



## STUDY OF LUMINESCENT PROPERTIES OF TERBIUM ACTIVATED $\text{Li}_2\text{SrSiO}_4$ PHOSPHOR

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### ABSTRACT

Properties of  $\text{Li}_2\text{SrSiO}_4$  doped Tb element synthesized by high temperature solid state diffusion method reported in this paper. Suitable quality in molar Percentage of Lithium carbonate ( $\text{Li}_2\text{CO}_3$ ), Strontium Carbonate ( $\text{SrCO}_3$ ), & silica ( $\text{SiO}_2$ ) and Terbium oxide ( $\text{Tb}_2\text{O}_3$ ) are taken and ground in acetone medium. The sample is taken in the alumina crucible and heated  $1200^\circ\text{C}$  for four hours. The furnace was allowed to chill temperature. The crucible was taken out and located the fabric is molted and stick with the bottom of the crucible. The prepared materials  $\text{Li}_2\text{SrSiO}_4:1.0\% \text{Tb}^{3+}$  phosphor was characterized by X-ray diffraction (XRD) and photoluminescence (PL). The crystallite size of powders samples were calculated from X-ray peak broadening of the diffraction using Scherrer's formula. The calculated average crystallite size of the  $\text{Li}_2\text{SrSiO}_4:1.0\% \text{Tb}^{3+}$  phosphor is 75 nm. The XRD patterns of the powders revealed that the structure of  $\text{Li}_2\text{SrSiO}_4:\text{Tb}^{3+}$  is orthorhombic. The photoluminescence excitation spectra identify that the  $\text{Li}_2\text{SrSiO}_4:\text{Tb}^{3+}$  phosphors are often successfully excited by 248 nm wavelength. The emission properties of  $\text{Li}_2\text{SrSiO}_4:\text{Tb}^{3+}$  phosphors are strongly dependence upon the concentration of rare-earth element  $\text{Tb}^{3+}$ . The CIE coordinates of the  $\text{Li}_2\text{SrSiO}_4:1.0\% \text{Tb}^{3+}$  are  $x=0.60$ ,  $y=0.31$ . From this the present phosphor is potential candidate for light emitting devices.

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### INTRODUCTION

Due to encouraging luminescent properties alkaline earth silicates material doped with rare earth have been increasing paid attention which makes them promising candidate for application in white light emitting diode, Display and solid-state lighting, multi color phosphor, long lasting phosphor, high efficiency Si-solar cells [1-10]. The unique optical properties of rare earth (RE) ions are attributed to electronic transitions occurring within the partially filled 4f energy shell, which makes these ions a favorite activator for different host materials. Because of its high chemical and physical stability, wide band gap and excellent radiation conversion efficiency, the silicate based compound has proven to be one of the best hosts for the incorporation of RE ions in a wide range of optical applications [11–15]. Recently, Wang *et al.* [16] synthesized the blue phosphor  $\text{Na}_2\text{CaSiO}_4:\text{Eu}^{3+}$  by high temperature solid-state reaction and the white light could be generated by mixing it with the yellow phosphor  $\text{Li}_2\text{SrSiO}_4:\text{Eu}^{2+}$ .

For that lithium compounds have not so much attention in the past until recently, driven by the requirements of energy storage and energy-saving applications, such as Li-ion batteries (LBs) and light-emitting diodes (LEDs). Due to applications, lithium-containing silicates with the general formula  $\text{ABC}_2\text{X}_4$ , such as  $\text{Li}_2\text{SrSiO}_4$ ,  $\text{Li}_2\text{EuSiO}_4$ ,  $\text{Li}_2\text{CoSiO}_4$  and  $\text{Li}_2\text{MnSiO}_4$ , [16-18] have been widely investigated. Structures are for eternity basic to understanding material properties. [20,21] However, in some situations, dynamic processes are not ignorable, such as the charging and recharging processes in batteries [22] and the popular carburizing, [23] used to enhance the mechanical strength of steels, due to the transfer of small atoms, such as B, C, and N, and defects from one site to another.  $\text{Li}^+$  is the smallest and lightest alkali metal ion and can naturally be incorporated into the interstitial sites in crystal lattices. The mobility and static displacement of small atoms may result in characteristic local symmetry breaking due to tiny distortions in the structure that do not spread over long-ranges [24]. In this paper  $\text{Tb}^{3+}$  doped

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$\text{Li}_2\text{SrSiO}_4$  phosphor are synthesized by Solid-State diffusion method and study the photoluminescence properties of said phosphor and we get more improved results. The aim of the present investigation is to examine or the silicate based phosphors.

