

KINETIC PARAMETER AND TL GLOW CURVE OF In DOPED NaCl CRYSTALS

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Abstract. The present work reports the thermally stimulated luminescence displayed by sodium with different percentages of indium as impurity the doped NaCl: In crystal after exposure to UV light is studied. The thermal glow curves exhibited by NaCl: In shows interesting results. The dependence of dopant concentration on TL in NaCl: In crystal is investigated. The interaction of ionizing radiations with matter leads to various effects, some of which leave memory in the target material. This memory effect can be seen as the after effects of the irradiation. This paper describes the sequence of the physical events beginning with the incidence of an ionizing particle. Leading to trail of atomic and electronic displacements which stabiles in the form of so called defect centers. The kinetics of the thermoluminescence process has been explained phenomenological. The TL phenomenon has found many particle applications. The most outstanding of these are in dosimetry and in archaeology. The paper deals mainly with the physical processes involved in the TL emission and allude briefly to its involvement in applied areas.

1. Introduction

The picture of the nature of thermoluminescence (TL) in insulating crystals is still slightly blurred. Although it is known that irradiated samples of crystalline alkali halides, for instance, release luminous energy when heated above the irradiation temperature, the inner mechanisms of the phenomenon are still debated. This is mostly due to the large number of the processes involved. Physical models of TL have been proposed by various authors [1-3]. The general scheme admits a discrete number of localized levels in the forbidden energy gap between the valence and conduction bands. Several levels below the bottom of the conduction band serve as electron traps, and by analogy several trapping levels for positive holes are assumed to be present above the valence band. Heating the sample causes the trapped electrons from one level to move in the empty conduction band from where they decay toward the valence band, releasing energy often in form of light. A single glow peak (GP) is so generated during the heating process. If more than one trapping levels exists in the band gap, multiple GPs are produced and the total TL curve may be difficult to be interpreted. Moreover, it is obvious that the trapping levels and the relative GPs are strictly related to the color centers (CCs) produced by the ionizing radiation and the impurities, which are often inserted on purpose in the crystals.

The complex and tangled mechanisms and the many activators involved make it almost impossible to understand the details of TL processes. Which is the one of the most common material among alkali halides for its peculiar optical properties [4,5], and is also popular as a solid dosimeter for ionizing radiation [6].

The study of alkali halide activated by specific impurities is of considerable important concentration of dopant used and also on the type of excitation employed. The analysis of TL glow curves of alkali halide (NaCl) due to the variation in concentration level of typical dopant (In) is presented in the paper.

2. Experiment

Sample preparation. The starting material used for the preparation of the NaCl:In crystal were NaCl powder and Indium chloride (InCl_3) the sodium chloride was added according to the proper ppm and known concentration of dopant Indium was added along with it. This mass was properly crushed and mixed using a mortar and pestle. The mixture so obtained was fixed in the central zone of a high temperature muffle furnace at $1000\text{ }^\circ\text{C}$ for 1 hour. After firing the mixture was then cooled by varying the temperature by $100\text{ }^\circ\text{C}$ at every hour. The resulting crystal was then effectively cut at known dimensions was used for the study for UV excitation 365 nm rays obtained from conventional UV sources was used and the different crystals were excited for 30 min and 60 min respectively and the TL glow curve was recorded with a PC based TL system supplied by Nucleonix.

General considerations. The TL spectrum is the graphical representation of light intensity plotted as a function of temperature (or time), and possesses one or more maxima, called GPs, which are associated with various energy level traps [7,8], TL is directly related to the band structure of solids and particularly to the effect of the impurities and lattice imperfections. These can be described as defect centers or just centers that may occur when ions of either signs move away from their original sites, thus leaving vacant sites, able to interact with free charge carriers and to trap them; alternatively, ions can diffuse in interstitial position and break locally the ideal lattice symmetry; finally impurity ions can perturb the lattice order, because of their sizes and valences, generally different from their neighbor ones. Moreover, these extrinsic defects can interact with the intrinsic, ones, and eventually either of them can aggregate in more complex configuration. From an atomic standpoint, a defect can be described by means of sign and number of charge carriers it may interacted with, and of the eventual existence of excited states. To such centers is associated a characteristic energy which may be defined is the amount of energy, when supplied, to set the trapped charges free, thus destroying the centre and restoring a situation of local order.

