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OPTIMIZATION OF CHEMICAL ETCHING PARAMETERS OF STRIPPABLE AND NON-STRIPPABLE SOLID STATE NUCLEAR TRACK DETECTORS (SSNTD) LR 115 TYPE II

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ABSTRACT

In this study, optimal experimental parameters, especially the optimum time and the residual thickness for the revelation of latent tracks left behind by alpha particles emitted by radon gas and its progeny on strippable and non-strippable Solid State Nuclear Track Detectors (SSNTD) LR 115 type II have been first determined. Then, the track density of the strippable films has been normalized. For a residual thickness of 6 µm, the values of the optimum time and the normalization coefficient of track density obtained are respectively 120 minutes and 0.26 ± 0.03. These values are in close agreement with those reported by different authors. The results of this study allowed us to select the optimal conditions for the chemical etching of the SSNTD used for radon gas monitoring in Côte d'Ivoire.

INTRODUCTION

There are many techniques used for environmental radon gas monitoring (Glenn, 1979; Zeeb and Shannoun, 2009; Obed *et al*, 2012). Among these techniques, the Solid State Nuclear Track Detectors (SSNTD) is one of the most used for its simplicity, its reliability, and its relatively low-cost compared to many other methods (Durrani and Bull, 1987; Quashie *et al*, 2011; Agba *et al*., 2015). The SSNTD LR 115 type II are intensively used, but some of the difficulties encountered are the quantity and the quality of the tracks counted on the films (Yip *et al*., 2003; Palacios *et al*, 2010; Metha *et al*., 2015). In fact, the aspect and the number of the latent tracks depend mostly on the chemical etching of the detectors after their collection.

For this reason, the optimization of the chemical etching parameters is very necessary and important. For acceptable results, the chemical etching depends on three (3) essential parameters: the nature and the concentration of the etchant, the temperature of the etching bath, and the etching time. Indeed, at high concentration and high temperature the etching is aggressive, which leads to a high background on the films during the tracks counting phase.

That's why a soft etching is preferred in the following experimental conditions with a 2.5 mol/LNaOH solution at the constant temperature of 60°C (Aniagyei *et al*., 1996; Nikezic and Janicijevic, 2002). This study reports data on strippable and non-strippable LR 115 type II films with the main purpose of determining the optimal chemical etching time for radon monitoring in Côte d'Ivoire. Additionally, a normalization factor of track density to a 6 µm residual thickness has been determined for the strippable detectors.

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MATERIALS AND METHODS

Chemical etching time and residual thickness

36 samples of strippable SSNTD LR 115 type II (purchased from DOSIRAD, France) have been irradiated with a Pu-239 radioactive source of activity 3055 α/s/2πSr through a collimator 21.79 mm high during 5 minutes. Then, these samples have been introduced in an etching bath of NaOH solution with the concentration 2.5 mol/ Lat the constant temperature of 60° C. After 80 minutes, three samples have been taken from the bath, rinsed with tap water, then put in distilled water before been dried in air. Five (5) minutes later, three more samples have been submitted to the same process. And so on until 135 minutes. After been dried, each sample has been picked with a lancet and posed on the plinth of an electronic comparator to determine the residual thickness. Then, it had been put between the electrodes of a spark counter for measurement. Four (4) samples of non-strippable SSNTD LR 115 type II have also been irradiated with the same radioactive source for 10 minutes, and submitted to a chemical etching from 90 to 130 minutes. The number of tracks has been counted under an optical microscope.

Normalization coefficient of track density

During our experiments, we noticed that the chemical etching is not reproducible. In fact, the removed layer thickness of SSNTD LR 115 type II is not always the same, even in identical experimental conditions. As the track density depends on the thickness removed, it was necessary to do a correction taking this layer into account. In the chemical etching conditions used (NaOH 2.5 mol/L at T = 60°C during 120 minutes), the average value of the residual thickness is about 6 µm. So, the track density has been normalized to this value. In order to check if the correction calculated for 5 minutes of exposure is also valid for another period of exposure, we exposed two (2) other packs of 15 films each to the same radioactive source. The first pack is exposed during 10 minutes and the other for 15 minutes. The same conditions as the one exposed during five (5) minutes have been applied to the two (2) packs. Then, the thickness of the residual layer of each film has been measured before counting the number of latent tracks under an optical microscope.

