REUSABILITY AND FRACTIONAL READ-OUT IN $\text{CaF}_2:\text{Tm}$ (TLD-300)

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ABSTRACT

The first part of this paper is concerned with the reusability of $\text{CaF}_2:\text{Tm}$ (TLD-300) ribbon without thermal treatment between read-out and irradiation. It has been checked up to a dose level of about 200 mGy and the results show that it is possible to reuse this material without annealing in the used dose range. In the second part of the paper a fractional method of TL readings is outlined. The peak separation is checked at different linear testing rates and with different reading times for each peak. The separation technique is then checked in a dose accumulation experiment.

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INTRODUCTION

Two papers on the annealing procedure and reusability of $\text{CaF}_2:\text{TM}$ (TLD-300) have recently appeared [1,2]. In these papers the authors state that a thermal treatment at 400°C for 1 hour, with or without a lower temperature treatment (100°C for 1 hour) is quite good for reuse of this material.

Since the annealing treatment is sometimes a tedious procedure, especially in routine work, we checked the reusability of TLD-300 without annealing procedure between irradiations. This study has been done in connection with a study of the applicability of peak height ratio of TLD-300, H_3 (150°C)/ H_5 (240°C), in beta dosimetry [3].

In this paper we present the results obtained on the reusability of $\text{CaF}_2:\text{TM}$ without annealing between read-out and irradiation.

Furthermore, some interesting observations can be made about the glow-curve of TLD-300 compared with the glow-curves of different other materials:

- there is a large separation between peaks 3 and 5,
- the stability of these two peaks and their ratio is very good, without too much fading.
- the two peaks have a different LET dependence.

Thus, it is possible to use this kind of material for some special applications, where a read-out of only one peak is needed. In this case, in order to obtain the dose assessment for each peak, a glow-peak separation technique can be used. This kind of technique has been studied by a few authors for different purposes. In Refs. [4,5,6] the separation technique is carried out with a control on the maximum temperature in a Harshaw reader.

This method has been applied with CaSO_4 , but it is not suitable for $\text{CaF}_2:\text{TM}$, since the second peak is not very well separated from the third one. Another technique has been proposed by Rank et al. [7], where the read-out process is stopped by the operator when the temperature of interest is reached: even in this case a good reproducibility in glow-peak separation is difficult to achieve.

For improving the procedures mentioned above, we have developed a different method based on time control and we optimized the technique studying the peak separation at different heating rates in $\text{CaF}_2:\text{Tm}$ (TLD-300) to achieve individual readings for peaks 2, 3 and 5.

EXPERIMENTAL

Reusability without annealing

$\text{CaF}_2:\text{Tm}$ (TLD-300) ribbons were purchased from Harshaw Chemical Company, USA. A Harshaw 2000 TLD reader, used for TL evaluation, was coupled with a Harshaw TLD glow-curve analyzer Model 2080. In this way it has been possible to determine both peak area and peak height of the glow-curve region of interest. In the read-out cycle a linear heating rate of 8°C sec^{-1} from room temperature to 300°C was used. The dosimetric properties of this material have been repeated elsewhere [8,9].

Twenty dosimeters from a new batch, as received from the manufacturer, were read in the TL reader. The procedure was repeated three times and four dosimeters were chosen with a standard deviation of the inherent background less than 1%. In the experiment no calibration factor was used for the detectors.

After this preliminary procedure, the group of four dosimeters was irradiated with 1.75 mGy of a calibrated beta source (^{90}Sr - ^{90}Y Studsvik beta source) and each dosimeter evaluated. The procedure was repeated 15 times. No annealing in oven or second readout was done. After these 15 irradiation/read-outs, the same dosimeters were irradiated at 175 mGy and the procedure was like the 1.75 mGy one.

A mean sensitivity $\bar{s}_i$ was obtained from the four readings of each i-cycle. Then the mean sensitivities were averaged over all the 15 cycles and the $\bar{s}$ value was calculated. After that the percentage deviation of each $\bar{s}_i$ from $\bar{s}$ was obtained (Fig. 1). The percentage deviation between the sensitivities obtained from the two sets of irradiation levels was less than $\pm 3\%$. The data for the peak ratio

$R = H_3/H_5$ were handled in the same way. The mean peak ratio $\bar{R}_i$ was obtained from the four readings for each i-cycle and then the $\bar{R}$ value and the percentage deviation were calculated. In this case also the maximum percentage deviation was within $\pm 3\%$ (Fig. 1).

Table 1 shows the variation in the peak ratio given as a percentage S.D. of the $\bar{R}$ in function of the two levels of irradiation.

Separation technique

$\text{Ca}_2\text{F:Tm}$ (TLD-300) ribbons were used for all the experiments.

The read-out systems were two: a manual Harshaw reader model 2000 B+C coupled with a Huston 2000 chart recorder, and a manual Harshaw reader model 2000 B coupled with the already mentioned glow-curve analyzer. The two read-out systems gave the same results. They are given as total TL light for the whole glow-curve or as peak area.

A linear heating rate of $21^\circ\text{C sec}^{-1}$ was used at first. The total procedure has been divided in three parts.

