

Development of a transparent single-grid-type MSGC based on LCD technology

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Abstract. We are developing a multi-grid-type MSGC based on the liquid crystal display (LCD) technology, which enables a large area and fine structure. Single-grid-type MSGC using transparent electrodes has been fabricated and successfully operated in several different gas mixtures. The use of LCD technology allows us to integrate some simple electronics using thin film transistors. Such an integrated device is our next target. The successful operation of Single-grid-type MSGC is the very important first step for us.

1 Introduction

We are working on the use of microfabrication techniques to the radiation detection for almost 20 years. In this period, we studied on MSGC (MicroStrip Gas Chamber), Glass GEM (Gas electron multiplier), and dedicated ASIC (Application Specific Integrated Circuit). Based on our experience in these individual components of present-day's gaseous radiation detectors, we are becoming aware of the importance of more integrated devices. Many principles of the signal readout method are invented but the difficulty of the application of each principle lies in the interface between the sensor part and the readout electronics. New important topics may even exist in the interfacing itself. Now we re-think about the MSGC. People are almost forgetting about the MSGC [1], however, during these decades, big progress has been made in the microfabrication techniques on the glass, in particular, in the field of liquid crystal display (LCD). Because an essence of the LCD technology is the formation of very precise electrode patterns on a large area glass plate, the LCD technology can readily be applied to the MSGC fabrication. One problem of the conventional MSGC was related to the substrate. The glass substrate isolates the anode and the cathode, however the high resistivity surface of the glass substrate causes a charge-up problem. Although the small-gap MSGC can solve this problem, it cannot operate at high gas gain since the anode and the cathode are too close in this geometry and the surface discharge is unavoidable. We have already shown a new configuration of MSGC using the multi-grid-type electrode structure [2], where the electrodes are not just the anode and the cathode but intermediate electrodes (grids) are inserted in between to stabilize the detector and increase gas gain.

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Also, we demonstrated that the MSGC with transparent electrodes can be operated in an Ar/CF₄ gas mixture. Scintillation light is emitted in this gas mixture [3] in the course of avalanche process, which can be seen through the transparent electrode and the glass substrate. The use of optical signal for position sensing was demonstrated [4]. The LCD technology relies on the transparent electrode such as indium tin oxide (ITO) and indium zinc oxide (IZO), which is favourable for the optical readout. Also, we could integrate some simple electronics with thin film transistors (TFTs) on the glass as already done in most of LCD panels. Thus, in principle, we can integrate all the necessary functions for a gaseous radiation detector with readout electronics on just one glass plate as shown in Figure 1.

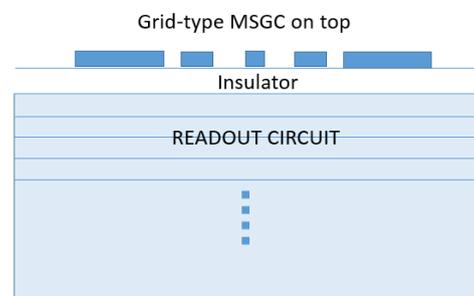


Figure 1. Concept of new generation of MSGC based on LCD technology.

This is definitely compact, efficient, and cost-effective. Besides the optical readout, we can also use induced charge [5], or direct coupling to the MSGC cathode. Based on such an idea, we are intensively working on the development of new generation MSGC. Radiation signals

can be transferred to the integrated readout circuit by visible photons, induced charges, or direct current (see Figure 2). The simplest readout circuit is just a TFT array with integrated capacitance, which is applied to the flat panel detector for medical applications, however, many other possibilities are being considered in our collaboration team. In particular, the signal readout electronics for the gas detector operated at high voltage often suffers from damages caused by spark events. If we use optical signals as the interface from micropattern gas detector to the readout circuit, we are completely free from the damage problem. Besides this, we could also utilize the charge signal.

HOW TO TRANSFER SIGNAL TO THE READOUT CIRCUIT

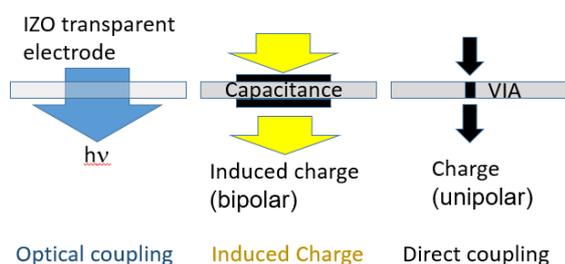


Figure 2. Three different signal readout schemes through the insulation layer. ‘VIA’ means electrical connection through the insulation layer.

