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Calibration of UV-Radiation Dose with Irradiation Time for CR-39 Track Detector by Using UV-visible Spectrophotometer

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Abstract: Nuclear track detector type CR-39 irradiated by two UV-irradiation methods at wavelength 254nm. First method was PEN-ray-lamp UV-irradiation with the distance 4cm between UV source to CR-39 detector and the range of irradiation time - TD were 10,100 and 1000 s. Second method was FLX-20 transiluminator 15W energy amount with the distance 10 cm between UV source to CR-39 detector and therange of irradiation dose - DT were 2, 6, 9 and 10J/cm2. The absorbance-A was determine from UV-visible spectroscopy at the measuring range from 300 – 500 nm for each method .The absorbance differences [ΔA]350 and [ΔA]550 for irradiated and un-irradiated CR-39 detector were measured between absorbance value at wavelength 350nm and 550nm respectively. In this study determined the linear relationship between the increasing of TD(s) and DT(J/cm2) with increasing of [ΔA]350 and [ΔA]550 .This work obtained that FLX-20transiluminator (second method) was used as a calibration route to PEN-ray-lamp (first method) after measuring the absorbance deference [ΔA]350 and [ΔA] 550 for CR-39 detector.

Keywords: Solid-State Detectors, Visible and Ultraviolet Spectra, Dosimetry, Ultraviolet Radiation Effects

1. Introduction

The effect of ultraviolet -UV radiation on the nuclear track detector type CR-39 investigated in many studies [1-3]. It was found that on extended exposureto uv- radiation, CR-39 detector slowly degrades and turns progressively yellow due to changes of its chemical and physical properties[1]. The effect of exposure to UV- radiation on CR-39 detector was also studies through determine the change in the bulk etch rate -V_b and track etch rate-V_t of CR-39 detectors at short UV wavelength[2].Where that chemical and physical properties of nuclear track detectors NTDs [4,5]were studied by Fourier Transform Infrared - FTIR spectrometry , thermal properties were also investigated , X-ray photoelectron spectroscopy – XPS , corresponding nano-mechanical and uv-visible spectrometry [1, 3]. There was relation between the changes in the chemical, physical and mechanical properties of CR-39 detectors under UV irradiation with the corresponding photo -degradation mechanisms in order to explain the variation of the etching behavior of CR-39 detectors in NaOH/H_2O [2].

Also Tse, K.C.C., et. al. (2008) provide he effects of UV irradiation type UVC exposure on the track etch rate-V_t and the detector sensitivity-V of CR-39 $SSNTD_s$ and take into account the investigated through the diameters and depths of alpha-particle tracks [6]. The formation of photo-stabilizers was studiesby using of uv–visible spectroscopy after UV - irradiation to the nuclear track detector type Lexan polycarbonate [7]. UV-visible spectroscopywasto determine the absorption different at limit wavelengthor foranalyses theshiftof the absorption edge from the ultraviolet region towards the visible light region [1].

CR-39 detector used as UV- dosimeter [8] by using three techniques , Alpha tracks diameters and tracks densities , FTIR spectrometry and uv–visible spectrometry [9] . There was many UV-radiation dosimeter technique as a erythemally weighted irradiances derived from polysulphone - PS and electronic ultraviolet - EUV dosimeters which compared with measurements obtained using a reference spectro-radiometer [10] .

Where Nagpal , J. S. (1998) [2] provide the integrating type personal UVR as UV - dosimeters which having response matching with the erythema action curve [2] . UV - radiation dosimetry was working by using of thermoluminescent phosphors-TLthrough response of most of the phosphors which depend on the radiant flux in unit ($\mu W.cm^{-2}$) [2] . Gunther Seckmeyeret . al. (2011) [10] was calibrating of UV-sensors by direct comparison to a reference instrument leads to reliable results by using of uv-visible spectrometry technique. In this study well be used UV-visible spectrometry technique to calibration of UV-radiation dose at the wavelength 254 nm for CR-39 detector from two irradiation method of UV-radiation .

2. Experimental Procedure

CR-39 is type of organic solid state nuclear track detector in the form of sheets with thickness 1200 μm , obtained from TASTRAK (Pershore Moulding , Track Analysis System Ltd . , UK) , molecular weight 274 a.m.u. , density 1.32 g/cm^3. These sheets were cut into small pieces each with 2cm × 2cm. CR-39 detector was irradiated by two ultraviolet radiation method at wavelength 254nm .

