Materials Research Bulletin 94 (2017) 113–121

Contents lists available at ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Synthesis and thermoluminescence studies of γ-irradiated Dy^{3+} doped $SrGd_2O_4$ phosphor

Jyoti Singh[a], J. Manam[a,*], Fouran Singh[b]

[a] Department of Applied Physics, Indian Institute of Technology (Indian School of Mines), Dhanbad, 826004, India
[b] Inter University Accelerator Center, New Delhi, 110067, India

ARTICLE INFO

Article history:
Received 21 March 2017
Received in revised form 9 May 2017
Accepted 26 May 2017
Available online 29 May 2017

Keywords:
A. Oxides
B. Luminescence
D. Defects
D. Phosphors

ABSTRACT

Dy^{3+} doped $SrGd_2O_4$ phosphors were synthesized via homogeneous precipitation cum auto-combustion method for the first time. Orthorhombic phase formation and granular morphology of $SrGd_2O_4$: Dy^{3+} samples were investigated through X-ray diffraction (XRD) and microscopic studies. Thermoluminescence (TL) characteristics of $SrGd_2O_4$: Dy^{3+} phosphors were taken after exposure of ^{60}Co γ-rays. The TL glow curve of as-prepared phosphors was well-resolved into five peaks 114 °C, 161 °C, 198 °C, 248 °C, and 293 °C by using computerized glow curve deconvolution program. The effect of impurity (Dy^{3+}) contents and heating rates for the TL glow curves were also studied. The linear behaviour of as-formed $SrGd_2O_4$: Dy^{3+} samples are observed within a wide range of dose of 80 Gy–2 kGy. Fading characteristics of $SrGd_2O_4$: Dy^{3+} phosphor was studied over the duration of 30 days. A comparative study was done to estimate different trapping parameters by employing Chen's peak shape method and CGCD simulation of TL glow curves.

1. Introduction

The phenomenon of thermoluminescence (TL) takes place when the irradiated insulating crystals store a fraction of deposited energy at the defect centres or colour centres and after heating the crystals, this stored energy is released in the form of visible light [1]. Under certain limitations, the radiation dose absorbed through the crystal is directly proportional to the amount of light emitted, thus TL phenomenon provides the basis of radiation dosimetry methods [2–8]. In the radiation dosimetry, the TL phosphors are utilized as a passive dosimeter for monitoring the integrated radiation doses obtained from various sources. Linear dose response, low fading, radiation resistant, simple TL profile, less dependence on the energy of irradiation, high chemical robustness, and high sensitivity are essential requirements for materials used for dosimetric applications. In order to fulfil all these requirements, doped materials are preferred as TL phosphors because a single host does not hold all these characteristics very often [8–12]. The appropriate combination of host-dopant and optimization of luminescent centres incorporated in the host lattice plays an important role in making sensitive phosphors [1–15]. TL responses of rare-earth doped oxide matrices are extensively studied due to their high chemical stability, wide range radiation dose response, less fading and high sensitivity to very small doses [3,6–8].

The thermoluminescence properties of doped/co-doped sulphate based matrices such as $CaSO_4$, $BaSO_4$ and $MgSO_4$ have been studied extensively [2,5]. Nowadays, LiF: Ti, Mg, α-Al_2O_3: C and $CaSO_4$: Dy materials are commonly used thermoluminescent dosimeters (TLD) owing to their excellent thermal stability, high sensitivity, reusability, dose response and high TL efficiency [2,6,7,10]. These materials are mainly applicable in radiation dosimetry for environmental and personnel monitoring. A lot of researches have been done to develop such synthetic materials which exhibit all the characteristics of a good TLD material [2–19]. On the basis of these researches, it was found that mixed alkali/alkaline oxide and sulphate matrices constitute a class of good TL phosphors and their TL performances are improved when an appropriate amount of activators are incorporated [8–18]. As a novel luminescent host, the structural and thermoluminescence properties of SrY_2O_4 [11–14] and $BaGd_2O_4$ [17] have been extensively investigated. The detailed TL studies of γ-ray induced $SrGd_2O_4$: Eu^{3+}/Y^{3+} phosphors are reported in our previous publication [20]. However, no research work has been claimed so far concerning to TL studies of $SrGd_2O_4$: Dy^{3+} host synthesized via homogeneous precipitation cum auto-combustion method.

