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Photoluminescence studies of $Sr_2Al_2CeO_7$ doped with Eu

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Abstract

The present paper reports synthesis and characteristics of Eu^{3+} (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 mol%) doped red-emitting phosphors of $Sr_2Al_2CeO_7$. The phosphor materials were prepared using standard solid state reaction technique without and with citric acid as flux. The formation of single phase compound was verified through X-ray diffraction (XRD) studies. The photoluminescence excitation and emission spectra were investigated. The phosphor can be efficiently excited by 254nm to realize an intense and very narrow red luminescence lines (595 nm) corresponding to the magnetic dipole transition $^5D_0 \rightarrow {}^7F_2$ of Eu^{3+} ions. The potential application is in the display and lamps for white light generation. Micrograph shows the morphology of the phosphor with irregular particles and the average size of 5 mm.

Keywords: Photoluminescence [PL], Rare Earth ions [RE ions], XRD, Solid State Reaction [SSR].

1.0 Introduction

The luminescence associated with Eu 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 1998, Danielson and co-workers reported unusual luminescence of the inorganic oxide compound Sr_2CeO_4 using combinatorial technique which exhibits the emission peak at 485 nm. Subsequently, several studies of this luminescent material were conducted, and some different routes have been developed to prepare the Sr_2CeO_4 powders and films, including traditional solid-state reaction. This phosphor exhibits blue-white luminescence efficiently under excitation with UV light. Sr_2CeO_4 also acts as a sensitizer to transfer the absorbed energy to the dopants (activators) such as rare earth ions. Since Sr_2CeO_4 was found as a novel and promising blue luminescent material by combinatorial chemistry method. Even thou we report the results of our investigations on Strontium Cerate by adding Aluminum oxide in the host and Eu ion as dopant in different concentrations as $Sr_2Al_2CeO_7$:Eu phosphors synthesized via solid state reaction.

2.0 Experimental

The inorganic compounds like Strontium Carbonate ($SrCO_3$), Cerium Oxide (CeO_2) and Aluminum oxide (Al_2O_3) of purity (99.9%) were used as starting materials and Eu_2O_3 as dopant in different mol%. We prepared $Sr_2Al_2CeO_7$:Eu phosphors by weighing, adding and ground into a fine powder using agate mortar and pestle about an hour. The grounded sample was placed in an alumina crucible and heated at 1200°C for 3 hours in a muffle furnace with a heating rate of 5°C/min. we ground in to powder after heating and cooling and did the following different characterizations on the prepared samples.

The Photoluminescence (PL) emission and excitation spectra were measured by Spectrofluorophotometer (SHIMADZU, RF-5301 PC) using Xenon lamp as excitation source. The XRD analysis was carried out with a powder diffractometer (Rigaku-D/max 2500)

using Cu Kα radiation. The microstructure of the sample was studied using a scanning electron microscopy (XL 30 CP Philips).

3.0 Results and Discussions

3.1 XRD Study

X-ray diffractogram of the $Sr_2Al_2CeO_7$:Eu (2mol%) sample prepared using solid state method is shown in figure 1. From XRD it is found that the majority phase is $Sr_2Al_2CeO_7$. However, sample has some reflection peaks that can be assigned to the presence of $SrCeO_3$ and $SrCO_3$ as un reacted compounds. This may indicate that heating temperature and time, in the solid-state reaction (1200ºC, 3h) was not enough to obtain the single phase.

