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Luminescence Properties of $Sr_2CeO_4:Tb^{3+}$ blue Phosphor

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ABSTRACT

The trivalent terbium doped Sr_2CeO_4 phosphors were successfully synthesized by solid state reaction and their luminescent characteristics were studied. The powders were fired at 1200^0 C for four hour at the rate of 300^0 C/hr. The present paper reports the XRD and spectroscopic study of blue emitting Sr_2CeO_4 phosphor doped with the rare earth element Terbium. The X-Ray diffraction pattern reveals the crystallite size of particle. The average crystallite size of the Sr_2CeO_4 phosphor is 22 nm. And when Tb doped with Sr_2CeO_4 phosphor the crystallite size is 35 nm. The photoluminescence study of these materials reveals the emission in the blue region. The emission color can be changed by tuning activator's concentration in Sr_2CeO_4 phosphors. Photoluminescence of Sr_2CeO_4: Tb was observed when the excitation of the samples was kept at 262nm, the emission peaks are decreases as concentration of terbium increases. The formations of thermoluminescence traps are less which leads to non availability of TL centers.

Keywords: Photoluminescence, Thermoluminescence solid state reaction, XRD, Phosphor.

INTRODUCTION

The popularity of oxide based luminescent materials is due to the facts that they exhibits superior photoluminescence and Cathodoluminescence properties which makes them useful as important components of color emission in field emission display (FED), plasma display panel (PDP) and lamps [1]. It is well known that the phosphors for field emission displays (FEDs) are required to have a high efficiency at low voltages, a high resistance to current saturation, a long service time and equal or better chromaticity than cathode ray tube (CRT) phosphors.[1] For full colour flat panel displays, unfortunately, it is difficult to find a suitable blue phosphor, because wide band gap materials are required, and the eye sensitivity is quite low in the blue spectral region.[2,3]

Recently, Danielson *et al*.[5] have successfully synthesized an unusual luminescent rare earth phosphor, Sr_2CeO_4, through the combinatorial method. The phosphor was found to exhibit an orthorhombic structure with one-dimensional chains of edge-sharing CeO6 octahedral [5]. The broad emission band is suitable for the doping of rare earth ions in pursuing new luminescent materials. The blue phosphors are very few and if a suitable blue phosphor is found then it can be added to the well studied red and green combination for white light emission from the phosphor. If blue phosphor Sr_2CeO_4 doped with trivalent rare earths europium and samarium emit in the red region of the visible spectra [9]. The rare earth materials exhibit excellent sharp- emission luminescence properties with suitable sensitization and effectively used in designing of white light emitting materials. Rare earth ion can be used to design unlimited new luminescent materials because of its special 4f energy level transition. Eu doped Y2O3 [13] and Silicate [14] are the most typical luminescent materials of the rare earth with extensive applications.

MATERIALS AND METHODS

For the synthesis of Sr_2CeO_4 doped Terbium solid state reaction method was used. The starting materials were Strontium Carbonate $SrCO_3$, Cerium Oxide CeO_2, and Terbium Oxide Tb_4O_7 supplied by National Chemicals, Baroda, (Gujarat State) of 99.9 % purity. These materials were taken in Stoichometric proportions of Sr: Ce as 2:1. $SrCO_3$ and CeO_2 with rare earth are weighed in molecular stoichiometry. These all materials were ground in an agate mortar and pestle, grinded thoroughly to get fine powder. This powder was taken in alumina crucible. After closing the cover the crucible was loaded in furnace and heated to the temperature 1200^0 C at the rate of 300^0 C/hr. The samples was kept at the set temperature for four hours then cooled down naturally. All samples were prepared by same technique.

