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Synthesis characterization and luminescence studies of gamma irradiated nanocrystalline yttrium oxide

N.J. Shivaramu [a], B.N. Lakshminarasappa [a,*], K.R. Nagabhushana [b], Fouran Singh [c]

[a] Department of Physics, Jnanabharathi Campus, Bangalore University, Bangalore 560 056, India
[b] Department of Physics (S & H), PES University, Bangalore 560085, India
[c] Inter University Accelerator Centre, P.O. Box No. 10502, New Delhi 110 067, India

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ABSTRACT

Nanocrystalline Y_2O_3 is synthesized by solution combustion technique using urea and glycine as fuels. X-ray diffraction (XRD) pattern of as prepared sample shows amorphous nature while annealed samples show cubic nature. The average crystallite size is calculated using Scherrer's formula and is found to be in the range 14–30 nm for samples synthesized using urea and 15–20 nm for samples synthesized using glycine respectively. Field emission scanning electron microscopy (FE-SEM) image of 1173 K annealed Y_2O_3 samples show well separated spherical shape particles and the average particle size is found to be in the range 28–35 nm. Fourier transformed infrared (FTIR) and Raman spectroscopy reveals a stretching of Y–O bond. Electron spin resonance (ESR) shows V^- center, O_2^- and Y^{2+} defects. A broad photoluminescence (PL) emission with peak at ~386 nm is observed when the sample is excited with 252 nm. Thermoluminescence (TL) properties of γ-irradiated Y_2O_3 nanopowder are studied at a heating rate of 5 K s^{-1}. The samples prepared by using urea show a prominent and well resolved peak at ~383 K and a weak one at ~570 K. It is also found that TL glow peak intensity (I_{m1}) at ~383 K increases with increase in γ-dose up to ~6.0 kGy and then decreases with increase in dose. However, glycine used Y_2O_3 shows a prominent TL glow with peaks at 396 K and 590 K. Among the fuels, urea used Y_2O_3 shows simple and well resolved TL glows. This might be due to fuel and hence particle size effect. The kinetic parameters are calculated by Chen's glow curve peak shape method and results are discussed in detail.

1. Introduction

Nanoparticles (NPs) are great scientific interest because they act as a bridge between bulk materials and atomic or molecular structures. A bulk material exhibits a steady state of physical properties regardless of its size. But, at the nanoscale, this is often not the case due to quantum confinement and/or high surface to volume ratio. High surface to volume ratio reduces the melting temperature of NPs. The properties of NPs can be modified by engineering their size, morphology and composition. It has been shown that various properties such as electrical, mechanical, optical, magnetic, etc. are highly influenced by the fine grained structure with improved properties. Quantum confinement of electrical carriers within NPs plays a vital role in transfer of energy and charge over nanoscale [1]. The materials on such scale have attracted many researchers in various fields of material science, biological science, etc. [2,3]. Currently the importance of nanomaterials in the field of luminescence has been increased. They have potential application such as display materials, tricolor lamps, solar energy converters, sensors, optical amplifier and thermoluminescent dosimeters [2–4].

Numerous techniques such as sol gel [5], co-precipitation [6], solid state reaction [7], hydrothermal [8] and solution combustion [9–11] have been reported for synthesis of nanomaterials. Among these, solution combustion method has greater advantages since it produces crystalline materials at low temperature with high surface to volume ratio. In addition, it has other advantages like high purity, homogeneity, control over stoichiometry and substitution of desired amount of dopants. It has been reported that, the luminescence properties of the as-formed nanoparticles are dependent on the nature of the fuel used in combustion method as it controls the particle size and morphology of the combustion products [12].

