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Thermoluminescence Studies of Combustion Synthesized $BaCa_2Al_8O_{15}:Dy^{3+}$ Phosphor

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Abstract:

In the present work $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor has been prepared by combustion method. Powder X-ray diffraction (XRD) analysis and thermoluminescence (TL) measurements were used for characterization. The trapping parameters namely activation energy and order of kinetics were calculated using peak shape and the results are discussed. Thermoluminescence (TL) glow curves of gamma irradiated $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor exhibit a single broad glow peak at 163.90 °C. The activation energy was found to be 0.72 eV. Frequency factor was found to be 2.49 x 10^6 s^{-1}.

Keywords:- combustion, thermoluminescence (TL), frequency factor

Introduction

Recently, radiation dosimetry is one of the interesting topics of research in the field of dosimetry of ionizing radiations and environmental radiation monitoring. Thermoluminescence (TL) is a very important technique due to its applications in various fields such as radiation therapy, film badge, dosimetry, pocket, dosimeter geology, space research and other research related areas [1–4]. In thermoluminescence first heating the irradiated phosphor due to this energy stored in the phosphor and then energy is released with the emission of light. Then we get the intensity of the emitted light as a function of temperature, the so called glow curve. By using this glow curve we can easily find out the trapping parameters, frequency factor, order of kinetics and various kinetic parameters of prepared phosphor material. Our literature survey shows that, thermoluminescence properties of aluminate based different rare earth doped phosphors are investigated to use as potential application in the field dosimetry of ionizing radiation [5–7]. Dysprosium doped materials usually show characteristics emission in blue, yellow and red region [8]. These emission colour of the luminescence is due to the red ($^4F_{9/2}\rightarrow{}^6H_{11/2}$), yellow ($^4F_{9/2}\rightarrow{}^6H_{13/2}$) and blue ($^4F_{9/2}\rightarrow{}^6H_{15/2}$) emissions of Dy^{3+} ion [9,10]. This luminescence is very strongly dependent on the host lattice. We have reported the $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor for its photoluminescence properties [11]. This study is focused on synthesis of $BaCa_2Al_8O_{15}:Dy$ phosphor by combustion method and investigation of thermoluminescence properties.

Experimental procedure

The Dy doped $BaCa_2Al_8O_{15}$ phosphors was prepared by the combustion method [12]. All the starting materials employed in the experiment are of Merck-analytical grade. The starting materials were $Ba(NO_3)_2$, $Al(NO_3)_3.9H_2O$, $Ca(NO_3)_2.4H_2O$, Dy_2O_3 and Urea (NH_2CONH_2, Merck) was used as fuel. Dy_2O_3 are converted in to nitrate

form by mixing of appropriate amount of dilute nitric acid. All the mixtures were mixed according to stoichometry ratio. The resulting colorless solution was further heated with stirring at 85–90 °C until a highly viscous wet gel was formed. The resulting gel is transferred into a vertical furnace maintained at 550^{0}C. Flame temperature as high at 1600^{0}C converts the vapour phase into mixed aluminates. The flame persists for about 30 seconds. The final product obtained is in the fluffy form, which is used for the further investigations. Some corresponding methods were used to characterize the prepared phosphor The prepared host lattice was characterized for their phase purity and crystallinity by X-ray powder diffraction (XRD) using PAN-analytical diffractometer (Cu-Kα radiation) at a scanning step of 0.010, continue time 20s, in the 2θ range from 10° to 70° , the average crystallite size was calculated by using Scherer's equation. The TL measurements were recorded with the help of Nucleonix TL reader in which the heating rate was 2°Cs^{-1}.

Result and Discussion

The XRD patterns of $BaCa_2Al_8O_{15}$ closely matched with the standard JCPDS file no. 00-015-0342, recently we have reported the same method [12]. Thermoluminescence dosimeters will readily respond gamma radiations. Analysis of TL glow curves has become more important in view of finding the trap depth, frequency factor and defect studies. Figure 1 shows the typical glow curve of various TL parameters of material. The TL glow curve of $BaCa_2Al_8O_{15}$:Dy for concentrations Dy= 0. 5 mole % is shown in figure 2. Before taking the TL, the sample is initially annealed at a temperature of 300 ^{0}C and then irradiated it for gamma ray dose of 5 Gy. To avoid possibility of any error, the TL measurements are done soon after irradiation of the sample. It is seen that only one glow curve of $BaCa_2Al_8O_{15}$:Dy at 163.90 ^{0}Cis obtained. The appearance of single peak in the glow curve of prepared material indicates that there is possibly only one kind of trapping site due to gamma irradiated effect. TL glow curve is analyzed based on glow curve shape method modified by Chen's [13]. Trapping parameters such as order of kinetics (b), activation energy (E) and frequency factor (s) were calculated for the 163.90 °C glow peak of $BaCa_2Al_8O_{15}$:Dy by using Chen's method [13]. To determine these parameters the following shape parameters were determined, the total half intensity width ($\omega=T_2-T_1$), the high-temperature half width ($\delta=T_2-T_m$), the low-temperature half width ($\tau=T_m-T_1$), where T_m is the peak temperature and T_1 and T_2 are temperatures on either side of T_m corresponding to half peak intensity. Table 1 gives the experimental peak shape parameters $BaCa_2Al_8O_{15}$:Dy phosphor for Dy=0.5mole%. The order of kinetics can be predicted from shape of glow curve by using symmetry factor μ_g stated by Chen can be given as,

