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First result of large size Scintillating Glass GEM imager

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Abstract. A large size x-ray imaging gaseous detector, which has 280 × 280 mm^2 effective area has been successfully developed and x-ray imaging has been demonstrated. The imaging system consists of a chamber filled with Ne/CF_4 scintillating gas mixture, inside of which Glass GEM (G-GEM) is mounted for gas multiplication. In this system electrons are generated by the reaction between x-rays and the gas, and visible photons by excited Ne/CF_4 gas molecules during the gas electron multiplication process in the G-GEM holes. These photons are simply detected with CCD-camera and a radiograph is formed. Here, we report on the properties of large size scintillation G-GEM and the results of using it as a digital x-ray imager with a large sensitive area.

1 Introduction

Gaseous detectors have been playing important role for various types of radiation measurements. Gas electron multiplier (GEM) is one of the most popular and successful types of micro-patterned gaseous detector (MPGD). [1–4] However, building a large size detector with MPGDs needs a lot of effort to install and maintain. In addition, signal readout is another big issue for operating MPGDs. For imaging with GEMs, readout pads needs to be carefully designed and so as the many channels of readout circuits which goes up to hundreds to thousands of channels. On the other hand, not all radiation measurements are required to be precisely measured. For instance, x-ray radiograph can be formed with simple integrating circuits such as CCDs and CMOS. [5, 6] From that point of view, gaseous scintillation with GEMs has been studied in past works, in order to simplify the signal readout for imaging. [7–10] Scintillation light caused during electron avalanche process with scintillation gas (such as CF_4) can be easily detected with optical camera. However, amount of photons produced is limited with conventional GEM ’s avalanche process and it is difficult to be detected with conventional optical camera. This is mostly due to the gas gain is not enough with single GEM ($\approx 10^3$). On the other hand, we have been developing Glass GEMs (G-GEM), which is promising electron multiplier with high gas gain and low charge ups [11, 12]. Gas gain of G-GEM reached up to 10^5 with a single G-GEM structure may contribute to high scintillation yield. In addition, we have fabricated large size G-GEM with 300 × 300 mm^2 glass substrate, which has 280 × 280 mm^2 effective area [13]. In this paper, we report on the development of large area x-ray imager using G-GEM and gaseous scintillation. Development of our first large-area Scintillating G-GEM detector is shown. We indicate the measured results of gas gain and optical signal to show that it worked properly. We then show the first result of gain x-ray imaging result with large-area Scintillating G-GEM.

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2 Properties of large size G-GEM and initial experiment

2.1 Principle of the setup

We have fabricated large size G-GEM using 300 × 300 mm^2 photo-etchable glass substrate, using fabrication process of HOYA Corporation. This glass is called PEG3, and the G-GEM has 280 × 280 mm^2 effective area. Properties of the large are G-GEM especially focusing on comparison with G-GEM fabricated in our past works [10, 12] which has 100 × 100 mm^2 effective area are shown in table 1. The outlook of the large area G-GEM is shown in Figure 1. As seen in the figure, the G-GEM are stiff enough and has a self-supporting structure, which results in easy to handle and needs no support for mounting.

On the other hand, CF_4 gas is known as a scintillation gas, and to achieve high enough yield of scintillation photons for imaging, gas gain needs to be high enough also. The mechanism of scintillation light yield during G-GEM ’s avalanche process is shown in Figure 2. Ne/CF_4 gas mixture is attractive gas for high gas amplification with low applying voltage. In this study, we first studied gain properties and scintillation light from Ne/CF_4 gas for x-ray imaging.

Table 1. Comparison with past reported Glass GEM and large size Glass GEM fabricated in this study.

