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TL glow curve shape and response of LiF:Mg,Cu,Si—Effect of heating rate

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Abstract

Glow curve structure of a recently developed LiF:Mg,Cu,Si TLD was found to be the same as that of LiF:Mg,Cu,P. In view of the reported effects of heating rate in LiF:Mg,Cu,P TLD, the study on LiF:Mg,Cu,Si was undertaken for its use in personal dosimetry applications. In LiF:Mg,Cu,Si, the thermally isolated main dosimetric peak did not exhibit any reduction in its TL response with increasing heating rate in the range from 1 to 30 °C s^{-1}. In the combined glow curve, the lower temperature peaks exhibited only a marginal impact on the response. However, an increase in the response of a lower temperature peak with increasing heating rate affected the shape of the combined glow curve. For 0.8 mm thick TLDs, heating rate dependent thermal lag resulted in a temperature lag of 62 °C higher than that of 150 μm TLD powder grains at 30 °C s^{-1}. With the increase in the heating rate, the full width at half maxima (FWHM) of the isolated main peak increased from 22 to 24.8 °C for the 0.8 mm thick TLDs and from 22.6 to 28.4 °C for the 150 μm powder grains. The impact of the effect of heating rate is discussed.

Keywords: LiF:Mg,Cu,Si; TL glow curve; Influence of heating rate

1. Introduction

Replacement of dopant P by Si in LiF:Mg,Cu,P, appears to have provided an improved LiF TLD material, namely LiF:Mg,Cu,Si (Lee et al., 2006). Recently, a study (Luo et al., 2006) on glow curve shape dependence on heating rate demonstrated that in LiF:Mg,Cu,P the total TL of combined glow peaks remains unchanged with the increasing heating rate whereas the response of its main dosimetric glow peak (peak 4) decreases and the response of its preceding lower temperature peak (peak 3) increases, apparently compensating for the decrease in peak 4. In view of this, it became important to investigate the shape of the glow curve and the impact of the low temperature glow peaks on the response of the main dosimetric glow peak of LiF:Mg,Cu,Si. This TLD (LiF:Mg,Cu,Si) with its improved thermal stability (Lee et al., 2006) appears capable to withstand much faster heating rates. For solid TLDs used in routine dosimetry, shifting of glow peaks to higher temperatures at fast heating rates requires a heating to higher temperatures to record a glow curve (Pradhan, 1995). The importance of the study lies in ensuring the usefulness of this material for personal dosimetry applications in which there is a requirement for evaluating a large number of dosimeters in the shortest possible time, obviously by using a fast heating rate. Apart from the integrated TL under a glow curve, the shape of the curve could also provide useful information on exposure; therefore, changes in the shape due to reasons other than radiation need to be ensured. In routine use, a change in the heating rate during readout cannot be ruled out due to various reasons including a varying contact with the heater.

2. Material and methods

LiF:Mg,Cu,Si TLD pellets of thickness 0.8 mm and diameter 4.5 mm (Lee et al., 2006) were used in this study. Studsvik ^{90}Sr–^{90}Y beta-ray reference irradiator (Model no. 6527) was used for an irradiation to about 14 mGy equivalent of ^{137}Cs gamma rays. Oven used for the annealing/heat treatment had accuracy better than ±1 °C. During annealing/heat treatment, the TLDs were held on a 0.25 mm thick platinum plate of size 5 × 5 cm^2. The TL readouts were taken in a Harshaw 4500 TLD reader using a contact heating where the temperature of the heater strip (planchette) is recorded as an indicator of the

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temperature of a TLD. The recommended flow of N_2 gas in the TLD reader was maintained during the readout. For recording the glow curves up to a maximum temperature of 300 °C, the heating rates of 1, 2, 5, 10, 20 and 30 °C s^{-1} were used and the TL readout times at these heating rates were 250, 126, 50, 26, 13 and 10 s, respectively. A region of interest facility available in the TLD reader was used to evaluate the responses of different glow peaks. A post irradiation annealing (PIA) at 160 °C for 10 min was used to remove the preceding lower temperature glow peaks and to obtain a thermally isolated main glow peak. The estimation of full width at half maxima (FWHM) of the isolated main glow peak were carried out by copying the ASCII files from the TLD reader to Excel and then moving to Origin on a separate PC. For the estimation of thermal lag in 0.8 mm thick TLD pellets, TLD powder grains of average size of 150 μm (ranging from 100 to 200 μm) were used and the thermally isolated glow peaks was recorded at different heating rates. The TLD powder grains were spread (no overlapping of grains) on the heating planchette ($6 \times 6\,mm^2$) of the TLD reader and the powder mass was kept ranging between 1.5 and 2.3 mg for the readouts. The precision in the measurements of TL readouts was always better than ±3% (1σ).

