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 circuit using think film transistors. Such an integrated device is our next target but the successful operation of S-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), ASIC(Application Specific Integrated Circuit), Glass GEM (Gas electron multiplier), and etc. Based on our experience in these individual components of present-day's gaseous radiation detectors, we are getting 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 as well. Or new important topics may exist in the interfacing itself. Now we try to re-think about the MSGC. People are almost forgetting about the MSGC [1], however, during these decades, big progresses are made in the microfabrication techniques on the glass, in particular, in the field of liquid crystal display (LCD). This LCD technology is very much compatible with MSGC. One problem of the conventional MSGC was related to the substrate. The glass substrate must isolate 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 . We have already re-invented the new configuration of MSGC using the multi-grid-type electrode structure [2], where the electrodes are not just the anode and the cathode but more intermediate electrodes (grids) are used to stabilize the detector and increase the gas gain. Also, we demonstrated that the MSGC with transparent electrodes can be operated in an Ar/CF_4 gas mixture. Ar/CF_4 gas mixture can emit the scintillation light [3], in the course of avalanche process, which can be seen through the transparent electrode and the glass substrate. Therefore, the use of optical signal for position sensing was demonstrated [4]. LCD technology relies on the transparent electrode such as indium tin oxide (ITO) and indium zinc oxide (IZO), which is favorable 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.

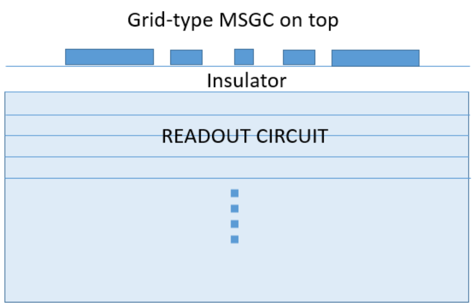

Figure 1. Concept of new generation of MSGC based on LCD technology.

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 new generation MSGC development. 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

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panel detector for medical applications, however, many other possibilities are being considered in our collaboration team.

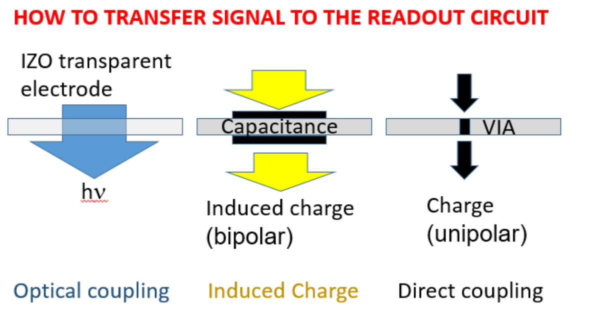

Figure 2. Three different signal readout schemes through the insulation layer.

Based on such an idea, we are trying to fabricate a test MSGC 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 every 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, 62µm, respectively. It is equipped with 20µm wide grid between the anode and the cathode. The grid is independently biased at an intermediate potential between the anode potential and the cathode potential. The gap widths between neighbouring electrodes are set at 10 µm. So, the most of detector surface is covered with conductive electrodes. All grid strips are connected together to apply a single bias voltage. Figure 4 shows the magnified part near the cathode edge. The test device was fabricated. The effective area of the test device was 15mm x 23 mm.

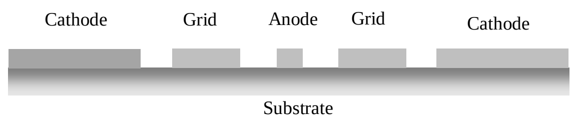

Figure 3. Cross sectional image of the electrode pattern of the designed S-MSGC.

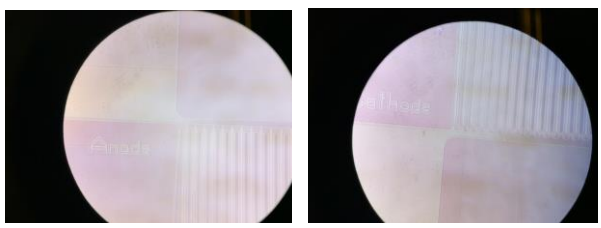

Figure 4. Left figure shows a microscopy image near the anode, right figure shows a microscopy image near the cathode.