	Past reported G-GEM[10, 12]	Large size G-GEM
Effective area	100 mm square	280 mm square
Substrate size	145 mm square	300 mm square
Hole size	180 μm	170 μm
Hole pitch	280 μm	280 μm
Substrate thickness	680 μm	700 μm
Number of holes	141,417	1,154,423

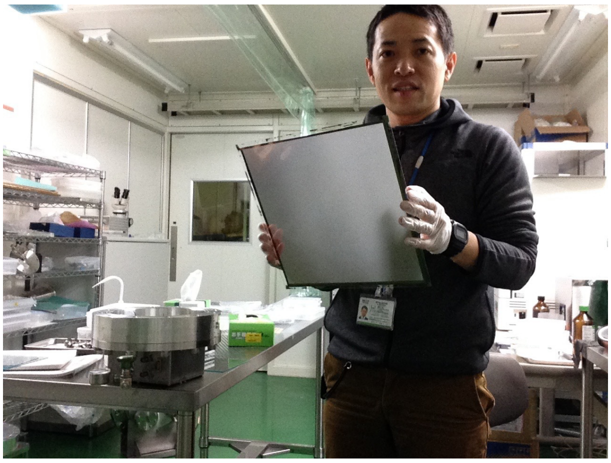

Figure 1. Outlook of the large size G-GEM (280 × 280 mm^2 effective area), fabricated with 300 × 300 mm^2 photo-etchable glass substrate. As the G-GEM is 700 μm thick, and has a perfectly self-supporting structure.

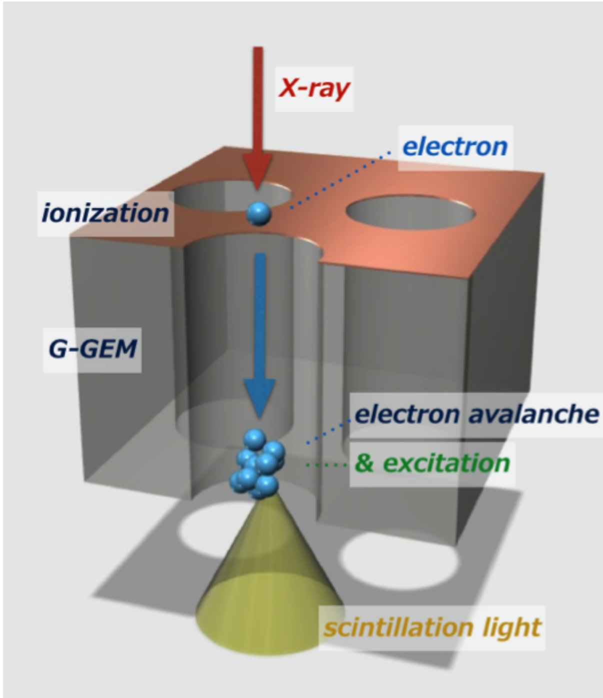

Figure 2. Diagrammatic sketch of scintillation light yield from G-GEM hole during electron avalanche process in scintillation gas.

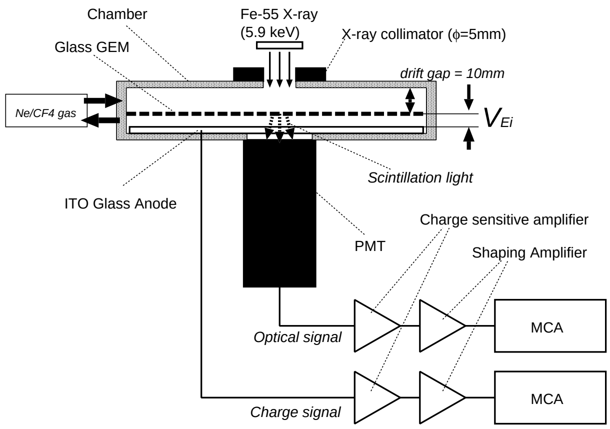

Figure 3. Experiment setup for measuring the basic performance of the scintillating G-GEM detector coupled with the photomultiplier tube (Hamamatsu R329) are described. ^{55}Fe x-ray (5.9 keV) source was used in this study, and the x-ray was collimated to ϕ =5mm at the entrance window of the chamber. Both the charge and the optical signal were recorded with MCAs.

