

FAST PREPARATION OF THERMOLUMINESCENT
LiF DOSIMETERS FOR THE USE

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Abstract — The author describes a technique of heating of thermoluminescent LiF dosimeters (TLD 100 rods) in a commercial reader without furnace annealing. The method is fast and simple and it renders these dosimeters more useful. The results of measurements with dosimeters heated by the method described are reproducible within 2—3%, which is sufficient for clinical use. Measured physical characteristics of dosimeters are presented in this article.

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Introduction — Thermoluminescent dosimeters (TLD's) are nowadays widely used in radiotherapy, diagnostic radiology and some other fields for dose measurements of different kinds of radiation (6, 8, 9).

Among TL materials, lithium fluoride (LiF) is the most extensively studied and frequently used in practice (1, 3, 4, 10, 11). The main disadvantage of LiF dosimeters is that they need a long thermal treatment prior to use (13). That could not be done in the TLD reader itself but in separate ovens. Only few authors (5) describe faster methods of annealing with respect to optimal results obtained by classical method of heating.

The aim of this work was to find out whether LiF dosimeters could be adequately heated in a conventional TLD reader without the need of furnace annealing and to simplify in this way the method of their preparation. We expected that the reproducibility of glowpeak areas would be worse than that obtained by furnace annealing, but still sufficient for clinical needs in radiotherapy.

Materials and methods — In our study LiF rods (6 mm dia. 1 mm. TLD 100, Harshaw co.) were used. TL signal from dosimeters was measured with Toledo 645 TLD reader (D. A. Pitman instr.)

with standard heating modul. The latter serves to match the heating cycle to different kinds of dosimeters by changing temperature and duration of each particular part of the cycle. We have selected the following cycle:

- 1) preheat — 16 s at 135⁰ C
- 2) read — 16 s at 270⁰ C
- 3) anneal — 16 s at 400⁰ C (later 300⁰ C)
- 4) cooling at natural cooling rate

The cycle lasts cca 80 seconds. After passing through it, the dosimeter is ready for next measurement. If the dosimeter had not been used soon after readout it passed the heating cycle prior to next use again. This was done to equalize its thermal history before each application. Because of considerable loss of sensitivity (see results) we have reduced the annealing temperature to 300⁰ C. Samples were readout 30 min after exposure. Measuring procedure was finally the following:

- 1) readout of dosimeter prior to irradiation
- 2) exposure to radiation
- 3) readout 30 min after irradiation

Dosimeters were exposed to gamma rays from Co⁶⁰ unit, to 8 MeV x-rays and electrons with energies from 6 to 16 MeV from the linear accelerator (MEL SL 75/20).

Calibrations with gamma rays and x-rays were made in a water phantom measuring 20×20×10 cm with the opening for thimble chamber. During irradiation, LiF dosimeter was placed in the opening in a lucite capsule (fig. 2).

For exposure to high energy electrons and other measurements special phantom was constructed consisting of two lucite plates (fig. 1). In the surface of the lower plate 20 hollows

were drilled for placing dosimeters. This plate was covered with another one the height of which was equal to the depth of the peak dose of radiation selected. In this phantom more samples could be exposed to radiation simultaneously. They could also be stored in it and easily identified. In order to avoid mechanical influence, dosimeters were handled with a vacuum tweezer.

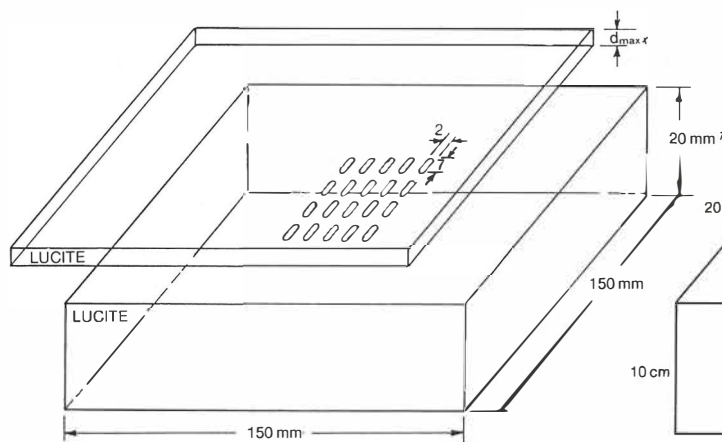


Fig. 1 — Lucite phantom for exposure and keeping of LiF dosimeters.

