Evaluation of Ambient Dose Equivalent of Silicon Carbide by Neutron Irradiation

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1. Introduction

Neutron transmutation doping (NTD) of semiconductors is an important method for applications that require high dopant homogeneity [1]. Silicon carbide (SiC) single crystal has been a substrate material for high power and high frequency electronic devices. When the SiC is irradiated by neutrons, Si, C and impurities become radioactive nuclides. Radiations emitted from these radioactive nuclides constantly damage to the SiC and operators until they have been completely decayed. In this study, the time variation of ambient dose equivalent H*(10) of radionuclides in the irradiated SiC is calculated in terms of safety.

2. Methods and Results

2.1 Monte Carlo simulation

A Monte Carlo particle transport simulation code PHITS (Particle and Heavy Ion Transport code System) version 3.02 was used for calculating the ambient dose equivalent of radionuclides in SiC. The DCHAIN program linked to PHITS was used to calculate the time variation of ambient dose equivalent during irradiation and cooling. Neutrons in NTD1 irradiation hole of HANARO research reactor were considered as a source term. Neutrons were assumed to be uniformly distributed on the surface of a vertical channel with a radius of 10.125 cm as the NTD1 irradiation hole. A sample for neutron irradiation was modeled as 5-inch cylindrical single crystal SiC with a volume of 3.8×10^3 cm^3. Aluminum, boron, iron and titanium that are major impurities in the SiC wafer were considered [2]. Concentration of each impurity was conservatively assumed as 10 ppm. For the t-dchain tally, the current of neutron beam was set corresponding to the neutron flux of 4.33×10^{13} $n/cm^2\cdot sec$ in SiC. Neutron irradiation time was set to 24 hours, and the ambient dose equivalent of each nuclide was calculated by the hour during irradiation. The total ambient dose equivalent was calculated until 10 days later after irradiation. And the ambient dose equivalent of main radionuclides was calculated for 1 days after irradiation.

2.2 Results of simulation

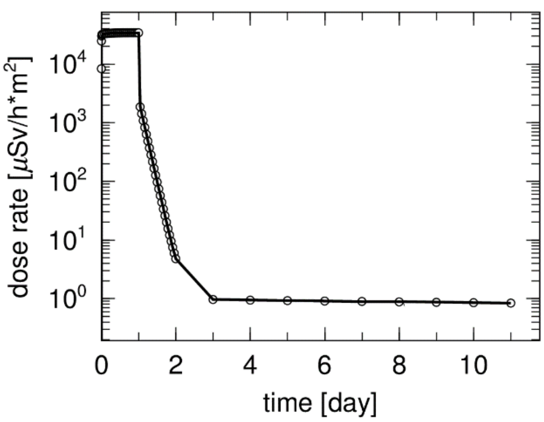

Fig. 1. Time variation of the total ambient dose equivalent of SiC during and after neutron irradiation of 1 day (plotted by ANGEL 4.50).

The time variation of the total ambient dose equivalent of SiC during and after neutron irradiation of 1 day is showed in fig. 1. Total ambient dose equivalent increases until the end of neutron irradiation, and it continues to decrease sharply for 2 days.

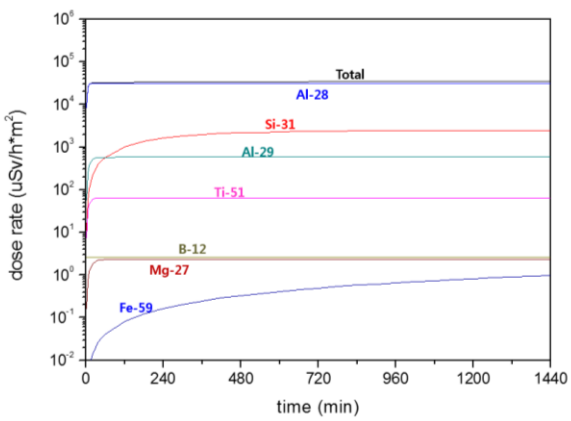

Fig. 2. Time variation of ambient dose equivalent of radionuclides in SiC during neutron irradiation of 1 day.

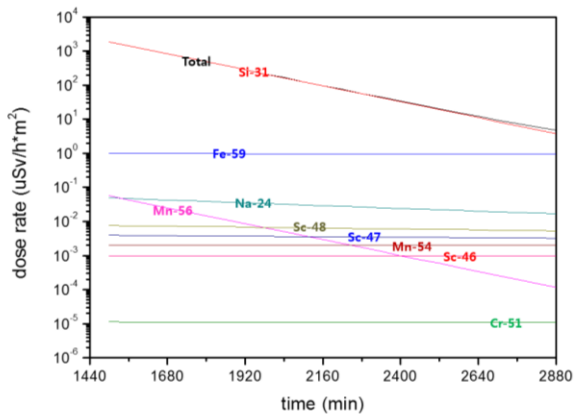

Fig. 3. Time variation of ambient dose equivalent of radionuclides in SiC after neutron irradiation of 1 day.

The time variations of ambient dose equivalent of neutron induced radionuclides in SiC during and after neutron irradiation are showed in fig. 2 and fig. 3, respectively. During the neutron irradiation, ^{28}Al produced by activation of impurity element ^{27}Al is a main contributor to ambient dose equivalent because of its short half-life. After the neutron irradiation, the radionuclides with short half-life are early decayed and ^{31}Si becomes the main contributor. Among the radionuclides produced by activation of impurity elements, ^{59}Fe represents the highest dose rate.

3. Conclusion

Total ambient dose equivalent of SiC is sufficiently decreased in 2 days because the main radionuclides ^{28}Al and ^{31}Si have short half-life in minutes or hours. The main radionuclides which contribute to dose rate are also evaluated to control the unintended effect and study the radiation damage to SiC by NTD. These results will be used as the basis for future study.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korea government (MSIP) (NRF-2017M2A2A6A05018527).

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