Glow curve shape method. The method based on the shape of glow curve proposed by Chen [9] was used to verify the trapping parameters calculation. The following shape parameters were determined: total half intensity width ($\omega = T_2 - T_1$); the high temperature half width ($\delta = T_2 - T_m$), and; the low temperature half width ($\tau = T_m - T_1$), where T_m is the peak temperature and the T_1 and T_2 are two temperatures on either side of T_m corresponding to half peak intensity. Table 1 shows the different parameter.

Order of kinetics. The order of kinetics (b) was determined by calculating the symmetry factor (μ) of the glow peak, using the known values of the shape parameters

$$\left\{ \mu_s = \frac{T_2 - T_m}{T_2 - T_1} \right\} \quad \text{----- (1)}$$

Activation energy. Activation energy (E) was calculated by using the Chen equations, giving the trap depth in terms τ , δ , ω . A general formula for E was given by Chen [9] as follow:

$$E_\alpha = c_\alpha \left[\frac{kT_m^2}{\alpha} \right] - b_\alpha (2kT_m) \text{-----(2)}$$

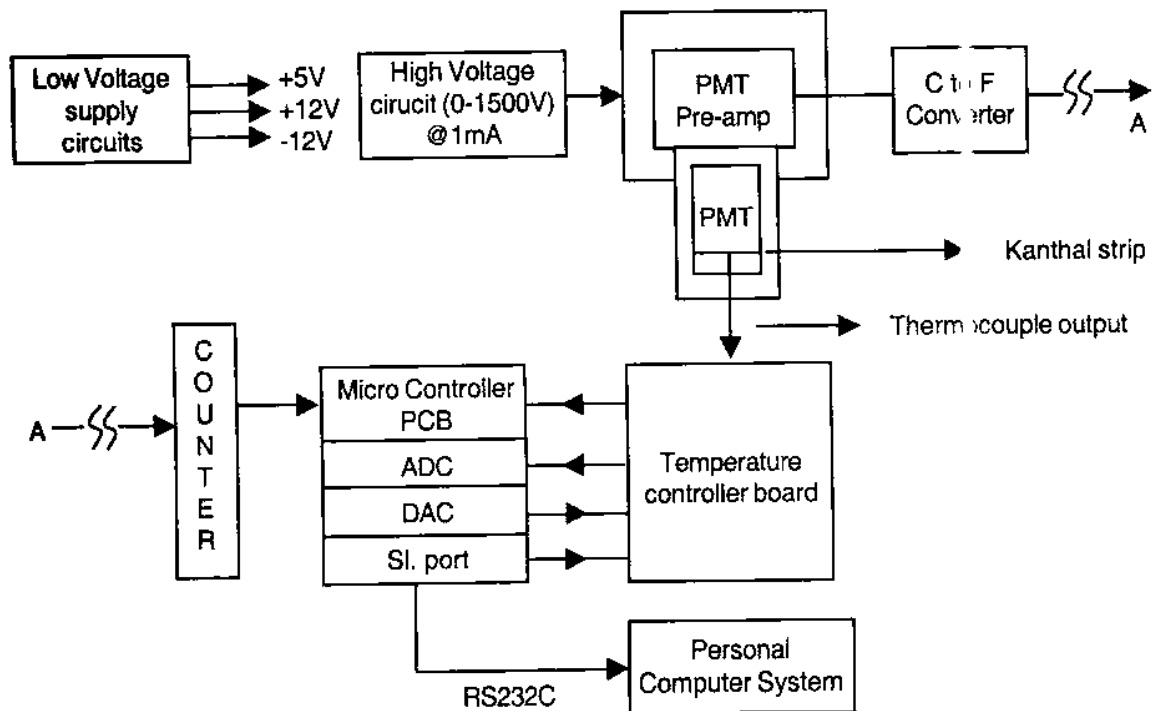


Fig. 1. Block Diagram of PC based TLD Reader.

