On the Ilich method of determination of activation energy of TL peaks with temperature dependent frequency factor

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Abstract

In the present paper, we have carried out an estimation of systematic errors involved in the calculation of activation energy by Ilich method for the case of temperature dependent frequency factor in thermo luminescence for computer generated peaks. We have applied Ilich method to some experimental TL peaks and determined the proportional error incurred in the determination of activation energy. The systematic errors as calculated for experimental TL peaks are within the range obtained for computer generated peaks.

Keywords: *Thermoluminescence, glow peak, Ilich method, temperature dependent frequency factor*

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1.0 Introduction

Thermally stimulated luminescence popularly known as Thermoluminescence (TL) is defined as emission of light above that expected for blackbody from some solid material commonly called phosphors. This emission is the release of energy stored within the solid through some type of prior excitation of solid electronic system by ionizing radiation such as X-rays, γ-rays etc. After irradiation, the phosphor is heated to emit TL. Activation energy(E), Frequency factor (s) and the order of kinetics(b) are important trapping parameters for TL emission[1-3]. Activation energy is linked with the life time of TL peak which is very much important from the point of view of dating and dosimetry[1,2]. Ilich method (ILM) [4,5] is a simple method for the determination of activation energy of TL process, is a simple variant of the wellknown Initial Rise method (IRM) proposed by Garlick and Gibson[6]. IRM requires a series of observations for determination of activation energy, whereas ILM requires a single observation. It is well known that in IRM there is a systematic error in the determination of activation energy [7] so that activation energy as determined by IRM is lower than actual activation energy. In view of this, activation energy as determined by ILM might be subjected to such systematic errors resulting in underestimation of evaluated activation energy. In the present paper, we attempt to estimate the systematic error in evaluation of activation energy of TL peaks both for the cases of temperature independent and dependent frequency factor[1,2]. Finally we examine the suitability of our findings by considering some experimental TL peaks.

1.1 Theory

The TL intensity $I(T)$ at temperature T for first order ($b = 1$) TL glow peak for the case of temperature dependent frequency factor can be expressed as [8]

$$I(T) = n_0 s_0 T^a \exp(-E/kT) \exp\left(-\frac{E}{kT} - (s_0/\beta)\int_{T_0}^{T} T'^a \exp(-E/kT')dT'\right)$$

(1)

The corresponding expression of $I(T)$ for non-first order kinetics ($b \neq 1$) is

$$I(T) = n_0 s_0 \exp(-E/kT)\left\{1 + \frac{(b-1)s_0}{\beta}\int_{T_0}^{T} T'^a \exp(-E/kT')dT'\right\}^{\frac{b}{b-1}}$$

(2)

where n_0 is the initial number of trapped electrons, 'a' is the temperature exponent of frequency factor and one can write [2]

$$s = s_0 T^a$$

(3)

with $-2 \leq a \leq 2$

β is the heating rate corresponding to the linear heating scheme

$$T = T_0 + \beta t \qquad (4)$$

where T is the temperature at any time tand T_0 is the initial temperature at t=0, k is the Boltzmann constant. In Ilich method, the activation energy can be expressed as [4]

$$E_{IL} = \frac{kT_c^2}{T_c - T_0} \qquad (5)$$

where T_0 is the temperature where the tangent to any arbitrary point (T_c, I_c) of the initial rise portion of the TL curve (Fig 1) intersects the temperature axis. The initial rise portion of the TL curve is limited upto 10-15% of its maximum intensity in the rising portion of the curve.
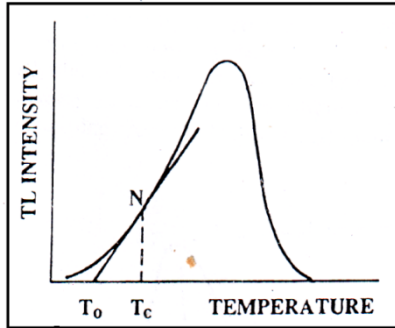

Fig. 1: Tangent Method proposed by Ilich.

1.1.1 Results and Discussion

In order to determine the activation energy by Ilichmethod using equation (5), we have to determine the temperature T_0 where the tangent to the glow curve at the point (T_c, I_c) meets the temperature axis. Now the equation to the tangent to the glow curve at the point (T_c, I_c) is given by

$$I - I_c = m(T - T_c) \qquad (6)$$

where $m = \left(\dfrac{dI}{dT}\right)_{T=T_c}$ is the slope of the tangent to the glow curve at the point (T_c, I_c). If the tangent intersects T-axis at the point $(T_0, 0)$ from equation (6) we get

$$T_0 = T_c - I_c / m$$

m has been found out by following the numerical technique outlined by Shastry [9]. Knowing T_0 and T_c, E_{IL} can be evaluated using equation (5). Knowing E_{IL} the proportional error (%) in the determination of activation energy is given by

$$\delta_{IL} = \frac{|E - E_{IL}|}{E} \times 100\% \qquad (7)$$

In Fig. 2, we depict the variation of δ_{IL} with b for $1 \le b \le 2.5$ for a=-2, 0, 2 using the initial rise portion of the glow curve up to the fractional intensity $x = \dfrac{I}{I_m} = 0.15$. δ_{IL} varies almost linearly with b and the variation is very slow. For a=-2, δ_{IL} increases with increase in b.
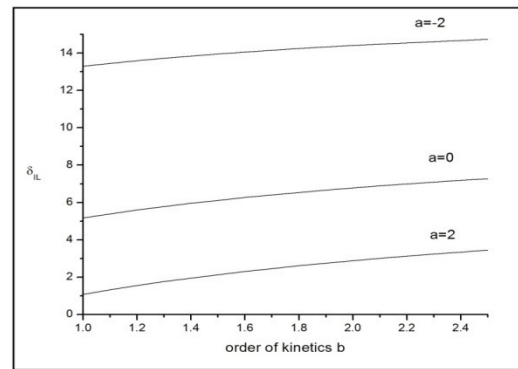

