FAST PREPARATION OF THERMOLUMINISCENT LiF DOSIMETERS FOR THE USE

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Abstract — The author describes a technique of heating of thermoluminiscent 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.

Introduction — Thermoluminiscent doseme-ters (TLD's) are nowadays widely used in radio-therapy, 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 disadvan-tage of LiF dosemeters is that they need a long thermal treatment prior to use (13). That could not be done in the TLD reader itself but in sepa-rate 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 dosemeters 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 radiothe-rapy.

Materials and methods — In our study LiF rods (6 mm dia. i mm. TLD 100, Harshaw co.) were used. TL signal from dosemeters 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 do-semeters by changing temperature and duration of each particular part of the cycle. We have selected the following cycle:

1) preheat — 16 s at 135^0 C
2) read — 16 s at 270^0 C
3) anneal — 16 s at 400^0 C (later 300^0 C)
4) cooling at natural cooling rate

The cycle lasts cca 80 seconds. After passing through it, the dosemeter is ready for next mea-surement. If the dosemeter had not been used soon after readout it passed the heating cycle prior to next use again. This was done to equa-lize its thermal history before each application. Because of considerable loss of sensitivity (see results) we have reduced the annealing tempera-ture to 300^0 C. Samples were readout 30 min after exposure. Meassuring procedure was fi-nally the following:

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

Dosemeters were exposed to gamma rays from Co^{60} 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 $20 \times 20 \times 10$ cm with the opening for thimble chamber. During irradiation, LiF dosemeter 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 dosemeters. 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 oreder to avoid mechanical influence, dosemeters were handled with a vacuum tweezer.
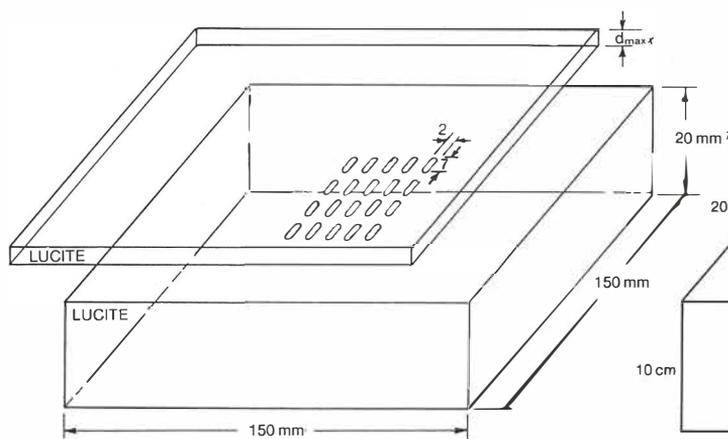
Fig. 1 — Lucite phantom for exposure and keeping of LiF dosemeters.

Fig. 2 — Exposure of TLD to Co^{60} gamma rays and 8 MeV x-rays in a water phantom.

Dosemeters were first calibrated with Co^{60} 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:

$$C = \frac{D_{co}}{S_{co}} \tag{1}$$

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

$$D = \frac{C \cdot S}{f_s \cdot f_E} \tag{2}$$

where S is the height of TL signal from dosemeter, 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 dosemeter 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 Co^{60} gamma rays:

$$f_E = \frac{S_E}{S_{co}} \tag{3}$$

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 dosemeter for various radiations and energies relative to Co^{60} gamma rays

