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Luminescence performance of europium doped yttrium oxide thin films

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Abstract

Europium doped yttrium oxide thin films have been deposited by spray pyrolysis method. The crystallite sizes are calculated \( \sim 50 \) nm using Scherrer's formula. Fourier transformed infrared spectroscopy (FTIR) reveals the broad absorption with peak at 875 cm\(^{-1}\). Surface morphology and elemental composition of the thin films are studied by field-emission scanning electron microscope (FESEM) equipped with an energy dispersive X-ray spectroscopy (EDS). The energy gap \((E_g)\) of the thin film sample is found to be \( \sim 5.37\) eV. The film exhibits photoluminescence (PL) emission at 525-550 nm, 585-601 nm, 612 nm and 620-632 nm under the excitation of 240 nm. Gamma (\(\gamma\)) irradiated films exhibits two well resolved thermoluminescent (TL) glows with peaks at 460 and 570 K. The TL glow curves are analyzed by glow curve shape method. The activation energy and the frequency factor are found to be \( \sim 0.6\) eV, \( \sim 3\times10^6\) s\(^{-1}\) for 460 K and \( \sim 0.53\) eV, \( \sim 46.72\times10^3\) s\(^{-1}\) for 570 K.

Keywords: Oxide thin film; Morphology; Energy gap; Activation energy; Photoluminescence; Thermoluminescence.
1. Introduction

Yttrium oxide (Y$_2$O$_3$) finds potential application, as a good protective coating material in a severely reactive environment because of its thermal stability, optically transparent over a wide wavelength range (0.28-8 μm), crystallographic stability up to 2325°C, high mechanical strength, high dielectric constant (k~18), high refractive index (n~2) and high band gap (~5.8 eV) and so on [1-3]. Europium doped yttrium oxide (Y$_2$O$_3$:Eu$^{3+}$) has been projected as a replacement of SiO$_2$ for dielectric films in electronic devices because of its high dielectric strength and low leakage current [4]. To develop luminescent properties, extensive research has been carried out on rare earth activated oxide phosphors due to their superiority in color purity, chemical and thermal stabilities [5, 6]. Y$_2$O$_3$:Eu$^{3+}$ is still consider as the best red oxide phosphor under the excitation wavelength of 254 nm with its tolerable atmospheric stability, reducing degradation under applied voltages and the lack of hazardous constituents seeing that opposed to sulphide phosphors [5, 7]. Y$_2$O$_3$:Eu$^{3+}$ exhibits red emission, this is merely obtainable red phosphors was being use in three band fluorescent lamps [8]. Y$_2$O$_3$:Eu$^{3+}$ has fascinated an immense arrangement of attention for using as red phosphors in fluorescent lamps, high resolution projection TVs, safety devices and low voltage displays namely cathode ray tube, plasma display panels and field emission displays [9, 10]. Y$_2$O$_3$:Eu$^{3+}$ also find its application as scintillating devices [11, 12].

Thermoluminescence (TL) is a powerful technique for the estimation of radiation doses. The energy absorbed during irradiation and the TL intensity on stimulation (heating) is proportional to the radiation flux (doses). A number of commercially accessible thermoluminescent dosimeters (TLD) are available for this purpose [13, 14]. Y$_2$O$_3$:Eu$^{3+}$ is a superior material for display and lamp applications. And, such materials
may be investigated for their probable application as TL dosimeters or scintillating detectors [15-17].

Spray pyrolysis is a conventional method for the deposition of thin films. It is a simple, low cost and creative technique for depositing oxide films over large area. Oxide thin films have been deposited by spraying and thermally decomposing solutions of the corresponding metal nitrates [18]. In spray pyrolysis, the film formation takes place by the condensation of atoms or molecules onto a heated substrate. Thus, the substrate temperature, carrier gas flow and solution flow rate play a significant role in forming the structure of the films ranging from amorphous to crystalline phase. Usually, slow reaction at lower temperatures (< 250°C) would yield foggy films due to insufficient thermal energy for the spreading of the droplets. At higher temperature (250-500°C) the evaporation and precipitate sublimation occurs in succession and the vapors diffuse towards the substrate, where they react chemically in heterogeneous gas-solid form, which can formulate make the final film. At the high temperature chemical reaction takes place prior to the vapor reaches the substrate and form the film [19].

