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Original Article

Production of Thermoluminescent Dosimetry (TLD) Chip from LiF Powder using Thermal Process Method and Comparing Energy and Density of its Traps with TLD_{100}

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Abstract *- Researchers have done many experiments to improve their dosimetry properties by adding impurities to Thermoluminescent (TL) materials. Adding impurities to the TL material requires cost, time, and equipment. The purpose of this study was to construct Thermoluminescent Dosimetry (TLD) chips through different thermal processes at temperatures near the melting point of Lithium Fluoride powder without adding impurities to improve their dosimetry properties, therefore without the additional expense of Lithium Fluoride chips similar to LiF: Mg, Ti (TLD_{100}) chips were made. In this study, it was observed that when new TLD chips made of Lithium Fluoride powder were heated to 830 °C and cooled rapidly, they had an almost identical TL glow curve and temperature TM of maximum TL intensity (glow peak) TLD_{100}. On the other hand, in this paper, we used three analysis methods to determine the trap depth (E) and contraction of trapped electrons (n). Computational equations such as Randall-Wilkins [1], Garlick-Gibson [2], Methods of Analysis Employing the Whole TL Glow Curve, and computerized curve fitting procedures were used to determine the concentration and energy of traps made of chips and compared with the concentration and energy of TLD_{100} traps.*

Keywords *- Thermoluminescent, Dosimetry, Energy of traps, Thermal process, Lithium luoride, TLD_{100}*

1. Introduction

TLD_{100} have a mostly wide application in Thermoluminescent Dosimetry. TLDs were used in the determination of surface doses of radiology and radiotherapy. TLD_{100} is made by adding impurities of Ti and Mg to lithium fluoride and crystalline growth. Adding impurities of type Ti and Mg increases the level of energy and the amount density of traps in the lithium fluoride crystal and, as a result, makes a different shape of the glow curve and the changes of the locations of the temperature peaks T_M (glow peak shape) [3].

In this study, the characteristics of TLD_{100} were compared with Lithium Fluoride powder chips, which have been made by heated close to the melting point and cooled at a rapid rate for one and a slow rate for the other. On the other hand, with the help of known mathematical equations, the density and energy for both chips, our TLDs made by a thermal process, and the TLD_{100} were calculated. The master's thesis [4] was about how TLD is made from Lithium Fluoride powder using a thermal process, explained in the thesis, with different heating rates. However, characteristics such as reproducibility, dose linearity, response to dose, preheating, annealing, dark current, and fading in 5 batches were performed in the master research project of that time, and acceptable results were obtained compared to TLD_{100}. I and some others have worked on many research papers in the field of adding impurity types to TLDs in the following years. However, the idea of making TLD chips without impurities was not feasible and poor results were expected. As my knowledge of the process increased, I realized it was possible; in fact, it is unnecessary to add impurities if the right heating procedure is carried out, reducing the cost of the process. This is the goal of my research.

In the master project [4] and this research, Lithium Fluoride powder with MERCK brand with serial number 5690 was used, and the chips were heated until they were nearly melted. The crystal lattice formations and the luminosity curves were investigated with different cooling rates. They have been reviewed. This paper aims to use only lithium fluoride powder with a purity percentage approved by the seller, through a thermal process around the melting point, reached the same or identical energy and density of traps, such as TLD_{100} chips. On the other hand, we know to make TLD_{100}s by adding impurities greatly pushes up the cost of the process due to the precision required in adding the impurities. This research suggests an alternative cheaper method to reach the

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same result. In this study, the characteristics of TLD_{100} were compared with Lithium Fluoride powder chips, which have been made by heated close to the melting point and cooled at a rapid rate for one and a slow rate for the other. On the other hand, with the help of known mathematical equations, the density and energy for both chips, our TLDs which were made by a thermal process, and the TLD_{100} were calculated.

2. Glow Curve Analysis Methods in Thermoluminescence Materials

When exposed to ionizing radiation, TL materials store some of the energy in the crystal lattice, which is trapped by electrons in traps related to anomalies and crystal structures. If these materials are heated after irradiation, the stored energy is released in the form of light photons. These photons are the result of an electron-hole pair, meaning that the more electrons escape from the traps, the more intense the light emitted from the heat sink. The only way for electrons to escape from these traps is to receive energy given to the electrons by heating the TL material. Traps have different energy levels, so different energies are needed to escape electrons from these traps [3].

