Effect of Thermal Treatments on Different Commercial Glasses for use as Radiation Detectors

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Abstract. The use of commercial transparent and colored (bronze, brown and green) glasses for high dose dosimetry in routine and as gamma radiation detectors have been investigated in this study. The different dosimetric techniques were employed using a densitometer, a spectrophotometer, and a thermoluminescent reader. However, these kinds of samples present a strong post-irradiation thermal decay at room temperature, that is a problem for high dose dosimetry purposes. In this work effort have been given to these material characteristics, submitting the glass samples during different time intervals to different thermal treatments. The different kinds of glass show possibility of their utilization for high doses, with the advantages of very low cost and easy handling.

1. Introduction

The interest for the radiation processing of high doses has been presenting advantagens for application in different areas as: food preservation, sterilisation of pharmaceutical products and treatments of several materials [1,2].

At the Calibration Laboratory of IPEN, Brazil, glass samples have been studied in relation to their main dosimetric properties: response reproducibility, retaliation, bath uniformity, detection range and dose response [3,4,5]. These kinds of glasses (transparent, bronze, brown and green) presented suitable characteristics as dosimeters of high doses (5kGy to 100 kGy), depending on the evaluation technique. As applications, glass radiation detection systems were tested in a flower irradiation process [4] and at a large irradiator [5], presenting adequate results and showing their usefulness for high dose dosimetry.

However, they present the disadvantage of the initial fast thermal decay in the first twenty-four hours after irradiation. This effect can be avoided by taking measurements always at the same time interval after each irradiation, or using special thermal treatments after the glass irradiation [6,7]. Caldas and Quezada [6] suggested a post-irradiation thermal treatment at $130^{o}C$ during 10 min in the case of transparent window glass. However, at this temperature, the glass response presents a deep decline, and later it stabilizes.

In this work different post-irradiation thermal treatment were realized to determine the temperature, wich destroys the color centers that decay quickly, and use the other color centers for dosimetric procedures.

2. Materials and Methods

The samples of commercial glasses (transparent, bronze, brown, and green), were produced by Cebracê, Brazil, by the "float" process at 1600 °C. This technology provides uniform thickness of a homogeneous mass, free of optical distortions. These samples were cut in the dimensions of 10x12x3 mm^3 for the measurements of optical density. For the thermoluminescence technique, the glass sample was cut into pieces of 4x7x3 mm^3 (0,210 g).

An analysis of the four types of glasses was obtained using the neutron activation technique at the Radiochemistry Department of IPEN, presented in Table 1. The concentrations of these elements in the colorless samples were only 645 $\mu g.g^{-1}$ (Fe) and 0.28 $\mu g.g^{-1}$ (Co). In the mixture used for fusion at Cebracê, the bronze color was achieved by adding 24 ppm Se, 0.38% Fe and 34 ppm Co; in the case of the brown samples, 16 ppm Se, 0.44% Fe and 68 ppm Co was sufficient. The green color was obtained by adding 0.53% Fe only.

Table 1. Results of neutron activation analysis of colored glass samples (the intervals correspond to 1σ)

Element	**Concentration ($\mu g.g^{-1}$)**			
	Transparent glass	Bronze glass	Brown glass	Green glass
Ca	66000±6000	68000±5000	65000±6000	73000±5000
Na	9.97±0.04	9.75±0.04	9.86±0.04	9.61±0.04
Rb	52±10	24±4	28±6	24±5
Fe	645±69	2409±256	2980±317	3368±358
Co	0.28±0.04	29±3	54±6	0.43±0.05

All irradiations were performed in air (room temperature) in the radiation field of a Gamma-Cell 220 (^{60}Co) system (dose rate of 4.48 kGy/h) under electronic equilibrium conditions achieved by covering the samples with 6-mm-thick Lucite plates.

Thermal treatments at 300°C during 30 minutes were applied to the glass samples for reutilization. The evaluation of glass samples was realized by using a simple densitometer M.R.A., Brazil, a Shimadzu UV-VIS scanning spectrophotometer, model 2101PC, double-beam and a Harshaw Chem. Co. thermoluminescence reader, model 200 A/B (heating rate of 10 °C). Due to the thermal fading of the glass sample spectra, all measurements in this work were taken exactly 1 hour after irradiations.

3. Results

The glass samples were irradiated with 5 kGy of gamma radiation. Their TL response and optical density response were recorded up to 60 days in order to verify their decay at room temperature. The glass response presented, after the first 24 hours post-irradiation time in the case of all three evaluation techniques, a reduction of about 25% for transparent glass, 20% for bronze glass, 22% for brown glass and 19% for green glass (Fig.1). Afterwards, the decrease rate slowed, tending to a constant value after about 30, 15, 20 and 12 days, using all techniques, for transparent, bronze, brown and green glass samples, respectively (Fig.1).

