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Thermoluminescence (TL) study of $CeSO_4Cl$: Dy Phosphor for γ- radiation dosimetry

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Abstract

$CeSO_4Cl$: Dy phosphor is prepared by wet chemical method. The thermoluminescence (TL) study of $CeSO_4Cl$:Dy phosphor has been presented in this paper. The strong sensitivity of the $CeSO_4Cl$: Dy phosphor is obtained with the broadness of the glow peak for various concentrations of Dy and different γ-rays doses. The phosphors $CeSO_4Cl$: Dy has a simple TL glow curve structure with a single prominent peak at around the temperature 169^0C indicating single trapping sites. The phosphor may be quite suitable for use in dosimetry of ionizing radiations.

Keywords: Thermoluminescence, Inorganic material, wet chemical, γ-radiation, dosimetry.

Introduction

The use of sulphates doped with rare earth (RE) ions as dosimeters have been investigated for many years. Some examples are $CaSO_4$: Dy, $CaSO_4$: Eu, P and $CaSO_4$: Tm. $CaSO_4$: Dy and $CaSO_4$: Tm phosphors have been widely used in environmental radiation monitoring due to their high dose response sensitivity and ease of preparation. At present, thermostimulated luminescence dosimeter (TLD) materials are widely used for personal and environmental radiation monitoring. Among the different types of TLD materials, RE-doped sulphates, especially $CaSO_4$: Dy or $CaSO_4$: Tm phosphors, developed are in use in many countries for dosimetry due to their high sensitivity, stability and low cost.

Blasse[1] has listed the Eu^{2+} doped compounds, which shows that the emission color of Eu^{2+} can vary in a broad range, from ultraviolet to red. The dosimetric characteristic of any TL phosphor mainly depends on its trapping parameters which describe the defect centers responsible for the TL emission. Recently Moharil et. al have reported several sulfate phosphor possessing properties useful for TL dosimetry of ionizing radiations[2-5]. Other than sulphates and mixed sulphates, some investigations are going in progress on halosulphate-based materials. Klement[6] synthesized the halosulphate $Na_6Ca_4(SO_4)_6F_2$ and characterized this compound by XRD. Also, the compounds $Na_6Pb_4(SO_4)_6Cl_2$[7,8], $Na_6Cd_4(SO_4)_6Cl_2$[9] and $Na_{6.45}Ca_{3.55}(SO_4)_6(F_xCl_{1-x})_{1.55}$[10]. Recently we have reported new halosulphate phosphors[11-14]. In this paper the thermoluminescence properties of $CeSO_4Cl$:Dy have been studied.

Material and Methods

$CeSO_4Cl$ (pure); and $CeSO_4Cl$: Dy phosphors were prepared by a wet chemical method. $CeCl_3$ and $Ce_2(SO_4)_3$ of analar grade were taken in a stoichimetric ratio and dissolved separately in double distilled de-ionized water, resulting in a solution of $CeSO_4Cl$ (equation). Water-soluble sulphate salt of Europium was then added to the solution to obtain $CeSO_4Cl$: Dy. Confirming that no undissolved constituents were left behind and all the salts had completely dissolved in water and thus reacted.

$$CeCl_3 + Ce_2(SO_4)_3 \rightarrow 3CeSO_4Cl$$

The compounds $CeSO_4Cl$ (pure) and $CeSO_4Cl$: Dy in its powder form was obtained by evaporating on 80^0c for 8 hours. The dried samples were then slowly cooled at room temperature. The resultant polycrystalline mass was crushed to fine particle in a crucible. The powder was used in further study. For TL characteristics samples were exposed to gamma rays from a Co^{60} source at room temperature at the rate of 0.995 kGy/hr for 500 rad (5 Gy). After desired exposures, TL glow curves were recorded for 2 mg of sample each time at a heating rate of 2^0C/sec. TL glow curves were recorded on TLD reader.

Results and Discussion

TL glow curves by the concentrations of Dy: Figure 1 shows the typical TL glow curves of $CeSO_4Cl$: Dy a) 0.1mol%, b) 0.2 mol%, c) 0.3 mol.% phosphor. The glow curves have been recorded at a heating rate of 2 $ksec^{-1}$ and irradiated at a dose rate of 0.995 $kGyh^{-1}$ for 5 Gy. Repetitive cycles of annealing and irradiation at the same dose reveal the same glow curve structure. Further, in changing the concentration level the general structure of the TL curve is not observed to undergo change in peak temperature, but intensity is found to increase as the concentrations of Ce increased. The low temperature peak of $CeSO_4Cl$: Dy_0.1mole% is obtained may be due to the effect of host material and is seen to be present at about 169 ^0C. The appearance of single peak in the glow curve indicates that there is possibly only one kind of trapping sites due to γ –irradiated effect. The glow curve peak for all concentrations is obtained at 169 ^0C as a main peak while other low intensity peaks also at the same temperature.

