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The Influence of Thermal Treatment on the Sensitivity and Glow-Curve of TLD-200

Manal K. Kabier*, Riyadh Ch.Abul-Hial

Department of Physics, College of Education for Pure Sciences, University of Basrah, Basrah, Iraq.

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ABSTRACT

The effect of heat treatments on the response of calcium fluoride-doped dysprosium (TLD200) to radiation was studied in this research. The thermal treatments researched before the radiation was conducted included 100°C/h, 200°C/h, 300°C/h, and 400°C/h. The following similarity values were derived from the study's thermal treatments: 11.5%, 12%, 13%, and 17%, respectively. The results indicate that the 400°C/h heat treatment increased the response, which is one of the best treatments compared to the heat treatments under investigation.

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1. Introduction

Thermoluminescence is the emission of light induced by heat. It is a process of absorbing energy from ionizing radiation [1,2]. The materials in which it occurs must be insulating or semiconducting [3]. Thermoluminescence has been the most widely used concept in radiation dosimetry, with applications ranging from environmental regulation to medical dosimetry, nuclear accidents, and others [4]. The concept of thermal luminescence is embodied in the exposure of the crystal to irradiation, resulting in the absorption of a portion of the radiation energy. Temporary effects cause some of the valence band electrons to shift to the conduction band and then back to the valance band. Intermediate energy levels known as "electron traps" may catch some of these electrons .The number of electrons is proportional to the amount of energy absorbed from the radiation. When the crystal is heated, the trapped electrons obtain the energy necessary to migrate to the luminescence center, emitting visible light [5, 6]. One of the most common materials used as meters for measuring ionizing radiation is calcium fluoride (CaF_2) doped with magnesium (CaF_2:Mn) and dysprosium (CaF_2:Dy) (TLD-200). Figure 1 illustrates the peaks of thermoluminescence change based on the type of impurity and shift towards higher temperatures (TM) and reduced thermal fading.[7]. And achieves stability in response to thermal dosimeters and zero dose [8]. Many researchers use doping to improve the properties of thermally luminescent materials [9, 10]. In this research, the effect of thermal treatments on (CaF_2: Dy) (TLD-200) was studied.

***Corresponding author email:** pgs.manal.kadhim@uobasrah.edu.iq

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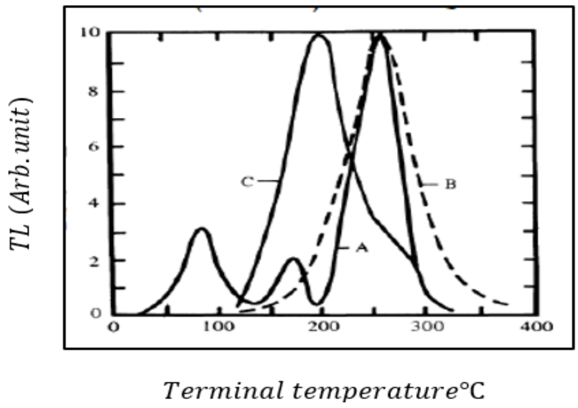

Fig. 1. Illustrates the thermoluminescence curves of the same crystal with different types of impurities. [7]

2. Apparatus and experimental procedure

2.1. Source of Radiation

The Cs^{137} cesium sources were used in this research work. It was produced in 1985, and its $t_{½} = 30.07$ Year. The isotopic fission cesium dose for the radiation approved in 2025, the value is 6.75 rad/min.

2.2. TL-200 CaF2: Dy Fumarate Regulators

These have dimensions of 0.035 x 1/8 x 1/8 inches, have Dysprosium [5], and are well known as TLD-200 [12] and were supplied by Harshaw Filtrol Partnership.

2.3. Digital thermometer

The digital was calibrated with an accuracy of up to ten degrees for the oven and lab temperature measure.

2.4. IBM SPSS Statistics 23

For the calculation of statistical transactions and their graphs, the most important software package in the field of processing was the SPSS program. This program me is distinctive because to its different characteristics. The most important distinguishing features are user-friendliness and smoothness of values.

2.5. Sample Preparation

For the study, twenty-one chemiluminescent dosimeter (TLD200) crystals were selected, and each crystal is made of calcium fluoride doped with dysprosium (CaF_2:Dy). The crystals were stratified into seven sets, each containing 3 dosimeters. To ensure accurate tracking throughout the entire experimental process, each dosimeter was assigned a unique identification number. None of the samples underwent any form of treatment or irradiation before measuring the initial weight and recording the baseline thermoluminescence (TLD200) readings. Figure 2 shows the steps of the work methods.

