

XAFS measurement of Sm-doped TiO₂ semiconductor thin films

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Introduction

Host semiconductors with wide band gap are generally known to excite the rare earth (RE) ion effectively, resulting in intense luminescence. TiO₂ is an attractive semiconductor for RE activation with a direct wide band gap (3.0-3.2eV). Furthermore, as described in this study, a TiO₂ crystal phase can be changed by post annealing temperature condition. In this work, we report the association between the photoluminescence property and local structure of Sm³⁺ ion in TiO₂. It was demonstrated by X-ray absorption fine structure (XAFS) measurements that the local structure of the Sm³⁺ ions played an important role in forming effective luminescent centers.

Experimental

The Sm-doped TiO₂ (TiO₂:Sm) thin films were deposited by laser ablating a TiO₂ ceramic target including 1.0 wt% Sm₂O₃. A Q-switched YAG laser (4 ω_0 =266 nm, 1 J/cm²) was used to ablate the target in a vacuum chamber in the O₂ pressure of 1 x 10⁻² Torr. The TiO₂:Sm thin films of 300 nm thick was formed on the Si(100) surface at room temperature. After the deposition, the samples were annealed at 700 °C, 900 °C, 1000 °C, and 1100 °C for 2 min in the O₂ atmosphere for optical activation of Sm. Detailed microstructure characterization was performed by X-ray absorption fine structure (XAFS) in the fluorescence yield mode at the BL-27B beamline of the Photon Factory synchrotron facility (KEK, Tsukuba, Japan) at the total ion beam current amounted to 400 mA, was monochromatic using a Si(111) double-crystal monochromator. Each sample was placed at a 45° angle to the incident X-ray beam and fluorescence yield was monitored using a 7-element Ge SSD.

Result and Discussion

Figure 1 shows the PL spectra of the Sm³⁺ ions in TiO₂ thin films at room temperature, indicating the optical activation of Sm in TiO₂. Four emission bands peaking at 582, 611, 662 and 725 nm originating from the ⁴G_{5/2}→⁶H_{J/2} (J = 5, 7, 9 and 11) transitions in Sm³⁺ ions were observed. The PL spectra for the sample annealed at 1100°C, which showed Rutile-TiO₂ crystal phase, did not exhibit detectable Sm³⁺-related emission. Figure 2 shows the radial structural function (RSF) around Sm, derived from the Fourier transform of XAFS spectra. The data window was chosen as the radius range from 1.1Å to 3.0Å, as shown by the slash lines in Fig.2. In this RSF, these small radii indicated the first nearest-neighbor

atoms from Sm are O, and Sm-O distance of the sample annealed at 700°C is the shortest one within these samples.

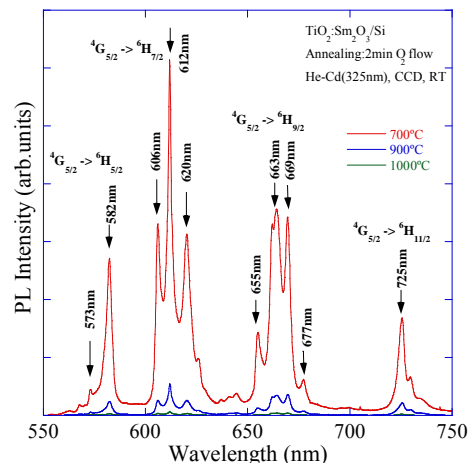


Fig1. PL spectra of Sm³⁺ ions in Anatase-TiO₂ thin films at room temperature.

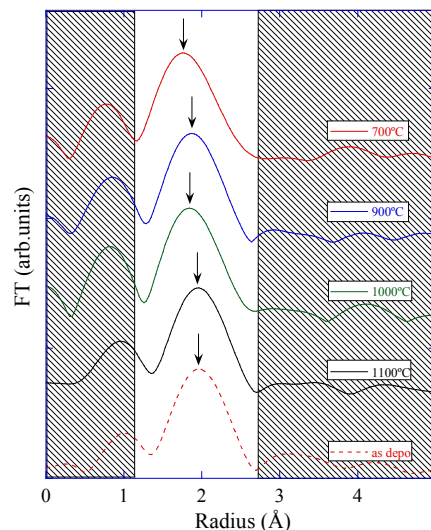


Fig2. Radial structural function around Sm of Sm-doped TiO₂ thin films.

References

- [1] F.Jing, S.Harako, S.Komuro, X.Zhao. J. Phys. D: Appl. Phys. 42 (2009) 085109 (7pp)
- [2] M.Ishii, S.Komuro, T.Morikawa. J. Appl. Phys. 94 (2003) 3823

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