MPGD R&D Activities in JAPAN

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Abstract.
Micro Pattern Gaseous Detector (MPGD) is one of key technology for fine particle tracking and imaging. Some part of recent MPGD R & D activities in Japan are reviewed.

1. Introduction

Micro Pattern Gaseous Detectors (MPGDs) are a relatively new kind of particle detector, which are based on gaseous multiplication using micro pattern electrodes instead of wires in wire chambers. The first MPGD; Micro Strip Gas Counter (MSGC), was invented by Anton Oed in 1988 [1], after that many type of MPGDs have been proposed. At the end of the 1990's, technical break-throughs were brought by invention of the GEM and the Micromegas [2, 3]. Those new two types of detectors were used in COMPASS as the first MPGDs in high energy physics experiments [4, 5], which achieved great success. Nowadays, more various types of MPGDs (e.g. MHSP, μ-PIC, THGEM,) are being actively developed [6, 7, 8]. These technologies allow for detectors with unprecedented spatial resolution, high-rate capability, large sensitive area, operational stability and increased radiation hardness. A large number of groups worldwide are developing MPGD devices for future experiments at particle accelerators, for experiments in nuclear and astroparticle physics, as well as for industrial applications such as medical imaging, material science, and security inspection.

The MPGD developments in Japan is very active as well as in Europe. From the early 1990's, the MSGC and capillary plate was developed for X-ray imaging and particle tracking [9, 10]. The μ-PIC is originally invented in Japan at 2001[7], and it is using for many type radiation imaging detector now. Recently, many scientific groups develop and/or apply the MPGD for particle/radiation detector in Japan. More than 70 participants are joined to annual Japanese MPGD workshop, which has been held since 2004. In this article, the activities related on MPGDs are reviewed as it was presented in CYGNUS2013.

2. MPGD applications

There are many aspects on MPGD applications in Japan. Using the high rate capability, time resolved X-ray imaging were realized by Kyoto Univ. using μ-PIC and GEM as shown in figure 1(a). The figure 1(b) shows small angle X-ray diffraction pattern. using this detector. Very wide ($\sim 10^5$) dynamic range can be displayed by using high speed data acquisition system [11].

Time resolved imaging is also very useful for neutron imaging. KEK group has been developing time resolved neutron radiography systems using GEM with Boron (figure 2(a)). The neutron spectroscopic imaging are available in spallation neutron source, for separating timing

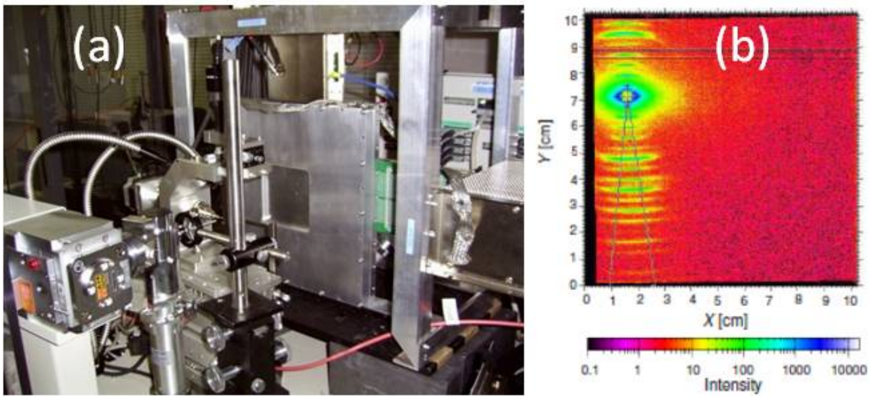

Figure 1. Picture of the time resolved X-ray imaging detector using μ-PIC (a), and the X-ray small angle diffraction image using synchrotron radiation (b). [11]

