Micro-Strip Gas Chamber

Two-dimensional Micro-Strip Gas Chambers (MSGCs) have been developed by the Station Equipment Group of JASRI and the SR Structural Biology Research Group of RIKEN in collaboration with Professor T. Tanimori of Tokyo Institute of Technology and his group in order to obtain real time X-ray images for SAXS experiments at the RIKEN Structural Biology beamline I (**BL45XU**) [1-5]. The introduction of microstructure electrodes to gaseous chambers has revolutionized many aspects of traditional radiation detectors. The MSGC is the most advanced of these devices, featuring spatial resolution on the order of 10 μm. Nevertheless, the ability of this novel technique to allow the establishment of stable electron multiplication on a realistic time scale has been seriously questioned in response to previous reports of decreased charge gain over time due to the charge-up phenomenon.

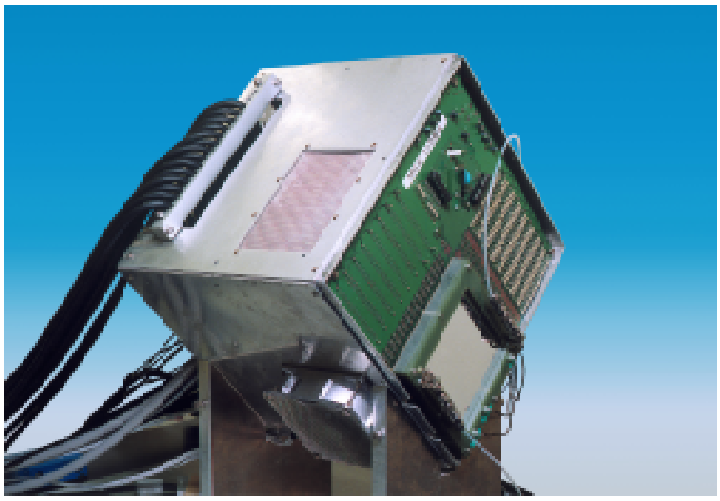

Fig. 1. Photograph of Micro-Strip Gas Chamber mounted on a mother board with anode- and back-strip preamplifier boards.

Figure 1 shows a photograph of the MSGC, which has a detecting area of 10.24 × 10.24 cm^2. This MSGC was made using Multi-Chip Module technology by Toshiba Corporation, and has 512 anode-, 512 cathode- and 512 back-strips with very fine pitches of 200 μm on a thin substrate of 20 μm (Fig. 2). The space between the drift plate and the substrate is filled with a mixture of Argon-Ethane or Xenon-Ethane gas. Conversion electrons generated by incident X-rays in the gas trace electric lines of force to the anode-strip and induce signals not only on the anode-strips but also on a few back-strips because of the thin substrate. This device can produce two-dimensional X-ray images by detecting both the anode- and back-strip signals, whereas most existent MSGCs can give only one-dimensional position information from the anode-strips.

We also developed a novel high speed readout system based on Complex Programmable Logic Devices (CPLD) on VME boards [6]. Figure 3 shows a block diagram of this new data-acquisition system. All signals from the anode- and back-strips are individually read out as differential ECL signals by IC-boards (64 strips/board) with pre-amplifiers (LeCroy-MQS104) and discriminators (LeCroy-

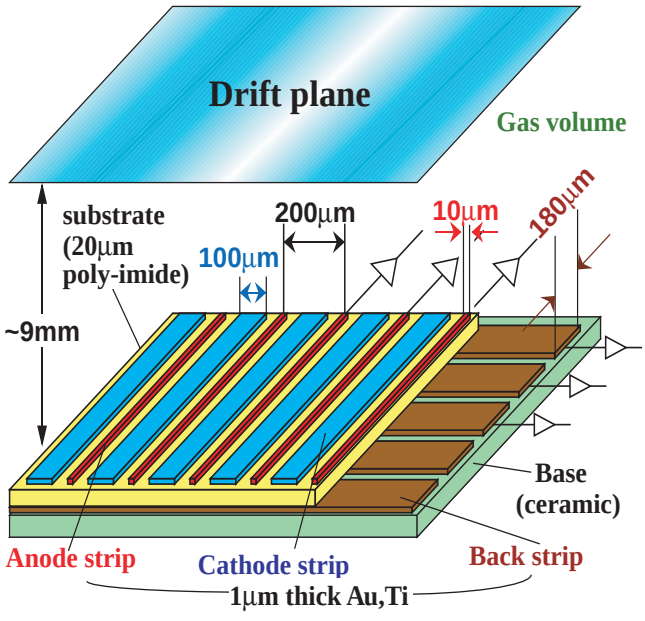

Fig. 2. Schematic of 2-dimensional MSGC.

