



## **Sr<sub>2</sub>SnO<sub>4</sub>:Sm<sup>3+</sup> PHOSPHOR FOR SOLID STATE LIGHTING**

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### **ABSTRACT**

**Sr<sub>2</sub>SnO<sub>4</sub> doped with Sm<sup>3+</sup> ion, was prepared by the co-precipitation method. X-ray powder diffraction (XRD) analysis confirmed the formation of Sr<sub>2</sub>SnO<sub>4</sub>:Sm<sup>3+</sup>. Photoluminescence measurements showed that the phosphor exhibited bright orange-red emission at about 610 nm attributed to <sup>4</sup>G<sub>5/2</sub> → <sup>6</sup>H<sub>7/2</sub> transition of Sm<sup>3+</sup> ion under UV excitation. Since, the excitation curve shows good overlap in n-UV region and also excitable at 408 nm the prepared phosphor can be used for solid state lighting application.**

**Keywords: photoluminescence; solid state lighting; co-precipitation Engineering and Technology**

### **INTRODUCTION**

Lamps based on the Hg-discharge provide about 50% of artificial light [1]. But Hg is potentially hazardous causing environmental pollution. This shifted research to a non Hg source of UV. Solid state lighting based on high-brightness LEDs has emerged as a new potentially revolutionary technology that could save up to half of energy used for lighting applications. Compared with the traditional lighting, white LED has several advantages; it has high efficiency, high brightness, long life time, compact, and eco-friendly characters [2–6]. Now these days the white light-emitting diode (LED) has become a necessary part of our daily life. Phosphor, which can be efficiently excited by the photon from visible, near ultraviolet (NUV) and ultraviolet (UV) region, is the critical material of the white LED producing. Considerable work has been done on developing tricolor phosphors under NUV light excitation [7-11]. Rare earth Eu<sup>3+</sup>

and Sm<sup>3+</sup> are two important ions that can emit red or reddish-orange light in a host lattice, resulting from the 4f-4f electron transition emission. In this paper, we report synthesis of Sr<sub>2</sub>SnO<sub>4</sub>:Sm<sup>3+</sup> phosphor for solid state lighting application using simple, fast, economic, one step, co-precipitation method.

### **I. METHODS AND MATERIAL**

Sr<sub>2</sub>SnO<sub>4</sub>:Sm<sup>3+</sup> phosphor was synthesized by co-precipitation method. In this case, initially stoichiometric amount of strontium chloride, stannic chloride and dopant (Samarium chloride) were dissolved in double distilled water separately. Then the solutions were mixed. Ammonium carbonate (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> solution was then added slowly to the mixture. Precipitate thus obtained in carbonate form was separated by filtering, dried and thoroughly crushed to yield fine powder. It was decomposed by heating in air at 1100°C for 3 hour to yield Sr<sub>2</sub>SnO<sub>4</sub>:Eu<sup>3+</sup> phosphor. X-ray diffraction patterns were recorded on Philips PANalytical X'pert Pro diffractometer. Photoluminescence (PL) spectra in the spectral range 220-700 nm were recorded at room temperature on Hitachi F-4000 spectrofluorimeter.

### **II. RESULTS AND DISCUSSION**

Fig. 1 shows the crystal structure of Sr<sub>2</sub>SnO<sub>4</sub>. In alkaline earth stannates, strontium stannate (Sr<sub>2</sub>SnO<sub>4</sub>) has an ordered tetragonal K<sub>2</sub>NiF<sub>4</sub>-type structure with space group *I4/mmm*, lattice parameters of *a*- and *c*-axis are 4.052 and 12.58°A [12,13] respectively. The structure of Sr<sub>2</sub>SnO<sub>4</sub> consists of SnO<sub>6</sub> octahedra, and the Sr<sup>2+</sup> ions are surrounded by five oxygen ions in the arrangement of tetra-pyramid which is linked by bottom side [14]. The Sr<sup>2+</sup> has the

only one chemical environment. From the structure of  $\text{Sr}_2\text{SnO}_4$ , we can observe that the sites of  $\text{Sn}^{4+}$  ions have inverse symmetry while the  $\text{Sr}^{2+}$  ions have the low symmetry [15]. Fig.2 shows the XRD analysis patterns of  $\text{Sr}_2\text{SnO}_4$ . The pattern matches well with ICDD file no. 87-2479.

