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CIE Chromaticity of MGB_4O_7: SM and MGB_4O_7: SM, LI Synthesized by Solid-State Reaction Method

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Abstract
Rare earth-doped magnesium tetraborate phosphors were successfully synthesized by the solid-state reaction method. The XRD pattern confirmed that the crystal structures were identified as orthorhombic with cell parameters a = 8.596, b = 13.72, and c = 7.956, and the space group is Pbca. The CIE coordinates were measured according to the CIE 1931 color chromaticity picture, which was found in the bluish-purple region. Thus, the synthesized samples are suitable candidates for blue-emitting nano phosphors and can be applied for various solid-state lighting applications.
***Keywords*: XRD, CIE, Solid-State reaction.**

1.1 INTRODUCTION

Borate phosphors are of great importance and have attracted several researchers' attention because of the ease of preparation in bulk quantities, simple TL glow curve, increased neutron, and gamma sensitivity, especially near tissue equivalence, and can be reused in some cases. These phosphors possess some unique properties such as high optical transparency, low cost of production, high solubility to rare earths, excellent mechanical and thermal stability, and high luminescence efficiency in the visible region. Because of all these factors, these compounds became more significant for studying the luminescence properties of photonic applications [1-3]. Rare earth-doped borate phosphors are very well known for today's generation as it has high emission efficiencies in the 4f-4f electron with shielding effect of the 5s and 5p orbitals on the f-f electron.

Magnesium tetraborate, MgB4O7, is one of the attractive compounds as a host material for dosimetry applications based on the OSL or TL technique for numerous reasons [4–9]. Its effective atomic number is low i.e. Zeff = 8.4, equivalent to soft biological tissue. Amid the various REIs, "trivalent samarium ion (Sm^{3+}) has displayed useful qualities such as high quantum efficiency due to large optical band gaps and efficient fluorescence". The wide spectra range of the Sm_2O_3 matrix extending from ultraviolet to infrared region has several applications in areas such as color display, medicine, solid state, communications, and optoelectronics [10-12]. The emission of reddish-orange light from Sm^{3+} activated compounds is "due to $^6G_{5/2}\rightarrow{}^6H_{5/2}$, $^6G_{5/2}\rightarrow{}^6H_{7/2}$, $^6G_{5/2}\rightarrow{}^6H_{9/2}$ and $^6G_{5/2}\rightarrow{}^6H_{11/2}$ transition bands with $^6G_{5/2}\rightarrow{}^6H_{5/2}$ as the hypersensitive transition whose position and intensity are strongly affected by the host ligand field [13-14]".

Phosphors doped with triple rare earth ions produced color emissions under the excitation wavelengths of 350, 360, and 370 nm, which might be promising materials for optoelectronic devices and security applications such as data encryption [15]. Under the excitation of UV light, borate compounds doped with Ce^{3+}, Tb^{3+}, and Mn^{2+} emitted white light for the first time [16]. Moreover, the synthesized compound is a suitable candidate for blue light emission which can be applied to various solid-state lighting applications [17].

In the present study Magnesium borate doped with Sm and codoped with Li has been synthesized by solid-state reaction method. The phase structure was identified by X-ray diffraction technique and CIE chromaticity coordinates have been examined with the help of PL emission data.

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1.2 EXPERIMENTAL TECHNIQUE

Rare earth-doped magnesium tetraborate phosphors were synthesized by solid-state reaction method. Himedia chemicals were used for the preparation of all the samples. The stoichiometric ratio of raw material was taken in the agate mortar along with the required amount of dopant. The concentration of the dopant may be varied from 1 to 5 mol%. The starting materials were mixed homogeneously and continuously grounded for 5 hours to obtain a fine powder. Acetone and distilled water were used as a wetting medium for the homogeneous mixing. Then the fine powder was kept inside the muffle furnace for the calcination process at 900°c for 5 hours. The starting materials (chemicals) used for the synthesis of borate phosphors are shown in Table 1.

