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Research Article

Study of the Sensitivity of Polymeric Nuclear Track Detectors to Alpha Particles

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Abstract: In this study, we studied the sensitivity of polymeric nuclear track detectors (LR 115 type II) to alpha particles. Our measurements, carried out in the optimal experimental conditions of the chemical etching, revealed that the strippable and non-strippable detectors used are all sensitive till 80% to alpha particles with energies between 2 and 4 MeV. The results of this study will allow us used any Solid State Nuclear Track Detectors (SSNTD) LR 115 type II (strippable or non-strippable) for the environmental radon measurements. Moreover, a height of collimator of 21.79 mm will be adopted in our measurement system in order to count an optimum quantity of nuclear tracks.

Keywords: Alpha particles, radon, sensitivity, SSNTD LR 115 type II, strippable, non-strippable,

INTRODUCTION

Solid State Nuclear Track Detectors (SSNTD) are highly used because of their simplicity in use and their relatively low-cost in comparison to other techniques (Durrani and Ilic, 1997; Quashie *et al*., 2011; Obed *et al*., 2012; Agba *et al*., 2015, 2016). However, they don't have the same sensitivity to ionizing particles. In fact, some of them detect heavy particles only like fission fragments while others detect alpha particles, neutrons, end even protons of low energy (Hakam, 1993; Leung *et al*., 2007). For a given particle, the study of the sensitivity of a SSNTD consists of the experimental determination of the range of energy in which the tracks are revealed on the detector by using a chemical etchant at selected concentration and temperature. Moreover, a good sensitivity has an impact on the quality and the quantity of the tracks observed on the films during the counting phase (Hakam, 1993; N'guessan, 2014; Messaoudi and Aouchar, 2015). In this study, we'll study the sensitivity of strippable and non-strippable SSNTD LR 115 type II to alpha particles. Those films are used to measure environmental radon in Côte d'Ivoire. In fact, this radioactive gas had been declared carcinogenic for lungs by the Word Health Organization (WHO) since 1987 (Zeeb and Shannoun, 2009; N'guessan *et al*., 2016).

MATERIALS AND METHODS

The present study has been conducted in the Department of Dosimetry and Ionizing Radiations located at the Nuclear Research Center/Nuclear Energy Commission of Algiers (Algeria).

Two packs, one of 10 strippable SSNTD LR 115 type II and the other of 10 non-strippable SSNTD LR 115 type II have been irradiated.

A 239Pu radioactive source of activity 3055 α/s/2πSr has been used in order to damage the initial energy of alpha particles in the air. For that, cylindrical collimators with a diameter of 2.5 cm and different heights have been used (Fig. 1).

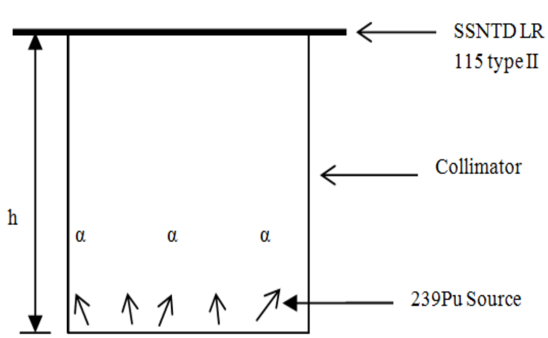

Fig. 1: Irradiation system

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Heights of the collimators: The different heights h necessary to damage the initial energy E_0 of the alpha particles to the energy E_1 at their arrival on the detector are calculated (Table 1) using the following relation:

$$h = R(E_0) - R(E_1) \quad (1)$$

(Nikezic and Janicijevic, 2002)
with E_0 = 5, 2 MeV;
where,

E = The energy of the α-particles emitted by the radioactive source
$R(E_1)$ = The distance travelled in the air by the α–particles of energy E_1 (MeV)
$R(E_0)$ = The distance travelled in the air air by the α–particles of energy E_0 (MeV)
h = The height of the collimator (mm)

The energies and the distances travelled in the air by the α-particles (Table 2) have been calculated using the Stopping and Range of Ions in Matter (SRIM) program (Ziegler *et al*., 2008).

Determination of the irradiation time: In order to standardize the irradiation flow, we calculated the duration of the exposure corresponding to each height of collimator using the following formula:

$$t_2 = t_1 \frac{\left[1-\left(1+\frac{R^2}{h_1{}^2}\right)^{-1/2}\right]}{\left[1-\left(1+\frac{R^2}{h_2{}^2}\right)^{-1/2}\right]}, \text{(Yip } et\ al.\text{, 2003)} \quad (2)$$

With t_1 = 5 mn; h_1 = 21.79 mm; R = 1.25 mm; and t_1 is the duration of the irradiation at the height h_1; t_2 the duration of the irradiation at the height h_2 and R the radius of the radioactive source. The results are reported in Table 3.

The irradiated films are etched in a solution of NaOH with a concentration 2.5 mol/L at 60°C during 120 min. Then, they have been counted with a spark counter for the strippable films and under an optical microscope for the non-strippable ones (Agba *et al*., 2016).