Initial Rise Methods: The experimental methods described in this section apply to any order of kinetics and are based on the analysis of the low-temperature interval of a peak. The initial rise analysis method was first suggested by Garlick and Gibson [2]. Garlick and Gibson propose this experimental method, which can be applied to any order of kinetic energy. By plotting Ln (TL) relative to 1 / KT for the initial part of the data, we calculate the trapped energy for this analysis performed for the first 10 points. According to equation (1), the amount of trapped electrons in the low-temperature tail of a TL glow peak can be assumed to be approximately constant since the dependence of n(T) on temperature T is negligible in that temperature region. In fact, as the temperature increases, the first exponential in equation (1) increases, whereas the value of the second term remains close to unity. This remains true for temperatures up to a cutoff temperature T_C, corresponding to a TL intensity I_C smaller than about 15% of the maximum TL intensity I_M. A further increase in temperature ($T > T_C$) makes the second term in equation (1) decrease; the competition between the two terms in equation (1) results in the peak shape of the TL glow curve [5,8].

$$I(T) = n.sexp(-\frac{E}{kT})\, exp\left[-\frac{s}{\beta}\int_{T_0}^{T_f} exp\left(-\frac{E}{kT'}\right)dT'\right] \quad (1)$$

Where
E = the activation energy or trap depth (eV)
k = Boltzmann's constant (eV K^{-1})
t = time (s)
T = the absolute temperature (K)

In a typical experimental situation, a linear heating rate β is used to heat the sample, resulting in the temperature varying as $T=T_0 + \beta t$, where β = linear heating rate (K s^{-1}), and T_0 = temperature at time t = 0 (K)

s = a constant characteristic of the electron trap, called the "pre-exponential frequency factor" or "attempt-to-escape frequency" (s^{-1}). This parameter is proportional to the frequency of the electron collisions with the lattice phonons.

Typically, the maximum values of **s** correspond to the values of the lattice vibration frequency, i.e. $10^{12} - 10^{14}$ s^{-1}.
N = the total trap concentration (m^{-3})
n = concentration of trapped electrons at time t (m^{-3})

By using this assumption of constant n(T), the thermoluminescence emission can be described by

$$I(T) \propto exp(-\frac{E}{kT}) \quad (2)$$

Considering equations 3 to 5, we can introduce: Methods of Analysis Employing the Whole TL Glow Curve; this method is based on integrating the glow peak when one peak is well separated from the other peaks. From the area under the luminosity curve from temperature T_0 to temperature T_f, the value of n (T) is calculated. Using this method, we draw a graph of $Ln(TL/n^b)$ with respect to 1 / kT, which gives a straight line and the slope of which is the energy E [5].

$$n = \int_{t_o}^{t_f} Idt = \frac{1}{\beta}\int_{t_o}^{t_f} IdT \quad (3)$$

Assuming first-order kinetics and substituting the Randall–Wilkins relations leads to

$$ln\left[\frac{I}{\int_{T_o}^{T_f} IdT}\right] = ln\frac{s}{\beta} - \frac{E}{kT} \quad (4)$$

This equation shows that in the case of first-order kinetics, the term ln(I /n(T)) is a linear function of 1/kT, with a slope –E and an intercept equal to ln(s/β).

May and Partridge [7] and Muntoni et al. [8] proposed the same method in the case of general order kinetics. In this case, the equation is

$$ln\left(\frac{I}{n^b}\right) = ln\frac{s'}{\beta} - \frac{E}{kT} \quad (5)$$

Which is graphically processed by plotting $ln(I/n^b)$ versus 1/kT.

b = the kinetic order, a parameter with values typically between 1 and 2

s' = the so-called effective pre-exponential factor for general order kinetics ($m^{3(b-1)}s^{-1}$). If the kinetic order b is known, one can obtain a broad range of temperatures in which the curve is a straight line. When the kinetic order is unknown,

several lines are drawn with various values of b and the best straight line is chosen [5].

Finally, the method of Computerized Curve Fitting Procedures, the subject of computerized curve fitting analysis, became very popular during the last decade with the development of sophisticated glow curve deconvolution techniques. Chen and McKeever [6,7] have summarized the curve fitting procedures commonly used to analyze multi-peak TL glow curves. They emphasize the primary importance of using a carefully measured TL glow curve since any errors in measuring the glow curve can lead to the wrong results in the computerized procedures. Such procedures are more likely to yield accurate results in the case of linear superposition of first-order Randall–Wilkins-type mathematical expressions [5,9,10].

3. Preparation of TLD using Lithium Fluoride Powder

In this study, Lithium Fluoride powder of MERCK product number 5690 with a melting point of 870 °C was used. In the first step, powdered Lithium fluoride was tableted (chip form) with the press machine, and next step, the chips were placed in the furnace. The chips were heated above 800 °C with a temperature accuracy of ±10 °C. The chips had gotten a ceramic form after the end of the heating period. For production, chips weighing 70 mg at 830 °C and above, 90 mg of powder should be used. Especially for chips made at 830 °C, some chips had lost most of their mass in the slow cooling phases. It was observed that the chips heated to 830 °C have curved intensity and temperature positions of their glow peak similar to that of TLD_{100} chips. For these chips, which were kept in the oven at 830 °C for one hour, we considered two cooling methods, quickly removed from the oven after the end of the heating period and letting to cool outside (rapid cooling), and secondly, letting them in the ambient temperature within the remaining oven for 24 hours (slow cooling). By investigating the effect of the heating program on the energy and density of the traps in the made chips and comparing them with the density of the traps and the energy of the TLD_{100} chips (control chips), it was decided that the chips made at a temperature of 830 °C with a rapid cooling rate are the best TLDs to replace TLD_{100}. Finally, it was decided to conduct research on calculating the energy and density of traps based on the equations of the Randall-Wilkins Model, Garlick-Gibson Model, methods of analysis employing the whole TL glow curve and computer analysis of the total glow curve.

