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Employment of Nuclear Track Detector CR-39 as a Radiation Dosimetry of Incident Alpha Particles at Different Angles

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ABSTRACT
The work includes the use of nuclear track detector CR-39, to study the absorbed dose of incident alpha particles at different angles (30˚, 60˚, 90˚), and different irradiation time (1, 2, 3, 4) min, after etching with 6.25N of NaOH solution at 70˚ C, and etching time of 8h. It was noted that when the irradiation time increased, the tracks number per unit area increased as well, and the absorbed dose rate also increased. When the angle of irradiation increases the absorbed dose rate increased and reached the maximum value at an angle 90˚ and it was 9.4865×10^{-5} Gy/s, while it reached the lowest value at an incidence angle 30˚, 4.7432×10^{-5} Gy / s.

Keywords: CR-39, absorbed dose, incident angles, irradiation time, track density, alpha particles.

توظيف كاشف الأثر النووي CR-39 لدراسة جرع الإشعاع لجسيمات ألفا وزوايا سقوط مختلفة

الملخص
تتضمن الدراسة استخدام كاشف الأثر النـووي CR-39 لدراسة الجرعة الممتصة جراء سقوط جسيمـــات ألفا على الكاشف بزوايا سقوط مختلفة (30˚, 60˚, 90˚) وبأزمنة تشعيع مختلفـة (1, 2, 3, 4)min بعد قشطه بمحلول هيدروكـسيد الصوديوم (NaOH) وبتركيز 6.25N ودرجة حرارة 70˚C وبزمن قشط 8h، ولوحظ أنه بزيادة زمن التشعيع تـزداد كثافـة الآثار لوحدة المساحة من الكاشف أي أن معدل الجرعة الممتصة يزداد وبشكل واضح، وبزيادة زاوية التشعيع تزداد الجرعـة الممتصة وتصل الى أقصى قيمة عند الزاوية 90˚ وكانت بواقع 9.4865×10^{-5} Gy/s، وأقل قيمة عند زاويـة الـسقوط 30˚ وكانت بقيمة 4.7432×10^{-5} Gy/s.

الكلمات الدالة: CR-39، الجرعة الممتصة، زوايا السقوط، زمن تشعيع، كثافة الأثر، جسيمات ألفا.

INTRODUCTION
Nuclear track detectors are one of the most important tools for the study of environmental radioactive contamination, especially the radioactive elements that comes as a result of the decay of uranium series ^{238}U to it's daughters especially the radon gas ^{222}Rn and short life daughters, ^{210}Po and lead ^{210}Pb, emitting alpha particles effects as a track on nuclear detectors (Tanner *et al*., 1999), and can be observed by using a number of etching solutions such as NaOH at different concentrations and constant temperature. Many researchers recommended a number of optimum conditions and most actively traded be a concentration of the etching solution at 6.25N and temperature 70˚C and etching time 8h (Fleischer *et al*., 1975; Khan *et al*., 1989; Nikezic and Yu, 2004). (Patiris *et al*., 2005) developed a program called TRIAC and was written in Matlab for pictures analysis. The nuclear track can be used as a dosimeters and to study the incident alpha particles spectrum.

(Srivastava and Virk, 2000) studied the effect of Lithium ions with 50MeV energy and (10^{11}-10^{13})ion/cm^2 intensity on the photoelectric absorption of SSNTD's CR-39, and observed that as the ions intensity increased the photoelectric absorption increased as well. (Abumurad *et al.*, 2005) showed that the absorbed dose of alpha particles in CR-39 increased as the irradiation time increased. (Sahoo *et al.*, 2012) studied the effect of irradiation of nuclear track detector with neutrons for different incidence angles and showed that as the incidence angles increase, the number of tracks per unit area of the detector increases as well, and the measured ratio of equivalent dose to the tracks density per unit area was (2.8 µSv/cm^2).

The aim of this work is to employ the nuclear track detector CR-39 to study the absorbed dose of 3MeV incident alpha particles at different angles (30˚, 60˚, 90˚) and at different irradiation times (1, 2, 3, 4) min through the knowing of number of tracks per unit irradiation area of the detector.

