

# An aging study of industrially produced micro-patterned gas detectors.

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**Abstract**—Micropatterned gas detectors like GEMs and MICROMEAS are being considered for time projection chambers (TPC) for linear collider experiments. These devices are made mainly of Kapton insulators and thick copper layers. Because in the micropatterned gas detectors a dense plasma of avalanche electrons and ions are created in a small volume, aging due to polymerization is a concern. A shot-term aging study on a single GEM foil produced by 3M using reel-to-reel flex circuit technology is reported.

## I. INTRODUCTION

Micropatterned gas detectors such as GEMs (Gas Electron Multiplier) and MICROMEAS (Micromesh gas detector) are playing important roles in the COMPASS experiment [1-2]. Recently these devices became candidates for charge readout in time projection chambers (TPC) to suppress ion-feedback and they are expected to perform better than wire chambers in terms of rate capability and position resolution. The position resolution is expected to be excellent due to the absence of the  $E \times B$  effect [3].

Recently, GEMs have been mass produced by 3M (ref 4). It is important to determine if the properties of 3M GEMs are similar to CERN made GEMs which are the “gold standard” in the field. In this article, the radiation hardness of a 3M GEM is studied for the first time.

Most micro-patterned gas detectors are made of chemically stable materials (mainly Kapton and copper and some seed materials for copper adhesion), and therefore chemical interaction with gases like DME or CO<sub>2</sub> in the absence of radiation is not a serious concern. However, once they are exposed to intense radiation and operated in high gas gain for extended periods of time, the small amplification regions are subject to gradual minor aging. In our previous aging study of double GEM in Ar-CO<sub>2</sub> gas, a slight gain drop was observed and GEM holes in the irradiated areas are deformed, probably

due to the loss of copper and Kapton [5]. The irradiated area is shown in fig 1. The discoloration may be due to an accumulation of hydrocarbons created by polymerization of impurities in the gas. The high electric field at the edge of GEM holes where the copper and Kapton meet tends to induce frequent micro discharge that could slowly damage the metal and the insulator. If the rate of the aging progress is slow, visible changes (e.g. gain drop) are seen only after a large dose is accumulated. In the aging study of double GEMs, in order to accumulate a sufficiently large charge per unit area ( $\text{mC}/\text{mm}^2$ ), it was necessary to irradiate a very small area of the GEM using a collimated beam (a few  $\text{mm}^2$  size) continuously with an intense X-ray source. This extreme condition may not be a realistic case in an experiment where more or less the total surface is irradiated and our study may be overestimating the severity of aging. In the present study, short-term aging was performed to check the reliability of mass produced GEMs. In this study, a large area of the GEM was irradiated.

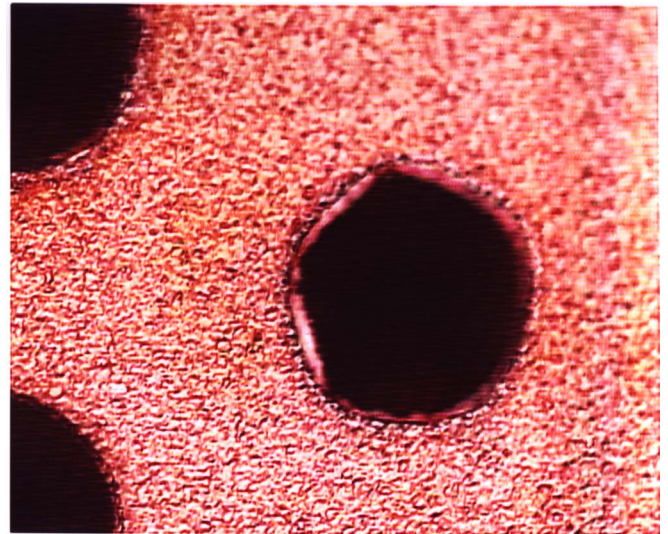


Fig. 1. Heavily irradiated area in a double GEM study after a total of  $25 \text{ mC}/\text{mm}^2$  of charge was accumulated. The shape of the GEM hole is clearly deformed and discolored, probably due to deposit of hydrocarbon, is visible (ref 5)

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## II. AGING STUDY SETUP

The experimental arrangement is shown in fig 2. A circular GEM of 2.5 cm diameter active area made using 3M's subtractive process is used. The drift gap is 1 cm and there was no electron collection board placed below the GEM. The charge accumulated was calculated by measuring the current from the GEM cathode (ion current). In order to minimize the ion current going to the drift electrode, a weak drift field (100V/cm) is applied. Thus the ion current measured in the GEM cathode is a good measure of the charge accumulated by the GEM. The GEM anode electrode was biased positively with respect to the GEM cathode and pulse height spectra were taken off the anode. The X-ray beam was aligned so that it is parallel to the GEM surface and positioned midway between the drift and GEM surface. In this arrangement, most primary ionization is produced in the drift gap. This beam setting however makes the irradiated area quite large (about 16 mm<sup>2</sup>) and it takes therefore a long time to reach a large amount of charge per mm<sup>2</sup>.