2.6. Heat Treatment Protocol

The investigation employed four levels of heat treatment to examine the effect of temperature on the TLD200 response. The chosen heating rates were 100°C/h, 200°C/h, 300°C/h, and 400°C/h. At each heating level:

- All 21 crystals underwent the given temperature rate for one hour.
- The crystals were allowed to cool to room temperature in an atmosphere-controlled environment after the heating cycle to avoid thermal shock or contamination.
- The treatment and analysis were done independently for each of the four levels of heating to facilitate comparative evaluation.

2.7. Gamma Ray Irradiation

The crystal samples were subjected to gamma irradiation with a standardized source after completion of each heat treatment. The durations of the exposure were modified among the groups to evaluate the dose response. The grouping and irradiation details are displayed in Table 1.

Table 1. Gamma Ray Exposure Schedule

Group	Crystal IDs	Exposure Duration
Group 1	1, 2, 3	6.75 mrad
Group 2	4, 5, 6	13.5 mrad
Group 3	7, 8, 9	20.25 mrad
Group 4	10, 11, 12	27 mrad
Group 5	13, 14, 15	33.75 mrad
Group 6	16, 17, 18	40.5 mrad
Group 7	19, 20, 21	47.25 mrad

To ensure accurate results, each dosimeter within a group received the same radiation dose under consistent conditions.

Thermoluminescence (TLD200) Measurement

Each crystal's TLD200 response was measured with a calibrated TLD200 reader after irradiation. The output was measured in arbitrary units and served as an indication of the dose of radiation retention and sensitivity. For each treatment condition:

- The luminescent output of each sample was measured.
- The sample with the highest TLD200 was selected.
- Evaluation was performed to find the dependence of TLD200 response, degree of thermal treatment, and time of gamma irradiation.

2.8. Experimental Repetition and Comparison

The full experimental cycle- including heat treatment, irradiation, and TLD20measurement- was repeated for each of the four designated heating rates (100°C/h, 200°C/h, 300°C/h, and 400°C/h). A comparison was made across all conditions to find the best combination of heat treatment and radiation exposure for the highest TLD200 sensitivity.

In addition, the other 21 dosimeters were heated to 100°C for one hour. The dosimeters were permitted to cool slowly from room temperature and were placed in the gamma source with each triplet group for the time period of 7(measurement) . The processes that were stated above are incorporated, and the temperatures used are 200°C, 300°C, or 400°C. After this, the thermal luminescence of each dosimeter is examined in detail for the reaction of the dosimeter.

