Radiation Measurements 44 (2009) 783–786

Contents lists available at ScienceDirect

Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Response of diffusion chamber with LR115 detector and electret to radon and progeny

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ARTICLE INFO

Article history:
Received 28 September 2008
Received in revised form
22 August 2009
Accepted 9 September 2009

Keywords:
Diffusion chamber
LR115 detector
Radon progeny
Electret

ABSTRACT

Cylindrical diffusion chamber for radon measurement equipped with nuclear track detector (LR115) and electret, was considered in this work. Electrets were used to attract positively charged radon progeny created by radon decay inside a chamber. Sensitivity of such setup has been determined for different distances between electret and LR115 detector. A possibility of progeny separation was observed, due to the existence of upper energy detection limit of LR115. Different geometries of detector and electret were tested in order to optimize this kind of device.

1. Introduction

Electret is electrostatic analogous of permanent magnet, with constant electric charge that creates strong electric field around it. Physics, production and characteristics of electrets were described by Sessler (1980). The first ^{222}Rn progeny, ^{218}Po, is formed as positively charged and it is possible to collect its atoms by electrostatic attraction using permanently charged dielectric, like *electret* (Mahat et al., 2001; Denman et al., 2007). Other electric device could be used for this purpose also. Electrets are used for radon measurements in two different ways. In the first method, reduction of the electret charge caused by ionizing radiation is measured (Kotrappa et al., 1988). Reduction is related with the total exposure to radon and progeny. In the second method, which is treated in the present report, Nuclear Track Detector, NTD and the Electret facing each other, are installed in diffusion Chamber for radon measurements (acronym ENTDC is used below) (Nikezic and Krstic, 1995). NTD measures alpha particles emitted by progeny collected on electret and alpha particles emitted by ^{222}Rn and uncollected progeny in surrounding air. The irradiation geometry is significantly changed in ENTDC in comparison to the NTD alone in diffusion chamber, influencing the sensitivity, which is defined as ratio of ^{222}Rn activity concentration, C_0 (Bq m^{-3}), to track density, ρ (track·m^{-2}) obtained per unit exposure time t (s). If design of ENTDC is performed properly its sensitivity would be larger than detector alone, reducing the statistical error of measurements and irradiation time.

Sensitivity of ENTDC with LR115 detector was considered in this paper. Distance between of electret and detector was varied in order to optimize the ENTDC. To calculate the sensitivity a computer code described previously by Nikezic and Yu (2006) was used.

2. Experimental methodology

2.1. Manufacturing the electret

The electrets were built by simultaneous acting of high temperature (250 °C) and strong electric tension (1100 V) on a circular Teflon piece for two hours. Strong electric field forced the polarized molecules within partially melted material, to direct according to the field direction. The piece of Teflon was run cooled with electric field on, enabling that polarized and directed molecules are “frozen”.

2.2. Description of ENTDC

Electret and detector are placed in conical diffusion chamber with dimensions: $R_1 = 2.6$ cm, $R_2 = 3.4$ cm and $H = 8.4$ cm (R_1 and R_2 are radii of their basis, and H is height of the chamber). Radon enters into the chamber through the filter paper and decays within it. By decaying of radon, its short-lived progeny are formed inside the chamber.

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doi:10.1016/j.radmeas.2009.09.003

Setup ENTDC shown in Fig. 1, was studied in order to determine detection efficiency to radon progeny. Special metal holder was manufactured to mount the detector in front of the electret at the distance, *d*. Both, detector and electret are circular in shape.

2.3. Detectors irradiation and processing

Detectors LR115 were cut in circular form with the radius $r_{det} = 2$ cm and fixed at the detector holder before irradiation. Several experiments were conducted here:

2.3.1. Experiment (A)

1. Detector in upper holder part of the holder (as in Fig. 1) and electret in the bottom.
2. Detector in the same position as in 1, but the Teflon disk (without electric charge) was used in lower holder.
3. Detector in the same position as in 1, without any electret neither Teflon.
4. Detector in the bottom of the chamber, also without any electret.

All setups 1–4 were irradiated in a box with high radon concentration for 2 days. After the irradiation the detectors were etched under standard conditions, at the temperature of 60 °C and 10% water solution of NaOH for 2 h. Track density was determined by standard optical microscope under the magnification of 400 x.

2.3.2. Experiment (B) – does electret really attract radon progeny

Bare electrets were put in the box with high radon concentration (4150 Bq/m^3) for 3 h. Then the electrets were taken out and measured by alpha spectrometry.