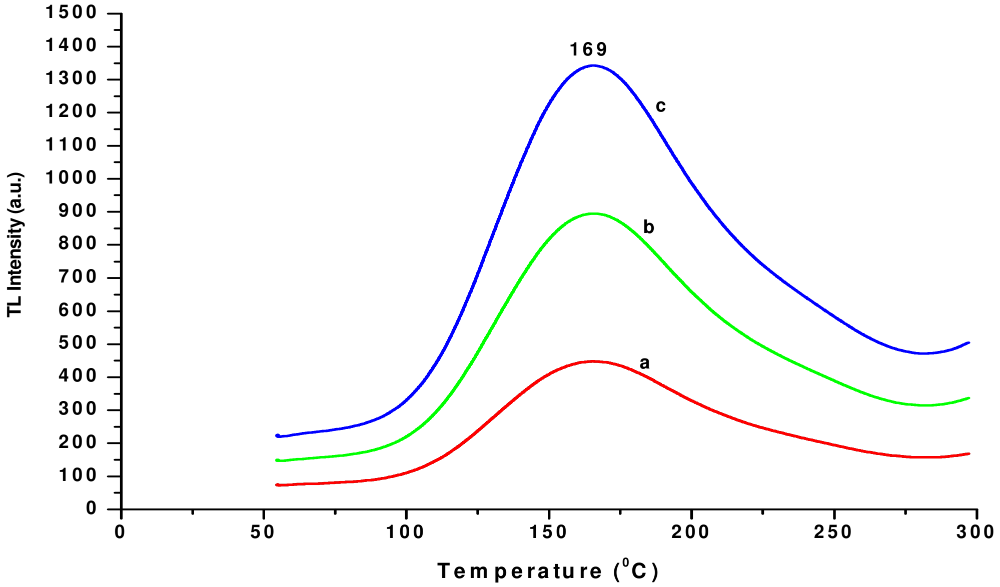

Figure-1
TL glow curve of $CeSO_4Cl$: Dy a) 0.1mol%, b) 0.2 mol%, c) 0.3 mol.% phosphor exposed to γ –rays for 5 Gy at the rate of 0.995 $kGyh^{-1}$

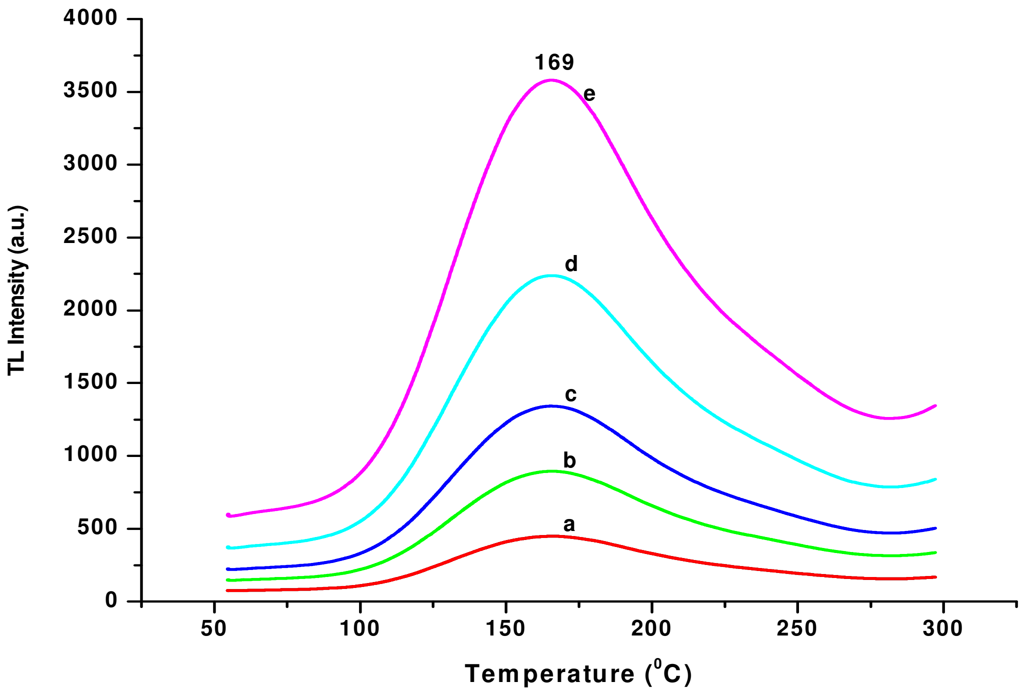

Figure-2
TL glow curves of $CeSO_4Cl$: Dy phosphor exposed to γ –rays for different doses at the rate of 0.995 $kGyh^{-1}$.
a) 0.1 Gy b) 0.5 Gy c) 1 Gy d) 5 Gy e)10 Gy

