Development of Gas Electron Multipliers for the X-ray Polarimetry Mission *GEMS*

Takanori Iwahashi[1], Toru Tamagawa[1], Asami Hayato[1],
Saori Konami[1], Fumi Asami[1], Kazuo Makishima[1],
Jean Swank[2] and Keith Jahoda[2]

[1] RIKEN / Cosmic Radiation Laboratory, 2-1 Hirosawa, Saitama 351-198, Japan
[2] NASA / GSFC
E-mail(TI): iwahashi@crab.riken.jp

Abstract

We have produced gas electron multiplier (GEM) ,which is one of the recently developed micro-pattern gas detector, using a laser etching technique since 2002. Our GEM was selected as a key device of the X-ray polarimetry mission, Gravity and Extreme Magnetism SMEX (*GEMS*). Since *GEMS* will be the first mission carrying RIKEN/SciEnergy GEM into Low Earth Orbit, we have evaluated the risks which impact the GEM in space. We carried out gain stability measurements, obtaining that the GEM had enough stable gain for space uses. We irradiated Fe ion beam to our GEM for studying robustness against discharges. Our GEM survived the 40-year equivalent beam irradiation.

Key words: GEMS, gas electron multiplier, X-ray polarimeter

1. Introduction

1.1. development of Gas Electron Multiplier

The gas electron multiplier (GEM) which was invented at CERN in 1997 is one of the recently developed micro-pattern gas detector [1]. The GEM is a 2-dimensional proportional counter. We have developed the GEM using a laser etching technique since 2002 [3],[4]. Our GEM (RIKEN/SciEnergy GEM) was selected as a key device of the X-ray polarimetry mission, Gravity and Extreme Magnetism SMEX (*GEMS*) [5].

1.2. The *GEMS* mission

The *GEMS* satellite will launch into Low Earth Orbit (LEO) at an altitude of 575 km and an inclination angle of 28.5° in 2014. During the 2-year lifetime of the mission, *GEMS* observes X-ray polarization from stellar objects; black holes, pulsars, magnetars, supernova remnants, etc. *GEMS* carries 3 independent telescopes (mirror and polarimeter pairs). The polarimeters have sensitive at an energy range of 2–10 keV. The polarimeters can image photoelectron tracks with a time projection chamber technique using the RIKEN/SciEnergy GEM.

2. Risks when using GEM in LEO

GEMS is the first mission carrying RIKEN/SciEnergy GEM onboard satellite. We have evaluated risks when using the GEM in LEO, since the typical space environment is severe for the GEM. In LEO, satellites pass through South Atlantic Anomaly (SAA) in which there is a significant flux of geomagnetically trapped protons. We can avoid damages due to discharges caused by the protons if turning off high voltage during the passage of SAA every 90 minutes.

Even outside SAA, galactic cosmic-rays accidentally hit satellites. The galactic cosmic-rays consist of protons and heavy ions. Heavier ions easily cause discharges because of their large energy deposit in material.

We present in this paper two experimental results for evaluating the risks. First is the gain stability after applying high voltage. Second is the robustness against discharges caused by the galactic cosmic-rays.

3. Gain stability measurement

Fig. 1 shows gain variation of our GEM and the one produced at CERN for a few hours after turning-on high voltage. Since the CERN GEM,which was produced using wet etching, needed a few hours to stabilize the gain, we can not use it in the LEO missions which repeat high voltage off and on every 90 minutes. In contrast, our GEM was stable enough.

4. Heavy ion irradiation test

4.1. galactic cosmic ray ions

The galactic cosmic ray ions are dangerous for the micro-pattern gas detectors since they might cause discharges and/or destroy the detectors (e.g. micro strip gas detectors onboard *INTEGRAL*). Fig. 2 shows the flux of

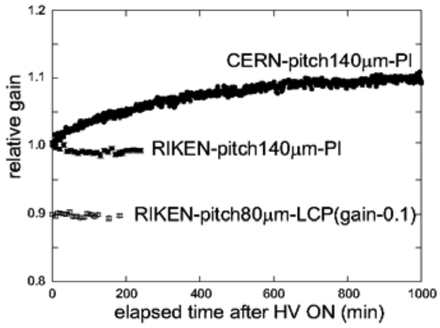

Fig. 1. Short-term gain stability of the RIKEN and CERN GEMs. The time-zero means the moment of turning on high voltage. The gain is normalized at the time-zero.

