Experimental studies of THGEM in different Ar/CO_2 mixtures*

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Abstract: In this paper, the performance of a type of domestic THGEM (THick Gaseous Electron Multiplier) working in Ar/CO_2 mixtures is reported in detail. This kind of single THGEM can provide a gain range from 100 to 1000, which is very suitable for application in neutron detection. In order to study its basic characteristics as a reference for the development of a THGEM based neutron detector, the counting rate plateau, the energy resolution and the gain of the THGEM have been measured in different Ar/CO_2 mixtures with a variety of electrical fields. For the Ar/CO_2(90%/10%) gas mixture, a wide counting rate plateau is achieved from 720 V to 770 V, with a plateau slope of 2.4%/100 V, and an excellent energy resolution of about 22% is obtained at the 5.9 keV full energy peak of the ^{55}Fe X-ray source.

Key words: THGEM, counting rate plateau, gas gain, energy resolution

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1 Introduction

Neutrons have been used to investigate the structure and dynamics of a material. Many efforts have recently been devoted to the development of the next generation of neutron facilities, which include SNS in USA, J- PARC in Japan, ISIS in UK, CSNS (China Spallation Neutron Source) in China, and ESS in Europe [1]. The neutron detector is one of the key components of these neutron scattering instruments. With the international development of the new generation neutron source, the traditional neutron detector based on ^{3}He has especially been unable to adequately satisfy the demands of the application of high flux. In addition, the problem of the global crisis of ^{3}He supply [2] means that research on a new style of neutron detector that can replace the old ^{3}He based detection technology has become extremely urgent.

As a good candidate, a boron coated GEM recently became the focus of attention [3]. This detector was first designed by Martin Klein using CERN standard GEM in 2006 [4]. It has outstanding and excellent characteristics, such as high counting rate capability (>10 MHz), good spatial resolution and timing properties, radiation resistance, flexible detector shape and readout patterns [5]. In 2011, IHEP and UCAS first successfully developed a kind of THGEM (THick Gaseous Electron Multiplier), which was manufactured economically by standard printed-circuit drilling and etching technology in China. Compared with the CERN standard GEM, THGEM has higher gain, sub-millimeter spatial resolution, and they offer the possibility of industrial production of large-area robust detectors, which is very suitable and adequate for the application of neutron detection.

In this paper, the THGEM is provided by the Zheng Yang-heng group of UCAS. It is a thinner-THGEM with a thickness of 200 μm, hole diameter of 200 μm, pitch of 500 μm and a very small rim of 5–10 μm. The thinner-THGEM is made of FR4 glass epoxy substrate, with 20 μm thick copper- cladding on both sides, and it has an active area of 50 mm×50 mm [6]. In order to study its basic characteristics as a reference for the development of this kind of domestic THGEM based neutron detector, the performance of the counting rate plateau, the energy resolution, and the gain have been measured

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in different Ar/CO_2 mixtures with different high voltages. According to the experiments, the working conditions optimized by the THGEM have been obtained, which will be very helpful for the design of this kind of THGEM based neutron detector in the future [7, 8].

2 Experimental setup

Figure 1 shows a schematic view of the detector configuration, consisting of cathode, anode and a single THGEM. The THGEM detector was operated in different Ar/CO_2 mixtures at a normal pressure and temperature. Measurements were carried out by using a ^{55}Fe X ray source (activity 10mCi), which was positioned in such a way that a collimated beam (ϕ1 hole) of X-rays perpendicularly entered the upper drift region. The ionization electrons generated by the interaction of ^{55}Fe 5.9 keV X-rays with Ar atoms were amplified in avalanche mode in the THGEM holes [8], and then entered the induction region, where they were finally collected by the anode. All three electrodes of the HV were supplied by the WIENER MPOD mini-HV power and the signals were readout with an ORTEC 142IH preamplifier, followed by an ORTEC 572A amplifier (shaping time t=2 μs) and an ORTEC multi-channel analyzer (trump-usb-8k).

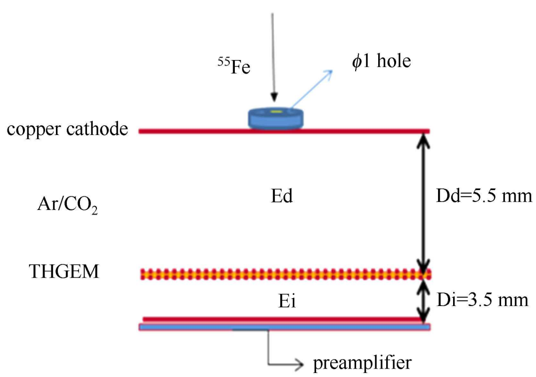

Fig. 1. Schematic view of a single THGEM detector with drift region Dd=5.5 mm and induction region Di=3.5 mm.

