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SIRAD – Personal radiation detectors

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ABSTRACT

SIRAD badge dosimeters provide a visual qualitative measurement of exposure to radiation for mid range dose exposure. This is performed using an active radiochromic dosimeter in a transparent window, combined into a badge assembly. When irradiated, the badges active window turns blue, which can be matched against the given colour chart for a qualitative assessment of the exposure received. Two peaks in the absorption spectra located at 617 nm and 567 nm were found. When analysed with a common computer desktop scanner, the optical density response of the film to radiation exposure is non-linear but reproducible. The net OD of the film was 0.21 when exposed to 50cGyand 0.31 at 200 cGy exposure when irradiated with a 6 MV x-ray energy beam and analysed using a broad spectrum light source. These values reduced when exposed with kilovoltage x-rays with an approximate 30% reducing in sensitivity at 50 kVp. The film provides an adequate measurement and visually qualitative assessment of radiation exposure for levels in the range of 0–50 cGy.

1. Introduction

Radiochromic film products have been used in many applications for radiation measurement (Butson et al., 1996, 2002, 2005, 2009; Carolan et al., 1997;Cheung et al., 2002, 2004, 2006a, b). When measuring low-level personal radiation, devices such as Thermoluminescent dosimeters (Kron et al., 1996; Soares 2010–2011) are adequate due to their high sensitivity and their portable nature. If higher levels of radiation are of concern, devices such as the SIRAD high dose personal radiation dosimeter badge may be used. The badge provides an automatic visually readable dose assessment via a calibrated colour change in its active window. The SIRAD badge is based on a radiochromic dye insert which changes colour automatically when exposed to radiation (Riel et al., 2006). With the SIRAD badge the change is from a clear to blue colour upon radiation in the dose range of 0 cGy–200 cGy. This paper investigates the changing visible light absorption characteristics of the SIRAD personal dosimeter after exposure to mega voltage and kilovoltage energy x-ray beams.

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2. Materials and methods

SIRAD radiochromic based radiation dosimetry badges are analysed for this absorption spectra study. For exposure delivery, the badges were placed in a solid water (Constanitinou et al., 1982) phantom of dimensions 30 cm × 30 cm during irradiation at 1.5 cm depth. The phantom was irradiated with a Varian 2100EX linear accelerator and applied doses ranging from 0cGy to 200 cGy (in water) were delivered to the SIRAD badges. Absorption spectra results for the SIRAD badges were measured using an Avantes AvaSpec-2048 reflectance photo spectrometer (Cheung et al., 2005a), 24 h after initial exposure. The AvaSpec-2048 device is a fibre optic Spectrometer with a 300lines/mm grating. Measurements were made in absorbance mode, and results are quoted as a reflective optical density (ROD). From the ROD(λ), a set of absorption spectra measurements were obtained over the wavelength region of 500 nm–650 nm. The SIRAD badges are also analysed using a desktop scanner at least 24 h after irradiation to minimise any effects from post irradiation colouration, which may occur (Cheung et al., 2005b). The desktop scanner used to measure the optical density of the active badge window was also used to measure the optical density of the calibration colour chart on the badge. Direct comparisons are made between these two areas for assessment of the dosimeters visual to actual exposure assessment accuracy.

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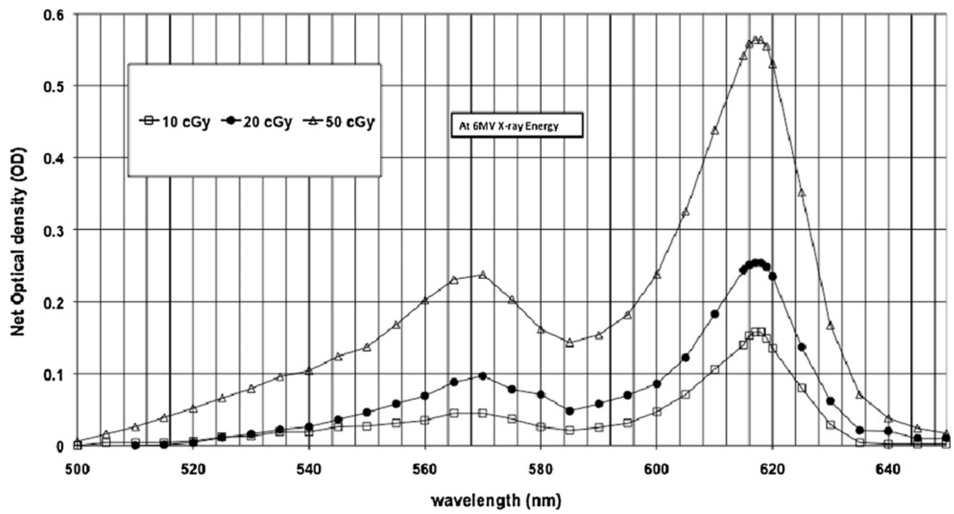

Fig. 1. Absorption Spectra response of the SIRAD Badge to 6 MV X-rays up to 50 cGy dose.

