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Micromegas in a bulk

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Abstract

In this paper, we present a novel way to manufacture the bulk Micromegas detector. A simple process based on the Printed Circuit Board (PCB) technology is employed to produce the entire sensitive detector. Such a fabrication process could be extended to very large area detectors made by the industry. The low cost fabrication together with the robustness of the electrode materials will make it attractive for several applications ranging from particle physics and astrophysics to medicine.

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1. Introduction

The driving factor in the development of new gaseous detectors comes from the advent of new accelerators, especially the Large Hadron Collider (LHC). Novel devices, able to handle much higher rates than those of wire chambers and provide a superior position and time resolution are being designed, in order to meet the additional requirements specific to each accelerator condition. An important objective is the reduction of the material budget and the dead regions (for instance, due to mechanical frames). The decision to take a safer path, however, at a much-increased price and with several drawbacks, such as the large mass, was made for the LHC inner tracking detectors because, at that time, no gaseous detector could prove to be a totally safe solution. After 4 years of intense research, it has become clear that various gaseous detectors can now match the requirements for a central tracking detector, at a much lower cost than the solid state detectors, and with better characteristics in terms of time resolution and amount of material.

Among the new innovative detectors, the Micromegas [1] approach has now reached maturity and is successfully used by many experiments like COMPASS, NA48, CAST, n-TOF, and under study for the future Linear Collider [2–6]. The detector is also under development for low energy neutrino experiments (HELLAZ, NOSTOS) [7–8], including coherent neutrino scattering, neutrino magnetic moment measurements and dark matter searches.

The micropattern detector technology of Micromegas offers a substantial advantage in counting rate, energy, spatial and time resolution, granularity on large surface and simplicity [9–11]. The amplification gap of Micromegas is obtained by suspending a mesh over the surface of anode strips or pads. The precise gap, which is quite narrow, usually 50–150 μm, is obtained by using adequate insulating spacers (pillars) printed on top of the anode plane by conventional lithography of a photoresistive film. The mesh is stretched and glued on a frame and then rested on top of the pillars. The challenge to the technician is with the handling of the mesh to obtain a rather good flatness and parallelism between the anode and cathode (mesh); then,

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by applying a voltage on the two sides of the gap, the intense electric field pulls down the mesh, and the flatness is thus defined by the height of the pillars which has an accuracy of better than 10 μm.

One important factor in the delay of the adoption of the new gaseous detectors has been the fact that the technology to build them is not straightforward, and the spread in their use was very much influenced by the capacity of large laboratories like CERN or Saclay to help by providing good prototypes.

We present here a new method of producing large area Micromegas elements in one single process that will make the mounting of the detector a simple procedure. Moreover, the technology used is robust and the probability of damaging the detector during mounting and testing is very small.

2. Fabrication process

In order to obtain large area detectors and a more reliable structure, a decision was taken to use a woven wire mesh, instead of the usual electroformed micromesh, as has been suggested and used for a low-background TPC [12]. There are several advantages in using these quite conventional meshes:

1. they exist in rolls of $2\,\mathrm{m} \times 40\,\mathrm{m}$ and are quite inexpensive,
2. they are commonly produced by several companies around the world,
3. there are many metals available: Fe, Cu, Ti, Ni, Au,
4. they are quite robust to stretching and handling.

For our first prototype we have used a stainless-steel cloth mesh made by stainless-steel wires of 30 μm diameter interwoven at a pitch of 80 μm.

We adopted a simple technical solution to build the whole detector in one process—the anode plane (e.g. FR4) carrying the copper strips, a photoresistive film (e.g. Vacrel) having the right thickness and the cloth mesh, are laminated together, at a high temperature, forming a single object. The photoresistive material is subsequently etched by a photolithographic method, producing the pillars. The procedure is schematically described in Fig. 1 [13].

The pillars have a cylindrical shape of 300 μm diameter and are printed with a distance of 2 mm, as shown in Fig. 2. We have constructed two prototypes using this method, one having an amplification gap of 75 μm and the second of 150 μm, both with a square active area of $9 \times 9\,\mathrm{cm}^2$.

The constructed prototypes were tested by introducing them in a gas vessel and using the experimental set-up shown in Fig. 3. The set-up consisted of the bulk detector preceded by a 10 mm drift region defined by a simple drift electrode made also by a cloth grid. The gas filling was a mixture of argon (95%) and isobutane (5%).

The primary ionization charges were produced in the drift volume by photoelectron generated via an X-ray ^{55}Fe source. The charges were then transported through the electric field to the bulk element and amplified in the small amplification gap of the Micromegas detector. Fast signals were induced in both anode and cathode planes. We have used a low-noise charge preamplifier to read-out the cathode–mesh signal. As expected, the rise time of the signal due to the ions produced during the avalanche process was quite fast, 60 ns for the 75 μm gap, whereas 150 ns for the 150 μm gap.

