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Effect of environment humidity to radon measurement with SSNTD

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Abstract For a passive radon detector of Solid State Nuclear Track Detector (SSNTD), the measurement results can be affected under an environment of high humidity. In order to correct this kind of measurement errors, experiments in normal radon laboratory were performed. The track films were etched in 6.25 mol/L NaOH solution at 70°C for 12 h, and rinsed with water for 6 h. The experiment results show that calibration factor of the SSNTD decreased with increasing humidity, because of increased stopping power of the moisture-absorbed film surface to α particles. Therefore, the calibration factor K should be corrected from the calculated result.

Key words Solid state nuclear track detector, Humidity, Influence

1 Introduction

With the increasing importance to human as a nuclear substance, radon has attracted increased research interest, and in many countries large-scale radon concentrations surveys have been conducted. Solid State Nuclear Track Detector (SSNTD), a passive radon monitors developed originally at the Karlsruhe Nuclear Research Centre, has been widely used in ionizing radiation measurements, and CR-39(allyl diglycol carbonate) is a particularly useful material for recording tracks left by α particles.

Since 1985, when SSNTDs were used for a nationwide indoor radon survey in Japan[1], they have been widely used because of their time-accumulation working manner, and the advantages of relatively cheap, small, handy, sturdy and easy mailing[2]. However, their measurement precision is limited by the reading errors resulted mainly from changes in the system bias in high humidity. In this work, calibration factor of SSNTDs in different percentages of humidity was investigated for a better understanding of the effect of environment humidity on SSNTD measurement.

2 Experimental

2.1 SSNTD device and principle

SSNTD is made of three parts: a diffusing cup, a glass fiber filter, and CR-39 film, which is used as etched track detectors, separately. The films are located at the bottom of the diffusing cup, which is covered with the glass fiber filter. The filter prevents infiltration of radon daughters and only lets radon permeate into the detector. The α particles irradiating the films and result in radiation damage along their tracks at atom-scale, named latent tracks[3]. The tracks produced by α particles in the films were visualized by chemical etching to enlarge the track damages into etch pits, which are big enough for observing them under an optical microscope.

2.2 Etching of track

The track etching device consists of a water tank in constant temperature and an etching cup. When the film is etched, the water tank should not have temperature gradient. In addition, cares should be taken against possible concentration gradient caused by the etchant evaporation[4].

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In the experiment, temperature variation of the CS-501 water tank was controlled within ±1℃, so as to achieve an ideal constant temperature for etching the SSNTDs. The etching cup of stainless steel or organic glass was used.

Along the paths of a charged particle penetrating the film, chemical bonds of the film are fractured, and displacements of the atoms and holes, which are termed as chemical active centers, are generated. Under the chemical activity of the etchant, the chemical active centers generated in the film are etched to pits quickly, hence the tracks.

Electron microscopic analysis shows that, for a charged particle-irradiated SSNTD having tracks intersecting with its surface, by immerging it in appropriate etchant with definite abduction time, the scathing section dissolves and forms tunnels along the tracks. And the detector is etched slowly. This chemical process is actually relative to the film component, etchant concentration, and temperature and time of the etching [1,5].

2.3 Track identification

The track identification is done by reading the irradiated films under a microscope. The track shape changes with the incident angle. For small incident angles, the track is long (Fig.1).

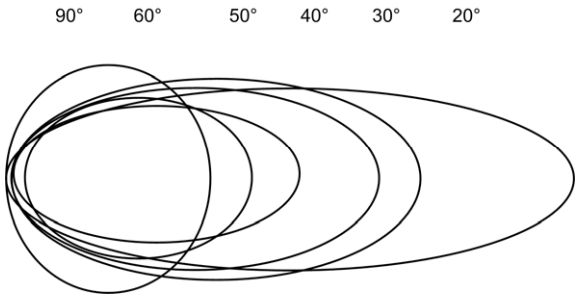

Fig.1 The α track shape with the radial angle.

Under the microscope, the round and ellipsoidal track has clear boundary. A round track with black border and bright point has the better three dimension arrangement, but the uniform ones are in appearance like a comet with little dark head and bright cauda. All of these distinguish with that for mechanical scathe distinctly.

2.4 Experimental

SSNTDs are usually placed for measurement of two to six months to accumulate the signal from radon and its daughters[6]. The mean radon concentration can be calculated with track density and the calibration factor K exposed at normal radon laboratory.

Because of the obvious effect of high humidity on the calibration factor K, the detector deployment should be designed carefully. Most of the SSNTDs were deployed in places of high humidity (>70%), and no detectors were placed under low humidity (<60%).

The track films were irradiated for 48 h at 20℃ under the radon concentration of 1600 Bq/m^3. Then, they were etched in 6.25 mol/L NaOH solution at 70℃ for 12 h, and rinsed by water for 6 h. These are results of experiments to optimize the conditions. The alkali residuals on the detector surface were purged, and the moisture was sipped up with filter paper, before the track observation with the microscope.

The calibration factor K (m·Bq·h) was calculated by Eq.(1),

$$K = (T–B)/(A·C·t) \quad (1)$$

where t is the exposure time (h), C is the average radon concentration (Bq/m^3), A is the observation area (m^2), T is the track density of the experimental films (N_{track}/m^2), and B is the track density of the blank films (N_{track}/m^2).

3 Results and discussion

Uncertainties of the experimental results were analyzed with the Dixon rules[7]. The calibration factors derived with the two types of filters are listed in Table 1.

From Table 1, the calibration factors K_1 and K_2 measured with 1# and 2# filter in different humidity conditions range from 0.917 to 1.414 and 1.046 to 1.533, respectively, with the lowest K value at the highest humidity.

According to the Dixon rules, the calibration factor K at 95 % humidity is a strange value. It is obviously smaller than others. The average K factor

obtained with 1# filter at 60–90% humidity is 53.2% larger than that at 95% humidity. Comparably, the average K factor with 2# filter at 60–90% humidity is 32.3% larger than that at 95% humidity.

Table 1 Calibration factors (in 10^{-4}) of SSNTD with two types of filters in different humidity conditions

Humidity/%	Filter 1#	Filter 2#
60	1.414	1.533
70	1.485	1.420
75	1.442	1.338
80	1.483	1.338
85	1.323	1.328
90	1.283	1.349
95	0.917	1.046

The calibration factors, K_1 and K_2, decreased with increasing humidity. The ΔK_1 and ΔK_2 ranged 0.303×10^{-4}–0.497×10^{-4} and 0.366×10^{-4}–0.487×10^{-4}, respectively. Especially, when the humidity is larger than 90%, the calibration factors decreased rapidly.

The key reason for this phenomenon is as follows. The moisture containing radon may coagulate at the surface of the film. It may infiltrate into the filter and form membranous water, which has stronger stopping power to α particles from radon and its daughters (the projectile range of an α particle in water is only one of thousand of its range in air). It can decrease the tracks recorded in the exposed film. So, the calibration factor K of the film at high humidity is lower than others, which was analyzed qualitatively in Ref.[8].

4 Conclusion

At high humidity condition, the moisture adhering to the surface of the films can affect detection of SSNTD films for measuring radon and its daughters. For radon measurement with SSNTDs at high humidity condition, the ΔK_1 and ΔK_2 of 0.303×10^{-4}–0.497×10^{-4} and 0.366×10^{-4}–0.487×10^{-4}, respectively, should be used to correct the calibration factor K, so as to obtain accurate result.

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