Wherefore, Y$_2$O$_3$:Eu$^{3+}$ thin films have been deposited through modification of the spray solution by some organic additives and Lithium (Li). They make possible to generate nonporous phosphor particles. Such nonporous structure particles cause the increase of crystallinity and thereby it leading to enhance the photoluminescence (PL) and TL behavior of gamma (γ) irradiated Y$_2$O$_3$:Eu$^{3+}$ thin films. In this work we account, PL and TL studies with Li doping as flux effect in Y$_2$O$_3$:Eu$^{3+}$ thin films deposited by spray pyrolysis. Hence, these samples might be applicants for wave guide and red phosphor, and also dosimetric up to a dose of 469.5 Gy.
2. Experimental

The spray pyrolysis unit is a home-made set up consisting of a simple glass nozzle made up to spray very fine and minute droplets, when the solution was taken up by the air compressor. Thin films were deposited by spraying the solution of desired concentration on heated substrates. The following optimized parameters were fixed as preparing Y₂O₃:Eu³⁺ thin films on heated quartz and Si (111) substrate. The distance between the nozzle and the substrate is ~30 cm, the solution flow rate is ~6.0 ml/minute, the compressed air is ~46.1×10⁴ Pa and the substrate temperature is at 325±5°C.

Y₂O₃:Eu³⁺ (Y₁.₉₄Eu₀.₀₆O₃) thin films were prepared with 0.05 M concentration of (99.99 % Y₂O₃ and Eu₂O₃ sd. fine chemicals) converted in to the respective nitrate by dissolving in 1:1 nitric acid and an excess nitric acid was removed by evaporation with the help of sand bath. Complexion ability is one of the primary characteristics that a fuel should possess. In the complexion agent disodium ethylene diamine tetra acetic acid (EDTA-Na₂) is an efficient due to the presence of amine groups in the molecules. Such molecules can effectively complex the metal ions of different sizes and formulating the chemical homogeneity at the end product. The stoichiometric quantity of EDTA-Na₂ was used as chelating fuel and lithium chloride (LiCl) 15wt. % of Y₂O₃:Eu³⁺ used as flux. Further, we have chosen 0.02M concentration of N,N-Dimethyl formaamide (DMF) used as a drying control additive for filled morphology and polyethylene glycol-6000 (PEG) 1wt. % of Y₂O₃:Eu³⁺ as polymer additives to modify the shape morphology of the particles. The deposited thin film samples were annealed at 700°C for 2 hours. The films were characterized by the glancing angle X-ray diffraction (GA-XRD) Rigaku X-ray Diffractometer SEA-107, through asymmetrical diffraction geometry at a fixed grazing
incidence angle of 2°. Then only more of the thin film could be exposed (not substrate).
The Fourier-transformed infrared spectra (FTIR) were recorded using Perkin Elmer FTIR spectrometer in the range of 600-4000 cm⁻¹. The morphology and the elemental composition of the thin films were studied by field-emission scanning electron microscope (FE-SEM) equipped with an energy dispersive X-ray spectroscopy (EDS) by using, FE-SEM ULTRA-55 (KARL ZEISS) with EDS. Optical absorption spectrum was recorded using Ocean optics CCD spectrometer USB 4000. PL measurements were performed on a shimadzu spectroflourimeter (Model RF 5301 PC) equipped with 150 W xenon lamp as an excitation source. Thin films samples were irradiated with γ-rays using cobalt (⁶⁰Co). The gamma source is incorporated with a sample rotating mechanism to obtain better uniformity of dose to the samples. The control system is programmable logic controller based with touch sensitive color screen software equipped with the data recorder. Thin films samples were covered with black paper to keep away from the entry of stray light. In the present work γ-dose irradiations were carried out to the thin films in the range of 187-563 Gy at room temperature (RT). TL glow curves of the γ-irradiated Y₂O₃:Eu³⁺ thin films were recorded in the temperature range of 350-700 K at a heating rate of 5 Ks⁻¹ by using a homemade TL set up. The homemade TL set up has inbuilt small metallic plate as heating strip, temperature programmer and photomultiplier tube (RCA 931B) equipped with multimeter recorder (Rishicom).