THEORETICAL PART

Depending on the nuclear track density, as well as on the time of irradiation of the detector by alpha particles, the intensity of the tracks, restricts the absorbed dose in the detector (Ammir *et al.*, 2013), the average absorbed dose for perpendicular alpha particles incident on the surface of the detector can be calculated by the following relation (Cember, 1996):

$$D'\ (Gy/s) = \emptyset_o \times 1.602 \times 10^{-10} \times \left(\frac{dT}{\rho dx}\right) \qquad \text{…………………(1)}$$

Where $\emptyset_o$ represents radiation flux which is defined as the number of particles falling on the unit area per unit time (particle/cm^2.s), and ρ is the medium density, and (dT/ρdx) is the mass stopping power of alpha particles and can be calculated for any energy through the program SRIM-2008 (Ziegler, 2008).

If the path of the beam makes an angle of θ with the surface of the detector. The absorbed dose rate can be calculated using the relation given by (Cember, 1996; Mheemeed *et al.*, 2009):

$$D'\ (Gy/s) = \emptyset_o \times 1.602 \times 10^{-10} \times \left(\frac{dT}{\rho dx}\right) \cos\theta \qquad \text{…..................(2)}$$

The flux of radiation can be calculate from the relation (Knoll, 1979 ; Mheemeed *et al.,* 2009)

$$\emptyset_o = \frac{S\,G}{A} \qquad \text{…………………………......………..……….………(3)}$$

Where A is the irradiated area, and S is the radioactive decay, and G is the geometric parameter and calculated from the relation (knoll, 1979 ; Mheemeed *et al.,* 2009)

$$G = \frac{1}{2}\left[1 - \frac{d}{\sqrt{d^2 + r_s^2}}\right] \qquad \text{……………………........…..….........…… (4)}$$

Where d is the distance between the radioactive source and the detector, and r is the radius of irradiated area .

EXPERIMENTAL PART

Nuclear track detectors CR-39 dimensions of 0.5x0.5 cm^2 and thickness of 0.66 mm, were irradiated with 3MeV alpha particles energy from ^{241}Am source through a collimator (activity 1µCi with main alpha energy 5.485MeV), for different incidence alpha particles angles, through the use of system especially designed for this purpose, and as shown in Fig.1(A,B), the incident angles (30 ˚, 60 ˚, 90 ˚) were restricted by placing the detector on stand with a hole of diameter 2mm that confront the collimator guiding the alpha particles, with different irradiation times (1, 2, 3, 4) min.

After irradiation, the detectors were etched with NaOH solution concentration of 6.25N at 70˚C in water bath type (memmret type W200). During etching process, purity and concentration of etching solution were controlled regularly and refreshed in every new usage. Etching detectors were cleaned in distilled water to remove the etchant and etch products from the detector surface. Number of tracks for different incidence angles and different irradiation times were counted under an optical microscope (Nikon with 400X as magnification), which was connected with digital camera (MDCE-5A) connected to a personal computer for images storage.

