

# Luminescent Properties of Sr<sub>2</sub>CeO<sub>4</sub>: Eu<sup>3+</sup>, Sm<sup>3+</sup> Phosphor and Its Characterizations

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### Abstract

The phosphors  $Sr_2CeO_4$ : 1.0 mol %  $Eu^{3+}$ , 2.0 mol %  $Sm^{3+}$  was successfully prepared by solid state reaction method. The starting materials Strontium Carbonate ( $SrCO_3$ ), Cerium Oxide ( $CeO_2$ ), Samarium Oxide ( $Sm_2O_3$ ), and Europium Oxide ( $Eu_2O_3$ ) was used. The powders were fired at 1200 °C for four hour at the rate of 300 °C/hr. X-ray diffraction (XRD), FTIR, Raman spectra and photoluminescence analysis were used to characterize the phosphors. The co-doping with Eu and Sm ions broadened the excitation band of the  $Sr_2CeO_4$ : Eu, Sm phosphors and enhanced their emission intensity under 300 nm light excitation. The strong emission and controllable light color are suitable for application in advanced lighting and displaying fields.

Keywords: Photoluminescence, solid state reaction method, XRD, Raman spectra Phosphor.

# **1.0 Introduction**

Rare earth doped matrices have many optical properties because of their special electronic transition among 4f energy levels. Powder phosphors doped with Eu<sup>3+</sup> are of particular importance for observing red color images on the monitors of CRD, TV, and other related electronics devices [1]. In recent decades, the luminescent properties of trivalent europium  $(Eu^{3+})$  have attracted much attention because of its potential use as a dopant, since it can emit red fluorescence with high luminescence efficiency under UV light excitation Eu<sup>3+</sup> behaves as an activator center for scintillation and luminescence phenomena. To enhance the emission intensity of europium, many workers have activated it by codoped it with either rare earth or transition metal ions in different matrices. It is known that interesting candidates for red phosphors include materials containing  $Eu^{3+}$  (f<sup>6</sup>), which emits fluorescence via a  ${}^{5}D_{0} \rightarrow {}^{7}F_{2}$  transition at 612 nm when the ion is present in a non-centrosymmetric site [2]. Compound Sr<sub>2</sub>CeO<sub>4</sub> was first discovered by Danielson et al. [3], using a combinatorial material synthesis technique. This phosphor exhibits efficient blue luminescence under the excitation of ultraviolet light, cathode ray or x-ray. It has been suggested that the luminescence of Sr<sub>2</sub>CeO<sub>4</sub> originates from a ligent-to-metal Ce4+

charge transfer (CT) based on its long decay time. The Sr<sub>2</sub>CeO<sub>4</sub>, in structure, is comprised of one dimensional chain of edge-sharing CeO<sub>6</sub> octahedra, in which the terminal Ce-O bonds are about 0.01nm shorter than the equatorial Ce-O bonds [4-9]. The excitation spectrum of Sr<sub>2</sub>CeO<sub>4</sub> shows two peaks around 262 nm and 399 nm and former stronger than the latter. The emission spectra for pure Sr<sub>2</sub>CeO<sub>4</sub> when excitation wavelength is 262 nm the emission peak is at 470 nm shows broad band due to  $f \rightarrow t_{1g}$  transition of Ce<sup>4+</sup> [10].

In the present paper we put forward the synthesis and characterization of  $Sr_2CeO_4$ : 1.0 mol %  $Eu^{3+}$ , 2.0 mol %  $Sm^{3+}$  via solid state reaction method.

# **1.1 Experimental**

Phosphors composed of  $Sr_2CeO_4$ :  $Eu^{3+}$ ,  $Sm^{3+}$  compounds were prepared by the conventional solid state reaction. The activator ions  $Eu^{3+}$  and  $Sm^{3+}$  were added in the form of  $Eu_2O_3$  and  $Sm_2O_3$  respectively. Commercially available high purity reagents (99.99%) of SrCO<sub>3</sub>, CeO<sub>2</sub>,  $Eu_2O_3$ , and  $Sm_2O_3$  were used for preparation of the samples. In this case the total weight of powder was 5gm, and the powders were mixed together using an agate mortar and pestle. The mixed batches were fired a muffle furnace in alumina boat type crucible at 1200 °C (300



