

# Photoluminescence and Structural Study of Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> Nanophosphor prepared by Homogenous Coprecipitation Method

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**Abstract:** Highly crystalline 1% to 5 % Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> nanoparticle was synthesized by simple and cost effective homogenous coprecipitation method. Thus formed precipitate was dried at 100°C followed by calcination at 600°C for 2 hours and at 800°C for 2 hours. The cubic phase crystalline structure of Y<sub>2</sub>O<sub>3</sub> and Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> particles was confirmed by XRD analysis. The lattice parameter (d) and crystalline size (D) were found to be ~3.05 nm, and ~34.91 nm respectively. (JCPDS- 43-1036). The surface morphology with spherical particles, elemental analysis and composition of thus synthesized Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> particles were proven by FESEM, EDX and FTIR investigations. Finally, the photoluminescence (PL) spectra shows one sharp and intense emission peak at 543 nm corresponding to <sup>5</sup>D<sub>4</sub> → <sup>7</sup>F<sub>5</sub> transition (bright green emission) of the phosphor particles.

**Key-Words:** Photoluminescence, homogenous coprecipitation, Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup>.

## 1.INTRODUCTION

The rare earth metal doped luminescent light emitting nanoparticle with lanthanide ion have potential applications in display devices and bioimaging due to their better photostability.<sup>1-4</sup> Y<sub>2</sub>O<sub>3</sub> is one of the best studied host matrix. In this study, Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> nanophosphor was synthesized by homogenous coprecipitation method using oxalic acid as a precipitant and CTAB as a capping agent.<sup>5,6</sup> Nanophosphor were characterized by XRD, FESEM, EDX, FTIR and PL techniques.

## 2.MATERIALS AND EXPERIMENTAL METHOD

### 2.1Preparations:

In the present work, all the chemicals used were purchased from Sigma-Aldrich (purity ≥ 99 %) and Alfa-Aesar (99.9%) and used without further purification. The 25 mL aqueous solution of mixed metal nitrates, [Y(NO<sub>3</sub>)<sub>3</sub>.6H<sub>2</sub>O] and [Tb

(NO<sub>3</sub>)<sub>3</sub>.6H<sub>2</sub>O] was prepared. The prepared solution was kept on magnetic stirrer for 1 hour at 40°C. The aqueous solution of oxalic acid was added as a precipitant drop wise in above prepared aqueous solution of mixed metal nitrates in presence of 1-2 mL CTAB for 2 hours, with constant stirring on magnetic stirrer at 40°C and pH about 6.5 to 7.0. After addition of oxalic acid is over, the formed precipitate was removed by filtration, the formed precipitate was dried in oven at 100 °C for 12 hours to get white powder. Finally, the powder was calcinated in muffle furnace at 600 °C for 2 hours and then at 800 °C for next 4 hours to get Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> phosphor material. With the same protocol, 1% to 5% Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> nanophosphors were synthesized by using appropriate amounts of Y(NO<sub>3</sub>)<sub>3</sub> and Tb (NO<sub>3</sub>)<sub>3</sub>.

### 2.2Characterization:

The XRD diffraction patterns were recorded by Pananalyticals XPert Pro system using CuKα<sub>1</sub> (1.540 Å) radiation. The FESEM images were obtained using Scanning Electron Microscope model JSM 6100 (Joel) with image analyser. The FTIR spectra were obtained by Shimadzu IR-Affinity (Diamond ATR) FTIR spectrophotometer. The PL investigations were carried out with Hitachi F- 7000 spectrophotometer with a 150-W xenon lamp as an excitation source.

## 3.RESULT AND DISCUSSION

### 3.1Structural, Morphological and Constitutional Characterization:

The diffraction pattern of Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> nanophosphors is shown in figure 1. The dominant observed peaks are assigned to (211), (222), (400) (441) and (622) reflections of cubic Y<sub>2</sub>O<sub>3</sub>. The presence of sharp, intense and narrow peaks confirming the sample quality of excellent crystallinity and fine grain size. The strongest diffraction peak with highest intensity

of spectral line was observed at 29.1657 ° which corresponds to the plane (222). The lattice parameter (d) and crystalline size (D) were calculated by Debye-Scherrer formula <sup>7</sup>, presented in Table 1.

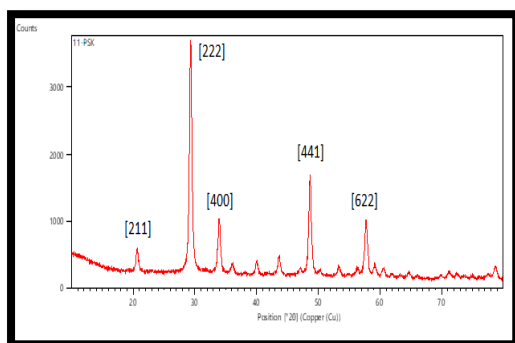


Fig. 1: XRD for Tb<sup>3+</sup> doped Y<sub>2</sub>O<sub>3</sub> nanoparticles

Table 1: XRD parameters of Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup>

The surface morphology and elemental composition of synthesized Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> was studied by FESEM and EDX analysis. Fig. 2 shows typical SEM micrograph and Fig. 3 shows EDX of Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup>.

