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Short induction gap gas electron multiplier (GEM) for X-ray spectroscopy

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Abstract

Experimental work was carried out to evaluate the performance of a Gas Electron Multiplier (GEM) operated with a micromesh readout plane that enabled the induction gap to be set at 50 μm. We measured the essential operational parameters of this system using Ar(75%)-isobutane (25%) as the counter gas mixture. The measurements included the effective gain, effective gain stability, and the X-ray energy resolution using a 5.89 keV X-ray source. These studies demonstrated several advantages of the current system when compared with the standard operation, such as lower operational voltages, higher effective gains and improved effective gain stability.

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Keywords: Gas Electron Multiplier; GEM; Effective gain; X-ray energy resolution

1. Introduction

A typical Gas Electron Multiplier (GEM) configuration [1] sets the induction gap at 1 mm or more where the induction gap is defined as the distance between the bottom GEM electrode and the readout plane. It is well known that Kapton-based GEMs are susceptible to absorption by water vapour and other counter gases [2]. One of the consequences of the absorption process is the sagging of the GEM foil thereby changing the induction gap from its initial set value. However, the effective gain of a GEM is strongly dependant upon the induction field [3,4]. As a result, GEM sagging leads to an effective gain instability [4]. One way to circumvent this is to introduce dielectric pillars between the GEM foil and the readout plane at regular interval [5]. In the present study, we have used a standard GEM that was coupled with a micromesh [6] readout plane with 50 μm tall Kapton pillars patterned on the micromesh at 2 mm pitch. The 50 μm induction gap had several distinct operational advantages. For example, the effective gain stability was improved owing to a good induction gap definition and the absolute voltage needed to sustain a particular induction field was lowered by a factor of 20.

2. Method

The X-ray sensitive area of the present detection system consisted of a 10 mm × 10 mm GEM, a micromesh and a 100 μm thick aluminium foil that defined the drift window. The drift distance was set at 5 mm whereas the induction gap was set at 50 μm. The GEM used here was of a standard geometry and was fabricated at the CERN TS-DEM workshop and consisted of a 50 μm thick copper clad (5 μm) Kapton foil with 70 (50) μm holes patterned at 140 μm hole pitch. The micromesh was also manufactured at CERN TS-DEM workshop and consisted of a 5 μm thick Copper mesh with 25 μm holes etched at a pitch of 50 μm with 50 μm tall and 150 μm diameter Kapton pillars distributed at 2 mm intervals [6].

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In the experimental studies described in the following sections, a Mn–K X-ray (5.89 keV) beam illuminated the detector drift space perpendicular to the GEM and micromesh planes through an entrance window near the end wall of the detector chamber. The entrance window consisted of 100 μm mylar mesh with 100 nm aluminium coating on one side. The entrance window was located approximately 10 mm away from the drift window. In this study, the detection chamber was operated at a constant gas flow rate where the gas composition was controlled by Brooks mass-flow controllers (model 5850E) built into a rig that was constructed using stainless-steel tubing. An argon (75%) and isobutane (25%) counter gas mixture was used throughout this study. The ambient pressure and the temperature of the detector box were recorded with every measurement. The global count rates used throughout these studies were kept in the region of 10 kHz.

The drift electrode and the GEM mesh were operated negative with respect to the micromesh that was held close to earth. The micromesh was connected electrically to an Ortec preamplifier (model 142A). The preamplifier output was then fed into an Oretc shaping amplifier (model 575A) with shaping time constants adjusted to 0.5 μs. The bipolar output of the shaping amplifier was in turn fed into an Ortec pulse height analyser (Ortec Trump-PCI-2 K plug in card with Maestro-32 software for Windows). The effective gain and the X-ray energy resolution were examined as a function of the induction field, E_I, and the voltage differences applied across the GEM holes, ΔV_{GEM}. The drift field, E_d, was maintained at approximately 3.5 kV/cm throughout these studies. The effective gain stability was also studied by monitoring the detector gain for a period of one month.

