Journal of Atomic, Molecular, Condensate & Nano Physics
Vol. 3, No. 1, pp. 55–60, 2016
ISSN 2349-2716 (online); 2349-6088 (print)
Published by RGN Publications

http://www.rgnpublications.com

Structure and Luminescence Properties of Y_2O_3:Eu^{3+} Nanophosphors

Article Type?

Mohd Faizan and Shabbir Ahmad*

Department of Physics, Aligarh Muslim University, Aligarh, India
***Corresponding author:** ahmad.shabbir@rediffmail.com

Abstract. Europium trivalent (Eu^{3+}, 2%) doped Y_2O_3 nanophosphors were synthesized by sol-gel method and annealed at temperature 600 °C and 900 °C. The phosphors were characterized by XRD, FTIR, UV-visible and PL spectroscopy. The average crystal size was in the range of 10-26 nm. FTIR spectra show that the intensities of all impurity peaks get reduce with increasing annealing temperature. The band gap was determined from the diffuse reflectance (DR) spectra using the K-M function. The photoluminescence spectra were describe by well known $^5D_0$-^7F_j transitions ($J = 0,1,2,3,4$) of Eu^{3+} ions.

Keywords. XRD; FTIR; UV-VIS; PL; Nanophosphors

PACS. 81.07.Bc; 61.05.cp; 32.30.Jc; 33.20.Ea; 33.50.-j

Received: February 17, 2015 **Accepted:** October 25, 2015

1. Introduction

Rare earth ions doped phosphors have attracted much attention of workers due to its unique optical properties. They have many potential applications in *white light emitting diodes* (WLEDs), *field-emission display* (FEDs), *plasma display panels* (PDPs), medical diagnostics, sensors etc. [1].

2. Experimental Details

The stoichiometric amounts of Eu_2O_3 and Y_2O_3 were dissolved in 5 ml HNO_3 and 50 ml double distilled water to convert into $Eu(NO_3)_3$ and $Y(NO_3)_3$ completely. The suitable amount of citric acid was added into the mixture and stirred for 2 h at 60 °C to get transparent solution. The pH of the solution was adjusted by adding ammonia drop wise till precipitation. The resulting solution was dried in oven at 120 °C for 10 h. Finally, the powder was heated in air at two different temperatures, 600 °C and 900 °C for 2 h.

3. Results and Discussion

3.1 XRD Analysis

The X-ray diffraction pattern of 2% Eu^{3+} doped Y_2O_3 nanophosphors are shown in Figure 1. The main observed peaks are assigned to (211), (222), (400), (440) and (622) reflections of cubic Y_2O_3 and are in well agreement with the reported data [2]. The strongest diffraction peak was observed at 29.150° which corresponds to the plane (222) for all samples. Moreover, the intensity of the spectral peaks were found to be enhanced with increasing annealing temperatures.

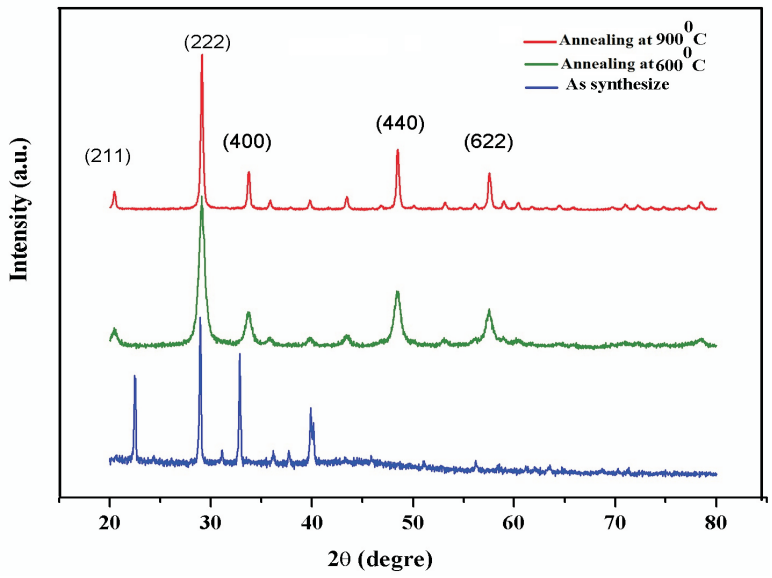

Figure 1. XRD patterns of phosphors.

