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Thermoluminescence Study of Y_2O_3: Tb

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Abstract

Nanophosphors were prepared by the combustion technique using yttria and terbia powder as precursors and urea as fuels. The particle is investigated by X-ray diffraction analysis. X-ray diffraction patterns confirm the formation of pure cubic phase of Y_2O_3 .The resulting product was characterized by FTIR spectra to evaluate the vibrational feature of the sample. TL emission spectra show intense peak around 520 nm.

Keywords: Nanophosphors, Y2O3, combustion method. PACS: 78.60.Kn

INTRODUCTION

Over past few years, the synthesis and characterization of nanomaterials have attracted much attention in display and lighting technology. Nanostructured materials possess properties, which are often uniquely different from those exhibited by their macroscopic counterparts due to perturbations of the electronic distribution induced by reduced dimensionality. The development of nanocrystalline phosphors has become pivotal due to the ever-shrinking size of today's technology.

In particular, this oxide is chosen as host because it is characterized by a low-phonon frequency, which makes the non-radiative relaxation of excited states inefficient. Moreover, it has excellent refractory properties with a melting point of 2450 °C and a high thermal conductivity [1].

As regards the doping ions, REs are considered to be the most promising elements as activator of nanophosphors since they have particular optical properties because of their special electronic configuration. The characteristic luminescence of RE ions is attributed to the 4f shell, which is not entirely filled [2].

Particular attention has been drawn to trivalent Tb ions ($4f^8$) as a doping element in hosts as yttrium or gadolinium oxide because of its narrow green bands originating from intra 4f-transitions. Soo et al.,[3] investigated the local structure of Tb-doped Y_2O_3 nanocrystals. Meng et al [4] reported the influence of size confinement on the energy transfer between Tb^{+3} ions in Y_2O_3 nanopowders.

Incorporation of rare earth in the nanocrystalline yttrium oxide matrix can be done by several techniques, such as the, polyol method [5], hydrothermal [6, 7], liquid phase reaction [8], aerosol pyrolysis [9], and sol–gel techniques [10], Pechini method [11]. In recent works, Combustion method has been successfully used in the synthesis of dielectrics networks doped with respect to prepare luminescent powder materials [1, 12-15].

EXPERIMENTAL DETAILS

In this study Europium oxide (99.99%), Yttrium nitrate (99.99%), nitric acid, urea (90%) were used as starting raw material. To prepare Y_2O_3:Tb^{+3}, $RE(NO_3)_3$ stock solutions was prepared by dissolving Tb_2O_3 in nitric acid .These two solution of $Y(NO_3)_3$ and $Tb(NO_3)_3$ were mixed according to the formula $(Y_{.95}Tb_{.05})_2O_3$ in a beaker and then a suitable amount of urea was added. A urea to metal nitrate was employed to prepare the precursor solution. Finally this sample was transferred to crucible and fired in a furnace at 600⁰C.The Synthesis reaction is

$$(2-2x)\ Y(NO_3)_3 + 2x\ Tb(NO_3)_3 + 5NH_2CONH_2 \rightarrow (Y_{1-x}Tb_x)_2O_3 + 5CO_2 + 8N_2 + 10H_2O$$

The morphologies and sizes of the Tb doped Y_2O_3 were determined by X-ray diffraction studies with Cu Kα radiation (λ=1.5418 A°).XRD data were collected over the range 20°-80° at room temperature. The X-ray diffraction patterns have been obtained from X-ray powder diffractometer. The particle size was determined using the sherrer's formula. The Shimatzu 1700 UV-VIS spectrometer is used to obtain the optical absorption spectra of Eu doped Y_2O_3. For recording TL, samples were exposed to UV radiations at different time. TL glow curves were recorded with the help of TLD reader (Model 1009I).TL spectra were recorded by using interference filters. FTIR spectra was also recorded to evaluate the vibrational feature of the sample.

RESULTS AND DISCUSSION

Morphological Analysis

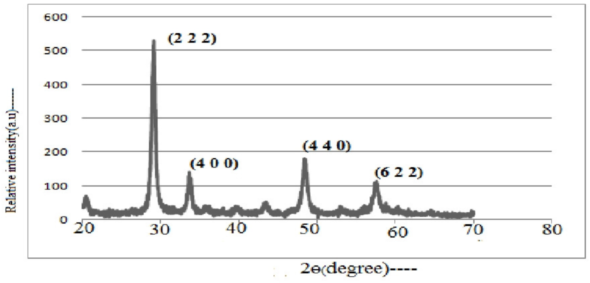

Fig1. XRD pattern of Y_2O_3:Tb

Fig.1 presents the XRD result for nanophosphor Y_2O_3: Tb. Four different peaks are obtained at 2ϴ values of 29.12⁰ , 33.78 °, 48.46° and 57.56 ° and the peaks correspond to diffraction at (222),(400) , (440) and (622) planes, respectively .The spectrum clearly shows the expected body centered cubic crystalline phase for the nanopowders in agreement with (ICSD #160890). Crystallite size estimated based on a simple Debye scherrer method yield value of around 15 nm.