3 Results and discussions

3.1 Plateau

In order to find the suitable working voltage for the detector in different Ar/CO_2 mixtures, its counter plateau was measured in different Ed (drift field) and Ei (induction field), the results are shown in Fig. 2. During the experiment, the total flow of Ar and CO_2 gas is 50 SCCM to ensure the amount of effective working gas in the chamber. The counts were recorded in every one minute and the voltage of THGEM was increased by the increment of 5 V until the spark discharge occurred. As Fig. 2 shows, it has a longer plateau in the Ar/CO_2 mixture ratio of 90%/10% and gets shorter with the increase of the proportion of CO_2. To a certain extent, the counting rate was independent on the Ed and increased with the Ei, so that the plateau was shifted left with the increasing of the Ei. For the gas mixture Ar/CO_2 (90%/10%), the induction field Ei of 2.0 kV/cm and the drift field Ed of 0.5 kV/cm, the plateau range of this kind of THGEM was from 720 V to 770 V and its plateau slope was about 2.4%/100 V, as shown in the top left of Fig. 2. This optimization would be helpful to understand the working range of the THGEM and find conditions with a lower HV.

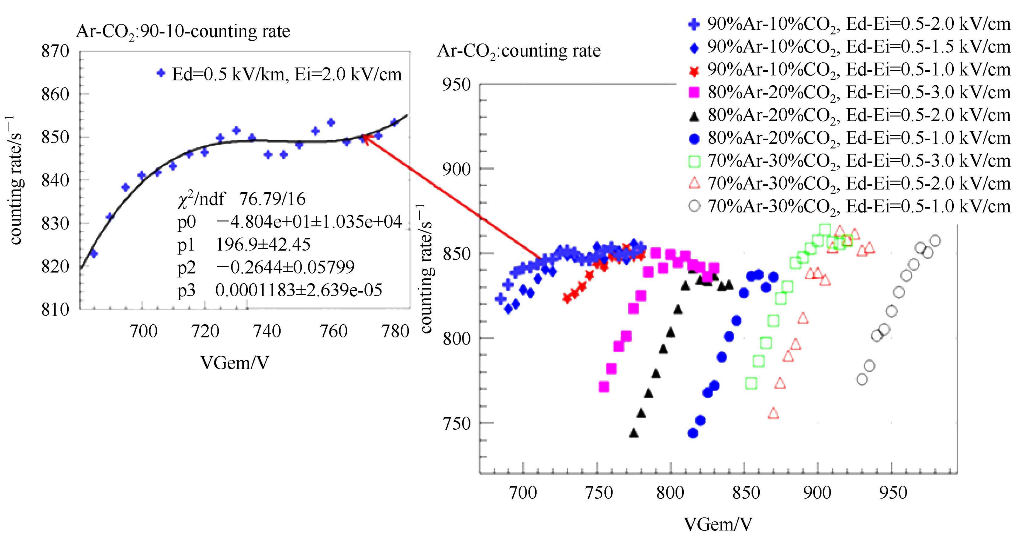

Fig. 2. Counting rate plateaus of the THGEM detector in the three different kinds of gas mixture (90%Ar/10%CO_2, 80%Ar/20%CO_2 and 70%Ar/30%CO_2) with Ed=0.5 kV/cm and Ei=1.0 kV/cm, 1.5 kV/cm, 2.0 kV/cm and 3.0 kV/cm.

3.2 Gain

By using the 5.9 keV full energy peak of the ^{55}Fe X-ray source, the effective gain was measured with the voltage of THGEM increased by the increment of 5 V in different Ar/CO_2 mixture, and different fields Ed and Ei. To a certain extent, the stronger the induction field Ei is, and the greater the voltage of the THGEM is, the larger the gain will be for the same gas mixture. As Fig. 3 shows, the gain increases exponentially with the voltage of the THGEM for each kind of gas mixture, and the single THGEM can provide a wide gain range from 100 to 1000. The gain decreases with the increase of the proportion of CO_2 in the gas mixture.