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<sup>o</sup>C/min) for 3 hr. in air All of the fired specimens were ground using an agate mortar and pestle, The powder were sieved to classify the powder size for the photoluminescence system measurements

. The crystalline phases of the synthesized samples were characterized by an X-ray diffractometer (XRD, reflection mode with filtered Cu K $\alpha$  radiation,  $\lambda = 1.54051 \text{ A}^0$  Rigaku, D Max` III VC, Japan). The FTIR spectrums were recorded on SHIMADZU, IR Affinity-1 model transmission spectrometer with KBr pellet method over the range 400- 4000 cm<sup>-1</sup>. The emission and excitation spectra (SHIMADZU, RF – 5301 PC) were measured at room temperature using a fluorescence spectrophotometer in the ranges of 400 - 700 nm and 250 – 400 respectively.

#### 1.1.1 Results and discussion

The structure and phase purity of the Sr<sub>2</sub>CeO<sub>4</sub>: 1.0 mol % Eu<sup>3+</sup>, 1.0 mol % Sm<sup>3+</sup> phosphors synthesized by solid state method was investigated by X-Ray Diffraction Method. Results are shown in Fig. 1. All diffraction patterns were obtained using Cu K $\alpha$  radiation ( $\lambda = 1.54051$  A°), at 30 kV and 15 mA. Measurements were made from 20 = 10° to 80° with steps of 0.02°.The crystallite size of powders samples were calculated from X-ray peak broadening of the diffraction using Scherer's equation

# $D = 0.9\lambda \setminus \beta$ . Cos $\theta$

Where, D is the crystallite size in nm,  $\beta$  the full width at half maximum (FWHM) of XRD lines.  $\lambda$  the radiation wavelength of X-ray ( $\lambda = 1.54051 \text{ A}^{\circ}$ ), and  $\theta$  the diffraction peak angle.



Fig. 1 XRD pattern of  $Sr_2CeO_4$ : 1.0 mol %  $Eu^{3+}$ , 2.0 mol %  $Sm^{3+}$ 

When Europium and Samarium doped with  $Sr_2CeO_4$ average crystallite size is 90.72 nm. The computer program POWD (an Interactive Powder Diffraction Data Interpretation and Indexing Program, Version 2.2) was used to calculate hkl and d values and lattice parameters are calculated. The XRD patterns of the powders revealed that the structure of  $Sr_2CeO_4$  is Orthorhombic, which are very close to the reported values JCPDS card No. 50-0115.

The synthesized by solid state reaction method have been subjected to Fourier Transform infrared studies, which are used to study analyze qualitatively the presence of functional group in the powder. The FTIR spectrums of powders were recorded using 011-100 IR affinity-1 made by Shimadzu FTIR Spectrometer by KBr pellet technique. From Fig.2, it is observed that the peak at 3591 cm-1 is assigned to H<sub>2</sub>O. The specimen might have absorbed moisture from the atmosphere. The absorption peaks at 1448.60, 1093.68, 858.35, and 480 cm-1 due to legand formation were assigned to stretching characteristics of SrCO<sub>3</sub>.The FTIR spectra clearly indicate that the functional group of pure Sr<sub>2</sub>CeO<sub>4</sub> and  $Sr_2CeO_4$ : 1.0 mol % Eu<sup>3+</sup>, 1.0 mol % Sm<sup>3+</sup> is not altered by addition of Europium and samarium depends [6].



Fig. 2 FTIR of  $Sr_2CeO_4$ : 1.0 mol %  $Eu^{3+}$ , 1.0 mol %  $Sm^{3+}$ 

The excitation spectrum of  $Sr_2CeO_4$ : 1.0 mol % Eu<sup>3+</sup>, 2.0 mol % Sm<sup>3+</sup> phosphors were monitored under 467 nm wavelength is shown in Fig. 3. It is observed that a broad excitation range from 240 to 400 nm shows peaks around 346 and 397 nm. These two excitation peaks may be related to different Ce<sup>4+</sup>-O<sup>2-</sup> distances in the lattice [2].



