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REPRODUCIBILITY AND EFFECT OF DELAYED READOUT ON LiF: Mg, Ti TLD TREATED WITH DIFFERENT PREHEAT TIME TECHNIQUES: A GLOW CURVE STUDY

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ABSTRACT

The glow curve in TLD-100 was compared by applying long preheat time, short preheat time techniques and without preheat technique before the TLD readout. Fading effect of the TLD signal upon certain storage time with long preheat time (100°C, 10 minutes using the oven) and–short preheat time techniques (100°C, 10 seconds using the reader) were also studied. 15 TLD-100 chips were used with 3 of the TLD chips were used for measuring background radiation. 12 TLD chips were annealed, irradiated, preheated long and short preheat time ~~t~~echniques) and analyzed. The TL signals output from TLD chips of without preheated were used as the control. Two sets of data were taken using TLD chips irradiated with 6 MV and 10 MV photon beams. TL signal output was recorded the highest for short preheat time, followed by long preheat time and no preheating. The TL signal loss upon certain storage time was also reduced when short preheat time technique was applied. By applying long preheat time technique the low temperature peak in the glow curve was completely removed for both energies. Whereas, TLD chips exposed to 6 MV and with short preheat time technique the low temperature peak did not disappear completely but decreased in intensity as compared to the control data by 19.80%, 37.69%, 48.19% and 100% at 24, 48, 72 and 96 hours after exposure prior to readout, respectively. Meanwhile, for 10 MV photon beam with short preheat time, the small peak intensity was reduced by 19.58% for readout at 24 hours after irradiation and 100% for 48,72 and 96 hours delayed time prior to readout. It was observed that the TLD-100 was highly dependent on preheat heating time before readout. Short preheat time technique was able to reduce post irradiation fading of TLD-100 dosimeters.

Keywords: preheat time techniques, TLD-100, TL Glow Curve.

INTRODUCTION

LiF:Mg,Ti or TLD-100 is one of the most commonly used thermoluminescent materials used in personal and environmental monitoring due to its good tissue equivalence and low fading at room temperature. Therefore, thermoluminescence (TL) studies on this sample have received considerable attention for the past three decades (S.W.S. McKeever, *et al*., 1995).TL dosimetry often gives inconsistency of reading, thus lead many investigations of TL glow peaks in TLD-100 during these past 35 years (G.C. Taylor et al., 1982) (X.L. Yuan, S.W.S. McKeever, 1988) (H.J. Kos, R. Nink, 1980). TLD-100 really presents a rather complex TL mechanism from a solid state point of view (J.L. Landreth, S.W.S. McKeever, 1985). It is believed that one of the most important causes of this conflict is the high influences of cooling rate on the TL glow curve, TL emission spectra and optical absorption (OA) structure of this material (A.J.J. Bos, *et al*., 1995) (B. Ben Shachar, Y.S. Horowitz, 1991) (A.N. Yazici 1988). Reproducibility and overall accuracy of dose estimations with TLD was assessed for standard procedures used in a variety of areas, such as diagnostic radiology, mailing and radiotherapy (Izewska *et al*., 2007). The TL dosimetry is based on the measurement of light intensity when a TL crystal irradiated with ionizing radiation is heated.

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The emitted light is due to release electrons or holes trapped in impurities in the crystal. The mostly used system is LiF doped with Mg and Ti. The trapped electrons and holes are at various energy levels and hence the emitted light as a function of temperature called “glow curve”. It is a complex curve which usually is supposed to be a convolution of at least four peaks, each one with different activation energy required to release the trapped electrons and consequently emit the light at different temperature ranges. A couple of these peaks are due to low-energy traps that allow their release even at room temperature. Hence, the integral of the emitted light, represented by the area under the glow curve, reduces with increasing the time elapsed between the irradiation of the TLD crystal and its readout, which is the term used for measuring its glow curve, the light emitted as a function of temperature, or more accurately the rate of heating temperature of the chip. This decrease in the emitted light is named usually as “fading” (Johnson T.L. *et al*., 1980). Fading has a significant effect on the shape of the TLD-100 standard readout glow curve. The two main fading mechanisms are a release of charge carriers from the shallow traps and migration of charge carriers from deep traps to shallower ones. The fading process is time dependent (A. Abraham *et al*., 2008) A simple technique can be applied to reduce the annoying pre-irradiation and post-irradiation fading (T. Izak Biran *et al*., 1996).

