PHOTOLUMINESCENCE PROPERTIES OF NANOCRYSTALLINE YBO_3: EU^{3+} PHOSPHOR

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Abstract

Nanoscale phosphors show superior performance characteristics than the bulk phosphors. This paper explains the synthesis of nanocrystalline YBO_3 doped with rare earth element Europium by modified combustion method. The sample was characterized by X-ray Diffraction (XRD), Field Effect Scanning Electron Microscopy (FESEM), and Photoluminescence (PL) properties. Diffractogram showed the nanocrystalline nature of as prepared sample. FESEM image confirmed the XRD result. Photoluminescence emission spectra showed strong red emission peak at 613 nm. The colour coordinates of the as prepared sample match fairly with standard CIE colour coordinates for red colour. Thus, YBO_3 doped with Eu^{3+} nanophosphor is a potential candidate for tricolor lamps and optical devices.

Keywords: *Nanoscale phosphor, YBO_3:Eu^{3+}, red emission, modified combustion method.*

Introduction

It has been almost two decades since the encouraging results of ZnS: Mn nanocrystals published by Bhargav *et al*[1]. The continuous research in luminescent nanomaterials is going on and encouraging results led the workers in the area of luminescence to find new methods and new materials for various applications like Fluorescent lamps, Field emission displays, Plasma display panels, Luminescent inks etc. Rare earth doped borate materials show chemical, electrical and mechanical stability and hence Nano- and microcrystalline rare-earth borates have been prepared by various synthesis methods, including solvothermal reactions[2, 3, 4], spray pyrolysis [5, 6], single-source precursor decomposition[7, 8] and sol–gel synthesis[9]. Borate compounds possess excellent optical properties. It is a well known fact that the boron atom can be coordinated by Oxygen atom to form variety of atomic groups, which are considered to be a dominant factor for optical properties of borates[10]. This study reveals the photoluminescent properties of Yittrium Borate YBO_3 doped with rare earth element Europium and studies its morphological properties.

Experimental

Yttrium oxide (Y_2O_3), Boric acid (H_3BO_3), and Europium oxide Eu_2O_3 were the starting AR grade materials (99.99% purity). Urea (NH_2CONH_2) was used as fuel for combustion and ammonium nitrate (NH_4NO_3) was used as an oxidizer. As reported earlier the combustion synthesis method is fast, cost efficient, easy method of phosphor synthesis[11, 12]. Moreover combustion synthesis does recently gather reputations as effective synthesis technique, which can neglect such steps as washing, filtration, drying, etc. The white voluminous foamy fine powder phosphor can be obtained in 3–5 min by combusting the paste of precursor mixture in a muffle furnace at the temperature of 400–600 °C. Initially, the solution boiled and underwent dehydration, followed by decomposition with the evolution of large amounts of gases (oxides of carbon, nitrogen and ammonia). Then, spontaneous ignition occurred and underwent smouldering combustion with enormous swelling, producing white foamy and voluminous ash. The voluminous and foamy combustion ash was then milled to obtain the phosphor powder. The phosphor powder was prepared according to formula $Y_{1-x}BO_3:xEu^{3+}$ where x=0.5, 1, 2, 5 mol %.

Results and discussion

X-Ray Diffraction Spectroscopy

The structural properties of the phosphors were studied using spectroscopic techniques. The X-ray diffractogram was matched with JCPDS file no.01-074-1929 in order to identify the products and check their crystallinity. Structure was characterized by XRD pattern using Rigaku diffractometer with Cu Kα radiation (λ = 1.5405 Å) operating at 40 kV, 30 mA. YBO_3 has monoclinic lattice structure. The XRD patterns of YBO_3 prepared by Combustion synthesis observed at different temperatures are shown in Fig. 1. The samples showed good crystallinity. The sample annealed at 700 □ C has less intensity as compared to the samples annealed at higher temperatures. It has been observed that as the annealing temperature changes from 700 to 800 the intensity increases, but doesn't change significantly for the samples annealed at 800-1000 □ C. The average crystallite size was calculated by peak broadening the major peaks (100) and (102). Using Debye-Scherrer formula[13] the average crystallite size was found to be 68 nm.

