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Study of the gamma radiation response of watch glasses

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Abstract

Some dosimetric properties of watch glasses were studied applying the thermoluminescence technique. The watch glass samples were powdered, and the selected grains were mixed with Teflon™. The mixture was pressed and sintered to produce pellets of watch glass–Teflon™ composites. The glow curves of the pellets show two peaks at 130 and 195 °C. Reproducibility of TL response was estimated to have a maximum coefficient of variation of 4.0%. The dose–response curve is sublinear between 0.5 and 20.0 kGy. The calibration curve is linear between 1.0 Gy and 1.0 kGy. The minimum detection limits were also determined. The gamma radiation dose response and the thermal stability of the materials were studied with the purpose to establish the best conditions of watch glasses for use in gamma radiation dosimetry.

Keywords: Thermoluminescence; Watch glasses; Radiation; Dosimetry; Gamma radiation

1. Introduction

Glass samples have revealed a potential use as radiation detectors since they are inexpensive, rigid, of small size, chemically inert and widespread materials (Bishay, 1970; Hassan et al., 2004; Ezz-Eldin et al., 1994; Gancheva et al., 2006; Da Costa et al., 2006, 2007; Engin et al., 2006). Some watch glasses have been reported to have potential use in ionizing radiation dosimetry (Wu et al., 1995). Commercial glasses have been subject of several studies (Caldas and Teixeira, 2002, 2004a; Rodrigues and Caldas, 2002; Narayan et al., 2007) with detailed descriptions of radiation effects and thermal treatments. Favourable characteristics for the development and utilisation of commercial glasses as dosimeters for high-doses (5–100 kGy) have been reported (Quezada and Caldas, 1999; Rodrigues and Caldas, 2002; Caldas and Quezada, 2002; Teixeira and Caldas, 2002). Dogan and Tugrul (2001) have obtained satisfactory results studying alkali-silicate and alkali-borosilicate glasses for use in high-dose dosimetry. Commercial or special glass dosimeters are important for the different high-dose levels, e.g. in medical, industrial and food irradiation applications. Glass dosimeters may be used in several high-level exposure applications, employing mainly densitometry, optical absorption, spectroscopy, thermoluminescence (TL), and electron spin resonance spectroscopy (ESR) (Bishay, 1970; Friebele and Griscom, 1979; Wu et al., 1995; Caldas and Teixeira, 2002). The profusion of electron-hole and recombination processes in glasses exposed to ionizing radiations is rich in interesting phenomena that involve charge and energy transfer processes which occur among populations of specific impurities and defects (Del Nery et al., 1994). By characterizing these resultant defect centres that occur when the glass is irradiated, it has been often possible to determine, or at least to postulate, pre-existing flaws in the glass structure that give rise to the defect centres. This paper describes a preliminary study of some essential dosimetric properties of watch glasses using TL. The results suggest that some kinds of watch glasses can be employed as TL dosimetric materials.

2. Materials and methods

The glass samples were powdered, and grains were obtained with diameter between 0.074 and 0.177 mm. The grains within the selected range of sizes were mixed with powdered Teflon™ (in open atmosphere of nitrogen), in the proportion

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of 1(watch glass):2(Teflon™). The mixture was pressed to 1.6×10^{11} N/m^2 and watch glasses–Teflon™ pellets of 50 mg with dimensions of 6.0 mm diameter and 0.8 mm thickness were produced. The pellets were sintered at 300 °C/1 h, followed by a 400 °C/1.5 h thermal treatment and slowly cooled. For the re-utilization purpose it was assured that the repetition of the new irradiation and further reading was free of spurious residual TL, by heating the pellets at 300 °C/1 h. The gamma irradiations of the pellets were performed with sources of ^{60}Co and the reading of the TL glow curves was carried out by using a Harshaw TL reader of Nuclear Instruments Systems, model 2000 A/B, heating rate of 10 °C/s; the data acquisition was obtained with a ADC-212 Pico Technology Ltd. software and a personal microcomputer.

3. Results and discussion

A group of 10 numbered pellets of watch glasses–Teflon™ composites were submitted five times to an identical procedure of thermal treatment of 300 °C/1h (defined for re-utilization) followed by the irradiation at 10 Gy (^{60}Co) and TL reading. The maximum variation coefficient was 4.0%.

The glow curves of watch glass–Teflon™ pellets of two different pieces (A and B) show two peaks at 130 and 195 °C (Fig. 1).

The fading of the TL response of glasses was already studied (Caldas and Teixeira, 2004b; Narayan et al., 2007).

To remove the TL peak 1 (130 °C) of the pellets of watch glass–Teflon™ composites, thermal treatments at 130 °C during different time intervals: 5, 10, 15, 30 and 60 min were tested (Fig. 2). The thermal treatments (10–60 min) presented the same results showing stability of the TL peak intensity. Therefore, the time interval of 10 min was chosen for the thermal treatments.

For the reutilization study of the TL response of the pellets, several thermal treatments at 300 °C were tested; preheating times from 10 to 60 min gave the same results. The best results were obtained with the thermal treatment of 300 °C/60 min: the TL response returned to the initial conditions, reproducing the same measurements obtained prior to the second irradiation process.

