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Research Article

ϒ- IRRADIATED COMBUSTION SYNTHESIZED POLYCRYSTALLINE ALUMINIUM OXIDE IN NEW KINETIC FORMALISM OF TSL GLOW CURVES

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ABSTRACT

Thermally Stimulated Luminescence is efficient and convenient tool for evaluation of trap parameters namely trap depth and frequency factor and order of kinetics. Here we evaluate the correct value of order of kinetics by reconsidering the data already reported in literature. The reason behind this is that the reported values of trap depth, frequency factor and peak temperature are not satisfying the peak temperature relation. A new method of analysis is considered for analyzing thermally stimulated luminescence glow curve data. Analysis shows that order of kinetics is different for both peaks. Evaluated values of order of kinetics helps in selection of material under study for radiation dosimetry.

Keywords: *Thermally Stimulated Luminescence, Actvation Energy, Frequency Factor, Order of Kinetics*

INTRODUCTION

Thermally Stimulated Luminescence (TSL), also known as Thermoluminescence (TL), is the emission of light observed during the heating of insulating or semiconductor materials, provided that they have been previously exposed to ionizing radiation (Chen and Mckeever, 1997; Martini *et al.*, 1997; McKeever, 1985). TSL technique is extensively used in dosimetry to measure different kinds of radiation doses. This gives information of distribution of artificially created or naturally occurring point defects. Ionizing radiations like UV, X-ray or ϒ-ray are generally used to activate material under consideration. TSL is an efficient technique to understand the charge trapping and detrapping mechanisms that result from the interaction of radiation with the existing defects in material.

Aluminium Oxide has more thermal and chemical stability and low effective atomic number and due to this property it is used as radiation dosimeter material (Rieke and Daniels, 1957). It is a highly sensitive luminescence dosimeter material. So, many work on TSL of transparent Al_2O_3 and Carbon doped Al_2O_3 crystals have been reported in literature (Summers, 1984; Mckeever *et al.*, 1999; Chthambo *et al.*, 2002). Combustion process for preparation of Aluminum Oxide using different fuels results in different particle sizes. Glycine and hydrazine fueled combustion process yields nanoparticles (Mimani *et al.*, 2001). The grain size affects the sensitivity, dose response and other parameters of TSL glow curves. A good compromise is to use powders with grain sizes between 75 and 200 μm (Bos, 2001). The objective of our present analysis is to understand the TSL behaviors of combustion synthesized polycrystalline γ-irradiated aluminum oxide in new kinetic formalism.

MATERIALS AND METHODS

Material and Method of Analysis

Here, we reconsider the experimental data already reported in literature by Nagabhushana *et al.*, (2008). They use urea as fuel which yields polycrystalline aluminum oxide. Polycrystalline aluminum oxide was synthesized by combustion technique (Nagabhushana *et al.*, 2007). These samples were packed in black paper and were irradiated with γ-rays (^{60}Co) for the dose ranging from 1·251 to 7·527 KGy. The TSL measurements were carried out at a heating rate of 5° K/s using PC based TSL analyzer system.

The evaluation of trap parameters i.e. activation energy (E_a) of the traps involved in TSL emission, frequency factor (s) and order of kinetics (ℓ) associated with the glow peaks of TSL are important aspects of TSL studies. Any complete description of the TSL characteristics of TSL material requires the knowledge of these parameters. Nagabhushana *et al.*, (2008) calculated the trap parameters by glow curve shape method (modified by Chen) and order of kinetics by symmetry factor.

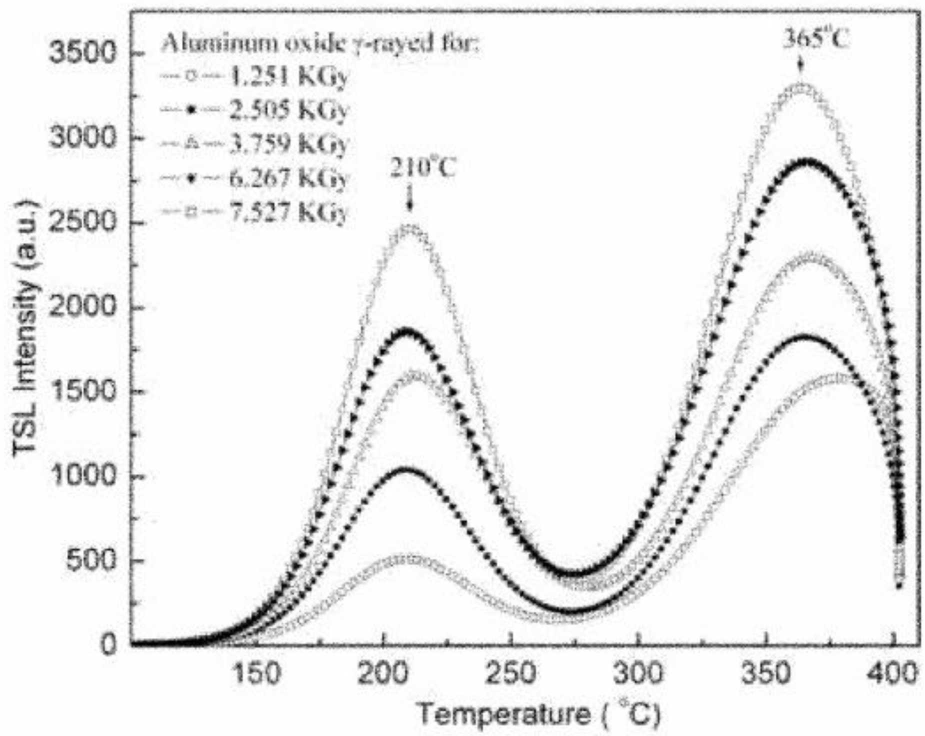

Figure 1: Thermally Stimulated Glow Curves of Aluminum Oxide at Irradiation of Different γ-Irradiation Dose (Nagabhushana *et al.*, 2008)