Optical Absorption Spectra

The study of optical absorption is important to understand the behavior of nano-crystals. A fundamental property is the band gap-the energy separation between the filled valence band and the empty conduction band. Optical excitation of electrons across the band gap is strongly allowed, producing an abrupt increase in absorption at the wavelength corresponding to the band gap energy. This feature in the optical spectrum is known as the optical absorption edge.

Fig. 2 shows the absorption spectra of Y_2O_3: Tb phosphor in the range of 190 nm -700 nm. The absorption edge is found at 223 nm. The band gap was calculated corresponding to absorption edge (223 nm). The band gap was found to be 5.5eV for Y_2O_3: Tb phosphors.

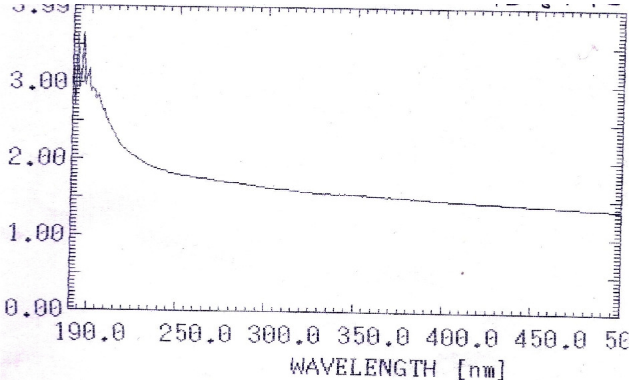

Fig 2. Absorption spectra of Y_2O_3: Tb phosphors

FTIR Analysis

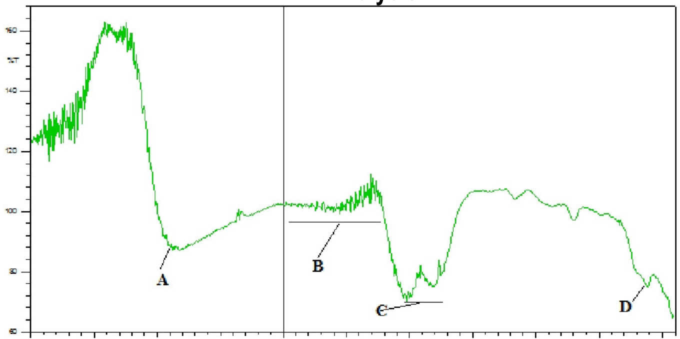

Fig 3. FTIR spectra of Y_2O_3: Tb

FTIR spectra of Y_2O_3: Tb that was synthesized at the heating temperature peak of 600°C is shown in Figure 3. A broad peak (A) at around 3000 cm^{-1} is originated from O-H stretching in hydroxyl groups. Overtone or combination band [B] located in the range 2000–1650 cm^{-1} [16]. Absorption at around[C]

1500– 1350 cm^{-1} might originated from C-H bend and C-C stretching, around 562 cm^{-1} from Y-O stretching [D] [17]. The absorption peaks resulted by bonding of metal ions usually appears at short wave numbers [18].

Thermoluminescence Process

Fig. 4 shows the TL glow curve of UV-irradiated Y_2O_3: Tb nanophosphor for different irradiation time. The TL glow curve show single peak at 297°C. It is seen that the TL intensity increase with increasing irradiation time. The terbium-doped yttria phosphor presents a TL glow curve with one peaks (T_{max}) centered around 297°C. Tb^{3+} ion acts as a recombination center affecting the TL response of the Y_2O_3 material. As the particle become smaller, ions at the surface are not saturated in coordination. Electrons or holes may be excited easily and escape from the ions and they are trapped at surface states located in the forbidden gap. When the sample is heated the electrons are de-trapped and their subsequent recombination with holes gives rise to the light emission. . The TL intensity is increased for higher exposed time because the new trapping center is created by increasing exposure time of UV radiation. The trapping centers provide energy states available between valance band and conduction band responsible for radiative recombination. As the radiation dose is increased the color centers increase so initially the intensity increase with increasing UV dose. After the color center get saturated so that TL intensity saturated for higher UV dose.