Based on such an idea, we are fabricating test MSGCs as the first step to the integrated device. We report some of the initial results in this paper.

2 Design and fabrication of transparent MSGC with a single grid

We have designed a new single-grid type MSGC (S-MSGC) using IZO electrode. Aiming at low energy X-ray imaging applications, we selected a fine pitch of 150 μm . We adopted a single grid inserted between the anode and the cathode as illustrated in Figure 3. The anode and cathode widths were set to 8 μm and 62 μm , respectively. It is equipped with 20 μm wide grid between the anode and the cathode. The grid is biased at an intermediate potential between the anode potential and the cathode potential. The gap widths between neighbouring electrodes are set at 10 μm , maximizing the surface covered with conductive electrodes. All grid strips are connected together to apply a single bias voltage. Figure 4 shows the fabricated test device. The effective area of the test device was 15 mm x 23 mm.

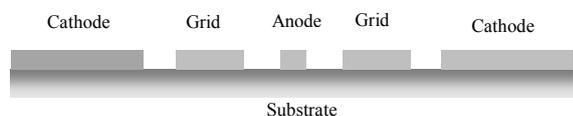


Figure 3. Cross sectional image of the electrode pattern of the designed S-MSGC.

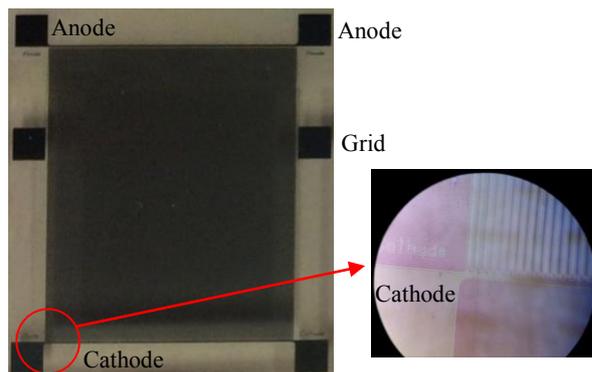


Figure 4. Left: Overall layout image of MSGC electrodes (For visualization purpose, opaque electrodes were used). Right: Microscopy reflection images of IZO electrodes (Near the cathode pad shown in the red circle in the left image). Contrast is adjusted and white part shows the electrode regions.

3 Test of the transparent S-MSGC

3.1 Charge signal measurements

The S-MSGC was tested under different gas mixtures. We have successfully operated our transparent S-MSGC in Ar (90 %) / CH₄ (10 %), Kr (90 %) / CO₂ (10 %), and Ar (90 %) / CF₄ (10 %). The applied voltage was around 400-550 V to the anode and 100-250 V to the grid. The anode strips were connected together and read out by a charge sensitive amplifier. The maximum gas gain was ~500. A clear photo peak was observed for an ⁵⁵Fe X-ray source. Figure 5 shows a result from Kr/CO₂ gas, where the anode was biased at 530 V and the grid voltage was 240 V. Figure 6 shows a result from Ar/CF₄ gas where the anode voltage was 500 V and the grid voltage was 250 V. This is a reasonable performance for the single-grid design.

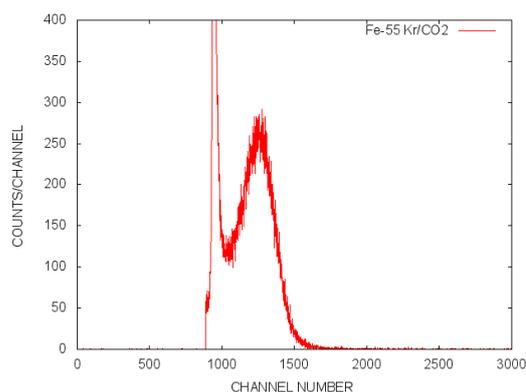


Figure 5. Observed pulse height spectrum for an ⁵⁵Fe source. The fabricated IZO S-MSGC was operated in a Kr/CO₂ gas mixture. The electric charge was read out from the common anode line.