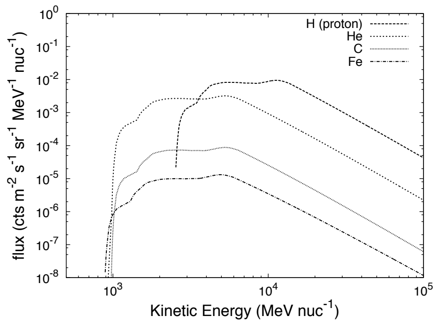

Fig. 2. The flux of incident particles assuming an orbit at an altitude of 600 km and inclination of 30 degrees. The flux is calculated by CREME96: FLUX DRIVER.

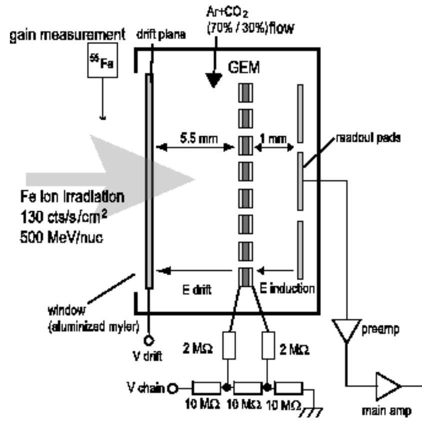

Fig. 3. Setup of irradiation test. Full-striped Fe ion beam comes from the synchrotron accelerator, HIMAC.

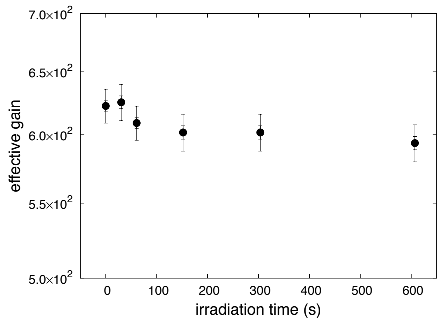

Fig. 4. Gain variation during the Fe ion irradiation test. The gain was obtained by using a ^{55}Fe source. The error bars show statistic and systematic errors. The data point at 607 s corresponds to the 40-year equivalent cosmic-rays.

major cosmic ray ions in LEO. Only one ion may short the GEM if the energy deposit of the ion is large enough. Since the energy deposit of an ion is proportional to the square of its atomic number, Fe is the most dangerous in the major cosmic-ray ions. Thus, we studied robustness of the GEM against discharges by irradiating Fe ions.

4.2. Fe ion irradiation

Fig. 3 shows a setup of the Fe ion irradiation test. We irradiated the Fe ion beam with an energy of 500 MeV/nuc provided by the heavy ion accelerator HIMAC located in Chiba, Japan. The flux of the Fe ion was 130 cts/s/cm^2. During the irradiation, we read signals from the center of read-out pads, and monitored the discharge with an oscilloscope. We paused irradiation while measuring the gain with a radio isotope ^{55}Fe.

Fig. 4 shows the gain variation during the irradiation. Our GEM survived more than 600 sec irradiation which is equivalent to 40-year fluences. We concluded that our GEM was robust enough against the discharges caused by cosmic ray heavy ions.

5. Summary

We have developed the GEM using a laser etching technique since 2002. *GEMS* that is the first X-ray polarimetry mission using the RIKEN/Scienergy GEM will be launched in 2014. We have evaluated risks when using the GEM in LEO. The GEM was stable enough in gain for space missions. The GEM was robust enough against the discharges caused by cosmic ray heavy ions.

References

[1] Sauli, F., NIM, A386, 531-534 (1997)
[2] Costa, E., et al., Nature 411, 662-665 (2001)
[3] Tamagawa, T., et al., NIM, A560, 418 (2006)
[4] Tamagawa, T., et al., NIM, A608, 390 (2009)
[5] Swank, J., "THE COMING OF AGE OF X-RAY POLARIMETRY", ROME (2009)
[6] Produit, N., Nucl. Phys. B150, 354-357 (2006)
[7] Hirao, Y., et al., Nucl. Phys. A358, 541-550 (1992)