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Synthesis, characterization and thermoluminescence studies of $Y_2O_3:Sm^{3+}$ nanophosphor

J.R. Jayaramaiah[a,b], B.N. Lakshminarasappa[a*], B.M. Nagabhushana[c]

[a]Department of Physics, Bangalore University, Bangalore-560 056
[b]Department of Physics, Government First Grade College, Hangal-581 104
[c]Department of Chemistry, M.S. Ramaiah Institute of Technology, Bangalore-560 054

1. Introduction

Nanoparticles have an immense interest in anticipation that this unexplored range of material dimensions will yield size-dependent properties. The physical and chemical properties vary drastically with size, which clearly represents a fertile field for materials research [1-3]. Among the various nanomaterials, luminescent nanoparticles have attracted increasing technological and industrial interest because of their optical and luminescence properties [4, 5].

Solution combustion is a wet-chemical method which does not require further calcinations and repeated heating. It is an exothermic reaction and occurs with the evolution of heat and light. Such a high temperature leads to growth of nanocrystalline materials. In any solution combustion fuel and oxidizer are required. When the mixture of fuel and oxidizer are ignited, combustion takes place. For the synthesis of oxides, metal nitrates are used as oxidizer and hydrazine based compounds are employed as fuels [6, 7].

Yttrium oxide has attracted much attention because of several physical properties (high k:10-18), wide band gap (~5.5 eV), high refractory properties with melting point (~2450 ^{0}C), high thermal conductivity (~33 $Wm^{-1}K^{-1}$), high refractive index (~2), wide transmission range (280-8000 nm) [8]. Rare earth doped solid state materials have become an important class of solids attracting much attention among researches, as is evidenced by the literature survey. The electronic energy of the 4f compounds (RE ions) have become a subject of enduring interest as they are useful as a spectral probe to study the perturbation effects in a host lattice and they are not much affected by the crystal field due to there inner $4f^n$ shell [9]. The spectroscopic investigations of the energy levels of Sm^{3+} ions doped in different hosts have been reported [10, 11]. In this work we report on self propagating low-temperature (<350^{o}C) Solution combustion synthesis of $Y_2O_3:Sm^{3+}$ nanoparticles using EDTA-Na_2 as fuel and to estimate the band gap energy and also the TL properties.

2. Experimental

Nanophosphor $Y_2O_3:Sm^{3+}$ was prepared by 'solution combustion synthesis'. Yttrium oxide (99.99%, sd.fine-chem), samarium oxide, nitric acid and EDTA-Na_2 were used as starting raw materials to prepare $Y_2O_3:Sm^{3+}$. The samples were characterized by the powder X-ray diffraction. The morphology was studied by scanning electron microscopy. The Fourier-transformed infrared absorption spectra were recorded using Nicollet Magna 550 spectrometer with KBr pellets in the range of 400 - 4000 cm^{-1}. The energy gap was calculated using ELICO (SL -159) UV-VIS spectrophotometer. The TL glow curves of $Y_2O_3:Sm^{3+}$ were recorded with an home made TL set up consisting of a small metallic heating strip, temperature programmer, photomultiplier tube (931B) and a multimeter recorder (Rishicom) at a heating rate of 5^oCs^{-1}. Then the TL glow curves obtained above were deconvoluted using Origin software.

3. Results and discussion

The samples of $Y_2O_3:Sm^{3+}$ were prepared by solution combustion technique. Stoichiometric amounts of Y_2O_3 and Sm_2O_3 were converted into nitrate by dissolving in 1:1 nitric acid and excess nitric acid was removed by evaporation on a sand bath. The Stoichiometric amount of EDTA-Na_2 was dissolved in double distilled water, the solution was poured in to the crystalline dish and the solution was placed in a muffle furnace. The temperature was maintained at<350^oC. The reaction mixture underwent thermal dehydration and ignited at one spot with liberation of gaseous products such as oxides of nitrogen and carbon. The combustion propagated throughout the reaction mixture without further need of any external heating, as the heat of reaction is sufficient for the decomposition of the redox mixture. The process was completed in about 5 minutes and resulted in voluminous nano powder.

The characterization of the combustion synthesized $Y_2O_3:Sm^{3+}$ in the present study was carried out using PXRD. Figure1 shows the PXRD patterns obtained for the sample. From the patterns, the peaks are in good agreement with the JCPDS No.41-1105. It is clear that the ambient phase of the sample studied is cubic single-phase nanoparticles. The crystallites sizes were found to be in the range 16-20 nm, inter planar spacing d=3.07 Å, cell constant a=10.634 Å and particle density ρ=5.068 g cm^{-3} were found [12, 13].

Figure 2 shows the SEM picture of $Y_2O_3:Sm^{3+}$ indicates the spatial structure, fluffy, crispy with pores and voids with loosely agglomerated particles. The morphologies of the synthesized sample depend on the nature and concentration of organic fuel. During combustion yttrium nitrate impregnates into the polymeric product and gets ignited. Heat dissipates by the evolution of gaseous products in minimization and thus it leads to localization of heat due to the polymeric nature of the fuel [14]. The characteristic peaks at 875, 568 cm^{-1} are due to stretching frequency of Y-O. The peak at 1434 cm^{-1} due to residual nitrate and organic matter in Y_2O_3 and the broad peak at 3414 cm^{-1} was corresponding to the stretching mode of O-H from the water crystallization in the complex [15, 16].

Figure 3(a) shows the optical absorption of combustion synthesized $Y_2O_3:Sm^{3+}$ recorded in the range 190-1000 nm. Figure 3(b) was obtained by plotting '$(\alpha E)^{2'}$ versus 'E' in the high absorption range and energy gap E_g was found to be 6.05 eV followed by extrapolating the linear region of the plots to $(\alpha E)^2 = 0$, if $\alpha \neq 0$, where 'E' is the photon energy and 'α' is the optical absorptions coefficient [17].

