An aging study of a MICROMEGAS with GEM preamplification

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Abstract

We have conducted the first study of the aging behavior of a MICROMEGAS detector with GEM preamplification. Because a MICROMEGAS is constructed with minimal insulation and because the electric field is parallel to the amplification gap, superior radiation hardness was previously reported in an Ar-Isobutane gas mixture in a stand-alone device. The MICROMEGAS is expected to tolerate an even larger accumulated charge in a cleaner gas mixture, such as Ar-CO_2. However, using a MICROMEGAS as a stand-alone device in this mixture could increase discharge probability and lead to faster degradation in detector performance. We show that this problem can be circumvented by employing GEM preamplification. Although it has been previously shown that a GEM ages when operated at a large gain, sharing the gain between a MICROMEGAS and the GEM creates a high-gain, very radiation-hard gas detector. We find that a MICROMEGAS + GEM combination exhibits no deterioration in performance after a total charge accumulation of 23 mC/mm^2.

Keywords: Type your keywords here, separated by semicolons ; MICROMEGAS; GEM; aging

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1. Introduction

A MICROMEGAS detector is a robust micropatterned gaseous detector with minimal insulator between the anode and the cathode [1]. The detector is being used by the COMPASS experiment at CERN [2]. In a MICROMEGAS, a thin metallic mesh is placed above the anode plane. Small insulating spacers create a narrow gap (100 μm) between the mesh and the anode plane. The gap defines the amplification region of the detector. The electric field lines in the amplification gap are similar to a parallel-plate gas chamber. However, because the MICROMEGAS gap is small, it does not require large bias to achieve reasonable gas gain, whereas in a parallel-plate gas chamber, the bias voltage required is prohibitively high because the amplification gap used is typically a few millimeters.

The MICROMEGAS in this aging study employs a new micromesh which was fabricated by Kapton-based photolithography [3]. The final micromesh resembles a one-sided GEM but with most insulating Kapton etched away, except for small 80 μm diameter pillar supports. Fig. 1 shows a photograph of a support pillar. The pillars are located every 1 mm, and the dead area of the detector is therefore insignificant [4]. As very little insulating material is present in the detector, there is minimal charge build-up on the mesh. This is one of the reasons for the MICROMEGAS rate capability, which can reach as high as 10^7 Hz/mm^2 [4].

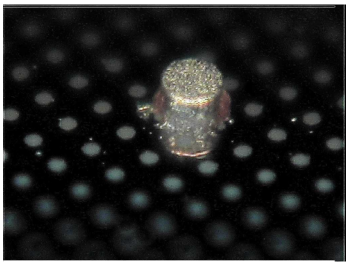

Fig. 1 A photograph of one of the supporting pillars. Its diameter is about 80 μm. The electrons go through the many small holes to enter the amplification region.

2. MICROMEGAS with GEM preamplification

The GEM (gas electron multiplier) is a Kapton-based micropatterned device that amplifies electrons and has high electron transparency so that amplified charge is transferred efficiently to a subsequent device [5] for further amplification or charge collection. We previously performed aging studies of both double GEM and triple GEM detectors in Ar-CO_2 gas [6-7]. The studies were performed in an ultra-clean environment where the gas quality was monitored by gas chromatography. No significant aging effect was observed in the triple GEM study, while there was a sign of moderate aging in the double GEM study. The aging of the double GEM was confirmed by optical inspection, which revealed dark deposits in the irradiated detector very near the GEM holes. This phenomenon appears analogous to the dark deposits seen on the thin anode strips of the MSGC (Microstrip Gas Chamber) after sustained irradiation [8]. In an MSGC, many electric field lines are concentrated and terminate on the anode. In a GEM, the lower electrode collects some electrons while the majority of electrons leave the GEM. The termination of field lines on the lower GEM electrode, combined with the electric field strength and the charge density in the vicinity of the lower electrode, presumably creates the conditions necessary for polymerization. In the triple GEM, it is possible to operate with lower amplification from each GEM while maintaining the same overall gas gain of a double GEM. For this reason, no aging was observed in a triple GEM. It is important to note that in both the double GEM and triple GEM aging experiments, the charge-collecting anodes did not exhibit aging. This is presumably due to a lower electric field strength and lower charge density at the anodes compared to the low electrode of the second GEM in the double GEM study.

A prior study suggested that the gain and aging behavior of a GEM and a MICROMEGAS may differ. In a MICROMEGAS, there is no analog of the lower electrode of the GEM, i.e. no structure in the mesh that intercepts avalanche electrons. Thus the gas gain achievable for the same gap and the same voltage is higher in a MICROMEGAS. This structural difference may make a MICROMEGAS less susceptible to aging than a GEM: in the former, the avalanche electrons are collected only by the anode strips or pixels, and these are analogous to the charge collection electrodes in the double and triple GEM aging studies, which did not exhibit aging in our previous experiments.

