24P051-P

Electrical insulating performance of Er_2O_3 coatings by MOD method
ＭＯＤ法による酸化エルビウム被覆の電気絶縁特性

Teruya Tanaka[1], Fuminobu Sato[2], Toshiyuki Iida[2], Takeo Muroga[1]
田中照也[1]，佐藤文信[2]，飯田敏行[2]，室賀健夫[1]

[1]*National Institute for Fusion Science*
322-6, Oroshi-cho, Toki, Gifu 509-5292, Japan
[2]*Graduate School of Engineering, Osaka University*
2-1, Yamada-Oka, Suita, Osaka 565-0871, Japan
[1]核融合科学研究所 〒509-5292 岐阜県土岐市下石町322-6
[2]大阪大学大学院工学研究科 〒565-0871 大阪府吹田市山田丘2-1

Electrical insulating performances of erbium oxide (Er_2O_3) ceramic coatings fabricated by the metal organic decomposition (MOD) method with the baking temperature of 600 ^oC have been measured to examine the applicability to suppression of an MHD pressure drop in a liquid Li cooled blanket system. The electrical conductivity of a 0.5 μm thick coating sample was 5.6 x 10^{-12} S/m at room temperature and the value was almost one order higher than that of sintered Er_2O_3 disc sample. Increase of the conductivity under a gamma-ray irradiation was almost same level as that of the sintered disc sample. The electrical breakdown in the 1 μm thick coating sample was observed for applied voltages of 29 - 40 V. The obtained results indicate that the MOD Er_2O_3 layer baked at ~600 ^oC could have superior electrical insulating performances.

1. Introduction

Fabrications of large area electrical insulating ceramic coatings by the metal organic decomposition (MOD) method have been studied for suppression of an MHD pressure drop in a liquid Li cooled blanket system. Erbium oxide (Er_2O_3) has been selected as one of candidates for the insulating coating in a liquid lithium coolant from the view point of the chemical stability. In the MOD process, ceramic coatings are obtained by immersion of a substrate plate into an organic liquid containing Er and baking the substrate plate in an oxidation atmosphere at >~500 ^oC. While it has been confirmed that the superior crystalinity could be obtained by baking at a higher temperature in our previous studies [1], it would be preferable to keep the baking temperature similar to a blanket operation temperature to avoid significant mechanical property changes in structural materials of a blanket. Electrical insulating performances of the MOD Er_2O_3 coatings fabricated with the relatively low baking temperature of 600 ^oC have been examined in the present study.

2. Experiments

Coating samples for conductivity measurements were fabricated on substrates of SiO_2 plates. An electrode layer was made on the substrate surface by DC sputtering of Pt. Er_2O_3 coating layers were fabricated on the Pt coated substrates by immersing into an MOD liquid and baked at 600 ^oC in air. The thickness of the coating layer was 0.5 μm. On the coating layer, 2 mmϕ electrodes were made by DC sputtering of Pt. The electrical conductivity was measured by applying a bias voltage to the Pt layer on the SiO_2 substrate and measuring an electrical current at the 2 mmϕ electrode on the Er_2O_3 coating layer. The measurement was performed at room temperature in a vacuum of ~2.5 x 10^{-2} Pa. Increase of the conductivity in a radiation environment, i.e. radiation induced conductivity (RIC), has also been measured under a ^{60}Co gamma-ray irradiation with a dose rate of ~2 Gy/s.

In addition to the electrical conductivities, a breakdown voltage of a coating layer is also an important property for the suppression of an MHD pressure drop in a blanket system. A coating sample for the examination of a breakdown voltage was fabricated on a polished SUS430 substrate with the thickness of 1.0 μm. A bias voltage was applied to the SUS430 substrate and a current flowing through the tungsten needle probe touching the coating surface was measured at room temperature in air.

3. Results and discussion

The electrical conductivity of the Er_2O_3 coating sample at room temperature was measured for a bias voltage of <0.5 V, i.e. electric field of <1 kV/mm. The current flowing through the coating layer was almost proportional to the bias voltage and the evaluated conductivity was 5.6 x 10^{-12} S/m (Fig.1). The conductivity measured for a sintered Er_2O_3 disc sample was in the order of 10^{-13} S/m around room temperature [2]. The conductivity of the MOD coating was almost one order higher than that of the sintered disc.

