Report on the initial rise, whole glow peak and peak-shape methods of kinetics on thermoluminesecence of synthetic quartz

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1 Experimental details

The sample of synthetic quartz annealed to $500°C$ was used. The samples were first heated up to 500°C to erase any residual information before subsequent irradiation and quickly cooled in air to room temperature. The sample was irradiated at ambient temperature using $^{90}S_r/^{90}Y$ as a β source at a nominal dose rate of 0.1028 Gy/s. After irradiation, TL was measured using a RISØ TL/OSL-DA-20 luminescence reader. The TL was detected by an EMI 9235QB photomultiplier tube through a 7mm Hoya U-340 filter (transmission band$250-390$ nm FWHM). Glow curve were measured at a linear heating rate of $1°C/s$. All the measurements were made in a nitrogen atmosphere to prevent spurious signals from air and improve thermal contact between the sample and the heater plate.

2 Results

2.1 Glow curve

Figure 1 show a glow curve of synthetic quartz measured at $1°C/s$ following irradiation of 1 Gy. At each experimental measurement, sample was read out twice. The second readout is considered to be the background of the reader plus sample; this was subtracted from the first one and all the analyses have been carried out after the subtraction.

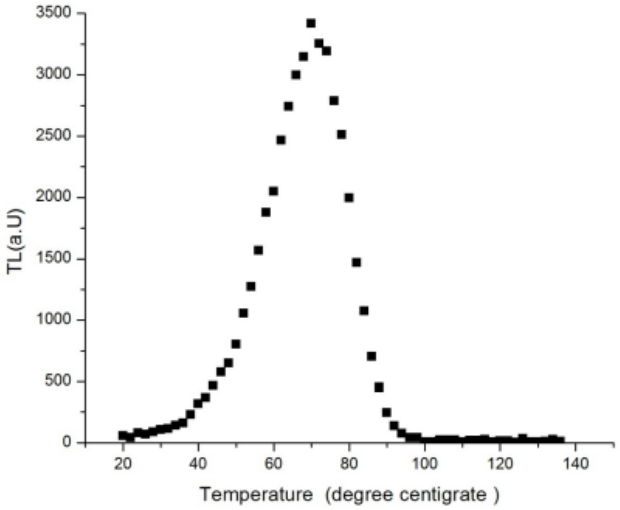

Figure 1: TL signal measured from annealed synthetic quartz at heating rate of $1°C/s$ after irradiation to 1.0 Gy.

2.2 Initial rise method

In the initial rise method, the amount of electron traps in the lower region of the TL glow peak is assume to be approximately constant, hence,the equation

$$I(t) = C\exp(-E/kT) \tag{1}$$

where C is the constant of proportionality, I is the intensity of the TL, E is the activation energy, k is the Botzmann constant and T is the absolute temperature. To estimate the activation energy using this method, data along the rising edge was taken $(5-15)\%$ of the TL peak were used to determine the activation energy. The plot of ln(I) versus 1/kT is linear with the slope equal to activation energy [1]. Figure 2 below shown the curve which gives the activation energy $E = (0.98 \pm 0.04)$eV

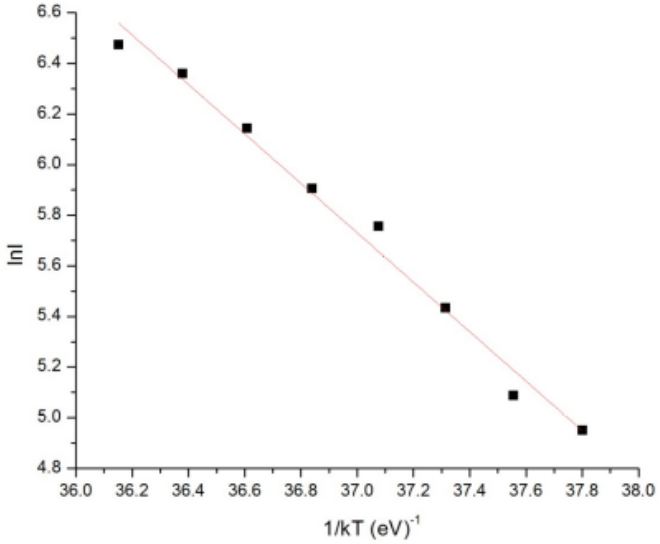

Figure 2: Plot of ln(I) versus 1/kT used to determine the activation energy of the TL peak