One effect of GEM preamplifcation on MICROMEGAS performance is a reduction of the spark rate in the combined device compared to a standalone MICROMEGAS. This has been studied in [9]. In this work, we examine the radiation hardness of the MICROMEGAS+GEM.

2.1. Detector structure

The GEM foil has an area of 10 cm x 10 cm with 140 μm pitch holes in 50 μm thick Kapton. The GEM is placed above the micromesh of the MICROMEGAS. The detector structure is drawn in Fig 2.

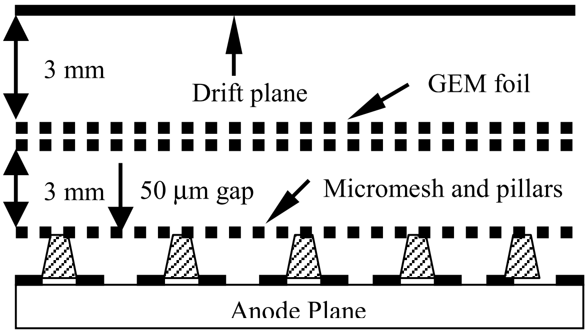

Fig 2. MICROMEGAS+GEM detector.

Primary electrons created in the drift region experience amplification twice. Some electrons may be created below the GEM; these electrons experience amplification only once. Our previous study showed that roughly the same gain on both devices gives the maximum rate capability of the whole detector [9]. If the total gas gain is shared roughly equally by two or more devices, the electron diffusion effect relaxes discharge conditions by avoiding the Raether condition, leading to stable operation.

3. Aging test setup in Ar+CO_2 gas mixture

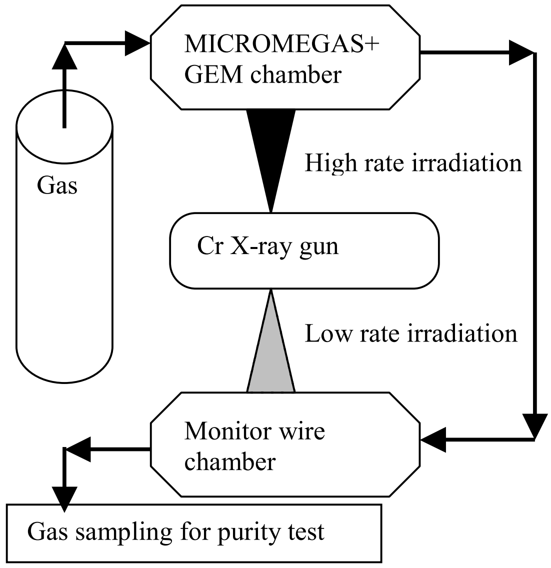

Fig. 3 Aging test setup. The main detector was irradiated at a high rate, but the monitor wire chamber was irradiated at low rates.

A schematic drawing of the aging test setup is shown in Fig. 3. The aging apparatus has been described in detail in [8]. An X-ray generator is the source of photons: one beam irradiates the detector under test while a second beam from the same target irradiates a single-wire proportional counter, which is used to monitor the effects of pressure and temperature on the gas gain. The monitor counter is also sensitive to any change in the intensity of the X-ray generator beam, and because it shares the same gas system with the detector under test, it is also sensitive to any change in the gas mixture's composition. The total charge accumulated by the MICROMEGAS+GEM is calculated by integrating the signal current over 600 hours. The integrated current was measured on the grounded anode strips. The anode current reflects the total number of electrons collected by the anodes. Gas gain was about 3,000, and the irradiation rate was about 17 nA/mm^2. Pulse height spectra were taken every hour on both the MICROMEGAS+GEM chamber (at the micromesh) and the monitor wire chamber. The micromesh was biased through an Ortec 142PC charge-sensitive preamplifier. The preamplifier has a rise time of a few hundred nanoseconds; a large part of the signal is therefore formed by slowly moving ions traveling in the amplificaiton gap. However, the distance the ions have to cover to induce signals is only 50 to 100 μm, and the slowly moving ions are quickly removed, minimizing the space charge effect. The GEM was biased through a resistor chain. At the end of the chain, an ammeter was connected to measure any changes in the current flowing in the chain and GEM. Both temperature and pressure in the room were measured as well.

4. Aging result

Initially, the MICROMEGAS and the GEM were biased at V_{mesh}= 380 V and V_{gem}= 400 V, but during the initial stage of irradiation, we observed a sharp gain drop as shown in Fig 4. This was probably because the micromesh was adjusting to high ion current. Due to its rapid onset, this gain drop clearly has nothing to do with traditional aging. This fact was confirmed by the optical inspection of both devices after the experiment. After about 5 mC/mm^2 of charge accumulation, the bias voltages of the MICROMEGAS and GEM were increased by 5 V and 10 V, respectively, and the radiation current was restored to the original level. The gain drop was not observed in the monitor wire chamber because it was irradiated at a low rate. In Fig. 4, after the gain was restored, both the MICROMEGAS+GEM chamber and the monitor wire chamber exhibited highly correlated fluctuations in gain. These changes were due to variations in the atmospheric pressure in the laboratory, with which they are inversely correlated.