3. Results and discussion

Figure 1(a) shows the GA-XRD patterns of Y₂O₃:Eu³⁺ thin film. The patterns are indexed according to JCPDS no. 41-1105 of cubic structure of Y₂O₃. The peak corresponds to reflection from the (211), (222) and (400) planes of Y₂O₃:Eu³⁺ thin film as
seen in Figure 1(a) are in well consistent with the JCPDS is shown in Figure 1(c). No additional peaks of other phases have been found. It indicates the substitution of ‘Li’ and ‘Eu’ ions were decomposed into Y$_2$O$_3$ completely, i.e. the Li and Eu ions have been effectively doped into the host lattice and thereby Y$_2$O$_3$:Eu$^{3+}$ thin films confirms the cubic phase. The diffraction (222) planes illustrate that the full width at half maximum (FW-HM) of the diffraction peak is narrower with high intensity in the thin film with Li doping than for the powder without Li doping as seen in Figure 1(a) and 1(b). It is evident that the Li is incorporated into the Y$_2$O$_3$ lattice serve as a self promoter for better crystallization. Further, it is observed and noticed that the asymmetric spectrum with vertex and shifted towards the small angle $\sim$ 0.5° from the peak at $\theta = 29°$ as seen in the Figure 1(a). This asymmetry with a vertex (splitting) and shifted might be due to residual stress (thermal expansion coefficient of substrate) or atomic peening effect, due to the formation of oxygen vacancies loop. This can be processed to accommodate locally the non stoichiometry of the films [3, 20]. The diffraction data reveals the (222) plane surface is the preferential orientation for films grown on substrate. The diffraction peak with higher intensity suggesting a higher degree of early crystallization growth, intensity of (222) plane peak increases, where as the intensity of (211), (400) and other planes peak decreases, which indicated that the (222) planes is the preferential orientation during the nanocrystal growth process attributable to Li doping.

The crystallites sizes of Y$_2$O$_3$:Eu$^{3+}$ film is calculated using Scherrer’s formula:

$$D = \frac{k\lambda}{\beta \cos \theta}$$

where $k=0.89$, $\lambda=0.154056$ nm represents the wavelength of Cu-K$_\alpha$ radiation, $\theta$ is the Bragg angle of the X-ray diffraction peak and $\beta$ represents the FW-HM of the diffraction
peak. The crystallites sizes are found the value of ~ 50 nm. Further, the interplanar spacing (d ~ 3.143 Å), the cell constant (a ~10.89 Å) and the particle density (ρ ~ 4.72 gcm⁻³) are calculate [20-22].

Figure 2 (a) shows the FTIR spectrum of Y₂O₃:Eu³⁺ thin film with Li recorded in the range 600-4000 cm⁻¹. The characteristic peak observed at 875 cm⁻¹ which is attributed due to the stretching frequency of Y-O. The peak at 1558 cm⁻¹ is corresponding to the covalent surface carbonate CO₃²⁻ in the substrate as seen in figure 2 (a) and (b). Figure 2(c) shows the FTIR spectrum of Y₂O₃:Eu³⁺ nanopowder without Li. The characteristic peak observed at 875 cm⁻¹ is attributed to stretching frequency of Y-O, the peak at 1435 cm⁻¹ is assigned due to the residual nitrate and organic matter in Y₂O₃:Eu³⁺ and the peak at 3415 cm⁻¹ is corresponding to the stretching mode of O-H. Further, it is noticed that the role of Li incorporate into Y₂O₃:Eu³⁺ thin film sample, the peaks at 1435 and 3415 cm⁻¹ are completely vanished consequently the peak at 875 cm⁻¹ become strong broadening in Y₂O₃:Eu³⁺ thin film with Li. It indicates that better crystallinity can be obtained [17].

Figure 3(a) shows the FE-SEM picture of Y₂O₃:Eu³⁺ thin film. The EDTA-Na₂ can chelate with metal precursors dissolved as an ionic form in water. The created chelates take part in esterification reaction with the DMF and PEG in the droplet evaporating in the oven. Then the surface precipitation of salts is suppressed and a volumetric one occurs. As a result, the filled and shape morphology may be achieved. The post heat treatment is indispensable to remove the carbon contaminants and to crystallize the amorphous phosphor. The FE-SEM image of the thin film shows its appearance as solid nonporous particles, surface consists of grains with non-uniform outgrowths in between the particles, with least agglomerate of loosely packed uniform
distribution of $\text{Y}_2\text{O}_3$ solid fine particles. The way in which grain growth took place as a
catalytic-like action played by the Li presence in $\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film. The size and shape
of solid nonporous nature of $\text{Y}_2\text{O}_3$:Eu$^{3+}$ particles directly affect the luminescent
performance [23-25]. Figure 3(b) shows the EDS spectroscopy analysis, EDS pattern
demonstrates that the elements of oxygen, yttrium and europium are rooted in the
$\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film, but the carbon and lighter element of lithium are not traced.

