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Natália F. Silva[1]; Tiago F. Silva[2]; Maysa C. Castro[1]; Hugo N. da Luz[3] and Linda V. E. Caldas[1]

[1] Instituto de Pesquisas Energéticas e Nucleares/Comissão Nacional de Energia Nuclear (IPEN/CNEN-SP)
Av. Professor Lineu Prestes, 2242
05508-000 São Paulo, SP, Brazil.

[2] Instituto de Física da Universidade de São Paulo (IFUSP)
R. do Matão, 1371
05508-090 São Paulo, SP, Brazil.

[3] Institute of Experimental and Applied Physics (IEAP)
Czech Technical University in Prague
Husova 240/5
110 00 Prague 1, Czech Republic

nsilva@ipen.br

Abstract. The TH-GEM based detector is a robust, simple to manufacture, high-gain gaseous electron multiplier. Its operation is based on a standard printed circuit board (PCB) coated on both sides by metallic material, perforated in a millimeter pattern, and immersed in gas. In order to study the feasibility of using TH-GEM type detectors in dosimetric applications for standard mammography beams, a prototype with adequate dimensions and materials was produced. The present work encompasses the calculations of electric fields by the Gmsh and Elmer software packages and the avalanche simulation using Garfield++ library of a TH-GEM detector filled with Ar/CO_2 mixture at atmospheric pressure.

Keywords. TH-GEM, mammography beam, dosimetry; Garfield++.

1. Introduction

The GEM based detector is a position sensitive gas detector. It consists of a thin polymer sheet (typical thickness of 50 μm), coated on both sides with a thin metallic layer (typical thickness of 3 μm), perforated in a hexagonal pattern with micrometric holes (typical hole diameter of 50 μm) and immersed in an appropriate gas. A potential difference is then applied between the two metallic layers, creating an intense electric field within each orifice. Each hole then acts as an independent proportional counter, multiplying the electrons released by ionizing radiation in the gas by the avalanche effect [1].

The Thick-GEM detector (TH-GEM) is a variation of the GEM detector. Its structure resembles that of an enlarged scale, with dimensions ten times larger than the GEM. Detectors of the TH-GEM type are often manufactured with a printed circuit board and are considered robust multipliers with high gains and fast signals in the order of nanoseconds [2]. The advantages of TH-GEM detectors concerning GEM are their simplicity of construction, low cost and robustness [3].

This work is part of the effort to study the viability of TH-GEM type detectors for low energy X radiation dosimetry, more specifically, for standardized mammography beams. In a previous publication [4], the detector geometry and materials were simulated in terms of acceptance and protection from spurious signals (scattered radiation) using the MCNP5 software [5]. Here, the objective is to better understand the operation and charge transport in a TH-GEM detector, to define operating standards for a prototype. Therefore, a series of numerical simulations were carried out with the software chain GMSH, ELMER and GARFIELD ++ [6, 7, 8] determining the magnitude of the electric field concerning the absolute gain and the gas mixture.

The use of this software chain to study the physical processes in GEM and TH-GEM detectors is reported in the literature in an X-ray fluorescence image system [9], aiming to characterize the detector in terms of absolute and effective gain, enabling the determination of an optimized detector configuration in terms of applied voltages and the gas mixture that fills the detector.

The electric field produced within the orifices is responsible for generating the avalanche of ionizations, but it presents some limits regarding the gas insulation and production of sparks. Besides that, electric fields in the drift and induction regions (above and bellow the TH-GEM plate, respectively) are important for the electron transport from the primary ionization location, passing through the amplification, until the collecting electrode.

The gas selection plays an important role in the detector performance since the processes of ionization, electron scattering and multiplication occur according to the gas properties. Different types of gas mixtures may be used. The main criteria for choosing the mixture are the ability of providing stable gain, low electron attachment, and low mean minimum energy of ionization [10]. Commonly used gas mixtures are Ar/CO_2 in concentrations: 70/30 and 80/20 and Xe/CO_2. The mixture Ar/CO_2 is the most used, due to the higher availability of the argon compared to xenon.

In this work, a TH-GEM type detector was simulated with dimensions of the prototype built. The profile of the electric field inside the detector was determined, and the detector was characterized in terms of absolute gain as a function of the voltage applied in the TH-GEM at different concentrations of Ar/CO_2.

2. Materials and Methods

In this work, a chain of simulation codes was used as follows:

• Gmsh [6]: A program used to define the geometry and the mesh suited for Elmer simulations.

• Elmer [7]: A finite element analysis program that can be used to calculate the electrostatic potential along the entire space in the detector geometry, and the results can be imported into Garfield++ for use in simulations;

• Garfield ++ [8]: A program for calculating the detailed simulations of multiple aspects of charge transport and the avalanche of ionizations in gaseous detectors;

The gas, as the interaction medium, is described by the Magboltz program [11], embedded within Garfield++. In this work, a mixture of Argon and CO_2 in the 90/10, 80/20 e 70/30 concentrations were considered.

An Intel® Core™ i7-7700 microcomputer was used for the simulations.

