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# Effect of Ultraviolet Radiation on CN-85 and CR-39 Detectors by UV-Visible Spectroscopy and (He-Ne) Laser Penetration Techniques

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Nuclear track detectors (NTDs) are affected by particulate and non-particulate radiations. However, the effect of ultraviolet radiatio, (as an electromagnetic non particulate) radiation was determined by changes in spectroscopic and optical parameters of irradiated nuclear track detectors. Nuclear track detectors, namely CR-39 and CN-85 were UV-irradiated at a fixed distance using a stable Pen ray UV lamp emitting wavelength (λ) at 254 nm. UV-visible spectroscopy was used to elucidate the effect at varying UV-exposure time ($T_{uv}$) (30-180 min). For measuring the optical changes of UV-irradiated nuclear track detectors, variations in penetration rate - P and laser penetration factor-$F_P$ of He–Ne laser beam was used. The maximum absorbance (A) at wavelengths 234 nm ($A_{234}$) and 260 nm ($A_{260}$) was greater in CN-85 in comparison to CR-39. This coincides with (P) and ($F_P$) of laser penetration. Furthermore, a linear relationship between absorbance $A_{234}$ and $A_{260}$ with UV-exposure time ($T_{uv}$) was detected in both detectors. Howoever, a polynomial relationship between laser penetration factor ($F_p$) and UV-exposure time ($T_{uv}$) was also observed. It could, therefore, be concluded that both detectors are suitable for UV-dosimetry at dose range applied in this study. Hence, the case of the technique may prove practical in some environmental and medical applications.

**Keywords: Nuclear track detector CR-39, Ultraviolet radiation, He–Ne laser, UV-visible spectroscopy.**

## INTRODUCTION

Nuclear track detectors (NTDs) are known to be molecularly influenced by particulate and non-particulate radiations. Photothermal spectroscopy, image analysis as well as their optical band gap were used to detect the changes in the thermal and optical properties of the these detectors [1-3].

In those studies α- and neutron-induced tracks were measured by the He–Ne laser transmission technique [4]. On the other hand, the effect of non-particulate radiation (ionizing and non-ionizing), were also studied using CR-39 and CN-85 detectors [4,5] at UV-visible, Fourier transform infrared-FTIR spectra [6] and, $CO_2$ diffusion [7]. The corresponding γ-dose from measured etched tracks was then calculated [7]. Accordingly, CR-39 and Lexan detectors were calibrated as low-LET radiation dosimeters [8,9].

Kumar *et al*. [2,3] determined the effect of ionizing radiation on CR-39 polymer. The effect of X-rays on CR-39 plastics was observed in UV-visible, Fourier transform infrared spectra [6] and by $CO_2$ diffusion [7]. The γ-radiation used for obtaining the structural modifications and the track registration response of some γ-irradiated polycarbonate detectors were measured by Sinha *et al*. [8]. Moreover, CR-39 and Lexan detectors were calibrated as low-LET radiation dosimeters [8,9].

The effect of non-ionizing radiation (IR, UV and laser) on nuclear track detectors was studied by Parashar *et al*. [10] by determining the effect of IR irradiation on some polymers in which they studied the modifications owing to irradiation by analyzing the XRD and UV-visible spectra. Rafique *et al*. [11] reported that the nonlinear absorption increases with increasing He–Ne laser fluencies by using AFM and Raman spectroscopy. The effects of UV radiation on nuclear track detectors were studied by Wong *et al*. [6]. A comparison between these effects of UV radiation on CR-39 and Lexan detectors which was irradiated by α particles was achieved.

For this purpose, Shweikani *et al*. [12] used three techniques: (1) alpha track diameters and track densities, (2) UV-visible spectrometry and (3) FTIR spectrometry. These techniques

were used to determine the effect of solar ultraviolet (SUV) and ultraviolet type A-UVA on CR-39 detectors.

The FTIR spectroscopy technique was used to determine the effect of UV irradiation on CR-39 detectors [13]. The effect of UV radiation on polyallyldiglycol carbonate (PADC) films were used for measuring the parameters such as the size of α-particle tracks, track etch rate and detector sensitivity [14]. Several techniques were used for determining the effect of UV radiation on nuclear track detectors. UV-visible spectroscopy technique was used for calibrating the UV-radiation dose with exposure time for CR-39 track detector [15].