## MATERIALS AND METHODS

The phosphors were prepared by solid state diffusion method. Stoichiometric amounts of starting materials, except for  $\text{Li}_2\text{CO}_3$ , which was 2mol% excess to compensate for the volatilization loss in  $\text{Li}_2\text{O}$ , is expected to be devoid of Li vacancies.  $\text{SrCO}_3$ ,  $\text{SiO}_2$  (all A.R. grade) and  $\text{Tb}_2\text{O}_3$  (99.99 purity) were ground well and preheated at  $500^\circ\text{C}$  for 4h in order to avoid lithium volatilization. After the preheat treatment, the obtained product was ground well and placed in an silica crucible inside the furnace and heated to  $1200^\circ\text{C}$  for 5h. The samples were kept at this temperature for 5 h and then cooled to room temperature. The result ant powder was crushed to fine particles using an agate pestle and mortar. This powder was used as a phosphor in further study

The prepared  $\text{Li}_2\text{SrSiO}_4$ : 1.0%  $\text{Tb}^{3+}$  phosphor was characterized by different techniques. The structural studies were carried out by X- ray diffraction technique in reflection with filtered  $\text{Cu K}\alpha$  radiation ( $\lambda = 1.54051 \text{ \AA}$ ) with Rigaku, D Max III VC, Japan. The photoluminescence excitation and emission spectra was recorded at room temperature using Spectro fluoro photo meter (SHIMADZU, RF – 5301 PC) using Xenon lamp as excitation source. The CIE coordinates (x, y) of prepared materials was calculated with color calculator version2, software from Radiant Imaging.

## RESULTS AND DISCUSSION

Fig 1 illustrates the TGA curves for the  $\text{Li}_2\text{SrSiO}_4$  precursors heated at rate of  $10^\circ\text{C}/\text{min}$ . The TG analysis showed two stages of weight loss accompanied by two endothermic peaks. The corresponding endothermic peak at 615 and  $1069^\circ\text{C}$  in DTA curve, corresponding to the weight loss shown in TG, was due to precursor dehydration. An apparent weight loss occurred at around  $614^\circ\text{C}$ , and no further weight loss was found at temperatures higher than  $980^\circ\text{C}$ .

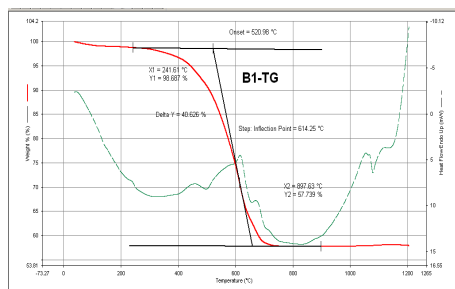


Fig. 1 TG of Precursor of  $\text{BaSrSiO}_4$

According to our experimental results, the silicon dioxide seemed to be stable in comparison with strontium carbonate in the range of  $25^\circ\text{C}$  to  $980^\circ\text{C}$

