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THE DOSE–RESPONSE OF HARSHAW TLD-700H

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Harshaw TLD-700H (^{7}LiF:Mg,Cu,P) was previously characterised for low- to high-dose ranges from 1 μGy to 20 Gy. This paper describes the studies and results of dose–response and linearity at much higher doses. TLD-700H is a near perfect dosimetric material with near tissue equivalence, flat energy response, and the ability to measure beta, gamma and X rays. These new results extend the applicability of Harshaw TLD-700H into more dosimetric measurement environments. The simple glow curve structure provides insignificant fade, eliminating special oven preparation methods experienced by other materials. The work presented in this paper quantifies the performance of Harshaw TLD-700H in extended ranges.

INTRODUCTION

With the introduction of LiF:Mg,Cu,P (TLD) material and improvements made over the years, there now exists a material that has many desirable properties. The idea of developing a high sensitivity thermoluminescence (TL) material by doping LiF crystals with Mg, Cu and P impurities was first proposed by Nakajima *et al.*[1] in 1978. The sensitivity of this new preparation was more than 20 times higher as compared with LiF:Mg,Ti (TLD-100), but it lost its high sensitivity after only one use[2,3].

In 1984, Wu *et al.*[2] demonstrated that it is possible to prepare high sensitivity LiF:Mg,Cu,P that maintains its high sensitivity during repeated re-use cycles. Initial characterisation[3] of this new preparation showed promising dosimetric properties and demonstrated that the material can be re-used with little loss of sensitivity (<5% following eight uses).

Today, an improved LiF:Mg,Cu,P is now available commercially as Harshaw TLD-100H, 600H and 700H (Thermo Electron Corporation, USA). The TL characteristics of LiF:Mg,Cu,P that are particularly useful for radiation dosimetry include high sensitivity as compared with LiF:Mg,Ti, almost flat photon energy response, insignificant fading and lack of supra-linearity[4]. Its simple glow curve structure, when read with pre-heat at 165°C, offers a negligible fade in an extended period up to 4 months[5]. The great reusability of over 1000 uses was presented in the previous study[6].

In addition, as shown in previous work[7–9], LiF:Mg,Cu,P can also be used in measurements involving high-dose ranges. This paper will demonstrate that Harshaw TLD-700H, ^{7}LiF:Mg,Cu,P can also be used for high-dose measurements up to 20 Gy. Applications at this level can include accident dosimetry and radiation therapy planning. The dosemeters, test set-up and results will be described.

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MATERIALS AND METHODS

The TLD material used in this test is Harshaw TLD-700H (^{7}LiF:Mg,Cu,P). It is in the form of a bare pressed pellet measuring 3.6 mm diameter × 0.38 mm. The manufacturing techniques used to produce TLD-700H have been refined to the point that very consistent performance is obtained. In addition, the residual signal has been reduced and the re-use performance improved. The material can be used bare, encapsulated in TLD cards with badges or in extremity configurations.

The TL response of LiF:Mg,Cu,P is sensitive to the readout temperature. Good control of the temperature during the processing is therefore critical to the successful practical application of this material in personnel dosimetry. A reader capable of precise control of the heating regime is an essential component of any LiF:Mg,Cu,P based TLD system. The Harshaw Model 3500 TLD reader used in this work provides this capability. This reader incorporates a linear time–temperature controlled ohmic heating technique. This heating technique has been in routine use for more than 40 y for LiF:Mg,Ti. The heating profile is linear and directly controllable through a closed-loop feedback to an operator-specified temperature, time and heating rate. The heating of the dosemeter is reproducible and efficient for a variety of chip thicknesses. The temperature is monitored by a thermocouple welded to the planchet just below the TLD material. This temperature signal is sent to a heater control circuit that compares the measured temperature with that called for by the user-defined heating profile (temperature as a function of time). It then adjusts the current in the heating element to maintain the temperature of the planchet to within ±1°C of the specified level. This closed-loop cycle ensures a high degree of accuracy and repeatability of the heating profile, critical to the successful application of LiF:Mg,Cu,P to dosimetry. The TL emitted light is measured using a photomultiplier tube (PMT) that is thermoelectrically cooled to 15°C. The PMT signal is accumulated via the charge integration technique. Care was taken during the test to stay well below the 100 μA absolute maximum anode current rating of the PMT.

