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Detection Simulation of SiC Semiconductor Detector

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1. Introduction

The potential of Silicon Carbide (SiC) has been long recognized in nuclear radiation detectors. Silicon carbide (SIC) is a semiconductor device with a wide bandgap energy and excellent heat conductivity. The leakage current caused by the thermal excitation is low, and the operability in a high temperature environment is excellent compared to existing semiconductor detectors. Also, in a high radiation environment, it has received attention as a material for detecting radiation (neutron).

As the field of application of a SIC neutron detector, the semiconductor detector used in cosmic rays was proposed by Ruddy [1]. Recently, X-ray and low-energy gamma ray spectrometry with SiC detectors has been reported [2]. Its usability has recently been being proved in neutron dose surveillance in BNCT (Boron-Capture Neutron Therapy) [3], thermal neutron detection in a waste drum [4], nuclear material surveillance [5], and fast neutron detection [6]. In addition, in 2006, an experiment was actually performed by Natsume [7] on spent nuclear fuel. SIC is suitable for radiation surveillance in a complex radiation field emitted from spent nuclear fuel and the pyropocess process. In the radiation field of spent nuclear fuel, neutrons and gamma rays are generated.

In this research, the performance of a SiC detector made at KAERI was evaluated to obtain a discriminated neutron signal. First, using neutron (^{252}Cf), alpha (^{241}Am), and gamma (^{60}Co) sources, a SiC semi-conductor detector was tested. The energy spectrum in a complex radiation field was simulated using the MCNPX 2.5. Finally, the experimental results by Ruddy were compared with the simulation results.

2. Methods and Results

A SiC neutron detector is usually based on Schottky or p-n diodes [8]. SiC pin diodes 5 mm x 5 mm in dimension were fabricated using chemical vapor-phase deposition (CVD) epitaxy onto 366 m N-type SiC substrate wafers with 20 mΩ -cm resistivity. The 5 mm x 5 mm SiC pin diode structure used in the experiment is shown in Fig. 1. Using neutron (^{252}Cf), alpha (^{241}Am), gamma (^{60}Co) sources, the SiC semiconductor detector was tested. The test results are shown in Fig. 2. The alpha source with a large LET (Linear Energy Transfer) was the biggest, as shown in Fig. 2. The small LET gamma source was smallest. Additionally, using the MCNPX 2.5, the SiC semiconductor detector was simulated.

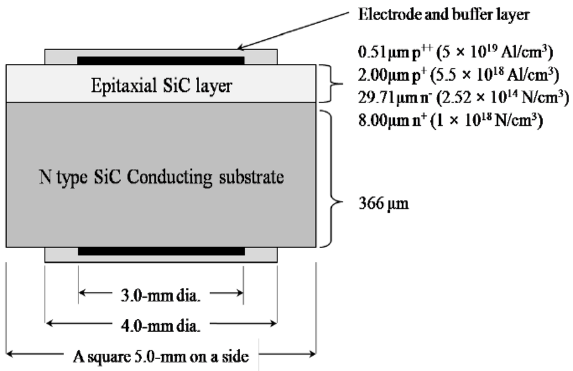

Fig. 1. SiC PIN diode structure

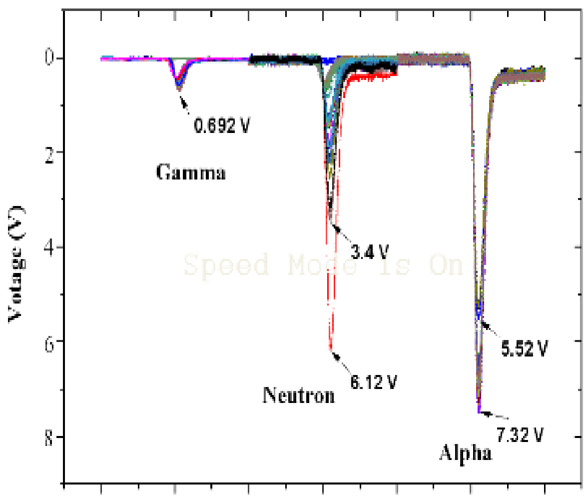

Fig. 2. Pulse of ^{252}Cf, ^{241}Am, ^{60}Co source

The energy of ^{60}Co (1.173 MeV, 1.332 MeV) was used and could confirm whether the detector result was similar to the experimental result. The showed up in the 1.173 MeV, 1.332 MeV peak like the result Fig. 3 trying the simulation. A SiC semiconductor detector was tested during gamma and neutron source measurement simulations. The energy used in the neutron simulation is 14 MeV. The reason for determining the neutron energy as the 14MeV is compared with the experiment result [9] of the Ruddy. The F8 tally with an energy bin was used to show the results. The results of the simulation are shown in Fig. 4. The simulation results were compared with Ruddy's experimental results. The simulation results are similar to those of Ruddy.

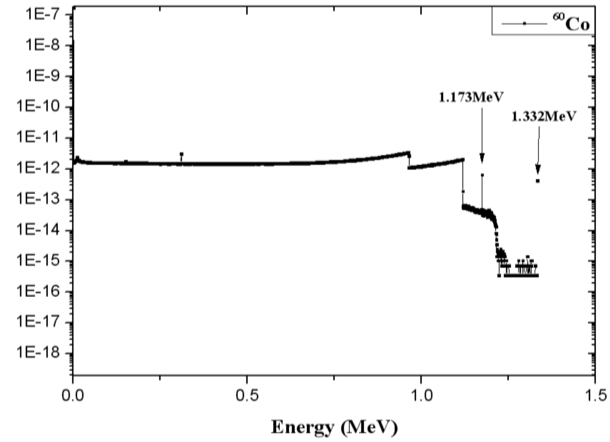

Fig. 3. Simulation results of ^{60}Co source

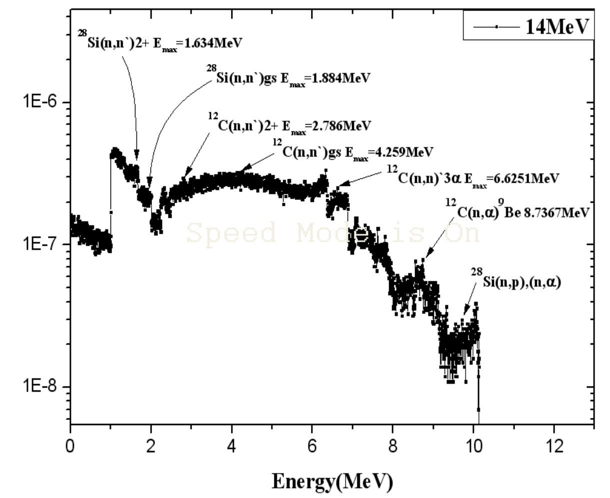

Fig. 4.Simulation results of 14MeV neutron

3. Conclusions

Research result, whether the SiC semiconductor detector operating or not was confirmed through the simulation according to the neutron, gamma. The simulation results were similar to those of Ruddy.

A further study is underway to investigate the discriminated neutron signal of a complex radiation field.

ACKNOWLEDGEMENT

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