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Optimization of track etched Makrofol etching conditions for short-term exposure duration

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Abstract

Exposure time of nuclear track detectors at humid environments is normally limited to a few weeks because filter used to avoid humidity is not completely waterproof and, after several months, some parts of detector start to degrade. In other really extreme measurement conditions, like high aerosol content, high or low temperatures, etc., the exposure time also requires a reduction. Then detector detection limit becomes a problem, unless radon concentrations were high. In those cases where radon levels are not high enough a better detection efficiency is required. In our laboratory we use passive detectors based on the track etched Makrofol DE foil covered with aluminized Mylar and they are analyzed by means of an electrochemical etching. Our standard etching conditions allow analyzing detectors generally exposed for periods between three and six months. We have optimized our etching conditions to reduce the exposure time down to a month for common radon concentration values.

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Keywords: Radon; Makrofol; etching conditions.

1. Introduction

When nuclear track detectors are exposed to high humidity environments, a waterproof filter is normally used to protect them. However, the duration of the exposure is normally limited because the filter is not completely waterproof and after several months some parts of detector start to degrade (Moreno et al. 2013). The same limitation on exposure time appears in other extreme measurements conditions like very high aerosol content, or temperature. In these scenarios the maximum sensitivity should be achieved to shorten the exposure time avoiding high lower detection limits.

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In our laboratory we use passive detectors based on the track etched Makrofol DE foil covered with aluminized Mylar that are electrochemically etched (Baixeras et al., 1996). Our standard etching conditions allow analyzing detectors generally exposed for periods from 3 to 6 months. We have tried to optimize our etching conditions to reduce the exposure time down to a month for common radon concentration values.

2. Methodology

Our standard etching conditions consist of 4 h chemical etching (EC) at 40 ºC, using 6M KOH mixed with 50% ethanol – purity ~96% – as etchant, followed by 1.5 h electrochemical etching (ECE), at 3 kHz frequency and $3.1 \cdot 10^6$ $V \cdot m^{-1}$ electric field strength.

A total number of 120 detectors has been exposed in a small radon chamber (Fig. 2) and 12 detectors have been etched at these conditions to obtain a reference track density, $\rho_{ref.}$. The rest has been grouped in 20 sets and has been etched changing some influent parameters on detectors response, like temperature (T), duration (t), electric field strength (E) and frequency (f), with the aim to obtain those parameter values that maximize relative efficiency, which does not depend on exposure.

A first group of 6 sets has been etched with small variations of our standard conditions (Table 1) and the second group of 12 sets has been electrochemically etched by two different steps, only varying duration and frequency of the first one (Table 2). A similar number of background detectors has been etched together with the exposed ones to obtain the net track density, ρ. Relative sensitivity ($\varepsilon_{rel} = \rho / \rho_{ref.}$) has been determined.

3. Results

For the 1st group of etching conditions (Table 1), those that present a higher relative sensitivity are 1.3, 1.4 and 1.5, which reduces duration of CE, increases duration of ECE and reduces the electric field strength.

Table 1. First group of etching conditions (temperature (T), duration of CE (t_{CE}), duration of ECE (t_{ECE}), electric field strength (E_{ECE}) and frequency (f_{ECE}) applied during the ECE) and the relative sensitivity (ε_{rel}) obtained.

Set	T ± 1 (ºC)	t_{CE} ± 0.02 (h)	t_{ECE} ± 0.02 (h)	E_{ECE} ± 10% ($V \cdot m^{-1}$)	f_{ECE} ± 10% (Hz)	ε_{rel}
Reference	40	4.00	1.5	$3.1 \cdot 10^6$	3000	1.00 ± 0.01
1.1	40	3.00	2.00	$3.1 \cdot 10^6$	3000	0.97 ± 0.07
1.2	45	3.00	2.00	$3.1 \cdot 10^6$	3000	0.93 ± 0.07
1.3	40	3.00	2.00	$2.6 \cdot 10^6$	3000	1.27 ± 0.10
1.4	40	3.00	2.50	$2.6 \cdot 10^6$	3500	1.25 ± 0.10
1.5	45	3.50	2.50	$2.1 \cdot 10^6$	2500	1.19 ± 0.09
1.6	45	3.50	2.00	$3.1 \cdot 10^6$	2500	0.99 ± 0.08

For the 2nd group of etching conditions (Table 2), short-circuits have been happened for frequencies higher than 1000 Hz, therefore sets 2.6, 2.7, 2.8 and 2.9 have been discarded from de analysis. Relative sensitivity presents similar values within the interval [250-1000] Hz (Fig.1.a). A frequency of 250 Hz has been selected to analyze the increase of 1st step duration. In this case relative sensitivity increases accordingly (Fig.1b). For durations longer than 5.33 h the risk of short-circuits reappears.

