

ELECTRICAL CHARACTERIZATION OF THE AMPLIFICATION PLATE OF A THICK-GEM DETECTOR FOR LOW ENERGY X RADIATION DOSIMETRY

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ABSTRACT

To evaluate the possible use of Thick-GEM detectors as dosimeters in standard mammography radiation qualities, a prototype is under development for tests. This is a collaboration project between the IPEN Calibration Laboratory and the High Energy Physics and Instrumentation Center (HEPIC-IFUSP). The prototype design takes into consideration many parameters that were obtained in an exploratory work using the Monte Carlo simulation code MCNP5. Using simulations, parameters such as typical dimensions and materials were optimized to match the characteristics of the detector to the requirements of a dosimeter for this purpose. At the present status of the project, electrical tests were undertaken to evaluate the quality of the amplification plate produced in-house. The amplification plate is composed of fiberglass with a thickness of 0.5 mm and 0.03 mm of copper on each side. The average diameter of the orifices in the plate is 0.25 mm, and the distance between centers is 1.00 mm. During the electrical tests, the amplification plate was in a gas chamber filled with Argon at atmospheric pressure. The leakage current was measured as a function of the applied voltage between the copper cladding of both sides. The electrical resistance of 15.3G Ω was obtained. Additionally, the breakdown voltage was observed at approximately 1.0 kV, limiting the maximum amplification voltages to this value.

1. INTRODUCTION

The GEM (Gas Electron Multiplier) detector was proposed for the first time at CERN as a position sensitive detector, aiming at the determination of trajectories of particles in high energy physics experiments. Its development is connected to an attempt to improve the counting rate capability and the signal degradation promoted by the accumulation of positive ions, both effects present in the multi-wire proportional counters (MWPC) in use. Later, these detectors found applications in several areas, including some related to the production of images with X-rays [1].

The Thick-GEM detector is a GEM detector variant. Its structure resembles that of a scaled GEM detector [2]. The Thick-GEM detector stands out not just for the high counting rate capability and much less signal degradation due to positive ions accumulation when compared to MWPC like the conventional GEM, but also for its simplicity of construction, low cost, robustness and shape diversity [3]. A dosimeter with properties of a Thick-GEM is highly desired for many applications, such as diagnostic and therapeutic medicine, industrial radiography and nuclear instrumentation. Besides, the high sensitivity provided by GEM and Thick-GEM detectors may extend their applications to dosimetry of very low doses.

To evaluate the possible use of Thick-GEM detectors as dosimeters in standard mammography radiation qualities, a prototype is under development for tests. Using simulations, parameters such as typical dimensions and materials were optimized to match the characteristics of the prototype for the requirements of a dosimeter for this purpose [4].

At the present status of the project, an amplification plate was produced and the electrical tests were performed to evaluate its quality. The amplification plate was produced in-house by a small dedicated Computer Numerical Control (CNC) machine. Results reported here indicate the high insulation provided by a good finishing of the production route and high breakdown voltage, roughly indicating a good homogeneity of the plate.

2. MATERIALS AND METHODS

The electrical tests were performed to evaluate the quality of the amplification plate produced in-house. The amplification plate, with 36 cm² of area, is composed of fiberglass with a thickness of 0.5 mm and 0.03 mm of copper on each side. Holes with 0.25 mm of diameter were produced in a hexagonal distribution, with center-to-center distance (pitch) of 1.0 mm. The cleaning process to remove residues of the drilling process includes a five minutes ultrasonic bath with isopropyl alcohol followed by a 20 h drying at 50°C.

Electrical tests were performed with the amplification plate immersed in Argon gas at atmospheric pressure and continuous slow flow. The leakage current was measured as a function of the applied voltage between the copper clads on both sides.

The equipment used for voltage and current measurements was the CAEN high voltage VME module, model V6521HN. It can range from 0 V to -6000 V and provides a maximum current of 20 μ A. For each voltage value, a current value was measured, and uncertainties were obtained from the equipment manual.

3. RESULTS

It is possible to detect sparks by voltage drop and current variation, events that are accompanied by the spark, almost always visible. Thus, it is possible to know where electric discharge is occurring.

Initially, sparks were observed in a single hole even with 100 V voltage applied between the clads (Figure 1). The cleaning process was repeated and the plate was placed back into the test chamber. This time, a random pattern of sparks in the orifices at a voltage of 1.0 kV was observed. The random pattern of sparks indicates that the limit of the Argon electrical insulation was achieved.

