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Study of the application prospects of film detectors for estimation of α-radiation density

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ABSTRACT

The aim of this research is to study the prospects of using the proposed methods of optical UV spectroscopy and X-ray diffractometry to determine the radiation density of the daughter products of radon decay - α-particles recorded using polymer track detectors. This paper presents the results of experiments on detecting the daughter products of radon decay - α-particles in a room on various floors for a fairly long time (within 6 months), the choice of which made it possible to determine not only the concentration dependences (growth in the density of registered α-particles) over time, but also to determine the lower limit for recording changes in the optical spectra of film detectors used to register α-particles. During the experiments, good convergence of the results of structural changes determined by optical spectroscopy and X-ray diffraction methods was established. These changes are caused by the processes of interaction of α-particles with a polymer detector, characterized by deformation distortion of the molecular chains of the polymer, leading to the formation of defects that affect changes in optical and electron density. The proposed methods were used to determine the connection between the interaction processes of α-particles with the molecular structure of polymer films used as detectors. It was determined that the most significant changes are observed at densities of registered α-particles above 10^4 cm^{-2}, the value of which is the threshold value for identification of radon decay products using film detectors without chemical etching.

1. Introduction

Over the past few years, more and more attention has been paid to issues related to the radiation safety of the population, not only in their direct or indirect interaction with sources of ionizing radiation or the consequences of radioactive contamination as a result of man-made disasters, but also to consideration of issues of protection from natural sources [1–3]. Adopted national and international programs for protection from the adverse effects of ionizing radiation are aimed primarily at reducing the risk of long-term exposure, as well as minimizing human interaction with sources of ionizing radiation [4]. At the same time, environmental safety problems associated with monitoring the effects of various types of ionizing radiation on living organisms, as well as monitoring background radiation in residential and non-residential premises are the most important, especially in places with anthropogenic sources of radiation, in particular, research centers, medical institutions, and nuclear power plants [5–7]. Moreover, in most cases, at facilities with operating sources of ionizing radiation, the greatest control is carried out over the radiation generating sources (X-ray machines, accelerators, stationary sources of ionizing radiation), while background radiation resulting from the decay of radon is controlled indirectly, due to the fairly low concentrations of radon in rooms, especially those that are constantly ventilated and disinfected [8–11]. Moreover, if in the case of man-made sources of ionizing radiation the methods of protection are quite well known, then from natural sources, it is first necessary to establish the nature of the occurrence of radiation, and only then actively engage in its elimination.

As is known, the most common natural sources include the noble gases radon and thoron (a decay product), as well as their daughter decay products in the form of α-particles, which have a high penetrating ability, capable of causing greater damage in comparison with radon and thoron particles due to their high initial energy (more than 5 MeV)

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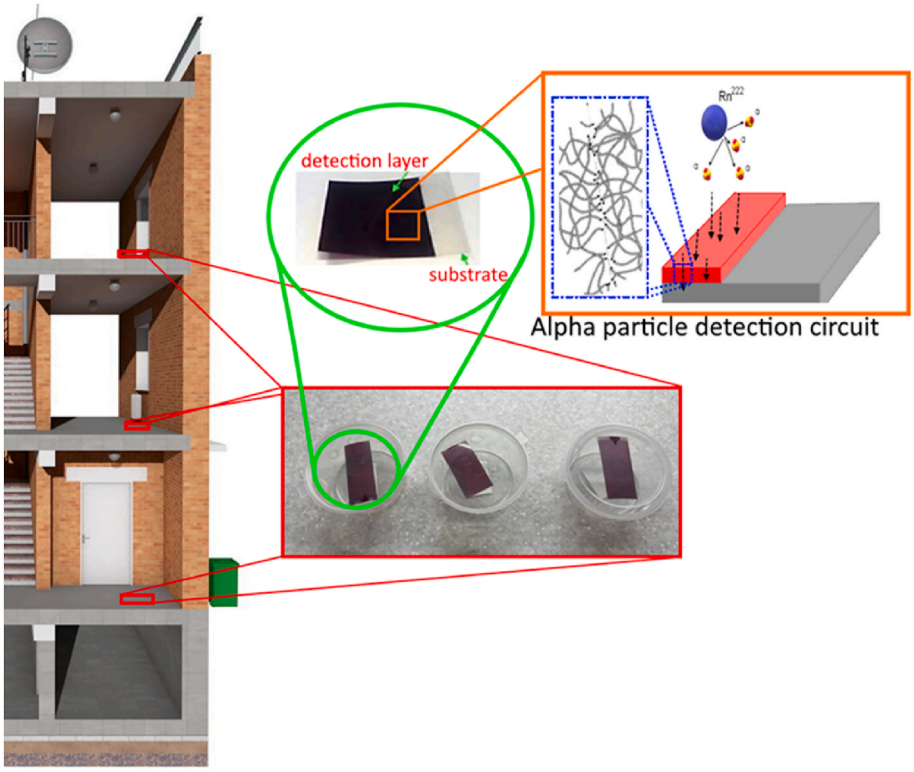

