Experimental study of a THGEM detector with mini-rims*

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Abstract: The gas gain and energy resolution of single and double THGEM detectors (5 cm×5 cm effective area) with mini-rims (rim less than 10 μm) were studied. The maximum gain was found to reach 5×10^3 and 2×10^5 for single and double THGEMs respectively, while the energy resolution for 5.9 keV X-rays varied from 18% to 28% for both single and double THGEM detectors of different hole sizes and thicknesses. Different combinations were also investigated of noble gases (argon, neon) mixed with a quantity of other gases (isobutane, methane) at atmospheric pressure.

Key words: THGEM, gas gain, energy resolution, mini-rim

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1 Introduction

In recent decades, Micro-Pattern Gas Detectors (MPGDs) have undergone rapid development. The most successful MPGDs are gaseous electron multipliers (GEM) [1, 2] and Micromegas [3]. GEM detectors can reach high gain and good position resolution in a triplet structure, thus they can be used in many applications. The disadvantage of the GEM detector is that it is prone to discharge, which can easily damage the detector. The development of the Thick Gas Electron Multiplier (THGEM) was motivated by the need for robust large-area, fast radiation imaging detectors with moderate localization resolution [4–7]. In general, THGEMs are manufactured using standard PCB technology by precisely drilling on double-face Cu-clad FR-4 or G10 substrates. A metal-free clearance ring surrounding the hole, the rim, is then obtained by Cu etching (Fig. 1(a)). The rim enhances the THGEM's immunity to discharge, leading to higher gains compared to rimless holes [8, 9]. However, large rims may be responsible for charging up and polarizing the substrate, thus it will take a longer time to reach a stable gain [10–12].

The THGEM detector has also been studied by us [13, 14]. However, there is a non-concentricity in the etching technique, which causes bias between the center of the drilled hole and the etched circular ring. This makes the THGEM discharge easily at high voltage. However, improving the accuracy of the ring has a high cost. In this work, THGEMs were produced without etching the rims in the PCB factory (Shenzhen King Brother Group), then some chemical treatments and ultrasonic cleaning processes were applied in our laboratory. The resulting THGEMs had mini-rims of less than 10 μm, with a good performance (robustness, high gain and stability) and at a considerably lower detector cost.

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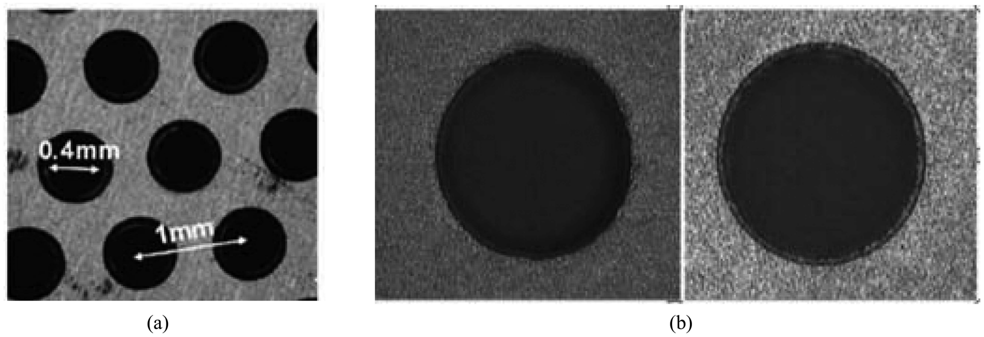

Fig. 1. Images of the THGEM plates. (a) The standard THGEM structure; (b) A single hole before (left) and after (right) the processes described in the text. The treated rim is less than 10 μm.

2 Configuration of the THGEMs

Three kinds of THGEM plates were investigated in this work, for the purpose of optimizing the dimensions of the detector. The thicknesses of the plates were 0.3, 0.5 and 0.8 mm respectively, while the hole diameters were the same as the plate thickness and the pitches were twice the plate thickness. The active area was designed to be 5 cm×5 cm. In this configuration, the ratio of the hole area to the active area (22.67%) was comparable to standard GEM detectors (70 μm thick and hole diameter, 140 μm pitch [2]).

The holes of the THGEM plates were drilled by the PCB manufacturer, and no rim was etched. The post processing included chemical treatment and ultrasonic cleaning. Fig. 1(b) is a comparison of the hole shape before and after these processes. From this figure a mini-rim (less than 10 μm) can be seen.

3 Results of the experiment

Single and double THGEM plates were measured using ^{55}Fe X-rays. The distance of the drift region and the induction region was set to 5 mm and 3 mm respectively, while the transfer distance for the double-THGEM was 3 mm.

The gain and energy resolution were measured for the three types of plates. In addition, Ar/isobutane(95/5) and Ne/CH_4(95/5) were used as the operating gas. The Ortec 142AH charge sensitive preamplifier, 450 primary amplifier and TRUMP-PCI-8K Multi-Channel Analyzer (MCA) were used for the electronic readout. The system was calibrated with an Ortec 415 pulse generator and a standard capacitor (2 pC/mV).

