Eurasian Journal of Physics and Functional Materials

Volume 4 | Number 2

Article 6

Pages: 154 - 159

6-22-2020

Suitability testing of polyethylene terephthalate film as a solid-state nuclear track detector for using in radon studies

D. Yerimbetova
L.N. Gumilyov Eurasian National University ,Kazakhstan

V. Stepanenko
Tsyb Medical Radiological Research Center - branch of FSBI NMRRC of the Ministry of Health of Russia ,Russian Federation

A. Kozlovskiy
L.N. Gumilyov Eurasian National University; Institute of Nuclear Physics ,Kazakhstan

K. Zhumadilov
L.N. Gumilyov Eurasian National University ,Kazakhstan ,

Recommended Citation

Yerimbetova, D.; Stepanenko, V.; Kozlovskiy, A.; and Zhumadilov, K. (2020) "Suitability testing of polyethylene terephthalate film as a solid-state nuclear track detector for using in radon studies," *Eurasian Journal of Physics and Functional Materials*: Vol. 4: No. 2, Article 6.
DOI: https://doi.org/10.29317/ejpfm.2020040206

Eurasian Journal of Physics and Functional Materials

2020, 4(2), 154-159

Suitability testing of polyethylene terephthalate film as a solid-state nuclear track detector for using in radon studies

D. Yerimbetova*[,1], V. Stepanenko[2], A. Kozlovskiy[1,3], K. Zhumadilov[1]

[1]L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan

[2]A. Tsyb Medical Radiological Research Center – branch of FSBI NMRRC of the Ministry of Health of Russia, Obninsk, Russia

[3]Institute of Nuclear Physics, Nur-Sultan, Kazakhstan

E-mail: erimbetova.dana@gmail.com

DOI: **10.29317/ejpfm.2020040206**
Received: 06.04.2020 - after revision

The present work describes the procedure for testing the suitability of a polyethylene terephthalate film (after irradiation with heavy ions it is widely used in various fields) as an alpha-track detector. The test was carried out in order to determine the prospects for the use of this film in studies evaluating the indoor and outdoor radon concentrations. The study was conducted using a radionuclide source of alpha particles Am-241. Irradiated film samples were chemically treated. In order to further compare the results, unirradiated film samples were also chemically etched under the same conditions. To determine the presence of tracks, compare and analyze their parameters, all samples were examined using a scanning electron microscope. SEM images of the investigated samples are shown. The results obtained showed the unsuitability of using these films for registration of alpha particles. Currently, studies of the indoor and outdoor radon concentrations are being carried out using solid-state nuclear detector LR-115 based on cellulose nitrate.

Keywords: polyethylene terephthalate film (PET), solid-state nuclear track detector (SSNTD), alpha radiation, radon concentration, radiation doses.

Introduction

The heavy radioactive gas radon makes the largest contribution to the average dose to the public from all sources of natural radiation. According to the International Commission on Radiological Protection (ICRP), radon-222 is a recognized cause of lung cancer, the second after smoking [1].

Various methods are used to study the concentration of radon. The method based on the use of solid-state nuclear track detectors (SSNTD) is widely used in radon measurements. The main advantage of this method is the possibility of simultaneous exposure of several detectors and their centralized chemical treatment.

A heavy charged particle passing through the detector causes intense ionization of the material. As a result, narrow lesions appear at the level of molecules along their trajectory. The sizes of latent tracks formed by heavy ions are very small (only about 10 nm in diameter) [2].

To measure the concentration of radon as a solid-state alpha-track detector, the films LR-115, CN-85 (cellulose nitrate) and CR-39 (allyldiglycol carbonate) are most often and very successfully used. Numerous studies have been carried out using detectors based on the above materials [3-11].

For several decades, polyethylene terephthalate film (PET) has been widely used in the creation of track membranes for use in various fields: in plasmapheresis of blood, filtration of water and biological media, etc. [12, 13]. Along with this, the film irradiated with heavy ions of PET is successfully used as a template for the synthesis of metal nanostructures. This method allows one to obtain nanostructures of various shapes and sizes [14-16].

The study consists of several main stages:

- preparation of detectors;
- exposure of detectors at the source of alpha particles;
- chemical etching of irradiated and non-irradiated detectors;
- research of detectors on a microscope;

Further, in case of detection of tracks on the detector:

- determination of the density of tracks on the detector;
- calculation of the calibration coefficient for this type of detector.

