COMMERCIAL WINDOW GLASS TESTED AS POSSIBLE HIGH DOSE DOSIMETER. ELECTRON AND GAMMA IRRADIATION

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The use of commercial window glass as possible high dose routine dosimeter has been investigated. Glass samples have been irradiated with doses in the range of 1–50 kGy using ^{60}Co γ source, 4 MeV and 12 MeV electron accelerators. The samples were given a post irradiation thermal treatment (150 °C for 20 min) in order to improve the post irradiation stability of the measured specific optical absorbance, since a rapid fading of the optical absorbance has been observed at room temperature immediately after irradiation. The optical absorbance measurements of the irradiated samples, kept in the dark and at room temperature, were carried on for several weeks. The samples submitted to heat treatment showed a decrease of about 10–15% of the specific optical absorbance that became much less pronounced after 10 days from the irradiation. The response of the window glass plates is energy and dose rate dependent. This study shows the feasibility of using commercial window glass as a routine dosimeter in a certain dose range after proper calibration in the irradiation plant where they are going to be used.

1. Introduction

The ionizing radiation-induced colour centres in many types of commercial glasses have been found suitable for radiation dosimetry [1, 2]. The use of glass samples as radiation dosimeters presents some advantages that make them attractive for the scope: they are recyclable (a thermal treatment at 300 °C for time >20 min is enough for re-use of the glass sample [3]), chemically inert, fast to measure, with little or no dependence on humidity and their use does not

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require special preparation. Beside that window glass, a common material that can be found everywhere, has the advantage to be very cheap. If its behaviour under γ and electron irradiation is fully studied and well characterized it can become a suitable material for environmental and radiation processing dosimetry. The main disadvantage presented by all types of glass detectors is the undesirable strong post-irradiation fading even at low temperature [4]. To overcome this problem it is advisable to submit the glass dosimeters to post-irradiation thermal treatment at 150 °C for 20 min and then measure the optical density at adequate time intervals, in this way calibration curves can be obtained for different time intervals after irradiation and subsequent thermal treatment [4].

The aim of this work is to investigate: 1) the dose rate and radiation energy effects on the response of commercial window glass irradiated with 3.4 MeV and 8.4 MeV electrons and ^{60}Co γ rays, and 2) the fading behaviour of the irradiated samples after post-irradiation thermal treatment.

2. Experimental

A commercial glass sheet, which composition is reported in [4], was cut into pieces of approximately 11x30 mm with c.a. 3 mm thickness for irradiation and optical measurements. To avoid grease contamination on glass surface, which may affect the absorbance measurements, the samples were carefully cleaned with ethyl alcohol. A thermal treatment at 300°C for 1h was used to get rid of any spurious optical signal. The optical spectra of non-irradiated samples were measured against air and used as reference to the optical spectra of the corresponding irradiated samples in order to obtain the irradiation induced changes of absorption.

Irradiations of the glass samples were done using electron accelerators and ^{60}Co γ source having the characteristics reported in Table 1. Dosimetry was done using the Fricke and ethanol-chlorobenzene chemical dosimeters. Electronic equilibrium was achieved by enclosing the samples as well as the chemical dosimeters in plastic phantoms with wall thickness of 0.4 g/cm^2. Dose reported here are referred as dose to water. As for the electron irradiation care was taken to keep the temperature of the samples during irradiation ≤50°C.

Spectrophotometers and thickness gauge were used to measure the specific absorbance changes (absorbance/dosimeter thickness = mm^{-1}) produced in the glass.

3. Results and Discussion

Sets of three samples were irradiated at different doses in the range of 1–50 kGy.

Table 1. Characteristics of the facilities used for irradiations

	Nominal beam energy (MeV)	Energy* (MeV)	Beam characteristics and dose rate
Institute of Isotopes Budapest	4	3.4	LINAC 2.6 μs p.l. - 50 p.p.s. 2.17 Gy/pulse
ISOF-CNR Bologna	12	8.4	LINAC 2 μs p.l. - 50 p.p.s. 6.95 Gy/pulse
Tunisian semi-industrial ^{60}Co γ source		1.25	1 kGy/h 6 kGy/h

*In the case of the electron accelerator the energy refers to most probable energy.

Radiation causes displacement of atoms in the glass network, and induces free electron and holes which are then trapped in defects such as vacancies, interstitials atoms, impurities [4, 5]. These new electronic configurations (colour centres), give rise to the coloration of the alkali-silicate glasses with two large optical absorption bands at around 410 and 600 nm (Fig. 1). These bands have been attributed to "non-bridging oxygen hole centre" (NBOHC:≡Si–O$^{\bullet}$) [5-7] which most probably overlaps with the band of peroxy radical ≡Si–O–O$^{\bullet}$ at 630 nm [6].

Both γ and electron irradiation did not affect the position of the absorbance bands [4], only the heights and the area of the bands changed due to increase of concentration of the colour centres with dose. Because of the rapid fading of the optical absorbance at room temperature after irradiation, the irradiated samples were submitted to post irradiation thermal treatment at 150°C for 20 min to improve their stability before optical measurements that were taken 24 h after irradiation and heat treatment (Fig. 1). Specific absorbances for the dose range 1-50 kGy at 410 nm are shown in Fig. 2 as dose response curves. The overall estimated uncertainty associated to these measurements is 9% at 95% confidence level.

