§28. Dynamic Radiation Effects in Electrical Property of Blanket Silicon Carbide Materials

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Silicon carbides (SiCs) are potential candidates as insulating materials in nuclear fusion systems such as separators or insulating flow channel inserts, between tritium breeding and neutron multiplier materials composing Li-Pb blanket modules. For use as the insulator, it is significantly important to understand the radiation effects in the electronic conduction of SiCs. So far, it has been reported that the electrical properties of insulating ceramics are dynamically modified by electrons that are excited from valence bands to conduction bands by the so-called dynamic radiation effects [1-2]. The present work within the EU-Japan Broader Approach (BA) materials activities is to understand fully fundamental aspects of dynamic radiation effects for SiCs; that is indicative of transportational behaviors of electrical carriers, which significantly contribute to electronic, ionic, and protonic conductions, for application of the SiC based ceramics and composites in advanced nuclear systems and future fusion devices.

In present study, CVD-SiC materials were carried out under gamma-ray and fast neutron irradiations, clearly in order to understand the basic radiation response for the electronic conduction of the SiC matrix materials, which is not due to impurity but crystalline structure.

Figure 1 shows effects of dose on RIC (●), σ_{RIC}, under gamma-ray irradiation (beam-on) and on the base conductivity (○), σ_{BC}, in the absence of radiation (beam-off) for the irradiated CVD-SiC samples at 5.9 Gy/s and 300 K in air. These relationships were determined from the Ohm's law using the increment of the currents when applied from 0 to +10 V and the volume of the samples. The radiation-induced current was also proportional to the applied voltage under a constant irradiation intensity. A rapid increase in the electrical conductivity; this is indicative of RIC, was observed at the beginning of the irradiation. Although the temperatures of the irradiated CVD-SiC samples were elevated from approximately 291 to 306 K, by heating due to gamma-rays, the increment of the irradiation temperature had little influence on the increment of the current. The σ_{RIC} value became approximately three times higher than σ_{BC} because of ionizing effects just after irradiation began, followed by a slight increase in dose up to approximately 50 kGy and then was almost constant in the dose up to approximately 1.47 MGy. In addition, the σ_{BC} also increased approximately twice at initial dose of approximately 0.4 MGy only than that before irradiation. These results indicate the occurrence of RIED [2].

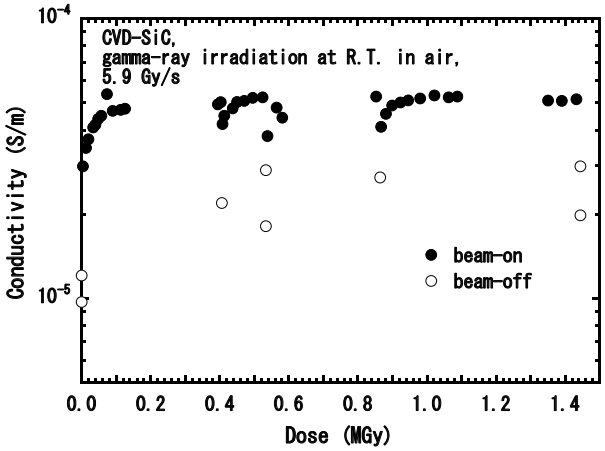

Fig. 1. Dose dependence of (●) RIC, σ_{RIC}, and (○) base conductivity, σ_{BC}, of CVD-SiC, where σ_{RIC} and σ_{BC} represent data on 1.17 and 1.33-MeV gamma-ray beam-on at approximately 5.9 Gy/s, and 300 K in air and -off, respectively.

Figure 2 shows effects of fast fluence on RIC (●), σ_{RIC}, under fast neutron irradiation (beam-on) and on the base conductivity (○), σ_{BC}, in the absence of radiation (beam-off) for the irradiated CVD-SiC samples at 2.1 Gy/s, 9.2×10^{14} n/m^{2}s, and 300 K in air. The occurrence of a slight RIC was observed at further low dose rate. The both results by gamma-ray and neutron irradiations show that the RIC greatly depends on the dose rates. Therefore, the RIC may be probably caused by electronic excitation due to gamma-rays and electrons from the fast neutron source and primary knock-on atoms or secondary ions with high energy, produced by elastic collision with neutrons, rather than neutron-electron interaction. In addition, the results of the σ_{BC} as well as σ_{RIC} exponentially showed a gradual increase in the maximum resultant fluence of approximately 8.4×10^{19} n/m^2.

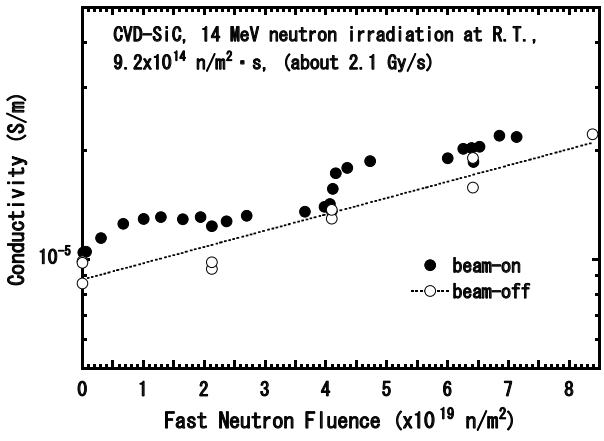

Fig. 2. Fast neutron fluence dependence of (●) RIC, σ_{RIC}, and (○) base conductivity, σ_{BC}, of CVD-SiC, where σ_{RIC} and σ_{BC} represent data on 14-MeV neutron beam-on at approximately 2.1 Gy/s, 9.2×10^{14} n/m^{2}s, and 292 K in air and -off, respectively.

1) Hodgson E.R., Nucl. Instr. Meth. Phys. Res. **B 191** (2002) 744.
2) Zinkle S.J., Hodgson E.R., J. Nucl. Mater. **191–194** (1992) 58.