Study on local structure and optical properties of photoluminescent material $YBO_3:Eu^{3+}$

Akiyuki Nishimura [1], Masato Tastumi [1], Kazuo Kojima [1], Tomoe Sanada [1], Hideshi Ishii [2], Iwao Watanabe [2]

1) Graduate School of Science and Engineering, Ritsumeikan University Kusatsu, Shiga 525-8577, Japan

2) SR Center, Ritsumeikan University, Kusatsu, Shiga 525-8577, Japan

1. Introduction

Rare-earth orthoborate phosphors such as $YBO_3:Eu^{3+}$ are known to have high quantum efficiency, high stability, exceptional optical damage threshold, and good VUV absorption. These phosphors have widely been used in fluorescent lamps, cathode ray tubes, field-emission displays, and plasma display panels.

Main photoluminescence peaks of $YBO_3:Eu^{3+}$ are composed of two transitions: the magnetic dipole transition of $^5D_0$-$^7F_1$ (orange color) and the electric dipole one of $^5D_0$-$^7F_2$ (red color) of Eu^{3+} ions. It is well known that the latter is hypersensitive to the symmetry of the local crystal-field for Eu^{3+} ions. When Eu^{3+} ions occupy some inversion sites, the magnetic dipole transition is allowed, but the electric dipole one is forbidden according to the selective rule, resulting in a poor chromaticity. The local structure of YBO_3 highly influences photoluminescent properties of $YBO_3:Eu^{3+}$.

Here we investigated the local structure of $YBO_3:Eu^{3+}$ using XANES, focusing our attention on the boron atom.

2. Experimental

$YBO_3:Eu^{3+}$ powder was prepared by Pechini sol-gel method. $Y(NO_3)_3{\cdot}6H_2O$, $Eu(NO_3)_3{\cdot}6H_2O$, and H_3BO_3 were added to water-ethanol solution with stirring. Excess H_3BO_3 was added to compensate the evaporation loss of boron at high temperatures. Citric acid (chelating reagent) and polyethylene glycol (cross-linking reagent) were added to the above solution. Through sol-gel reaction, a gel sample of $Y_{0.92}Eu_{0.08}BO_3$ was obtained. The sample was annealed at 500 °C for 2 h and then heat treated at 700, 725, 750, 800, 900, 1100, 1200, or 1400 °C for 5 h.

B K-edge XANES spectra for the sample and reference samples of B_2O_3 and BPO_4 were

measured using a beamline BL-2 at SR Center of Ritsumeikan University. The spectra were recorded in the total electron yield (TEY) and fluorescence yield (FY) modes.

We also measured XRD patterns, IR spectra, photoluminescence spectra, and photoluminescence quantum yield values of the samples.

3. Results

Figs. 1 and 2 show the B K-edge XANES spectra, measured in the TEY and FY modes, respectively, of the $Y_{0.92}Eu_{0.08}BO_3:Eu^{3+}$ sample and the reference samples. In XANES spectra of B_2O_3, a peak at 193 eV is attributed to the electronic transition of B 1s to unoccupied B 2pz (π^*) and a broad peak is assigned to the transition of B 1s to unoccupied B σ^* of trigonal B species. In XANES spectra of BPO_4, a peak at 199 eV is attributed to the transition of B 1s to the unoccupied B σ^* and a broad peak around 204 eV may be due to the transition of B 1s to high-energy unoccupied σ^* of tetrahedral B species. From these figures, it is found that the amounts of tetrahedral B species increase with increasing the heat-treatment temperature and this tendency is more remarkable in the bulk (Fig. 2) than on the surface (Fig. 1) of the $Y_{0.92}Eu_{0.08}BO_3:Eu^{3+}$ sample.

We will intriguingly compare the results of XANES with those of Eu^{3+} photoluminescence spectra, XRD, and IR.

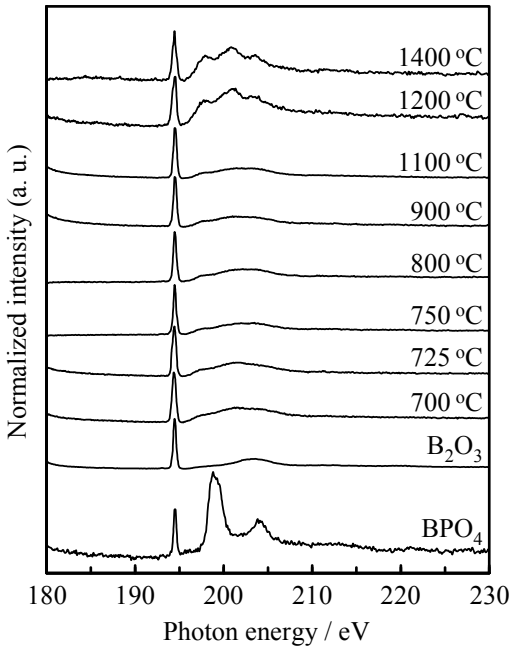

Fig. 1. B K-edge XANES spectra of $Y_{0.92}Eu_{0.08}BO_3$ samples heat treated at various temperatures, measured in the TEY mode.

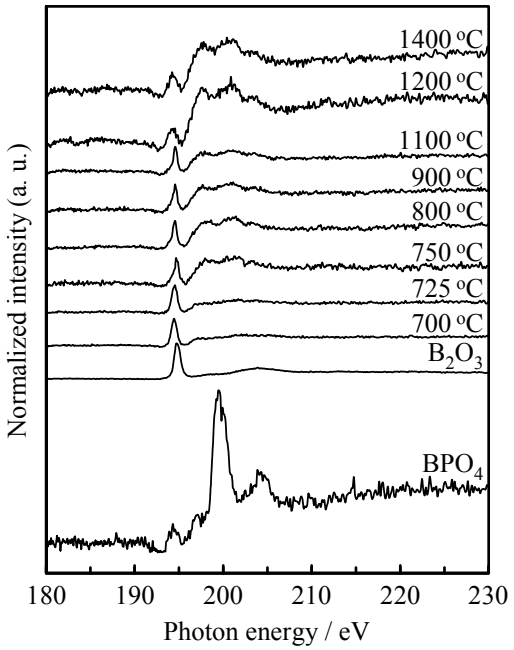

Fig. 2. B K-edge XANES spectra of $Y_{0.92}Eu_{0.08}BO_3$ samples heat treated at various temperatures, measured in the FY mode.