Investigation of TLD-200 in the dose-response range useful for environmental radiation dosimetry

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Abstract

Dose-response of TLD-200 (CaF_2:Dy), was investigated in the dose range from 20.905 m Rad to 167.24 mRad at the dose rate 8.38 mRad/min, It has been studied the characteristic (symmetry of the groups and linearity) of TLD-200 using ^{137}Cs source. Then, TLD_S with reproducibility better than 3% are selected. After that, TLD200 dose response is determined. For each dosage value, measurements were conducted three times and the average was taken. All sixty TLDs were grouped into twelve categories for ease of use. The TLDs were divided into groups based on their reaction to predetermined dosage value. The fluctuation of the dosimeters reaction is the least in particular set of TLDs .For each of the twelve groups, the dosage (mRad)-response (nC) linearity curve of TLDs was extremely close to unity.

Keywords: -Dosimeter, Dose–response, Thermoluminescence, fading, Pre-irradiation

I. INTRODUCTION

Thermoluminescence is the emission of light by certain minerals and other crystalline materials when they are heated after being stimulated by ionizing radiation. The light energy emitted comes from electron displacements inside the crystal lattice of such a material generated by earlier high–energy radiation exposure. The use of thermoluminescence in radation dosimetry was initially proposed by Daniels et al (1953) [1] .The characteristics of TL materials have been thoroughly studied and reported [2-4]. S.W.S Mckeevers thermoluminescence of solids (1985) provides an excellent discussion of the definition and theory of thermoluminescence [5] is derived from electron displacements within the crystal lattice of such a substance caused by previous exposure to high-energy radiation were the first to propose the use of thermoluminescence in radiation dosimetry [1]. The characteristics of TL-materials have been intensively studied and published [2-4]. Thermoluminescence of solids by S.W.S Mckeever 1985 an excellent review of the definition and theory of thermoluminescence [5]. Impurities or activators in solid state crystalline dielectric materials create Thermoluminescence dosimeters. The activators supply two different sorts of centers (traps and luminescent sites). Radiation interactions cause electrons to be lifted from the valence to conduction band in the thermoluminescence dosimeter. They pass through the conduction band and into the electron trap, where they are joined by a hole. The material utilized and the depths of trap dictate the stability of these traps. Most traps are relatively stable at room temperature. When the temperature of the material climbs above room temperature, these traps may be distributed in a controlled manner Recombination at a luminous center allows light to be emitted once these traps are released. The following is a description of the process, which is also known as thermoluminescnce [6]:

1-Iradiation

By absorbing external energy (ionization radiation), electrons escaped the valence band and migrated to electron traps in the conduction band .The valance band holes migrate to hole traps.

2-storage

Local ionizing radiation introduces electrons to the crystal lattice, with some being collected and stored during imprecation.

3-Eviction

The ability for electrons to escape from an external stimulus (energy, U V wavelengths, or heat) is supplied .Depending on the phosphor material (dosimetry type), flaws and heating these three stages might take milliseconds or years to complete.

Because of its close tissue equivalence (effective atomic number 16.3,compared to 7.4 for tissue),low signal fading (5 percent-10 percent per year),wide linear response range (mRad-104 Rad), and high sensitivity, the TLD-200 dosimeter, based on calcium fluoride doped with dysprosium (CaF_2:Dy), is routinely used for dosimetry in environmental [7]. Because inaccurate processes are necessary when measuring ambient radiation doses using a TL-dosimetr, miss-irradiation doses can have a substantial influence on peoples safety .Even though the manufacture made all of the TLDs in the same batch, their sensitivity differs. As a result , determining the sensitivity of each TLD is critical. TLDs reaction to different dosages isn’t usually linear. From literature review ,popularity of a thermoluminescent materials (natural or artificial) as a dosimetry system based on the ease of dosimeter handing the high sensitivity ,the linear dose response and greater accuracy ,many investigation have been carried out in this direction [8-10]. The purpose of this study was to examine the Caf2:Dy phosphor's TL-dose response in the low dose range for its using an environmental radiation dosimetry, personal dosimery and medical application.