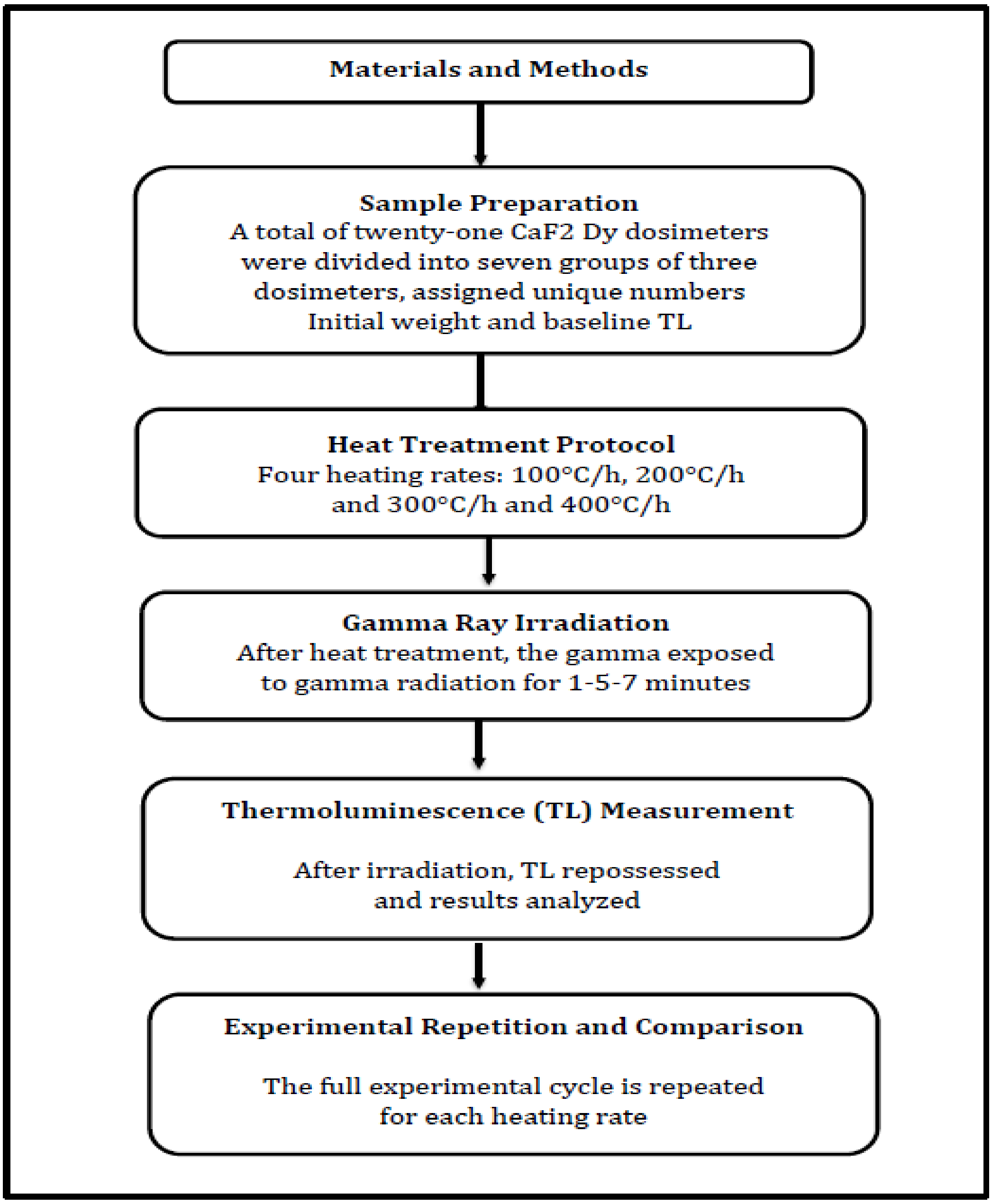

Fig. 2. Illustrations of the way of working

3. Results and discussion

The research looked at how TLD200 dosimeters (CaF_2:Dy) react with light after being heated and then exposed to gamma rays.)The findings show a clear correlation between heat treatment temperature and thermoluminescence, providing additional guidance on optimizing the sensitivity of the dosimeters. The research proves that both heat treatment and the time of gamma irradiation influence the thermoluminescent response of TLD200 dosimeters. Further studies should explore additionl refinements to the dosimeter's thermal processing techniques and changes in the materials used to improve the effectiveness of thermoluminescent dosimeters for various purposes. The peaks indicate that constant heat loss occurs across all treatments, since there is no shift in the high-temperature regime, unlike what is observed in the case of doping, as shown in Figure 3.

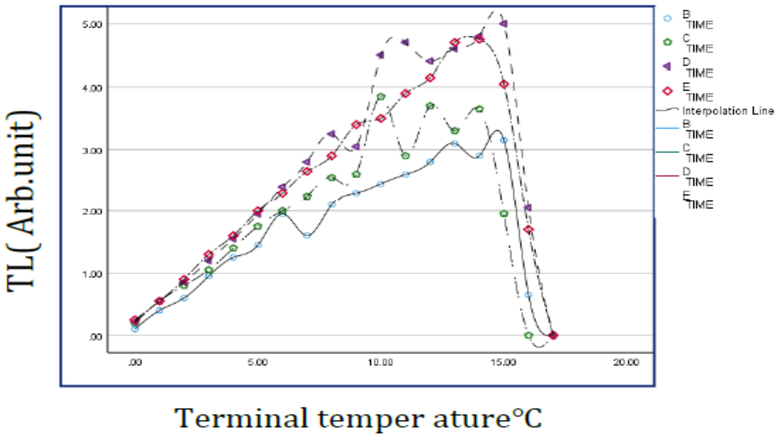

Fig.3. Typical glow curves of TLD-200 after phosphor has been annealed at 100, 200, 300, and 400 °C/h), read soon after irradiation with 6.75 mrad/m.

Table 2. The summary includes statistical data for the thermoluminescence curves at the four temperatures under study.

Descriptive Statistics			
	Maximum	**Mean**	**Std. Deviation**
$TL - 100$°C	3.1500	1.688889	1.0494474
$TL - 200$°C	4.9500	2.144444	1.4005134
$TL - 300$°C	5.0000	2.550556	1.5969842
$TL - 400$°C	5.0500	2.730556	1.7479516
Valid N=18 ,	Minimum=0 0.00		

Table 3. Pearson Correlation coefficient for thermoluminescence readings representing the glow curve for each temperature.

Correlations				
	$\boldsymbol{TL - 100}$°C	$\boldsymbol{TL - 200}$°C	$\boldsymbol{TL - 300}$°C	$\boldsymbol{TL - 400}$°C
100°C	1	.962**	.960**	.980**
200°C	.962**	1	.978**	.969**
300°C	.960**	.978**	1	.988**
400°C	.980**	.969**	.988**	1

The thermoluminescence curves for the above four temperatures depicted in Fig.3, as well as the statistical data, are given in Table 2. The number of samples (N=18), readings: minimum-maximum, and arithmetic mean and standard deviation for each case are presented. Table 3 shows the Pearson correlation coefficient between the data in Table 2, it reveals there is a very strong correlation close to 1 and (**) significant.