3. Results and discussion

Fig. 1 shows typical glow curves of 0.8 mm thick LiF:Mg, Cu,Si pellets recorded 30 min after the irradiation by ^{90}Sr–^{90}Y beta rays by using heating rates of 1, 10 and 30 °C s^{-1}. The glow curve structure is similar to that of LiF:Mg,Cu,P (Luo et al., 2006). At a heating rate of 1 °C s^{-1}, there are three well separated glow peaks at 105, 154 and 205 °C. To keep the nomenclature the same as that normally used for LiF:Mg,Cu,P, these peaks for LiF:Mg,Cu,Si were denoted in an ascending order of the temperature as peaks 2, 3 and 4. The contributions of the integrated area under peaks 2, 3 and 4 were 6.0%, 6.3% and 84.7%, respectively, of the total TL area of the combined glow curve at a heating rate of 1 °C s^{-1}. Peak 4 was the main dosimetric peak with a feeble tail on its higher temperature side which has negligible contribution to the total TL (Lee et al., 2006). In the use of the region of interest facility provided in the TLD reader, a dosimeter to dosimeter dependent variation of temperature interval for recording the area around a peak was from 41 to 49 °C for peak 2, 40 to 48 °C for peak 3 and 49 to 55 °C for peak 4 with little correlation with the heating rate. With the increase in the heating rate the overlapping of the peaks increased and at 30 °C s^{-1}, peaks 3 and 4 appeared inseparable.

Fig. 2 shows the glow curves of the 0.8 mm thick LiF:Mg,Cu,Si TLD pellets at a heating rate of 30 °C s^{-1}. The glow curve recorded 30 min after the irradiation exhibited a well separated peak 2 and peak 3 merged with the main dosimetric peak. The glow curve recorded after room temperature storage of 10 days following the irradiation is void of peak 2. However, even 10 days after the exposure, peak 3 (Fig. 2) remains significant (though reduced). The thermal bleaching by PIA of 160 °C for 10 min is able to remove the lower temperature peaks 2 and 3.

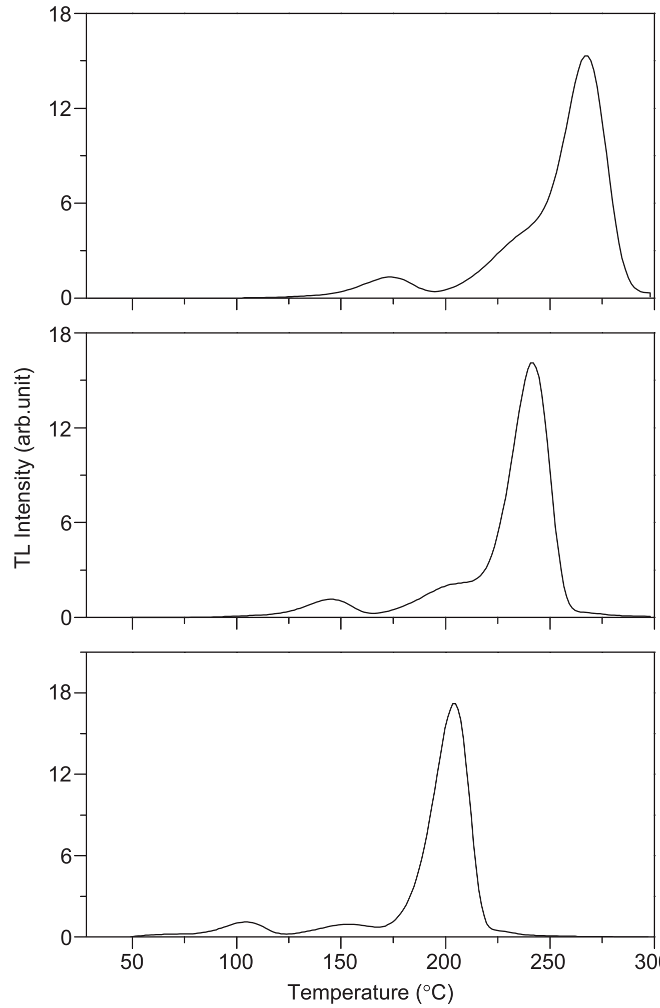

Fig. 1. Typical glow curves of 0.8 mm thick LiF:Mg,Cu,Si TLD pellets recorded 30 min after an irradiation. The heating rates for the bottom, middle and top curves were 1, 10 and 30 °C s^{-1}, respectively. The TL intensities should not be intercompared as the glow curves are not corrected for the sample to sample variations.

Table 1 shows the shifts in the temperatures of glow peaks with increasing heating rates. These were considered qualitatively similar to those reported by Luo et al. (2006) and Stadtmann et al. (2006) for LiF:Mg,Cu,P. For the 0.8 mm thick TLD pellets, the sample to sample variation in the peak temperature (not in the TL response) increased with heating rate due to the contact heating. In eight TL readouts at 30 °C s^{-1}, the temperature of the isolated peak 4 varied from 260 to 292 °C (275.8 ± 4.4 °C 1σ) for the 0.8 mm thick TLDs and from 212 to 216 °C (±0.6 °C) for 150 μm TLD powder grains. The variations for the TLD pellets were also much smaller at lower heating rates (±1.3 °C at 10 °C s^{-1} and ±1.1 °C at 5 °C s^{-1}). The heating rate dependent thermal lag for the 0.8 mm thick pellets was 62 °C higher than that of 150 μm grains of the TLD powder (Table 1) at a heating rate of 30 °C s^{-1}. Information on the shift in the peak temperature is necessary to arrive at the maximum readout temperature at a heating rate to cover the glow curve and to ascertain the peak shape.