II.MATERIAL AND METHOD

A series of experiments are conducted by using twelve groups of thermoluminscence dosimeters (Calcium fluoride activated by dysprosium CaF_2:Dy (TLD-200) and each group contain 5 dosimeters. Harshaw TLD-200 (CaF_2:Dy) is the TLD material used in this teast.The ^{137}Cs gamma source was located in the Department of physics ,College of Education for pure Science, University of Basrah in Basrah, Iraq, in the Irradiation Unit of the Thermoluminescnce Laboratory. It has a size $(0.35 \times 1/8 \times 1/8)inch$. The aforementioned irradiation source is used to irradiate the Ca_2F:Dy dosimeters .The strength of ^{137}Cs source was (1 curie) in 1985 .The dose rat, which is adjusted to provide by this sourse, is approximately (20 mRad/min) in February, 1985 reduced to (8.4) mRad) during this work(July 2022). Harshaw model 2000B/C is the name of the TL reader. To decrease oxygen induced light effects nitrogen gas was utilized to cleanse the readchamber during the measurement [11]. The following TTP (time-temperature profile) was used to record dose response. 1-pre-heat at 100 ^{0}C for 0 seconds to prevent any short-term fading 2- heat at a rate of 15 ^{0}C/sec 3-maxmuimim temperature :320 ^{0}C 4-Anneal:bake for two hours at 400 ^{0}C ,then for one hour at 100 ^{0}C .Before the test, the TLDs were calibrated .The reaction of the TLD material can be affected by prior irradiation and thermal history [12], thus before each gamma-irradiation, the dosimeters of each material were independently annealed and stored in a secure area so that they were ready for measurement. A built-in standard light source was used to assess the TLD readers sensitivity during the TL measurement, and it was determined to be consistent within 1.5 percent. The symmetry of the groups was also calculated after giving them a fixed dose of 11 mRad, and then the thermoluminesnce was read for them. The results showed that the highest value within one group is 20%. Knowing that the permissible limit is 30% [13-17]. The irradiation dosimeter was irradiated, with doses ranging from 20.905 mRad to 167.24 mRad at the dose rate 8.38 mRad/min. Before utilizing the TLD reading system, it must be :heated uo to 30 minutes.

III. Experiment and Result

Dose response is one of the most important properties of TL materials as well as a materials used for dosimetry purposes. 12 groups of TL200 has been performed which each group contains 5 dosimeters and the average mass of each dosimeter is 29.5 mgm. Each group has been irradiated respectively, using the following doses: (20.905, 41.81, 83.63, 125.43 and 167.24) mRad.

Table 1 shows the response (nc) of each group of TLDs at various doses. Figure 1 shows the dose-response linearity curve for the matched TLD group. Table 2 lists the curve characteristics, such as the linear curve equation and correlation coefficient for each. These findings show that there is a good correlation between the response and the corresponding doses for each of the TLD groups, which is equivalent to or more than 0.99. As can be observed, the dose-response linearity of TLDs is quite close to unity.

Table 1: Response of each group of TLDs at various doses

Group No	Response of TLDs (m Rad) for various doses				
	20.905 m Rad	41.81 mRad	83.62 mRrad	125.43 mRad	167.24 mRad
G_1	34 ± 1.4 nC	68.775 ± 2.2 nC	122.675± 4.7 nC	189.9 ±14.2 nC	237.333±30.7 nC
G_2	34.5 ± 1.62 nC	68.25 ± 3.4 nC	129.225 ± 3.04 nC	186.125 ±14.31 nC	250.9 ± 18 nC
G_3	33.15±0.65 nC	59.55± 4.88 nC	118.125±1.24 nC	174.85±14.3 nC	232.8±10.5 nC
G_4	36.15±1.49 nC	67.85± 1.11 nC	126.475± 6.28 nC	184.7± 10.2 nC	251.75± 8.22 nC
G_5	33.3± 1.4 nC	66.45±1.47 nC	123.725± 1.87 nC	183.875±19.42 nC	252.3±9.63 nC
G_6	27.275± 4.06 nC	47.925±9.71 nC	101.8±8.96 nC	154.4±14.5 nC	207.366±8.83 nC
G_7	30.95±3.37 nC	59.525± 7.11 nC	113.65±12.11 nC	182.375±12.11 nC	235.125±25.11 nC
G_8	30.45±1.8 nC	62.375±1.57 nC	121.9±7.3 nC	178.325±14.48 nC	230.8±20.81 nC
G_9	32.275±2.1 nC	60.35± 3.9 nC	121.65± 5.89 nC	171.45± 18.03 nC	232.75±12.8 nC
G_{10}	28.925±4.7 nC	51.425±8.76 nC	95.233±8.01 nC	133.166±18.57 nC	180.033±32.6 nC
G_{11}	26.98±2.45 nC	58.48±5.5 nC	115.68±12 nC	166.75±15.17 nC	222.5±26.39 nC
G_{12}	31.78±3.03 nC	60.62±5.11 nC	114.92±11.36 nC	167.04± 17.84 nC	212.54±23.35 nC

