Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Development of A Beta Radiation detector Based on Semi-insulating GaAs Semiconductor.

Jang Ho Ha, Yong Kyun Kim, Se Hwan Park, Sang Mook Kang, Jung Bok Kim
Korea Atomic Energy Research Institute(KAERI), Daejon 305-600, jhha@kaeri.re.kr

1. Introduction

In the spent fuel and radioactive production facility the beta-particle monitoring is important for the safety of workers. Conventional method for the measurement of the beta-ray in nuclear industry is performed by the plastic scintillation detector with an accumulation system.

A bulk semi-insulating(SI) GaAs seems to be one of the most important candidates for the radiation hard semiconductor particle detector operated at room temperature and in air. GaAs has been studied as a radiation detector since 1960[1]. The bulk GaAs structure found that it was more radiation hard device than typical Si diodes.[2] In general semiconductor devices are operating in vacuum and thermal cooling condition. It is one of the limitations to apply semiconductor devices even though with good advantages.

Present investigation is motivated for the purpose of developing a beta-particle monitoring system without vacuum and cooling systems and it is small and light enough which can be transportable by worker.

2. Methods and Results

2.1. Manufacture and Experimental Procedures.

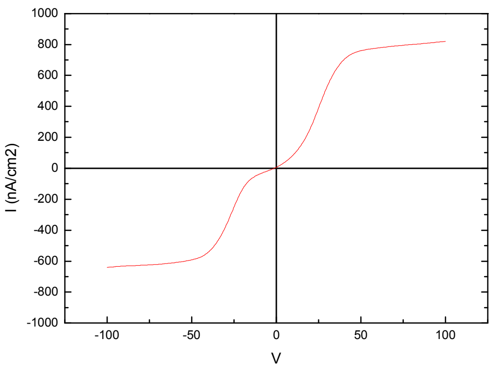
Detector structure has been fabricated by SI GaAs wafers grown by LEC (liquid encapsulated Czochralski) growth method. The undoped semi-insulating wafer was a orientation of (100) and a diameter of 50.8mm. Front surface was polished and back surface was etched after lapping. Resistivity was measured as a 7.58×10^7 Ohm-cm and the Hall electron mobility was a 6800 cm^2/V-s.

Figure1. Photos of the fabricated SI-GaAs bulk diode structure detector.

The effective dimension of the GaAs SI bulk detectors was about 10x10mm with a 350micron thickness as shown in figure 1. The surfaces of the GaAs structure was prepared using the standard processes; sawing and etching Metal contacts on the surfaces were fabricated by using a thermal evaporator in vacuum condition. Metalizations were done by fabrication of Au metal at front side and Ni at rear.

2.2. Discussion and Result.

The leakage current response for the Au-GaAs-Ni structure detector according to bias voltage was measured between -100 to 100V ranges by a high



precision electrometer, Keithley 6517A. I-V curve has a symmetric tendency with respect to zero bias voltage and the saturation current region was observed above 50V to 100V as shown in figure 3.

Figure 3 I-V characteristic curves for the Au-GaAs-Ni structure.

In general Schottky diode has rapid increase at specific voltage called breakdown voltage. The measured I-V curve seems to be indicated that this structure has major Ohmic contact property with small Schottky barrier height below saturation voltage. However, it needs further study.

Beta-ray response was measured by using a Sr-90 source at room temperature and a 1-atm normal pressure. Pulse height spectrum was obtained by standard electronics which consists of a preamplifier, a shaping amplifier, and a multi-channel analyzer(MCA). The detector performance was compared with the commercial silicon surface barrier(SSB) detector made by EG&G ORTEC.

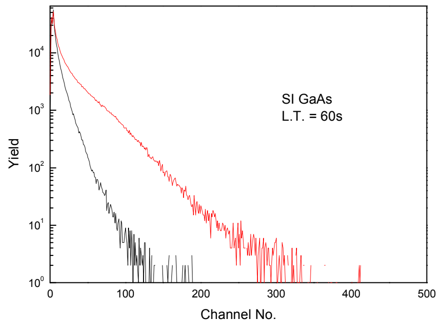


Figure 3 Beta-ray spectrum measured by using Sr-90 for the Au/Ni-SI-GaAs-Ti/Au system.

Figure 3 is the typical spectrum measured by SI-GaAs detector for the Sr-90 beta radiation source. . The energy resolution for the electron is difficult to determine, because of the lack of mono-energy electron source with several MeV. This detector performance was checked previously by the 5.5 MeV alpha-ray of Pu-238, which gives larger energy deposition than that of Sr-90The energy resolution for 5.5MeV alpha particle was determined about 1.4 MeV in an air and room temperature.

In alpha-ray measurement the 5.5 MeV alpha-ray peak is clearly separated from the background level, but beta-ray case we can not measure any peak structure. The reason why the beta-ray did not give any peak structure is caused by the physical intrinsic property due to beta decay. Beta decay is known as the three-body decay mechanism containing neutrino emission. It means that the energy of the measured beta-particle is not given any unique energy. The energy of beta-ray varies according to the energies of the other emitted particle, neutrino. Typically the beta-ray energy distribution for the three-body reaction has a monotonic decreasing structure with respect to energy increasing.

The beta-ray measurement by the fabricated SI GaAs detector indicated that this detector has ability to distinguish beta-rays from the background by setting an appropriate energy discrimination level.

The spectrum as shown in figure 3 shows beta-ray distribution mixed with background. In order to investigate the origin of low energy contribution, we compared the performance with the SSB detector purchased from EG&G. The minimum depletion depth is 100 micron and active area was 150mm^2 and partially depleted type guaranteed 16keV energy resolution for alpha particle. It can be available to use at 1-atm air The low energy part contribution is turns out to be mainly electrical noises originated from connector and ground loop, and partially from gamma-ray and light leakage contribution.

3. Conclusion

We investigated Au and Ni different metallization contact structure detector based on SI GaAs. This type of detector shows Schottky metal/semiconductor characteristics as a result of measuring leakage current as a function of base voltage in -100 to 100V. The fabricated detector with Au-GaAs-Ni structure shows a good beta-ray response even though in 1-atm air pressure at normal temperature.

Acknowledgements

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

Reference

[1] W.R. Harding et al., Nature 187 (1960) 405

[2] H. K. Gersch, et al., Nuclear Instrument and Methods in Physics Research A489 (2002) 85