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Photoluminescence Studies of Eu^{3+} Activated Sr_2SiO_4 Phosphor

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***Abstract**: Trivalent Europium doped strontium orthosilicate phosphor ($Sr_2SiO_4:Eu^{3+}$) phosphor synthesized by high temperature solid state reaction method. The obtained phosphor was characterized by X-Ray diffraction (XRD), scanning electron microscope (SEM), energy dispersive x-ray spectroscope (EDX), and photoluminescence (PL). The analysis of XRD data conveyed that the sample was crystalline, single phase, orthorhombic structured with space group Pmnb. An agglomeration of particles with irregular shapes was observed from the SEM micrographs. The compositional verification was done employing energy dispersive analysis of x-rays. The PL emission spectra of the $Sr_2SiO_4:Eu^{3+}$ phosphor excited at 394nm consisted peaks at 587, 612 and 702nm corresponding to $^5D_0 \rightarrow {}^7F_1$, $^5D_0 \rightarrow {}^7F_2$, $^5D_0 \rightarrow {}^7F_4$ transitions of Eu^{3+} respectively. The Commission International de I'Eclairage (CIE) color coordinates of Sr_2SiO_4; Eu^{3+} phosphor were calculated and found as x = 0.601 and y = 0.397 lying in red region.*
Keywords: - XRD, Phosphor, Photoluminescence, CIE coordinates.

1 INTRODUCTION

During the past few years, the development in photonic technology has focused on a certain area more efficiently such as nanostructure materials. Eu^{3+} is known to be specific activator for red phosphor material owing to its characteristics of abundant energy level structure. Many researchers have investigated structural and optical properties of Eu^{3+} doped in different host matrices [1-2]. Generally rare earth ions have small cross sectional area of optical absorption in glassy host, which may decrease the photoluminescence (PL) [3-4]. However, PL emission can be enhanced by the efficient energy transform mechanism from wide band gape semiconductors.

In recent years, great interest have been focused on oxide of silicate based host lattice doped with rare earth ions (RE^{3+} = Eu^{3+}, Dy^{3+}, Ce^{3+}) in light emitting diodes (LEDs) because it offer the advantages of energy conservation, high luminosity, long life time, reliability and environmental protection [5-7]. The rare earth ions play an important role to improve the luminescence efficiency. The local symmetry of RE ions reduces the OH groups after doping of RE ions in host, and generates new oxygen vacancies in the host lattice hence result in enhanced luminescence efficiency [8, 9].

Here, we have synthesized pure orthorhombic phase Sr_2SiO_4: Eu^{3+} for LEDs by conventional high temperature solid state reaction route. The sample was structural characterized by different techniques such as X-ray Diffraction, Scanning electron microscopy, Energy dispersive analysis of x-ray diffraction. Photo- luminescence study of as prepared sample has been done using photoluminescence.

2 Experimental

The polycrystalline $Sr_{1.99}Eu_{0.01}SiO_4$ phosphor was prepared by the solid state reaction method. The starting materials $SrCO_3$ (99.99%), SiO_2 (99.99%) and Eu_2O_3 (99.99%) of analytical grade were taken in powder form. All the starting material were weighed according to designed stoichiometric amount and thoroughly mixed in the agate mortar for 2 hours. The powdered mixture was calcined at 800˚C for 4 hours. This calcined mixture was again ground for 2 hours and was annealed at

1100˚C for 3h [10]. The annealed powder mixture was grind to obtained fine powder of as prepared phosphor.

To confirm the phase and crystal structure, the sample was XRD characterized by Bruker D8 advanced X-ray Diffractometer using Cu K_α radiation (λ=1.54060Å) with angular range (,20º<2θ<80º). Surface morphology studies were carried out using SEM instrument of model JEOL JSM-5600 with a resolution of 3.5 nm, magnification power of x 18-300000 kV (in 136 steps), acceleration voltage of 0.5-30 kV (53 steps) and elemental composition was verified using EDAX technique employing energy dispersive spectrometer, model INCA Oxford. Photoluminescence measurements were carried out using Edinburgh Instrument FLS920-s fluorescence spectrometer. All the characterizations were carried out at room temperature.

3 Result and discussion

3.1 XRD characterization

Figure 1 shows the XRD pattern of Eu^{3+} activated Sr_2SiO_4 phosphor prepared by solid state reaction method. The XRD pattern of Sr_2SiO_4: Eu^{3+} phosphor has several diffraction peaks, which are in completely agreement with those of the standard JCPDS card (JCPDS 32-1256) card [11]. The sample are indexed to orthorhombic structure with space group Pmnb and the lattice parameters calculated from the XRD spectrum, were nearly, a= 5.6654Å, b=7.0737Å, c= 9.7336Å. The average crystalline size of the phosphor was calculated to be 59nm using by Debye Scherrer's formula t= kλ/ βcosθ where 't' is the average size of the particle, 'β' is FWHM and 'θ' is Bragg's angle. It can concluded that the XRD spectrum confirmed that the phosphor has been successfully prepared and the low concentration doped Eu^{3+} ion did not change the single phase structure.

