§15. Effects of Ion Beam Irradiation on Electrical Insulating Performance of Er_2O_3 Coating

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A change in the electrical insulating performance of a ceramic material in a radiation environment is one of concern in the development of the MHD coating for the Li/V-alloy blanket system. Especially in profound studies for Al_2O_3 materials, permanent degradations of the insulating performances due to irradiation damage have been reported as radiation induced electrical degradation (RIED). In the present study, electrical insulating properties of the Er_2O_3 candidate material for the MHD coating have been examined under high-energy ion beam irradiations.

Specimens of Er_2O_3 coating were made at Osaka University by the RF sputtering method. Considering that the range of 1 MeV H^+ particles calculated by SRIM code is ~5 μm in an Er_2O_3 layer, the coating layer was grown to 2.0-2.4 μm on a well polished stainless steel plate. The substrate was at room temperature during the fabrication. On the surface of the Er_2O_3 coating layer, Pt electrodes of ~2 x 2 mm^2 have been deposited with the thickness of 200 nm for the electrical measurement. As shown in Fig. 1, the electrical conductivities of the Er_2O_3 coating layers were measured by connecting an electrometer and a voltage source to the Pt electrodes and the substrates, respectively. Ion beam irradiations have been performed at Institute for Materials Reserach (IMR), Tohoku University. A beam of 1 MeV H^+ or 2.8 MeV He^+ was irradiated on the Er_2O_3 coating layer through the Pt electrode at room temperature. The maximum damage induced by the irradiation was calculated to be ~2.2 x 10^{-2} dpa with the SRIM code. Between irradiations of programmed fluences, the beam was stopped and a change in the inherent electrical conductivity was examined. The radiation induced conductivity (RICs) was also evaluated under the beam irradiation.

Figure 2 shows the changes in the electrical conductivities of the Er_2O_3 coatings induced by the ion beam irradiations. The inherent conductivity of the sample #1 (coating thickness: 2.0 μm) measured during stopping the beam increased by two orders with the irradiation damage of up to ~9.3 x 10^{-3} dpa. In contrast, significant change was not observed in the magnitude of the RIC measured under the beam irradiation. Our previous RIC measurements for ceramic materials under irradiations imply that a magnitude of the RIC is not affected by a leakage current through local paths of grain boundaries, cracks etc. In the sample #1 of the present study, a local path of the leakage current was considered to be induced by the ion beam irradiation. In the irradiation on the sample #2 (coating thickness: 2.4 μm), no significant change was observed in the inherent conductivity up to the damage of ~2.2 x 10^{-2} dpa. A strong electrical field of ~1 kV/mm was applied during the irradiations of 1.5 x 10^{-2} to 2.2 x 10^{-2} dpa on the sample #2.

The present results indicate that the insulating performance of the Er_2O_3 material would not degrade up to the order of ~2.2 x 10^{-2} dpa under the strong electric field at room temperature. However, there is a possibility that a local path of a leakage current could be induced in the coating layer by irradiations. Further irradiation experiments are planed to study the mechanism of the permanent electrical degradation and the relation with the coating conditions.

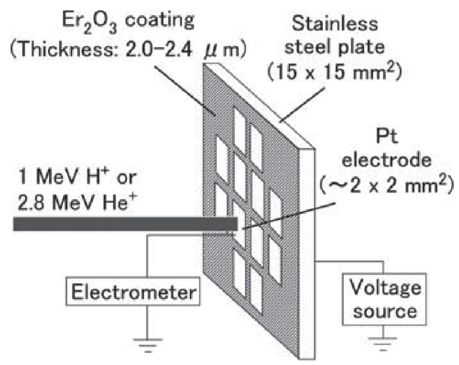

Fig. 1. Schematic drawing of ion beam irradiation on Er_2O_3 coating samples and electrical conductivity measurement.

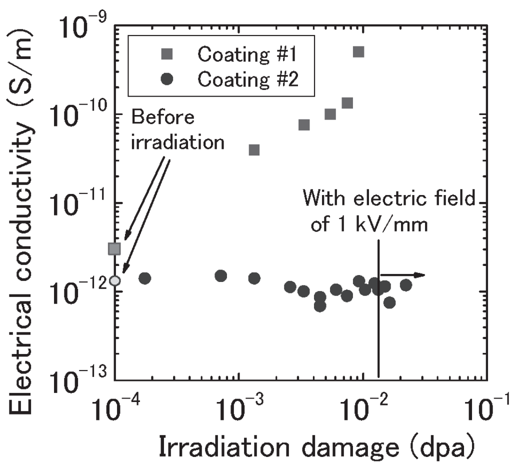

Fig.2. Permanent changes in electrical conductivities of Er_2O_3 coating samples induced by ion beam irradiations.