Performances of RETGEM with resistive electrodes made of kapton foils*

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Abstract: THGEM with resistive Kapton electrodes (RETGEM) has been developed to make the THGEM more tolerant to discharges. At higher gains with resistive electrodes, serious discharges may travel to the streamer mode, in contrast to violent sparks in conventional GEMs. These streamers are mild and less dangerous to the detector and the front-end electronics. RETGEM looks very promising, and its basic properties are being studied. Recently we developed and tested the THGEM with electrodes using 20 um thick resistive kapton foils. The new RETGEM performs at a lower discharge current, has a lower discharge probability, and has a good energy resolution of 27% and a high effective gas gain and long-term stability.

Key words: RETGEM, resistive electrodes, Kapton foil, GEM

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1 Introduction

Recently hole-type gaseous detectors have opened up new possibilities in the detection of photons and particles [1–3] and have many good characteristics over wire chambers. The most popular hole-type detector today is the so-called Gas Electron Multiplier (GEM) suggested by Sauli [1].

In spite of great progress in the development and optimization of the GEM it is still a rather fragile detector, for example, it requires clean, dust-free conditions during its manufacturing and assembly and can easily be damaged by sparks, which are almost unavoidable at high gain operations. Studies performed previously indicate that the maximum achievable gain of the hole-type detectors increased with their thickness. Based on these studies A. Breskin has developed a so-called “THick GEM” (THGEM) [4]: printed circuit board with Cu on both sides (with a thickness of around 0.2–1.5 mm) and with drilled-through holes. This detector allows one to achieve a maximum gain that is almost 10 times greater than that of a conventional GEM.

A systematic study of this device and its further improvements were performed by Breskin’s group. Instead of drilling out the Cu around the edges of the holes, they manufactured protective dielectric rims using lithographic technology [4, 5]. In recent years, a detector named Resistive Electrode Thick GEM or RETGEM has been developed [6, 7]. The RETGEM using different coated films such as kapton or others materials can operate at gains of more than 10^4. At higher gains possible discharges may travel to the mild streamer mode, instead of generating violent sparks in a conventional THGEM, thereby reducing the danger of damaging either the detector or the

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front-end electronics. We have developed and tested the THGEM with domestic made (Ningbo CEN Electronic Material Co., Ltd.) resistive Kapton foils electrodes.

2 Experimental setup

2.1 Fabrication of the RETGEM

The detectors studied in this work were manufactured from standard printed circuit boards (PCBs without a Cu layer) having a thickness of 0.2 or 1 mm. On both surfaces of the PCB sheets a resistive Kapton of 2 μm thick was glued. Prior to drilling we glued 35 μm thick Cu foil to both sides of the kapton sheets. After the drilling process was finished the Cu foils were removed by etching in the active area of the RETGEM board, except for the Cu frame around the resistive electrode region, which was kept to preserve the connection to the HV electrodes (see Fig. 1, Fig. 2). These modifications allow one to achieve excellent quality not only for good hole-drilling but also for obtaining optimal rims. The surface resistivity of this material depending on a particular sample may vary from 1 to 8 MΩ/□. The holes (0.3 mm in diameter with a pitch of 0.6 mm) were drilled by a CNC machine operating at up to 100000 revolutions per minute (RPM) followed by global etching, to achieve an active area of 30 mm×30 mm.

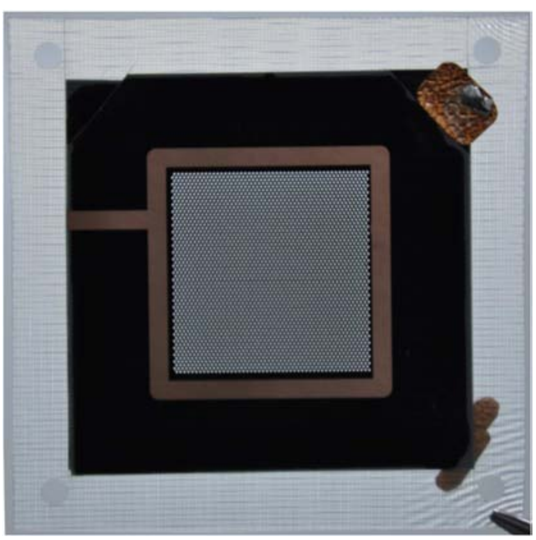

Fig. 1. Photo of the RETGEM made of resistive kapton.

