Improved Thermoluminescence Properties of Natural NaCl Salt Extracted From Mediterranean Sea Water Relevant to Radiation Dosimetry

F. Khamis and D. -E. Arafah

ABSTRACT

Thermoluminescence (TL) technique has been used to characterize and determine the dosimetric properties of natural sodium chloride (NaCl) salt extracted from the Seawater of the Mediterranean Sea. The TLD grade material was prepared by evaporation and annealing the powder obtained from the aqueous solution. The TL properties include the response to theβ-irradiation dose and the effects resulting from annealing up to 700°C, heating rate and fading. The analysis involve using total Glow Curve Deconvolution (GCD) to separate the inherent overlapping TL-peaks and determine the TL characteristics and the trapping parameters using general order (GO)kinetics (activation energy, kinetic order, peak position of trap and the frequency factor). The GL-curves exhibit well defined TL-peaks around 140°C, 225°C and 380°C and response depending on the annealing temperature due to variations due to formation of the structural defects. A linear response was noticed over the delivered range of absorbed doses up to 4Gy. The fading results gave evidence that TL emission is due to a redistribution of trapping levels and indicate that the prominent TL-peak near 225°Cis useful for TL-dosimetric applications.

Keywords: TL emission spectrum, annealing, glow curve analysis, Retrospective dosimetry.

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I. INTRODUCTION

Thermoluminescence (TL) has been largely recognized to be a defect related phenomena due to the presence of impurities and defects that can markedly influence the TL-response and sensitivity materials and several models have been proposed to explain the observation of GL-curves that may vary in complexity ranging from one to several TL-peaks [1,2]. The method is useful, handy and efficient for obtaining information on the trapping states and defect distribution of insulators. In crystalline materials, however, the energy levels are due to structural defects or the presence of intrinsic and/or extrinsic atoms in the crystal. Electrons and holes created as a result of irradiation of the material can be trapped at defect sites and subsequent heating causes the release of some of the stored energy as photons, depending on certain processing conditions [3,4].

Generally, studies of the luminescence properties in alkali halides and impurities activated alkali halides which have long been known to represent interesting and potential materials in the field of radiation dosimetry because the amount of light emitted is generally related to the initial radiation dose and energy is a challenging task in the development of radiation dosimetry, to find possible dosimetric material. The physical basis of TL, in alkali halides is thought to be due to the recombination of trapped

electrons (F and F aggregate color centers) and interstitial halogen atoms (H centers) produced during irradiation, see e.g. [1,5]. Color centers production by γ -irradiation in NaCl, KCl and KBr were reported by [6]. In fact, there are other defects that might also be responsible for some parts of the glow curve. These defects can be mainly interstitials and vacancies among others; however, trapped electrons or holes in pre-existing impurities and other point imperfections might also be important [7].

The common natural mineral Sodium Chloride (NaCl), salt is a very wide band gap (~ 8.5 eV), of natural origin, crystallized from sea water, lakes, saline ground water and also mined as solid rock [8]. The natural material, has been extensively studied and is known to exhibit luminescence properties depending on the composition and structure that may vary, and has been studied for its thermal, optical and infrared stimulated luminescence [9,10,11,12,13]. The luminescence emissions of natural (halite) and synthetic NaCl (pure and doped) minerals have also been extensively investigated due to their radiation sensitivity and possess TL and optical stimulated luminescence (OSL) properties for applications in retrospective dosimetry [13], geological dating and identification of irradiated food [11]. In this category, sodium chloride (NaCl) has been known to be a suitable candidate for TL retrospective dosimetry and promising dosimetric properties. Attempts of several studies using natural salt show the presence of impurities (e.g. Mg, Mn, O, As, Cu)with some exhibiting activator, some

showing sensitizer and others acting as killer or (quenching), with TL output demonstrating the combined effect of these elements and characterizing the TL of the material [14,3].