The gain obtained was quite satisfactory for both amplification gaps, reaching a maximal value before break down of about 2×10^4. Fig. 4 shows the measured gain as a

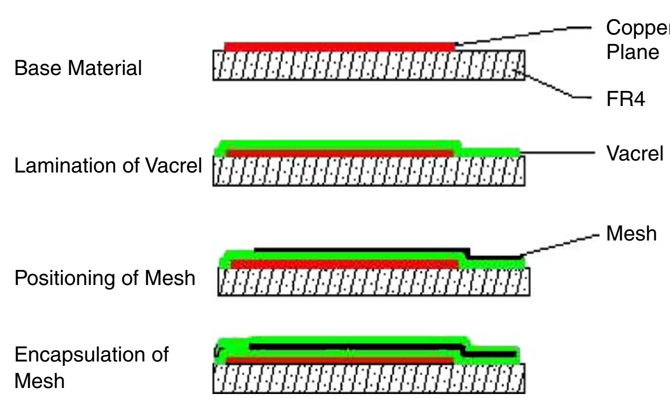

Fig. 1. Schematic of the fabrication procedure of the bulk Micromegas.

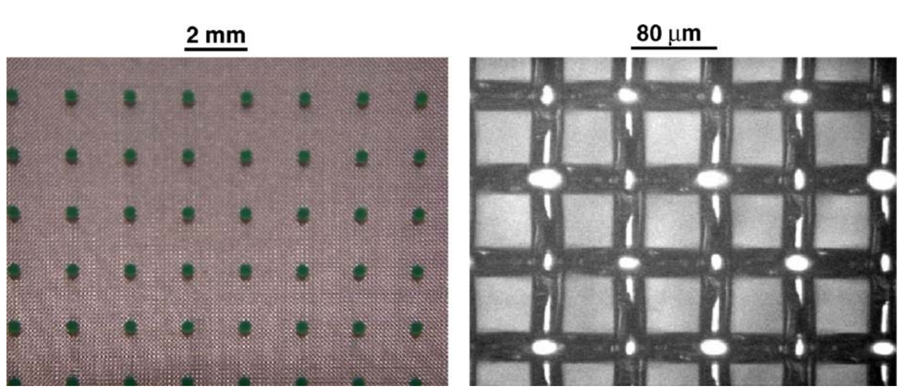

Fig. 2. Photographs of the bulk detector elements. The picture at left shows a small area of the detector; the 400 μm in diameter pillars every 2 mm are visible. On the right side is a microscopic view showing details of the woven wire mesh.

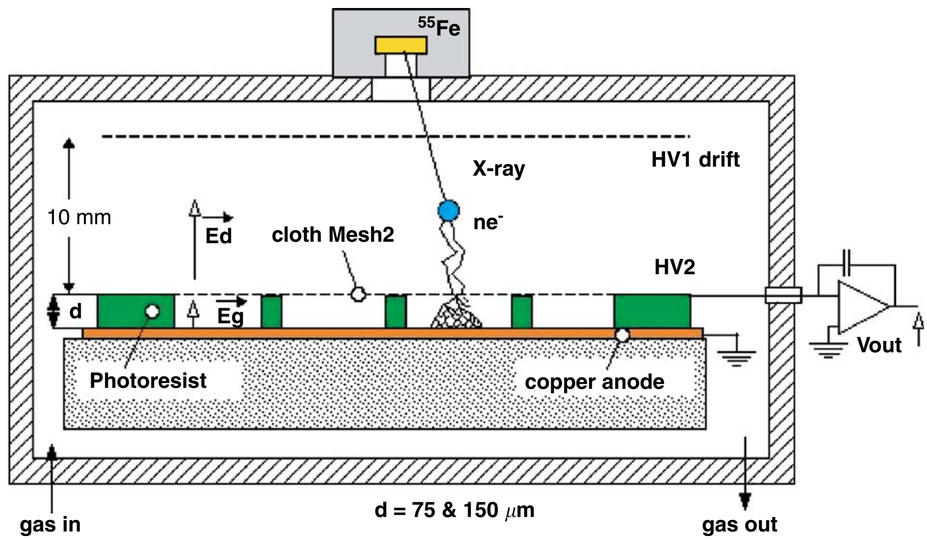

Fig. 3. Schematic drawing of the test chamber.

