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Kinetics of Thermoluminescence Glow Curves of $Y_4Al_2O_9$ Phosphor

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ABSTRACT
Phosphor materials are very useful for display devices. Characterization of material is must for selection of suitable one. Thermoluminescence is one of the most efficient and convenient tool for characterization of material. In the present paper we reconsider the Thermoluminescence study of Eu^{3+} doped $Y_4Al_2O_9$ with different concentrations of doping material, already reported in literature, to evaluate order of kinetics involved. Order of kinetics involved in process depends on extent of retrapping. Here a new method of analysis is adopted for the analysis of Thermoluminescence glow curves in order to evaluate order of kinetics. It is found that it changes with concentration of doping material.

Keywords: *Thermoluminescence, Orders of kinetics, Phosphors, Irradiation Dose, Heating Rate.*

INTRODUCTION

Phosphor is luminescent material that emits light when exposed to radiation such as ϒ-ray,ultraviolet light, visible, and infrared radiation or an electron beam. Hundreds of thousands of phosphors have been synthesized, each one having its own characteristic colour of emission and period of time during which light is emitted after excitation ceases. Phosphors excited by ultraviolet, visible, and infrared radiation are used principally in the fluorescent lamps commonly employed for general illumination. Thermoluminescence (TL) is emission of light from some minerals and certain other crystalline materials. The light energy released is derived from electron displacements within the crystal lattice of such a substance caused by previous exposure to high-energy radiation. Heating the substance in suitable temperature range enables the trapped electrons to return to their normal positions, resulting in the release of energy. The intensity of the emission can be correlated to the length of time that a given substance was exposed to radiation; the longer the time allowed for the radiation to build up an inventory of trapped electrons, the greater the energy released. Because of this feature, thermoluminescence has been exploited as a means of dating, dosimetry and characterization of luminescent material.

During the past decades, nanostructured materials have been developed to form a novel type of luminescent materials for display applications. The Y_2O_3-Al_2O_3 system is a hopeful material for refractory coatings and for ceramic and semiconductor processing technology [1,2]. In this paper

thermoluminescence study of $Y_4Al_2O_9:Eu^{3+}$ phosphor [3] is reinvestigated to evaluate order of kinetics.

MATERIAL METHOD

The starting materials are: Y_2O_3, Al_2O_3 Eu_2O_3, and H_3BO_3 (as a flux) in molar ratio (0.1% to 2.5% of Eu) and are used to prepare the phosphor. A new modified solid state reaction method was used by Vikas Dubey et. al. [3] to synthesize $Y_4Al_2O_9:Eu^{3+}$ phosphor. The Eu^{3+} activated $Y_4Al_2O_9$ phosphor was prepared via high temperature modified solid state diffusion. The mixture of reagents was ground together to obtain a homogeneous powder. After being ground thoroughly in stoichiometric ratios by using an agatemortar by dry grinding for nearly 45 minutes, to ensure the best homogeneity and reactivity, powder was transferred to alumina crucible and then heated in a muffle furnace at 1300^0C for 4 hours [4]. The phosphor materials were cooled to room temperature naturally.

Thermoluminescence glow curves were recorded by Vikas Dubey et. al. [3] at room temperature by using TLD reader I1009 supplied by Nucleonix Sys. Pvt. Ltd.Hyderabad [17–19].The obtained phosphor under the TL study is irradiated with UV radiation using 254 nm UV source. Heating rate used for TL measurement is 6.7^0K/s. In his work Vikas Dubey et. al. [3] used , Chen's peak shape method [8,9] to determine trap parameters, namely Activation Energy () and frequency factor (s) of the observed TL glow peaks of material under consideration. Here, considering the reported values of actvation energy and frequency factor as such, we calculate the order of kinetics involved in different reported TL glow curves of $Y_4Al_2O_9:Eu^{3+}$ phosphor.

RESULTS AND DISCUSSION

TL glow curves of $Y_4Al_2O_9:Eu^{3+}$ phosphor for 5 min exposure of UV radiations from a 254UV source and for different concentrations of doping material Eu^{3+} as reported in literature [3] is given Fig.1. It is clear that two glow peaks at 119^0C and 275^0C were observed. In the study of variation of TL glow peak intensity as a function of doped Eu concentration, it is observed that TL intensity increases linearly with Eu concentration up to 1moL% and thereafter, it decreases with increasing doping concentration. TL glow curves for 10 min and 15 min UV exposure times are shown in Fig.2 and Fig.3 respectively.