Irradiation of dosemeters with 8 MeV x-rays was done in a water phantom at 5 cm depth similarly as with Co^{60} 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
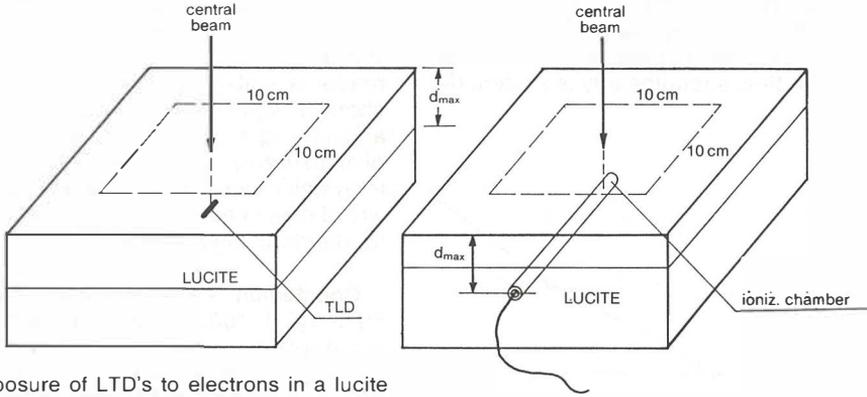
Fig. 3 — Exposure of LTD's to electrons in a lucite phantom (a). Determination of absorbed dose with Farmer ionization chamber. d_{max} is the depth of maximum absorbed dose for electrons with energy selected (b).

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 dosemeter. Namely to the Burlin's cavity theory, the absorbed dose in the dosemeter $D_{LiF}(E)$ is related to the absorbed dose in the surrounding medium (water, lucite) $D_{med}(E)$ by:

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

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

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

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 dosemeters 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 dosemeters 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 succesive 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 dosemeter was evaluated by two subsequent readouts of irradiated dosemeter. TLD's were first exposed to 100 cGy and then to 400 cGy, while the annea-

ling 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 dosemeters to 300 °C, the residue increases but remains yet at a neglegible 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 dosemeter

Fading effects were studied by varying the interval between exposure (50 cGy) and readout of dosemeter from 15 minutes to 100 hours. TL signal, surprisingly, increases during first hours and begins to fall about one day after exposure (fig. 4).
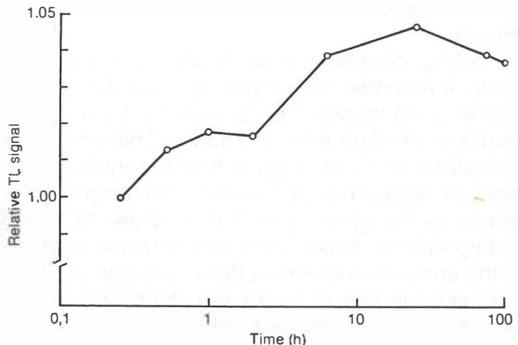
Fig. 4 — The effect of time elapsed from exposure to readout of dosemeter on relative TL signal normalized to unity after 15 minute interval.

Linearity of TL response and exposure was evaluated within 400 cGy interval. Dosemeters show linear response to exposures lower than 200 cGy. After that, supralinearity is evident (fig. 5).
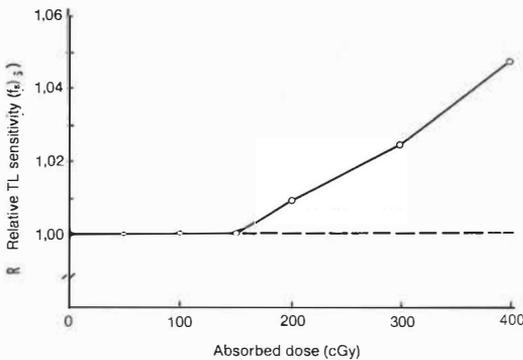
Fig. 5 — The effect of exposure on relative TL sensitivity (f_E in equation 2).

Reproducibility of glow-peak areas was tested with ten unused dosemeters 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 dosemeters with similar findings. Results were reproducible within 2—3 %.

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

LiF dosemeters 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 dosemeter 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 dosemeters 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 dosemeter 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 dosemeters (TLD 100 rods) could be adequately heated in a commercial reader without furnace annealing. In this way we can avoid the major di sadvantage of LiF dosemeters i.e. long preparation for their use. We have adjusted the heating cycle of our TLD reader so as to fit as much as posible to LiF dosemeters.

Energy dependance, supralinearity and the residual signal after readout of dosemeters, 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 dosemeters could not be completely annealed.

The cleanliness of dosemeters 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 dosemeters is fast and simple so that results are obtained soon after measurement. Dosemeters 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 uvečava 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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