Large area thermal-bonding Micromegas used in high pressure gaseous TPC of PandaX-III experiment

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Abstract: The PandaX-III experiment, located at the China Jinping Underground Laboratory II (CJPL-II), currently employs a TPC filled with 10 bar ^{136}Xe gas to investigate neutrino-less double beta decays . The readout plane of the TPC is comprised of 52 thermal-bonding Micromegas detectors, each measuring 200×200 mm². Significant improvement has been made in the research on the Micromegas. It is the first large-area gaseous detector operating in high-pressure gas with high gain up to 10^4, low radiopurity background and good energy resolution with 20% @ 5.9 keV in 10 bar Ar/Iso (97.5/2.5). Now, more than 52 micromegas detectors had been produced and the detector assembly was completed.

1. Introduction

Thermal-bonding method provides a concise and etching-free mass-productive process to fabricate Micromegas-like detector [1]. 52 Micromegas detectors, each measuring 200×200 mm², are used to construct the readout plane of the TPC in the PandaX-III experiment.

To meet the experimental requirements, all detectors are required to operate with good energy resolution and stability, as well as low radioactivity in 10 bar ^{136}Xe. The improved manufacturing process and the corresponding test results will be show in the poster.

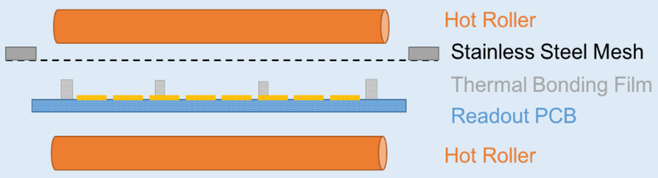


Fig 1. Schematic diagram of thermal-bonding method

2. Radiopurity

To maintain a low radiopurity background, flexible printed circuit boards (PCBs) and other low-radioactivity materials are utilized in the production of Micromegas. Given that the radioactivity of oxygen-free copper is extremely low, the overall radioactivity of the Micromegas detector is determined by summing the radioactivity of the other four main materials. And the radioactivity level is comparable to that of Microbulk Micromegas.

Fig 2. Schematic diagram of structure and corresponding materials of thermal-bonding Micromegas.

Table 1. Radioactivity test results of thermal-bonding Micromegas.

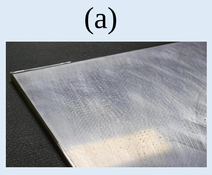
Unit: μBq/cm²

Sample	^{232}Th	^{238}U	^{40}K	^{60}Co
PCB	0.91±1.42	0.28±0.55	22.6±9.07	0.37±0.31
SS wire mesh	0.24±0.12	0.08±0.04	0.69±0.58	<0.02
Film	1.00±0.33	11.57±1.57	1.67±1.28	<0.01
Epoxy glue	1.40±0.75	0.05±0.25	<0.02	<0.03
Total	**3.55±1.64**	**11.98±1.68**	**24.96±9.18**	**0.37±0.31**
Microbulk-Micromegs	**<9.3**	**26.3±13.9**	**57.3±24.8**	**<3.1**

3. Gain and stability

The resistive Ge layer contributes to improved stability [2]. Thanks to lower spark frequency and better stability, the gain of Micromegas can reach as high as 10^4 in 10 bar gas. when operating in the PandaX-III experiment, the gain is typically on the order of a hundred, at which level the detectors exhibit excellent stability.

(a)



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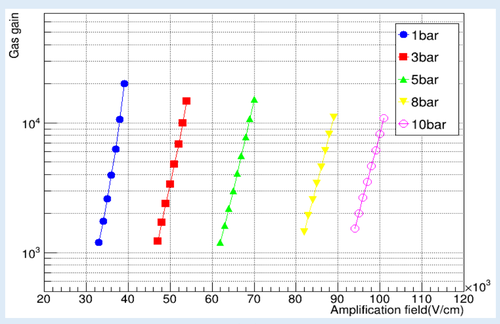
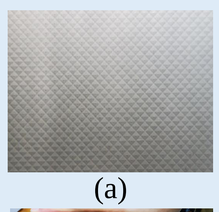


(c)

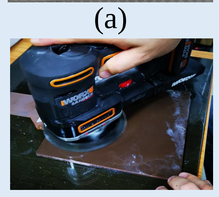
Fig 3. (a) Lab for Ge plating. (b) Ge layer on PCB.
(c) Gain of Micromegas in Ar/Iso(97.5/2.5) gas mixture.

