HIGH DOSE DOSIMETRY USING GLASS DETECTORS IN ELECTRON BEAMS

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Abstract

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The suitability of four different kinds of commercial glass samples for high dose dosimetry in electron beams was verified, with the main objective being to obtain a system that would allow immediate confirmation of irradiation (by colour changes in the material) as well as rapid and economic dose evaluation. Calibration curves were obtained through optical absorption and thermoluminescence measurements, the glass detectors being irradiated with electron beams of 1.06 MeV from a Dynamitron accelerator. The thermal fading at room temperature was studied over 54 days. The results show that glass samples can be utilized as reusable routine dosimeters, with the main advantage of very low cost, using relatively simple readout equipment as a densitometer or a single beam spectrophotometer, using non-destructive techniques and hence allowing repetition of the measurements if necessary.

1. INTRODUCTION

X rays, radionuclide sources of gamma radiation and electron beams are used for radiation processing. The dosimetry plays a very important role in quality control programmes. Almost all dosimetric systems for high doses have some disadvantages. Several dosimetry methods used in radiation processing have been discussed [1–3], including glass [4–5], though in this latter case only for gamma radiation. A comparative study of electron beam dosimeters for radiation processing was made by Thalacker et al. [6]. Although the alanine dosimeter constitutes one of the best and most precise transfer systems for high doses, the cost of an electron spin resonance (ESR) readout instrument required for this type of dosimeter prohibits its use for routine dosimetry in radiation processing plants.

Weyl [7] showed as early as 1949 the possibility of using special glass for dosimetry. Zheng et al. [4] tested window glass as a routine dosimeter for high doses of gamma radiation, using the spectrophotometric technique. These authors observed a linear relationship with the absorbed dose (^{60}Co radiation) between 0.2 and 50 kGy, with no appreciable dose rate dependence between 60 Gy·h^{-1} and

2.4 $kGy \cdot h^{-1}$ and no appreciable temperature dependence for irradiation at temperatures in the range 0 to 50°C. The thermoluminescence phenomenon was recently applied to high dose dosimetry (gamma radiation) using plastic samples [8]. Caldas [5] studied the dosimetry properties of Brazilian glass samples through optical absorption (OA) and thermoluminescence (TL) measurements. These samples presented reutilization possibilities, batch uniformity and a useful range between 1 and 10^4 Gy in the TL case, and between 10^2 and 10^3 Gy for the OA case, but the response fading has to be taken into consideration.

The present work aims to verify the possibility of the application of commercial glass samples for high dose dosimetry in electron beams, in order to obtain a simple and economic evaluation system.

2. MATERIALS AND METHODS

Four different kinds of Brazilian commercial glass samples were studied, denominated A, B, C, and D. Their dimensions are 10 × 10 mm, with a thickness varying between 1.85 and 3.75 mm.

The detectors were irradiated in electron beams of 1.06 MeV from the Dynamitron accelerator of the Instituto de Pesquisas Energéticas e Nucleares in similar conditions to those under which the polymer treatment processes are normally performed, varying the absorbed dose in glass between 2.5 and 12.5 kGy.

The changes in optical densities were measured using a Macbeth-Ansco model TD 504 (USA) densitometer and a Micronal model B 34211 (Brazil) single beam spectrophotometer. In the latter case the measurements were taken at the wavelengths of 415, 451 and 541 nm. A Harshaw Chemical Co. model 2000 AB (USA) system was used with a heating rate of $6°C \cdot s^{-1}$ for the thermoluminescence readings. The glow curves taken between room temperature and 300°C presented a peak at about 180°C, as in the case of gamma radiation [5].

All data in the calibration curves represent the mean values obtained for three samples, corrected for sensitivity and mass (in the case of thermoluminescence). Measurements were always taken before and after the irradiations.

3. RESULTS

In order to verify the possibility of application of the Brazilian glass samples in high dose dosimetry in electron beams, several dosimetric properties were studied, i.e. reutilization, reproducibility and thermal fading; the minimum detectable absorbed doses and the calibration curves were also determined.

3.1. Reutilization and reproducibility

The detectors were submitted ten times to an irradiation of 10 kGy and a heat treatment of 300°C during 15 min for this study. No appreciable decrease in the responses could be observed. The samples are therefore reusable at least ten times without the need for new calibration. Taking measurements respectively with the spectrophotometer, the densitometer and TL system, the obtained reproducibility varied between 3.0 and 5.6%, 4.2 and 6.4%, 9.0 and 11.5%.

3.2. Minimum detectable absorbed dose

Taking three times the standard deviation of ten measurements of unirradiated samples, the minimum detectable absorbed dose was determined for each kind of glass sample. The values presented a variation between 200 and 440 Gy (spectrophotometer), 370 and 400 Gy (densitometer), 1.5 and 3 Gy (TL system).

