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Manufacture and performance of the thermal-bonding Micromegas prototype

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ABSTRACT: The micro-mesh gaseous structure (Micromegas) has been significantly developed since it was proposed in 1995 at Saclay (France). Some new construction methods different from "bulk" etching technique are under R&D. Here we report the results of several prototypes manufactured with thermal-bonding method, The details of this method and the performances of the chambers are presented. For a $200 \times 200\,\mathrm{mm}^2$ prototype, the energy resolution of 16% (FWHM) for 5.9 keV x-rays is achieved at a gain of 2000–4000. In addition, the sparking-resistant chammber with a Gemanium anode is under studying.

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

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1 Introduction

Micromegas is a modern micro-pattern gaseous detector [1], which has two stages, a 3–5 mm drift region (0.1–0.2 kV/mm electric field)) for particle primary ionization and electron drift, and a ~ 0.1 mm avalanche region (3–5 kV/mm) for electron multiplication. The small avalanche gap ensures high rate capability and good time resolution, as well as excellent spatial resolution by using narrow strips [2].

The prototypes introduced in this paper are manufactured by using thermal-bonding films as spacers instead of traditional etching pillars [3]. This new method makes the fabrication much easier and cost less. The materials (mesh with different parameters and thermal-bonding film with variety thicknesses) are easy to obtain. The fabrication (compared with bulk-etching) is environmental pollution-free and easier to achieve. Our R&D work aims to develop large area and good performance chambers for possible application of particle experiments. Extensive experimental studies of the stability and performance of these prototypes have been carried out in the laboratory.

2 Materials and manufacture

2.1 Materials and device

The materials and devices used in manufacturing the prototypes are listed below.

1. Micro-mesh, 350 lines per inch (LPI) stainless steel woven wire mesh with pitch/wire diameter of 75/22 μm (figure 1 (left)).

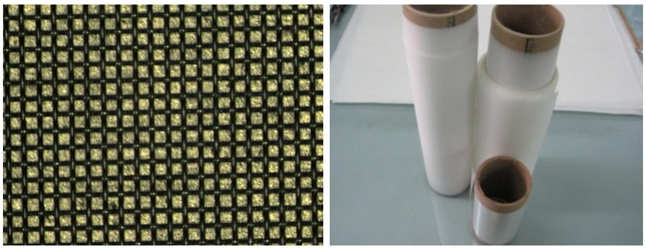

Figure 1. The microscope view of mesh (left) and the photo of thermal-bonding film (right).

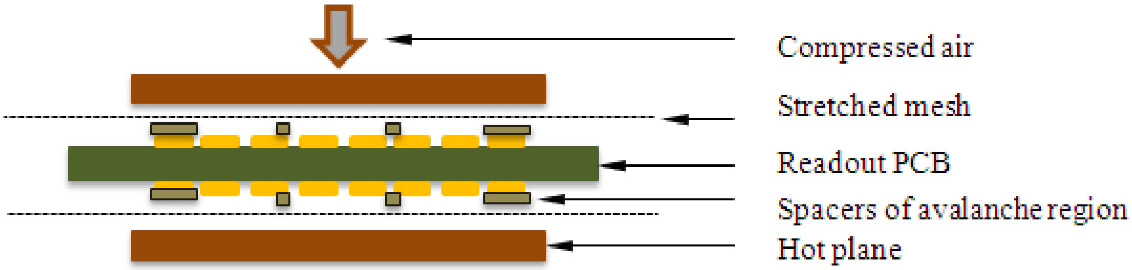

Figure 2. The schematic diagram of thermal-bonding process.

2. Thermal-bonding film, tough polyester-film with a permanent, dry (hot-melt type) adhesive on both sides (figure 1 (right)). Different thickness from several tens to a few hundreds μm can be easily obtained.

3. Hot-press, provides heating (up to 300°C) and pressure (60–200 kg) for attaching.

2.2 Manufacture

The thermal-bonding films are arranged on the readout PCB as frame and spacer of the avalanche region. The spacer films (sometimes fishing lines are also used) are 2–4 mm dimension pads, which are placed at intervals of $\sim$15 mm. Then a stretched mesh (1.8 $\sim$ 2.0 N/mm tension) is put on to the PCB (shown in figure 2). An avalanche of $\sim$ 0.1 mm gap is achieved after the hot-press pressuring on. The same operation is employed on the other side of the PCB to protect the PCB from bending under the high tension of the mesh. Another avalanche gap is formed at the same time. This back-to-back structure can be used as an x-y sensitive chamber. Its low material budget makes it possible be used for some potential applications of e.g. rare event detection in underground dark matter experiments [4].

3 Performance of several small prototypes

3.1 Gas gain

With different spacers (shown in table 1), several chambers of $65 \times 65\ \text{mm}^2$ are fabricated. Their performances are tested with the electronic chain of a charge-sensitive amplifier and a shaper. The 5.9 keV X-rays of ^{55}Fe source are employed to calibrate the detectors in the gas flow mode. The gas mixture is Ar/CO_2 with a ratio of 93/7 (same for the following test).

