Phys. Med. Biol. **43** (1998) 2407–2412. Printed in the UK PII: S0031-9155(98)90934-4

Effects of read-out light sources and ambient light on radiochromic film

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Received 20 January 1998, in final form 3 March 1998

Abstract. Both read-out light sources and ambient light sources can produce a marked effect on coloration of radiochromic film. Fluorescent, helium neon laser, light emitting diode (LED) and incandescent read-out light sources produce an equivalent dose coloration of 660 cGy h^{-1}, 4.3 cGy h^{-1}, 1.7 cGy h^{-1} and 2.6 cGy h^{-1} respectively. Direct sunlight, fluorescent light and incandescent ambient light produce an equivalent dose coloration of 30 cGy h^{-1}, 18 cGy h^{-1} and 0 cGy h^{-1} respectively. Continuously on, fluorescent light sources should not be used for film optical density evaluation and minimal exposure to any light source will increase the accuracy of results.

1. Introduction

Radiochromic film, owing to its relatively energy-independent active layer, has become an effective dosimeter for the assessment of absorbed dose, especially in areas of high dose gradient (Butson *et al* 1996). Previous investigators have obtained dosimetric information in areas such as around brachytherapy sources (Muench *et al* 1991), at tissue interfaces (Meigooni *et al* 1993) and with radiosurgical beams (McLaughlin *et al* 1994). Whilst relatively low sensitivity is seen for Gafchromic MD-55 1 and 2 media, (i.e. approximately 3–5 Gy needed to produce a reproducible response), these dose limits are attainable for most radiotherapy applications. Owing to this low radiation sensitivity, the effects of ambient light and source read-out light on Gafchromic MD-55-2 film may influence the final measured results if an appropriate level of care and handling is not observed. Common light sources used to measure the optical density of Gafchromic films include, helium neon lasers, ultrabright diodes, incandescent and fluorescent white light sources. The effects of these light sources, as well as ambient light sources, are studied in this note.

2. Materials and methods

2.1. Read-out light sources

Measurements were performed under four possible Gafchromic dosimetry light sources. These being (i) helium neon laser, (ii) ultrabright LED, (iii) incandescent light and (iv) fluorescent light. Details about each source are given as follows.

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0031-9155/98/082407+06$19.50 © 1998 IOP Publishing Ltd

(i) A 1 mW helium neon laser with wavelength 632.8 nm was used. The film was placed 3 mm from the beam aperture for experiments. The diameter of the laser beam was approximately 1 mm. Measurement of luminance was unable to be performed due to the band pass wavelength restriction (400–520 nm) on the Minolta/Air Shields fluoro-lite meter 451 used.

(ii) A red GaAlAs 3000 mcd ultra bright LED in a clear plastic housing (peak wavelength 660 nm according to the manufacturer's specifications) was used. The film was placed 3 mm from the LED surface for experiments. As with the helium neon laser, luminance was unable to be measured.

(iii) A 60 W incandescent light source with a plastic diffuser (0.3 mm thickness) was used. The film was placed approximately 15 cm from the light source on a clear glass sheet, thickness 5 mm. Luminance from 400–520 nm at this position was measured as 6.4 ± 1.0 μW cm^{-2} nm^{-1}.

(iv) A 40 W fluorescent light source was used, with and without a 3 mm plastic diffuser. The film was placed approximately 15 cm from the light source. Luminance from 400–520 nm at this position was measured as 16.3 ± 1.7 μW cm^{-2} nm^{-1}.

In all instances, measurements were performed using two 1 cm $\times$ 1 cm square pieces of MD-55-2 Gafchromic film, batch number 941206. A control film of the same dimensions from the same piece of film was placed in a light-tight envelope and used in all experiments as a standard for background readings. Coloration of the films was recorded periodically over a 175 h period with an RFA300 densitometer converted to read Gafchromic film with an ultrabright red LED as described in (ii). Gafchromic film should be handled using either soft gloves or tweezers to avoid fingerprints and other contaminants which affect read-out. By attaching a paper or plastic tab on the side of the film with sticky tape, it can be easily handled without touching the film. Gafchromic film is prone to scratching which can also affect the optical density read-out. Care should be taken not to slide the film on surfaces with any force.

2.2. Ambient light sources

Experiments were performed under different ambient light sources and exposures. Sunlight, fluorescent light and incandescent light were tested for coloration effects on Gafchromic film.

2.2.1. Sunlight. Gafchromic film was placed in full and filtered sunlight during spring time (October) in Australia. Both full and filtered conditions were through a 0.5 cm thick glass window with the filtered sunlight projected through 50% black plastic shade cloth. Luminance in the 400–520 nm waveband varies considerably due to climatic conditions and time during the day. For full sun conditions, luminance varies from 25 μW cm^{-2} nm^{-1} up to 85 μW cm^{-2} nm^{-1} between the hours of 07.00 and 18.00. For filtered light conditions, the luminance varies between 5 μW cm^{-2} nm^{-1} and 20 μW cm^{-2} nm^{-1}.

