ANALYSIS OF THE DOSIMETRIC PEAK OF GRAPHITE MIXED MgB_4O_7:Dy TLD

por

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ABSTRACT--Magnesium borate (MgB_4O_7:Dy) has been used as beta dosemeter quite successfully when mixed with graphite. Literature quotes different temperatures for the dosimetric peak at the same heating rate. This works shows that, for the same heating rate of 1°C.s^{-1}, the use or not of a pre-reading heat treatment of 100 C for 10minutes, affects the peak temperature, indicating that it is composed of more than one peak and/or it has kinetics of order different from 1. The parameters of two peaks, one at 133°C (order 1) and another at 156°C (order 2), which ajusted a experimental glow curve are presented.

INTRODUCTION

Magnesium borate MgB_4O_7:Dy has been used as a beta dosemeter quite successfully when mixed with graphite (Prokic, 1982; 1985; 1986). The carbon absorbs most of the light generated below the surface of the thermoluminescent dosemeter (TLD) making the layer which effectively contributes to the TL reading quite thin and, therefore, adequate for beta dosimetry. Before using the chips of MgB_4O_7:Dy mixed with graphite in the dosimetry of beta applicators used in therapy, we decided to investigate their TL characteristics, specially because literature quotes the temperature of the dosimetric peak at various values from 158°C to 217°C, as shown in table 1. Such temperatures were obtained from TLDs either mixed with graphite or not, irradiated with beta- or gamma-radiation. The glow curves were generated at different heating rates, which, however, do not explain the discrepancies observed. In this work the behaviour of the dosimetric peak and its kinetics were investigated.

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MATERIAL AND METHOD

The chips of Magnesium borate mixed with graphite used in this work were manufactured at the Boris Kidric Institute of Nuclear Sciences, Yugoslavia, and have a diameter of 4.2mm and a thickness of 1.0mm. No special pre-irradiation treatment is necessary since the reading process is sufficient for annealing the TLDs (Prokic & Christensen, 1984). Furthermore, it has been reported that repeated annealing at 300°C changes the TLDs' sensitivity (Ranogajec-Komor et al., 1984). The chips were irradiated with gamma-radiation from Co-60, under electronic equilibrium conditions, at the National Laboratory of Ionising Radiation Metrology (LNMRI) at dose levels of 0.25Gy and 2.5Gy. They were read at the Brazilian Centre for Physical Research (CBPF) in a computerised photocounting system designed and built by one of the authors (Souza). The reading process, sampling and data acquisition are all controlled by computer. In the case of the heating system, the actual heating rate is measured and registered at every 0.5s during reading time. The acquired data are recorded in floppy discs.

Table 1 - Temperature of the dosimetric peak of MgB_4O_7:Dy

Reference	Temperature (°C)	Heating rate (°C s^{-1})
Prokic, 1980	210	
Driscoll, Mundy & Elliot, 1981	200	10
Barbina et al., 1982	190	
Prokic, 1982	217	
Oduko et al., 1984	170	1
Prokic, 1985	190	11
Ogunleye, Richmond & Cash, 1985	190	
Prokic, 1986	200	
Uchrin, 1986	158	5
Ranogajec-Komor & Osvay, 1986	173	10
Campos & Fernandes, 1990	180	9.7

RESULTS

Tab-1 shows that, for the same heating rate (around 10°Cs^{-1}), four groups reported different values for the temperature of the dosimetric peak: 173°C, 180°C, 190°C and 200°C. This could be due to the dosemeters' opacity which only enables detection of the light emitted near the surface. This emphasises the importance of the difference between the temperatures of the top and the bottom surfaces of the TLD, which depend on its thickness and thermal conductivity. Another important influence on the peak temperature is the heating rate, although its effect should decrease for lower rates. Another reason for differences in the dosimetric peak temperature could be the fading induced by a pre-reading heat treatment or due to the time elapsed between irradiating and reading the TLDs. In this case, it should be expected that the dosimetric peak has kinetics of order different from 1 or it is the sum of several peaks of different stability at room temperature.

Table 2 summarises our findings with different dose, heating rate and the use or not of a pre-reading heat treatment of 10 minutes at 100°C. It can be observed that the total dose does not affect the peak temperature, which was 177°C for a heating rate of 5°C%.s^{-1}. For all samples, treated or not, the peak temperature increased with increasing heating rate, while, for samples read at the same heating rate, it is shown that theature increased with increasing heating rate, while (Figure 1). However, further work is necessary since, for some conditions, only one sample was analysed.

Table 2-Temperature of the dosimetric peak at different conditions

Dose (Gy)	Heat treatment (100°C, 10 min)	Heating rate (°C s^{-1})	T_{peak} * (°C)	n **
0.08	yes	5	177 ± 11	5
0.25	yes	5	177 ± 12	20
2.5	yes	1	164	1
2.5	yes	0.6	161	1
0.25	no	2	164 ± 11	6
2.5	no	1	160 ± 11	6

* T is accompanied of ± $n^{-1/2}$

** n is the number of samples analysed

In order to study the kinetics of the dosimetric peak, a fit of one of the experimental glow curves, which was obtained at a heating rate of 1°Cs^{-1}, w1as tried with the use of the Randall and Wilkins (1945a & b) equation for first order kinetics, through software specially developed by one of us (Souza). Figure 2 shows the experimental curve and the best fit that could be achieved without change in peak height and crossover of the curves. Lower values of the activation energy, associated with lower frequency factors, would cause the peak to remain at the same temperature but to become much wider thus producing crossover of the experimental and fitted curves. The figure indicates that neither branches are described by a first order curve, although the left branch could be further adjusted by the introduction of the peak 1around 120°C reported in the literature (Barbina et al., 1982; Prokic, 1985; 1986; Campos & Fernandes, 1990). However, the right branch of the curve remains without a good fit, as shown in Fig.3.