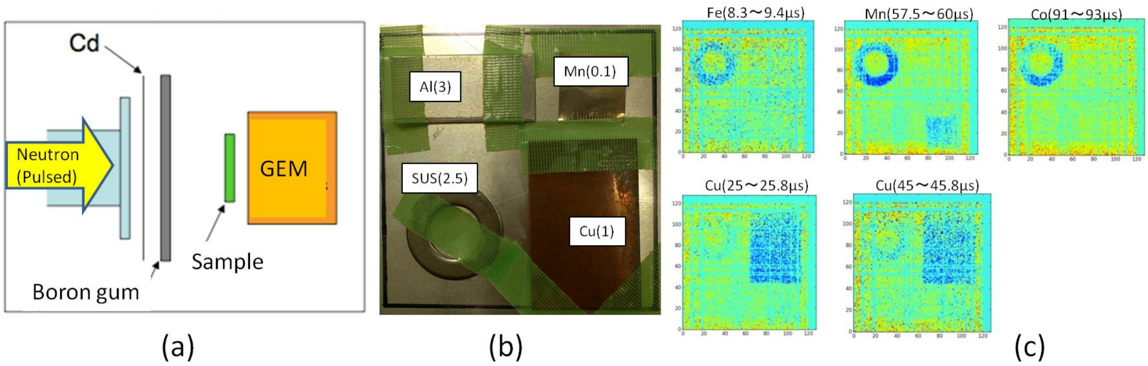

Figure 2. Neutron radiography using boron GEM at KEK (a). The sample with different metal on one sheet (b) is set in front of the GEM. The neutron pulse from spallation source is arrived at sample with time distribution, which correspond to neutron energy. Differences of neutron absorption spectrum for each elements are observed time resolved neutron imaging as shown (c).

window, that correspond the neutron time of flight. Figure 2(c) shows the neutron transparent image of sample (figure 2(b)). The different images of each time window correspond to different neutron energy [12].

The MPGD properties of both fine position and timing resolutions make possible the small time projection chambers (TPCs), by which sub-millimeter size of charged particle are traced. Using the "fine" TPCs, gamma ray camera, fine neutron imaging and dark matter wind detector are developed using combination of GEM and μ-PIC. The gamma-ray camera is realized by ETCC (Electron Tracking Compton Camera) method. Figure 3 shows the schematic principle of operation of ETCC. The arrival directions of incident gamma-ray (from several hundred keV to several MeV) can be resolved by measuring both Compton scattered gamma-ray (energy and position) by scintillator and track of recoiled electron by small TPC. Those cameras are developing for the field of gamma astronomy and medical imaging in Kyoto University. [13, 14]. Fine neutron imaging is realized by observing proton and triton tracking which is produced by n(^{3}He, T)p reaction in small TPC. Figure 4 shows transparent image of the wrist watch [15]. For dark matter search, it is thought that trajectories of recoiled nucleons by WIMP can be observed using small TPC. Details of this type experiments will be described in other articles in this proceedings.

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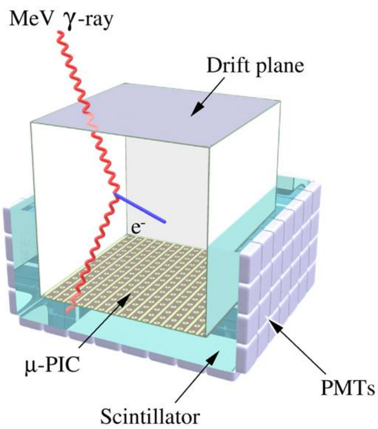

Figure 3. Schematic principle of operation of ETCC method using μ-PIC and scintillators. Both scattered gamma and recoiled electron track are measured at one event. Then, incident direction of gamma-ray can be resolved.

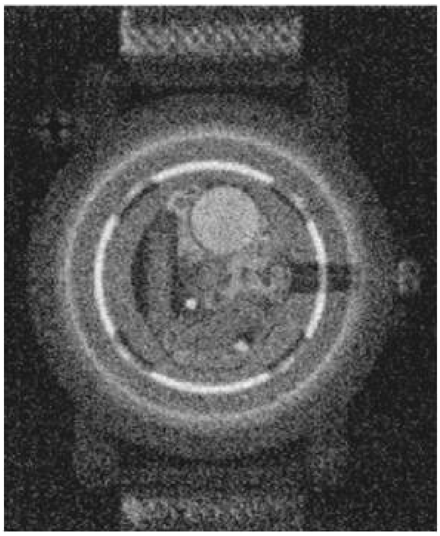

Figure 4. Fine neutron imaging demonstrated by transparent imaging of the wrist watch. This picture was obtained by μ-PIC micro TPC with ^{3}He gas.

