# §7. Evaluation of Electrical Conductivity of High Purity Single Crystal SiC Material under Gamma-ray Irradiation

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In the development of fusion reactors, silicon carbide (SiC) materials have been studied as attractive candidates for advanced blanket systems. The design study of the double cooled Li-Pb blanket system is aiming a high temperature operation of up to ~800 °C by installing SiC flow channel plates which moderate the maximum temperature of ferritic steel duct walls.[1,2] In addition, a function of electrical insulation is also required for the SiC flow channel plates to suppress the MHD pressure drop in a circulation of a Li-Pb coolant. In the present study, electrical conductivities of high purity single crystal SiC plates have been examined under $^{60}$Co gamma-ray irradiations to predict insulating performances of SiC materials in a radiation environment of a fusion reactor.

Schematic drawing of the present experiment is shown in Fig.1. A semi-insulating SiC plate of 10 x 10 x 0.39 mm$^3$ was prepared by cutting SiC wafers supplied from Cree Inc. For electrical measurements, electrodes of 200 nm in thickness were deposited by Pt sputtering on the surfaces of the plates. Electrical conductivity of the SiC plate was evaluated by two-terminal I-V (current-voltage) curve measurements. The electrical conductivities under a radiation environment were examined by $^{60}$Co gamma-ray irradiations at the Institute of Scientific and Industrial Research (ISIR) of Osaka University. The dose rate at the sample position was estimated to be 2.3 Gy/s by a gamma-ray transport calculation using the MCNP Monte Carlo code. All of the measurements without and under the irradiations were performed in a vacuum chamber evacuated to ~$10^{-3}$ Pa at room temperature.

Figure 2 shows the I-V curve of the semi-insulating SiC plate. The inherent conductivity without irradiation was 3.0x$10^{-14}$S/m. Under the gamma-ray irradiations, the electrical current in the plate increased due to the effect of radiation induced conductivity (RIC). The magnitude of the RIC evaluated from the curve was 4.3x$10^{-8}$ S/m for the dose rate of 2.3 Gy/s. Figure 3 shows the dose rate dependence of the magnitude of the RIC obtained by changing the position of the gamma-ray source. The result indicates that the magnitude of the RIC is almost proportional to a dose rate. In the results in Fig. 3, the values for 2.3 Gy/s was scattered by a factor of four. The magnitude of the RIC might be affected by a condition of electron trapping levels in the crystal.

From the extrapolation of the present result, the magnitude of RIC in the high purity SiC plates is estimated to be the order of $10^{-4}$ S/m for a first wall condition of several kGy/s. The magnitude of the RIC is dominantly affected by drift distance of charge carriers excited in a material. Since the influence of impurities, defects and grain boundaries which reduce the drift distance of charge carriers are considered to be smallest in high purity single crystals, the magnitude of the RIC would be largest in the present high purity single crystal plates. The present result indicates that the RICs in SiC materials would not prevent achievement of the insulating performance of 100 S/m which has been required for the SiC flow channel plates of the Li-Pb blanket system[3].

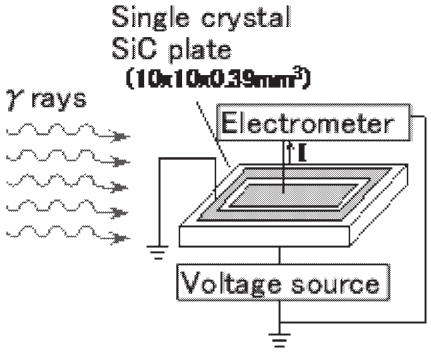


Fig. 1 Schematic drawing of electrical conductivity measurement of high purity single crystal SiC plate.

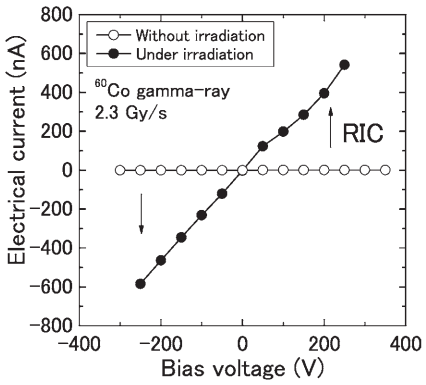


Fig. 2 Example of I-V (current-voltage) curves of high purity SiC plate.

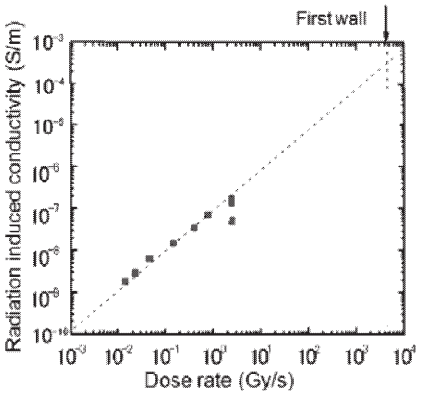


Fig. 3 Dose rate dependence of radiation induced conductivity (RIC) of high purity SiC plate.

1) P. Norajitra *et al.*, Fusion Engineering and Design, 69 (2003) 669-673.
2) M. Abdou *et al.*, Fusion Sci. Tech., 47(2005) 475-487.
3) S. Smolentsev *et al.*, Fusion Sci. Tech. 50 (2006) 107-119.