MVL407). These signals are encoded by the CPLD to *x*- and *y*-positions as centers of upper and lower priority strips. The signals are considered to be multi-events if the distance between the upper- and lower-priority electrodes exceeds seven strips, and are subsequently rejected from further processing. If both anode- and back-strips are hit in the same clock phase, this event is considered to be a valid signal. One X-ray event occupies 32 bits in the present system, consisting of *x*-, *y*-positions, a cyclic timer and trigger flags. These data are saved on a hard disk as event-by-event data after being temporarily stored on a memory board (512 MB maximum). Two-dimensional image data with 1024 × 1024 pixel resolution are reconstructed from the raw data using an on-/off-line analyzer on a Sun workstation. Because the data contains timing information, any time flame data can be reconfigured. This system is operated at 10 MHz allowing the acquisition of time-resolved X-ray images with μsec resolution.

The microstructure electrodes were expected to enable us to obtain good spatial resolution, as well as allow stable operation under intense irradiation. Indeed, some studies have attempted to use the MSGC as a tracking detector in high-energy physics experiments. There still remain, however, crucial problems that prevent the MSGC from stable operation due to discharge of the electrodes and charge-up of the substrate under high-intensity irradiation. In order to avoid the charge-up effect, we introduced a conductive substrate into the MSGC. Thus, an excellent high rate capability of $10^{6\sim7}$ cps/mm^2 has been realized, but the gas gain decreased drastically in this approach.

One solution to the decrease in gain is to insert an intermediate gas-multiplier between the drift plane and the MSGC. To do this, we introduced a capillary plate consisting of a bundle of fine glass capillaries with an inner diameter of 100 μm [7]. Figure 4 shows a cross section of the capillary – MSGC combined system. The capillary plate has a 9.5 × 9.5 cm^2 detection area and a 57% optical opening aperture ratio. Both sides were coated with ~400 nm-thick layer of Inconel metal. Inserting the capillary plate into the MSGC creates three functional volumes: the X-ray conversion region, the intermediate electron amplification region, and main electron amplification region. By simulating the electron trajectory, the electric fields applied to these three regions were determined in such a way that all the electrons generated in the conversion volume could reach the main amplification region passing through the capillary tubes; *i.e.*, the electronic opening aperture is unity.

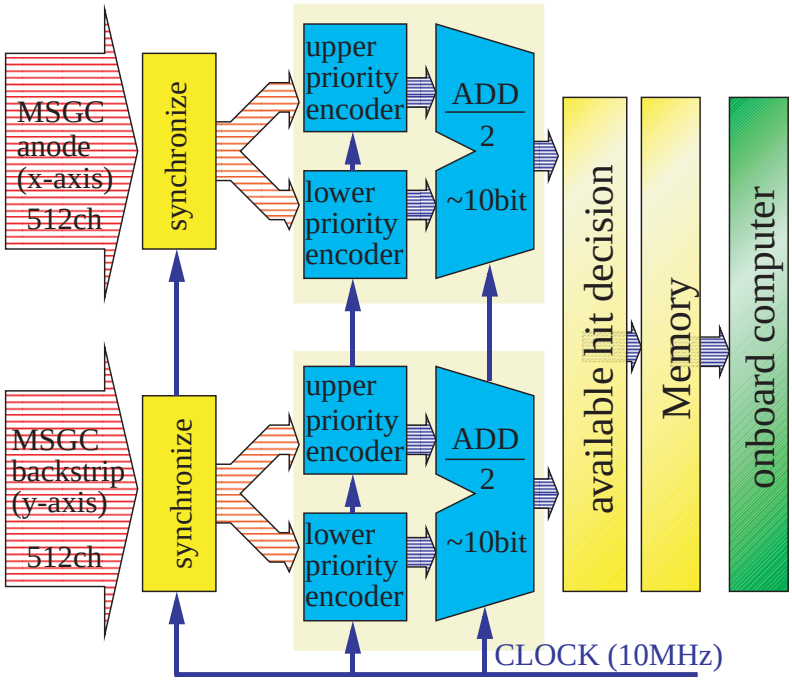

Fig. 3. Diagram of MSGC data encoding.