Zaki *et al.* [16] used UV irradiation to reduce the track formation time on thin PADC films by using FTIR spectrometry. FTIR spectrometry and UV-visible spectrometry techniques were used to determine the possibility of using nuclear track detectors CR-39 as UV dosimeters [12]. In this study, the effect of UV irradiation is calculated for CR-39 and CN-85 detectors as UV-radiation dosimeters by using UV-visible spectroscopy and laser penetration techniques.

## EXPERIMENTAL

Two types of nuclear track detectors were used in this study. The first one was CN-85 detectors with thickness 250 μm (1 cm × 1 cm) and density 1.42 g. $cm^{-3}$, manufactured by the Eastman Kodak Company, Rochester, New York and having a chemical formula $C_6H_8O_9N_2$. The second type of nuclear track detectors was the CR-39 detector with thickness 200 μm (1 cm × 1 cm) and density 1.32 g. $cm^{-3}$, supplied by TASTRAK type (Track Analysis System Ltd.), UK and having a chemical formula $C_{12}H_{18}O_7$.

The arrangement setup of ultraviolet lamp, both detectors (CR-39 or CN-85), jack (holder), timer and power supply is shown in Fig. 1.

CR-39 and CN-85 detectors are exposed to UV irradiation at a wavelength-λ of 254 nm by using a UV lamp source type PEN-Ray Lamp Company SAN GARIEL Inc. The distance between UV lamp source and NDTs samples (CR-39 or CN-85) was 15 cm. CR-39 or CN-85 detectors were irradiated with UV radiation in a dark room. UV- exposure times-$T_{uv}$ were 30, 60, 120, 150 and 180 min. UV-visible spectroscopy technique was used for measuring the optical absorbance-A of CN-85 and CR-39 detectors. UV-visible spectroscopy system from

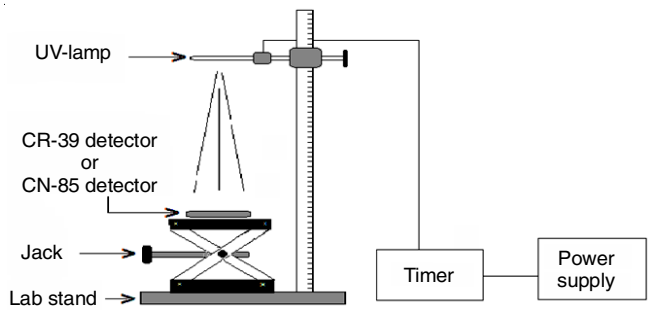


Fig. 1. Ultraviolet irradiation setup for both detectors (CR-39 or CN-85), UV lamp, Jack (holder), timer and power supply

Jasco, Model V-670 with a scan speed of 200 nm/min, in the range of 200-900 nm was used. The absorbance-A for CR-39 and CN-85 was meassurmed at the wavelengths 260 nm and 234 nm, since these wavelengths have the maximum response to UV-radiation [17].

Laser penetration technique was used for measuring the penetration rate-P of He–Ne laser with power 15 mW and wavelength 632 nm. The spectrofluorophotometer model (RF-1501 Shimadzu, Ltd.) was used for measuring the penetration rate-P, at a distance of 13 cm from the detector.

## RESULTS AND DISCUSSION

UV-visible technique was used for measuring the UV-visible spectrum at a range of 200-350 nm for CR-39 and CN-85 detectors after UV-exposure time $T_{uv}$ with periods 30, 60, 120, 150, 180 min). UV-visible spectra are shown in Fig. 2 for CR-39 and CN-85 detectors. For both detectors, Fig. 2 shows an increase in the values of absorbance-A with an increase in UV-exposure time $T_{uv}$ from 30 min to 180 min. The maximum absorbance-A, for the CR-39 detector at 180 min (UV-exposure time $T_{uv}$) was 4.79 at a wavelength of 204.7 nm (Fig. 2a).

The maximum absorbance-A, for the CN-85 detector at 180 min (UV-exposure time-$T_{uv}$) was 3.99 at a wavelength of 277.3 nm (Fig. 2b). For CR-39 and CN-85 detectors, the relationship between UV-irradiation time- $T_{uv}$ and absorbance-A at wavelengths 234 nm ($A_{234}$) and 260 nm ($A_{260}$) are shown in Figs. 3 and 4, respectively.

