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A new gaseous detector — micro mesh gaseous structure*

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Abstract The structure and working principle of Micromegas (MICRO Mesh Gaseous Structure) is discussed. Some radiation sources of α and X rays are used to test this detector. The optimized electric-field intensity of the conversion gap is obtained. The transmission of electrons and the uniformity of the amplification gap are also presented. The energy resolution of the 5.9 keV peak is better than 27%.

Key words micromegas, structure, electric field, energy resolution, uniformity

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1 Introduction

The MICRO Mesh Gas Structure (Micromegas) is a new gaseous detector initially developed for tracking in high-rate, high-energy physics experiments since 1990s. It shows higher counting rate capacity up to 10^8 mm$^{-2}\cdot$s^{-1}, position-sensitive with spatial resolution better than 100 μm and good performance of radiation hardness[1—3], which has been developed since 1996 at Saclay, France[4].

This new type of gaseous detector is based on a simple geometry with planar electrodes. It consists of a drift gap (or conversion gap) and a thin amplification gap. The two gaps are separated by a thin mesh. The primary ionization happens in the drift gap. The avalanche happens in the region of the high electric field in the amplification gap. The printed electrodes of any shape collect the electrons from the avalanche.

Micromegas is widely used in particle physics and is a suitable candidate in high-intensity X-ray detection and tomography. With proper neutron converters made of a thin solid target it can also be applied in high-flux neutron detection and tomography[5]. With its simple structure and low cost, it has been adopted by many experiments in particle physics experiments, such as charged particle localization, the Time Projection Chamber (TPC), and neutron or X-ray imaging.

We have made a series of Micromegas and have done some tests with radiation sources. The goal of these tests is to learn the properties and working principle of Micromegas.

2 Structure and working principle of Micromegas

Figure 1(a) shows a schematic representation of a typical Micromegas detector. It consists of a drift gap (3—10 mm) and a thin amplification gap (50—100 μm). The properties of the electric field in two gaps have been studied by MC simulation with Garfield[6]. The simulated electric field lines in two gaps are showed in Fig. 1(b). The voltage of drift electrode and mesh is −650 V and −560 V, respectively, and Micromegas is operated in a mixture of gas of 90%Argon+10%Isobutane, at a temperature of 300 K and a pressure of 1 atm. The field lines shown as dotted lines are compressed towards the mesh hole with a diameter of a few microns and exhibit a funnel-like shape, which plays the role of focusing the electrons from the drift gap on the amplification gap through the hole. The electric field in the amplification region is very high, near 100 kV/cm, and the one in the conversion region is quite low. Therefore, the ratio between the electric field in the amplification gap and that in the drift gap can be tuned to large values,

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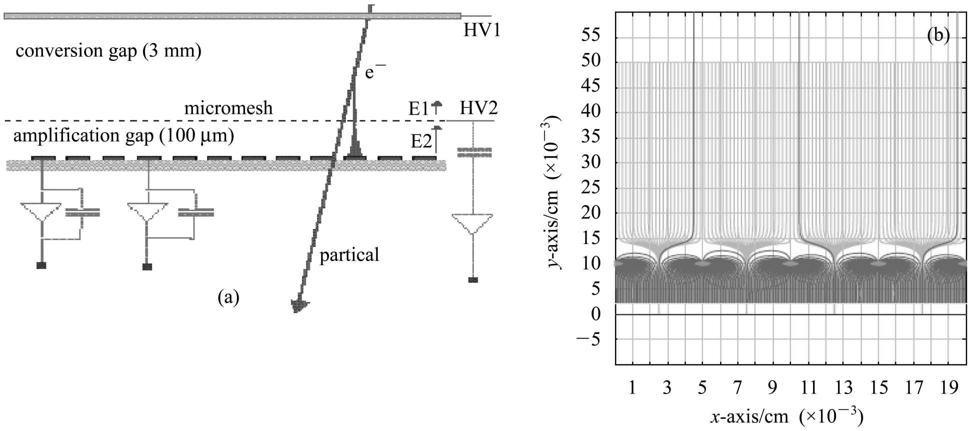

Fig. 1. (a) A schematic view of Micromegas; (b) The simulated 2D electric field line.

as is required for an optimal function of the device. So in the amplification gap, the ions can quickly be collected on the mesh and only a few fractions of ions can escape to the drift gap[7].