The lower detection limits were obtained taking three times the value of the standard deviation of five measurements of five pellets composites thermally treated at 130 °C/10 min and

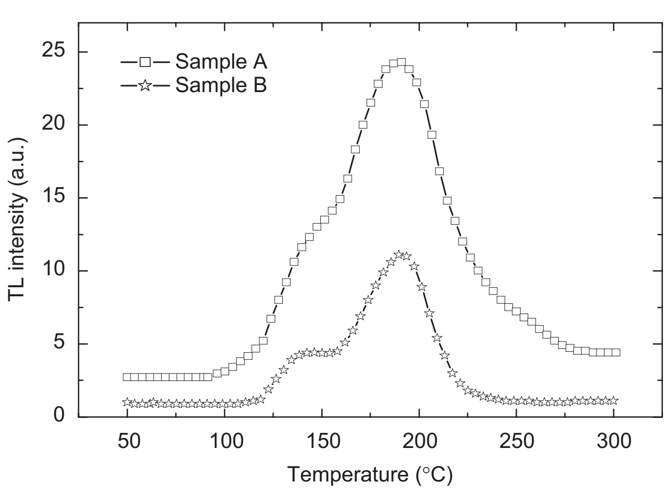

Fig. 1. TL glow curves of watch glass–Teflon™ pellets obtained 1 h after irradiation (10 kGy, ^{60}Co).

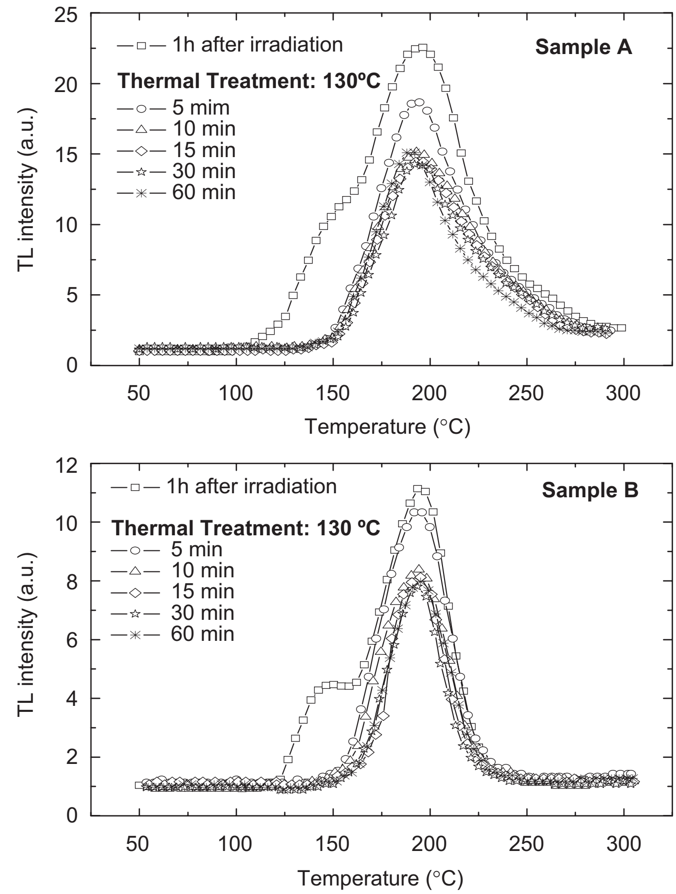

Fig. 2. TL glow curves of watch glass–Teflon™ pellets irradiated with 10 kGy (^{60}Co).

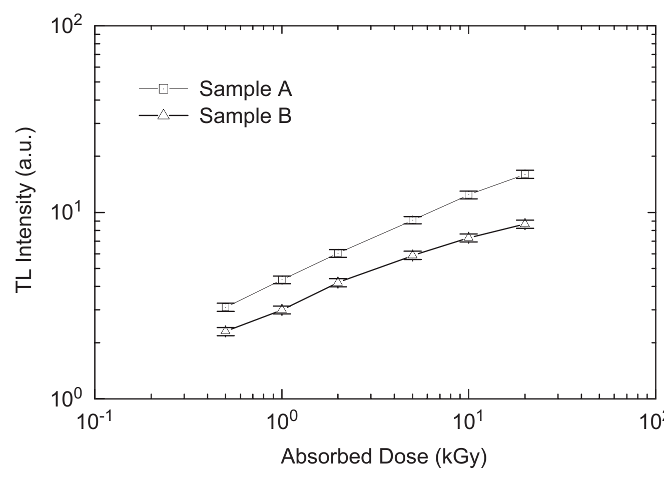

Fig. 3. Dose-response curves of watch glass–Teflon™ pellets.

non-irradiated, expressed in units of absorbed dose, giving the limiting dose of 1 Gy.

For the dose–response curves, the pellets were thermally treated at 130 °C/10 min and irradiated to doses between 0.5 and 20 kGy of ^{60}Co (Fig. 3). The temperature interval was integrated at 50–300 °C. Sublinear behaviour was observed for both samples.

4. Conclusions

The studied dosimetric characteristics (reutilization, reproducibility, dose response) show that the watch glasses can be used for high-dose dosimetry, when ensuring that the time interval between measurement and irradiation is the same as the one used during calibration. The advantages of these samples are reduced size, very low cost and easy handling.

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