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A review on the lifetime of trapped electrons relevant to TL glow peaks

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Abstract

Generalised expressions for lifetime of trapped electrons corresponding to thermoluminescence (TL) peak obeying non-first order kinetics (1≤ b<2) and mixed order kinetics have been derived. The increase in lifetime has important implications in long range TL dating. The kinetic parameters of TL peaks of gamma irradiated $BaSO_4$ co-doped with Dy,Mn have been determined using computerized glow curve deconvolution (CGCD) technique and hence lifetime have been evaluated using newly derived expression.The suitability of the formula has been applied to TL peaks of colorless quartz.

Keywords: Lifetime, thermoluminescence

PACS Code:78.60K

1. INTRODUCTION

The lifetime of trapped electrons in an insulating material exhibiting thermoluminescence is closely related to activation energy E and frequency factor s. Mean lifetime τ is the average life expectancy of the electrons in its trap before heating to record thermoluminescence (TL). It is given by the sum of the times of existence of all the electrons in the electron traps, divided by the initial number of electrons in the trap. There is a convention to estimate lifetime using the first order kinetics model irrespective of the order of kinetics of the TL or linearly modulated OSL peaks [1-2]. Experimentally it can also be estimated from the isothermal decay curves [3]. Recently Singh and Gartia [4] have reported a new method of determination of trapping parameters of glow peaks relevant to dosimetry and dating from their lifetime.

In the present study, the expression for the lifetime of electrons for both partially and completely filled traps following nonfirst order kinetics (b≠1) has been derived. An expression for lifetime is also derived for TL peaks obeying mixed order kinetics. It has been shown that the lifetime of electrons corresponding to TL peaks following nonfirst order or mixed order kinetics, which are applicable to TL dating and dosimetry can be extended. The technique has been applied to TL glow curves of $BaSO_4$:Dy,Mn and colorless microcline.

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2. THEORY

The expression for TL intensity at a time t and temperature T(K) (b=1) is given by

$$I(t) = -\frac{dn}{dt} = ns\exp(-\frac{E}{kT}) \qquad (1)$$

where n(cm^{-3}) being the concentration of trapped electrons, E(eV) the activation energy, s frequency factor and k the Boltzmann constant. Under Garlick and Gibson's second order kinetics model, the expression for TL intensity is given by

$$I(t) = -\frac{dn}{dt} = \frac{n^2 s}{N}\exp(-\frac{E}{kT}) \qquad (2)$$

Rasheedy [5] and Gartia etal [6] modified Chen's general order kinetics model as

$$I(t) = -\frac{dn}{dt} = \frac{n^b}{N^{b-1}}s\exp(-\frac{E}{kT}) \qquad (3)$$

Case 1: The case of first order kinetics b=1
Solving equation (1) one can write

$$n = n_0\exp(-st\exp(-\frac{E}{kT})$$

Mean lifetime τ can be calculated as

$$\tau = \frac{1}{n_0}\int_0^\infty tns\exp(-\frac{E}{kT})dt = \frac{1}{s}\exp\left(\frac{E}{kT}\right) \qquad (4)$$

Case 2: the case of non-first order kinetics (b≠1)in the range 1<b<2.From (3) one gets

$$n = n_0[1+(b-1)f^{b-1}ts\exp(-\frac{E}{kT})]^{\frac{-1}{b-1}} \qquad (5)$$

where $f = \frac{n_0}{N}$ is the filling factor. If τ' denotes the mean lifetime of electron for (b≠1) kinetics, then it is given by

$$\tau' = \frac{1}{n_0}\int_0^{n_0} t\,dn = \frac{\tau}{(2-b)f^{b-1}} \qquad (6)$$

Thus the lifetime τ' depends not only on the E and s at a temperature T as in the case of b=1 but also on the order of kinetics b and filling factor f. It implies that lifetime is dependent on the initial number of electrons filled in the trap. For completely filled traps f=1, equation (6) reduces to that derived by Singh and Gartia [4].