The 900 °C annealed phosphor has shown narrower diffraction peaks which indicates the improvement in the crystalinity of the Y_2O_3 phase as well as the minimization of the strain in the crystal. The average crystal size in the samples are calculated using Scherrer equation.

$$D = \frac{0.89\lambda}{\beta \cos\theta}, \tag{1}$$

where D is average crystal size, λ is the wavelength of X-ray ($\lambda = 0.1541$ nm); β and θ are FWHM of X-ray diffraction and the Bragg angle respectively. The average crystal size of the powders annealed at 600 °C and 900 °C for 2 h were found to be 10.17 nm and 25.26 nm respectively.

3.2 FTIR analysis

FTIR spectra of samples are shown in Figure 2. The broad band at 3450 cm^{-1} is assigned to O-H vibration. The peaks appearing at 1396 and 1524 cm^{-1} come from citrate group due to C-O stretching vibration [3]. The absorption band centered at 560 cm^{-1} is attributed to Y-O vibration [3]. It can be observed from the spectra that the intensities of all impurity peaks (due to CO, OH, etc.) decrease with increase in annealing temperature, whereas, the intensity of Y-O band at 560 cm^{-1} increases.

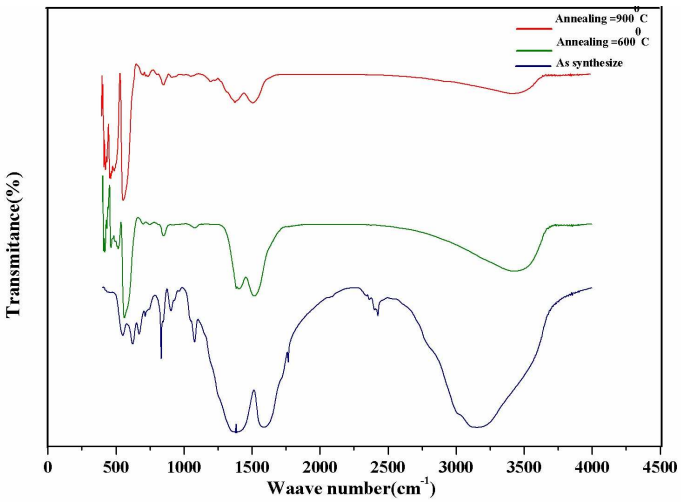

Figure 2. FTIR spectra of phosphors.

3.3 Diffuse Reflectance Spectra and Calculation of Band gap

The diffuse reflectance spectra of the Y_2O_3:Eu^{3+} phosphors have been shown in Figure 3. The stronger absorption bands were observed in the range 190 to 300 nm.

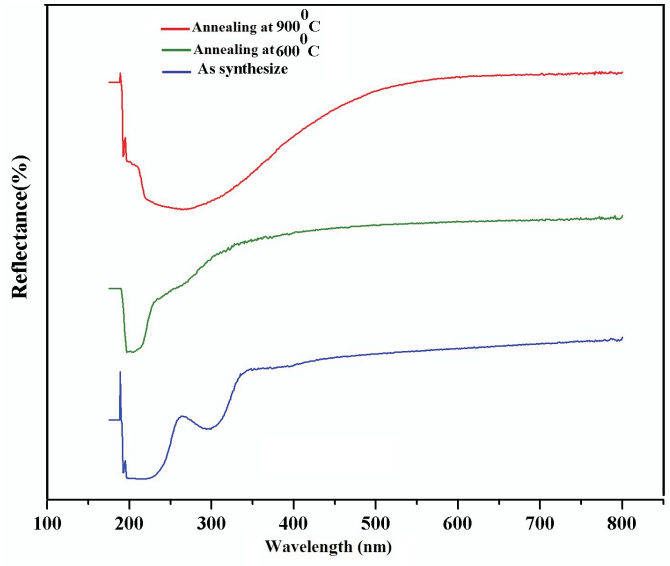

Figure 3. Diffuse reflectance spectra of phosphors.

