



## EVALUATION OF TRAPPING PARAMETERS OF $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl:Dy}$ BY VARIOUS TECHNIQUES

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### Abstract

In this paper thermoluminescence displayed  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl:Dy}$  is discussed. Modified solid state diffusion method was used for the preparation of phosphor. Dy (0.5 mol%) doped  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl}$  after exposure to  $\gamma$ -irradiation is studied for which revealed a prominent glow curve at 261°C Trapping parameters and their estimated error values have been calculated by Chen's peak shape method, initial rise method and whole glow peak method. Values of activation energies estimated by all these techniques are comparable.

**Keywords:** Thermoluminescence, Activation energy, Trapping parameters.

### 1.Introduction

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." Thermoluminescence (TL) technique has wide range of applications such as in radiation dosimetry and to dating techniques in archeology and geology. The dosimetric characteristic of any TL phosphor mainly depends on its trapping parameters which describe the defect centers responsible for the TL emission. The analysis of TL glow curves gives the trapping parameters of the traps such as the traps depth (E), frequency factor (s) and order of kinetics (b). Various experimental techniques such as initial rise (IR) method, curve fitting methods, Chen's half width methods, heating rate methods, isothermal decay analysis methods, etc., have been developed to determine these parameters from TL glow curves [1–5]. In this paper the trapping parameters of  $\gamma$ -ray irradiated  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl:Dy}$  phosphor are calculated by

Chen's peak shape, isothermal luminescence decay and the whole glow peak method.

In this paper the various theoretical methods and analytical expressions used to analyze TL glow curves are presented

## 2. Experimental Details

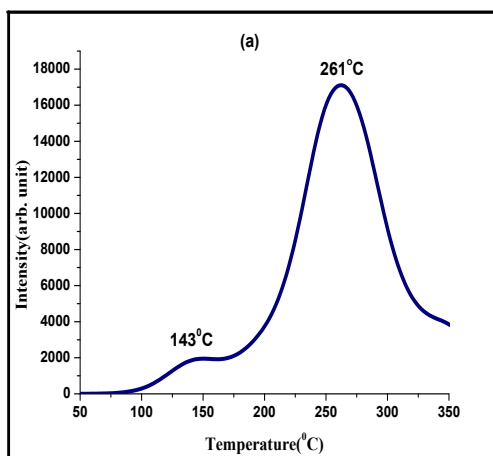
Strontium haloborate phosphors were synthesized *via* modified solid state reaction. Analytical grade strontium nitrate ( $\text{Sr}(\text{NO}_3)_2$ ), boric acid ( $\text{H}_3\text{BO}_3$ ), ammonium chloride ( $\text{NH}_4\text{Cl}$ ) and dysprosium oxide ( $\text{Dy}_2\text{O}_3$ ) were used as raw materials. The stoichiometric amount of raw materials were mixed and grounded in an agate mortar. The concentration of dysprosium was taken 0.5 mol%, the mixture was transferred to silica crucible and kept in preheated furnace at  $600^\circ\text{C}$  for 2 h., after cooled to room temperature, the samples were reground again and finally fired at  $800^\circ\text{C}$  for 24 h. Prepared phosphors were then crushed to get the powder form. Finally the powder was annealed for 1h and then quenched from  $600^\circ\text{C}$ .

Balanced chemical reaction is given as-



## 3. Results and Discussion

Figure 1 shows typical TL glow curve for  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl}:\text{Dy}$  sample for 0.5 mol% Dy concentration for 0.6 Gy exposure. The prominent glow peak observed at high temperature around  $261^\circ\text{C}$  with one shoulder peak around  $143^\circ\text{C}$ .



**Figure 1:** Typical glow curve for  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl}:\text{Dy}$  phosphor exposed to  $\gamma$ -ray radiation for 0.5mol% of Dy.

