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Thermoluminescence response of sodalime glass irradiated with photon and electron beams in the 1–20 Gy range

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ABSTRACT

The thermoluminescence response of a watch commercial glass was studied after irradiation with photons and electrons, in the range 1–20 Gy, of interest in accidental dosimetry; a linear response was obtained with both beams. This result, together with the satisfactory time stability of the thermoluminescence signal, indicates this glass as a potential material for retrospective dosimetry applications.

1. Introduction

Various authors have recently proposed the use of glass samples as ionizing radiation detectors in different fields (Correcher et al., 2009; Engin et al., 2010; Balogun et al., 2003); above all, there is an increasing interest on glasses which can be in contact or very close to exposed persons and can be used as emergency dosimeters. Glass has valuable properties such as easy handling, chemical inertness and rigidity. The radiation induced effects in the irradiated glass can be indeed employed for dose evaluation, by means of two physical techniques, i.e. thermoluminescence (TL) (Teixeira et al., 2008; Narayan et al., 2008) and electron spin resonance (ESR) (Gancheva et al., 2006; Teixeira et al., 2005).

In the present work, the TL response of a commercial watch glass was investigated using glass chips obtained by a simple cutting procedure. In particular, samples of disk-shaped sodalime watch commercial glass have been irradiated with a 6 MV photon beam and a 10 MeV electron beam, both used in radiation therapy. An analysis of the glow curve has been carried out in order to characterize the TL signal related to irradiation. For each beam, a linear dose response behavior has been found and the dependence on beam quality is under investigation. Furthermore, a high homogeneity has also been observed and the signal fading has been analyzed. These results suggest the use of watch glass for accidental dosimetry; work is in progress to investigate the possibility of applying the single aliquot regenerative dose (SAR) protocol (Hong et al., 2006) or the multiple aliquot additive dose (MAAD) method (Bassinet et al., 2006) for dose reconstruction.

2. Materials and methods

2.1. Sample preparation

Experiments were carried out with a commercial watch glass, provided by Ghignone U. & Co. (Milan, Italy), that is composed of the following main elements (weight percentage): SiO_2 (72.5%), Na_2O(12.7%), CaO(5.0%), MgO(6.0%), Al_2O_3(1.6%) and is classified as sodalime glass (Longo et al., 2010). Samples of disk-shaped glasses (diameter 30 mm, thickness 2.0 mm) were irradiated as a whole; after irradiation they were cut in little pieces (chip characteristics: size usually 3×3 mm^2, weight in the range 30–100 mg) suitable to be placed on the planchet of the Harshaw 3500 TL reader. No sample treatment was performed before TL measurements.

To study the time stability of the TL signal, chips cut from irradiated disks were read after increasing time intervals of storage under the following conditions: i) dark; ii) a mixture of natural and artificial light (laboratory conditions). The average temperature was in each case (20 ± 5) °C.

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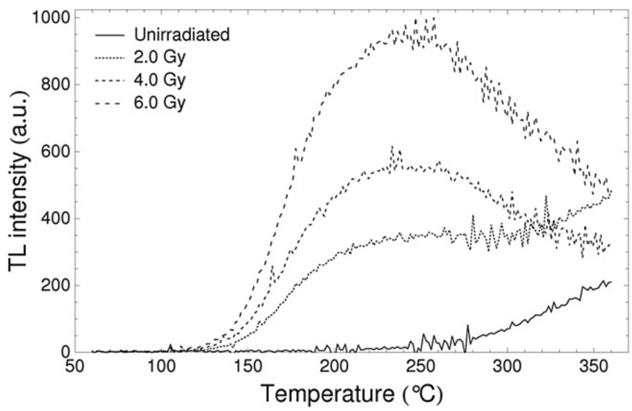

Fig. 1. Glow curves of glass chips unirradiated or irradiated with the electron beam at 2-4-6 Gy.

2.2. Irradiation

Irradiations were carried out with a 6 MV photon beam and with a 10 MeV electron beam, both produced by the Linear Accelerator Siemens Primus Low used in the Radiotherapy Unit of the ARNAS, Palermo. The samples were irradiated in the dose range between 1 and 20 Gy inside a perspex phantom. Dose values were calculated using the dose rate previously measured with a reference ionization chamber and the irradiation time, with an overall uncertainty of about 3%.

2.3. Thermoluminescence measurements

All the glow curves were recorded with an Harshaw 3500 TL reader; the instrumental parameters were set as follows: voltage 500 V, preheat at 60 °C for 10 s, heating rate 5 °C/s, final temperature 360 °C. A filter to partially reject black body radiation was used.

3. Results and discussion

3.1. Glow curve features

The glow curve of the irradiated glass shows a single peak, centered at about 230 °C, regardless the beam and the dose. As an example, Fig. 1 shows the glow curves of single chips cut from glass disks, previously unirradiated or irradiated with the electron beam at 2-4-6 Gy. The glow curve of the unirradiated sample overlaps with the planchet emission curve, indicating the absence of a significant contribution due to natural radiation. For each recorded glow curve, the integrated TL signal was calculated as the sum of the counts recorded by the TL apparatus in the temperature range 230°C ± 90 °C, and normalized to the chip mass. The background signal due to the planchet was always subtracted.