4. Results and Discussion

In this section, we obtain the glow curve of the chips and analyze the glow curve using mathematical methods to calculate the energy and density of the traps. Chips were sintered at 830 °C, and according to the cooling time, samples were divided into two groups, fast (group1) and slow cooling (group 2).

Most of the chips subjected to slow cooling at 830 °C (group 2) evaporated, so only three of them that were identical in appearance and weight were evaluated in our experiments.

In this project, the TLD reader model V2.02, 1993, made in Hungary, has been used, and the heating program used for all chips is as follows:

Preheating from 50-120 °C within 12 seconds, from 120-300 °C with a heating rate of 10 °C/s for 18 seconds and a constant temperature of 300 °C until 7 seconds were used to obtain the glow curve. Finally, the annealing time of the chips was also considered to be one hour at 300 °C.

4.1. Investigation of the Glow Curve and the Location T_M of Glow Peaks in the TLD Chips

The chips, including groups 1,2 and $TLD_{100,}$ were irradiated using Cobalt 60, and the readout of TLD_S was done using a TLD reader under the same conditions of preheating, heating rate, and annealing. Their experimental data was determined such that the magnitude of the TL luminosity and the temperature at which the glow curve had the highest intensity (T_M glow peak).

The curves in Figures 1-3 show the glow curves of Group 2 (slow cooling), Group 1 (fast cooling), and TLD_{100}, respectively. The values of changes in the mean maximum radiation intensity (I_M) and changes in the mean temperature at maximum intensity (T_M) in these three groups were calculated, and the corresponding graphs were drawn.

As shown in Fig. 1, the glow curves of Group 2 have glowed peaks around 200-240 °C, and their maximum TL intensity is between 100 and 300. The advantage of this group is their symmetrical glow curve.

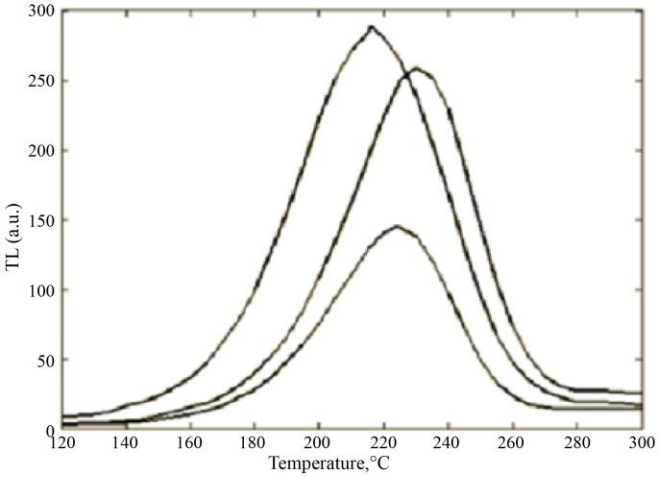

Fig. 1 The glow curve for 3 chips (group 2) which sintered on 830^{0}C with a slow cooling rate and had been exposed to 4Gy

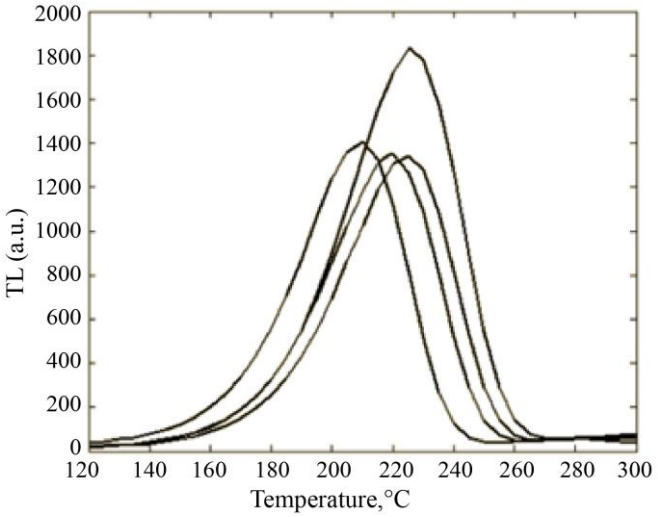

Fig. 2 The glow curve for 4 chips (Group 1) which sintered on 830^{0}C, with fast cooling rate and was exposed to 4Gy