* Corresponding author.
E-mail address: jairam.manam@gmail.com (J. Manam).

http://dx.doi.org/10.1016/j.materresbull.2017.05.052
0025-5408/

In the present work, we have synthesized $SrGd_2O_4$: Dy^{3+} phosphors using homogeneous precipitation cum auto-combustion process aiming at achieving improved thermoluminescence. The crystal- and micro-structures of as-prepared phosphors were characterized through XRD, field emission scanning electron microscopy (FESEM) and transmission electron microscopy (TEM), respectively. The TL characteristics of as-prepared samples were examined after irradiation of γ–rays with ^{60}Co γ –source. An effort was made to investigate the effect of doping concentration, γ-doses, and heating rates on the TL glow curves. The trapping parameters associated with the prominent TL glow peaks of γ-irradiated $SrGd_2O_4$: Dy^{3+} was also determined.

2. Experimental

2.1. Sample preparation

The powder samples of $SrGd_{2(1-x)}Dy_{2x}O_4$ (where, x = 0, 1, 2, 3 and 5 mol%) samples were prepared by homogeneous precipitation cum auto-combustion method after controlled heating at 1200 °C for 3 h in air ambience. Firstly, the stoichiometric amounts of starting materials $Sr(NO_3)_2$ (Otto Chemie Pvt. Limited 99%), $Gd(NO_3)_3{\cdot}6H_2O$ (Otto Chemie Pvt. Limited, 99.9%) and $Dy(NO_3)_3{\cdot}xH_2O$ (Sigma-Aldrich, 99.9%) were dissolved in the excess of ethanol. The above mixture taken in a glass beaker was stirred well for 30 min under heating at 80 °C to get a homogeneous clear solution, after that, the quantity of urea (H_2NCONH_2) along with the boric acid (little amount works as a flux) was added [5,26,29,30]. The molar ratio of the reactants $Sr(NO_3)_2$: $Gd(NO_3)_3$: $Dy(NO_3)_3{\cdot}xH_2O$: $(NH_2)_2CO$ is 1: 2(1-x): 2x: 6.667 (where, x = 0–5 mol%) [19,20]. Afterward, the obtained solution was continuously stirred at 100 °C for at least 3 h until the liquid totally evaporated and white powders were left. In the next step, the powders were ground properly and then introduced into a muffle furnace at 1200 °C for 3 h. The samples prepared by following method show the pure $SrGd_2O_4$ phase than the samples prepared by simple combustion route [16].

2.2. Sample characterization

The different characterizations such as XRD, FE-SEM, TEM and thermoluminescence studies (TL) were performed to examine the various characteristics of the samples. The X-ray diffraction (XRD) patterns of as-prepared samples were recorded on Bruker-D8 Focus X-ray powder diffractometer with Cu Kα = 1.5406 Å over the range 2θ = 20–70°. The morphological studies of samples were done by the field-emission scanning electron microscope (FESEM Supra-55, Germany) images. The as-synthesized samples were exposed with γ-rays obtained from ^{60}Co target in the dose ranging from 80 Gy to 2 kGy at room temperature. The TL studies of these γ–irradiated samples were carried out using Harshaw 3500 TLD Reader and Nucleonix TL reader (Model 1009I). The TL glow curves of γ-irradiated samples were also recorded by heating the samples at the different heating rates 3, 5 and 7 °C/s, respectively.