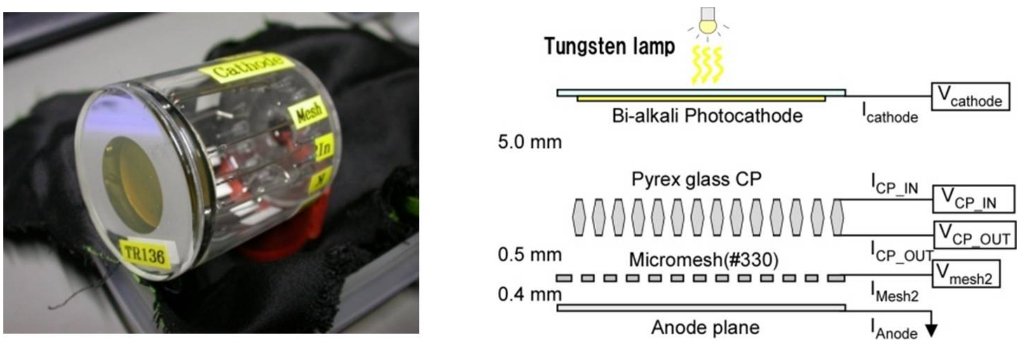

Figure 5. Picture of gaseous PMT and schematic principle of operation, which is developed in Yamagata Univ., TMU and HAMAMATSU. Photo electrons in gas are multiplied by glass capillary and metal mesh.

Not only the particle imager/tracker, photo detection is one of topical application of the MPGDs. The gaseous PMTs using micro mesh and glass capillary plate are developed by Yamagata Univ., TMU and HAMAMATSU group (Figure 5) [16]. Large effective area with moderate position and timing resolution has been achieved, and also it can be easily operated under a very high magnetic field. This type of photodetector is promising for holding good properties of both conventional PMTs and semiconductor detector.

3. Material studies for MPGD

Nevertheless the MPGD has already been used for many applications, many requirements are remained for future experiments. One of most critical problem is spark problem between the electrodes. It is well known that the occasional discharges are invoked when the total electrons (primely electrons times gas multiplication) exceed 10^{7-8} in one event, which is called as "Raether limit" [17, 18, 19]. Those sparks can potentially damage the electrodes. A number of sparks (for some situations, only one spark) makes the conductive path between HV electrodes

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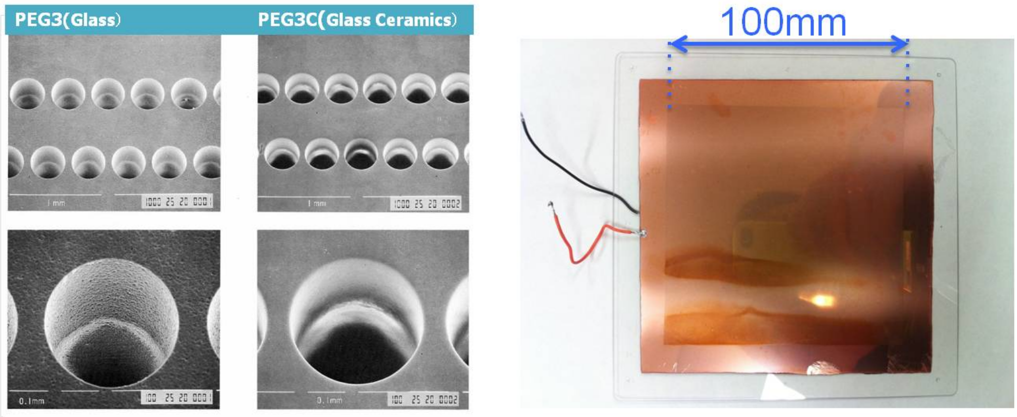

Figure 6. Microscopic picture of small holes and over view of glass GEM. Those are fabricated by using PEG3 glass provided by HOYA corp.

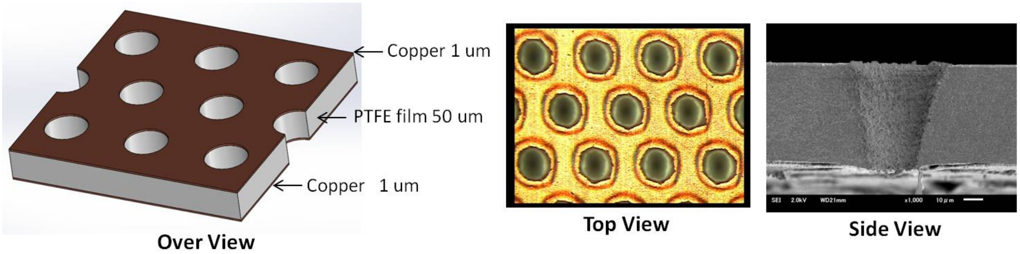

Figure 7. Schematic view and microscopic views of PTFE GEM. Substrate is made from PTFE with 50 μm thickness, and the holes are drilled by laser.

on the substrate, and it cause permanent damage to the detector.