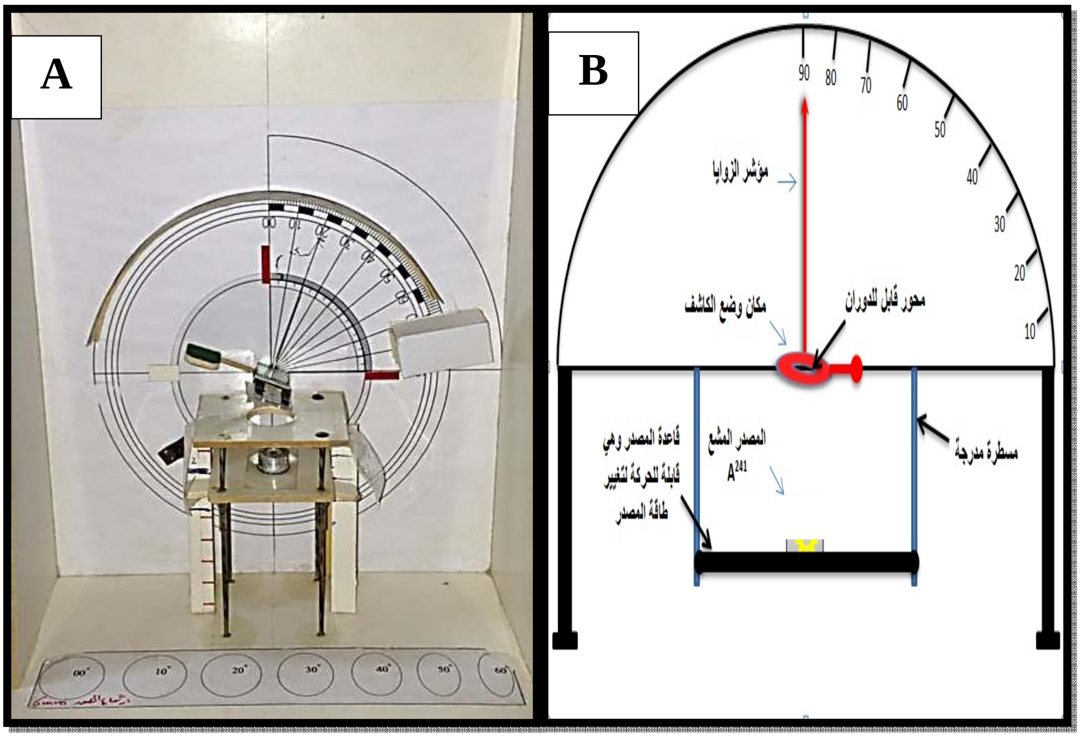

Fig. 1: (A) System of irradiation at different angles, (B) Scheme of irradiation system at different angles

RESULTS AND DISCUTION

Emitting alpha particles generated a number of tracks on the detector, and alpha particles will incident on the detector at different angles, and different radiation time as shown in Fig. 2(A, B). Absorbed dose rate calculated in our study from relation (1) for the perpendicular incident, and relation (2) for the oblique. The mass stopping power of alpha particles of 3MeV energy was calculated through the program SRIM 2008, and found a value of 1150 MeV.cm^2/g. To find the value of flux from equation (3) we must find the irradiated area by knowing its radius (0.1cm), and the geometrical factor.

