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Analysis of the Thermoluminescence(TL) glow curves of β-irradiated NaCl at room temperature

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Abstract

Thermoluminescence (TL) technique was used for the investigation of trapping levels in NaCl crystals in the temperature range (298-698) °K. In this investigation, the TL glow curves of NaCl powder irradiated by β-rays at RT(295 K) was subjected to rigorous Computerised Glow Curve Deconvolution(CGCD) using the general order kinetics equation. The activation energies lie between (0.74 to 1.85)eV and the frequency factor(s) lie in the range (5.26×10^{9} to 4.35×10^{14}) s^{-1} . The most intense glow peak occurred at (591 ± 4)°K with activation energy of (1.47 ± 0.07)eV and the frequency factor(s) is ($2.07 \pm 3.22)\times10^{12}$ s^{-1}. The present study highlights the importance of TL in characterization of material like NaCl in dosimetry, dating etc.

Keywords: Thermoluminescence(TL), NaCl, CGCD, frequency factor(s), activation energy(E).

1. INTRODUCTION

Alkali halides are perhaps the best of all ionic compounds. Because of their own rather extreme properties; however, they have not been used as much as materials of more direct commercial interest, such as semi-conductor etc. Nevertheless, their case of crystallistion and purification have made them the subject of much detailed investigation and from these studies a wealth of valuable information on solid state behaviour has been gathered [1]. The structure of the majority of the alkali halides follows that of NaCl. The chemical reagent NaCl can be used as TL phosphor for the purpose of radiation dosimetry. One of its main advantage is low cost and ready availability. Therefore NaCl powder can therefore be used as a material for 'one time' TL dosimeters which avoids the complications of annealing procedures required in the re-use of TL dosimeters in conventional TL technique [2]. The presence of stable TL peaks at high temperature provides practical applications of NaCl as a tool in TL dating [3-4], which result from the stored charge carriers in deep traps at ambient temperature

(~ 300K) for long time (10^3 to 10^9 years).

The selection of NaCl as material of choice for demonstration of TL technique in characterizing imperfections is mainly because of its classic wide band gap (E_g ~ 8.5eV) model system and its excellent TL database [5-6]. The other reason for its selection is correlation of TL peaks with thermal annealing of F-centers [7-8].

2. EXPERIMENTAL

2.1 TL data acquisition at high temperature.

NaCl powder used in this study was of annular grade manufactured by Ranbaxy Lab. Ltd., India. The sample was gently hand crushed in an agate mortar to a uniform size of (90-100) μm. 10mg of the crushed material was used in each measurement.

2.2 The equipment

The measurements on TSL for the present investigation were carried out in the "Risø TL/OSL System Model TL/OSL-DA-15"[9] at the Luminescence Dating Laboratory, Earth Sciences Department, Manipur University. The samples were irradiated at room temperature with an inbuilt beta irradiation (^{90}Sr) source with a dose rate of 0.084Gys^{-1}. The irradiated samples were read out in flowing nitrogen atmosphere. The details of the equipment are provided in earlier papers [10-11]. All data are presented after subtraction of the background emission.

2.3 Theoretical techniques used

All the TL glow curves were analyzed routinely using Computerised Glow Curve Deconvolution(CGCD) method [6]. In this work, the number of glow peaks has been determined using the 2nd order derivative plot [12].
The theoretical technique used for the analysis of the glow curves has been given in detail in the recent papers [11,13]. The equation governing the TL process for general order kinetics (1 ≤ b ≤ 2) following Pagonis et. al. [14] can be written as

$$I(t) = n_o s'' \exp\left(-\frac{E_t}{kT}\right)\left[1 + (b-1)\frac{s''}{\beta}\int_{T_o}^{T}\exp\left(-\frac{E_t}{kT'}\right)dT'\right]^{\frac{-b}{b-1}}$$

…….. (1)
where

$s'' = s' n_o^{(b-1)}$ effective frequency factor for general order kinetics (s^{-1}),
E = activation energy (eV), k= Boltzmann constant(eVK^{-1}),
β = dT/dt (heating rate), T = absolute temperature(K),
t = time (sec),
$T = T_o + \beta t$, T_o = temperature at time t = 0 sec (K),
n_o= No. of trapped electrons at time t = 0 sec (in m^3),
b = order of kinetics ($1 \le b \le 2$),
s′ = the effective pre-exponential factor for general order kinetics (in $m^{3(b-1)}$ s^{-1}).

The goodness of fit is judged from the value of Figure of Merit (FOM) [15] and Chi-square (χ^2) test of normalcy of error distribution [16].

3. RESULT AND DISCUSSION

The TL glow curves of 10mg of pure NaCl powder recorded with a heating rate of 5°Cs^{-1} are presented in Figure 1. The samples are β-irradiated at

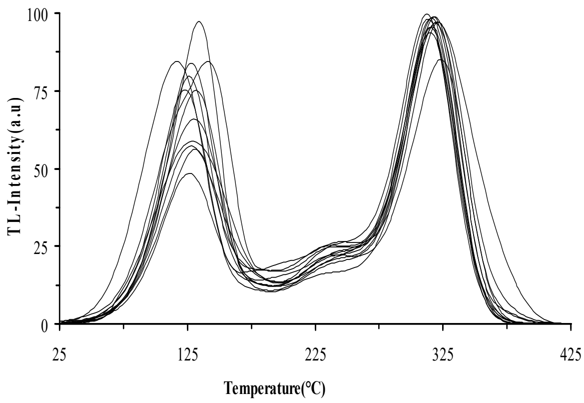

Fig. 1: A set of twelve glow curves of β-irradiated at RT (22°C) NaCl powder with a dose of 15Gy.

