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Development of large-area glass GEM

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ABSTRACT

We have developed a new gaseous radiation detector, referred to as the Glass GEM (G-GEM). The G-GEM is composed of a photosensitive etching glass (PEG3) substrate from HOYA Corporation, Japan. Since a large-area detector is required for imaging device applications, we newly developed a large-area G-GEM prototype with a sensitive area of $280 \times 280\ mm^2$. In this study, we investigated its basic characteristics and confirmed that it worked properly and had sufficient uniformity across the entire sensitive area. It had high gas gain of up to approximately 7700, along with good energy resolution of 26.2% (FWHM) for a 5.9-keV X-ray with a gas mixture of Ar (90%) and CH4 (10%). The gain variation across the sensitive area was almost within the range of $\pm 10\%$.

1. Introduction

Gas electron multipliers (GEMs) are some of the most widely used micro-pattern gaseous detectors (MPGDs) [1]. A GEM is composed of a thin polyimide (~50-μm thickness) insulator sandwiched between thin copper layers. This device has numerous minute holes, each of which functions as an individual proportional counter when a high voltage is applied across the GEM. GEMs are used only as electron multipliers and are usually separated from the signal readout function; they therefore enable flexible design of the readout electrodes. In addition, they can be stacked to form a cascade GEM structure to yield a higher gas gain. GEMs also operate at a high count rate because of its numerous holes which work individually. The fine pitch of holes gives the high intrinsic position resolutions, although the actual resolutions can be decided by the combination of the readout system. These devices are used in a variety of fields such as high-energy physics [2,3], neutron detection [4], X-ray imaging [5], and visible photon measurement [6].

We recently developed a new GEM-derived detector, the Glass GEM (G-GEM) [7]. The substrate of this device is composed of the commercially available photosensitive etching glass PEG3, manufactured by HOYA Corporation, Japan [8]. The holes of the G-GEM are uniformly and finely formed using a photolithography technique, and the thickness, hole diameter, and hole pitch of the standard size G-GEM are 680, 170, and 280 μm, respectively. The G-GEM has potential for use as a sealed-type detector, since the glass is not outgassing material; Outgassing degrades the purity of the sealed gas and the detector performance. Further, the low electrical resistivity of PEG3 prevents the substrate from unfavorable charge accumulation (charge-up), which causes gain variation. If a G-GEM has enough thickness, it will have sufficient mechanical strength to support itself even if it has a large-area, and the G-GEM will not suffer from a bending problem. This self-supporting capability also enables a simple detector setup, since no tensioning tools are required. To date, we have been continuing research and development of the standard-size $100 \times 100\ mm^2$ G-GEM, and demonstrating its excellent characteristics [9,10].

The G-GEM is a promising candidate as a detector for use in highly sensitive portable X-ray or β-ray imaging devices. The high gas gain of more than 10^4 of a single G-GEM structure may contribute to compact readout electronics for each pixel. In addition, the outgas-free property of the G-GEM enables long-term gas-sealed operation of the detector; therefore, a portable imaging device can be achieved due to elimination of the need for high-pressure gas canisters. We have previously demonstrated the 2D imaging capability of the G-GEM utilizing a gas proportional scintillation principle [9].

However, a larger sensitive area is required for practical imaging applications. Although it is possible to achieve a large-

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area imaging device by constructing an array of standard-size G-GEMs, such a device will have non-negligible insensitive regions along the edges of each individual G-GEM, which would lead to additional boundary problems between neighboring detectors and degrade the image quality. The setup for such a device would also be complicated, because of the individual power lines and position-fixing structures of each G-GEM. These problems would all be overcome by the fabrication of a single large area G-GEM. In this paper, we report on the development of our first large-area G-GEM prototype. We indicate the measured results of gain and energy resolution to show that it worked properly. We then show the result of gain uniformity to confirm that the large-area G-GEM was uniformly fabricated across its sensitive area.

2. Large-area G-GEM prototype

The first prototype of the large-area G-GEM is shown in Fig. 1. This device has a sensitive region of $280 \times 280\ mm^2$, which is approximately eight times larger than the conventional, standard-size G-GEM. The other dimensions are similar to those of the standard-size G-GEM. The thickness, hole size, and hole pitch are 700, 170 and 280 μm, respectively. The large-area G-GEM with these parameters had enough strength to support by itself under the setup condition described in the next chapter. The resistance between the top and the bottom of the device is 29 MΩ, which is lower than that of the standard-size G-GEM, the resistance of which is usually in the region of several hundred MΩ. Each of the surface electrodes is composed of a chromium layer (a few hundred Å) on the glass surface, and a copper layer (∼2 μm) on the chromium.