The response of the glass to irradiation looks to be energy dependent more than dose rate dependent. This effect can be explained with the fact that for the same dose the higher the energy of the radiation the greater is the number of colour centres formed. At doses >40 kGy an almost horizontal plateau is reached. According to [8] the non linear dose dependence can be interpreted in terms of two different processes: first activation of pre-existing defects (precursors) forming colour centres which saturate with dose because of their limited concentration in glass, and then bond breaking that creates new defects in the glass network.

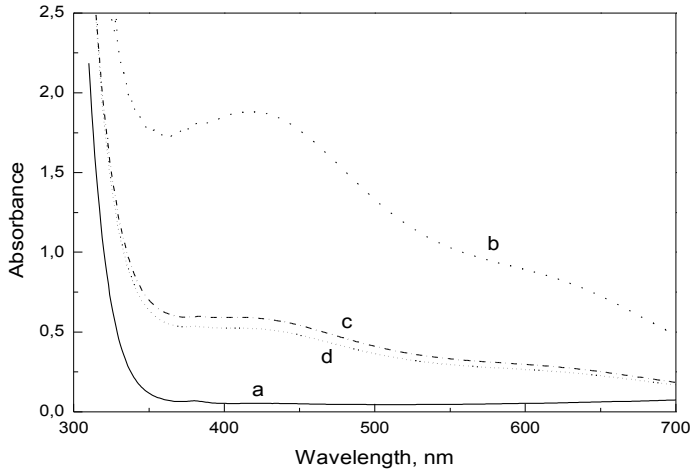

Figure 1. Optical absorption spectra of glass: a) unirradiated; b) after irradiation with 8.4 MeV electrons (25 kGy); c) after heat treatment (150ºC for 20min.); d) 24 hours after heat treatment.

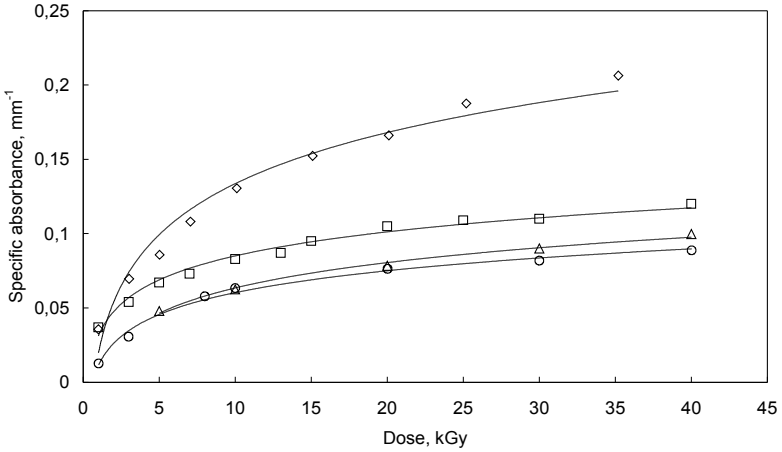

Figure 2. Response curves of irradiated glasses: (◇) 8.4 MeV electrons; (□) 3.4 MeV electrons; (△) γ rays 6 kGy/h; (○) γ rays 1 kGy/h. Optical measurements taken at 410 nm.

The optical fading of the irradiated and heat treated glasses kept in the dark at room temperature was followed for several weeks (Fig. 3). A 10–15% decrease of the optical absorbance was observed after 10 days from the irradiation, followed by a much slower decrease in the remaining days. The decay of absorption can be fitted by the sum of two first order decay kinetic curves and it is the depth of the

traps in this material that determines their decay characteristics [5].

Thus if the irradiated glasses get the reported thermal treatment they might be used as dosimeters in radiation processing. It should be borne in mind that evaluation of the absorbance has to be done at the same time when, after irradiation and heat treatment, the corresponding calibration curves have been obtained.

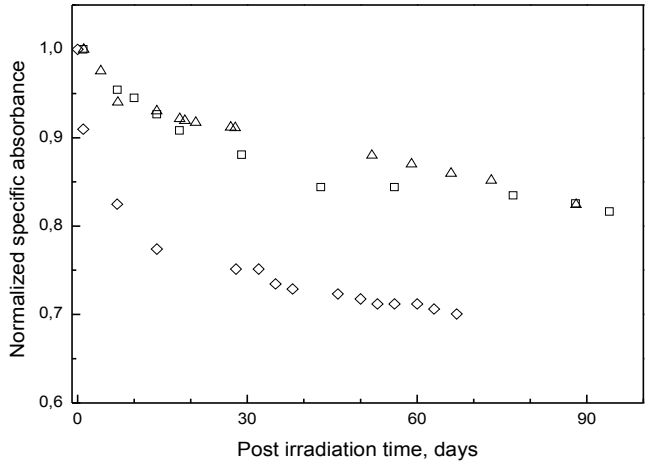

Figure 3. Post-irradiation fading of glass samples: (◇) 8.4 MeV electrons (25 kGy); (□) 3.4 MeV electrons (25 kGy); (△) γ rays (6 kGy/h, 30 kGy). Specific absorbance at 410 nm.

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