RESULTS AND DISCUSSION

Determination of the chemical etching time and the residual thickness

Chemical etching time

Our experimental results of the chemical etching time are reported in tables 1 and 2. Using these data, two graphs of the track density as a function of the etching time are drawn, as shown in figures 1 and 2. The two graphs (Figures 1 and 2) show the same trend for both strippable and non-strippable films. Indeed, the track density increases with the duration of the chemical etching till 120 minutes. After this value, the track density decreases. So, one can consider that 120 minutes is the optimal etching time for any type of SSNTD LR 115 used here. This value is in agreement with those reported by MAYAKI (Mayaki, 1995).

Table 1. Track density as a function of the chemical etching time for strippable films

Chemical etching time (min)	Track density (tr/cm^2)
80	3471
85	3547
90	4085
95	5299
100	5933
105	5227
110	6619
115	6740
120	7538
125	6935
130	5744
135	6901

Table 2. Track density as a function of the chemical etching time for non-strippable films

Chemical etching time (min)	Track density (tr/cm^2)
90	48737
110	49579
120	51555
130	48036

Residual thickness

The use of a spark counter necessitates that the residual layer thickness of the films measured should be comprise between 5.5 and 6.5 µm (Cross and Tommasino, 1970). In order to meet this requirement, a study of the residual thickness of the strippable detectors LR 115 as a function of the duration of the chemical etching has been carried out. The results obtained are given in table 3. The initial thickness was 12.45µm for all films. The data provided in table 3 have been used to draw figure 3. On this figure, the residual thickness evolves as the contrary of the chemical etching time. At the optimal etching time (t = 120 minutes), the thickness of the residual layer recorded is 5.77 µm. This value fits well the criteria of the spark counter use conditions.

Table 3. Residual thickness as a function of the chemical etching time

Chemical etching time (min)	Residual thickness (µm)
80	8.65
85	8.23
90	8.08
95	7.29
100	7.28
105	6.57
110	6.23
115	5.65
120	5.77
125	5.67
130	5.33
135	5.06

Determination of the normalization coefficient of the track density

For 5, 10, and 15 minutes exposures, the track density as a function of the thickness of the layer removed are collected in tables 4, 5 and 6. For five (5) minutes exposure, the variation of the track density as a function of the etching time of the strippable films presents a linear zone between 80 and 120 minutes (Figure 1).

Table 4.Track density as a function of the thickness removed (t = 5 min)

Thickness removed (µm)	3.80	4.22	4.37	5.16	5.42	6.22	6.68
Track density (tr/cm^2)	3471	3547	4085	5299	5933	6619	7538

Table 5.Track density as a function of the thickness removed (t = 10 min)

Thickness removed (µm)	5.10	5.70	6.00	6.27	6.71
Track density (tr/cm^2)	5776	6510	7239	8235	8890

Table 6. Track density as a function of the thickness removed (t = 15 min)

Thickness removed (µm)	5.30	5.80	6.17	6.59	6.94
Track density (tr/cm^2)	6100	6600	7446	8324	9150

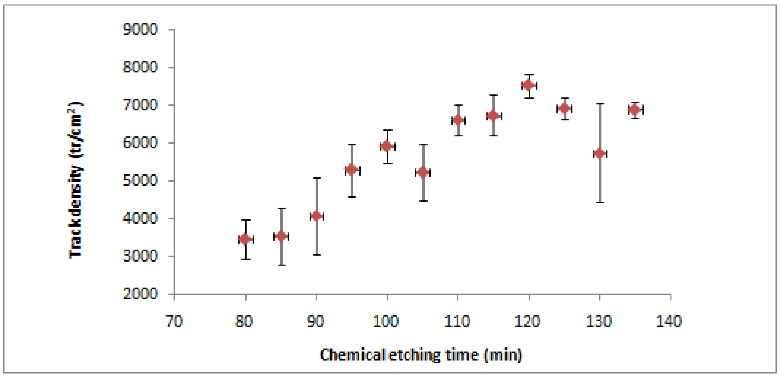

Figure 1. Variation of the track density as a function of the chemical etching time for strippable films