METHODOLOGY

Types of LiF TLD detectors used are LiF:Mg,Ti TLD chips (Harshaw TLD-100, Bacron, USA). TLD-100 is a lithium fluoride doped with magnesium and titanium having dose dependence up to 100 MGy and is approximately tissue equivalent.

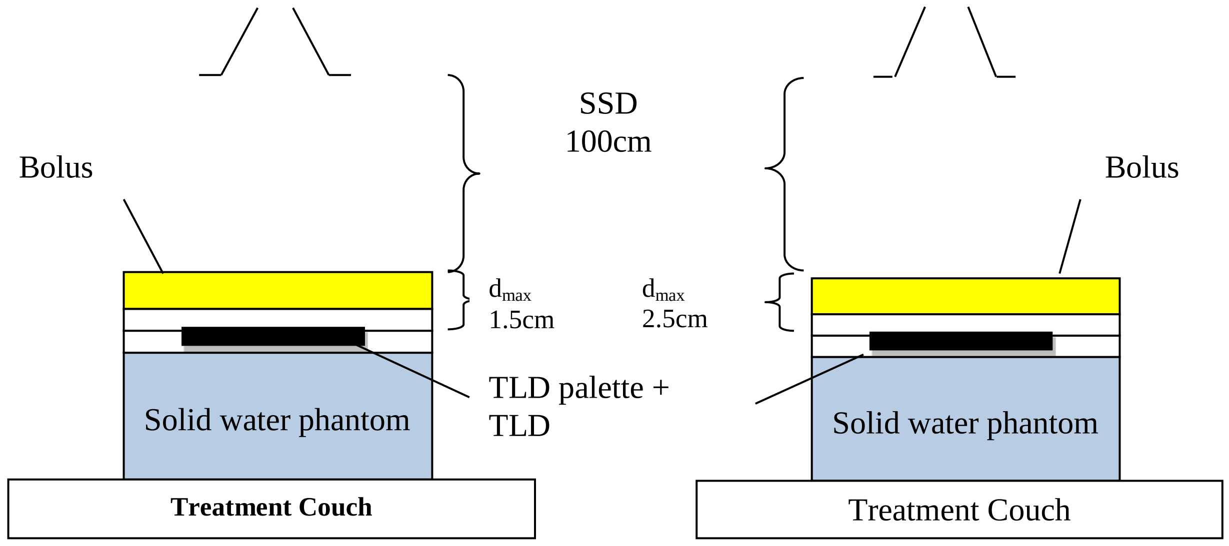
Siemens Primus Version 7 LINAC (S/N: 3347) with nominal energy 6 MV photon comprises of a drive stand, gantry (treatment couch) and console electronic cabinet was used in this study.

PTW-TLDO 1400 TLD oven is used in annealing procedure. It can be programmed to preheat the TLDs for 100°C for 10 minutes (preheat time). It should be brought up to the preselected temperature and allowed to stabilize well before dosimeter insertion.

Harshaw TLD Model 3500 was used for TLD Readout. The Harshaw 3500 operates on WinREMS Software, which runs under Windows® on a separate computer, providing user interface while the reader control the applications software.

A solid water phantom is a material with density close to water and it is used in the measurements of radiation dosimetry.

TLD-100 were irradiated using 6 MV and 10 MV photon beam. The TLDs were placed in a TLD palette of 1.0 cm thickness (including 0.5 cm the palette cover). The TLD palette was sandwiched between solid water phantom blocks and bolus. For both photon energies, the TLDs were exposed with the standard field size of 10 cm × 10 cm, 100 MU, the source to surface distance (SSD) of 100 cm and the depth of maximum dose (d_{max}) which is the build-up factor for energy used (1.5cm for 6MV and 2.5cm for 10MV photon). The set up geometry is shown in figure 1 (a) and (b). All the TLDs were kept in a room temperature for 24 hours before measuring the TL signal output using the TLD reader.



