Charging up studies in thick Gas Electron Multipliers

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Abstract. Gaseous ionization detectors that have insulating media exposed to the active gas volume have issues related to charging up of the insulators during the course of its use[1]. The time- dependent variation of detector response in hole-based Micro-Pattern Gaseous Detectors (MPGDs), especially THick Gas Electron Multipliers (THGEMs), is one of the challenging problems that has been attributed to “charging up” and “charging down”. Experimental studies of stabilization of THGEM gas gain with time in argon-based mixtures under various experimental conditions will be presented here. Effects of different sources with varying irradiation rates on the gain saturation process have been studied. It has been observed that low-rate source shows two-step gain stabilization phenomena, one short-term saturated gain, another long-term saturated gain, whereas high-rate source shows just one-step gain saturation. While this two-step stabilization has been attributed to the charging up of the rim by earlier studies, its effect seems to be subdued for high-rate irradiation according to the present studies. The results provide an insight into the dynamics of gain saturation in THGEMs.

1. Introduction

Micro Pattern Gaseous Detectors (MPGDs) are being used widely in particle and nuclear physics experiments all over the world for their good position resolution, high rate capabilities and timing resolution [1]. Emergence of lithography and printed circuit technology has led to extensive development in the field of MPGDs [2]. THGEMs are GEMs derived from standard GEM design, with modified geometrical parameters and production technology. These are generally made of Printed Circuit Boards (PCB) with etched cylindrical holes unlike standard GEMs. Thickness of these PCBs vary from 100µm to few mms and hence, these detectors are robust as compared to standard 50µm GEM foils. Thorough understanding of the physics related to these MPGDs is important for the proper application of these detectors.

Time-dependent variation of gain in these dielectric based MPGDs is one of the demanding problems in high-rate experiments. Charging up and charging down of GEM dielectric are two such phenomena which significantly affect the gain-stabilization and the optimum working voltage range. The first study on charging up phenomenon dates back to 1997 [3].

In recent times, there have been a large number of studies on this phenomenon, probably due to its significance in the high-rate experiments happening world-wide. Several numerical [3, 4] and experimental studies [5, 6, 7] report that there is a transition period during which the effective gain changes once a detector is given voltage bias and irradiated with a source. The gain eventually ends up saturating after few minutes or even hours, depending on the type of detector used and the rate of irradiation. This phenomenon of variation in detector gain on irradiation with a source at a given voltage bias is even more obvious in THGEMs, due to thick dielectric used in their construction[8, 9, 10]. In this work, an experimental study has been carried out with THGEMs (figure 1) irradiated with different radiation sources. Details of the detector set-up (figure 1 and figure 2) and experimental procedure (figure 3) are given in the section 2 which is followed by gain evolution measurements done with different irradiation sources in section 3.

2. Experimental set-up

The experimental set-up consists of a FR4-PCB THGEM of size 40 mm x 48 mm mounted between a drift cathode and readout anode. The FR4 electrode is nearly 800 µm thick with 50 µm copper coating on both sides, having cylindrical holes of diameter 500 µm with etched rims of width 100 µm. Holes are arranged in hexagonal pattern mimicking standard GEM and hole to hole distance (pitch) is 1 mm. Drift gap is chosen to be 8 mm and induction gap is 4 mm. Drift field, THGEM amplification field and induction fields have been applied using CAEN N471 and CAEN N471A power supply modules.

Argon-carbon dioxide based mixture in the volumetric ratio of 90:10 has been used for the experiment with a flow rate of 5-10 sccm. The detector set up has been kept in an aluminium box and irradiated with different 5.9 keV Fe-55 sources. Measurements have been done by connecting the readout to a CAEN A1422 pre-amplifier and CAEN AH401D pico-ammeter for the energy spectra and current measurement respectively. Figure 4 shows the Fe-55 spectrum obtained with the THGEM detector.

