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Measurement of basic features of Thick-GEM and Resistive-GEM

R. Akimoto, H. Hamagaki, T. Gunji, Y.L. Yamaguchi and Y. Hori

Center for Nuclear Study, Graduate School of Science, University of Tokyo,
7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan

E-mail: r.akimoto@cns.s.u-tokyo.ac.jp

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ABSTRACT: Recently, Thick-GEM (TGEM) whose geometry is at the millimeter-scale has been developed to overcome the disadvantages of micro-scale Gas Electron Multiplier (GEM) such as fragility against a discharge, difficulty in obtaining enough gain at low pressure and so on. In addition, TGEM with resistive electrodes (RETGEM) also has been developed to make TGEM more tolerant with a discharge. Active research is carried out worldwide for applications such as liquid Argon detectors, Cerenkov light detectors, sampling elements in calorimeter and low-pressure time projection chamber. TGEM and RETGEM look very promising, but their basic properties have not yet been studied thoroughly.

TGEM and RETGEM with different geometries were made and the basic properties such as the voltage dependence of gain, the energy resolution and the gain variation as a function of time at different gain levels were measured.

A gain of about 10^4 was obtained with Ar(90%) + CH_4 (10%) gas mixture for both TGEM and RETGEM. The gain variation as a function of time of TGEM at the gain $\sim$ 2000 was within 6% after the correction by pressure and temperature. On the other hand, the gain variation as a function of time of TGEM was large at higher gain and can not be explained by only the correlation between the gain and the value of pressure over temperature. The gain variation as a function of time of RETGEM was within 4% after the correction by pressure and temperature. The achieved energy resolution was $\sim$ 13% (TGEM) and $\sim$ 10% (RETGEM). The energy resolution of RETGEM is comparable to that of micro-scale GEM.

KEYWORDS: Micropattern gaseous detectors (MSGC, GEM, THGEM, RETHGEM, MICROMEGAS, InGrid, etc); Cherenkov detectors; Gaseous imaging and tracking detectors

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Contents

1 Introduction

Gas Electron Multiplier (GEM), which is a micro pattern gaseous detector, is made of a thin insulator foil (typical thickness is 50 μm) with metal electrode plates at both sides and pierced holes (typically 70 μm in diameter) in closely-packed array [1]. The GEM with such micro-scale is denoted as 'standard GEM' in this report. With voltage difference of several hundreds volts applied to the both sides of the GEM foil, electron multiplication occurs inside the holes.

GEM has the following advantages.

- Two dimensional position information is not lost during electron multiplication.
- No degradation of performance is observed in high rate [2].
- High gas gain can be obtained with safe operation using a multi-layer configuration.
- Ion feedback can be suppressed.

GEM has been applied to many detectors not only for physics [3], but also for the fields of medical research and nondestructive testing [4]. On the other hand, the standard GEM has some disadvantages such as fragility against a discharge and difficulty in obtaining enough gain at low pressure. GEM with millimeter scale has been developed recently to overcome the described disadvantages of the standard GEM [5]. It is called as Thick-GEM (TGEM). Since the electron density inside the hole is more rarefied due to the larger hole diameter, discharge probability of GEM is expected to be small. TGEM is manufactured with PCB technology using a drill to pierce the holes. Furthermore, TGEM with high resistive electrodes has also been developed to make TGEM more tolerant with a discharge. It is called as RETGEM and originally developed at CERN [6]. Owing to the high resistivity, the voltage difference in the hole region is automatically reduced when a large

	TGEM					RETGEM
	#1	#2	#3	#4	#5	
Thickness	0.5 mm		1.0 mm			
Diameter of insulator	0.3 mm	0.5 mm	0.3 mm	0.5 mm	0.45 mm	0.3 mm
Distance between holes	0.6 mm	1.0 mm	0.6 mm	1.0 mm	0.6 mm	
Rim	With				Without	

Table 1. The geometrical configurations of TGEM and RETGEM.

current is drawn due to a discharge. Thus, a continuous discharge could be efficiently suppressed. Furthermore, since the electrodes are made of an organic compound, the material budget is smaller than metal electrodes.

