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Investigating the photoluminescence and structural properties of a $LiBO_2:sm^{3+}$ phosphor produced using the solid state diffusion approch

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Abstract: The solid state diffusion approach, which is both popular and convenient, was used to synthesise phosphorus-doped lithium metaborate ($LiBO_2$). Photoluminescence (PL) and X-ray diffraction (XRD) were used to characterise these phosphors, which revealed that the manufactured sample had a uniform, crystalline structure. We determined that the phosphors had an average particle size of 38.785 nm in our X-RD characterisation, suggesting that the material was nanomaterial. A photoluminescent phosphor's emission spectra will exhibit an efficient orange at 606 nm, stimulated by UV light at 401 nm.Solid state lighting devices, made possible by studying lithium metaborate phosphors doped with Sm3+ elements, are an important part of sustainable lighting technology and help the food industry cut down on the usage of toxic fertilisers.

Keywords – *lithium metaborate, photoluminescence, Sm^{3+} doped phosphors, solid state diffusion method, and lithiummetaborate doped with Sm^{3+}.*

1. Introduction:

Photoluminescent materials, particularly rare-earth-doped phosphors, in recent years, these materials have attracted considerable attention because of their impressive optical characteristics, including high quantum efficiency, excellent stability, and tunable emission spectra. Among these, the incorporation of samarium (Sm^{3+}) ions into various host matrices has been widelyinvestigated for their potential applications in lighting, display technologies, and scintillation. The choice of the host material plays a crucial role in determining the luminescent behavior, as it affects the absorption and emission characteristics of the dopant .Lithium borate ($LiBO_2$) is a promising host for phosphors due to its excellent thermal stability, low phonon. energy, and the ability to accommodate a variety of dopants. These properties make $LiBO_2$ a favorable Candidate for enhancing the luminescent performance of Sm^{3+} ions. The Photoluminescence of Sm^{3+} doped phosphors, specifically in the $LiBO_2$ matrix, exhibits a unique emission profile, typically characterized by sharp, well-defined peaks due to transitions between the energy levels of Sm^{3+} ions. However, the optimization of their luminescent properties requires careful control over the synthesis process. In this study, we present the synthesis and detailed photoluminescence characterization of $LiBO_2:Sm^{3+}$ phosphors prepared via the solid-state diffusion method. This approach is favored for its simplicity, cost-effectiveness, and ability to achieve uniform distributions of the dopant ions within the host matrix . By exploring the effects of various synthesis parameters, including the doping concentration of Sm^{3+}, the reaction temperature, and the diffusion time, we aim to gain deeper insights into the Photo-luminescent

properties and potential applications of $LiBO_2:Sm^{3+}$ as an efficient phosphor for optoelectronic devices [1-4]. Suitable UV-LED illumination solutions. As such, investigating phosphors capable of efficient UV emission is of paramount importance for advancing UV-LED technologies and fulfilling the current technological gap.

2. Material preparation and characterisation

The required stoichiometric amounts of the individual ingredients, based on their molar ratios, are carefully mixed and ground in an agate mortar to achieve a homogeneous mixture. This mixture is then transferred to a China basin and placed in a preheated muffle furnace, where it is sintered at 500°C for 5 hours. After sintering, the material is allowed to cool the room temperature inside a closed furnace. Once cooled, the contents of the China basin are transferred to a mortar and ground for 30 minutes. The resulting powder is then placed in silica crucible and sintered again in a preheated muffle furnace at 700°C for 5 hours. After this second sintering, the material is once again cooled to room temperature inside the furnace. Finally, the phosphors are ground for another 30 minutes in a mortar and pestle.The samples were ground into a fine powder and tested using different techniques. The crystal structure was examined with high-resolution X-ray diffraction (XRD). Luminescence spectra were recorded using a spectrofluorometer with a Xenon flash lamp as the excitation source, and all measurements were taken at room temperature .

