International Journal of Engineering, Science and Mathematics
Vol. 6Issue 8, December 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
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TSL Properties of γ-irradiated BaS:Bi Nanostructures

Dr. Devendra Prasad

Abstract

Thermally Stimulated Luminescence is a simple technique for studying the distribution of artificially created or naturally occurring point defects. In present work we are reconsidering the these studies on nanostructures of Bismuth doped Barium Sulphide in accordance with new method of analysis. Orders of kinetics for different glow curves are recalculated. Order of kinetics values are not same as already reported in literature. The results of different doses and different heating rates on glow curves have been discussed. Effect of various heating rates on thermally stimulated luminescence response of nanocrystalline BaS : Bi are found to be in agreement with new suggested method.

Keywords:

Thermally Stimulated Luminescence;
Orders of kinetics;
Glow Curves;
Irradiation Dose;
Heating Rate.

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1. Introduction

Whenever an insulator or a semiconductor is irradiated, electrons are excited from the valance band to the conduction band. Most of excited electrons return to the valence band after a very short time ($\approx 10^{-8}$ s) emitting a photon. The emission of photon thus obtained is known as fluorescence. If the excited electron instead of returning back to the valence band goes to some metastable state or is trapped in some trap level present in the forbidden gap, the electron can stay there for a longer time. Once the electron is trapped in a trap centre, it needs energy to be raised to the conduction band and only then it can return to the valence band (as direct transition from trap level to valence band is prohibited). As soon as it gets the required amount of energy to be excited to the conduction band from the trap level it shows a delayed luminescence known as phosphorescence. If the required energy is supplied thermally, the phenomenon is called Thermally Stimulated Luminescence (TSL), also known as Thermoluminescence (TL). TSL or TL is one of the most studied physical phenomena. It is useful research tool for the characterization of the materials, such as study of the defects in solids, as well as a powerful tool in dosimetric applications. Alkaline earth sulphides are well known from their luminescent properties. Ionising radiations like UV, X-ray, gamma ray electrons, etc produce localized levels in the activated phosphors and the energy storage by such traps is studied by using the conventational TSL glow curve method. The materials having dimensions in nanometer range are defined as nanomaterials. Within this dimension, the properties of matter are considerably different from the individual atoms, molecules and bulk materials. The physical, chemical, electrical and optical properties of these materials are size- and shape-dependent and they often exhibit important differences in the bulk properties.

In TSL glow curve of nanomaterials peak temperature shifts towards higher side and they show a large linear range over very high doses as compared to their bulk counterparts [1-2]. The traps created in nanomaterials are deeper than in bulk materials. The different behaviours of nanomaterials can be explained on the basis of quantum confinement effect and large surface to volume ratio. In this paper we reconsider the work reported by Singh et al [3] which reports the response of TSL glow curves of BaS : Bi nanocrystalline after exposure to gamma ray at various doses in reference of new method of analysis. In already reported literature the effect of different doses and different heating rates on glow curves has been determined.

2. Material used and method of analysis

Here we study the TSL glow curves of BaS : Bi nanocrystalline structure. The material was prepared by solid state diffusion method. The details of material preparation have given by Singh et al [4]. Phosphors BaS:Si were exposed to γ-rays for various doses at room temperature. One hour exposure from this source corresponds to 115 mR. TL glow curves were recorded at heating rate of 2K/s, 5 K/s and 10 K/s.

Singh et al [3] have used Chen's peak shape method [5] and glow curve deconvolution function to analyze the TSL glow curve and calculated the trapping parameters namely, activation energy (E_a), frequency factor (s) and order of kinetics (ℓ) for Bi doped BaS nanostructures. This approach is similar to earlier reported by Furetta et al [6] for analyzing the TSL glow curve where they did deconvolution based on Gaussian function and then analyzed the individual peak using Chen's peak shape [5] method. Singh et al [3] deconvoluted the TL glow curves based on Gaussian functions into four peaks which were also confirmed by the thermal cleaning method [7]. The isolated peaks were analyzed by Peak shape method to evaluate the peak parameters. The calculated parameters were used as initial parameters for the GCD basic function suggested by Kittis et al [8] for the first, second and general order kinetics glow peaks.

3. Result and Discussion

The experimental glow curve, as reported by Singh et al [3] for Bi (0·4 mol.%) doped BaS nanostructures at heating rate of 2 K/s, which has been deconvoluted into four peaks using GCD function is shown in Fig.1. The position of the respective peaks, trap parameters and order of kinetics at heating rate of 2K/s is shown in Table 1. In third column the calculated values of fundamental relaxation time τ_0 is given which is inverse of frequency factor *s*.