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Table 1. Spacers of the prototypes.

Chamber	T1	T2	T3	T4	T5
Spacers	0.128 mm Thermal-bonding film	0.12 mm Thermal-bonding film	0.15 mm Thermal-bonding film	0.15 mm Thermal-bonding film	0.092 mm fishing line
Avalanche gap	$\sim$ 0.13 mm	$\sim$ 0.01 mm	$\sim$ 0.1 mm	$\sim$ 0.1 mm	$\sim$ 0.09 mm

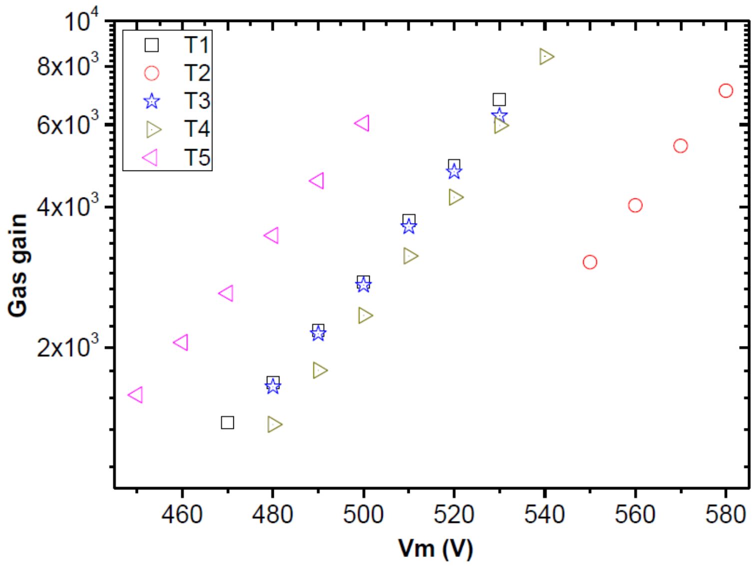

Figure 3. Gas gain vs. the mesh voltages.

Figure 3 shows that the prototypes with larger avalanche gaps need to work at higher voltage. At the same time these prototypes (standard mode, without resistant anode protection) can reach a higher gain of 6000 $\sim$ 8000. This satisfies some low rate applications, in which the gas gain is required to be less than 5000 and the sparking rate is not harsh (e.g. T2K [5]).

3.2 Track measurement

3.2.1 Electronics

The front end electronics (FEE) used is SFE16, which is developed at CERN [6]. It is an amplification-shaping-discrimination chip with intermediate shaping time range. The signal collected at the anode of the detector is amplified by SFE16, and compared to a proper threshold for discrimination. If, on a channel, the signal crosses the threshold, a LVDS pulse is sent at the output of this channel. The duration of this pulse corresponds to the signal duration above the threshold (time-over-threshold, TOT). The outputs are then sent to a 32-channel High Performance general purpose TDC (HPTDC) [7] for digitization.

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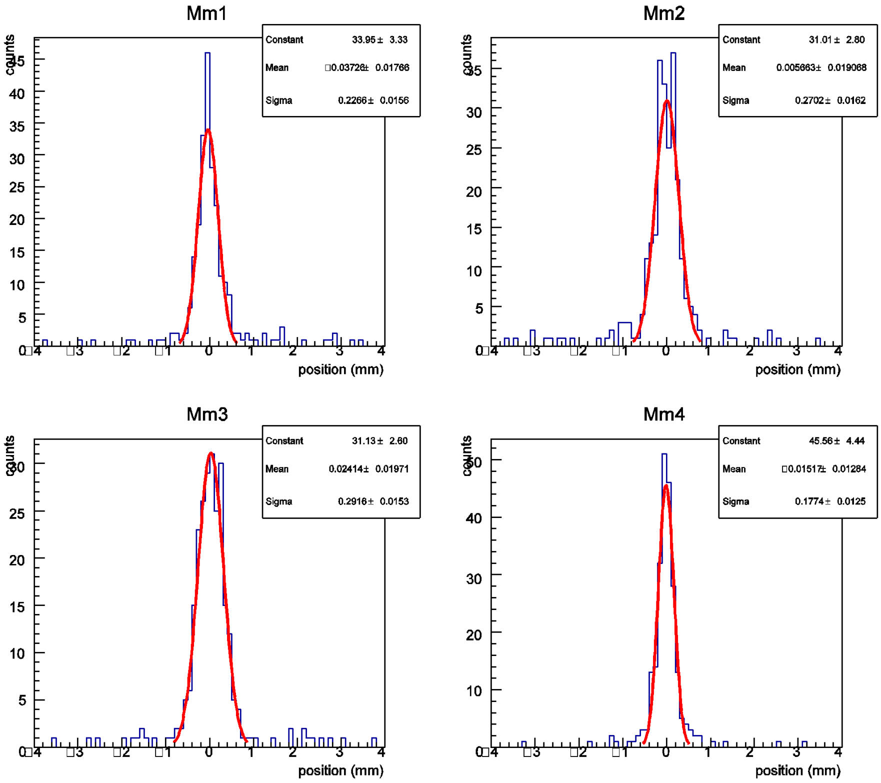

Figure 4. The deviation from fitting tracks of four chambers.