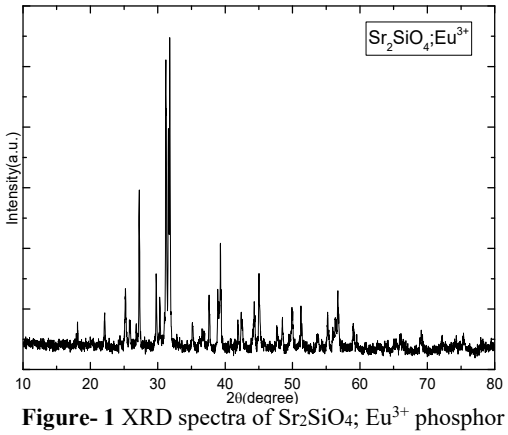

Figure- 1 XRD spectra of Sr_2SiO_4; Eu^{3+} phosphor

3.2 SEM and EDAX

The morphological studies have been carried out via the analysis of SEM image as represented in Figure 2. The close observation reveals that the particles are well separated and there are no definite grain boundaries. The average particle size has been calculated using ImagJ software and the size was found to be 68 nm, which is in close proximity to the calculated one from the powder x-ray diffraction. The observations of the SEM image revealed that an agglomeration process has taken place while the sample formation [12, 13]. The elemental analysis has been carried out using energy dispersive analysis of x-ray diffraction technique. The EDAX spectrum of Sr_2SiO_4:Eu^{3+} phosphor has been displayed in the Figure 3. From the spectrum, one can observe the presence of all the constituents of the synthesized phosphor and within the experimental limits, there is no loss of any of the integral element of the sample.