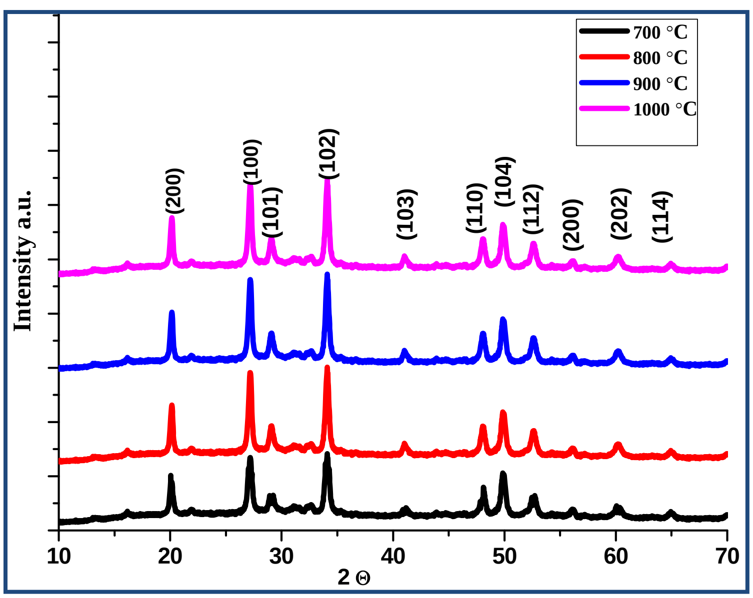

Fig 1: X-ray Difftactogram of $YBO_3:Eu^{3+}$ observed at different temperatures

Figure 2 shows the XRD patterns of $YBO_3:Eu^{3+}$ observed for different concentrations of activator (Europium). No change in phase of YBO_3 was observed after changing the concentration of activator. It shows the phase purity of the prepared samples.

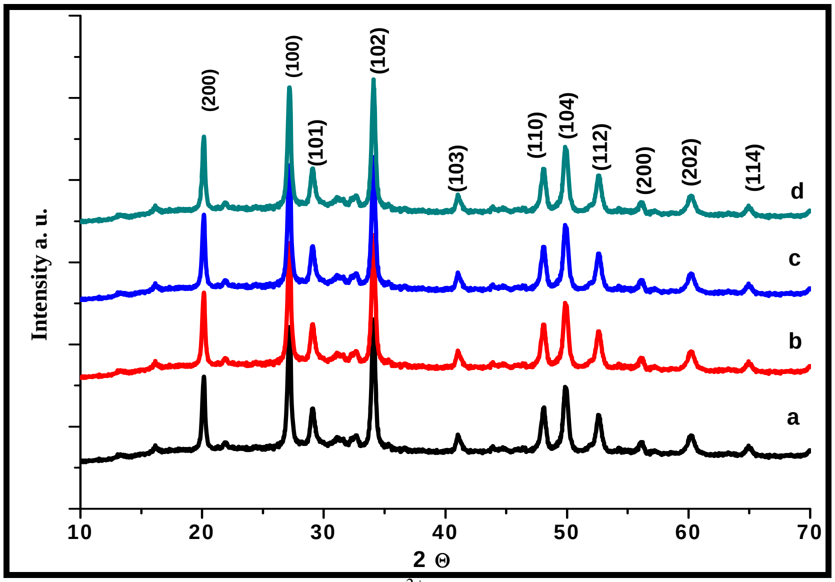

Fig 2: X-ray Difftactogram of $YBO_3:Eu^{3+}$ observed for different Eu concentrations (a) 0.50 mol %, (b) 1 mol %, (c) 2 mol %, (d) 5 mol %

Photoluminescent properties:

Figure 3 shows the photoluminescence emission spectra for $YBO_3:Eu^{3+}$. The photoluminescence properties of the phosphor were measured using Hitachi F-7000 Fluorescence Spectrophotometer at room temperature. The slit width of 1nm was kept. The intense red emission of Eu^{3+} was observed at around 612 nm. The excitation spectrum has broad band with maximum intensity at 248 nm.

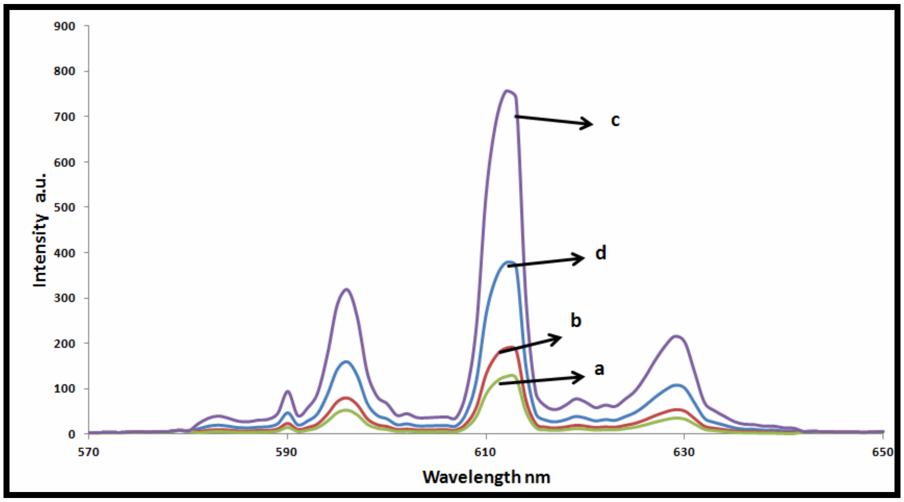

Fig 3: Photoluminescence emission spectrum of $YBO_3:Eu^{3+}$ observed for different Eu concentrations (a) 0.50 mol %, (b) 1 mol %, (c) 2 mol %, (d) 5 mol %

