Nuclear Data for Science and Technology (1988 MITO), 403- 405, Copyright © 1988 JAERI.

STUDIES ON THE PHYSICAL CHARACTERISTICS OF THE TLD-LiF DOSIMETERS

R.B.AKBARI

TEHRAN UNIVERSITY,SCIENCE FACULTY,PHYSICS DEPARTMENT
KARGAR AVENUE,TEHRAN-IRAN

Abstract : I have investigated the physical characteristics of the TLD-LiF Chips, Powder,Discs and Rods with 30%,100%,30%and 8% Lithium Floride by weight,respectively.TLD-LiF chips were used for glow curve studies,where powder,discs and rods were used for the dose levels 0.5 mGy up to 10 mGy.The accuracies were found to be ±15%, ±10% and±3% for the dose levels of ;0.5 mGy,5 mGy and 10 mGy respectively.

Reusability after annealing ,washing,and the sterilization did not significantly affect these dosemeters response and very little effect on the ideal energy dependence were observed.

Glow curves stability was also investigated by using ^{90}Sr source exposure and heating at 300°C for reading. The hight of the glow curves were increased linearly by the increment of the time of exposure(radiation exposure).

The desirable physical specifications of TEFLON used with excellent characteristics of the TLD-LiF makes it a small,simple,reusable andmechanically flexable dosemeter which has a density close to the body tissues.

Keywords: Build-up,Backscatter,Radiation Response,Energy Dependence,Fading,Tribothermoluminescence,High Exposure.

Introduction

The general theory and the characteristics of thermoluminescence dosemeters have been discussed in the literature;Cameron[2],Lin[7],Fowler[4], and Cameron[3] and many others.For dosimetry and protection purposes the first phosphor suggested was TLD-LiF by Daniels[1].

In the past 35 years continued research on the properties of the TLD-LiF has led to the development of useful dosimetry systems and TLD-LiF is available in many suitable forms. However, it is well known that TLD-LiF is not a system for absolute dosimetry in the sense of a calorimeter or a free-air ionization chamber.TLD measurements are relative measurements based upon the response to an unknown dose with values measured with known doses.Thus,to obtain accurate calibration data to calibrate the TLD-systems, dosemeters should be exposed to a series of known doses,which were determined using an absolute technique.As far as possible the conditions should be kept constant.Also,the use of TLD-LiF for a variety of studies with various radionuclides makes it necessary to examine in some detail the performance of the various dosemeters available.

In this study depending on the conditions of the measurements for which the TLD was to be used different arrangements for the exposure of the dosemeters were set-up.Factors such as build-up and backscatter,radiation response,energy dependence,fading,tribothermoluminescence effect, and high exposure effect were experimentally studied and discussed.

Materials and Methods

Materials

Four types of TLD-LiF were used:(A)Rods;MR-LiF-7 Harshaw(1.4mm X1.4mm X8mm length rectangular shaped rods,containing 8% phosphor.(B)Powder TLD-100,LiF-7 as powder with grain size 78-126um containing 100% phosphr.(C)Discs;TEFLON discs,D-LiF-7 0.4mm thick and 12.7mm diameter,containing 30% phosphor.(D)TLD-LiF Chips;two in one frame and were only used for glow curve studies.

TLD Dispenser.TLD powder was dispensed with an automatic volumetric vibrating dispenser into cylinderical gelatine capsules(5x15mm)or into sachets.Thirty milligrams of powder was dispensed for each container.

TLD-READER.All thermoluminescence dosemeters were measured in the Pitman TOLEDO 654 TLD READER and Harshaw Automatic READER were used only for reading TLD chips.

Annealing.Annealing of all TLD-LiF phosphors was carried-out in two ovens,one for 300°-400°C and the other for 80°C.

Methods

Read out procedures,heat treatment and handling were kept approximately constant in all measurements.The standard light source supplied with the instrument were used to check the constancy of the response of the PM tube.