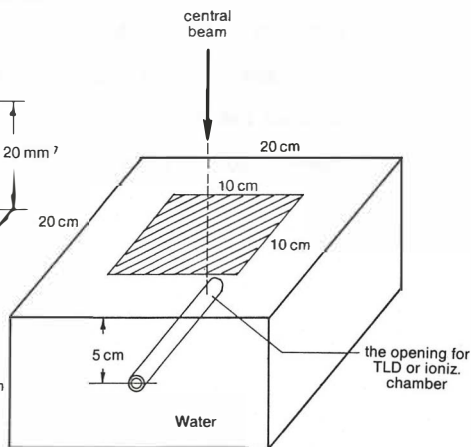


Fig. 2 — Exposure of TLD to Co⁶⁰ gamma rays and 8 MeV x-rays in a water phantom.

Dosimeters were first calibrated with Co⁶⁰ gamma rays. They were irradiated to about 100 cGy in a water phantom at 5 cm depth (fig. 2). Measured TL signal S_{Co} was compared with the dose D_{Co}, determined with calibrated ionisation chamber which was exposed in the identical mode as TLD's. Using the ratio:

$$C = \frac{D_{Co}}{S_{Co}} \quad (1)$$

we could calculate the unknown absorbed dose D at the point of dosimeter, when irradiated:

$$D = \frac{C \cdot S}{f_s \cdot f_E} \quad (2)$$

where S is the height of TL signal from dosimeter, irradiated to unknown absorbed dose, f_s is the supralinearity factor (see fig. 5) and f_E is the factor responsible for the sensitivity of LiF dosimeter to radiations of various energies. Factor f_E was determined by comparing the response of TLD to the known amount of radiation selected (S_E) with the response to the same amount of Co⁶⁰ gamma rays:

$$f_E = \frac{S_E}{S_{Co}} \quad (3)$$

Measurements were made for 8 MeV x-rays and 6 to 16 MeV electrons (table 1).

Energy	Relative TL signal
Co ⁶⁰	1,0
8 MeV x-rays	0,97
electrons (MeV)	
6	0,89
8	0,90
10	0,90
12	0,91
14	0,92
16	0,94

Table 1 — Relative TL signal from LiF dosimeter for various radiations and energies relative to Co⁶⁰ gamma rays

Irradiation of dosimeters with 8 MeV x-rays was done in a water phantom at 5 cm depth similarly as with Co⁶⁰ rays. When using high energy electrons, the samples were placed in our lucite phantom at the depth of peak absorbed dose for energy selected. Absorbed dose at that point was determined by exposure of calibrated Farmer ionisation chamber at the same