Materials and methods

For the experiment, polyethylene terephthalate films of the Hostaphan type manufactured by Mitsubishi Polyester Film (Germany) 12 μm thick were used.

As a source of alpha radiation, Americium-241 with an activity of 340 Bq produced by the Scientific and Technical Center "RADEK" was used. The energy of the intense alpha particle is 5.486 MeV, the half-life is 432.17 years.

Film samples were cut into $3 \times 3\,\text{cm}^2$ squares and irradiated with alpha particles emitted from a 241 Am point source, applying a detector to the source in 180° geometry relative to the source.

The exposure time of the detectors varies (17, 23, and 30 days) to obtain different doses of alpha particles. The dose rate to which the detectors are exposed was calculated by the Rad Pro calculator version 3.26 program, designed to calculate the dose rate of radiation from radioisotopes by entering its activity and the distance between the source and the detector. Doses for each time are shown in Table 1.

Table 1.
Doses calculated according to exposure time.

Sample	Dose rate, μSv/h	Exposure time, hour	Dose, μSv
1	unirradiated	-	-
2	0.3376	336 (14 days)	113.43
3 and 4	0.3376	528 (22 days)	178.25
5 and 6	0.3376	720 (30 days)	243.07

After irradiation, the detectors were chemically etched in a 2.2 M sodium hydroxide (NaOH) solution at a temperature of $87 \pm 0.1\,^{\circ}$C. Chemical etching is the most widely used method of many other methods for fixing and enlarging hidden tracks created in solid state track detectors.

Chemical etching conditions depend on many parameters, such as etching time, type, molar mass and the temperature of the etching solution.

The etchant solution is obtained using the following equation [17]:

$$W = W_{eq} \times N \times V, \tag{1}$$

where:

W: weight of NaOH needed to prepare the solution, mg

W_{eq}: equivalent weight of NaOH = 40.

N: molar mass = 2.2 M.

V: volume of distilled water = 1000 ml.

NaOH pellets are dissolved in distilled water using a stirrer to obtain a homogeneous solution, then a volumetric flask (1000 ml) is filled with the solution and the detectors are immersed in it. A volumetric flask containing an etching solution and detectors are placed in a tank with a water bath at a temperature of $87 \pm 0.1\,^{\circ}$C for various time intervals.

A water bath is a laboratory device made of a container filled with heated distilled water and equipped with a thermostat to heat the water to the desired temperature (Figure 1).

After removing the detectors from the etching solution, they must be processed in neutralization solutions and dried. To do this, they were immersed in a 1% solution of acetic acid, then washed with distilled water, and then wiped with special paper to clean the film samples from the etching solution well and to obtain good microscopic images and calculation of alpha particle tracks.

Results and discussion

The processed detectors based on polyethylene terephthalate were investigated using a JEOL-7500F scanning electron microscope (SEM). The microscope is

