



Synthesis, characterization and affect of excitation wavelength on emission intensity of Sm^{3+} doped Sr_2CeO_4 phosphor

Ch. Vijay Anil Dai #, T. Niranjana Kumar*, K. Suresh@ and KVR Murthy[§]

Department of Physics, AG & SGS College of Arts and Sciences, Vuyyuru-521 165, A.P, India

* Department of Physics, AMAL College, Anakapalle-531 001, A.P, India

@ Department of Physics, The Bapatla College of Arts and Sciences, Bapatla-522 101, A.P, India

[§] Display Materials Laboratory, Applied Physics Department, Faculty of Technology and Engineering, M. S. University of Baroda, Vadodara-390 001, India

Corresponding author email: sureshkukkamalla@gmail.com

Abstract - The photoluminescence (PL) spectra of Sr_2CeO_4 phosphor doped with Sm^{3+} ions of concentration (0.5 mol%) is reported. The powder phosphor has been synthesized using a conventional solid state reaction method. The phosphor was characterized by means of X-ray diffraction, scanning electron microscopy and FT-IR. The photoluminescence emission peaks of $\text{Sr}_2\text{CeO}_4:\text{Sm}^{3+}$ phosphor was observed around 467, 567 and 610nm. The broad emission band peak at 467nm is due to $f \rightarrow t_{1g}$ transition of Ce^{4+} . The emission peaks at 567nm and 610nm are due to the transitions of Sm^{3+} ion. The photoluminescence emission spectra were recorded under the excitation wavelengths at 254, 260, 280 and 340nm respectively in order to study the effect of excitation wavelength on emission intensity. The CIE colour co-ordinates show that the emission colour of the phosphor is blue.

Keywords: Synthesis, X-ray diffraction, Scanning Electron Microscopy, Luminescence, Photoluminescence

1. INTRODUCTION

The search for blue phosphor emitters has been increasing due to their applicability in many fields, such as cathode ray tubes (CRTs), projection televisions (PTVs), fluorescent tubes, X-ray detectors and field emission displays (FED)¹. Even in the paper industry, fluorescent dyes that absorb UV and emit in blue color are widely used as organic optical brightening agents (OBA) and new inorganic ones have been under investigation². Concerning many of these applications, the availability of systems consisting of uniform particles in size and shape³ is also an essential prerequisite for improved performance, and new synthetic routes are being developed in order to reach these systems.

Recently, a new promising blue phosphor, Sr_2CeO_4 was developed by combinatorial synthesis⁴ and prepared by different routes also. This material has been found to exhibit luminescence under excitation with cathode and X-rays⁵. In addition it has also been established that Sr_2CeO_4 exhibits photoluminescence under excitation with irradiation of ultraviolet rays^{6,7}. Therefore, it has been attracted that Sr_2CeO_4 has good potential for application as a blue phosphor in lamps and in field emission displays. The luminescence associated with Eu^{3+} contained in different host lattices has

found applications related to its red light emission which is important in the fields of displays, sensors and lasers. The past few decades have seen a lot of work reported on the use of divalent/trivalent europium as a dopant in phosphors as they have very good optical properties (in the blue to red regions) which make them part of many display devices. Among all the rare-earth ions, Eu^{3+} is the most extensively studied, owing to the simplicity of its spectra and also its use in commercial red phosphors. The luminescence spectrum of Eu^{3+} reveals spectroscopic transitions from the visible to the near-infrared region.

In view of the above, Samarium doped Sr_2CeO_4 phosphor is less studied. So instead of Eu^{3+} we used Sm^{3+} (0.5 mol%) rare earth ion in the Sr_2CeO_4 host phosphor sample was prepared by the solid state reaction method. Especially our aim is to find out the effect of excitation wavelength on the emission intensity of the phosphor. Phase identification, morphology, FT-IR, CIE and Photoluminescence spectra of phosphor sample was carried out and presented in this paper.

