博士論文（要約）

Study on glass based micropattern gas detectors

（ガラス基板を用いたマイクロパターンガス検出器の研究）

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Current health care system are developing rapidly due to the continuous increasing needs. Medical imaging is a very important tool for the diagnostics and screening. Among these, mammography is a very important tool to examine the human breast for diagnosis and screening for the early detection of breast cancer, typically through detection of characteristic masses or microcalcifications.

Although the digital mammography is going to replace the traditional, film-based mammography due to its various advantages, the progress is some years later than in general radiology, mainly because of the significantly increased expense of the equipment. There are two methods of image capture used in digital mammography that represent different generations of technology, which are the direct conversion scheme using photoconductors that permit the conversion of incident X-rays into signal charges and the indirect conversion scheme using scintillators that convert incident X-rays into optical photons. However, amorphous materials used in the direct conversion for the large area detectors suffers from the incomplete charge collection and large fluctuations due to charge trapping and de-trapping of charge carriers by various traps or defects in the bandgap. And the scintillators used indirect conversion for X-ray require high efficiency, large light output and large resolving power. But the organics (molecular) scintillator is inefficient for X-ray and inorganics (crystalline) is expensive. Both the semiconductor and the scintillator are expensive for large area detectors.

Usually in the application of computed tomography (CT) gaseous detectors are not preferred because its lower sensitivity and lower attenuation coefficient for the X ray of 60~70keV than the solid detectors. But the typical X-ray energy in the mammography is around 20keV for which the sensitivity and attenuation coefficient of gaseous detector is enough. And this make the application of gaseous detectors in mammography practical.

The widely used Liquid Crystal Display (LCD) technology is able to fabricate large area display with very low cost. This technology intends to integrate many fine pixels as to ~100μm on one device, which is compatible with micro pattern gaseous detectors such as micro-strip gaseous chambers (MSGC). Nowadays the LCD technology is able to fabricate the very fine pixels, thin electrodes and switching amorphous transistor on the same glass. If we can integrate the electrodes micro pattern, and readout electronics for a gaseous radiation detector on one glass plate, we can acquire a detector with characteristics like compact, large-area, cost effective, efficient for the low energy X-rays. So this detector is promising as a large-area imaging device, especially for the mammography. As a glass based

MPGD, we can expect it have other characteristics like high output with high gas gain, good spatial resolution, and non-outgassing for sealed operation.

The objectives of this research are to propose and develop a glass based MSGC fabricated by the LCD technology for the detection of low energy X-rays of digital mammography imaging, which will have advantages over semiconductor and scintillator detectors in that large-area cost effective, high output, and compact design.

In our work, two different design of the MSGC structure were designed and fabricated by the LCD technology. The first detector is a MSGC detector fabricated by the LCD technology with transparent electrodes. To avoid sparks damaging the electrical readout, we used optical readout for indirect coupling. In the concept design, all the detector components was integrated on one glass plate. The MSGC use a transparent IZO electrodes to let the photons pass through. One the other side of the glass substrate, a photodiode array and TFT array collect the optical photons through the glass substrate. Since the MSGC provide an amplification of the signal, the light yield will be enough to be collected by the photodiode.

In this approach, a MSGC with IZO electrodes was designed and tested shown in figure 1. With a single grid structure, it shows good energy resolution for the electrical readout. and the gas gain is around 150 which is reasonable for the design. For the optical readout, we used a MPPC to collect the photons because of the relative lower gas gain. And the photon energy resolution is also good even not as good as electrical signals. The light yield we calculated is comparable to other's work with similar condition.

This showed that the fabrication process of IZO electrodes by LCD technology seems be able to fabricate MSGC with 8um structure, which would work as a large-area cost effective, and high output and compact detector after combined with the TFT photodiode array.

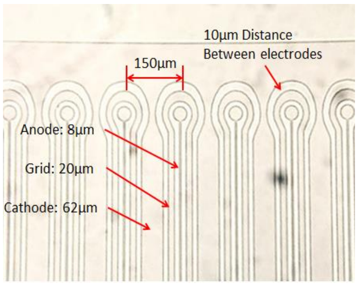

Figure 1 micro pattern of the MSGC

Figure 2 Damaged grid due to sparks

Although the current version have problems of lower gas gain and low robustness due to the cascade design of grid, with the future optimization of multi grid design and parallel grid design, these problems will be solved.

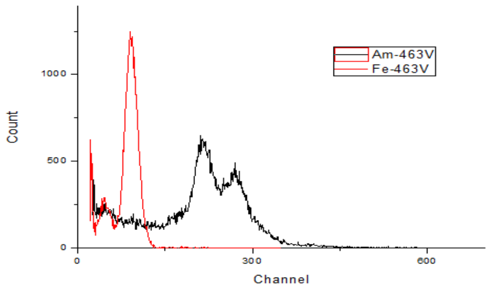

Figure 3 electrical readout of MSGC

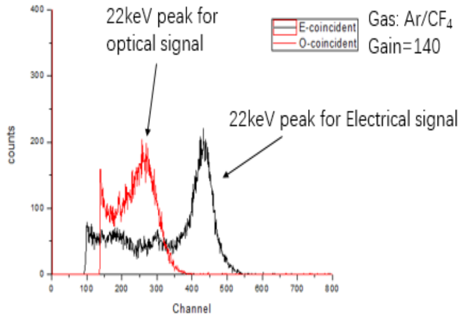

Figure 4 opical readout of MSGC(^{109}Cd)