There are mainly two way to solve the discharge problem. One is to make the MPGD substrate for holding tolerances against the sparks. Another one is to make the MPGD electrodes for reducing damage from sparks. Those researches and developments are under intense investigation by some of Japanese MPGD group with unique method.

For the substrate of the MPGDs, the polyimide has been used conventionally in many cases because of the tolerance to the high voltage, radiation and heat. Also machining performances are rather good for making micro pattern. However, since polyimide is made from organic material, it can be carbonized by sparks on the surface. Therefore, there are researches for using substrate with non carbonized material.

Univ. of Tokyo group has made the GEM substrate by special glass. Their material is photo-etchable, called PEG3, made by HOYA cooperation. Figure 6 shows the microscopic picture of small holes and over view of glass GEM. They have made GEM (THGEM) with thickness of 680 μm and hole diameter of 170 μm using PEG3. The maximum gas gain is attained to close to 10^5 under Ne/CF_4 (90:10) mixed gas. This glass is not only non-organic material, but also outgas free, then it is expected to use for sealed gas application.

Tokyo IRI and RIKEN group has developed GEM with PTFE (polytetrafluoroethylene) substrate. They made the holes by laser drilling, and form the electrodes by copper sputtering. Thickness of the substrate is 50μm, which is same as standard (conventional) GEM. Figure 7 shows schematic view and microscopic views of their PTFE GEM. Their preliminary tests show the gas gain of more than 2×10^4, which is about 10 times grater than conventional GEM with same substrate thickness. The most characteristic property of this GEM is the tolerance to the sparks. No damages were observed by more than 20000 sparks in 20mm $\times$ 20mm prototype.

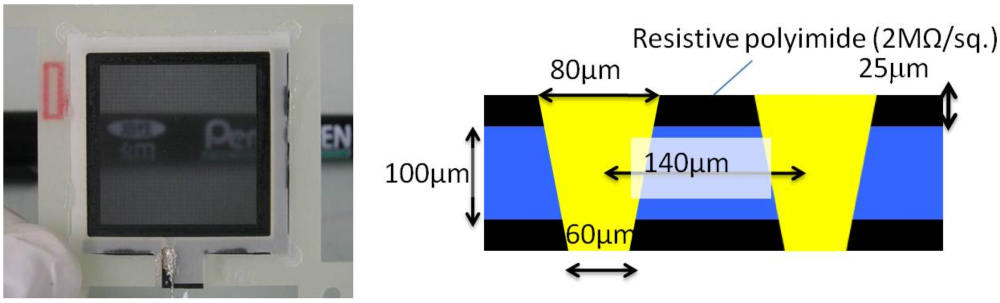

Figure 8. Overview of resistive GEM and its schematic structure.

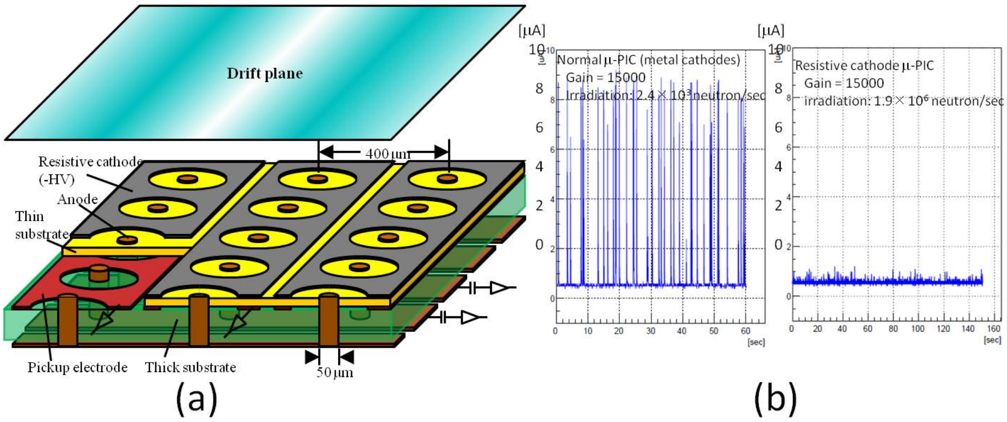

Figure 9. Schematic structure of resistive μ-PIC (a), and spark monitor under intense neutron for both resistive and conventional μ-PIC. Note that the neutron intensity in resistive one is about 10^3 times greater than conventional one.