2. EXPERIMENTAL

$\text{Sr}_2\text{CeO}_4:\text{Sm}^{3+}$ phosphor sample was prepared by the conventional solid state reaction method. Strontium carbonate (SrCO_3) and Cerium oxide (CeO_2) high purity chemicals were used as

stating materials for preparation of host and added them in stoichiometric proportions of Sr:Ce as 2:1. The Samarium oxide is doped in the host material at 0.5 mol% as an activator ion. The compounds were weighed, mixed and was grounded into a fine powder and fired at 1300°C for 3 hours in a muffle furnace. The obtained powder was characterized by means of scanning electron microscopy (SEM, JEOL JSM-6700F) and powder X-ray diffraction (XRD, Rigaku-D/max 2500 and Cu $K\alpha$ radiation).The photoluminescence spectra were recorded at room temperature using Spectrofluorophotometer (SHIMADZU, RF-5301 PC) using Xenon lamp as an excitation source. The CIE analysis was done using Radiant Imaging software 2.0 version.

3. RESULTS AND DISCUSSION

3.1 XRD study

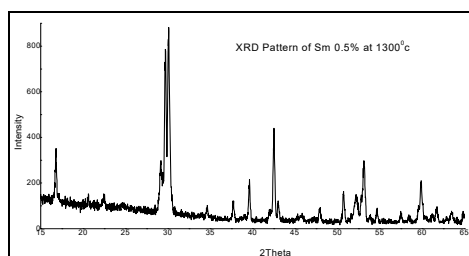


Figure 1 XRD pattern of Sm (0.5 mol%) doped Sr_2CeO_4 phosphor heated at 1300°C

In order to determine the crystal structure and phase purity of the phosphor, X-ray diffraction (XRD) analysis was carried out. Fig.1 shows the XRD pattern of $Sr_2CeO_4:Sm^{3+}$ (0.5%) heated at 1300°C. This reveals that the structure of Sr_2CeO_4 is triclinic, which agrees with the findings of previous research works of Jiang et al⁵ and Serra et al⁸. However, the data reported by Danielson et al⁴, Sankar et al⁹ and Shu-Jian Chen et al¹⁰ indicate an orthorhombic structure. The XRD pattern of $Sr_2CeO_4: Sm$ (0.5%) shows the formation of a single-phase compound.

3.2 SEM study

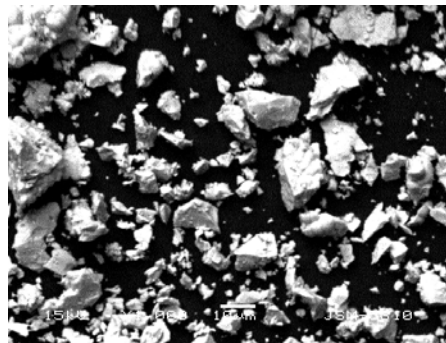


Figure 2 SEM image of Sm (0.5 mol%) doped Sr_2CeO_4 phosphor heated at 1300°C

Fig.2 shows the SEM image of Sm (0.5 mol%) doped Sr_2CeO_4 phosphor particles obtained by the standard solid state reaction at 1300°C. From the image it is observed that the shape of the particles is irregular and the particles are highly agglomerated and the mean size of the particles was 2-3 μ m.

3.3 Photoluminescence Excitation and Emission study

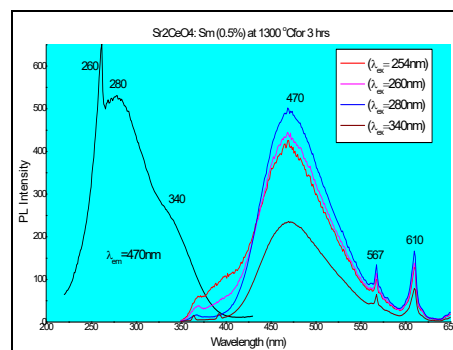


Figure 3 The Excitation and Emission spectra of and $Sr_2CeO_4: Sm^{3+}$ (0.5%) phosphor