Mukherjee et al., studied the morphology and luminescence properties of combustion synthesized Y_2O_3:(Eu,Dy,Tb) nanoparticles using various fuels namely, glycine, phenyl alanine, arginine, glutamic and aspartic acids. They observed that glycine and arginine based nanoparticles exhibit smooth surface and improved luminescence properties when compared to those prepared using other amino acids (fuels) [12]. Ramakrishna et al. reported the effect of different fuels viz diformyl hydrazine (DFH), sugar and urea on structural, photo and thermoluminescence properties of combustion synthesized Y_2SiO_5 nanopowders. SEM micrographs of DFH fuel used sample showed almost spherical shape with agglomerated particles. The TL intensity is found to be higher in DFH used samples when compared to sugar and urea used

* Corresponding author.
E-mail address: bnlnarasappa@rediffmail.com (B.N. Lakshminarasappa).

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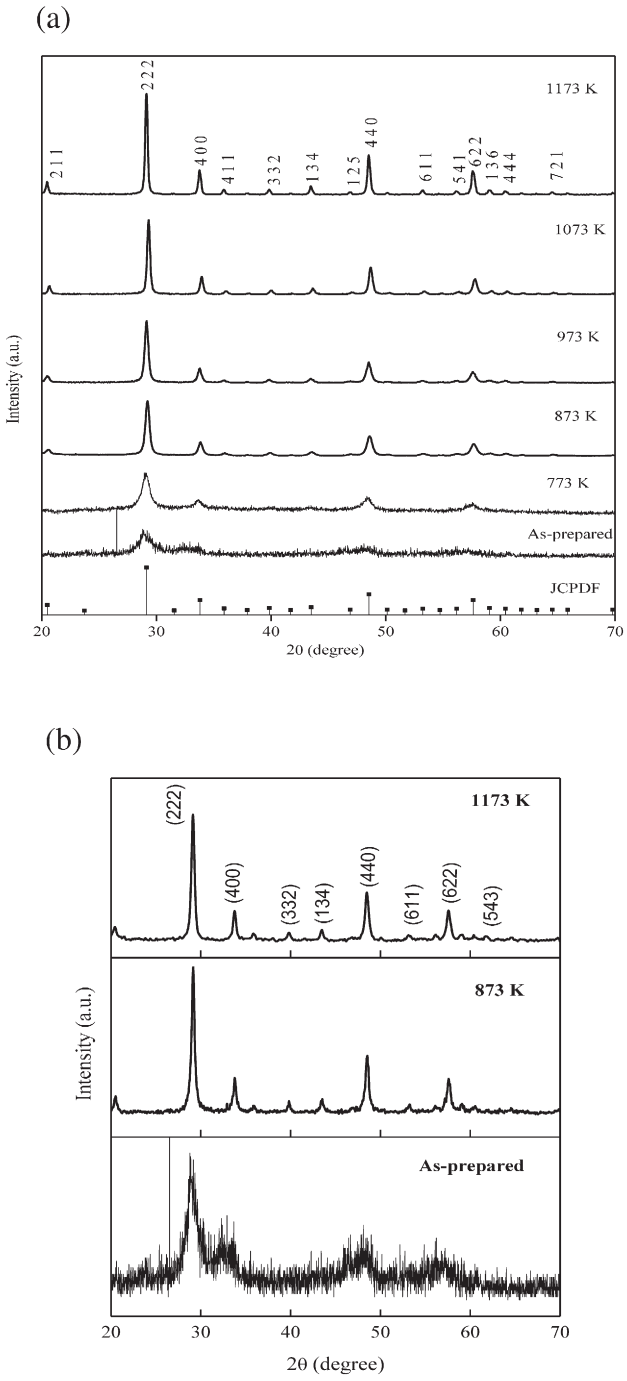

Fig. 1. (a) XRD patterns of U:Y_2O_3 as a function of annealing temperature. (b) XRD patterns of G:Y_2O_3 as a function of annealing temperature.