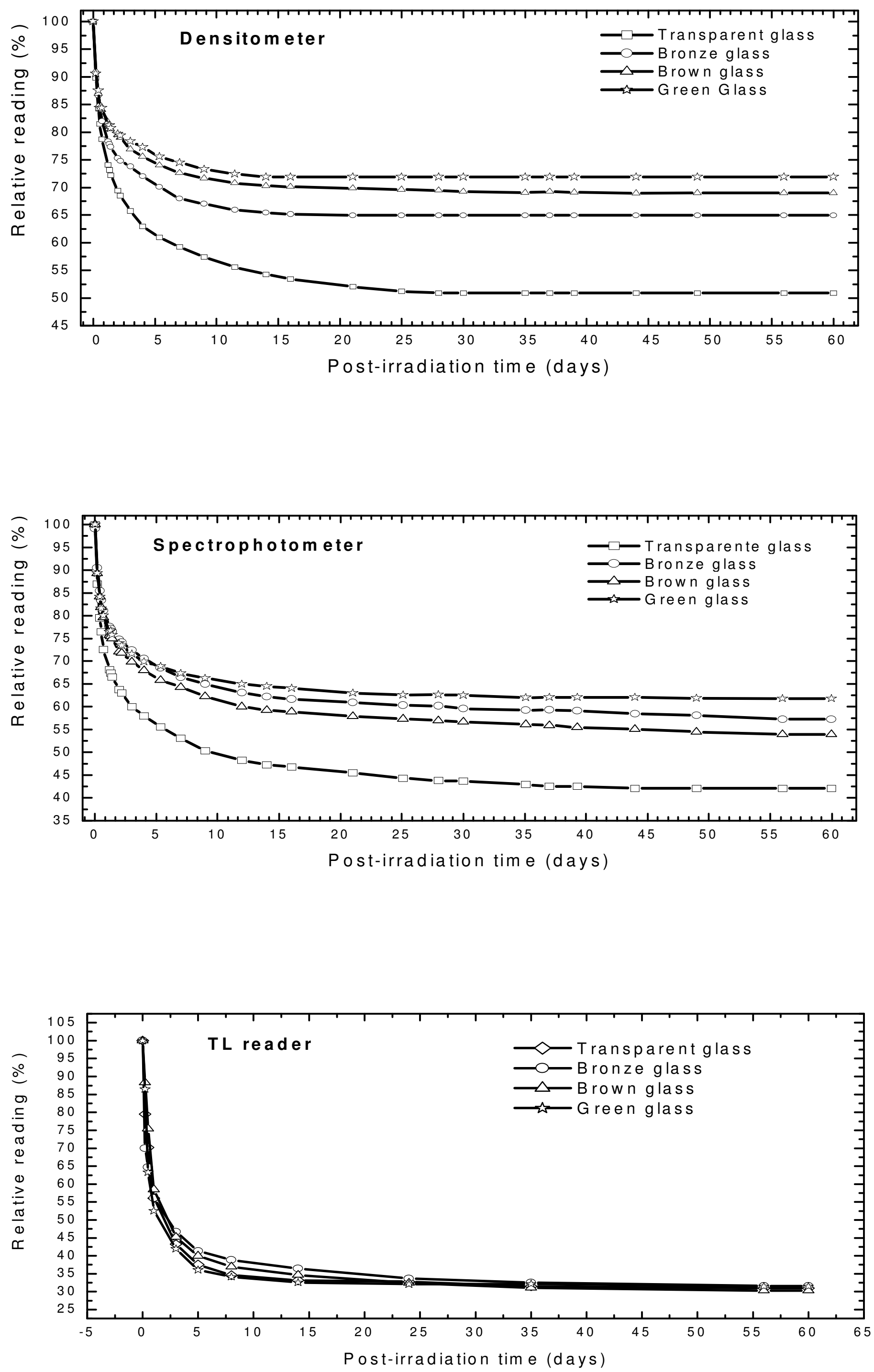

FIG. 1. *Thermal fading at room temperature up to 60 days of glass samples (transparent, bronze, brown and green), after an irradiation of 5 kGy (^{60}Co).*

The influence of post-irradiation thermal treatments on the glass samples response fading was studied after an irradiation of the glass samples with 5 kGy of absorbed dose. These glass samples were treated during 15 minutes at different temperatures, and the results are presented in Fig. 2, for measurements taken by the densitometer, the spectrophotometer and the TL reader. The thermal treatments were realized with the purpose of determining the temperature, which may destroy the instable color centers that fade rapidly at room temperature.

