ISSN 2321-807X

Synthesis and Characterizations of Strontium Cerium Oxide Phosphor

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ABSTRACT

A new Strontium Cerium Oxide ($Sr_4Ce_2O_7$) blue phosphor with, orthorhombic structure was synthesized via standard solid state reaction method using strontium oxide and cerium oxide as a raw materials. The samples were characterized by Thermo analytical techniques (TG, DTA, and DTG), Fourier transformation infrared (FTIR) spectroscopy, Raman spectroscopy, and Photoluminescence studies at room temperature. In excitation spectra two excitation bands were located at 361 and 391 nm respectively. The emission spectrum was a broad band peaking at 474 nm, which was suitable for the doping of rare earth ions.

Keywords

TG, DTA, FTIR, Raman spectroscopy,$Sr_4Ce_2O_7$, X-ray diffraction .

Academic Discipline And Sub-Disciplines

Physics , Luminescence

SUBJECT CLASSIFICATION

Spectroscopy, Optical properties

TYPE (METHOD/APPROACH)

Solid state reaction method

Council for Innovative Research
Peer Review Research Publishing System
Journal: Journal of Advances in Chemistry

Vol 3, No. 1
editor@cirworld.com
www.cirworld.com, member.cirworld.com

ISSN 2321-807X

1 INTRODUCTION

The development of new compound for ultraviolet- excited phosphor is of great importance for flat panel display and illumination technology. Compared with organic materials and sulfide phosphors, Oxide- based phosphors have the advantages: stable crystalline structure and physical and chemical stability. Therefore oxide based phosphors, especially rare earth (RE) based oxides, are attracting more and more attention [1-5]. For full colour RE- based phosphors, the red and green emissions are generally generated by the f-f transitions of Eu^{3+} and Tb^{3+} while the blue one is caused by the d-f transitions of Eu^{2+} or Ce^{3+}. To date, satisfactory red and green phosphors have been commercially available. However, comparable materials for blue emission are still lacking and they are the target of many research works [6-7]. White light-emitting diode(LED), the so- called next generation solid state lighting (SSL), with the advantages of long lifetime, saving energy consumption, and environmental friendly characteristics are attracting more attentions [8]. In view of application, white LEDs are expected to open up a great number of exciting new application field: white light sources to replace traditional incandescent and fluorescent lamps, backlights for portable electronics, medical, and architecture lighting etc [10]. The broad emission band is suitable for the doping of rare earth ions in pursuing new luminescent materials [11]. In this paper, we report here a new composition of blue strontium cerium oxide ($Sr_4Ce_2O_7$) was synthesized using solid state reaction method in air atmosphere. To the best of my knowledge, there is no literature is available on thermal analysis, Fourier transform infrared (FTIR), Raman spectra and luminescent properties of the synthesized new strontium Cerium Oxide ($Sr_4Ce_2O_7$).

2 MATERIALS AND METHODS

The starting materials were; Strontium Carbonate $SrCO_3$, Cerium Oxide Ce_2O_3, of 99.5 % purity. The starting materials were taken in Stoichiometric proportions of (4:1) were thoroughly homogenized in agate mortar for 45 min and then transferred to alumina crucibles for heat treatment in air in muffle furnace. The compounds were subjected to heat treatment at 1050 – 1200 ^{0}C for 40 -50 hours with three intermediate grindings and heating and finally cooled to room temperature by furnace shut off. All samples were prepared by same technique.

Thermo gravimetric analysis (TG, DTG, and DTA) of $Sr_2Ce_2O_7$ blue phosphor was carried out in air atmosphere in 30–1200^0 C temperature range using a Perkin Elmer Diamond TG/DTA instrument. The initial mass of sample taken for recording the TG/DTA curves was 64.778 mg and hold for 1.0 min at 30^0 C, and then heating rate was maintained at 10^0 C/min. The powder X- ray diffractograms (XRDs) of the compounds were recorded using an automated Rigaku Miniflex X-ray diffractometer (D Max III VC, Japan). The observed (hkl) reflections and their intensities were compared with the calculated ones generated using the computer program POWD (an Interactive Powder Diffraction Data Interpretation and Indexing Program, Version 2.2). The FTIR spectra of $Sr_4Ce_2O_7$ were recorded on SHIMADZU IRAffinity-1 spectrophotometer with KBr pellet method over the wave number range 400–4,000 cm^{-1}. The photoluminescence excitation and emission spectra were recorded at room temperature using Spectrofluorophotometer (SHIMADZU, RF – 5301 PC) equipped with a 150 W Xenon lamp as excitation source