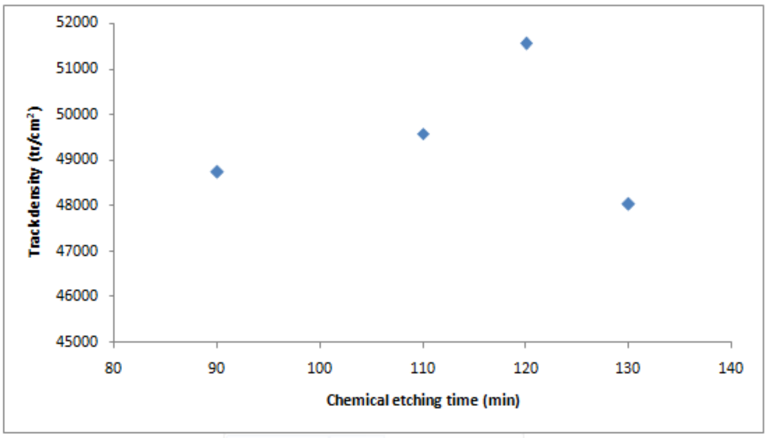

Figure 2. Variation of the track density as a function of the chemical etching time for non-strippable films

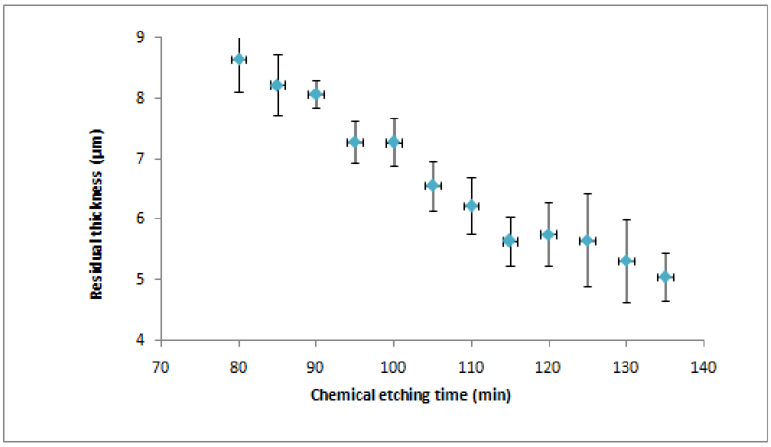

Figure 3.Variation of the residual thickness as a function of the chemical etching time for strippable films

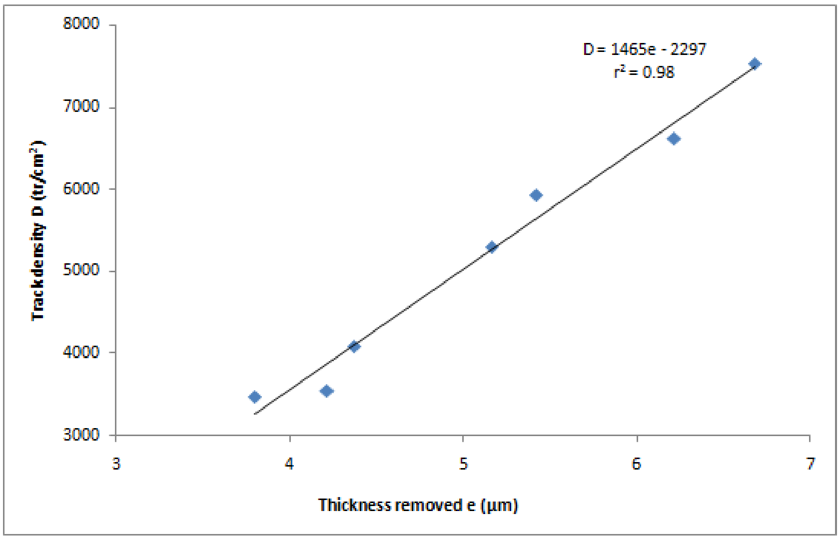

Figure 4. Variation of track density D as a function of the thickness removed e (t = 5 min)

