International Journal of Luminescence and applications
Vol6 (1) February, 2016, pages 76-78

Charge retrapping in excited phosphors: The phenomenon and its manifestations

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Abstract

An excited phosphor generally relaxes to its original configuration in the form of emission of photons and phonons. The relaxation may be isothermal or non-isothermal being manifested as isothermal decay or thermally stimulated relaxation (luminescence). Both the phenomena have their origin from trapping levels and recombination centers specific to the individual phosphor. During the manifestation of relaxation of the pre-excited state the charges untrapped from trapping levels may be re-trapped if the retrapping probability (A_n) is not negligible compared to the recombination probability (A_m). The consequence in such a situation is expected to be manifested in form of regenerated/ recuperated signals that may be weak or significant depending upon the ratio $\gamma=A_m/A_n$. Regenerated TL in $Ca_xSr_{1-x}S:Eu^{2+},RE^{3+}$ forms the basis of the concept of charge retrapped in the excited phosphors.

Keywords: Charge Retrapping, Recombination Probability (A_m), Retrapping Probability (A_n), Thermoluminescence.

1 INTRODUCTION

The phenomena of regenerated thermoluminescence and recuperation have been often reported in the literature that essentially tells about the appearance of weak TL signals in LiF (TLD-100), quartz, feldspar, $CaSO_4$-Dy, CaF_2-Dy etc in the second readout for materials whose complete zeroing of charge from trap-levels did not take place in the first readout [1–6]. These phenomena essentially have their origin to charge retrapped in shallower traps from deeper traps that generally not studied because of blackbody radiation. For example, it is pretty common to record TL up to ~500°C or so or even less although, TL peaks in many materials occur above 500°C [6–8]. Therefore there exist many possibilities of untrapping of charge from the deep traps and their subsequent retrapping in shallow trapping levels, if their retrapping probability A_n is not negligible. Thus a fundamental question does arise: what is the value A_n of regenrated TL peaks. This communication demonstrates the role of CGCD to shed light into the fascinating phenomenon, which has bearing on the reliability of dosimetry at low doses and dating of young samples.

2 EXPERIMENTAL DETAILS

The material used for the study is a persistent luminescent material of commercial grade obtained from Jash Marketing, Hyderabad, India [9]. It is identified as $Ca_xSr_{1-x}S:Eu,RE^{3+}$. This is based on XRD and EDAX analysis. Its emission occurs at 647 nm. The excitation source used is an intense blue LED (10 W). The duration of excitation is controlled with the aid of EXPEYE Junior [10], an instrument developed by IUAC, New Delhi. The functioning of lighting LED is controlled by python program written by our group. Recording of TL and R-TL measurement are carried out with the help of Nucleonix TL Reader Type-TL 1009 (Nucleonix Systems Private Limited, Hyderabad). The heating rate used is 1°C s^{-1}.

3 RESULTS AND DISCUSSION

TL of $Ca_{1-x}Sr_xS:Eu,RE^{3+}$ recorded with different extent of fading at RT for blue LED excited sample is shown in Fig.1. The total TL output decay very fast within 30 min. with substantial loss of the major TL peaks that are highly overlapped. The regenerated TL for different cycles of readout are recorded upto 350oC and two of them are shown in Fig.2. The results show interesting features.

(i) In the first cycle afterglow is detectable by the PM tube and clearly defined TL peaks are observable, a thing unrevealed in Fig.1

(ii) In the fifth cycle the features are similar revealing as many as 7-8 TL peaks. Such complexity has not been reported till today in any paper in the system $Ca_{1-x}Sr_xS:Eu$ or CaS:Eu/ Sr S:Eu.

CGCD of two typical TL curves of Fig.1 and 2 are shown in Fig.3. The best fit parameters are shown in Table 1, which clearly shows that all the TL peaks follow non-first order kinetics. i.e. retrapping probability (A_n) is not negligible. This is consistent with our earlier work

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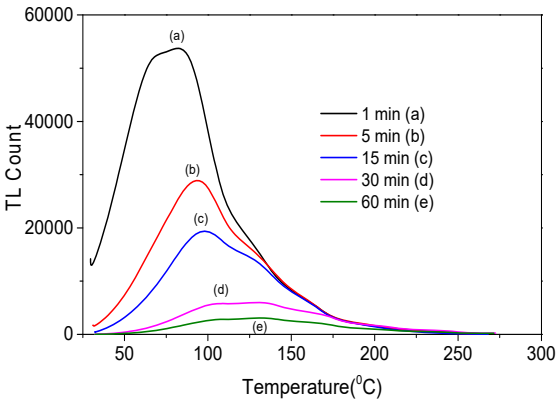
wherein we have evaluated the value of A_m/A_n=35[11]. The order of kinetics in quartz, feldspar and flourite as evaluated by our group CGCD is also non-first order [12–14] (11,12,13). In all these system regenerated TL is reported [6–8].

