Nuclear Instruments and Methods in Physics Research A 724 (2013) 1–4

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Development of a glass GEM

Hiroyuki Takahashi [a,*], Yuki Mitsuya [a], Takeshi Fujiwara [b], Takashi Fushie [c]

[a] Department of Nuclear Engineering and Management, The University of Tokyo, Japan
[b] Nuclear Professional School, The University of Tokyo, Japan
[c] Hoya Corporation, Japan

ARTICLE INFO

Article history:
Received 5 June 2012
Received in revised form
25 April 2013
Accepted 29 April 2013
Available online 16 May 2013

Keywords:
Proportional counter
X-ray
GEM
MPGD
Position-sensitive detector

ABSTRACT

Gas electron multipliers (GEMs) apply the concept of gas amplification inside many tiny holes, realizing robust and high-gain proportional counters. However, the polyimide substrate of GEMs prevents them from being used in sealed detector applications. We have fabricated and tested glass GEMs (G-GEMs) with substrates made of photosensitive glass material from the Hoya Corporation. We fabricated G-GEMs with several different hole diameters and thicknesses and successfully operated test G-GEMs with a $100 \times 100\ \text{mm}^2$ effective area. The uniformity of our G-GEMs was good, and the energy resolution for 5.9 keV X-rays was 18.8% under uniform irradiation of the entire effective area. A gas gain by the G-GEMs of up to 6700 was confirmed with a gas mixture of Ar (70%)+CH_4 (30%). X-ray imaging using the charge division readout method was demonstrated.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Gaseous radiation detectors are used in various applications. Since the gas electron multiplier (GEM) was introduced [1], its multi-stage high-gain capability and robustness have attracted many researchers, and many efforts have been made to develop the fabrication methods [2–4]. Although the double GEM or triple GEM structure can achieve a very high total gas gain, a higher gas gain in a single GEM is preferable to prevent unwanted discharge and reduce the number of stages for simplicity. Therefore, thick alternative substrates such as printed circuit boards have been investigated [5]. In this study, we developed new glass GEMs (G-GEMs) with substrates made of a photo-etchable glass called PEG3 from the Hoya Corporation. The fabrication process is shown in Fig. 1. The photo-etchable glass used for the substrate in this study is cerium–silver-doped lithium–aluminum-silicate glass. Under illumination with UV light, cerium is oxidized and releases one electron. In the first annealing step, the released electrons reduce the positively charged doped metal ions (Au, Ag, Cu). The neutral metal atoms have high mobility, and they move to form metal clusters within the substrate. In the second annealing step, at a higher temperature, these metal clusters act as seed crystals for crystallizing the glass around them. The crystal can then be easily etched with hydrogen fluoride to form holes. Finally, a Cr/Cu layer is sputtered as an electrode for the G-GEM.

The use of glass material produces a self-standing, outgas-free substrate. The outgassing problem is particularly important for sealed counters such as those in neutron detectors and gas photomultipliers. Another favorable feature of photosensitive glass is its compatibility with photolithography techniques. Thus, we can obtain a very fine electrode pattern on the glass material. In fact, we have made patterns that form guard rings to suppress the effective capacitance around the holes; however, in the present study, we focus on a normal structure.

Table 1 summarizes the characteristics of the glass substrates. We selected PEG3 because it shows a rather low volume resistivity, which is favorable for removing the surface charge. Another potential advantage of this material is its opaqueness; therefore, we could realize a see-through structure if indium tin oxide (ITO) electrodes are used with this glass.

2. Design and fabrication of G-GEMs

Because the fabrication process of the photosensitive G-GEM substrate relies entirely on the photolithography technique, we can define a very fine structure for the holes. However, we selected a hole diameter of 120–170 μm and a hole pitch of 360 μm as our standard dimensions considering the yield and requirements for neutron detection applications. To prevent metal spilling into holes, we filled the holes with resist before applying the metal layers. After coating the substrate with metal, we removed the resist.

---

[*] Correspondence to: Department of Nuclear Engineering and Management, Faculty of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan. Tel.: +81 3 5841 7007; fax: +81 3 3818 3455.
E-mail address: leo@n.t.u-tokyo.ac.jp (H. Takahashi).

0168-9002/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.nima.2013.04.089

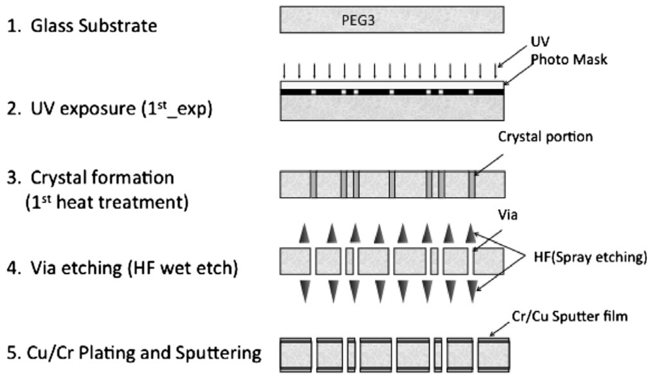

Fig. 1. Fabrication process of G-GEMs.