3. Effective gain and X-ray energy resolution

Fig. 1 shows the variation of the effective gain as a function of the induction field for the range $E_I = 0.4$–40 kV/cm for a number of different voltages across the GEM holes (ΔV_{GEM} = 400, 450 and 500 V). The effective gain increases almost linearly with increasing induction field. When E_I exceeds values above 15 kV/cm, further electron multiplication begins in the induction region (parallel plate amplification mode).

Fig. 2 shows the variation of the X-ray energy resolution at 5.89 keV as a function of the induction field for different voltages across the GEM holes. For induction fields, E_I, lower than 2 kV/cm, the X-ray energy resolution was rather poor due to most electrons being directed to the lower GEM electrode. The optimum X-ray energy resolution was observed in the induction field region 2–15 kV/cm, beyond which rapid deterioration in the X-ray energy resolutions occurred.

Fig. 3 shows the variation of the effective gain as a function of voltage applied across the GEM holes for a number of different induction fields (E_I = 6, 12, 20, 30 and

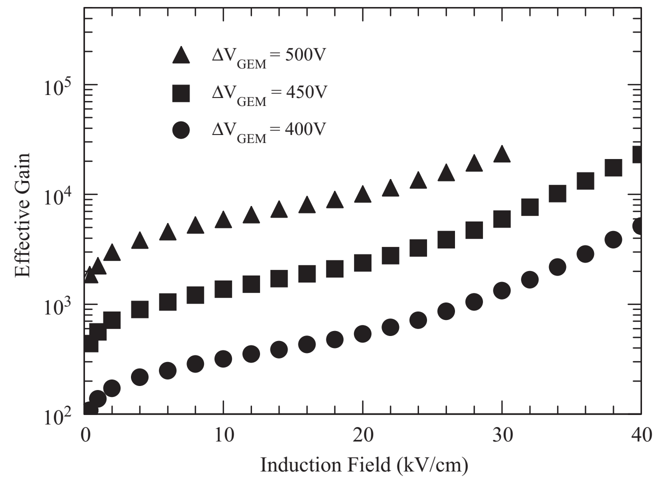

Fig. 1. A plot of the effective gain as a function of the induction field using Ar(75%)-isobutane(25%) for ΔV_{GEM} = 400, 450 and 500 V. In all cases the drift field $E_d = -3.5$ kV/cm.

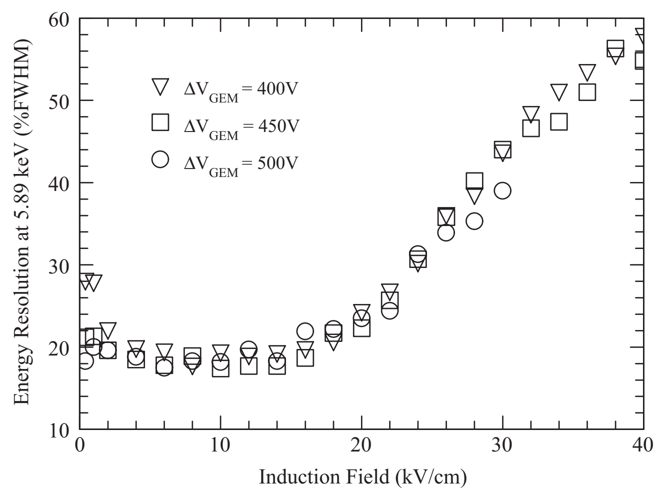

Fig. 2. X-ray energy resolution (% FWHM) of the Mn K X-rays (5.89 keV) as a function of the induction field using Ar (75%)-isobutane (25%) for ΔV_{GEM} = 400, 450 and 500 V. In all cases $E_d = -3.5$ kV/cm.