The Micromegas is based on the planar electrodes. The drift electrode is made from 5 cm × 5 cm 400 LPI (lines per inch) steel mesh pasted on an epoxy frame, and the same mesh is used as the amplification electrode. The 400 LPI of tabby form, 400 LPI of bias form and 500 LPI of tabby form of stainless steel meshes have been used to make chambers as electrodes. The diameters of the steel wire are 22 μm and 25 μm. The parameters of the mesh are listed in Table 1.

Table 1. The parameters of the mesh.

type	diameter of wire/μm	size of hole/μm
350LPI (tabby form)	24	47.2—48.2
400LPI (tabby form)	21.7	40.5—41.1
400LPI (bias form)	26.4	34.2—36.4
500LPI (bias form)	21.7	27.7—29.9

The PCB (print circuit board) with anode strips of gold-coated copper of 6 mm, with 6.5 mm pitch, is printed on a 1.5 mm thick substrate. The thickness of the copper strips is 5 μm. Nylon fish fibers of 100 μm, with 2 mm pitch, which keeps the 100 μm thickness of amplification gap, were stretched and glued on one side of the PCB. The thickness of the conversion gap is 3 mm. The conversion-drift electric field was defined by applying negative voltages on the micromesh (HV2) and a slightly more negative voltage on a second electrode (HV1), spaced by 3 mm in order to form a conversion-drift space. Two metal frames of 8 mm thickness were fixed on both sides of Micromegas to keep it stable. The whole structure was placed in a hermetical vessel with a standard gas mixture of 90%Ar + 10%isobutene flowing through it, at one atmospheric pressure.

3 The test system

The test system includes the gas mixture system, the power supply, the amplifier, and the data analysis system. Fig. 2 shows the test system sketch.

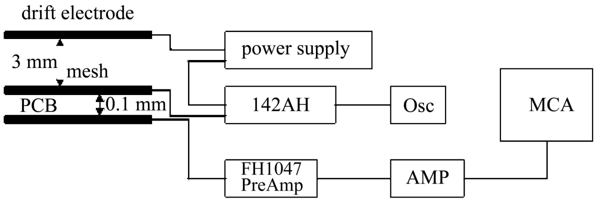

Fig. 2. The test system sketch.

A negative high voltage (HV1) is applied on the drift electrode and a 30 V higher voltage (HV2) is applied on the micromesh via ORTEC preamplifier model 142 AH. The signal from the PCB anode strip passes through the FH 1047 charge-sensitive preamplifier and connected to the BH1218 amplifier, and then is measured by a multi-channels analyzer (MCA) or observed by the oscillograph.

The Micromegas chamber is put in a compact airtight box. There are 4 blind holes on the mother board of 8 mm for fixing the chamber. The 5 mm thick cover board has a 5 cm × 5 cm window in the center covered by a 10 μm thick polythene film.

4 The experiment result

4.1 Tests with α-ray

Micromegas was put in a box, the distance from the drift electrode to the box's inside cover is about 14 mm, and the thickness of the cover is about 5 mm. Fig. 3 shows a sketch of the test system.

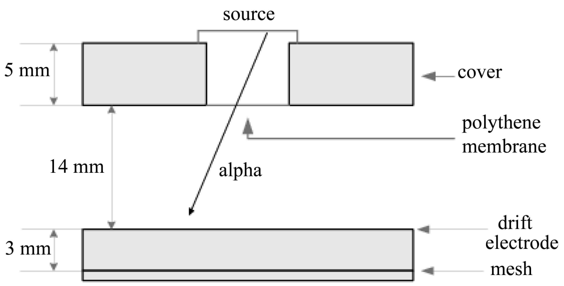

Fig. 3. The test system for the α source.