The present study focuses on determining the TL characteristics and the dosimetric properties of the commonly extracted natural NaCl salt samples collected from the Mediterranean Sea water and subjected to different annealing temperature conditions.

II. EXPERIMENTAL

Natural salt extracted from the surface water of the Mediterranean Sea contains sodium chloride (NaCl), samples were collected from the Seawater of the Libyan sea shore of the Mediterranean Sea. The extracted powder was obtained by evaporating the collected seawater in beakers using a hotplate that was kept at a temperature of 100° C, for about 2-3days.The resulting powder representing the crystallites was then crushed and grinded to powder, and the residue was sieved using a mesh of particle size less than \leq 63 μ m. Samples used in the measurements were pressed under a 0.05 Ton pressure to form of circular disc pellets each of mass 10mg, with dimensions 5mm diameter and thickness about 1mm.

The effect of the annealing temperature was investigated by preparing four sets of samples. Each set constitutes eight samples that are read directly to check for reproducibility, effect of exposure dose, heating rates and finally the fading characteristics of the phosphor. The optimum annealing condition was determined by varying the annealing temperature from room temperature (RT) up to 700 °C/1h, using porcelain crucibles and a microprocessor controlled furnace. Samples were then left to cool slowly to RT prior to the irradiation process. The samples were irradiated using ⁹⁰Sr-⁹⁰Y beta particles with 2.87 μGys⁻¹dose rate. The samples were irradiated from 0 up to 4 Gy.

TL-measurements were performed using TL-Reader Harshaw model 3500 with different linear heating rates up to 4 °C/s from RT up to 400 °C. To study the changes in the TL intensity with time (fading), all investigated samples were irradiated with 1 Gy. They were stored in the dark in laboratory condition and measure the TL intensity at different intervals for three weeks.

The black body radiation was always recorded before and after each read out and subtracted from all GL-curves.

III. TL GL-CURVES ANALYSIS

The glow curves of natural salt were deconvoluted using the general order kinetics expression, namely

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

Where: n_o = initial concentration (cm^{-3}) of filled trapped charge carriers at time t= θ at initial temperature T_o = 0K and T = final temperature (in K), $s'' = s'n_o^{(b-1)}$ in units of frequency(s^{-1}) similar to that in the first order (b=I) kinetics. Equation (1) above includes the second order kinetics (b = 2) and reduces to the first order kinetics when, $b \rightarrow 1$. The

kinetic order is, however, one of the unknown parameters, and therefore we decided to use the general order (GO) kinetics with b may take any value between 1 and 2. Typically the maximum values of s correspond to values of the lattice vibration frequency, i.e. $10^{12}-10^{14}s^{-1}$. s'=an empirical parameter acting as an "effective" or pre-exponential frequency factor (in $cm^{3(b-1)}s^{-1}$). $\beta=$ heating rate (in $K.s^{-1}$); assumed linear: $T=T_0+\beta t$, E= activation energy or trap depth (in eV), k= Boltzmann constant (=8.617x10⁻⁵ $eV.K^{-1}$). The main two trapping parameters in thermoluminescence (TL), the activation energy and the frequency factor, are often calculated and later used for the evaluation of the stability of the TL signal at a given temperature. In several cases, "anomalous" values of these parameters, either very high or very low have been reported in the literature [15,16].

The frequency factor values are calculated from the TL-peak parameters, given by [17, 18]; namely

$$\frac{\beta E}{kT_{M}^{2}} = s \left[1 + (b-1) \frac{2kT_{M}}{E} \right] e^{-\frac{E}{kT_{M}}}$$
 (2)

Next, the method of the variable heating rate (VHR) was adopted in determining the activation energy and frequency factor. This is based on the shift of the maximum temperature (T_M) to higher temperatures when the heating rate is increased. By using several heating rates, and setting the condition for maximum TL-intensity, the following linear equation is obtained [20]:

$$\ln\left(\frac{T_M^2}{\beta}\right) = \frac{E}{kT_M} + \ln\left(\frac{E}{sk}\right) \tag{3}$$

A plot of $\ln(T_M^2/\beta)$ versus (T_M) using Eq. (3) gives a straight line from which the slope and intercept represent the activation energy or trap depth (E) and the frequency factor (s).

