A High Gain MSGC with a Capillary Plate

Yuji NISHI[1)], Atsuhiko OCHI[1)], Toru TANIMORI[1)] and Hidenori TOYOKAWA[2)]

1)Tokyo Institute of Technology, 2)SPring-8/JASRI

1 . Introduction

We have been developing the two-dimensional Micro-Strip Gas Chambers (MSGC) in order to obtain the real time X-ray images for the SAXS experiments at the RIKEN beamline I (BL45XU) [1-5]. In this report, we mention the basic behavior of gas multiplication and the imaging performance of a high gain MSGC combined with a capillary plate. The MSGC was made using Multi-Chip Module technology, and has lots of anode-, cathode- and back-strips with very fine pitches of 200 µm on a thin substrate of 20 µm (see Fig. 1). These electrodes enable us to get a good position resolution of a few tens µm, and we also expected that it could be operated stably under intense irradiation. Indeed, some studies have been attempted to use the MSGC as a tracking detector in high-energy physics experiments. However, there still remain crucial problems preventing the MSGC from stable operation: discharge of the electrodes and charge-up of the substrate under high intense irradiation.

In order to avoid the charge-up effect, we introduced a conductive substrate into the MSGC. Thus, an excellent high rate capacity of $10^{6\sim7}$ cps/mm^2 could be realized, but the gas gain decreased drastically. One solution to the gain decreasing is to insert an intermediate gas-multiplier between the drift plane and the MSGC. In this study, we introduced a capillary plate as such a device.

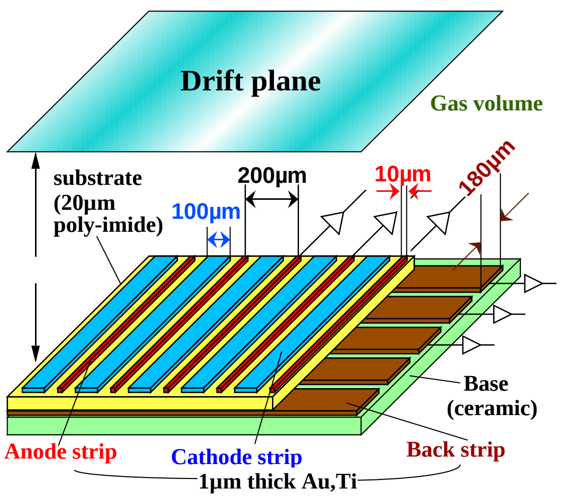

Fig. 1 Schematic of the MicroStrip Gas Chamber.

2. Capillary Plate as Intermediate Multiplier

Figure 2 shows a schematic view of the capillary plate, which consists of a bundle of fine glass capillaries with an inner diameter of 100 µm. It has a 9.5 cm x 9.5 cm detection area and 57 % opening aperture ratio. Both sides were coated with Inconel metal of ~ 400 nm in thickness.

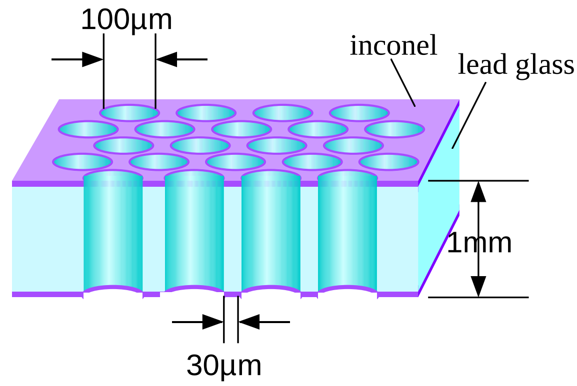

Fig. 2 Schematic of the capillary plate.

Figure 3 shows a cross section of the capillary-MSGC combined system. The capillary plate was installed between the drift plane and the MSGC. The drift space and the inside of the capillaries was filled with a gas mixture of Ar and C_2H_6, or Xe and C_2H_6.

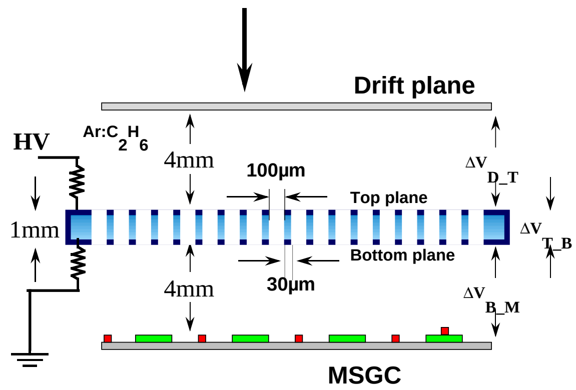

Fig. 3: Schematic of the capillary-MSGC combined system.