Table 1 Chemical composition of raw materials for the synthesis of phosphors

S.No,	Phosphor	Raw materials	Temperature	Hours
1	MgB_4O_7: Sm	$MgCO_3$, H_3Bo_3, Sm_2O_3	900	5
2	MgB_4O_7: Sm, Li	$MgCO_3$, H_3Bo_3, Sm_2O_3, Li_2CO_3	900	5

After the calcination process, the sample was taken out from the muffle furnace and allowed to cool at room temperature. Then, the resultant phosphor was again grounded for a few minutes and used for further characterization studies. All the above experimental processes were performed under ambient conditions.

1.3 X-RAY DIFFRACTION (XRD) PATTERN

The X-ray diffraction (XRD) pattern of borate phosphors was examined by a PANalytical X'pert Powder X-ray Diffractometer in the 2Θ range from 10 to 55°, with CuKα radiation of λ= 1.5406 Å. The X-ray diffraction (XRD) pattern of the synthesized MgB_4O_7: Sm and MgB_4O_7: Sm, Li phosphor are shown in Figures 1 and 2. A small amount of dopants does not influence the crystal phase and the structure of MgB_4O_7. The XRD patterns were matched with those of standard JCPDS database 31-0787, and all the diffraction peaks obtained were matched very well. The crystal structure was identified as orthorhombic with cell parameters a = 8.596, b = 13.72, and c = 7.956, and the space group is Pbca [18].

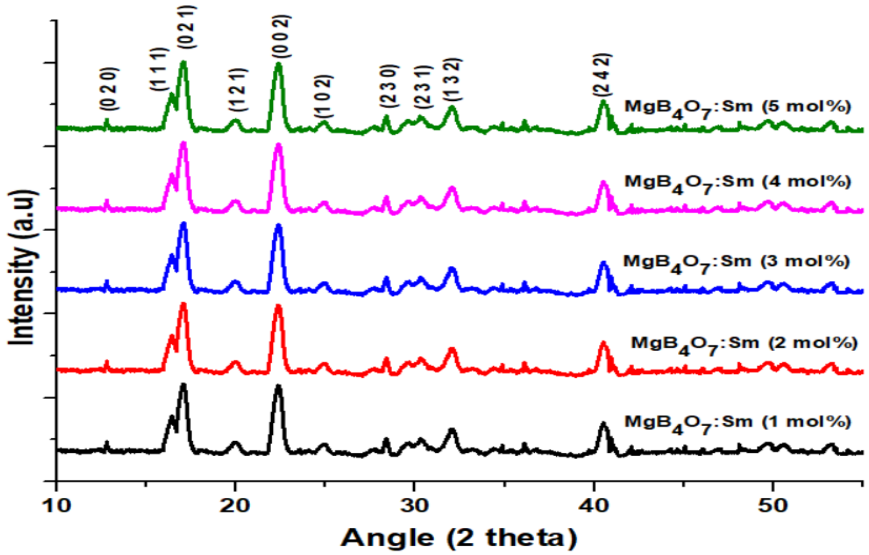

Figure 1. XRD patterns of MgB_4O_7: Sm phosphors (1 – 5 mol%).

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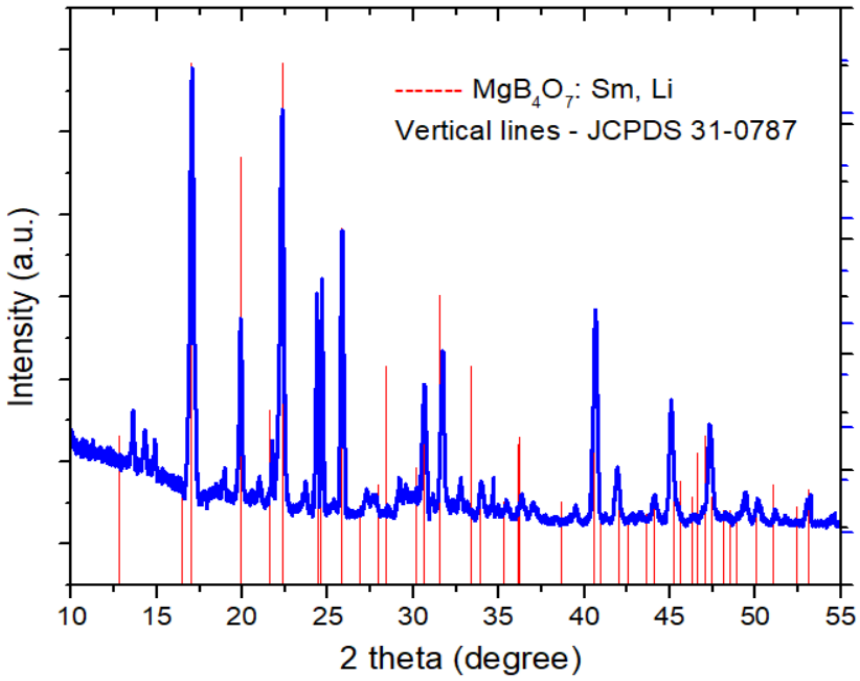

