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Recent GridPix results: An integrated Micromegas grid and an ageing test of a Micromegas chamber

H. van der Graaf*, A.A. Aarts, M. Chefdeville, S. van der Putten

NIKHEF, Amsterdam, The Netherlands

Abstract

We have constructed a new gas-filled detector in which we combine a Micromegas with a CMOS pixel chip. In a next step, a procedure to construct a Micromegas-like grid onto a Si wafer, using chip production technology ('wafer post processing'), has been developed. An ageing test of a Micromegas chamber has been carried out. After verifying the chamber's proportionality at a very high dose rate of X-rays, we irradiated the device until ageing became apparent.

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Keywords: Ageing; Micromegas; InGrid; Integrated grid; Wafer post-processing; SU-8

1. Introduction: the GridPix chamber

Recently we have combined a Micromegas grid with the Medipix 2 pixel CMOS chip [1–3]. In a small drift volume of $14 \times 14 \times 14\,\mathrm{mm}^3$, primary electrons from cosmic muon tracks drift towards the grid. After passing a grid hole, they enter the 50 μm wide gap between the Micromegas, put at a potential of around −400 V and the pixel (anode) chip, put at ground potential (see Fig. 1). Due to the strong electric field, the electron will initialize an electron avalanche, and the resulting charge signal can activate the preamp–shaper–discriminator circuitry in the pixel beneath the hole. We have recorded track images from minimum ionizing cosmic muons (see Fig. 2); from this data we could derive that the efficiency for detecting single electrons was better than 90% [1].

This 'GridPix' readout can be applied in gas-filled detectors in general, but the application in TPCs, in μ-TPCs and in TRDs may boost their performance since individual 3D information of all primary electrons becomes available.

With a drift gap of only 1 mm, the GridPix detector can be applied as vertex detector in environments of intense radiation (Gas On Slimmed SI Pixels: GOSSIP). Whereas in Si vertex detectors the signal is generated by means of electron–hole pairs in the depletion layer, in GOSSIP electron–ion pairs are created in the drift volume: a single electron is sufficient for track detection. In Si, the signal is amplified by low noise amplifiers, while in GOSSIP the signal is amplified in the avalanche gap. Since the input pads of the pixels can be rather small, the source capacity at the preamp input can be as small as 20 fF. Given the pulse height distribution, the fast signal development [1], and a gas gain of 1 k, the parameters of the low-noise amplifiers in the GOSSIP pixel chip can be chosen such that the power can be as low as 1 μW per pixel, using the gas flow as cooling. The standard CMOS pixel chip can be thinned to 30 μm, reducing the detector's mass to a minimum. This thin Si appears as a foil, and opens a new window on ultra-light detector construction. Furthermore, in GOSSIP, there is no bias current.

2. InGrid

By means of 'wafer post processing' we constructed a Micromegas-like grid onto a Si wafer [4]. With this technology, a CMOS pixel chip can be combined with a grid, forming an integrated readout device of a gas volume

*Corresponding author. Tel.: +31 615012328; fax: +31 205925092.
E-mail address: vdgraaf@nikhef.nl (H. van der Graaf).

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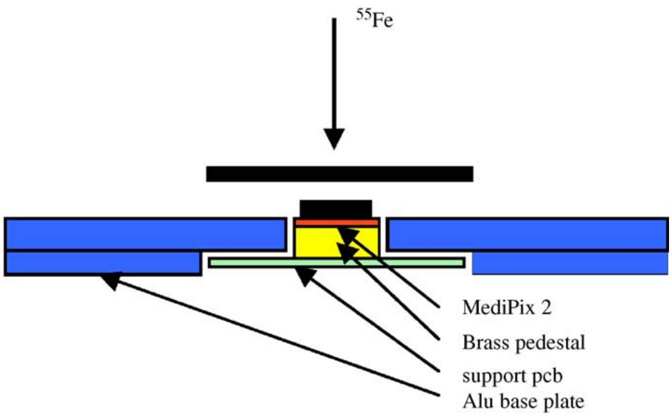

Fig. 1. The Micromegas chamber with its gas cover and cathode removed. The Micromegas foil is fixed onto a frame which is pressed down onto the Medipix 2 chip.

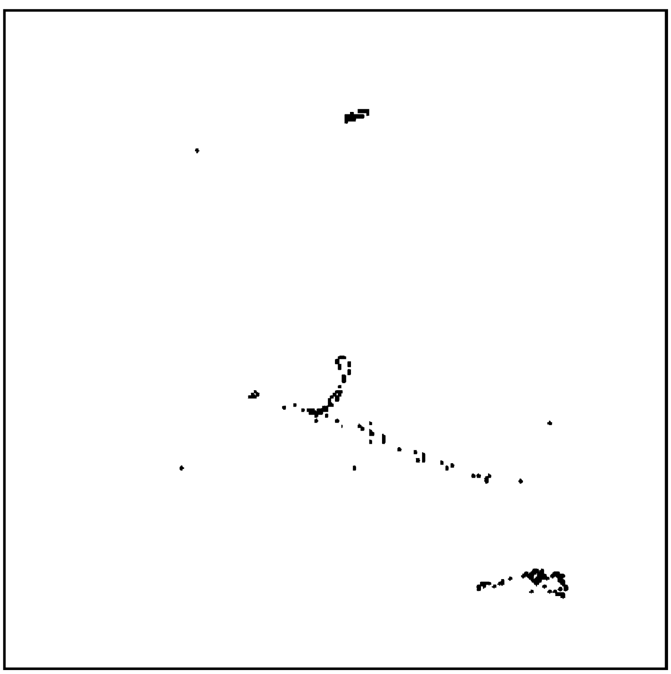

Fig. 2. Image of a muon track; active area: $14 \times 14\,\text{mm}^2$. A δ-ray is clearly visible.