3. Results and discussions

3.1. XRD studies and morphology

Fig. 1a represents the XRD patterns of virgin and Dy^{3+} doped $SrGd_2O_4$ phosphors. The XRD patterns of as-synthesized samples exhibit a set of sharp and well-defined diffraction peaks which are

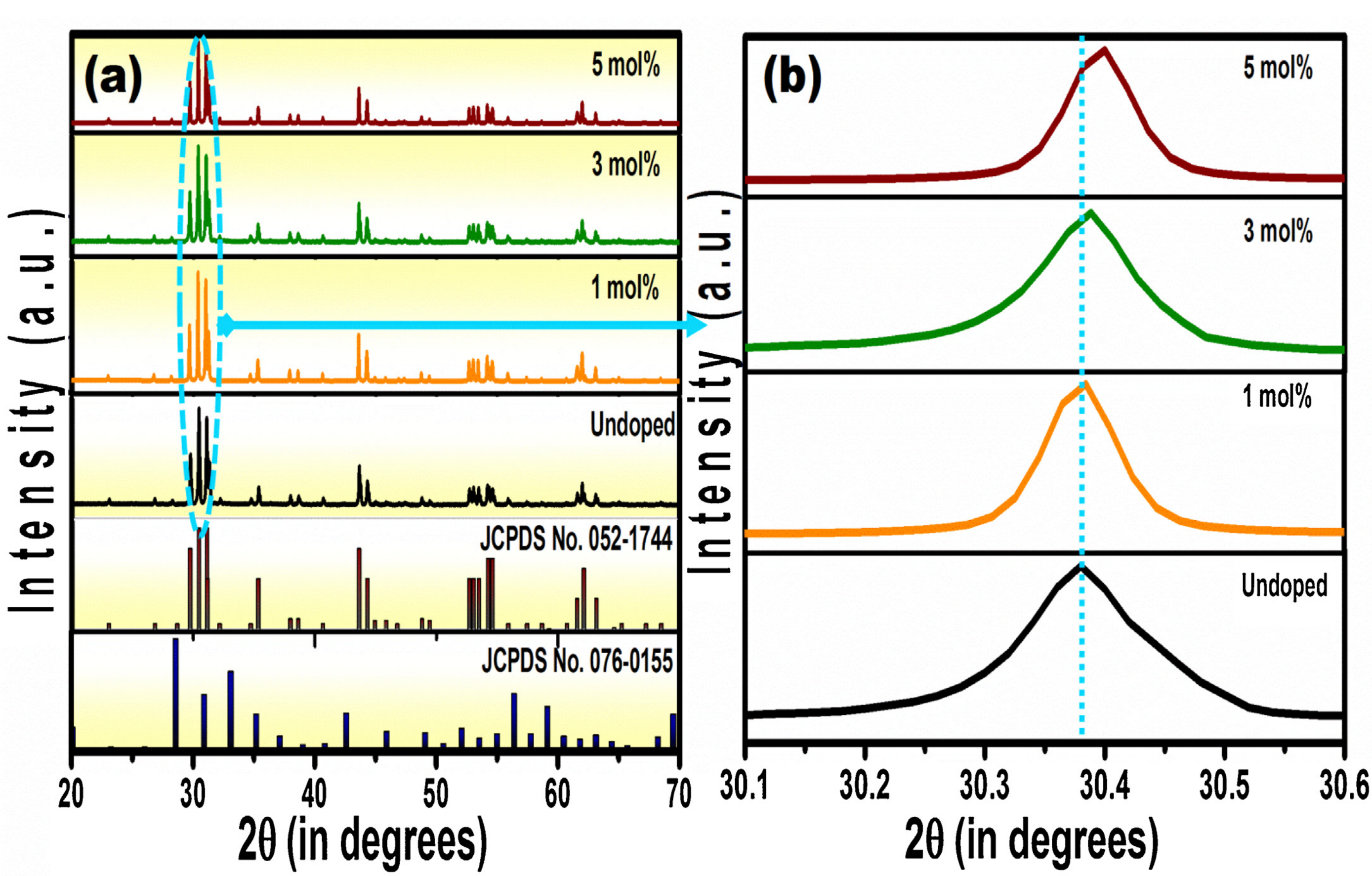

Fig. 1. (a) XRD plot and (b) shifting of XRD peaks towards higher angle side of undoped and Dy^{3+} doped $SrGd_2O_4$ samples.