TGEM and RETGEM look very promising, but their basic properties have not yet been studied thoroughly. TGEM and RETGEM with different geometries were made, and the basic properties such as the voltage dependence of gain, gain variation as a function of time and energy resolution were measured.

2 Geometrical configurations of TGEM and RETGEM

Figure 1 shows the plane views of TGEM and RETGEM. TGEM consists of a glass epoxy with 18 μm-thick copper electrodes. The electrodes of RETGEM are made of an organic compound and the resistance of the electrodes is about 100 kΩ/cm. Two configurations were tried for hole geometry; with and without rim. The cross sectional figure of TGEM with rim is shown at figure 2. The purpose of having rim of 75μm around a hole, as shown in figure 2, is to reduce a discharge frequency by suppressing the concentration of field flux to the hole edge.

The geometrical configurations of TGEM and RETGEM are summarized at table 1. TGEMs with five different geometrical configurations were made; two different thickness, two different hole diameter and with and without rim. The geometrical characteristics of the TGEM without rim is the same with TGEM3 apart the diameter of the insulator. The geometrical characteristics of RETGEM is also the same with TGEM3 apart the rim. It is difficult to make rim at RETGEM due to the manufacturing aspect.

3 Setup

Figure 3 shows the schematic view of the test setup. In the measurement, ^{55}Fe (X-ray: 5.9 keV) with an intensity of 80 kBq was used. The measurements were done with GEM in a single element. Distances between cathode mesh and GEM, and between GEM and anode pad are 20 mm and 1.5 mm, respectively. The voltage differences between cathode mesh and GEM, and between GEM and anode pad are 400 V. A signal was read using pad with active size of 10 $\times$ 10 mm^2 and was recorded using a VME ADC module. Ar(90%) + CH_4 (10%) gas mixture (P10) was used and gas flow was kept 300 cc/min. Measurements have been done at atmospheric pressure and at room temperature ($\sim$ 300 K).

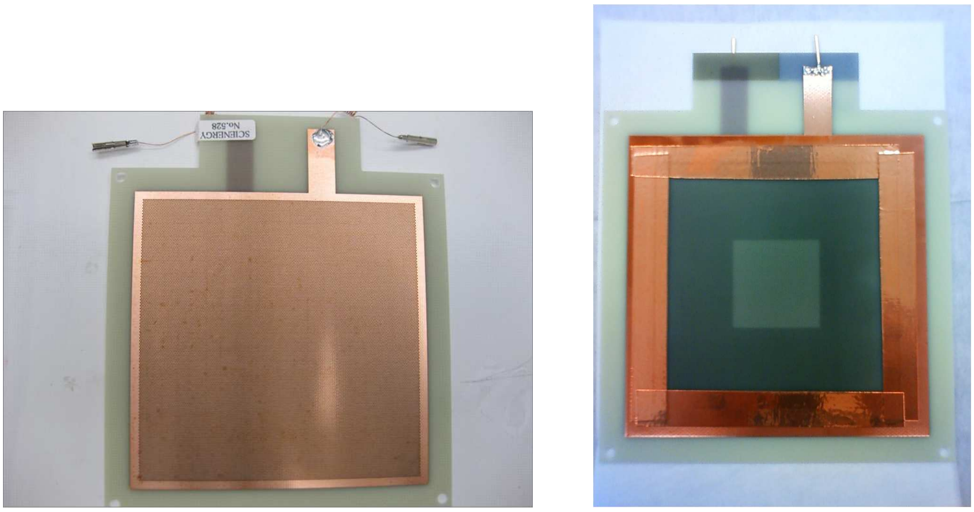

Figure 1. The plane view of TGEM (left) and RETGEM (right).