IV. RESULTS AND DISCUSSION

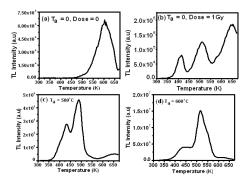
A. Effect of the annealing temperature

The as prepared GL-curve samples that are directly read at RT are presented in Fig. 1(a). Such GL-curves, directly read with no imparted beta dose, are best described by one TL-peak structure or a superposition of many luminescence centers around 600 K. This suggests that the naturally crystallized NaCl salt prepared from sea water exhibits luminescence properties depending on the composition and structure that may vary. It also indicates that the luminescence is apparently a result of a single one TL-peak type defect or the superposition of formation of more than one TL-peak as a consequence of one or many type luminescence centers. However the GL-curve is, recognized to be formed of more than one trap and the TL-peaks are responsible of its generation as no single TL-peak gives a best fit for the whole curve.

The 1 Gy β -irradiation dose results in altering the defect structure as evidenced from Fig.1(b) which results in separating the un-irradiated and originally low intensity intrinsic one peak defect structure into three main TL-peaks of varying intensities centered at 413 K, 511 K and 653 K together with a weak signal shoulder appearing near 580 K. On the basis of the realizing and understanding the defects

in alkali halides, the TL in e.g. NaCl is due to luminescence centers formed within the lattice. The TL center is the complex formed by the emission center, inherent impurity ion, or impurity ion vacancy (IV) (dipole), in association with nearby negative ion vacancies. It is therefore suggested that the centers may be situated in isolation or in pairs or in higher aggregates in the lattice [19]. Upon irradiation, the electrons from the impurity centers eject and get trapped into the nearby vacancies. The peak centered at 413 K is associated with isolated TL emission from the samples on account of de-excitation of electrons from traps and their subsequent recombinations at parent emission centers, whereas the peaks near 511 K and 653 K are related to higher aggregates of IV -dipoles and complex trapping sate defects.

The characteristic GL-curves which exhibit alterations in the concentration of electrons within traps also influence the transition probability and is a function of the temperature of annealing. In Fig. 1(c, d and e). The temperature of annealing was varied between RT and 700 °C and the samples were read directly after 1Gy irradiation. Inspection of the GL-curves more closely reveals that significant changes are taking place not only to the peak positions but also distinct variations of the intensities of the TL-peaks are occurring. The changes occurring to the average number of electron population and consequently changes in the composition and the defect structure are also expected as clearly seen in Fig.1(c, d and e). The GL-curves of NaCl following the annealing at 500, 600 and 700 °C/1h, respectively, correspond to annealing step in F-center concentration. Such changes cause, perturbations to the density of electrons within the traps, and are considered key features in altering both the transition probabilities and the density of charge distribution which affect the trapping and recombination processes. The effects of increasing the temperature of annealing, results in a shift towards higher temperatures and an increase of the intensity of the prominent TL-peak detected near 513 K, cf. Fig. 1(d), which has been markedly enhanced with the generic relation, such that nearby lower and higher temperature peaks are reduced. The originally recorded three TL-peaks, Fig. 1(b), appear as two distinct TL-peaks with increasing the temperature of anneal from 500to 700 °C.



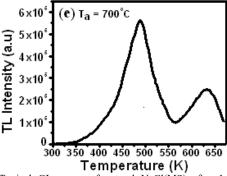
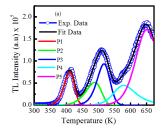
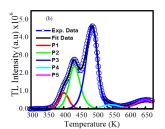
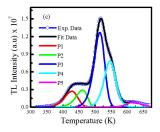


Figure 1 Typical GL-curves of natural NaCl(MS) after 1 Gy β-dose irradiation (b through e) illustrating the effects of 1h annealing at different temperatures. GL-curves are measured at a constant heating rate of 2 ${\rm Ks}^{-1}$.

