Nuclear Instruments and Methods in Physics Research A 362 (1995) 273–276

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

A large area, high gain Micro Gap Chamber

F. Angelini [a], R. Bellazzini [a,*], M. Bozzo [b], A. Brez [a], M.M. Massai [a], R. Raffo [a], G. Spandre [a], M. Spezziga [a], A. Toropin [a,c]

[a] *INFN-Pisa and University of Pisa, Pisa, Italy*
[b] *INFN-Genova and University of Genova, Genova, Italy*
[c] *INR-Academy of Sciences, Moscow, Russian Federation*

Received 20 January 1995

Abstract

A new approach to the construction of the Micro Gap Chamber is presented. A 10×10 cm^2 MGC has been built using a 8 μm thick polyimide layer as anode–cathode insulator. Studies on gas gain, uniformity of response along the strip and charging-up have been carried out in laboratory by using X-ray sources. Very large proportional gains, up to $\sim 210^4$, have been reached working with gas mixtures based on Ne–DME. The simplified technology for the detector fabrication opens the possibility to produce very large area MGCs.

1. The detector

The Micro Gap Chamber [1] fulfills almost all the stringent requirements of the tracking system of the next generation of experiments (CMS, ATLAS, HERA-B) which are being designed for the new high-energy, high luminosity accelerators like LHC and HERA [2–4]. It has good space and time resolution, high rate capability, 2D capability and considerable flexibility.

Being an almost full metal device, charging or other substrate effects are not a problem anymore [5–7]. On the contrary, the extrapolation of the detector design to large sizes (10 cm × 10 cm and more) is still an open problem. The possibility to manufacture very large area MGC is limited by the currently available 6 in. wafer technology at the silicon processing foundries. To overcome this limitation we have investigated a new and simpler way to produce large area MGCs.

First prototypes of a 10×10 cm^2 MGC have been fabricated [1] using 8 μm thick polyimide film as anode–cathode insulator. Because almost no insulating material is left exposed into the gas there is no need of applying any special treatment to the dielectric to reduce its electrical resistivity and to avoid charging. A schematic cross section of the detector is shown in Fig. 1.

The manufacturing process starts with the evaporation of 1 μm thick aluminum layer (metal 1) on a standard window-glass substrate of 1.5 mm thickness. Many other materials can be used as substrate such as silicon, sapphire, or even plastics or fiber-glass [8], with thickness down to 200–300 μm. Metal 1 can be suitably patterned if a 2D device is requested.

The second processing step is the deposition, by spinning, of a thin layer of a liquid, photosensitive, polyimide (Probyimide 10000 by Ciba-Geigy, Basel, Switzerland). The polyimide is firstly soft baked at 180°C, then photolithographically patterned (by washing in a bath of acetone) and finally hardened at high temperature ($\sim$ 600°C). The polyimide pattern consisting of 17 μm wide, 8 μm thick, strips at 200 μm pitch, is shown in Fig. 1. A second aluminum layer (metal 2) is then evaporated on top of it and patterned with a lift-off technique to get anode strips, 9 μm wide. Figs. 2a and 2b show microphotographs of

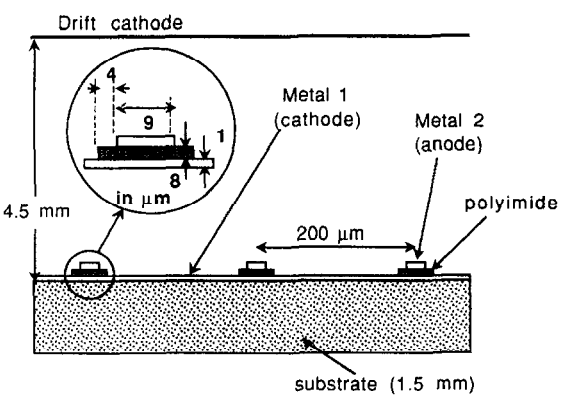

Fig. 1. A schematic cross section of the detector.

* Corresponding author. Tel. +39 50 880 271; fax +39 50 880 317; e-mail:bellazini@pisa.infn.it.

[1] By IMT (previously BAUMER IMT) Zurich, Switzerland.

