

Photoluminescence studies of $Y_2O_3:Sm^{3+}$ nanophosphor irradiated with 6 MeV E-beam

S.Yeshodamma^{a,d}, D.V.Sunitha^{a*}, H. Nagabhushana^b, G.R.Navyashree^a, K.Hareesh^c, N.Bhoraskar^c, S.D.Dhole^c

^aSchool of Physical Sciences, Reva University, Yelahanka, Bangalore 560064, India

^b Prof. C.N.R. Rao Centre for Advanced Materials Research, Tumkur University, Tumkur 572 103, India

^c Department of Physics, Savitribai Phule Pune University, Pune 411 007, India

^d Department of Physics, Cambridge Institute of Technology, K.R.Puram, Bangalore 560 036, India

(*Corresponding author: E-mail: sunithaprasad8@gmail.com; Mob: +91-7760884884)

Abstract

$Y_2O_3:Sm^{3+}$ (3 mol%) nanophosphors was synthesized by solution combustion technique using Aloe Vera gel as a fuel. The pristine and E-beam irradiated samples were subjected to powder X-ray diffraction studies (PXRD). Pristine sample revealed the formation of highly crystalline cubic phase of Y_2O_3 . Whereas the E-beam irradiated sample showed decrease in crystalline nature by the creation of defects. Photoluminescence (PL) spectra taken for pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors showed characteristic emission peaks at 570, 608 and 656 nm corresponding to $^4G_{5/2} \rightarrow ^6H_J$ ($J= 5/2, 7/2, 9/2$) transitions of Sm^{3+} ion respectively.

Keywords: E-beam, photoluminescence, transitions

1. Introduction

From past three decades, a lot of efforts has been made by the researchers to study how nanomaterials are superior than bulk counterparts. By controlling the size and shape the material properties such as physical, electrical, mechanical and thermal properties can be easily tuned by varying the synthesis technique, controlling the rate of reaction and maintaining different atmospheric conditions [1, 2]. Another important technique to modify the material properties is by irradiating the obtained materials with highly energetic beams such as X-rays, γ -rays, electrons, ions, protons, etc [3, 4]

Yttrium oxide (Y_2O_3) is an important host matrix used for various applications such as coating, solid state lasers, display devices, etc due to its high melting point, large energy band gap, good thermal conductivity, high mechanical strength, etc [5]. Therefore, efforts have been made to study the luminescent properties of Sm^{3+} ion doped Y_2O_3 host matrix. Low temperature, less cost, highly

homogeneous, self-propagating solution combustion technique was used for the synthesis of $Y_2O_3:Sm^{3+}$ nanophosphor and PL studies were carried out for pristine and E-beam irradiated samples.

2. Experimental technique

2.1. Synthesis of $Y_2O_3:Sm^{3+}$ nanophosphor

Yttrium nitrate, ($Y(NO_3)_3 \cdot 6H_2O$; 99% pure) and Samarium nitrate ($Sm(NO_3)_3 \cdot 6H_2O$; 99% pure) procured from Sigma Aldrich and Merck Ltd., were used as a starting materials for the synthesis of $Y_2O_3:Sm^{3+}$ (3 mol%) nanophosphor. Aloe vera gel extracted from Aloe vera plant was used as a fuel in solution combustion technique. The stoichiometrically calculated nitrates and 10 ml of Aloe vera gel extract was taken in a Petri dish and stirred well using magnetic stirrer. The obtained aqueous mixture was placed in the combustion chamber at a temperature of ~ 400 °C. Exothermic reaction took place in the combustion chamber resulting in formation of $Y_2O_3:Sm^{3+}$ phosphor.

The obtained phosphor was grinded and made in the form of pellets of 6 mm diameter and 0.1 mm thickness by using a hydraulic pellet press and the pellets were calcined at a temperature of 750 °C for 3 hr. For PXRD and PL studies one of the samples was kept unirradiated and another was exposed to 6 MeV E-beam of fluence 9×10^{13} e⁻cm⁻².