Comparison with the main TL-peak, indicates that the intensity is reduced and became only 2.7% of that at the highest temperature of anneal, 700 °C. This is possible if one assumes that some energy is available which is sufficient to cause these alterations and induce the observed changes. Such an energy is available and sufficient, and the perturbations result in markedly reducing all the trapping centers and eventually evidence of attempts to destroy the TL centers associated with the lower temperature TL-peaks near 400 K is clear. The data emphasize that the original traps responsible for each TL-peak vary and are generally a function of the annealing temperature. The observed changes imply that the annealing temperature is viable and the defect structure is part of formation of a large complex defect that is mobile within the lattice. It is, however, expected that the movement would be towards a large concentration gradient that is found near 513 K, and is a consequence of prolonged annealing times, resulting in a decrease of TL-output (cf. Fig. 1(e)); such that the sensitivity at first increases with the annealing temperature, reaches a maximum at 600 °C and then decreases uniformly. In a study of the Turkish natural salt, [20], found that TL output of the main dosimetric peak at around 493 K decreases with the annealing temperature 300 °C on wards. The variation of the intensity of TL signal with the temperature of annealing is much more sensitive in the case of natural salt NaCl. To check the response of individual TL-peaks, the GL-curves have been deconvolved as shown in Fig. 2 and the relevant parameters of the main TL-peaks are listed in Table1.







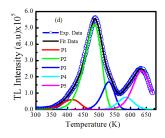


Figure 2 De-convolution of GL-curves of natural NaCl(MS) obtained at different annealing temperatures and following β -irradiation to a dose level of 1Gy.

TABLE 1 TRAPPING PARAMETTERS OF NATURAL SEA SALT SAMPLES DETERMINED FROM GL-CURVE DECOVOLUTION USING GERALORDER (GO) KINETICKS.

Temper	GERALORDER (GO) KINETICKS. General Order (GO) kinetic parameters						
ature	TL	Activati	Kineti	Freque	TL-peak,	Initial	
of	-	on	c	ncy	T_M	Conc. of	
anneal,	pea	energy	order	factor s	in (K)	electron	
T_a $(^{\circ}C)$	k	E (eV)	b	(s^{-1})		s, no	
	\mathbf{P}_1	1.02	1.22	2.39×1 0^{10}	411	3.06×10	
	\mathbf{P}_2	0.82	1.00	1.14×1 0^6	488	3.21×10	
0	P_3	1.28	1.27	1.50×1 0^{10}	517	4.89×10	
	P ₄	1.29	2.50	5.95×1 0 ⁸	579	4.34×10	
	P ₅	1.36	1.82	1.13×1 0 ⁸	628	1.62×10	
	\mathbf{P}_1	1.11	1.53	5.95×1 0 ¹¹	401	3.66×10	
	P_2	1.36	2.00	5.60×1 0 ¹³	432	1.09×10	
500	P ₃	1.42	1.44	3.59×1 0 ¹²	487	2.06×10	
	P_4	1.43	2.50	9.63×1 0 ¹⁰	543	1.86×10	
	P_5	1.52	1.48	2.42×1 0 ⁹	650	3.89×10	
	P ₁	0.83	1.21	2.84×1	427	1.44×10	
	P_2	0.99	1.00	0^{7} 4.74×1	461	1.35×10	
				0^8		5	
600	P ₃	1.56	1.24	1.19×1 0 ¹³	515	5.38×10	
	P ₄	1.81	1.59	3.30×1 0 ¹⁴	546	4.73×10	
	P ₅	2.19	2.26	2.65×1 0^{15}	550	8.31×10	
	\mathbf{P}_1	0.52	1.06	7.18×1 0 ³	415	4.34×10	
	P_2	0.74	1.00	1.84×1 0 ⁵	485	3.50×10	
700	P_3	1.41	1.26	1.26×1 0 ¹¹	531	8.45×10	
	P ₄	1.58	1.66	2.00×1 0 ¹¹	585	4.76×10	
	P ₅	1.60	1.59	2.22×1 0^{10}	635	1.70×10	