Figure 4(a) shows the optical absorption spectra of $\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film with Li
and $\text{Y}_2\text{O}_3$:Eu$^{3+}$ nanopowder (no Li) was recorded in the range of 190-800 nm. The spectra
reveals the absorption band for Li doping thin film with peak at 260 nm and the
absorption band with peak at 295 nm for the nanopowder (no Li). The film thickness was
measured by the gravimetric method and its value is $\sim$125 nm. The most characteristic
method to calculate the energy gap ‘$E_g$’ is the Tauc-relation:

$$\alpha E = K (E - E_g)^{\frac{1}{n}} \quad (2)$$

where ‘$E$’ is the photon energy, ‘$\alpha$’ is the optical absorption coefficient, ‘$K$’ is constant
and ‘$n$’ is dependent on the optical transition assigned a value of 2 and 1/2 for direct
allowed and indirect allowed transition respectively. The optical band gap energy of the
Li co-doped $\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film and $\text{Y}_2\text{O}_3$:Eu$^{3+}$ nanopowder (no Li) are estimated for
direct allowed transition. Since it give the best linear fitting in the band edge region. This
indicates that the allowed direct transition is responsible for the inter band transition in
$\text{Y}_2\text{O}_3$ [26]. Figure 4(b) is drawn by plotting $(\alpha E)^2$ versus ‘$E$’ in the high absorption range
for the Li co-doped $\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film. The energy gap $E_g$ is found the value of 5.37 eV
for the Li co-doped $\text{Y}_2\text{O}_3$:Eu$^{3+}$ thin film by extrapolating the linear region of the plot to
$(\alpha E)^2 = 0$, if $\alpha \neq 0$, but for the $\text{Y}_2\text{O}_3$:Eu$^{3+}$ nanopowder (no Li) $E_g$ is found the value of
5.5 eV (not shown in the figure). It is evident that the Li is rooted in the Y\(^{+}\) sites and creates oxygen vacancies, and the result in decrease the band gap of Y\(_2\)O\(_3\):Eu\(^{3+}\) thin film.

Figure 5(a) shows the PL excitation spectrum of the Y\(_2\)O\(_3\):Eu\(^{3+}\) thin film phosphor. The excitation spectrum was obtained by monitoring the \(^5\)D\(_0\)\(\rightarrow\)^7F\(_2\) transition (612 nm) of Eu\(^{3+}\). The excitation spectrum reveals the peak at 240 nm, and the same energy of wavelength is appended as the excitation wavelength [27]. Figure 5(b) shows the PL emission spectrum of Y\(_2\)O\(_3\):Eu\(^{3+}\) thin film. The film exhibits a strong red emission centered at 612 nm. The emission of Eu\(^{3+}\) consists of a broad band with a maximum at 612 nm with shoulders at 535-540 nm, 583-601 nm, 625-632 nm and 692 nm. The spectrum is due to the characteristic optical properties of Eu\(^{3+}\) ions in the cubic Y\(_2\)O\(_3\) host structure. The emission spectrum is composed of \(^5\)D\(_0\)\(\rightarrow\)^7F\(_j\) (j = 0, 1, 2, 3, 4) transition lines of Eu\(^{3+}\) with the \(^5\)D\(_0\)\(\rightarrow\)^7F\(_2\) hyper sensitive transition (612 nm) being the most prominent emission. The other emission peaks are located at 535-540 nm (\(^5\)D\(_1\)\(\rightarrow\)^7F\(_1\)), 583-601 nm (\(^5\)D\(_0\)\(\rightarrow\)^7F\(_1\)), 625-632 nm (\(^5\)D\(_0\)\(\rightarrow\)^7F\(_3\)) and 692 nm (\(^5\)D\(_0\)\(\rightarrow\)^7F\(_4\)) which is expected from the Judd-Ofelt selection rules [17, 28, 29]. On the other hand, the incorporation of Li ion into host material is an efficient way to improve luminescent performance, due to the self-promoter for an early and better crystallization. Several mechanisms are proposed for Li ion doping as flux effect, creation of oxygen vacancies, which might act as a sensitizer for the effective energy transfer due to the mixing of charge transfer states. Occupation of Y\(^{3+}\) sites by Li\(^{+}\) ions would naturally give rise to a substantial number of vacant sites in the oxygen ion array [30-37]. The crystal symmetry of Y\(_2\)O\(_3\) belongs to the cubic phase with space group Ia\(^3\) which is similar to Gd\(_2\)O\(_3\). This structure having two crystallographic different sites to the impurities (Li\(^{+}\) and Eu\(^{+}\) ions), one is C\(_2\) and the other is S\(_6\) symmetry. The effective ionic radii of Li doped Y\(_2\)O\(_3\):Eu\(^{3+}\)
thin film are 0.76, 0.94 and 0.90 Å for the Li⁺, Eu³⁺ and Y³⁺ ions respectively, Li⁺ and Eu³⁺ ions are not to occupy C₂ and S₆ sites in a statistical way, Li⁺ ions will be occupied C₂ sites with more population in the lattice. A more reduced symmetry of these sites would result in the enhanced luminescent properties [38].

