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Low-dose, low-energy photon induced Thermoluminescence (TL)

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Abstract

For testing the phenomenon of thermoluminescence (TL) at its lowest practical limit, TL induced by low-energy photon (hv ≤ 3.0eV) at low-dose of 0.1sec pulse is studied in this work. It is found that red emitting (1.92 eV) $Ca_{1-x}Sr_xS$: Eu^{2+} persistent luminescent material gives enough light upon excitation with the short pulse of blue photon (hv= 2.7eV), measurable with satisfactory reliability by Nucleonix TL- reader Type- TL 1009. The traps and recombination centres of the red afterglow phosphor are discussed.. This finding has potential in designing emergency signage by adopting appropriate optical engineering and in an altogether different perspective it will facilitate industry-user communication for tailor-made TL-reader in India.

.**Keywords: *Thermoluminescence, Low-energy photon excitation, Low-dose.***

1 INTRODUCTION

Semiconducting /insulating solids are used widely for their thermoluminescence properties because they find wide application in radiation dosimetry. These radiations in principle can be of varieties of ionising and non-ionising radiations, the more common being X-rays, γ-rays, e-beams etc. Low energy visible photons are new entrants to the field of TL as excitation source. It has two practical applications. These are: (i) Persistent luminescent materials can be studied to determine the trap-levels relevant to the mechanism that has many simple as well as novel applications [1]. (ii) For mathematical modelling of TL curves, one need not resort to expensive X-rays or γ-rays source, but a simple low power LED is sufficient. Both these aspects form the main part of the present work.

2 EXPERIMENTAL DETAILS

The persistent luminescent material used in the experiment is of commercial grade obtained from Jash Marketting, Hyderabad, India [2]. It is identified as $Ca_xSr_{1-x}S$: Eu^{2+},RE^{3+} (RE^{3+} refers to trace levels of unidentified rare earth ions). This is based on XRD and EDAX analysis. Its emission occurs at 647nm. The excitation source used is an ordinary blue LED. The duration of excitation is controlled with the help of EXPEYE Junior [3], an instrument developed by IUAC, New Delhi. The functioning of lightning LED is controlled by python program written by our group. The TL measurement is 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}. This is just to minimise the thermal lag.

3 RESULTS AND DISCUSSION

TL of $Ca_xSr_{1-x}S$: Eu^{2+},RE^{3+} red emitting afterglow phosphor measured with different dose of excitations are shown in Fig.1. TL of background illumination from two computer screen in the dark room is also measured (Fig.2). A comparison of the three TL curves shows that the glow curve pattern is pretty complex. The CGCD of one of them is shown in Fig.2 which reveals the presence of as many as eight TL peaks. The best-fit peak parameters and the lifetime of the charge related to them are presented in Table1. The lifetime at room temperature (τ_{300}) is calculated using the equation derived by Singh and Gartia [4]. It is given as

$$\tau_{300} = s^{-1} \exp(E/kT)/(2-b) \quad \text{------------(1)}$$

where,

E = the trap depth
s = frequency factor
T = the absolute temperature (300K)
k = the Boltzmann constant
b = order of kinetics

Table 1 clearly shows that as many as five trapping levels contribute to persistent luminescence in this phosphor. Though the number of TL peaks in Table1 are eight in number, their origin is due to only five trap levels. That

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more than one TL peaks can have same activation energy was argued by Gartia [5] and substantiated in subsequent works [6-7]. The values of frequency factor 's' evaluated by us lie in the realistic range of 10^9-10^{12} s^{-1} unlike the low as well as high values (10^3-10^{14}) reported in large number of publications and documented in literature[8].

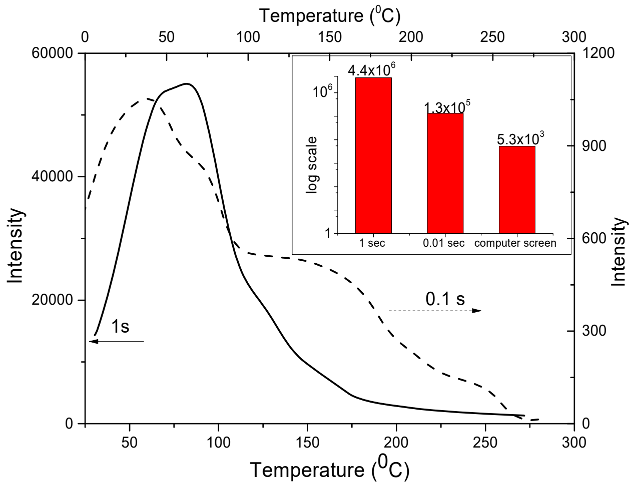

Fig.1: TL curve of $Ca_xSr_{1-x}S$: Eu^{2+},RE^{3+} phosphor for different dose of excitation. Inset shows histogram of area of TL curve for various excitations.