2.2 Experimental devices

During this experiment, the ^{55}Fe X-ray is used as a radioactive source. Ionization is produced in the upper drift region by 5.3 keV photoelectrons generated by the interaction of the ^{55}Fe 5.9 keV X-ray with Ar atoms. The ionized electrons are amplified as avalanche in the RETGEM holes then enter the lower inductive region, and finally are collected by the anode. All electrodes are biased with CAEN N470 HV power supplies and the signals are recorded in pulse-counting mode with an ORTEC 142 preamplifier (charge sensitivity 1 V/pC) followed by an ORTEC 450 amplifier (shaping time τ=0.5 μs) and an ORTEC TRUMP-PCI-8K multi-channel analyzer. The RETGEM is mounted on a polyethylene (PE) frame and installed in a gas-tight polymethyl methacrylate (PMMA) made chamber, which is continuously flushed with 1 atm of pre-mixed gas.

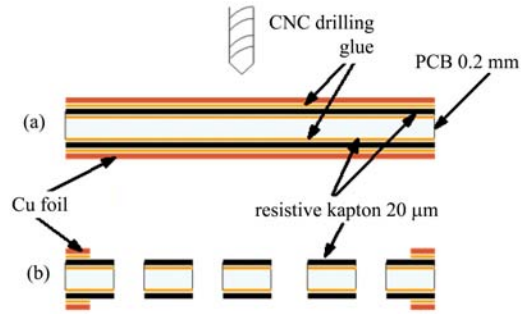

Fig. 2. Two-step process in drilling holes in improved RETGEM.

3 Performance of the thinner RETGEM

3.1 Tuning the $E_{\rm ind}$ and the $E_{\rm drift}$

The measurement results show that the induction electric field $E_{\rm ind}$ does not obviously influence the energy resolution of the RETGEM. A suitable induction electric field of $E_{\rm ind}$=3.0 kV/cm has been chosen as a compromise between collection efficiency and discharge.

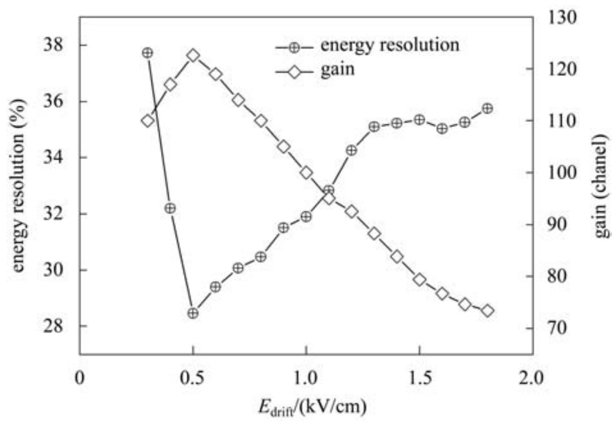

Fig. 3. Dependence of the energy resolution and gain on the $E_{\rm drift}$.

In order to evaluate the influence of $E_{\rm drift}$ on energy resolution and gas gain, the $\Delta V_{\rm RETGEM}$ is set to constant (550 V Ar/iC_4H_{10} (90/10). As shown in Fig. 3, the electric fields $E_{\rm drift}$ in the detector are regulated between 0.3 kV/cm and 1.8 kV/cm. The energy resolution and gain of the RETGEM detector varies rapidly with $E_{\rm drift}$ (shown in Fig. 3). The energy resolution reaches a minimum, and the gain reaches a maximum at $E_{\rm drift}$=0.5 kV/cm. The dependence of the energy resolution and gain on the drift field illustrates that $E_{\rm drift}$ plays an important role in the RETGEM detector performance. The proper $E_{\rm drift}$ increases the probability of the primary ionized electrons drift into the RETGEM holes, thus results in good energy resolution and large gain.

We obtain the optimized values of $E_{\rm drift}$= 0.5 kV/cm and the $E_{\rm ind}$=3.0 kV/cm which will be used in the following sections.

3.2 Gain in different gas mixtures

The gains of two kinds of RETGEM working with three kinds of gas mixture are shown in Fig. 4. For the same gain, the 200 um RETGEM working voltage is much lower than that of the 1 mm RETGEM obtained in this work. The thinner one easily works at a gain of up to 3000 with only a single RETGEM board. The thicker one can work at a gain of even higher than 10000 in the Ne mixture (see the curve in the uppermost gain region in Fig. 4, whereas the standard GEM needs a triple cascade setup to obtain the same gain. Among the two kinds of ratio of Ar/iC_4H_{10}, the lower the component of iC_4H_{10}, the lower the operating voltage is needed.