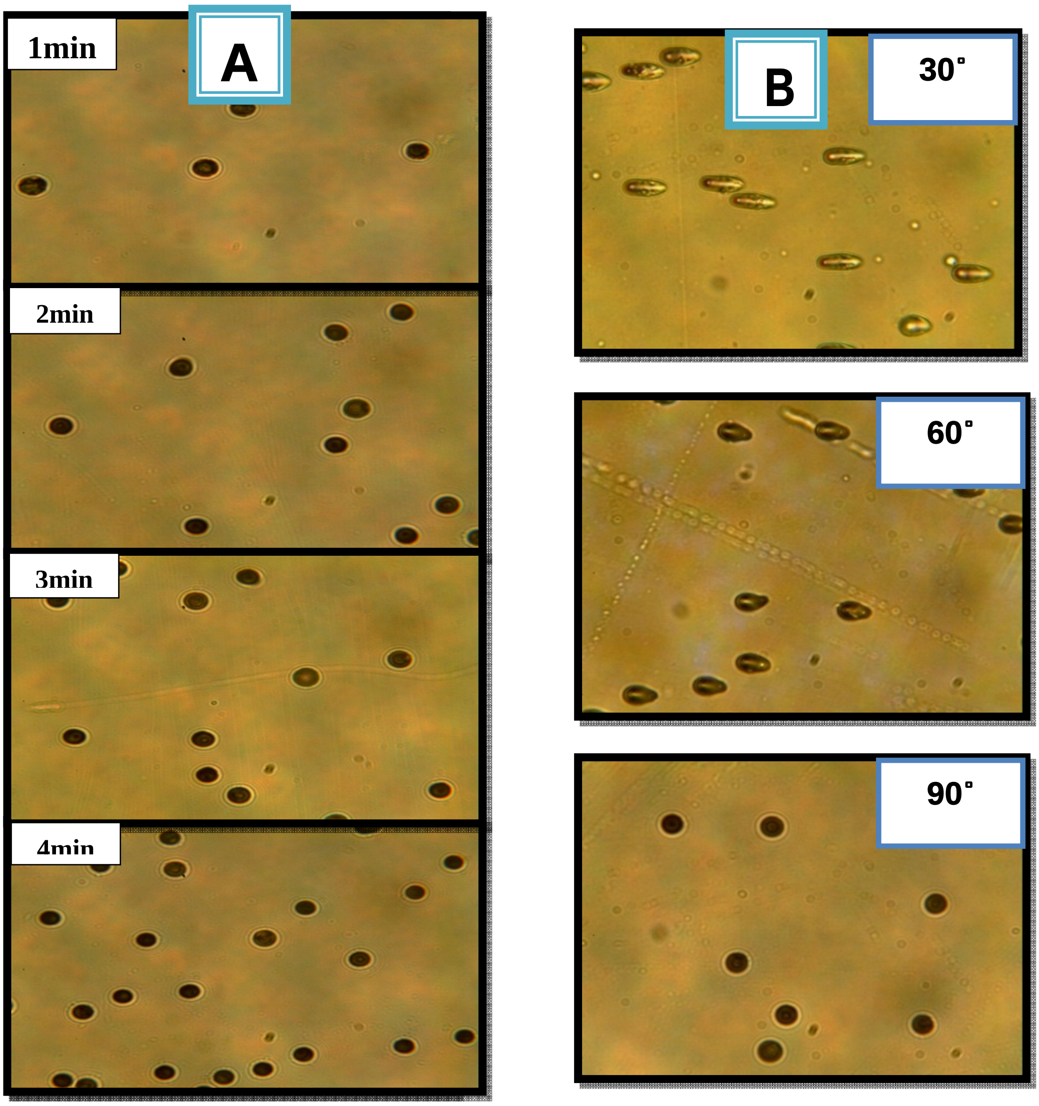

Fig. 2: Samples of images of tracks taken by the digital camera (A): for different irradiation times, (B): for different incidence angles

Figs. (3,4,5) show the relation between the tracks counts per view and the irradiation time at a constant etching time 8h, for different irradiation angles (30˚, 60˚, 90˚). It is clear that as the irradiation time increases, the tracks number increase as shown from the relation between them, which observed their dependence on the stopping power (Hussein, 2013).

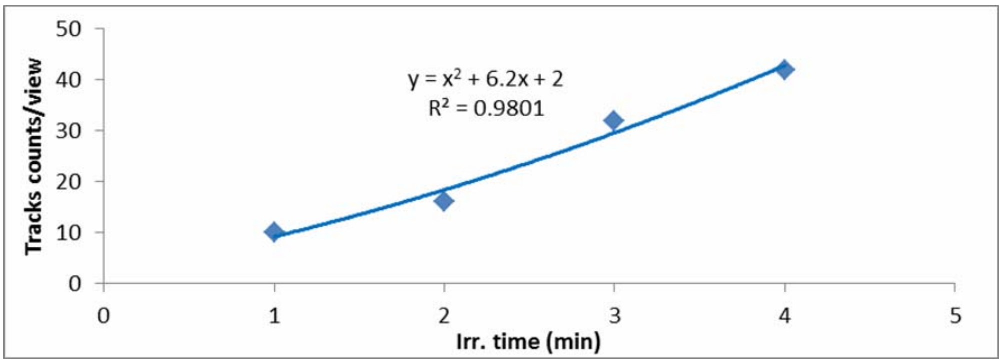

Fig. 3: Relation between the tracks counts per view and the irradiation time at constant etching time 8h, at angle 30˚.

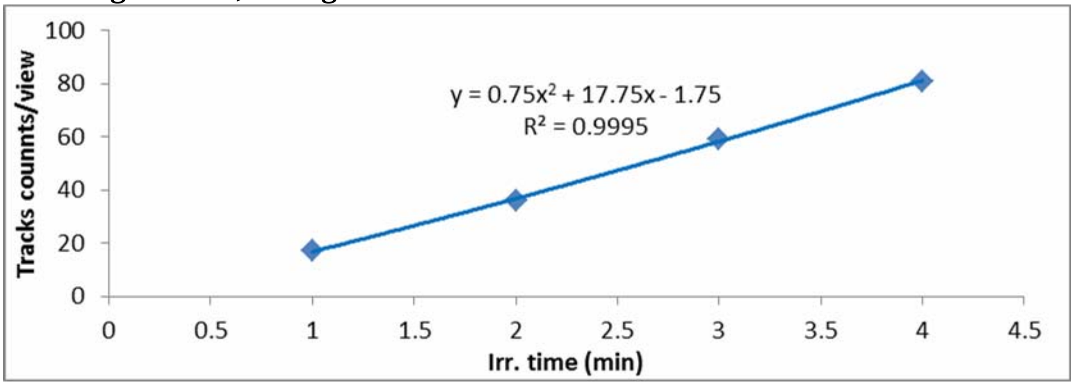

Fig. 4: Relation between the tracks counts per view and the irradiation time at constant etching time 8h, at angle 60˚.

