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Effect of Eu^{3+} concentration on photoluminescence and thermoluminescence behavior of YBO_3:Eu^{3+} phosphor

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ABSTRACT

The present paper reports the synthesis, photoluminescence (PL) and thermoluminescence (TL) studies of Eu^{3+} doped YBO_3 phosphor. The samples were prepared by the conventional solid state reaction method with different concentrations of Eu^{3+} ions, which is the most suitable method for large-scale production. The prepared phosphor sample was characterized using X-ray diffraction (XRD), Field Emission Gun Scanning Electron Microscopy (FEG-SEM), high resolution transmission electron microscopy (HRTEM), Fourier Transform Infrared Spectroscopy (FTIR), photoluminescence (PL), thermoluminescence (TL) and CIE coordinate techniques. The PL emission was observed in the range 575–650 nm range for the YBO_3 phosphor doped with Eu^{3+}. Excitation spectrum found at 237, 254 and 395 nm. Sharp peaks found around 594, 612 and 628 nm with high intensity. From the XRD data, using the Scherer's formula the calculated average crystallite size of Eu^{3+} doped YBO_3 phosphor is around 201 nm. Thermoluminescence study was carried out for the phosphor with UV, beta and gamma irradiation. The present phosphor can act as single host for red–orange light emission in display devices.

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1. Introduction

Red light emitting Eu^{3+} phosphors are extensively used in lamp and display applications, and many Eu^{3+} doped materials are being examined for use in new flat panel display technologies. Among them yttrium and lanthanide orthoborates of formulation $LnBO_3$ (Ln = rare earth (RE), Y) have proved to be potential candidates for such applications [1]. The luminescence of the rare earth ions in inorganic hosts has been extensively investigated during the last few decades. At present, the most widely used red-emitting phosphor for plasma display panel (PDP) is $(Y,Gd)BO_3:Eu^{3+}$ [2,3]. However, the colorimetric purity of $(Y,Gd)BO_3:Eu^{3+}$ is not sufficient to produce a high quality color TV picture due to the emission $^5D_0$–$^7F_1$ (592 nm, red–orange color) as the most prominent group in the luminescence spectrum. Much attention has been paid for other borates for luminescence [4–7]. Over the last few years, much attention has been paid to the synthesis and luminescent properties of Eu^{3+}-doped rare-earth orthoborates ($REBO_3$) due to their desirable properties as ideal vacuum ultraviolet phosphors, whose progress is key to the development of plasma display panels (PDPs) [20]. Various synthesis techniques have been developed to prepare high-quality $REBO_3:Eu^{3+}$ phosphors, such as solid-state reaction (SR) [20,21], co-precipitation [22,23], microwave heating [24], spray pyrolysis [25], and sol–gel method [26], but most of them only aimed at the enhancement of photoluminescence. For PDP phosphors, both luminescent efficiency and color purity are required. Unfortunately, as a red phosphor, the intensity of red emission of $REBO_3:Eu^{3+}$ is lower than that of the orange one, leading to a poor chromaticity.

Since the red emission, which comes from $^5D_0$ to $^7F_2$ transition, is hypersensitive to the symmetry of the crystal field around Eu^{3+} and will be relatively stronger if the symmetry of the crystal field is low, we attempted to reduce the symmetry of the crystal field to solve the chromaticity drawback of $YBO_3:Eu^{3+}$, in terms of increasing the contribution of $^5D_0$–$^7F_2$ transition. The synthesis of nanosized $YBO_3:Eu^{3+}$ was a possible solution because of the high disorder near its surface, and we achieved this approach by thermal decomposition of precursors that contained RE–EDTA and H_3BO_3–EDTA complexes [26–28]. The lower site symmetry of Eu^{3+} in smaller-sized samples, the ratio of red emission to orange emission increased, leading to a better chromaticity. However, because of the existence of residual unburnt organic impurities as well as the uncompleted crystallization at lower temperatures ($\leqslant$700 °C), as-prepared samples exhibited a much lower luminescent intensity in comparison with the sample prepared by SR. Moreover, since the whole process, which involved an incompleted burning step before pyrolysis, was pollution causing and uncontrolled, it may still have a long way to go for practical uses. Our present work is aiming to develop controlled $YBO_3:Eu^{3+}$ doped phosphor for display devices applications.

2. Experimental method

To prepare $YBO_3:Eu^{3+}$ doped phosphor with variable concentrations of europium. Y_2O_3, Eu_2O_3 and H_3BO_3 were used as starting material. These substances are mixed in a proper molar ratio in which Eu^{3+} have molar ratio 0.1–2.5 mol%. The reactant mixtures were taken in a quartz boats and heated in presence of air at 500 °C for 1 h followed by heating at 1000 °C for 1 h for calcination in muffle furnace. The mixture was grinded by using agate mortal and pastle after every heating. The mixture was grounded together to obtain a homogeneous powder. After being grounded thoroughly for nearly 45 min, to ensure the best homogeneity and reactivity, powder was transferred to alumina crucible, and then heated in a muffle furnace at 1250 °C for 2 h. The phosphor materials were cooled to room temperature naturally. All samples were found out to be white who are studied for photoluminescence.

The sample was characterized using X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), FEGSEM (Filed Emission Gum Scanning Electron Microscopy) and high resolution transmission electron microscopy (HRTEM). The XRD measurements were carried out using Bruker D8 Advance X-ray diffractometer. The X-rays were produced using a sealed tube and the wavelength of X-ray was 0.154 nm (Cu K-alpha). The X-rays were detected using a fast counting detector based on Silicon strip technology (BrukerLynxEye detector). Observation of particle morphology was