3. Result and Discussion

The glow curve obtained for UV excitation of NaCl:In crystal for various concentration of In are shown in graph from the Fig. 2 to Fig. 10. Thermal stimulation causes the correlated recombination of the interstitial and F-centre vacancies. The luminescence results from the recombination of the hole with the F-centre electron. This mechanism is similar to that for NaCl:In because neither the electron nor the hole enter their respective de-localized bands. Once again the thermoluminescence is characterized by monomolecular kinetics.

First-order or monomolecular, kinetics is a natural consequence of this type of localized recombination. Because the excited electron does not reach the conduction band but remain in the "field" of the defect centre, the rate of photon emission (i.e., recombination rate) depends only on the concentration of excited electron. The main

effect of adding impurities to the crystals is to reduce the size of some of the glow peaks and to introduce some others, first – order kinetics are consistent with correlated recombination between an H – centres and its associated F – centre along the direction.

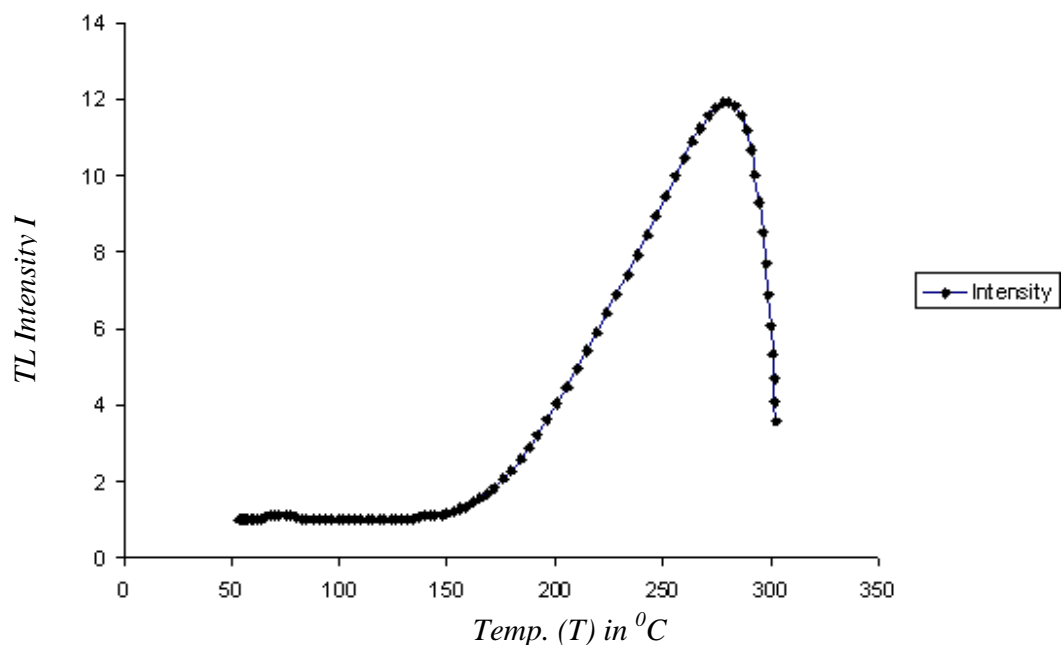


Fig. 2. NaCl pure crystal 10 min UV exposure.

