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Electron Beam Induced Radiation Damage of the Semiconductor Radiation Detector based on Silicon

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1. Introduction

A Silicon Surface Barrier (SSB) semiconductor detector which is generally used to detect a charged particle such as an alpha particle was developed [1, 2, 3]. The performance of the developed SSB semiconductor detector was measured with an I-V curve and an alpha spectrum. The response for an alpha particle was measured by Pu-238 sources. A SSB semiconductor detector was irradiated firstly at 30sec, at 30μA and secondly 40sec, 40μA with a 2MeV pulsed electron beam generator in KAERI. And the electron beam induced radiation damage of a homemade SSB detector and the commercially available PIN photo-diode were investigated. An annealing effect of the damaged SSB and PIN diode detector were also investigated using a Rapid Thermal Annealing (RTA). This data may assist in designing the silicon based semiconductor radiation detector when it is operated in a high radiation field such as space or a nuclear power plant.

2. Experimental

2.1 Construction of a SSB semiconductor detector

An n-type silicon wafer of a (1, 1, 1) crystal plane and 2 kΩcm was used to make a SSB semiconductor detector. 4" wafer was cut in the shape of 3 cm diameter circle using a diamond saw. A cut wafer is etched in a wet station.

An etched wafer was kept in a clean room to form a silicon dioxide layer during 1 or 2 days. 99.99% Au was evaporated using a Thermal Evaporator to make a surface barrier which is called a Schottky contact and then, 99.99% Al was evaporated on the other surface of a cut wafer to form an Ohmic contact [4,5]. These contacts represent the diode characteristics. The thickness of the evaporated two metals was about 300Å.

2.2 Alpha spectrum and I-V Characteristics of the constructed SSB semiconductor detector

The alpha spectrum from a Pu-238 was also measured by mounting a SSB detector inside the ORTEC Soloist. The measurement of the alpha spectrum was performed under a state of a vacuum to prevent the interaction of an alpha particle and air. The alpha spectrum was analyzed with the Gamma-vision program. Figure 2 shows that the 43 keV energy resolution from the 5.499 MeV energy peak to the 5.456 MeV energy peak is clearly observed.

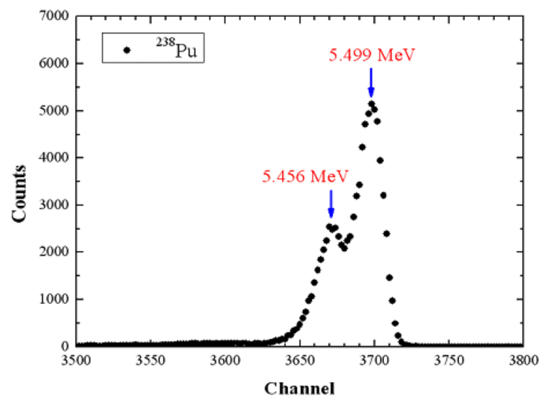

Figure1. An alpha spectrum measured with a homemade SSB semiconductor detector.

The currents were measured by biasing the voltage on both sides of a SSB detector. The Keithley 6517A was used to bias the voltage and to read the current. During the measurement, a shielding box was used to exclude the dark current induced by light or external electromagnetic waves. The measured I-V characteristic is shown in Figure 2.

2.3 Electron beam induced radiation damage and the Annealing process

An electron beam induced radiation damage effect was investigated in a comparison with a homemade SSB detector and a PIN diode which was produced by Sensor Tech Lab. 2mm diameter hole and 4mm thickness stainless steel was used as a collimator to focus an electron beam in the detection region of a detector. So, a radiation damage effect was only produced by the detection area of the semiconductors. I-V characteristics of a SSB detector and a PIN diode are shown in Figures 2 and 3.

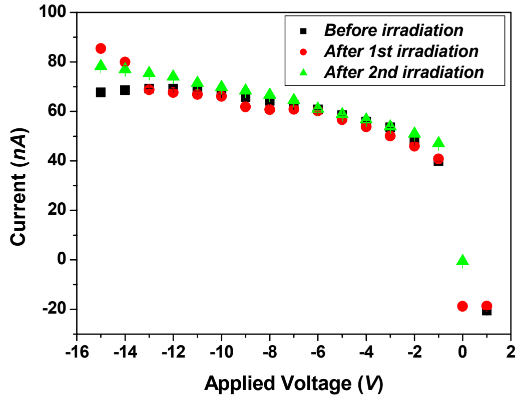

Figure2. I-V characteristics of a constructed SSB detector for a 2 MeV electron induced radiation damage. The first electron beam current was 30μA, 30sec and the second was 40μA, 40sec. After an irradiation, the leakage currents were not changed significantly.

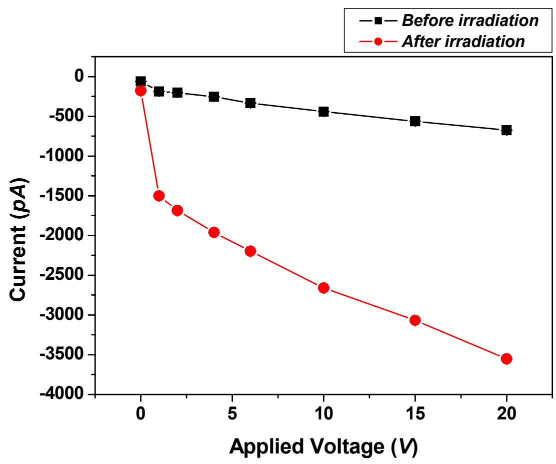

Figure3. I-V characteristics of a PIN diode. After irradiation, leakage currents were increased about 7 times in magnitude.

I-V characteristics of the SSB semiconductor detector were not changed significantly, so the annealing process was performed for only the PIN diode in the Ar environment at 60 degree Celsius. An annealing process was generally performed at 600 ~ 1000 degree Celsius because it starts to recrystalize an epitaxial layer and activate an amorphous layer partially at round 600 degree. But in our case, a PIN diode was coated with a protection epoxy which has a below 100 ℃ melting point. So, the annealing temperature was set at 60℃. I-V characteristics with an annealing time are shown in Figure4. The leakage currents were increased, contrary to the expectations.

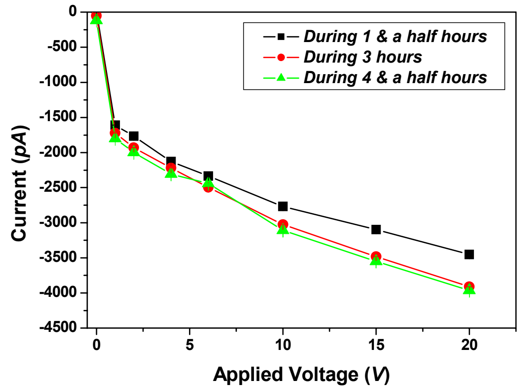

Figure4. I-V curves of the damaged PIN diode after the annealing processes.

3. Conclusion

A Silicon Surface Barrier (SSB) semiconductor detector was developed. The performance of the developed SSB semiconductor detector was measured with the I-V curve and an alpha spectrum. And the electron beam induced radiation damage of the homemade SSB detector and the commercially available PIN photo-diode were investigated. An annealing effect of the damaged SSB and PIN diode detector were also investigated. This data may assist in designing the silicon based semiconductor radiation detector when it is operated in a high radiation field such as space or a nuclear power plant.

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