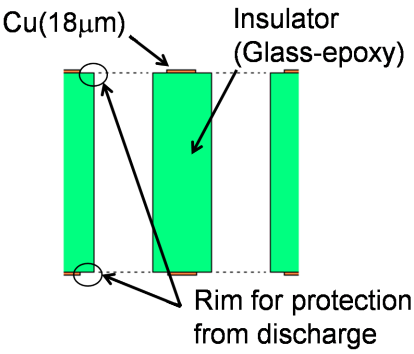

Figure 2. The cross sectional figure of TGEM with rim.

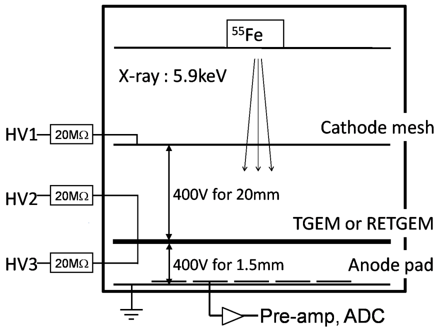

Figure 3. The schematic view of test setup

4 Result

In the case of the TGEMs other than TGEM3, a continuous discharge occurred before obtaining enough gain to separate the signal from the background. Two TGEMs were tested for each geometrical configuration and the similar results were obtained for both of the two TGEMs with the same geometrical characteristics. The following measurements were done using only TGEM3 and RETGEM.

4.1 Energy resolution

Figure 4 shows the charge distributions of TGEM3 and RETGEM at gain of ~ 2000. The highest peak corresponds to 5.9 keV and the escape peak (2.7 keV) was clearly seen in both cases. The energy resolution is defined as RMS of the Gaussian which is fitted to the highest peak. The energy resolution of TGEM3 is about 13%. It is significantly worse than that of the standard GEMs ($\sim$ 10%) [7]. The energy resolution of RETGEM is about 10%, which is comparable to that of standard GEMs.

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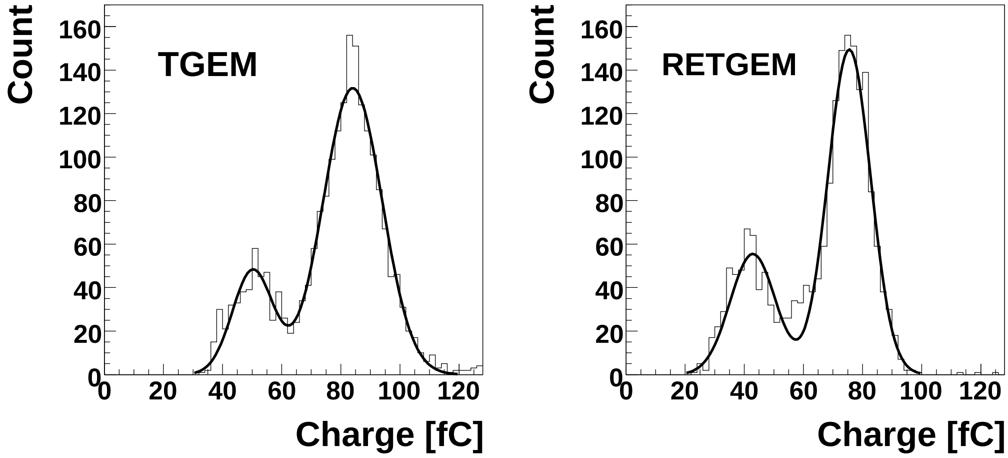


Figure 4. The charge distributions for TGEM and RETGEM.

