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THERMOLUMINESCENCE STUDIES OF $CaSO_4$: DY, P PHOSPHOR

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ABSTRACT:

The phosphor CaSO4: Dy and CaSO4: Dy, P was synthesized by Co-Precipitation method. The structure of the prepared material was confirmed with X-ray diffraction (XRD) analysis. The thermoluminescence (TL) properties of this phosphor were studies in detail. It shows two TL glow peaks P_1 and P_2 at 161 ˚C and 343 ˚C respectively. The activation energy for first and second deconvoluted peaks are 1.145 eV and 0.95 eV respectively while frequency factors for peaks P_1 and P_2 are 6.78 X 10^{12} s^{-1} and 8.74 X 10^6 s^{-1} respectively. The dose variation of gamma-rays is found to be linear from 5 Gy to 25 Gy dose. We have checked the impact of P activator on $CaSO_4$: Dy phosphor and found to be used as a TLD material in radiation dosimetry.

KEYWORDS: Thermoluminescence, $CaSO_4$: Dy, P, Activation energy, Frequency factor

1. INTRODUCTION

$CaSO_4$: Dy is extremely prominent phosphor. Lots of works have already done on $CaSO_4$: Dy with various co-dopants. $CaSO_4$: Dy is used for personal as well as environmental monitoring applications. Especially in India, this phosphor is used as the detector material in TLD badges used for countrywide personnel monitoring programs. $CaSO_4$ doped with rare earths shows very high sensitivity with negligible fading. Thermoluminescence (TL) is an extensive technique used for dosimetry for ionizing radiations as the energy absorbed during irradiation and the TL intensity on stimulation (heating) is proportional to the radiation flux (doses). The study on rare earth doped $BaSO_4$ and $CaSO_4$ has been continuing as an active area of research for the last few decades because of their high thermoluminescent sensitivity and negligible fading [2–8]. Moreover the luminescent studies of these compounds are of interest because of their high effective atomic number, low cost or easy to prepare and easy handling process. Phosphors doped with suitable impurities increases the TL sensitivity and can be applied as an X-ray imaging and storage phosphor. Efforts are still being made to synthesis different TL phosphors using different techniques. We have synthesized phosphorus doped $CaSO_4$: Dy by co-precipitation method and its various thermoluminescence properties including activation energy (E) and frequency factor (s) are carried out in this paper.

2. RESULTS AND DISCUSSION

2.1 EXPERIMENTAL

$CaSO_4$: Dy, $CaSO_4$: Cu and $CaSO_4$: Dy, P phosphors were prepared by the method of co-precipitation. All the chemicals used were analytical reagents grade. The details can be found in our earlier works [9]. Details of the experimental set-up for gamma exposures and TL measurements can also be found in our earlier works [9]. Samples were exposed to gamma rays from a ^{60}Co source at RTM Nagpur University for various exposures at room temperature an amount of 5 mg phosphor in fine powder form was used for recording the glow curves. As synthesized host samples were then subjected to the XRD analysis on Rigaku miniflex X-ray diffractometer with scan speed of 10.00 deg. /min and with Cu Kα radiation. While TL characteristics were carried out on TL 1009I reader designed and offered by Nucleonix system with constant heating rate of 5 ˚C / sec.

2.2 XRD ANALYSIS

Fig. 1 shows XRD pattern of $CaSO_4$: Dy, P phosphor prepared by co-precipitation method. It was checked with the help of Rigaku Miniflex X-ray diffractometer with scan speed of 10.00 deg / min and with Cu Kα radiations. It is fully in agreement with ICDD file 01-072-0503. The reported lattice constants are a = 6.991 Å, b = 6.996 Å and c = 6.238 Å with z = 4 and volume of unit cell 305.09 $Å^3$ and the values for α = 90˚, β = 90.30˚, γ = 90˚. Thus it can be said that the formed material is in single phase with Centrosymmetric structure with space group Amma.