Figure 6 shows the TL glow curves of Y₂O₃:Eu³⁺ (Y₁.₉₄Eu₀.₀₆O₃) thin films γ-rayed for a dose in the range of 187.8–563.4 Gy and the maximum TL glow peak intensity is observed at 469.5 Gy. TL glow curve for 469.5 Gy was deconvoluted using Origin software [17]. Two prominent and well resolved TL glows with peaks at 460 and 570 K are as shown in Figure 7. Figure 8(a) shows the deconvoluted TL glow curves of Y₂O₃:Eu³⁺ thin film after γ-irradiated for different doses in the range of 187.8–563.4 Gy. The glow peaks intensity is plotted as a function of γ-dose and it indicates that the creation of trapping centers increases with increase of γ-dose up to 469.5 Gy, further decrease with increase of γ-dose is shown in Figure 8 (b).

The supra linearity function f(D) is defined as:

\[ f(D) = \left( \frac{F(D)}{F(D_1)} \right) \left( \frac{(D)}{(D_1)} \right) \] (3)

where ‘F(D)’ is the TL intensity at a dose ‘D’ and ‘D₁’ is a low dose at which the TL response is linear. If f(D)=1 the region is linear, if f(D)>1 is supra linear and f(D)<1 sub linear. The supra linearity function f(D) is calculated at the region (i) is linear f(D) ~ 1, for the two glow peaks [17, 39].

The effective atomic number ‘Z_{eff}’ has been defined as:

\[ Z_{eff} = \sqrt{\sum_i a_i z_i^{m_i}} \] (4)
where ‘a_i’ is the fractional electron content of element ‘i’ with atomic number ‘z_i’. The value of ‘m’ will typically range from 3 to 4, with 3.5 a logical value. ‘Z_{eff}’ of Y_2O_3:Eu^{3+} thin film sample is calculated to be ~ 38.16 [40]. TL glow curves are analyzed based on glow curve shape method. A typical result for a glow curve γ-rayed for 469.5 Gy is shown in Figure 9. The order of kinetics of glow curves are calculated by measuring the symmetry factor μ_g ~ 0.48 [μ_g = δ/ω (0.48), (δ/ τ) = 0.93 for 460 K] and μ_g ~ 0.49 [μ_g = δ/ω (0.49), (δ/ τ) = 0.97 for 570 K]. The values of τ, δ and ω are calculated, where ‘τ’ is the low-temperature half width of the glow curve i.e. τ=T_m-T_1, ‘δ’ is the high temperature half width of the glow curve i.e. δ= T_2-T_m and ‘ω’ is the full width of the glow peak at its half height i.e. ω=T_2-T_1. From the values of the geometrical factor it is clear that the two glow peaks obey the general order kinetics. The trap depth also known as the activation energy of the luminescence centers is calculated using Chen’s equation.

$$E_α = c_α \left( \frac{kT_m^2}{α} \right) - b_α \left\{ 2kT_m \right\}$$

where ‘k’ is Boltzmann constant, ‘T_m’ is the glow peak temperature. The constants ‘c_α’ and ‘b_α’ are also calculated by the Chen’s equation [41, 42].