Table 1: Energy E of the α-particles as a function of the height of the collimator h

Height of the collimator h (mm)	Energy of α-particles E (MeV)
0.2	5.18
5.2	4.7
7.01	4.52
9.08	4.31
11.43	4.05
14.05	3.76
16.06	3.52
21.79	2.78
24	2.45
26	2.14
28	1.79
30.09	1.39
35.21	0.215
37	0

Table 2: Distance travelled in the air by α-particles as a function of their energies

Energy of α-particles (MeV)	Distance travelled in the air by α-particles (mm)
0	0
0.22	1.88
1.39	7.00
1.79	9.09
2.14	11.09
2.45	13.09
2.78	15.30
3.52	21.03
3.76	23.04
4.05	25.66
4.31	28.01
4.52	30.08
4.70	31.89
5.18	36.89

Table 3: Duration of the irradiation t as a function of the height h of the collimator

Height of the collimator h (mm)	Duration of the irradiation t
0.2	40 s
5.2	1 mn 5 s
7.01	1 mn 18 s
9.08	1 mn 36 s
11.43	2 mn 2 s
14.05	2 mn 37 s
16.06	3 mn 8 s
21.79	5 mn
24	5 mn 52 s
26	6 mn 43s
28	7mn 38 s
30.09	8 mn 40 s
35.21	11 mn 30 s
37	12 mn 36 s

Table 4: Track density as a function of the energy of α-particles (strippable films)

Energy of α-particles E (MeV)	Track density (tracks/cm^2)
0	67
0.215	137
1.39	472
1.79	2539
2.45	4915
2.78	5575
4.05	4494
4.31	3211
4.52	1702
5.18	568

Table 5: Track density as a function of the energy of α-particles (non-strippable films)

Energy of α-particles E (MeV)	Track density (tracks/mm^2)
0	17.34
1.39	18302
2.14	23071
2.45	25385
2.78	27489
3.52	17741
3.76	22666
4.05	15111
4.31	12000
4.7	1777

The track density of the SSNTD LR 115 type II: The track density as a function of the energy of the alpha particles reaching the film has also been studied for the two types of films. The results of this measurement are summarized in Table 4 and 5.

Table 6: Percentages of α-particles detected by strippable films as a function of their energy

Energy of the particles E (MeV)	5.18	4.52	4.31	4.05	2.78	2.45	1.79	1.39	0.215	0
Percentages (%) of α-particles	10.2	30.5	57.6	80.6	100	88.2	45.5	8.5	2.5	1.2

Table 7: Percentages of α-particles detected by non-strippable films as a function of their energy

Energy of the alpha particles E (MeV)	4.7	4.31	4.05	3.76	3.52	2.78	2.45	2.14	1.39	0
Percentages (%) of α–particles	6.5	43.7	55	82.5	64.5	100	92.4	83.9	66.6	0.1

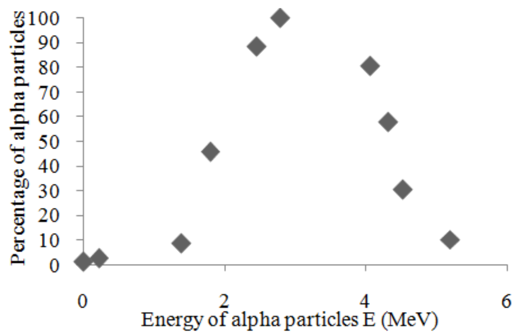

Fig. 2: Variation of the percentages of α–particles as a function of their energy(strippable films)

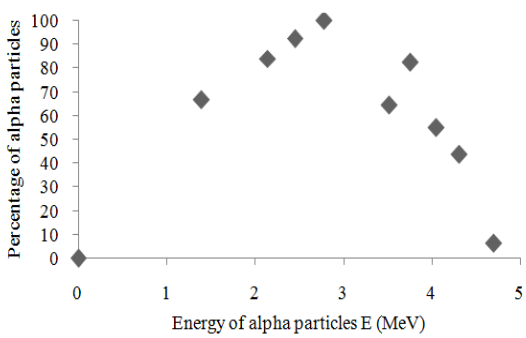

Fig. 3: Variation of the percentages of α–particles as a function of their energy (non-strippable films)

RESULTS AND DISCUSSION

Table 1 shows that the energies of the α-particles vary as a function of the distance between the detector and the radioactive source. This can be explained by the short length of the distance travelled by those particles which are restrained by the air in the collimator. This parameter will be taken into account during the preparation of the system which will be used for environmental radon gas monitoring.

Table 2 indicates that the distance travelled in the air by the α-particles vary as a function of the energy. One can notice that this distance increases with the energy of the particles emitted. The particles are slowed down until their total absorption when the thickness of the air increases. One can also note that the energy of the α-particles arriving on the SSNTD decreases with the height of the collimator. The energy decreases when the height of the collimator increases, even after a long time of irradiation (Table 3).

Table 4 and 5 show that the tracks density counted increases with the energy of the particles arriving on the film. For both tables, one can notice that this density is optimum for α-particles with a value of energy equal to 2.78 keV. This value is taken as a reference (normalized at 100%) to deduce the percentages of the track density of the other energies. The calculated values of percentages are compiled in Table 6 and 7. Graphs on Fig. 2 and 3 are drawn using the data in these tables.

The two graphs have the same trend. They increase from the beginning until a maximum energy. After this maximum, the graphs decrease toward zero percentage.

The analysis of the (2) graphs (Fig. 1 and 2) shows that, with some uncertainties, strippable and non-strippable SSNTD LR 115 type II are both sensitive till 80% to α-particles with an energy between 2 and 4 MeV. This result is an added data to previous findings about the sensitivity of polymeric nuclear track detectors to α-particles (Durrani and Ilic, 1997).

CONCLUSION

The comparative study of the sensitivity to α-particles of strippable and non-strippable SSNTD LR 115 type II gave similar results. In fact, he two types of films are sensitive till 80% to α-particles with energies between 2 and 4 MeV. So, it is possible to use any type of SSNTD LR 115 type II for environmental radon gas monitoring.

Moreover, this study showed that, to obtain an optimum irradiation of strippable and non-strippable SSNTD LR 115 type II by an alpha emitter radioactive source like radon gas and its progeny, the appropriate height of the collimator to use is 21.7 mm.

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