(a) (b)

Fig. 1: Set-up geometry showing TLDs in position for irradiation with 6 MV (a) and 10 MV (b) photon beam.

No preheat technique

TLD chips were then been kept in a room at a standard room temperature for 24 hours. The TLDs were then read using the TLD reader with no preheat setup to obtain the TL signal. The procedures were repeated by using 10 MV photon energy. This setting was use as a control in the study.

Long preheat time technique

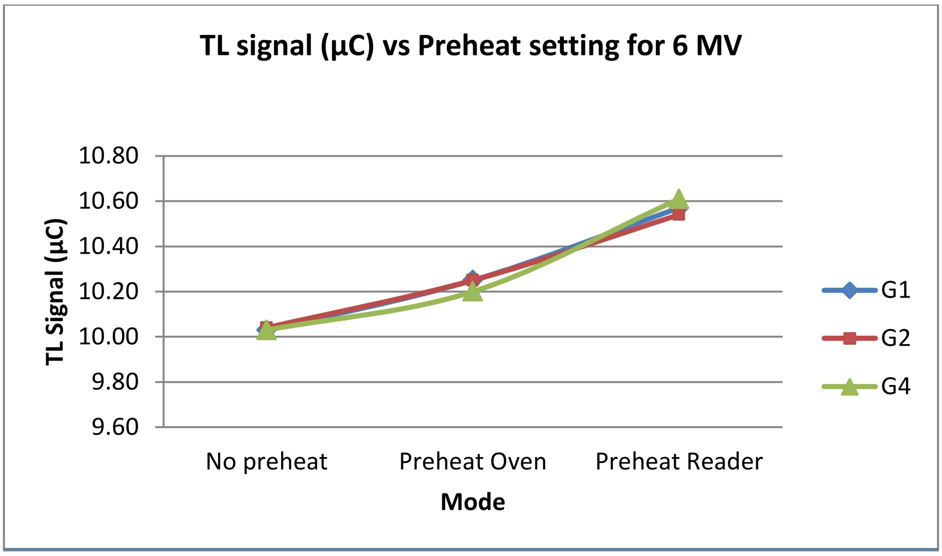
TLD chips were then been kept in a room with a standard room temperature for 24 hours. TLD chips underwent the preheat using the programmable oven with a temperature of 100°C for 10 minutes just before the TLD readout. The procedures were repeated for 48, 72 and 96 hours post-irradiation before readout. The same procedures were repeated for 10 MV photon energy. The average signal, glow curve and the fading pattern were observed for both photon energies.

Short preheat time technique

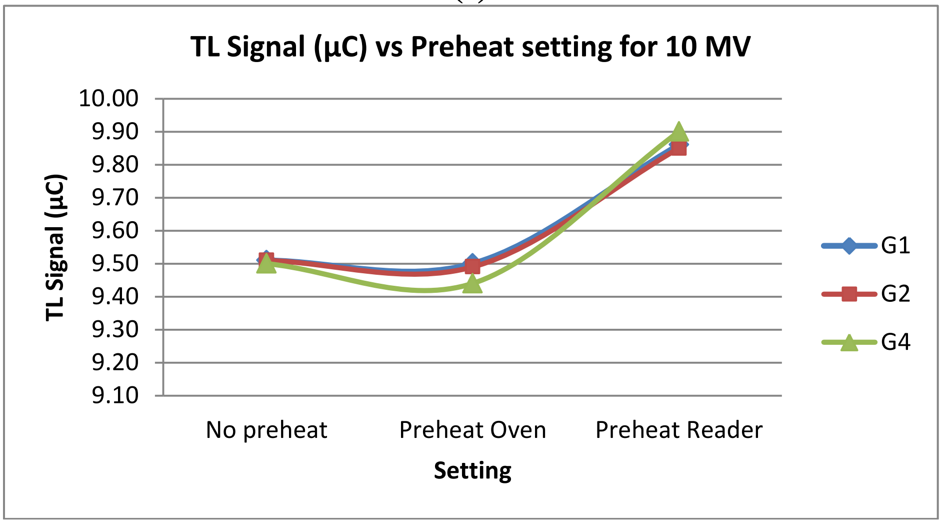
TLD chips were then been kept in a room with a standard room temperature for 24 hours. TLD chips underwent the preheat using the TLD reader itself with a temperature of 100°C for 10 seconds followed by TLD readout. The procedures were repeated for 48, 72 and 96 hours post-irradiation before readout. The same procedures were repeated for 10 MV photon energy. The average signal, glow curve and the fading pattern were observed for both photon energies.

