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Measurement and Simulation of Neutron response at Cf-252 neutron field using SiC Diode Detector

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1. Introduction

Recently, a silicon carbide (SiC) semiconductor detector is drawing attention as a neutron detector in the harsh environment because of its discriminative characteristics. SiC is very resistant to high temperature and intense radiation field, compared with the other semiconductor materials. In this sense, SiC is expected to be a semiconductor material well suited for nuclear power plant applications such as in-core reactor neutron flux monitoring and safeguarding nuclear materials. The SiC diode detector could be expected to replace the SPND. In our previous study, several types of 4H SiC p-i-n diode detector were fabricated and tested. This study is focused on the prediction of neutron response for SiC diode detector before in-core experiment.

2. Methods and Results

2.1 Fabrication

3 inch diameter × 366 um thick 4H-SiC wafer was obtained from Cree, Inc. The wafer was cut to size of 5×5 mm^2. Ti/Cr and Ni/Cr metallizations were carried out on each side of wafers. Ni or Ti as the buffer layer was metallized by sputtering and Cr as the electrode was covered on them by the thermal evaporator. Two types of diode sensor were prepared and one of them, the Ni/Cr diode has a 2 μm ^{6}LiF layer with a diameter of 2 mm on Si side to enhance a thermal neutron signal. Fig. 1 display To prevent oxidation, the ^{6}LiF layer was covered with a 6 μm-thick layer of electrode material. Fig. 1 shows electrode structures of the SiC diode.

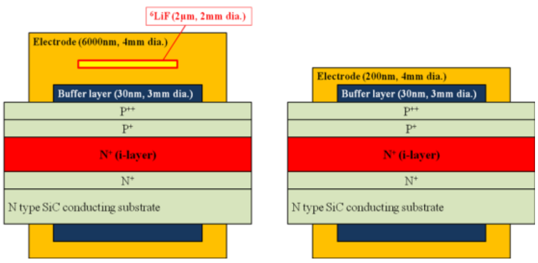

Fig. 1. A schematic cross-section of the SiC p-i-n diode sensor, one with 6LiF and one without. The red-colored area means an intrinsic region of the p-i-n diode.

By inserting the SiC sensor into two sheets of Ag-plated ceramic substrate, the signal wires and electrodes on the wafer became physically connected. The fabricated detectors are shown in Fig. 2.

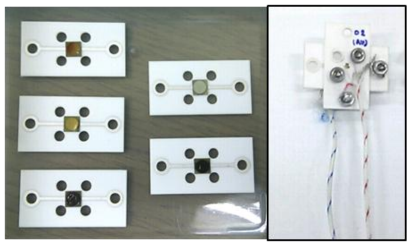

Fig. 2. Fabricated SiC p-i-n diode detectors.

2.2 Depletion depth measurement

The depletion depth of SiC p-i-n diode was evaluated through experiment of a charged particle response and CV measurement. Each detector was connected to a Cremat CR-110 charge sensitive preamplifier and an ORTEC 575A amplifier. The source used in the experiment was ^{238}Pu at a several distance with collimation in air. By a change of the distance between source and detector, an incident energy was diversified. Measurements were recorded for 10 minutes. The reverse bias was supplied to the detector by an Aptec AHV-1B. Each pulse height spectrum of the charged particles was obtained by increasing the bias until the shift of a peak centroid was saturated. The voltage which a peak was saturated indicated that the depletion depth was equivalent to the range of that energy. The ranges of alpha particles for each energy were calculated using Monte Carlo simulation code. Correlation curve between depletion depth and square root of the voltage was obtained.

Thickness of the metal film evaporated on SiC wafer was evaluated using Alpha-step.

2.3 Neutron response experiment

Neutron response experiment was carried out in pure neutron field with ^{252}Cf source at Korea Research Institute of Standards and Science (KRISS). The neutron energy distribution was controlled by diversifying the thickness of a polyethylene moderator and a distance between a source and the detector, and calculated. Emission rate of the source was ~5×10^7 s^{-1} and pulse height spectrums were obtained with respect to several neutron fields. Fig. 3 shows neutron energy distributions at detection positions. Monte Carlo simulation of the SiC detector was carried out and calculation was verified by comparing results.

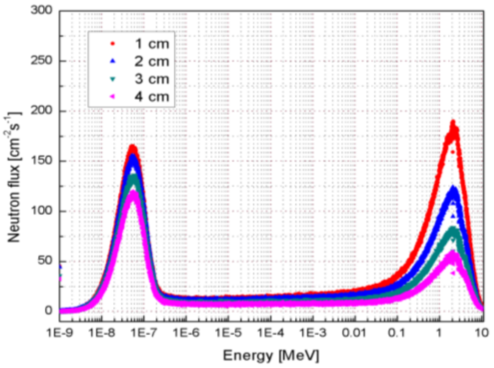

Fig. 3. Neutron energy spectrum from the polyethylene-moderated Cf-252 source.

3. Conclusions

In this research, through the experiment of the standard neutron field, the calculation using Monte Carlo simulation could be verified. On the basis of that result, it would be possible to predict neutron responses at different environments such as reactor core and spent fuel with better accuracy. In near future, neutron monitoring experiment of SiC detector assembly at in-core and spent fuel storage pool will be performed.

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