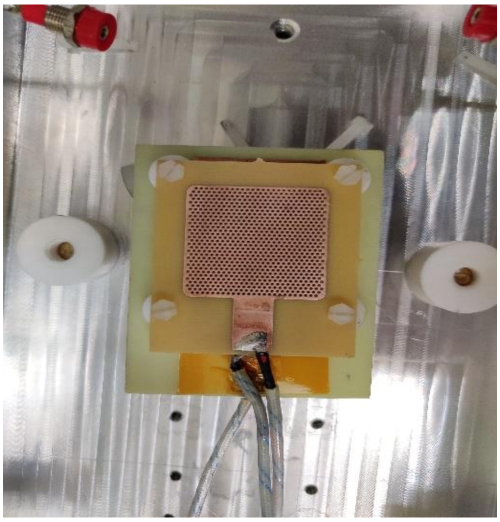


Figure 1. THGEM foil used for the experiment

Figure 2. Aluminium box containing all the connections

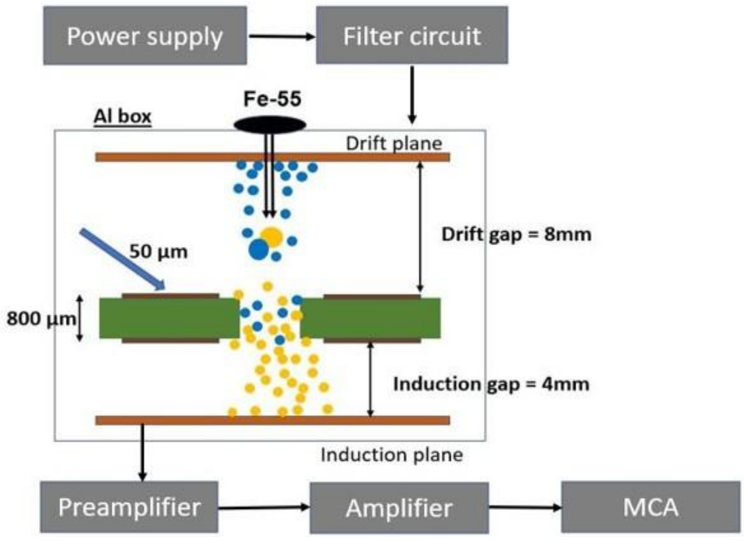


Figure 3. Schematic of the complete experimental setup

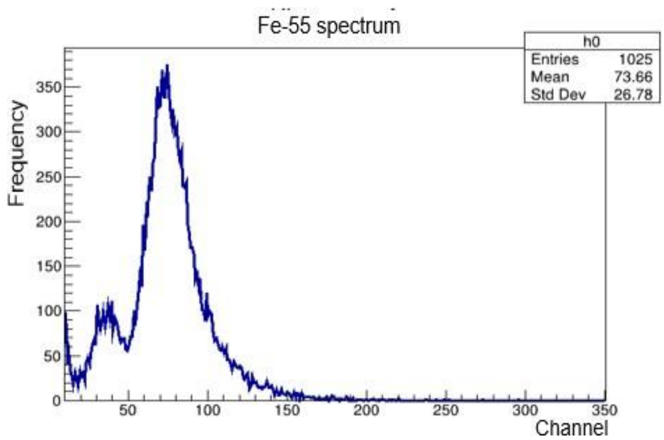


Figure 4. Fe-55 energy spectrum obtained for THGEM in Ar:CO_2 mixture in the ratio 90:10

Table 1. Experimental configuration.

Measurements	E_{Drift} (kV/cm)	ΔVGEM (V)	$E_{Induction}$ (kV/cm)	Rate(kHz)
Test of history of irradiation	0.75	2000-2050	1.0	0.0527
Transparency of THGEM at different drift fields	0.25-1.25	1900	1.0	0.0527
Evolution of gain with irradiation rates	0.5	1900	1.0	0.0527, 0.687
Evolution of gain with ΔVGEM	0.5	1800-1900	1.0	0.687