From experimental results [3] it may be infer that perturbation of crystalline field due to different characteristics of the dopant ions (which supposedly replaces the yttrium sites) results in change in TL glow curve structure by either enhancing or quenching the TL efficiency. The traps and the glow curve structure are also dependent upon the morphology of the surface area which in turn depends on the nanocrystallite size.The nanocrystallite size depends also on the dopant ion. The presence of dopant ions also modifies the TL recombination as well as retrapping efficiency which was found to be different for each irradiation type and the specific exposed material.

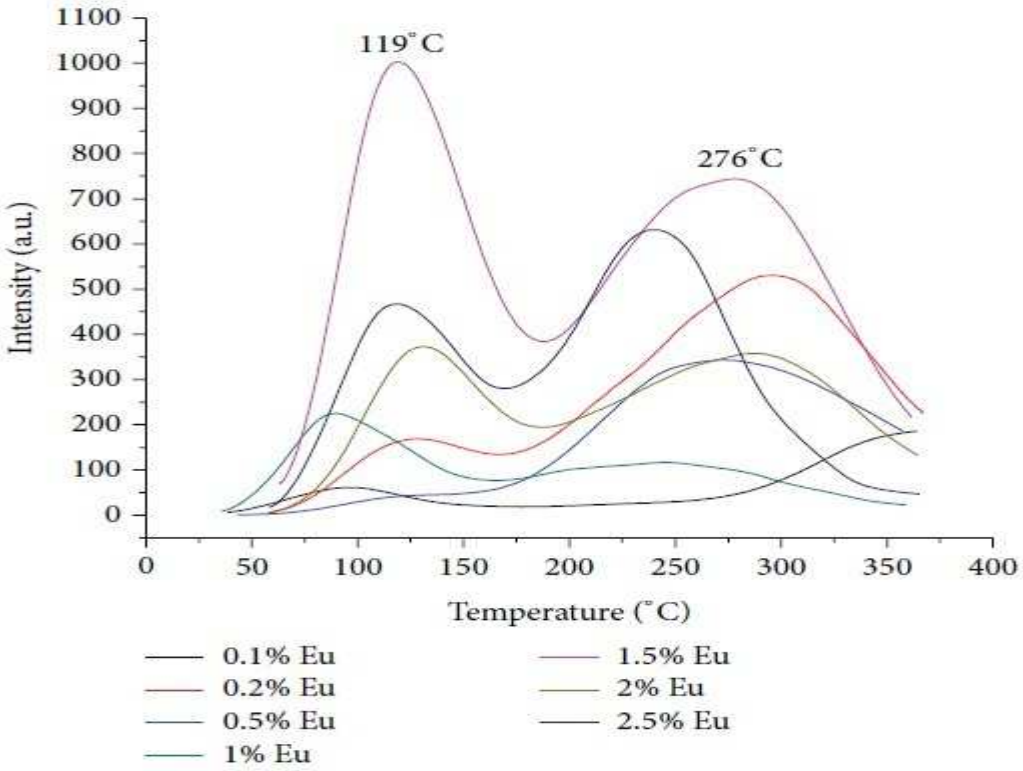

Fig.1 TL glow curves of phosphor for different doping concentrations with 5 min UV exposure [3].