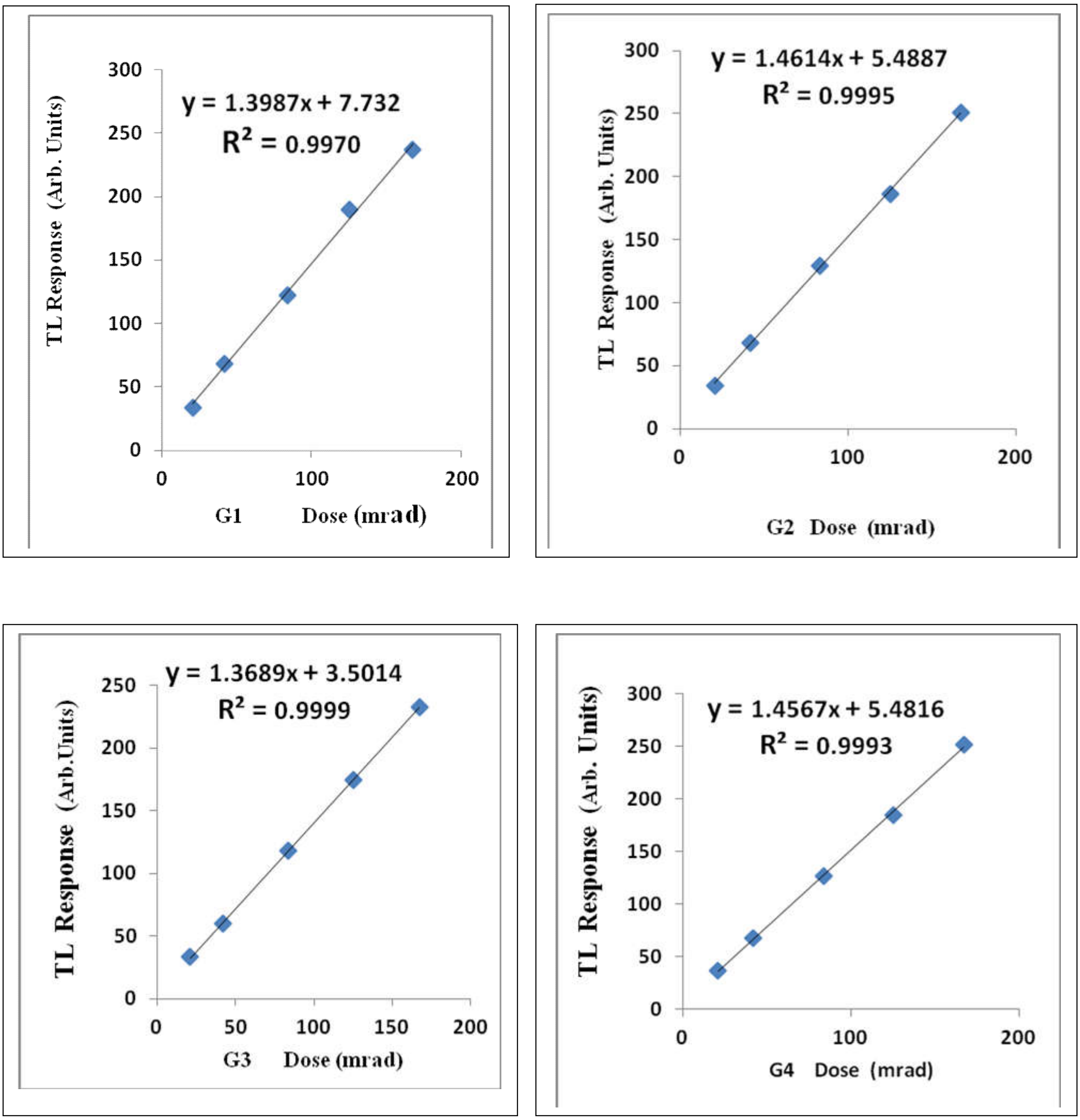

Fig. 1: A few representative sample of the dose-response linearity graph of the corresponding TLD group.