During the measurements, nitrogen gas was used to purge the read chamber to reduce oxygen induced light effects. Glow curves were recorded using the following TTP (time–temperature profile).

Pre-heat: 50°C at 0 s
Rate: 10°C s^{-1}
Maximum temperature: 240°C
Acquire time: 30 s
Anneal: 240°C for 10 s

A 100 Curie ^{137}Cs, J. L. Sheperd Model 70 Irradiator was used in this study for dosing the pellets. This source delivers ~0.42 mGy s^{-1} for a source-to-dosemeter distance of 22.9 cm (9 in.). The ability to measure beta, X rays and the mixtures was demonstrated in a large-scale study conducted by the US Navy to characterise LiF:Mg,Cu,P as a replacement for LiF:Mg,Ti in their personal dosimetry programme(8).

The TLDs were calibrated before the test. Calibrations consisted of normalising the sensitivities of the TLDs used. For each data point, there were three TLDs read using the TTP previously described. Each TLD was first cleared by one readout on the reader and then irradiated to a known dose. The dose readout followed within 30 min. Note that there was no adjustment for fade time. Dose levels were as follows: 0.002, 0.004, 0.01, 0.07, 0.2, 0.7, 2, 14, 20, 25, 50 and 74 Gy.

RESULTS AND DISCUSSION

The results show that the TLD-700H (^{7}LiF:Mg, Cu,P) material starts a sub-linear dose–response at ~20 Gy. It is interesting to compare this with the well-studied material LiF:Mg,Ti that starts to over-respond at ~1 Gy.

The glow curves from the testing shown in Figure 1 show a consistent shape over the dose range from 0.002 to 74 Gy. The dose–response vs. the delivered dose is shown in two different scales, as shown in Figures 2 and 3. Figure 2 shows a log–log scale of the response vs. the delivered dose. Figure 3 shows a linear scaling. A sub-linear trend is realized, with a slope of 0.8299 up to 74 Gy. (*Note*: The linear slope would be 0.99 if fit up to 20 Gy, 0.96 up to 25 Gy and 0.91 up to 50 Gy.) Results from the R^2 test shown in Figure 3 give a result of 0.99. Using a polynomial curve fit (Figure 4), it is shown that the material under-responds by:

- 4% at 10 Gy;
- 8% at 20 Gy;
- 13% at 30 Gy;
- 25% at 74 Gy.

Figure 5 shows a plot of the dose–response for peaks 2, 3 and 4 over the range of interest. A Harshaw deconvolution technique was applied to

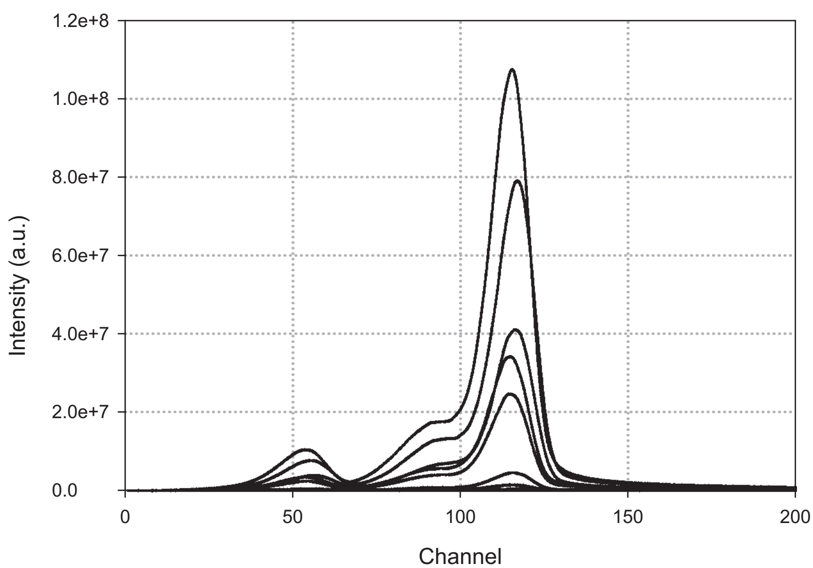

Figure 1. Glow curves: range 0.002–74 Gy Harshaw TLD-700H, ^{7}LiF:Mg,Cu,P.

