Positron Annihilation Lifetime Study on Neutron-irradiated Silicon Carbide

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1. Introduction

Positron annihilation lifetime spectroscopy (PALS) has been studied for the defect of the materials such as semiconductors, metal alloys, polymers, and compounds. It is sensitive to atomic defects or defect clusters, which is appropriate for analyzing radiation-induced defects.

Silicon carbide (SiC) is well-known as one of the power semiconductor materials applicable for an electric vehicle. For better quality, neutron transmutation doping can be adopted for stable resistivity. However, neutron irradiation of SiC can be damaged by the fast neutron in HANARO.

In this study, neutron-irradiated damage of SiC was analyzed by PALS.

2. Materials and Methods

An encapsulated Na-22 positron source with a 5-µm titanium window (POSN-22, Eckert & Ziegler) was centered at two identical SiC samples. A high purity semi-insulating (HPSI) SiC wafer was cut by a 1 × 1 cm^2. The HPSI SiC samples were divided into four groups for different neutron irradiation times. Three groups were irradiated by the thermal and fast neutrons in HANARO for one, two, and three hours, respectively. The other group was not irradiated. The pneumatic transfer system #1 was used for neutron irradiation.

Two photomultiplier tubes (PMT) (R329-02, Hamamatsu Photonics K. K.) with fast timing plastic scintillation crystals (BC-422Q, Saint Gobain Crystals) were connected to PMT bases (265A, Ortec). A high voltage of -2.1 kV was applied to both PMTs (556, Ortec). Two constant fractional differential discriminators (CFDDs) (418, Ortec) selectively processed 1.27-MeV gamma rays from the beta decay of Na-22 and 0.511-MeV gamma rays from positron annihilation. A time-to-amplitude converter (TAC) (566, Ortec) generated time different logic signals from two gamma rays within 50 ns. An analog-to-digital converter/multi-channel analyzer (927, Ortec) sent the digitized signals to a personal computer. PAL spectra were analyzed by the *PALSfit3* software to unfold the positron lifetimes.

3. Results

Table 1 and Fig. 1 show the positron lifetimes and intensities of the neutron-irradiated SiC. Positron mean lifetime was increased by increasing neutron irradiation time. The τ_1-values, which are related to the bulk lifetime in the sample, were decreased by neutron irradiation. The intensities of τ_2 were increased by neutron irradiation.

Table 1. Positron lifetime of neutron irradiated silicon carbide

	τ_1 (ns)	τ_2 (ns)	τ_3 (ns)	Mean lifetime (ns)
No irradiation	0.116	0.209	0.577	0.167
1 hour	0.081	0.174	0.502	0.168
2 hours	0.098	0.192	0.554	0.170
3 hours	0.110	0.205	0.601	0.174

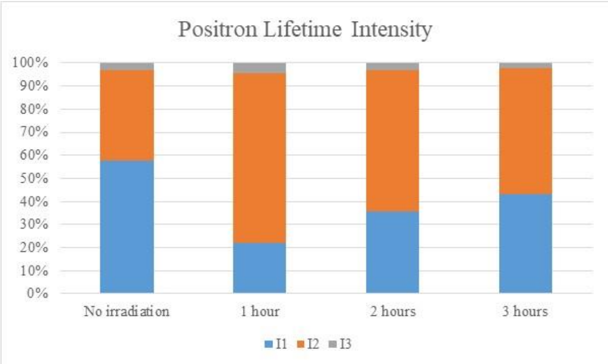

Fig. 1. Positron lifetime intensity of neutron irradiated silicon carbide. I_1, I_2, and I_3 are the intensity of positron lifetime τ_1, τ_2, and τ_3, respectively.

4. Discussion

After neutron irradiation, the microstructure of SiC was changed based on the positron lifetime. The amount of defect was increased by increasing neutron irradiation time because fast neutron induced atomic defect [1, 2]. The τ_2-values about and less than 0.2 ns were identified as Si or C vacancy based on the theoretical calculations [3].

5. Conclusions

We analyzed the change in the defect of SiC using PALS. After neutron irradiation, the defect condition was changed, and PALS can be applicable for the defect change in SiC. Up to three-hour neutron irradiation using HANARO, only Si or C single atomic vacancy can be evaluated.

For a better understanding of defects in SiC by neutron irradiation, coincidence Doppler broadening spectroscopy will be applied to the same SiC samples.

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