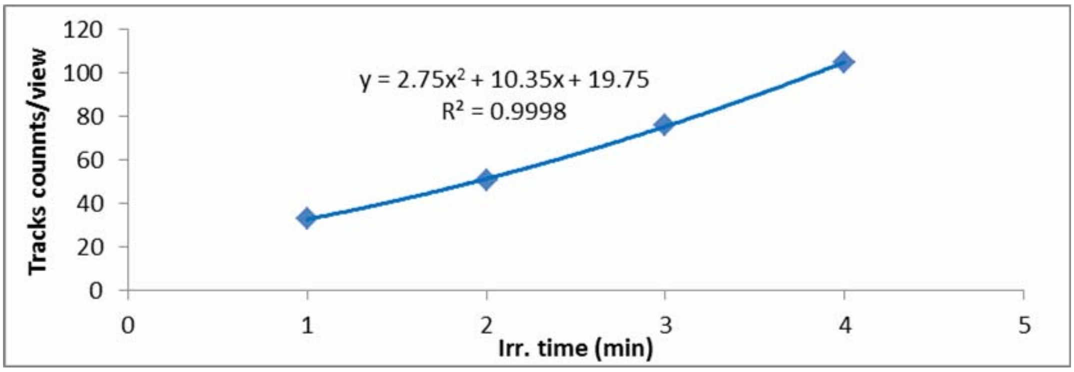

Fig. 5: Relation between the tracks counts per view and the irradiation time at constant etching time 8h, at angle 90˚.

The calculated dose rate value was $9.4865x10^{-5}$ Gy/s for the perpendicular incidence and $8.2155x10^{-5}$ Gy/s and $4.7432x10^{-5}$ Gy/s for the angle 60˚ and the angle 30˚ with the surface of the detector, respectively.

Figs. (6,7,8) show the relation between the absorbed dose in the irradiated detector CR-39 and the incident angles 30˚, 60˚ and 90˚ respectively, and the different irradiation times (1, 2, 3, 4) min, at fixed etchings time of 8h. It is worth noting that when the angle of incidence is increased, the absorbed dose by the detector will increase because the increasing of the stopping power of the detector, as shown in related figures.

The time of irradiation converted into the terms of the number of tracks for irradiated area in the detector CR-39, for the purpose of using of Figs. (9,10,11) as a calibration curves to find the absorbed dose in the detector for different irradiation times with constant etching time of 8h, by knowing the tracks number, note that the exposure area of the detector was $0.0314cm^2$, which includes 77.886 views.

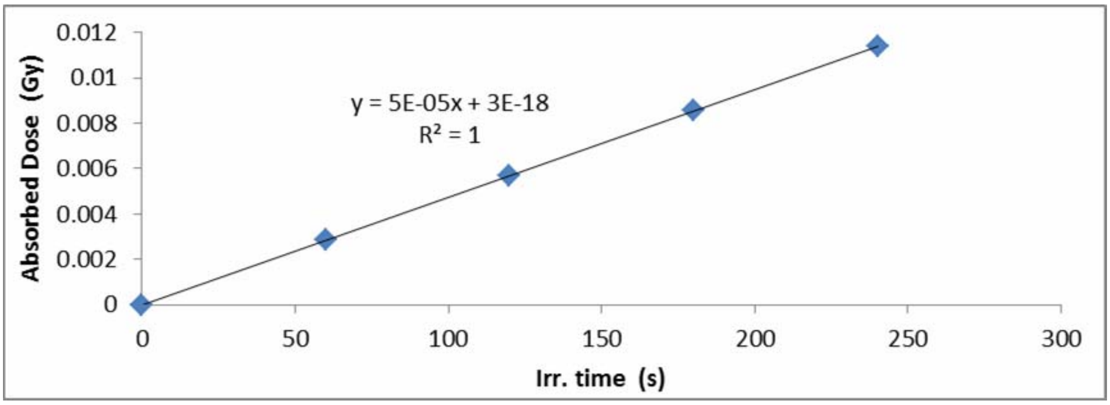

Fig. 6: Relation between the absorbed dose in the irradiated nuclear track detector CR-39, and the irradiation time at constant etch time 8h, at angle 30˚