Figure 2. XRD pattern of MgB_4O_7: Sm, Li (2 mol%) along with JCPDS data 31-0787.

1.4 CIE CHROMATICITY COORDINATES

To determine the CIE 1931 (Commission International d'Eclairage) values, the Photoluminescence emission spectra were helpful to identify the coordinate values. The CIE chart demonstrated all the available colors on the basis of the incorporation of three elementary colors [19]. The chromaticity coordinates can be determined with help of tri-stimulus values using the following equations.

$$x = X / X+Y+Z \quad (1)$$
$$y = Y / X+Y+Z \quad (2)$$
$$z = Z / X+Y+Z = 1-x-y \quad (3)$$

where,
x, y and z are tri-chromatic coefficients that are ascribed to red, green, and blue, which are also defined by chromaticity coordinates.
The standard (x, y) chromaticity coordinates values are (0.33, 0.33), which was mentioned in the CIE 1931 chromaticity picture. That values are equivalent to the white color emission when it is cornered in the middle. Figure 3 and 4 depicted the CIE Chromaticity Diagram of MgB_4O_7: Sm and MgB_4O_7: Sm,Li.. The CIE coordinates (x, y) and CCT values were measured according to CIE 1931 color chromaticity picture, which is given in table 2. Luminescence colors of both the phosphors are found in the bluish-purple region. Thus, the synthesized samples are promising materials for blue- emitting nano phosphors and can be applied for various solid-state lighting applications.

Table 2. The CIE Chromaticity coordinates and CCT values

S.No.	Sample	X	Y	CCT
1	MgB_4O_7: Sm	**0.212**	**0.11**	**1939.52**
2	MgB_4O_7: Sm,Li	**0.219**	**0.073**	**1818.71**

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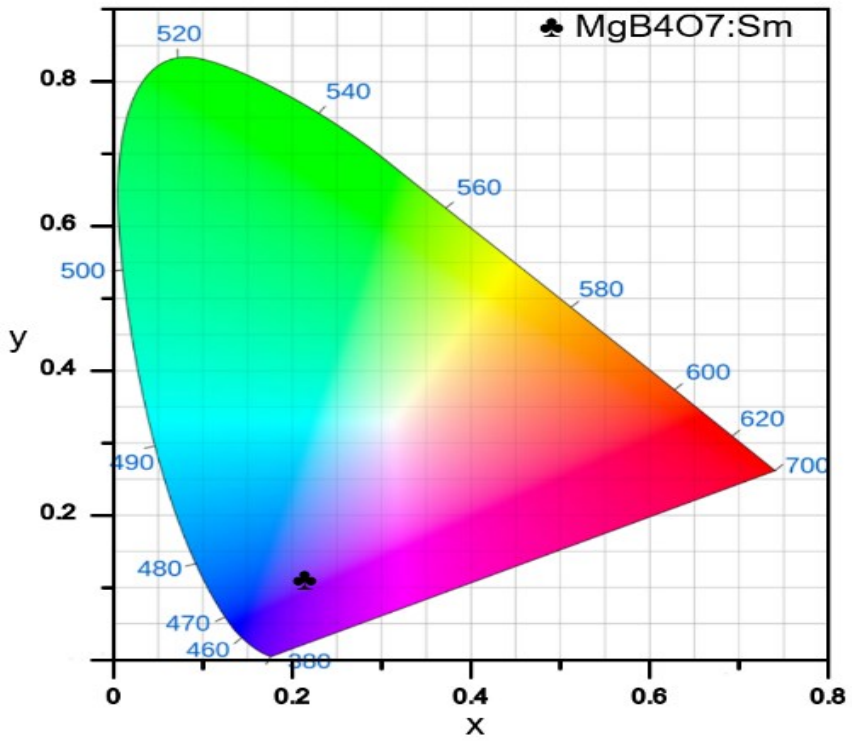

Figure 3. CIE Chromaticity Diagram of MgB_4O_7: Sm.