3. Results and calculations

Two different intensities of Fe-55 sources with irradiation rates 53 Hz/mm^2 and 686 Hz/mm^2 have been used for the experiment. Table 1 shows different electric configurations used for the experiment. Studies [9, 10] show that measurements of charging up is largely affected by the history of irradiation of dielectric. Therefore, it is very crucial to electronically clean the detector to remove all the previously accumulated charges. To ensure this, aluminium box containing the detector has been flushed with nitrogen gas for 24 hours with flow rate of 5 sccm and then it has been flushed with Ar-CO2 mixture for 12 hours with flow rate close to 10 sccm at a given voltage bias. This makes the detector free of any signature of the previously used irradiation source and also allows it to undergo dielectric polarization. To observe the effect of history of irradiation, initially a clean (or unused, with no history of irradiation) detector has been irradiated with a low-rate source (53 Hz/mm2) at GEM bias voltage 2000 V and then once the gain saturated, the source has been removed and voltage bias has been kept unchanged for around 16 hours. After this attempt of discharging the dielectric, voltage bias is increased by 50V, then on irradiation with the same source, it has been observed that there is hardly any change in gain unlike the gain evolution for a clean detector (figure 5) which suggests that the dielectric holds on to most of the accumulated charges even after 15-16 hours of discharging. This discharging time is expected to depend on the thickness of the dielectric, source irradiation time as well as on the gas flow-rate [9].

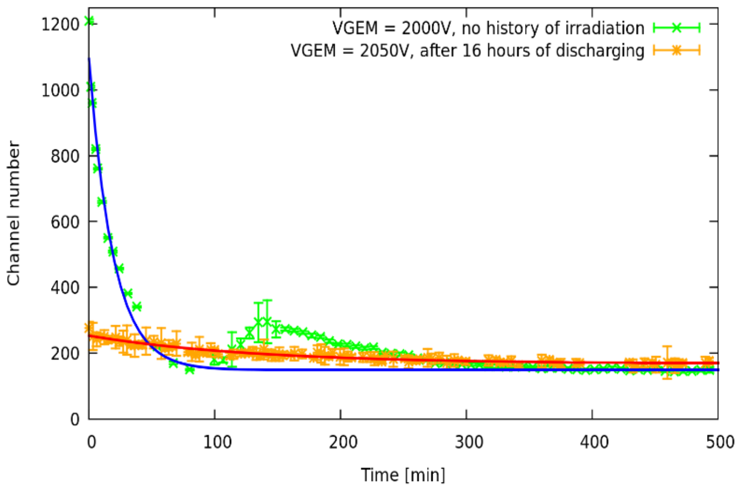


Figure 5. Time evolution of gain with and without history of irradiation

Figure 6 shows the variation of readout gain with different drift field values. It is clear that foil transparency initially increases with drift field, attains a maximum value and finally decreases on further increasing the drift field.

Sources with different irradiation rates show different time scale for gain saturation as shown in the figure 7. Gain for high-rate source (686 Hz/mm2) falls sharply within few minutes which is followed by gain saturation, whereas gain for low-rate source (53 Hz/mm2) takes few tens of minutes to reach saturation. Moreover, for a given ΔVGEM , in gain (ΔCh; change in MCA channel number) for high-rate source is greater than that for low-rate source. The operating voltage range and corresponding gain values have been found to depend on temperature, pressure and humidity of the lab. Less humidity is found to favor these types of detectors.