#### 4. Calculations of trapping parameters:

##### 4.1 Chen's Peak Shape Method

For the determination of kinetic parameters the following shape parameters are to be evaluated- $\omega = T_2 - T_1$  (total half intensity width),  $\delta = T_2 - T_m$  (the high temperature half width) and  $\tau = T_m - T_1$  (low temperature half width). Order of kinetics can be evaluated from the symmetry factor ( $\mu_g$ ) of the glow peak ( $\mu = \delta/\omega$ ) and it depends on shape of glow peak. The value of  $\mu_g$  for first and second order kinetics is 0.42 and 0.52 respectively. For glow peak P<sub>1</sub>,  $T_1=123.11^\circ\text{C}$ ,  $T_m=141.32^\circ\text{C}$  and  $T_2=160.82^\circ\text{C}$  and for peak P<sub>2</sub>,  $T_1=227.306^\circ\text{C}$ ,  $T_m=258.11^\circ\text{C}$  and  $T_2=287^\circ\text{C}$ . For both these peaks the geometric factor is around 0.5 indicate that it obeys second order kinetics. The activation energy **E** and frequency factor **s** can be calculated from the equations shown below [6,7]. The values of  $c_\gamma$  and  $b_\gamma$  are given in table 1.

$$\mathbf{E} = \mathbf{c}_\gamma \mathbf{kT}_m^2 / \gamma - \mathbf{b}_\gamma 2\mathbf{kT}_m \text{ ----- (1)}$$

$$\beta \mathbf{E} / \mathbf{kT}_m^2 = \mathbf{s} [1 + (\mathbf{b} - 1) 2\mathbf{kT}_m / \mathbf{E}] e^{(-\mathbf{E} / \mathbf{kT}_m)} \text{ ----- (2)}$$

Where  $\gamma$  stands for  $\tau, \delta, \omega$  which are respectively determined by ( $\tau = T_m - T_1$ ), ( $\delta = T_2 - T_m$ ) and ( $\omega = T_2 - T_1$ );  $k$  is Boltzmann constant ( $k = 8.617 \times 10^{-5}$ ) and  $\beta$  is heating rate ( $5^\circ\text{C/s}$ ). Constant 'b' represents the order of kinetics here ( $b=2$ ).

**Table 1:** Values of  $c_\gamma$  and  $b_\gamma$  depending on  $\tau, \delta, \omega$  (for second order of kinetics)

	$\tau$	$\delta$	$\omega$
$c_\square$	1.81	1.71	3.54
$b_\square$	2.0	0	1.0

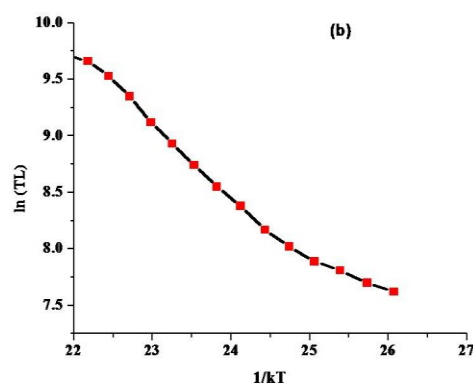
Trap depth observed for prominent peak is 1.31 eV. Corresponding frequency factor is found to be and  $4.28 \times 10^{12} \text{s}^{-1}$ . From the data it is clear that the glow peaks follow second order of kinetics and hence there is a chance of retrapping. The traps could be either electron traps or hole traps or of both kind.

## 4.2 Initial rise method

Initial rise technique is based on the analysis of the low temperature interval of a peak. This method was first proposed by Garlick and Gibson [8] According to this method the amount of trapped electrons in the low temperature tail of a TL glow curve can be presumed to be approximately constant, as the dependence of  $n(T)$  on temperature  $T$  is negligible in that temperature region. This remains true for temperatures up to a cutoff temperature  $T_c$ , corresponding to a TL intensity smaller than about 10-15% of the maximum TL intensity ( $I_m$ ). [29] The TL intensity  $I$  is proportional to  $\exp(E/kT)$ , assuming the frequency factor to remain the same and there is no overlapping of glow peaks, i.e.

$$I(T) = C \exp(-E/kT)$$

Where  $C$  is the constant,  $I(T)$  is the TL intensity at any temperature  $T$ , when the sample is heated at a linear heating rate of  $b = dT/dt$ ,  $E$  is the thermal activation energy and  $k$  is Boltzmann's constant. A plot of  $\ln(TL)$  versus  $1/kT$  over the initial rise region gives a straight line and from the slope  $-E/k$ , activation energy  $E$ (eV) can be calculated. The important necessity for this initial rise analysis is that the concentration of the trapped carriers remains approximately constant at any instant. But this assumption becomes invalid beyond the cut-off temperature.