4. Resistive electrodes

The damages by sparks are not only the detector structure, but also readout electronics and operation condition while HV recovery. It cause long dead time for detection. To reduce the influence of the spark, there are researches to make the electrodes with resistive material.

RIKEN group has developed GEM foil with resistive electrodes, those are replaced from conductive layers[20]. Figure 8 shows picture of resistive GEM and schematic structure. The resistive electrodes are made from carbon loaded polyimide foils, and those are attached to LCP foils of 100μm thickness on double side. The holes are drilled by laser with conical shape of 60-80 μm diameter. It was the first resistive GEM with attaining high (> 300) gas gain.

The μ-PIC with resistive electrodes has been developed at Kobe University group [21]. As shown in figure 9(a), cathode electrodes are replaced with resistive material, which is made from carbon loaded polyimide. The signals are read both from anodes and pickup electrodes, those are lied under cathode via insulator. The spark between anode and cathode is strongly suppressed due to voltage drop on resistive cathode. Figure 9(b) shows anode HV current monitor under intense fast neutron (up to $\sim 10^6$ neutron / second) of resistive μ-PIC and conventional μ-PIC. Spikes in this graph mean the sparks. From these test results, the spark rate of resistive μ-PIC was reduced 10^{3-5} times comparing with using conventional μ-PIC.

The MicroMEGAS with resistive anodes are developed for LHC upgrade at Kobe Univ. and ICEPP. The signals are read as a induced charge by readout strips those are printed under substrate. Figure 10 shows the schematic structure of MicroMEGAS with sputtered electrodes, and the figure of detector (without gaseous vessel). It should detect the MIP (muon) under intense HIP particles. Strong reduction of the spark probability is essential, and this type of

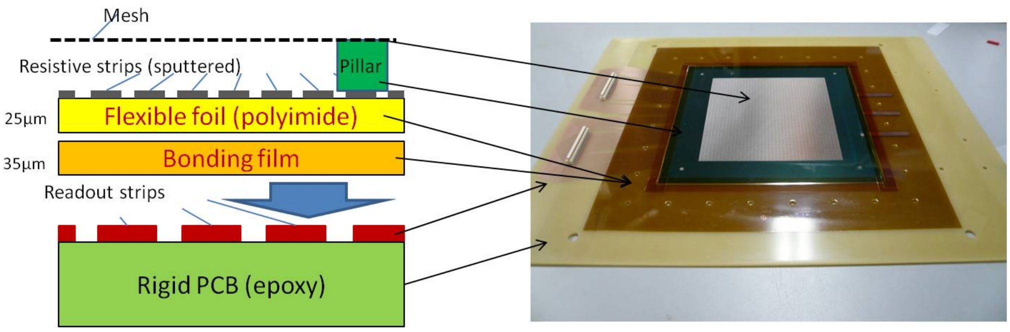

Figure 10. Schematic structure and picture of resistive MicroMEGAS, which is developed as a prototype of ATLAS upgrade. Resistive layer is formed by carbon sputtering on the polyimide.

resistive MicroMEGAS have shown very promised results in many tests. For using this as a part of ATLAS detector, it is also necessary to establish the way for making large size with low cost. Kobe and ICEPP have developed two new production methods for resistive strips. One is screen printing, and another is carbon sputtering. Screen printing makes rather rough patterns, however the very low cost is available in production. On the other hand, sputtering with lift off method makes very fine patterns, and resistivity control is also accurate (within 10% at 500kΩ/sq.). The production cost is moderate, but it is higher than the screen printing.

5. Summary

The MPGD researches and developments are growing up in Japan. Both application developments and basic detector studies are very active. The variety type of MPGDs are developed in various field of science and technology with their original ideas. Especially, the material studies of substrates and electrodes are growing recently, and those studies will be expected to open the new field of experimental physics. I would also like to remark that the introduced works are only some part of Japanese MPGD activities. There are many other attractive MPGD studies in Japan.

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