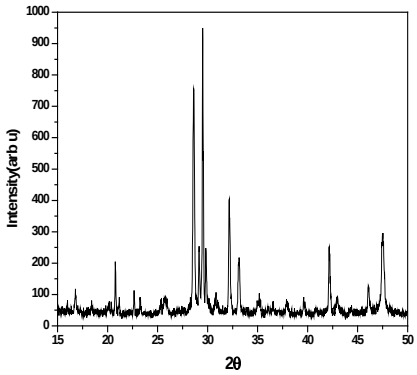


Fig.1:XRD of $Sr_2Al_2CeO_7$:Eu

3.2 Photoluminescence Study

All the samples prepared by using solid state method shows orange red emission under 254nm excitation (not shown). The emission spectra of all the samples without and with flux are shown in figure 2 and 3 respectively. Both spectra were measured at room temperature, with 254nm excitation. In the emission spectra, only one band with maximum at 595 nm is detected for all samples at 300 K. The peak at 595nm is altered emission of Eu which is attributed to magnetic dipole component, the emission at 616nm was also observed with less intensity. The peak at 595nm is attributed to $^5D_0$ - $^7F_1$, the peak at 616nm is attributed to $^5D_0$ - $^7F_2$, all the transitions are allowed transitions of Eu^{3+}.

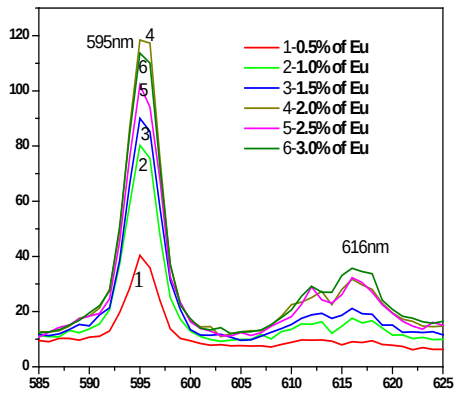


Fig- 2: Emission spectra of $Sr_2Al_2CeO_7$:Eu(2%) without flux.

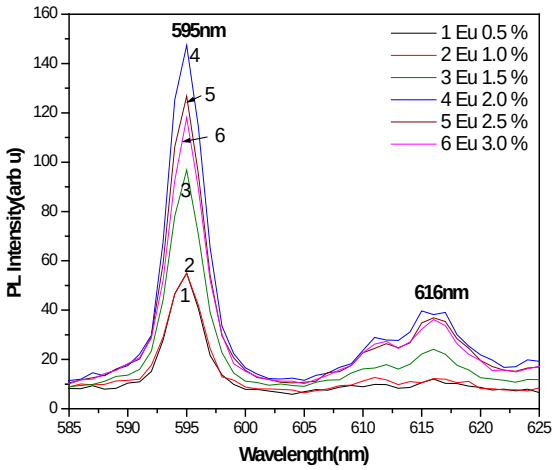


Fig- 3: Emission spectra of $Sr_2Al_2CeO_7$:Eu(2%) with flux

From PL emission study it is observed that the intensity of 595nm peak is increased by increasing the Eu concentration up to 2.0 mol% and then decreased as the Eu concentration increases. It is also observed that when cetric acid is added as flux to the starting materials, the emission peaks intensity of 595 and 616nm are increased by 10%. Table-1 show the variation of Intensity for different peaks with Eu Concentrations of $Sr_2Al_2CeO_7$:Eu without and with citric acid as flux for better comparison.

3.3 SEM Study

Fig-4 and 5 are the SEM of $Sr_2Al_2CeO_7$:Eu(2.0 mol%) phosphor, from the macrographs it is found the phosphor particles are agglomerated and non-uniform size and shape are observed.

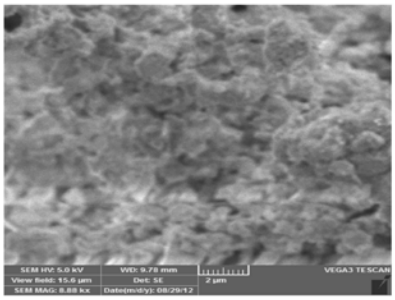


Fig-4:- SEM image of $Sr_2Al_2CeO_7$:Eu (8.88KX)