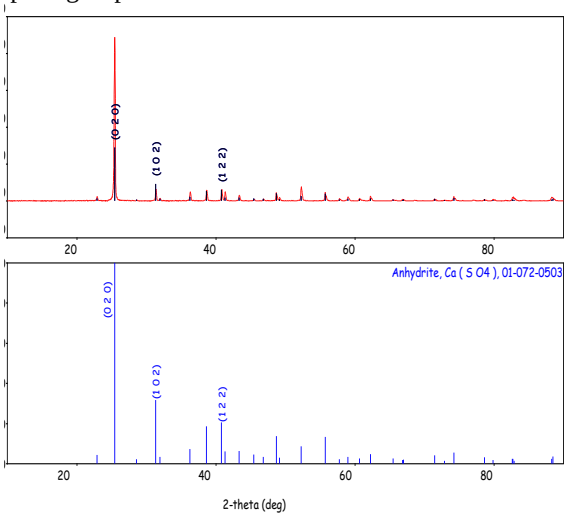

Fig. 1 *XRD pattern for $CaSO_4$: Dy, P phosphor*

2.3 THERMOLUMINESCENCE (TL) STUDIES

The TL glow curves of $CaSO_4$: P and CaSO4: Dy, P is as shown in Fig 2 and Fig. 3 respectively. Here we consider only low temperature main peak of this phosphor for the applications of this phosphor for low temperature dosimetry applications. The glow curve temperature for both sample, without P and with P doped CaSO4: Dy have the same value i.e. 162 ˚C for the main first low temperature peak.

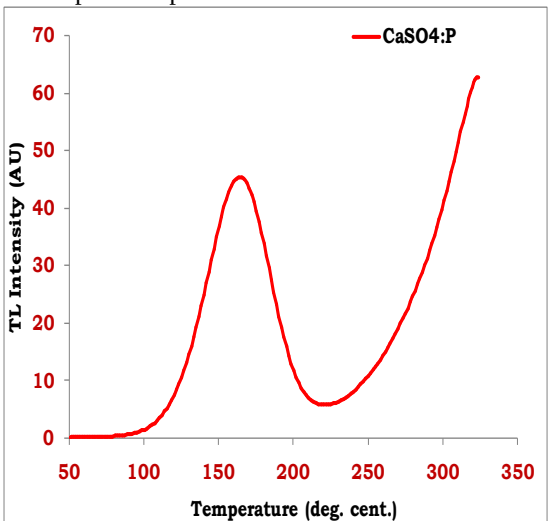

Fig. 2 *TL glow curve of $CaSO_4$: P*

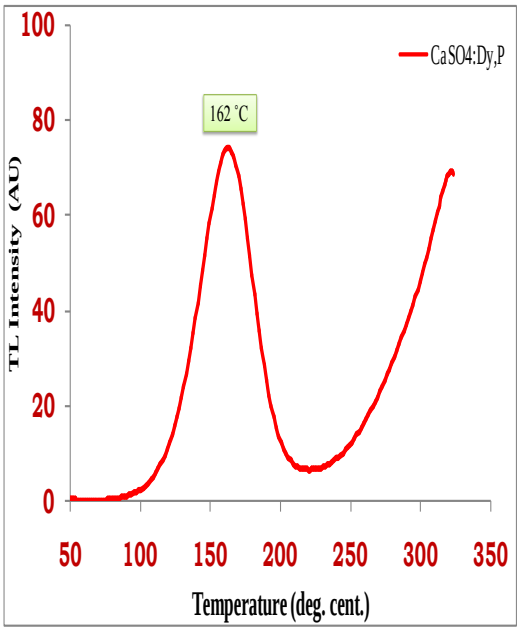

Fig. 3 *TL glow curve of $CaSO_4$: Dy, P*

Fig. 4 consists of the deconvoluted curve of CaSO4: Dy, P phosphor. The glow curve consists of two peaks about 161 ^{0}C and 343 ºC. Glow curve analysis is useful for dosimetric studies such as studying TL dose response for each glow peak and determining lifetime of trapped electron in the phosphor. The stability of TL glow peak, which is of Para- mount importance to dating and dosimetry, depends mainly on the activation energies.

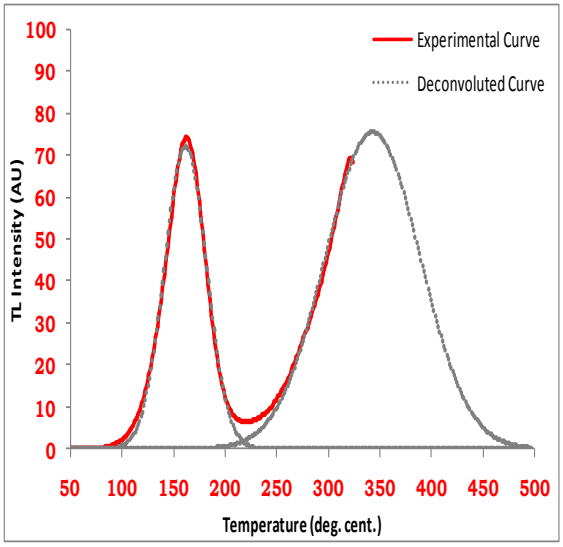

Fig. 4 *Deconvoluted TL glow curve of $CaSO_4$:Dy,P*

We employed the peak shape method to analyze the activation energy of the $CaSO_4$: Dy, P phosphor using Eq. (1) [10]

