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Photoluminescence properties of Dy³⁺ doped SrAl₂B₂O₇ phosphor

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Abstract- Dy³⁺activated SrAl₂B₂O₇ (SABO) phosphors were prepared by solution combustion technique. and characterized by XRD, photoluminescence (PL) and SEM techniques. The PL spectra shows an efficient blue and yellow band emissions (excited by 350 nm), corresponding to ${}^{4}F_{9/2}$ - ${}^{6}H_{15/2}$ and ${}^{4}F_{9/2}$ - ${}^{6}H_{13/2}$ transitions of Dy³⁺ ion, respectively. There were two main emission spectra of SrAl₂B₂O₇:Dy³⁺ were at 483 and 575 nm. Luminescence quenching was noticed at optimum Dy³⁺ concentrations due to the exchange interaction among the excited Dy³⁺ ions.

Keywords: Alumino-borate, combustion synthesis, X-ray diffraction, photoluminescence *PACS Code:* 78.55.*Hx*

1.0 Introduction

Solid state lighting (SSL) technology is emerging as a highly competent and feasible alternative to the existing technology. SSL is the backdrop of the growing importance for energy saving and environmental friendliness. This is an interesting field for researchers especially to produce white light sources having wide applications in the fields of LCD displays, colored displays, traffic signals, automotive displays and cellular phone illumination and so on [1]. White-light emitting diode (WLED) is considered to be the next generation SSL source that will replace the conventional incandescent and fluorescent lamps because of its high luminous efficiency, energy saving and environmental safety [2]. WLED are having certain advantages such as high brightness, low power consumption, longevity, reliability and excellent low temperature performance. Dy³⁺ is capable of emitting several interesting wavelengths between its f-f transitions, which are having potential applications in various fields. Among the rare earth (RE) ions, Dy³⁺ is one of the important RE ions for the preparation of phosphor materials which is playing a major role in the preparation of white light emitting phosphors. The Dy^{3+} ions have two characteristic intense emission bands in the visible region corresponding to the transitions ${}^{4}F_{9/2}$ - ${}^{6}H_{13/2}$ (yellow) and ${}^{4}F_{9/2}$ - ${}^{6}H_{15/2}$ (blue) [3].

In this work SrAl₂B₂O₇ phosphor host material doped with Dy³⁺ was synthesized via solution combustion technique and their luminescent characteristics under n-UV excitation were investigated. Also, the concentration dependence of luminescence intensities and the chromatic properties of Dy^{3+} ions were discussed.

2. Experimental

1.1. Sample preparation

The powder samples of SABO: Dy3+ was prepared by using solution combustion synthesis. In our previous studies, many borate host materials were successfully synthesized using combustion method [4-9]. Stoichiometric amounts of high purity starting materials, Sr(NO₃)₂ (A.R.), Al(NO₃)₃.9H₂O (A.R.), Dy(NO₃)₃·6H₂O (high purity 99.9%), H₃BO₃ (A.R.), CO(NH₂)₂ (A.R.) have been used for phosphors preparation. Stoichiometric amounts of the ingredients were thoroughly mixed in an agate mortar with adding little amount of double distilled water. The materials were then transferred into china basin and heated on heating mantle at about 70°C so as to obtained clear solution. The solution was then introduced into a pre-heated muffle furnace maintained at temperature 550 °C for combustion. The solution boils; foams and ignites to burn with flame which gave a voluminous, foamy powder. Following the combustion, the resulting foamy samples were crushed to obtain fine particles and then annealed in a slightly reducing atmosphere at temperature 750°C for 2 h and suddenly cooled to room temperature.

1.2. Material characterizations

The phase and surface morphology of as prepared phosphors were characterized by X-ray diffraction measurements using Rigaku Miniflex II X-ray



Diffractometer with Cu K α radiation (λ =1.54059 Å) with scan speed 2°/min and field emission - scanning electron microscopy (FE-SEM) (Hitachi, Model-S4800 type II). The PL & PLE measurements at room temperature were performed on Hitachi F-7000 Spectroflurometer with spectral resolution of 2.5 nm.