The excitation and emission spectra of $Sr_2CeO_4: Sm^{3+}$ (0.5%) phosphor is shown in fig.3. The excitation spectrum shows an excitation peaks at 260, 280 and 340 nm for the emission at 467 nm monitored at 470nm wavelength. The emission spectrum shows a broad band due to $f \rightarrow t_{1g}$ transitions of Ce^{4+} . This is mainly due to the charge transfer position of the $Ce^{4+}-O^{2-}$ ligand as described by Danielson et al⁴. The two excitation peaks may be assigned to the two kinds of Ce^{4+} ions present Sr_2CeO_4 . There are two different $Ce^{4+}-O^{2-}$ bond lengths in the lattice and hence two different charge transfer transitions. The hump around 340nm evident in the excitation curve may be attributed to the above mechanism.

Fig.3 shows the emission spectrum of $Sr_2CeO_4: Sm^{3+}$ when excited at 254, 260, 280 and 340nm recorded at room temperature. The emission

spectrum for Sm^{3+} (0.5%) doped phosphor shows peaks at 470, 567 and 610nm. the broad emission with peak at 470nm in the range from 400-550nm is due to the $f \rightarrow t_{1g}$ transitions of Ce^{4+} . The peaks depicted in the spectra at 567nm and 610nm are from the transitions (${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{5/2}$ and ${}^4\text{G}_{5/2} \rightarrow {}^6\text{H}_{7/2}$) of the characteristic emission of Sm rare earth ion. From the emission spectra it is observed that the excitation wavelength increases from 254nm – 280nm the emission intensity is increased and its intensity is decreased when the excitation wavelength is 340nm. The phosphor shows high intensity under 280nm excitation wavelength. The results are in good agreement with the results of other workers¹³⁻²¹.

3.4 FT-IR study

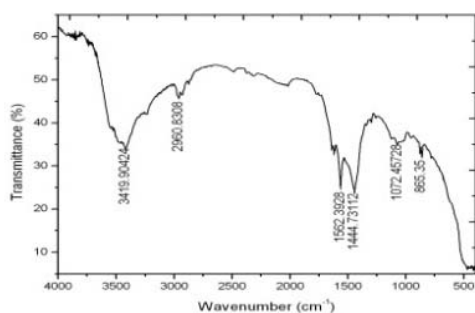


Figure 4 FT-IR spectrum of $\text{Sr}_2\text{CeO}_4: \text{Sm}^{3+}$ (0.5%) phosphor

Fig.4 shows the FTIR graphs of $\text{Sr}_2\text{CeO}_4: \text{Sm}^{3+}$ (0.5%) phosphor. From the figure the observed bands are at 3420, 2961, 1562, 1445, 1072, 865, 465 cm^{-1} . From FTIR it is observed that most of the bonds are due to Sr-O, Ce-O and Sm-O stretching and the O-H stretching band is observed at 3420cm^{-1} . The band around 3420cm^{-1} is due to the H-OH stretching of absorbed water molecule from the atmosphere

3.5 CIE study

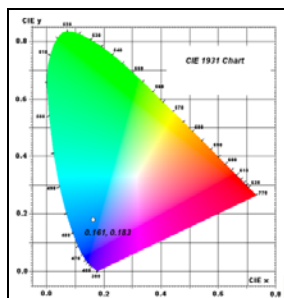


Fig.5 shows the CIE diagram of $\text{Sr}_2\text{CeO}_4: \text{Sm}^{3+}$ (0.5%) phosphor shows the CIE colour co-

ordinates of the (0.5 %) doped phosphor under 280nm excitation wavelength. The colour coordinates of the phosphor are $x=0.161$, $y=0.183$. From the figure the phosphor emitting cyan colour and are useful in producing white light in the field of lamps and display devices. The correlated colour temperature (CCT) of the phosphor is undefined.