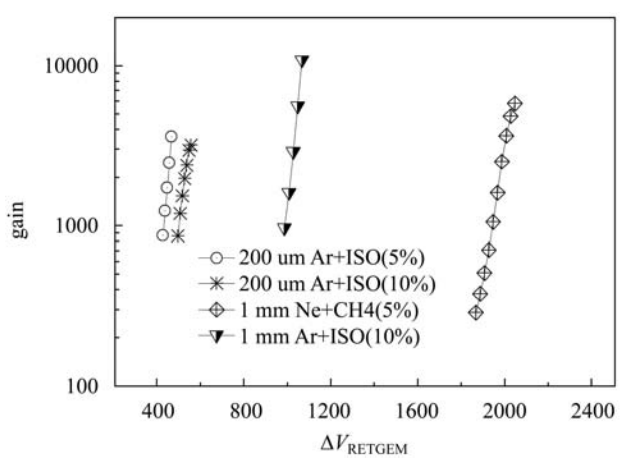

Fig. 4. Gain curves in different gas mixtures.

3.3 The stability and the energy resolution

The gain stability of 200 um thick RETGEM is tested. The gas gain of the detector is measured every ten minutes and the results show that the variance of gas gain is lower than 3% at the gain 1800 in ten hours.

Figure 5 shows the best energy resolution 27%(FWHM) of a single 200um RETGEM operating at $\Delta V_{\rm RETGEM}$=540 V and a gain of 3.0×10^3 in an Ar/iC_4H_{10} (9/10) mixture.

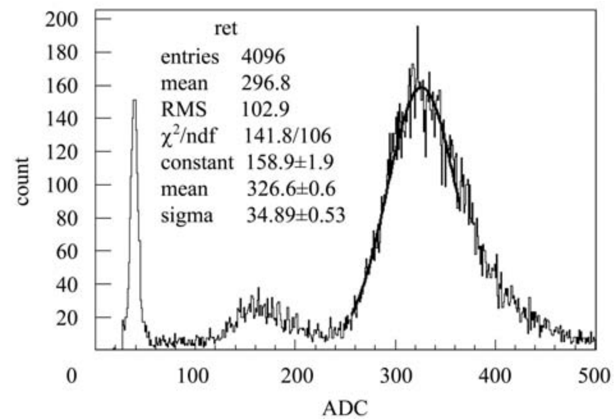

Fig. 5. Energy resolution 27% in Ar/iC_4H_{10} (90/10).

3.4 The discharge performance of the RETGEM

The discharge probability of the RETGEM in Ar/iC_4H_{10} (90/10) is shown in Fig. 6. As the detector works at the gain of 3.0×10^3, the discharge probability of the RETGEM is 10^{-4}. Charges of about 14% of the discharge have been measured, and this means that the RETGEM travels to a streamer mode [8]. We know that the effective current of the streamer mode is on the uA level but the effective current of the spark mode is on the mA level [9]. So the discharge of the RETGEM is mild and is less dangerous for the detector and the front-end electronics.

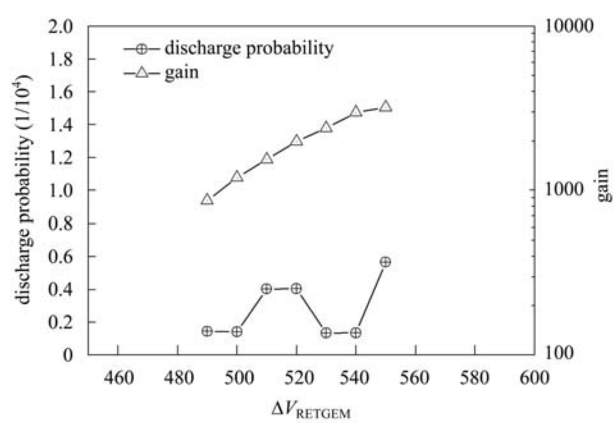

Fig. 6. Discharge probability of the RETGEM in Ar/iC_4H_{10} (90/10).

4 Conclusion and prospects

In conclusion, from the results of the RETGEM discharge measurement, we know that the discharge of the RETGEM is mild and, to some extent, it would reduce the danger of damage to either the detector or the front-end electronics. The achieved energy resolution of around 27% is sufficient for the RETGEM. Thus we believe that the RETGEM has good potential in many applications, for example in the time projection chamber (TPC). Certainly, more tests would be needed to capture the performance of the RETGEM in detail.

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