The frequency factor is given by

$$\frac{βE}{kT_m^2} = Se^{-\frac{E}{kT_m}}$$

The mean activation energies and the frequency factors are found and the values are ~ 0.6 eV, ~3×10^6 s^{-1} at 460 K and ~ 0.53 eV, ~6.72×10^3 s^{-1} at 570 K.
4. Conclusions

Y$_2$O$_3$:Eu$^{3+}$ thin films have been deposited by spray pyrolysis. GAXRD patterns of Y$_2$O$_3$:Eu$^{3+}$ thin films confirms the cubic phase with (222) planes. The crystallite sizes and the particle density are found and the respective values are $\sim$ 50 nm and $\sim$ 4.72 gcm$^{-3}$. FTIR spectrum reveals the broad absorption with peak at 875 cm$^{-1}$. The FE-SEM image shows its appearance as solid nonporous fine particles structure with less agglomerate of loosely packed uniform distribution. The energy gap of Y$_2$O$_3$:Eu$^{3+}$ thin film is found the value of 5.37eV. PL emission spectrum is analyzed and the emission peak at 612 nm. TL glow curves are analyzed and the trap depth for the luminescent centers at 460 K and 570 K. The $\gamma$-irradiated Y$_2$O$_3$ thin films perform a good TL response up to the $\gamma$-irradiation dose of 469.5 Gy. Hence, Li co-doped Y$_2$O$_3$:Eu$^{3+}$ sprayed thin films are applicants for red phosphor and dosimetric.

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References


Figure captions

**Figure 1.** XRD spectrum of (a) Y$_2$O$_3$:Eu$^{3+}$ thin film, (b) Y$_2$O$_3$:Eu$^{3+}$ powder and (c) JCPDS patterns of Y$_2$O$_3$.

**Figure 2.** FTIR spectrum of (a) Y$_2$O$_3$:Eu$^{3+}$ thin film with Li, (b) Empty substrate and (c) Y$_2$O$_3$:Eu$^{3+}$ nanopowder.

**Figure 3.** (a) FESEM photograph of Y$_2$O$_3$:Eu$^{3+}$ thin film and (b) EDS pattern of Y$_2$O$_3$:Eu$^{3+}$ thin film.

**Figure 4.** (a) Optical absorption of Y$_2$O$_3$:Eu$^{3+}$ thin film and nanopowder and (b) Variation of ($\alpha E$)$^2$ with photon energy.

**Figure 5.** (a) Photoluminescence excitation spectrum of Y$_2$O$_3$:Eu$^{3+}$ thin film and (b) Photoluminescence emission spectrum of Y$_2$O$_3$:Eu$^{3+}$ thin film.

**Figure 6.** Thermoluminescence glow curves of Y$_2$O$_3$:Eu$^{3+}$ thin film for different $\gamma$-dose.

**Figure 7.** Deconvoluted TL glow curves of Y$_2$O$_3$:Eu$^{3+}$ thin film.

**Figure 8.** (a) TL glow curves curve of Y$_2$O$_3$:Eu$^{3+}$ thin film for different $\gamma$-dose and (b) Variation of glow peak intensity with $\gamma$-dose.

**Figure 9.** Representative diagram of different parameters used in the analysis of glow-curve shape method.
Figure 1.
Figure 2.
Figure 3.
Figure 4.

- Thin film $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$
- Powder $\text{Y}_2\text{O}_3:\text{Eu}^{3+}$

Absorption (a.u.)

Wavelength (nm)

Energy (eV)

$E_g = 5.37 \text{ eV}$
Figure 5.
Figure 6.

$Y_2O_3:Eu^{3+}$ thin film γ-rayed for:
- 187.8 Gy
- 281.7 Gy
- 375.6 Gy
- 422.55 Gy
- 469.5 Gy
- 516.45 Gy
- 563.4 Gy

TL Intensity (a.u.) vs Temperature (K)
Figure 7.

469.5 Gy γ-rayed Y$_2$O$_3$:Eu$^{3+}$ thin film

TL Intensity (a.u.)

Temperature (K)

460 K

570 K
Figure 8.
Figure 9.

469.5 Gy γ-rayed Y$_2$O$_3$:Eu$^{3+}$ thin film
Highlights

- $Y_2O_3:Eu^{3+}$ thin films deposited by spray pyrolysis.
- [222] planes are preferential orientation during crystal growth.
- The FE-SEM shows the particles appear as nonporous in nature.
- The energy gap of $Y_2O_3:Eu^{3+}$ film is found the value $\sim 5.37$ eV.
- Thermoluminescence centres at 460 K and 570 K glow peaks are calculated.