Fig. 2: Variation of δ_{IL} with order of kinetics for different values of 'a' in Computer simulated glow curve (E=1 eV, s=10^{12} s^{-1})

As b varies from 1 to 2.5, δ_{IL} increases from 13.3% to 14.7% for a=-2. For a=2, δ_{IL} increases slowly from 1.07% to 9.44% as b increases from 1 to 2.5 whereas the variation is from 5.17% to 7.17% for a=0. We have calculated δ_{IL} for different values of E and observed that δ_{IL} is almost independent of the input value of E used in the calculation. In Fig. 3 we exhibit the variation of δ_{IL} with $\log s_0$ for $b = 2$. The variation is almost linear. For a=0 and a=2 δ_{IL} increases slowly with s_0. For a=2 δ_{IL} varies from 1.75% to 2.88% as s_0 varies from 10^8 to 10^{12} units.
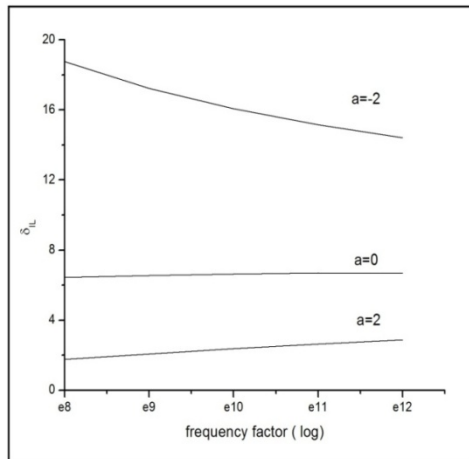
Fig. 3: Variation of δ_{IL} with $\log s_0$ for different values of 'a' in Computer simulated glow curve(E=1 eV, s=10^{12} s^{-1})

For a=0, the corresponding variation is from 6.45% to 6.68%. On the other hand for a=-2, δ_{IL} decreases from 18.77% to 14.47% as s_0 increases from 10^8 to 10^{12} units. For other values of b similar results have been obtained.

Now we apply ILM to some experimental TL peaks namely

   i) 103^0C and 219^0C peaks of X-irradiated light emitting porous Silicon (LEPSi) [10]
   ii) 252^0C, 285^0C and 322^0C peaks of X-irradiated orthoclase feldspar after thermal cleaning up to 220^0C [11]

For all the peaks the activation energy has been determined by rigorous program of curve fitting[2] are denoted by E_{cf}. If we consider E_{cf} as the standard or reference value of activation energy, the proportional error(%) in the activation energies of experimental TL peaks by ILM can be expressed as

$$\delta_{ILE} = \frac{\left| E_{cf} - E_{IL} \right|}{E_{cf}} \times 100\% \qquad (8)$$

The values of E_{IL}, E_{cf} and E_{ILE} have been cited in Table 1, from which it is evident that the values of δ_{ILE} of the experimental peaks are within the range of values of δ_{IL} obtained in the present work.

Table 1. Proportional errors(%) in the determination of activation energy of some experimental TL peaks by Ilich Method.

System	Peak Temperature T_m (^0C)	E_{IL}	E_{cf}	δ_{IL}
(i)LEPSi	103	0.64	0.68	5.00
	213	0.76	0.80	4.50
(ii)Orthoclase Feldsper	252	1.35	1.42	5.05
	285	1.51	1.59	4.97
	322	2.10	2.20	4.80

2.0 CONCLUSION

In the present work, we have theoretically calculated the proportional error involved in the calculation of activation energy of TL peaks of arbitrary orders of kinetics. We have also calculated the proportional error involved in the calculation of activation energy by Ilich Method for some experimental TL peaks and the proportional errors are within the range of calculated theoretical errors. We conclude that the Ilich method can be used for the determination of activation energies of TL peaks of arbitrary orders of kinetics both for the cases of temperature dependent and independent frequency factor.

References:

1. R. Chen,V. Pagonis,Thermally and Optically stimulatedluminescence, A simulation approach, Wiley,Chicester, (UK) 2011.
2. R. Chen, S. W. S. McKeever,Theory of Thermoluminescence and Related Phenomenon, World Scientic(Singapore) 1997.
3. C. M. Sunta, Unraveling Thermoluminescence, Springer (New Delhi, India) 2015.

4. B. M. Ilich,Sov. Phys. Sol. St. 21 (1979) 1880
5.C. Bacci,P. Bernardini, A.Damilano, C. Furetta, B.Rispoli,J. Phys. D: Appl. Phys.22 (1989) 1751.
6. G. F. J. Garlick, A. F. Gibson, Proc. Phys. Soc. 40(1948)574.
7.C. Christodoulides,J. Phys. D: Appl.Phys.18 (1985)1665.
8. R. J. Fleming,J. Phys. D: Appl.Phys.23 (1990)950.
9.S. S. Shastry,Introductory Method of Numerical Analysis,PHI,(New Delhi, India) 2009.
10.D. W. Cooke, B. C. Bernet, E. H. Farnum, W. L. Hults, R. E. Muenchausen, J. L. Smith, Appl Phys Lett70(1997) 3594.
11. A. N. Singh,Ind. J of Phys A 73(1999) 647.