3. Result and Discussion

3.1 XRD-Studies

3.1.1 X-ray Diffraction Pattern

Fig.1 exhibits the powder X-ray diffraction (XRD) patterns of $Sr_{(0.97)}Al_2B_2O_7:_{0.03}Dy^{3+}$ and it was found to be in good agreement with the reported standard data in ICDD file no. 01-089-9063. The result clearly implies that the obtained samples are single phase and the doping of Dy^{3+} does not cause any significant change in the host structure. There are two possible sites available for the incorporating Dy^{3+} in the SrAl₂B₂O₇ lattice is either Al³⁺ sites or Sr²⁺ sites.



Fig. 1 The XRD patterns of Sr(0.97)Al2B2O7:0.03Dy³⁺ phosphors, (ICDD Card No. 01-089-9063)

3.2 FE-SEM micrograph analysis

The FE-SEM image of $Sr_{(0.97)}Al_2B_2O_{7:0.03}Dy^{3+}$ sample prepared by solution combustion method is as shown in **Fig. 2**. The shapes of the particles were observed to be random in nature with some agglomeration among the crystalline grains. The crystalline size of the phosphor was observed to be varied in the range 0.3-2 µm.



Fig. 2. FE-SEM image of Sr_(0.97)Al₂B₂O₇:0.03Dy³⁺ phosphor.

3.2 Photoluminescence

The excitation and emission spectra is as shown in Fig. 3. The excitation spectrum in the spectral range 200-400 nm recorded for 3.0 mol% Dy³⁺-doped SABO phosphor monitoring the emission at 575 nm. The spectrum displayed a several bands centered at 261, 325, 350, 367 and 388 nm corresponding to the intrinsic f-f transitions of Dy³⁺ ion from the ground state ${}^{6}\text{H}_{15/2}$ to the excited states ${}^{6}P_{3/2}$, ${}^{4}I_{9/2}$, ${}^{6}P_{7/2}$, ${}^{6}P_{5/2}$, ${}^{4}F_{7/2}$ and ${}^{4}G_{11/2}$ respectively. The intense peaks observed at 350 and 388 nm indicate that the near UV. Furthermore, the intensity of peaks increases with the increase of Dy³⁺ ion concentration and reaches a maximum for 3.0 mol% and then decreases as shown in inset of Fig. 3. This may be due to the self-quenching of excited Dy³⁺ ions, when the concentration of Dy^{3+} is more than 2.0 mol%.



Fig. 3. Excitation and emission spectra of Sr0.97Al2B2O7:0.03Dy³⁺ phosphor.

The emission spectra of Dy^{3+} -doped SABO (0.1-5 mol%) phosphors recorded in the spectral range 460–650 nm by exciting at 350 nm wavelength are shown in Fig. 4. The intense emission bands observed at 483 nm (blue) and 575 nm (yellow) are assigned to ${}^{4}F_{9/2}$ - ${}^{6}H_{15/2}$ and ${}^{4}F_{9/2}$ - ${}^{6}H_{13/2}$ transitions of Dy^{3+} ions



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respectively. It is also well known that the ${}^{4}F9/2$ - ${}^{6}H_{15/2}$ (blue) transition hardly varies with the environment, while the ${}^{4}F_{9/2}$ - ${}^{6}H_{13/2}$ (yellow) is the hypersensitive transition, which is strongly influenced by the ligand environment. The relative intensities of these two emission band depend strongly on the local symmetry of Dy³⁺ ions.





Fig. 4. Emission ($\lambda_{ex} = 350$ nm) spectra of Sr₁. $_{x}Al_{2}B_{2}O_{7:x}Dy^{3+}$ phosphors (x=0.001, 0.005, 0.01, 0.03, 0.05 mole).

The CIE chromaticity coordinates for $Sr_{0.97}Al_2B_2O_{7:0.03}Dy^{3+}$ was calculated from the PL spectra under 350 nm excitation and marked with a white star in the CIE 1931 chromaticity diagram in **Fig. 5**. The chromaticity coordinates (x,y) of this phosphor are calculated to be (0.29,0.0.70), respectively, which indicates that the emission color of the as prepared phosphors is located in the yellow region.

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