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Synthesis and Trap parameter study of $Sr_2B_2O_5:Tb^{3+}$ phosphor

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Abstract:

$Sr_2B_2O_5:Tb^{3+}$ phosphor was prepared by combustion method and studied its trap parameter. The XRD pattern of the prepared phosphor is well match the JCPDS file. In present study the trapping parameters such as order of kinetics(b), activation energy(E) and frequency factors (s) have been calculated for the glow peaks of $Sr_2B_2O_5:Tb^{3+}$ by using Chen's method. The trap depth of the prepared phosphor was found to be 0.570 eV. The frequency factor was found to be $0.5\times10^7 s^{-1}$.

Keywords: Phosphor, Borates, trap parameter, XRD

1.Introduction:

As a significant family of luminescent materials, borates have attracted much attention, not only as a number of compounds with different structure, but owing to their environmental benignity, outstanding thermal stability, and prospective low-cost synthesis [1]. Borates have attracted much attention due to its high sensitivity, low cost and easy preparation amongst the all known TL materials [2]. As a host borate compounds played a very important role for the development of luminescent materials [3]. As phosphor materials for a several applications various borate materials used as a host and doped with rare earth ions and other ions have been reported earlier by various groups [4-5]. As a thermoluminescence dosimetry (TLD) phosphors material several borate compounds find important application. Some of the low *Z* phosphors, used in personal dosimetry application are $Li_2B_4O_7$:Cu [6-7] and MgB_4O_7:Dy [8]. Between tissue equivalent LiF:Mg,Ti (Zeff =8.4)[9] phosphor, and high *Z* $CaSO_4$:Dy (Z_{eff}=15.5) [10] TLD phosphor CaB_4O_7 (Z_{eff}=12.58) [11] is an intermediate Z phosphor. The combustion process to prepare the precursor powders, however, is very facile and only takes a few minutes, which has been extensively applied to the preparation

of inorganic phosphors [12]. In this paper we have reported the thermolumineseence properties of $Sr_2B_2O_5:Tb^{3+}$ phosphor prepared by combustion method.

2. Experimental:

In present work we prepared $Sr_2B_2O_5$ phosphor doped with trivalent terbium by using a combustion synthesis method. The starting materials were $SrNO_3$ (A.R.) (99.999%), H_3BO_3 (A.R.) (99.999%) and NH_2CONH_2 (A.R.) (99.999%), from Merck as raw materials to prepare the phosphor material with and without dopant. To synthesize $Sr_2B_2O_5:Tb^{3+}$ phosphor, the raw materials were measured in the preferred ratio and mixed in an agate mortar by adding up an amount of urea as a fuel. Then grinded for minimum time duration of 20 to 30 min each concentration separately. Finally, the mixture was placed into a porcelain crucible and then using vertical furnace, fired at 550°C in air atmosphere for very short time duration. After firing, the samples take out from the furnace and then cooled slowly it at room temperature. The product of heated phosphor material obtained was crushed again in an agate mortar, for time duration of 45 to 60 min each, after that the crushed sample is again fired at 600°C for 12 hour duration in an air atmosphere. After completing heating process the sample slowly cooled and then kept it outside from the furnace. The product of prepared phosphor material obtained was crushed in an agate mortar to convert it into fine particle for obtaining fine powder sample. The phase structure of samples obtained in the powder form without dopant was confirmed by taking the X-ray diffraction (XRD. Thermoluminescence (TL) spectra of the sample were recorded at our workplace; this could help us to know the quality of prepared phosphor as a dosimetry, scintilators.

3. Results and Discussion:

3.1 X Ray Diffraction

The phase purity of the prepared phosphor by combustion synthesis method was confirmed by powder XRD measurement. XRD pattern of the prepared $Sr_2B_2O_5$ phosphor was well matched with the reported XRD pattern [13].