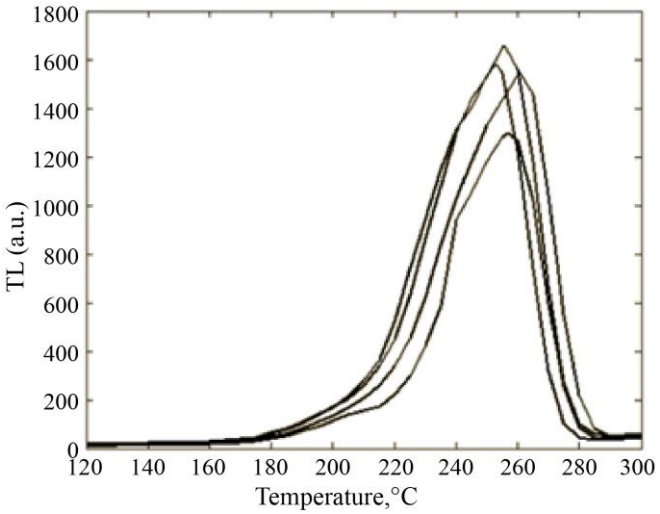

Fig. 3 Glow curve of 4 TLD_{100} chips, irradiated under Gy4

Fig. 2 shows the glow curve of group 1, the luminosity peaks of the chips being about 200-240 °C, and their TL intensity ranging from 1200 to 1800[1]. As can be seen from the four groups, in Group 1 chips, three of them have approximately the same luminosity intensity, and the intensity of luminosity in Group 1 is approximately 3-4 times that of Group 2.

Fig. 3 shows the TL glow curve of the TLD_{100} (control groups). The temperature T_M of the glow peak was shown at 250-260 °C, and the I_M of glow peaks is between 1200 to 1800[1]. The TLD_{100} chips have three luminosity curves of almost identical intensity; therefore, the batch of control groups has almost the same glow curve as group 1. By examining the glow curves in Figures 1, 2, and 3 and comparing them to each other, it can be concluded that the glow curve of Group 1 is similar to that of the control group. Whilst the glow peak of group 1 and 2 chips have a temperature range of 220-240 °C, and the control chips range between 250-260 °C.

Consequently, according to the theory of TL materials, it can be predicted that the energy of the traps can be obtained around 1eV. On the other hand, it should be noted that the brightness intensity of both groups (control and group 1) was above 1000. So, this is an advantage for group 1, which is as intense as the control group.

4.2. Analysis of Energy and Density Traps of TL Material

In this section, the chips were divided into three groups, Group 1, Group 2 and the control chips. The energy and density of the traps were calculated using the theories of Randall-Wilkins, Garlick-Gibson, and analysis of the shape of the curve and computer analysis of the total glow curve. The chips of all three groups were exposed to the same 4 Gy irradiation. According to the equations of Randall-Wilkins, and Garlick-Gibson, we calculated the energy of the trap's low-temperature curve using the analysis of the initial increase method. The calculations are shown in Tables 1, 2 and 3.

Table 1 shows the energy of the traps calculated by analysis of the initial increase for group 1 during the three times the irradiation of 4 Gy was applied and found with a maximum error of 13% and a 0.09 maximum variance of samples.

Table 1. The energy of the traps was determined using the initial increase method for group 1, which was irradiated under 4Gy three applications.

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) The third irradiation)
1	0.750	0.678	0.669
2	0.613	0.704	0.677
3	0.612	0.637	0.597
4	0.781	0.765	0.718
Average Energy E(eV)	0.689	0.696	0.665
	$\Delta E_{Max} = \pm 13\%$	$\Delta E_{Max} = \pm 10\%$	$\Delta E_{Max} = \pm 8\%$

Table 2 shows the energy of the traps calculated using the initial increase method for slow cooling of the chips at 830 °C (group 2), which was again three times irradiated under 4Gy. For group 2, the energy of traps was calculated with a maximum error of 18% and maximum variance samples of 0.09. In these heat processes, only three chips had the same mass and surface area, while the rest of the chips were different in mass and surface area.

Table 2. For group 2, the energy of the traps was determined using the initial increase method, which was irradiated three times under 4Gy

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	0.679	0.674	0.805
2	0.674	0.691	0.775
3	0.506	0.534	0.594
Av. En. (eV)	0.620	0.633	0.725
	$\Delta E_{Max} = \pm 18\%$	$\Delta E_{Max} = \pm 16\%$	$\Delta E_{Max} = \pm 18\%$

Table 3. Results of energy of traps, obtained using the initial increment method for TLD_{100}, irradiated under 4Gy three applications.

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	0.611	0.620	0.655
2	0.588	0.658	0.630
3	0.755	0.51	0.622
4	0.512	0.542	0.943
Av.En. (eV)	0.617	0.590	0.713
	$\Delta E_{Max} = \pm 17\%$	$\Delta E_{Max} = \pm 8\%$	$\Delta E_{Max} = \pm 32\%$

Table 3 shows the energy of the traps, determined using the initial increase method for control groups, which was also irradiated three times under 4Gy. For group control (TLD_{100}) energy of traps was calculated with a maximum error of 32% and with a maximum variance of 0.15.

As shown in Tables 1-3, the variance of samples was determined for TLD_{100} and the Group 1 chips, which were between 0.1-0.15 and 0.05-0.09, respectively. So, the advantage of chips made at 830 °C and cooled rapidly is that at low temperatures, around 50-160 °C, the energy changes of traps in group 1 are smaller than TLD_{100}.