3.3. Thermal fading

The thermal fading at room temperature was studied taking daily measurements over 54 days of three irradiated (10 kGy) samples of each kind of glass. As can be seen in Fig. 1, initially the OA response of the glass samples C (spectrophotometer, 415 nm) shows a rapid decay, but after about 8 days it becomes linear and slow. The associated uncertainty in these measurements was 3.2%. The glass

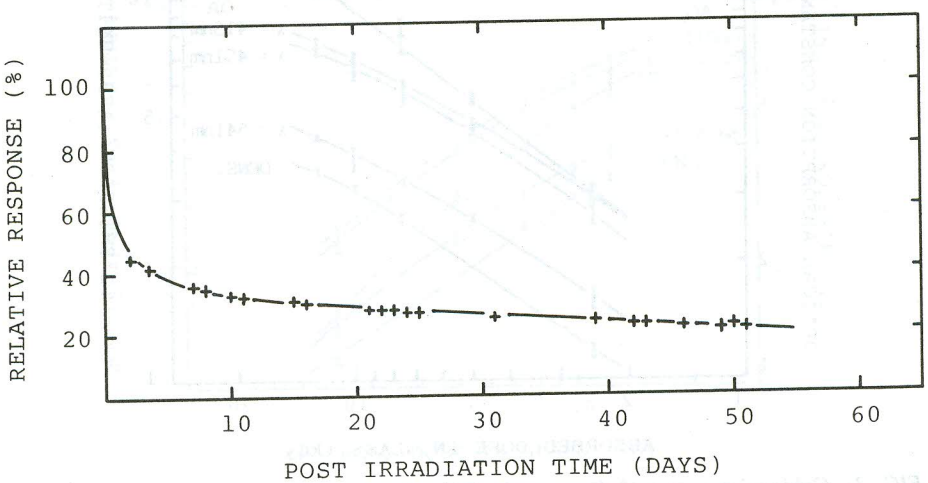

FIG. 1. Thermal fading at room temperature of the glass samples C irradiated with electron beams (1.06 MeV, 10 kGy). Measurement technique: spectrophotometer (λ = 415 nm).

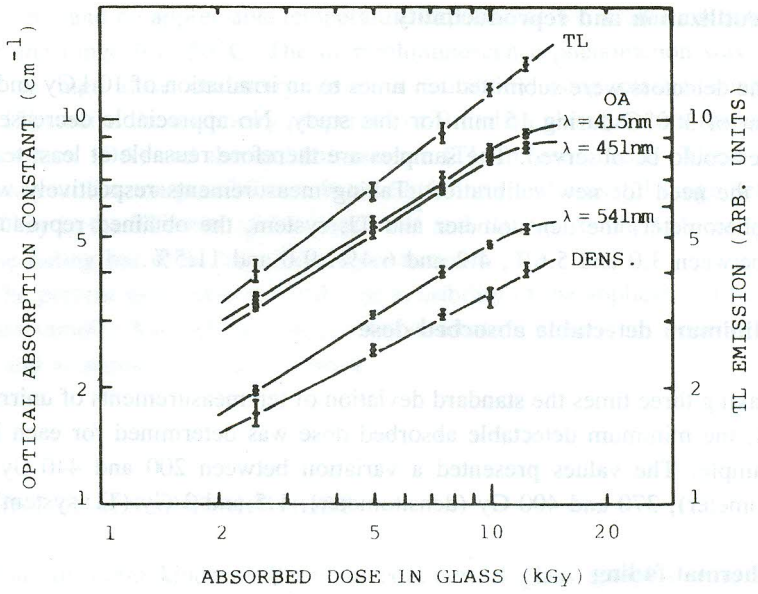

FIG. 2. Calibration curves of glass samples A irradiated with electron beams. Measurements taken with densitometer (DENS.), spectrophotometer (OA) and thermoluminescent system (TL).

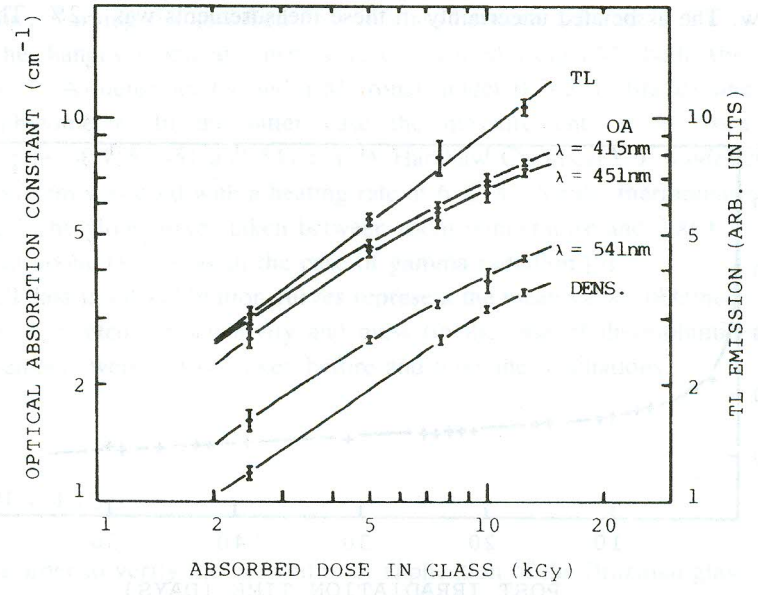

FIG. 3. Calibration curves of glass samples B irradiated with electron beams. Measurements taken with densitometer (DENS.), spectrophotometer (OA) and thermoluminescent system (TL).

