

## Photoluminescence properties of green emitting SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>: Tb<sup>3+</sup> phosphor

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**ABSTRACT :** The Powder samples of SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>:Tb<sup>3+</sup> were prepared by solution combustion method. The synthesis is based on the exothermic reaction between the fuel (Urea) and Oxidizer (Ammonium nitrate). The structures of the prepared powder samples were confirmed by powder XRD technique. The photoluminescence properties of the powder samples were investigated under UV excitation. The phosphor SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>:Tb<sup>3+</sup> shows strong absorption over a wide UV region and exhibits intense green emission peaking at about 544 nm corresponding to <sup>5</sup>D<sub>4</sub> → <sup>7</sup>F<sub>5</sub> transitions of Tb<sup>3+</sup> under 254 nm UV excitation.

**Keywords:** Alumino-Borates, Combustion Synthesis, XRD, Photoluminescence.

### I. INTRODUCTION

Recently, the compounds of the alumino borate family seem to be promising for high luminescent efficiency and good thermal stability [1–4]. The alumino borates doped with rare earth ions have attracted much attention because of their high UV transparency and non-linear properties. In addition, borates have exceptional optical damage threshold and able to withstand the harsh condition in vacuum discharge lamps or screens. More recently SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub> was proposed as a non-linear optical material and the rhombohedra structure of SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub> is described from the (BO<sub>3</sub>)<sup>∞</sup> planes perpendicular to the original axis being linked alternatively by Al–O–Al bridges and Sr atoms [5,6]. The strontium atoms in centro symmetric structure of SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub> located between double layers composed of AlO<sub>4</sub> tetrahedra and BO<sub>3</sub> triangles, in large cavities formed by six oxygen atoms at the vertices of an octahedron and six more distant oxygen atoms also with an octahedral arrangement. Luminescence originating from transitions between 4f levels is predominantly due to electric dipole or magnetic dipole interactions. The intensity of electric dipole transitions depends strongly on the site symmetry in a host crystal. Magnetic dipole f–f transitions are not affected much by the site symmetry because they are parity-allowed.

### II. EXPERIMENTAL METHOD

Inorganic borate phosphors were prepared by a novel method described earlier [7-9], which is a variation of the combustion synthesis. The method based on exothermic reaction in which ammonium nitrate used as oxidizer and urea is used as fuel. Fig.1 shows the stepwise preparation of samples by using combustion synthesis technique. The stoichiometric amounts of high purity starting materials, Sr(NO<sub>3</sub>)<sub>2</sub> (A.R.), Al(NO<sub>3</sub>)<sub>3</sub>.9H<sub>2</sub>O (A.R.), Tb<sub>2</sub>(SO<sub>4</sub>)<sub>2</sub> (high purity 99.9%), H<sub>3</sub>BO<sub>3</sub> (A.R.), CO(NH<sub>2</sub>)<sub>2</sub> (A.R.) have been used for sample preparation. The starting materials with little amount of DD water were mixed thoroughly in agate mortar to obtain homogeneous solution. The excess water has been removed by slow heating (700C) and the solution then transferred directly to the pre-heated furnace (550°C) for combustion. Following the combustion, the resulting foamy samples were crushed to obtain fine particles. The prepared materials were characterized by powder XRD. Powder X-ray diffraction measurement were taken on Rigaku Miniflex X-ray Diffractometer and compared with the ICDD file. PL& PLE measurements at room temperature were performed on Hitachi F-7000 spectrophotometer in the range 200 –700 nm with spectral resolution of 2.5 nm and PMT voltage of 400 Volts.

