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

Fabrication and Testing of a Particle detector based on Bulk Semi-insulating Silicon Carbide

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1. Introduction

It has been shown that SiC is a useful material for radiation-resistant electronics, high-temperature electronics and high-frequency/high-power devices due to its excellent electronic and physical properties [1-2]. The high electron saturation drift velocity of 2×10^7 cm/sec in the SiC material, together with the large breakdown voltage of 4×10^6 V/cm also makes this material also a promising candidate for its use as a detection medium in particle detectors [3]. Due to the similar properties as a diamond such as the band gap, the intrinsic carrier density, the resistivity, the cohesive energy and the tightly bound structure, a detector based on semi-insulating SiC has the possibility of low leakage currents, a good radiation resistance and sensing the charge created during an ionization [4]. An advantage of SiC in comparison to a diamond is the 1.4 times larger number of electron/hole pairs per 100 um created by minimum ionizing particles and therefore a better signal-to-noise ratio can be expected. This difference is mainly due to the smaller energy required to produced an electron-hole pair in SiC [5]

The purpose of our study is to develop a particle detector which will be applied to nuclear power plants and nuclear material storage facilities. In this study, we fabricated a bulk semi-insulating SiC semiconductor detector and measured the current-voltage characteristics and particle response of the bulk SI-SiC detector.

2. Experimental

2.1 Cutting process

We used 6H-SiC wafer of 2 inch supplied by Dow Corning Co.. The properties of the 6H-SiC wafer are an upper 1000 ohm-cm resistivity, 380 um thickness, and (0001)-oriented type. We prepared 10×10 mm2 samples by using a semiconductor diamond saw. Because the Mohs hardness of the SiC semiconductor is about 9.0, the cutting process worked at an upper 30000 rpm of the blade speed and a 2.0 mm/min moving speed. This condition doesn't show a chipping at the edges of the SiC samples. Also, the cutting process used a UV-tape to fix the wafer to the cutting table. Generally, the cutting process uses a wax to fix the wafer onto the working table of the diamond saw devise. After the cutting process, the wax was removed by an organic solvent or acetone from the wafer surface. The use of wax causes a wafer surface pollution and a process time increase. Therefore, the use of UV tape supplied two advantages, the time and its clean. After the cutting process, we clearly observed that there were no stains on the SiC wafer surface due to the UV-tape.

2.2 Fabrication of SiC radiation detector

The surface of the SiC wafer was prepared by using the standard etching process by H_2SO_4 and H_2O_2 solutions and rinsed with deionized (DI) water, and the removal of an oxidation layer by a HCl solution
In this study, the etching process only used acetone and it was rinsed with deionized water(DI water) because of its excellent chemical properties. It shortened the work time of the etching process. Metal contacts on the surface were fabricated by using a thermal evaporator in a vacuum condition. The contact process was under the following conditions ; 1.2×10^{-5} Torr, 80 ℃ heating, and a 360°/min rotation speed of the SiC samples holder. The SiC radiation detector has metal contacts of Au(2000Å) at the front and Ni(300Å) at the rear (Au/Ni/SiC wafer). Also, both the front-surface and the back-surface have the same metal contact structure.

2.3 I-V characteristic of SiC radiation detectors

To measure the current-voltage curve, the PCB layer was made of a FR4 substrate with a 10×10 mm^2 electrical contact pad. The SiC sample was fixed by a conducting epoxy onto the PCB layer and contacted by a wire for the electrical characteristics and detection properties measurements. I-V characteristics of the bulk-SiC radiation detector were measured by using Keithley 4200-SCS with a self voltage source. We typically took the measurement under a biased voltage from the -100 to 100 V range.

2.4 Alpha Response spectrum

The SiC detector was placed in a shielding case to protect it from noise and light and the preamplifier was connected by a BNC to BNC type.

Alpha response was evaluated by a Pu-238 source with 5.5 MeV at room temperature and an atmospheric pressure. Pulse height spectra were obtained by an eV-Product's preamplifier, ORTEC's shaping amplifier, and a multi-channel analyzer.

