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About ageing and fading of Cr-39 PADC track detectors used as air radon concentration measurement devices

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ABSTRACT

PADC detectors are widely used as air radon concentration measurement devices and the typical procedure that a Radon Service Laboratory uses to manage the detectors provides a calibration phase followed by the field measurement. The calibration is performed in a reference radon concentration atmosphere, using high radon concentration values in order to achieve typical exposure values of few MBq h m^{-3} with an exposure time of few days. On the other hand the field measurement is characterized by long term exposures lasting up to six months and by radon concentrations that are quite lower than the ones used in the calibration.

The aim of this study is to check whether the calibration procedure is actually representative of a field measurement, or, in other words, whether and how much ageing or fading can affect the calibration factor.

We found that the ageing and fading effect can produce a decrease in the detector sensitivity leading to an underestimation of the radon concentration up to 40% for exposure lasting few months. An important issue is that both ageing and fading can be ascribed to a decrease in the track etching velocity V_t.

In the paper we also provide an algorithm to compensate for the sensitivity variation due to fading/ageing effect.

1. Introduction

Since the radon concentration may strongly vary from one season to another, a general accepted criterion to assess the risk due to radon exposure is to perform a long term measurement spanning over one year. This criterion is also implemented by the Italian act (D.Lgs 241/00).

This implies that a radon monitoring service supplies detectors that stay for several months out of the laboratory. Moreover the detectors undergo uncontrolled and unmonitored environmental conditions. A Radon Service Laboratory should prove that the detector sensitivity is unaffected by different environmental conditions, or modify its analysis systems in order to compensate the sensitivity changes due to the storage before (ageing), after (fading) and during the exposure.

The aim of this work is to understand the mechanism involved in the variation of sensitivity and to supply a suitable analysis algorithm to compensate it.

2. Theory

The classical theory of track formation (Fleischer et al., 1974) provides that complex effects of track repair can lead to an annealing effect on latent tracks; nevertheless a simple approach shows that fading is a function of the temperature according to a Boltzmann equation. This effect was also confirmed, particularly in CR39 plastics, by recent studies (Diwan et al., 2003; Rana, 2007).

A partial repair of a latent track can lead to a drop of the track etching velocity V_t.

This heavily affects the detector sensitivity because, according to Eqs. (1) and (2), reduces the limit angle φ and, consequently, the detection efficiency ε.

$$\varphi = \arcsin\frac{V_b}{V_t} = \arcsin\frac{1}{V} \tag{1}$$

$$\varepsilon = 1 - \sin\varphi = 1 - \frac{1}{V} \tag{2}$$

where $V = V_t/V_b$.

The above equations hold under the hypothesis of constant V_t.

Eq. (2) can be written expressing V as a function of track parameters (Nikezic, 2000).

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Table 1
Scheme of the FAT.

Group	Subgroup	No of detectors exposed	No of detectors unexposed (background)	Exposure date	Etching date	Storage	Exposure value (kBq h m^{-3})
A	A1	10	2	Jul-08	Jul-08	freezer	1391
	A1_Cf	2	–	Jul-08	Jul-08	freezer	^{252}Cf
	A2	10	2	Jul-08	Oct-08	freezer	1391
	A2_Cf	2	–	Jul-08	Oct-08	freezer	^{252}Cf
	A3	10	2	Jul-08	Jen-09	freezer	1391
	A3_Cf	2	–	Jul-08	Jen-09	freezer	^{252}Cf
B	B1	10	2	Jul-08	Jul-08	Ambient	1391
	B1_Cf	2	–	Jul-08	Jul-08	Ambient	^{252}Cf
	B2	10	2	Jul-08	Oct-08	Ambient	1391
	B2_Cf	2	–	Jul-08	Oct-08	Ambient	^{252}Cf
	B3	10	2	Jul-08	Jan-09	Ambient	1391
	B3_Cf	2	–	Jul-08	Jan-09	Ambient	^{252}Cf
C	C1	10	2	Oct-08	Oct-08	freezer	1455
	C2	10	2	Jan-09	Jan-09	freezer	1288
	C3_Cf	2	–	Apr-09	Apr-09	freezer	^{252}Cf
D	D1	10	2	Oct-08	Oct-08	Ambient	1455
	D2	10	2	Jan-09	Jan-09	Ambient	1288
	D3_Cf	2	–	Apr-09	Apr-09	Ambient	^{252}Cf
E	E2	10	2	Jul-08–Jan-09	Jan-09	Ambient	1288 + 1391
F	F1	10	1	Jul-08–Oct-08	Oct-08	Ambient	410
	F2	10	1	Jul-08–Jan-09	Jan-09	Ambient	921