The mathematical behaviour of $T_{uv}$ with $A_{234}$ and $A_{260}$ is a linear relationship, as shown in Table-1 for CR-39 and CN-85

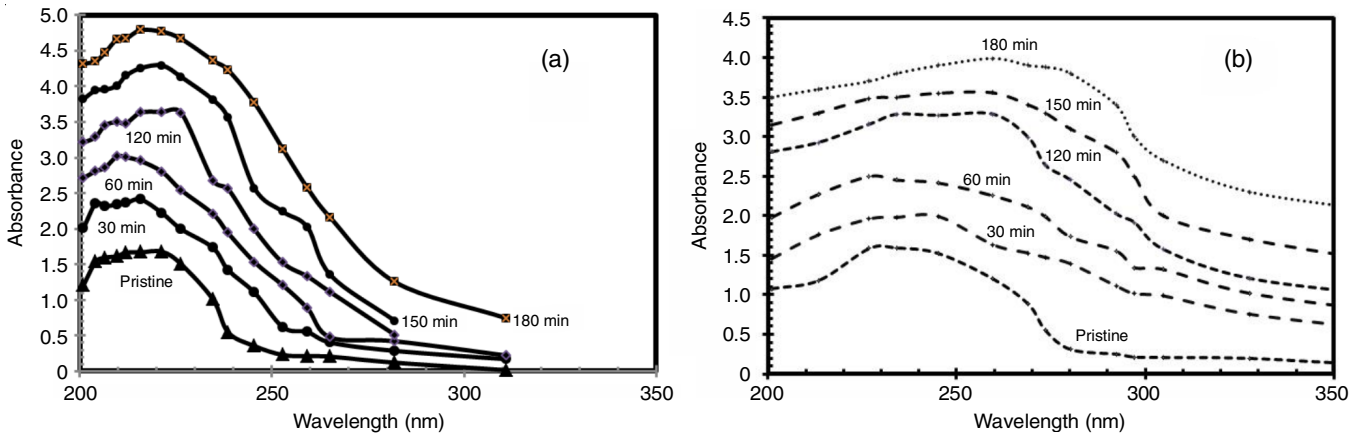


Fig. 2. UV-visible spectra at a range of 200–350 nm of pristine and UV-irradiated detectors with UV-exposure time $T_{uv}$ (30, 60, 120, 150 and 180 min) comparing with pristine sample; (a) CR-39 detector, (b) CN-85 detector

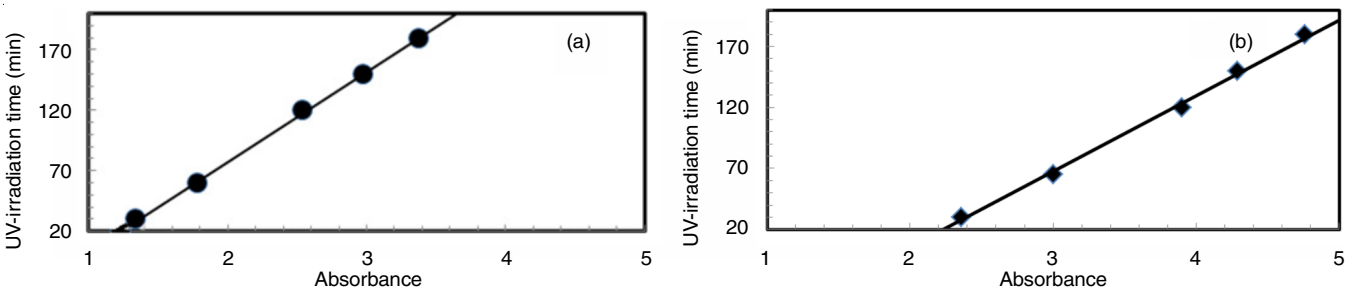


Fig. 3. Variation of UV-irradiation time-$T_{uv}$ (min) as a function of absorbance-A at wavelength 234 nm for (a) CR-39 detector and (b) CN-85 detector

