A Self-powered semiconductor alpha-ray detector for a harsh environment

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1. Introduction

SiC is known as a useful material for radiation-resistance electronics, high—temperature electronics and high-power/frequency device. Radiation detector based on semiconductor with large band energy gap is the most promising for an ionizing detector in the field of the harsh radiation environment. For the purposes of radiation hard detector, the large band gap and low leakage current is important parameters. In the harsh environment like nuclear spent fuel management, alpha spectrometry in vacuum was known to be given good resolution to be sufficient to separate isotope abundance in nuclear material. However, it takes long time to get the result in filed like spent fuel treatment facility. The main disadvantage is the alpha spectrometry is come from the nuclear material loading and unloading process in vacuum, even though the result is sufficient enough. Therefore present study is focused on the radiation detector development of high resolution alpha-particle detector applicable in air and room temperature without external power supply.

2. Methods and Results

2.1. Detector Fabrication.

Detector structure has been fabricated by n-type 4H-SiC wafer produced by Cree Co., which has an orientation of (0001) on-axis and a diameter of 50.8mm and a thickness of 0.350mm. Schottky structure was fabricated based on a n-type wafer with a 0.5um buffer layer and a 5.12 um rare doped layer. The dimension of the 4H-SiC SI bulk detectors is 10x10mm with a 388micron thickness.

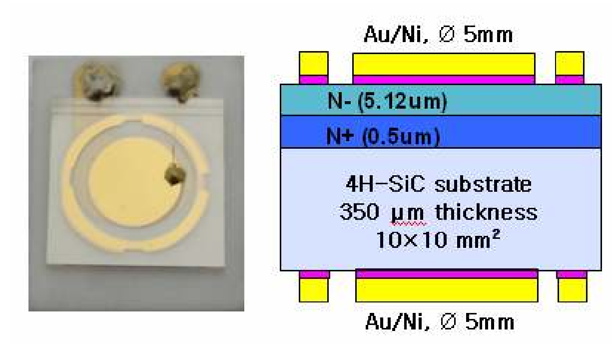

Figure1. Photos and structure of the fabricated SiC schottky structure detector.

The 4H-SiC detector was prepared using the standard processes; dicing with diamond saw, and etching by H_2SO_4 and H_2O_2 solution and H_2O_2 , H_2SO_4 and H_2O_2 solution, and rinsed with de-ionized water, and the removal of an oxidation layer by a HF solution. Metal contacts to extract electric charge from SiC were fabricated on the surfaces by using a thermal evaporator operating in 10^{-6} Torr vacuum. The metal contacts consist of a Au layer on a thin Ni inter-layer. The thickness was monitored by thickness gauge. The detector was mounted on the Epoxy substrate with electric signal readout by using conductive epoxy.

2.2. Experimental Procedures

Alpha response with energy resolution at room temperature and in air was measured by using an Am-241 alpha-ray source with an energy of 5.5 MeV. To avoid energy moderation by air the source was attached closely to detector surface as possible, several mm. All measurement was performed in the radiation shielding box to protect from the radiation and light. The detector was biased from 0 to 90V to find out optimal operation voltage. Alpha radiation was reconfirmed by two methods. One is by using a thin metal plate which is sufficient enough to stop alpha particles. Other is the alpha range check in accordance with pressure from 10^{-6} Torr to 1atm normal pressure. Pulse height spectra were obtained by standard electronics which consists of a preamplifier, a shaping amplifier, and a multi-channel analyzer (MCA).

2.3. Result and Discussion

We measured an alpha-ray response as a function of a biased voltage. From determining peak centroid channels, the charge collection efficiency(CCE) was extracted.

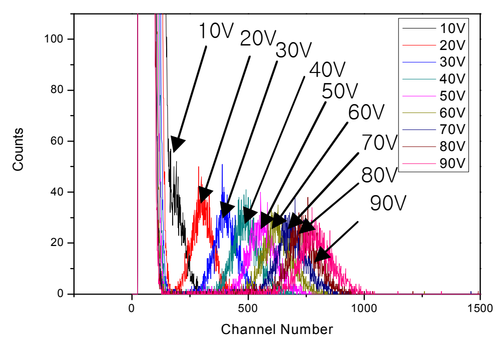

Figure 2. Alpha-ray response as a function of a biased voltage.

Detector charge collection efficiency of SiC detector was over 80% even at a zero-biased voltage. Above 20V CCE was reached at 100%.

To determine a detection response accurately, data acquisition speed was controlled by a source strength so as not to make electrical noise. Electrical noise originated from the connector and ground loop, and partially from the gamma-ray and light leakage.

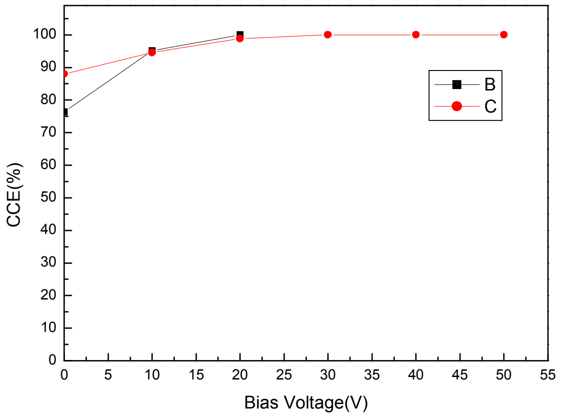

Figure 3. Charge collection efficiency(CCE) with respect to a biased voltage.

3. Conclusion

The Schottky diode type of 4H-SiC detector was fabricated based on a n-type substrate. The detectors have the structure of multi-layers with Au/Ni/Si-C/Ti/Au. Even at zero-baised voltage, detector was wolking, however 5.5 MeV alpha-ray was competing with a detector noise. Over 20V detector charge collection efficiency was reached 100%. Detectors showed a good response for the alpha-radiation for 5.5 MeV alpha-rays at room temperature and in air.

Acknowledgements

This work has been carried out under the Nuclear R&D program of the Ministry of Science and Technology (MOST) of Korea.

Reference

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