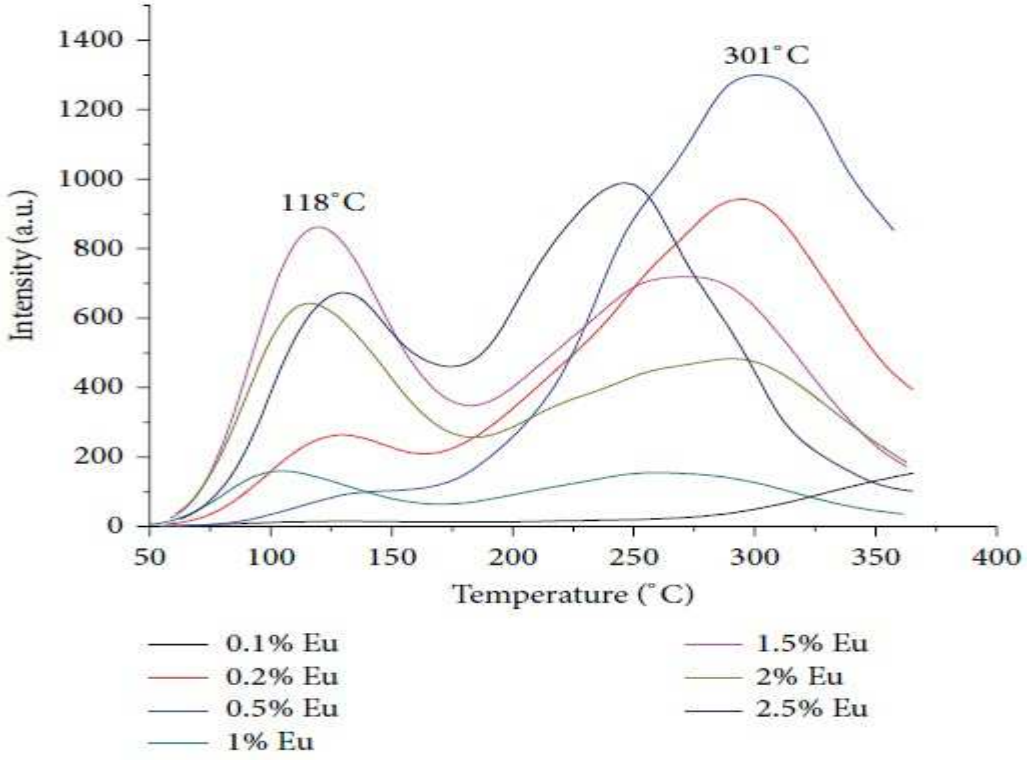

Fig.2 TL glow curves of phosphor for different doping concentrations with 10 min UV exposure [3].

Selection of right dopant concentration, optimization of TL efficiency, improvement in sensitivity and dose linearity can be made for given radiation. The glow curve of any material is characteristic of the different trap levels that lie in the band gap of the material. In the reference of glow curve, characterization is defined in terms of certain physical parameters, named as Activation Energy (E_a), Frequency Factor (s) and Order of Kinetics (ℓ). For different TL applications, knowledge of these physical parameters is essential.

Vikas Dubey et. al. [3] in their study use Chen's peak shape method [8,9] to determine the kinetic energy parameters of the glow peak of the phosphor under consideration. Their reported