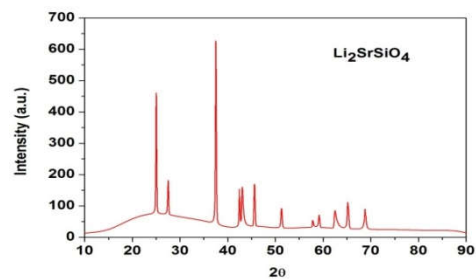


Fig 2 XRD of  $\text{BaSrSiO}_4$  at temperature  $1200^\circ\text{C}$

All diffraction patterns were obtained using  $\text{Cu K}\alpha$  radiation ( $\lambda = 1.54051 \text{ \AA}$ ), at 30 kV and 15 mA. Measurements were made from  $2\theta = 10^\circ$  to  $80^\circ$  with steps of  $0.02^\circ$ . The crystallite size of powders samples were calculated from X-ray peak broadening of the diffraction using Scherer's formula. The calculated average crystallite size of the  $\text{Li}_2\text{SrSiO}_4$  phosphor is 115 nm. The XRD patterns of the powders revealed that the structure of  $\text{Li}_2\text{SrSiO}_4$  is triclinic. All the reflections are indexed on the basis of a hexagonal unit cell of  $\text{Li}_2\text{EuSiO}_4$  (JCPDS No. 47-0120) [13, 22], indicating that the doping of  $\text{Tb}^{3+}$  does not change the crystalline structure of  $\text{Li}_2\text{SrSiO}_4$ . It was reported that  $\text{Li}_2\text{SrSiO}_4$  has a hexagonal crystal structure with the  $\text{P3}_121$  space group, similar to  $\text{Li}_2\text{EuSiO}_4$ . This result also demonstrates that the  $\text{Tb}^{3+}$  ions are in the position of  $\text{Sr}^{2+}$  ions because the size of  $\text{Tb}^{3+}$  ( $r = 0.092 \text{ nm}$ ) is near to  $\text{Sr}^{2+}$  ion ( $r = 0.112 \text{ nm}$ ).

## Photoluminescence studies

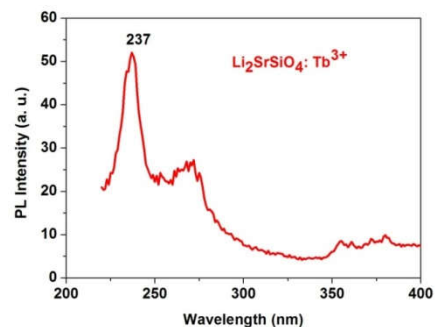


Fig 3 Excitation spectra of  $\text{Li}_2\text{SrSiO}_4$ :  $\text{Tb}^{3+}$

Figure 3 shows the PLE and PL spectrum of  $\text{Li}_2\text{SrSiO}_4$ : 1.0% $\text{Tb}^{3+}$  phosphor. The excitation spectrum consists of two absorption bands. One from 220-255nm with maximum at about 237nm and other from 255-350nm which is due to the spin-allowed  $^4\text{F}_8 \rightarrow ^4\text{F}_7^5\text{d}_1$  transition of  $\text{Tb}^{3+}$  and the 4f-4f transition of  $\text{Tb}^{3+}$  respectively [23]. Upon 238nm excitation, the emission spectrum is composed of blue (381, 414, 420, 436, 468nm) and bluish-green (487nm), green (487, 551, 589 nm). The blue and blue-green emission peaks at 381, 414, 420, 468, 459 and 471nm are originated from  $^5\text{D}_3 \rightarrow ^7\text{F}_j$  ( $J=3-6$ ) transitions and green emission peaks at 493, 551 and 589 nm are assigned to  $^5\text{D}_4 \rightarrow ^7\text{F}_j$  ( $J=3-6$ ) transition of  $\text{Tb}^{3+}$  respectively [19].

The most intense peaks at 383 nm (blue) and 544, 553 nm (green) are due to  $^5\text{D}_3 \rightarrow ^7\text{F}_6$  and  $^5\text{D}_4 \rightarrow ^7\text{F}_5$  transition respectively. The green emission transition was split into two components centered at 544 and 553 nm. The splitting was identified as Stark splitting and the results agree closely with results reported elsewhere [20] indicating that the  $\text{Tb}^{3+}$  emission features observed under VUV excitation are similar to those observed under UV excitation. The excitation and

emission spectra consequences indicate that the  $\text{Li}_2\text{SrSiO}_4:\text{Tb}^{3+}$  may act as a potential blue and green light emitter for UV-LEDs