3. Experimental setup

We investigated the basic characteristics of the large-area G-GEM using the experimental setup shown in Fig. 2. The single G-GEM was placed inside an aluminum chamber, supported by eight ceramic poles placed along the edges. The anode was a single planar electrode which was an aluminum coated glass plate, and placed at a distance of 2.0 mm from the bottom of G-GEM (induction gap). The stainless mesh cathode was placed 19.0 mm above the device (drift gap). The cathode mesh was supported by ceramic poles. The drift electric field and induction field were 16 and 340 V/mm, respectively. We used a gas mixture of Ar (90%) and CH_4 (10%) at atmospheric pressure in the gas flow mode. The G-GEM was irradiated by a ^{55}Fe 5.9-keV X-ray source with a radioactivity of 183 kBq. In order to create the potential differences across the drift, G-GEM, and induction, we applied the high voltages to the cathode mesh using an ORTEC 660, and to the

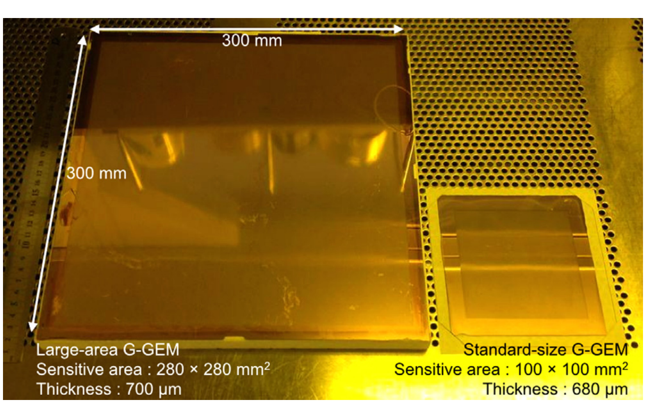

Fig. 1. Large-area and conventional standard-size G-GEMs.

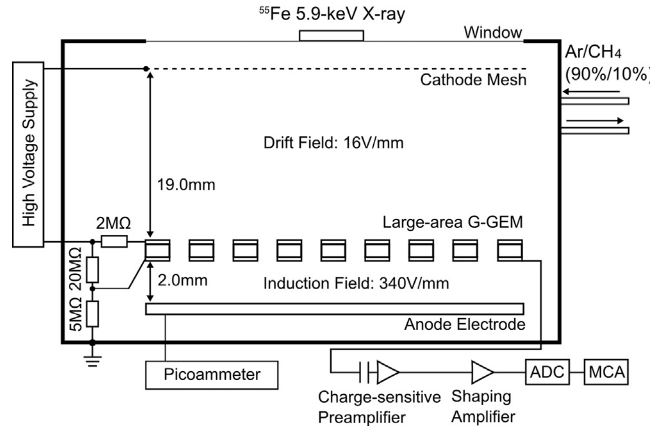

Fig. 2. Experimental setup schematic.

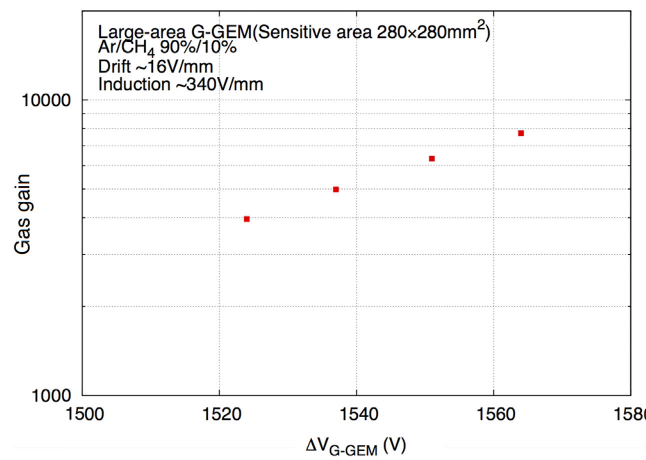

Fig. 3. Gas gains of the single large-area G-GEM. $\Delta V_{G\text{-}GEM}$ is the voltage between the top and bottom sides of the device, calculated based on the resistance of the G-GEM (29 MΩ) under the effects of the voltage-supply resistor chain shown in Fig. 2.

end of the resistor ladder using a Clear-pulse 6673NN. The setup was operated under negative voltages and the anode electrode was placed at the ground potential. The maximum voltages applied were −2560 V for the cathode mesh and −2360 V for the resistor ladder. The potential gap, $\Delta V_{G\text{-}GEM}$, between the top and bottom of the G-GEM was calculated from the parallel resistance of the G-GEM resistance measured as 29 MΩ and the ladder resistances. A picoammeter (Keithley 6517 A) was connected to the anode electrode in order to measure the current based on the amplified charges collected at the anode.

A charge-sensitive preamplifier, which was composed of the operational preamplifier, JRC072BD, was connected to the bottom of the G-GEM for the observation of the pulse signals from the induced charges, and for the measurement of the pulse height spectra. The spark protection circuit was positioned before the preamplifier, which was composed of a 1-kΩ resistor and three diodes. The shaping amplifier used was a Clear-pulse 4419, the analog-to-digital converter (ADC) was a FAST ComTec QUAD ADC 7074, and the multichannel analyzer (MCA) was a FAST ComTec MPA-3.

4. Experiments and results

First, we calibrated the gas gain characteristic of a single large-area G-GEM. The gain was defined as the ratio of the number of