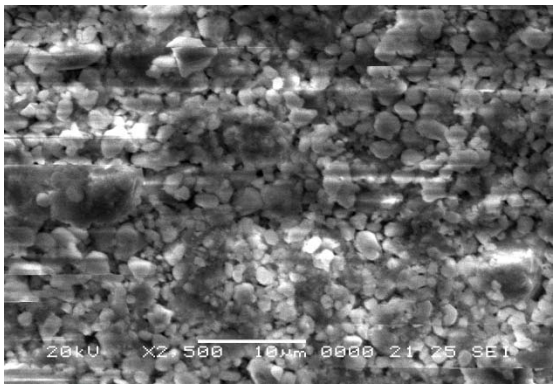

Figure- 2 SEM image of Sr_2SiO_4; Eu^{3+} phosphor

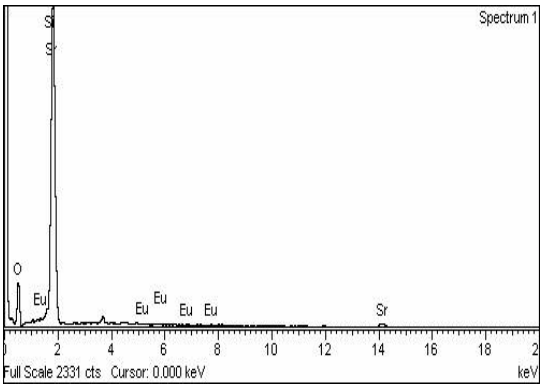

Figure- 3 EDAX spectra of Sr_2SiO_4; Eu^{3+} phosphor

3.3 Photoluminescence

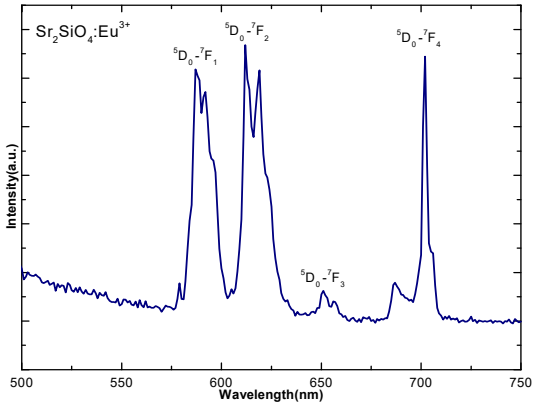

Figure- 4 Excitation spectra of Sr_2SiO_4; Eu^{3+} phosphor

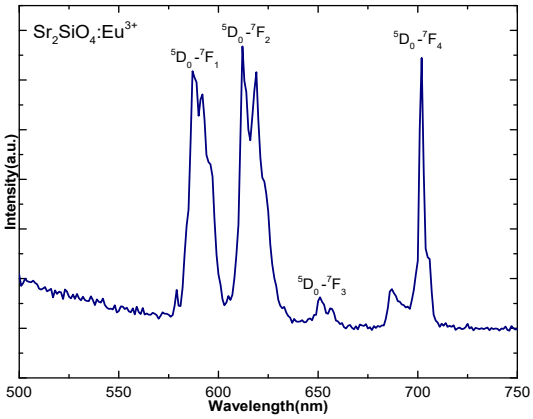

Figure- 5 Emission spectra of Sr_2SiO_4; Eu^{3+} phosphor

In order to study the luminescent properties of Eu3+ doped Sr2SiO4 phosphor under the excitation of 394nm. The spectra of excitation and emission of the sample were recorded at room temperature shown in Figure 4 and Figure 5. The excitation spectrum of the as prepared sample for the 612nm emission is shown in Figure 4. The strongest sharp peak at 394nm corresponding to the $^7F_0 \rightarrow {}^5L_6$ transition of Eu^{3+} was observed. In addition of this characteristic transition peak, there are less intense excitation peaks located at 319nm, 362nm and 386nm attributed to the intra-configurational 4f-4f transitions, which are forbidden transitions of Eu^{3+} ion as well as hypersensitive transitions. These transitions can be assigned to $^7F_0 \rightarrow {}^5H_6$, $^7F_0 \rightarrow {}^5D_4$ and, $^7F_0 \rightarrow {}^5G_4$ transitions respectively. The emission spectra of Sr_2SiO_4; Eu^{3+} phosphor, shown in Figure 5, for the excitation of 394nm was recorded in the range 500-750nm. The emission spectra of the as prepared phosphor was found comprising of series of sharp emission peaks corresponding to the transition from the excited state $^5D_0$ to the ground state ^7F_j (where j=0,1,2,3,4) transitions. The emission at 587nm (orange region) is assigned to $^5D_0 \rightarrow {}^7F_1$ transition of Eu^{3+}, which belongs to magnetic dipole. The sharp emission peak at 612nm (red region) is assigned to $^5D_0 \rightarrow {}^7F_2$ transition of Eu^{3+} and was ascribed to electric dipole. The emission at 651nm is attributed to $^5D_0$-$^7F_3$ transition. Similarly, the emission at 702nm is attributed to $^5D_0$-$^7F_4$ transition [14]. The emission at 587 and 612nm exists, when Eu^{3+} ion replaces Sr^{2+} ion in the host lattice [15].

3.6 CIE

The CIE (Commission International de I'Eclairage) coordinates of Sr_2SiO_4; Eu^{3+} phosphor was obtained (after excitation the sample at ~394nm) for the photoluminescence emission data using CIE 931. The CIE co-ordinates for Sr_2SiO_4; Eu^{3+} phosphor were found to be $x = 0.601$ and $y = 0.397$ as summarized in Table 1 The CIE chromatic diagram of Eu^{3+} doped strontium silicate excited at wavelength 394nm is shown in Figure: 6. The values of CIE coordinates correspond to red region and are in agreement with the reports elsewhere [16]

4 CONCLUSION

In this work, we have studied the luminescent and structural properties Eu^{3+} doped Sr_2SiO_4 phosphor, which was successfully synthesized by high temperature solid state reaction method. The result of XRD confirmed the crystallite Sr_2SiO_4:Eu^{3+} belongs to the single phase, orthorhombic structure with space group Pmnb. For the excitation at 394nm, the phosphor Sr_2SiO_4; Eu^{3+} emitted red light displayed emission peaks at 587nm, 612nm, and 702nm corresponding to the transitions $^5D_0 \rightarrow {}^7F_0$, $^5D_0 \rightarrow {}^7F_1$, and $^5D_0 \rightarrow {}^7F_4$ respectively of Eu^{3+}. The PL emission in the red region has been confirmed from the calculated CIE coordinates, which were found to be $x = 0.601$ and $y = 0.397$.

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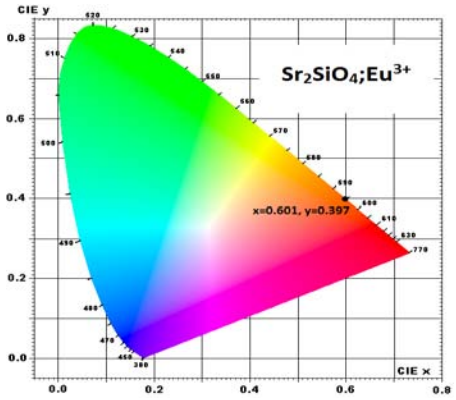

Figure: 6

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Table 2 CIE Co-ordinates for Sr_2SiO_4; Eu^{3+} (1.0 %)

Phosphor	Excitation(nm)	Strong Emission (nm)	(x,y) co-ordinates	Color region
Sr_2SiO_4; Eu^{3+}	394	612	(0.601,0.397)	red

Figure-6 CIE color chromaticity