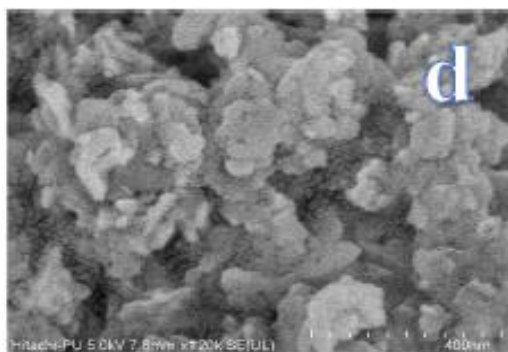


Fig. 2: FESEM for Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> at 800 °C

Fig. 3: EDX spectrum for Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup>

The FESEM image shows uniform shape and formation of agglomerates of little spheres, after calcination at 800 °C. The sample showed spherical surface morphology and connectivity, with grains and the formation of a nano-sized particles. The nonuniform nature of the particles is due to presence of cracks, pores, and voids may be due to uneven distribution of temperature during the calcination process. <sup>8</sup> The fluffy nature and porosity in the

particles probably created due to gases molecules escaping through interiors of the powder during the calcinations. In EDX spectrum, identification of the characteristic and distinct lines for the major emission energies of elemental Y, Tb, and O are

Plane (hkl)	2 θ (deg)	Int. (%)	FWHM	d (obs) Å	D (nm)
( 211 )	20.646	8.16	0.4757	4.29863	30.94
( 222 )	29.284	100.0	0.4287	3.04731	34.91
( 400 )	33.913	22.87	0.4728	2.64119	32.02
( 441 )	48.623	43.61	0.4356	1.87101	36.47
( 622 )	57.715	24.49	0.4961	1.59602	33.32

observed, correspond to peaks in the spectrum. It correctly identified the yttrium, terbium and oxygen in Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> sample.

The FTIR spectrum of Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> is shown in Figure 4.

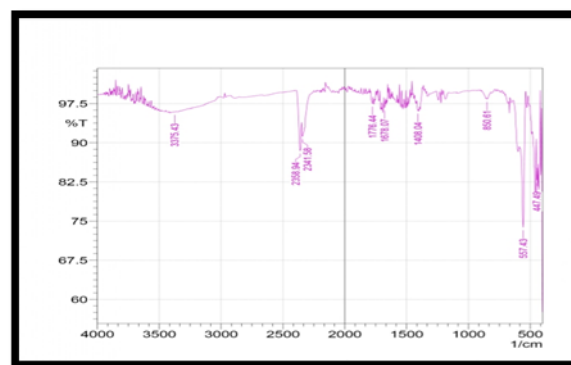


Fig. 4: FTIR spectrum for Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> prepared by HCP method

FTIR spectrum displays different peaks from 4000 - 600 cm<sup>-1</sup> which confirms presence of various constituents in Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> phosphor. The broad absorption at 3375 cm<sup>-1</sup> can be assigned to moisture absorbed on the surface of the sample. The broad peak at 2368 cm<sup>-1</sup> is due to asymmetrical modes of CO<sub>2</sub>. The absorption bands at 1776 cm<sup>-1</sup> may be assigned to CO<sub>3</sub><sup>2-</sup> in the bond-stretching mode while at 1678 cm<sup>-1</sup> is the evidence for carboxylate group. Absorption at 1408 cm<sup>-1</sup> indicates the C-O asymmetric stretching mode vibrations. The intense absorption bands at around 557 and 447 cm<sup>-1</sup> are attributed to O–Y–O asymmetric stretching vibration mode of the surface bridging oxide and symmetric stretching vibration mode for the O–Y–O linkage present in pure cubic phase Y<sub>2</sub>O<sub>3</sub> sample.<sup>9</sup> These results confirm an acceptable stoichiometry of Y<sub>2</sub>O<sub>3</sub>:Tb<sup>3+</sup> phosphor.

### 3.2 Photoluminescence (PL) Characterization:

The excitation spectra of 1% to 5%  $Tb^{3+}$ -doped  $Y_2O_3$  nanophosphors at emission wavelength of 543 nm are shown in Figure 5.