3.2. Trap parameter study of $Sr_2B_2O_5:Tb^{3+}$

3.2.1. Order of kinetics

Kinetic parameters of any TL materials glow peak is responsible for its dosimetric properties,

because thermoluminescence is one of the type of luminescence which exhibited by certain crystalline materials, such as minerals, when from electromagnetic radiation or other ionizing radiation earlier absorbed energy is re-emitted as light upon heating of the material. The fact is different from black body radiation [14]. Information regarding the mechanism responsible for TL emission in material finds out from kinetic parameter. Excellent information of kinetic parameters of any TL material obtained from reliable

dosimetric studies of that TL material. On the position of the trapping levels within the forbidden gap TL strength fading of irradiated material on storage depends [15]. The determine of trapping parameter or kinetic parameter from the thermoluminescence glow curve is an vital area of interest and various techniques have been developed for the determination of trapping parameters such as activation energy, order of kinetics and frequency factor. This method is proposed by the scientist chen and depend on the shape of glow curve. The calculation of trapping parameters by Chen's half width method understood by the diagram shown in figure 1 [16].

To find out this parameter the subsequent shape parameters were determined: the total half intensity width ($\omega=T_2-T_1$), the high temperature half width ($\delta= T_2-T_m$), the low temperature half width ($\tau= T_m-T_1$). Where T_m is the peak temperature and T_1 and T_2 are temperatures either side of T_m corresponding to half peak intensity. The TL glow curve of $Sr_2B_2O_5:Tb^{3+}$ powder sample, γ-irradiated at room temperature for 5 Gy as shown in figure 2.

Order of kinetics is find out by calculating symmetry factor (μ_g) of the glow peak from the known values of shape parameters,

$$(\mu_g)=\delta/\omega=(T_2-T_m)/(T_2-T_1) \quad (1)$$

In fig.3. T_1=125°C, T_m=162°C and T_2=201°C

Now inserting these values in equation (1), symmetry factor (μg) is finding about 0.5131578 suggest that the peak obeys first order kinetics.

Furthermore, Balarin has also proposed the formula for finding out order of kinetics.

$$\gamma=\delta/\tau=(T_2-T_m)/(T_m-T_1) \quad (2)$$

The parameter (**γ**) for 162°C glow peak of $Sr_2B_2O_5:Tb^{3+}$ was found to be 1.054054 which suggests that this peak obeys first-order kinetics.

3.2.2. Activation Energy

Activation energy (E) was calculated by using Chen's equation which gives the trap depth in terms of τ_1, δ_1, ω_1. General formula for activation energy is as follows,

The activation energy (E),

$$E = c_\alpha (k \times T_m^2 / \alpha) - b_\alpha (2k \times T_m) \quad (3)$$

Where, α is τ, δ, or ω are the constants c_α and b_α for the three equations (τ, δ, or ω).

k is Boltzmann constant and T_m is maximum peak temperature.

The values of c_α and b_α are summarized as below,

$c_\tau = 1.510 + 3.0(\mu - 0.42)$ $\quad$ $b_\tau = 1.58 + 4.2(\mu - 0.42)$

$c_\delta = 0.976 + 7.3(\mu - 0.42)$ $\quad$ $b_\delta = 0$

$c_\omega = 2.52 + 10.2(\mu - 0.42)$ $\quad$ $b_\omega = 1,$

With μ = 0.42 for the case of first-order TL glow peaks, and $\mu = 0.52$ for the case of second-order peaks. T_m is the peak temperature at the maximum position T_1 and T_2 are, respectively, the temperatures on either side of T_m, corresponding to half intensity,

$\tau = T_m - T_1$ is the half-width at the low temperature side of the peak

$\delta = T_2 - T_m$ is the half-width toward the fall-off side of the glow peak

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

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

Values of c_α and b_α depending on the τ, δ, ω. Table 1 shows the experimental peak shape parameter values.

Table 1 :- Experimental peak shape parameter

	τ	δ	ω
$\mathbf{c}_\alpha$	1.81	1.71	3.54
$\mathbf{b}_\alpha$	2.0	0	1.0

Where α stand for τ_1, δ_1, ω_1 which are respectively determined by the half width.

For first order kinetics the values of C_α depending on τ_1, δ_1, ω_1 are 1.81, 1.71 and 3.54 respectively and the values of b_α, depending on τ_1, δ_1, ω_1 are 2.0, 0 and 1.0 respectively.

