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Short communication

Preparation of YBO$_3$:Dy^{3+},Bi^{3+} phosphors and enhanced photoluminescence

Wei Zhang*, Shixin Liu, Zhengfa Hu*, Yunling Liang, Zuyong Feng, Xia Sheng

School of Physics & Optoelectronic Engineering, Guangdong University of Technology, Guangzhou 510006, China

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ABSTRACT

Bi^{3+} and Dy^{3+} co-doped YBO$_3$ phosphors were successfully synthesized by solid-state-reaction method at 900 °C. The co-doping of Bi^{3+} and Dy^{3+} into YBO$_3$ results in enhanced yellow emission band while the blue emission band remains relatively unchanged. The emission intensities of the studied materials were investigated as a function of different Bi^{3+} ion concentrations. The results show that they could be efficiently excited by UV light of 270 nm, indicating a potential application for the phosphors in the fluorescent lamps.

1. Introduction

Borate phosphors have recently gained much attention for their role in applications such as screens in plasma display panels, field emission displays, and white color light emitting diodes because of their high chemical stability and high luminescence efficiency [1–3]. Lanthanide-doped phosphor systems have a wide range of applications in various fields ranging from luminescence to dosimetry, and have been extensively investigated. Orthoborates REBO$_3$ (RE = Y, La, Gd, and Lu) doped with lanthanide ions (Eu^{3+}, Ce^{3+}, Dy^{3+}, or Tb^{3+}) have been researched most often because of their strong photoluminescence intensity [4–9]. Among the REBO$_3$ phosphors, YBO$_3$ has attracted most attention because of excellent vacuum ultraviolet absorption, high chemical stability, and exceptional optical damage threshold. So YBO$_3$ is considered to be a promising host material for plasma display panels. Particularly YBO$_3$:Eu^{3+}, represent both an important class of materials for plasma display panels (PDPs) and a possible new generation of light emitting diodes (LED) [10,11], not only due to their high quantum under vacuum ultraviolet (VUV) excitation but also their high ultraviolet (UV) transparency and exceptional optical damage threshold [12,13].

As Bi^{3+} is promising to serve as an activator or a sensitizer in phosphors, a number of theoretical and experimental researches have addressed the luminescent properties of Bi^{3+} under ultraviolet (200–400 nm) excitation [14–18]. Recently, Bi^{3+} and RE^{3+} co-doped YBO$_3$ phosphors have received attention because researchers hope to improve the efficiency of phosphors through Bi^{3+}-sensitizing activators [19–23]. To our knowledge, the luminescence of Bi^{3+} and Dy^{3+} co-doped YBO$_3$ phosphors were less reported. In this paper, a series of YBO$_3$:Dy^{3+} phosphors with different Bi^{3+} doping concentration are prepared by solid-state-method and their photoluminescence properties are investigated under UV excitation.

2. Experimental

$Y_{1x-y}BO_3$:xDy^{3+},yBi^{3+} phosphors with different Bi^{3+} ion concentration ($x = 0.02$, $y = 0$, 0.01–0.06) were synthesized by the solid-state reaction method. Y$_2$O$_3$ (99.9%), H$_3$BO$_3$ (A. R.), Bi$_2$O$_3$ (A. R.), Dy$_2$O$_3$ (99.9%) were used as raw materials. The stoichiometric amounts of starting materials were completely ground for one hour after mixed in an agate mortar, and then the mixtures were put in an alumina crucible and calcined at 900 °C for 8 h in air. After the calcination process, the as-synthesized samples were cooled down to room temperature, and finally the fine powders were obtained after regrinding.

The crystal structure of the samples was characterized by Beijing Purkinje General Co., XD-2 X-ray powder diffractometer (CuKα, 36 kV, 20 mA). The morphology and microstructure of the samples were observed by a high resolution scanning electron microscopy (SEM) QUANTA 400F. Luminescence decay curves were measured with a PLS920P spectrometer (Edinburgh Instruments Ltd., Livingston, U.K.), using excitation of nanosecond flash-lamps. The excitation and emission spectra of samples were measured by the

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* Corresponding authors. Tel.: +86 20 39322266; fax: +86 20 39322265.
E-mail addresses: Weizh55@aliyun.com (W. Zhang), Zhfhu@gdut.edu.cn (Z. Hu).

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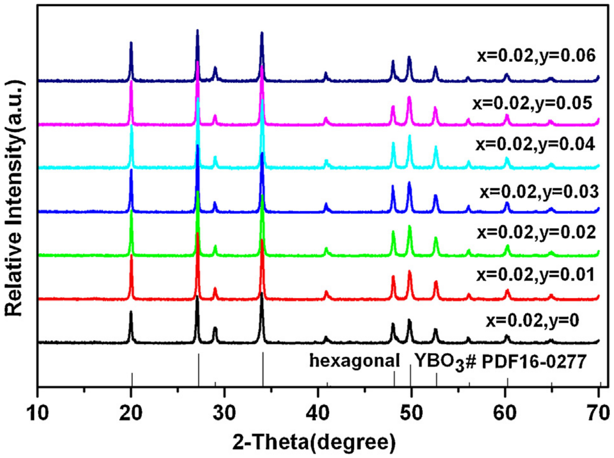

Fig. 1. XRD patterns for $Y_{1-x-y}BO_3$:$x$$Dy^{3+}$,$y$$Bi^{3+}$ (x = 0.02, y = 0.01–0.06) phosphors.

Inc. Hitachi F-7000 fluorescence spectrometer (Japan). All the measurements were performed at room temperature.