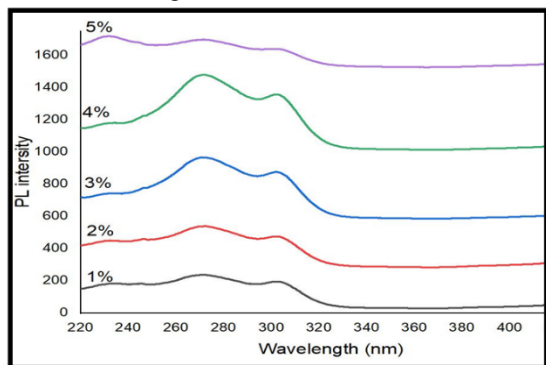


Fig. 5: Photoluminescence excitation spectra of  $Tb^{3+}$  doped  $Y_2O_3$  nanophosphors

The  $Tb^{3+}$  ions ( $4f^8$ ) as a dopant, in host,  $Y_2O_3$ , affect the luminescence properties because of its narrow green bands originating from intra  $4f$ -transitions. The excitation spectra consist of two overlapping broad bands at  $\sim 275$  and  $307$  nm. These bands are due to either charge transfer absorption or  $Tb^{3+}$  intra-band  $4f^8 \rightarrow 4f^7 5d^1$  excitation.

The emission spectra of 1% to 5%  $Tb^{3+}$ -doped  $Y_2O_3$  nanophosphors under excitation wavelength of 272 nm are shown in Figure 6.

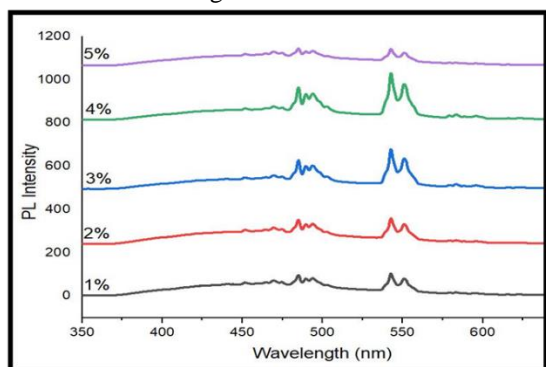


Fig. 6: Photoluminescence emission spectra of  $Tb^{3+}$  doped  $Y_2O_3$  nanophosphor

The emission spectra are complex, contains several groups of sharp lines due to electronic transitions of the  $Tb^{3+}$  ion. The  $Tb^{3+}$  ion have main emission bands due to the  $^5D_4 \rightarrow ^7F_j$  transitions where,  $j = 4, 5$  and  $6$ . The most intense, dominant and strongest transition observed at approximately 543 nm, which is characteristic of the bright green emission of  $Tb^{3+}$  ion corresponding to the  $^5D_4 \rightarrow ^7F_5$  transition, while the other peaks at 487 and 555 nm corresponds to the  $^5D_4 \rightarrow ^7F_6$  and  $^5D_4 \rightarrow ^7F_4$  respectively. The doping concentration of  $Tb^{3+}$  ion varied from 1% to 5%, where result shows that, the line positions and line widths in the emission spectra did not changed due to change in  $Tb^{3+}$  ion concentration. As the dopant

ion concentration is 5%, the optimum luminescence intensities of phosphor nanoparticles can be achieved.<sup>10</sup> Also, in this spectra slight broadened peak is observed. It indicated that some of  $Tb^{3+}$  ions might have gone to particle boundaries confirming the presence of  $Tb^{3+}$  ions in unsymmetrical environments.<sup>11</sup> Therefore, it was confirmed that, the prepared phosphors have better  $Tb^{3+}$  ion distribution and higher potential applications with continuous emission efficiency.<sup>12</sup>

#### 4.CONCLUSION

The doped nanophosphor,  $Y_2O_3:Tb^{3+}$  was successfully synthesized by homogenous co-precipitation method using  $[Y(NO_3)_3 \cdot 6H_2O]$  and  $[Tb(NO_3)_3 \cdot 6H_2O]$  as a precursor in presence of aqueous solution of oxalic acid (precipitant) and CTAB (capping agent) under controlled specific and well defined experimental conditions. The HCP method is an efficient, easy and eco-friendly approach to minimize the synthesis cost of the phosphor while the luminescent properties are retained. The crystalline cubic phased spherical nanoparticles have been identified and confirmed by XRD and FESEM analysis. The crystalline size is found to be in the nanometer range and the evidences for presence of dopant  $Tb^{3+}$  ion in a host crystal lattice have been revealed by EDX, FTIR analysis. The luminescent characteristic was found to be increased due to incorporation of  $Tb^{3+}$  ions (activator) with specific concentrations in  $Y_2O_3$  matrix. The excitation and emission spectral analysis confirms fabrication of nanosized phosphors,  $Y_2O_3: Tb^{3+}$  with bright green luminescence of 543 nm having the average nano crystalline size  $\sim 35$  nm. The brilliant luminescence characteristics make it a possible nano phosphor for display applications. Thus, this study may facilitate their employability in several manufacturing of fluorescent lamps, display devices, and bioimaging due to their photostability and biocompatibility.

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CONFLICT OF INTEREST

The Author declares no conflict of interest.

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