

International Journal of Luminescence and applications Vol5 (4) December, 2015, pages 489-491

Effect of optical bleaching on TL and OSL for K₂SO₄:Eu²⁺

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Abstract

In this paper, the optical bleaching characteristics of $K_2SO_4:Eu^{2+}$ are reported. Continuous wave optically stimulated luminescence (CW-OSL) curve for $K_2SO_4:Eu^{2+}$ was compared with that of commercial phosphor $Al_2O_3:C$ (Landauer). The CW-OSL sensitivity for $K_2SO_4:Eu^{2+}$ is ~ 71 % of the sensitivity of $Al_2O_3:C$ by considering average of the counts for first second. The thermoluminescence (TL) glow peak for the phosphor was observed at 160°C for heating rate of 4°C/s. The main highlights of this article are the optical bleaching studies of the phosphor. The optical bleaching was studied by using 470 nm blue LEDs for different illumination times.

Keywords: Potassium sulphate; Optically Stimulated Luminescence Dosimetry (OSL); Order of Kinetics; Bleaching; Dosimetry.

PACS Code:

INTRODUCTION

Sulphates are known to be good thermoluminescent materials. Rare earth (RE) doped CaSO₄ phosphors have been studied for quite some time[1]. Dy[2,3] and Tm [4] are known to be efficient activators for thermoluminescence (TL) in a CaSO₄ host. CaSO₄:Eu and CaSO₄:Sm were found to exhibit interesting photoluminescence (PL) properties and the possibility of using these phosphors in radiophotoluminescence (RPL) dosimetry[5] and UV dosimetry using TL [6] was indicated. Thermoluminescence in other alkaline earth sulfates was also studied subsequently. In recent years Dhoble et al have reported several sulphate based phosphors which possess some properties useful for TLD of ionising radiations [7,8,9,10,11]. They also studied the thermoluminescence in Li2SO4:P, Dy and Li₂SO₄:P, Eu phosphors [12].

Europium enters Li_2SO_4 and Na_2SO_4 lattices in trivalent form, which is stable with respect to exposures to gamma rays and hence could not be used for RPL dosimetry [13]. Sakaguchi et al have investigated the TL phenomenon of alkaline metal sulfate crystals doped with rare earth [14]. Upadeo and Moharil also studied the $Eu^{3+} \rightarrow Eu^{2+}$ conversion in several sulphates and observed efficient $Eu^{3+} \rightarrow Eu^{2+}$ conversion in Rb₂SO₄, K₂SO₄ and Cs₂SO₄ [15]. BaSO₄:Eu is well known PSL phosphor [16]. However, OSL in other sulphates is not reported. In this context the OSL characteristics of K₂SO₄:Eu²⁺ are studied.

EXPERIMENTAL

The phosphor was synthesized by simple wet chemical process using GR grade K_2SO_4 (Loba make, 99%). For the preparation of K_2SO_4 :Eu²⁺, K_2SO_4 was first dissolved in double distilled water. 1000 ppm Europium nitrate was added to this aqueous solution of K_2SO_4 . The solution was then allowed to evaporate slowly at 60°C on a hot plate. The dried powder was taken in a porcelain crucible and melted in a furnace preheated at 1200°C. The impurity concentration for europium was optimized to 0.1 mol%.

The PL spectra for the phosphors were recorded on Hitachi Fluorescence spectrophotometer (Model No: F- 4000). All TL and OSL readouts were carried out on Riso TL/OSL reader equipped with a ⁹⁰Sr/⁹⁰Y beta-ray source. The reader is fitted with an EMI 9635QA PM Tube. Blue Light (470 nm) with a optical intensity of 22 mW/cm² was used for the stimulation and OSL signal was recorded for 60 seconds. Integrated OSL data for the first second of stimulation was used to compare the OSL sensitivities. For OSL/TL measurements all the phosphors were exposed to a test dose of 100 mGy using the 90 Sr/ 90 Y beta-ray source.

RESULTS AND DISCUSSIONS

Figure 1 shows the Photoluminescence (PL) spectra of K_2SO_4 :Eu²⁺.



Fig. 1: PL spectra of K₂SO₄:Eu²⁺

Phosphor shows sharp emission at about 405 nm for 316 nm excitation with a shoulder at 250 nm. This confirmed that Eu incorporated in host lattice is in divalent form.

