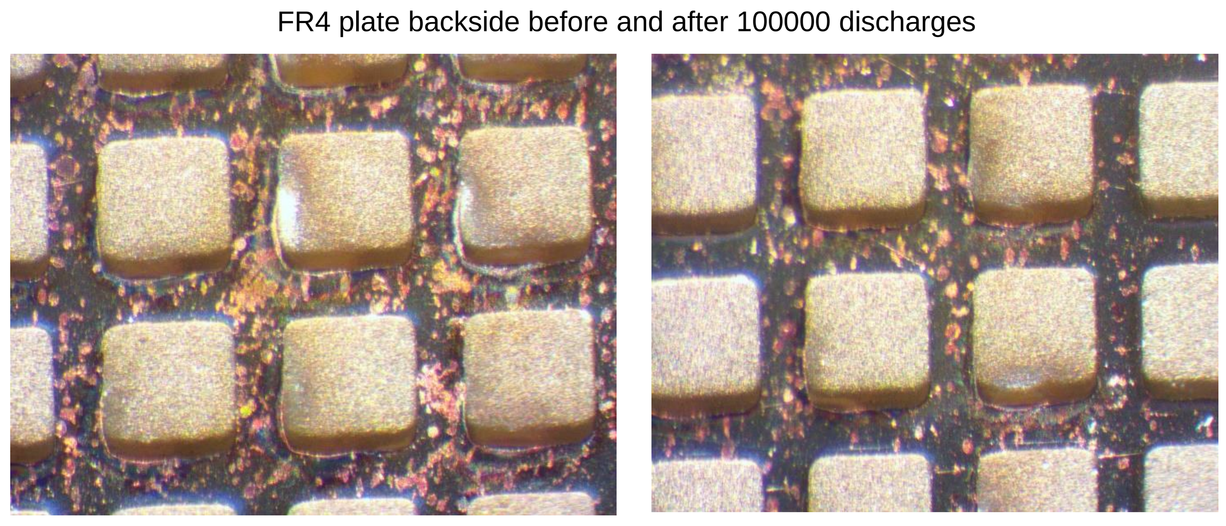


FR4 plate backside before and after 100000 discharges

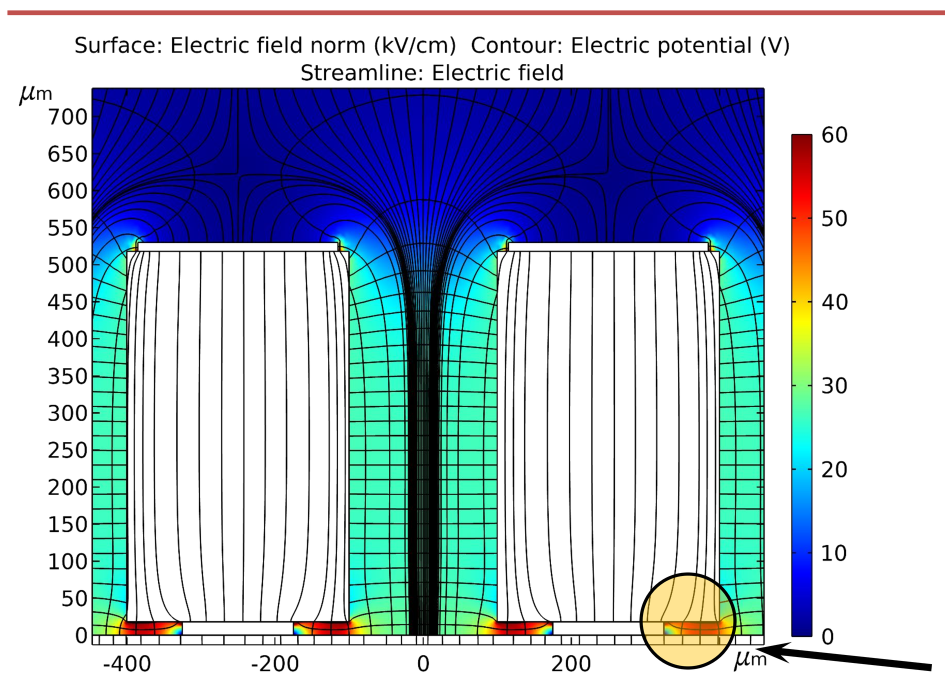
The further increase of the discharge energy by adding a capacitance of **1nF** resulted in significant damage to the detector after the accumulation of **100,000** discharges.







Charge evacuation grid and DLC layer directly below alpha source and on the side. DLC layer erosion and copper deformation is clearly visible



The resistive DLC layer protects the detector from the discharges. The discharges still produce damage in the DLC layer and the amount of damage depends on the discharge energy. In our particular configuration the amount of damage becomes significant at discharge energy of approximately 0.3 mJ (34+330 pF @ 1300V). The accumulated damage eventually degrades the detector performance. To limit the discharge energy for this particular configuration, the detector should be segmented to pieces of <300 pF capacitance, which corresponds to ~60x60 mm segments. The nature of the damage to the DLC layer and the field map of the device suggests, that the discharges occur between top electrode and charge evacuation grid due to gas "pockets".