0168-9002/95/$09.50 © 1995 Elsevier Science B.V. All rights reserved
SSDI 0168-9002(95)00194-8

both ends of the strips at two different stages of processing: the polyimide pattern over metal 1 and the subsequent superimposed pattern of anode strips. At both ends of the anode–cathode structure is visible also a second layer of polyimide used to passivate the detector edges to avoid sparking effects (Fig. 2b).

The thickness of the insulator (8 μm) is greater than in our previous design [5] where a 5 μm thick silicon oxide was used. The thicker dielectric layer further reduces the anode–cathode capacitance (< 0.5 pF/cm), increases the gas amplification volume and eventually the gain, and provides more dielectric strength. The technology we adopted is quite simple. It implies neither deposition and etching of silicon oxides nor ion implantation and therefore it is accessible to many companies outside the silicon processing world.

2. Laboratory tests

The detector was tested in laboratory by using a high intensity ^{55}Fe radioactive source and a 5.4 keV Cr X-ray source. Fig. 3 shows a typical signal from the sum of two anode strips obtained when illuminating the detector with an extended ^{55}Fe source ($V_{\text{cathode}} = -370$ V, $V_{\text{drift}} = -3400$ V). The gas mixture was Ar–DME (50–50).

Fig. 4 shows the short term measurement of the gain stability when the detector was irradiated with 5.4 keV X-rays at a rate of 5×10^5 photons/mm^2 s. The drift field was ~ 0.7 kV/mm. The anode–cathode potential difference was 360 V.

As it results from Fig. 4 gain variations in the first seconds of exposure are negligible.

The uniformity of gain along the strip has been mea-

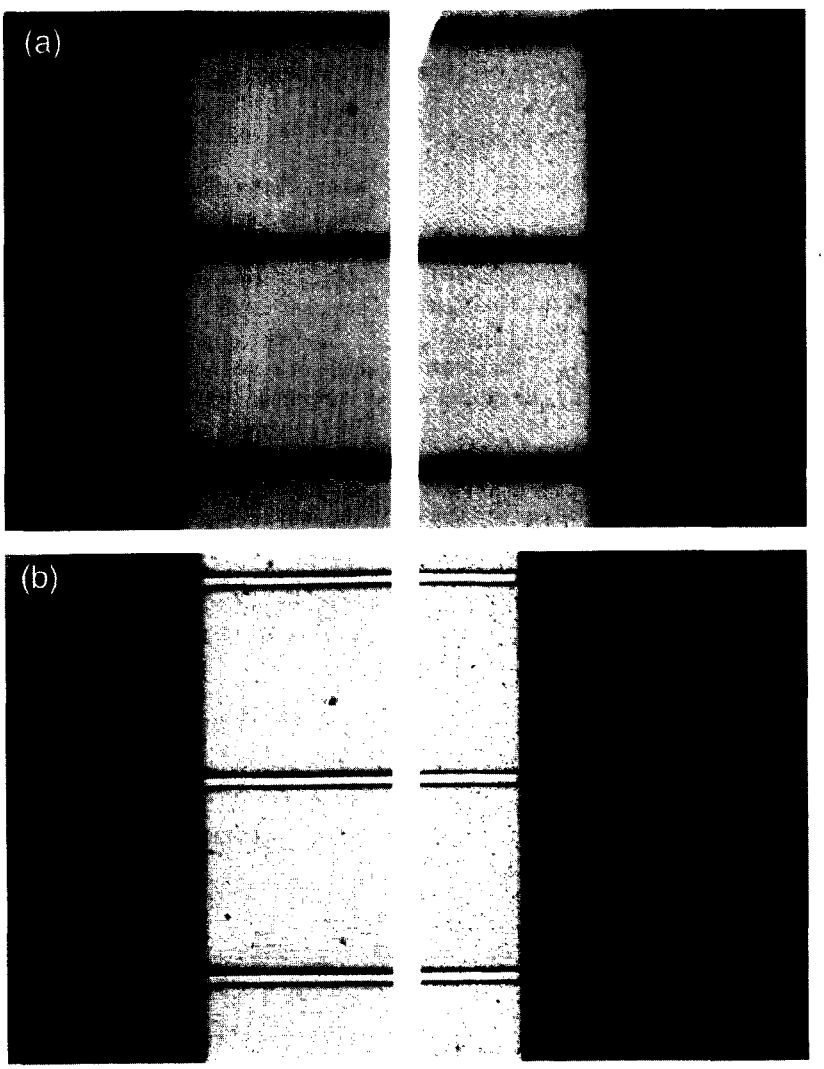

Fig. 2. Micro-photographs of both ends of the strips at two different stages of processing (a) the polyimide pattern over metal 1, (b) the subsequent superimposed pattern of anode strips.