First method PEN-ray-lamp model F S / Shirophpto Industrial Ltd. Japan with 4cm distance from CR-39 detector to ultraviolet source , and second method was FLX-20 model FLUO-LINK FLX system from transilluminator, power 15W with 10cm distance from CR-39 detector to ultraviolet source . The measuring of absorbance-A was determine by using of UV-visible spectrometry technique model UV-1601 PC from SHIMADZU Company at the wavelength range 300- 550 nm .

3. Results and Discussion

UV-visible spectrum was measuring at the wavelength range 300-550 nmforCR-39detector after UV-irradiation by first method PEN-ray-lamp with irradiation times-T_D (s) 10 s , 100 s and 1000 s comparing with un-irradiated detector as shown in (Figure – 1:a) .Where at the second method FLUO-LINK FLX system the irradiation doses-D (J/cm^2) were 2 J/cm^2 , 6 J/cm^2 , 9 J/cm^2 and 10 J/cm^2 comparing with un-irradiated detector as shown in (Figure – 1:b) .

From (figure-1:a) obtained there was decreasein absorbance -Awith increase of irradiation time-T_D(s) for PEN-ray-lamp. Also, from (figure -1: b)there was decrease in absorbance –A with increase of UV-irradiation dose-D (J/cm^2) for FLUO-LINK FLX system .The values of absorbance deference [ΔA] at the wavelength300nmand 550nm as $[\Delta A]_{350}$ and , $[\Delta A]_{550}$ were calculated by using equ. (1) and equ. (2) respectively

$$[\Delta A]350 = [\Delta A]350,irr. - [\Delta A]350 ,un\text{-}irr. \quad (1)$$

$$[\Delta A]550 = [\Delta A]550,irr. - [\Delta A]550 ,un\text{-}irr \quad (2)$$

Where $[\Delta A]_{350,irr.}$, $[\Delta A]_{350\ ,un\text{-}irr}$: absorbance deference at 350nm for irradiated and un-irradiated respectively by UV-radiation

$[\Delta A]_{550,irr.}$,$[\Delta A]_{550\ ,un\text{-}irr}$: absorbance deferenceat 550 nm irradiated and un-irradiated respectively by UV- radiation.

The values of $[\Delta A]_{350}$ and $[\Delta A]_{550}$ which determine by PEN-ray-lamp methodwere increase with increase of UV-irradiation time-T_D (s) at the wavelength 350nm and 550 nm as shown in (figure-2 :a) and (figure–2:b) respectively .

The equations which reflect the relation between $[\Delta A]_{350}$, $[\Delta A]_{550}$ and UV-irradiation time - T_D(s) to PEN-ray-lamp method were calculated from (Figure-2:a) and (Figure–2: b) by equ. (3) and equ. (4) respectively

$$\ln TD(s) = \{ [\Delta A]350 – 0.04\}/0.024 \quad (3)$$

$$\ln TD(s) = \{ [\Delta A]550 – 0.03\}/0.030 \quad (4)$$

FLX-20 transiluminator The values of $[\Delta A]_{350}$ and $[\Delta A]_{550}$ which calculated by PEN-ray-lamp method were also increase with increase of UV-irradiation dose (J / cm^2) at the wavelength 350nm and 550nm as shown in (figure-3:a) and (figure-3 :b) respectively .

The equations which reflect the relation between $[\Delta A]_{350}$, $[\Delta A]_{550}$ and UV-irradiation dose - D(J/cm^2) to FLX-20 transiluminator were calculated from (Figure– 3 : a) and (Figure - 3: b) by equ. (5) and equ. (6) respectively.

$$D(J/cm2) =\{ [\Delta A]350 – 0.103\} / 0.009 \quad (5)$$

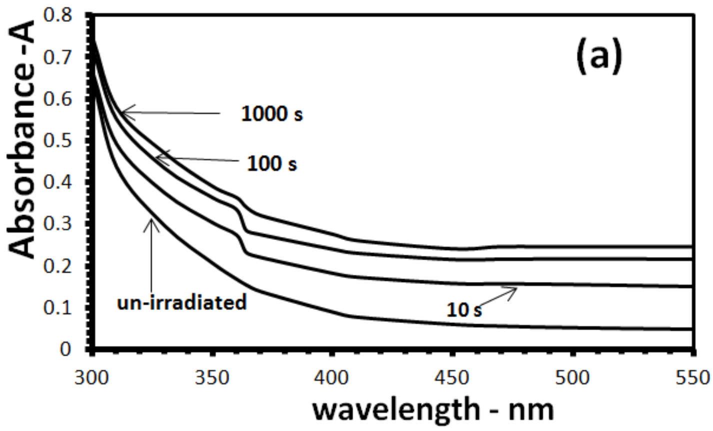
$$D(J/cm2) =\{ [\Delta A]550 – 0.0095\} / 0.007 \quad (6)$$

From (Figure –2) and (Figure –3) show there were linear relation ship for two irradiated methods between $[\Delta A]_{350}$, $[\Delta A]_{550}$ with UV -irradiation time -T_D(s) and UV-irradiation dose (J /cm^2) .