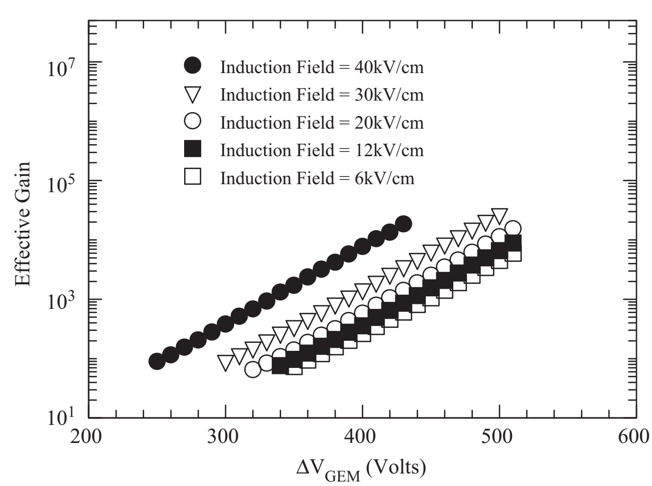

Fig. 3. Effective gain as a function of the potential across the GEM holes (ΔV_{GEM}) using Ar (75%)-isobutane (25%) for a number of different induction fields. In all cases the drift field $E_d = -3.5$ kV/cm.

40 kV/cm). The highest effective gain at the lowest induction field used here was found to be approximately 6000. Increasing the induction fields to values higher than 6 kV/cm shifted the effective gain-voltage (ΔV_{GEM}) characteristics. The highest gain observed was approximately 27,000 when the induction field was set at 30 kV/cm.

The X-ray energy resolution at 5.89 keV associated with each curve in Fig. 3 is plotted in Fig. 4. It is clear from Figs. 1–4 that although effective gain increased with induction fields higher than 6 kV/cm, this was accompanied by a degradation in the corresponding X-ray energy resolution [5]. Fig. 5 shows an optimum pulse height spectrum at 5.89 keV when the GEM was operated at an effective gain of 1900 ($\Delta V_{GEM} = 470$ V, $E_I = 6$ kV/cm, $E_d = -3.5$ kV/cm). The X-ray energy resolution derived from this figure was found to be 15.2% FWHM.

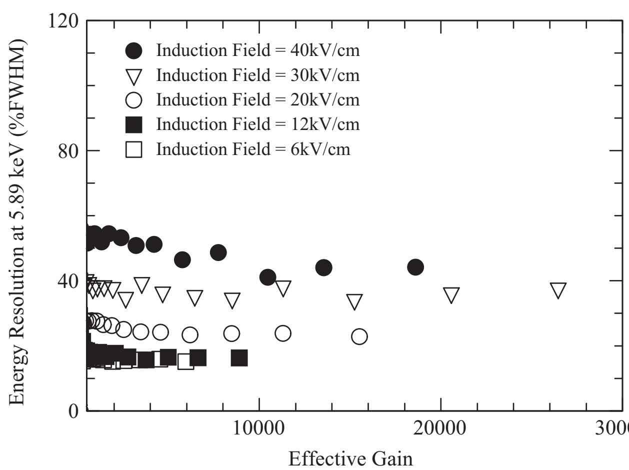

Fig. 4. X-ray energy resolution (%FWHM) of the Mn K X-rays (5.89 keV) as a function of the effective gain using Ar (75%)-isobutane (25%) for a number of different induction fields. In all cases the drift field $E_d = -3.5$ kV/cm.

4. Effective gain stability

The effective gain of flow type gaseous detectors is influenced by the ratio P/T [7 and references therein], where P is the gas pressure in mB and T is its absolute temperature in K. Fig. 6 shows the effective gain of the present GEM over a one month period plotted as a function of P/T. Fitting an exponential curve to the data gives the effective gain sensitivity of the detector to changes in the ambient conditions. In the present case, this evaluates to 1.55 K/mB as shown in Fig. 6. Assuming that P is roughly constant at around 1000 mB and allowing for maximum temperature excursion of $\pm 5\,^{\circ}$C from 20 °C would result in a maximum gain excursion of $\pm 8.9\%$.

5. Conclusion

A short gap GEM was successfully operated with an induction gap of 50 μm to investigate parameters relevant to the X-ray detection. These included measurements of the effective gain and X-ray energy resolution as a function of the induction field and the voltage applied across the GEM holes.

The highest effective gain was found to be approximately 27 000 when the voltage across the GEM holes was set at 500 V and induction field at 30 kV/cm. However, the best X-ray energy resolution was found to be 15.2% FWHM when the voltage across the GEM holes was 470 V (effective gain 1900) and the induction field was 6 kV/cm.