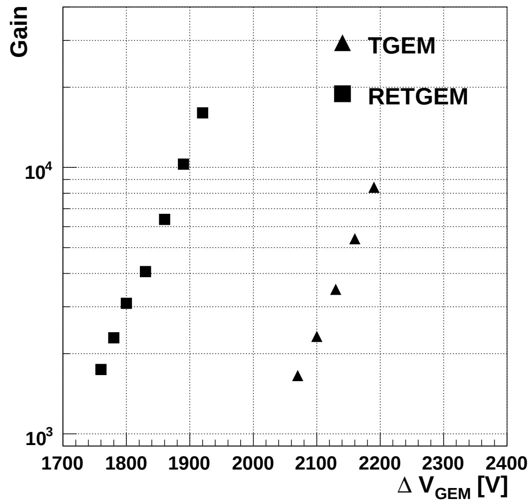


Figure 5. The voltage dependence of gain of TGEM and RETGEM.

4.2 Voltage dependence of gain

Figure 5 shows the voltage dependence of gain for TGEM3 and RETGEM. The gain (G) is calculated as follows;

$$G = \frac{\mu}{q_e \cdot n_e},$$

where μ is the mean value of the 5.9 keV peak, q_e is the elementary electric charge and n_e is the number of electrons created by the absorption of 5.9 keV X-ray. The voltage difference between GEM electrodes is called as ΔV_{GEM} in this report. The triangle and square symbols represent the results of TGEM and RETGEM, respectively. The gain of TGEM3 achieved nearly 10^4, and that of RETGEM achieved over 10^4. A continuous discharge started at ΔV_{GEM} = 2220 V (TGEM) and at ΔV_{GEM} = 1920 V (RETGEM). Thus, the measurements could not be conducted beyond these settings.

