



# Synthesis and luminescence studies of $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$ phosphors



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## ABSTRACT

The polycrystalline sample of dysprosium doped  $\text{NaSr}_4(\text{BO}_3)_3$  is prepared by employing modified solution combustion synthesis method. The as-synthesized phosphors were characterized by X-ray powder diffraction (XRD), photoluminescence excitation (PLE) and photoluminescence (PL) spectra. By Exposing with gamma-rays, its thermoluminescence properties were studied. Kinetic parameters were calculated using peak shape method. The effect of dose variation of gamma rays on  $\text{NaSr}_4(\text{BO}_3)_3$  were also studied. The PLE spectra show the excitation peaks from 300 nm to 400 nm is due to the 4f–4f transitions of  $\text{Dy}^{3+}$ . This mercury-free excitation is useful for solid state lighting and light-emitting diodes. The emission of  $\text{Dy}^{3+}$  ions upon 350 nm excitation, is observed at 482 nm (blue) due to the  ${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{15/2}$  transitions and 574 nm (yellow) due to  ${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{13/2}$  transitions. The CIE chromaticity coordinates ( $x = 0.35$  and  $y = 0.40$ ) for  $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$  phosphors are simulated and located in the bluish-white region

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## 1. Introduction

Phosphors are applicable for display, fluorescent lamps, X-ray screens and solid state lighting. Hence the demand of high quality phosphors raised day by day [1–6]. Specially talking about Borates we can say that it has so many merits including low synthetic temperature, easy preparation and high luminescent brightness which make them a good host [7–9]. Borates have attracted more attention due to their affluent crystal-structure, broad transmittance spectra and wide band-gap [10,11]. Borates like  $\text{NaSrBO}_3$  and  $\text{NaSr}_4(\text{BO}_3)_3$  are reported by high temperature solid state method [12,13]. Borates possess excellent properties as host structures of phosphors in which isolated planer  $[\text{BO}_3]^{3-}$  groups were in good or suitable configuration [14]. The  $\text{NaSr}_4(\text{BO}_3)_3$  phosphor may show such applications due to presence of isolated planar  $[\text{BO}_3]^{3-}$  group at appropriate position. Several borate compounds find important applications as TLD phosphors such as  $\text{LiCaBO}_3:\text{Tb}$ ,  $\text{Dy}$  [15] and  $\text{SrB}_4\text{O}_7:\text{Cu}$  [16] is used in personal dosimetry. A variety of BO-atomic group are considered to be a dominant factor in their physical properties and a class of phosphors with good performances, especially when doped with proper activators [17]. Combustion synthesis is a good low cost, one step, and low temperature method for the synthesis of borates and Silicates [18,19]. In borate compounds boron atom is coordinated by oxygen atoms to form a variety of atomic groups that affect the physical properties in general and optical properties in particular [20]. In this paper, synthesis by

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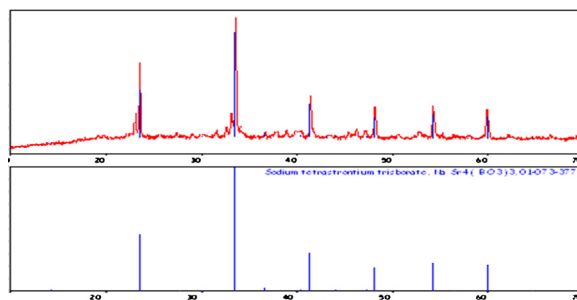


Fig. 1. XRD pattern for  $\text{NaSr}_4(\text{BO}_3)_3$ .

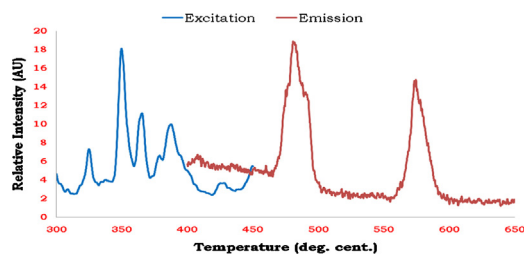


Fig. 2. Excitation ( $\lambda_{em} = 482 \text{ nm}$ ) and Emission ( $\lambda_{ex} = 350 \text{ nm}$ ) Spectra for  $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$ .

modified combustion method and thermoluminescence properties of  $\text{Dy}^{3+}$  doped alkali alkaline borate hosts  $\text{NaSr}_4(\text{BO}_3)_3$  have been reported.

## 2. Experimental

Polycrystalline  $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$  phosphor is prepared by well established solution combustion technique. During the reaction, the stoichiometric amounts of ingredients all precursor metal nitrate, urea (fuel),  $\text{NH}_4\text{NO}_3$  (oxidizer) and  $\text{Dy}_2\text{O}_3$  (activator) calculated on the basis of molar ratio and were thoroughly mixed in the agate mortar by adding little amount of double distilled water, an aqueous homogeneous solution was obtained. The solution was then transferred into a china basin. The china basin was then kept into preheated muffle furnace maintained at  $(550 \pm 10)^\circ\text{C}$ . The solution boils foams and ignites to burn with the flame and a voluminous, foamy powder was obtained. The entire combustion was over in 5 min. Following the combustion, the resulting fine powder was annealed in open air at  $750^\circ\text{C}$  for 90 min and allowed to cool down at room temperature. The conformation of crystallite and phase of prepared sample was authenticate by using X-ray diffraction techniques and studied for their thermo luminescence properties.

## 3. Results and discussion

### 3.1. X-Ray diffraction pattern for $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$

Fig. 1 represents the XRD pattern for polycrystalline sample of  $\text{NaSr}_4(\text{BO}_3)_3:\text{Dy}^{3+}$  prepared using combustion method. The results are confirmed by comparing the observed XRD with standard ICDD file (01-073-3773) which is in good agreement and show peak to peak matching. The space group for  $\text{NaSr}_4(\text{BO}_3)_3$  is Ia-3d (230). Also the symmetry allowed crystal structure properties for  $\text{NaSr}_4(\text{BO}_3)_3$  are Centrosymmetric.

### 3.2. Photoluminescence studies

The confirmed sample doped with dysprosium is studied for the photoluminescence properties under UV to N-UV excitation source. Fig. 2 represent the excitation and emission spectra for the 0.005 mol Dy doped  $\text{NaSr}_4(\text{BO}_3)_3$  sample. From the figure it is clearly seen that under the excitation of 350 nm, the emission spectrum exhibits two sharp emission lines, which belong to the characteristic emission of trivalent Dy ion. The emission line in the region near 482 nm is attributed to the  $\text{Dy}^{3+}$  typical transition  ${}^4\text{F}_{9/2} \rightarrow {}^6\text{H}_{15/2}$  while the emission line peaking at 574 nm is assigned to the transition of  ${}^4\text{F}_{5/2} \rightarrow {}^6\text{H}_{13/2}$  of  $\text{Dy}^{3+}$ . The excitation spectra for 350 nm emission have several bands at 325, 350, 366 and 388 nm, which correspond to the characteristic 4f–4f transitions of  $\text{Dy}^{3+}$ . The strongest one is at 350 nm, which is attributed to the  ${}^6\text{H}_{15/2} \rightarrow {}^4\text{G}_{7/2}$  transition of  $\text{Dy}^{3+}$ . The CIE coordinates of the photoluminescence of the Dy complex are calculated as  $x=0.35$  and  $y=0.40$  which are located in the white region. [21]

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