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NOTE

Fluorescent light effects on FWT-60 radiochromic film

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Abstract

FWT-60 radiochromic film has been tested for colouration effects from fluorescent light sources and shown to produce a marked colouration when exposed to office fluorescent light sources showing an approximate 1 OD unit per 0.5 J m^{-2} exposure to a broad ultraviolet (UV) UVA + UVB spectrum at the peak absorption wavelength. This produces a measurable and quantifiable response to UV exposure. By choosing an appropriate wavelength of readout or band pass, the level of sensitivity can be changed to match the application or exposure level measurement required. These levels of UV response are significantly higher in sensitivity than other radiochromic films such as Gafchromic MD-55 by an order of magnitude. This feature may be of use for measurement of integrated UV exposure from fluorescent lights when required and produces a quantifiable history of total exposure.

Introduction

Ultraviolet radiation dosimetry can be performed with a large array of detectors and exposure measurement systems. Amongst these are products such as passive detectors like polysulphone film (Davis *et al* 1976, Parisi and Kimlin 2004, Airey *et al* 1997), a film product designed to match the action spectrum of human skin, biological specimens such as spore films (Quintern *et al* 1997) or standard broad-band or band-pass radiometers (Wengraitis *et al* 1998). More recently other forms of films based on phenyl-oxide chemicals (Lester *et al* 2003) and radiochromic film products such as Gafchromic media (Butson *et al* 2000) have been investigated. Gafchromic film was shown to produce an adequate measure of UVA at a exposure level around 5 J m^{-2} to 30 J m^{-2}. Another type of radiochromic film product is produced by Far West Technologies and is called FWT-60. The film was specifically designed for x-ray dosimetry at high x-ray doses. However, the film also exhibits a degree of interaction with UV radiation. This can produce two effects. Firstly, it could cause uncertainties in x-ray dosimetry due to UV interactions from light sources such as fluorescent lights or the sun. Secondly, UV interactions could produce an adequate dosimetry tool for UV exposure to low levels of UV from the above-mentioned light sources. This short note investigates and quantifies the effects of indoor fluorescent light sources on FWT-60 radiochromic film.

Materials and methods

The FWT-60 radiochromic dosimeters are composed of hexa(hydroxyethyl) pararosaniline nitrile. The matrix that holds the dye is nylon (Miller *et al* 1988). The film has a density of approximately 1.15 g cm^{-3} and a composition (by mass) of 63.7% C, 12.0% N, 9.5% H and 14.8% O. It has a physical thickness of 0.05 mm (Larson 2003) and is easily handled with the use of a plastic or paper tag, stuck to the side of the film. FWT-60-20F radiochromic film, lot number 1045, was used for the fluorescent light UV exposure study. For UV exposure delivery, the films were held at 5 cm distance from a 'white light' 40 W fluorescent light tube on a matt black backing sheet. This emission spectrum, due to the mercury emission lines, contains both UVA and UVB rays. The UV exposure levels were measured using an Optix, UVTex A + B_{idm} radiometer in dose mode which allows a quantitative measure of integrated exposure. The detector was held at the same position throughout the exposure periods as the films. Precautions in handling of FWT-60 radiochromic film outlined by Butson *et al* (2003) were performed. The film during storage and film analysis was kept in temperatures of 22 °C ± 2 °C and humidity 30%–70% which reduces effects of time, temperature and humidity dependent evolution and readout (Ningnoi and Ehlermann 1994, Mclaughlin *et al* 1996) of the absorption spectra of the film. The film was only removed from a light tight envelope during exposure and readout to reduce extra effects from ambient light (Butson *et al* 1998). The film was cut into 1 cm × 3 cm strips and attached to a paper tag using unidirectional bonding tape for handling purposes for analysis and easy insertion into the spectrophotometer. The absorption spectra results were measured using a Shimadzu UV-160 UV-visible recording spectrophotometer (Butson *et al* 2002). Wavelength range of analysis was from 500 nm to 700 nm in 5 nm steps. The Shimadzu UV-160 has a spectral bandwidth of 3 nm with an accuracy of ±0.5 nm. The film was held in a quartz holding container during analysis. Spectra data were then analysed to calculate sensitivity values at various specific wavelengths for UV exposure.

Results and discussion

Figure 1 shows the changes in optical density (net OD) produced in the visible absorption spectrum for FWT-60 radiochromic film when exposed to broad-band UV from fluorescent light sources with the measured intensity of UVA + UVB quoted. Results are shown over the wavelength range of 500–700 nm as this is the main region where significant changes are measured with the absorption peak located at 605 nm. Results are for one representative film sample at each exposure level. As can be seen a significant change occurs at the visible peak with a net OD change of 1 OD unit recorded for 0.5 J m^{-2} exposure. This change decreases as we go away from the absorption peak producing various lower levels of OD change per unit exposure. Figure 2 shows the net change in OD for varying exposure at various wavelength of analysis for the FWT-60 film and compares results to MD-55-2 Gafchromic radiochromic film for a sensitivity comparison. The net OD versus exposure response for FWT-60 is nonlinear but is modelled adequately with a third-order polynomial function. As can be seen the highest level of change is seen at the wavelength peak and all results are significantly higher than the results recorded for MD-55-2 film. These results may be determined a detrimental effect if the