An Ar:DME=9:1 gas mixture was chosen for this study because it gives a very large gas gain at low GEM bias. Both gases are the purest available commercially but the DME is not as clean as for example CO<sub>2</sub>. Some CERN made GEMs are also believed to chemically react with DME but for the present short-term aging study, the choice of gas is likely to be significant. The 3M GEMs have not shown any degradation due to the chemical reaction with DME so far.

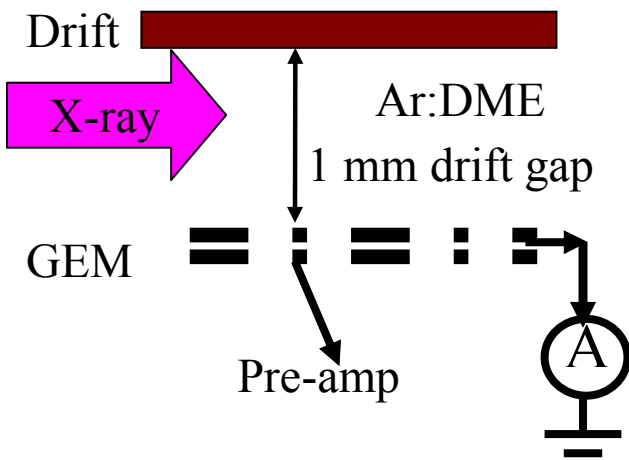


Fig. 2. A single GEM aging setup. The GEM anode is connected to an Ortec 142 PC preamplifier and the cathode is connected to a picoammeter. There is no electron collector below the GEM and consequently all electrons are collected by the GEM anode.

## III. AGING RESULT

The gas gain as a function of voltage across the GEM in an Ar-DME (9:1) gas mixture and a weak drift field (100 V/cm) is shown in fig 3. The x-ray flux was adjusted so that the single GEM detector would not be operated above its rate limit. This limit was checked by increasing the X-ray beam current as a function of monitoring the drift and GEM cathode current. The dependence of the measured current on the x-ray beam current is plotted in fig 4. Up to 10 mA, the detector current response is linear with the X-ray beam current. The X-ray current was chosen to be 4 mA during the aging run and reduced to 2mA for a short time to take pulse height spectra. In addition to the current reduction, an absorber was inserted in the beam to further reduce the x-ray flux while spectra were accumulated. In this way one can minimize the pile-up effect in the shaping amplifier that could worsen the energy resolution.

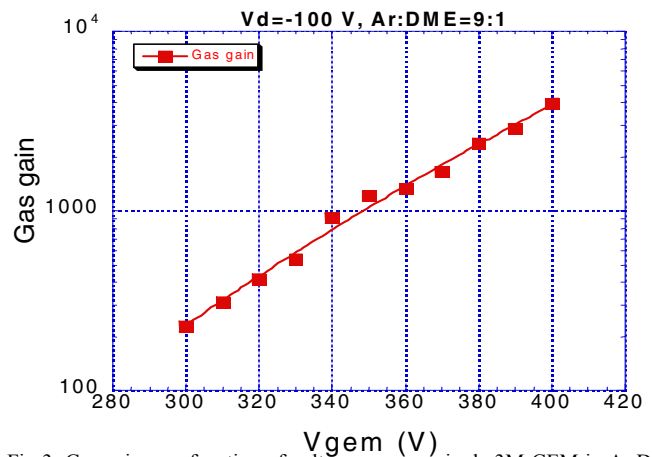


Fig 3. Gas gain as a function of voltage across a single 3M GEM in Ar:DME (9:1) gas mixture. The drift field is 100 V/cm and electrons were collected by the GEM lower (anode) electrode.

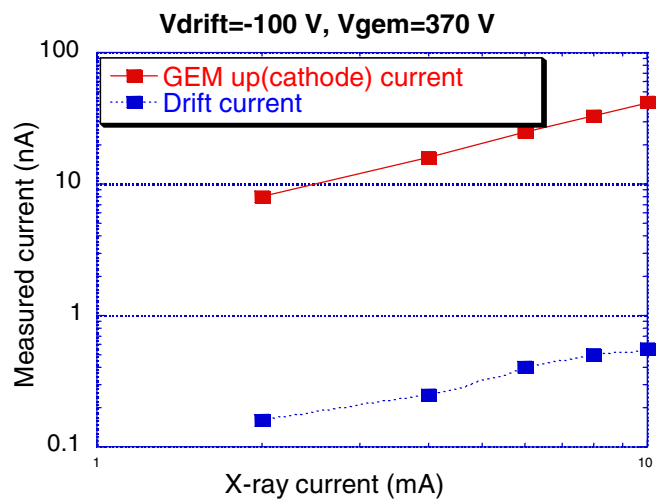


Fig. 4. The dependence of the GEM cathode and drift current (nA) as a function of X-ray beam current (mA).