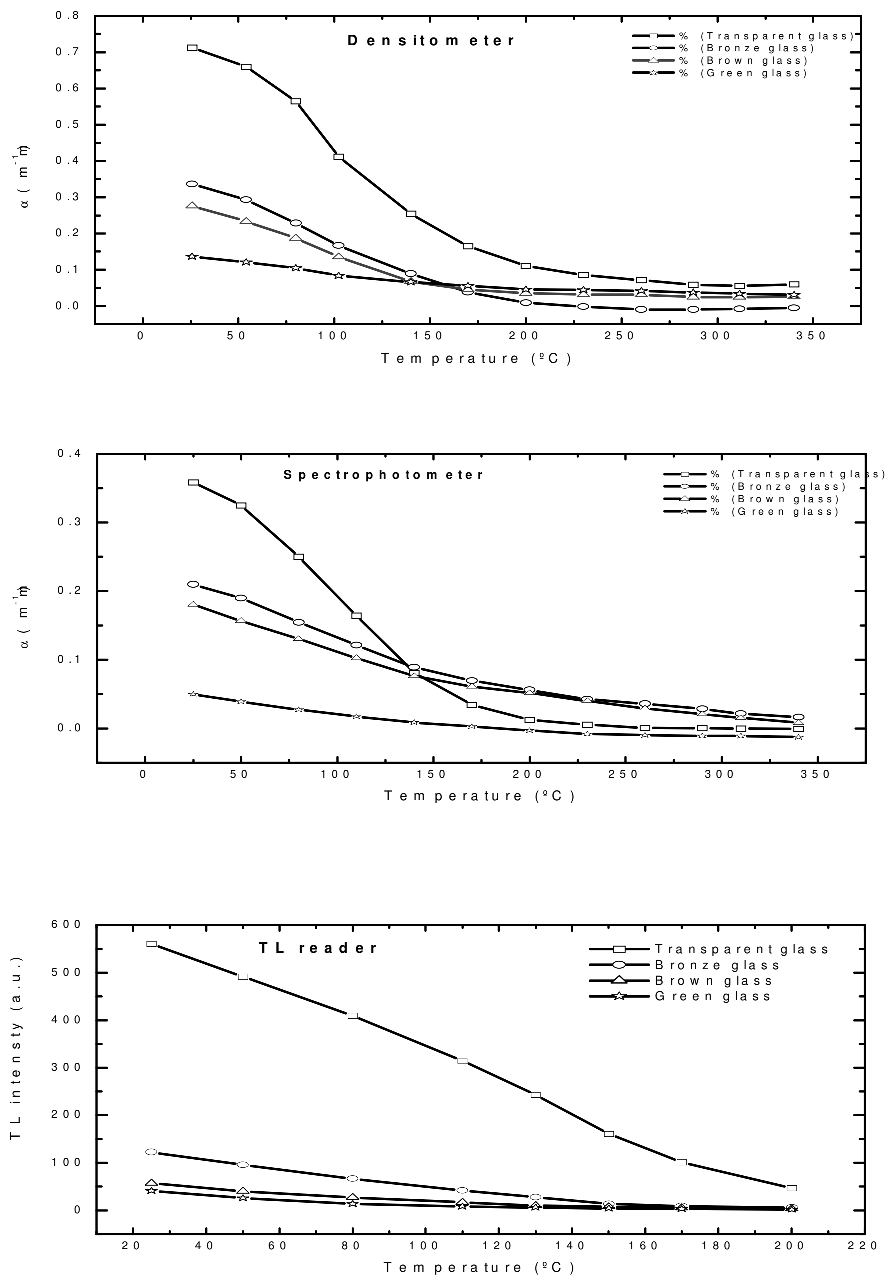

FIG. 2. *Thermal treatment for 15 minutes during different temperatures, at room temperature of glass samples (transparent, bronze, brown and green), after an irradiation of 5 kGy (^{60}Co). The measurements were taken by using a densitometer, a spectrophotometer and a TL reader.*

4. Conclusions

The post-irradiation thermal treatment of the glass samples showed that the absorbance and the TL peak decrease with the temperature in very similar ways. This suggests that the colour centres responsible for the absorbance at 420 nm (transparent glass) and at 380 nm (bronze, brown and green glass) are the same centres responsible for the TL peak.

The less intense TL peak is not favourable for dosimetric procedures because of its fading at room temperature.

Dosimeters of commercial glasses continue to be studied because of their potential use as high dose dosimeters. These materials present good reproducibility, and they can be reused or discarded because of their extremely low cost and relatively easy characterization.

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