4. Energy resolution

Although the flexible PCBs contribute to low radiopurity, the uneven surface of them also makes the energy resolution worse. A straightforward method is to polish the PCB using sandpapers to make their surface smooth to optimize the energy resolution. After the polishing process, the energy resolution of Micromegas is about 20% @5.9keV in10 bar Ar/Iso(97.5/2.5) gas mixture.



(a)



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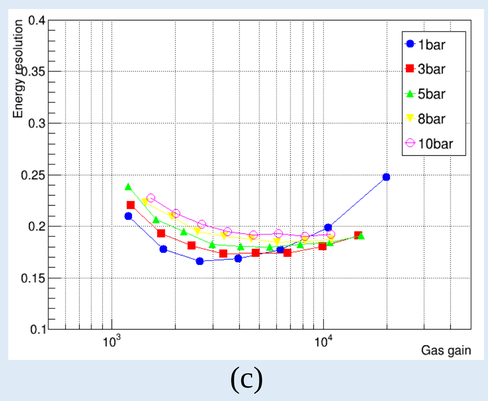
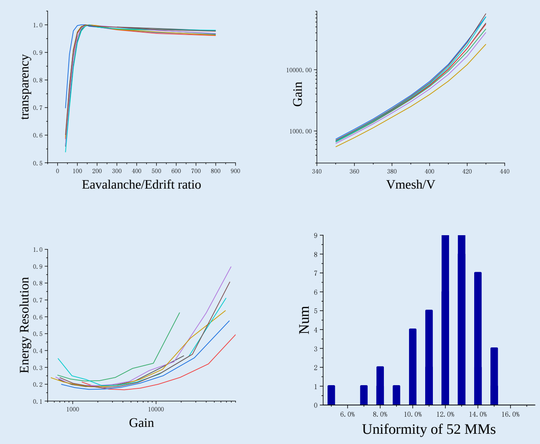


(c)

Fig 4. (a) Uneven surface of flexible PCB.(b) Photo of polishing.
(c) Energy resolution of Micromegas in Ar/Iso(97.5/2.5) gas mixture.

5. mass production and assembly of Micromegas

A fabrication process optimized for mass production of the Micromegas was developed, and more than 52 micromegas detectors had been produced. They operated with similar performance. Up to now, 52 detectors had been installed in the full TPC of PandaX-III.



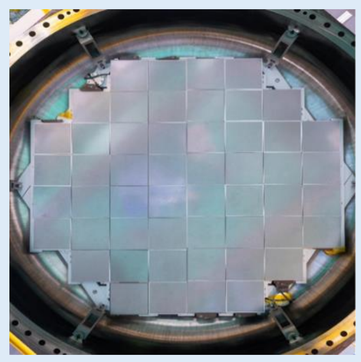


Fig 5. (a) The test results of transparency, gain, energy resolution and uniformity of Micromegas detectors.(b) Assembly of 52 detectors.

6. Conclusions and outlook

Great progress had been made in the investment of thermal-bonding Micromegas used in PandaX-III. More than 52 detectors had been produced and the assembly of detectors was completed. Currently, an improved version of the Micromegas, characterized by lower radioactivity and enhanced stability has been developed and is scheduled for installation in the upcoming upgrade of PandaX-III.

References

[1] Jianxin Feng, Zhiyong Zhang, et al. *A thermal bonding method for manufacturing Micromegas detectors*. Nuclear Inst. and Methods in Physics Research, A 989 (2021) 164958.
[2] Jianxin Feng, Zhiyong Zhang, et al. *A novel resistive anode using a germanium film for Micromegas detectors.* Nuclear Inst. and Methods in Physics Research, A 1031 (2022) 166595.