Table-1 obtained the equations which calculated from aboveliner relations ship for two uv-irradiatedmethods. These relationsmay be used as a conversion equations of UV - irradiation time - $T_D(s)$and UV-irradiation dose D (J/cm2) .

These equations which obtained in the (table -1) may be used directly calculate the uv-irradiation dose in unit (J /cm^2) for PEN-ray-lamp by measuring the values of $[\Delta A]_{350}$ and $[\Delta A]_{550}$, which equivalent to these values in FLX-20 transiluminator . The relation of uv-radiation dose with value of absorbance-A in uv-visible spectrum was also consider through measuring the optical band gap after irradiation due tochain scission in the nuclear track detector type Lexan polycarbonate [11] . The change in absorbance afteruv-irradiation depend on theenergy transfer to CR-39 detectors by uv-irradiation leads to excitation and ionization of the molecular chains , hence to radical formation, main chain scission , and also to cross-linking of polymeric chains [1] .

This study open field to use CR-39nuclear track detector after determination the absorbance-Aat the wavelength 350nm and 550 nm as UV -radiation dosimeter in many fields such as an environmental solar ultraviolet radiation dosimeter [12] and industrial or ultraviolet laboratory measurements.



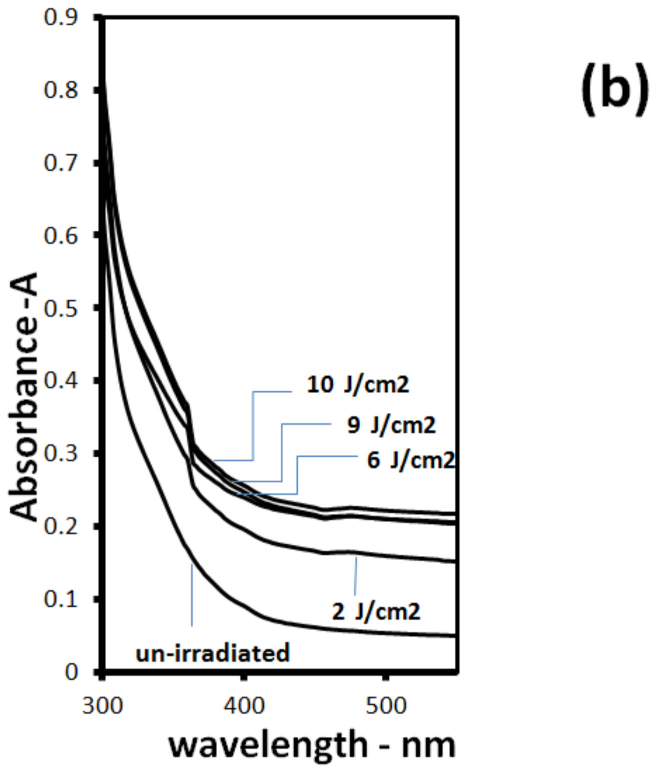
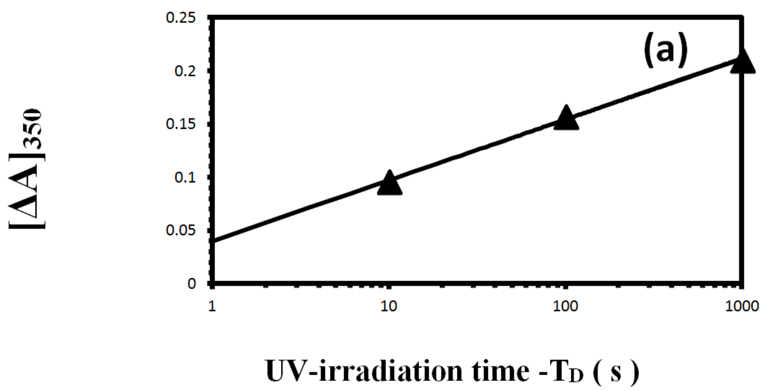