Characterization of marerials

The Phosphor Sr_2CeO_4 doped with Terbium synthesized by solid state reaction method and fired at the temperature 1200^0 C at the rate of 300^0 C/hr. The phase structures of the phosphor powders were studied by using X-ray diffraction with Cu-*Kα* radiation at λ = 1.54051 ˚A using Rigaku, D Max III VC, Japan was taken from NCL Pune. The room-temperature photoluminescence (PL) measurement was performed with a spectrofluorophotometer (SHIMADZU, RF – 5301 PC) using Xenon lamp as excitation source and Thermoluminescence (TL) was studied with pre-irradiated samples at Display research Lab. Department of Applied Physics, Faculty of Engineering and Technology, M. S. University of Baroda.

RESULTS AND DISCUSSION

X- ray diffraction (XRD)

The structure and phase purity of the Sr_2CeO_4 phosphor and Sr_2CeO_4 doped with Terbium the concentration (1.0 %) synthesized by solid state method was investigated by X-Ray Diffraction Method. Results are shown in Fig. 1 and 2 for the pure Sr_2CeO_4 and for Sr_2CeO_4: Tb (1.0%). Diffraction patterns were obtained using Cu Kα radiation (λ = 1.54051 A°), at 30 kV and 15 mA.

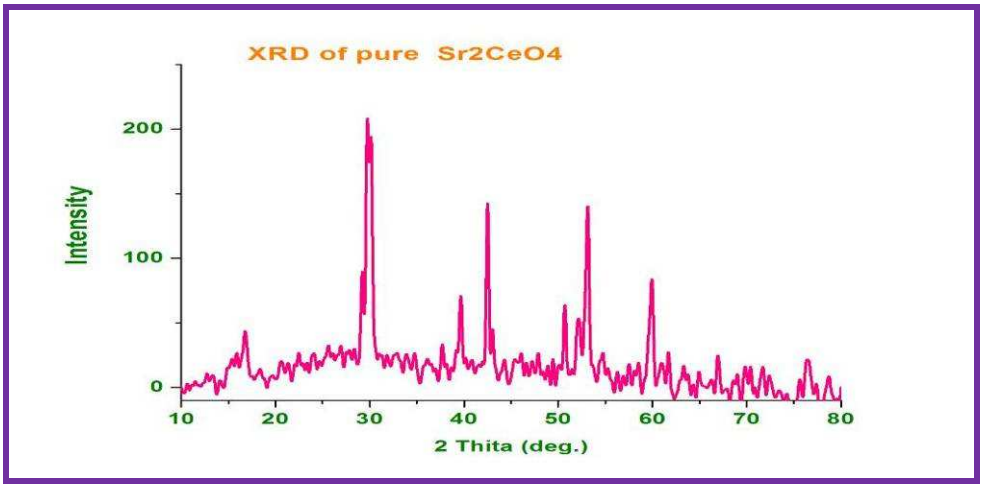

Figure 1 XRD Pattern of Sr_2CeO_4

Measurements were made from 2θ = 10° to 80° with steps of 0.02°. The computer program POWD (an Interactive Powder Diffraction Data Interpretation and Indexing Program, Version 2.2) was used to calculate lattice parameters are a= 4.8000,b=16.6795, c= 7.7510, V = 620.55.Which are found to be in good agreement with the JCPDS values.

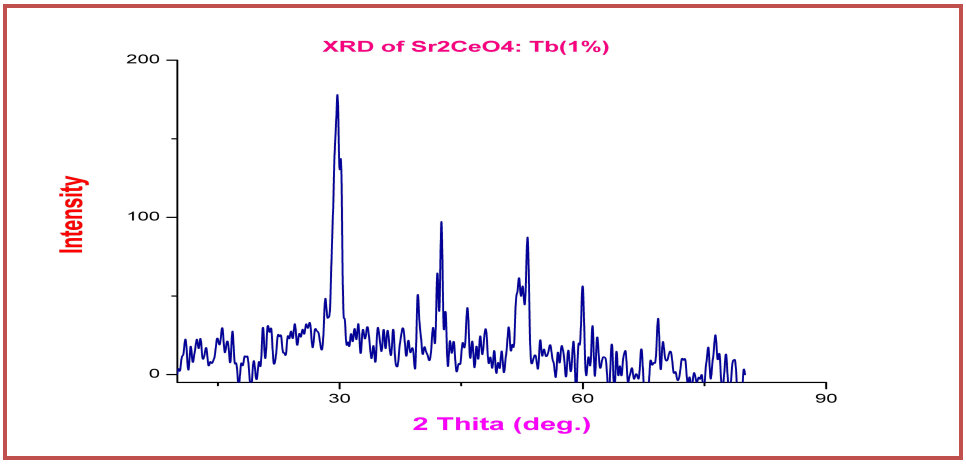

Figure 2 XRD Pattern of Sr_2CeO_4: Tb (1.0%)