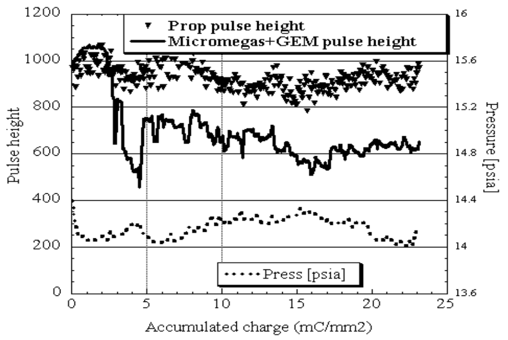

Fig 4. Pulse heights of MICROMEGAS+GEM and the monitor wire chamber. The changes in the pressure in the laboratory are also shown.

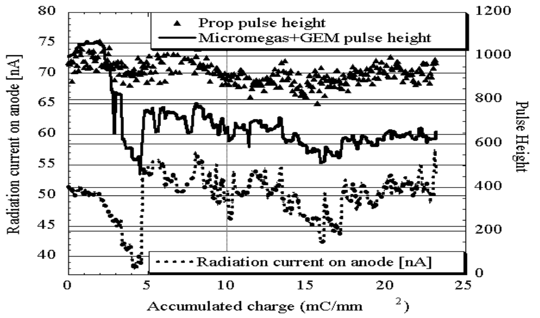

Fig 5. Signal current, pulse height of the MICROMEGAS+GEM, and the monitor wire chamber as a function of accumulated charge.

The signal current induced by the irradiation measured on the anode (electron current) responded to the pressure changes qualitatively in the same way as the pulse height. However, Fig. 5 shows that the drop in current is much smaller than the drop in pulse height. Moreover, after the additional voltage was added to the MICROMEGAS and the GEM, the electron current exceeded its original value whereas the pulse height did not return to the original value. This large discrepancy can be attributed to the functioning of the preamplifier, which, when connected to the micromesh (cathode), records the summed effect of charge movements in different locations. For example, the ions exiting the mesh and traveling to the drift region have some cancellation effect with respect to the ions arriving on the mesh from the avalanche region of the MICROMEGAS. Thus, even if the total gain increases, the pulse height recorded by the preamplifier does not grow as much as the number of avalanche electrons. The electron current measured on the anode is insensitive to this effect, and all electrons in the avalanche are recorded regardless of their origins.

Optical inspection at the end of the aging test revealed no visible deposit on either the MICROMEGAS or GEM. The amount of charge accumulated was similar to that in our previous double GEM and triple GEM studies. The MICROMEGAS+GEM outperformed double GEMs and had comparable radiation hardness to a triple GEM, but with one less preamplification device in the chamber.

5. Summary

The first study of aging in a MICROMEGAS +GEM chamber has been performed. An early sharp gain drop was observed, and the voltage on both the MICROMEGAS and GEM had to be raised to restore the initial gain. This phenomenon does not appear to affect overall detector performance as long as sufficient voltage is applied on the mesh. The MICROMEGAS+GEM accumulated a charge of 23 mC/mm^2 without loss of performance. The aging result presented here demonstrates that the combination MICROMEGAS+GEM has aging performance superior to that of a double GEM; its performance is comparable to that of a triple GEM, but with one less preamplification device; the MICROMEGAS+GEM has a simpler construction and uses less material than the triple GEM.

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References

[1] I. Giomataris, et al., Nucl. Instr. and Meth. A 376 (1996) 29.
[2] D. Thers, et al., Nucl. Instr. and Meth. A 469 (2001)133.
[3] A. Delbart, et al., Nucl. Instr. and Meth. A 461 (2001) 84.
[4] G. Charpak, et al., Vienna Conference on Instrumentation, Vienna, Feb. 2001.
[5] F. Sauli, et al., Nucl. Instr. and Meth. A 386 (1997) 531.
[6] S. Kane, et al., IEEE Nuclear Science Symposium, Lyon, Oct. 2000.
[7] S. Kane, et al., Vienna Conference on Instrumentation, Vienna, Feb. 2001.
[8] E. Gerndt, et al., Nucl. Instr and Meth. A 422 (1999) 282.
[9] S. Kane, et al., International Conference on advanced technology and particle physics, Como, Oct. 2000.
[10] S. Kane, et al., IEEE Nuclear Science Symposium, San Diego, Nov. 2001.