Table 1: Molar ratio of ingredients used for material preparation:

Compound	Molar Ratio
Sr <sub>(1-x)</sub> Tb <sub>x</sub> Al <sub>2</sub> B <sub>2</sub> O <sub>7</sub>	Sr(NO <sub>3</sub> ) <sub>2</sub> : Al(NO <sub>3</sub> ) <sub>3</sub> .9H <sub>2</sub> O : Tb <sub>2</sub> (SO <sub>4</sub> ) <sub>2</sub> : H <sub>3</sub> BO <sub>3</sub> : CO(NH <sub>2</sub> ) <sub>2</sub> (1-x) : 2 : x : 3 : 4 (x = 0.02, 0.05, 0.1, 0.2)

### III. RESULT AND DISCUSSION

### 3.1 sem image of phosphor powder

Fig. 1 show the SEM image of  $\text{Sr}_{0.99}\text{Al}_2\text{B}_2\text{O}_7:\text{Tb}^{3+}_{0.01}$  powder prepared at 800 °C. It was observed that the microstructure of the phosphor consisted of irregular grains with heavy agglomerate phenomena. The average size of the  $\text{Sr}_{0.99}\text{Al}_2\text{B}_2\text{O}_7:\text{Tb}^{3+}_{0.01}$  particles is about 5–15  $\mu\text{m}$ . The results show that  $\text{SrAl}_2\text{B}_2\text{O}_7:\text{Tb}^{3+}$  phosphor has a good crystalline and a relatively low sinter temperature.

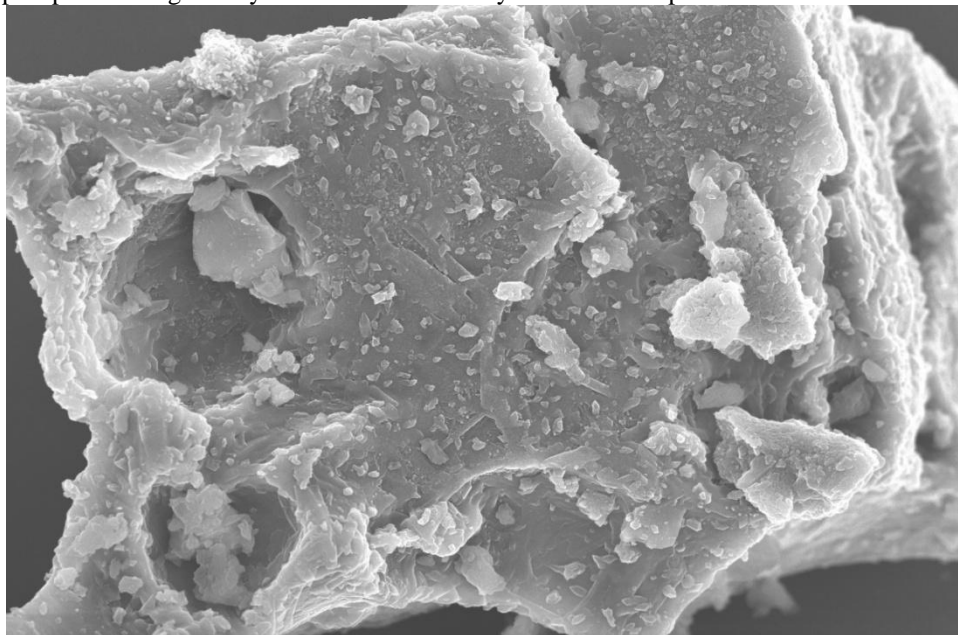


Fig 1: SEM image of  $\text{Sr}_{0.99}\text{Al}_2\text{B}_2\text{O}_7:\text{Tb}^{3+}_{0.01}$ .

### 3.2 X-ray Diffraction Pattern

The powder XRD pattern of  $\text{SrAl}_2\text{B}_2\text{O}_7$  (Fig.2), have been compared with standard ICDD file no. 01-070-4573 and found in good agreement. The crystal structure of the prepared  $\text{SrAl}_2\text{B}_2\text{O}_7$  can be refined to be Rhombohedral, space group C2/c with  $a = 4.893 \text{ \AA}$ ,  $b = 4.893 \text{ \AA}$  and  $c = 47.780 \text{ \AA}$ .