B. Heating rate dependence

The method of variable heating rate (VHR), which is based on the shift of the maximum temperature (T_M) to higher temperatures when the heating rate is increased, was adopted for determining the activation energy and frequency factor, cf. Eq. (3). Fig. 3(a, b) show GL-curves and TL-peaks of each glow curve, as determined from the deconvolved curves, which annealed at 600 °C/1h natural salt samples after 1 Gy recorded at different heating rates up to 4 Ks⁻¹. The curves clearly indicate that the temperature at

maximum intensity (T_M) of the prominent TL-peaks exhibits shifts to higher temperatures with the increase of the heating rate, as expected. The obvious relationship of the normalized curves (TL-intensity/ β) is, however, a decreasing behavior of the TL-intensity as a function of the heating rate; a phenomenon that is frequently met in practice when dealing with TL, due to thermal quenching [21]. Clearly, the GL-curves retain the same shape at various heating rates, indicating that insignificant changes to the nature of the GL-curve or preexisting defects types and structure are preserved.

In Fig. 3(c), the linear behavior obtained from the plot of $\ln(T_M^2/\beta)$ versus $(1/T_M)$ determines the activation energy or trap depth (E) from the slope and the frequency factor (s), from intercept. The set of values of (E and s) determined from the respective TL-peaks detected at(418, 430, 439, 448K) for P₁; (488, 508, 512, 516K) for P₂; and (596, 600, 612, 614 K) for P₃ at the various heating rates, namely $\beta = 1$, 2, 3 and 4 K.s⁻¹, are respectively $(0.68 \text{ eV} \text{ and } 6.94 \times 10^6 \text{ s}^{-1})$; $(0.94 \text{ eV} \text{ and } 2.39 \times 10^7 \text{ s}^{-1}) \text{ and } (1.55 \text{ eV} \text{ and } 1.05 \times 10^{12} \text{ s}^{-1}).$ Nonetheless, with close examination of the prominent TLpeak, i.e. P₃, the value determined represents typically the maximum values corresponding to the lattice vibration frequency, i.e. 10^{12} - 10^{14} s⁻¹. Therefore, the comparison is limited to the value of E and s determined from the kinetic analysis Eq.(3). The corresponding values of 1.56 eV and 1.19×10¹³ s⁻¹, clearly indicate that the frequency factor is about an order of magnitude larger than that determined from Figure 3c, but is still within the expected value corresponding to the lattice vibration frequency, and therefore the determined values assert that the prominent TL-peak detected at 515 K is suitable and useful for dosimetric applications.

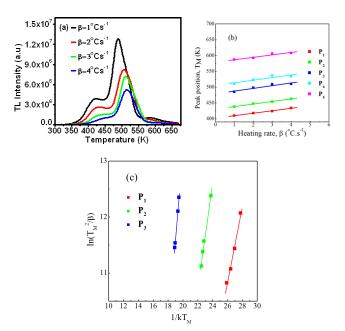


Figure 3 Normalized GL-curves of varying the heating rate illustrating the effects on the shape and position of natural salt sea after annealing at 600 °C and 1 Gy β -irradiation, in(a), and showing peak positions as a function of heating rate (in b). Plot of $\ln(T_M^2/\beta)$ vs. $(1/kT_M)$ is shown (in c) to obtain the activation energy and frequency factor.