2.3.3. Experiment (C) – dependence of sensitivity on distance

Holder was prepared in such a way that the distance, *d*, between electret and detector could be changed. Dependence of the detector response on the distance, *d*, was investigated. The following distances were tested 0.5; 1; 1.5; 2; 2.5; 3; 3.5 and 4 cm. The exposure was performed in the box with high radon concentration that was measured with well calibrated NTD in the bottom of the diffusion chamber in Fig. 1 (without holder). Results are presented below.

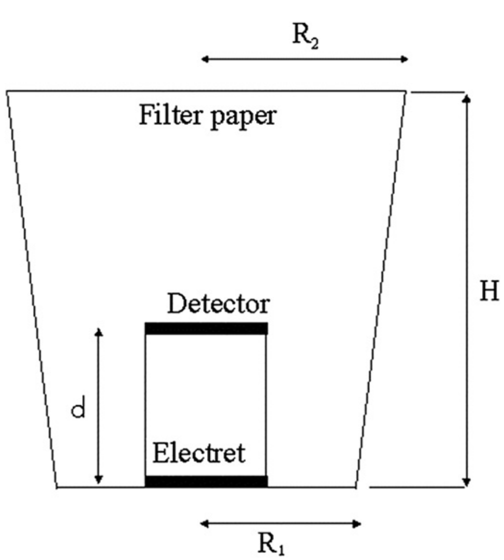

Fig. 1. Diffusion chamber with the electret-detector holder. Different combinations were tested experimentally.

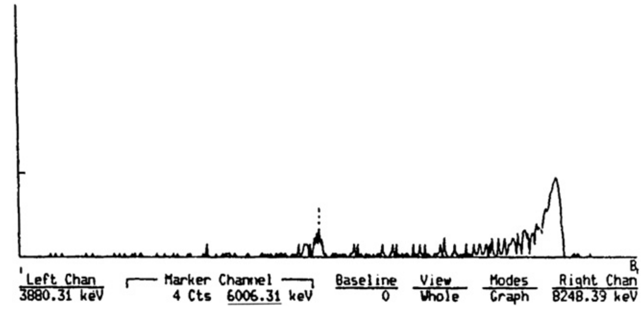

Fig. 2. Results of alpha spectrometry of radon progeny electro statically deposited onto electret.

3. Results

3.1. Experiment A

The following track densities were obtained in this experiment: $\rho_1 = (143 \pm 8)\,m^{-2}\,s^{-1}$, $\rho_2 = (87 \pm 4)\,m^{-2}\,s^{-1}$, $\rho_3 = (87 \pm 5)\,m^{-2}\,s^{-1}$ and $\rho_4 = (93 \pm 6)\,m^{-2}\,s^{-1}$.This results confirm that electret attracted some radon progeny because the track density in the chamber with electret (case 1) is about 40% larger than when the piece of uncharged Teflon was used (case 2). Results in cases (3) and (4) are close to each other, suggesting that gravitational settling does not play important role in radon progeny deposition within diffusion chamber.

3.2. Experiment B

The results are presented in Fig. 2. Two peaks corresponding to 6 MeV (^{218}Po) and 7.69 MeV (^{214}Po) are clearly seen. This means that electret acts as it was expected, attracting the positively charged radon progeny. By analyzing the results given in Fig. 2 we could concluded about the factor of electrostatic collection of ^{218}Po and ^{214}Bi (^{214}Po). The system of differential equation was developed below to describe progeny build up on electret.

3.3. Experiment C

Dependence of detector sensitivity on the distance to the electret is given in Fig. 3. It is seen that efficiency increases with the distance, but not monotonically. One peak appears about 2 cm, and the second is on 4 cm. The first peak is attributed to the attracted

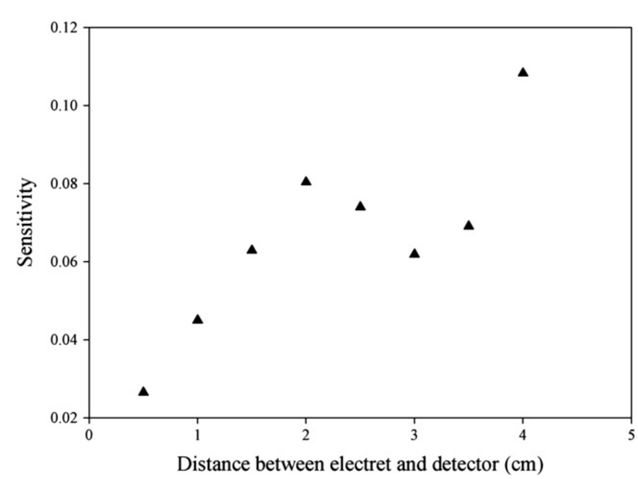

Fig. 3. Detector sensitivity as a function on distance (experimental results).