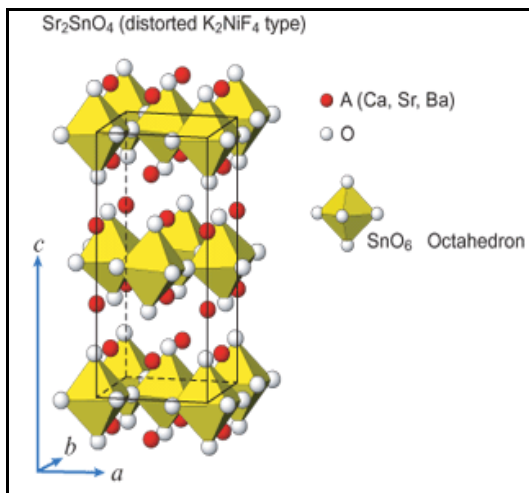


Fig.1 Crystal structure of  $\text{Sr}_2\text{SnO}_4$

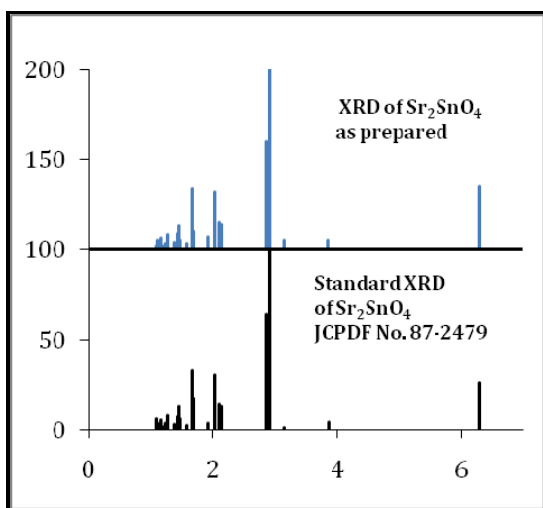


Fig.2 XRD analysis patterns of  $\text{Sr}_2\text{SnO}_4$

Fig.3 shows results of PL measurements on  $\text{Sr}_2\text{SnO}_4$  activated with (1 mol%) Sm. One may expect Sm to enter as divalent ion at  $\text{Sr}^{2+}$  substitutional site. However, no emission that can be attributed to  $\text{Sm}^{2+}$  was observed. Broad emission lines are observed around 567, 575, 610 and 660 nm. The 567, 575 nm lines can be attributed to  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$ , 610 nm peak to  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  and small 660 nm to  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{9/2}$  transitions of  $\text{Sm}^{3+}$ . The  $\Delta J$  values for these transitions are 0, 1 and 2 respectively. Hence the emission line due to  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$  is allowed as a magnetic-dipole

transition and  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  is allowed as a partly magnetic and partly a force dielectric-dipole transition. However, the emission line at 660 nm is allowed only due to electric dipole transition. Therefore, the effect of a crystal field on emission line at 660 nm is larger than that of 567, 575 and 610 nm. Namely the emission intensity at 660 nm is weak when the  $\text{Sm}^{3+}$  ions are in the symmetric site and is strong when  $\text{Sm}^{3+}$  ions are in the asymmetric site. A PL spectrum indicates that 660 nm peak is weaker than other peaks i.e. Most of the  $\text{Sm}^{3+}$  ions are in the symmetric site [16]. The excitation spectrum of  $\text{Sr}_2\text{SnO}_4:(1 \text{ mol}\%) \text{Sm}^{3+}$  monitored at 610 nm consists of a broad band peaking around 262 nm can be assigned to charge transfer band of  $\text{Sm}^{3+}-\text{O}^{2-}$ . The excitation spectra also shows some sharp peaks at 348, 365, 380, 408, 422, 470 nm attributed to ground state  ${}^6\text{H}_{5/2} \rightarrow {}^4\text{K}_{15/2}$ ,  ${}^4\text{D}_{3/2}$ ,  ${}^6\text{P}_{7/2}$ ,  ${}^6\text{P}_{3/2}$ ,  ${}^4\text{G}_{9/2}$ , and  ${}^4\text{I}_{13/2}$  transition of  $\text{Sm}^{3+}$  respectively [17,18]. Since excitation spectrum shows good overlap in n-UV region, it can be used for solid state lighting purpose.