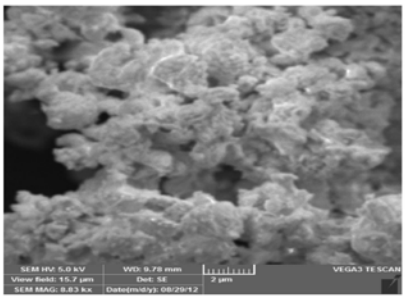
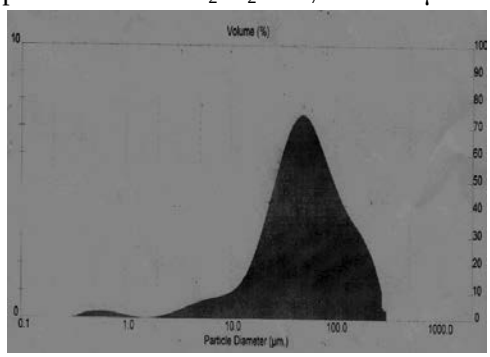


Fig-5:- SEM image of $Sr_2Al_2CeO_7$:Eu (8.83KX)

3.4 Particle size Study

The Particle size distribution histograms of the $Sr_2Al_2CeO_7$:Eu particles as shown in the below Fig-6. The prepared phosphor specimen particle size was measured by using laser based system Malvern Instrument U.K. The mean diameter of the particle size of $Sr_2Al_2CeO_7$:Eu is 50µm.

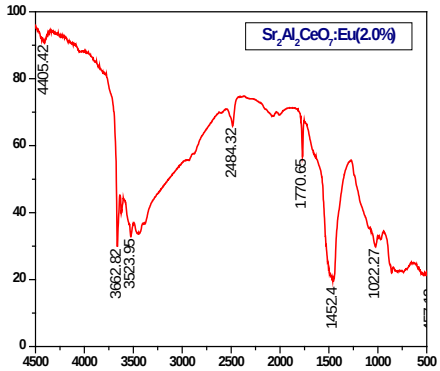


As such many molecular particles agglomerate and from as a crystallite and many crystallites together become a particle. In the present case approximately 0.3548 M^2/gram specific surface is found for the $Sr_2Al_2CeO_7$:Eu phosphor.

Fig-6:- Particle size of $Sr_2Al_2CeO_7$:Eu

3.5 FTIR Study

In order to determine the chemical bonds in a molecule FTIR analysis was carried out. Fig.7 shows the FTIR spectrum of $Sr_2Al_2CeO_7$:Eu. From FTIR spectrum it is observed that the peak at ~3523 cm^{-1} is assigned to intermolecular H sharp band of H_2O. The specimen might have absorbed moisture from the atmosphere. The absorption peaks at 2484 and 1424 cm^{-1} are the stretching and bending vibrations of the molecules respectively.



S No	Excitation wavelength(nm)	Eu mol % concentration	Intensity(arb u)			
			Without flux		With flux	
			595 nm	616nm	595 nm	616nm
1	254nm	0.5	39	9	54	12
2		1.0	81	17	54	12
3		1.5	87	21	97	25
4		2.0	118	31	148	40
5		2.5	102	31	127	37
6		3.0	111	34	118	35

Table-1:Variation of Intensity for different peaks with Eu Concentrations of $Sr_2Al_2CeO_7$:Eu without and with citric acid as flux.

4.0 Conclusions

$Sr_2Al_2CeO_7:Eu^{3+}$ phosphor powder was successfully synthesized by conventional solid state reaction technique. The $Sr_2Al_2CeO_7:Eu^{3+}$ phosphor shows an orange-red emission under 254nm excitation. The peak at 595nm is altered emission of Eu which is attributed to magnetic dipole component, the emission at 616nm was also observed with less intensity which is attributed to electric dipole component of Eu . The peak at 595nm is attributed to $^5D_0$ - $^7F_1$, the peak at 616nm is attributed to $^5D_0$ - $^7F_2$, all the transitions are allowed transitions of Eu. The intensity of these two peaks are increases as increasing the Eu concentration and also increasing intensity when added citric acid as flux. From XRD it is observed the phosphor is in single phase. The results indicate that $Sr_2Al_2CeO_7:Eu^{3+}$ phosphor can be selected as a potential candidate for device applications.

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