

## Optical Characterization of $\text{Sr}_2\text{CeO}_4: \text{Gd}^{3+}$ Phosphor prepared by Solid state Diffusion Method.

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### Research Article

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#### ABSTRACT

In this paper  $\text{Sr}_2\text{CeO}_4: \text{Gd}^{3+}$  phosphors were synthesized by solid state reaction method and their luminescent characteristics were studied. The samples were characterized by XRD, FTIR, and Photoluminescence. The X-Ray diffraction patterns reveal the crystallite size of powder. The doped compound emits blue light when the concentration of the doped  $\text{Gd}^{3+}$  was 2.0 mol %. A broad excitation band ascribed to the  $\text{Ce}^{4+} - \text{O}^{2-}$  transition was observed and under the excitation at ultraviolet region. The color co-ordinates of  $\text{Sr}_2\text{CeO}_4$  are  $x = 0.17$  and  $y = 0.20$ , it is in blue color region.

#### INTRODUCTION

Rare earth doped phosphors have attracted much attention for their extensive applications such as, color display devices, energy saving fluorescent lamps, solid state lasers etc <sup>[1, 2]</sup>. Doping of trivalent rare earths into the host can help and modify the emission characteristics of any phosphor. Doping forms an integral part of any material to be synthesized or the core area, be it semiconductors used in display or insulators like phosphor for the display industry. Now a day, trivalent rare earths ( $\text{RE}^{3+}$ ) are used widely to prepare luminescent materials (phosphors) that can be excited using any kind of energy as the excitation source. These materials are prepared by incorporating the  $\text{RE}^{3+}$  ions as dopant in different host matrices <sup>[3-9]</sup>. The rare earth doped phosphors is the most exciting field, which is attracting attention of the scientist and researchers all over the world. In this paper we present synthesis of  $\text{Sr}_2\text{CeO}_4: \text{Gd}^{3+}$  phosphor and characterized by different techniques such as XRD, FTIR, and luminescent properties.

#### MATERIALS AND METHOD

$\text{Sr}_2\text{CeO}_4$  blue phosphor was synthesized by the solid state reaction method. Strontium Carbonate  $\text{SrCO}_3$ , Cerium Oxide  $\text{CeO}_2$  and Gadolinium Oxide  $\text{Er}_2\text{O}_3$  of 99.5 % purity were used as starting materials to prepare  $\text{Sr}_2\text{CeO}_4$  phosphor. A Stoichiometric mixture of these powders was thoroughly homogenized in agate mortar for 1hr. and then transferred to alumina crucibles. The homogenized mixture was heated in air at 1200 °C for 4h in a muffle furnace with heating rate of 300 °C/hr. Finally cool down to room temperature by furnace shut off. All samples were prepared by same technique. The samples are prepared by doping Gd in the host material with change of concentrations as 0.1, 0.5, 1.0, 1.5, and 2.0 %.

#### Characterization

Powder X-ray diffraction (XRDs) of compounds was recorded using Rigaku, D Max III VC, Japan. SEM in conjunction with EDS was recorded on Hitachi S-4800. The FTIR spectra of  $\text{Sr}_2\text{CeO}_4$  were recorded on SHIMADZU IRAffinity-1 spectrophotometer with KBr pellet method over the wave number range 400-

$4,000\text{ cm}^{-1}$ . The photoluminescence spectra were recorded at room temperature using Spectrofluorophotometer (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

X-ray powder diffraction (XRD) data of  $\text{Sr}_2\text{CeO}_4: 1.0\% \text{Gd}^{3+}$  phosphor was collected at room temperature on a Regaku Miniflex X-ray diffractometer at National chemical laboratory (NCL), Pune. All diffraction patterns were obtained using  $\text{Cu K}\alpha$  radiation ( $\lambda = 1.54051\text{ \AA}$ ). The current in the X-ray tube was 15 mA; the voltage was 30 kV. The regular resolution in  $2\theta$  scan was  $0.02^\circ$  over a  $2\theta$  range of  $10^\circ$ - $70^\circ$ . Fig. 1 shows XRD pattern of  $0.5\% \text{Gd}^{3+}$  doped  $\text{Sr}_2\text{CeO}_4$ . The crystallite size of samples was calculated from X-ray peak broadening of the diffraction using Scherer's formula. The calculated average crystallite size of particles of the  $\text{Sr}_2\text{CeO}_4: 0.5\% \text{Gd}^{3+}$  phosphor is 28 nm. The structure of  $\text{Sr}_2\text{CeO}_4: 0.5\% \text{Gd}^{3+}$  is orthorhombic. The computer program POWD (an interactive Powder diffraction Data Interpretation and Indexing Program, Version 2.2) was used to calculate hkl and d values were found to be in good agreement with the JCPDS data card No. 50-0115. The CIE coordinates (x, y) of prepared materials was calculated with color calculator version2, software from Radiant Imaging.