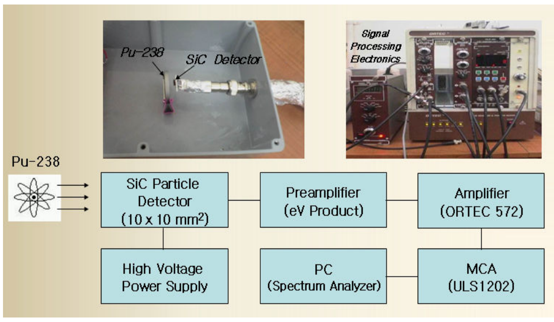

Figure.1 Photo and diagram of the experiment system

3. Results and Discussion

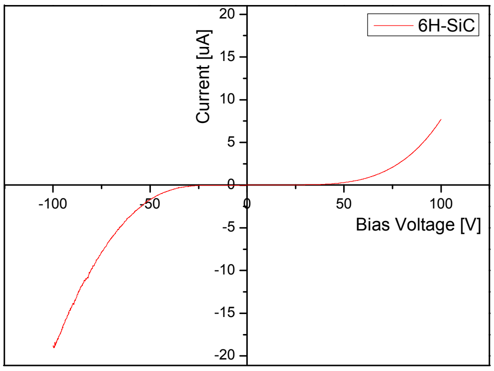

Figure.2 The current-voltage characteristics of SiC detector

The forward and reverse current-voltage characteristics were measured in the range from -100 to 100 V and they are presented in Fig.2. The measurement was performed at room temperature and an atmospheric pressure. The highest forward and reverse currents from the Au/Ni-SiC-Ni/Au particle detector is 8 uA, -20 uA, respectively. The current was rapidly increased at -40 V and 50V biased voltages, respectively. The I-V curve of the device shows a symmetric pattern. From the I-V curve, we found the formation of the Schottky contacts.

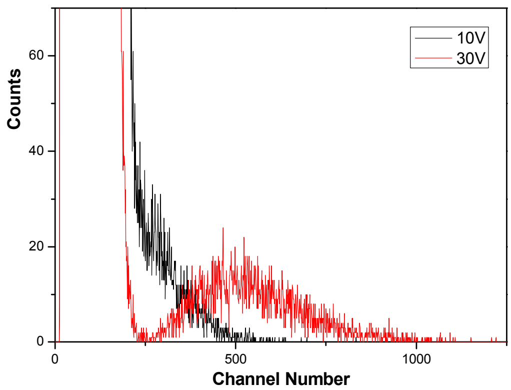

Figure.3 The alpha spectrum as a function of the bias voltages (10V and 30V)

The alpha particles were normally incident through the anode, and a signal was extracted to the preamplifier via the cathode. Figure 3 shows the pulse height spectrums of the bulk SI-SiC particle detector by using 5.5 MeV alpha particles from the Pu-238 source. The spectrums were acquired with 10 V and 30 V biased voltages, a 3 μs shaping time and a 600 sec collection time in an air condition and at room temperature. The source was placed approximately 3 mm from the surface of the Au/Ni-SiC-Au/Ni detector. Clearly, there are full-energy peaks in the bias voltage of 30V, although the intrinsic energy resolution is not especially good. There are several reasons for the relatively poor energy resolution. These include the fact that an irradiation was performed in air not a vacuum and the charge collection was not sufficient because of the low bias voltage.

4. Conclusion

A bulk semi-insulating SiC detector was fabricated by a sample process. We constructed the forward and reverse current-voltage(I/V) curves and acquired the pulse height spectra for the bias voltage of 30V, although the intrinsic energy resolution is not especially good. As a result, the bulk SI-SiC semiconductor detector shows a response for an alpha source and it is promising as an alpha particles detector in an air condition and at room temperature.

Acknowledgement

This work has been carried out under the Nuclear R&D program of the Ministry of Science and Technology (MOST) of Korea. We are also supported by the Science Research Center / Engineering Research Center program of MOST / Korea Science and Engineering Foundation (grant # R11-2000-067-02001-0).

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