Determination of TL Kinetic parameters of a phosphor

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Abstract
Present paper reports the methods of evaluating the kinetic parameters like trap depth, frequency factor etc. by using the Glow Curve of a phosphor. Peak shape method is found to be suitable amongst all reported methods. This method provides the nearest possible values of all studied kinetic parameters which are discussed in details. MS -Excel sheet is prepared for calculation.

Keywords: Phosphor, kinetic parameters, glow curve, TL

INTRODUCTION
Mechanoluminescence (ML) is a type of luminescence induced by any mechanical action on solids. The light emission Thermoluminescence (TL) is defined as the emission of light from a semiconductor or an insulator when it is heated, due to the previous absorption of energy from irradiation. The graph of the amount of light emitted during the TL process as a function of the sample temperature is known as a “TL Glow Curve”.

The simplest model which describes the TL is OTOR Model (One Trap One Recombination Center Model).

Let

\[ \begin{align*}
N &= \text{total concentration of the traps in the crystal (m}^{-3}) \\
n(t) &= \text{the concentration of filled traps in the crystal (m}^{-3}) \text{ at time } t \\
n_h(t) &= \text{concentration of trapped holes in the recombination center.} \\
N_0 &= \text{concentration of filled traps at time } t = 0 \\
\beta &= \text{heating rate}
\end{align*} \]

In a simple Thermoluminescence model, when temperatures increases, electrons of the trap level goes into the conduction band (transition 1) and then it may follow two path of transition either 2 or 3 as shown in the figure1. When electrons after transition 3 reaches the Recombination level, holes available there recombines with the electron reaching which releases the energy, which is the cause of Thermoluminescence.

Following are the equations governing different order of kinetics:

\[ \begin{align*}
\frac{\beta E}{T_m} &= s \exp \left( \frac{E}{kT_m} \right) \text{ I Order Kinetics} \\
\frac{\beta E}{T_m} &= s \exp \left( \frac{E}{kT_m} \right) \left[ 1 + \frac{2kT_m}{E} \right] \text{ II Order Kinetics} \\
\frac{\beta E}{T_m} &= s \exp \left( \frac{E}{kT_m} \right) \left[ 1 + (b - 1) \frac{2kT_m}{E} \right] \text{ General Order Kinetics}
\end{align*} \]

METHODS FOR EVALUATION OF THERMOLUMINESCENCE

There can be many methods to evaluate the kinetic parameters of phosphors out of which few are listed below:
1) Initial Rise Method
2) Peak position method
3) Different Heating Rate method
4) Peak Shape Method

Initial Rise Method

This method is based on the analysis of the low temperature interval of peak. The initial rise method was first suggested by Garlick and Gibson.

The amount of trapped electrons in the low temperature tail of a TL glow peak can be assumed to be approximately constant, since the dependence of \( n(T) \) on temperature \( T \) is negligible in that temperature region. In fact the temperature increases, the first exponential in equation (1) increases, whereas the value of second term remains close to unity. This remains true for temperatures up to a cutoff temperature \( T_c \), corresponding to a TL intensity \( I_c \) smaller that about 15% of the maximum TL \( I_m \). A further increase in temperature \( (T > T_c) \) makes the second term in equation (1) decrease; the competition between two terms in equation (1) results in the peak shape of the TL glow curve.

By using this assumption of constant \( n(T) \), the thermoluminescence emission can be described by

\[ I(T) \propto \exp \left( -\frac{E}{kT} \right) \]

Following figure shows the initial rise part of a single TL glow peak. In applying the initial rise method, a graph of \( \ln(I) \) is made, and a straight line is obtained. From the slope \( -E \) of the line, the
activation energy $E$ is evaluated without any knowledge of frequency factors.

**Different Heating rate method**

For calculating the trap depth from above mentioned method, we need to take two different glow curves of the same sample giving two different heating rates as $\beta_1$ and $\beta_2$. The following equation can be utilized:

$$E = \frac{c_1}{\beta_1} - \frac{c_2}{\beta_2}$$

**Peak position method**

Following equation is given for calculating the trap depth using only the peak position of a glow curve:

$$E = \frac{c_3}{T_{m1}} - \frac{c_4}{T_{m2}}$$

OR

$$E = \frac{c_5}{T_{m1}} - \frac{c_6}{T_{m2}}$$

**Peak shape method**

The most accurate method for measuring kinetic parameters is peak shape method. The following factors are to be calculated using the geometrical properties of the glow curve:

- $T_m$ is the peak temperature at the maximum.
- $T_1$ and $T_2$ are, respectively the temperatures on either side of $T_m$, corresponding to half intensity.

$$\tau = T_m - T_1$$

$\delta = T_2 - T_m$ is the half-width at the high temperature side of the peak.

$\omega = T_2 - T_1$ is the total half-width.

$\mu = \delta/\omega$ is so-called geometrical shape of symmetry factor.

Trap depth can be calculated by using $\tau$, $\delta$ and $\omega$ in the following way:

$$E_\alpha = c_\alpha \left( \frac{KT^2}{\alpha} \right) - b_\alpha (2KT_m)$$

Where $\alpha$ is $\tau$, $\delta$ and $\omega$. The values of $c_\alpha$ and $b_\alpha$ are summarized as below:

- $c_\tau = 1.510 + 3.0 (\mu - 0.42)$
- $b_\tau = 1.58 + 4.2 (\mu - 0.42)$
- $c_\delta = 0.976 + 7.3 (\mu - 0.42)$
- $b_\delta = 0$
- $c_\omega = 2.52 + 10.2 (\mu - 0.42)$
- $b_\omega = 1$

With $\mu = 0.42$ for the case of first order TL peaks and $\mu = 0.52$ for the case of second order peaks.

**Evaluating kinetic parameters (using glow curve data)**

A glow curve for a sample phosphor for different UV exposure time is shown below.

**RESULTS**

Peak Shape Method gives the nearest value of Kinetic parameter. The trap depth measured for a sample phosphor is found to be in the range of 0.47 eV to 0.58 eV. The frequency factors varies from $1 \times 10^8$ to $2 \times 10^7$ and the peak seems to be of second order kinetics.

**REFERENCES**


