Journal of Physics: Conference Series

PAPER • OPEN ACCESS

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To cite this article: N F Silva *et al* 2018 *J. Phys.: Conf. Ser.* **975** 012043

Construction of the TH-GEM detector components for metrology of low energy ionizing radiation

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Abstract: The Gas Electron Multiplier (GEM) detector was originally proposed as a position sensitive detector to determine trajectories of particles prevenient from high-energy collisions. In order to study the potential of TH-GEM type detectors in dosimetric applications for low energy X-rays, specifically for the mammography standard qualities, it was proposed to construct a prototype with characteristics suitable for such use. In this work the general, structural and material parameters applicable to the necessary conditions were defined, establishing the process of construction of the components of a prototype.

Keywords: TH-GEM, dosimetry, Gaseous detector, low energy.

1. Introduction

The Gas Electron Multiplier (GEM) detector was first proposed by Sauli as a position-sensitive detector, aiming the determination of trajectories of particles provenient from high-energy collisions. Subsequently, these detectors found applications in several areas related to the production of x-ray images [1].

The TH-GEM detector (Thick GEM) is a variation of the GEM detector [2]. Its structure resembles that of an extended scale GEM detector. The advantages of the TH-GEM detector are many, outstanding for its high sensitivity and low cost.

In order to study the suitability of TH-GEM detectors for low energy X-rays dosimetry, specifically for the standardized mammography qualities, it was proposed the construction of a portable prototype of a TH-GEM detector with characteristics that fulfill the dosimetric constraints. This work establishes the process of construction of some components of this prototype, describing their dimensions and fundamental characteristics. The information will be used in the future as a technical guide for the construction of equivalent dosimeters.

1.1 Operation of the TH-GEM detector

The basic constituent of a TH-GEM detector is the amplification plate, which is a thin non-conductor plate (thickness of approximately 0.5 mm) coated on both sides by metallic layer. This plate presents holes of approximately 0.3 mm diameter in a hexagonal pattern, and is immersed in a rarefied gas. A high potential difference applied between the coatings creates an intense electric field configuration within the holes. Each individual hole acts as a proportional counter, multiplying the electrons produced in the ionizations in the gas induced by an incident radiation in an avalanche process, and generates a measurable charge which is collected by an electrode [3]. Figure 1 shows a cross-section of the TH-GEM type detector, where $\vec{E}_d$ is the electric field in the region where the incident radiation interacts with the gas producing an electron, and $\boldsymbol{V_d}$ is the voltage for the collection of this electron (drift region). The subscript *o* represents the region of a orifice of the polymer plate, being $\vec{\boldsymbol{E}}_{\boldsymbol{o}}$ and $\boldsymbol{V_o}$ the electric field in the region where the avalanche of ionizations occurs and the voltage necessary. Lastly, $\boldsymbol{V_t}$ is the voltage needed to guide the electrons in the region of the electric field $\vec{\boldsymbol{E}}_{\boldsymbol{t}}$ to the collector plate.

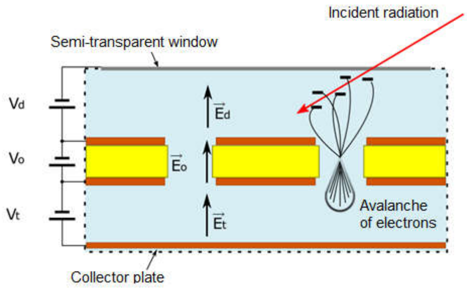


Figure 1 – Schematic illustration of a TH-GEM type detector. Adaptation of [1].

More than one plate can be used in series to further amplify the cascade effect.

In the case of a GEM detector, the plate is perforated in a micrometric pattern with its dimensions being 5 to 20 times smaller than in the case of TH-GEM detectors. Like the TH-GEM detectors, in GEM detectors an electric potential is applied between both sides of the coating and the plates are also emerged in a rarefied gas. As the dimensions are proportionally smaller, the required difference of potential between both sides of the amplification plate are also smaller. A great advantage of the GEM and TH-GEM detectors is their easy adaptation in a adaptable format [5].

2. Materials and methods

The construction of the components was done at the mechanical workshop of the Laboratory of Material Analysis with Ion Beams of the University of São Paulo (LAMFI-USP), which is participating in this project in the form of institutional collaboration (Figure 2).