3.1 Single THGEM result

Figure 2 shows the gain of single THGEM plates of different thicknesses. From this figure one can see that the thicker the THGEM the higher the work voltage. The maximum gain of a single THGEM can reach about 5×10^3. The energy resolution, which is also shown in this figure, varies from 18% to 28%. The energy resolution is calculated by the formula $R = \mathrm{FWHM}/\mathrm{ADC} = 2.35\ \sigma/\mathrm{ADC}$, where σ and ADC refer to the full width at half maximum and the mean

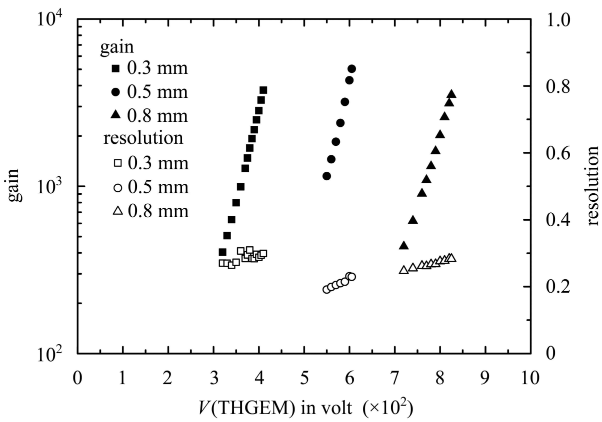

Fig. 2. The gain and energy resolution of single THGEM. In an Ar/isobutane(95/5) mixture, the drift field is 1 kV/cm and induction field 2.7 kV/cm.

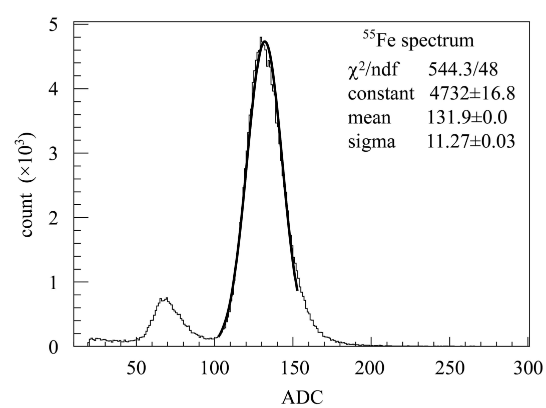

Fig. 3. A typical ^{55}Fe energy spectrum, in Ar/isobutane(95/5) mixture. The energy resolution is 2.35×11.27/131.9=20.08%.

value of the energy spectrum by Gaussian fitting, respectively. A typical energy spectrum with a resolution of 20.08% is shown in Fig. 3.

In addition, the influence of the drift and induction fields on the gain and energy resolution were investigated, and the results are shown in Fig. 4. From this figure we can see that the energy resolution becomes worse if the drift field is larger than 1 kV/cm; at the same time, the gain decreases. At higher induction fields, however, higher gain can be reached although the resolution loses a little to some extent. It is best for the induction field not to exceed 3 kV/cm. As an optimization, the drift field and the induction field were chosen to be 1 kV/cm and 2.7 kV/cm respectively in the following measurements.

3.2 Double THGEM results

In this section, the gain of the double-THGEM for the three plate thicknesses was measured in different gases. Fig. 5(left) shows the gain of one of the two THGEM plates, while the other was fixed at a reasonable voltage. The ratio of V_{THGEM} to thickness was kept the same for the three thicknesses of plates. In this figure we can see that the gain in the argon and isobutane mixture is about 4×10^4 while in the neon and methane gas the gain is 2×10^5.

In addition, we studied the influence of the transfer field, which is the field between the two THGEM plates. Fig. 5(right) shows a plateau after 0.6 kV/cm. The energy resolution improves slightly as the transfer field increases.

As the gain reached the 10^5 level, we briefly tested the double-THGEM plates without amplifiers. It was confirmed that the signals can be read out directly from an oscilloscope (with 50 Ω impedance) even without pre- and primary amplifiers. Fig. 6 is a signal waveform graph near the breakdown point, from which the gain is estimated to be about 3×10^5 using the approximate formula $g = VT/2\mathrm{Re}N$, where V is the amplitude (~6 mV), T is the signal width (~100 ns), R is 50 Ω, e is the electron charge and N the primary ionization number (~166 in the neon and methane mixture). This calculation is consistent with the value measured with the amplifiers.