2.3 Whole glow peak method

The whole glow peak method, are based on the measurement of the area under the glow peak. The area, n(T) of the peak over certain temperature range from T_i initial region of the peak up to final region of the peak T_f is given by the equation

$$n(T) = \frac{1}{\beta}\int_{T_i}^{T_f} I dT \tag{2}$$

where β is the heating rate and I is the TL intensity. In case of general order of kinetic, transformation of equation (2) gives

$$\ln \frac{I}{n^b} = \ln \frac{s'}{\beta} - \frac{E}{kT} \tag{3}$$

Where n is the area under the glow peak, b is the order of kinetics, $s'(m^{3(b-1)})$ is the effective frequency factor for general order kinetics and E is the activation energy [1]. For a specific value of b, the plot of $ln\frac{I}{n^b}$ versus 1/kT is linear curve with slope equal to activation energy and the intercept $ln\frac{s'}{\beta}$ along the y-axis. The plot was found most linear for $b = 1.2$, the activation energy and the effective frequency factor were evaluated as $E = 0.99 \pm 0.01$ eV and $s' = (2.99 \pm 0.4) \times 10^{12}/s$. The value of activation energy evaluated using this method is in agreement with result obtained from initial rise method

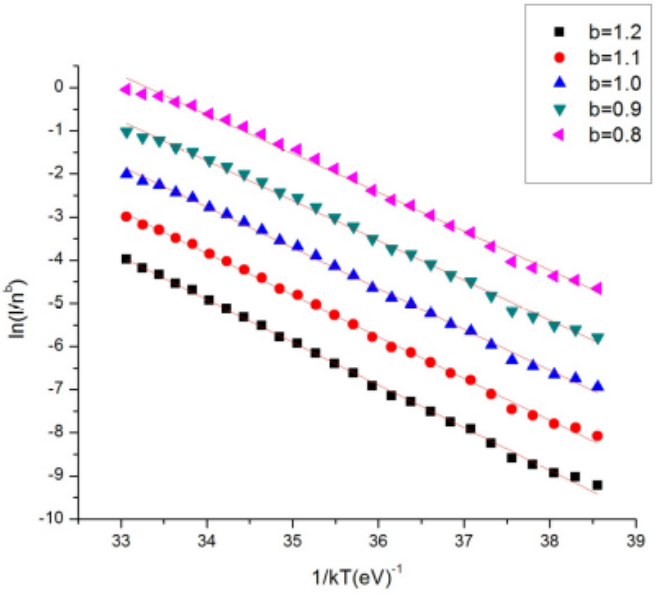

Figure 3: A plot of ln $\frac{I}{n^b}$ versus 1/kT for different values of the order of kinetics.

2.4 Peak- shape method

In peak – shape method, we considered the geometry of the TL peak. The activation energy E_α ascociated with a peak temperature T_M is evaluated using Chem's equation

$$E_\alpha = C_\alpha \frac{(kT_M^2)}{\alpha} - b_\alpha(2kT_M) \tag{4}$$

where T_M is the peak temperature at the maximum intensity, k is the Botzmann constant,α stand for τ, the half width at the fall - off side or ω, is the total half- width of the glow peak. The values of C_α and b_α are summarized [1].