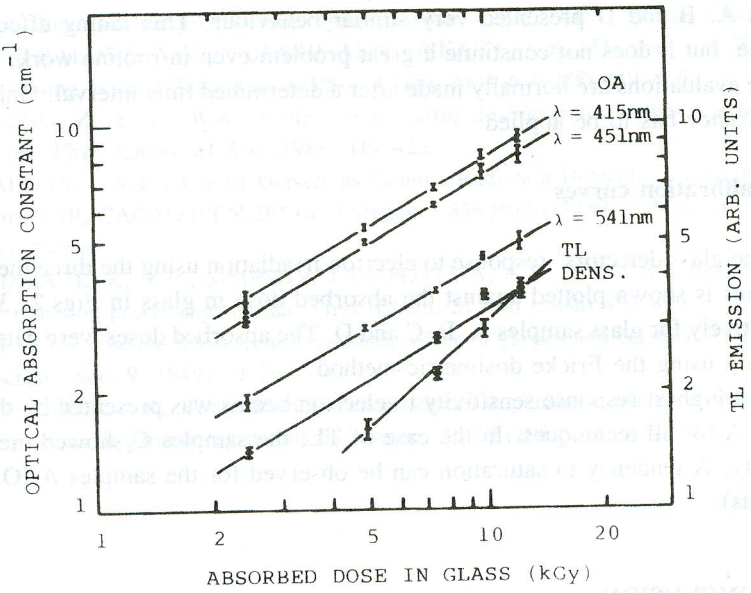

FIG. 4. Calibration curves of glass samples C irradiated with electron beams. Measurements taken with densitometer (DENS.), spectrophotometer (OA) and thermoluminescent system (TL).

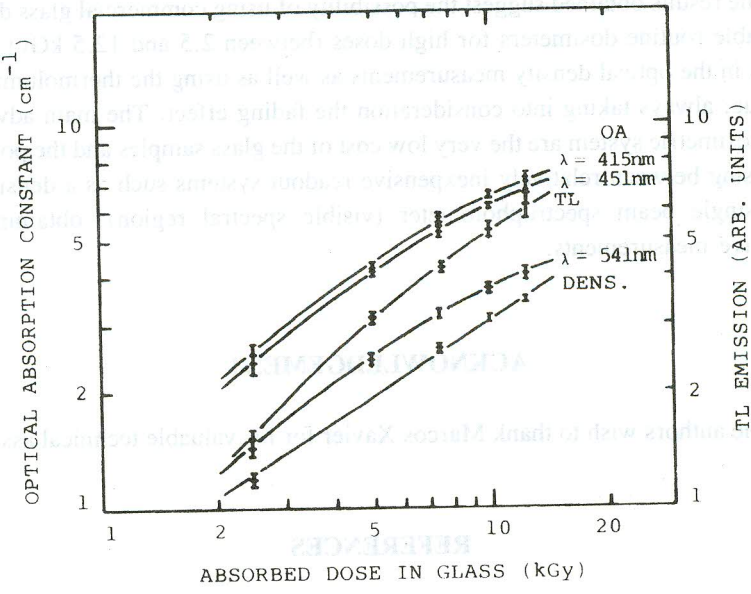

FIG. 5. Calibration curves of glass samples D irradiated with electron beams. Measurements taken with densitometer (DENS.), spectrophotometer (OA) and thermoluminescent system (TL).

samples A, B and D presented very similar behaviour. This fading effect is not desirable, but it does not constitute a great problem even in routine work, because the dose evaluations are normally made after a determined time interval. Only a correction factor has to be applied.

3.4. Calibration curves

The glass detectors' response to electron irradiation using the three measuring techniques is shown plotted against the absorbed dose in glass in Figs 2, 3, 4 and 5 respectively for glass samples A, B, C and D. The absorbed doses were determined previously using the Fricke dosimetric method.

The highest response sensitivity to electron beams was presented by the glass samples A for all techniques. In the case of TL, the samples C showed the lowest sensitivity. A tendency to saturation can be observed for the samples A (OA measurements).

4. CONCLUSION

All four kinds of glass samples can be used as Yes/No dosimeters, by changes of their colour due to electron irradiation, allowing immediate confirmation of irradiation.

The results obtained suggest the possibility of using commercial glass detectors as reusable routine dosimeters for high doses (between 2.5 and 12.5 kGy) through changes in the optical density measurements as well as using the thermoluminescent technique, always taking into consideration the fading effect. The main advantages of this dosimetric system are the very low cost of the glass samples and the possibility of choosing between relatively inexpensive readout systems such as a densitometer and a single beam spectrophotometer (visible spectral region), obtaining non-destructive measurements.

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