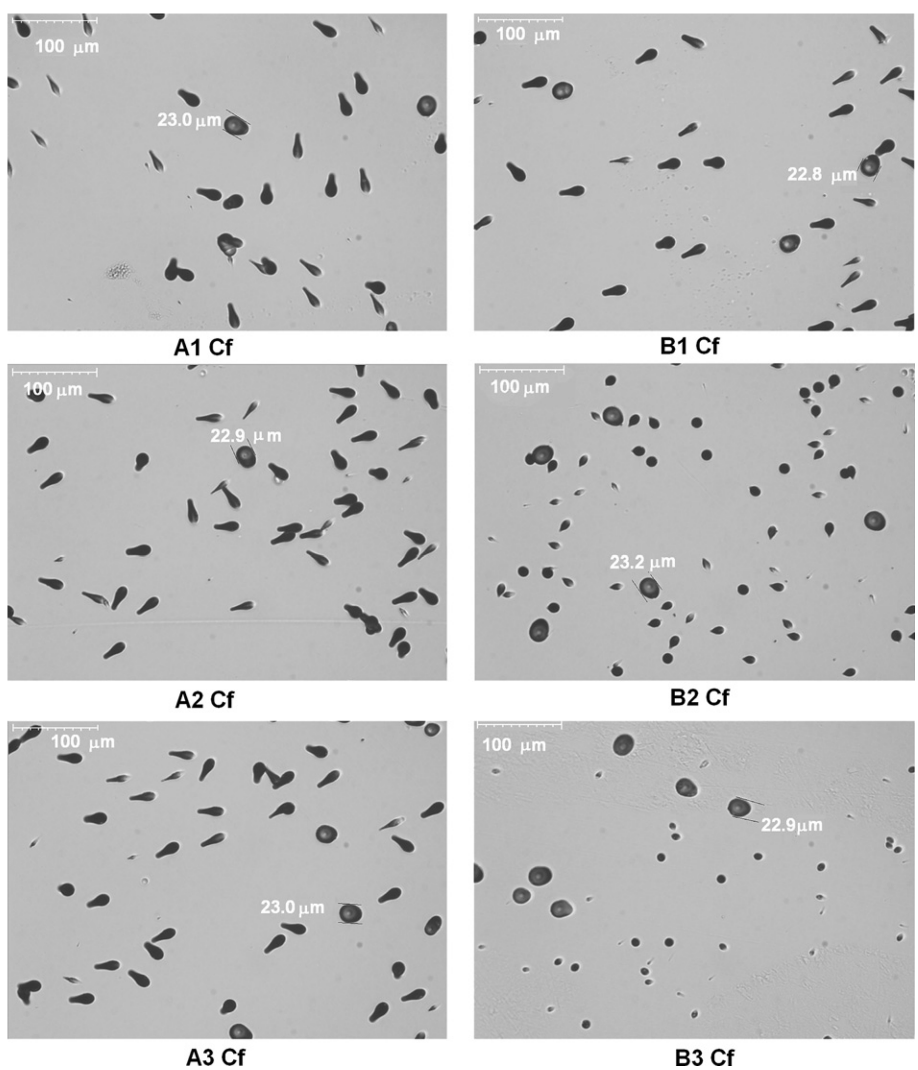

Fig. 1. Frame grabs of the surface of detectors exposed to ^{252}Cf.