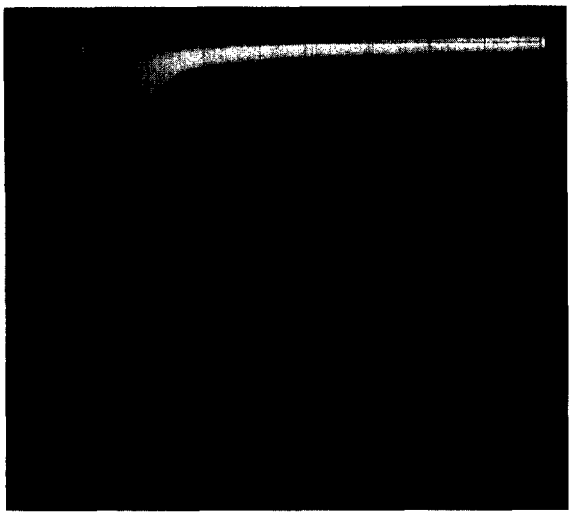

Fig. 3. The signal from the OR of two anode strips when the detector is illuminated with a ^{55}Fe source ($V_{cathode} = -370$ V, $V_{drift} = -3400$ V).

sured by using a ^{55}Fe source. A variation of less than 5% has been measured (Fig. 5).

The dependence of the gain on the anode–cathode voltage has been studied by using a ^{55}Fe source. For this measurement the OR of four anode strips was sent to the pulse-height analyser.

In Fig. 6 the position of the photopeak is plotted as a function of the anode–cathode voltage for two different gas mixtures: Ar–DME (70/30) and Ne–DME (70/30).

As Fig. 6 shows the mixture with neon allows to work at higher voltages w.r.t. the mixture with argon and consequently to reach much higher gains. The maximum of 480 V reached with Ne–DME corresponds to a gain of ~ 19000. This large gain is a property of the gas mixture itself more than the specific MGC design. Indeed we have obtained similar or even greater gains (up to 2.7×10^4) working with MGCs of the previous generation with 5 μm

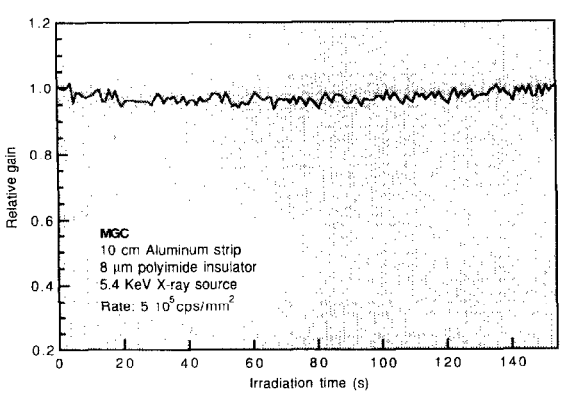

Fig. 4. Short term measurement of gain stability.

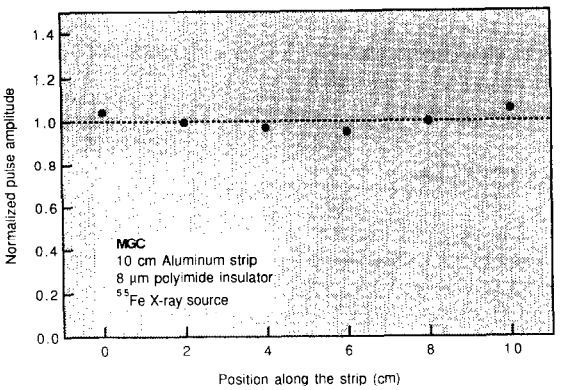

Fig. 5. Uniformity of response along the 10 cm strip.

