

§11. Ion-beam induced Luminescence of Heated Er₂O₃

Kato, D., Sakaue, H.A., Tanaka, T., Murakami, I., Muroga, T., Sagara, A., Gaigalas, G. (Vilnius Univ.)

This study is undertaken to develop optical methods for *in-situ* characterization of radiation-induced defects in Er₂O₃ by energetic ion bombardment. The characterization is important for qualification of Er₂O₃ 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 (4f¹¹) ⁴F_{9/2} → ⁴I_{15/2} transition of Er³⁺ at C₂ cation sites. Recently, measurements are performed with heated samples in order to investigate the luminescence at higher temperatures. We found that the luminescence vanishes above 670 K. However, the mechanism still remains unknown. In the present work, we investigate line broadening of the luminescence as a function of temperatures in order to elucidate the mechanism.

Ion-beam induced luminescence 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. The target sample (high purity (3N) sintered Er₂O₃ plate, 25mmϕ and 1mm thick, TEP CORP.) is mechanically attached on a micro ceramic heater equipped with a thermocouple (25mm × 25mm wide, MS-1000R, SAKAGUCHI E.H VOC CORP.). Temperature control of the heater is performed automatically with the aid of a thermoregulator (SCR-SHQ-A, SAKAGUCHI E.H VOC CORP.). The temperature of the sample is deduced assuming thermal equilibrium with the ceramic heater.

Figure 1 shows the luminescence spectra of a sample maintained at different temperatures from RT upto 723 K. Intensity variation of three lines (A+B+C) and line broadening of them with temperature change are shown in Fig. 2. A full-width at half-maximum of an emission line σ [cm⁻¹] is related to an apparent decay rate W [s⁻¹] as,

$$\sigma \simeq 5.309 \times 10^{-12} W. \quad (1)$$

The decay rate can be fitted to Arrhenius equation after subtracting a constant value ($W_0 \simeq 4.2 \times 10^{12}$ s⁻¹) as,

$$W = W_0 + W_{th} \times \exp[-E/k_B T], \quad (2)$$

where W_{th} and E/k_B stand for a pre-exponential factor and a characteristic temperature for the thermally activated part of the decay rate, respectively. Noted that a

set of values of W_{th} and E/k_B determined from measurements for temperatures ramping up and those ramping down are different. The constant part W_0 is read as the decay rate at the low temperature limit. An oscillator strength of spontaneous photoemission deduced from W_0 is approximately $f \simeq 2.3 \times 10^{-4}$, provided that the apparent line broadening is dominated by resonance broadening.

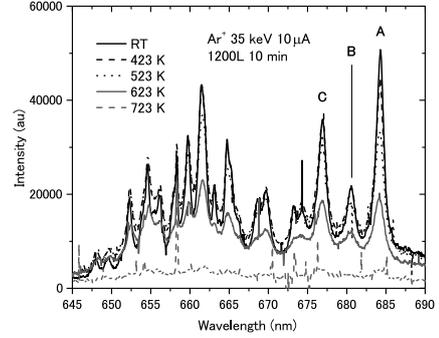


Fig. 1: Luminescence spectra (640 - 690 nm) induced by Ar⁺ ion (35 keV) irradiation at five temperatures from RT to 723 K. Strong lines A, B, and C are due to transitions between the Stark levels: ⁴F_{9/2} $M = 1/2, 9/2, 9/2$ → ⁴I_{15/2} $M = 9/2$, respectively.

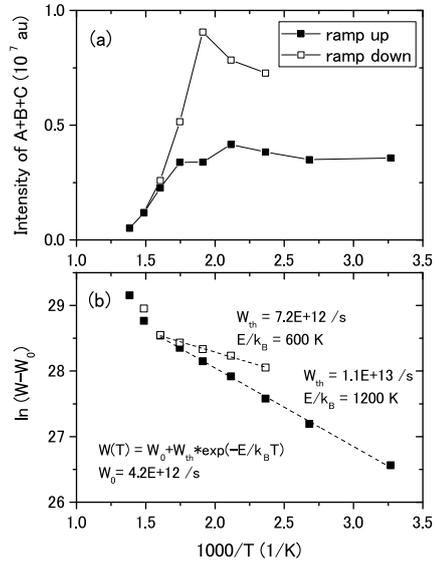


Fig. 2: a) Luminescence intensity of A+B+C and b) apparent decay rates of the upper levels evaluated from line broadening as a function of inverse temperatures. Solid squares and open squares are measurements for temperatures ramping up and those ramping down, respectively.