3 Test of fabricated transparent MSGC with a single grid

3.1 Charge signal measurements

The S-MSGC was tested under different gas mixtures. We have successfully operated our fabricated transparent S-MSGC in Ar (90%) / CH_4 (10%), Kr (90%) / CO_2 (10%), Ar (90%) / CF_4(10%). The applied voltage was around 400-550 V to the anode. 100-250V to the grid. The maximum gas gain was ~500, however, we could observe a photo peak for an ^{55}Fe X-ray source. Figure 5 shows a result from Kr/CO_2 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 S-MSGC, although we could achieve much higher gain with increasing the number of grids.

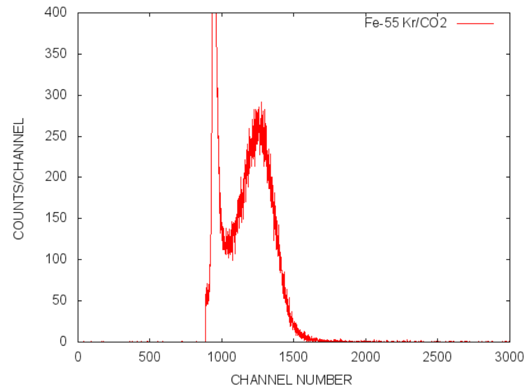

Figure 5. Observed pulse height spectrum for an ^{55}Fe source in a Kr/CO_2 gas mixture.

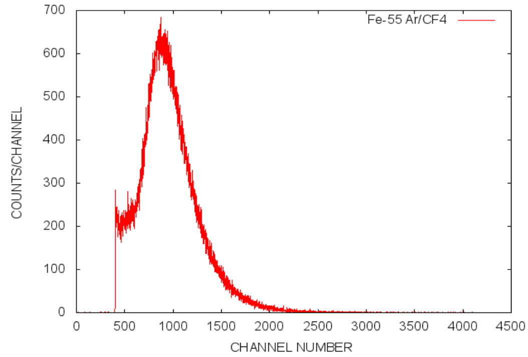

Figure 6. Observed pulse height spectrum for an ^{55}Fe source in an Ar/CF_4 gas mixture.

Kr gas shows a higher mass attenuation coefficient between 17keV and 30keV than the Xe gas. Thus, X-ray diagnostics applications are considered with the Kr gas mixture. On the contrary, visible light photons are emitted during the avalanche process in Ar/CF_4 gas. These photon signals can be used as position sensing and/or pulse height measurement. In particular, the signal readout electronics for the gas detector operated at high voltage often suffer from damage caused by spark events. If we use optical signals as an interface from micropattern gas detector and the readout circuit, we are completely free from the damage problem. Besides this issue, we could also utilize the charge signal, too.

3.2. Optical signal readout

Optical signals can be used for Ar/CF_4 gas mixtures. It emits red light around 600nm and photodiode is suitable.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 10mm x 10mm effective area photodiode is visible through IZO S-MSGC.