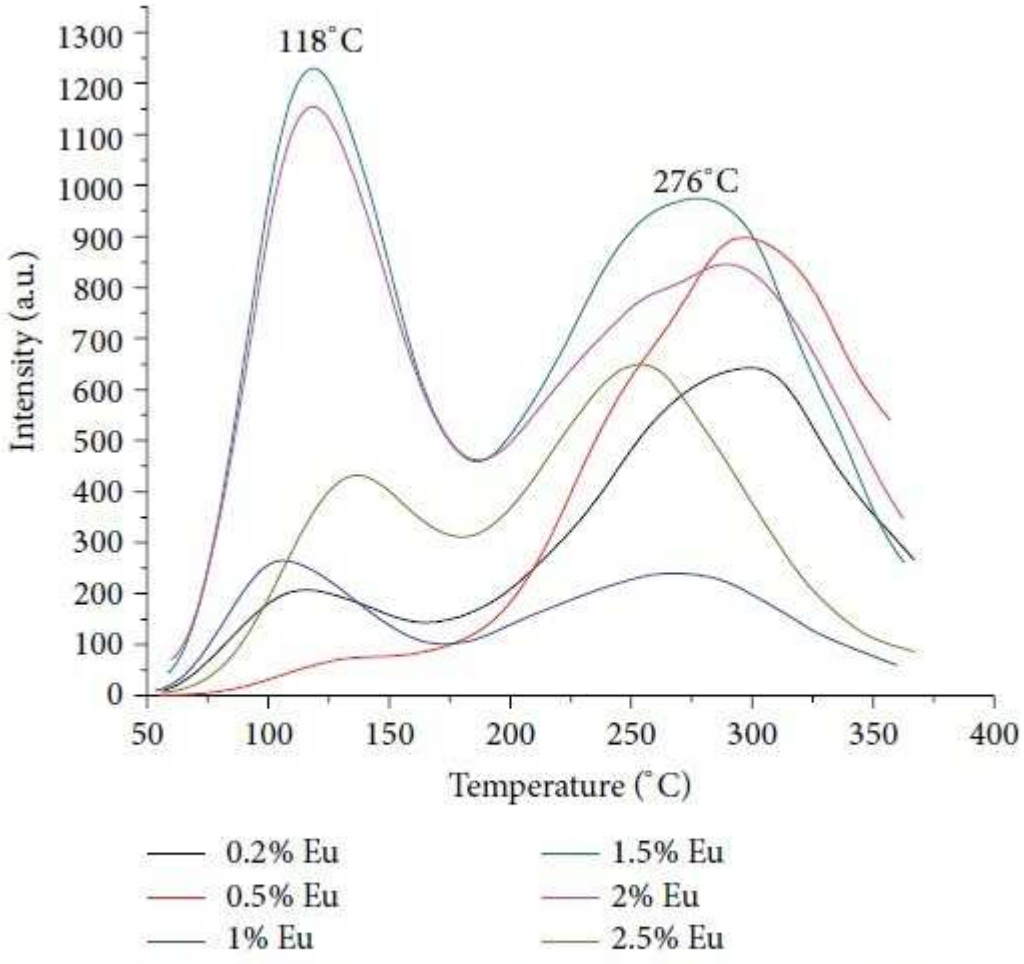

Fig.3 TL glow curves of phosphor for different doping concentrations with 15 min UV exposure [3].

parameters [3] along with some other evaluated parameters are given in Table.1. The new evaluated parameters are τ_0, the Fundamental Relaxation Time (inverse of frequency factor s), and $\frac{b E_a \tau_m}{k}$, given in fifth and seventh columns respectively, where b is linear heating rate, τ_m is relaxation time at peak temperature and k is Boltzmann's constant. To explain mechanism involved in TL glow curve, there are so many theories are reported in literature and on which different analysis method for analysis of glow curves are present and method adopted by

Table.1

Different reported [3] and evaluated parameters from TL glow curves of UV irradiated $Y_4Al_2O_9$:Eu doped phosphor.

Doping Concentration	T_m (^{0}K)	E_a (eV)	S (s^{-1})	τ_0 (s)	T_m^2 ($^0K^2$)	$\frac{bE_a\tau_m}{k}$ ($^0K^2$)	ℓ	x
0.1%	367	0.58	1.00E+09	1.00E-09	134689	4161.279	32.36721	0.969105
0.2%	400	0.66	3.00E+09	3.33E-10	160000	3540.764	45.18799	0.97787
1%	360	0.63	1.00E+09	1.00E-09	129600	32360.27	4.004911	0.750307
1.5%	392	0.63	2.00E+09	5.00E-10	153664	3083.089	49.84093	0.979936
2%	402	0.64	2.00E+09	5.00E-10	161604	2628.491	61.48167	0.983735
2.5%	390	0.66	2.00E+09	5.00E-10	152100	8677.965	17.52715	0.942946

Vikas Dubey et. al. [3] (Chen's peak shape method) is one of them. In all theories condition for peak temperature is same and is given by

$$T_m^2 = \frac{b\,E_a\,\tau_m}{k} \qquad (1)$$

So the reported values of trapping parameters and peak temperature must satisfy the eq.(1). But the values shown in sixth and seventh columns of Table.1 are not same, means peak temperature relation is not satisfied. In order to remove this shortcoming here we apply a new method of analysis suggested by Prakash [10] and Prasad et al [11] to calculate order of kinetics and extent of retrapping involved in TL glow curves of $Y_4Al_2O_9$:Eu.

In new method equation for TL intensity and peak temperature are given by following relations

$$I = (1-x)n_0 s \exp\left[\left(-\frac{E_a}{kT}\right) - \frac{s\,(1-x)}{b}\int_{T_o}^{T}\exp\left(-\frac{E_a}{kT'}\right)dT'\right] \qquad (2)$$

and

$$T_m^2 = \frac{\ell\, b\, E_a \tau_m}{k} \qquad (3)$$

where I is TL intensity at temperature T, x is extent of retrapping, n_0 is the initial concentration of trapped carriers per unit volume, T_o the temperature at which TL glow curve starts to appear, T′ any arbitrary temperature in the range T_o to T. Extent of retrapping is related with order of kinetics ℓ as

$$\ell = \frac{1}{1-x} \qquad (4)$$

As per this new method of analysis order of kinetics ℓ and extent of retrapping x is evaluated and presented in eighth and ninth columns of Table.1 respectively.

CONCLUSION

In order to use the $Y_4Al_2O_9$ Phosphor material as luminescent material in display devices, in TL applications like dosimetry and dating clear knowledge Activation Energy (E_a), Frequency Factor (s) and Order of Kinetics (ℓ) is essential. From the reported TL study, we calculate more accurate values of order of kinetics for different glow curves. Order of kinetics depends on the experimental conditions. These evaluated values are helpful in selecting the material under consideration for display devices and dosimetric purposes.

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