§11. Ion-beam Damage and Luminescence of Functional Materials for Fusion Reactors

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Ceramics coating is being developed for electric insulating of Li/V-alloy blanket systems [1]. Er_2O_3 is the prime candidate of the coating materials because of its higher corrosion resistivity with liquid Li. Er_2O_3 coating serves also as a tritium permeation barrier of blanket systems made of other breeder and coolant such as Flibe and Li-Pb [2]. However, neutron damages of the coating in fusion reactors are a big concern. We are investigating applicability of optical methods to evaluation of damages in the ceramics coating.

Optical transitions of trivalent Er ions (Er^{3+}) in Er_2O_3 crystals are known rather strong and sharp [3] due to localized 4f valence orbital. The ground state of Er^{3+} has an incomplete 4f sub-shell ($4f^{11}$). The intra-4f transitions from lower excited states to the ground state are observed as luminescence in Infrared and visible ranges. In the present study, visible spectra of sintered Er_2O_3 samples bombarded by Ar^+ ion-beams were measured [4].

The experimental apparatus consists of an ion-beam source, a collision chamber, and a CCD spectrometer. The ion source is a part of medium current ion implanter (ULVAC IM-200MH-FB, Freeman-type) originally designed for semiconductor production. Ion-beam extracted from the ion source is introduced into the collision chamber (see Fig. 1) after analyzing the mass to charge ratio by a magnet. The ion-beam induced photon emissions were measured in a visible range of 450-750 nm using Ar^+ ions at 33 keV. Three broad emissions at 500-520, 540-570, and 640-690 nm were observed (see Fig. 2). The emission band at 640-690 nm is clearly identified as ($4f^{11}$) $^4F_{9/2}$ - $^4I_{15/2}$ transition of trivalent Er^{3+} ions in the C_2 cation sites of pure Er_2O_3 crystals. Intensity of the emission band at 640-690 nm decreases substantially during continuous ion-beam irradiation, which indicates depopulation of the crystalline oxide in the irradiated region. Dose dependence of the emission spectra suggests creation of electron conduction layers on surface of the heavily damaged samples.

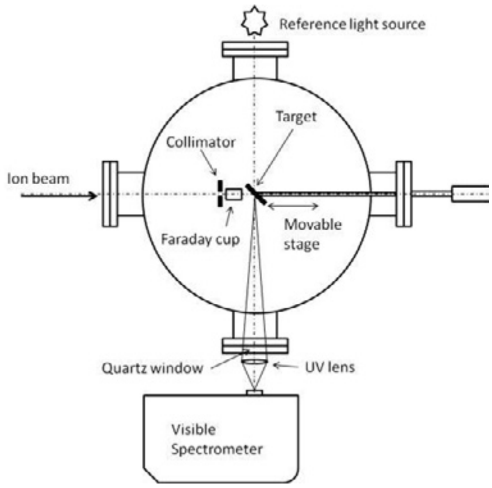

Fig. 1. Schematic illustration of the collision chamber and the visible spectrometer [4].

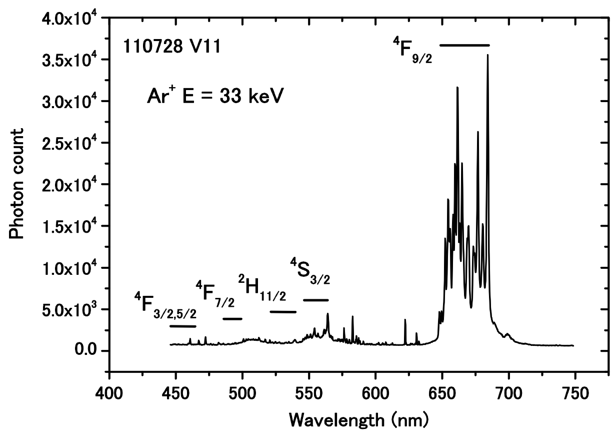

Fig. 2. Ion-beam induced luminescence spectrum in a visible range [4]. The spectrum was obtained using a grating of 300 Grooves/mm.

1) Muroga, T. et al.: J. Nucl. Mater. **367-370** (2007) 780.
2) Levchuk, D. et al.: J. Nucl. Mater. **367-370** (2007) 1033.
3) Polman, A.: J. Appl. Phys. **82** (1997) 1.
4) Kato, D. et al.: Plasma and Fusion Res. **7** (2012) 2405043.