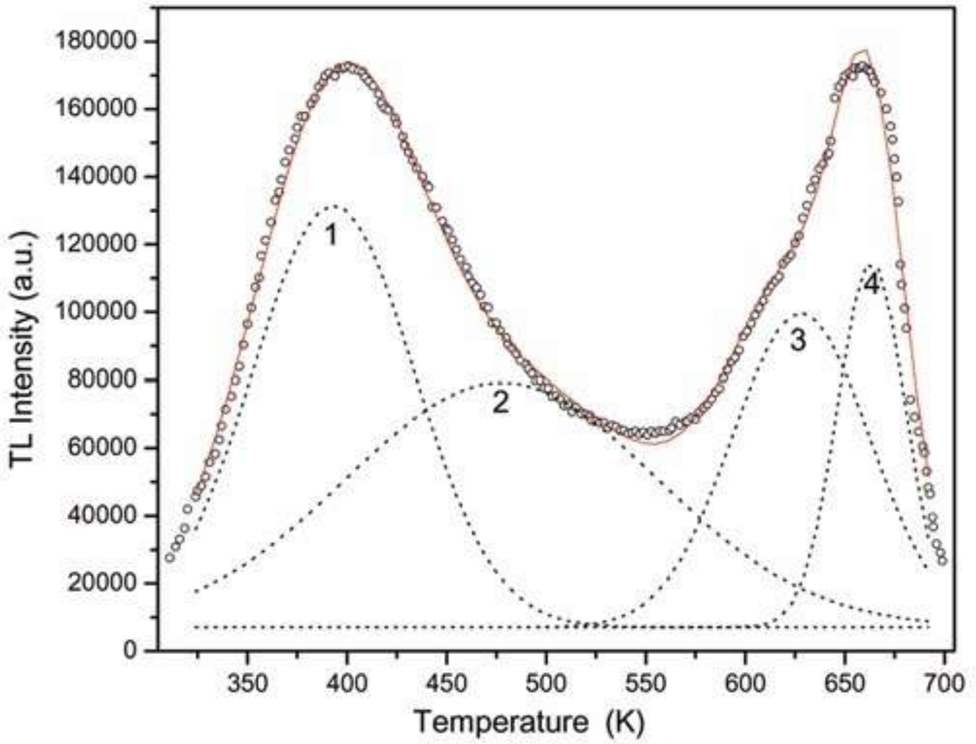

Fig.1 The experimental (–o–) and fitted theoretical (--) glow curve of BaS :Bi exposed to gamma radiation. Deconvoluted single fitted glow curves marked as 1, 2, 3, 4 (.......) are also shown.

In fifth and sixth column of Table.1 square of peak temperatures and calculated values of $\frac{bE_a\tau_m}{k}$ are given respectively. Where b (here 2 K/s) is linear heating rate, τ_m is relaxation time at peak temperature, calculated from Arrhenius relation and k is Boltzmann's constant. In most of the

Table.1

Reported values of E_a, s, T_m and calculated values of τ_0, T_m^2, and $\frac{bE_a\tau_m}{k}$.

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)
0.35	1.05E+06	9.52E-07	395	156025	226.1266
0.38	3.64E+08	2.75E-09	477	227529	0.250859
1.2	1.38E+09	7.25E-10	626	391876	92526.55
1.8	9.98E+10	1.00E-11	663	439569	20183698

earlier suggested mechanism responsible for appearance of TSL glow curves and analysis methods, relation for peak temperature [9] is given by

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

From Table.1, after comparing last two columns, it is clear that 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 reanalyze the data reported by Singh et al [3] corresponding to TSL properties of BaS:Bi specimen.

According to mechanism, responsible for appearance of TSL glow curve, suggested by Prakash [10] TSL intensity and peak temperature are given by following relations

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

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′

Table.2

Order of kinetics and Trapping parameters for TSL glow curves of BaS:Bi

E_a(eV)	τ_0(s)	T_m(^{0}K)	ℓ
0.35	9.52E-07	395	689.9897
0.38	2.75E-09	477	907000.9
1.2	7.25E-10	626	4.235282
1.8	1.00E-11	663	0.021778

any arbitrary temperature in the range T_o to T. Extent of retrapping is related with order of kinetics ℓ as