The standard annealing procedure suggested by Cameron[2] was applied to all TLD-LiF except that a constant 15 minutes cooling time at room temperature prior to annealing at 80°C was used, and was found to give ±1% reproducibility in repeated measurements.This procedure was carried out before each re-use of the dosemeters.

A group of dosemeters was annealed and exposed to a known dose. This was repeated several times and the reproducibility of the dose measurements was found to be ±5%.

A detailed description of the TLD read out system is given in the operation and service manual.

The calibration exposure of the TLD-LiF phosphors was carried out with fixed geometry and under constant conditions,only the time for each exposure was changed.

To minimize scatter an optical bench was used. For exposures at 7 cm and 20 cm distances (7 cm was used for exposure to Tc-99m radiation). For dose calculations the following expression was used;

$$D=0.26\frac{\Gamma A}{d^2} \quad Gy\text{-}MBq^{-1}\text{-}h^{-1} \quad \text{at one cm}$$

in which D is the exposure doses Γ is the gamma-ray constant and d is distance in cm,and A is the activity of the source at the time of exposure which was measured by an NPL1383A calibration chamber.The decay of a short-lived radionuclides during the exposure time was also taken into account. In general,the activity and hence the exposure rates were known to better than $\pm 5\%$.

Measurements and Results

Build-up and Backscatter Factors

In most exposures in which broad and unfiltered beams of radiation were used(e.g.in exposures with radionuclides,to obtain electronic equilibrium) a set of measurements in identical measuring conditions were carried out to find out the build-up region for the response of TLD-LiF at energies of 140,662 and 1250 keV.The maximum dosage build-up with Tc-99m,Cs-137 and Co-60 occured at 0.7mm,2mm and 5mm of tissue equivalent material,respectively.

Radiation Response and Energy Dependence

Radiation Response.To study the radiation response and the energy dependence of the TLD-LiF in different geometrical configurations and sets of dosemeters were exposed to radiations from point sources of Co-60,Cs-137,Ra-226,Au-198 ,Tc-140 and also to X-rays from a 250 kVp X-ray machine.The effective energies of the photons emitted being determined by HVL measurements with Al and Cu filters.The energies were finally assumed to be 1250,662,840,410 and 140 keV from radionuclides and 140,53,41,30 and 24 keV from the X-ray machine,respectively.(see Table 1).

In Table 1 the responses of the TLD-LiF in terms of Counts per 10mGy at different energies are shown and also(in brackets)normalized to 1.0 for Co-60 response.

Energy Dependence. The responses of TLD-LiF per unit absorbed dose against photon energies are shown in Figure (1).All types of dosemeters show a linear response to doses in the range of 0.5-10 mGy,for energies of 140-1250 keV.The standard deviation of an individual measurement at 1mGy was found to be $\pm 5\%$.

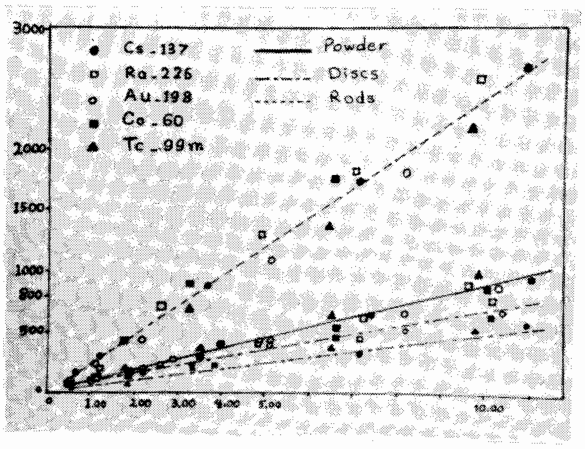

Figure 1.TLD-LiF Dose response curves;for rods, powder and discs,from 0.5-10.0 mGy (drown by eye).

Figure (2) shows the results of two separate sets of experiments carried out to determine the energy dependence of the TLD-LiF dosemeters.