2.2.2. Fluorescent light. The film was exposed by two 40 W fluorescent tubes at a distance of 1.5 m. They were placed on top of a bookshelf directly under the light source. Measurements were performed with the fluorescent lights uncovered and with a 3 mm plastic diffuser over them. Luminance from 400–520 nm at this position was measured as 0.64 ± 0.1 μW cm^{-2} nm^{-1} for uncovered fluorescent lights and 0.59 ± 0.1 μW cm^{-2} nm^{-1} for covered lights.

2.2.3. Incandescent light. The film was exposed to a 60 W incandescent light at a distance of 1.8 m. The film was placed on top of a table directly under the light source. Measurements were performed with the incandescent lights uncovered and with a 3 mm plastic diffuser over them. Luminance from 400–520 nm at this position was measured as 0.085 ± 0.02 μW cm^{-2} nm^{-1}.

3. Results

3.1. Read-out light sources

Figure 1 shows the equivalent dose coloration of Gafchromic MD-55-2 film exposed to various types of light source at close range as would be expected in typical densitometry systems. The equivalent dose was calculated by comparing the coloration of experimental films due to a set of standard doses given by a 6 MV x-ray beam produced by a medical linear accelerator. Results show a dramatic effect in coloration for fluorescent lights. Increases in coloration were also seen for helium neon lasers (approximately 7.5 Gy equivalent dose for 175 h of exposure), incandescent lights (approximately 5 Gy equivalent dose for 175 h) and ultrabright LEDs (approximately 3 Gy equivalent dose for 175 h).

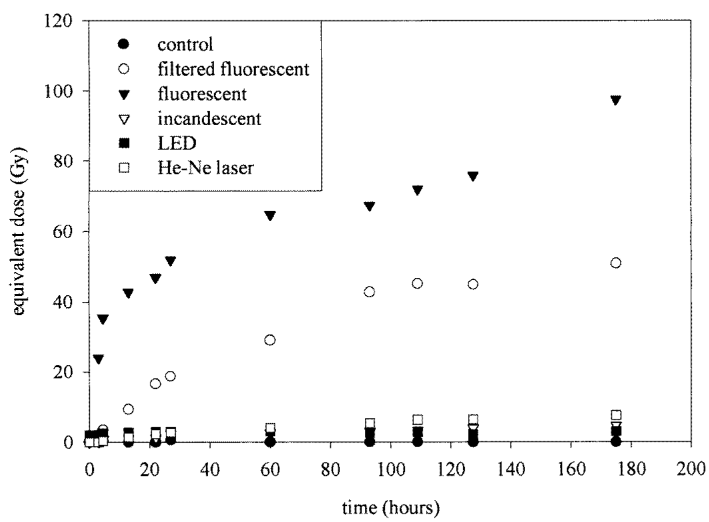

Figure 1. Equivalent dose coloration of MD-55-2 Gafchromic film associated with exposure to various read-out light sources.

Figure 2 shows a matrix plot for the coloration obtained by the laser light source in equivalent Gray. The laser produced a definite coloration within the beam aperture. A slight blurring and non-uniformity is seen around the beam which is assumed to be due to small alignment errors associated with each replacement of the film after densitometer read-out.

3.2. Ambient light sources

Figure 3 shows the equivalent dose of ambient light sources. The largest effect was seen with direct sunlight accumulating approximately 50 Gy equivalent dose from 175 h of exposure.

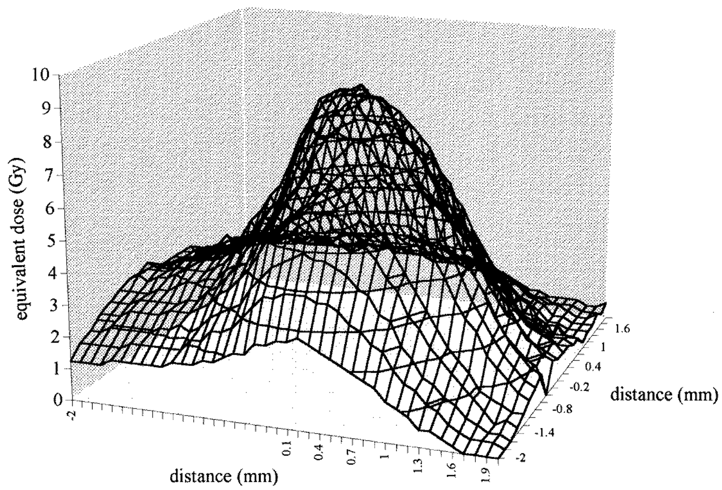

Figure 2. Matrix plot of equivalent dose coloration of MD-55-2 Gafchromic film exposed to 632.8 nm helium neon laser light after 175 h of exposure.