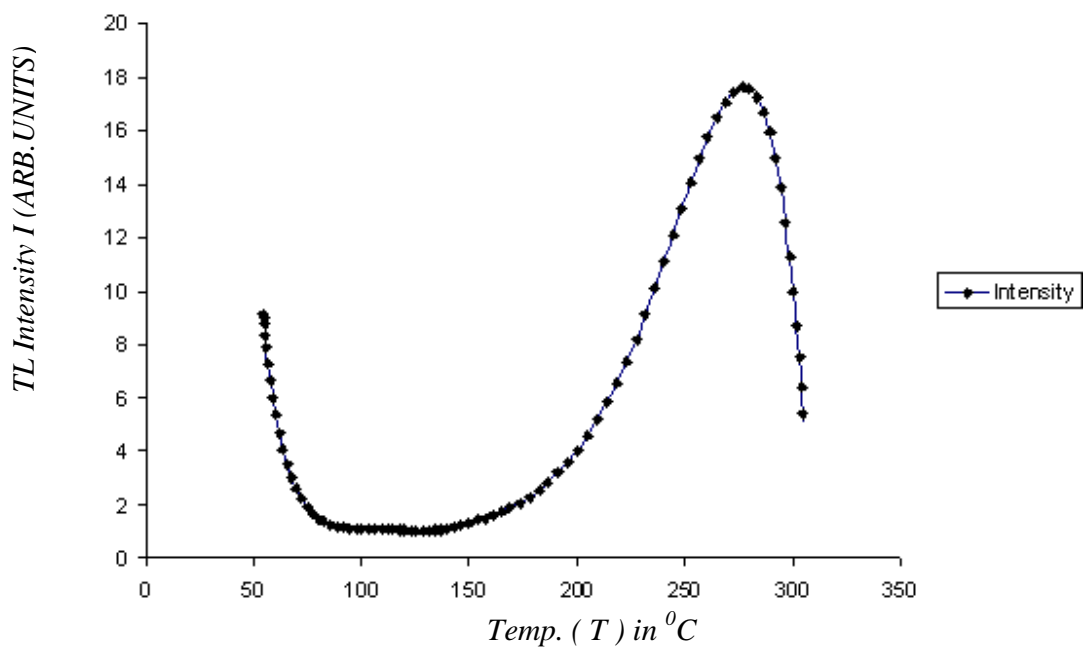


Fig. 3. NaCl pure UV exposure 30 min.

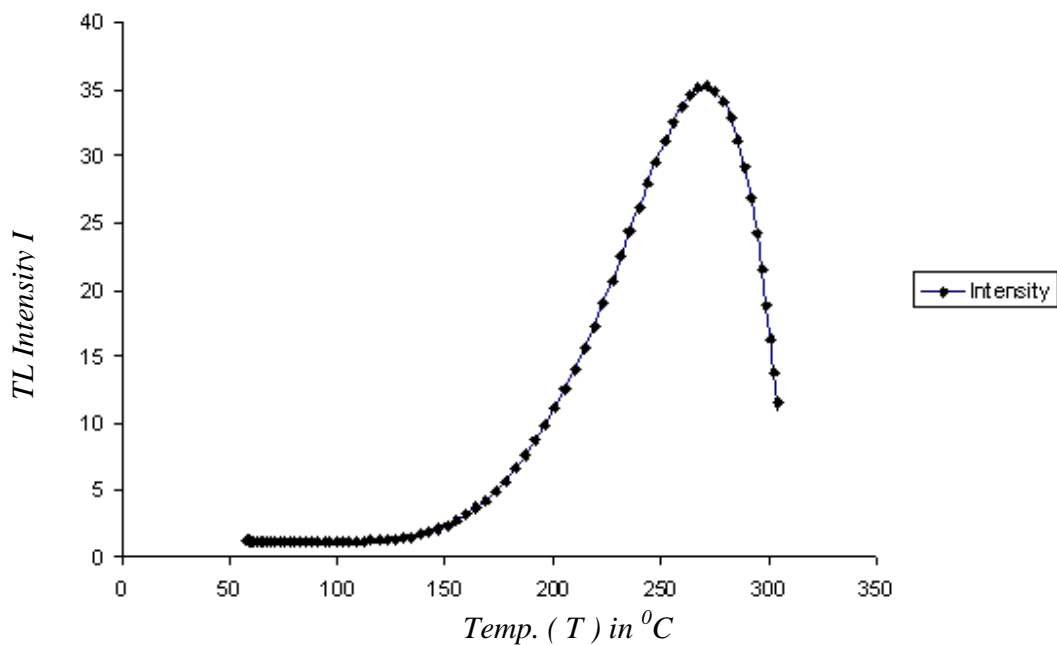


Fig. 4. NaCl:In 100 ppm 30 min UV exposure.