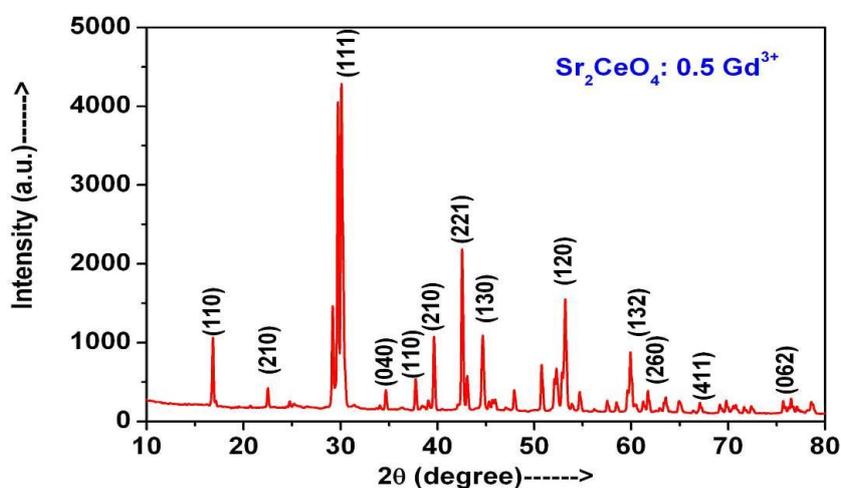


Figure 1: XRD pattern of  $1.0\% \text{Gd}^{3+}$  doped  $\text{Sr}_2\text{CeO}_4$

Morphology of  $\text{Sr}_2\text{CeO}_4: \text{Gd}^{3+}$  phosphor was examined by using Hitachi S4800 SEM instrument at the department of Chemical and Technology, North Maharashtra, Jalgoan. Fig. 2 illustrates FESEM photograph of  $\text{Sr}_2\text{CeO}_4: 1.0\% \text{Gd}^{3+}$  phosphor.



Figure 2: FESEM of  $\text{Sr}_2\text{CeO}_4: 1.0\% \text{Gd}^{3+}$

It shows rectangular shape morphology and some irregular shapes are also seen in the photograph. They are loosely agglomerated.

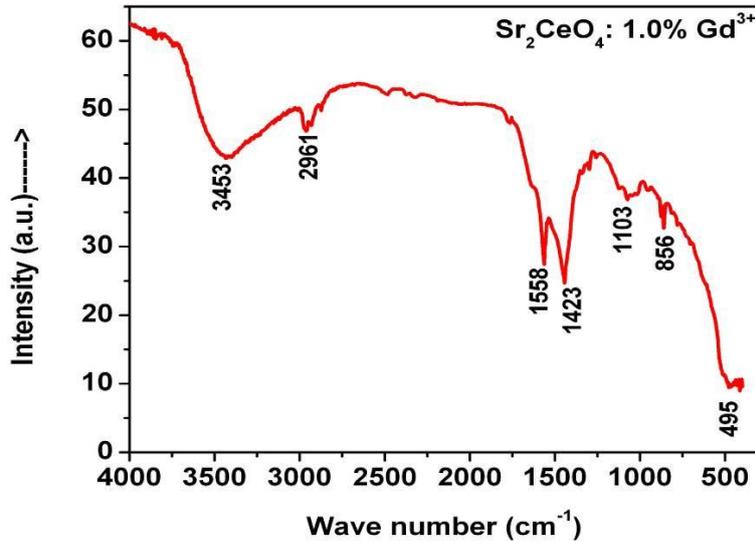


Figure 3: FTIR of Sr<sub>2</sub>CeO<sub>4</sub>: 1.0%Gd<sup>3+</sup>

The FTIR spectra of the Sr<sub>2</sub>CeO<sub>4</sub>: 1.5% Gd<sup>3+</sup> is shown in Fig. 3 the peaks at 3453 cm<sup>-1</sup> are assigned to water molecules that may be present due to absorption of moisture and 2961 cm<sup>-1</sup> is assigned to the hydrogen bonding in water and impurities, usually present in KBr respectively. The absorption peaks at 1558, 1423, 1103, 856 and 495 cm<sup>-1</sup> were assigned to stretching characteristics of SrCO<sub>3</sub> [10].