Fig.1:Thermoluminescence of $Ca_{1-x}Sr_xS$:Eu at different time elapsed, $t_{elapsed}$= 1 min, 5 min, 15 min, 30 min and 1 hr with heating rate, β=1°Cs^{-1}, initially excited with short pulse (1s) intense blue LED.



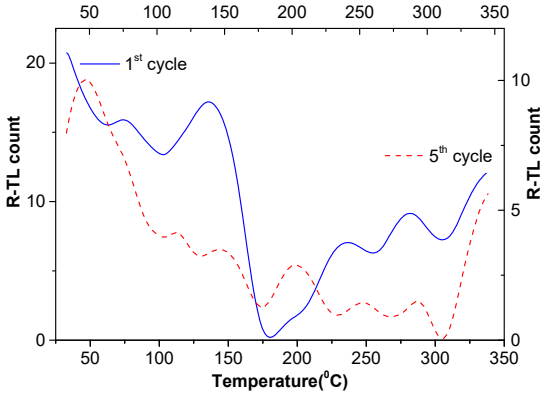


Fig.2: Regenerated TL of $Ca_{1-x}Sr_xS$:Eu at different cycles of partial TL record followed by second heating up to 350° C.

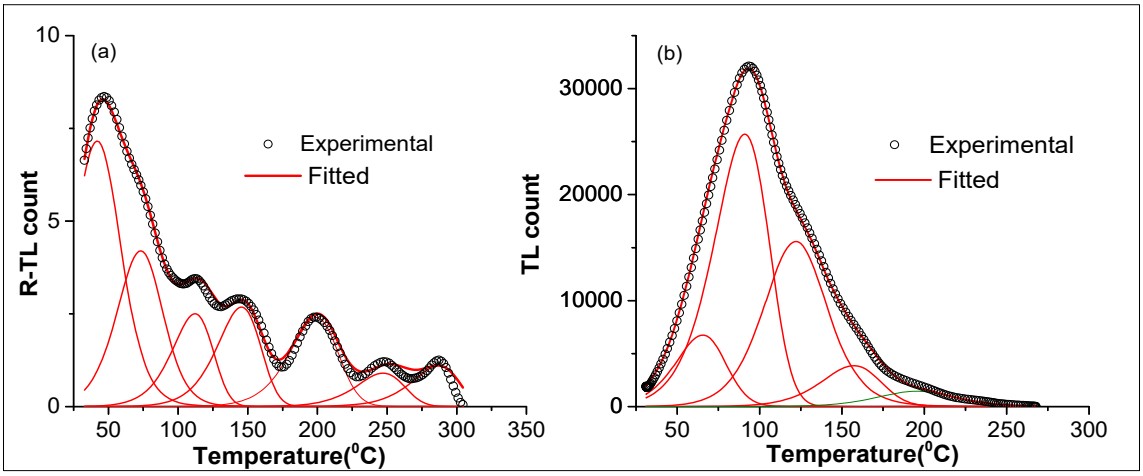


Fig.3 CGCD of (a) regenerated TL (5th cycle) and (b) TL curve of $t_{elapsed}$ =5 min (graph (b) in Fig.1) of $Ca_{1-x}Sr_xS$:Eu RE^{3+}.

Table 1: Comparison of best fit trapping parameters of R-TL and TL curve of $t_{elapsed}$ =5 min of $Ca_{1-x}Sr_xS$:Eu RE^{3+}

Peak	R-TL			TL after $t_{elapsed}$=5 min.		
	E(eV)	b	s(s^{-1})	E(eV)	b	s(s^{-1})
P_0	0.59	1.53	$1.87x10^{8}$	-	-	-
P_1	0.75	1.50	$5.90x10^{9}$	0.75	1.20	$1.60x10^{10}$
P_2	0.90	1.10	$4.23x10^{10}$	0.75	1.40	$1.57x10^{09}$
P_3	1.00	1.10	$7.53x10^{10}$	0.90	1.46	$1.49x10^{10}$
P_4	1.20	1.20	$4.02x10^{11}$	0.98	1.20	$1.86x10^{10}$
P_5	1.40	1.10	$2.47x10^{12}$	1.05	1.50	$1.31x10^{10}$
P_6	1.50	1.20	$1.70x10^{12}$	-	-	-

4 CONCLUSIONS

The presence of non-first order TL peaks in TL emitting materials in all probability will to some extent, show recuperation, if total zeroing of trapped charge is not achieved in first readout

5 ACKNOWLEDGEMENTS

Ngangbam Chandrasekhar is thankful to the authority of Manipur University for providing the UGC Non-Net fellowship.

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