3.2.2 Cosmic test

Four prototypes of $65 \times 65\,\text{mm}^2$ are stacked as a tracking telescope system. With 1 mm readout strip pitch, 32 strips of each chamber are read out and digitized. A $200 \times 50\,\text{mm}^2$ plastic scintillator is used to provide the trigger signals for the system.

The tracks of cosmic muons recorded by four chambers are fitted by a linear function. The difference of meassured incident position and the tracking (fitting line) position indicates the spatial resolution of each chamber. As shown in figure 4, a spatial resolution of less than $300\,\mu$m is obtained for all 4 chambers. It is a reasonable value since the cluster sizes (i.e., fired readout strip numbers) of the avalanches are mostly one (in the case of 1 mm strip-pitch).

4 $200 \times 200\,\text{mm}^2$ prototype

In order to enhance the active area, so that it can be used in further particle experiments. A $200 \times 200\,\text{mm}^2$ chamber is manufactured, 176 spacer-films of $\phi 4$ mm are arranged as a staggered distribution, total spacer area is about 5.5%. Its performance is tested with a ^{55}Fe source. The following figures (figure 5, 6) shows the energy resolution and gas gain. The good resolution spectrum indicates that larger area chambers can be manufactured with fair performance.

In addition, a $0.2\,\mu$m thick Germanium plated anode prototype with the same active area is fabricated. The high surface resistivity is employed for sparking resistance [8]. Its performance is under testing in the laboratory.

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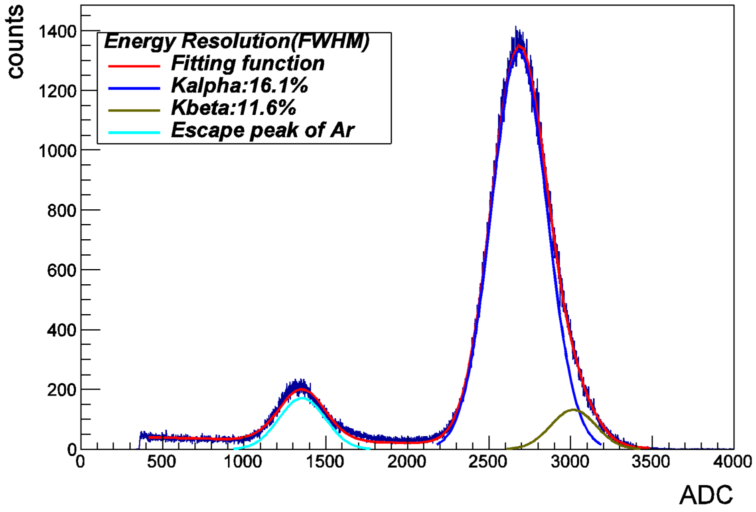

Figure 5. The typical 5.9 keV X-rays energy spectrum, where the fitting function is a triple Gaussion (for the Kα, Kβ and the escape peak of Argon) plus a linear background (for noise).

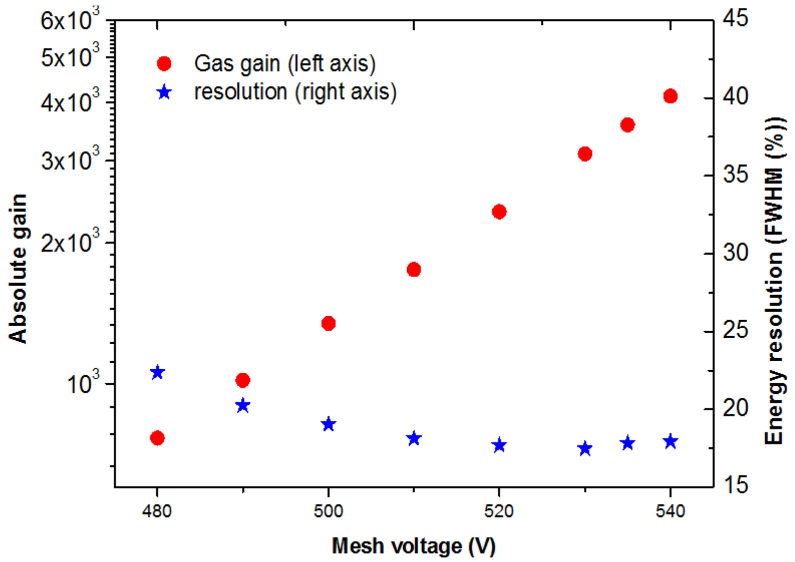

Figure 6. The gain and energy reslution as a function of the mesh voltage.

5 Conclusions

A thermal-bonding method has been developed to manufacture the Micromegas. Several small prototypes are studied to verify the stability and performance of this method. A telescope system composing of four 1mm-pitch chambers is tested with the TOT electronics. A $200 \times 200\,\mathrm{mm}^2$ prototype has been fabricated and tested. Good energy resolution and appropriate gas gain are obtained. Further studies like sparking protection and X-rays imaging are ongoing.

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