3 RESULT AND DISCUSSIONS

3.1Thermal analysis

Fig.1 shows simultaneous TG, and DTA curves of the precursor prepared by solid state reaction method. Initial mass loss of about 0.417% in TG curve in the range of temperature 116.68 ^{0}C to 265.93 ^{0}C arises due to starting of reaction. The mass loss of about 18.66 % occurs through the broad range 565.43 ^{0}C to 1200 ^{0}C due to the reaction between $SrCO_3$ and Ce_2O_3 accompanied by release of CO_2 it is in good agreement with the calculated value 18.83 %.The step inflection point in this stage occurs at 1061.55 ^{0}C and onset temperature is 965.80 ^{0}C. After this stage TG curve did not show an appreciable mass change in the temperature range of 1080- 1200 ^{0}C, indicate that the precursor is thermally stable in this range.

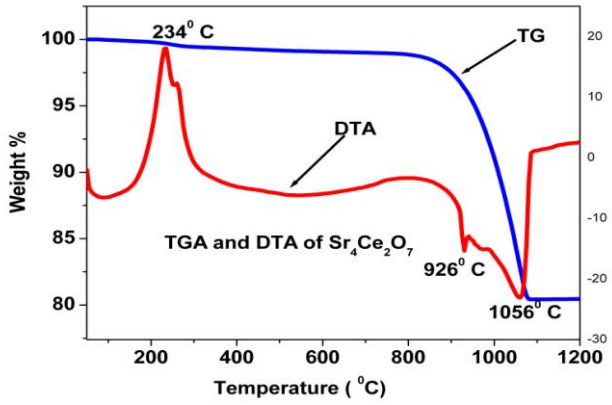


Fig. 1: TG, DTA curve of $Sr_4Ce_2O_7$

ISSN 2321-807X

The endothermic maximum below 100 ^{0}C in DTA curve is due to loss of water absorbed by the samples when handled in air. The exothermic at temperature 233.37 ^{0}C is occurs due to the phase change in starting of reaction between $SrCO_3$ and Ce_2O_3. The endothermic at 926 ^{0}C and 1056 ^{0}C in DTA curve corresponds to the mass loss due to the release of CO_2.

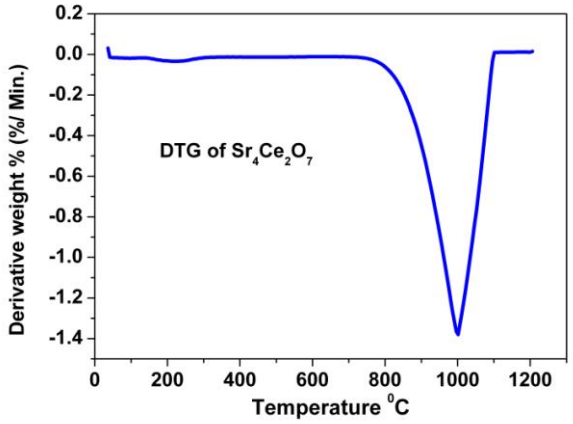


Fig. 2: DTG curve of $Sr_4Ce_2O_7$

The curve DTG shown in Fig. 2 the sharp endothermic peak at 980 ^{0}C is attributed due to the loss of CO_2. This endothermic peak observed in the DTG curve indicates that the starts at 965^0 C and inflection occurs at 1061 ^{0}C. The peak observed in the DTG curve corresponding to the weight loss in the TG curve. Beyond the temperature 1100 ^{0}C, the reaction proceed and finally a stable residue $Sr_4Ce_2O_7$. No further loss is found, suggesting that the $Sr_4Ce_2O_7$ can be prepared at higher than 1100^0 C. Following chemical reaction is expected to occur during the decomposition stage,

$$4SrCO_3 + Ce_2O_3 \rightarrow Sr_4Ce_2O_7 + 4CO_2 \uparrow$$

3.2 X-ray diffraction

Several samples of $Sr_4Ce_2O_7$ have been synthesized by solid state reaction method. Duplicate compositions have also been made to check on the consistency of behavior. We kept the muffle Furness temperature at 1200^0 C for 40 -50 hours then the structure and phase purity of the synthesized $Sr_4Ce_2O_7$ phosphor was investigated by X-Ray Diffraction Method. Results are shown in Fig. 3. All diffraction patterns were obtained using Cu Kα radiation (λ = 1.54051 A°), at 30 kV and 15 mA. Measurements were made from 2θ = 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

$$D = 0.9\lambda / \beta . Cos\theta$$

Where, D is the crystallite size in nm, β represents full width at half maximum (FWHM) of XRD lines, λ is the radiation wavelength of X-ray (λ = 1.54051 A°), and θ is diffraction peak angle.

