

§9. Quench of Ion-beam Induced Luminescence of Er_2O_3 at Elevated Temperatures

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This study is undertaken to develop optical methods for *in-situ* characterization of radiation-induced defects in Er_2O_3 by energetic ion bombardment. The characterization is important for qualification of Er_2O_3 coatings as electric insulation of Li/V-alloy blanket systems and as hydrogen permeation barriers.

A potentially useful luminescence band in 640-690 nm is identified as $4f^{11} \ ^4F_{9/2} - \ ^4I_{15/2}$ transition of Er^{3+} at C_2 cation sites. It has been demonstrated that ion bombardment on a plasma splay coating sample and a sintered bulk sample quenches preferentially the luminescence band at the room temperature. This is explained by a model assuming ion induced decrystallization of the target. In the present work, quench of the luminescence is found at elevated temperatures. This is explained by defect mediated luminescence model [1]. In collaborations with theoretical research group of Vilnius University, state-of-the-art *ab-initio* calculations for excited levels of Er^{3+} ions are carried out [2, 3].

The Er_2O_3 sample (high purity (3N) sintered plate, 15mm \times 15mm wide and 1mm thick, TEP CORP.) is mechanically attached on a micro ceramic heater equipped with a thermocouple (25mm \times 25mm wide, MS-1000R, SAKAGUCHI E.H VOC CORP.). Ceramic fiber papers are used to thermally insulate the ceramic heater from a target holder on which the ceramic heater is set. Temperature control of the heater is performed automatically with the aid of a thermoregulator (SCR-SHQ-A, SAKAGUCHI E.H VOC CORP.). With this experimental setup, temperatures of the target sample were gradually varied in vacuum. The temperature of the target sample is deduced assuming thermal equilibrium with the ceramic heater.

Ion-beam induced luminescence of the target sample is measured with an experimental apparatus at NIFS consisting of an ion-beam source, a collision chamber, and a UV-visible spectrometer equipped with a Peltier cooled CCD camera. The ion source is a part of medium current ion implanter (ULVAC IM-200MH-FB) originally used for semiconductor production (Freeman-type). Ar^+ ion-beams extracted from the Freeman ion source are introduced into the collision chamber after analyzing the mass to charge ratio by a magnet. Photon emission is measured at a right angle to the ion-beam axis. The sample surface is leaned 45 degrees toward the line of sight so that the photons emitted in an area of the ion-beam spot are collected by a condenser lens focused on a slit of the spectrometer.

Figure 1 shows luminescence spectra induced by Ar^+ ion irradiation (35 keV) at five temperatures from 373 K to 773 K. The luminescence intensities in 640 – 690 nm

decrease as the target temperature increases. Strong lines A, B, and C are assigned to the lines due to transitions between the Stark levels: $^4F_{9/2} \ M = 1/2, 9/2, 9/2 \rightarrow \ ^4I_{15/2} \ M = 9/2$, respectively. The population distribution in the upper Stark levels obtained by analyzing intensity ratios among them is in the thermal equilibrium at the ambient temperature.

Characteristic lifetime of the upper levels was evaluated from the line broadening. The lifetime decreases as the temperature increases. This may indicate that non-radiative depopulation of the upper levels is facilitated at high temperatures. However, the intensity decay of the luminescence lines is significantly delayed. This delayed quench of the intensity is explained by O vacancy mediated luminescence model [1].

Atomic energy levels and E2 and M1 transition rates were calculated for the $[\text{Xe}] \ 4f^{11}$ ground configuration in Er^{3+} by using relativistic multiconfiguration Dirac-Hartree-Fock and configuration interaction calculations. The Breit transverse interaction and leading QED effects are included as perturbations. Different strategies for describing electron correlation effects were tested and evaluated. The calculated energy levels were compared with experiment and results from semi-empirical methods. Comparing with NIST recommended values we see that our *ab-initio* calculations for the energy spectrum agrees to within 9.8 % for the free ion in the SD V+C+CV strategy and better than 6.9 % in the CIS calculations. By an analysis of the ASFs compositions of the levels in Er^{3+} , we found that *LS*-coupling is preferable to *jj*-coupling.

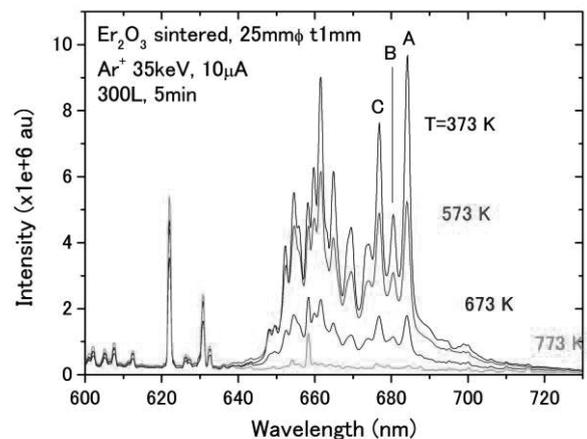


Fig. 1. Ion-beam induced luminescence of Er_2O_3 .

- 1) Kato, D, et al.: Plasma Conference 2014 (Toki Messe, Niigata, 18-21 Nov., 2014) 19PB-106.
- 2) Radziute, L., Gaigalas, G., Kato, D. et al.: J. Quant. Spec. Rad. Trans. **152** (2015) 94.
- 3) Radziute, L., Kato, D., Gaigalas, G. et al.: Phys. Scr. **90** (2015) 054001.