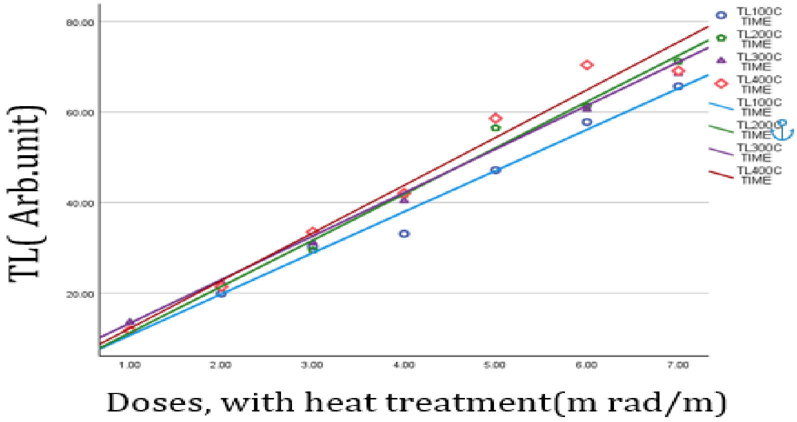

Fig.4. Represents the thermoluminescence resulting from TLD 200 after heat treatment with different doses.

Table 4. Statistical coefficients for the relationship between dose and thermoluminescence for each temperature.

Descriptive Statistics				
	Minimum	**Maximum**	**Mean**	**Std. Deviation**
$TL - 100℃$	11.8	65.70	37.9714	19.75396
$TL - 200℃$	11.60	71.20	41.8857	22.15186
$TL - 300℃$	13.60	68.50	42.2186	21.03139
$TL - 400℃$	11.80	70.40	43.8429	23.09912
Valid N =7				

Table 5. Pearson Correlation coefficient between thermoluminescence results and dose for each temperature.

Correlations				
	$TL - 100℃$	$TL - 200℃$	$TL - 300℃$	$TL - 400℃$
100℃	1	.988**	.983**	.984**
200℃	.988**	1	.997**	.988**
300℃	.983**	.997**	1	.989**
400℃	.984**	.988**	.989**	1

Table 4 illustrates the statistical coefficients for the doses with the temperatures for each case, and Table 5 represents the correlation coefficient, which is somewhat strong, approaching 1, and(**) of significant significance.

4. Conclusion

The results from heating TLD-200 before irradiation at 400°C/h had a noticeable impact on the shape or size of the glow curve when compared to heating at 100°C/h, 200°C/h, and 300°C/h. The increased area under the glow curve and the absence of shifts in the thermoluminescence peaks toward higher temperatures indicate increased sensitivity for TLD-200. Furthermore, the peak of the glow curves remains at the same temperature during the heat treatment. These results are in good agreement with those of other investigations in the literature. CaF2:Dy After heat treatment at 400 °C, TLD200 exhibits a better reaction because the heat treatment redistributes and organizes the deep electron traps, improving the thermoluminescence characteristics and thermoluminescence curve.

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تأثير المعالجات الحرارية على منحنى التوهج وحساسية TLD-200

منال كاظم خابر*، رياض جاسب أبو الهيل

قسم الفيزياء، كلية التربية للعلوم الصرفة، جامعة البصرة، البصرة ، العراق.

معلومات البحث

الاستلام	16 نيسان 2025
المراجعة	2 حزيران 2025
القبول	4 حزيران 2025
النشر	30 حزيران 2025

الكلمات المفتاحية

التوهج الحراري، المعالجات الحرارية، التلاشي الحراري، أجهزة قياس الجرعات، TLD200.

الملخص

دُرِسَ في هذا البحث تأثير المُعاملات الحرارية على استجابة الديسبرسيوم المشوب بفلوريد الكالسيوم (TLD200) المُستخدَم في الإشعاع. كانت المُعاملات الحرارية التي دُرِسَت قبل الشعيع عند ١٠٠ درجة مئوية/ساعة، و٢٠٠ درجة مئوية/ساعة، و٣٠٠ درجة مئوية/ساعة، و٤٠٠ درجة مئوية/ساعة. وكانت نتائج الاستجابة لهذه المُعاملات الحرارية ١٢٪، و١٣٪، و١٧٪، و١١,٥٪ على التوالي. وتُشير النتائج إلى أن المُعاملة الحرارية عند ٤٠٠ درجة مئوية/ساعة زادت من الاستجابة، وهي من أفضل المُعاملات مُقارنةً بالمُعاملات الحرارية قيد البحث.

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