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Characterisation of N2-GEM: a beam monitor based on Ar-N_2 gas mixture

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Abstract: The gas recycle is nowadays an important issue for gaseous detectors operation under study and for this reason, scientists are testing new gas systems for GEM detectors. Since some gas purifier does not allow to use oxygen, the standard Ar-CO_2 (70%–30%) cannot be used; thus, new gas mixtures are under investigation. This paper presents the study of a triple GEM detector filled with new gas mixture based on Argon and Nitrogen (Ar-N_2) at different concentrations: 90%–10%, 80%–20% and 70%–30%. The GEM detector characterisation has provided the High Voltage working point for the gas mixtures and a comparison between the Ar-CO_2 and the Ar-N_2.

Keywords: Micropattern gaseous detectors (MSGC, GEM, THGEM, RETHGEM, MHSP, MICROPIC, MICROMEGAS, InGrid, etc); X-ray detectors; Electron multipliers (gas)

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1 Introduction

Gas detectors based on Gas Electron Multiplier (GEM) [1] technology are constantly developed for different applications, such as high energy physics [2], plasma physics [3] and matter physics [4]. GEM detectors usually work with an active flow gas containing Ar as active and CO2 as quenchig gases, but recent studies have brought to develop a new configuration of these devices, completely sealed, based on the gas recycle. The re-use of the gas mixtures brings to have an economic saving, less greenhouse gas emission [5] and it opens to the use of gases more expensive than Argon, such as Xenon or Kripton. Sealed GEM detectors however have to be coupled with suitable purification systems to remove humidity and molecular oxygen in the gas mixture, that can originate from material out-gassing also in the long period. A simpler and somehow minimal closed gas circuit for GEMs would anyway require at least a gas purification system. Optimal purification systems, such as the White Knight Series Gas Purifier [6], are effective in removing both water and molecular oxygen, but they also act on carbon dioxide, adsorbing and being quickly saturated by the latter. As a consequence it is not possible to use gas mixtures containing CO_2. On this purpose a new gas mixture based on Argon and Nitrogen (Ar-N_2) has been studied. The N_2 acts as quencher in place of CO_2. This paper shows the preliminary characterisation with X-rays of a triple GEM detector prototype using three different concentrations of Ar-N_2: 90%–10%, 80%–20% and 70%–30%. Aim of the prototype is to explore the adeguacy of working performance of such a detector that, if verified, will open to future applications of GEMs filled with such a mixture.

2 The N2-GEM detector

The detector (figure 1.a) is a triple GEM detector, made of a cathode, three 10×10 cm^2 GEM foils and a 256-pad pixelated anode. A GEM foil is a kapton layer, sandwiched between two copper layers and micro-perforated with bi-conical holes. The technology is based on the electron multiplication: once X-Rays enter in the detector active volume, they ionize the gas mixture liberating electron-ion pairs. With the application of a potential difference between the two sides of each layer, the electrons are guided along the Drift region into the holes, where they are multiplied and then collected to the padded anode.

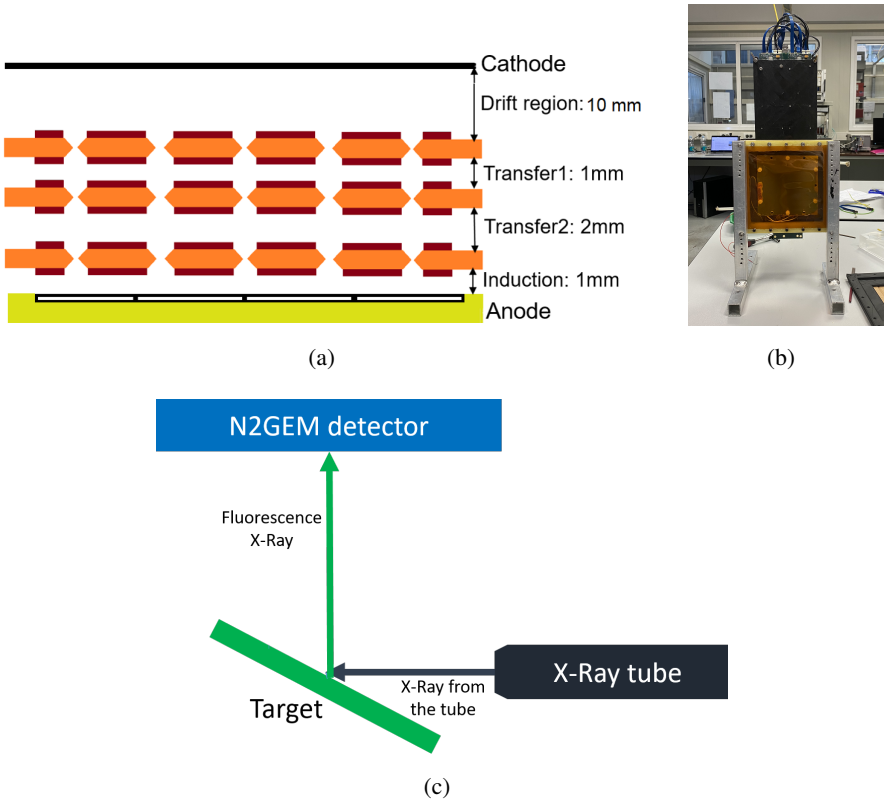

Figure 1. a) Image of the detector scheme. b) Picture of N2-GEM with the GEMINI electronic readout. c) Experimental setup scheme. The used target during the measurements is the Titanium (K_α = 4.5 keV).