C. Effect of the irradiation dose

The GL-curves of TL recorded by varying the β -radiation dose from 0.5 Gy up to a maximum dose of 4 Gy is studied at RT as shown in Figure 4. The GL-curves of

natural salt result in the detection of the two prominent TLpeaks around 453 K, 515K and the presence of a small shoulder observed at the high temperature end near about 540 K, with the main TL-peaks representing the trapping states by the electronic charges. The main TL-peak detected at 515 K is, however, attributed to recombination of the F-H

As the dose is further increased, the predominant TLpeak is that detected at 515 K. Upon increasing the irradiation dose, the temperatures at maximum of the peaks is observed to exhibit shifts of 10 K within the whole GLcurve temperature range. As the dose is further increased, above 1 Gy, the GL-curves show a small shoulder, with temperature maximum occurring near 560 K. The area under the glow curves of the samples is noted to increase uniformly with the increase of the irradiation, exhibiting a linear behavior of dose response. In general, irradiation of the natural salt only affects the mobility of the free charges generated by radiation but has insignificant effect on restructuring the existed defects, and thus similar shape GLcurves are expected with varying intensity depending on the imparted dose.

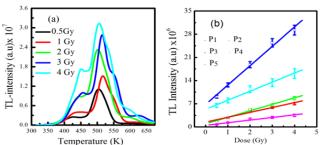
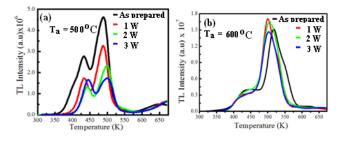


Figure 4 (a) Typical GL-curves showing the variation of TL-peaks on the imparted β-irradiation dose up to 4 Gy of natural sea salt annealed at 600 °C and measured with a heating rate of 2 Ks-1. The linear TL-response from each TL-peak is illustrated in (b).

B. The effect of TL Fading of natural salt NaCl

The fading and the effect of storage time of natural Mediterranean Sea salt, NaCl on the normalized glow curves and prominent TL-peak intensities are studied in Figure 5(a and b) for two different annealing times, 500 °C and 600 °C, respectively, and after 1 Gy irradiation, over a period of three weeks. The fading data clearly indicate that the efficiency and stability for NaCl salt to maintain the defect structure and retains TL characteristics is higher with annealing at 600 °C better than with annealing at 500 °C, a desired property which is favorable in dosimetric applications. The plot of the TL signal against time of storage shown in Fig. 5c, gives evidence that samples retained more than 98% of the signal and its characteristics over the whole period of three weeks.



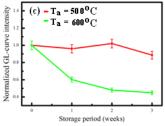


Figure 5 Glow curves of fading data of natural NaCl(MS) irradiated with 1 Gy and annealed at 500 °C/1h in (a), and 600 °C/1h in (b), illustrating the retained TL signal as a function of the storage period, up to three weeks. In (c), intensities of the prominent TL-peaks detected near 425 K and 500 K, are shown as a function of the storage time for each annealing temperature.

In comparison, annealing at 500 °C clearly indicates that a much larger loss, of more than 50% is obtained over the whole period of three weeks. The ratio of the prominent TLpeaks detected near 430 K and around 515 K is almost constant to within 10%. In addition the satellite shoulder TL-peak detected near 575 K shifts to lower temperature and become part of the peak structure detected near 575 K. This TL-peak which is the most sensitive defect level within the GL-curve is potentially useful as a prominent TL-peak in dosimetric applications due to its stability at higher temperatures and better sensitivity. Indeed, within the GLcurve the peak satellites at both temperature sides are insignificant; thus, focusing on the prominent TL-peak detected near 515 K, which is about more than four times sensitive than that recorded at 430 K, with the temperature of anneal of 500 °C.