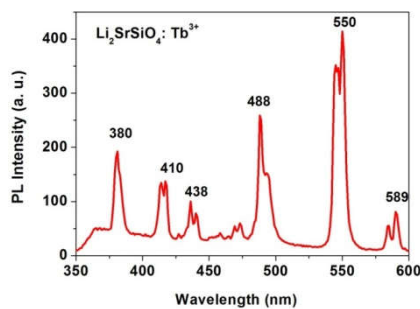


Fig 4 Emission spectra of  $\text{Li}_2\text{SrSiO}_4:\text{Eu}^{3+}$

Figure 4 shows the PL emission spectra of  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  ion. Figure 5 shows the relationship between  $\text{Tb}^{3+}$  concentrations onr relative luminescence intensity of the  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  phosphor and it is the maximum at 1.0 mol%. CIE (The Commission International de l'Eclairage) method is well defined to express the colors in color coordinates. This system recognizes that the human visual system uses three primary colors, red, green and blue. Every natural colors like red, green, and blue can be identified by (x, y) coordinates. The CIE coordinates of the  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  ( $x=0.69, y=0.31$ ) are shown in the Fig.6.

The chromatic coordinates (x, y), was calculated using the color calculator program radiant imaging [27]. The location of the color coordinates of  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  phosphor on CIE chromaticity diagram presented in figure 5 indicates that the color properties of the phosphor prepared by solid state reaction method are approaching those required for field emission displays.

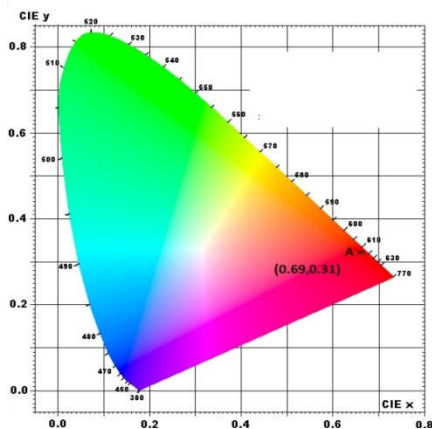


Fig 5 CIE coordinates of  $\text{Li}_2\text{SrSiO}_4: 1.0\%\text{Eu}^{3+}$ .

Table 1 CIE coordinates of  $\text{Li}_2\text{SrSiO}_4: 1.0\%\text{Eu}^{3+}$

Doping concentrations of	CIE Co-ordinates for $\lambda_{\text{Exci}} = 248 \text{ nm}$		Color
	x	y	
$\text{Li}_2\text{SrSiO}_4: 1.0\%\text{Eu}^{3+}$ .	0.69	0.31	red

## CONCLUSIONS

- In the present work, the  $\text{Tb}^{3+}$  doped phosphor  $\text{Li}_2\text{SrSiO}_4$  were synthesized by using solid-state diffusion method.
- The formation of this compound was confirmed by the XRD and SEM technique.

- The result revealed that the  $\text{Li}_2\text{SrSiO}_4: 1.0 \text{ mol } \% \text{Tb}^{3+}$  would be a potential red phosphor.
- Upon the excitation with ultraviolet (UV) irradiation, the phosphors show a strong emission at around 383nm (blue) and 544nm (green) corresponding to the  $^3\text{D}_3 \rightarrow ^7\text{F}_6$  and  $^3\text{D}_4 \rightarrow ^7\text{F}_5$  transitions of  $\text{Tb}^{3+}$ .
- The excitation and emission spectra consequences indicate that the  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  may act as a potential blue and green light emitter for UV-LEDs
- The Obtained CIE coordinates are suitable for lighting device.  $\text{Li}_2\text{SrSiO}_4: 1.0\% \text{Tb}^{3+}$  may act as a potential blue and green light-emitter for UVLEDs