We measured the MCA spectra of an alpha particle with the Micromegas detector by varying the distance in a step of 1.2 mm between the ^{241}Am α source and the Micromegas window made of a 10 μm thick polyethylene film. The alpha particles pass through the air, penetrate the window and reach the drift gap. Fig. 4(a) shows the change of the pulse-height spectra's peak with the distance from the α source to the outside cover of the test box. Compared with Fig. 4(b), we can see that the experiment's result is consistent with the simulated result by the use of Garfield and Srim[8]. The simulation traces α particles from the source, through the different air paths and polythene membrane to the drift gap and records the energy deposit in the gap. The energy deposit reaching a maximum both in the experiment curve (pulse-height) and in the simulation curve (primary electron numbers) at the distance of 5—6 mm is due to the Bragg Peak of energy deposit of alpha particles stopped at the drift gap.

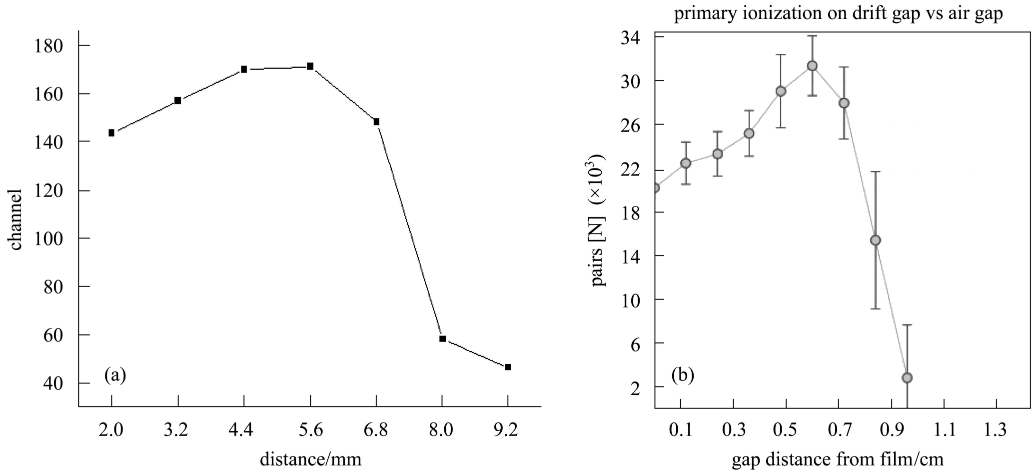

Fig. 4. (a) The change of α energy deposition (spectrum peak) with α-paths; (b) The energy deposition simulated varying with α-paths.

4.2 Tests with X-ray

(1) The transmission

In order to find an appropriate voltage of the drift electrode, we changed the voltage of the drift electrode from −560 V to −1200 V and with −550 V fixed voltage on the mesh to measure the energy spectra of 5.9 keV X-ray from the ^{55}Fe source. The channel of the photoelectric peak varied smoothly with the voltage of the drift electrode. It was obvious that the transmission of electrons through the mesh varied with the ratio of electric-field intensity of the amplification gap over the one of the conversion gap[4]. We can get a higher transmission by lowering the voltage of the drift electrode, which increases the field ratio. But when the electric-field intensity of the conversion gap is too low, the initial ionized electrons can not drift to the micromesh completely because of the recombination of the initial ionized ions. So it is needed to find an appropriate voltage of the drift electrode at which most electrons can pass through the micromesh to the amplification gap. Fig. 5(a) shows how the channel of photoelectric peak varies with the electric potential of the conversion gap. In the gas mixture of 90%Ar+10%isobutane, the electric-field intensity should reach at least 100 V/cm (corresponding to the peak of the curve) so that most electrons can pass through the micromesh. As we see in Fig. 5(a), above 100 V/cm, the larger the electric-field intensity is, the fewer the primary electrons pass through the mesh. It is necessary to keep the conversion gap in the electric field intensity low enough so that a nice energy resolution can be obtained, and the ion backflow through mesh can also be suppressed.