2.2. Characterization of samples

PXRD patterns were recorded on Shimadzu made Model PXRD-7000 by using Cu-K α radiations at a wavelength of 1.54 Å. The PL studies were recorded using Horiba Fluorolog-3 spectrofluorimeter at an excitation wavelength 407 nm.

3. Results and discussion

3.1. Powder X-ray diffraction results

The PXRD patterns of pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors are shown in Fig.1. The obtained diffraction patterns are in good agreement with standard JCPDS file no. 83-0927. Pristine nanophosphor showed sharp high intense diffraction pattern where as E-beam irradiated sample showed broadened less intense peaks.

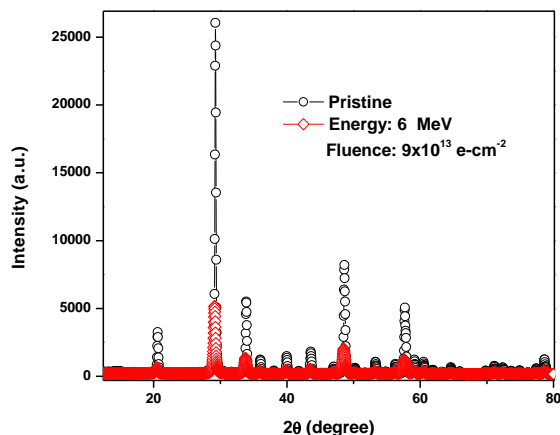


Fig.1. Diffraction patterns of pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors. Further, particle size and micro strain was estimated using Debye Scherer's formulae [6, 7]

$$D = \frac{0.9\lambda}{\beta \cos\theta} \text{ and } \varepsilon = \frac{\beta \cos\theta}{4}$$

where, β' is the full width at half maximum of the diffraction peak, ' λ ' is the incident X-ray wavelength (1.54 Å) and θ is the Bragg's diffraction angle. The estimated particle size and micro-strain is found to be 24 nm, 1.345×10^{-3} in pristine and 44 nm, 1.981×10^{-3} in E-beam irradiated nanophosphors respectively. The decrease in diffraction peak intensity, increase in particle size and micro-strain in E-beam irradiated samples indicates the creation of defects and lattice disorder due to E-irradiation.

3.2. Photoluminescence (PL)

PL spectrum was recorded for pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphor at an excitation wavelength 407 nm. From Fig.2 characteristic emission peaks were observed at 570, 608 and 656 nm corresponding to $^4G_{5/2} \rightarrow ^6H_J$ ($J = 5/2, 7/2, 9/2$) transitions of Sm^{3+} ion respectively. The PL emission peak at 570 nm corresponds to magnetic-dipole (MD) transition with selection rule values $\Delta J = 0$ and ± 1 corresponds to magnetic-dipole (MD) transition with selection rule values $\Delta J = 0$ and ± 1 . Whereas 656 nm emission peak corresponds to electric dipole transition obeying the selection rule of $\Delta J' \leq 6$ where J or $J' = 0$ when $\Delta J = 2, 3, 6$. But 608 nm emission

peak exhibits both electric and magnetic dipole transitions partially with selection rule $\Delta J = \pm 1$ [8, 9].

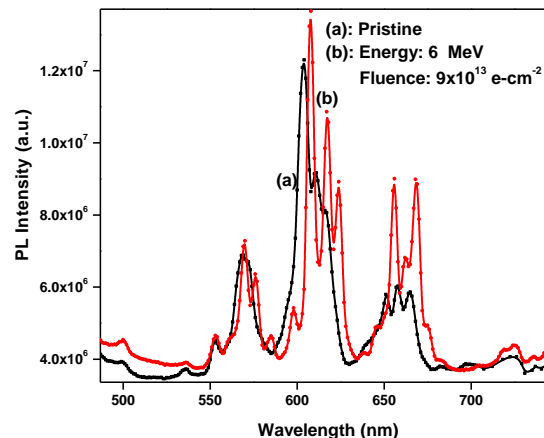


Fig.2. PL emission spectrum of pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors

The PL intensity of E-beam irradiated nanophosphor was more when compared to pristine samples because density of defects increases with electron irradiation. The recombination of electrons and holes takes place due to radiative transitions resulting in high PL intensity.