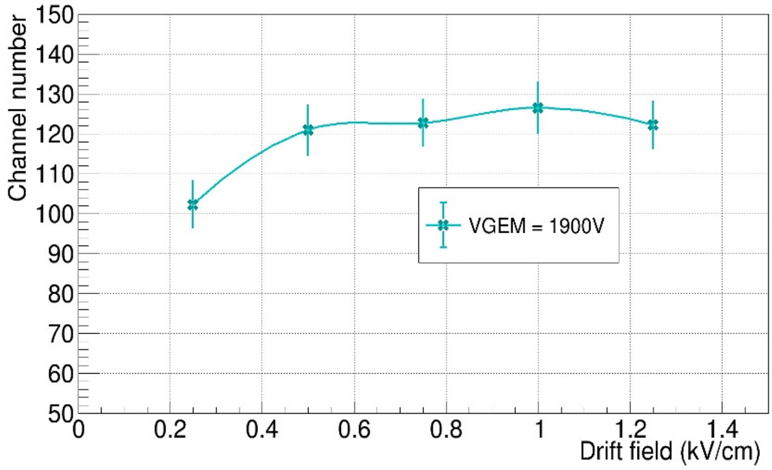


Figure 6. Variation of gain with different drift field values

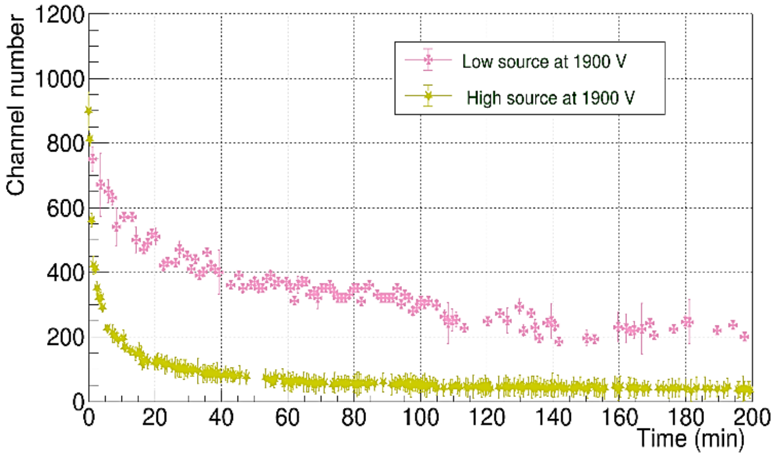
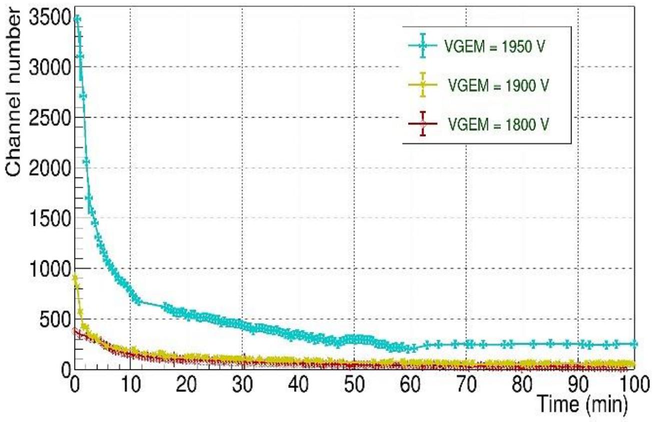


Figure 7. Evolution of gain for high and low rate sources

Table 2. Initial and final saturated gain values for different THGEM voltages with Fe-55 source.

ΔVGEM	Ch_{max}	Ch_{min}	ΔCh
1800100	380	30	350
1900	899	65	834
1950	3450	250	3200

Figure8 shows the variation in gain due to charging up of the detector with different bias voltages at a given temperature, pressure and humidity. It can be seen that maximum initial gain increases sharply as we increase the bias voltage, whereas saturated gain values are not that apart. Total change in gain (ΔCh) is higher for higher bias voltage.



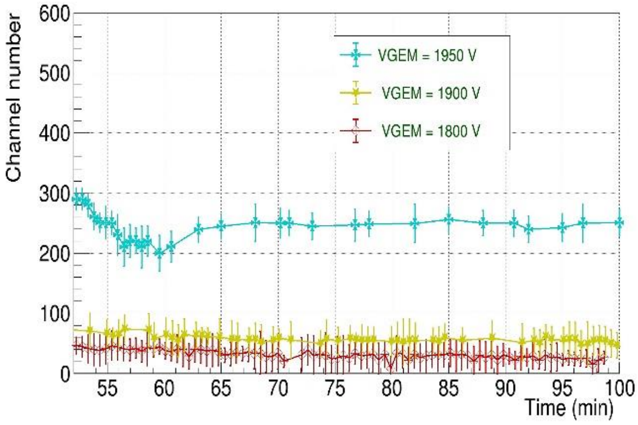


Figure 8. Radiation charging up of THGEM with different values of ΔVGEM showing (a) total gain evolution and (b) saturated gain

4. Conclusion

Experimentally it is observed that charging up of THGEM dielectric decreases its gain initially and finally the gain saturates. This evolution of gain is found to depend on irradiation rate of the source. A high-rate source charges up the dielectric faster than a low-rate source, which results in sharp reduction in gain in case of high-rate source. Additionally, total change in gain for a high-rate source is found to be larger than total change in gain for a low-rate source. This is due to the larger accumulation of charges on the dielectric by a high-rate source. The charging up phenomenon can be influenced by other geometrical parameters like presence and absence of rim, which shall be investigated in future.

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