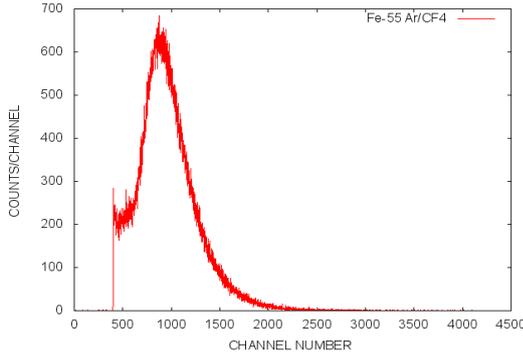


Figure 6. Observed pulse height spectrum for an ^{55}Fe source. The IZO S-MSGC was operated in an Ar/CF_4 gas mixture.

Kr gas shows a higher mass attenuation coefficient between 17 keV and 30 keV than Xe gas. Thus, X-ray diagnostics applications are considered with the Kr gas mixture.

3.2. Optical signal readout

Visible light photons are emitted during the avalanche process in Ar/CF_4 gas. The red light at wavelength around 600 nm is suitable for detection by photodiodes. These photon signals can be used for position sensing and/or pulse height measurement. The cross sectional view of the test setup is shown in Figure 7 and the photograph taken from top is shown in Figure 8 where the IZO electrode pattern is not seen (because of its transparency) and only the Hamamatsu S3590 10 mm x 10 mm effective area photodiode is visible through IZO S-MSGC.

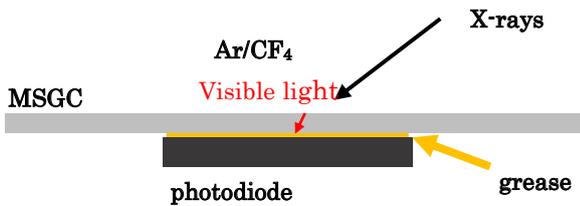
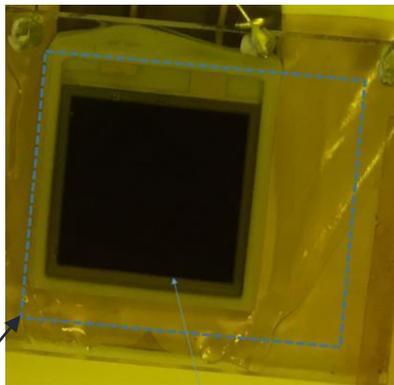


Figure 7. Cross sectional view of the test setup of an optical signal readout



Effective area

Hamamatsu PIN PD

Figure 8. Photograph of IZO S-MSGC with a photodiode.

The anode voltage was 508 V and the grid voltage was 239 V. The bias voltage of the PIN photodiode was 75 V. Figure 9 shows the pulse height spectra recorded from the PIN photodiode for different radiation sources. BG was obtained without the X-ray source and is considered as the noise level of the measurement system. Due to the large size of the PIN photodiode, the noise level of the preamplifier was quite large. Then, the pulse height spectra do not show photo peaks. However, the pulse height distribution shows longer tail for higher energy X-rays. This implies that larger optical signals are obtained when illuminated by higher energy X-rays, which indicates that the optical signal pulse is due to the radiation detection. This result is encouraging because the readout system is just one large PIN photodiode, whose capacitance is about 40 pF. If we utilize a small photodiode such as $150\ \mu\text{m} \times 150\ \mu\text{m}$ in size, the capacitance is much smaller than that of the large PIN photodiode ($10\ \text{mm} \times 10\ \text{mm}$ effective area). Such photodiodes can be integrated just below the S-MSGC pixel of the same pixel size ($\sim 150\ \mu\text{m}$) and this can solve noise problems.

For further optimization of the detector, we are also thinking about the double grid version. Single grid is useful and easy to operate, however, in terms of gas gain, multi-grid design is better. For example, with a test device of two-grid structure, shown in Figure 10, much higher gain was reached. Figure 11 shows a charge spectrum of the two-grid MSGC for ^{55}Fe X-rays. The resolution is significantly improved compared to that of the S-MSGC (Figures 5 and 6). The anode pitch was $80\ \mu\text{m}$ and the anode width was $2\ \mu\text{m}$ in this case. Using the latest LCD process, these parameters can be realized.