RESULTS

As shown in Fig. 2, TL signal output was recorded highest for both 6 MV (a) and 10 MV (b) photon energies when the TLDs were given high rate preheat technique (using TLD reader) compared to low rate preheat (using TLD Oven) and no preheat.



(a)



(b)

Fig. 2: Graph of average TL signal (μC) versus the preheat mode for TLDs irradiated with 6 MV (a) and 10 MV (b).

The glow curve of TLD treated with long preheat time technique also having the highest peak as compared to short preheat time and no preheat techniques for 6 MV photon energy as shown in Fig. 3. It is also observed that the small peaks were eliminated for short preheat time. As for 10 MV photon beam in Fig. 4, although the long preheat time technique did not produce the highest glow peak, the elimination of small peaks were also well observed.

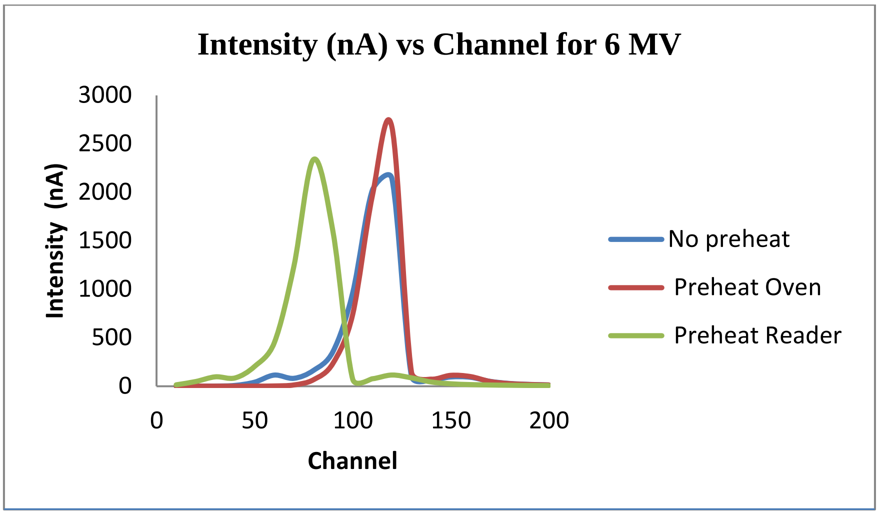


Fig. 3: The glow curves with different preheat time techniques for TLDs exposed with 6 MV photon.

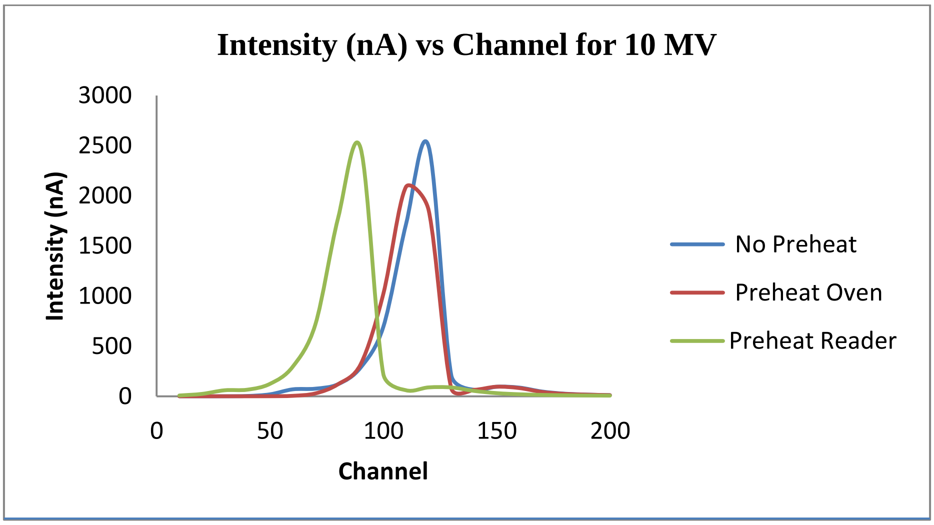


Fig. 4: The glow curves with different preheat time techniques for TLD chips exposed with 6 MV photon.