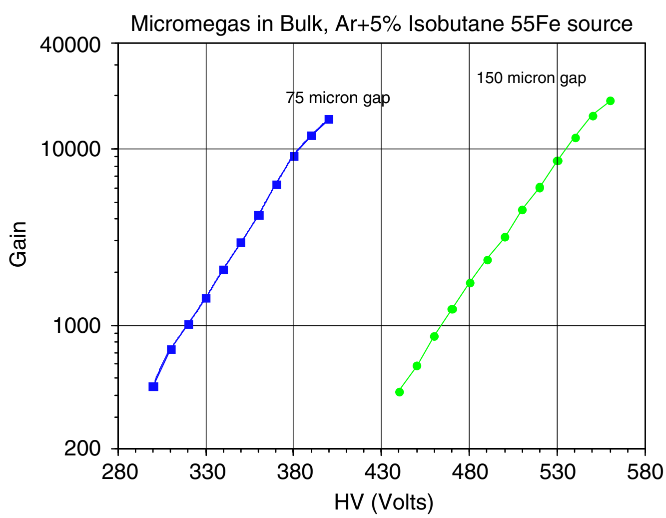

Fig. 4. Gain curves obtained by the two prototype detectors.

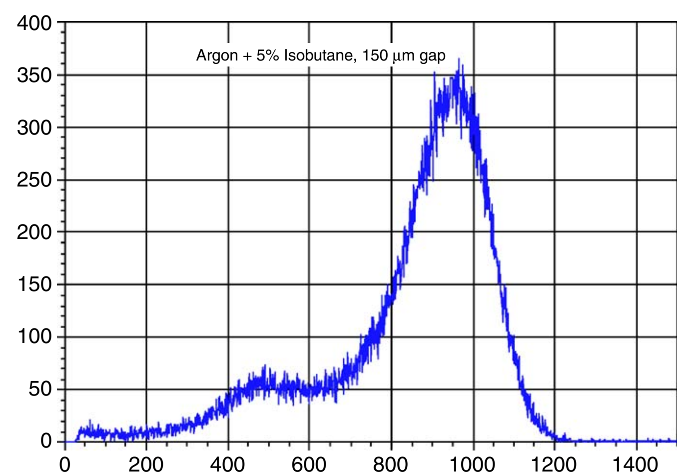

Fig. 5. Energy resolution of the 150 μm gap detector, measured with ^{55}Fe 5.9 keV X-rays.

function of the applied voltage for the two bulk detectors. Applied voltages are quite reasonable ranging from 300–400 and 400–500 V, respectively, for the 75 and 150 μm amplification gaps.

The energy resolution was measured by the pulse height distribution of the collected signal in the mesh, proportional to the deposited energy. As shown in Fig. 5, the energy resolution is quite reasonable, about 20% (FWHM) for the 5.9 keV deposited energy. To reach the better energy resolution of a conventional Micromegas equipped with a thin mesh, we would need to laminate a thinner cloth mesh thickness (smaller wires).

3. Future improvements and discussion

To benefit from this progress, we propose to perfect this technology for use in high rate particle physics experiments or in those that require large surface detectors. Thus, we aim with this project to focus on the following objectives:

- The use of a thinner and flatter mesh will bring a significant improvement. In order to obtain a smooth surface and a lower thickness, we will employ an industrial standard process that consists of passing the cloth mesh through a pair of heavy rolls to decrease the thickness and flatten the intersections. We expect an improvement of the energy resolution and an easier passage of the drifting electrons.
- Build large area (several m^2) by low-cost industrial process.
- Develop by the same technology double-stage amplification detectors that can be useful to cope with very-high intensity hadron beams or operation in high pressure xenon gas mixtures, as it is required in medical applications.

- Dividing the mesh in many sectors, by cutting it with diamond discs or laser beams, could improve the rate capability in hadron beams; the capacitance of each sector is highly reduced with an obvious benefit in case of a spark in the detector—the charge released in the spark is reduced (protection) and the dead time of the detector is roughly divided by the number of sectors.
- Apply the same procedure on a flexible anode board (for instance a thin Kapton). This will allow a further reduction of the material budget of the detector and open the way for a curved Micromegas.
- In the present study, we adopted a conservative choice for the diameter and the pitch of the spacers. We will push the technology as much as possible to obtain larger pitch and smaller diameter of the pillars in order to reduce the detector dead space to a negligible level.

The improvement of the Micromegas technology permits its consideration on an equal basis with the detector technologies used so far for the main interaction region. The recommended approach for the selection of the proper detector usually includes the realistic estimation of the cost, the evaluation of the difficulty of construction and in the implementation of the operational requirements, and the realization of the physical characteristics required. The selection sometimes depends on the type of experiment one wishes to undertake, where the various approaches to micropattern gaseous detectors may present specific advantages. But, it seems reasonable for us to argue that the simplicity of the construction, the low material budget and cost, together with the excellent spatial and time accuracy of the Micromegas, will make their use necessary in applications where solid-state detectors have been previously used.

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