To perform the tests, the detector has been build with a Drift region of 10 mm, a Transfer region 1 (T1) of 1mm, a Transfer region 2 (T2) of 2 mm and an Induction gap of 1 mm.

The electronic readout, called GEMINI [7], is a 180 nm system on chip (SOC). Each chip is made of 16 channels, thus 4 boards with 4 chips have been installed on the detector to have 256 channels, i.e. one per pad. The chip is made of a preamplifier, to convert the charge signal from the detector into voltage signal, and a comparator, to set a threshold for each channel. The threshold is necessary to obtain the digital output from the chip, which is proportional to the time that the signal stays over the threshold. The time over threshold (ToT) information is processed by an FPGA and sent to a Linux server with an optical fiber. This system allows to process data in real time, obtaining both the ToT spectra and 2D image (figure 2.a obtained in a time window of 45 s), without pile-up issues even at the high rates.

3 Detector characterisation

The detector (figure 1.b) has been assembled and tested in ISTP-CNR with an X-Ray tube [8]. X-Rays emitted by the tube impinge on a metallic target in order to generate monochromatic fluorescence X-Rays (figure 1.c). The target used in the test is Titanium that emits fluorescence X-Rays with an energy of 4.5 keV (K_α line). The X-rays impinging on the detector directly ionize the gas and generate readable signals. The detector has been placed in front of the target and filled with three

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different Ar-N_2 gas concentration: 90%–10%, 80%–20% and 70%–30%. Then, a measurement with the Ar-CO_2 has been performed with the same detector at the same condition in order to have a comparison between Ar-CO_2 and Ar-N_2. The threshold has been set at 40 LVDS to all GEMINI channels; this value allows to separate counts given by the X-Rays from the background as shown in previous works [9]. The figure 2.c reports three High Voltage (H.V.) scan for the three different Ar-N_2 concentrations; the H.V. shown in the graph is the sum of the three H.V. of each GEM foil (HV = HV_{GEM1} + HV_{GEM2} + HV_{GEM3}) and a counting rate plateau (in the order of 10^4 c/s) is reached for all three cases, thus the detector has a stable counting rate in the H.V. range (1045–1070)V of 90%–10%, (1130–1170)V of 80%–20% and (1240–1250)V of 70%–30%. The count rate is comparable with the standard mixture Ar-CO_2 obtained with the same detector in the same conditions, thus demonstrating that a similar tuning of the triple-GEM characteristics may be achieved also with Ar-N_2.

As expected, increasing the N_2 concentration, the counting rate decreases. This is justified by the fact that a lower concentration of Ar inside the detector leads to lower gas ionization by X-Rays. The counting rate plateau is reached for all the three gas mixture at different H.V., but for safety reasons it is preferable to work applying to the detector the lowest possible voltages compatible with the measurements. In fact, high voltages can bring discharges and damage the device. In the present case it is possible to use the gas mixture Ar-N_2 90%–10% which has a counting rate plateau in the H.V. range of 1045V-1070V, i.e. in the same H.V. region has the standard Ar-CO_2 70%–30% [9]. In fact, as shown in figure 2.c, applying an H.V. in the range of (1030–1070), both detector configurations (Ar-N_2 and Ar-CO_2) show the same trend. Figure 2.b shows two ToT spectra obtained with the two different (Ar-CO_2 and Ar-N_2) gas mixtures using the fluorescence X-Rays from a Titanium target. For both cases, the spectra have been obtained considering all the pads at 1050 V and then normalised for the area. From the graph, it is visible the main peak (the K_α of the Titanium) and the Ar peak escape around 50 ns, thus the use of the Ar-N_2 do not have, as consequence, a spectroscopy degradation capability of the detector performance.