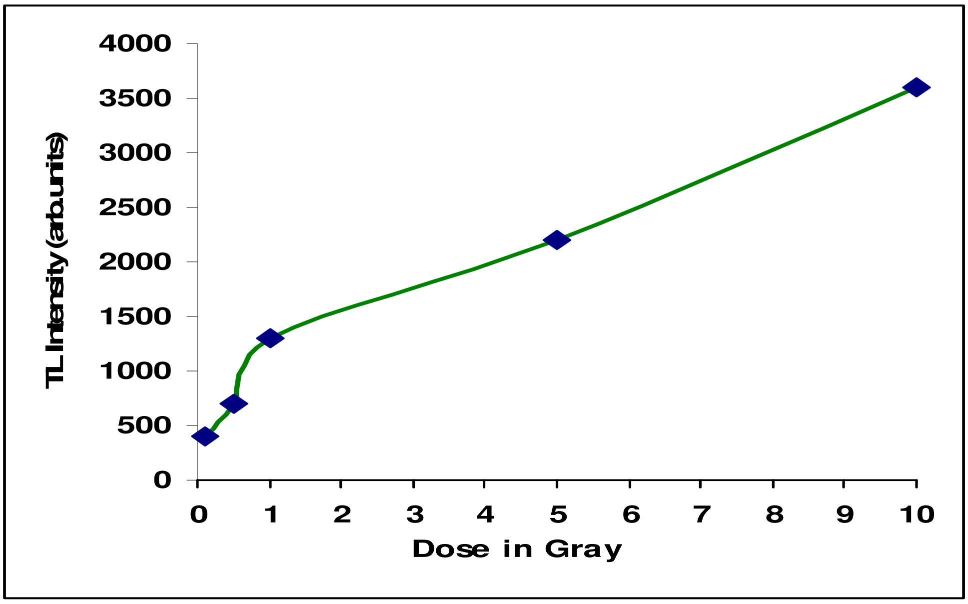

Figure-3
TL response to γ-irradiation of $CeSO_4Cl$: Dy phosphor at the rate of 0.995 $kGyh^{-1}$

TL glow curves by the γ- rays dose: Figure 2 shows TL glow curves for *γ* –irradiated $CeSO_4Cl$: Dy phosphor with varying doses with a linear heating rate 2 $^0C.sec^{-1}$ which exhibits a single glow peak at 169^{0}C. All the phosphors were exposed to a dose range of 0.5 Gy to 10 Gy. It is observed that TL intensity increases with the increase in dose. This change in the relative intensity of the peaks has been attributed to the change in the population of the luminescent/trapping centers. With a simple glow curve structure, easy method of preparation and no saturation in the exposed range $CeSO_4Cl$: Dy phosphor resembles the characteristics close to an ideal phosphor. Generally, Dy and Mn doped phosphors are the efficient TLD materials, such as doping in $CaSO_4$ and LiF materials. However the sensitivity of all the phosphors is up to the dosimetric level even for only to the 10 Gy dose of *γ* –rays.

TL response curves: A TL response curve of $CeSO_4Cl$: Dy phosphor exposed to different doses of *γ* –rays is given in figure 3. The peak heights were used for measuring the TL intensities. On exposing the phosphor to doses ranging from 0.5 Gy to 10 Gy, it was found that phosphor exhibits a linear response to *γ* –rays doses through out the dose range. Below 1 Gy it is sub-linear but after this it is linear. This range is in a good result for the material which can be used as a dosimeter. The total amount of light emitted (response) is not perfectly proportional to the absorbed dose. Response / Gy is greater at higher dose levels. Because the higher exposure creates additional traps and hence makes the material more sensitive, this is known as supralinearity. The response / Gy for most TLD depend upon radiation type and quality. More appreciable results are expected for higher *γ* –rays doses to explain behavior of TL material.

Conclusions

From the results it can be concluded that, the sensitive typical TL glow curves was obtained for various concentrations of Dy in $CeSO_4Cl$ host which was recorded at a heating rate of 2 $ksec^{-1}$ and irradiated at a dose rate of 0.995 $kGyh^{-1}$ for 5 Gy. It was also found that higher the concentration of Dy, higher is the TL intensity. TL sensitivity also measured by giving different γ-radiation doses and found that the phosphor is also suitable for higher doses. A TL response curve of $CeSO_4Cl$: Dy phosphor exposed to different doses of *γ* –rays is linear. Below 1 Gy it is sub-linear but after this it is linear. This range is a good for the dosimeter material. More results are expected for higher *γ* –rays doses to explain behavior of TL material. The detail study for higher γ-radiation doses is under consideration.

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