§18. Ionoluminescence of a Thin Rear-earth Oxide Film by Slow Highly-charged Ions

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i) Introduction Slow highly charged ions (HCIs) impinging on solid targets deposit its large potential energies on local areas of target surfaces, which results in enhanced emission of secondary particles and photons. Tona *et al.*[1] observed strongly enhanced ionoluminescence of a thin organic-dye film by bombardment of highly-charged iodine ions with L-shell vacancies.

Recently, optical transitions useful to evaluate radiation damages in Er_2O_3 coatings are being searched for advanced nuclear fusion materials research[2]. In a visible range, a potentially useful luminescence band due to $4f^{11}$ $^4F_{9/2}$ - $^4I_{15/2}$ transition of Er^{3+} cations has been observed at 640-690 nm by electron and singly-charged ion bombardments [2, 3]. In the present work[4], photon emission induced by HCI-beams has been investigated with the thin Er_2O_3 film.

ii) Experiment Target samples are thin polycrystalline Er_2O_3 films of about $500 - 600$ nm thickness coated on stainless steel substrates by using Metal Organic Chemical Vapor Deposition (MOCVD)[5]. Kobe Electron Beam Ion Source (Kobe-EBIS)[6] was used to produce intense HCI-beams (*e. g.* Ar^{12+} ion-beams of a few hundreds pA in current for acceleration voltages of 3 kV). A LN-cooled CCD camera (VersArray 1300F) is used to detect an induced photon emission. Quantum efficiency (QE) of the CCD camera has a broad peak centered around 700 nm (QE distributes in a wavelength rage of $400 - 1100$ nm). An optical filter (YIF-BA600-690S) is used to limit photon detection in a wavelength range of $607-680$ nm where the strong ionoluminescence due to the $^4F_{9/2}$ - $^4I_{15/2}$ transition by Er^{3+} cations is anticipated[2, 3].

iii) Results and discussion Figure 1 shows charge-state (q) dependence of detected photon counts of Ar^{q+} HCI induced emission from the Er_2O_3 film. Photon emission increases rapidly along the charge state (potential energy) of projectile ions. Kinetic energies of ions also change along the charge state, because a constant acceleration voltage of 3 kV was used for all the charge states. In Fig. 2, the photon emission intensity is plotted as a function of kinetic energy of the HCIs along with electronic stopping cross sections of Ar^+ ions on Er_2O_3 used in the TRIM code. It is clearly seen in the figure that the induced photon emission increases more rapidly than expected by the electronic stopping of Ar^+. This suggests a potential energy effect of the HCIs in the photon emission.

Some of the photon emission can also be ascribed to line emission of sputtered neutral Er atoms which falls into a band width of the optical filter used in the present measurement. Further investigation will, therefore, be made using another optical filter of a narrower band width to separate the ionoluminescence of the oxide cations from the line emission of the sputtered neutrals.

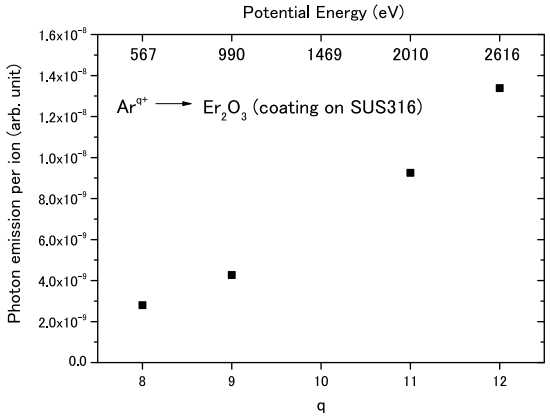

Fig. 1: Charge-state dependence of photon emission induce by Ar^{q+} HCI-beams on an Er_2O_3 film.

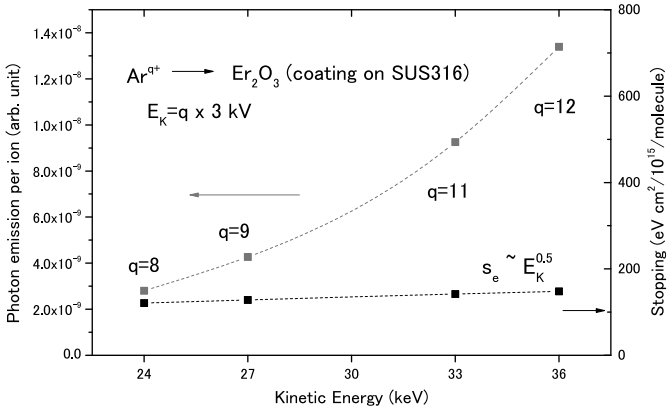

Fig. 2: Kinetic energy dependence of photon emission intensity induced by Ar^{q+} HCI-beams on an Er_2O_3 film.

1) M. Tona *et al.*, Phys. Rev. A (2008) vol.77 052902.

2) T. Tanaka *et al.*, J. Nucl. Mater. (2011) vol.417 794.

3) D. Kato *et al.*, Plasma Fusion Res. (2012) vol.7 2405043.

4) D. Kato *et al.*, presented at the 25th Int. Conf. on Atomic Collisions in Solids (ICACS-25), Oct. 21-25, 2012, Kyoto, Japan.

5) Y. Hishinuma *et al.*, J. Nucl. Mater. (2011) vol.417 1214.

6) M. Sakurai *et al.*, J. Vac. Soc. Jpn. (2005) vol.48 317; (2007) vol.50 390; (2012) vol.55 180.