4 Discussion and conclusions

The N2-GEM detector characterised with X-Rays has shown good results. The three gas mixtures used to perform this study have shown a counting rate plateau in three different H.V. region. As expected, the total counts decrease with the increase of N_2 concentration and the study shows a similar behavior for the Ar-N_2 90%–10% gas mixture and the standard Ar-CO_2. Thus it will be possible to use the Ar-N_2 with X-Rays obtaining similar results as the Ar-CO_2. In the future, further tests will be performed to provide a complete characterisation of the gas mixture as, for example, the gas gain curves. Once all the gas parameters are obtained, it will be possible to test the Ar-N_2 with a fully sealed GEM detector. Moreover, we can anticipate that, thanks to the n(^{14}N, p)^{14}C reaction, the gas mixture itself may work as a "converter" for the detection of thermal neutrons with GEMs; the presented experiments show that it is possible to use GEMs with this gas mixture and thus can be considered as the first step for the implementation of future neutron GEM beam monitors with high transmission characteristics.

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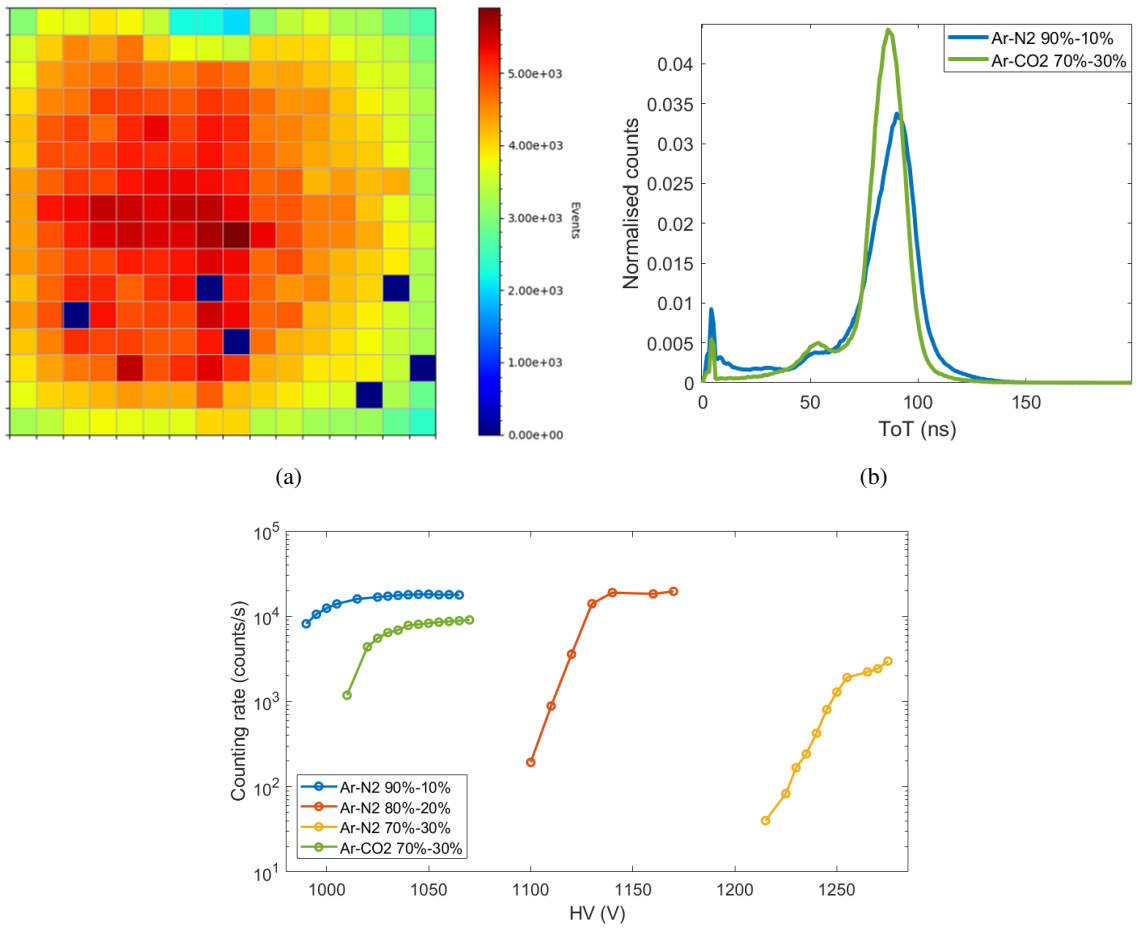

Figure 2. a) 2D spatial map obtained with the X-Rays for the Ar-N_2 90%–10% concentration in a time window of 45 s. The applied H.V. is 1050 V. b) Comparison between the spectra obtained with the $ArCO_2$ 70%–30% (green line) and Ar-N_2 90%–10% (blue line), both considered in their counting plateau region (1050V). The spectra have been normalised for their area. c) H.V. scans (where HV = HV_{GEM1} + HV_{GEM2} + HV_{GEM3}) of the three different Ar-N_2 gas concentrations: 90%–10% (blu line), 80%–20% (red line) and Ar-N_2 70%–30% (yellow line) and comparison between the H.V. scans performed with Ar-N_2 90%–10% (blue line) and Ar-CO_2 70%–30% (green line).

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