3. Results and discussion:

3.1 Photoluminescence Spectroscopy :

The emission and excitation spectra of $LiBO_2$: Sm^{3+} for different concentration and **Highest Emission graph of $LiBO_2$,** are shown in fig 1(A), 1(B) and 1(C). The emission spectrum was measured by monitoring the emission wavelength at 606 nm. The excitation spectrum exhibited excitation peak at 401 nm which is assigned to the electronic transition 4f-4f of the Sm^{3+} ion [2]. Under excitation of 401 nm the emission spectra of the phosphor show two main bonds at 606 nm (orange) corresponds to the transition → $^4F_{9/2}$ $^6H_{15/2}$ and 625 nm (red) associated with the transition $^4F_{9/2}$ → $^6H_{13/2}$. The first transition $^4F_{9/2}$ $^4F_{9/2}$ → $^6H_{15/2}$ is magnetic dipole transition and other one $^6H_{13/2}$ belongs to forced electric dipole transition [5]. It is found that intensity of Sm decreases with increase of the concentration of Sm^{3+} ion. It is found to be maximum for 0.5 mol % of Sm^{3+}[3-4].

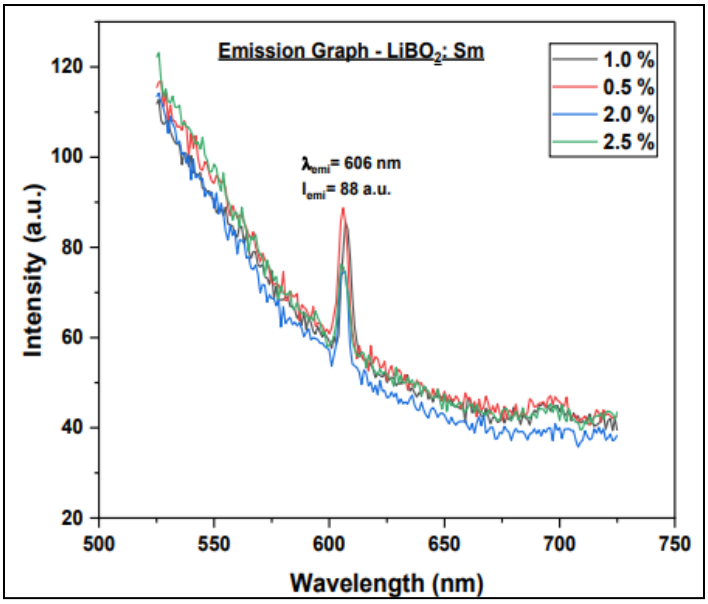

Figure 1(A): Emission graph – $LiBO_2$: Sm^{3+}

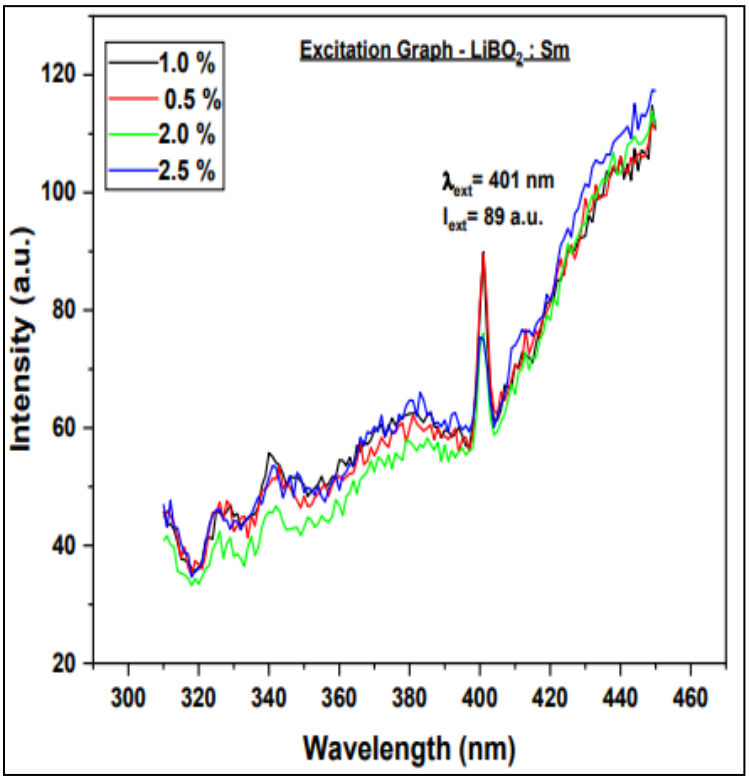

Figure 1(B): Excitation graph – $LiBO_2$: Sm^{3+}

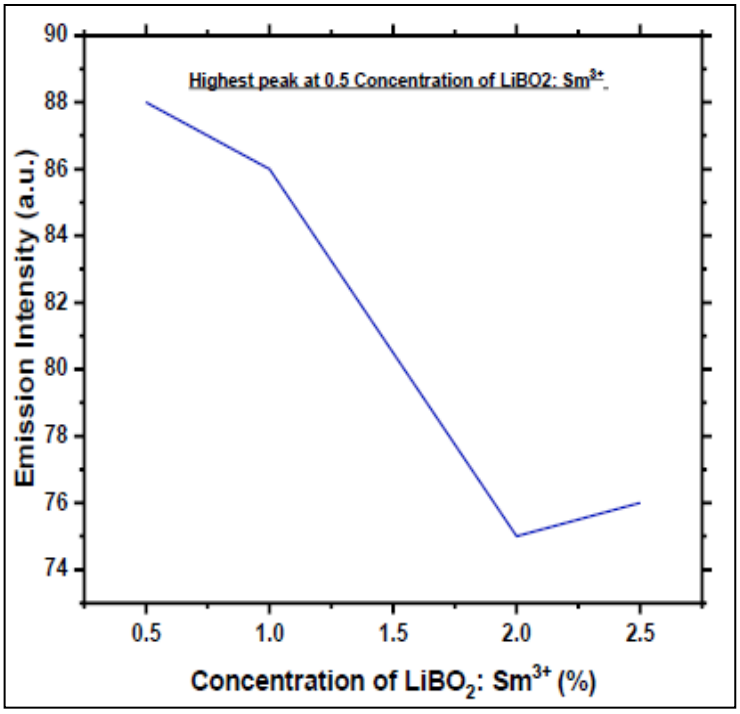

Figure 1 (C): Highest Emission graph of $LiBO_2$:

Table 1: Photoluminescent Paramenters of LiBO2: Sm3+ at different concentrations

Concentration LiBO2: Sm^{3+}	Emission Wavelength	Emission Intensity	Excitation Wavelength	Excitation Intensity
1.0 %	607 nm	86 a.u.	401 nm	89 a.u.
0.5 %	606 nm	88 a.u.	401 nm	88 a.u.
2.0 %	607 nm	75 a.u.	400 nm	76 a.u.
2.5%	605 nm	76 a.u.	400 nm	75 a.u.

3.2 X-Ray Diffraction Analysis

The X-Ray Diffraction (XRD) results in figure 2(A) and 2 (B) show that the final product is uniform and formed in a consistent way. The average particle size is 38.785 nm, indicating that the sample is a nanomaterial. The dislocation density is 5.797×10^{-4} nm^{-2}, and the strain is 2.912×10^{-3}. These results suggest that the phosphors have a crystalline structure[5-6].

