Preliminary characterization of PRESAGE® for 3D dosimetry of 62 MeV proton beam

T Gorjiara[1], A Kacperek[2], Z Kuncic[1], C Baldock[1,4] and S Doran[3]
[1]Institute of Medical Physics, School of Physics, University of Sydney, NSW 2006, Australia
[2]Douglas Cyclotron, Clatterbridge Centre for Oncology, Wirral, UK
[3]CRUK Clinical Magnetic Resonance Research Group, Institute of Cancer Research, Surrey, UK
[4]Faculty of Science, Macquarie University, NSW 2109, Australia

E-mail: simon.doran.icr.ac.uk

Abstract. PRESAGE® has previously shown potential for 3D dosimetry of heavy particles. A new formulation has specifically developed for dosimetry of protons/heavy ions. This work provides a preliminary characterization the new formulation of PRESAGE® by measuring optical absorbance and dose response after irradiating by a 62 MeV proton beam for a dose range of 0.5 – 20 Gy. Results show linear dose response and the evolution over time of the optical density of the 3D dosimeter.

1. Introduction

Polymer gel dosimeters are manufactured from radiation sensitive chemicals, which upon irradiation polymerize as a function of the absorbed radiation dose [1]. These gel dosimeters which record the radiation dose distribution in three-dimensions (3D) have specific advantages when compared to one-dimensional dosimeters and two-dimensional dosimeters [2]. These 3D dosimeters are radiologically soft-tissue equivalent [3] with properties that may be modified depending on the application. The 3D radiation dose distribution in polymer gel dosimeters may be imaged using magnetic resonance imaging (MRI) [4, 5], optical-computerized tomography (optical-CT) [6, 7], x-ray CT [8, 9], ultrasound [10, 11, 12] or vibrational spectroscopy [13, 14].
Using proton beams for radiotherapy is an advanced method for cancer treatment. Because of the high dose gradients at the distal end of the delivered distribution, 3D verification is of great importance in proton dosimetry, to ensure correct coverage of tumor volume and sparing of healthy tissues. Ionization chambers, which are the recommended dosimeters for proton beams [15, 16], are not ideal for measuring two dimensional (2D) or 3D dose distributions. Therefore, treatment with proton beam can benefit from having an accurate 3D dosimeter with reproducible measurements with comparable with an ionization chamber, and having similar dimensions to the target volume [2, 17].

PRESAGE® is a polyurethane-based radiochromic 3D dosimeter with a linear dose response [2, 18-21], which has already shown considerable promise for proton/heavy ion dosimetry [22-26]. However, similar to 3D polymer gel dosimeters, dose response saturation (lower dose measurement) has been observed at the Bragg peak of protons/heavy ions due to high LET (Linear Energy Transfer)

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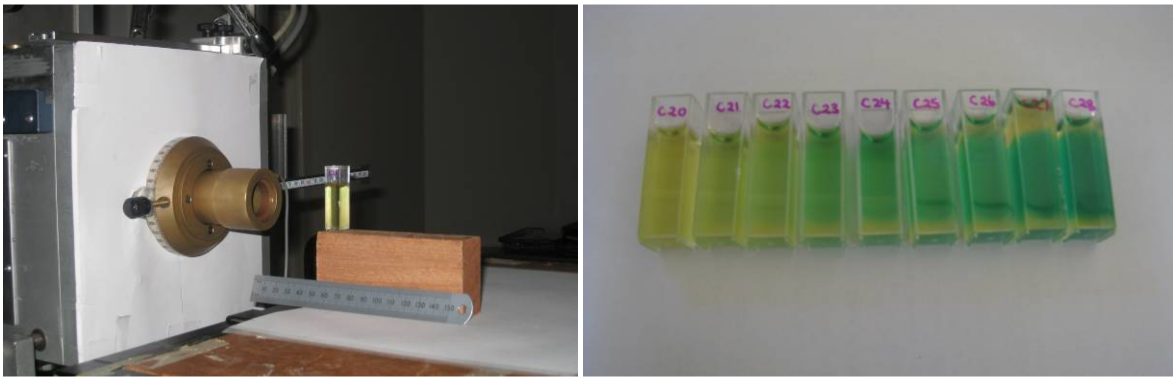
[2, 23-27]. The saturation effect has been reported less pronounced in the preliminary studies on a new formulation of PRESAGE®, developed for heavy particle dosimetry [28, 29].