Figure 1. *UV-visible spectrum at the range 300-550 nm for CR-39 detector after UV –irradiated by following irradiation method. (a) PEN-ray-lamp UV - source with irradiation times-T_D 10 s, 100 s and 1000 s comparing with un-irradiated detector . (b) FLX-20 transiluminator with irradiation dose 2J/cm^2 , 6 J/cm^2, 9 J/cm^{2}and 10J/cm^{2}comparing with un-irradiated detector.*



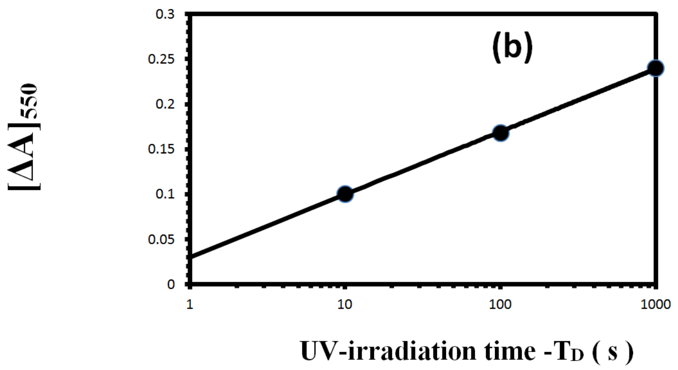


Figure2. *Absorbance differences* $[\Delta A]_{350}$ *,* $[\Delta A]_{550}$ *with UV-irradiation time-*T_D *from the irradiation method PEN-ray-lamp , (a) For*$[\Delta A]_{350}$ *(b) for* $[\Delta A]_{550}$ *.*

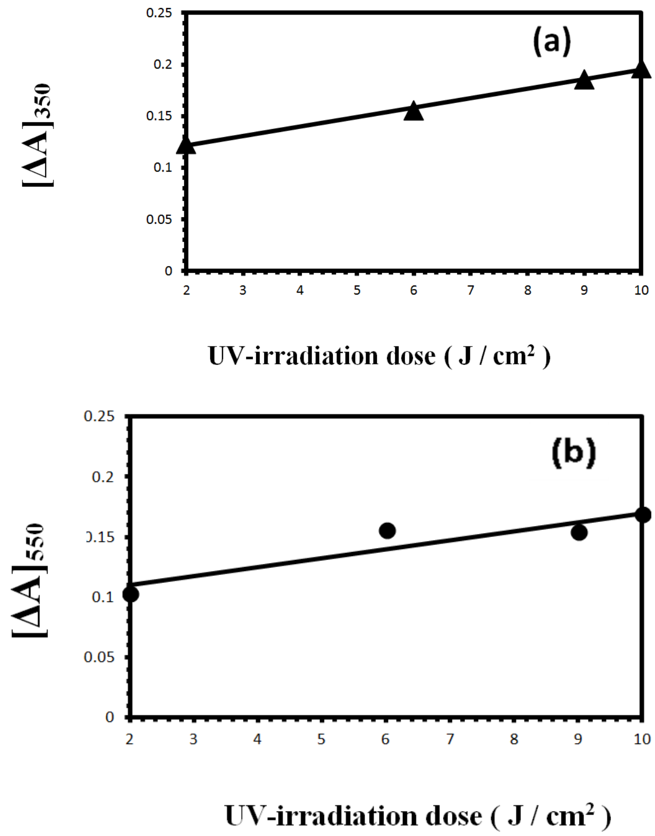


Figure3. *Absorbance differences*$[\Delta A]_{350}$*,*$[\Delta A]_{550}$ *with UV-irradiation dose (J/* cm^2 *) from the irradiation method FLX-20 transiluminator (a)For* $[\Delta A]_{350}$*, (b) for* $[\Delta A]_{550}$*.*

Table 1. *Conversion equations of UV-irradiation time -*T_D *(S) and UV-irradiation dose D (J/*cm^2*) with* $[\Delta A]_{350}$ *and*$[\Delta A]_{550}$ *for PEN-ray-Lamp and FLX-20 transiluminator UV -irradiation methods respectively .*

[ΔA]	**UV-irradiation method**	
	PEN-ray-lamp	**FLX-20 transiluminator**
$[\Delta A]_{350}$	$\ln T_D(s)=\{ [\Delta A]_{350} - 0.04\}/0.024$	$D\ (J/cm^2)=\{ [\Delta A]_{350} - 0.103\}/0.009$
$[\Delta A]_{550}$	$\ln T_D(s)=\{ [\Delta A]_{550} - 0.03\}/0.030$	$D\ (J/cm^2)=\{ [\Delta A]_{550} - 0.0095\}/0.007$

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