RT (295°K) with a dose of 15Gy. In all cases, the curves exhibit two distinct peaks along with weak peaks in between them. One typical CGCD results of the glow curves is presented in Figure 2. The CGCD result shows the entire glow curve can be fitted with five TL peaks whereas in some cases six TL peaks are required.

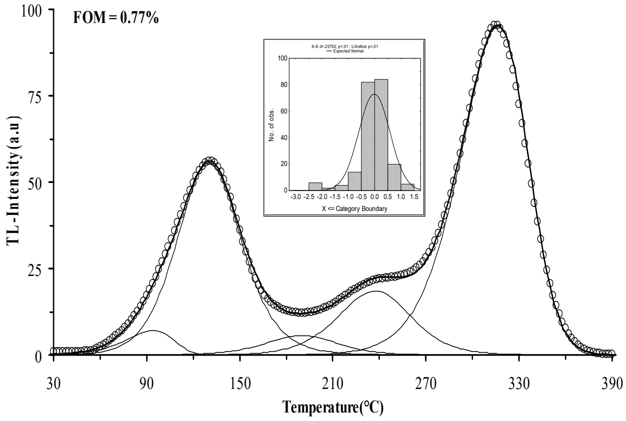

Fig. 2: CGCD of typical glow curves of NaCl (showing peaks). (**Inset**: Histogram of errors with the expected normal curve in fitting glow curve)

The results of the CGCD analysis are presented in Table 1. In all the cases the prominent peaks occurred around (403±5) °K and (591±4)°K with an activation energy of (0.86±0.05)eV and (1.47±0.07)eV, which are well in agreement with earlier studies [7,17-18]. The spectroscopy of traps in NaCl is presented in Figure 3. It shows more than one TL- peaks have the same activation energy. Again the frequency factors(s) for all the TL peaks lie in the range (10^9-10^{14}) s^{-1}. The electrons trapped at (591±4)°K have a trap depth of (1.47±0.07)eV are expected to have a life-time(τ) of the order of 8×10^4 years at RT, which can be useful in dosimetry[19]. It may also be relevant in TL dating of NaCl, a material often found in nature [13,20].

Table 1: Results of CGCD of NaCl glow curves

Pea -k No.	T_m (°K)	Trap-depth, E (eV)	Frequency Factor, s (s^{-1})	Kinetics, b
P_1	370±7	0.74±0.03	$(5.26\pm5.58)\times10^9$	1.01±0.04
***P_2**	**403±5**	**0.86±0.05**	**$(3.77\pm2.77)\times10^{10}$**	**1.57±0.27**
P_3	457±9	0.99±0.07	$(1.17\pm3.47)\times10^{11}$	1.54±0.28
P_4	511±2	1.20±0.03	$(2.41\pm3.25)\times10^{11}$	1.72±0.14
***P_5**	**591±4**	**1.47±0.07**	**$(2.07\pm3.22)\times10^{12}$**	**1.19±0.14**
P_6	625±8	1.85±0.08	$(4.35\pm3.25)\times10^{14}$	1.07±0.08

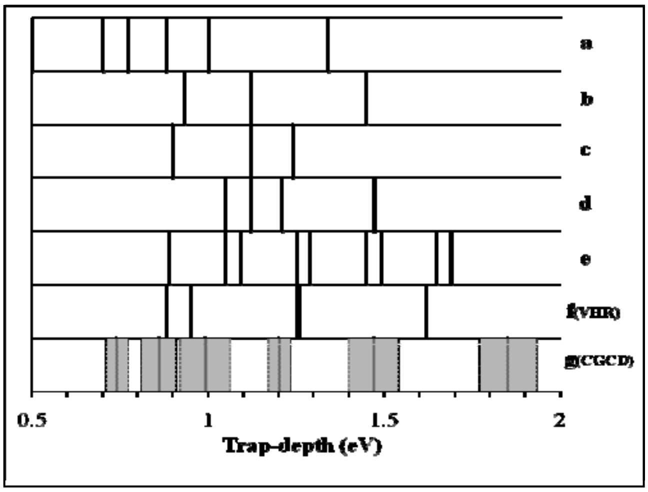

Fig. 3: : Trap spectroscopy of NaCl.
a, b, c, d, e, f, and g represent data of [21], [17], [7], [18], [22], [23] and present study.

4. CONCLUSION

i) The TL glow curves of NaCl system can be defined by the peaks at [370±7, **403±5** , 457±9, 511±2, **591±4,** 625±8] °K.

ii) The present data agree well with that of the earlier studies barring those of Mariani and Alvarez Rivas.

iii) The frequency factors(s) for all the TL peaks lie in the range (10^9-10^{14}) s^{-1}.

iv) The electrons trapped at (591±4)°K has a trap depth of (1.47±0.07)eV are expected to have a life-time(τ) of the order of 8×10^4 years at RT. Thus NaCl can be useful as a good candidate for dosimetry and TL dating.

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