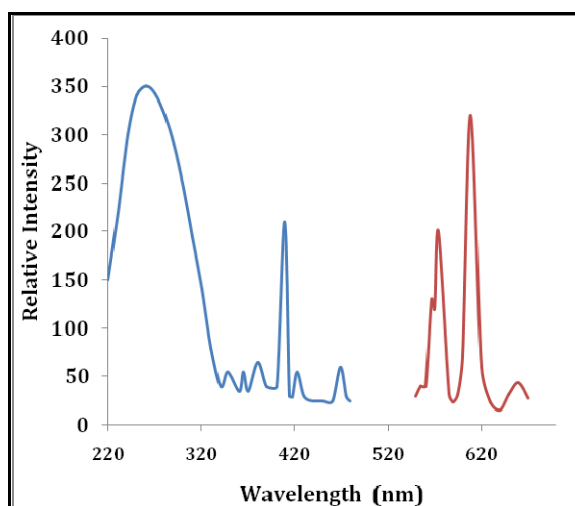


Fig. 3 PL spectra of  $\text{Sr}_2\text{SnO}_4:\text{Sm}^{3+}$

### III. CONCLUSION

We report and discuss  $\text{Sm}^{3+}$ -activated  $\text{Sr}_2\text{SnO}_4$  red phosphor materials prepared by a co-precipitation method. Single-phase  $\text{Sr}_2\text{SnO}_4$  is formed by heating to over  $1100^\circ\text{C}$  for 3 hrs.  $\text{Sr}_2\text{SnO}_4:\text{Sm}^{3+}$  shows bright orange-red luminescence with a dominant emission peak at 610 nm attributed to  ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$  transition of  $\text{Sm}^{3+}$  ion under UV excitation. Since, the excitation curve shows good overlap in n-UV

region and also excitable at 408 nm the prepared phosphor can be used for solid state lighting application.

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#### IV. REFERENCES

- [1] S. Kuck, I. Sokolska, M. Henke, M. Doring, T. Schefer, J. Lumin. 102 (2003) 176.
- [2] E.F. Schubert, J.K. Kim, Science 308 (2005) 1274.
- [3] S. Nakamura, T. Mukai, M. Senoh, Appl. Phys. Lett. 64 (1994) 1687.
- [4] M.P. Saradhi, U.V. Varadaraju, Chem. Mater. 18 (2006) 5267.
- [5] C.X. Li, J. Lin, J. Mater. Chem. 20 (2010) 6831.
- [6] Z. Cui, G. Jia, D. Deng, Y. Hua, S. Zhao, L. Huang, H. Wang, H. Ma, S. Xu, J. Lumin. 132 (2012) 153.
- [7] M. Seibald, T. Rosenthal, O. Oeckle, C. Maak, A. Tücks, P. Schmidt, D. Wiechert, W. Schnick Chem. Mater. 25 (2013) 1852.
- [8] R. J. Yu, S. L. Zhong, N. Xue, H. J. Li, H. L. Ma, Dalton Trans. 43 (2014) 10969.
- [9] H. P. Ji, Z. H. Huang, Z. G. Xia, M. S. Molochev, V. V. Atuchin, M. H. Fang, S. F. Huang, Inorg. Chem. 53 (2014) 5129.
- [10] L. Wang, X. Wang, T. Takeda, N. Hirosaki, Y. Tsai, R. Liu, R. Xie, Chem. Mater. 27 (2015) 8457.
- [11] Y. Q. Li, H. P. Ma, Y. J. Hua, Q. H. Yang, C. X. Li, D. G. Deng, S. Xu, J. Rare Earths 34 (2016) 7.
- [12] Yu-Chung Chen, Yen-Hwei Chang, Bin-Siang Tsai, Journal of Alloys and Compounds 398 (2005) 256–260
- [13] JCPDS 87-2479
- [14] B.J. Kennedy, Aust. J. Chem. 50 (1997) 918
- [15] H.M. Yang, J.X. Shi, M.L. Gong, Journal of Alloys and Compounds 415 (2006) 213–215
- [16] D.R. Taikar, C.P. Joshi, S.V. Moharil, Luminescence 32 (2017) 902–907.
- [17] W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49 (1968) 4424–4442.
- [18] E. Pavitra, G. Seeta Rama Raju, Yeong Hwan Ko and Jae Su Yu, Phys. Chem. Chem. Phys. 14 (2012) 11296–11307