3. Results and discussion

Fig. 1 shows the XRD patterns of $Y_{1-x-y}BO_3$:$x$$Dy^{3+}$,$y$$Bi^{3+}$ (x = 0.02, y = 0, 0.01–0.06) phosphors and the simulated YBO_3 from the data of the PDF file No. 16-0277. No peaks corresponding to impurities or second phases are detected, which indicates that Dy^{3+} and Bi^{3+} ions are substituted into the Y^{3+} sites without the formation of any additional phase at low concentrations. The well-defined sharp diffraction peaks also implied that these samples have high crystallinity. And the XRD patterns of $Y_{1-x-y}BO_3$:$x$$Dy^{3+}$,$y$$Bi^{3+}$ (x = 0.02, y = 0, 0.01–0.06) slightly shift to lower angles compared with the simulated YBO_3 from the data of the PDF file No. 16-0277. It may be due to the larger diameters of Dy^{3+} and Bi^{3+} relative to Y^{3+} according to Bragg's law [24]. The results show that the doped Dy^{3+} and Bi^{3+} do not affect the crystal structure of YBO_3 and may be completely dissolved into the host lattice [25].

The typical SEM images in Fig. 2(a–d) show the morphology of $Y_{1-x-y}BO_3$:$x$$Dy^{3+}$,$y$$Bi^{3+}$ (x = 0.02, y = 0, 0.01, 0.02 and 0.03) particles, respectively. The annealed phosphor powders have a fine size and regular morphology. These characteristics of the powders allow several advantages, including high packing densities, good slurry properties, and smoother light intensity distributions. The doped Bi^{3+} increasing does not cause much impact on the size of the particles but on the gap between the particles. The main size of the powders measured from the SEM images is 0.6 μm while the gap between the particles becomes smaller with the increase of Bi^{3+} ions, measured from the figure. This result indicates that the doped Bi^{3+} and Dy^{3+} ions do not affect the formation of grains with good crystallinity.

Fig. 3 shows the emission spectrum and excitation spectrum of Bi^{3+} singly doped sample $Y_{0.99}BO_3$:$0.01Bi^{3+}$. One broad band with maxima at 363 nm observed at its excitation wavelength (270 nm). According to literature [26], this broad band can be attributed to the transition from excited states $^3P_1$ to ground state $^1S_0$ of Bi^{3+}. The spectrum monitoring the emission at 363 nm in Fig. 3 consist

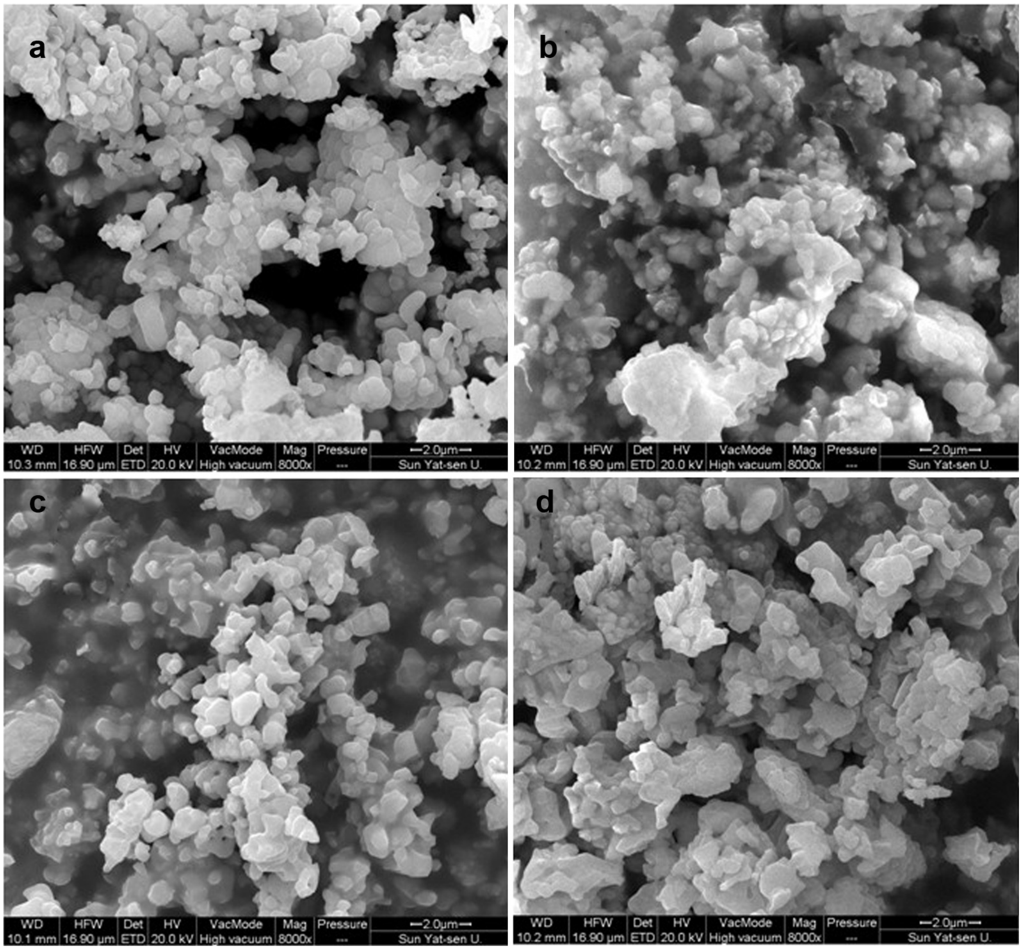

Fig. 2. SEM images of $Y_{1-x-y}BO_3$:$x$$Dy^{3+}$,$y$$Bi^{3+}$ (x = 0.02) phosphors ((a) y = 0, (b) y = 0.01, (c) y = 0.02 and (d) y = 0.03).