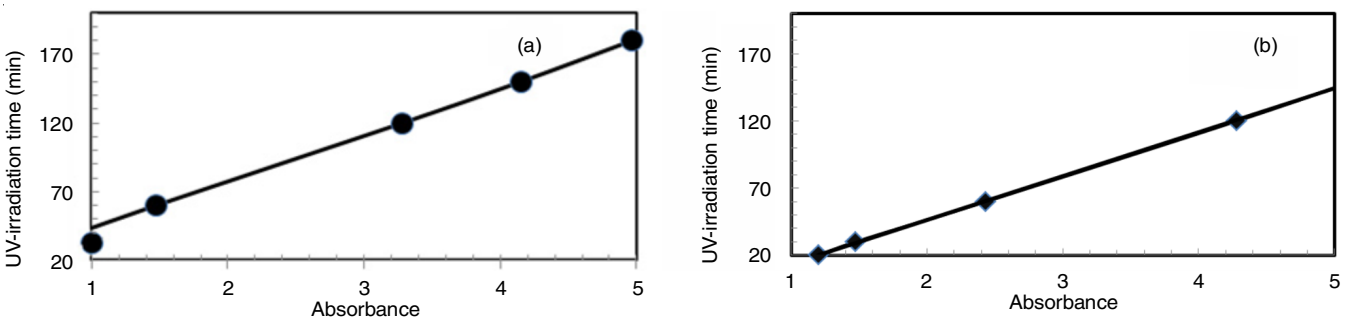


Fig. 4. Variation of UV-irradiation time-$T_{uv}$ (min) as a function of absorbance-A at wavelength 260 nm for (a) CR-39 detector and (b) CN-85 detector

detectors. Moreover, the linear relationship between $T_{uv}$ and the values of absorbance-A determines the relationship between the increase of UV-exposure time of the CR-39 detector with the increase of absorbance-A difference at wavelengths 350 nm and 550 nm [15].

TABLE-1
LINEAR RELATIONSHIP EQUATIONS FOR ABSORBANCE (A) AT WAVELENGTHS 234 nm AND 260 nm WITH UV-IRRADIATION TIME ($T_{uv}$) FROM 30 min TO 180 min FOR CR-39 AND CN-85 DETECTORS

| Detector | Linear relationship equations at wavelength | |
|---|---|---|
| | 234 nm | 260 nm |
| CR-39 | $T_{uv} = 74.7\ A_{234} + 71.3$ | $T_{uv} = 33.7\ A_{260} + 10$ |
| CN-85 | $T_{uv} = 62.1\ A_{234} - 117.9$ | $T_{uv} = 32.6\ A_{260} - 18.9$ |

The values of $A_{234}$ (Fig. 3b) and $A_{260}$ (Fig. 4b) for the CN-85 detector were greater than those for the CR-39 detector. This observation indicates that the CN-85 detector is more sensitive to UV-radiation than the CR-39 detector. This behaviour of sensitivity for CN-85 and CR-39 detectors is reported by Zaki *et al.* [16] by calculating the energy density of the laser beam for α-particle irradiation on these detectors. The UV response of CR-39 and CN-85 detectors at 234 nm (Fig. 3), were obtained in other studies at a wavelength 235 nm by determining the differential of UV-absorption spectra of CR-39 irradiated with protons at a different fluence [18]. El-Farrash *et al.* [19] reported that the exposure to UV radiation increases the mean track size, bulk etch rate and track etch rate of the CR-39 detector at two peaks corresponding to 254 and 350 nm lines and decreases at 300 nm. Table-1 shows the linear relationship equations concering $A_{234}$ and $A_{260}$ for CR-39 and CN-85 detectors with $T_{uv}$. The values of $T_{uv}$ for CR-39 and CN-85 detectors were calculated by using the equations in Table-1 after determination the values of $A_{234}$ and $A_{260}$.

Fig. 5 shows the behaviour of relationship to laser penetration rate P with $T_{uv}$ for CR-39 and CN-85 detectors compared to un-irradiated detectors at $T_{uv} = 0$. The maximum values of laser penetration rate P at a $T_{uv}$ value of 150 min were 0.34 and 0.31 for CR-39 and CN-85 detectors respectively. Another parameter used in the laser penetration technique is the penetration factor- $F_p$ which was calculated by the following equation:

$$F_p = \ln(P_o/P_{uv})$$

where $P_o$ and $P_{uv}$ are the laser penetration rates-P for UV-irradiated and unirradiated detectors, respectively.

The behaviour of the laser penetration factor $F_p$ with $T_{uv}$ is shown in Fig. 6 for CR-39 and CN-85 detectors. By determining the laser penetration rate (P), the maximum response appear at $T_{uv}$ equal to 150 min for CR-39 and CN-85 detectors (Fig. 5).