The fading characteristic are finally described by the kinetic parameters, as determined from total curve fitting technique (GCD), namely: activation energy E of the traps involved in TL emission, the maximum temperature peak (position of traps) T_M, the frequency factor s, are listed in Table 2. The latter was obtained from the GO kinetics equation, Eq.(2). Nonetheless, the curve fitting technique which employs the two methods, agree in the values of the common parameters in both methods. Finally, the activation energy values appear to increase with the storage time.

TABLE 2 TRAPPING PARAMETERS, AS DETERMINED FROM CURVE FITTING, OF NATURAL SEA SALT SAMPLES annealed at

			600°	C/1h				
Time		General Order (GO) kinetic parameters						
of	TL	Activatio	Kinet	Frequen	TL-peak,	Initial		
stora ge	- naa	n energy E (eV)	ic order	cy factor s (s ⁻¹)	in (K)	Conc. of electrons,		
(wee	pea k	E (ev)	b b	3 (3)		n_o		
ks)	n		υ			no		
	\mathbf{P}_1	0.83	1.21	2.84×10	427	1.44×10 ⁵		
0	\mathbf{P}_2	0.99	1.00	4.74×10	461	1.35×10 ⁵		
	\mathbf{P}_3	1.56	1.24	1.19×10	515	5.38×10 ⁵		
	P_4	1.81	1.59	3.30×10	546	4.73×10 ⁵		
	P_5	2.19	2.25	2.65×10	550	8.31×10^{4}		
	\mathbf{P}_1	0.93	1.17	9.61×10	419	1.011×10		
1	\mathbf{P}_2	1.20	1.04	2.44×10	447	8.38×10^{4}		
	\mathbf{P}_3	1.45	1.1	3.03×10	497	5.24×10 ⁵		
	P_4	1.55	1.36	4.49×10	526	4.40×10 ⁵		
	P ₅	1.94	2.00	1.91×10	576	3.80×10^4		

2	\mathbf{P}_1	1.07	1.70	3.31×10	423	1.22×10 ⁵
	P_2	1.29	1.53	1.61×10	452	1.10×10 ⁵
	P_3	1.57	1.61	4.16×10	500	6.10×10 ⁵
	P_4	1.69	1.69	1.12×10	526	3.56×10 ⁵
	P ₅	2.07	2.5	2.76×10	589	5.06×10^4
3	\mathbf{P}_1	1.04	1.65	2.84×10	416	9.77×10 ⁴
	P_2	1.25	1.53	7.03×10	448	9.79×10^{4}
	P_3	1.56	1.66	3.60×10	498	5.55×10 ⁵
	P ₄	1.66	1.52	6.35×10	524	2.88×10 ⁵
	P ₅	2.05	2.5	4.00×10	582	4.29×10 ⁴

V. CONCLUSION

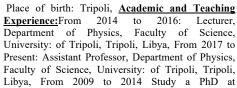
Examination of the Thermoluminescence characteristic of thermally treated natural salt collected from Mediterranean Sea was thoroughly carried out to check the reliability for prospective use of NaCl as a potential reusable TL dosimeter. The salt was obtained by evaporation from the solution and subjected to different annealing temperatures up to 700 °C and kept for 1 hour. The TLresponse was observed to be enhanced with the increase of the annealing temperature showing a maximum response at 600 °C and then drops afterwards. The GL-curves exhibit a linear response with the imparted dose and the fading was monitored over a period of three weeks. The GL-curves recorded at different heating rates up to 4 °Cs⁻¹ were used to determine the frequency factor. The results indicated that the annealing of NaCl salt at the above temperature can act as an efficient β-dosimeter. The analyses revealed that the newly developed natural salt dosimeter consists of the prominent TL-peaks with the main peak centered near 225 °C. From the GL-curves recorded at various heating rates, the activation energy and frequency factor was determined from the mixed order kinetic equation. The properties of the phosphor investigated indicate that the extracted NaCl salt from natural sources is an interesting novel material for a potential use as an efficient solid state dosimeter for dosimetric applications of ionizing radiations at high temperatures.

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