oxide thickness insulator. This behaviour can be explained if we consider that the ionization and excitation potentials of neon, 21.5 and 16.6 eV respectively, are much higher than the ionization and excitation potentials of argon (15.7 and 11.6 eV respectively) and the ionization potential of DME (10 eV). Being more difficult to excite, neon (and helium as well) produces much less UV light than heavy noble gases as argon or xenon. Feedback from UV photons is therefore strongly depressed in mixtures based on light noble gases. Furthermore, the large gap between the ionization potential of DME and the ionization and excitation potentials of neon favours the channelling of the energy transferred from the electric field to the electrons, as kinetic energy, into ionization of the DME molecules more than into ionization or excitation of neon.

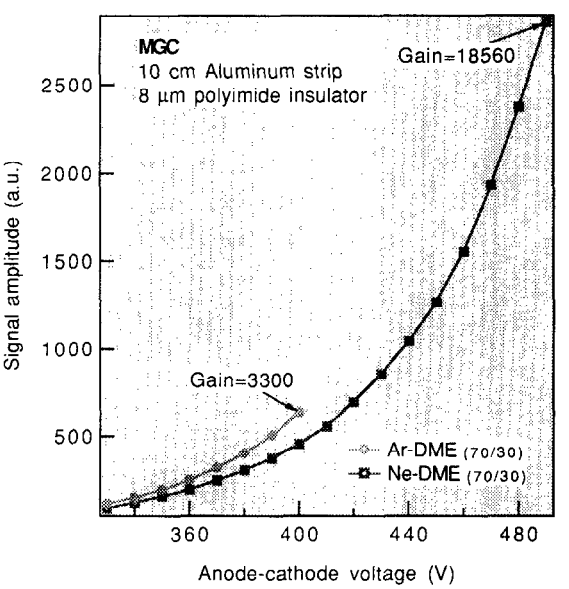

Fig. 6. Pulse height as a function of the anode–cathode voltage. Gas mixtures: Ar–DME (70/30), Ne–DME (70/30).

Obviously, the possibility to get large gains even when working at lower voltages implies a further safety factor in the operation of this device.

3. Conclusions

The approach to the construction of the Micro Gap Chamber described in this paper, is simply a proof of principle of the possibility to manufacture such device with very large areas.

The main limitation of the present design comes from the choice of patterning the polyimide before the deposition and patterning of metal 2 (the anode strips). This makes rather difficult, and nonuniform, the etching of metal 2 which sits on top of the thin dielectric strips. Better results will be obtained with our next prototype where the polyimide patterning will be made after the metal 2 etching, as last step of the processing. For this purpose we will use the self-aligned technique, already described in a previous paper [5], and ion-beam or plasma etching of the polyimide.

The other important result is the demonstration of the possibility of reaching very high gain, well in excess of 10^4, by using gas mixtures based on Ne–DME (or He–DME). It opens real perspectives to the utilization of MGC in so demanding applications as the tracking system at LHC and HERA.

Acknowledgements

We thank G. Decarolis, M. Favati, C. Magazzu' of INFN-Pisa and A. Morelli of INFN-Genova for their enthusiastic technical support.

References

[1] F. Angelini et al., Nucl. Instr. and Meth. A 335 (1993) 69.
[2] CMS Collaboration, Technical Proposal, CERN/LHCC 94-38 LHCC/P1, December 1994.
[3] ATLAS Collaboration, Technical Proposal, CERN/LHCC 94-43 LHCC/P2, December 1994.
[4] HERA-B, Proposal, DESY-PRC 94/02, May 1994.
[5] F. Angelini et al., Nucl. Instr. and Meth. A 349 (1994) 412.
[6] W.G. Gong et al., LBL - 35779, July 1994.
[7] J. van der Marel et al., paper presented at the Int. Workshop on MicroStrip Gas Chamber, Legnaro, Italy (1994).
[8] J. Moromisato, paper presented at the Int. Workshop on MicroStrip Gas Chamber, Legnaro, Italy (1994).