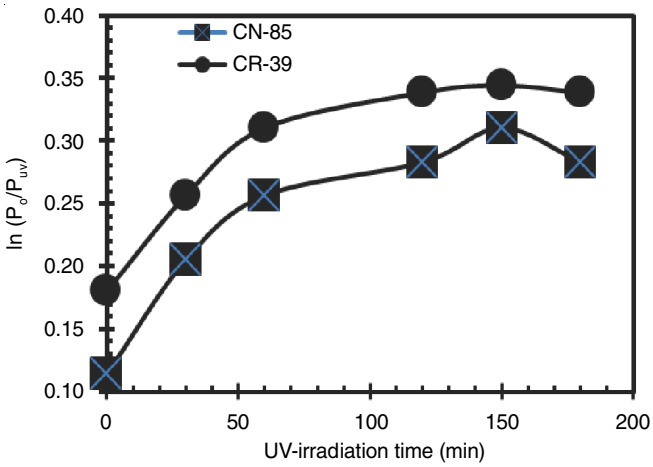


Fig. 5. Laser penetration rate- P in CR-39 and CN-85 detectors for different UV-exposure time-$T_{uv}$ (min)

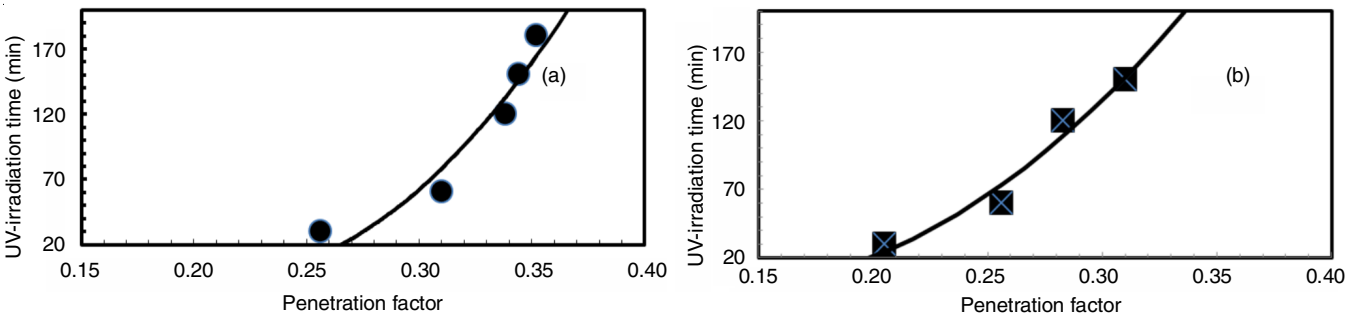


Fig. 6. Variation of penetration factor - $F_p$ as a function of UV-irradiation time- $T_{uv}$ (min) for (a) CR-39 detector and (b) CN-85 detector

The value of laser penetration factor $F_p$ increases with the increase of $T_{uv}$ for both detectors (CR-39 and CN-85). Laser penetration factor- $F_p$ values were 0.34 and 0.31 at irradiation time-$T_{uv}$ of 150 min for CR-39 and CN-85 respectively. Shweikani *et al.* [12] determined the relationship between the change of transmission in UV-visible spectroscopy of CR-39 detector with exposure time of solar ultraviolet (SUV) and reported that this transmission decreases exponentially with exposure time up to 120 min. The mathematical behaviour of $T_{uv}$ with laser penetration factor-$F_p$ is a polynomial relationship as shown in Table-2 for CR-39 and CN-85 detectors.

TABLE-2
POLYNOMIAL RELATIONSHIP EQUATIONS FOR PENETRATION FACTOR ($F_p$) OF CR-39 AND CN-85 DETECTORS WITH UV-EXPOSURE TIME ($T_{uv}$) FROM 30-180 min

| Detector | Polynomial relations equation | Responses value $F_p$ |
|---|---|---|
| CR-39 | $T_{uv} = 7058(\ln F_p)^2 - 2887.2 \ln F_p + 293.9$ | 0.22 |
| CN-85 | $T_{uv} = 4840.5 (\ln F_p)^2 - 1281.9 \ln F_p + 84$ | 0.15 |

Table-2 shows the polynomial relation equations for the penetration factor $F_p$ with $T_{uv}$ regarding CR-39 and CN-85 detectors. The responses of the penetration factor- $F_p$ for CR-39 and CN-85 detectors were 0.22 and 0.15 respectively. This indicates that the UV-irradiation response of the CN-85 detector is greater than that of the CR-39 detector by using the laser penetration technique.

## Conclusion

The quantitative molecular effects of UV-radiation on nuclear track detectors, CN-85 and CR-39 detectors were used as parameters for calculating the radiation dose. UV-visible spectroscopy and He–Ne laser penetration factors (P and $F_p$) employed in manifesting this dose showed progressive linear relation with UV-exposure time, revealing the possibility of using these detectors in UV-radiation dosimetry.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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