§16. Examination of Electrical Degradation of Ceramic Coating Materials Using Ion Beam Irradiation

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In the development of the electrical insulating coating for the liquid Li cooled blanket system, radiation damage is one of the concerned factors degrading the performance. Previous studies on Al_2O_3 insulators have reported the possibility of RIED (Radiation Induced Electrical Degradation), which is permanent electrical degradation due to irradiation damage, under the condition of high neutron fluence, high temperature and high electric field. However, almost no data is available for the irradiation effects on the candidate coating materials such as Er_2O_3, Y_2O_3, $CaZrO_3$, AlN etc. The objective of the present study is to examine the effect of irradiation damage on the ceramic materials using a high-energy ion beam. Result of preliminary irradiation experiment on Er_2O_3 coating is described in this report.

Schematic arrangement of the ion beam irradiation is shown in Fig.1. A sample of Er_2O_3 coating was made on a stainless steel plate of 15 x 15 x 2 mm^3 by the RF sputtering method at University of Tokyo. Thickness of the coating was 1 μm. Electrical performance of the coating sample was examined at NIFS. On the surface of the coating, three Pt electrodes of 2 x 2 mm^2 were made by sputter deposition with thickness of ~100 nm. Bias voltage was applied to the stainless steel plate. Electrical insulating performance of the coating was evaluated by measurement of currents flowing into the electrodes. The electrical conductivities under the three electrodes were 1.7 x 10^{-10}, 5.4 x 10^{-11} and 6.9 x 10^{-10} S/m.

Ion beam irradiation was performed in Institute for Materials Research of Tohoku University. A beam of 1 MeV H^+ was collimated to 1mm in diameter and injected into the Pt electrodes. During the irradiation, the electrodes were grounded to prevent electrical breakdown due to charge up in the coating layer. The irradiation flux of the H^+ beam was 7.9 x 10^{11} $H/cm^2/s$. The total fluences at the three electrodes were 1.0 x 10^{15}, 1.0 x 10^{16} and 2.6 x 10^{16} H/cm^2, respectively.

Figure 2 shows examples of current-voltage (I-V) characteristics measured before and after the ion beam irradiation. Both of the curves indicate ohmic characteristics. Electrical conductivities after the irradiation were 2.6 x 10^{-10} S/m (fluence: 1.0 x 10^{15} H/cm^2, conductivity before irradiation: 1.7 x 10^{-10} S/m), 9.6 x 10^{-10} S/m (1.0 x 10^{16} H/cm^2, 5.4 x 10^{-11} S/m) and 1.3 x 10^{-7} S/m (2.6 x 10^{16} H/cm^2, 6.9 x 10^{-10} S/m), respectively. Significant change was observed for the order of 1.0 x 10^{16} H/cm^2 in the present experiment. By calculation using the charged particle transportation code TRIM, it is estimated coarsely that the range of hydrogen ions was 5-10 μm in the Er_2O_3 layer and displacement after the irradiation of 2.6 x 10^{16} H/cm^2 corresponded to ~0.005 dpa.

Further irradiation is planed to examine the relation between the insulating performance and various factors of fluence, temperature, applied electric field etc. Examination of luminescence emission spectrum under ion beam irradiation is also planned to obtain information on the defect formation.

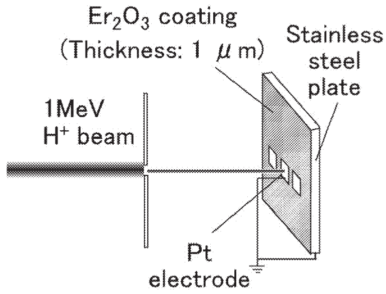

Fig. 1 Schematic arrangement of ion beam irradiation on Er_2O_3 coating.

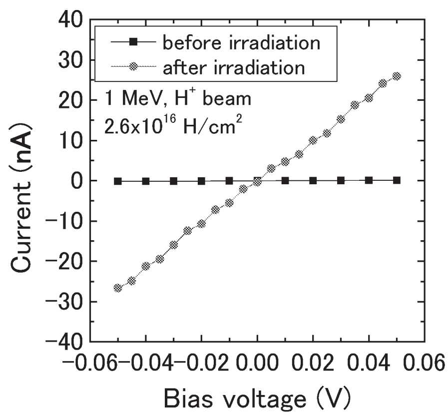

Fig. 2 Example of current-voltage (I-V) characteristics before and after irradiation
(Electrode: 2 x 2 mm^2, Thickness of coating: 1 μm)