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Microarticle

Responses of Gafchromic EBT3 films with polypropylene barriers to UV radiation

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ABSTRACT

The present paper proposed to use Gafchromic EBT3 films covered with 2, 4 and 6 polypropylene-film barriers for long-term monitoring of solar UV radiation. The usable range for the films with 2 barriers was from ~4 to ~40 Jcm^{-2}, that for the films with 4 barriers was from ~20 to ~200 Jcm^{-2}, and that for the films with 6 barriers was from ~100 to ~600 Jcm^{-2}. As such, using films with 4 and 6 barriers could extend the usable range up to 200 and 600 Jcm^{-2}, respectively, which would be useful for consecutive 4-d and 12-d UV exposure measurements, respectively (considering a possible maximum UV exposure of 50 Jcm^{-2} per day).

Introduction

The solar ultraviolet (UV) radiation reaching the surface of the Earth consists of UVA (315–400 nm) and UVB (280–315 nm). The Gafchromic EBT3 film which is commercially available for clinical dosimetric applications [3,4] was found to be useful for monitoring solar (UVA + UVB) exposures [6] with the usable range (i.e., UV exposures corresponding to coloration changes of the film far from saturation) up to ~30 Jcm^{-2} [5]. However, our own preliminary studies showed that the maximum UV exposure recorded during summer time could reach 50 Jcm^{-2} per day, so the methodology would need modifications to become suitable for longer-term measurements (e.g., over 1 day for better statistics and to eliminate day-to-day fluctuations). The present work proposed to use EBT3 films covered with polypropylene (PP)-film barriers to extend the usable ranges. UVC (100–280 nm) was not considered in the present work since it was absent from solar radiation reaching the surface of the Earth, and the active layer of an EBT3 film was sandwiched between polyester films which almost completely blocked transmission of UVC radiation (see e.g., Ref. [7]). The erythemal action spectrum was not needed since it was not an objective of the present work to assess the health hazards of UVA or UVB.

Materials and methods

ISP Gafchromic EBT3 films (Lot no A03181301) were used in the present study, and were cut into smaller films with a size of 1.5 × 1.5 cm^2. We reduced the UV irradiance on the EBT3 films by covering them with 2, 4 or 6 PP-film barriers, each with a thickness of 0.3 mm (Easy Mate Blue PP Cover Sheet PJ29721040B). The covered EBT3 films were supported by another PP film backing which was black in color (Easy Mate Black PP Cover Sheet PH29721040BK). The films with barriers and backings were exposed to (UVA + UVB) using a Cole Parmer 15 W UV bench lamp (9815-series), with the (UVA + UVB) irradiance (Wm^{-2}) revealed using a Solarmeter® Model 5.0 (UVA + UVB) Total UV meter from Solartech Inc. (MI, USA), the latter having been calibrated on 12 March 2014 to ensure the accuracy of readings to be ±5%.

After UV exposures, the EBT3 films were transferred into light tight boxes kept under constant temperature and relative humidity. After 24 h, the central parts of the films with an area of 0.75 × 0.75 cm^2 were scanned using an Epson Perfection V700 desktop flatbed scanner in the reflection mode with a resolution of 50 dots per inch (dpi) [5] to generate 48-bit RGB color images. No filters or correction functions were applied to raw pixel value results. The red component of the images was evaluated using ImageJ (http://imagej.nih.gov/ij/). Changes in the color of the EBT3 films were characterized by the net reflective optical density (*Net ROD*) defined as *Net ROD* = log (P_u/P_t) where P_u and P_t were the pixel values obtained for the unexposed and exposed films, respectively [1]. The orientation of films should be fixed as this would affect *Net ROD* [2]. Calibration procedures followed those described in Ref. [5].

Results and discussion

The relationships between (*Net ROD*) and log(*Exposure*) for EBT3 films covered with 2, 4 and 6 barriers are shown in Fig. 1, which are best fitted by the equations:

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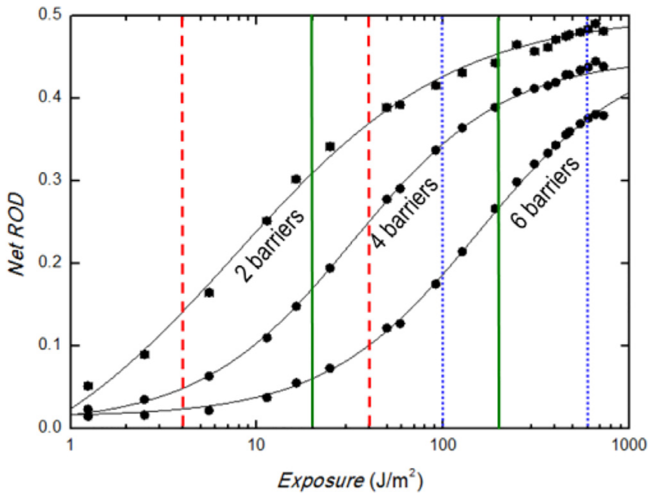

Fig. 1. Responses of EBT3 films covered with 2, 4 and 6 polypropylene-film barriers supported on a black backing to (UVA + UVB) exposures. Data points represent mean and error bars represent the SEM ($n = 3$). The curves are best-fit sigmoidal relationships given by Eqs. (2) to (4). The usable ranges for 2, 4 and 6 barriers are represented by regions contained by the red dashed lines, green solid lines and blue dotted lines, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

$$\text{For 2 barriers}: \textit{Net ROD} = -0.000830 + (0.494) / \{1 + 10^{[0.879(1.06 - \log(\textit{Exposure}))]}\} \quad (2)$$

$$\text{For 4 barriers}: \textit{Net ROD} = 0.00618 + (0.444) / \{1 + 10^{[1.06(1.52 - \log(\textit{Exposure}))]}\} \quad (3)$$

$$\text{For 6 barriers}: \textit{Net ROD} = 0.0149 + (0.448) / \{1 + 10^{[1.05(2.19 - \log(\textit{Exposure}))]}\} \quad (4)$$

all with $R^2 = 0.999$. The usable range for the films with 2 barriers (contained by the red dashed lines) was from ~4 to ~40 Jcm^{-2}, that for the films with 4 barriers (contained by the green solid lines) was from ~20 to ~200 Jcm^{-2}, and that for the films with 6 barriers (contained by the blue dotted lines) was from ~100 to ~600 Jcm^{-2}. As such, using films with 4 and 6 barriers could extend the usable range up to 200 and 600 Jcm^{-2}, respectively, which would be useful for consecutive 4-d and 12-d UV exposure measurements, respectively (considering a maximum UV exposure of 50 Jcm^{-2} per day). In future, different materials can be explored as barriers and backings to further enhance the responses of EBT3 films to UV radiation.

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