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

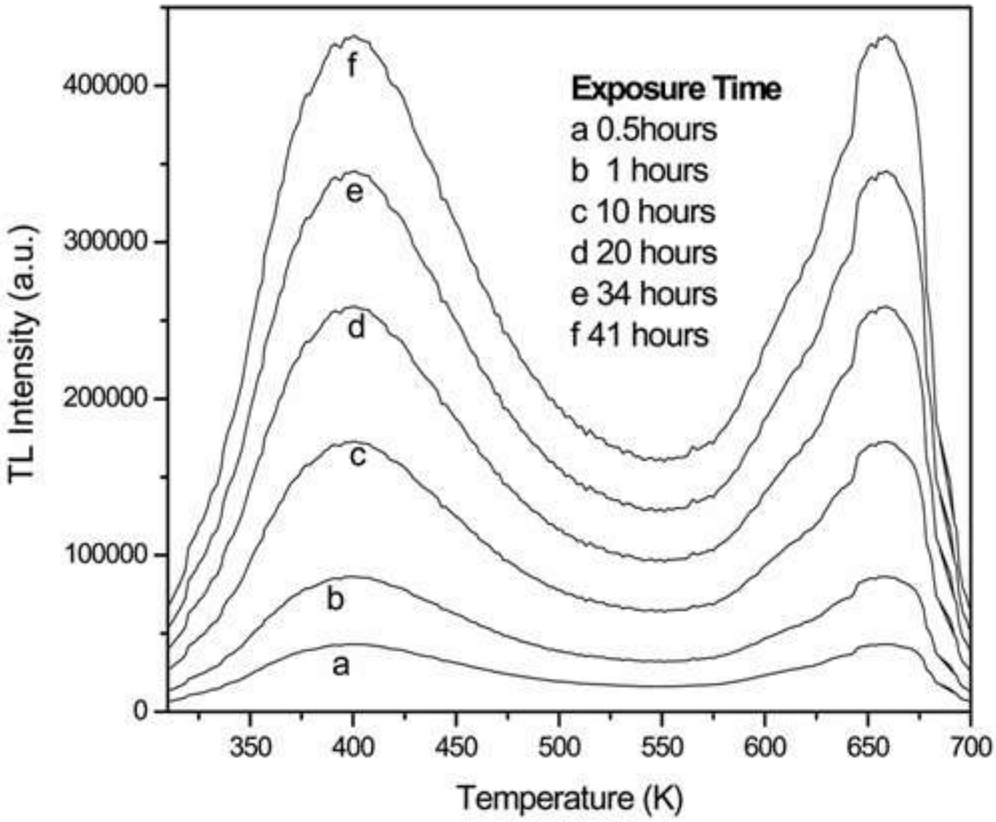

Fig.2 TSL glow curves of nanocrystalline BaS:Bi after different exposure times at a heating rate of 2 K/s.

As per the new method of analysis, order of kinetics is evaluated from reported data of TSL of nanocrystalline Bi doped BaS [3] specimen and presented in Table.2. TSL glow curves for this specimen exposed to various doses of gamma rays as reported by Singh et al [3] are given in Fig.2. From figure it is clear that glow curve structure and the peak shape does not change for the

exposure dose which is in agreement with new approach but slight shifting in peak temperature with radiation dose is a new observation. The peak intensity for first peaks of TSL glow curves at

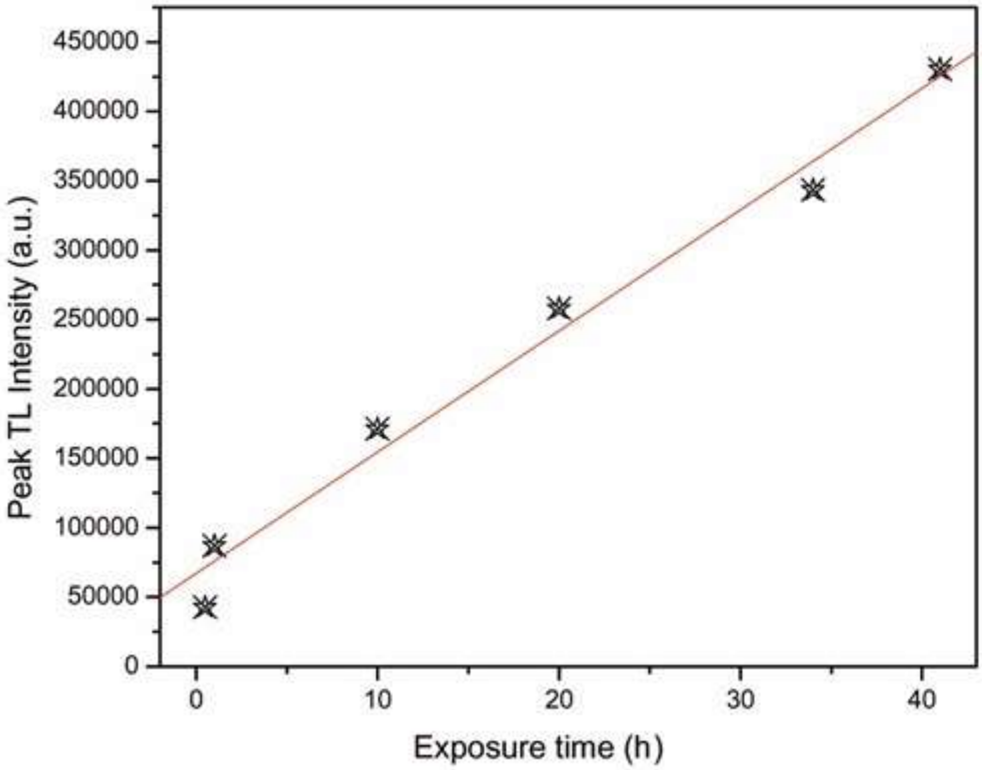

Fig.3 The peak TSL intensity of nanocrystalline BaS : Bi as a function of exposure time at the heating rate of 2 K/s [3].