3. Results

The first step was to define a detector geometry and creating a mesh of that geometry in the Gmsh software. After that, the Elmer finite element analysis program was used to calculate electrostatic fields using the mesh. During this process, materials were assigned to different parts of geometry, material properties (such as the dielectric constant) and boundary conditions.

The result was a value of the electrostatic potential at each finite element vertex. This list, along with the Elmer mesh format, can be imported into the Garfield++ library. Once imported into Garfield++, this is equivalent to creating all the detector geometry to be used in the charge transport in gas simulation. At this moment of the simulation chain, the boundary conditions are defined for periodicity, which dictates how Garfield++ repeats the field map in spatial coordinates.

The geometric parameters used in the construction of TH-GEM are listed in Table 1.

Table 1: TH-GEM parameters

Description	Value (cm)
Orifice radius	0.0125
Dielectric thickness	0.05
Copper thickness	0.003
Distance between amplification plate and external electrodes	1.00

Figure 1(a) shows the magnitude of the electric field inside a hole of the amplification plate and Figure 1(b) the value of the electric field (V/cm) along an imaginary line passing through the center of a hole (vertical line from top to bottom in Figure 1(a)). A voltage of 1 kV was applied between the copper clad of the amplification plate, and it was used as a 1 kV/cm for drift and transfer field. This was the maximum voltage obtained in the experimental electrical characterization of the amplification plate reported in a previous work [12].
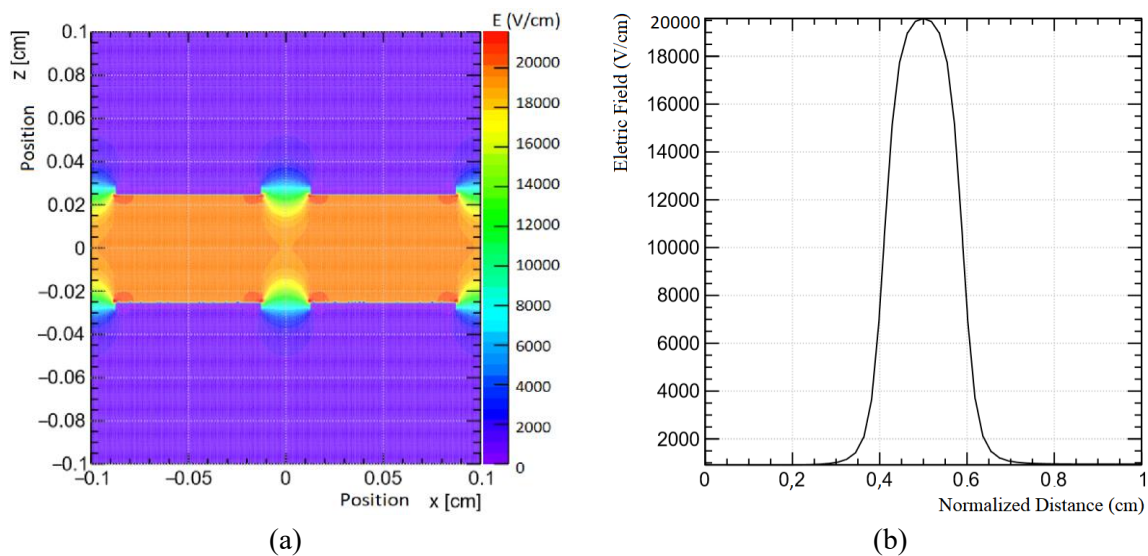

(a)   (b)

Figure 1: (a) Electric field (V/cm) in a hole of the TH-GEM amplification plate; (b) Magnitude of electric field in V/cm, along an imaginary line passing through the center of a hole, over normalized distance. A voltage of 1 kV was applied between the copper clad of the amplification plate, and it was used as a 1 kV/cm for drift and transfer field.

Figure 2 shows a typical simulation for the electron traces including the electron avalanche within the orifices in the electric field configurations used in Figure 1 and the signal induced on an electrode for this ionization. A single electron was produced in the drift region, guided to the orifice and 4 new electrons were generated.
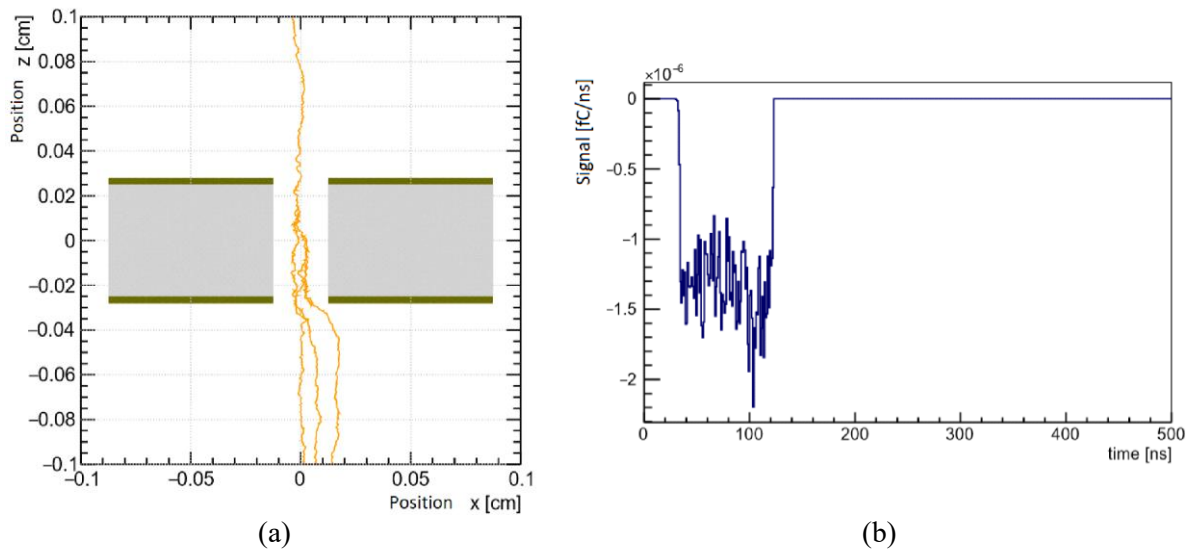
(a)   (b)