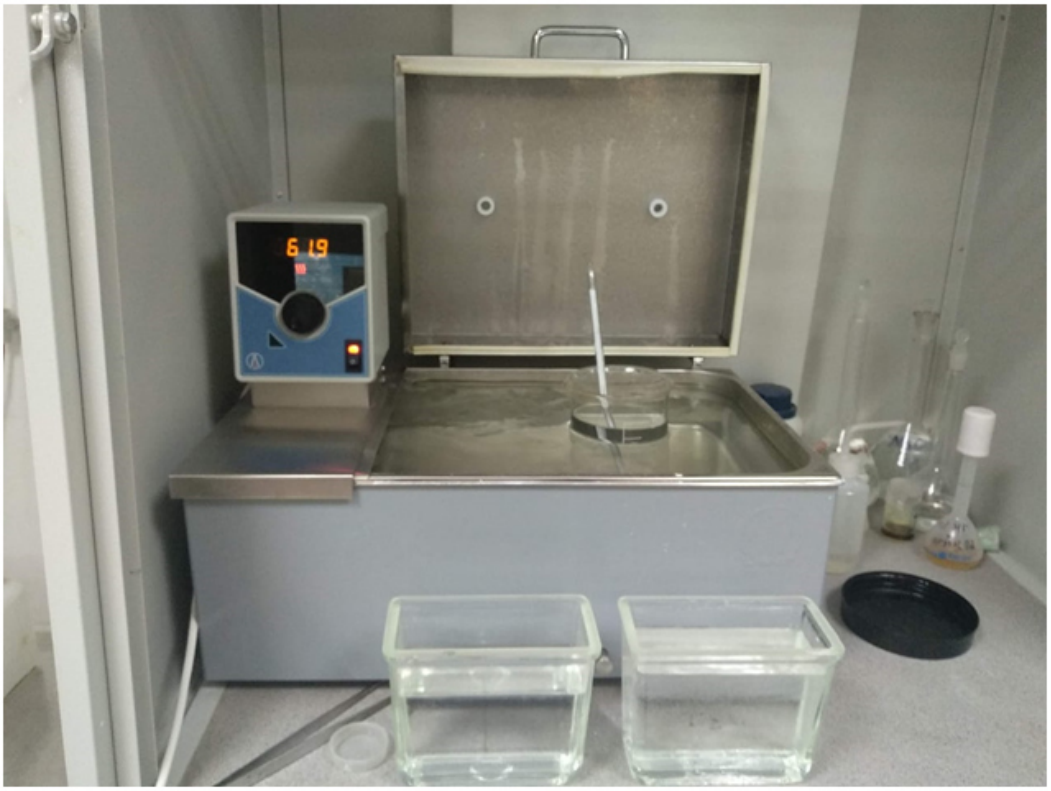

Figure 1. The device of a water bath for chemical etching of film samples.

connected to a computer for storing and viewing images. The obtained images of PET film samples on SEM are shown in Figure 2.

There are no visible structural changes on the surface of the initial samples. All changes are due to the degradation of the film itself under the influence of the chemical etching of the samples.

Table 2 shows the time of exposure to alpha source and chemical etching time of film samples.

Table 2.
The time of irradiation and chemical etching of film samples.

Sample	Time of exposure to alpha source	Chemical etching time
Sample 1	unirradiated	15 min
Sample 2	14 days	15 min
Sample 3	22 days	5 min
Sample 4	22 days	16 min
Sample 5	30 days	9 min
Sample 6	30 days	12 min

Conclusion

From the obtained results it was found that particle tracks were not detected on the film samples, and from the comparative analysis between the unirradiated and irradiated samples, no changes were observed in the latter. Visible defects on the surface of the films are a consequence of the destruction of the structure of the