According to the average energy of traps, the bar chart of trap energy in groups 1, TLD_{100}, and 2 was shown in Fig. 4. As can be seen in Fig. 3, the energies of the traps for group 1 are similar at each irradiation, indicating that in the mass production of TLD chips made by heating up to 830 °C and rapidly cooling, the dose-response of group1, is more uniformed compared toTLD_{100}.

4.3. Methods of Analysis Employing the Whole TL Glow Curve

Using methods of analysis, the Whole TL Glow Curve (WTLGC), the energy of the traps was calculated and is shown in Tables 4-6 for groups 1, 2 and TLD_{100}.

Pursuant to the results of Tables 4-6 for group 1, the average energy of the traps is higher than 1 eV. Thus, the fading time of the chips made in Group 1 is longer than in the chips of Group 2 and the control group. Whereas the maximum changes of traps energy around the average values were 8% and 7% for the control and 1 group, respectively. On the other hand, for group 2, 18% was obtained, which is greater than the numbers obtained for group 2 and the control.

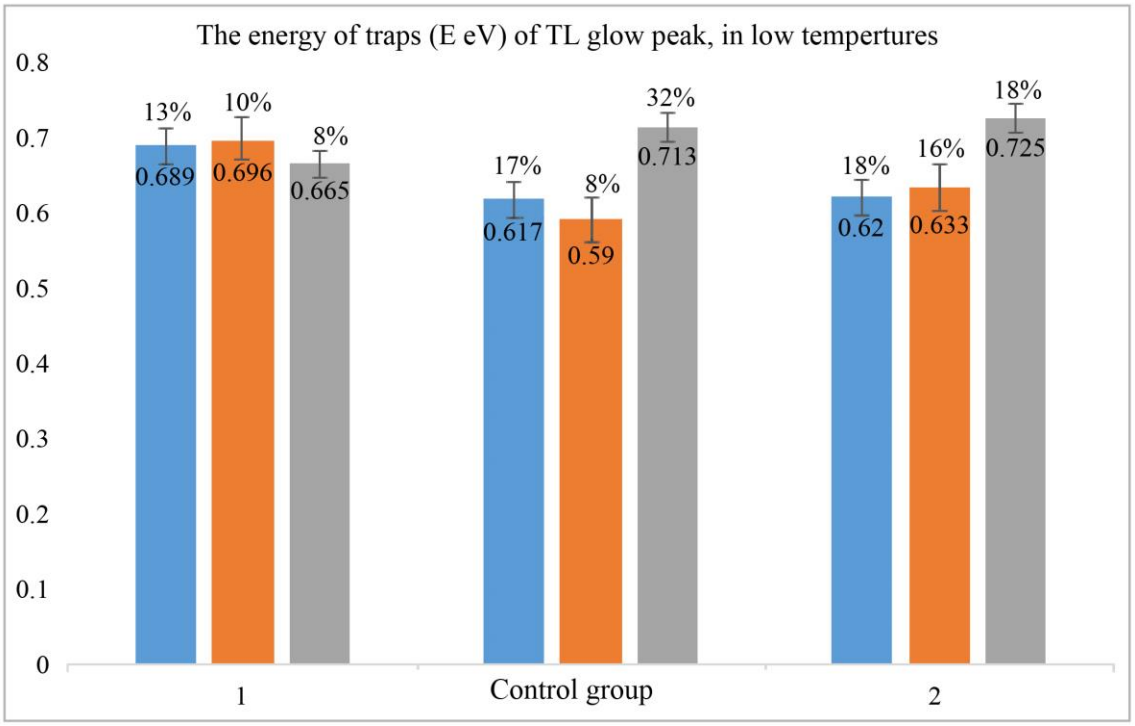

Fig. 4 The energy comparisons of the traps calculated by the initial increase method for groups 1, TLD_{100} and 2

Table 4. Trap energy was calculated using the WTLGC method of group 1, which had been exposed to 4 Gy three applications.

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	1.473	1.192	1.130
2	1.383	1.176	1.081
3	1.346	1.277	1.248
4	1.086	1.025	1.082
Av. En.(eV)	1.322	1.167	1.135
	$\Delta E_{Max} = \pm 18\%$	$\Delta E_{Max} = \pm 12\%$	$\Delta E_{Max} = \pm 9\%$

Table 5. Traps energy was calculated using the WTLGC method of group 2, which had been exposed to 4 Gy three applications.

Num. of chips	E(eV) (The first irradiated)	E(eV) (The second irradiated)	E(eV) (The third irradiated)
1	0.975	1.001	0.942
2	0.920	0.923	0.936
3	0.883	0.890	0.900
Av. En.(eV)	0.926	0.938	0.926
	$\Delta E_{Max} = \pm 5\%$	$\Delta E_{Max} = \pm 7\%$	$\Delta E_{Max} = \pm 3\%$