Table 1
Charactersitics of substrate materials.

	PEG3	PEG3C	Polyimide
Thermal conductivity (W/mK)	0.795	2.72	~0.3
Young's modulus (Gpa)	79.7	90.3	18.6
Relative permittivity	6.28	5.26	3.55
Volume resistivity (Ω cm)	8.5×10^{12}	4.5×10^{14}	~1018

Fig. 2. Photograph of a G-GEM.

Table 2
Five different G-GEMs.

Number	Metal	Thickness (μm)	Hole size (μm)	Resistance between the front and the rear surfaces (MΩ)
#1	Copper	700	170	280
#2	Copper	700	140	315
#3	Copper	580	120	180
#4	Chromium	580	120	60
#5	Chromium	420	120	50

The effective area of our G-GEM is set to 100×100 mm^2. However, the maximum size of the glass is currently limited by the size of the ingots of the glass material, which we hope can be extended to 300×300 mm^2. The yield of G-GEM fabrication has been continuously improved; it is currently about 80–90%. Fig. 2 shows a photograph of the G-GEM, and Table 2 lists the characteristics of the five G-GEMs that we fabricated and tested. The resistances are measured across the G-GEM substrates and greatly affected by the thicknesses of G-GEMs. For example resistances of G-GEM 1 and G-GEM 2 are almost identical because their thickness is same. However, the thickness of G-GEM3 is smaller than that of G-GEM 1, therefore, G-GEM3 provides lower resistance compared with G-GEM1.

We tested the abovementioned G-GEMs with Ar (70%)+CH_4 (30%) at atmospheric pressure in a gas flow mode. Fig. 3 shows the experimental setup. Our custom-designed CMOS ASIC preamps [equivalent noise charge: 880 electrons, full width at half-maximum (FWHM)] were used. Pulse signals were obtained from a single planar anode as a function of the voltage across the GEM layer. The pulse height was measured using a general-purpose shaping amplifier and multi-channel analyzer (MPA3 from FastComtec). An ^{55}Fe source was used for the gas gain measurement. The drift field was set to 42 V/mm, and the induction field was set to 250 V/mm for G-GEMs 1–3 and 500 V/mm for G-GEMs 4 and 5. Fig. 4 shows the measured gas gains for these G-GEMs. Although G-GEMs 3 and 4 had the same dimensions, G-GEM 4 showed a higher gas gain. The highest gas gain of 6700 was achieved by G-GEM 5. This is attributed to the lower voltage across the G-GEM substrate needed to realize a higher electric field thanks to its thickness. Generally speaking, lower

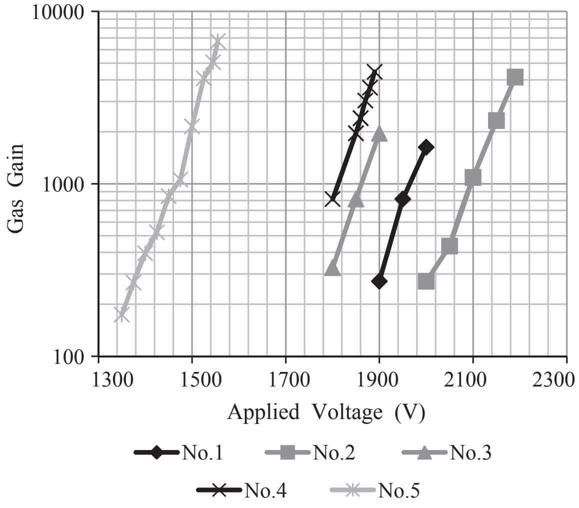

Fig. 4. Gas gain and applied voltage.

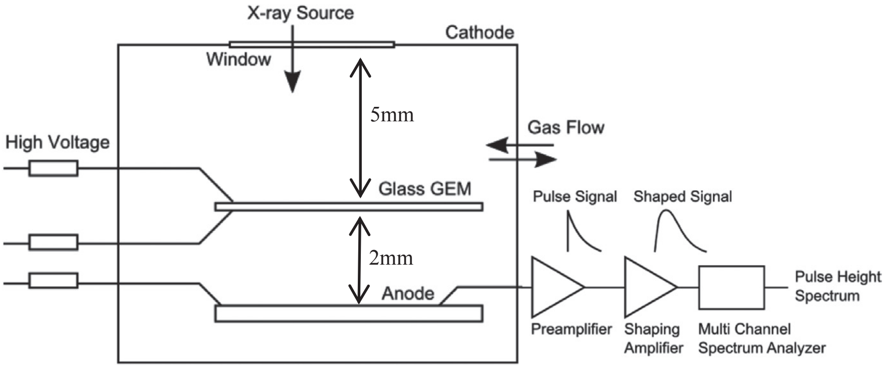

Fig. 3. Experimental setup.

Download English Version:

https://daneshyari.com/en/article/8179526

Download Persian Version:

https://daneshyari.com/article/8179526

Daneshyari.com