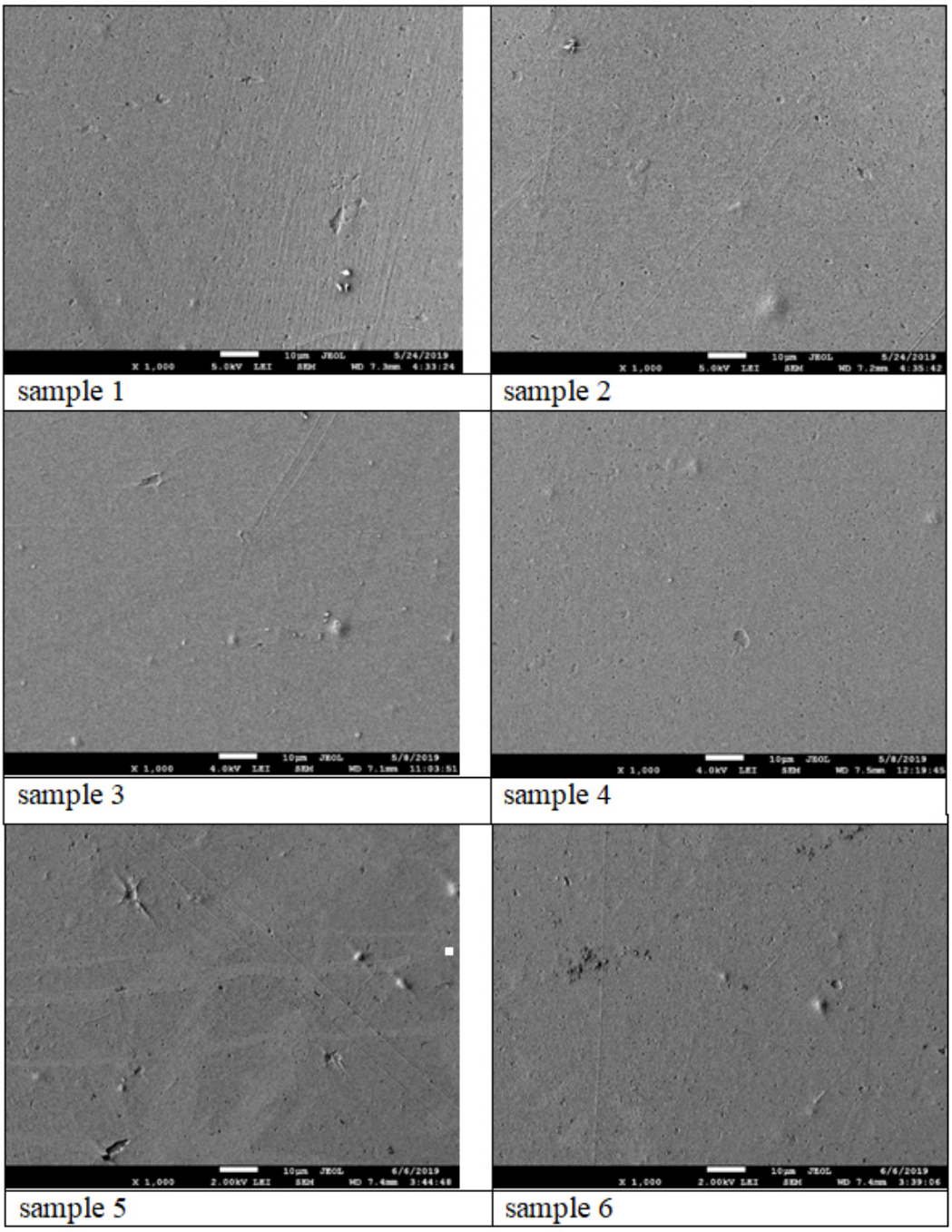

Figure 2. SEM images with magnification $\times 1000$.

surface of the film during chemical etching. In this regard, we can conclude that the PET film for the detection of alpha particles of low activity (and hence natural radon) is not applicable.

Currently, indoor and outdoor radon concentration measurements using a solid-state nuclear track detector based on the LR-115 film in the process.

References

[1] ICRP, Radiological Protection against Radon Exposure (2014) ICRP Publication 126. Ann. ICRP 43(3).
[2] D. Nikezic et al., Mater. Sci. Eng. R. **46**(3-5) (2004) 51-123.
[3] A. Hesham et al., Journ. Radiat. Res. Appl. Sci. **9** (2016) 41-46.
[4] T. Valmari et al., Radiat. Protec. Dosim. **152**(1-3) (2012) 146-149.
[5] L. Chunikhin et al., Radiatsionnaya gigiena **9** (2016) 43-46.
[6] K. Mahamood et al., Radiat. Prot. Environ. **41** (2018) 136-142.
[7] S. Bucci et al., Radiation Protection Dosimetry **145**(2-3) (2011) 202-205.
[8] M. Torres-Duran et al., Eur Respir J. **44** (2014) 994-1001.
[9] A. Ulug et al., Nuclear Technology & Radiation Protection **1** (2004) 46-49.
[10] P. Pereyra et al., Journal of Nuclear Physics, Material Sciences, Radiation and Applications **4**(1) (2016) 99-106.
[11] V. Mehta et al., Optoelectronics and advances materials – rapid communications **8**(9-10) (2014) 943-947.
[12] K. Anil et al., Handbook of membrane separations. Chemical, pharmaceutical, food and biotechnological applications. Second Edition (FL, USA: CRC Press, 2015) 878 p.
[13] E. Filippova et al., XXI International Scientific Conference Tomsk **1** (2015) 308-310.
[14] A. Sergeev et al., Modified track membranes. Series Critical technology. Membranes **1** (2004) 19-28.
[15] V. Reutov et al., Russian Chemical Journal **46**(5) (2002) 74-80.
[16] N. Pervov, Candidate's thesis. Moscow (2006) 139 p.
[17] L. Jebur, N. Kadhim, Mast.dissertation. Al-Mustansiriya University (Iraq) (2016) 117 p.