Irradiation effect and TL behaviour

by

Dr. Devendra Prasad
Department of Physics (Basic Science)
U P Textile Technology Institute, 11/208, Souterganj, Kanpur 208001(UP) INDIA

Abstract

Radiation significantly influences thermoluminescence behaviour across various materials, including food samples, phosphors, and nanocrystals etc. Here in present paper reevaluation of TL decay parameters of coriander from already reported experimental curves has been made according to new method of analysis of TL glow curve. It has been found that this method has been found useful for detection of irradiated coriander. Aim of this work is to reinvestigate the TL properties of coriander as a function of the gamma irradiation dose.

Keywords: Thermoluminescence, Irradiation dose, Decay parameters, Radiation effect.

Introduction:

Thermoluminescence (TL) is a phenomenon where irradiated materials emit light upon heating, and its decay parameters namely activation energy (E_a), frequency factor (s) and order of kinetics (L) are critical for understanding the material behaviour. Out of several properties, to eliminate insect infestation ionizing radiation processing for foodstuffs treatment is being adopted feruently[1-4]. To increase the level of safety in foods for consumers, irradiation of foods materials is increasing in practice. Irradiation technology is often used since it is safer, economical and is not associated to toxicity in foods [3, 5-7]. One of the most common methods for irradiated food identification are of physics and chemistry nature like TL in irradiated foods [8]. As the inorganic fraction present in the spices, the TL method is suitable [8-12] for identification of irradiated foods allowing the evaluation of the TL properties as a function of the dose response, reproducibility of TL signals, fading, and the structure of the TL glow curves due to polymineral fraction content in foodstuffs [13-20]. In Coriander (*Coriandrun sativum L.*) significant polymineral fraction is present reveals to analyze its TL properties for detection purposes of previously irradiated foodstuffs. Gamma rays irradiation treatment of accurate dose represent a good alternative to sterilize or disinfest the product before distribution to the consumers. Some international regulatory authorities recommends dose limit up to 10 kGy for dehydrated herbs, spices and seasonings [21-22]. Here aim of this work is to reanalyse already experimentally reported glow curve in the light of new method of analysis.

Material and Method of Analysis:

E.Cruz-Zaragoza et.al.[23] reported the experimental work of TL behaviour of γ-irradiated coriander. They have taken 4 mg of powder sample for each grain size was deposited onto aluminum discs for irradiation and TL readouts. The samples were irradiated at 0.5 Gy – 15 kGy gamma doses. The 05-400 Gy dose irradiation was carried out with a Gammacell-200 (369.7 mGy/min), while for high doses (500-15 kGy) the Gamma beam 651PT irradiator (97.533 Gy/min) loaded with cobalt-60 sources was used. All samples irradiated were kept in dark condition and at room temperature (21°C), in order to avoid the effect of environmental light on TL response. A Harshaw TLD3500 reader was used for TL measurements with 2 K/s heating rate, and a constant flux of nitrogen in the chamber sample was maintained in order to reduce spurious TL signals. The TL glow curves of the samples at different given doses are reported [23]. Due to closely overlapping glow peaks E.Cruz-Zaragoza et.al.[23] have analyze

glow curve by deconvolution method. The deconvolution was done by considering the general equation and the decay parameters are obtained using the Sequential Quadretic Programming Glow Curve Deconvolution [24-27].
The experimentally reported [23] glow curves are reanalyzed by Prakash method [28]. According to this method TL intensity I is given by

$$I = (1-x)n_0\, s \exp\left[-\frac{E_a}{kT} - \frac{s\,(1-x)}{b}\int_{T_0}^{T} exp\left(-\frac{E_a}{k\,T'}\right) dT'\,\right] \qquad \ldots (1)$$

where x is the extent of retrapping in T L process, n_o the initial concentration of trapped carriers per unit volume, s the escape frequency factor or pre-exponential factor, E_a the trap depth or activation energy, k the Boltzmann's constant, b the linear heating rate, T_o the temperature at which TL glow curve starts to appear and T' an arbitrary temperature in the range T_o to T. Temperature T_m at which peak of the T L spectrum appears is given by the relation [28]

$$T_m^2 = \frac{b\,E_a \tau_m}{(1-x)\,k} \qquad \ldots (2)$$

where τ_m is the relaxation time at the peak temperature T_m. Relaxation time τ at any temperature T is given by Arrhenius relation [29]

$$\tau = \tau_0 \exp\left(\frac{E_a}{k\,T}\right) \qquad \ldots (3)$$

where τ_0 is the fundamental relaxation time (inverse of escape frequency factor s such that $\tau_0 = \frac{1}{s}$). Extent of retrapping $\boldsymbol{x}$ is related with the order of kinetics ℓ through the relation

$$\ell = \frac{1}{1-x} \qquad \ldots (9)$$

Result & Discussion:

The TL glow curves of the samples at different given doses are reported by E.Cruz-Zaragoza et.al.[23]. As reported the glow curves were in a broad range 273 -670 K at different gamma doses and peaked around 437-455 K. The radiative recombination of thermally detrapped charges with a defect centre results in a glow curve and provides an identification of previously irradiated foodstuffs. To characterize the main TL properties of the polymineral fraction, the TL decay parameters, namely the activation energy (Ea) of the traps, frequency factor s and order of kinetics (**ℓ**) were calculated. Result of reanalysis of experimentally reported deconvoluted curves as per Prakash method [28] are tabulated in Table. 1 and Table.2 as

Table.1Reported Tm and calculated TL decay parameters for glow curves of Coriander exposed to 10kGy (Immediately after irradiation).

Peak	Tm (K)	τ_0(s)	E_a(eV)	ℓ
1	392.36	5.26E-09	0.7	1.84
2	431.6	2.22E-10	0.91	0.94
3	480.93	2.23E-11	1.12	0.73
4	526.76	2.51E-12	1.32	0.85
5	607.64	2.78E-12	1.49	1.68
6	648.41	4.74E-13	1.75	0.55

Table.2 Reported Tm and calculated TL decay parameters for glow curves of Coriander exposed to 10kGy (After 5 days of irradiation).

Peak	Tm (K)	τ_0(s)	E_a(eV)	ℓ
1	415.78	4.08E-12	0.95	5.86
2	448.67	2.00E-13	1.21	0.92
3	492.22	3.32E-14	1.34	4.46
4	533.59	4.69E-15	1.56	3.08
5	608.27	9.01E-15	1.8	1.20
6	653.97	3.34E-15	2.1	0.17

From above result we see that there is only slight change in E_a ans s values whereas in new method of analysis concept of order of kinetics is different.

Conclusion:

In the present study we found that the adopted method of analysis is also good for calculation of TL decay parameters from deconvoluted TL glow curves. Calculated values of E_a, s and ℓ are quiet helpful in characterization of material under consideration and the method is suitable for detecting fresh coriander processed by irradiation. Gamma radiation profoundly affects TL decay parameters, enabling food irradiation detection, and also in other material science applications. These findings highlight the versatility of TL analysis in understanding radiation effects and improving safety standards.

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