Temperature Dependency and Alpha Response of Semi-Insulating GaAs Schottky Radiation Detector at Low Bias Voltage

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1. Introduction

The last decade has seen a growing interest in semiconductor radiation detectors operated at room or nearly room temperature. Great efforts have been invested in the development of radiation detectors based on semi-insulating (SI) GaAs. The main reasons are as follows: (ⅰ) high resistance against radiation damage; (ⅱ) it possesses a good energy resolution, which relates to its active volume; (ⅲ) such a detector also exhibits fast signal rise times, which results from a high mobility and drift velocity of charge carriers; (ⅳ) its large band gap energy allows a SI GaAs detector to operate at room temperature. Other important features are a good technology base and low production and operating costs [1,2,3].

An alpha particle monitoring method for the detection of Pu-238 and U-235 is becoming important in homeland security. Alpha measurement in a vacuum is known to provide a good resolution sufficient to separate an isotope abundance in nuclear materials. However, in order to apply it to a high radiation field like a spent fuel treatment facility, a nuclear material loading and unloading process in a vacuum is one of the great disadvantages [4]. Therefore, the main technical issue is to develop a detector for alpha detection at air condition and low power operation for integration type device. In this study we fabricated GaAs Schottky detector by using semi-insulating (SI) wafer and measured current-voltage characteristic curve and alpha response with 5.5 MeV Am-241 source.

2. Experimental

2.1 Fabrication of GaAs radiation detector

Detector structures have been fabricated by SI GaAs wafers grown by the LEC (liquid encapsulated Czochralski) growth method. The undoped semi-insulating wafers were an orientation of (100) and a diameter of 50.8mm. Front surface was polished and the back surface was etched after a lapping. Resistivity was measured as a 7.58 x 10^7 Ohm-cm and the Hall electron mobility was a 6,800 cm^2/V-s. The dimensions of the GaAs SI bulk detectors were about 10x10 mm^2 with a 350 um thickness. Prior to a metallization process, the surfaces of the GaAs wafer were etched by H_2SO_4 and H_2O_2 solutions and rinsed with de-ionized (DI) water, and the removal of an oxidation layer by a HCl solution was performed. Metal contacts on the surface were fabricated by using a thermal evaporator in a vacuum condition. On the front and the back surface a layered structure of Au/Ni was deposited in order to obtain Schottky contact. The thickness of the metallic layers is 2000Å, 300Å for Au, Ni, respectively.

2.2 I-V characteristic of GaAs radiation detectors

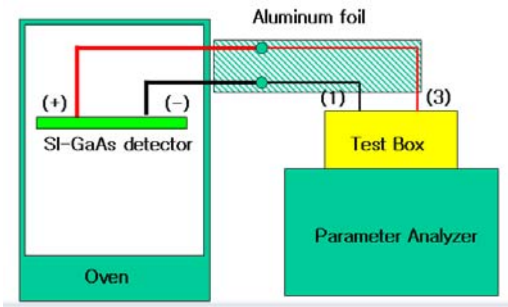

Figure.1 Diagram of the experiment system for the current-voltage characteristic measurement.

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 GaAs sample was fixed by a conducting epoxy onto the PCB layer and contacted by a wire for the electrical characteristics and detection properties measurements. The I-V characteristics of the SI GaAs Schottky radiation detector were measured by using HP parameter analyzer in Oven. We took the measurement under a biased voltage from the -40 to 40 V range and at ten different temperatures (32, 35, 40, 50, 60, 70, 80, 90, 100, 110 ℃)

2.3 Alpha Response spectrum

The GaAs radiation 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 Am-241 source with 5.5 MeV at room temperature and an atmospheric pressure. Pulse height spectra were obtained by charge sensitive preamplifier based on hybrid chip, ORTEC's shaping amplifier, and a multi-channel analyzer.

3. Results and Discussion

The current-voltage characteristics were measured in the range from -40 to 40 V and at ten different temperatures and an atmospheric pressure. Figure. 2. shows the leakage current as a function of temperature at 10, 20, 30 V biased voltages. The shape of the leakage current corresponds to a linear in log scale with y axis at all biased voltage cases. The leakage current was increased by about one order of magnitude for a 30 ℃ increase in temperature.

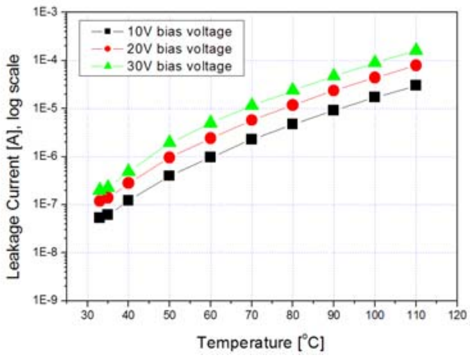

Figure.2 The leakage current as a function of the temperature at 10, 20, 30 V biased voltage conditions.

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 SI-GaAs Schottky detector by using 5.5 MeV alpha particles from the Am-241 source. The spectrums were acquired with 0, 3, 5, 7, 10 V biased voltages, a 3 µs shaping time and a 180 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 biased voltages of 0, 3, 5, 7, 10V.

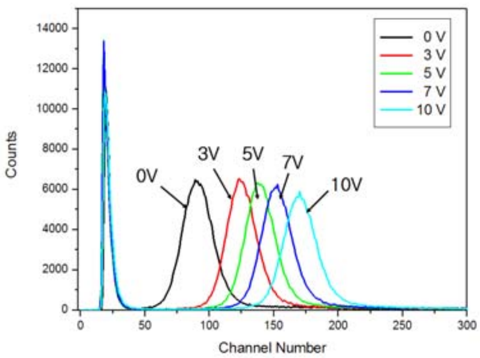

Figure.3 The alpha spectrum as a function of the biased voltages at 0, 3, 5, 7, 10 V.

To determine the performance of the detector, we calculated its energy resolution in FWHM (Full Width Half Maximum) for 5.5 MeV alpha particles from Am-241 source. An alpha energy resolution of 32%, 20% at FWHM of the detector has been obtained at the biased voltage 0 , 10 V, respectively. The energy resolution improved as the bias voltage increased.

Generally, the standard depletion of the GaAs detector is about 1 um/V. Therefore, the energy resolution will enhance as the thin wafer used at the same biased voltage in this study.

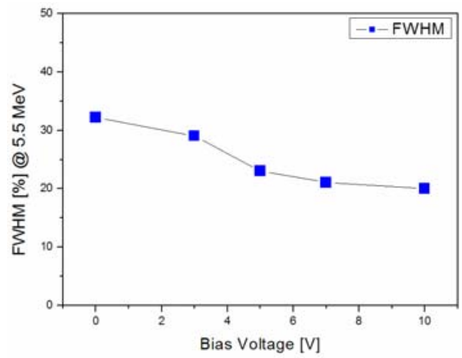

Figure.4 The Full Width Half Maximum (FWHM) as a function of the biased voltages at 0, 3, 5, 7, 10 V.

4. Conclusion

We fabricated GaAs Schottky detector by using semi-insulating (SI) wafer and measured current-voltage characteristic curve and alpha response with 5.5 MeV Am-241 source. The shape of the leakage current corresponds to a linear in log scale with y axis at all biased voltage cases. The leakage current was increased by about one order of magnitude for a 30 ℃ increase in temperature. An alpha energy resolution of 32%, 20% at FWHM of the detector has been obtained at the biased voltage 0 , 10 V, respectively. The energy resolution improved as the bias voltage increased.

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