The XRD patterns of the powders revealed that the structure of Sr_2CeO_4 is Orthorhombic, when crystallites are less than approximately 100nm in size appreciable broadening in the X-ray diffraction lines occurs [8]. The crystallite size of the particles of powder samples were calculated using Scherrer equation

$d = 0.9\lambda / \beta.\cos\theta,$

Where, β represent full width at half maximum (FWHM) for XRD peak. The average crystallite size of the Sr_2CeO_4 phosphor is 22 nm. And when Tb doped with Sr_2CeO_4 phosphor the crystallite size is 35 nm.

Luminescent properties

The excitation spectra of the Sr_2CeO_4 and Sr_2CeO_4 doped with terbium prepared by solid state reaction method are shown in fig. 3 and 4 respectively. The spectrum displays a broad band with

two strong peaks, one at ~ 262 nm and the other at ~399 nm. The two bands could be assigned to the different Ce^{4+}- O distances in the lattice [3]. The excitation band of the sample could be attributed to the transition $t_{1g} \rightarrow f$, where f is the lowest excited charge transfer state of the Ce^{4+} ion and t_{1g} is the molecular orbital of the surrounding ligand in the six-fold oxygen co-ordination [6].

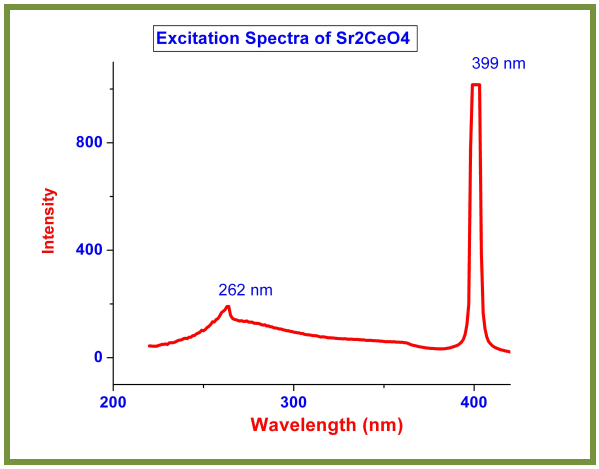

Figure 3 Excitation spectra for Sr_2CeO_4

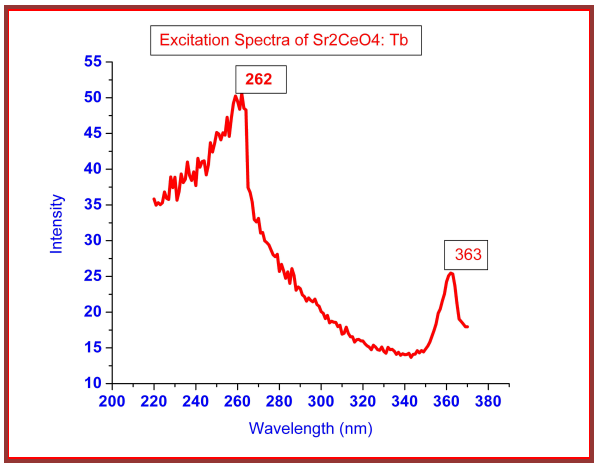

Figure 4 Excitation Spectra of Sr_2CeO_4: Tb

The excitation spectrum of Sr_2CeO_4 doped with terbium shows two peaks around 262 nm and 363 nm and former stronger than the latter.