Figure 4 shows the deconvoluted TL glow curves of γ- irradiated $Y_2O_3:Sm^{3+}$ for doses in the range from 1.116 – 3.906 kGy in the temperature range 350 – 650 K. This behaviour of the sample is useful for dosimetric application. Each of these TL glow curves are analyzed based on glow curve shape method modified by Chen`s [18]. A typical result for a glow curve γ- rayed for 3.35 kGy is shown in Figure 5. The order of kinetics of glow curves are calculated by measuring the symmetry (geometrical) factor $\mu_g \sim 0.48$ ($\mu_g = \delta/\omega$). The values of τ, δ and ω were calculated, where 'τ' is the low-temperature half width of the glow curve i.e. $\tau = T_m - T_1$, 'δ' is the high-temperature half width of the glow curve i.e. $\delta = T_2 - T_m$ and 'ω' is the full width of the glow peak at its half height i.e. $\omega = T_2 - T_1$. From the values of the geometrical factor it is clear that the two glow peaks obey the general order kinetics. The trap depth i.e. the activation energy of the luminescence centers was calculated using Chen`s equation [19].

4. Conclusions

$Y_2O_3:Sm^{3+}$ nanoparticles have been prepared by the EDTA-Na_2 assist combustion technique at low temperature and in a very short time. PXRD pattern confirms the cubic phase. The crystallite size ~18 nm, the particle density 5.068 gcm^{-3}, the cell constant a=10.634 Å and the interplanar spacing d=3.07 Å were found. The SEM pictures indicated the spatial structure, fluffy, crispy with pores and voids with loosely agglomerated particles. The energy gap of $Y_2O_3:Sm^{3+}$ synthesized in the present work was found to be 6.05 eV. Combustion synthesized $Y_2O_3:Sm^{3+}$ nanophophor shows good TL response with general order kinetics. TL glow curves were analyzed. The mean activation energy and the frequency factor were found to be 0.933 eV and 0.099 GHz.

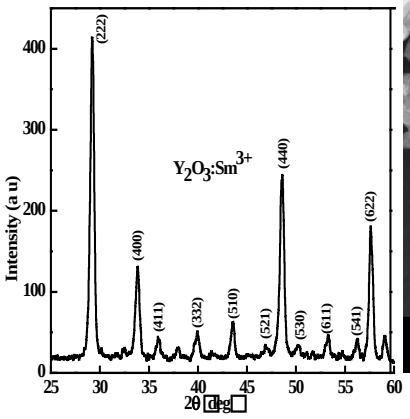

Figure 1

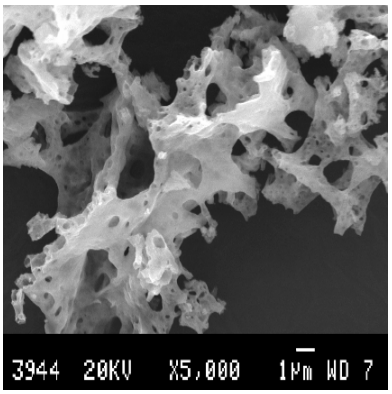

Figure 2

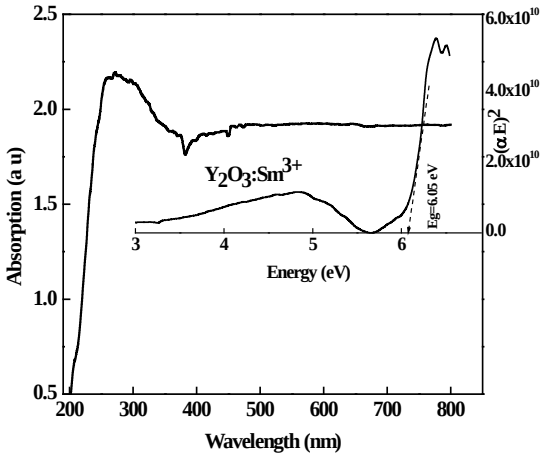

Figure 3

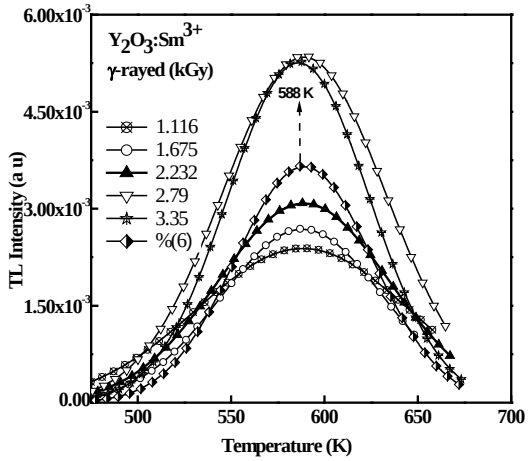

Figure 4

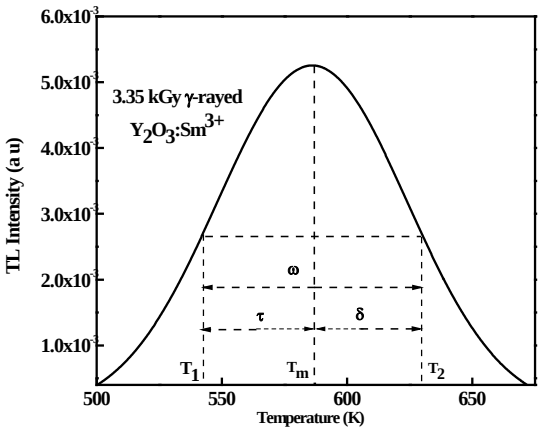

Figure 5

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