The results show that for individual calibration carried out with a particular radionuclide, the response is linear with dose. However,this response may vary with repeated use of the discs and so calibration carried out on different occasions may differ in the response per unit dose.

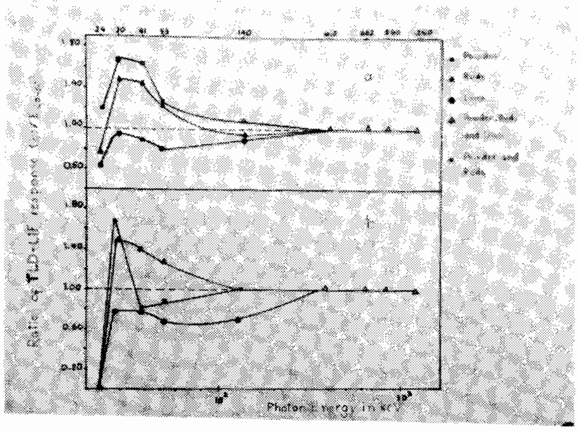

Figure 2.TLD-LiF response against the photon energy from 24-1250 keV;normalized to 1.0 at Co-60, gamma-rays(a) External annealing only and (b)Internal annealing as well as external .

The results show that in the exposure with Cs-137 and Tc-99m carried out at a later date,the response per unit dose had decreased.

The response of each dosemeters declines sharply in value at lower energies,probably because of absorption of photons in the gelatine capsules orsachets and matrix of the dosemeters,or the photon flux gradient across the LiF.For energies above 30 keV in both Figures (2/a&b),the reponse dropped sharply for the powder .However,it is concluded that amongst various forms of TLD-LiF in the form of powder gives a flatter response down to 40 keV,than the other types.

The minimum detectable dose for a series of non-irradiated powder samples, discs and rods was found to be 0.02 mGy,and is evaluated as 3σ(σ is the standard deviation of the background readings in 10 measurements).

Fading

When using TLD-LiF for a period of 2-6 weeks either for monitoring or dosimetry studies it is necessary to establish the extent of fading over that period.

In this study powder and rods after annealing were exposed to 1.0 Gy of Co-60 gamma-rays.All dosemeters were stored at room temperature.Four to six dosemeters were read out imidiately,and at 1, 24,48 hs intervals up to a maximum of 45 days,see Figure(3).

In Figure 3 the reading obtained at the first 24h was taken as 100%,the value at zero time being about 10% greater.This being due to the response of a low temperature peak,in the glow cure,At the end of first,second,third and forth weeks readings of 98,94,95 and 98% were obtained,respectively. The rods and powder showed similar results.Thus, fading of TLD-LiF apears to be independent of the size and shape of the dosemeters.

Exposure Effect on Glow Curve

TLD-LiF chips were used to study the response to the exposure to the β-rays from Sr-90 sourc-

Table 1.The response of TLD-LiF per 10mGy against the photon energy from 24 to 1250 keV

No.	Photons	Effective energy of radiation (keV)	TLD-LiF rods sensitivity 21600 (Counts/10mGy)	TLD-LiF discs sensitivity 03300 (Counts/10mGy)	TLD-LiF powder sensitivity 02200 (Counts/10mGy)
	X-rays				
1	50 kV	24	1979 (0.780)	51 (0.740)	106 (1.270)
2	90	30	3755 (0.480)	68 (0.980)	142 (1.710)
3	120	41	3450 (1.360)	63 (0.920)	140 (1.670)
4	150	53	3146 (1.240)	55 (0.80)	111 (1.340)
5	250	140	2156 (0.850)	63 (0.910)	98 (1.180)
	Gamma-rays				
6	$^{99}Tc^{m}$	140	2012±140 (0.793)	60±6 (0.850)	95±11 (1.15)
7	^{198}Au	410	2254±204 (0.890)	69±8 (0.990)	90±6 (0.944)
8	^{137}Cs	662	2508±387 (0.980)	72±8 (1.030)	87±4 (1.070)
9	^{226}Ra	840	2555±348 (1.006)	74±8 (1.050)	82±8 (0.988)
10	^{60}Co	1250	2537±121 (1.000)	70±4 (1.000)	83±3 (1.000)

Figures in the brackets show response which are normalised to Co-60 response.