$$E = c_\gamma(kTm^2/\gamma) - b_\gamma(2kT_m) \quad \text{---------} \quad (1)$$

as shown in figure 4. where γ stands for τ, δ, or ω. The values of τ, δ, and ω are respectively determined by low-temperature half-width ($\tau = T_m - T_1$), high-temperature half-width ($\delta = T_2 - T_m$) and full width ($\omega = T_2 - T_1$). For first-order kinetics, the values of the c_γ and b_γ depending on τ, δ, or ω [10] and k is Boltzmann constant. To analyze the frequency factor s of the glow curve values the activation energy obtained from Eq. (1) and heating rate (β) at which the glow curves are recorded were used in Eq. (2). The summary of calculated result is represented in Table 2.

$$\beta E / kTm^2 = s\, e^{[-E/kT_m]} \quad \text{---------} \quad (2)$$

Table 1 Kinetic parameters for $CaSO_4$: Dy, P phosphor

Phosphor	Peak	E(eV)	S(s^{-1})	T_m(°C)
$CaSO_4$:Dy, P	P_1	1.145	6.78 X 10^{12}	161
	P_2	0.950	8.74 X 10^6	342

Fig. 5 shows the comparison of this prepared phosphor with the commercially available LiF: Mg, Cu, P (called TLD-100H) phosphor available in our laboratory. The intensity of this prepared phosphor is very less as compared to TLD-100H but the peak temperature reduce by certain value which make this phosphor useful for low temperature dosimetry applications.

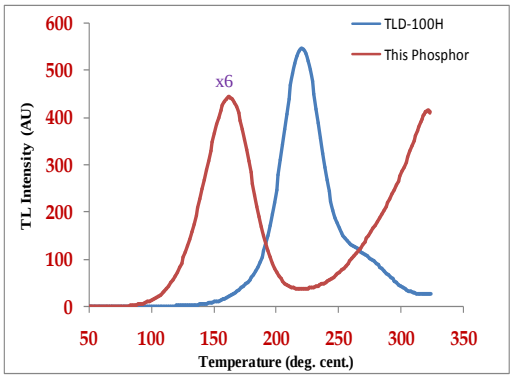

Fig. 5 *Comparison of $CaSO_4$: Dy, P with LiF: Mg, Cu, P (TLD-100H)*

The TL material is said to be good when its response to absorbed dose is linear over the wide range. To study the linearity five samples were irradiated simultaneously for each level of dose. Each data point corresponds to the mean of the five readings. The linearity is observed in the range from 5Gy to 25Gy as shown in Figure 4.

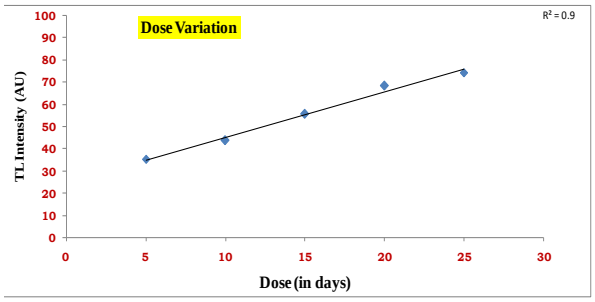

Fig.6 *Dose response of $CaSO_4$: Dy, P*

3. CONCLUSION

We synthesized $CaSO_4$: Dy, P phosphor by one step, low cost and low temperature co-precipitation method. TL characteristics and some dosimetric properties of $CaSO_4$: Dy, P phosphor was investigated in details. The trap parameters, i.e., activation energy and frequency factor of the TL glow curve of the sample were calculated by peak shape method. The TL and dosimetric characteristics implied the potential of $CaSO_4$: Dy, P phosphor as γ-ray TL materials in radiation dosimetry for lower temperature.

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