Case 3: The case of mixed order kinetics

Following Chen etal [7] the mixed order kinetics can be written as

$$I(t) = -\frac{dn}{dt} = sn(n+M)\exp(-\frac{E}{kT}) \qquad (7)$$

where M is the number of electrons in ther-mally disconnected electron traps. In terms of lifetime τ in equation (6) and a parameter $\alpha = \frac{n_0}{n_0 + M}$, equation (7) reduces to

$$n = \alpha M[\exp(\frac{Mt}{\tau}) - \alpha]^{-1} \qquad (8)$$

Then the mean lifetime corresponding to TL peak following mixed order kinetics is

$$\tau'' = \frac{1}{n_0}\int_0^{n_0} t\,dn = \frac{1}{n_0}\int_0^{n_0} \frac{\tau}{M}\ln\{\alpha(1+\frac{M}{n})\}dn$$

$$\tau'' = \frac{\tau}{M}\ln\alpha + \frac{\tau}{Mn_0}\int_0^{n_0}\{\ln(n+M) - \ln(n)\}dn.$$

Then after integration it reduces to

$$\tau'' = \frac{\tau}{n_0}\ln(\frac{n_0}{M\alpha}) = \frac{\tau}{n_0}\ln(\frac{n_0+M}{M}) \qquad (9)$$

Here again, the mean lifetime depends on M, n_0 and α. α can be estimated from the shape factor μ_g.

2. RESULT and DISCUSSION

Fig 1 shows the complex TL glow curve of $Ba_{.92}SO$: $Dy_{.04}Mn_{.04}$ annealed at 873K and irradiated with 600 Gy of γ- rays. It consists of TL curves without and with thermal cleaning. When the phosphor is heated upto a particular temperature i.e T_{C1} = 387 K to erase the electron trap responsible for the first peak at 377 K. The TL recorded after thermally cleaning consists of two peaks at 406 and 450 K. Similarly the phosphor was thermally cleaned upto 464 K and a TL glow curve having peak at 482 K could be recorded. By thermal cleaning technique, the presence of at least four TL peaks can be established

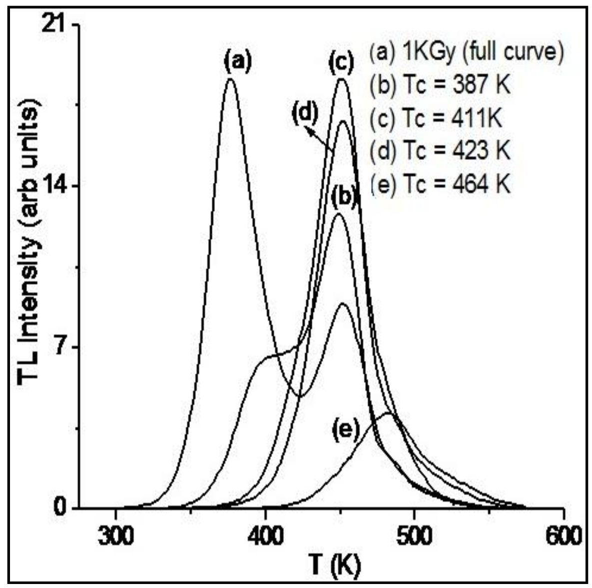

Fig 1. TL glow curves of $BaSO_4$:Dy,Mn irradiated with 1 KGy of γ-rays(No and with different T_c).

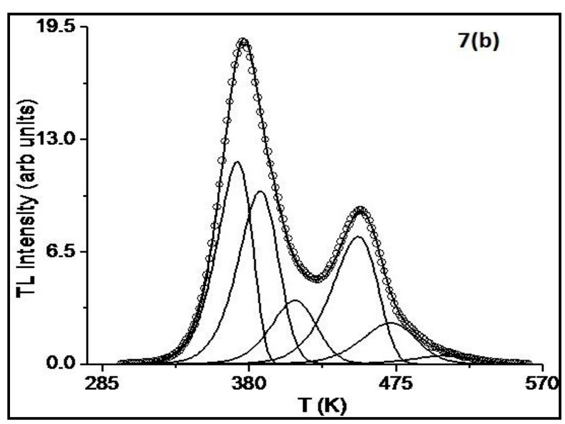

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Fig 2. (a): CGCD of TL peaks of $BaSO_4$:Dy,Mn

Fig. 2(a) shows CGCD of TL peaks of $Ba_{.92}SO$: $Dy_{.04}Mn_{.04}$ annealed at 873K and irradiated with 1000 Gy of γ-rays. The whole TL glow curve can be deconvoluted into six TL peaks with activation energies 1.06, 1.12, 1.18, 1.20, 1.26 and 1.34 eV respectively. Figures 2(b,c) shows the CGCD of TL glow curves of the phosphor thermally cleaned at 387,464K. The glow curve can be deconvoluted into five TL peaks. The kinetic parameters are shown in