Table 1 shows the post-irradiation fading of the TLDs. It was noticeable that the TL signal was improved when short preheat time technique was used. The TL signal with both preheat time techniques was compared with the TL signal from the control group and thus gave the percentage difference which indicates amount of fading signal on TLD with delayed of reading time.

Table 1: Percentage TL signal output increased (positive percentage) and decreased (negative percentage) with different readout times for both energies.

Energy	Delayed time of reading (hours)	Oven Preheat		Preheat Reader	
		TL Signal (μC)	% Difference	TL Signal (μC)	% Difference
6 MV	24	10.24	2.09	10.57	5.38
	48	10.07	0.40	10.20	1.69
	72	9.80	-2.29	10.14	1.10
	96	9.73	-2.99	10.21	1.79
10 MV	24	9.48	-0.32	9.87	3.79
	48	9.02	-5.15	9.33	-1.89
	72	9.12	-4.10	9.37	-1.47
	96	8.98	-5.57	9.23	-2.94

The percentage of low temperature peak reduction for all preheat techniques at both 6 MV and 10 MV photon is shown in Table 2. It is observed that both long and short preheat techniques resulted significant reduction of low temperature peaks on the TL Glow Curves.

Table 2: Percentage reduction of TL low temperature peaks.

Energy	Delayed time of reading (hours)	Preheat Oven		Preheat Reader	
		Intensity small peak (nA)	% small peak reduction	Intensity small peak (nA)	% small peak reduction
6 MV	24	0.00	100.00	89.89	19.80
	48	0.00	100.00	61.29	37.69
	72	0.00	100.00	53.37	48.19
	96	0.00	100.00	0.00	100.00
10 MV	24	0.00	100.00	65.94	19.58
	48	0.00	100.00	0.00	100.00
	72	0.00	100.00	0.00	100.00
	96	0.00	100.00	0.00	100.00

DISCUSSIONS

In average, the TL signal output was expected to be the highest when short preheat time technique was applied, followed by long preheat time technique and without preheat time. This expectation was fulfilled when 6 MV photon beam was used and was in agreement with the result reported by *T.Izak Biran, S.Malchi, Y.Shamai and Z.B.Alfassi* as shown in Figure 2(a) (T. Izak Biran *et al*., 1996). Whereas, when 10 MV photon beam was used and low rate preheat technique was applied, the TL signal output was decreased by 0.32% as shown in Figure 2(b).

It was clearly showed that preheat applied time influenced the peak of the glow curve. The TLD peak intensity was at the lowest value when there was no preheat compared to the applied preheated techniques before readout as shown in Figure 3. The highest peak found at the short preheat time technique (using the reader) followed by the long preheat time technique (using the programmable oven). The peak intensity of the glow curve was dependant on the period of preheating time, however, for 10 MV photon in Figure 4, the highest peak intensity was not achieved with short preheat time technique. This phenomenon was due to the preheat time applied was not long enough to remove the peak 1 (low temperature peak) of the glow curve. In the previous study conducted by *H.Stadtmann, C.Hranitzky, N.Brasik* and *T.Izak Biran, S.Malchi, Y.Shamai Z.B.Alfassi,* 30°C/s of heating rate was used whereas only 10°C/s heating rate was used in this study (T. Izak Biran *et al*., 1996). However, both energies of 6 MV and 10 MV agreed that the low temperature peak intensities were eliminated using short preheat time technique.

Another observation that can be seen was the shift of glow curve peak towards the left of the graph when the short preheat time technique was used. This trend is similar to the previous study conducted by *T.Izak Biran, S.Malchi, Y.Shamai and Z.B.Alfassi* but there was no scientific explanation given. The result obtained was different with the result reported by *H.Stadtmann, C.Hranitzky and N.Brasik* as their study reported that the glow curve had the temperature shift towards the right of the graph as the detector thickness and the heating rate were increased (H. Stadtmann *et al*., 2006).