Table 2. Second group of etching conditions (temperature (T), duration of CE (t_{CE}), electric field strength (E_{CE}) and frequency (f_{CE}) applied during the CE, duration of ECE (t_{ECE}), electric field strength (E_{ECE}) and frequency (f_{ECE}) applied during the ECE) and the relative sensitivity (ε_{rel}) obtained.

Set	T ± 1 (ºC)	t_{CE} ± 0.02 (h)	E_{CE} ± 10% ($V \cdot m^{-1}$)	f_{CE} ± 10% (Hz)	t_{ECE} ± 0.02 (h)	E_{ECE} ± 10% ($V \cdot m^{-1}$)	f_{ECE} ± 10% (Hz)	ε_{rel}
Reference	40	4.00	CE	CE	1.5	$3.1 \cdot 10^6$	3000	1.00 ± 0.01
2.1	40	4.00	$3.0 \cdot 10^6$	100	1.5	$3.1 \cdot 10^6$	3000	0.83 ± 0.07
2.2	40	4.00	$3.0 \cdot 10^6$	250	1.5	$3.1 \cdot 10^6$	3000	0.92 ± 0.08
2.3	40	4.00	$3.0 \cdot 10^6$	500	1.5	$3.1 \cdot 10^6$	3000	0.92 ± 0.08
2.4	40	4.00	$3.0 \cdot 10^6$	750	1.5	$3.1 \cdot 10^6$	3000	0.88 ± 0.07
2.5	40	4.00	$3.0 \cdot 10^6$	1000	1.5	$3.1 \cdot 10^6$	3000	0.94 ± 0.08
2.6	40	4.00	$3.0 \cdot 10^6$	1500	1.5	$3.1 \cdot 10^6$	3000	0.87 ± 0.08
2.7	40	4.00	$3.0 \cdot 10^6$	2000	1.5	$3.1 \cdot 10^6$	3000	0.62 ± 0.06
2.8	40	4.00	$3.0 \cdot 10^6$	2500	1.5	$3.1 \cdot 10^6$	3000	0.69 ± 0.06
2.9	40	4.00	$3.0 \cdot 10^6$	3000	1.5	$3.1 \cdot 10^6$	3000	0.59 ± 0.05
2.10	40	4.67	$3.0 \cdot 10^6$	250	1.5	$3.1 \cdot 10^6$	3000	1.04 ± 0.08
2.11	40	5.00	$3.0 \cdot 10^6$	250	1.5	$3.1 \cdot 10^6$	3000	1.12 ± 0.09
2.12	40	5.33	$3.0 \cdot 10^6$	250	1.5	$3.1 \cdot 10^6$	3000	1.15 ± 0.10

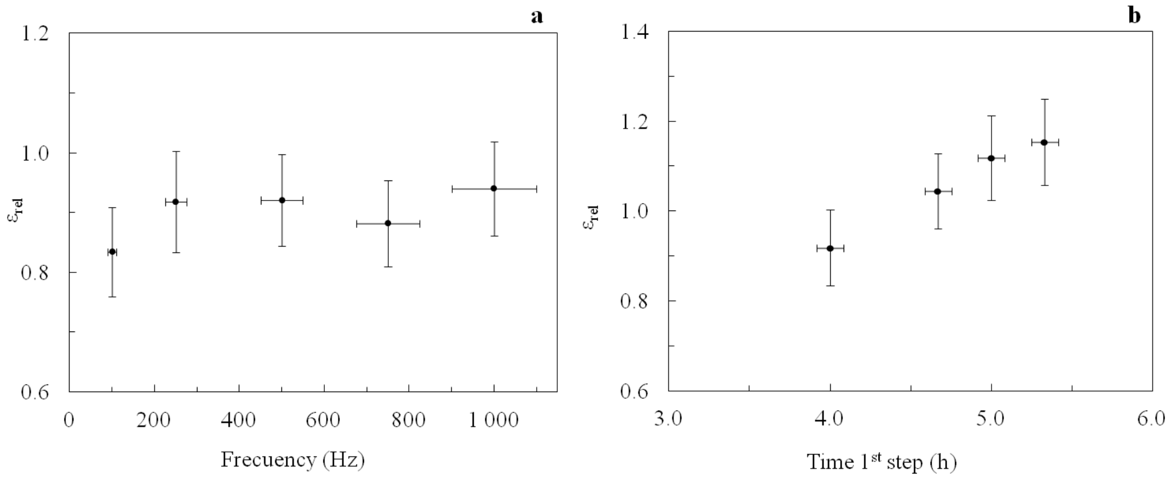

Fig. 1. (a) Relative sensitivity versus frequency and (b) relative sensitivity versus duration of the first etching step.

4. Conclusions

The duration of ECE longer than our standard shows higher relative sensibilities. In the two-step etching method, the relative sensibility increases with increasing duration of CE. It is necessary to continue the optimization process exploring other parameters and additional values of those parameters already analyzed till now.

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