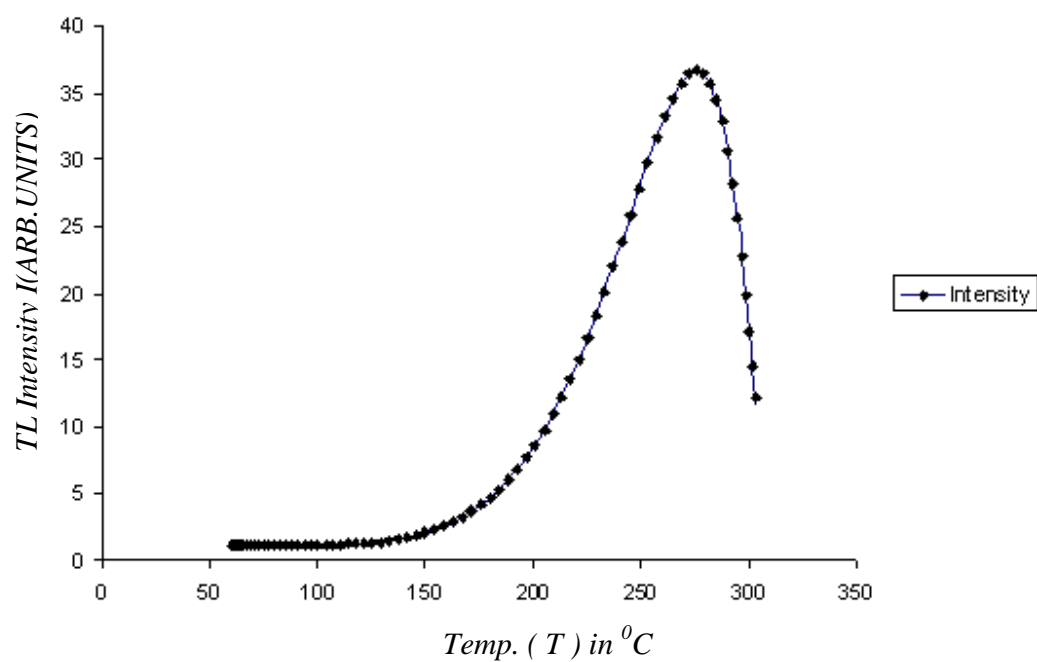


Fig. 5. NaCl:In 500 ppm 30 min UV exposure.

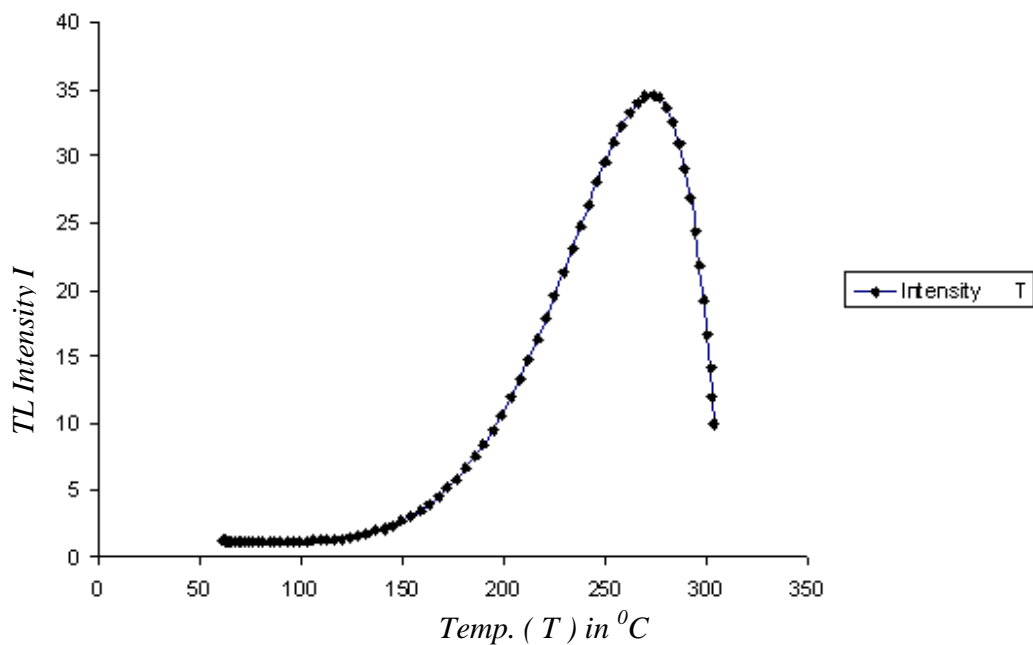


Fig. 6. NaCl:In 1000 ppm 30 min UV exposure.