Table 1
Homogeneity test on chips cut from different glass disks irradiated at 15 Gy.

chip	mass/mg	TL signal/10^4	TL/mass
A	31.8	9.84	3094
B	60.4	17.7	2931
C	41.0	12.5	3049
D	45.9	14.8	3224
E	39.2	11.9	3036

3.2. Time stability of the TL signal

The time trend of the mass normalized TL signal was analyzed: two disks were irradiated at 2 and 5 Gy with photons, and subsequently cut in twenty-five chips each, stored as described in Section 2.1. For both storage conditions, the main reduction of the signal was observed to occur in the first 50 h, when it turned out to be between 70% and 80% of the original signal; afterward, the signal remained almost constant even after about one week. As an example, Fig. 2 shows the TL signal as a function of storage time (laboratory conditions) after irradiation at 2 Gy. The knowledge of the fading trend could be useful for application in retrospective dosimetry.

3.3. Homogeneity analysis

A check on the homogeneity of the TL response of chips taken from different glass disk samples, irradiated at the same dose, was first carried out. The glass chips differed among each other in size and mass; the dependence of the TL signal on the chip mass was therefore studied. Table 1 shows the results obtained with glass chips cut from disk samples irradiated at 15 Gy with the 6 MV photon beam; despite a variation in mass up to a factor of two, the TL signal normalized to the mass shows a coefficient of variation of only 3.5%; similar results were obtained with all samples, regardless the dose.

3.4. TL signal vs. dose

To study the dose dependence of the TL signal, glass disk samples were irradiated, each one at a specific dose up to 20 Gy,

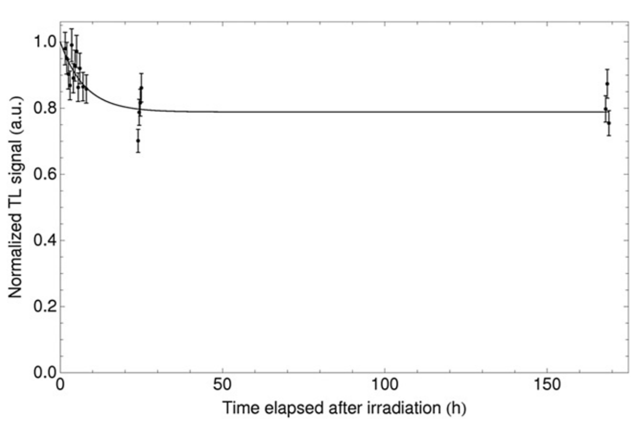

Fig. 2. TL signal fading of glass irradiated at 2 Gy (laboratory conditions).

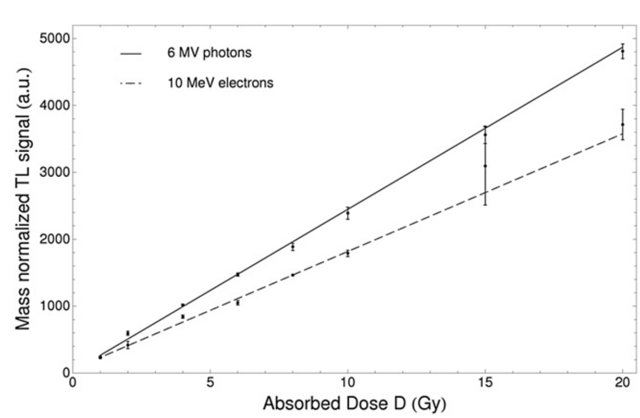

Fig. 3. TL vs dose response (experimental data and best fitting straight line).

Table 2
Best fitting parameters for the TL signal vs dose D analysis (TL = a + bD).

	a	b	R^2
6 MV photons	23 ± 11	242 ± 4	0.998
10 MeV electrons	57 ± 16	176 ± 3	0.999

with the beams used in this work; three chips were taken from each disk, and the corresponding glow curves were recorded. For each chip, the TL signal was obtained as described in Section 3.1.

For each dose D, the average TL signal of the three chips was used to study the dose response behavior. The Lowest Detectable Signal (LDS) was evaluated as the average TL signal of ten unirradiated chips plus three standard deviation; the TL signal of the chips irradiated at the lowest dose (1 Gy) was more than four times the LDS.

Fig. 3 reports the best fitting calibration straight lines (TL = a + bD) obtained for watch glasses exposed to 6 MV photons and 10 MeV electrons, respectively. A good linear response was observed for each beam, as also confirmed by the R^2 correlation coefficient. Table 2 shows the fitting parameters. The higher sensitivity observed for photons with respect to electrons could be due to the different Linear Energy Transfer (LET) of the two beams.

4. Conclusions

The results discussed in this paper show that the watch glass investigated in this work is potentially a good candidate for retrospective dosimetry in radiological emergency, due to its crucial features:

- The watch glasses are in contact with the exposed person
- Good physical and chemical features: chemical inertness, insolubility, rigidity, small size
- Easy sample preparation
- Homogeneity of the TL response
- Linearity of the TL response
- Time stability

Further analyses are required with other radiation beams, to better study the dependence of the TL response on the LET. The applicability of a method (SAR or MAAD) for retrospective dose evaluation will be investigated, even after irradiation of the glass in a mixed radiation field. To this aim, further study on the homogeneity, fading under various storage conditions and sensitivity stability are in progress.

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