CONCLUSIONS

PL studies of $\text{Sr}_2\text{CeO}_4: \text{Sm}^{3+}$ phosphor prepared by solid state reaction method are presented in this article. XRD pattern reveals that the structure is triclinic, which agrees with the findings of previous research works of Jiang et al⁸ and Serra et al. The XRD pattern shows the formation of a single-phase compound. SEM image shows particles obtained by solid state reaction at 1300°C are agglomerated and the mean size of the particles was 2-3 μm . The emission spectrum shows a broad band due to $f \rightarrow t_{1g}$ transitions of Ce^{4+} . The two excitation peaks may be assigned to the two kinds of Ce^{4+} ions present in Sr_2CeO_4 . The Sr_2CeO_4 phosphor doped with Sm^{3+} (0.5%) shows highest PL intensity when excited with 280nm. The red emission is lower than the blue emission may be due to the charge is not transferred from host to activator ion may be the ion concentration, synthesis and heating temperature defects. However this phosphor can be useful in lamps and display applications.

REFERENCES

1. T.Jüstel, H.Nikol, C.Ronda, *Angew. Chem., Int. Ed.* **1998**, 37, 3084
2. W.M.Li, T.Hanninen, M.Leskela, J.Saari, A.Hase, *J. Alloys Compd.* 2001, 323, 236.
3. B.S.Jeon, G.Y.Hong, Y.K.Yoo, J.S.Yoo, *J. Electrochem. Soc.* 2001,148, H128
4. E.Danielson, M.Denenney, D.M.Giaquinta, J.H.Golden, R.C.Haushalter, E.W.McFarland, D.M.Poojary, C.M.Reaves, H.W.Weinberg, X.D.Wu, *Science* 1998, 279, 837.
5. Y.D.Jiang, F.Zhang, C.J.Summers, *Appl. Phys. Lett.* 1999, 74, 1677
6. L.Van Pieteron, S.Soverna, A.Meijerink, *J. Electrochem. Soc.*, 2000, 147, 4688
7. C.H.Park, C.H.Kim, C.H.Pyun, J.H.Choy, *J. Lumin.* 2000, 87-89, 1062
8. O.Serra, V.P.ASeverino, P.S.Calefi and S.A.Cicillini, *J. Alloys Compounds* 323-324 (2001) p.667.
9. R.Sankar and G.V.Subba Rao, *J. Electrochem. Soc.* 147 (2000) p.2773
10. S.J.Chen, X.T.Chen, Z.Yu, J.M.Hong, Z.Xue and X.Z.You, *Solid State Commun.* 130 (2004) p.281
11. S.Shionoya and W.Yen, *Phosphor Handbook*, CRC Press, Boca Raton, FL, 1999



12. G. H. Dieke, Spectra and energy levels of rare earth ions in crystals, Wiley, Newyork, 1968.
13. Rahul Ghildiyal, Pallavi Page and K V R Murthy, J of Luminescence, Vol.124, Issue 2, 2007, P 217-220.
14. Pallavi Page, R Ghildiyal and K V R Murthy, Materials Research Bulletin, 43 (2), (2008) p 353-360.
15. Pallavi Page, R Ghildiyal K V R Murthy, MRB, Vol.41, 10, (2006), 1854-1860.
16. Pallavi Page, K V R Murthy, Philosophical Magazine Letters, Vol.90, No.9, Sept2010, 653–662.
17. K.Suresh, K.V.R.Murthy, Ch.A.Rao, N.V.P.Rao, B.SubbaRao, J of Luminescence, 133 (2013) 96-101.
18. K.Suresh, K.V.R.Murthy, Ch. A.Rao, N.V.P.Rao, ISRN Cond. Matt. Physics, (2011) article ID 392917, 1(2)
19. K.V.R. Murthy et. al., Journal of Luminescence, Vol.124, Issue 2, (2007), 217-220.
20. K.V.R.Murthy et al., J of Radiation Measurements, Vol36 (1-6), (2003) 483-485.
21. R.Seema, K.NandaKumar, published by Applied Science Innovations Private Ltd, India