An electric field is formed by bias voltages of the anode-strips, the cathode-strips, the drift plane and both sides of the capillary plate. The backstrips were connected to the ground. Figure 4 shows a cross section view of simulated tracks of electrons between the drift plane and the MSGC using two-dimensional approximation. As shown in this figure, almost all electrons ionized in the volume_A (see Fig. 3) can go through the capillary and reach the anodes of the MSGC. Incident X-rays converted in the volume_A will, therefore, emit photo-electrons, and these electrons will be multiplied not only by the capillary plate but also by the MSGC. Photo-electrons converted in the volume_B will, on the other hand, be multiplied only by the MSGC.

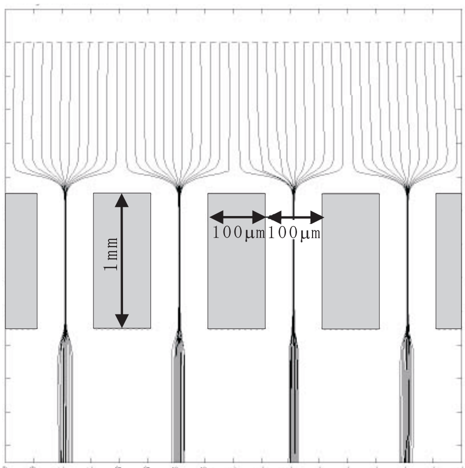

Fig. 4: Tracks of electrons simulated by two-dimensional approximation .

Very high surface resistivity of normal capillaries easily let us infer the unstable operation of its gas multiplication under a high intensity of X-ray irradiation due to the charge-up effect on the surface of capillaries. In fact, sensitivity of highly bright parts on a diffraction image diminished soon with irradiation of X-rays. Because of such an instability, the quantitative evaluation on the performance of this device was hardly done.

In order to avoid such a charge-up effect, we adopted to give a conductivity on the surface of capillaries as well as the substrate of the MSGC. This process yielded a conductivity of about 40 MΩ between both sides of the capillary plate, and the current of about 25 μA was obtained with a supplied voltage of I kV. On the other hand, the current generated by the intense X-rays (12 keV) of 10^6 cps/mm^2 is estimated to be comparable to the above current even when the gas multiplication reaches to several hundreds. Therefore, the charge-up effect will be insignificant. This approach dramatically improved the performance of the capillary-MSGC combined system.

3. Gas Multiplication Measurement

The measurement of gas multiplication was performed with a conventional X-ray generator. In this measurement, the mixture gas of $Ar:C_2H_6$ = 9:1 was used. The capillary plate and the MSGC were set vertically to incident X-rays. It was difficult to read out signals directly from the capillary plate because an electric current amounted to a few tens μA. Therefore, we measured pulse height spectra obtained from summed cathode signals. Figure 5 shows the pulse height spectrum of 8 keV X-ray, and one can see double peaks there. The higher peak corresponds to the X-rays converted in the volume_A, and lower one in the volume_B. The effective gain of a capillary plate was estimated from this figure. The gain variation of the capillary plate as a function of ΔV_{T_B} is shown in Fig. 6. It successfully reached higher than 3000.

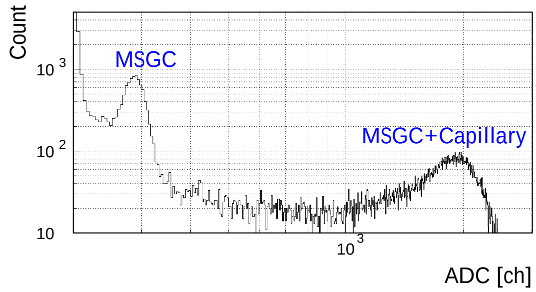

Fig. 5: Energy spectrum of Cu characteristic X-rays.

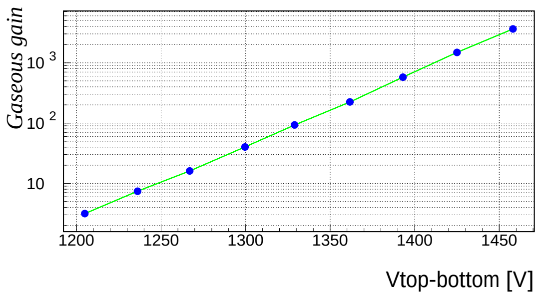

Fig. 6: Gas gain of a Capillary plate as a function of applied voltage.

