A Preliminary Study for Residual Radioactivity Assessment After Neutron Irradiation of Silicon Carbide

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1. Introduction

Silicon carbide (SiC) single crystal has been an excellent substrate material for high power and high frequency electronic devices because of its excellent thermal and electrical properties compared with silicon. Neutron transmutation doping (NTD) of semiconductors is an important method for applications that require high dopant homogeneity, for example in electric power devices [1]. For neutron transmutation doping, SiC is irradiated by neutron and the components of SiC become radioactive nuclides. These radioactive nuclides can be a problem for safety and quality control. In this study, assessment of residual radioactivity after neutron irradiation of SiC is conducted using Monte Carlo simulation and most influential component is discussed.

2. Materials and methods

2.1 PHITS simulation

Assessment for the residual radioactivity after neutron irradiation of SiC is conducted using a general purpose Monte Carlo particle transport simulation code PHITS (Particle and Heavy Ion Transport code System) version 3.02. For simulating the radioactivity of components after neutron irradiation, the t-dchain tally of PHITS and DCAHIN-SP program are used. PHITS automatically generate an input file of DCHAIN-SP by using t-dchain tally and DCHAIN-SP can calculated the time variation of induced activity and ambient dose equivalent H*(10) rate at 1m away from the point source during irradiation and cooling time. Thermal energy neutron and source power of 4×10^{14} n/cm^2·sec are adopted as a source input.

2.2 Modeling of silicon carbide sample

A SiC sample for the simulation of neutron irradiation is modeled after a typical cylindrical single crystal with a diameter of 50 mm and a length of 50 mm. Aluminum, boron, iron and titanium that are major impurities in the SiC wafer are considered as components of the sample [2]. The concentration of each impurity is conservatively assumed as 10 ppm.

3. Results and discussion

Relative radioactivity, dose rate and ambient dose equivalent H*(10) of five dominant radionuclides after neutron irradiation for five minutes are listed in table 1. Most of residual radioactivity is come from silicon and radioactivity of each elemental impurity is different from each other. Aluminum-28 has dominant radioactivity (4.30 %) because of large neutron capture cross section of aluminum. Also the ambient dose equivalent from Al-28 is 98.07 percent of total dose equivalent.

Table 1. Relative radioactivity, dose rate and ambient dose equivalent of elements after neutron irradiation

Nuclide	Relative radioactivity [%]	Relative dose rate [%]	Ambient dose equivalent [μSv/h·m^2]
Be-8	0.03	0	0
B-12	0.11	0.06	4.103
Al-28	4.30	98.07	6.689×10^3
Si-31	95.46	1.19	8.131×10^1
Ti-51	0.11	0.67	4.6×10^1

Time variation of ambient dose equivalent H*(10) rate during and after neutron irradiation is showed in Fig.1. The dose rate is sharply decreased for 20 minutes because the half-life of Al-28 is 134.5 seconds.

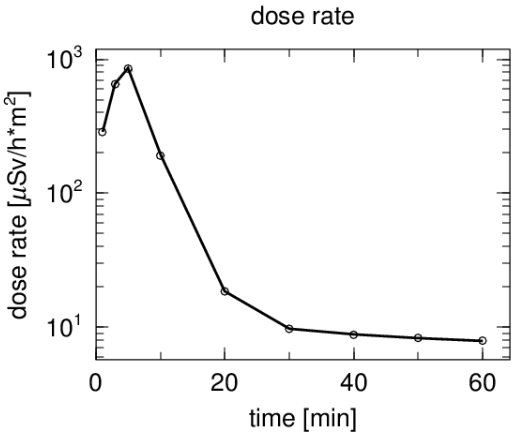

Fig. 1. Time variation of ambient dose equivalent H*(10) rate at 1m away from the SiC during and after neutron irradiation (plotted by ANGEL 4.50).

4. Conclusion

Assessment for residual radioactivity after neutron irradiation of SiC is conducted using PHITS simulation. As a result, aluminum that is an impurity in SiC has dominant residual radioactivity and ambient dose equivalent after neutron irradiation. Thus the concentration of aluminum in SiC should be controlled for safety and quality assurance.

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