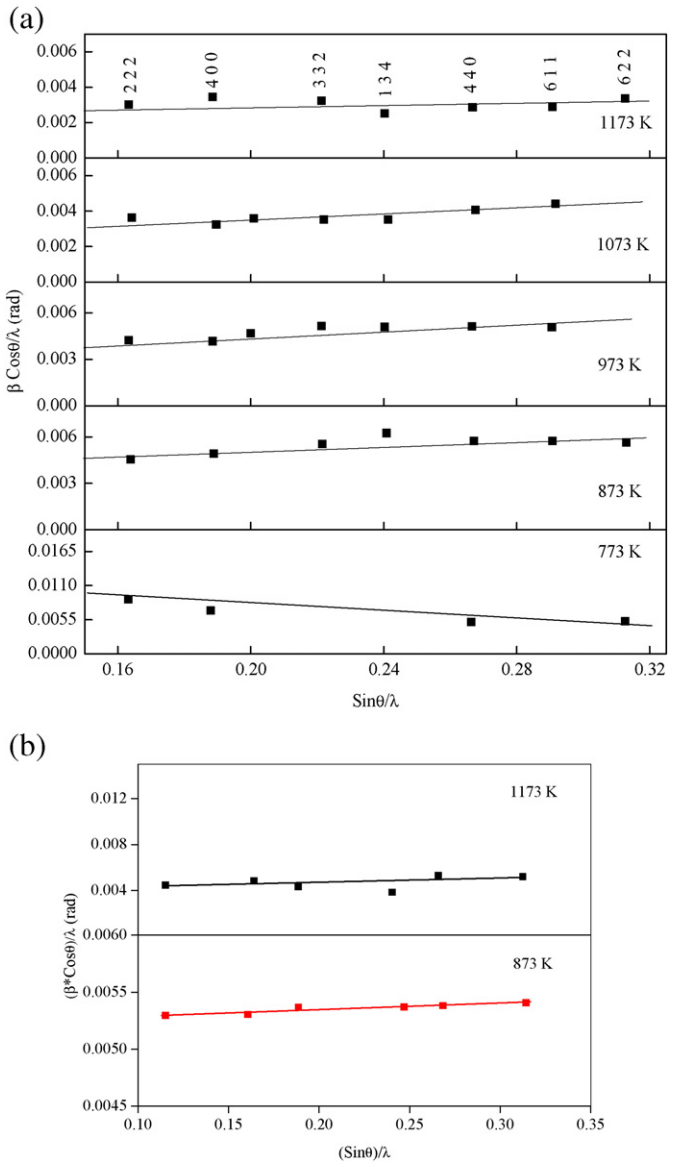

Fig. 2. (a) W–H plot for the combustion synthesized pure U:Y_2O_3. (b) W–H plot for the combustion synthesized pure G:Y_2O_3.

samples under UV and gamma irradiation. They concluded that DFH used Y_2SiO_5 indicates better dosimetric properties [13]. However, efforts are still being made for improving the TL dosimetric properties by using different fuels. TL technique has attracted many researchers from all over the world since this technique is simple and finds wide applications in various fields such as radiation therapy, space research, geology, archeology and other related areas [14–16].

Table 1
XRD structural parameters of U:Y_2O_3 and G:Y_2O_3 annealed at different temperatures.

Fuels	Annealed temperature (K)	Crystallite size (D) (nm)		Lattice constant a, (Å)	Cell volume (Å^3)	Density, ρ (gm cm^{-3})	Dislocation Density δ ($\times 10^{15}$)	Inter-planar space in at. (222) (Å)	Lattice strain (%)	
		Debye Scherer	W–H method						W–H method	Calculated
Urea	773	14.40	10.54	10.590	1187.68	5.052	4.823	3.057	−0.74	0.339
	873	16.68	25.13	10.596	1189.80	5.042	3.594	3.059	0.34	0.176
	973	18.94	26.82	10.603	1192.06	5.033	2.788	3.061	0.28	0.163
	1073	24.50	32.46	10.609	1193.95	5.025	1.666	3.062	0.22	0.140
	1173	29.42	37.31	10.612	1195.07	5.020	1.155	3.063	0.08	0.117
Glycine	873	15.2	19.1	10.590	1187.68	5.052	4.33	3.057	0.09	0.21
	1173	19.2	25.0	10.596	1189.80	5.042	2.71	3.059	0.07	0.18