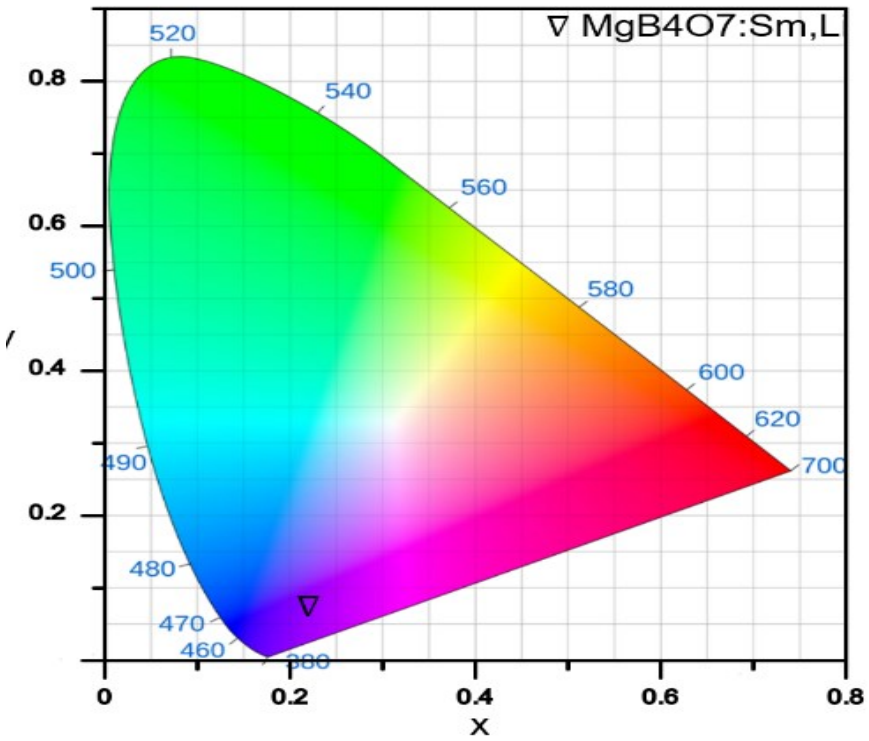

Figure 4. CIE Chromaticity Diagram of MgB4O7: Sm.Li.

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1.5 CONCLUSION

Rare earth-doped magnesium tetraborate phosphors were successfully synthesized by solid-state reaction methodsss. The XRD pattern confirmed that the crystal structures were identified as orthorhombic with cell parameters a = 8.596, b = 13.72, and c = 7.956, and the space group is Pbca. The CIE coordinates (x, y) and CCT values were measured according to the CIE 1931 color chromaticity picture. Luminescence colors of both the phosphors are found in the bluish-purple region. Thus, the synthesized samples are promising materials for blue-emitting nano phosphors and can be applied for various solid-state lighting applications.