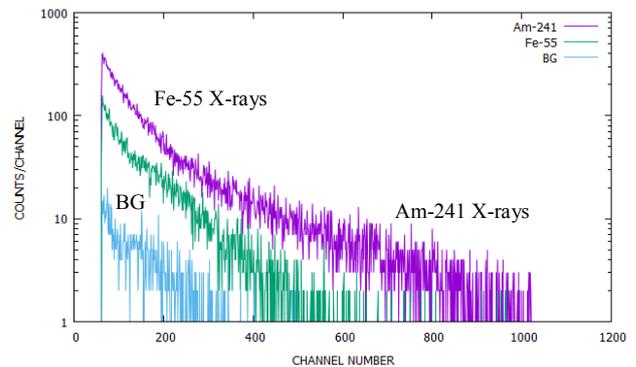


Figure 9. Pulse height spectra obtained with PIN photodiode placed just behind the IZO MSGC (i.e. Optical measurement).

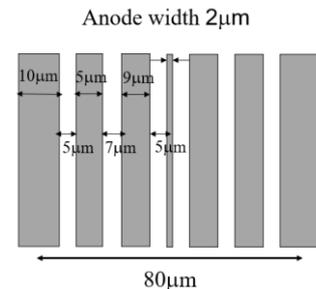


Figure 10. Electrode pattern of a double-grid-type MSGC test device.

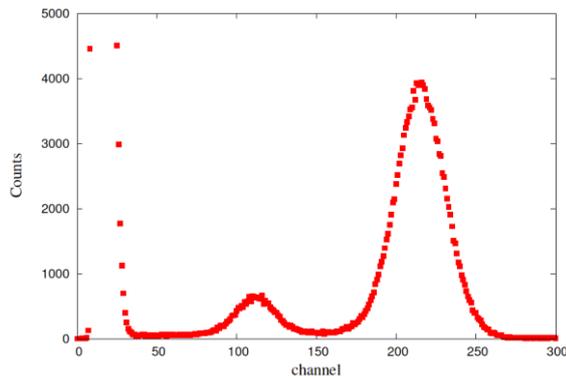


Figure 11. Pulse height spectra of the 80 μm anode pitch double-grid-type MSGC obtained with an ^{55}Fe source.

4 Integration of readout circuits

To take the full advantage of the LCD technology, integration of the readout circuit based on TFTs (Thin Film Transistors) on the same glass as the MSGC is promising. We are currently investigating the possibilities of such an integrated device and developing a circuit component using TFTs. In this approach, the use of an IGZO (indium gallium zinc oxide) is promising. Figure 12 illustrates the TFT characteristics of IGZO for this approach. It provides a very low leakage current or high resistance, which is useful for charge accumulation device. Therefore, multiplexing readout and integrator circuit will be a primary choice in this device. Also, IGZO is typically operated at tens of volts, which means the device is tolerant to the high voltage when a gaseous detector brings a giant pulse or some discharge, and is promising for the direct coupling to the gas detector signal readout.

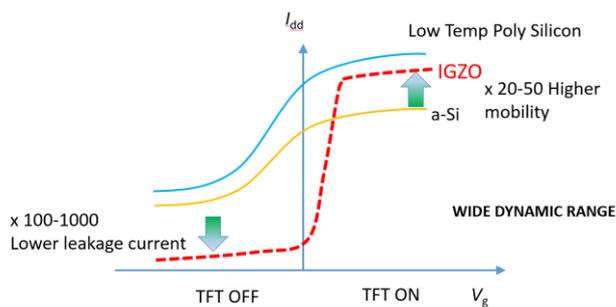


Figure 12. General characteristics of thin film transistor (TFT) available in different process technology.

4 Conclusions

We consider X-ray applications and reconsider the use of transparent multi-grid-type MSGC principle. The LCD technology is very promising for the new generation of MSGCs and the transparent IZO electrodes used in this process can provide a new readout scheme with optical photons. We have fabricated a single-grid-type MSGC (S-MSGC) using IZO. The detector has been successfully

operated and we also measured optical signals by using a PIN photodiode through the glass substrate with Ar/CF₄ gas. Circuit integration on the same glass substrate is being considered. We anticipate that the highly integrated gaseous detector glass plate may find many applications not only for X-rays but also for many other areas.

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