It can be seen that for TLD chips exposed with 6 MV and 10 MV photon beam, the TL signal output was decreasing when it was read at delayed time of reading after 48, 72 and 96 hours. However, TLD chips exposed with 10 MV photon beam had a higher percentage of the TL signal reduced which was in the range of 0.32-5.57% while for TLD chips exposed with 6 MV photon beam had the TL signal loss in the range of 2.29-2.99%. This pattern changed when ~~rate~~ short preheat time technique was used as for the TLD chips exposed with 6 MV photon beam, the TL signal on the first day of reading (after 24 hours) gave 5.38% higher value to compared with the one that was not treated with preheat technique. The TL signal read after 48, 72 and 96 hours after exposure was also increased by 1.69%, 1.10% and 1.79% respectively. Whereas TLD chips exposed with 10 MV photon and treated with short preheat time technique having the TL signal increased by 3.79% on the first day after exposure (24 hours) but it was decreasing rapidly to 1.89%, 1.47% and 2.94% for 48, 72 and 96 hours delayed time respectively before readout. Therefore, the short preheat time technique seems to be able to reduce the post irradiation fading of the TLD dosimeter, TLD-100.

CONCLUSION

TLD-100 exposed with 6 MV photon beam was slightly sensitive than 10 MV photon beam by 5.3%. In addition, when short preheat time technique had improved the sensitivity of the TLDs by 5.4% and 3.8% for 6 MV and 10 MV photon beam, respectively. The short preheat time technique also reduced the fading effect of TLD-100. The long preheat time technique had removed the small peak on the glow curve that could interfere the TL signal output consistency. Conversely, the small peak on the glow curve could not be removed totally with high rate preheat technique but it was reduced to a measureable value. In conclusion, TLD-100 was highly dependent on the preheat time before readout.

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REFERENCES

Abraham A., Weinstein M., German U., Alfassi Z.B, and Machlev Z. (2008). Reassessment of doses in TLD-100 after long storage times. *Radiation Measurements*. Vol. 43, 802-804.

Beerten, K., Woda, C., Vanhavere, F., (2009). Thermoluminescence dosimetry of electronic components from personal objects. *Radiat. Meas.*Vol. 44, 620–625

Ben-Shachar, B., Horowitz, Y.S., (1991). Anomalous thermally induced fading of annealed and unannealed LiF:Mg, Ti (TLD-100, Harshaw) using computerized glow curve deconvolution. *J. Phys. D*. Vol. 24, 1649–1657.

Biran T.I, Malchi S., Shamai and Alfassi Z. (1996). Low pre and post irradiation fading of LiF:Mg,Ti (TLD-100,TLD-600,TLD-700) using a preheat technique. *Radiation Protection Dosimetry.* Vol.64, No.4,pp. 269-274.

Bos, A., (2006). Theory of thermoluminescence. Radiat. Meas. 41 (Suppl. 1), S45–S56

Bos A.J.J., Vijverberg R.N.M., Piters T.M., McKeever S.W.S. (1995). Effects of cooling and heating rate on trapping parameters in LiF: Mg, Ti crystals *J. Phys. D: Appl. Phys*. Vol. 25, 1249-1257.

Doremus, S.W., Higgins, G.A., (1994). Pre-irradiation fade and post-irradiation fade for LiF:Mg, Ti, TLD-600 and TLD-700, as a function of time. *Radiat. Prot. Dosim*. Vol. 54, 119–125.

Fuksa E., Horowitza Y., Osterb L. (2008). Investigation of the properties of composite glow peak 5 in slow cooled TLD-100. *Radiation Measurements* 43. 249-253.

Furetta, C., (2010). *Handbook of Thermoluminescence* second ed. World Scientific, Singapore.

Harvey J.A. and Kearfott K.J. (2011). Effects of high ambient temperature on glow peak fading properties of LiF:Mg,Ti Thermoluminescent dosimeters. *Radiation Protection Dosimetry*. pp. 1-7.

Horowitz, Y.S., (1990). Fading in LiF:Mg, Ti. Radiat. *Prot. Dosim*.Vol. 32, 147.