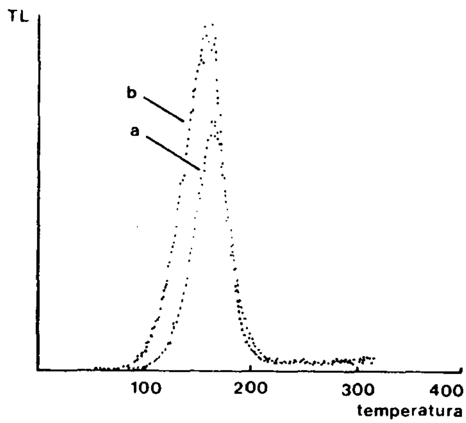

Fig.1 - Glow curves of magnesium borate submitted (a) and not submitted (b) to pre-reading rate treatment, corrected for the individual colibration factors of the samples analysed.

If the equation of Garlick and Gibson (1948) for kinetics of order 2 is used, a good fit is obtained for the right branch as can be seen in figure 4. If a peak of first order kinetics is added at 133°C, a very good fit of the whole experimental curve is obtained as shown in figure 5. Table 3 presents the parameters used in the fitting of these two peaks, although the frequency factor obtained for peak 1 is greater than what is considered reasonable, i.e., $10^{12}s^{-1}$ to $10^{14}s^{-1}$, which is related to the lattice vibration frequency.

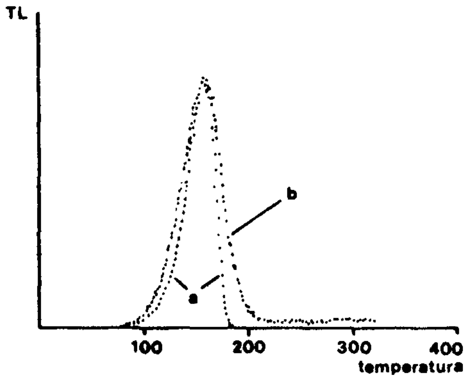

Fig.2 - Peak of first order kinetics (a) fitted to experimental glow curve (b)

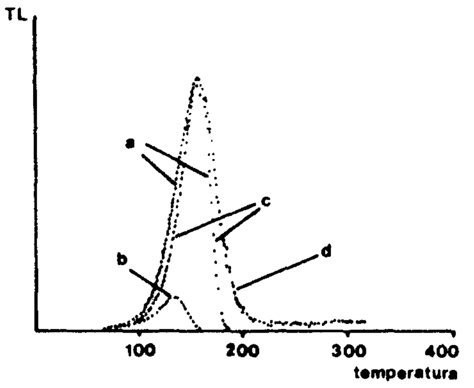

Fig.3 - The sum (a) of two peaks of first order kinetics (b) and (c) fitted to experimental glow curve (d).

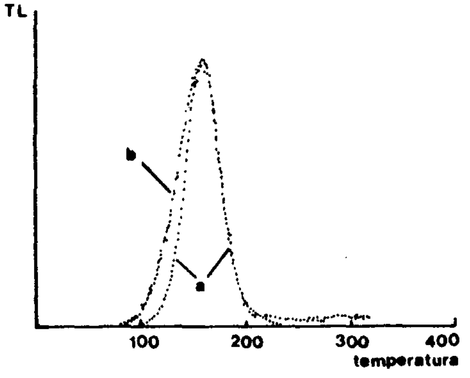

Fig.4 - Peak of kinetics of order 2 (a) fitted to experimental glow curve (b)

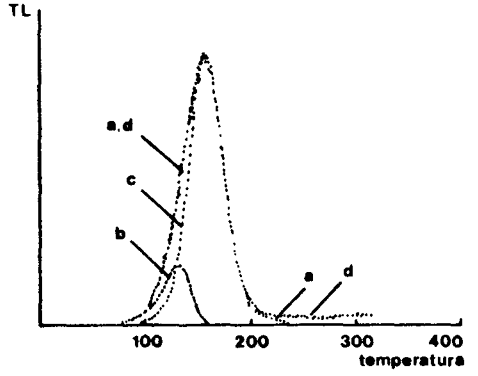

Fig.5 - The sum (a) of peak of kinetics order 1 (b) and peak of kinetics order 2(c) fitted to experimental glow curve (d)

Table 3 - Parameters of the dosimetric peak (heating rate of $1^{o}Cs^{-1}$)

Parameters	Peak 1	Peak 2
Temperature (°C)	133	156
Kinetics order	1	2
Activation energy (eV)	1.05	1.45
Frequency factor (s^{-1})	8×10^{15}	* 8×10^{12}

*for peak 2, the value presented is s^* and not s, the frequency factor
$s^* = s\, n^2 N_o^{-1}$, where n_o is the initial population
N is the number of traps

CONCLUSION

This work has shown that the pre-reading heat treatment affects the temperature of the dosimetric peak, suggesting that it is either composed of more than one peak and/or it has kinetics of order different from 1. A good fit of the experimental glow curves was obtained with the combination of two peaks, of kinetics of order 1 and 2 respectively (Table 3). However, further experimental work is necessary to confirm the kinetics order of both peaks.

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