The second detector is a MSGC detector fabricated by the LCD technology with direct electrical readout. The advantages of this approach is that readout out electronics can be integrated on the glass using IGZO TFT technology to increase the signal to noise ratio. A multi-layer cross-strip detectors with the IGZO TFT preamplifier on the same glass was designed and tested. This detector can achieve the gas gain of 870, and have a 2D readout for imaging , which is able to be adjusted flexibly as shown in figure 7. The insulator of the fabricated process can stand over 800V which is more than expected and encouraging. This detector seems also a a large-area cost effective, and high output and compact detector although sometimes suffer from the sparks damaging problems.

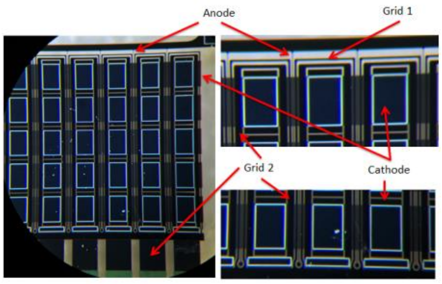

Figure 5 photo of Cross-strip MSGC

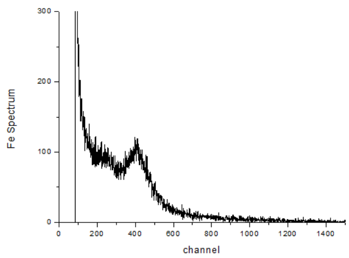

Figure 6 electrical readout of ^{55}Fe source

The third approach is using a hybrid structure contain a glass GEM and a glass MSGC to compensate the lower gas gain of MSGC. In this hybrid structure, we have achieved a gas gain of 10^6 without losing much complexity of structure. The first step test showed that the hybrid structure can increase the gas gain one or two order easily by just increase the HV voltage to a certain value, without any other change in the configuration as shown in figure 8.

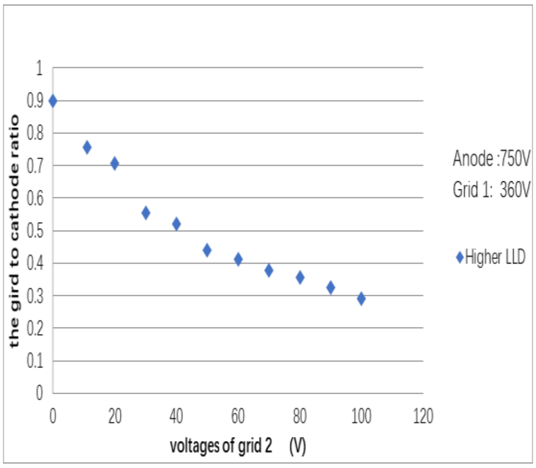

Figure 7 pulse height ratio of 2D readout

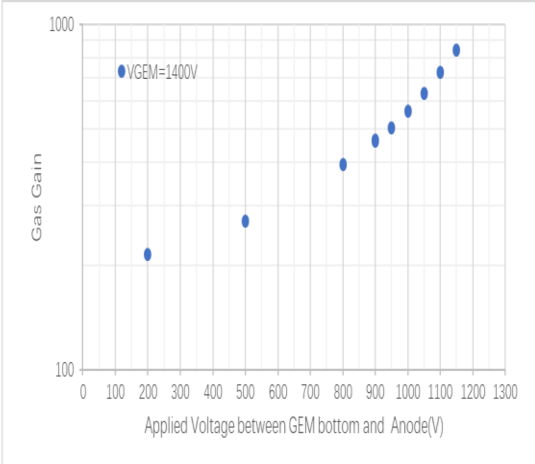

Figure 8 additional gas gain due to PPAC

The next step is a test of the structure which contains a glass GEM and a glass MSGC to compensate the lower gas gain of MSGC. In the hybrid structure, a gas gain of 10^6 can be expected without losing much complexity of structure. Since the glass GEM and glass MSGC both large area available, the hybrid structure can be easily equipped by large-area cost effective detectors without increasing much complexity of the structure.

In summary, we have investigated the glass based MSGC and glass GEM's application as a large-area cost effective, high output and compact detector for the mammography. Both substrates work well, which means the LCD technology fabrication process is able to fabricate as thin as 8um electrode with good enough performance to work as micro pattern gaseous detectors. The IZO MSGC was tested using compact optical readout design. Even though the single grid design cannot stand too high voltage and the gas gain is just around 150, the electronic signal showed good energy resolution. the photon generation efficiency is 750ph/MeV and 0.02photons/electron. A multi-layer MSGC with 2D electrical readout was tested and characterized. The gas gain of the substrate achieved 870. The charge division ratio of electrodes was measured. And individual readout for 2D imaging was prepared. Glass GEM coupled with parallel plate structure was also investigated in this work. It showed that it's possible to achieve 10^6 gas gain with single stage in this setup.