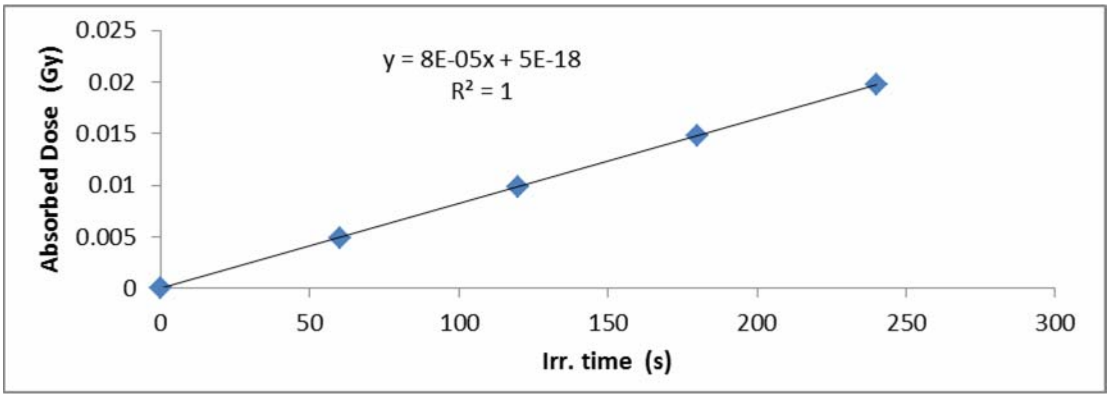

Fig.7: Relation between the absorbed dose in the irradiated nuclear track detector CR-39, and the irradiation time at constant etch time 8h, at angle 60˚

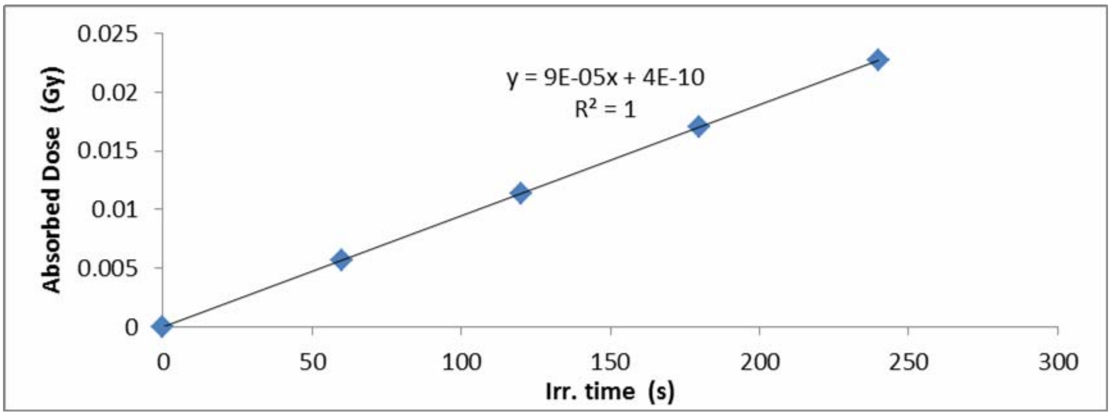

Fig. 8: Relation between the absorbed dose in the irradiated nuclear track detector CR-39, and the irradiation time at constant etch time 8h, at angle 90˚

It is clear from the figures below that at the increasing number of tracks with increasing of the irradiation time, the absorbed dose in the detector increases.

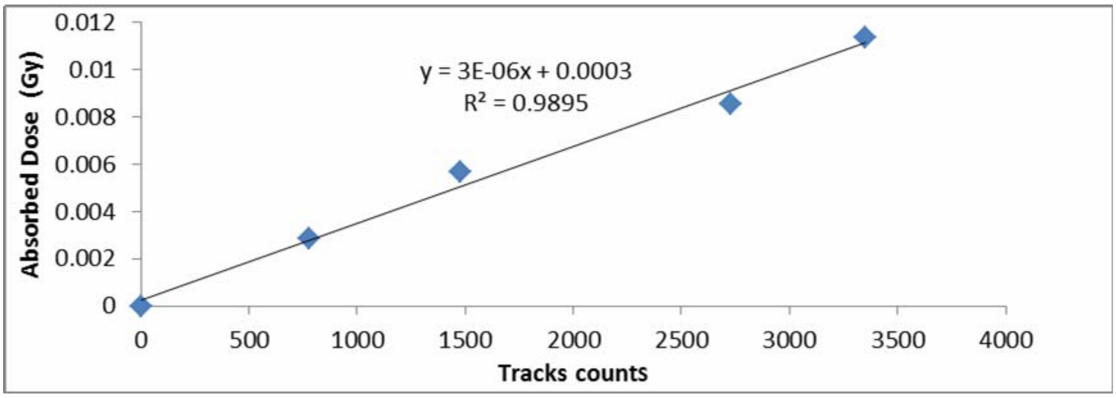

Fig. 9: Relation between the absorbed dose and tracks count at constant etch time 8h, at angle 30˚