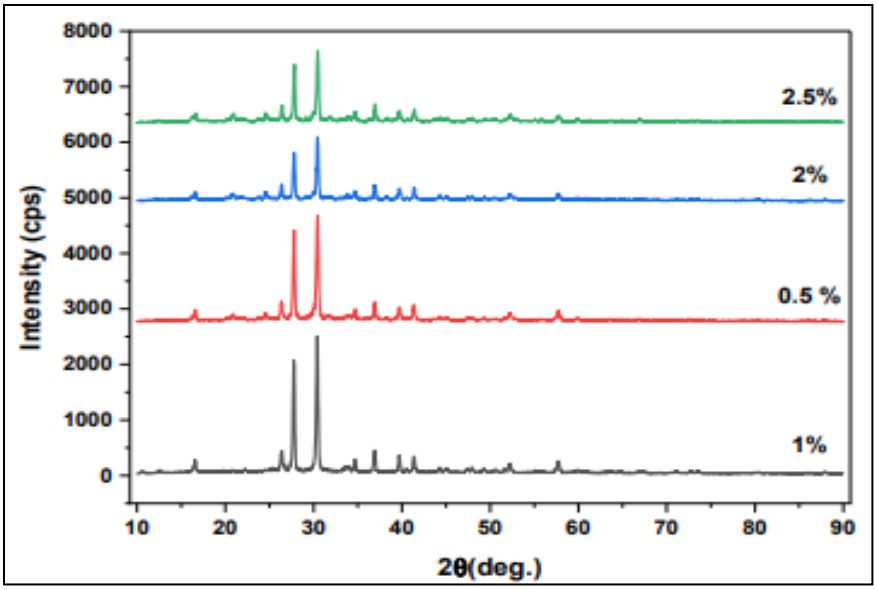

Figure 2(A): XRD graph for LiBO2: Sm^{3+} doped for different conc.

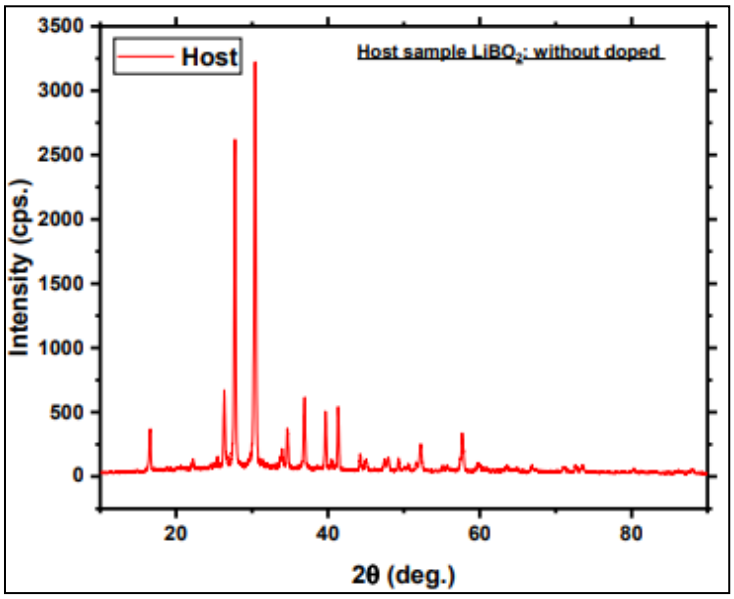

Figure 2(B): XRD graph for LiBO2: Sm^{3+} without doped

Table 2 : XRD parameters of synthesized samples obtained from XRD analysis

Sr. No.	2 theta (deg.)	d (ang.)	Height (eps.)	FWHM	Crystallite size (nm)	Strain	Dislocation density (nm^{-2})
1	26.348	3.3790	406	0.210	38.872	3.912×10^{-3}	6.618×10^{-4}
2	27.738	3.2136	1847	0.204	40.116	3.600×10^{-3}	6.214×10^{-4}
3	30.394	2.9385	2302	0.235	35.034	3.770×10^{-3}	8.147×10^{-4}
4	34.674	2.5850	221	0.216	38.534	3.017×10^{-3}	6.735×10^{-4}
5	36.898	2.4341	411	0.211	39.690	2.758×10^{-3}	6.348×10^{-4}
6	39.646	2.2715	341	0.191	44.218	2.310×10^{-3}	5.114×10^{-4}
7	41.326	2.1829	378	0.188	45.167	2.174×10^{-3}	4.901×10^{-4}
8	52. 198	1.7570	148	0.300	29.490	2.670×10^{-3}	1.149×10^{-4}
9	57.644	1.5978	19	0.239	37.944	1.890×10^{-3}	6.945×10^{-4}

4. Conclusion :

In conclusion, the XRD analysis of LiBO2:Sm^{3+} phosphors show that product is homogeneous with average particle size of 38.785 nm, confirming it as a nonmaterial. The dislocation density and strain values are 5.797×10^{-4} nm^{-2} and 2.912×10^{-3}, respectively. The emission spectra exhibit strong orange (606 nm) and red (650 nm) emissions when excited by 401 nm UV light, corresponding to the characteristic transitions of Sm^{3+} ions. These findings suggest that Sm-doped $LiBO_2$ phosphors are promising candidates for solid-state lighting applications.

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