$$C_\tau = 1.510 + 3.0(\mu - 0.42), \quad b_\tau = 1.58 + 4.2(\mu - 0.42) \tag{5a}$$
$$C_\delta = 0.976 + 7.3(\mu - 0.42), \quad b_\delta = 0 \tag{5b}$$
$$C_\omega = 2.52 + 10.2(\mu - 0.42), \quad b_\omega = 1 \tag{5c}$$

where, $\tau = T_M - T_1$, $\delta = T_2 - T_M$ and $\omega = T_2 - T_1$ and this is related to geometrical factor as; $\mu = \frac{\delta}{\omega}$

Theoretically, geometrical factor μ range between 0.42 and 0.52 for first-and second order kinetics respectively. The activation energy E for different values of α can be evaluated using values of C_α and b_α corresponding to τ, δ and ω respectively [1]. The activation energy evaluated were $E_\tau = (0.93 \pm 0.14)$ eV, $E_\delta = (0.91 \pm 0.19)$ eV and $E_\omega = (0.93 \pm 0.09)$ eV, the geometrical factor,μ was found 0.41 ± 0.11 which implied first- order kinetic

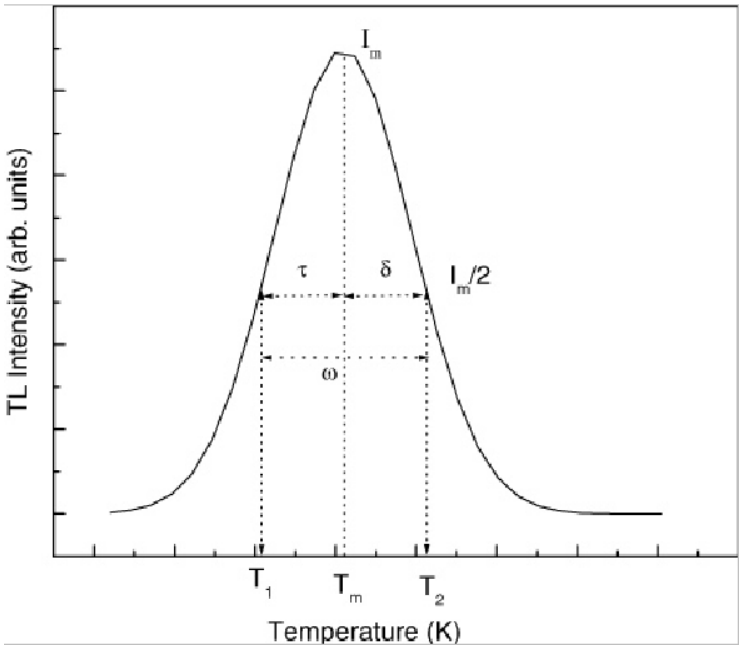

Figure 4:
The diagram for different quantities in the glow curve peak- shape method used to determine the trap parameters reproduced from [2].

Table 1.0 summary of the results of initial rise, peak shape and whole glow curve methods

Methods	E eV	s(/s)	references
Initial	0.98 ± 0.04		$R^2 = 0.99$ Fig 2
Chen's τ	0.93 ± 0.14		
Chen's δ	0.91 ± 0.19		
Chen's ω	0.93 ± 0.09		
Whole glow peak	0.99 ± 0.01	$s'(2.99 \pm 0.40) \times 10^{12}$	$R^2 = 0.99$ Fig3

The results obtained in this report is in agreement with Kitis [3] reported the value of activation energy as (0.91 ± 0.01) eV at temperature $110°C$ and Yazice [4] (0.90 ± 0.01)eV at temperature $96°C$ of synthetic quartz.

References

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[3] A Necmeddin Yazici *and Mustafa Topaksu*. The analysis of thermoluminesecence glow peaks of unannealed synthetic quartz.J.Phys.D: Appl.Phys 36(620-627)2003

[4] G. Kitis *V. Pagonis, H. carty and E. Tatsis*. Detailed kinetic study of the thermoluminesecence glow curve of synthetic quartz. Radiation protection dosimetry.100(225-228) 2002