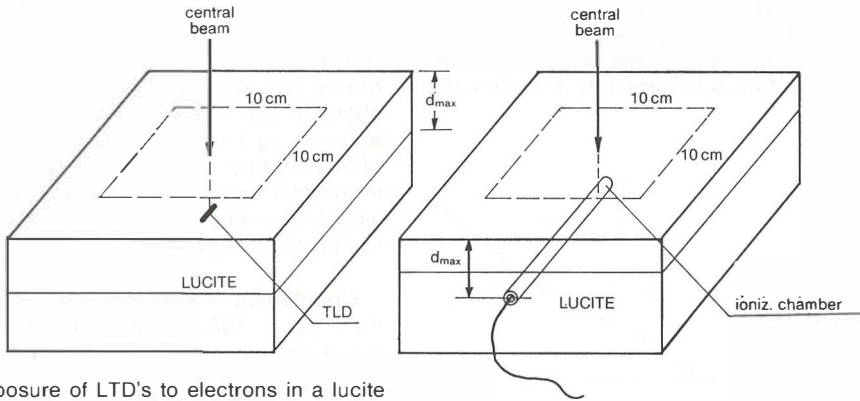


Fig. 3 — Exposure of LTD's to electrons in a lucite phantom (a). Determination of absorbed dose with Farmer ionization chamber. d_{max} is the depth of maximum absorbed dose for electrons with energy selected (b).

depth and exposure time in another lucite phantom (fig. 3). No conversion to absorbed dose in medium (7) has been applied to the absorbed dose determined with LiF dosimeter. Namely to the Burlin's cavity theory, the absorbed dose in the dosimeter $D_{LiF}(E)$ is related to the absorbed dose in the surrounding medium (water, lucite) $D_{med}(E)$ by:

$$D_{LiF}(E) = S_{med}^{LiF}(E) \cdot D_{med}(E) \quad (4)$$

$S_{med}^{LiF}(E)$ is the ratio of collisional stopping powers for LiF and medium. The ratio f_E , defined by:

$$f_E = S_{med}^{LiF}(E) / S_{med}^{LiF}(Co) \quad (5)$$

is almost equal for water (LiF/water) and for lucite (LiF/lucite). It differs from unity for less than 1% for all energies used (2). In that case, the above correction is not necessary.

Results — Table 1 shows the sensitivity of LiF dosimeters for radiation of various kinds and energies relative to Co^{60} gamma rays. We could notice a decrease of sensitivity to high energy radiation.

When measuring the decrease of sensitivity of TLD's with multiple use, ten dosimeters were repeatedly exposed to 50 cGy of Co^{60} rays and readout. The mean of all ten readings was taken as the result. Annealing temperature was first set to 400°C. After 40 successive exposures and readouts the sensitivity decreased for 16% i.e. 0.4% per cycle. Experiment was repeated by lowering the annealing temperature to 300°C. Here, the decrease of sensitivity amounted to 0.1% per cycle only.

The residual signal after readout of dosimeter was evaluated by two subsequent readouts of irradiated dosimeter. TLD's were first exposed to 100 cGy and then to 400 cGy, while the annealing

temperature was set to 400°C. The experiment was repeated at 300°C. At 400°C, the residue was only about 0.001% of the first reading which is almost equal to the amount of the dark current from PM tube of TLD reader. When heating dosimeters to 300°C, the residue increases but remains yet at a negligible level (table 2).

Annealing temperature	Exposure (cGy)	
	100	400
300°C	0.01 %	0.1 %
400°C	0.001 %	0.001 %

Table 2 — Effect of exposure and annealing temperature on the residual signal after readout of dosimeter

Fading effects were studied by varying the interval between exposure (50 cGy) and readout of dosimeter from 15 minutes to 100 hours. TL signal, surprisingly, increases during first hours and begins to fall about one day after exposure (fig. 4).

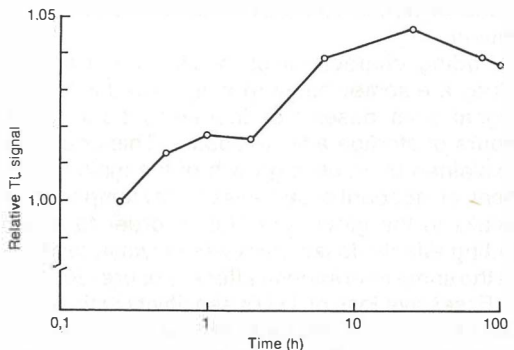


Fig. 4 — The effect of time elapsed from exposure to readout of dosimeter on relative TL signal normalized to unity after 15 minute interval.