The single GEM was continuously irradiated at a charge density of  $1 \text{ nA/mm}^2$  for about 100 hours. The dependence of the gas gain determined from pulse height spectra for both a single wire monitor chamber and the GEM as a function of accumulated charge is shown in fig 5. Responses from both detectors are very similar indicating that the GEM detector did not age. The initial sharp drop may be related to charge up in the Kapton. The gain increase at the later stage of the aging run comes from a rise in atmospheric pressure in the room. The measured atmospheric pressure and GEM pulse height are plotted in fig 6. The GEM pulse height and the atmospheric pressure are anti correlated as expected.

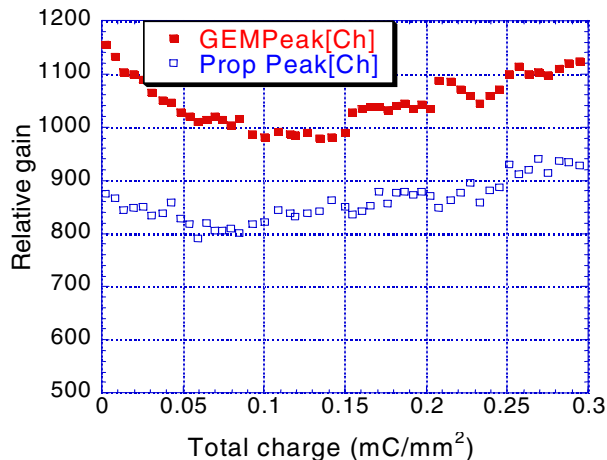


Fig. 5 Relative gas gain measured by pulse height of a single wire chamber and GEM detector as a function of the total accumulated charge per unit area.

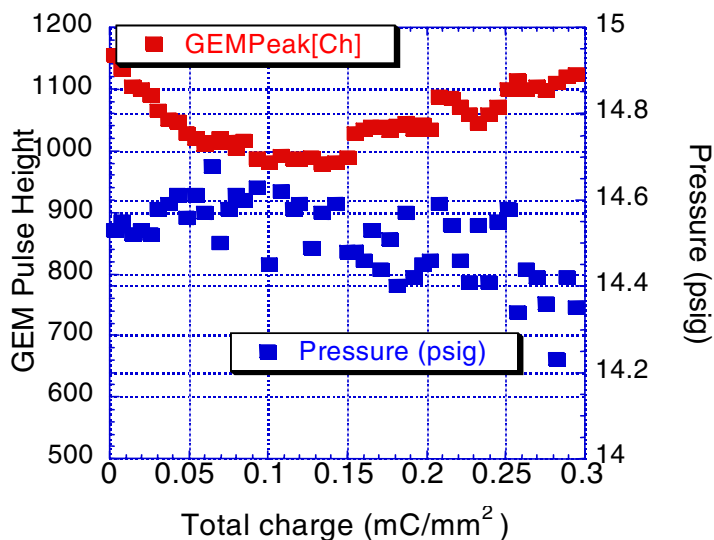


Fig. 6 Pulse height of the GEM detector and atmospheric pressure as a function of the total accumulated charge per unit area.

The dependence of the energy resolution was measured on the accumulated charge is shown in fig 7. The energy resolution remained constant throughout the aging run and this is another indication that the GEM detector did not age at this level of charge accumulation.

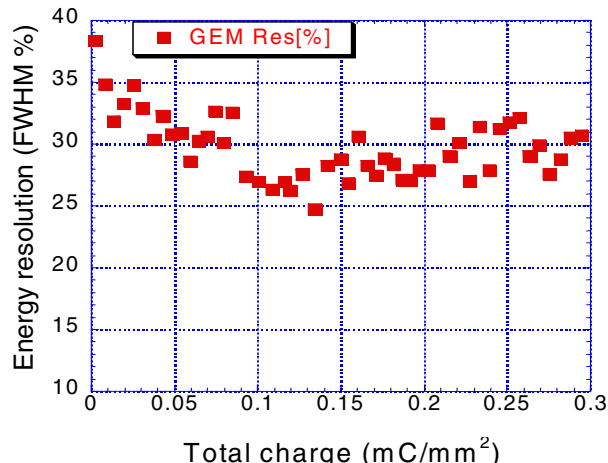


Fig. 7 Energy resolution of the GEM detector as a function of the total accumulated charge per unit area.

#### IV. SUMMARY

A short-term (100 hours) aging test was performed with a single mass produced GEM detector in an Ar:DME gas mixture and about  $0.3 \text{ mC/mm}^2$  was accumulated. The irradiation was achieved with an X-ray beam parallel to the GEM surface to ensure that a large area of the GEM was irradiated. Both pulse height and energy resolution remained fairly constant throughout the aging experiment. The GEM detector showed an initial sharp drop in gain and this may be related to a charge up effect on the Kapton insulator. The rise in pulse height in the latter stage of the experiment is due to a drop in the atmospheric pressure and the GEM detector responded to the pressure as predicted. The absence of aging is encouraging, however it is necessary to do longer-term aging study to test the radiation hardness of a 3M GEM and we plan to do this with a more intense X-ray beam.

#### V. REFERENCES

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