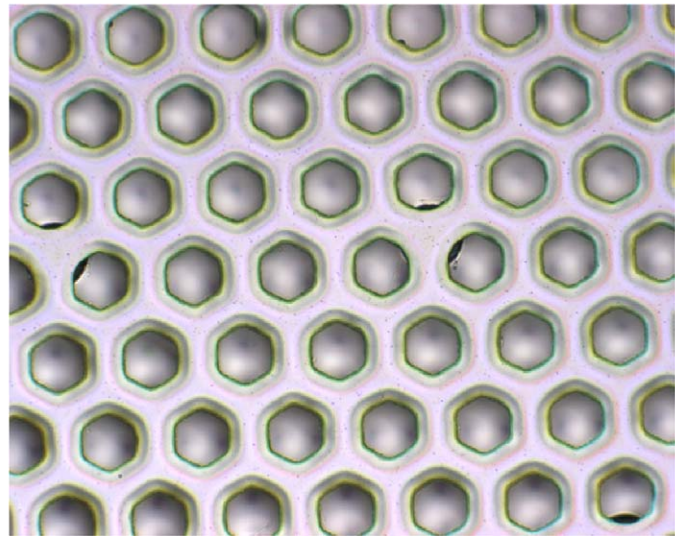

Fig. 3. Top view of InGrid. Note the insulating pillars (SU-8 epoxy) centred between the grid holes.

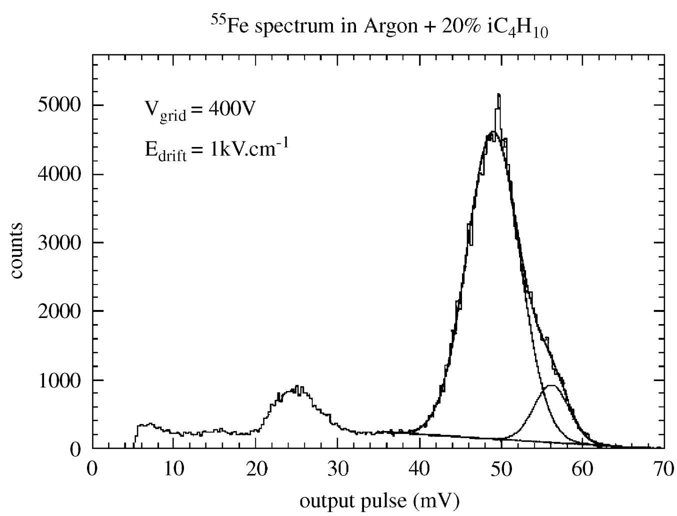

Fig. 4. The pulse height distribution of ^{55}Fe photons. Note the non-symmetrical photo peak due to the 6.49 keV photons.

(InGrid). The sub-μm precision of the grid dimensions and avalanche gap size results in a uniform gas gain. The diameter of the insulating pillars between the Si wafer (anode) and the grid can be as small as 30 μm: they can, therefore, be positioned between the grid holes, thus avoiding dead regions (see Fig. 3).

On a 4″ wafer, 19 fields were designed with different geometry: the grid hole pattern (square and hexagonal), the hole pitch and the hole shape (square, round and hexagonal) were varied. As grid support, pillars (with several diameters and pitches), as well as 'dykes', were made from SU-8 epoxy. In the latter, each grid hole has its own gas-filled cell.

We tested the InGrid wafer in a small chamber in which a drift volume was formed by placing a cathode foil 10 mm above the wafer.

We connected a low-noise charge sensitive preamplifier [5] with an integrating time constant of 1 μs to the grid. The charge signal from the grid is completed within 50 ns, and the preamp output signal is therefore precisely proportional to the charge signal from the grid [1].