High rate capability of a conductive capillary plate is also tested. Figure 7 shows the gain variation as a function of incident flux from the X-ray generator, where the upper line shows the total gas gain (capillary x MSGC), and middle one shows the gain of the MSGC. The lower line corresponds to the gain of a capillary plate which was calculated from division of upper two lines. As shown in this

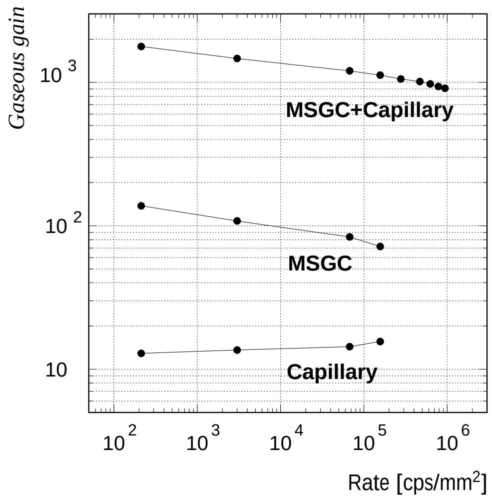

Fig. 7 Gas gain dependence of incident X-ray flux

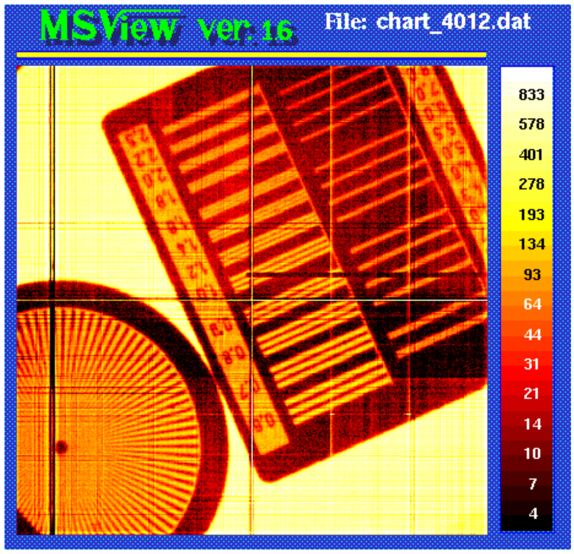

Fig. 8 Test chart picture using Xe gas

figure, the gain of the capillary plate never decrease up to 10^5 cps/mm^2 flux. The decrease of total gain is almost caused by the gain decrease of the MSGC. We have been trying to reduce the gain variation of the MSGC by controlling the surface of insulator, but we have not succeeded to remove it completely yet.

In these experiments, sometimes discharges occurred in the capillary plate, but there never appeared a short circuit. It was found that the capillary plates are very resistible to the discharge.

4. Imaging Performance

The imaging performance was investigated by measuring X-ray transmission using the capillary-MSGC combined system at the SAXS experimental station of the RIKEN beamline I. The X-ray energy was 12.4 keV. Figure 8 shows the transmission image for the test chart, where the gas mixture of $Xe:C_2H_6$ = 7:3 was used. From this image, the position resolution was estimated as 94 µm (RMS). From the measurement with Ar: C_2H_6 = 8:2, on the other hand, a poor _position resolution was measured to be 280 µm(RMS). Xe gas provides a better position resolution and a higher efficiency than Ar gas, because Xe gas has higher photo-electric absorption coefficient and range of electrons is shorter than in Ar gas.

In the case of Xe gas, however, it is commonly said that discharges tend to take place. Therefore, we could not get enough gas gain with Xe gas only by the MSGC because the bias voltage was limited. By using the capillary plate as a intermediate electron multiplier for the MSGC, on the other hand, even Xe gas could give a very high gain.

5. Conclusion

In this study, it was confirmed that the capillary plate worked as an intermediate electron multiplier for the MSGC. The gas gain of the capillary plate successfully reached about 3000. The surface conductivity of the MSGC and the capillary could dramatically improve the performances of our system. It could stably be operated at the counting rate up to 10^5 cps/mm^2, below which the decrease of gas gain was negligible and damages of strips are extremely suppressed. A good efficiency and a position resolution (94 µm RMS) could be achieved by using the mixture gas of Xe and C_2H_6.

Now using the high gain MSGC with the capillary plate, real time X-ray quantitative analyses come to be available for the SAXS experiments.

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