Linearity of TL response and exposure was evaluated within 400 cGy interval. Dosimeters show linear response to exposures lower than 200 cGy. After that, supralinearity is evident (fig. 5).

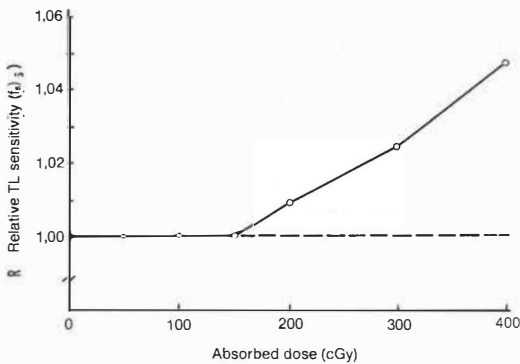


Fig. 5 — The effect of exposure on relative TL sensitivity (f_e in equation 2).

Reproducibility of glow-peak areas was tested with ten unused dosimeters which were 15 times successively exposed to 50 cGy and readout. The standard deviation of 15 readings was 2.3%. Measurements were repeated with other batches of dosimeters with similar findings. Results were reproducible within 2–3%.

Discussion — Avoiding the need of furnace annealing the usability of LiF dosimeters is essentially increased. Dosimeters heated by the method described, show satisfactory characteristics although the reproducibility of results is slightly worse of that obtained by standard heating method.

LiF dosimeters show decreased sensitivity to high energy beams with respect to gamma rays from Co^{60} . According to Paliwal and Almond (7) the amount of decrease for high energy electrons is about 10%. Our results confirm this theory.

Fading characteristics of LiF, found in our study are somewhat surprising because the TL signal from dosimeter increases during first hours of storage after exposure. This could be explained by relative growth of the main glow-peak on account of decrease of low temperature peaks in the glow-curve (3). In order to avoid fading effects dosimeters were always readout at the same time interval after exposure (30 min).

Excessive loss of TLD's sensitivity with multiple use at 400 °C led us to reduce the annealing temperature to 300 °C. As a consequence, the residual signal was essentially increased but remained at an acceptable level.

The fall of sensitivity is caused by influence of radiation and high temperature on LiF crystal. The amount of light collected by PM tube of the reader is limited by possible impurities and mechanical injuries on the surface of dosimeter and heating-tray that reduces the reproducibility of measurements. We have also noticed that after greater exposures (i.e. a few Gy) the sensitivity of dosimeter remains increased and falls to its standard value after read-cycle is repeated.

Conclusion — We have found that LiF dosimeters (TLD 100 rods) could be adequately heated in a commercial reader without furnace annealing. In this way we can avoid the major disadvantage of LiF dosimeters i.e. long preparation for their use. We have adjusted the heating cycle of our TLD reader so as to fit as much as possible to LiF dosimeters.

Energy dependance, supralinearity and the residual signal after readout of dosimeters, prepared in this way, are similar to those achieved with furnace annealing. Fading characteristics could be explained by corresponding theory. The reproducibility of the main glow-peak area is worse than that obtained by the standard method of heating. Evidently, with the in-reader heating LiF dosimeters could not be completely annealed.

The cleanliness of dosimeters and heating tray of the reader and their periodic change are of great importance for the stability of measurements.

The described method of heating of LiF dosimeters is fast and simple so that results are obtained soon after measurement. Dosimeters prepared in this way are used with a lot of success in our radiotherapy practice (12).

Sažetak

Brza priprema termoluminiscentnih LiF dozimetara za merenje doze

Autor opisuje metodu zagrevanja termoluminiscentnih LiF dozimetara (TLD 100) u TLD čitaču bez dodatnih peći. Metoda je brza i jednostavna što uvećava njihovu upotrebljivost. Rezultati merenja sa dozimetrima, pripremljenim po opisanom postupku, ponovljivi su u granicama 2–3%, što je dovoljno za kliničke potrebe. U članku su prikazani rezultati merenja fizikalnih osobina tih dozimetara.

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