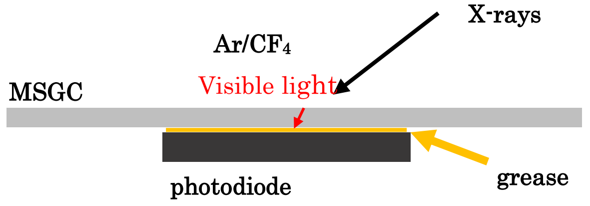

Figure 7. Cross sectional view of the test setup of an optical signal readout

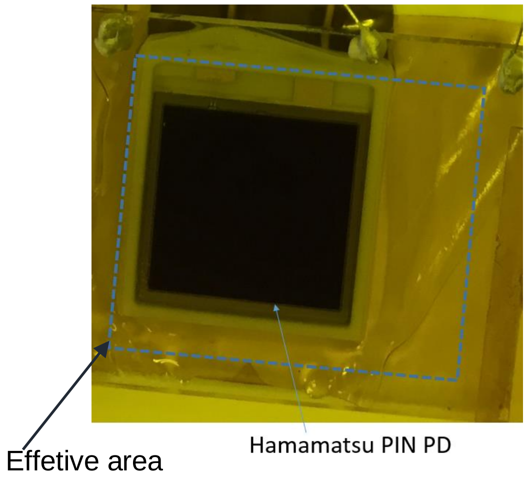

Figure 8. Setup of an optical signal readout

The anode voltage was 508V and the grid voltage was 239V. The bias voltage of the PIN photodiode was 75V. Figure 9 shows the pulse height spectra recorded from PIN photodiode signals for different radiation source. As can be seen from this figure, pulse height distribution is shifted to right according to the energy of the radiation source is increased. This result is encouraging because the readout system is just a large PIN photodiode, whose capacitance is about 40 pF. If we utilize a small pixel such as 150 µm x 150µm, whose capacitance is much smaller than the large PIN photodiode (10 mm x 10mm effective area). The photodiodes can be integrated just below the S-MSGC pixel as the same size of the pixel (~150µm) 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 the gas gain, larger number of grids is better. For example, if we utilize two grids between the anode and the cathode as shown in Figure 10, the pulse height spectra obtained with an Fe source, where a very nice spectrum is obtained as shown in Figure 11. The pitch was selected to 80 µm pitch and the anode width was 2 µm in this case.

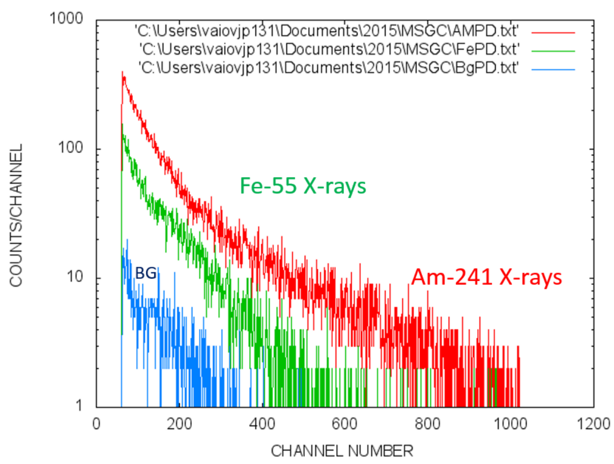

Figure 9. Pulse height spectra obtained with PIN photodiode placed just behind the IZO MSGC.

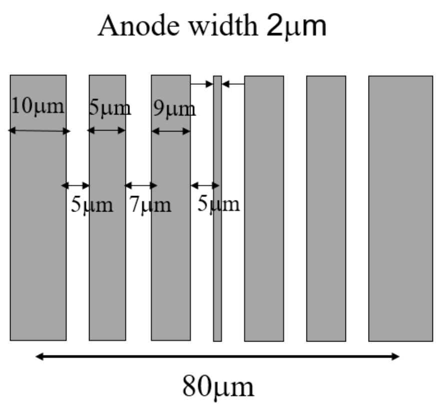

Figure 10. Electron pattern for a double grid type MSGC test device.

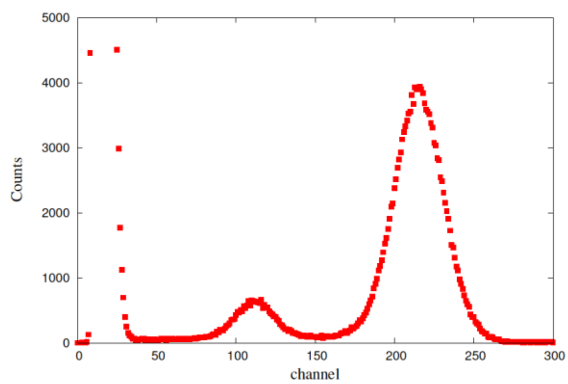

Figure 11. Pulse height spectra obtained with an ^{55}Fe source.

4 Consideration of 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 is promising for the direct coupling to the gas detector signal readout.

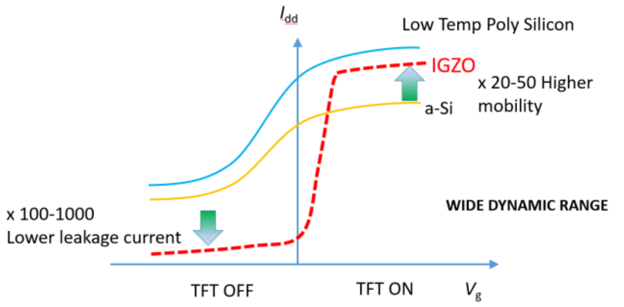

Figure 12. General characteristics of thin film transistor (TFT) available in different process technology.

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 anode width was 8 μm and the anode pitch was 150 μm. The detector has been successfully operated and we also measured optical signals by using a PIN photodiode through the glass substrate with Ar/CF_4 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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