Sparks can be detected in two ways: by a voltage drop and by a current variation (events that occurs with the visible spark). In this case, the sparks at the edges are disregarded because at the saturation voltage of TH-GEM, sparks occurs in several holes, so the edge is not a limiting factor in its operation.

After this conditioning process, data acquisition was initiated.

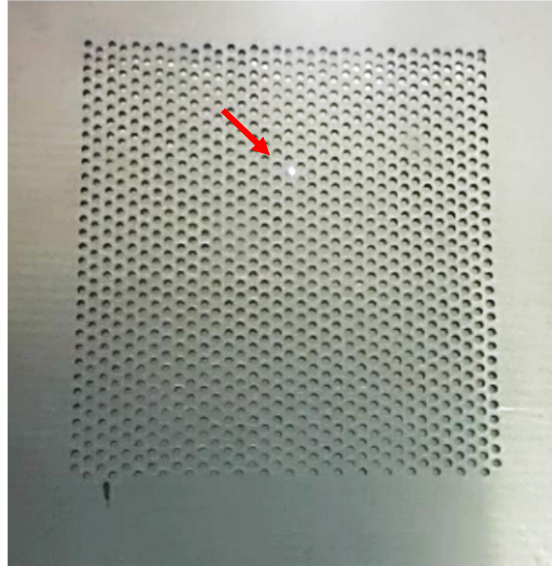


Figure 1 – Spark in a single hole with 100V, of the amplification plate of a Thick-GEM detector.

Leakage currents were recorded for applied voltages between 100.0 V and 1.0 kV. Figure 2 shows the results obtained for the leakage current as a function of the applied voltage between the copper clad on both sides of the amplification plate of the Thick-GEM detector.

The plate insulation (resistance) value was obtained through the slope of a linear regression in the first six data points. The choice of these points was made regarding its linearity, since the seventh point shows a non-linear tendency as observed in Figure 3, indicating that at the voltage of 600 V current losses are observed.

The resistance value obtained was of $(15.3 \pm 0.4) \text{ G}\Omega$. The obtained interception parameter of the linear regression was $(58 \pm 8) \text{ V}$, representing an internal resistance of the voltage source of approximately $4 \text{ n}\Omega$.

Sparks were observed when voltages achieved values of approximately 1.0 kV as already reported. Therefore, this was considered as the limit voltage applicable to this plate.

This value is close to the nominal dielectric strength of Argon at atmospheric pressure (reported as 7kV/cm in uniform electric field condition in [5]), providing evidences that the insulation achieved is close to the physical limit in the test conditions.

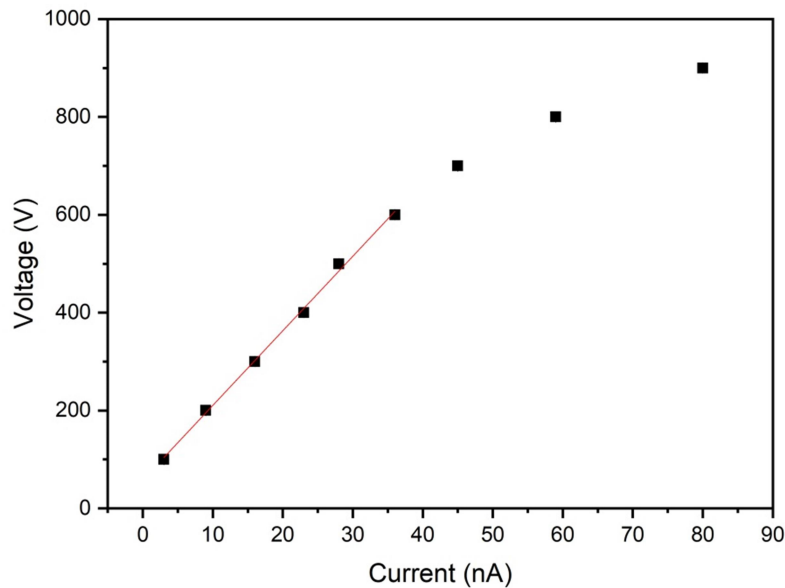


Figure 2 – Applied voltage to the amplification plate of a Thick-GEM detector versus the measured current. Uncertainties are not visible.

3. CONCLUSIONS

The electrical resistance of $(15.3 \pm 0.4) \text{ G}\Omega$ was obtained as the insulation of the amplification plate. Tests were performed in pure Argon environment at atmospheric pressure and constant low flux of gas for continuous renovation. The breakdown voltage was observed to be approximately 1.0 kV, limiting the maximum amplification voltages to this value.

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