The excitation spectra of solid state reaction derived Sr<sub>2</sub>CeO<sub>4</sub>: xGd<sup>3+</sup> calcinated at 1200 °C for 4h, as shown in fig. 4 The excitation spectra is broad spectra from 220 to 300 nm and centered located at 254nm. The broad band could be assigned to the legend to-metal charge transfer from O<sup>2-</sup> to Ce<sup>4+</sup>.

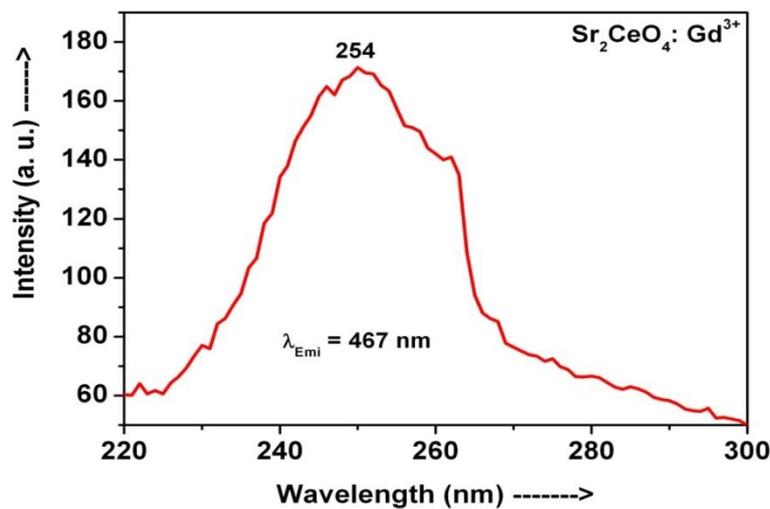


Figure 4: PL excitation spectrum of Sr<sub>2</sub>CeO<sub>4</sub>: Gd<sup>3+</sup>

Fig. 5 is the PL emission spectra of Sr<sub>2</sub>CeO<sub>4</sub>: Gd<sup>3+</sup> (0.1, 0.5, 1.0, 1.5 and 2%) with 254nm Excitation. The doping of Gd<sup>3+</sup> in Sr<sub>2</sub>CeO<sub>4</sub> did not show any change in PL properties of the phosphor except reduction in PL intensity of 467 peak when excited with 254 nm.

This phenomenon continues till the dopant concentration reaches 2% wherein 70% intensity reduced when compared to 0.1mol% Gd<sup>3+</sup> in the host phosphor. However when excited with 254nm the phosphor emitted show broad emission spectrums from 350nm to 600nm peaking at a perfect blue region 467nm. Peak at 365nm is the crystal field of the phosphor normally due to high crystal field the decrease of PL intensity is reported

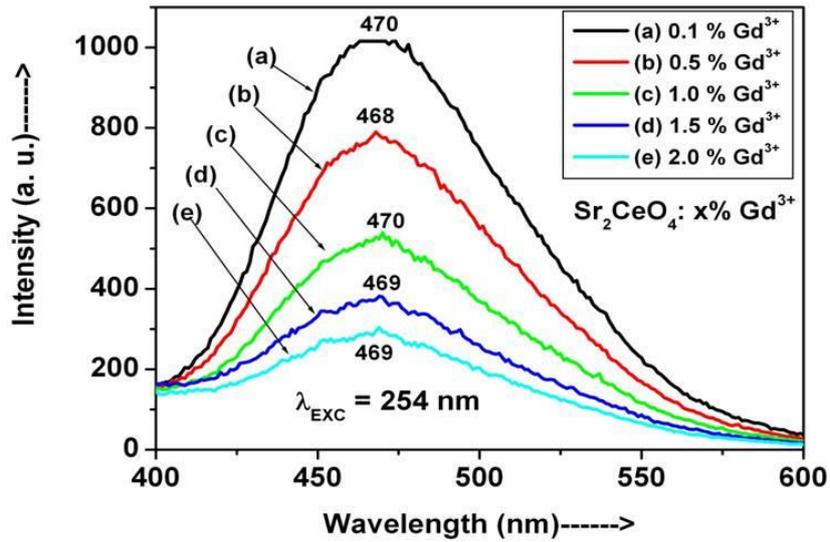


Figure 5: PL emissions spectra of  $\text{Sr}_2\text{CeO}_4: x\% \text{Gd}^{3+}$  at  $\lambda_{\text{Exc}} = 254 \text{ nm}$

Table 1: Intensities of emissions of  $\text{Sr}_2\text{CeO}_4: \text{Gd}^{3+}$  at  $\lambda_{\text{Exc}} = 254 \text{ nm}$