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The activation energy for162°C glow peak of $Sr_2B_2O_5:Tb^{3+}$ was calculated by using above equation (3) using low temperature half width, high temperature half width and full width of the peak at its half height was found to be at 0.570 eV.

2. Frequency Factor

Frequency factor (s) was calculated by using the equations given by Chen and Winer from the order of kinetics and activation energy that was determined.

$$\beta \times E/(k \times T^2 m) = s[1+(b-1)2k \times Tm/E \times \exp(E/k \times Tm)] \quad (4)$$

Where β =heating rate.

The frequency factor for the 162°C glow peak of $SrB_2O_5:Tb^{3+}$ when calculated by using equation (4) was found to be $0.5 \times 10^7 s^{-1}$.

The thermoluminescene glow curve of the prepared sample gives the information's about the nature of traps presents in the thermoluminescence material and the amount of energy absorbed by the incident radiation in the material [17].

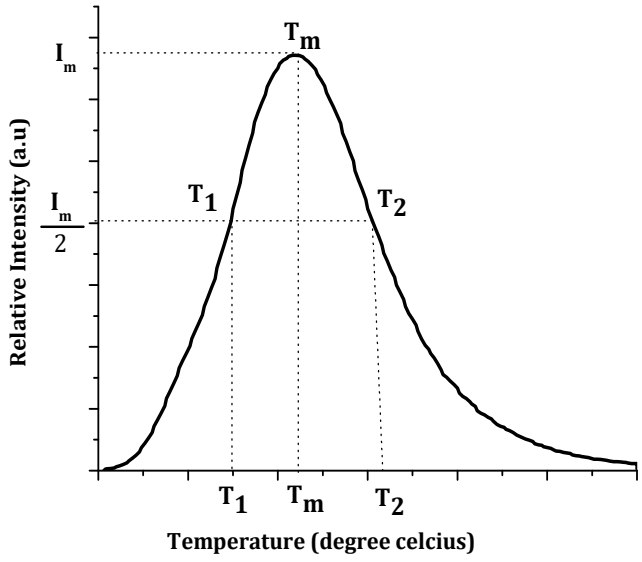

Figure: 1. Chen's model for the characterization of trapping parameter by thermoluminescence for single peak

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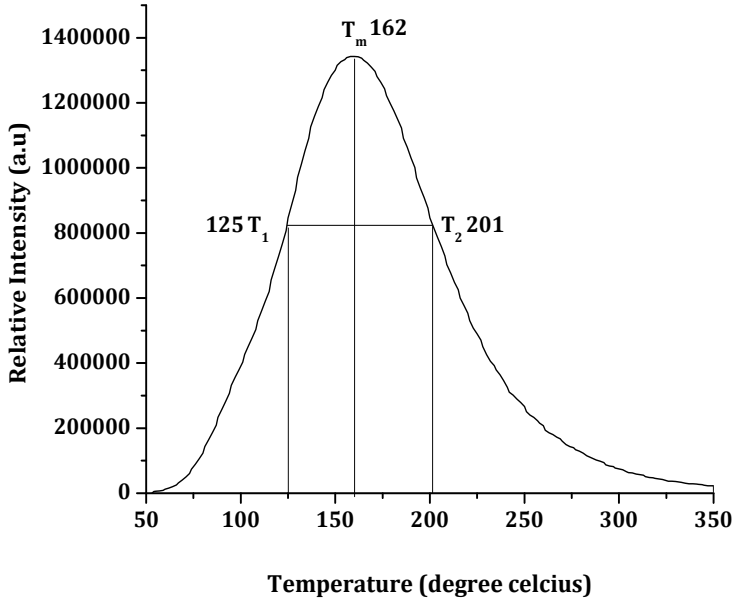

Figure: 2. The TL glow curve of $Sr_2B_2O_5$:Tb^{3+} phosphor irradiated by γ-rays at room temperature.

Conclusions:

$Sr_2B_2O_5$:Tb^{3+} phosphor was successfully prepared by combustion method. The TL peak in prepared phosphor shows first order kinetics. The TL glow curve shows a single peak at 162°C. The kinetic parameter such as activation energy, frequency factor were found to be 0.570 eV, $0.5\times10^{7}s^{-1}$ respectively.

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