The effective gain shift with time experienced during our previous studies [4] was overcome by the simple introduction of 50 μm tall Kapton pillars between the lower GEM electrode and the readout plane. Effective gain shifts observed during the one month run were consistent with the changes in ambient pressure and temperature over that period.

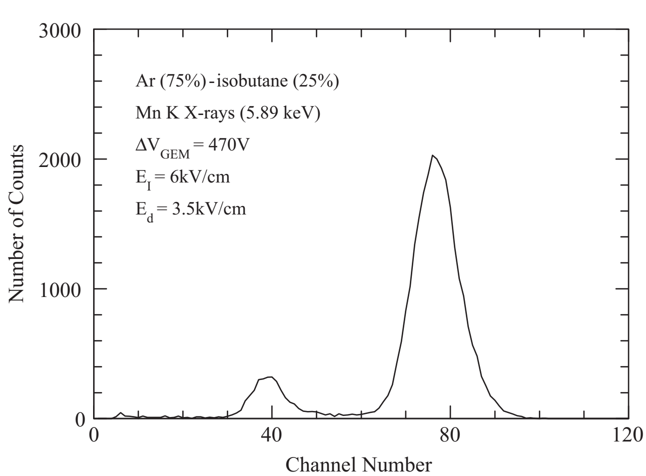

Fig. 5. A typical pulse height spectrum for 5.89 keV X-rays using the GEM at an effective gain of 1900 in Ar (75%)-isobutane (25%) with $\Delta V_{GEM} = 470$ V, $E_I = 6$ kV/cm and $E_d = -3.5$ kV/cm.

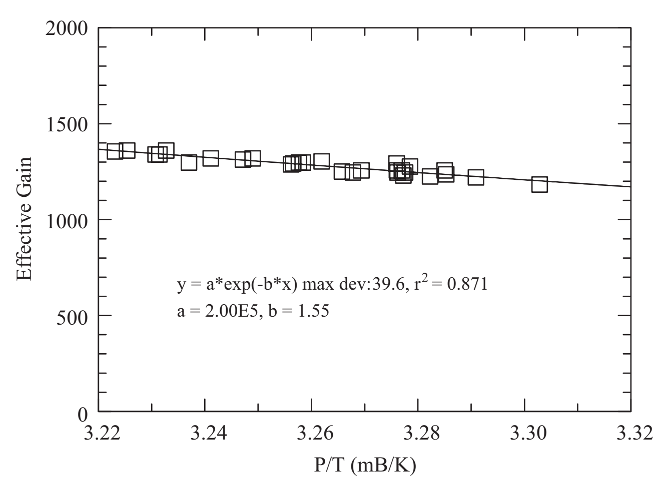

Fig. 6. The effective gain measured over a period of one month using Ar (75%)-isobutane (25%) as a function of the ambient parameter P/T. $\Delta V_{GEM} = 450$ V, $E_I = 6$ kV/cm and $E_d = -3.5$ kV/cm.

References

[1] F. Sauli, et al., GEM: a new concept for electron amplification in gas detectors, Nucl. Instr. and Meth. A 386 (1997) 531.
[2] J.I. Collar, et al., Nucl. Instr. and Meth. A 515 (2003) 439.
[3] F. Sauli, et al., Further developments and beam tests of the gas electron multiplier (GEM), Nucl. Instr. and Meth. A 419 (1998) 410.
[4] J.A. Mir, et al., Operational characteristics of a GEM-MSGC system for X-ray detection, IEEE Trans. Nucl. Sci. NS-52 (6, Part 2) (2005) 2927.
[5] G. De Lentdecker, et al., Nucl. Instr. and Meth. A 459 (2001) 211.
[6] Y. Giomataris, Nucl. Instr. and Meth. A 419 (1998) 239.
[7] J.E. Bateman, et al., Studies of the gain properties of microstrip gas counters relevant to their application as X-ray and electron detectors, IEEE Trans. Nucl. Sci. NS-49 (4, Part 1) (2002) 1644.