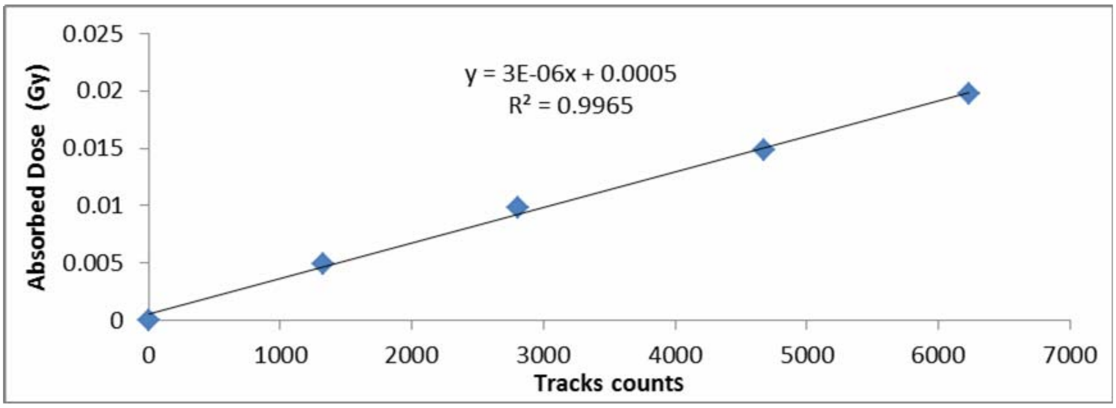

Fig. 10: Relation between the absorbed dose and track counts at constant etch time 8h, at angle 60˚

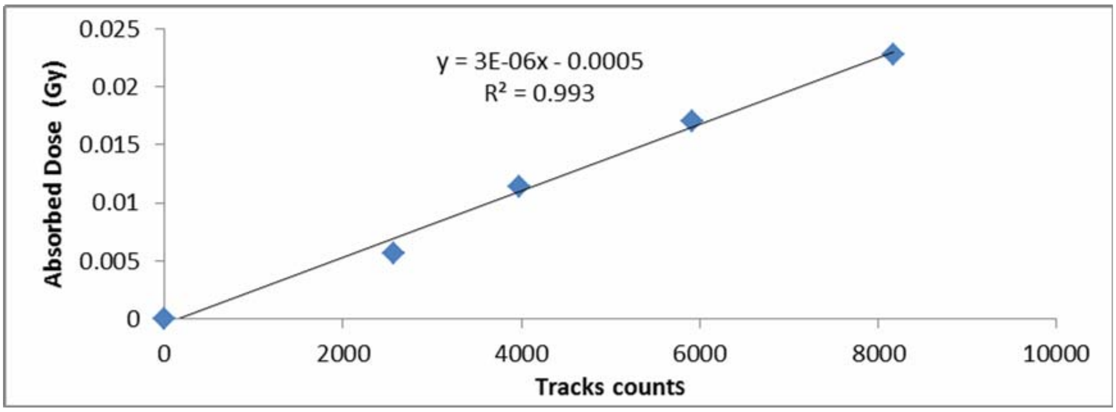

Fig. 11: Relation between the absorbed dose and tracks count at constant etch time 8h, at perpendicular angle 90˚

CONCLUSIONS

The number of tracks increases with increasing the incidence angles.

The absorbed dose rate depends on the number of tracks in the detector and the highest value was 9.4865×10^{-5} Gy/s at perpendicular angle, and the lowest value was 4.7432×10^{-5} Gy/s at oblique angle of 30˚ with the horizontal surface of the detector. Calibration curves can be used to find the absorbed dose in the detector for different irradiation times and constant etching time of 8h, by knowing the tracks number.

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