Kubelka-Munk theory [4] was used to calculate the band gap of Y_2O_3:Eu^{3+} nanophosphor. The K-M function is given by equation

$$F(R_\infty) = \frac{(1-R_\infty)^2}{2R_\infty}, \tag{2}$$

where R_∞ is diffuse reflectance of the sample which is defined as

$$R_\infty = \frac{R_{\text{sample}}}{R_{\text{reference}}}. \tag{3}$$

The relation between band gap (E_g) and linear absorption coefficient α is given by Tauc relation

$$\alpha h\nu = A(h\nu - E_g)^2, \tag{4}$$

where A is proportionality constant and hν is photon energy. Using equations (2) and (4) following equation can be obtained.

$$[F(R_\infty)h\nu]^2 = A(h\nu - E_g). \tag{5}$$

The value of band gap E_g is obtain by extrapolating the linear fitted region at $[F(R_\infty)\text{h}\nu]^2 = 0$ in the plot of $[F(R_\infty)\text{h}\nu]^2$ versus hν which has been shown in Figure 4. In the present case, the band gap was estimated to be 5.52 eV.

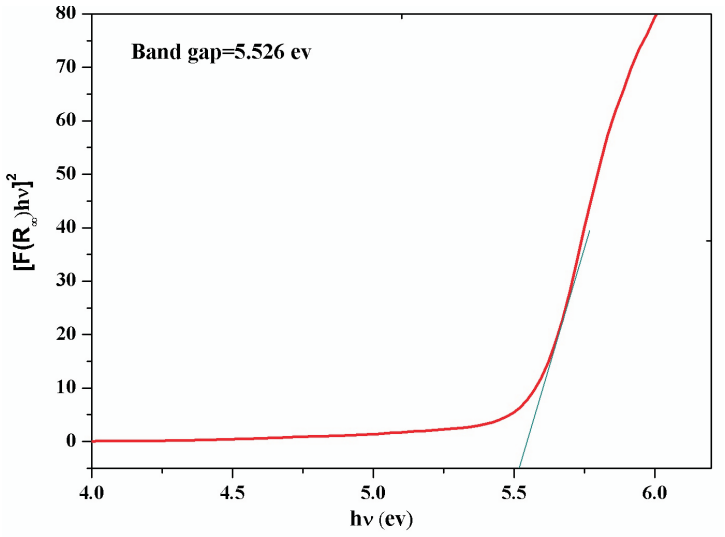

Figure 4. Tauc plot for optical band gap.

3.4 Photoluminescence Studies

The emission spectra of Eu^{3+} doped Y_2O_3 nanophosphor under excitation wavelength of 230 nm are shown in Figure 5. The emission peaks observed at 580, 592, 611, 629 and 695 nm, which corresponding to transitions $^5D_0$-^7F_j ($j = 0,1,2,3,4$) respectively, are shown in Figure 6. These assignments are in well agreement with the earlier report [5]. The most intense peak correspond to $^5D_0$-$^7F_2$ transition was observed at 611.37 nm.