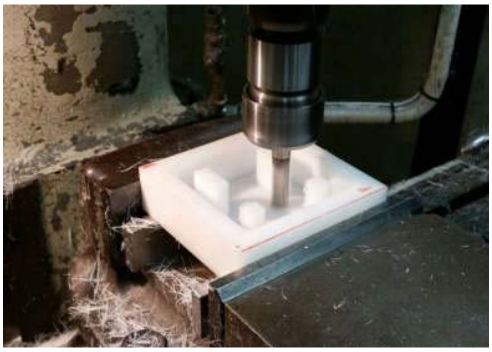


Figure 2 – Construction of the detector base in the machining workshop of the Laboratory of Material Analysis with Ion Beams of the University of São Paulo.

For the detector base the polyoxymethylene material was used, density 1.41 g/cm^3, because it is a rigid and resistant material, and offers a good electrical insulation and good machining characteristics. In order to simplify the construction of the detector, the squared format for the base, with sides of 11.00 cm, was determined.

For the entrance window, 6 μm thick aluminum foil was used, density 2.6989 g/cm^3.

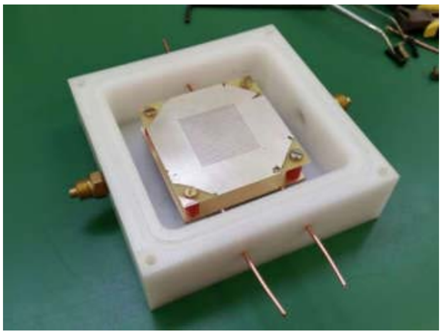
The amplification and collector plate were made of fiberglass printed circuit boards, density 2.49 g/cm^3, coated by copper, density 8.96 g/cm^3[6]. The copper plates received a chemical treatment that created a thin silver cover on top to prevent for oxidation. The chemical treatment was done on both the amplification plate and the collector.

The perforation of the amplification plate was done using a CNC device constructed at the LAMFI-USP laboratory for internal use to fabricate small printed circuits.

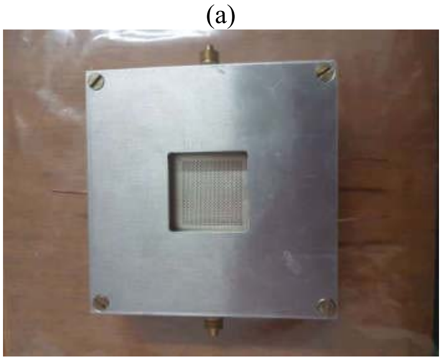
The gas inlet and outlet were positioned on opposite sides of the detector to ensure the renew process in the amplification area by a continuous flux of gas. The electrical feedthroughs were provisionally implemented as three 2 mm diameter copper wires, and glue to avoid gas leakage.

3. Results and discussion

It was possible to construct a TH-GEM detector, with sides of 11 cm (Figure 3). The whole system weights approximately 300 g.



(a)



(b)

Figure 3 – Photo of the TH-GEM detector components: a) without the shield; b) with the shield.

The thickness of the 6 mm shield was defined by Monte Carlo simulation with code MCNP5 [7]. The geometry, the materials that compose the detector, the experimental configuration and the characteristics of the radioactive sources were specified. The energy deposited at the sensitive volume was observed, and the thickness of the shield was increased until an efficiency value of 98.5% was achieved. The diameter of the orifices and of the etched rim of the amplifier plate were measured using a USB digital camera with up to 1000x magnification. These dimensions are shown in the caption of Figure 4.

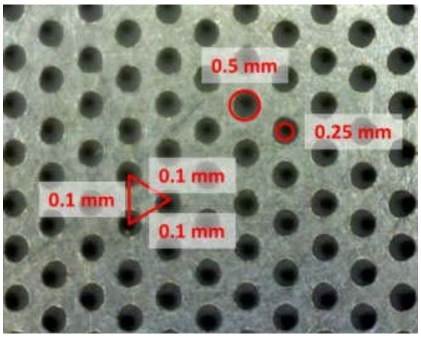


Figure 4 - Amplification plate seen through the digital microscope. The average diameter of the orifices in the fiberglass plate is 0.25 mm, the diameter of the etched rims is 0.5 mm, and the distance between the center of one orifice to the other is 0.1 mm

4. Conclusion

It was possible to construct the components of the TH-GEM portable detector. These processes allowed the elaboration of the geometry of the detector accordingly to previous simulations, which will also guide the choice for the gas that will fill the detector and the values expected in the experimental tests for collected charge.

Acknowledgments

The authors acknowledge the partial financial support from the Brazilian agencies: CNEN, FAPESP, CNPq, CAPES and MCTIC (Project: INCT – Radiation Metrology in Medicine).

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