The results showed a stable and lincar increase in the exposure time,Mojaveri[15].

High Exposure and Age Effect

The TLD-LiF powder which had been used for therapautic and protection purposes throughout years where the history of exposure to this batch was not known were examined and compared with a new batch of powder.Five samples from each were exposed to a 40mGy CO-60 gamma-rays.The ratio of signal from non-irradiated samples was obtained. It was concluded that the high dose and cronic exposure of TLD-LiF phosphor had decreased the signal to background ratio by a factor of 4.

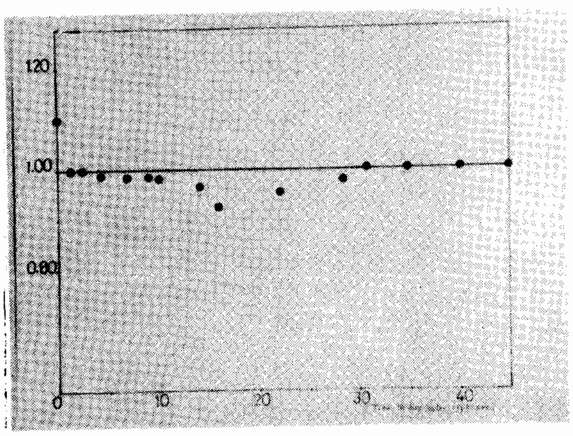

Figure 3.Fading of TLD-LiF powder during 45 days after exposure to 1.0 Gy,gamma-rays from Co-60.

The colour of the old powder had also changed to a yellow tint which could be recognized distinctly with the naked eye,Akbari[12,13] and Reisdanaeh Fard[14].

Comparison with Literature

The results obtained for TLD-LiF response to radiation and energy dependence agree with the findings by Suntharalingham[5] and Cameron[9] and Webb[11].

From the sets of experimental measurements at ten different photon energies the average values which are shown in Figure(2),it is concluded that the highest response at 30keV,a result which is in agreement with the work of Enders[10] and Hedee[8].The results of fading and independency of the size and shape of the dosemeters agree with the theoretical studies of Webb[6].

DISCUSSION

Dose measurements for the staff dosimetry and protection purposes ,the TLD-LiF technique is prefered to film,because of its better energy dependence and the small size of the dosemeters.

It is a reasonable advise to keep separate the groups of dosemeters used for therapautic dosemeters from the groups for protection and diagnostic purposes.

REFERENCES

1. F.Daniels:Project No.4-12-80-001(1954)
2. J.R.Cameron:Health Phys.25,10(1964)
3. J.R.Camerom:Health Phys.525,12(1966)
4. J.F.Fowler:Radiat.Dos.,241-290(1966)
5. N.Suntharalingham:Health Phys.1595,12(1966)
6. G.A.M.Webb:Brit.J.of Appl.Phys.18,7(1967)
7. F.M.Lin:Health Phys.495,14(1968)
8. W.R.Hendee:Inter.J.of.Appl.Radia&Isot.431,19 (1968)
9. J.R.Cameron:Radiat.Dos.105-127(1970)
10. G.W.R.Enders:Health Phys.665.18(1970)
11. G.A.M.Webb:Health Phys.89.23(1972)
12. R.B.Akbari:Ph.D.ICR London Univ.,227-247(1978)
13. R.B.Akbari:Inter.Symp.Nu.Med.(1983)
14. F.Reisdanaeh Fard: MSc.Thes.64-98(1986)
15. A.E.Mojaveri:BSc.Project.(1986).