The conductivity of the MOD coating increased to 1.05 x 10^{-11} S/m under the gamma-ray irradiation of ~2 Gy/s and the magnitude of the radiation induced conductivity (RIC) was evaluated to be 4.9 x 10^{-12} S/m. The magnitude of the RIC in the MOD coating is almost same level compared with that in the sintered Er_2O_3 disc sample. From the previous measurement of RICs at high temperatures, it is considered that magnitudes of RICs reflect drift behaviors of charge carriers inside grains. The present result of the RIC measurement indicates that the electrical insulating property of the Er_2O_3 grains grown by the MOD method at 600 ^oC is similar to that of Er_2O_3 powders which are used in fabrication of the sintered disc sample and show higher crytalinities. The one order higher conductivity of the MOD coating layer measured before the gamma-ray irradiation might be due to electrical currents through grain boundaries.

The breakdown voltage of a 1 μm thick Er_2O_3 coating on a SUS430 substrate was examined by increasing the magnitude of the DC bias voltage by steps of 1 V. Responses obtained at four measurement points on the coating are shown in Fig. 2. The breakdown voltages that the coating completely lost the insulation were 29 – 40 V. These applied voltages correspond to the electrical field strengths of 29 – 40 kV/mm in the coating layer. For the condition of a magnetic field of 10 T, coolant flow velocity of 1 m/s and duct width of 0.1 m, the electrical potential different in the blanket duct will be ~1 V [3, 4]. The measured breakdown voltage is significantly higher than the expected potential difference.

4. Conclusion

Electrical insulating performances of Er_2O_3 coatings fabricated by the MOD method have been examined at room temperature. The coating samples in the present study have been baked at 600 ^oC which could avoid significant mechanical property changes of structural materials of a blanket system. While the electrical conductivity of 0.5 μm thick MOD Er_2O_3 coating was almost one order higher than that of sintered Er_2O_3 disc sample, it still showed a superior insulating performance. The increase of the electrical conductivity of the MOD coating under a gamma-ray irradiation of ~2 Gy/s, i.e. radiation induced conductivity, was almost same as that of sintered disc sample. The electrical breakdown voltage examined for the 1.0 μm thick MOD coating was significantly higher than the potential difference expected in the Li cooled blanket system. The examination of the insulating performances and their stability at the blanket temperature of ~650 ^oC is being performed at present.

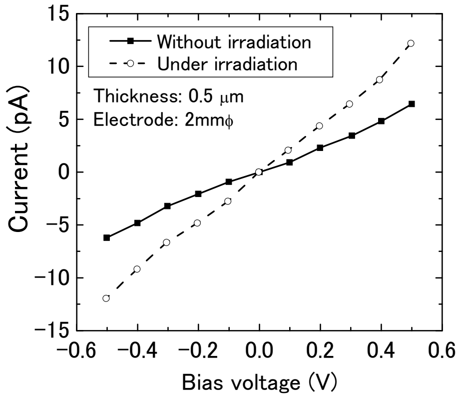

Fig.1. Voltage-current curves obtained in conductivity measurements without irradiation and under a gamma-ray irradiation with a dose rate of ~2 Gy/s.

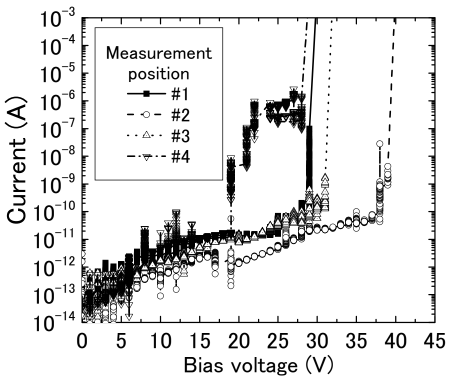

Fig.2. Responses in a breakdown voltage measurement.

Acknowledgment

The authors would like to express their gratitude to Dr. D. Zhang for fabrication and property improvement of the coating samples. This study has been conducted under the NIFS research program of UFFF021.

References

[1] D. Zhang et al.: Journal of Nuclear Materials 417 (2011) 1249.

[2] T. Tanaka et al.: Journal of Nuclear Materials 367–370 (2007) 1155.

[3] H. Hashizume: Fusion Engineering and Design **81** (2006) 1431.

[4] S. Malang et al.: Fusion Engineering and Design **27** (1995) 570.