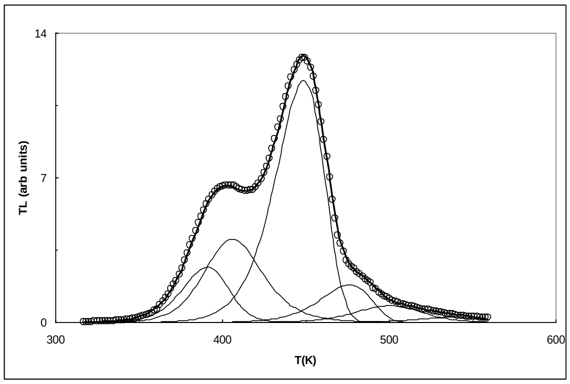

Fig 2(b). CGCD of $BaSO_4$:Dy,Mn with T_c=387K.

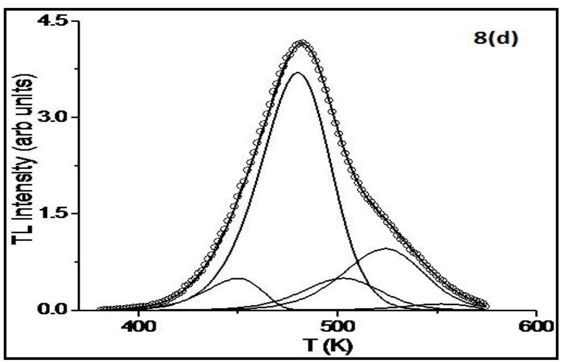

Fig 2(c). CGCD of $BaSO_4$:Dy,Mn with T_c=464K.

Table 1. Assuming the first order kinetics, lifetime of the electrons associated with the deconvoluted peaks are given. For TL peaks following non-first order kinetics, the lifetime is also calculated and shown in table 1. For the analysis by the present method we have selected data on colourless microcline feldspar following non-first order kinetics. It is to be noted that feldspar is a good candidate for TL dating . Sharma etal [7] applied the computerized glow curve deconvolution (CGCD) technique to determine the spectroscopy of traps in colourless microcline. Table 2 shows trapping parameters of NTL peaks of colorless microcline. It is observed that almost all the peaks follow non-first order kinetics (b≠1). As there was no expression for lifetime of the TL peaks following the non-first order kinetics, in the sixth column lifetime τ of trapped electrons corresponding to the constituent peaks in the composite TL glow curve assuming the first order kinetics are given. Using equation (6) the lifetime τ' with the respective non-first order kinetics (b≠1) is given in the seventh column. Since equation (6) is not valid for b=2, we have calculated τ' by assuming b=1.99. Thus it clearly shows that the lifetime of the trapped electron has been extended. This result has a positive consequence and has relevance for long range TL/OSL dating.

In the first order kinetics model , retrapping of trapped electrons is neglected in contrast to the second order kinetics (b=2) and general order kinetics model s where retrapping of the trapped electrons are taken into consideration. Thus elongation of lifetime is justified for TL peaks following non-first order kinetics.
To show the application of long range dating table 2 gives the lifetime of electrons associated with TL peaks of colorless microcline.

Table 1: Kinetic parameters of TL glow curves (without and with thermally cleaned) as obtained by CGCD method for $Ba_{.92}SO_4$: $Dy_{.04}Mn_{.04}$ annealed at 873K and irradiated with 1 KGy (β=1.37 K/s)

Tc (K)	T_m (K)	E(eV)	b	s(s^{-1})	τ'= τ/(2-b) (yrs.)
No T_c	372.1	1.06	1.03	$2.6x10^{13}$	0.209
	387.4	1.12	1.25	$2.4x10^{13}$	2.434
	410.2	1.18	1.40	$2.3x10^{13}$	27.351
	450.4	1.20	1.06	$2.7x10^{12}$	514.467
	471.7	1.26	1.40	$2.5x10^{12}$	5982.157
	506.3	1.34	1.50	$1.6x10^{12}$	$2.22x10^5$
387	390	1.12	1.20	$3.9x10^{13}$	1.498
	410.5	1.17	1.50	$2.5x10^{13}$	16.9333
	448.5	1.20	1.04	$2.7x10^{12}$	514.467
	476	1.27	1.40	$2.6x10^{12}$	8547.463
	511	1.34	1.50	$1.3x10^{12}$	$2.735x10^5$
464	450	1.20	1.01	$2.8x10^{12}$	496.0933
	479	1.26	1.50	$1.5x10^{12}$	9970.262
	503	1.34	1.50	$2.2x10^{12}$	$1.616x10^5$
	524	1.41	1.50	$2.9x10^{12}$	$1.962x10^6$
	552	1.52	1.00	$6.0x10^{12}$	$7.396x10^7$