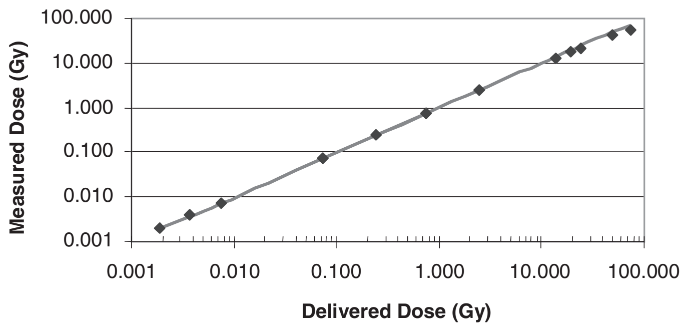

Figure 2. Harshaw TLD-700H ^{7}LiF:Mg,Cu,P 0.38 mm (0.015 in.) pellet.

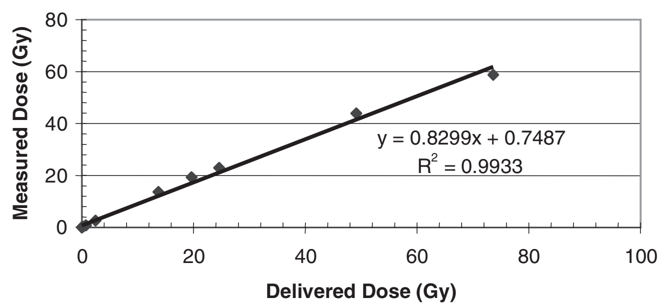

Figure 3. Linearity: Harshaw TLD-700H, ^{7}LiF:Mg,Cu,P 0.38 mm (0.015 in.) pellet.

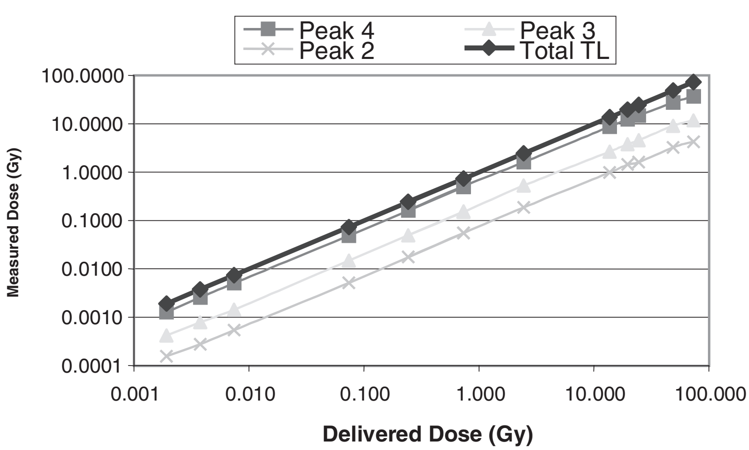

Figure 4. Individual peaks: Harshaw TLD-700H.

extract these data. The total TL signal of the combined peaks is also plotted adjacently. All of the individual peaks show a similar linear function as the total TL signal. Note that error bars are too small to be shown on the graphs in the figures presented in this paper.

CONCLUSION

This material would be very suitable for high-dose work. The pelletised Harshaw TLD-700H (^{7}LiF:Mg,Cu,P) material has a useable linear dose range up to 20 Gy. At 74 Gy, it has an under-response of

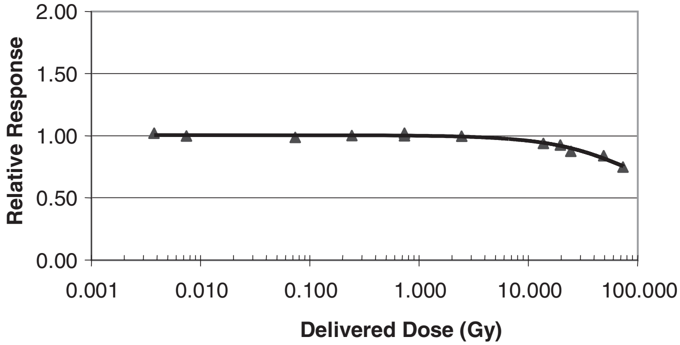

Figure 5. Dose–response: Harshaw TLD-700H, ^{7}LiF:Mg,Cu,P.

~25%. Ranges beyond 74 Gy would require further testing.

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