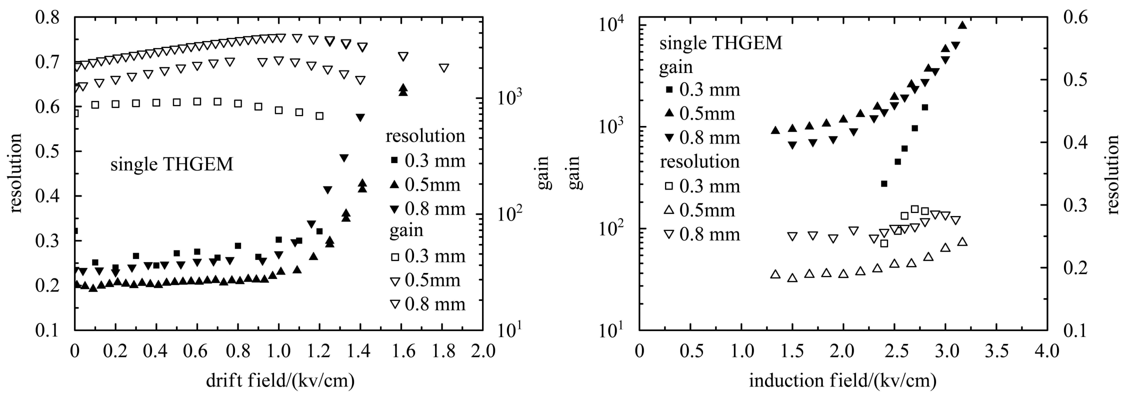

Fig. 4. The influences of drift (left) and induction (right) fields on the gain and resolution in an Ar/isobutane(95/5) mixture. The THGEM thickness is 0.5 mm and the voltage is 595 V.

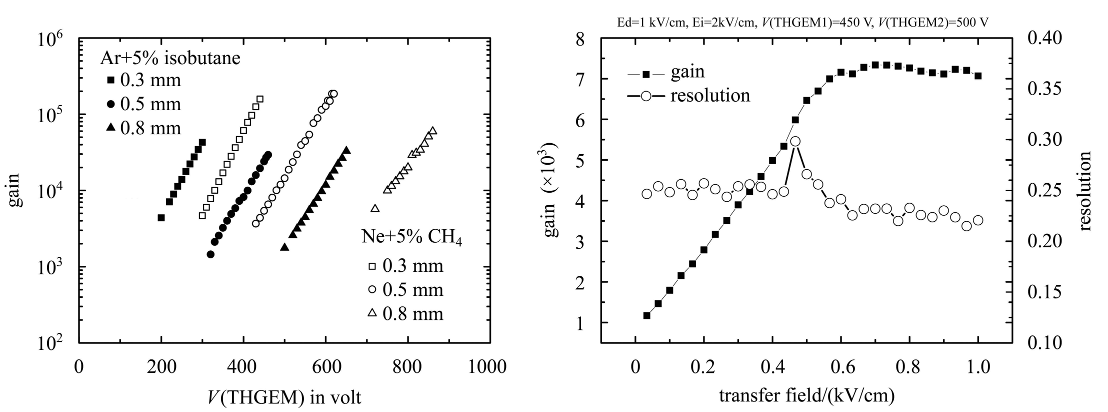

Fig. 5. The double-THGEM results. (left) The gain in different gases; (right) The influence of the transfer field. The gas is Ar/isobutane (95/5). The bad resolution at 0.45 kV/cm is due to some electromagnetic interference.

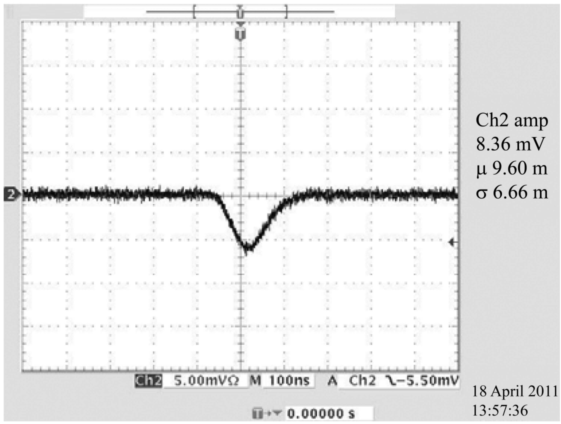

Fig. 6. A signal without amplifiers.

4 Conclusion

The THGEM detector has been widely researched and applied in many areas. In this paper, THGEMs with mini-rims have been studied and good performances achieved. Some characteristics of the THGEMs we studied are:

1) They are very robust, and will not easily be damaged by electrical discharge.

2) High gain and good energy resolution can be reached, as long as the cleaning is done carefully.

3) They are very cheap to produce (about 0.1 RMB per square centimeter). The chemical treatment can be easily implemented in the laboratory.

In the future, we plan to study THGEMs with other geometries (hole size, thickness and pitch), as well as larger areas (10 cm×10 cm). We believe mini-rim THGEMs can be used in a broad range of applications, such as photon detectors with CsI cathodes, dark matter search in noble-liquids, and so on.

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