$$\mu_g=\delta/\omega=T_2-T_m/T_2-T_1 \quad (1)$$

Inserting the above values into eqn(1), the geometrical factor is about 0.62, indicating that it obeys second-order kinetics. The activation energy E for second order kinetics can be calculated from the Equations [13].

$$E = c_\alpha\left(\frac{kT_m^2}{\alpha}\right) - b_\alpha(2kT_m) \quad (2)$$

and $$s = \frac{\beta E_\alpha}{k T_m^2 \left[1 + (b-1)\left(\frac{2k T_m}{E_\alpha}\right)\right]} \exp\left(\frac{E_\alpha}{k T_m}\right) \quad (3)$$

Where, α stands for τ, δ and ω respectively, β is the heating rate, k is Boltzmann constant and b is order of kinetics which can be obtained from equation (1). The peak shape parameters τ, δ and ω were initially determined for temperatures T_1, Tm and T_2. These values are used to calculate the geometric factor μ_g from equation (1) which determines the order of kinetics. Table 2 gives the values of trapping parameters of the 163.90°C glow peak of $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor calculated by Chen's method. The frequency factor (s) calculated from equation (3) which is tabulated in Table 3.

Table 1. Experimental peak shape parameters $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor

Peak Temp (°C) Tm	Half Width (τ)	Half Width (δ)	Full Width (ω)	Geometric factor (μ_g)
163.90	41.58	69.84	111.42	0.62

Table 2. Trap depth of $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor

Eτ	Eδ	Eω	Mean value
0.66 eV	0.94 eV	0.56 eV	0.72 eV

Table.3. Trap frequency factor (S) of $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor

Sτ	Sδ	Sω	Mean value (/s)
5.10 x 10^6 /s	0.8 x 10^6 /s	1.51 x 10^6 /s	2.49 x 10^6 /s

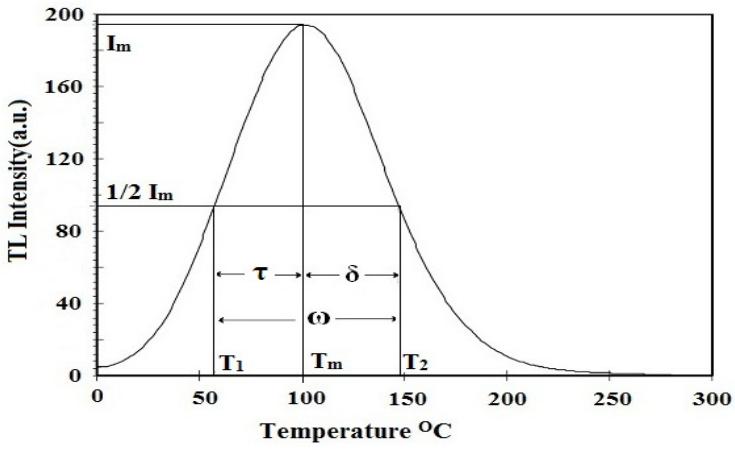

Fig. 1. A typical thermoluminescent glow curve phosphor showing various parameters

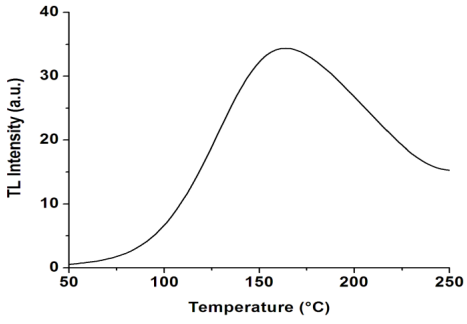

Fig.2. Thermoluminescence glow curve of $BaCa_2Al_8O_{15}:Dy^{3+}$ phosphor

Conclusions

Dy^{3+} doped $BaCa_2Al_8O_{15}$ phosphor was prepared by combustion method and studied for their thermoluminescence charactterstics. Kinetic parameter and trap depth were calculated by using Chens' method. The phosphor $BaCa_2Al_8O_{15}$: Dy^{3+} is found to have second order kinetics in TL studies. TL glow curve shows a single peak at 163.90°C pointing to the fact that only one type of defect centers present in the phosphor. The activation energy and frequency factor were found to be 0.72 eV and 2.49×10^6 s^{-1} .

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