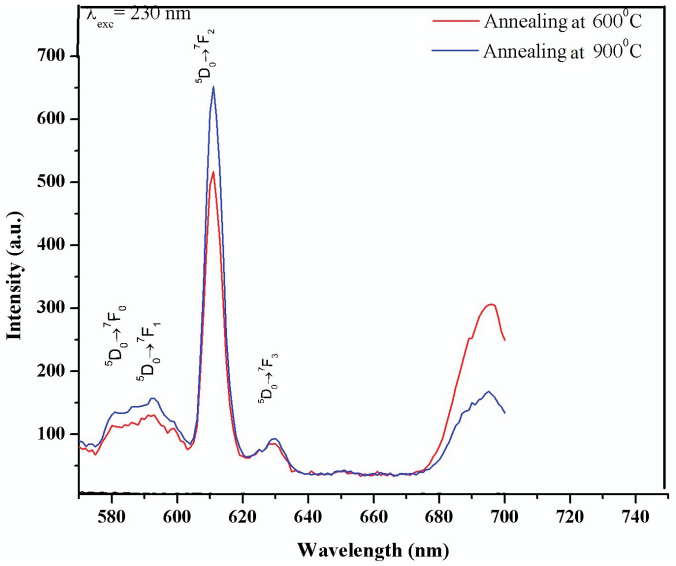

Figure 5. PL emission spectra of phosphors.

The transitions, $^5D_0$-$^7F_0$, $^5D_0$-$^7F_2$ and $^5D_0$-$^7F_3$, originate from C2 sites by electric dipole transitions while $^5D_0$-$^7F_1$ originates at both S6 and C2 sites by magnetic dipole transitions [5]. It is observed that the intensities of emission peaks increase with increasing annealing temperature. This is due to reduce quenching and increase in particle size with increasing annealing temperature.

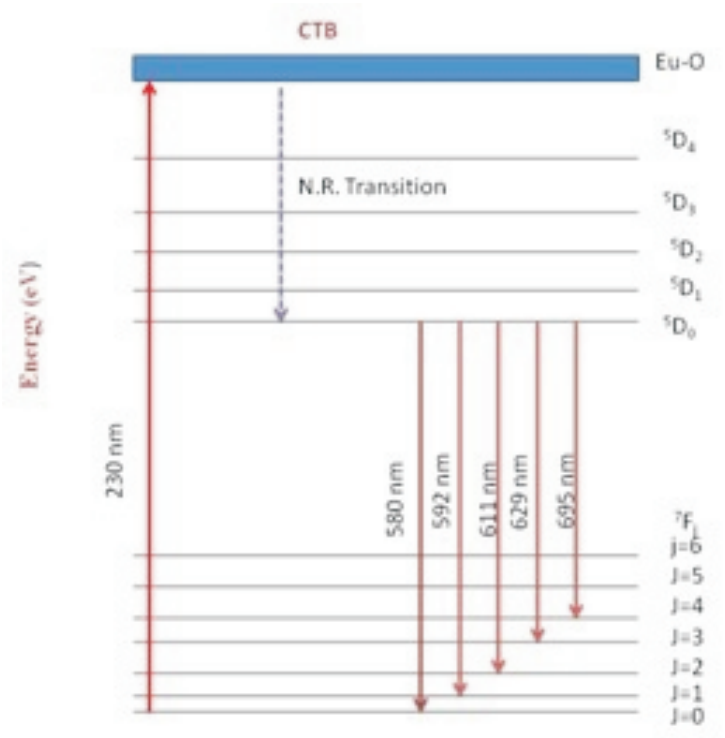

Figure 6. Energy level digram Eu^{3+} ion.

4. Conclusion

The red emission Y_2O_3: Eu^{3+} nanophosphor was prepared by sol-gel method. The XRD result shows that phosphor is crystalline in nature and average crystal size is found in the range of 10-26 nm. The nanophosphors possess optical band gap of 5.52 eV as measured using K-M theory. The emission peaks were assigned. The phosphor shows strong red emission at 611 nm. The photoluminescence intensity increases with increasing annealing temperature.

Acknowledgement

The authors are grateful to the University Grants Commission, New Delhi, Government of India, for financially support to this work.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed equally and significantly in writing this article. All the authors read and approved the final manuscript.

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