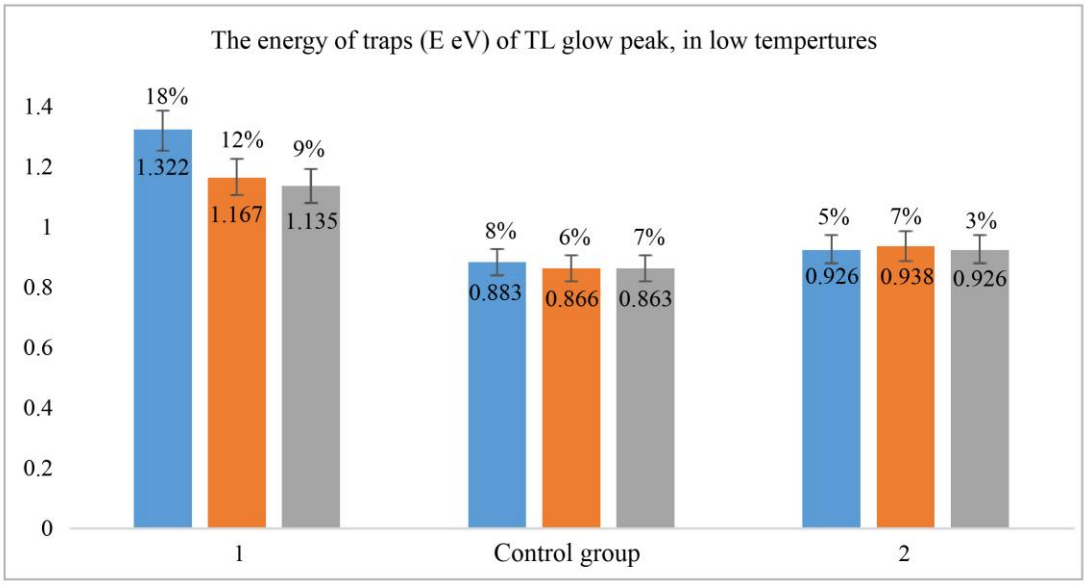

Fig. 5 The energy comparisons of the traps calculated by the WTLGC method for groups 1, TLD_{100} and 2

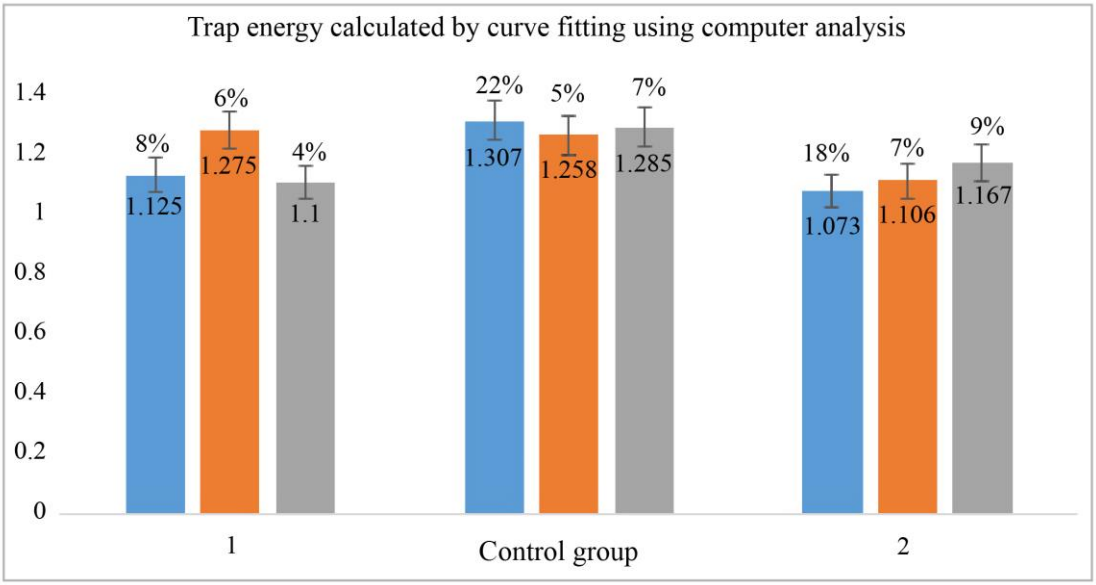

Fig. 6 The energy comparisons of the traps calculated by the computerized curve fitting method for groups 1, TLD_{100} and 2

Table 6. Traps energy was calculated using the WTLGC method for the TLD_{100} group, which had been exposed to 4 Gy three applications

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	0.869	0.874	0.839
2	0.845	0.921	0.923
3	0.969	0.852	0.873
4	0.850	0.817	0.818
Av. En.(eV)	0.883	0.866	0.863
	$\Delta E_{Max} = \pm 8\%$	$\Delta E_{Max} = \pm 6\%$	$\Delta E_{Max} = \pm 7\%$

Consistent with the average energy of traps, the bar chart of the trapped energy in groups 1, TLD_{100}, and 2 are shown in Fig. 5, obtained by the WTLGC method. As shown in Fig. 6, the energy changes of the traps for group 2 and the control are smaller than for group 1. However, the energy of group 1 traps is larger than that of group 2 and the control. As a result, the calculated energy in the WTLGC method shows that the average energy depth of group 1 traps is higher than the average energy depth of the control group.