- First part, or initial setting. Using the linear heating rate of $21^\circ\text{C sec}^{-1}$ a whole glow-curve was recorded. Then, a set of read-out times, from zero to that of interest, have been chosen to obtain each peak separately. Fig. 2 shows how the read-out times were chosen. The first read-out corresponding to Δt_1 , stops when t_1 is overtaken. Then the sample cools down. The second read-out, Δt_2 , stops at t_2 . After cooling the third read-out starts up to t_3 . The same figure shows how the single glow-peaks appear after the fractional read-out procedure.
- Second part or comparison. This part includes two different checks. The first one is to compare the peak areas in the whole glow-curve with the areas in the separated glow-peaks. The second check consists of calculating the TL loss between the whole glow-curve area and the sum of the three separated glow-peak areas.

- Third part. If one or more of the previous checks are not acceptable for a good peak separation, in terms of minimum TL loss, a new heating rate or/and a new set of read-out times is chosen.

Table 2 shows the results obtained at different heating rates and the corresponding sets of read-out times. From Table No. 2 one can see that the TL loss is about the same with heating rates of $10^{\circ}\text{C sec}^{-1}$ and $6^{\circ}\text{C sec}^{-1}$. For practical use, because the reading time is shorter, the heating rate of $10^{\circ}\text{C sec}^{-1}$ has been used.

After having obtained a suitable condition for evaluating the peaks separately, the reproducibility of the method was checked. For this purpose, only the 3rd and 5th peaks have been considered, because the 2nd peak is not useful in practice owing to its low temperature and, consequently its high fading rate.

This check has been carried out using five chips over five cycle of measurements for each sample at the same dose level. Furthermore, different levels of irradiation have been used. Figs. 3 and 4 show the results. Referring to Fig. 3 the percentage standard deviation (10%) of the average TL readings, cycled five times, was of 2% for both peaks.

Accumulation study

Using the separation technique in $\text{CaF}_2:\text{Tm}$, it is possible to determine both the daily dose, by the third peak evaluation only, and then the cumulative dose using the read-out of the fifth peak after a stated time. This procedure could be useful in personnel and accident dosimetry. To test the feasibility of the separation technique in the accumulation study, the following procedure has been used:

- irradiation at 3.5 mGy followed by read-outs of both 3rd and 5th peaks;
- irradiation at 3.5 mGy followed by a read-out of the third peak only;
- irradiation at 3.5 mGy followed by a read-out of both peaks;
- irradiation at 3.5 mGy followed by a read-out of the third peak only;
- irradiation at 3.5 mGy followed by a read-out of the third peak only;

- irradiation at 3.5 mGy followed by a read-out of both peaks. And so on up to an accumulated dose of five times 3.5 mGy in peak five.

The read-outs were performed using a linear heating rate of $10^{\circ}\text{C sec}^{-1}$ with the corresponding read-out times given in Table 2.

Fig. 5 shows the results of the dose accumulation in peak 5, given as peak area as a function of dose. The plot shows a very good linearity confirming the value of the separation technique.

CONCLUSIONS

As shown in Fig. 1 and Table 1, it is possible to reuse the $\text{CaF}_2:\text{Tm}$ without annealing procedure between read-out and irradiation in the dose range up to 175 mGy.

Further studies need checking the behaviour of this material in higher dose regions, as well as the stability of TL signals in function of the time elapsed between irradiation and read-out. Another point of study is the one to check if any annealing procedure could improve the sensitivity and the peak ratio of this material.

$\text{Ca}_2\text{F}:\text{Tm}$ (TLD-300) seems to have very good properties for using it in special applications where the read-out needs to be done at different periods of time. The good resolution between peaks allows to use the technique of peak separation.

The application of this technique allows the reading of only one peak and the storage of TL light in the remaining peak to achieve dose information over a longer period of exposure: this fractional read-out could be very important in personal and accident dosimetry.

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FIGURE CAPTIONS

- Fig. 1: Relative percentage deviation as a function of reading cycles.
- Fig. 2: How the read-out times (Δt_i) for each peak are chosen. In the insert each separated peak is shown.
- Fig. 3: Reproducibility of the separation technique. A dose of 350 mGy has been used to test the fractional readings.
- Fig. 4: Linearity of fractional readings.
- Fig. 5: Dose accumulation in the fifth peak only

TABLE CAPTIONS

Table 1: Variation in the peak ratio as a function of dose.

Table 2: Optimized TLD-300 glow-peak separation conditions for different heating rates with different TL loss.

Table 1

Variation in the peak ratio
as a function of the two dose levels

Dose	$\bar{R}$	S.D. %
1.75 mGy	3.4	3
175 mGy	3.4	3

Table 2

Optimized TLD-300 glow-peak separation conditions
for different heating rates with different TL loss

Heating rate $^{\circ}\text{C sec}^{-1}$	Glow-peak separation times(*)			TL loss %
	2nd peak Δt_1 sec	3rd peak Δt_2 sec	5th peak Δt_3 sec	
21	5	10	15	20
16	6	11	22	10
10	12	19	35	5
6	18	29	52	4-5

*) Each Δt_i from $t = 0$

Fig.1

Fig.2

Fig.3

Fig.4

Fig.5