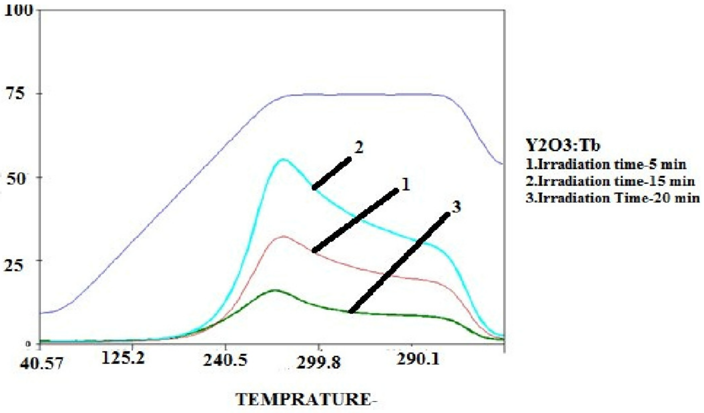

Fig 4. TL glow curve of UV-irradiated Y_2O_3: Tb

Calculation of Kinetic parameters

The activation energy of Y_2O_3: Tb phosphor is calculated by Initial rise method.

Initial Rise Method

The method is based on the fact that as the glow curve initially begins to rise, the density of unoccupied recombination centers and the density of trapped electrons remain approximately constant, and hence the TL intensity is strictly proportional to exp(-E/kT).

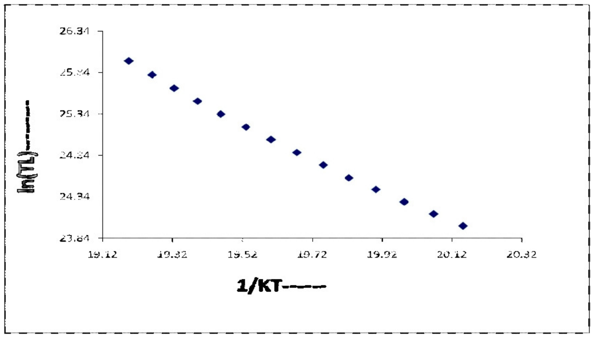

Fig 5. ln(TL) versus 1/KT graph to determine activation energy for maximum

TL peak

Fig. 5 show graph of ln (TL) Vs 1/KT for maximum TL glow peak of fig 4. In applying initial rise method, a straight line is obtained .From the slope of line, activation energy E is evaluated for Y_2O_3: Tb nanophosphors for 15 min irradiation time. The activation energy of Eu doped Y_2O_3 is found 1.64 eV.

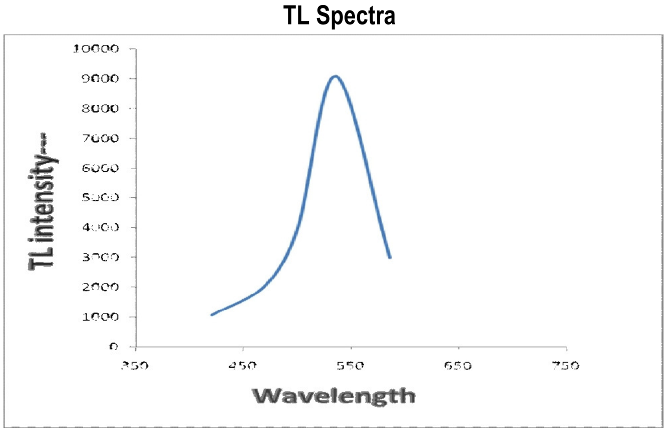

Fig 6. TL spectrum of Y_2O_3: Tb

Figure 6 shows the TL spectrum of Y_2O_3: Tb ranges from 300 to 700 nm. The emission band was observed at 520 nm in green region of the spectrum.

CONCLUSION

We have investigated the Thermoluminescence phenomena in the Y_2O_3: Tb (5 mol %) phosphor prepared with combustion synthesis. The TL properties of Tb doped Y_2O_3 nanophophor has been investigated for UV irradiation and it is seen that at a particular irradiation time 15 min high intensity of glow peak was found. From optical absorption edge, the band gap energy was found to be 5.5 eV for Y_2O_3: Eu. TL spectrum of Y_2O_3: Tb shows the emission band at 520 nm in green region of the spectrum.

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