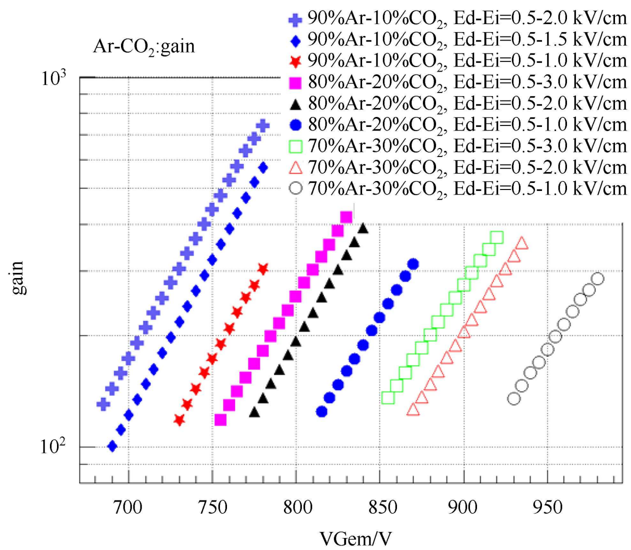

Fig. 3. The experimental gain in the three different kinds of gas mixture (90%Ar/10%CO_2, 80%Ar/20%CO_2 and 70%Ar/30%CO_2) with Ed=0.5 kV/cm and Ei=1.0 kV/cm, 1.5 kV/cm, 2.0 kV/cm and 3.0 kV/cm.

As mentioned above, the influence of drift field Ed on gain is very small, to a certain extent. Fig. 4(a) shows the gain as a function of Ed in different Ei in the Ar /CO_2 (90%/10%) gas mixture. In different Ed, the gain has nearly no change at the voltage 770 V of THGEM for each Ei and increases with the Ei. Similarly, Fig. 4(b) shows the gain change with Ed in different Ei in the Ar/CO_2(80%/20%) gas mixture. It shows similar results as those in the Ar/CO_2 (90%/10%) gas mixture. For the Ar/CO_2 (70%/30%) gas mixture, the same regularity exists, although, due to no common appropriate voltage of THGEM, the a similar figure has not been presented.

3.3 Energy resolution

Energy resolution is one of the most important parameters related to the detector's performance. The energy resolution was measured using the 5.9 keV full

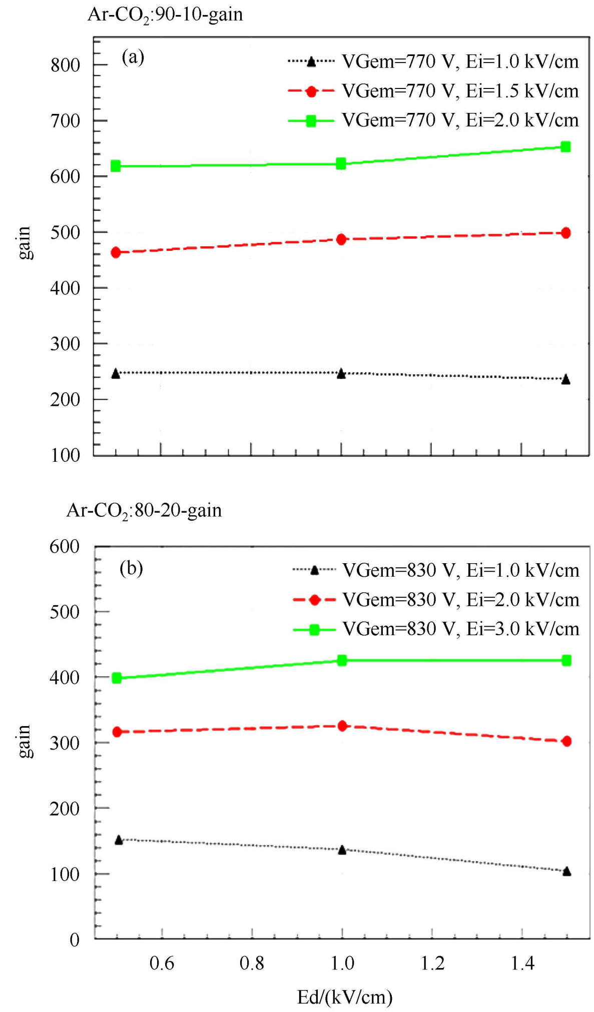

Fig. 4. Gain vs Ed is in different Ei and in same voltage of the THGEM. (a) Gain changes with the Ed in an Ar/CO_2 (90%/10%) gas mixture and the voltage of the THGEM VGem=770 V. (b) Gain changes with the Ed in an Ar/CO_2 (80%/20%) gas mixture and the voltage of the THGEM VGem=830 V.