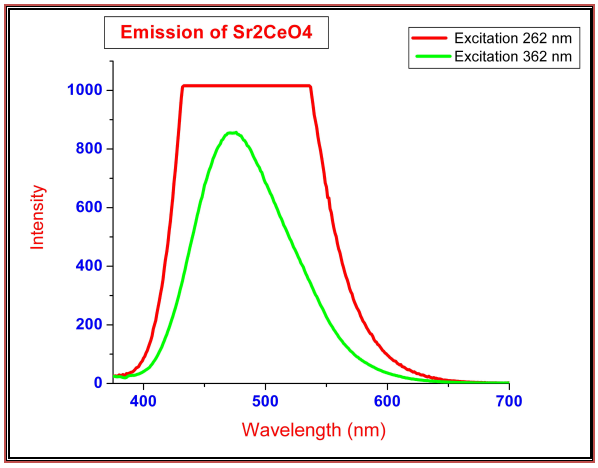

Figure 5 PL Emission Spectra of Sr_2CeO_4

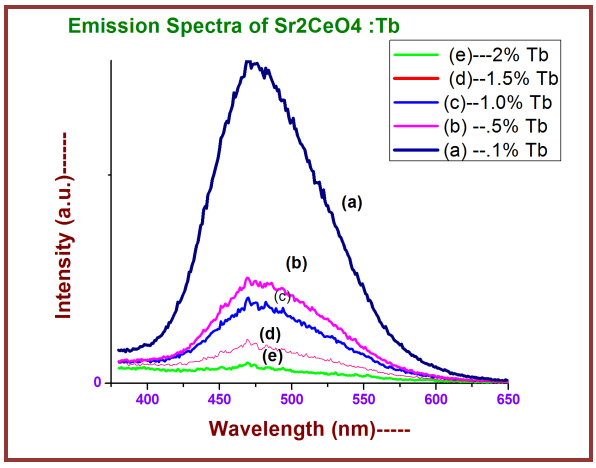

Figure 6 PL emission of Sr_2CeO_4: Tb (1.0 %)

The emission spectrum of Sr_2CeO_4 excited at 262nm and 362 nm is shown in Fig. 5. The spectrum shows broad band in the region 300 - 700 nm with a peak around 470 nm. The emission band can be assigned to the $f \rightarrow t_{1g}$ transitions of Ce^{4+} ions. The emission spectrum of Sr_2CeO_4 observed with 362 nm excitation is similar to that observed with 262 nm. The only difference is the emission intensity for excitation at 262 nm is higher than that for excitation with 362 nm. However the effect of terbium dopent modified the emission of Sr_2CeO_4 phosphor and the intensity was slightly decreased. The emission spectrum of samples with Terbium doping is shown in figure 6. When the excitation of the samples was kept at 262nm, the emission peaks are decreases as concentration of terbium increases.

Thermoluminescence properties

The Thermoluminescence of Sr_2CeO_4 and Sr_2CeO_4: Tb phosphors did not yield any TL, because the phosphors were of the nano form having a crystallite size of 22 nm when Tb doped with Sr_2CeO_4 phosphor the crystallite size is 35 nm. This is known phenomena that nano crystallite does not have any luminescent centers and the crystallite is a stable and perfect one. The formations of Thermoluminescence traps are less which leads to non availability of TL centers.

CONCLUSION

Sr_2CeO_4 and Sr_2CeO_4: Tb powder phosphors were successfully prepared by Solid state reaction method. The dependences of the photoluminescence on doping species, doping concentration are investigated. It is found that Terbium doping with different concentration can effectively change the photoluminescence of the Sr_2CeO_4 powder phosphor. The nano crystallite does not have any luminescent centers and the crystallite is a stable and perfect one. PL emission of pure Sr_2CeO_4 phosphor was observed at 470 nm which is blue emission this conform the formation of nano blue phosphor to good PL. and photoluminescence of Sr_2CeO_4: Tb was observed when the excitation of the samples was kept at 262nm, the emission peaks are decreases as concentration of terbium increases. The formations of thermoluminescence traps are less which leads to non availability of TL centers.

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