CW-OSL response of K_2SO_4 :Eu²⁺ stimulated with 470 nm blue light was studied. Figure 2 shows the CW-OSL of K_2SO_4 :Eu²⁺ compared with the commercial phosphor Al₂O₃:C (Landauer). The CW-OSL sensitivities were compared by averaging out the OSL counts for first second of stimulation.



Fig. 2: CW-OSL curves of K₂SO₄:Eu compared with Al₂O₃:C (Landauer)

The CW-OSL sensitivity for K_2SO_4 :Eu²⁺ is ~ 71 % of the sensitivity of Al₂O₃:C by considering average of the counts for first second.

The thermoluminescence (TL) glow curve was recorded at the heating rate of 4°C/s as shown in figure 3. TL glow peak of K₂SO₄:Eu²⁺ was observed at 160 °C with a shoulder at 82 °C. The geometrical factor μ_g for the main TL glow peak is approximately equal to 0.43 ± 0.02 which indicates that the order of kinetics for the corresponding TL process is one [17].



Fig. 3: TL glow curve of K₂SO₄:Eu for 100 mGy of ⁹⁰Sr/Y beta-ray source

The effect of optical bleaching on TL glow curve of the phosphor (Figure 4a) is to decrease TL intensities. This confirms the participation of TL traps in the OSL process. The optical stimulation in this case was done with the 22 mW/cm² optical power using 470 nm blue LEDs and the TL was recorded for a test dose of 100 mGy. For 10 seconds of illumination, the area under TL glow peaks in the phosphor reduced to about 22%. From figure 4a, it can be seen that the TL glow peak temperature T_m is unchanged with an optical bleaching which is typical characteristic of first order kinetics. Hence from these observations it may be concluded that TL processes in the phosphors obey first order kinetics. The optical bleaching of TL glow curves for the phosphor obeys the exponential decay as shown in figure 4b.



Fig. 4: Effect of optical bleaching on (a) TL glow peak and (b) residual TL of K₂SO₄:Eu phosphors

Figure 5a shows the effect of optical bleaching on CW-OSL in the phosphor. The CW-OSL curves were

recorded for beta exposure of 600 mGy. For bleaching, the samples were illuminated using blue LEDs with optical power of 5 mW/cm². Optical bleaching subsequently decreases the CW-OSL sensitivities of phosphor. Quantitatively about 85 % reduction in the sensitivities was observed in CW-OSL sensitivity within 10 s. Although optical bleaching reduces the OSL output of phosphor, it does not affect the nature of decay profile for CW-OSL curves. From these observations it may be concluded that optical bleaching does not affect the CW-OSL profile of the phosphor.



Fig. 5: Effect of optical bleaching on (a) CW-OSL curves and (b) integral area under CW-OSL curves of K₂SO₄:Eu phosphors

CONCLUSION

In this paper we report the optical bleaching characteristics of K_2SO_4 : Eu^{2+} . The CW-OSL curve for K_2SO_4 : Eu^{2+} was compared with that commercial phosphor Al_2O_3 :C (Landauer). The CW-OSL sensitivity for K_2SO_4 : Eu^{2+} is ~ 71 % of the sensitivity of Al_2O_3 :C by considering average of the counts for first second. The thermoluminescence (TL) glow peak for K_2SO_4 : Eu^{2+} was observed at 160 °C for heating rate of 4 °C/s.

The main highlights of this article are the optical bleaching studies of the phosphor. The optical bleaching was studied by using 470 nm blue LEDs for different illumination times. There occurs gradual decrease in height and area for both TL glow peak and CW-OSL curves. The optical bleaching for the phosphor obeys the exponential decay. The TL glow peak in K₂SO₄:Eu²⁺ was depleted approximately upto 22% of its initial value whereas 85 % depletion was observed in CW-OSL sensitivity within 10 s.

So on the basis of above observations it may be concluded that OSL in K₂SO₄:Eu²⁺ is correlated with 82 °C and 160 °C glow peaks. As the μ_g value of the main TL glow peak is approximately equal to 0.43 \pm 0.02, the corresponding order of kinetic is one and same is confirmed with the optical bleaching test. The peak

position for TL curves and decay constant for CW-OSL curves are independent of optical bleaching indicating that TL and OSL processes obey first order kinetics.

ACKNOWLEDGEMENT

Authors are grateful to Board of Research in Nuclear Sciences (B.R.N.S) (sanctioned No. 2013/36/BRNS-8/0647) for financial support to this work.

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