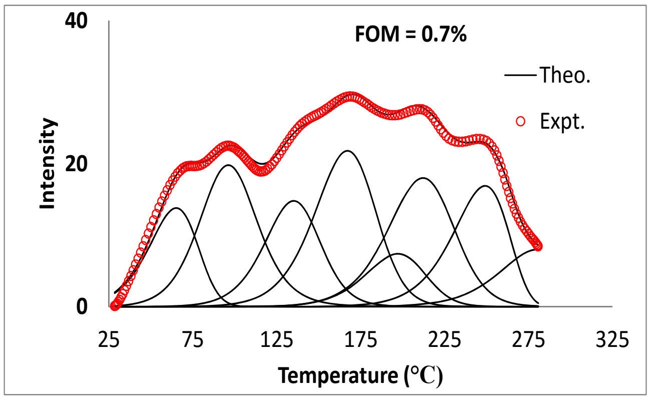

Fig.2: CGCD of TL curve for illumination with background computer screens.

Table 1: Best fitted peak parameters of CGCD

T_m (°C)	I_m(rel.)	E (eV)	s (s^{-1})	b	τ_{300}	Remarks
65	13.8	0.70	1.93E+09	1.13	5.71 min	Relevant to Persistent luminescence
96	19.8	0.90	1.43E+11	1.78	11.64 hr	
135	14.8	1.05	6.64E+11	1.50	15.21 days	
167	21.8	1.05	6.55E+10	1.35	118.64 days	
197	7.4	1.20	4.57E+11	1.30	14.32 yrs	Relevant to dosimetry
212	18.0	1.20	1.70E+11	1.40	44.92 yrs	
249	16.9	1.40	1.96E+12	1.00	5.36×10^3 yrs	
280	8.0	1.40	3.02E+11	1.20	4.34×10^4 yrs	

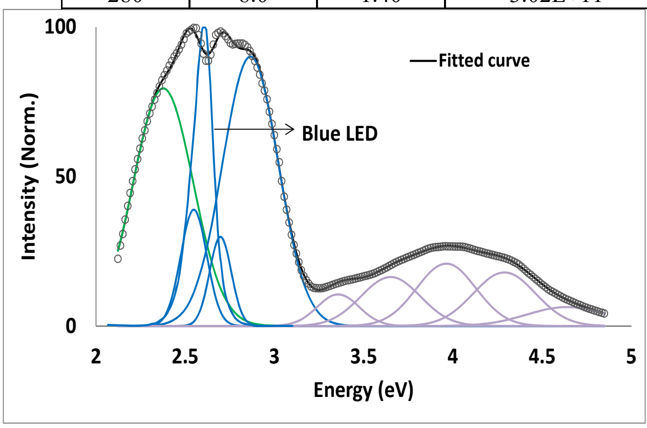

Fig.3: Deconvolution of excitation spectrum of $Ca_xSr_{1-x}S$: Eu^{2+} [9] and emission spectrum of blue LED.

Table2: Best fitted parameters of the deconvoluted excitation spectrum.

Peak. No.	Position			Int.(Rel)	FWHM (eV)
	eV	nm	colour		
P_1	2.38	521	green	79.4	0.39
P_2	2.55	486	blue	38.9	0.17

P_3	2.70	459	blue	29.8	0.14
P_4	2.86	434	blue	90.0	0.37
P_5	3.36	369	Near UV	10.6	0.27
P_6	3.65	340	Near UV	16.4	0.39
P_7	3.96	313	Mid UV	20.8	0.39
P_8	4.29	289	Mid UV	17.9	0.41
P_9	4.64	267	Deep UV	6.3	0.51

The excitation spectrum of $Ca_xSr_{1-x}S$: Eu^{2+} reported by Poelman et. al [9] is deconvoluted using PeakFit Software. The result is shown in Fig.3. The best fitted output parameters of the constituent bands are presented in Table2. The emission spectrum of the blue LED is also shown in Fig.3. Table2 shows that red emitting $Ca_xSr_{1-x}S$: Eu^{2+},RE^{3+} phosphor can be excited efficiently by blue LED.

4 CONCLUSION

The excitation spectrum of $Ca_xSr_{1-x}S$: Eu^{2+},RE^{3+} red emitting afterglow phosphor being wide, spread over the visible range, blue LED is capable of inducing enough TL. The same is true for background illumination of computer screen that is enough for TL excitation in the phosphor. Appropriate optical engineering may be capable to design red emergency signage where blue/green afterglow phosphor that has long persistent luminescence, may excite $Ca_xSr_{1-x}S$:Eu^{2+},RE^{3+} for whole night with red illumination.

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