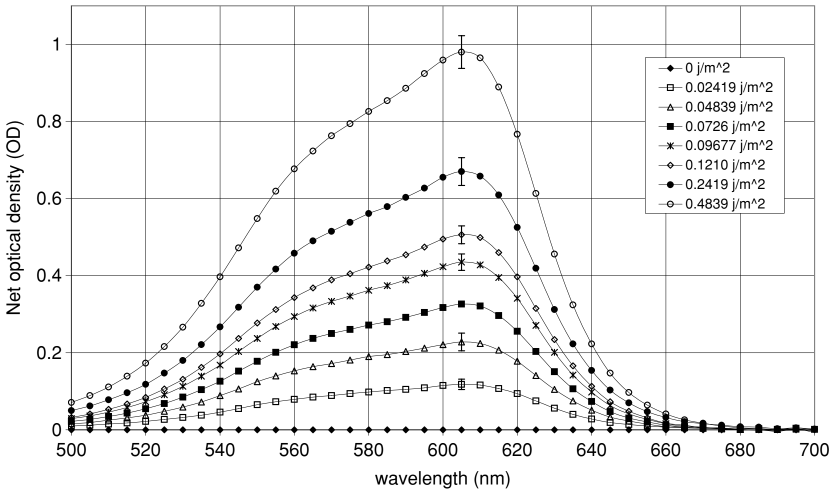

Figure 1. Net absorption spectrum for FWT-60 radiochromic film when exposed to office fluorescent light containing ultraviolet rays.

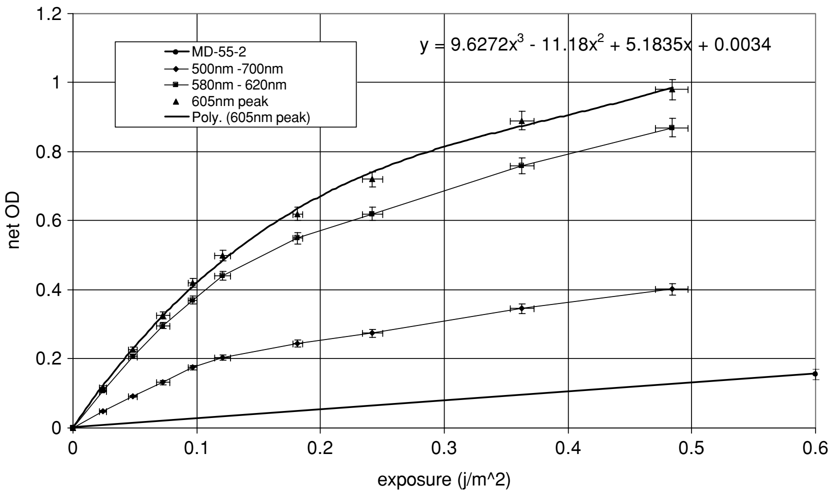

Figure 2. Ultraviolet exposure dose measurement using FWT-60 radiochromic film. The result for MD-55-2 film is also shown for comparison.

film is specifically used for x-ray dosimetry where the effects of UV exposure from fluorescent lighting within the hospital or industrial environment may be unwanted. This could produce a large uncertainty in measured x-ray dose if precautions in handling of the film when in UV light are not adopted or control films are not kept matched to their UV exposure. As the film undergoes an approximate 0.015 OD units per hour change when exposed to office fluorescent lights and the average response to x-rays (at 6 MV energy) is 0.077 OD kGy^{-1} (Butson *et al* 2004), a 1 h exposure causes the equivalent colouration of approximately 200 Gy. Thus uncertainty in results could quickly amount under standard office fluorescent light exposure (based on a standard desktop position which is approximately 2 m from the fluorescent light source). However the effects may be quite useful for measurement of Ultraviolet exposure at low levels, which were not currently available with conventional radiochromic detectors. If measurement were required in the order of 0 J m^{-2} to 0.5 J m^{-2}, FWT-60 film would be an ideal detector for two-dimensional analysis of UV exposure levels. The film would of course require calibration against a known standard dosimeter such as a radiometer but following this calibration the film could act as a relative dosimeter for UV exposure. The response of FWT-60 to x-rays and net optical density measured at specific wavelengths has been noted to vary depending on the temperature and humidity during irradiation and readout of the films. An approximate 5% variation in net OD change is seen from temperatures of 10 °C to 60 °C and a variation of 10% for humidity changes of 20% to 60% relative humidity (Butson *et al* 2003). It is assumed that a similar effect will be noticed during UV exposure due to the intrinsic nature of the radiochromic chemical reactions however the magnitude of this effect will need to be quantified and verified in future work to ascertain the effects on accuracy of UV dosimetry with this film.

Conclusion

FWT-60 radiochromic film produces a significant colouration when exposed to fluorescent radiation caused by the UV component within the light source. This colouration is dependent on the exposure level given and is adequately fitted by a third order polynomial. The net optical density change measured at 605 nm absorption peak was 1 OD unit per 0.5 J m^{-2}. This level of colouration is significant for uncertainty and error levels in x-ray dosimetry when the film is unintentionally exposure to UV during x-ray irradiation. Due to this fact, the film could also be used as a UV dosimeter in the 0–0.5 J m^{-2} exposure range. FWT-60 radiochromic film could produce an adequate measurement of ultraviolet exposure in a two-dimensional film manner.

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