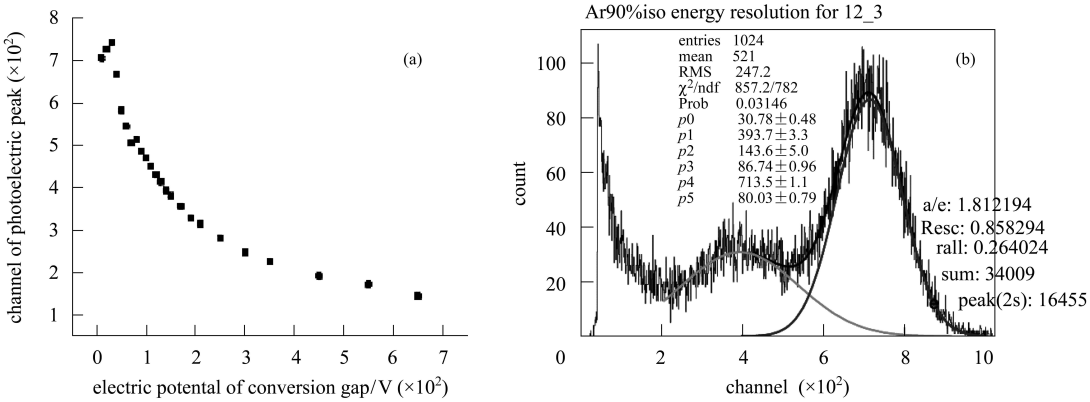

Fig. 5. (a) Photoelectric peak varies with electric potential of the drift gap; (b) Energy spectrum of the ^{55}Fe X-ray source.

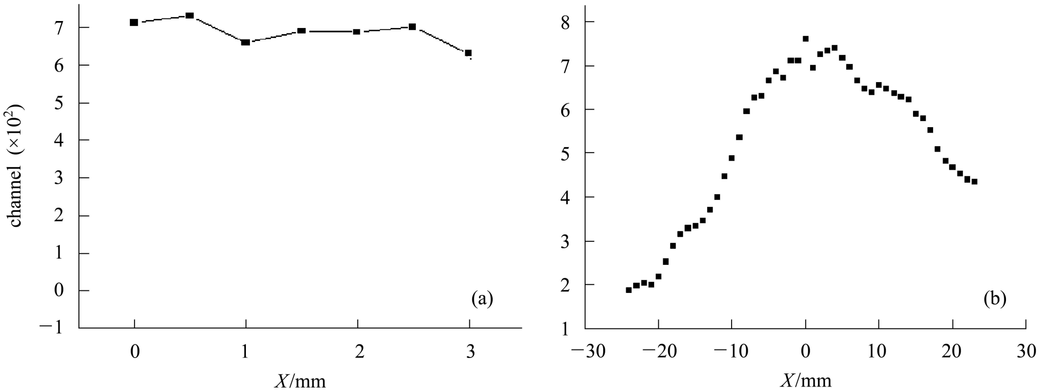

Fig. 6. (a) The channel of the 5.9 keV peak that varies with the test points in a small area; (b) The channel of 5.9 keV peak that varies with the test points in a wider area.

(2) The Uniformity of the amplification gap

The uniformity of the amplification gap is the main factor for influencing energy resolution. In the experiment we used an X-ray beam of 0.65 mm diameter from the ^{55}Fe source, and a series of points in the sensitive area of Micromegas were tested. The energy spectra were recorded for analysis. Fig. 5(b) is one of the energy spectrum. The energy resolution of the 5.9 keV peak is about 27%.

Figure 6(a) shows that the uniformity in a small area is fairly good, but in Fig. 6(b) we can see that the uniformity in a wider area is not so good. The thickness of the amplification gap at the edge is bigger than that in the center. According to the simulation of gain varying with the thickness of the amplification gap, it can be estimated that the thickness of the left edge is about 135 μm, and that of the right edge is about 115 μm, assuming that the middle thickness of the gap is 100 μm.

5 Conclusion

The Micromegas used in the test was made in May 2008. The energy resolution is an important standard to evaluate the performance of Micromegas. The X-ray energy spectra of a different site were analyzed to measure the uniformity of the amplification gap. In the future we will try a new fabrication process to improve the energy resolution and the uniformity of the amplification gap.

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