different dose of irradiation is plotted in Fig.3. The linearity over a wide range of doses may be explained on the basis of track interaction model described by Mahajna et al [12] and Horowtz et al [13]. The same may also be explained on basis of large surface to volume ratio which results in a higher surface barrier energy for nanoparticles. Thus on increasing the doses, the energy density crosses the barrier and a large number of defects produced in the nanomaterials ultimately keep on increasing with the dose till saturation is achieved.

Influence of various heating rates on TSL response [3] of nanostructures of BaS : Bi material are shown in Fig. 4. From this figure it is clear that as heating rate increases the glow peak temperature shifted to higher temperature and TSL intensity decreases. The reduction in TSL intensity is ascribed to thermal quenching effect as explained by Akselrod et al 1998 [14], the efficiency of which increases as temperature increases. This effect is also in agreement with new mechanism and analysis method [10,11].

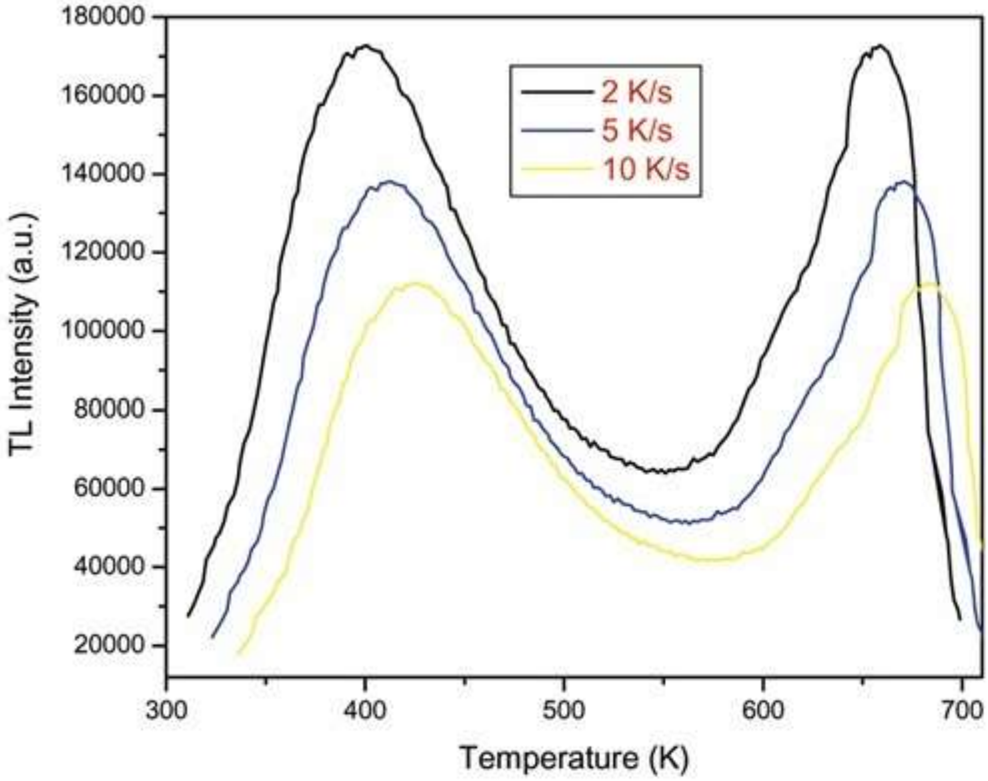

Fig.4 Influence of different heating rates on TSL response of nanostructures of BaS : Bi.

4. Conclusion

The thermally stimulated luminesence studies on nanostructures of BaS : Bi irradiated with gamma rays are reconsidered here in light of new method of analysis. Order of kinetics for this sample at heating rate of 2 K/s is recalculated according to this new approach. The results are different from earlier reported results. Influence of heating various rates on TSL response of material under consideration is same as suggested in new method of analysis. As before using a material as a phosphor for radiation dosimetry, a prior knowledge of traps and kinetic parameters of a sample is desirable, the present may helpful in selection of material for TSL dosimetry.

Acknowledgements:

The author is thankful to the Director of his institute for providing the facilities and also thankful to Prof. Jai Prakash, Ex Pro Vice Chancellor, Pt. D D U Gorakhpur University, Gorakhpur for inculcating research temper.

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