4.4. Computerized Curve Fitting Procedures

Another method is to calculate the energy of traps using experimental data obtained from the luminosity curve and fitting them to the proposed mathematical equations. One of the proposed equations (1) to fit the experimental data on the luminosity curve proposed by Kitts et al. was offered. An important advantage of using the experimental data fit with Equation (1) method is that the computer program can obtain a trap energy value more accurately than other methods. The results of this method are shown in Table 7.

As seen in Table 7, the average total energy of the traps was 1.118 eV, with an average variance sample of approximately 0.05.

Table 8 shows that the average total energy of the traps was 1.116 eV, with an average variance sample of approximately 0.09.

Table 9 shows that the average total energy of the traps was 1.283 eV with an average variance sample of approximately 0.11.

Table 7. Trap energy calculated by curve fitting by computer analysis for Group 1 chips over three 4Gy irradiation applications

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	1.17	1.10	1.13
2	1.06	1.13	1.09
3	1.06	1.09	1.06
4	1.21	1.19	1.12
Av. En.(eV)	1.125	1.128	1.100
	$\Delta E_{Max} = \pm 8\%$	$\Delta E_{Max} = \pm 6\%$	$\Delta E_{Max} = \pm 4\%$

Table 8. Trap energy calculated by curve fitting by computer analysis for group 2 chips over three 4Gy irradiation applications

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	1.17	1.11	1.22
2	1.17	1.18	1.22
3	0.88	1.03	1.06
Av. En.(eV)	1.073	1.067	1.167
	$\Delta E_{Max} = \pm 18\%$	$\Delta E_{Max} = \pm 7\%$	$\Delta E_{Max} = \pm 9\%$

Table 9. Trap energy was calculated by curve fitting using computer analysis for the control group chips (TLD_{100}) over three 4Gy irradiation applications

Num. of chips	E(eV) (The first irradiation)	E(eV) (The second irradiation)	E(eV) (The third irradiation)
1	1.60	1.29	1.36
2	1.19	1.19	1.26
3	1.20	1.23	1.32
4	1.24	1.32	1.20
Av.En. (eV)	1.308	1.258	1.285
	$\Delta E_{Max} = \pm 22\%$	$\Delta E_{Max} = \pm 5\%$	$\Delta E_{Max} = \pm 7\%$

Suppose we refer to Fig. 1, 2, and 3; the temperature of glow peaks (T_M) for groups 1 and 2 range between 220-240 °C, while their averages were around 230 and 225 °C, respectively. Whereas for the control group, T_M was between 250-260 °C, the average of which is close to 260 °C. By examining the theory and equations for the TLDs luminosity curve presented for T_M, it is clear that the trapped energy of chips has to be observed to be close to each other with little variation. By evaluation at Tables 7, 8 and 9 or as shown in Fig. 3, the average energy of the traps was determined for all 3 groups of chips above 1 electron volt. According to the T_M that was obtained, the average energies of the traps 1.118, 1.116, and 1.283 eV are determined for group 2, group 1 and the control group, respectively. So, it can be suggested that calculating trap energy using computerized curve fitting analysis is more accurate than other methods.

4.5. Density of Traps (n)

The number of traps per unit volume (cm^{-3}) or the density of traps is proportional to the area below the glow curve. The surface area below the glow curve is expressed in equation (3):

In fact, by integrating the T_0 interval in the initial increase region to the maximum available temperature T_f, the area of the luminosity curve is determined. The area below the luminosity curve indicates the density of the traps or the number of electrons trapped in the crystal traps that have been released by receiving heat. Table 10 shows the average level below the luminosity curve of groups 1 and 2 compared to TLD_{100}, which is irradiated at an amount of 4Gy.

Table 10. Density of traps groups of 2,1 and the control was determined.

The average area of the glow curve of the chips with 4 Gy radiations.	Group 2	Group1	The Control Group
The first radiation	1356	8393	6916
The second radiation	1366	7219	6622
The third radiation	1449	7628	7018

The mean area under the glow curve was calculated for group 2 with a mean of 1390 with a minimum accuracy of 96%, group 1 with a mean of 7747 with a minimum accuracy of 92% and the control group (TLD_{100}) with a mean of 6852 with a minimum accuracy of 97%. According to the results, the chips made at 830 °C with a fast cooling rate (group 2) have an average trap density greater than the control group (TLD_{100}), which is actually an important advantage for group 2 chips. This result shows that this large amount of trap density can be achieved without impurities, only with a heating program near the melting point and with an appropriate cooling rate. As seen in Fig. 7, changing the cooling rate of chips from 830 °C to slow cooling or rapid cooling causes a change in the average density of traps for groups 2 and 1, from 1390 to 7747.

