§16. Examination of Irradiation Damage in Electrical Insulating Coating Using Ion Beam Irradiation

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Permanent electrical degradation of ceramic materials due to irradiation damage is called RIED (Radiation Induced Electrical Degradation) and one of concerned issues for the long-term usage in a fusion blanket environment. The candidate ceramic materials of the electrical insulating coating developed for reduction of the MHD pressure drop in the Li/V-alloy blanket system (Er_2O_3, Y_2O_3, AlN etc.) will be used in the condition of high fluence, high temperature and high electric field where the RIED has been reported in the studies on Al_2O_3. However, almost no data can be found for the irradiation damages on the candidate materials. The purpose of the present study is to examine the irradiation damage in the candidate ceramic coating materials using ion beam irradiation.

While the thickness of the insulating coating in the Li/V-alloy blanket system would be several tens μm, that of a sample for the in-situ measurement of electrical conductivities under irradiations should be less than several μm considering the ranges of ion beams injected into the ceramic materials. Although some Er_2O_3 samples of ~1 μm in thickness were fabricated on polished stainless steel plates with the RF sputtering method in this year, high insulating performance required for the conductivity measurement could not obtained due to small pores observed on the coating surfaces. Therefore, in parallel with the effort for improving the coating quality, spectrum measurement of ion beam induced luminescence, which is considered to include the information on the irradiation damages, has been performed for an Er_2O_3 coating layer.

A sample of Er_2O_3 coating was fabricated on a SiO_2 plate with the RF sputtering method with the thickness of 1.5 μm. The schematic arrangement of the irradiation is shown in Fig. 1. Visible light spectrum of ion beam induced luminescence in the Er_2O_3 layer was measured under irradiation of 100 keV H^+ beam at room temperature with a spectrometer. The beam flux was ~5.5 x 10^{13} $H^+/cm^2/s$. After the first measurement, 100 keV Ar^+ beam of 5.6 x 10^{16} ions/cm^2 was irradiated. From the second measurement, 100 keV H^+ beam was irradiated continuously up to the fluence of 2.2 x 10^{17} H^+/cm^2.

Figure 2 shows the results of the spectrum measurements of ion beam induced luminescence in Er_2O_3. Since the erbium is rare earth and has the suitable properties for light emission, data on luminescence spectra from Er doped in Si substrates and Er_2O_3 on Si substrate have been reported in the studies on optoelectronic devices. In the present ion beam irradiation, two peaks were observed in the visible light region as same as the reported cathode luminescence spectrum [1]. The peaks at ~560 nm are corresponding to emissions between the levels of $^2H_{11/2}$ -> $^4I_{15/2}$ and/or $^4S_{3/2}$ -> $^4I_{15/2}$ and the peaks at ~650 nm re corresponding to those between $^4F_{9/2}$ -> $^4I_{15/2}$ and/or $^4F_{7/2}$ -> $^4I_{13/2}$ as described in literature [1]. During the irradiations, the heights of the peaks around ~650 nm has been decreased with the ion fluence, while significant change has not been observed in the peaks around ~560 nm.

It is estimated by ion transport calculation using the SRIM code that the irradiation of H^+ beam of 2.2 x 10^{17} ions/cm^2 introduced damage of ~2 dpa in the Er_2O_3 coating layer, which is depending on the depth from the surface. The information on the mechanism corresponding to the decreasing in the peak heights could be found also in literatures on luminescence studies for optoelectronics devices. It is considered that the measurement of the infrared (~1.5 μm) peak emitted from Er^{3+} and the temperature dependence of the spectra would be important in the future luminescence experiments to examine the relations with the electrical insulating performance under irradiations.

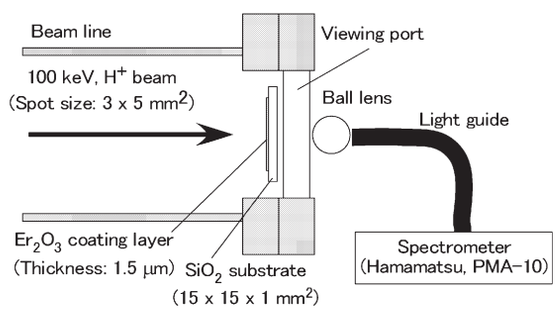

Fig. 1. Schematic arrangement of spectrum measurement of ion beam induced luminescence.

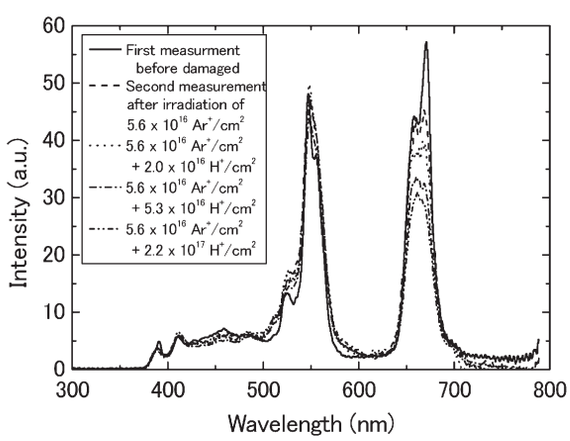

Fig. 2. Visible light spectra of luminescence in Er_2O_3 coating layer under 100 keV H^+ beam irradiation. Peak heights around 650 nm have been decreased with ion fluence.

[1] E. Nogales *et al*. J. Phys. D: Appl. Phys. 35(2002) 295-298.
[2] A. Kasuya *et al*., Appl. Phys. Lett. 71(1997)2728-2730.