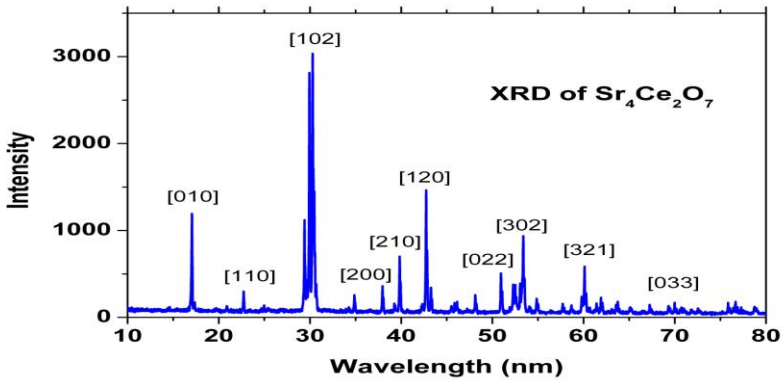


Fig. 3: XRD pattern of $Sr_4Ce_2O_7$.

The calculated average crystallite size of the $Sr_4Ce_2O_7$ phosphor is 49 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 which are reported in table 1.The XRD patterns of the powders revealed that the structure of $Sr_4Ce_2O_7$ is orthorhombic having lattice parameters a= 5.9431 A°, b= 5.1929 A°, c=7.0644 A° and cell volume V=218.02 (A°) ^{3}. JCPDS data card of $Sr_4Ce_2O_7$ material is not available.

ISSN 2321-807X

3.3 FT-IR Spectrometry

The synthesized $Sr_4Ce_2O_7$ by solid state reaction method have been subjected to Fourier transform infrared studies, which are used to analyze qualitatively the presence of functional group in the powder. The FTIR spectrums of powders were recorded using IR affinity-1 made by Shimadzu FTIR Spectrometer by KBr pellet technique. The FTIR spectrum of the $Sr_4Ce_2O_7$ is shown in Fig. 4. The peaks at 3700 cm^{-1} are assigned to water molecules that may be present due to absorption of moisture. 3450 and 1110 cm^{-1} is assigned to the hydrogen bonding in water and impurities, usually present in KBr respectively. The absorption peaks at 1770, 1450, 1022, 856, 705 and 699 cm^{-1} were assigned to stretching characteristics of $SrCO_3$ [4]. The absorption peak between 600-300 cm^{-1} is assigned to the metal oxide frequency band.

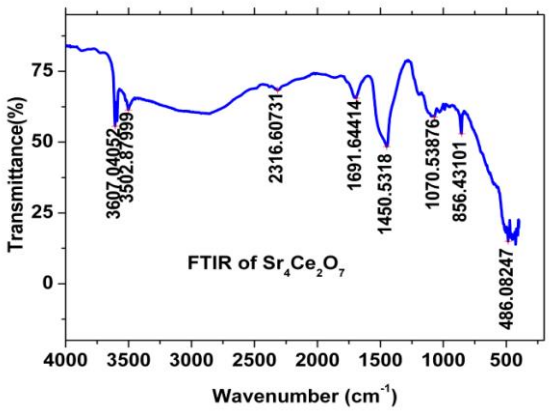


Fig. 4: FTIR spectrum of $Sr_4Ce_2O_7$.

3.4 Raman spectrometry

Raman spectra are used as a complement of FTIR spectra for studying phase and structure of $Sr_4Ce_2O_7$. The Raman shift at 704 cm^{-1} is assigned to symmetric stretching mode of $SrCO_3$ which coincide well with the IR features. The shift at 553 cm^{-1} is attributed to antisymmetric bending vibration. Two strong Raman shift at 286 and 387 cm^{-1} are detected, which can be attributed to the stretching modes of the Ce-O_2 and Ce-O_1 of CeO_6 octahedra in $Sr_4Ce_2O_7$ respectively. So the contribution of Ce-O_2 bonds increases corresponding with Ce-O_1 bonds to induce the charge transfer [4], which related to the luminescence of this material.

