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SiC Bulk Semi-insulating Semiconductor Detector for an Alpha Radiation

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1. Introduction

A bulk semi-insulating(SI) SiC seems to be one of the most important candidates for the radiation hard semiconductor particle detector operated at room temperature and in air. 4H-SiC has been studied as a radiation detector since 1970. In order to ensure a long-term reliability and the quality of the conventional ohmic contacts have to be improved. The bulk SiC structure was found to be a better radiation hard device than typical Si diodes.[1-3]

Alpha-particle monitoring method for the detection of actinides, specially, Pu-238 and U-235, which can be available for a nuclear weapon grade, are tending to be important. Alpha spectrometry in a vacuum was known to give a good resolution to be sufficient to separate on isotope abundance in a nuclear material. However, in order to apply it to a high radiation field for example, a spent fuel treatment facility, the nuclear material loading and unloading process in a vacuum is one of the great technical challenges. Therefore, the main technical issue is how to achieve the development of an alpha spectrometry at an air.[4]

Our study is focused on development of high resolution alpha-particle detector applicable in air and room temperature.

2. Methods and Results

2.1. Manufacture and Experimental Procedures.

Detector structure has been fabricated by SI SiC wafer. The undoped semi-insulating wafer was a orientation of {0001}and a diameter of 50.8mm. Front silicon surface was polished and back carbon surface was etched after a lapping. Resistivity was measured more than 10^5 Ohm-cm. The dimension of the SiC SI bulk detectors was about 10x10mm with a 350micron thickness as shown in figure 1. The SiC sensor was prepared using the standard processes.[5] Metal contacts on the surfaces were fabricated by using a thermal evaporator in a vacuum condition. Contacts were fabricated at each side with Au/Ti at the front side and Ni/Au at the rear.

The leakage current response according to the biased voltage was measured by a high precision electrometer, Keithley 6517A.

X-ray response was measured by using an Am-241 source with 59-keV, and alpha response was measured by using a Pu-238 source with 5.5-MeV at room temperature and a 1-atm normal pressure. Pulse height spectra were obtained by ORTEC and eV-products preamplifiers, as well as a shaping amplifier, and a multi-channel analyzer.

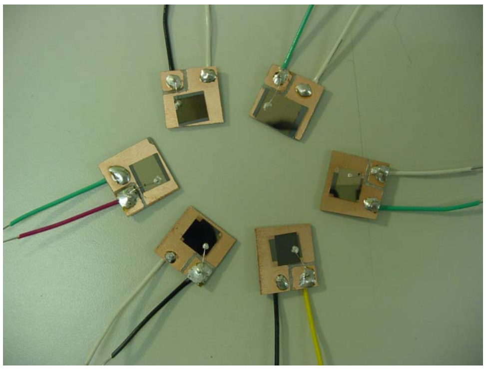

Figure 1 Photos of the fabricated SI-4H-SiC bulk detector

2.2. Discussion and Result.

Alpha radiation was confirmed by using a thin metal plate which is sufficient enough to stop alpha particles. We also measured the alpha response as a function of the vacuum pressure to recheck the alpha radiation by confirming whether it was measured over the range in air or not.

The detector performance was compared with the commercial silicon surface barrier (SSB) detector made by EG&G ORTEC.

I-V property was measured for the Au/Ti-SiC-Ni/Au detector by an electrometer. I-V curve has a symmetric tendency relative to a zero bias voltage.

The alpha response was measured as a function of the bias voltage and distance between the source and the detector to determine the effective bias voltage and effective dynamic range. The Au/Ti-4H-SiC-Ni/Au system was investigated in detail according to the biased voltage. Figure 2 is the spectra of 5.5 MeV alpha particles obtained at 20V. Each spectrum shows a good alpha peak, and a background in a relatively lower energy was also measured. The lower energy range is thought to consist of the gamma-ray and noises coming form the light leakage and so on.

We measured the alpha responses for the Au/Ti-SiC-Ni /Au metallization system as a function of the distance between the Pu-238 source and the detector. As the distance between the source and the detector is increased, the alpha peaks are shifted towards a lower voltage, which can be understood as the moderation effect of the alpha particle energy in the air gap between the source and the detector.

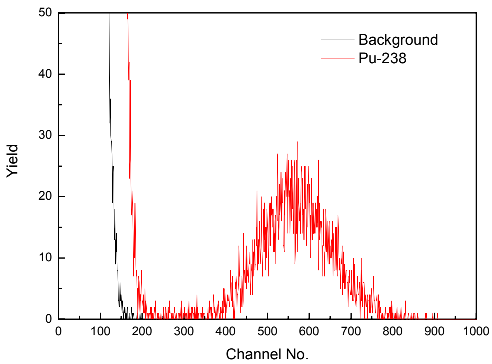

Figure 2 Alpha spectra measured at 20V bias voltages for the Au/Ni-SiC-Ti/Au system.

We also measured alpha particles from Pu-238 with and without the Al absorber which covers in the front of the alpha source to distinguish the measured radiation type, alpha or gamma-ray. The Al absorber thickness was determined by an alpha particle range simulation in the Al material which is sufficient enough to stop alpha particles.

In order to investigate the origin of a low energy, we compared it with the SSB detector purchased from EG&G, which can be used at a 1-atm air pressure. SSB is a ruggedized partially depleted type with a guaranteed 16keV energy resolution for an alpha particle in a vacuum. The minimum depletion depth is 100 micron and the active area was 150mm^2. Figure 6 is the measured spectra with the Pu-238 alpha source. From this investigation, the low energy seems to consist of mainly electrical noises which originated from the connector and the ground loop, and partially from the gamma-ray and the light leakage contributions.

By using the TRIM Monte Carlo simulation code, the energy depositions in the SiC detector according to a given geometry by considering the distances between the source and the detector were simulated. When analyzing, we assumed that the deposition energies simulated in the TRIM code are the same as the peak position in the alpha spectra obtained in the SiC detector. By combining the two results we reduced the energy to peak conversion parameters.

The calibrated alpha spectrum was obtained by an irradiation at the front side, operating at a 20V bias voltage.

3. Conclusion

We investigated different metallization contact systems based on SI SiC. The Au/Ti-SiC-Ni/Au system shows a good energy response for an alpha particle. The energy resolution curve provided some evidence that the resolution is deeply related with the leakage current tendency. However, it is still open as how to interpret it.

As a result, the bulk SiC SI detector showed a good response for the alpha-particles.

Acknowledgements

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