Sample Description	Emission at 254nm Excitation	
	Wavelength (nm)	Intensity (a.u.)
$\text{Sr}_2\text{CeO}_4: 0.1\% \text{Gd}^{3+}$	470	>1016
$\text{Sr}_2\text{CeO}_4: 0.5\% \text{Gd}^{3+}$	468	790
$\text{Sr}_2\text{CeO}_4: 1.0\% \text{Gd}^{3+}$	470	539
$\text{Sr}_2\text{CeO}_4: 1.5\% \text{Gd}^{3+}$	469	381
$\text{Sr}_2\text{CeO}_4: 2.0\% \text{Gd}^{3+}$	469	304

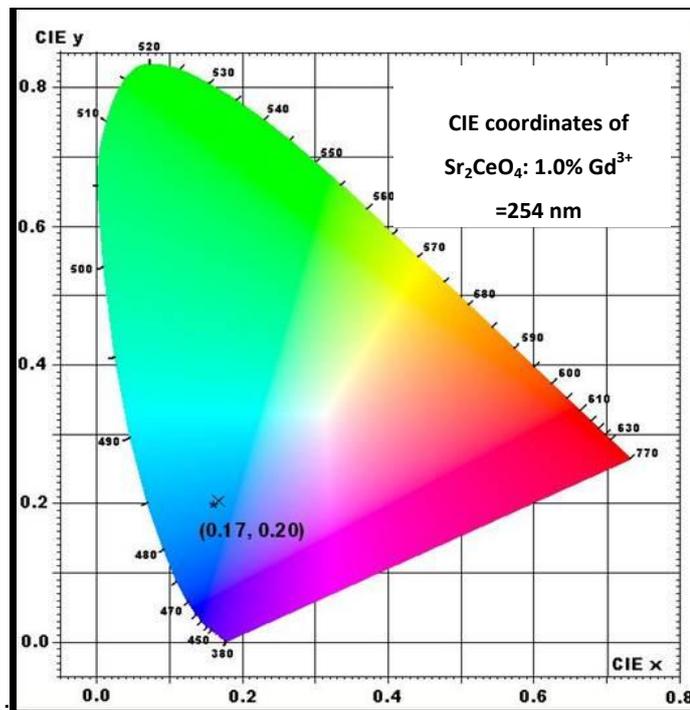


Figure 6: CIE coordinates of  $\text{Sr}_2\text{CeO}_4: x\% \text{Gd}^{3+}$  at  $\lambda_{\text{Exc}} = 254 \text{ nm}$

The chromatic coordinates (x, y), was calculated using the color calculator program radiant imaging [10]. The location of the color coordinates of Sr<sub>2</sub>CeO<sub>4</sub>: 1.0% Gd<sup>3+</sup> phosphor on CIE chromaticity diagram presented in fig. 6. The chromatic coordinates of Sr<sub>2</sub>CeO<sub>4</sub>: 1.0% Gd<sup>3+</sup> phosphor at 254 nm excitation wavelength are x = 0.17 and y = 0.20, it is in blue color region. It is summarized in the table 2

**Table 2: CIE coordinates for Sr<sub>2</sub>CeO<sub>4</sub>: 1.0 % Gd<sup>3+</sup>**

Phosphor	Excitation (nm)	Strong Emission (nm)	(x,y) Coordinate	Color region
Sr <sub>2</sub> CeO <sub>4</sub> : 1.0 % Gd <sup>3+</sup>	254	467	(0.17, 0.20)	Blue

### CONCLUSION

- Sr<sub>2</sub>CeO<sub>4</sub>: xGd<sup>3+</sup> (x = 0.5, 1.0, 2%), was successfully synthesized by solid state reaction method.
- The XRD study confirms that the Gd<sup>3+</sup> doped Sr<sub>2</sub>CeO<sub>4</sub> compound has orthorhombic structure at room temperature. The average crystallite size of the trivalent Samarium doped with Sr<sub>2</sub>CeO<sub>4</sub> the crystallite size is 38 nm.
- FESEM photograph shows rectangular shape morphology and some irregular shapes are also seen. They are loosely agglomerated.
- The same broad PL spectrum of the host material Sr<sub>2</sub>CeO<sub>4</sub> was observed i.e., from 350nm to 625nm. But the intensity decreases with the increase of the concentration of doping Gadolinium. The Gd<sup>3+</sup> atom may occupy the Ce atoms in the Sr<sub>2</sub>CeO<sub>4</sub> compound which decreases the effect of Ce ion as a result the intensity was decreased.
- The chromatic coordinates of Sr<sub>2</sub>CeO<sub>4</sub>: 1.0% Gd<sup>3+</sup> phosphor at 254 nm excitation wavelength are x = 0.17 and y = 0.20, it is in blue color region.

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