This work is a preliminary study on the characterization of the new formulation of PRESAGE® for a 62 MeV proton beam, commonly used to treat different ocular melanomas. Previous formulations have shown good temporal stability when stored correctly, but the manufacturer recommends minimizing exposure to visible light and it has been demonstrated that ultraviolet radiation is particularly efficient in causing a colour change [30]. It has also previously been shown that there is a marked temperature-related effect [31] One of the aims of this study was thus to investigate the impact of different storage conditions on the optical response of the dosimeter.



(a) (b)

Figure 1: (a) Placement of PRESAGE® cuvettes in front of an unmodulated 62 MeV proton beam and (b) irradiated PRESAGE® cuvettes with a dose range of 0.5 Gy – 8 Gy.

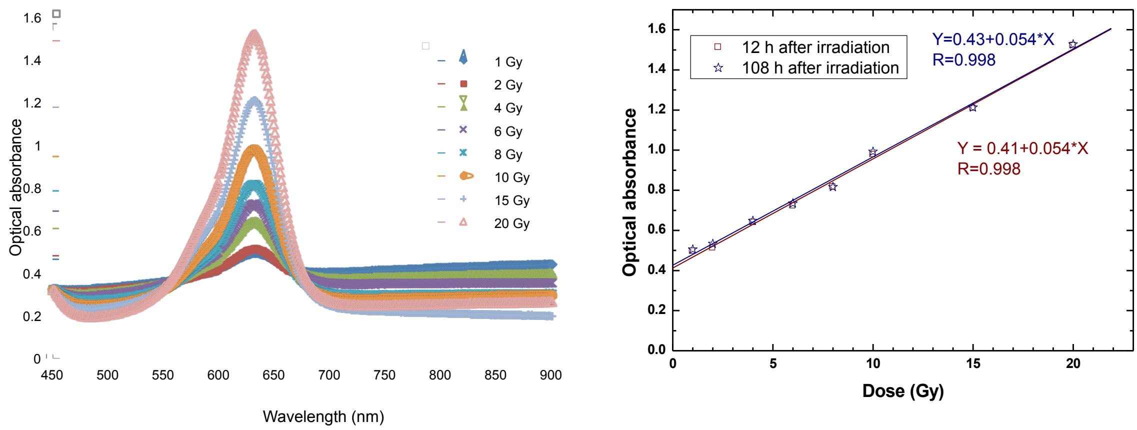
2. Method and Materials

Eight cuvettes filled with the new formulation of PRESAGE® were irradiated by an unmodulated 62 MeV proton beam from the Douglas Cyclotron at the Clatterbridge Center for Oncology, UK. The duration of irradiation was adjusted in a way to deliver 0.5, 1, 2, 6, 4, 8, 10, 15 and 20 Gy dose to the nine PRESAGE® cuvettes. The set-up of the experiment and irradiated cuvettes are presented in figure 1. To investigate stability and provide a calibration curve, the optical absorbance of samples was measured 12 hours and 108 hours after irradiation using a CAMSPEC M350 double beam spectrophotometer. Three sets of four PRESAGE® cuvettes were also irradiated by a 6 MV x-ray beam with 2, 4, 10 and 20 Gy dose to evaluate how storage condition (i.e., temperature and light) effects the optical of PRESAGE® samples. After irradiation, one of these sets stored in the refrigerator and the second set stored in the dark at room temperature. The third set of cuvettes was stored at room temperature, but experienced periods of both light and darkness. Initially, the samples were exposed to light from a fluorescent tube and darkened very rapidly, to the extent that it became impossible to read them correctly with our spectrophotometer. They were then placed in the dark and, finally, placed in a sunlit position. The optical absorbance of these samples was measured over a period of time (up to 760 hours post-irradiation) using the spectrophotometer.