2.2 Gain properties with Ne/CF_4 gas and Scintillation light measurement

In order to investigate scintillation light from G-GEM with Ne/CF_4 gas, initial experiments were carried out using ^{55}Fe source and photo multiplier tube (PMT). Figure 3 is the experimental setup. We installed a G-GEM in a gas filled chamber with drift cathode 10 mm , and a readout 2 mm gap from the optical window which plays a role as a readout anode. The chamber was flushed with an Ne/CF_4 (90:10) gas mixture at 50 mL/min of flow rate. High voltages to the G-GEM ’ s electrodes were applied with individual voltage supply. The drift field was 1 kV/cm, and induction field was 2 kV/cm. In this setup, charge and scintillation light produced with G-GEM were read at the same time using two MCAs. First, charge signal was read out from a charge sensitive preamplifier connected to the anode electrode placed in the bottom of G-GEM. The output from charge sensitive amplifier output was connected to a shaping amplifier and a MCA for taking pulse height spectra (figure 4). At the same time, scintillation light from G-GEM were detected with PMT placed right under the chamber. PMT was also connected to charge sensitive amplifier, shaping amplifier and MCA, and pulse height spectra of ^{55}Fe were recorded at the same time. The spectra obtained in this measurement in Figure 5. Due to the efficiency of light collecting was not good enough in this setup, we could not observe clear peak of 5.9 keV x-ray, beside the energy spectra obtained with charge signal. However, the result indicates high yield of scintillation photons were produced with G-GEM and Ne/CF_4 gas. Gas gain curve of this G-GEM is shown in Figure 6. Gas gain reached up to 7 × 10^3 stably with single G-GEM and Ne/CF_4 gas.

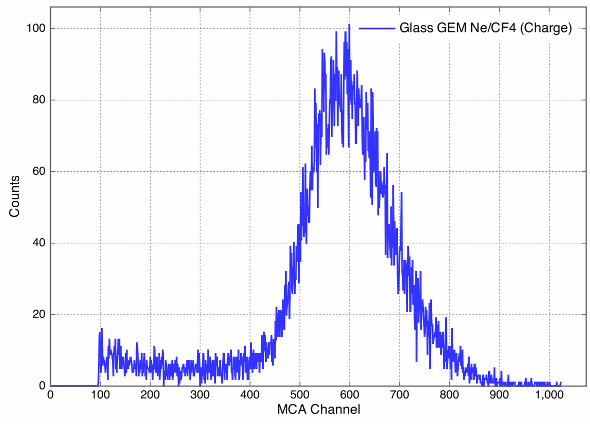

Figure 4. Measured pulse height spectrum with ^{55}Fe X-ray source (5.9 keV). Energy spectrum of charge readout is shown. Energy resolution is 29% in FWHM.

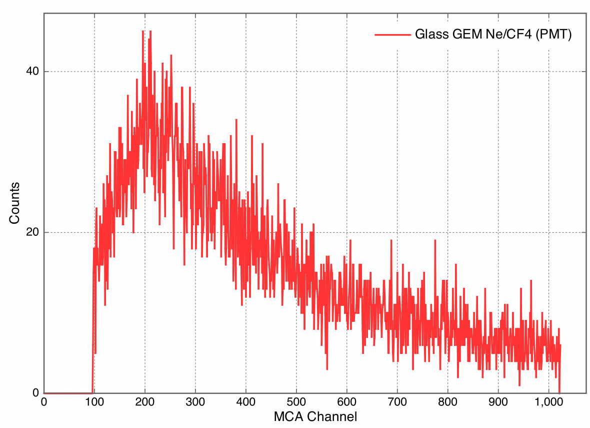

Figure 5. Energy spectrum taken at the same time using a photomultiplier tube directly coupled under optical window placed in the bottom of the gas chamber.

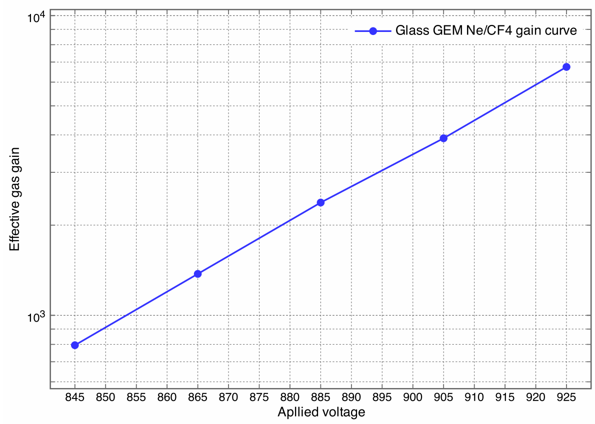

Figure 6. Gas gain curve achieved with G-GEM and Ne/CF4 (90:10) gas. Maximum gain reached up tp 7×10^3, applying 925 V to a single G-GEM.