Figure 2: (a) Electron avalanche in a TH-GEM detector simulated with Garfield++. The lower readout electrode is invisible in the geometry, but it is located in the horizontal plane at which the drift lines of all of the electrons escaping the orifice terminate; (b) electron induced signal produced on the lower readout electrode by the avalanche.

Absolute gain is the multiplication factor of the amplifier board. Due to the complexity of measuring absolute gain experimentally, the use of computer simulation for its determination is an option. For each electric field value inside an orifice, shown in Figure 3(a), a value was estimated for the absolute gain resulting from the avalanche effect for 100 electrons generated. Figure 3(b) shows the results obtained for different gas mixtures and pure Argon. It is possible to observe from the data obtained that the greatest absolute gain obtained is for pure Argon. For higher concentrations of CO_2 in the mixture, the gain decreases.
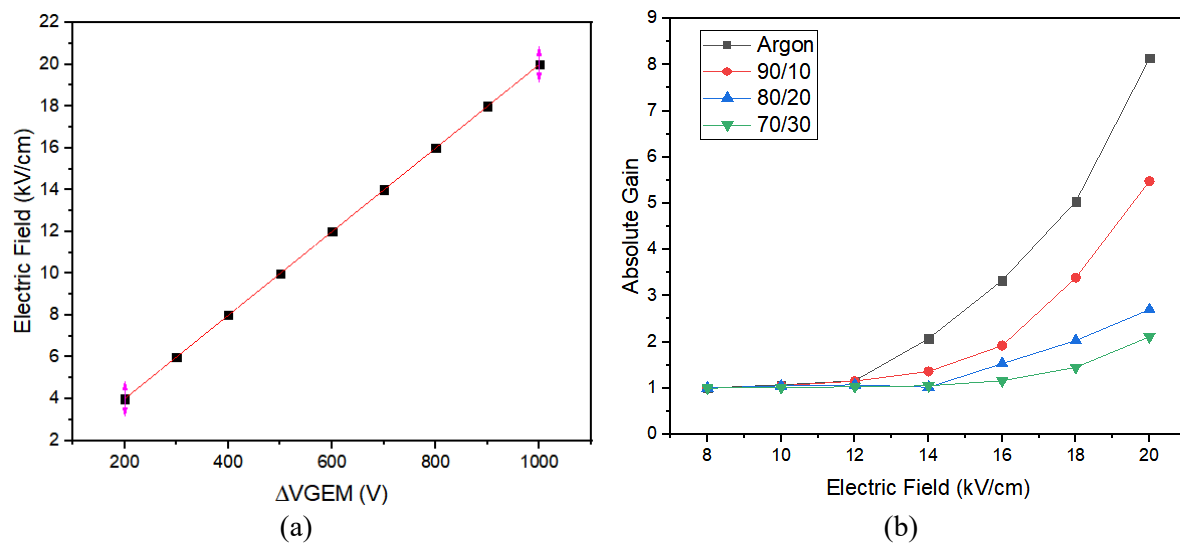
Figure 3: (a) Maximum electric field values obtained for each potential difference applied to the amplification plate; (b) Absolute gain obtained by simulation as a function of the electric field within an orifice for different gas mixtures and pure Argon.

4. Conclusions

In this work, the first results are reported by adopting a free software chain for numerical simulation of the physical functionalities of the TH-GEM detector. With this simulation it was possible to determine that the maximum electric field possible to achieve in the produced amplification plate as 20 kV/cm at the center of the orifices. A small amplification factor (one electron produced four new electrons) was observed in the electron avalanche calculation within a hole of the amplification plate. As the objective of this device is its use as a dosimeter for high fluxes, this low gain was considered as adequate to avoid charge saturations. In addition, it was possible to obtain a shape of the electrical signal as response to one single primary ionization at the electrode using the weighting potential maps. Therefore, it was possible to establish a simulation routine for the dimensions of the detector, making it possible to study the gain and other physical parameters of the TH-GEM based detector to adapt it to the dosimeter function for mammography beams.

Acknowledgments

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