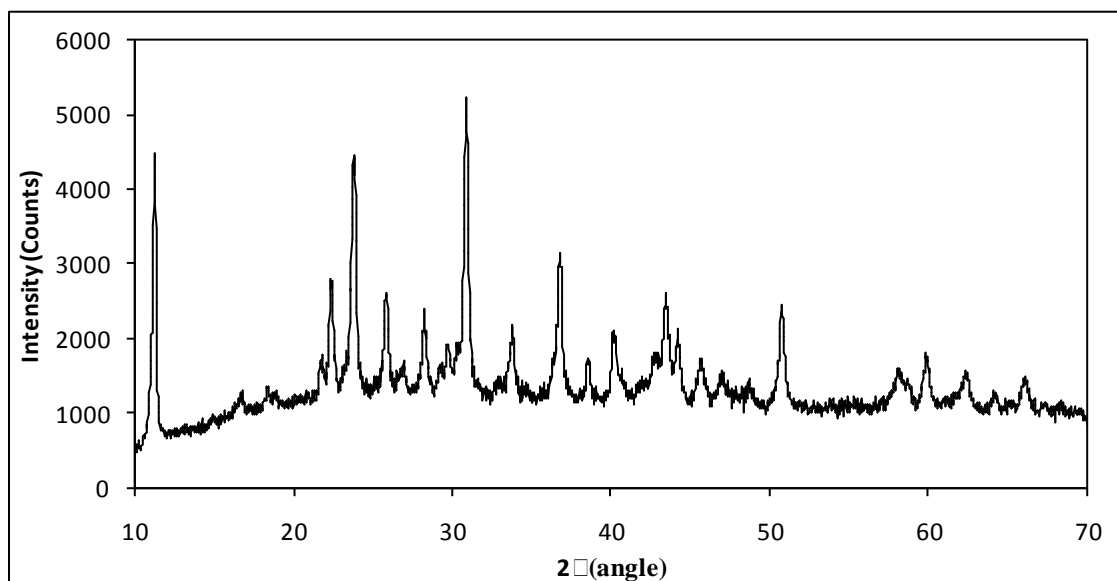


Fig 2: The X-ray powder diffraction patterns of  $\text{SrAl}_2\text{B}_2\text{O}_7:\text{Tb}^{3+}$ .

### 3.3 Photo Luminescence of $\text{SrAl}_2\text{B}_2\text{O}_7:\text{Tb}^{2+}$

Fig. 3 shows the excitation and emission spectra of  $Tb^{3+}$  doped  $SrAl_2B_2O_7$  phosphors. The excitation spectra of  $SrAl_2B_2O_7: Tb^{3+}$  was recorded by monitoring the green emission of  $Tb^{3+}$  ion at 544 nm and shows absorption band at 234 nm, which is due to the spin-allowed  $^4f_8 \rightarrow ^4f_7$  5d transition of  $Tb^{3+}$  and the  $4f \rightarrow 4f$  transitions of  $Tb^{3+}$ , respectively. In order to produce stronger emission, the excitation wavelength of 254 nm is adopted in this study, according to the excitation spectrum of  $Tb^{3+}$  doped  $SrAl_2B_2O_7$  phosphors. The  $Tb^{3+}$  doped  $SrAl_2B_2O_7$  phosphor shows sharp characteristic emissions, several bands centered at 490, 544, 586, and 623 nm corresponding to transitions from the  $^5D_4$  level to the  $^7F_6$ ,  $^7F_5$ ,  $^7F_4$ , and  $^7F_3$  levels, respectively [10]. The prominent emission peak has been observed at 544 nm. However, some very weak emissions in the blue region that originates from the higher energy  $^5D_3$  level was also been observed. Since the  $^5D_3 \rightarrow ^5D_4$  transition is resonant with  $^7F_6 \rightarrow ^7F_0$  transition, the emission of  $^5D_3 \rightarrow ^7F_j$  transitions often be quenched for high  $Tb^{3+}$  concentration doped samples due to the cross relaxation  $^5D_3 + ^7F_6 \rightarrow ^5D_4 + ^7F_0$  [11]. Fig. 5 shows the variation of emission intensity with the concentration of  $Tb^{3+}$ . It has been seen that the critical concentration of  $Tb^{3+}$  in  $SrAl_2B_2O_7: Tb^{3+}$  phosphor is about 1 mol%.