3. Results and discussion

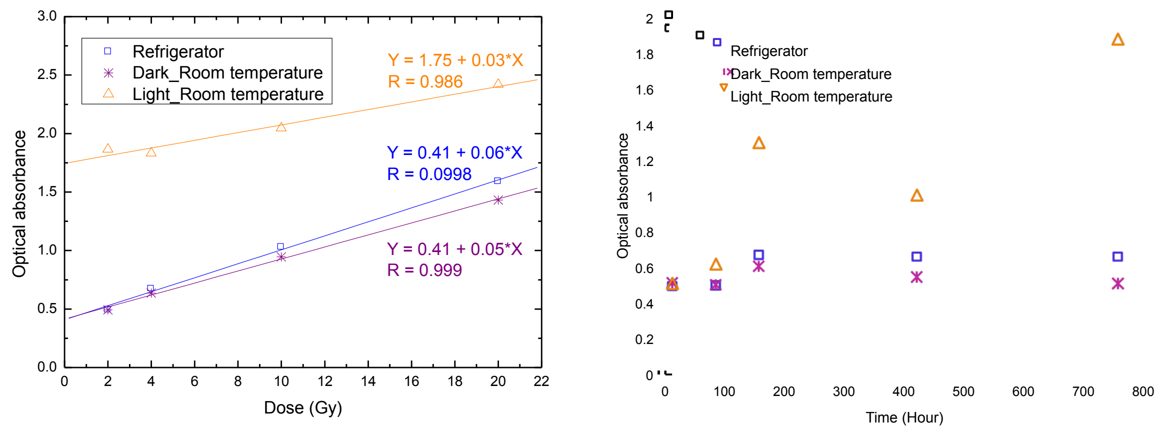
Figure 2(a) shows the optical absorbance of irradiated PRESAGE® cuvettes versus the wavelength (nm). The maximum absorbance was observed for the 633 nm wavelength. The plotted calibration curves at this wavelength versus dose for the spectrophotometer readings 12 hours and 108 hours after irradiation are presented in figure 2(b). Linear response with dose increase and good stability with time are evident.

Figure 3(a) shows the optical absorbance of the PRESAGE® cuvettes at 633 nm wavelength versus dose in the different storage conditions 80 hour post-irradiation. As anticipated, optical absorbance of the PRESAGE® dosimeter changes significantly with light due to sensitivity of PRESAGE® dosimeter to ultraviolet (UV) radiation. The optical density of PRESAGE® stored at dark in room temperature seems slightly lower than the one kept in the refrigerator. In figure 3(b) the optical absorbance of the 20 Gy irradiated PRESAGE® cuvettes is presented over a period of post-irradiation time in the different storage conditions. Changes over the time are observed in optical absorbance of PRESAGE® for all the storage conditions, but are most marked for the sample which was stored in the light. Here, an initial rapid increase is followed by significant fading while the dosimeter was in the dark and another large rise when the sample was returned to the light.



(a) (b)

Figure 2: The optical absorbance of nine irradiated PRESAGE® cuvettes by an unmodulated 62 MeV proton beam (a) 12 hours after irradiation and (b) at 633 nm 12 hours and 108 hours after irradiation by.



(a) (b)

Figure 3: The optical absorbance of irradiated PRESAGE® cuvettes (a) versus dose, at 633 nm, 80 hours after the irradiation and (b) for 20 Gy dose, at 670 nm, over a period of post-irradiation time in the fridge, in the dark at room temperature and in the light at room temperature.

4. Conclusion

The new formulation of PRESAGE®, developed for proton dosimetry, shows linear response with dose increase and good dose stability with time, providing that it is stored appropriately. Post-irradiation storage of PRESAGE® in the refrigerator seems the best way of preserving the dose data in the dosimeter. Storage in the light significantly degrades dose data of the PRESAGE® 3D dosimeter. The effect has been shown to be reversible, but it is highly unlikely that the originally stored dose information could be recovered in this way.

5. References

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