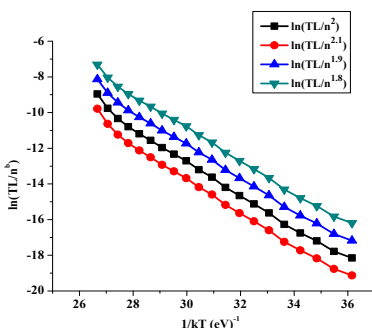
**Figure 2 :** Initial rise plot of  $\ln(TL)$  versus  $1/kT$  for 261°C peak in  $Sr_2B_5O_9Cl:Dy$

The initial rise technique can be used only when the glow peak is well defined and is clearly separated from the other peaks. In applying the initial rise method, a graph of  $\ln(TL)$  versus  $1/kT$  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 the frequency factor  $s$  [7]. The slope of the regression line gives the activation energy  $E$ . The activation energy for the prominent peak is calculated as 1.32 eV.

### 4.3 The whole glow-peak method

In the whole glow-peak area method, the area  $n(T)$  under the glow peak is calculated starting at temperature  $T$ , to the maximum temperature available [9]. The maximum available temperature is  $261^\circ\text{C}$ . The area  $n(T)$  under the glow peak can be approximated by using the sum of all the data points from any temperature  $T$  upwards, up to the maximum temperature available in the data. In our case, we are given  $\Delta T = 2 \text{ K}$  and  $\beta = 5^\circ\text{C/s}$ .

We graph  $\ln(I/n^b)$  versus  $1/kT$  for various values of  $b$  between 1.8 and 2.1, and find the value of  $b$  that gives a linear graph. The maximum available temperature is  $261^\circ\text{C}$ . We set up a spreadsheet to calculate the quantities  $\ln(I/n^b)$  and  $1/kT$  as shown in figure 3. Additional columns are created in the spreadsheet for the quantities of  $\ln(TL/n^b)$  for several values of the kinetic order  $b = 2.0, 2.1, 1.9,$  and  $1.8$ . Finally, several graphs are drawn of  $\ln(TL/\text{Area}^b)$  versus  $1/kT$  as shown in Figure 3.



**Figure 3:** Graphs of  $\ln(TL/\text{Area}^b)$  versus  $1/kT$  for several values of kinetic order  $b$ .



A regression line is fitted to the four graphs above:

$$b = 1.8: R^2 = 0.995$$

$$b = 1.9: R^2 = 0.996$$

$$b = 2.0: R^2 = 0.997$$

$$b = 2.1: R^2 = 0.994.$$

The regression line for  $b = 2.0$  gives the largest regression coefficient  $R^2$ . Within the accuracy of the given experimental data and within the framework of the whole glow-peak method of analysis, we can conclude that the given TL glow peak data follow second-order kinetics. The values of  $E$  can be calculated from the best-fitting regression line. Best  $E$  value is obtained as 0.99 eV which is in good agreement with the  $E$  values obtained from rest of the methods.

## Conclusion

In the present work  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl}:\text{Dy}$  phosphor has been synthesized by modified solid state synthesis. The activation energies and frequency factors determined for prominent peak ( $261^\circ\text{C}$ ) of  $\text{Sr}_2\text{B}_5\text{O}_9\text{Cl}$  material using Chen's peak shape method, initial rise method and whole glow peak method have been illustrated. The trap depth of peak obtained by PS method is 1.31 eV with the frequency factor  $4.28 \times 10^{12} \text{s}^{-1}$ . Activation energy calculated by initial rise method is obtained as 1.32 eV and that of whole glow peak method is 0.99 which is approximately equal to 1 i.e activation energies estimated by all these techniques are in good agreement.

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## References

- S.W.S. McKeever, (1985). Thermoluminescence of Solids, Cambridge University Press, p.75.
- J. Azorin, C. Furetta, and A. Gutierrez, (1989) . J. Phys. D: Appl. Phys. 22 458.
- Y. Kirsh, (1992). Phys. Stat. Sol. A 129 ,15.
- S.W.S. McKeever, (1980) . Nucl. Instrum. Methods 175 ,19.
- G.C. Taylor, and E. Lilley, (1978). J. Phys. D: Appl. Phys. 11, 567.
- S.W.S. McKeever, (1985). Thermoluminescence of solids, Cambridge University Press.
- R.Chen, (1969). J.Appl. Phys. 40, 570.
- G.F.J. Garlick, and A.F. Gibson, (1948). The electron traps mechanism of luminescence in sulphide and silicate phosphors. Proc. Phys. Soc. Lond. 60, 574.
- V. Pagonis, G. Kitis, and C. Furetta, (2005). Numerical and Practical Exercises in Thermoluminescence,.