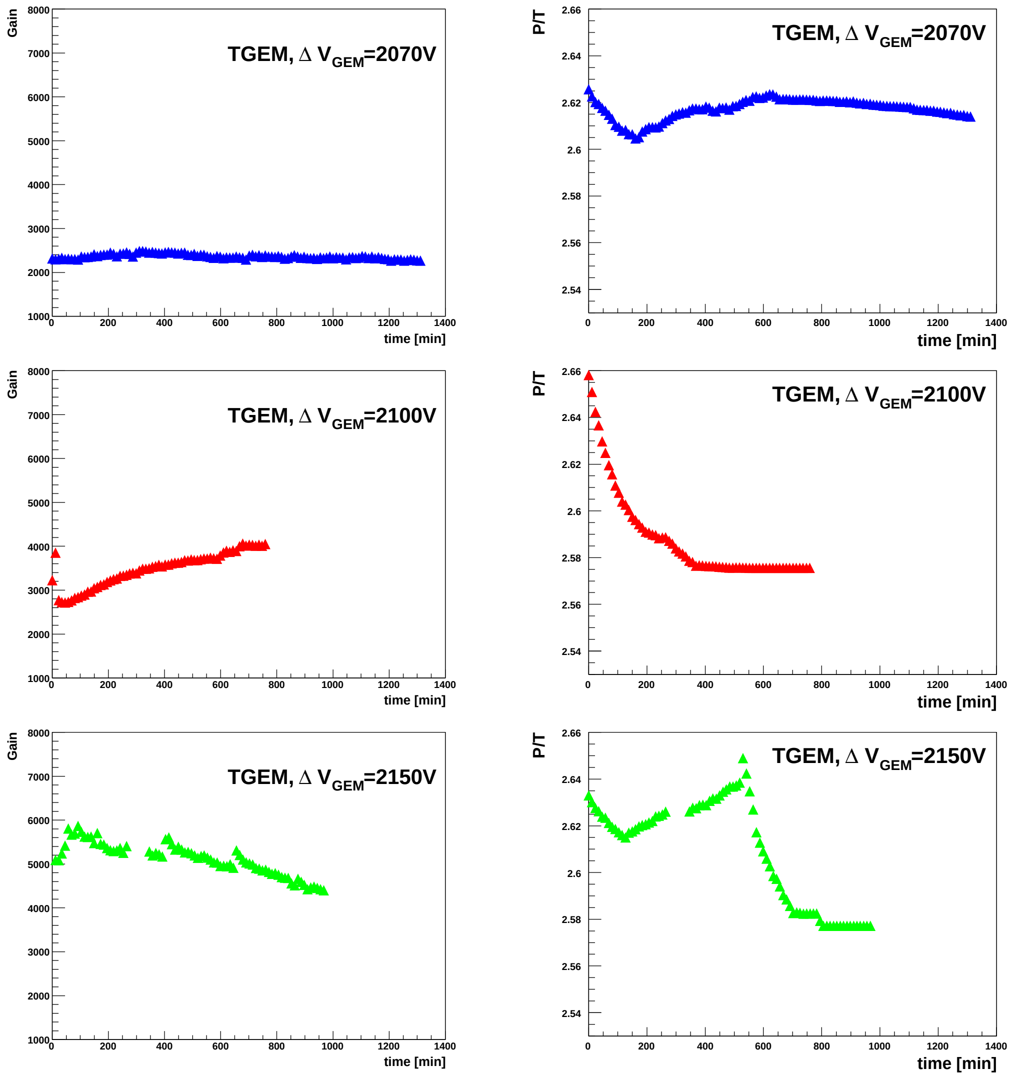


Figure 6. Left: Gain variation as a function of TGEM with ΔV_{GEM}=2070 V, 2100 V and 2150 V. Right: Time variation of P/T during the measurement.

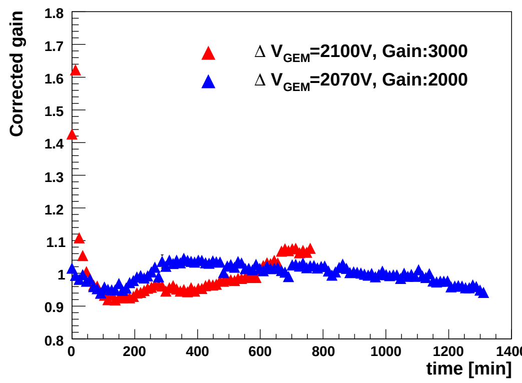
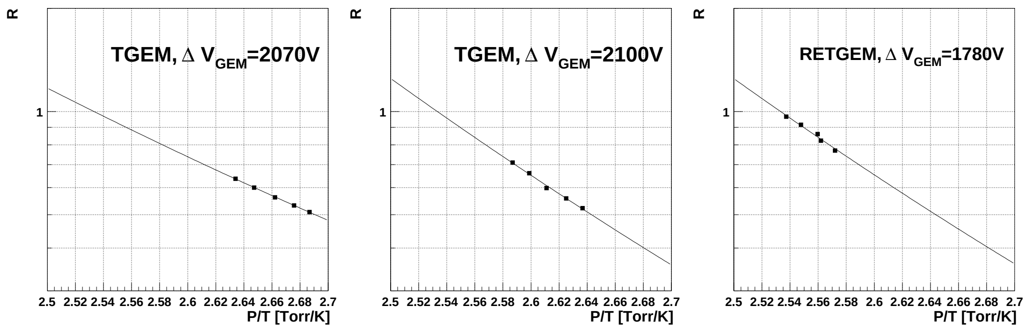


Figure 7. The P/T dependence of the relative gain of TGEM.



(a) (b) (c)

Figure 8. Gain dependence of P/T. (a): TGEM with ΔV_{GEM} = 20700 V. (b): TGEM with ΔV_{GEM} = 2100 V. (c): RETGEM with ΔV_{GEM} = 1780 V.

4.3 Gain variation as a function of time

The left plots in figure 6 show the gain variation as a function of time for TGEM3. The top-left, middle-left and bottom-left figures show the result with ΔV_{GEM} = 2070 V, 2100 V and 2150 V, respectively.