energy peak of the ^{55}Fe X-ray source. Fig. 5 shows the results of three kinds of gas mixture, with the voltage of THGEM increased by the increment of 5 V in different field Ei. There are three regions with clear boundaries related to the ratio of CO_2 in the gas mixture. As the ratio of CO_2 decreases, the working voltage of the THGEM will get lower and the energy resolution will also get smaller. A much better energy resolution is obtained in the Ar/CO_2 (90%/10%) gas mixture. As the voltage of THGEM increases, the energy resolution will also obviously get better. The induction field Ei has a bit affection on the energy resolution and the drift field has nearly no effect on the energy resolution from 0.5 to 3 kV/cm (measured and not included in the figure). As a sum-

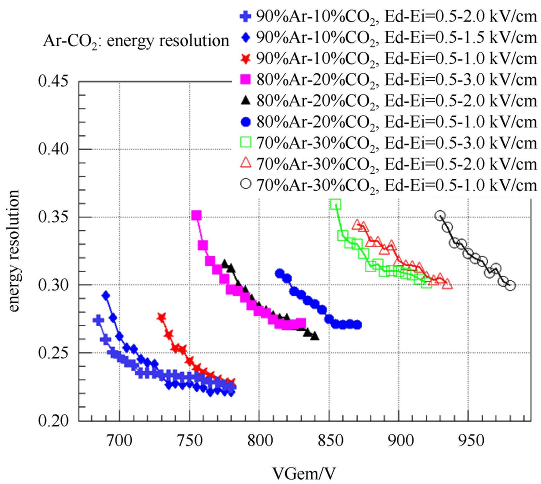

Fig. 5. The energy resolution in the three different kinds of gas mixture (90%Ar/ 10%CO_2, 80%Ar/ 20%CO_2 and 70%Ar/30%CO_2) with Ed= 0.5 kV/cm and Ei=1.0 kV/cm, 1.5 kV/cm, 2.0 kV/cm and 3.0 kV/cm.

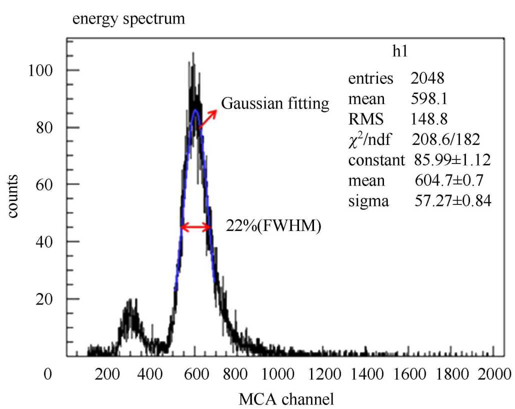

Fig. 6. A pulse height spectrum in the Ar/CO_2 (90%/10%) gas mixture, Ed=0.5 kV/cm, Ei=2 kV/cm and the voltage of the THGEM VGem=770 V with ^{55}Fe source.

mary for the optimization, the best working points of this kind of THGEM are recommended as follows: the Ar/CO_2 (90%/10%) gas mixture, the drift field 0.5 kV/cm, the induction field 2 kV/cm and the voltage range of THGEM from 720–770 V, which will give the better energy resolution smaller than 25%.

Figure 6 shows a pulse height spectrum obtained with a ^{55}Fe source in the Ar/CO_2 (90%/10%) gas mixture. To obtain energy resolution it is fitted with the Gaussian function, which indicates that the energy resolution (FWHM) of the detector based on THGEM is about 22%. With such an energy resolution, the detector can entirely separate the 3 keV of Ar escape peak from the ^{55}Fe main X-ray peak located at 5.9 keV.

4 Conclusion

In this paper, the experimental performance of a kind of domestic THGEM working in Ar/CO_2 mixtures is presented in detail. The effective gain of single THGEM can reach about 1000 in the Ar/CO_2 mixture. As the ratio of CO_2 decreases from 30% to 10%, the working voltage of the THGEM will get lower, the plateau will get longer, and the energy resolution will also get much better. As the induction field Ei increases from 1 to 3 kV/cm, the performance of THGEM improves. The drift field Ed (0.5 to 1.5 kV/cm) has nearly no influence on the performance of THGEM. As a summary for the optimization, the best working points of this kind of THGEM are recommended as follows: the Ar/CO_2 (90%/10%) gas mixture, the drift field 0.5 kV/cm, the induction field 2 kV/cm and the voltage range of THGEM from 720–770 V, which will give the better energy resolution smaller than 25%. According to our experiments, this would be very helpful for the future design of this kind of THGEM based neutron detector.

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