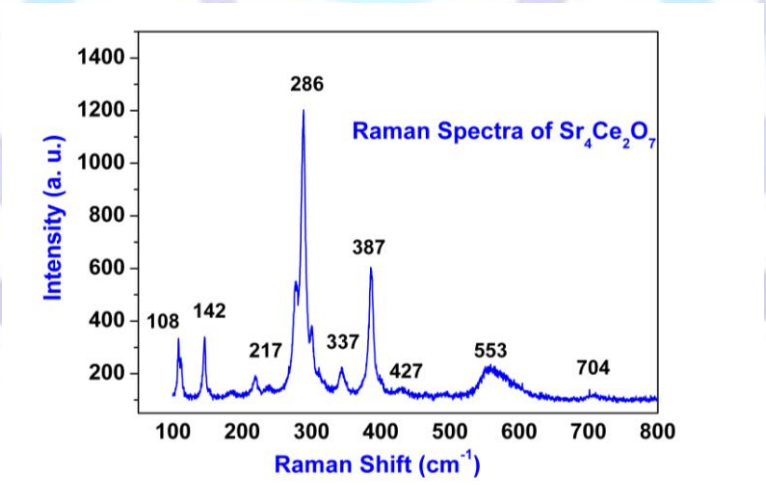
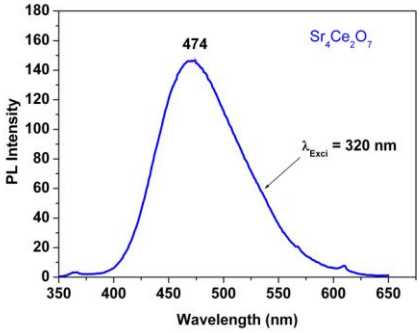


Fig. 5: Raman spectrum of $Sr_4Ce_2O_7$.

3.5 Luminescent properties

Fig. 5 shows the excitation spectra of $Sr_4Ce_2O_7$ blue phosphor. The excitation spectra consist of two bands observed at low and high wavelength; respectively. The luminescence of $Sr_4Ce_2O_7$ is thought to originate from a legend-to-metal charge transfer. The emission spectrum excited by 320 nm as shown in fig. 6. The spectrum shows broad band in the region 300 - 700 nm with a peak around 474 nm. The emission band can be assigned to transitions of Ce^{3+} ions.



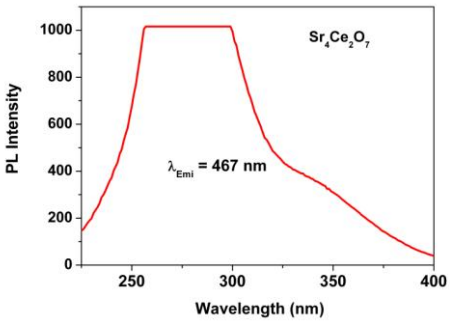


Fig.6: Excitation spectrum of $Sr_4Ce_2O_7$ **Fig. 7: Emission spectrum of $Sr_4Ce_2O_7$**

4 CONCLUSIONS

- A new Strontium Cerium Oxide $Sr_4Ce_2O_7$ was successfully synthesized by solid state reaction method.
- The XRD patterns of the powders revealed that the structure of $Sr_4Ce_2O_7$ is Orthorhombic,
- The emission spectra of $Sr_4Ce_2O_7$ phosphor was observed under excitation 320 nm, phosphor shows broad emission from 350 – 650 peaking at 474nm.
- The as synthesized $Sr_4Ce_2O_7$ phosphor with strong blue- white emitting could be a good candidate for advanced display devices.

ACKNOWLEDGMENTS

The author expresses their sincere thanks to Dr. K. V. R. Murthy, M. S. University Baroda. We are also thankful to Dr. N. O. Girase, the Principal, and Dr. K.D. Girase Vice principal, S. V. S's Dadasaheb Rawal College, Dondaicha for continuous encouragement.

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ISSN 2321-807X

Author' biography with Photo

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