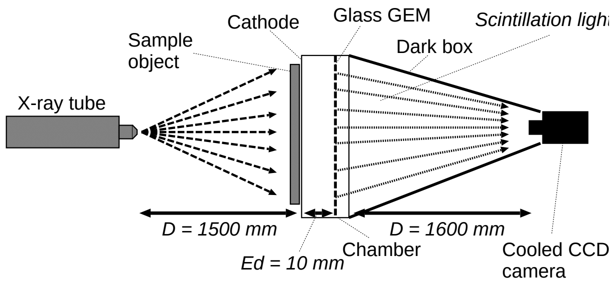

Figure 7. Schematic and detection principle of scintillating G-GEM detector. Electrons created in reaction with x-rays are multiplied by the G-GEM in the chamber. Scintillation light emitted during the electron avalanche process is detected with a CCD camera placed behind the chamber, and form an x-ray transmission image.

3 Imaging test of large size Scintillating Glass GEM

Figure 7 illustrates the schematic and detection principle detection principle of x-ray imaging with a scintillating G-GEM detector. For the x-ray window of the chamber, a 20 μ m thick Kapton film coated with 20 nm Aluminum layer was used. In this experiment, gas gain of G-GEM were set to approximately 3×10^3. Using this setup, we investigated the first x-ray imaging test with the large size scintillating G-GEM detector. Detailed experimental conditions and equipment used in this study is shown in table 2. The sample object for demonstating x-ray imaging is shown inf figure 8. A tool box made out of plastics are filled with screws and connectors. X-ray tube were placed in front of gas chamber, and in the same line, optical cooled CCD camera (Bitran BH-50L) were placed behind the chamber. Camera is looking towards the optical window of the chamber surrounded with dark box. First demonstrating x-ray transmission image taken by large size Scintillating G-GEM is shown in figure 9. X-ray image of 280 × 280 mm^2 are successfully taken in 5 seconds of exposure time with simple optical camera.

Table 2. Detailed setup and equipment used in imaging test with large size scintillating G-GEM Detector

Electron multiplier	280 mm square G-GEM
Scintillation gas	Ne/CF_4 (90:10)
Gas gain	3×10^3
Optical camera	BITRAN BH50L(300,000pixels)
Lens	Fujinon 25 mm F0.85
x-ray source	Amptek Mini-x (25kV, 50μA)

4 Summary

A large size scintillating G-GEM detector that 280 × 280 mm^2 in size was developed and operated successfully. The gain properties and gas scintillation yield with Ne/CF_4 gas were quantitatively studied, and succeeded in achieving fine X-ray transmission images with the scintillating

Figure 8. A photograph of tool box filled in with screws an connectors, used as a sample object for x-ray imaging demonstration of scintillating G-GEM detector.

Figure 9. X-ray transmission image of a tool box obtained by large size scintillating G-GEM detector with an x-ray tube voltage of 25 kV, current 50 μA. Effective area of the x-ray image is 280 × 280 mm^2. The image was taken with an exposure time of 5 seconds (gas gain: 3,000).

G-GEM detector. Using the high yield photon emission from the Ne/CF_4 gas mixture, the scintillation light from the high gain G-GEM can be easily detected with a commercially available CCD camera coupled to a conventional lens system. Although the data acquisition rate is restricted due to the speed of the CCD readout, the optical readout is very simple and attractive. Moreover, the CCD camera can provide fine imaging due to the very large number of channels (up to 3×10^6). Therefore, we conclude that our detector has the potential to be an alternative to flat-panel detectors, imaging plates, x-ray films, and CMOS sensors for digital x-ray imaging.

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