Fig.3 Excitation spectra of  $Sr_2CeO_4$ : 1.0 mol %  $Eu^{3+}$ , 2.0 mol %  $Sm^{3+}$ 



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However the effect of 1.0 mol %  $Eu^{3+}$ , 2.0 mol %  $Sm^{3+}$  doping modified the emission of  $Sr_2CeO_4$  phosphor and the intensity was slightly decreased.



Fig.4 Emission spectra of  $Sr_2CeO_4$ : 1.0 mol % Eu<sup>3+</sup>, 2.0 mol % Sm<sup>3+</sup>

Fig. 4 represent the emission spectra of  $Sr_2CeO_4$ : 1.0 mol % Eu<sup>3+</sup>, 2.0 mol % Sm<sup>3+</sup> phosphors for excitation wavelength 300, 346, 375 nm, consist of the characteristics lines of Eu<sup>3+</sup>, Sm<sup>3+</sup> corresponding to transition from the excited  ${}^5D_0$  level:  ${}^5D_2 \rightarrow {}^7F_{1,2,3}$ ,  ${}^5D_1 \rightarrow {}^7F_{1,2}$ , and  ${}^5D_0 \rightarrow {}^7F_{0,1,2}$  located at 467, 491, 511, 537, 557, 568,586, and 616 nm [11]. The blue  ${}^5D_2 \rightarrow {}^7F_1$  and red  ${}^5D_0 \rightarrow {}^7F_2$  intensity was strongest. The emission is the electric dipole transition of  ${}^5D_0 \rightarrow {}^7F_2$ . When Eu<sup>3+</sup>, Sm<sup>3+</sup> concentration is 1.0 mol % and 2.0 mol %, the broad band emission originates from Sr<sub>2</sub>CeO<sub>4</sub> host itself and Eu<sup>3+</sup>, Sm<sup>3+</sup> co-doped sample. The emission lines in the blue, green, and red region coexist.

#### 2.0 CONCLUSION

Sr<sub>2</sub>CeO<sub>4</sub>: 1.0 mol % Eu<sup>3+</sup>, 2.0 mol % Sm<sup>3+</sup> phosphors were successfully prepared by the solid state reaction method in present work. The XRD spectra indicating that the structure is orthorhombic. When trivalent Europium and samarium doped with Sr<sub>2</sub>CeO<sub>4</sub> the crystallite size is 52 nm. The emission is the electric dipole transition of <sup>5</sup>D<sub>0</sub> → <sup>7</sup>F<sub>2</sub>. When

 $Eu^{3+}$ ,  $Sm^{3+}$  concentration is 1.0 mol % and 2.0 mol % respectively, the broad band emission originates from  $Sr_2CeO_4$  host itself and  $Eu^{3+}$ ,  $Sm^{3+}$  codoped sample. The emission lines in the blue, green, and red region coexist. The phosphor can be a good blue emitting phosphor material for lamps and display devices.

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### **References:**

- 1. Xiuzhen Xiao, Bing Yan, J. of Phy. And Chem. Of solids, 69, (2008) 1665-1668.
- 2. W.J. Park et al., Materials Science and Engineering B, 146, (2008) 95-98.
- 3. E. Danielson et al., J. Mol. Struct. 470, (1998), 229.
- 4. Nikifor Rakov et al., J. of Luminescence, 131, (2011), 342-346.
- 5. Pradip Z. Zambare et al., Archives of Physics Research, 2(2), (2011), 74-79.
- R. Sankar and G.V. Subba Rao, J. of The Electrochemical Society, 147(7), (2000), 2773-2779.
- Zhang Chunxiang et al., J. of Rare earth 28(4), (2010), 513-518.
- Zhang Chunxiang, Shi Jianshe, Yang Xujie, Lu Lude and Wang Xin J. of Rare earths, 28 (2010) 513-518.
- 9. Chunxiang Zhang, Wenjun Jiang, et. al. J. of Alloys and Compounds, 474, (2009) 287-291.
- Pradip Z. Zambare et al., Journal of Chemical and Pharmaceutical Research, 4(4) (2012), 1990-1994.
- 11. Ch. Atchyutha Rao, K V R Murthy et al., Der Pharma Chemica, 3(6), (2011), 174-181.