Table 2**:** Dose response curve analysis

Group No	Curve equation	R2
G_1	Y=1.3987x +7.732	0.9970
G_2	Y=1.4614 + 5.4887	0.9995
G_3	Y=1.3689x +3.5014	0.9999
G_4	Y=1.4567 x+5.4816	0.9993
G_5	Y=1.4762x +2.316	0.9990
G_6	Y=1.2438 x +1.4514	0.9993
G_7	Y=1.4132 x+0.2425	0.9993
G_8	Y=1.3694x +4.5348	0.9990
G_9	Y=1.3602 x + 4.2665	0.9990
G_{10}	Y=1.0195 x +8.2397	0.9991
G_{11}	Y=1.3235 x +1.8709	0.9992
G_{12}	Y=1.22 x +8.5027	0.9984

IV. CONCLUTION

A good fit was found between all groups for dose-response linearity reached to 167.24 mRad by using thermoluminescence technique, the difference between the corresponding result it is very close to unity. So the TLD-200 is suitable dosimeters for dose monitoring for environmental radiation dosimetry.

References

1. J.R.Comeron ,N.Suntharalingan and G.kenney: Thermoluminescent and Dosimetry University of Wisconsin press 1969.

2. A.F.Mckinlay,Thermoluminescence Dosimetry,Medical Physics Handbooks 5,CRC Press,Adam HilgerLtd,Bristol,1981.

3. Y.S.Horowitz.(Ed),Thermoluminescence and,thermolumines-cent Dosimetry,Volumes I,IIand III .,CRC Press,Boca Raton,Florida,1984.

4. S.W.S Mckeever, Thermoluminescence of solid, Cambridge Solid State Series Cambridge University Press, Cmbridge ,1985.

5. Thaer M Salman, Alaa Y AL-Ahmad, H. A Badran, C. A Emshary, Diffused transmission of laser beam and image processing tools for alpha-particle track-etch dosimetry in PM-355 SSNTDs, Phys. Scr. 90 (2015) 085302 (8pp).

6. K.Keizars, M .Forrest Beth , J .W.Rink "Natural Residual Thermoluminescence as a Method of Analysis of Sand Transport along the Coast of the St. Joseph Peninsula, Florida" Journal of Coastal Research. **24**: 500. doi:10.2112/04-0406.1.2008.

7. M. Oberhofer and A Scharmann, Applied Thermoluminescence Dosimetry, EcSc. Eec. Eaec, Brussels and Luxembourg 1981.

8. Y .S Horowitz, L.Oster and H.Datz, Thermoluminescence dose-response and other characteristics of the high-temperature TL in LiF: Mg,Ti(TLD 100),Radiat Prot Dosimetry ,124(2) (2007),pp: 191-205.

9. M.G Nunes ,L.L.Campos,study of $CaSO_4$:Dy and LiF:Mg,Ti detectors TL response to electron radiation using a SW Solid Water phantom, radiation Measurements 43 (2008), pp:459-462.

10. H. A. Bdran, Riyadh C. H. Abul-hail, and Mohammed T. Obeed, Study on effect of Gamma radiation on some linear and nonlinear properties of Pyronine Y, AIP Conference Proceedings 2290, 050035 (2020).

11. A. Al-Salihi, R.D. Salim, R. K. Fakher Alfahed , H. A. Badran, Effect of Solar radiation induced and alpha particles on Nonlinear behavior of PM-355 film, IOP Conf. Series: Materials Science and Engineering 928 (2020) 072056.

12. W. Morrison Jackson, J. D.Spaulding, J. E.Noakes gleon, L. Murphy, Health physics, 48(6), (1985).

13. D. Sibony,Y. Horowitz, L. Oster, The effect of sample/ planchet geometry and temperature resolution on the reproducibility of glow curve shapes and precision of dose measurement in LiF-TLD-100 Thermoluminescent dosimetry. Radiation Measurement 2014.

14. B. Burgkhardt, E. piesch, Radiation production dosimetry, 6. (1-4) (1984), p:338.

15. T. M Salman, A. Y. AL-Ahmad, H. A. Badran , C. A Emshary, Diffused transmission of laser beam and image processing tools for alpha-particle track-etch dosimetry in PM-355 SSNTDs, Phys. Scr. 90 (2015) 085302 (8pp).

16. R. K. Fakher Alfahed, A. Imran, M. S Majeed, H. A. Badran, Photoluminescence characterizations and nonlinear optical of PM-355 nuclear track detector film by alpha-particles and laser irradiation, Phys. Scr. 95 (2020) 075709 (8pp).

17. L. Raffaele at al, Dose-response of TLD 100 in the dose range useful for Hypo fractionated radiotherapy, An international journal 1(8) (2020) p:338.