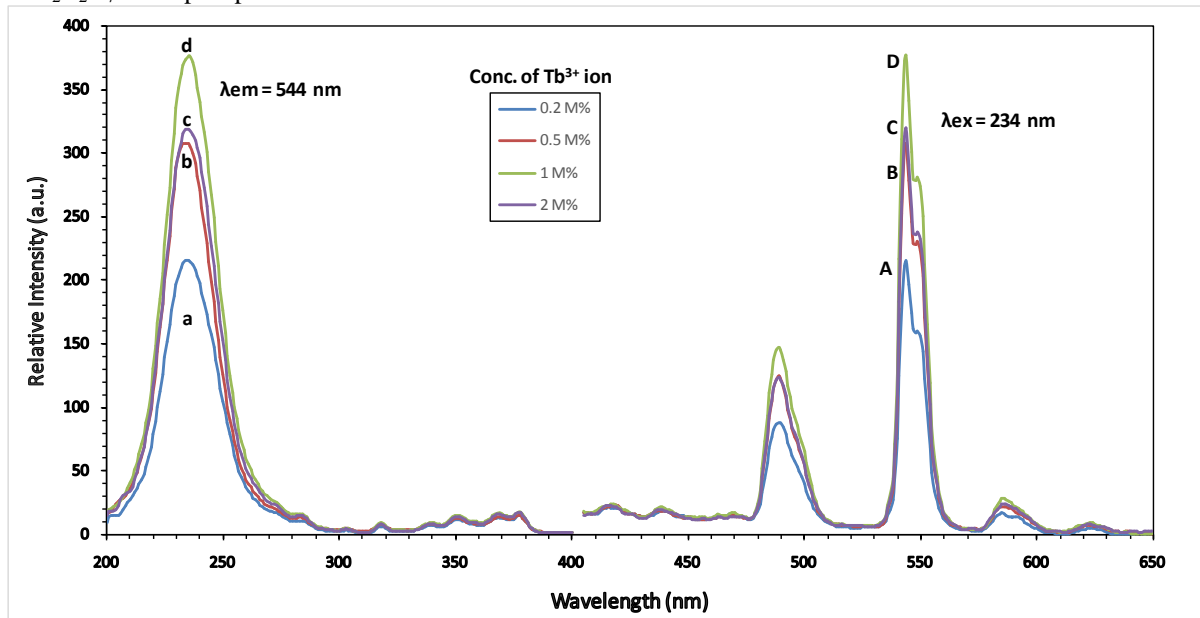


Fig 3: Excitation (a, b, c, d) and Emission (A: 0.02, B: 0.05, C: 0.2, D: 0.1) of  $Tb^{3+}$  in  $Sr_{(1-x)}Al_2B_2O_7$ .