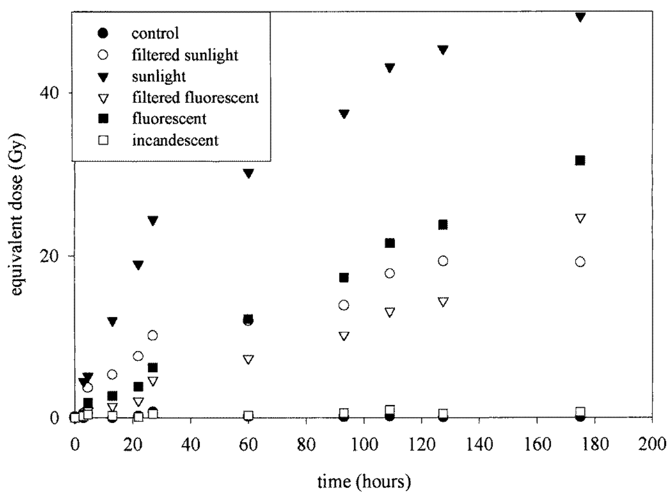

Figure 3. Equivalent dose coloration of MD-55-2 Gafchromic film associated with exposure to various ambient light sources.

Fluorescent lights also produce a significant effect on coloration with approximately 20–30 Gy equivalent dose after 175 h. Ambient incandescent lights, however, produced a negligible effect on film coloration.

4. Discussion

4.1. Read-out light sources

Many types of light sources and read-out systems have been used to measure radiochromic film dose response. These include incandescent and fluorescent light sources (Butson *et al*

1996, Stevens *et al* 1996), helium neon lasers (Cheung *et al* 1997, Reinstein *et al* 1997) and ultrabright LEDs (Carolan *et al* 1997). As shown by figures 1 and 2, the read-out light source can seriously affect the measured optical density of the film. Fluorescent light sources, even after 3 h of exposure at close range, can produce an equivalent dose of up to 20 Gy, most likely due to their high ultraviolet content. This equates to approximately 11 cGy equivalent dose coloration per minute. Stevens *et al* (1996) have used a document scanner for evaluation of Gafchromic film. This device exposes the film to fluorescent light for a few seconds. This produces a negligible coloration. However, other devices which use a continuous illumination of fluorescent light should be avoided for film analysis. A relatively smaller but still distinguishable effect on coloration is seen using incandescent, LEDs and helium neon lasers at close range. Equivalent dose coloration rates are approximately 1.7 cGy h^{-1}, 2.6 cGy h^{-1} and 4.3 cGy h^{-1} for LEDs, incandescent lights and lasers respectively. The coloration would be negligibly small if the film is read and then placed back in a light-proof envelope; however, if unintentionally left under the light source for some time, spurious results could be obtained.

4.2. Ambient light sources

Fluorescent light sources have been investigated previously and shown to affect Gafchromic film, due to their UV content (Meigooni *et al* 1996). Similar effects were observed where fluorescent light and filtered fluorescence were found to produce an equivalent dose coloration of approximately 18 cGy h^{-1} and 13 cGy h^{-1} respectively. Direct sunlight produced a more significant effect, with an equivalent dose coloration of approximately 30 cGy h^{-1} and only 10 cGy h^{-1} for filtered sunlight which showed the high UV content of sunlight. Incandescent light sources do not produce significant UV rays and there is an associated negligible coloration of film. The duration of fluorescent light exposure is the main consideration for clinical use of Gafchromic film. A normal patient treatment including set-up time would be approximately 15–20 min. A film placed on the patient during a single fraction would therefore only receive an equivalent coloration of 4–6 cGy if removed at the end of treatment.

In the case of a radiosurgical procedure, if the film was left attached to the patient for an estimated 1–2 h set-up time, an equivalent coloration of 20–40 cGy equivalent would be seen. These values would be considered to lie within the error values associated with Gafchromic film evaluation.

The effects of ambient lights could be significant in the case of accumulated dose measurement by placing the Gafchromic film on a patient's head cast. If the film is left unprotected for a 5 week period up to 20 Gy equivalent coloration could be seen. In this case, a small light-proof envelope should be used to hold the film whilst it remains on the head cast.

5. Conclusions

Both read-out light systems and ambient light can affect the coloration of Gafchromic film. Devices like document scanners which use fluorescent light for a few seconds will not produce significant coloration of Gafchromic film, but other continuous light fluorescent sources should be avoided to reduce unwanted film coloration.

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