Development of SiC Neutron Detector and its Application to Harsh Environment

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1. Introduction

Silicon carbide(SiC) semiconductor is a possible candidate for neutron detector, which can be used at harsh environments such as neutron monitoring at nuclear reactor and near the spent fuel. The wide bandgap of SiC compared to that of conventional semiconductors such as silicon and germanium makes SiC an attractive material for applications at high dose and high temperature. Korea Atomic Energy Research Institute(KAERI) has developed the SiC neutron detector. SiC detectors with PIN diode structure or Schottky structure were fabricated, and the α energy spectrum and neutron were successfully measured with the detectors. LiF neutron converter was deposited on top of the metal electrode of the SiC detector to make the neutron detector.

The radiation hardness of the SiC neutron detector was studied by measuring and comparing the detector characteristics such as leakage current and α energy spectrum before and after the neutron irradiations of 2.2×10^{15}n/cm^2 and 5.4×10^{17}n/cm^2.

In present work, the radiation hardness of SiC detector to the neutron fluence of 10^{18} n/cm^2 was studied. Also, fabrication of a detector assembly, which can measure the neutron flux in the reactor core, was introduced.

2. Experiment and Analysis

SiC neutron detectors with four different electrode structures such as aluminium, Cr/Au, Ni/Au, Ti/Au were meausred. The detector has PIN diode structure, and it is shown in figure 1. After fabricating the detector, the I-V curve and the α energy spectrum was measured.

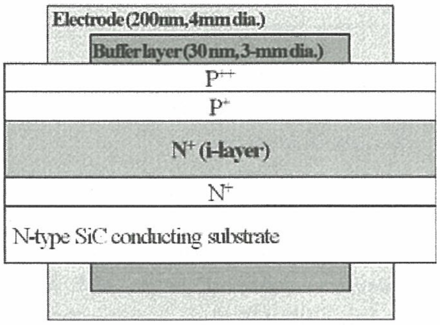

Fig. 1. SiC Detector with PIN diode structure.

The SiC detector is square shape with size of 5 × 5 mm^2. Ceramic plate with metal electrode on it was contacted to the SiC detector on both sides of the detector to collect the electric signal from the detector. I-V curve of the detector was measured with Keithley semiconductor characterization system (Model No 4200). α energy spectrum was measured with the detector. ^{238}Pu source was positioned in front of the detector, and a collimator with diameter of 2 mm was placed between the source and the detector. The signal from the detector was processed with preamplifier(CREMAT CR-110), and shaping amplifier(ORTEC 575A).

The neutron was irradiated with fluence of 1.6×10^{18} n/cm^2 at HANARO research reactor of KAERI. After the neutron irradiation, the I-V curve and the α energy spectrum was measured to see the neutron irradiation effect on the detector performance. Figure 2 shows the peak count of the α energy spectrum before and after the neutron irradiation. Before the neutron irradiation, the α energy spectrum can be measured without biasing on the detector. However, after the neutron irradiation, the α energy spectrum could not be measured if the high voltage was not biased on the detector. After biasing with 10 V, the α energy spectrum could be successfully measured.

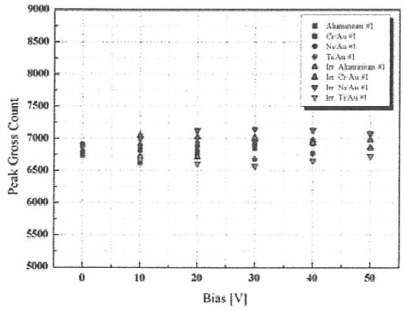

Fig. 2. α peak counts of the detectors before and after the neutron irradiation.

A neutron detector assembly was fabricated to measure the neutron flux inside the reactor core. A neutron detector with LiF layer and a neutron detector without the LiF layer was in the assembly. Signals from the detector was collected through MI cable. The experiment was performed at HANARO reactor. The signal from the detector was measured as the reactor power went on. The neutron signal from the spent fuel was also measured with the detector at Post Irradiation Examination Facility(PIEF) of KAERI.

3. Conclusion

SiC semiconductor can be a neutron detector applicable at spent fuel and reactor. The radiation hardness of the detector to the neutron irradiation was measured in the present work. The SiC neutron detector can be operative at neutron flux upto 10^{18} n/cm^2. A detector assembly was fabricated to measure the neutron flux at reactor core of HANARO research reactor of KAERI. Also, the radiation from the spent fuel was measured with the detector at PIEF of KAERI.

4. References

[1] F. Moscatelli et al., IEEE Trans. Nucl. Sci. 53(3) 1557 (2006).

[2] J. S. Park et al., J. Kor. Phs. Soc., "Effect of Metal Electrode on the Radiation Toelrance of SiC Neutron Detector", accepted.