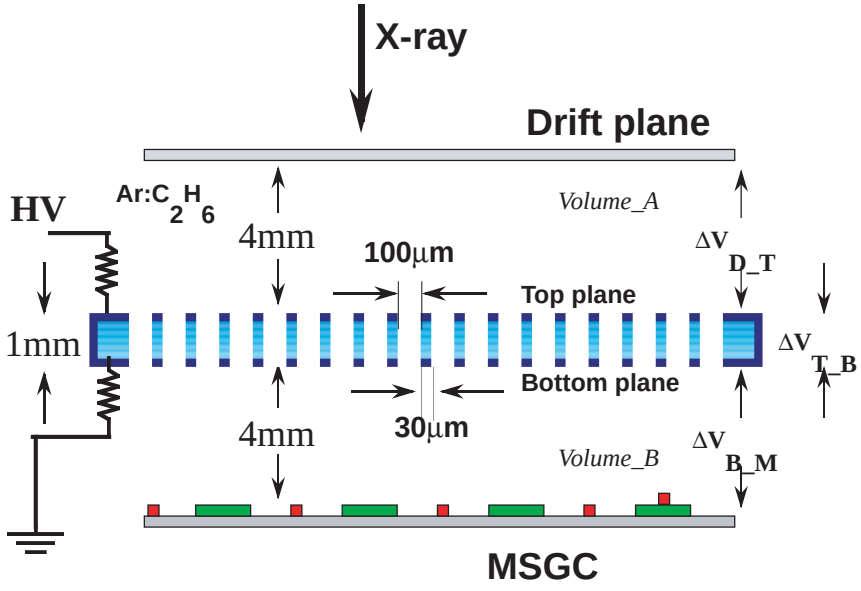

Fig. 4. Schematic of capillary - MSGC combined system.

The high surface resistivity of normal capillaries was predicted to result in unstable gas multiplication under high intensity X-ray irradiation due to the charge-up effect on the capillary surface. As predicted, the X-ray sensitivity of high-intensity regions of diffraction images diminished quickly upon X-ray irradiation. In order to avoid such a charge-up effect, we decided to provide a conductivity to the capillary surface as well as to the MSGC substrate. This process yielded a conductivity of about 40MΩ between the two faces of the capillary plate, resulting in a current of about 25 μA with a supplied voltage of 1 kV. Meanwhile, 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 is on the order of a several hundred times. Therefore, the charge-up effect will be rendered insignificant. This approach dramatically improved the performance of the capillary-MSGC combined system. No appreciable change in the charge gain was observed over several hours.

The measurement of gas multiplication was performed with 8 keV X-rays from a conventional X-ray generator. In this measurement, a mixture of argon:ethane gas (9:1) was used. Direct signal read-out of the capillary plate was difficult because the electric current was less than 30 μA. Therefore, we measured the pulse height spectra obtained from summed cathode signals, which formed double peaks. The higher peak corresponds to the X-rays converted between the drift plate and the capillary plate, while the lower one represents the conversion between the capillary plate and MSGC. The effective gain of the capillary plate successfully surpassed 3000 and was nearly independent of the counting rate up to 10^5 cps/mm^2. In this measurement, small discharges sometimes occurred while operating at higher gains but no short circuit of the capillary plate was observed.

The spatial resolution was determined to be 94 μm (RMS) at 8 eV by measuring X-ray transmission of a test chart, in which a 7:3 xenon/ethane gas mixture was used. When an argon:ethane (8:2) mixture was used, however, poor spatial resolution (280 μm RMS) was observed. The detection efficiency of MSGC at 12.4 keV was simulated by EGS-4 to be 11%,

where the effective thickness of the xenon:ethane (7:3) gas mixture was assumed to be 4 mm. When an argon/ethane (7:3) mixture was used, on the other hand, the efficiency was estimated to be 0.8%. Xenon gas provides better spatial resolution and a higher efficiency than argon gas because xenon has a higher photoelectric absorption coefficient and shorter range of electrons than argon.

In the case of xenon gas, however, it is commonly said that discharges tend to take place. This phenomenon limited the gas gain obtained with xenon by the MSGC alone because of a limited bias voltage. By using the capillary plate as an intermediate electron multiplier for the MSGC, however, a high gas gain was obtained even with xenon gas. The device could be operated stably at a counting rate up to 10^5 cps/mm^2, below which the decrease in gas gain was negligible and strip damage is extremely suppressed. At a result, the first time-resolved X-ray imaging studies using this configuration were carried out at beamline **BL45XU** in July 1999 [8].

Hidenori Toyokawa

SPring-8 / JASRI

E-mail: toyokawa@spring8.or.jp

References

[1] A.Ochi *et al*., SPring-8 Annual Report (1996) 205.
[2] H.Toyokawa *et al.,* SPring-8 Annual Report (1997) 224.
[3] Y.Nishi *et al*., SPring-8 Annual Report (1998), to be published.
[4] T.Tanimori *et al.*, Nucl. Instrum. and Meth. A **381** (1996) 280.
[5] T.Tanimori *et al.*, J. Synchrotron Rad.**5** (1998) 256.
[6] A.Ochi *et al.*, J. Synchrotron Rad.**5** (1998) 1119.
[7] Y. Nishi *et al.*, SPIE Proc. **3774** (1999) 87.
[8] A. Ochi *et al.*, SPIE Proc. **3774** (1999) 76.