In Fig. 4, the energy resolution of the InGrid field of Fig. 3 is shown. The non-symmetry of the photo peak of ^{55}Fe photons is clearly visible. The source emits X-ray quanta of 5.90 and 6.49 keV with a ratio of 9:1. Due to differences in absorption, we left this ratio free in the fit to the pulse height spectrum. The width (RMS) of the

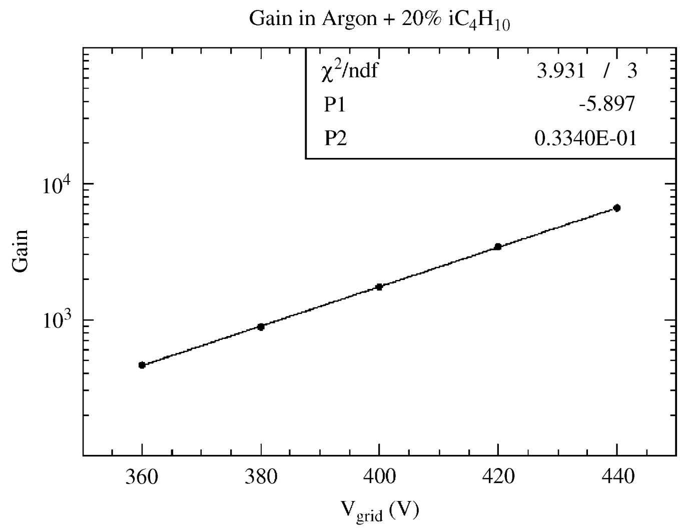

Fig. 5. The gas gain as a function of the grid potential.

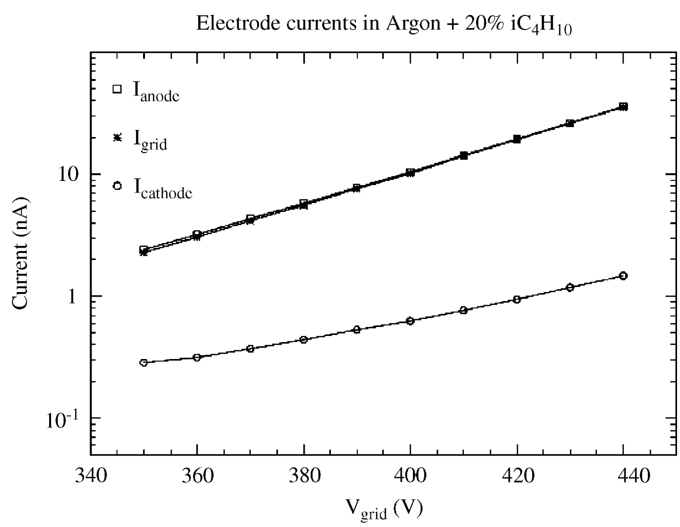

Fig. 6. The current through anode, grid and cathode for a fixed irradiation rate with ^{55}Fe photons.

5.90 keV peak was $\sigma = 6.5\%$. We found similar results from the InGrid field with a 'dyke' geometry.

We have calibrated the gas gain carefully by injecting precisely known charge pulses into the grid. In Fig. 5 the gas gain versus the grid potential is shown for a mixture Ar/Isobutane 80/20. The precise exponential relation is expected given the precision in InGrids geometry. In Fig. 6 the anode, grid and cathode currents are shown: the small fraction of ions entering back into the drift volume is compatible with previous measurements [6].

3. Ageing test

In the most common ageing effect, deposits are formed on the chamber electrodes. Assuming that this effect is proportional to the integrated charge density, GOSSIP should withstand a large irradiation dose due to its large ratio of the anode surface and gas volume, and due to the low gain (~1 k). In a first test, the ageing of a Micromegas chamber was measured using a 90/10 Ar/Methane mixture. The chamber was built from standard materials, including Kapton tape, G10, Viton O-rings, PVC insulated wires, and epoxy (Araldite).

The Micromegas grid, mounted in a frame, was placed onto a polished aluminium anode block. By means of a carefully calibrated charge preamplifier the charge signals from the grid could be measured, and the currents through the anode, the grid and the cathode could be registered by measuring the voltage drop over serial resistors. With this set-up, irradiated with photons from an ^{55}Fe source, we certified the absolute relation between the gas gain, current and counting rate, and dark currents were below the level of 0.1 nA

We then irradiated the chamber with 8 keV X-ray quanta from a Cu target, which, in its turn, was irradiated with photons from an X-ray tube. We varied the current through the tube and found that the chamber current changed proportionally up to a current density of 0.5 μA/mm^2 (reached with the maximum power of the X-ray tube, combined with a gas gain of 11 k). We then covered half of the grid surface with Pb, shielding this part of the detector from irradiation.

During a period of two months, we noticed a slow but regular decrease of the anode current. After collecting 0.3 C/mm^2 at the irradiated area of the anode block, we re-calibrated the chamber: no change in the ^{55}Fe pulse height spectrum was observed at the non-irradiated region of the anode. At the irradiated area, the gain was reduced by a factor ~4. A clean white deposit containing Si, C and O was found on the anode. The Micromegas was clean, while the cathode foil showed a deposit containing similar elements as the anode [7].

4. Conclusions and future plans

With a GridPix chamber, diffusion of primary electrons may become the only limit to their spatial resolution. This may determine the maximum drift length.

With InGrid, integrated readout chips can be made. The good energy resolution suggests the study of InGrids with a smaller multiplication gap, resulting in faster charge signals with a smaller spread in single electron response. The gain, required for a sufficient single electron efficiency of GOSSIP, may be further reduced, being beneficial against ageing and good for the stability of the chamber under HV. A first ageing test indicated that the processes in Micromegas chambers and wire chambers are similar.

Acknowledgments

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