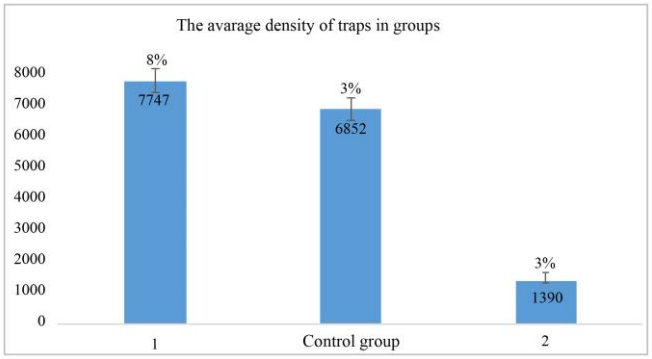

Fig. 7 The average density of traps in three stages of radiation is 4Gy

5. Conclusion

Using Lithium Fluoride powder, various TLD chips are made, but so far, the most applicable methods for making TLD chips were crystal growth and the addition of impurities as activators. In fact, adding impurities to LiF powder increases the energy and density of the traps. This study aims to determine the best thermal program for the production of TLD, which has the closest and most similar glow curve to TLD_{100}. It is worth mentioning that other properties of TLDs, such as fading, reproducibility, linear dose-response etc., have already been tested a few years ago [4].

In this study, as shown in Figures 1 and 2, the brightness curve of the chips made at a temperature of 830 °C with a rapid decrease in temperature (group1) has the energy and density of a suitable trap such as TLD_{100}. Considering that the energy of the traps made by the chips above 1 electron volt and their peak temperature (TM) is also above 220 °C, the chips of group 1 have time stability and respond to a dose similar to TLD_{100}. If Lithium Fluoride powder is sintered as a chip at 830 °C, it can be concluded that this chip is one of the suitable materials for making TLD.

On the other hand, these chips are ceramic due to sintering at temperatures close to melting, so they show high resistance to corrosion and abrasion. However, during the same three irradiations, the density of the traps was obtained with different values, which indicates the error of repeatability of the chips. The reproducibility of the response to the dose of chips under the same irradiation was determined by a 3% error for the control group (TLD_{100}) and an 8% error for group1. Therefore, to reduce the reproducibility error, it is recommended to research the change in the program of heating rate to obtain the luminance curve or changing the annealing process of group 1 so that the recurrence error of the chips such as TLD100 is 3%, and also suggest, that the effect of quantum changes on the low energy of traps in the glow curve of research TL materials be investigated.

References

[1] J.T. Randall, and M.H.F. Wilkins, "Phosphorescence and Electron Traps - I. The study of Trap Distributions," *Proceedings of Royal Society Series A*, vol. 184, pp. 365-389, 1945. [CrossRef] [Google Scholar] [Publisher Link]

[2] G.F.J. Garlick, and A.F. Gibson, "The Electron Trap Mechanism of Luminescence in Sulphide and Silicate Phosphors," *Proceedings of the Physical Society*, vol. 60, no. 6, 1984. [CrossRef] [Google Scholar] [Publisher Link]

[3] Mufeed Maghrabi, Tariq Al-Abdullah, and Ziad Khattari, "Analytical Expressions for the Mixed-Order Kinetics Parameters of TL Glow Peaks Based on the Two Heating Rates Method," *Journal of Fluorescence*, vol. 28, pp. 597–603, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[4] M.A. Shafaei, R. Koohi, and N. Tejabor, "*Investigation of the Possibility of Making Lithium Fluoride Chips for Use in Radiation Therapy*," Thesis Submitted for the Degree of M.Sc./ Ferdowsi University of Mashhad /Autumn, 1996.

[5] Pagonis, Vasilis, George Kitis, and Claudio Furetta, *Numerical and Practical Exercises in Thermoluminescence*, Springer, 2006. [Google Scholar]

[6] R. Chen, and S W.S. Mckeever, *Theory of Thermoluminescence and Related Phenomena*, Singapore: World Scientific, 1997. [Google Scholar]

[7] Adrie J. J. Bos, "Thermoluminescence as a Research Tool to Investigate Luminescence Mechanisms," *Materials*, vol. 10, pp. 1-22, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[8] May, C.E., and Partridge, J.A., "Thermoluminescent Kinetics of Alpha-Irradiated Alkali Halides," *The Journal of Chemical Physics*, vol. 40, pp. 1401-1409, 1964. [CrossRef] [Google Scholar] [Publisher Link]

[9] V. Kiisk, "Deconvolution and Simulation of Thermoluminescence Glow Curves with Mathcad," *Radiation Protection Dosimetry*, vol. 156, no. 3, pp. 261-267, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[10] M. S. Rasheedy, "A Modification of the Kinetic Equations Used For Describing the Thermoluminescence Phenomenon," *Journal of Fluorescence*, vol. 15, pp. 485–491, 2005. [CrossRef] [Google Scholar] [Publisher Link]

[11] Nikolai I. Kobasko, "Thermal Waves, Thermal Diffusivity and Possibility of Relaxation Time of Materials Evaluation," *SSRG International Journal of Applied Physics*, vol. 6, no. 3, pp. 66-73, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[12] Samuel Sami Howard, "Investigation of Low-Temperature Desalination Process by Flashing, PV-Thermal, Thermal Storage, and Magnetized Nanofluids," *SSRG International Journal of Thermal Engineering*, vol. 9, no. 1, pp. 1-11, 2023. [CrossRef] [Google Scholar] [Publisher Link]