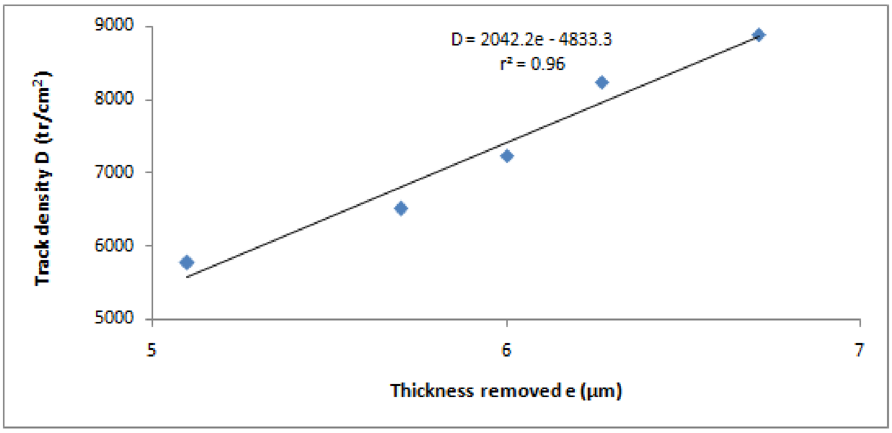

Figure 5. Variation of track density D as a function of the thickness removed e (t = 10 min).

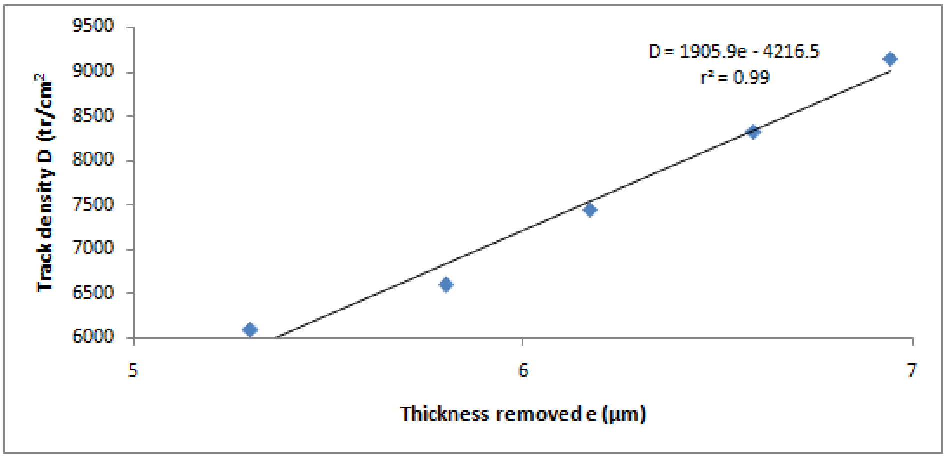

Figure 6. Variation of track density D as a function of the thickness removed e (t = 15 min).

In that zone, the variation of the track density as a function of the thickness removed (Figure 4) gives a straight line, and the equation derived is:

$D = 1465e – 2297$

Where D is the track density counted and e is the thickness of the active layer of the film removed after chemical etching.

For the normalization thickness

$e = 6$ µm, we have: $D = D_o = 6a + b$.

The ratio D_o/D can be written in the form:

$D_o/D = 1/ [1+\alpha(e-6)]$;

So, $D_o = D/ [1+\alpha(e-6)]$, with $\alpha = 1/ (6+b/a)$;

Where α is the normalization coefficient of track density for 6 μm and D_o the track density normalized to a removed thickness of 6 μm.

Table 7. Comparison of different measured values of normalization coefficients

Authors	SEIDEL	TORRI	HAKAM	Present work
Normalization coefficient (α)	0.30	0.28	0.27 ± 0.06.	0.26 ± 0.03.

For the previous straight line (Figure 4), the value of α found is 0.23. The measurement of the track density as a function of the thickness removed, for 10 and 15 minutes exposures (Figure 5 and 6) show the same behaviours as Figure 4, but the straight lines obtained have different equations. The normalization coefficients found are respectively 0.28 and 0.26. For our study, the average value of the normalization coefficient is α = 0.26 ± 0.03. This value is close to those reported by SEIDEL (0.30), TORRI (0.28), and HAKAM (0.27± 0.06) (Hakam, 1993), as summarized in Table 7.

Conclusion

In this study, optimal experimental chemical etching conditions have been determined for strippable and non-strippable SSNTD LR 115 type II. These conditions are: a NaOH 2.5 mol/L solution maintained at the temperature t = 60°C during 120 minutes. The normalized coefficient of the track density measured for these detectors with 6 μm residual thickness is (0.26 ± 0.03). Theses parameters helped us work in optimal conditions. Moreover, thanks to the normalization, it is also possible to compare our results to those recorded by different laboratories.

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