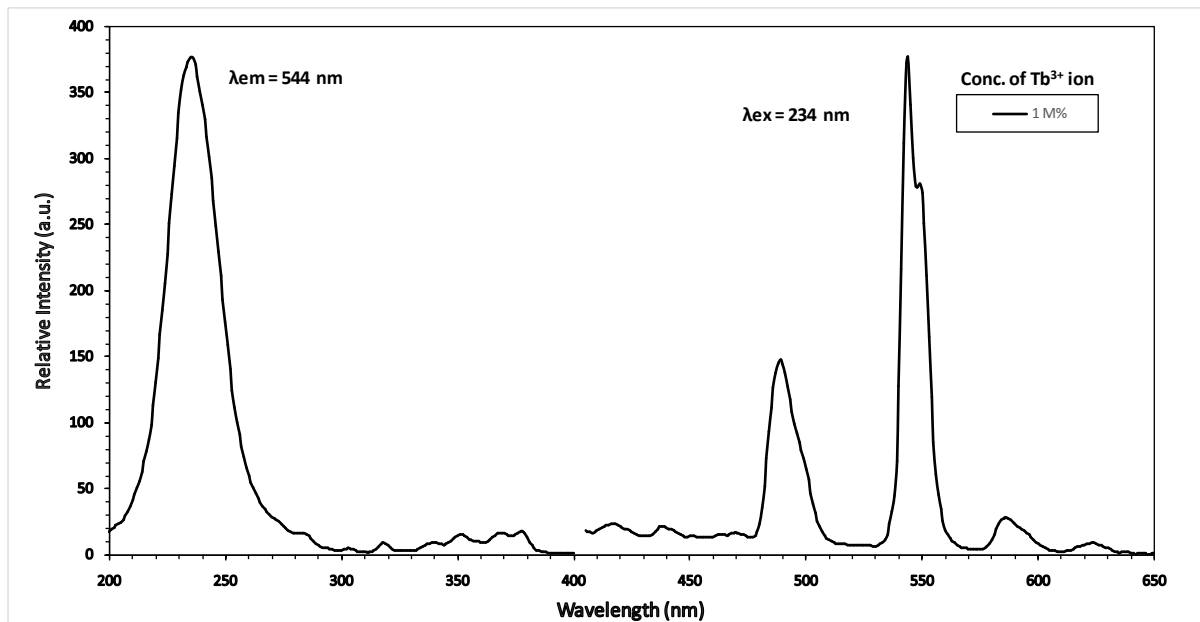


Fig 4: Photoluminescence spectra of  $SrAl_2B_2O_7: Tb^{3+}$ , Emission spectra monitored at 234 nm excitation and Excitation spectra monitored at 544 nm emission.

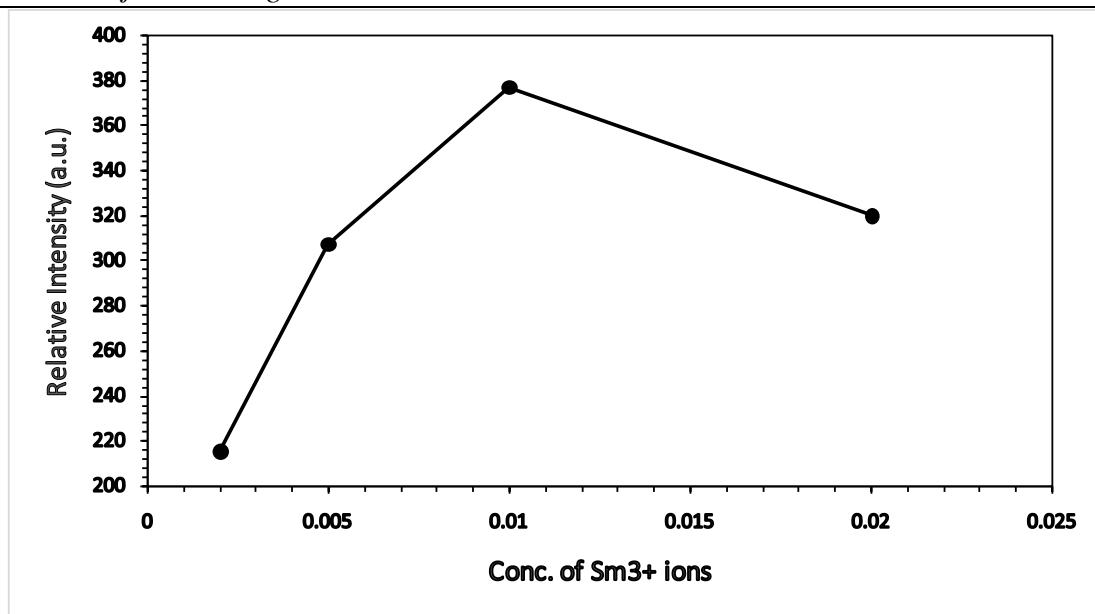


Fig 5: Concentration quenching of Tb<sup>3+</sup> in SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>.

#### IV. CONCLUSION

In the present work, powder samples of green emitting phosphors SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>:Tb<sup>3+</sup> were prepared by using solution combustion technique and its photoluminescence properties were reported. The structure conformation of synthesized phosphor was characterized using powder XRD. SEM of calcined powders for 4 hr indicated spherical highly agglomerated powders. The PL spectra show the strongest emission at 544 nm corresponding to the <sup>5</sup>D<sub>4</sub>→<sup>7</sup>F<sub>5</sub> transition of Tb<sup>3+</sup> in SrAl<sub>2</sub>B<sub>2</sub>O<sub>7</sub>. It has been observed that the host sample does not show any photoluminescence, however when Tb<sup>3+</sup> ions were doped, phosphors showed characteristic emission of Tb<sup>3+</sup>.

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