The gain of GEM changes as the pressure(P) and the temperature(T) changes. The gain variation due to the variation of P/T can be corrected at narrow P/T region [7]. The following function is used to correct the gain of TGEM with ΔV_{GEM} = 2070 V;

$$R = exp\left(29.87 \cdot \frac{1}{P/T} - 11.79\right).$$

For the gain of TGEM with ΔV_{GEM} = 2100 V,

$$R = exp\left(41.88 \cdot \frac{1}{P/T} - 16.53\right).$$

These functions are determined by fitting the data taken with the different pressure near the atmospheric pressure and with almost the same temperature ($\sim$ 300 K) (figure 8). Figure 7 shows the result of the corrected gain of TGEM. The blue and the red triangles represent the results with ΔV_{GEM} = 2070 V and with ΔV_{GEM} = 2100 V, respectively. The gain variation of TGEM with ΔV_{GEM} = 2150 V can not be explained by only the variation of P/T. The corrected gain of TGEM with ΔV_{GEM} = 2070 V was within 6% and larger gain variation was seen at higher gain.

The gain of RETGEM was also corrected by P/T and the following function was used for the correction;

$$R = exp\left(43.16 \cdot \frac{1}{P/T} - 17.04\right).$$

After 100 minutes, the corrected gain was almost stable and the variation of the corrected gain is within 4% (figure 10).

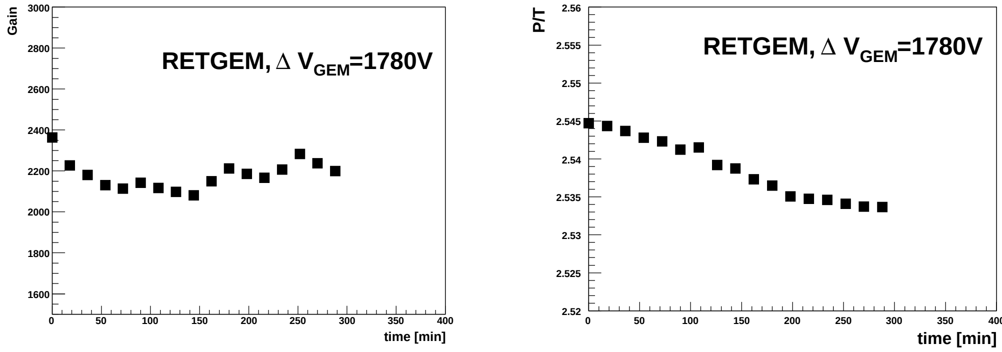


Figure 9. Left: Gain variation as a function of time of RETGEM with ΔV_{GEM}=1780 V. Right: The P/T value during the measurement.

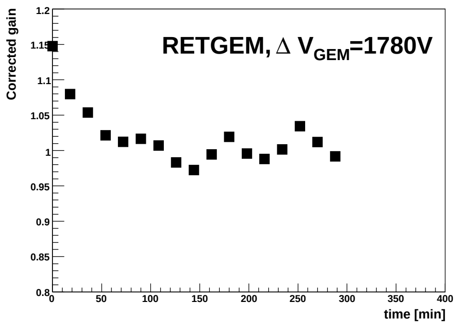


Figure 10. The corrected gain of RETGEM. The data are normalized by the mean value of datum.

5 Summary and outlook

TGEM with different geometrical configurations and RETGEM which has high resistive electrodes were made, and their basic properties such as voltage dependence of gain, energy resolution and gain variation as a function of time were measured.

For all TGEMs apart TGEM3, measurements could not be conducted due to a discharge. At this measurement, the energy resolution can be achieved $\simeq$ 13% (TGEM) and $\simeq$ 10% (RETGEM), which is comparable to that of micro-scale GEM ($\sim$ 10%). The gain was obtained near 10^4 with TGEM and over 10^4 with RETGEM without a continuous discharge. The gain variation as a function of time of TGEM with ΔV_{GEM} = 2070 V was within 6% after the correction by P/T and larger gain variation was seen at higher gain. The gain variation as a function of time of RETGEM was within 4% after the correction by P/T. Since the gain variation as a function of time is a critical for stable operation, it is interesting to study the gain variation as a function of time of RETGEM with higher gain and for longer time.

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