## References

1. M. Aykol, S. Kim, V. I. Hegde, D. Snyderker, Z. Lu, S. Q. Hao, S. Kirklin, D. Morgan, C. Wolverton, *Nat. Commun.* **2016**, 7, 13779.
2. J. Wen, Z. D. Gu, H. Guo, L. X. Ning, C. K. Duan, Y. C. Huang, S. B. Zhan, M. Yin, *Inorg. Chem.* **2018**, 57, 6142.
3. J. Y. Chen, C. F. Guo, Z. Yang, T. Li, J. Zhao, *J. Am. Ceram. Soc.* **2016**, 99, 218.
4. M. P. Saradhi, U. V. Varadaraju, *Chem. Mater.* **2006**, 18, 5267.
5. H. He, R. L. Fu, H. Wang, X. F. Song, Z. W. Pan, X. R. Zhao, X. L. Zhang, Y. G. Cao, *J. Mater. Sci.* **2008**, 23, 3288.
6. T. G. Kim, H. S. Lee, C. C. Lin, T. Kim, R. S. Liu, T. S. Chan, S. J. Im, *Appl. Phys. Lett.* **2010**, 96, 061904.
7. L. H. Liu, R. J. Xie, N. Hirotsaki, Y. Q. Li, T. Takeda, C. N. Zhang, J. G. Li, X. D. Sun, *J. Am. Ceram. Soc.* **2010**, 93, 2018.
8. V. P. Dotsenko, S. M. Levshov, I. V. Berezovskaya, G. B. Stryganyuk, S. Voloshinovskii, N. P. Efrushina, *J. Lumin.* **2011**, 131, 310.
9. M. B. Xie, H. B. Liang, Y. Huang, Y. Tao, *Opt. Express* **2012**, 20, 15891.
10. L. Chen, A. Q. Luo, Y. Zhang, F. Y. Liu, Y. Jiang, Q. S. Xu, X. H. Chen, Q. Z. Hu, S. F. Chen, K. J. Chen, H. C. Kuo, *ACS Comb. Sci.* **2012**, 14, 636.
11. L. L. Zhang, J. H. Zhang, X. Zhang, Z. D. Hao, G. H. Pan, H. J. Wu, *J. Lumin.* **2016**, 180, 158.
12. B. Haferkorn B, G. Meyer, *Z. Anorg. Allg. Chem.* **1998**, 624, 1079.
13. J. Kim, D. Ahn, C. Kulshreshtha, K. S. Sohn, N. Shin, *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.* **2009**, 65, i14.
14. J. M. Zhong, W. R. Zhao, L. C. Lan, J. Q. Wang, J. H. Chen, N. H. Wang, *J. Alloys Compd.* **2014**, 592, 213.
15. C. Jousseume, F. Ribot, A. Kahn-Harari, D. Vivien, F. Villain, *Nucl. Instrum. Methods Phys. Res., Sect. B* **2003**, 200, 425.
16. S. I. Nishimura, S. Hayase, R. Kanno, M. Yashima, N. Nakayama, Yamada, *J. Am. Chem. Soc.* **2008**, 130, 13212.
17. M. Avdeev, Z. Mohamed, C. D. Ling, *J. Solid State Chem.* **2014**, 216, 42.
18. V. V. Politaev, A. A. Petrenko, V. B. Nalbandyan, B. S. Medvedev, E. S. Shvetsova, *J. Solid State Chem.* **2007**, 180, 1045.
19. Y. Hirano, T. Iwata, K. Momma, K. Fukuda, *Powder Diffr.* **2010**, 25, 4.

20. H. F. Yang, A. J. Liang, C. Chen, C. F. Zhang, N. B. M. Schroeter, Y. L. Chen, *Nat. Rev. Mater.* **2018**, *3*, 341.
21. A. Zunger, *Nat. Rev. Chem.* **2018**, *2*, 0121.
22. A. P. Wang, S. Kadam, H. Li, S. Q. Shi, Y. Qi, *NPJ Comput. Mater.* **2018**, *4*, 15.
23. D. W. Kim, H. H. Cho, W. B. Lee, K. T. Cho, Y. G. Cho, S. J. Kim,
24. H. Y. Wang, Y. F. Zhao, X. M. Yuan, K. M. Chen, R. H. Xu, *Phys. Procedia* **2013**, *50*, 124.

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