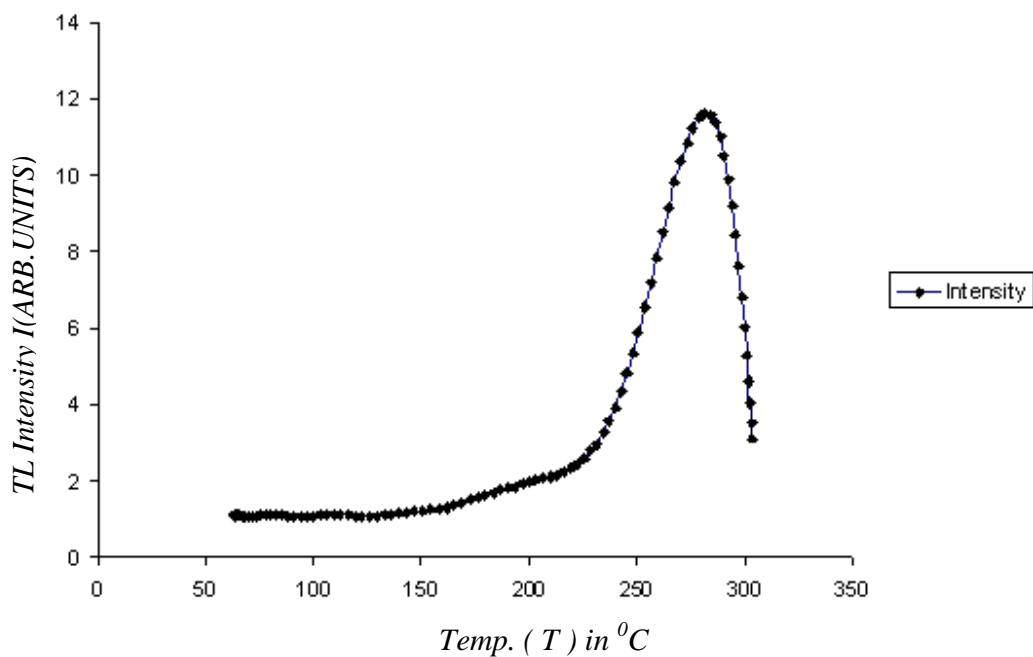


Fig. 7. NaCl:In pure exposure 60 min UV exposure.