The intense red emission peak at 612 nm is characteristic $^5D_0 \rightarrow {}^7F_2$ electric dipole transition of Eu^{3+} ions and the less intense emission at 596 nm is due to magnetic dipole transition $^5D_0 \rightarrow {}^7F_1$. The sample shows strong red emission due to the presence of the Eu^{3+} ions as luminescence centres in the structure. It consists of four main peak groups associated with the transitions from the excited $^5D_0$ level to ^7F_J (J = 1−4) levels of Eu^{3+} ions. The red emission band at 612 nm is more intense than the orange emission band at 596 nm. Hence, the chromaticity for powder grown is improved, and the colour is redder if compared to the common orange-red emission of aluminates. In general, the intensity of the bands corresponding to the transitions between different J levels is related to the local site symmetry of the Eu^{3+} ions. As per the selection rules, the intensity of the $^5D_0 - {}^7F_1$ transition is relatively high as compared to $^5D_0 - {}^7F_2$ transition, when Eu^{3+} ions occupy the sites with inversion symmetry. But, if the dopant ions are located in the C_1 site missing inversion symmetry, the probability of the $^5D_0 - {}^7F_2$ transition increases[14]. As the sample having 2 mol % of Eu^{3+} concentration in the host matrix of YBO_3 shows high emission intensity as compared to the other samples containing Eu^{3+} concentration as 0.5 mol %, 1 mol % and 5 mol % , the optimal concentration for our samples was found to be 2 mol % of Eu^{3+}. The CIE colour coordinates of the samples were found to be x=0.6762, y=0.3225 which match fairly with standard CIE colour coordinates of red colour.

Field Effect Scanning Electron Microscopy (FESEM) analysis:

The morphology of the prepared sample was studied by FESEM imaging analysis. The image shows voids all over the surface which is the result of combustion synthesis method used to prepare the sample. The FESEM micrograph shows small oval shaped particles distributed in the phosphor structure. The particle size was found to be in the range of 60-100 nm [Figure 4].

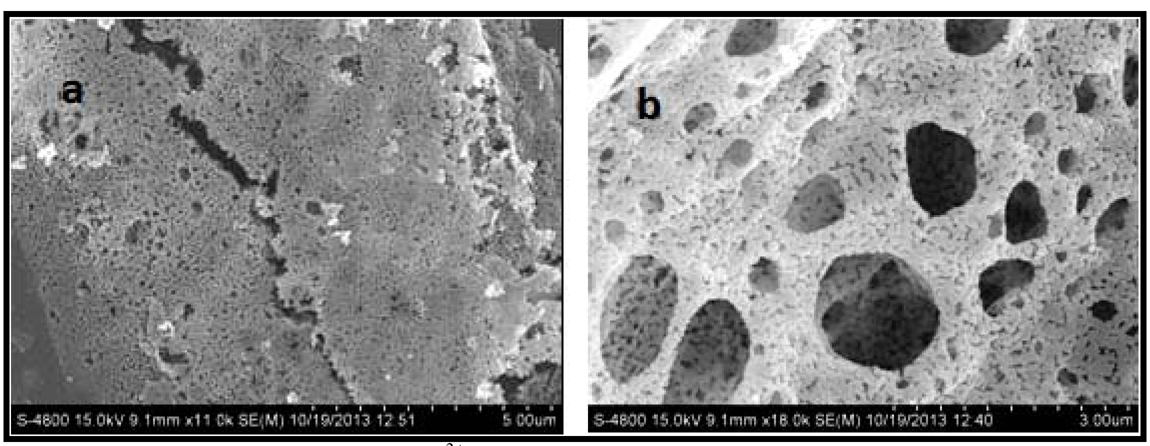

Fig 4: FESEM images of $YBO_3:Eu^{3+}$ for the sample containing Eu concentration of 2 mol %

This result confirms the particle size calculated by XRD measurement. The particles were randomly distributed all over the surface not oriented in any particular direction. Thus, the XRD analysis and FESEM images show nanocrystalline nature of as prepared samples.

Conclusions

Europium doped nanocrystalline Yttrium borate YBO_3 was successfully synthesized by combustion method. Different concentrations of Eu^{3+} ions were tried and optimal concentration of Eu^{3+} ions was found to 2 mol %. Nanocrystalline nature of the samples was studied and confirmed by XRD analysis. The photoluminescence emission spectra show intense red colour emission peaking at 596 nm, 612 nm and 627 nm. The FESEM analysis confirmed the XRD result of nanoscale phosphor particles. Thus YBO_3:Eu^{3+} nanocrystalline phosphor can be used as potential candidate for tricolour lamps and optical devices.

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