RESULTS AND DISCUSSION

Thermostimulated luminescence glow curves of γ-irradiated combustion synthesized aluminum oxide for different doses (Nagabhushana *et al.*, 2008) given in Figure 1. There are two well resolved peaks at 210^0C and 365^0C. Reported values of E_a, s and ℓ are given in Table 1. Along with the already reported (Nagabhushana *et al.*, 2008) value, values of fundamental relaxation time τ_0 and term $\frac{bE_a\tau_m}{k}$ are also calculated and given in column three and six of Table 1, respectively. Where, τ_0 is inverse of frequency factor, b is linear heating rate, τ_m is relaxation time at peak temperature and k is Boltzmann's constant.

There are so many theories are reported in literature for the appearance of TSL glow curve. 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 equation (1). But the values shown in fifth and sixth 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 Prasad *et al.*, (2012) to calculate order of kinetics of TSL glow curves of aluminum oxide.

Table 1: Trapping parameters and peak temperature of TSL curves of Aluminum Oxide

E_a(eV)	s (s^{-1})	τ_0(s)	T_m(^{0}K)	T_m^2 (^{0}K^2)	$\frac{bE_a\tau_m}{k}$ (^{0}K^2)
1.01	7.51E+09	1.33E-10	483	233289	28306255
1.52	2.68E+11	3.73E-12	638	407044	56270164

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

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$$I = (1-x)n_0 s \exp\left[\left(-\frac{E_a}{kT}\right) - \frac{s\,(1-x)}{b}\int_{T_0}^{T}\exp\left(-\frac{E_a}{kT'}\right)dT'\right] \quad (2)$$

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

where, I is TSL 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 TSL 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

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

According to new method of analysis order of kinetics is evaluated and presented in Table 2.

Table 2: Order of Kinetics and Trapping Parameters for TSL Glow Curves of Aluminum Oxide

E_a(eV)	τ_0(s)	T_m(^{0}K)	ℓ
1.01	1.33E-10	483	0.864022
1.52	3.73E-12	638	1.215792

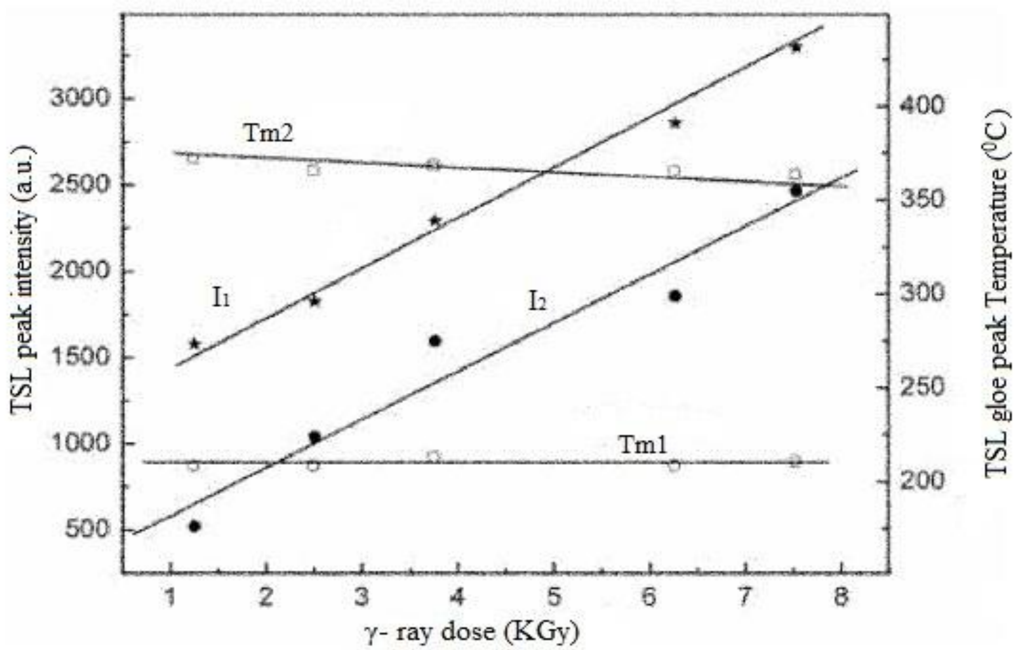

Figure 2: Variation of TSL Intensity and TSL Glow Peak Temperature with γ-Ray Dose in Combustion Synthesized Aluminum Oxide (Nagabhushana *et al.*, 2008)

From Table 2 it is clear that the evaluated values of order of kinetics are different from values reported by Nagabhushana *et al.*, (2008). Variation of peak TSL intensity and peak temperature with irradiation dose as reported by Nagabhushana *et al.*, (2008) shown in Figure 2. This variation of peak intensity and peak temperature on irradiation dose is in accordance with new equation of intensity.

Conclusion

Here we reanalyze the data already reported in literature in a new kinetic formalism. The previous data did not satisfy the peak temperature relation. We evaluate the order of kinetics for both peaks with the help of modified relation of peak temperature. Order of kinetics is different for both peaks. Reported dependence of peak intensity on irradiation dose is found to be same as per the modified TSL intensity equation. This study along with its fading, annealing behavior, energy response and reproducibility behaviors helps in selecting combustion synthesized aluminum oxide as radiation dosimetric material.

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