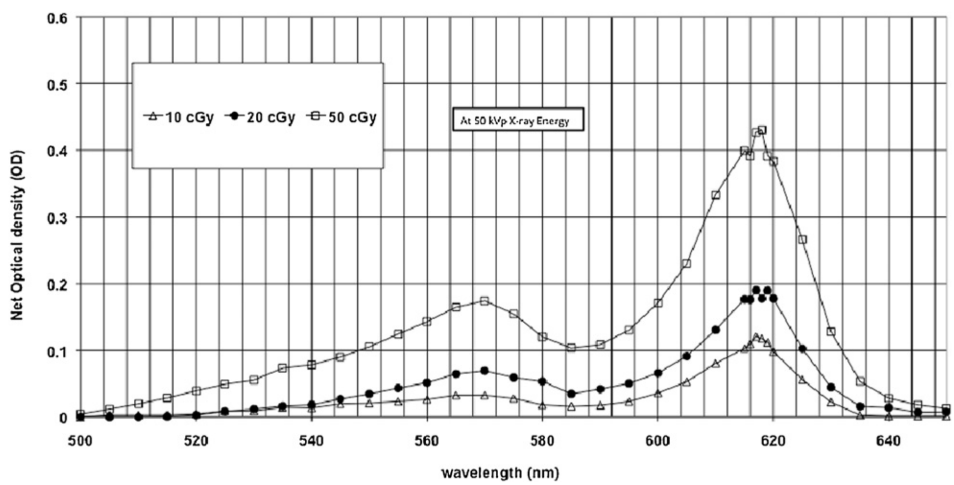

Fig. 2. Absorption Spectra response of the SIRAD badge to 50 kVp X-rays up to 50 cGy dose.

3. Results and discussion

Fig. 1 shows the net optical density absorption spectra for the SIRAD Badges in the wavelength region of 500 nm–650 nm when exposed using 6 MV x-rays. Results are given for a selection of badges ranging in applied exposures of up to 50 cGy. As can be seen, there are two main absorption peaks in the spectra, which are located at 567 nm and 617 nm. The 617 nm peak produced the largest change in optical density per unit exposure. A net Optical density change of 0.564 is seen for the 50 cGy exposure at its peak wavelength. This response is approximately linear with dose when read out at this wavelength up to exposures of 50 cGy.

Fig. 2 shows the same net Optical density results but when the badge is irradiated using 50 kVp x-rays. As can be seen, the response is lower at these energies and these results equate to an approximate 30% reduction in sensitivity for net optical density change per unit exposure. Results for the 6 MV x-ray exposure were the closest to the calibration chart supplied on the SIRAD badge. This would mean that from our results, exposure to a 25.5 keV photon equivalent beam would result in an approximate 30% underestimation in exposure. However, a significant colour change is still visually readable resulting in an immediate estimation of exposure levels and alerts the wearer of potential further radiation risk.

The badges provide a measure of radiation exposure and have been produced as a dosimetry tool for areas such as dirty bomb monitoring. They can also be used in any area where higher dose levels are expected. The main advantage of the SIRAD badge is that they provide a visually readable analysis of exposure in a lightweight, easily worn design. It must be noted that the SIRAD badge, like most radiochromic materials produces a post irradiation colouration effect whereby the chemical reaction caused by ionising radiation continues for a given period after exposure.

4. Conclusion

The SIRAD badge dosimeter permanently changes colour upon irradiation with high energy x-rays and thus has the ability to measure radiation exposure. Results have shown that the colour change from clear to blue is achieved with an absorption spectra produced which has peaks at 617 nm and 567 nm. The calibrated colour chart provided on the SIRAD badge provides an adequate qualitative measure of exposure for 6 MV high energy x-ray over the range of doses from 0 cGy to 50 cGy. The results at 50 kVp produced a 30% lower sensitivity per unit colour change which highlights the energy dependence of response of the SIRAD badge.

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