Izewska, J. Dietmar G., Bera, P. Thwaites, D. Arib, M. Saravi, M. Sergieva, K. Li, K. Garcia, F., Kumar, A. Bulski, M.. (2007). A methodology for TLD postal dosimetry audit of high-energy radiotherapy photon beams in non-reference conditions. *Radiotherapy and Oncology*. Vol. 84, 67–74.

Jarvis, A., Caffrey, J.A., Hamby, D.M., (2011). A review of instruments and methods for dosimetry in space. Adv. *Space Res*.Vol. 47, 563–574

Johnson, T.L., Luersen, R.B., (1980). Fading of unannealed LiF (TLD-600) for thermal neutrons and gamma rays. *Health Phys*.Vol. 38, 853–856.

Kos H.J., Nink R. (1980). New method for the optimization of thermoluminescence sensitivity in LiF:Mg,Ti. *Phys. Stat. Sol.* (a) Vol. 57, 203.

Landreth J.L., McKeever S.W.S. (1985). 5.5 eV optical absorption, supralinearity, and sensitization of thermoluminescence in LiF TLD-100. *J. Phys. D: Appl. Phys.* Vol 18, 1919.

McKeever, S.W.S (1985). *Thermoluminescence of Solids.* Cambridge Universiti Press, Cambridge. Pp. 1-376.

McKeever S.W.S., Moscovitch M., Townsend P.D. (1995). Thermoluminescence Dosimetry Materials: Properties and Uses. Nuclear Technology Publishing.

Mobit P.N., Maylesy P. and Nahum A. E. (1996). The quality dependence of LiF TLD in megavoltage photon beams: Monte Carlo simulation and experiments. *Phys.Med. Biol* 41, 387-398.

Moscovitch, M., Horowitz, Y., (2006). Thermoluminescent materials for medical applications: LIF:Mg,Ti and LiF:Mg,Cu,P. *Radiat. Meas*. Vol. 41, S71–S77

Salah N., (2011). Nanocrystalline materials for the dosimetry of heavy charged particles: a review. *Radiat. Phys. Chem*. 80, 1–10

Taylor G.C, Lilley E., (1982) Photoluminescence and thermoluminescence of Ti centers in LiF (TLD-100). *J. Phys. D: Appl. Phys.* Vol. 15, 1243.

Teixeira M.A., Ferraz G.M., Caldas L.V.A., (2008) b. Descalvado sand for high-dose dosimetry. *Radiat. Meas. Vol*. 43, 1163–1165

Straube, U., Berger T.G., Reitz G., Facius R., Fuglesang C., Reiter T., Damann V.,Tognini M., (2010). Operational radiation protection for astronauts and cosmonauts and correlated activities of ESA medical operations. *Acta Astronaut*. Vol.66, 963–973.

Shachar B.B, and Horowitz Y.S. (1991). Anomalous thermally induced fading of annealed and unannealed LiF:Mg,Ti(TLD-100) using computerized glow curve deconvolution. *J Phys. D: Appl. Phys*. Vol. 24, 1649.

Stadtmann H., Hranitzky C. and Brasik N. (2006). Study of real time temperature profiles in routine TLD readout-Influences of detector thickness and heating rate on glow curve shape. *Radiation Protection Dosimetry*. Vol. 119, No. 1-4, pp. 310-313.

Teixeira, I.M., Da Costa, Z., Da Costa, C., Pontuschka, W., Caldas, L., (2008). Study of the gamma radiation response of watch glasses. *Radiation Measurements*. Vol. 43, 480–482.

Yazici A.N. (2004). The influence of heating rate on the TL response of the main glow peak 5 and 4+5 of sensitized TLD-100 treated by two different annealing protocols. *Nuclear Instruments and Methods in Physics Research*. B 215 174-180.

Yazici A.N. (1988). The Effect of Pre-Irradiation Heat Treatment on the Evaluated Trapping Parameters of LiF:Mg,Ti (TLD-100) *Radiation Protection Dosimetry.* Vol. 80, 379-384

Yuan X.L., McKeever S.W.S. (1988). Impurity clustering effects in magnesium-doped lithium fluoride. *Phys. Stat. Sol.* (a) Vol. 108 , 545.