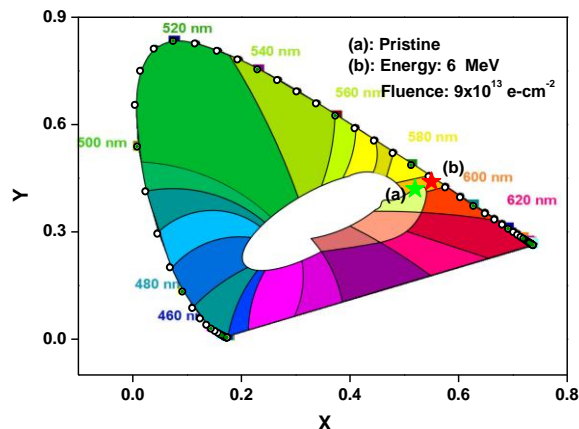


Fig.3. CIE diagram of pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors

The CIE (Commission International de l'Eclairage) [10] was used to estimate the color co-ordinate values of pristine and E-beam irradiated $Y_2O_3:Sm^{3+}$ nanophosphors. From Fig. 3 it is observed that pristine sample showed co-ordinate values in orange region whereas E-beam irradiated sample lies in orange-red region. Hence, E-irradiation can be used to tune the color co-ordinate values.

4. Conclusion

E-beam is a promising and potential technique used for the modification of the material properties. PXRD results showed the decrease in diffraction peak intensity with E-fluence. The PL spectrum was recorded at an excitation wavelength 407 nm. The PL emissions were due to Sm^{3+} ion transitions at $^4\text{G}_{5/2} \rightarrow ^6\text{H}_j$ ($J= 5/2, 7/2, 9/2$) PL intensity was enhanced in E-beam irradiated samples. The increase in PL intensity was due to the creation of lattice disorder resulting in non-radiative transitions. The CIE co-ordinate value of E-beam irradiated nanophosphor was found to be in orange-red region.

Acknowledgement

One of the author (DVS) thanks Chancellor, Dr.P.Shamaraju for their constant support and encouragement.

References

- [i] T. Gougousi, Z. Chen, Thin Solid Films, 516 (2008) 6197-6204.
- [ii] L.R. Singh, R.S. Ningthoujam, V. Sudarsan, I. Srivastava, S.D. Singh, G.K. Dey, S.K. Kulshreshtha, Nanotechnology 19 (2008) 055201–055208.
- [iii] Numan Salah, S.P. Lochab, D. Kanjilal, Jyoti Mehra, P.D. Sahare, Ranju Ranjan, A.A. Rupasov, V.E. Aleynikov, J. Phys. D: Appl. Phys. 41 (2008) 085408-8.
- [iv] Y. Ali, V. Kumar, R.G. Sonkawade, A.S. Dhaliwal, H.C. Swart, Vacuum 99 (2014) 265-271.
- [v] S. Som, S.K. Sharma, S.P. Lochab, Mat. Res. Bull., 48 (2013) 844–851.
- [vi] P. Klug, L.E. Alexander, X-ray Diffraction Procedure, Wiley, New York, 1954.
- [vii] R. Sathyamoorthy, S. Chandramohan, P. Sudhagar, D. Kanjilal, D. Kabiraj, K. Ashokan, Sol. Energy Mater. Sol. Cells 90 (2006) 2297–2304.
- [viii] H.Deng, Z.Zhao, J. Wang, Z. Hei, M. Li, H. Noh, J. H. Jeong, R. Yu, J. Sol. State Chem. 228 (2015) 110–116.
- [ix] G.S.R. Raju, S. Buddhudu, Spec. chim.Acta Part A 70 (2008) 601–605.
- [x] C.S. McCamy, Color Res. & App. 17 (1992) 142-144.