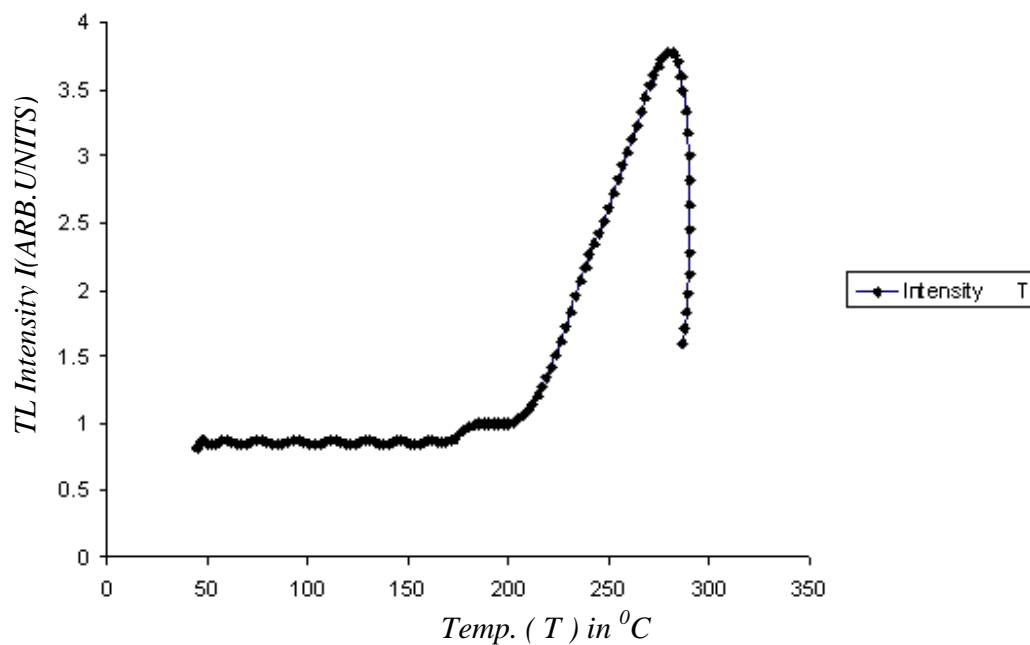


Fig. 8. NaCl:In 300 ppm 60 min UV exposure.

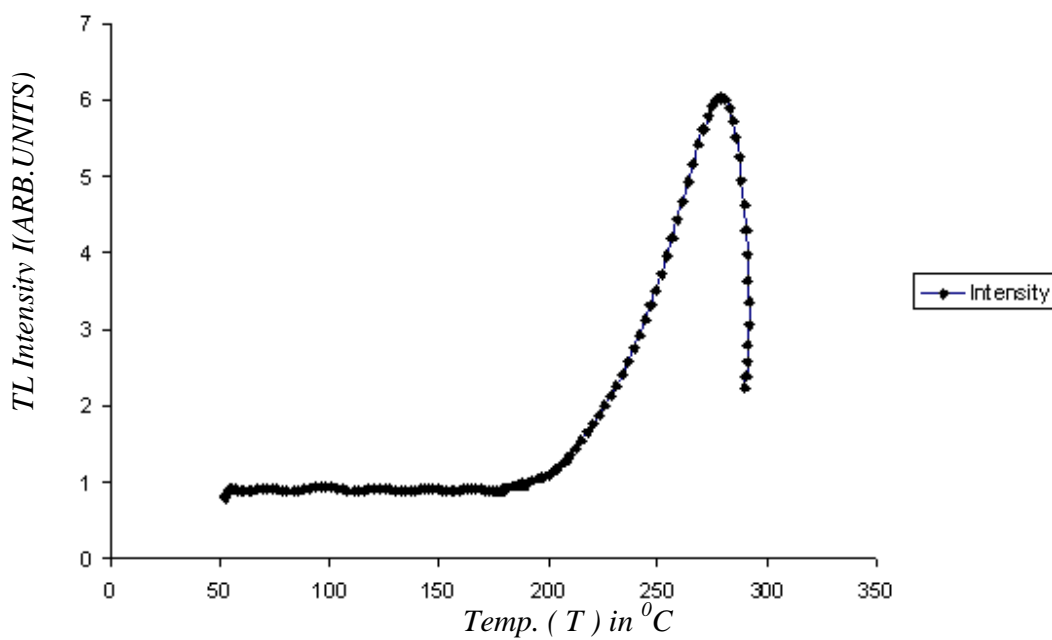


Fig. 9. NaCl:In 500 ppm 60 min UV exposure.