1.6 REFERENCES:

[1] Mhareb, M. H. A. (2020). Physical, optical and shielding features of $Li_2O–B_2O_3–MgO–Er_2O_3$ glasses co-doped of Sm_2O_3. Applied physics A, 126, 1-8.
[2] Mhareb, M. H. A., Almessiere, M. A., Sayyed, M. I., & Alajerami, Y. S. M. (2019). Physical, structural, optical and photons attenuation attributes of lithium-magnesium-borate glasses: role of Tm_2O_3 doping. Optik, 182, 821-831.
[3] Lakshminarayana, G., Yang, R., Mao, M., & Qiu, J. (2009). Spectral analysis of RE^{3+} (RE= Sm, Dy, and Tm): $P_2O_5–Al_2O_3–Na_2O$ glasses. Optical materials, 31(10), 1506-1512.
[4] Prokić, M. J. N. I. (1980). Development of highly sensitive $CaSO_4$: Dy/Tm and MgB_4O_7: Dy/Tm sintered thermoluminescent dosimeters. Nuclear Instruments and Methods, 175(1), 83-86.
[5] Driscoll, C. M., Mundy, S. J., & Elliot, J. M. (1981). Sensitivity and fading characteristics of thermoluminescent magnesium borate. Radiat. Prot. Dosim.;(United Kingdom), 1(2).
[6] Prokic, M., & Bøtter-Jensen, L. (1993). Comparison of main thermoluminescent properties of some TL dosemeters. Radiation Protection Dosimetry, 47(1-4), 195-199.
[7] Prokić, M. (2007). Individual monitoring based on magnesium borate. Radiation protection dosimetry, 125(1-4), 247-250.
[8] Yukihara, E. G., Milliken, E. D., & Doull, B. A. (2014). Thermally stimulated and recombination processes in MgB_4O_7 investigated by systematic lanthanide doping. Journal of luminescence, 154, 251-259..
[9] Kitagawa, Y., Yukihara, E. G., & Tanabe, S. (2021). Development of Ce^{3+} and Li^{+} co-doped magnesium borate glass ceramics for optically stimulated luminescence dosimetry. Journal of Luminescence, 232, 117847.
[10] Wang, D., Guo, Y., Wang, Q., Chang, Z., Liu, J., & Luo, J. (2009). Judd–Ofelt analysis of spectroscopic properties of Tm^{3+} ions in K_2YF_5 crystal. Journal of alloys and compounds, 474(1-2), 23-25.
[11] Pal, I., Agarwal, A., Sanghi, S., & Aggarwal, M. P. (2011). Structural, absorption and fluorescence spectral analysis of Pr^{3+} ions doped zinc bismuth borate glasses. Journal of alloys and compounds, 509(28), 7625-7631.
[12] Olivier, M., Pirasteh, P., Doualan, J. L., Camy, P., Lhermite, H., Adam, J. L., & Nazabal, V. (2011). Pr^{3+} -doped ZBLA fluoride glasses for visible laser emission. Optical Materials, 33(7), 980-984.
[13] Rao, C. S., & Jayasankar, C. K. (2013). Spectroscopic and radiative properties of Sm^{3+}-doped K–Mg–Al phosphate glasses. Optics Communications, 286, 204-210.
[14] Maheshvaran, K., Linganna, K., & Marimuthu, K. (2011). Composition dependent structural and optical properties of Sm^{3+} doped boro-tellurite glasses. Journal of Luminescence, 131(12), 2746-2753.
[15] Kashif, I., & Ratep, A. (2023). Various Color Light Emission from Single, Double, and Triple Eu $^{3+}$/Tb $^{3+}$/Tm $^{3+}$ Doped Borate Glass Excited by UV Light. Journal of Fluorescence, 1-13.
[16] Zhang, J. C., Parent, C., Le Flem, G., & Hagenmuller, P. (1991). White light emitting glasses. Journal of Solid State Chemistry, 93(1), 17-29.
[17] Hargunani, S. P., Sonekar, R. P., Singh, A., Khosla, A., & Arya, S. (2022). Structural and spectral studies of Ce^{3+} doped $Sr_3Y(BO_3)_3$ nano phosphors prepared by combustion synthesis. Materials Technology, 37(7), 450-461.
[18] Annalakshmi, O., Jose, M. T., Madhusoodanan, U., Venkatraman, B., & Amarendra, G. (2013). Synthesis and thermoluminescence characterization of MgB_4O_7: Gd, Li. Radiation measurements, 59, 15-22.
[19] Karunakaran, R. T., Marimuthu, K., Babu, S. S., & Arumugam, S. (2009). Structural, optical and thermal investigations on Dy^{3+} doped $NaF–Li_2O–B_2O_3$ glasses. Physica B: Condensed Matter, 404(21), 3995-4000.