3.CONCLUSION

A generalized formula for calculating lifetime of electrons associated with non-first order kinetics and mixed order kinetics has been derived. The formula has been applied to the experimental TL glow curves of $BaSO_4$:Dy,Mn and colorless microcline. This technique has a good implication for applying to TL peaks of quartz, feldspar and dosimetric phosphors which are widely used materials for TL dating and dosimetry.

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References:

1. M.J. Aitken, *Thermoluminescence dating*, Academic Press, New York,1985.
2. M.J. Aitken, *Optically luminescence dating*, Academic Press, New York,1985
3. Y.S.Horowitz,, B Ben Shachar, D. Yossain, J. Phys. D: Appl. Phys. 26(1993) 1475R. P. Rao, Proc. Of IIIrd ICLA2008, Macmillan Adv. Res. Ser. 102.
4. L. Lovedy Singh and R.K.Gartia, Radiation Effects and Defects in solids 166(2011) 297
5. M.S. Rasheedy J. Phys. : Condens. Matter. 5(1993) 633.
6. R.K.Gartia,S.D. Singh, and P.S. Mazumdar, On the non-first order kinetics: the case of plateau test, Phys. Status Sol (a) 138 (1993) 238
7. B.A. Sharma,.,A.N. Singh, S.N. Singh and O.B., Singh, Application of computerized glow curve deconvolution to determine the spectroscopy of traps in colorless microcline, Radiat. Meas., 44 (2009)32-37.

Table 2. Comparison of electron lifetimes for colorless microcline Along with trapping parameters given in Sharma etal [7].

T_m	E(eV)	$S(s^{-1})$	b	τ in yrs	τ' in yrs	β(K/s)
149.6	0.72	1.80E+07	1.8	4.27E-03	0.02137	
201.1	0.99	1.60E+09	1.1	2.12E+00	2.355546	
233.9	1.23	9.00E+10	2.0	5.06E+02	50642.73	
275.1	1.41	5.20E+11	1.9	1.09E+05	1093920	
303.9	1.57	2.60E+12	2.0	1.24E+07	1.24E+09	1
330.4	1.68	5.50E+12	1.6	4.56E+08	1.14E+09	
366.0	1.74	2.40E+12	1.8	1.13E+10	5.63E+10	
405.9	1.85	2.40E+12	1.6	8.78E+11	2.19E+12	
437.9	1.99	5.70E+12	1.4	9.46E+13	1.58E+14	
474.1	2.21	3.90E+13	1.1	8.41E+16	9.35E+16	
501.9	2.34	7.10E+13	1.6	7.96E+18	1.99E+19	
531.9	2.57	6.00E+14	1.6	8.52E+21	2.13E+22	
566.9	2.73	8.10E+14	2.0	3.57E+24	3.57E+26	
182.2	0.72	2.30E+07	1.8	3.34E-03	0.016724	
235.2	1.01	2.90E+09	1.1	2.58E+00	2.869716	
272.2	1.22	5.20E+10	1.9	5.90E+02	5898.527	
300.2	1.42	8.70E+11	1.8	9.72E+04	485794.2	
328.3	1.5	7.20E+11	1.9	2.79E+06	27910715	5
357.2	1.65	3.90E+12	1.8	1.96E+08	9.8E+08	
388.2	1.73	3.80E+12	1.9	4.78E+09	4.78E+10	
432.2	1.87	5.40E+12	1.8	8.61E+11	4.31E+12	
464.2	2.02	1.50E+13	1.8	1.18E+14	5.9E+14	
502.2	2.24	8.60E+13	1.4	1.25E+17	2.09E+17	
564.6	2.35	8.20E+14	2.0	1.02E+18	1.02E+20	