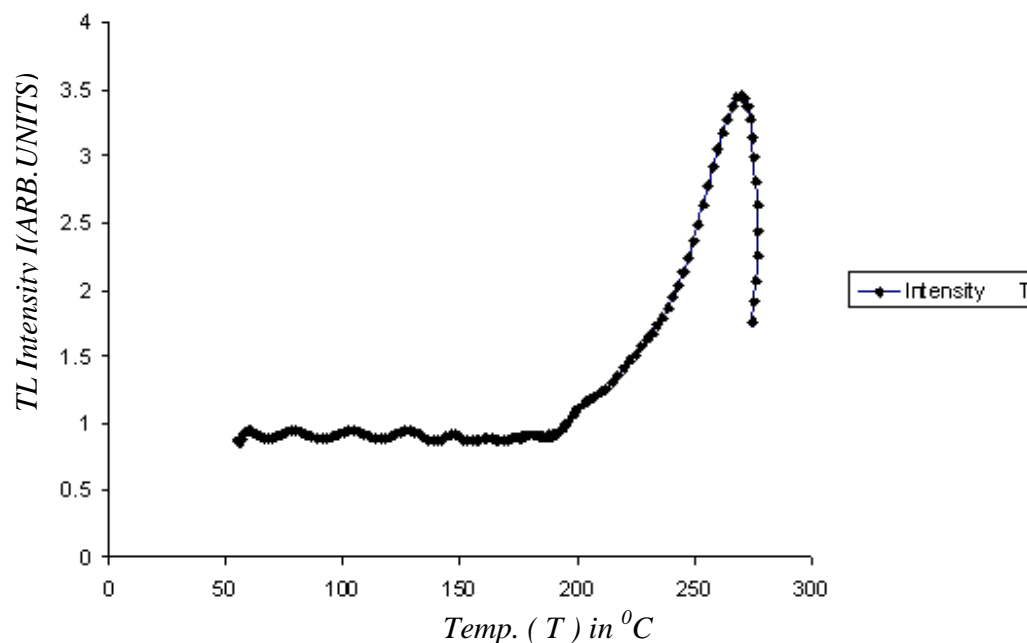


Fig. 10. NaCl:In 1000 ppm 60 min UV exposure.

Especially for temperature above 250-290 °C, there are enough experimental data to determine with a reasonable certainty the number of traps involved, which can be more numerous than the ones discovered here. Moreover, it is necessary to remember that in the present work nominally pure NaCl crystals have been used, which in any case contain impurities in ppm amounts, enough to generate complex CCs related to F – centers, as usually known and shown recently in detail [11,12]. Moreover, a comparison with the known energy diagrams of the various CCs, which up to now have been associated with the GPs, does not seem useful at moment.

Table 1 shows the different parameters of TL glow curve of NaCl:In crystals. To analyze the observed TL curves the symmetry factor (μ) [$\mu = \delta / \omega$, $\delta = T_2 - T_m$, $\omega = T_2 - T_1$, T_m being the peak temperature at the maximum, T_1 and T_2 are respectively, the temperatures on either side of T_m , corresponding to half intensity is calculated [9]. The peak parameters (peak temperature, full widths, and shape factor) are shown in Table 1. The variation of shape factor (μ) implies that the first peaks is of first order kinetics. Since the shape factor is not unique for the intense peak one can speculate it as a consequence of overlapping of neighboring peaks.

Table 1. Shape factors (μ), Activation Energy E and Order of Kinetics b of In doped NaCl pure crystal and irradiated by UV exposure 365 nm Source:

exposure time	T_1	T_m	T_2	$\tau = T_m - T_1$	$\delta = T_2 - T_m$	$\omega = T_2 - T_1$	$\gamma = \delta / \tau$	$\mu = \delta / \omega$	order of kinetics, b	activation energy E
NaCl pure 10 min	219.4	282.82	299.99	63.42		80.59	0.270735	0.213054	1	0.561511967
30 min pure	231.64	280.05	301.87	48.41	21.82	70.23	0.450733	0.310693	1	0.750142939
100 ppm 30 min	223.21	271.67	299.14	48.46	27.47	75.93	0.566859	0.361781	1	0.725685755
500 ppm 30 min	229.23	275.64	300.68	46.41	25.04	71.45	0.539539	0.350455	1	0.772523307
1000 ppm 30 min	220.84	273.36	300.35	52.52	26.99	79.51	0.513899	0.339454	1	0.668457012
NaCl pure 60 min	253.65	283.91	300.04	30.26	16.13	46.39	0.533047	0.347704	1	1.261163001
100 ppm 60 min	244.32	287.34	302.48	43.02	15.14	58.16	0.351929	0.260316	1	0.876745466
300 ppm 60 min	233.49	283.16	289.32	49.67	6.16	55.83	0.124019	0.110335	1	0.737920382
500 ppm 60 min	244.44	280.95	291.83	36.51	10.88	47.39	0.298001	0.229584	1	1.021531521
1000 ppm 60 min	243.04	271.13	275.75	28.09	4.62	32.71	0.164471	0.141241	1	1.300670644

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