Fig. 1. Schematic arrangement of detectors in a building on different floors, as well as the principle of recording daughter products of radon decay in the form of α – particles using film detectors.

[12,13]. At the same time, a fairly large number of different studies have shown that the impact of radon and its daughter decay products is dominant among all types of ionizing radiation on living organisms, capable of leading, due to its nature, to the absence of color or odor, as well as good solubility in water [14,15]. Comparing the negative effects of ionizing radiation on living organisms, it can be concluded that α-particles have the greatest destructive capacity compared to beta and gamma radiation, due to more pronounced interaction processes that can lead to the emergence of mutations due to changes in DNA. According to the work [16], 55 % of the natural impact of all types of ionizing radiation on humans is the share of radon. Moreover, the greatest impact due to higher concentrations of radon in air and water is observed in regions near uranium deposits, as a result of its natural decay. Due to its volatility, radon can be found everywhere in the air, and due to attachment to various aerosols, it can enter the body through the respiratory tract, where it continues to disintegrate, having a negative effect on living cells, causing mutations and the formation of cancer cells.

In this regard, monitoring the determination of radon concentration in residential and office premises in which a person spends most of his time is very important and necessary, since accurate knowledge of changes in concentrations depending on the seasons or the structural features of buildings, including the number of floors, will not only prevent negative impacts in the event of identifying unacceptable concentration standards, but also draw conclusions about possible ways to eliminate them.

This article presents the results of assessing changes in the concentration dependence and volumetric activity of radon in one building with office and warehouse premises depending on the number of floors (measurements were carried out on different floors of the same building). As a method for detecting radon decay products, a method was chosen based on the use of polymer film detectors of the LR-115 type 2 type, which are two-layer polymer films in which a nitrocellulose layer is used to detect decay products, and a transparent polyester backing serves as the basis for the film detector. The use of similar detectors LR-115 type 2, CR-39 for recording daughter products of radon decay is quite well known in the case of long-term measurements [17–19], which are carried out to determine dose and concentration dependencies. The ease of use of these detectors is due to the detection mechanisms, which consist in the fact that the daughter products of radon decay in the form of α - particles interact with the polymer film of the detector, leaving in it a structurally changed area - a latent track. These latent tracks can then be chemically etched and the number of latent tracks formed during the exposure time can be determined using optical or scanning electron microscopy. However, the use of film detectors in this form imposes several limitations associated with the etching of latent tracks for direct counting, which in turn excludes the possibility of further use of film detectors for recording decay products, making these detectors disposable, and also excluding the possibility of measuring the kinetics of accumulation of dose dependences using the same detector. In turn, the use of X-ray structural analysis and optical UV–Vis spectroscopy methods to record structural changes caused by the interaction of α-particles with the molecular structure of film detectors and the formation of latent tracks makes it possible to eliminate the procedure of chemical etching of tracks, thereby opening up the possibility of using film detectors to assess the radiation dose accumulation kinetics. In a number of recent works [20–22], the structure of the latent track resulting from the interaction of a charged particle is presented in the form of a region with changed electronic and optical density, changes in which are caused by ionization processes of interaction of incident charged particles with the polymer structure. At the same time, the dielectric nature of the polymer responds quite well to changes caused by elastic and inelastic interactions of charged particles, which leads to a change in the distribution of radial electron density along the particle trajectory, as well as structural distortions associated with deformation and athermal processes caused by the transformation of the kinetic energy of incident particles into thermal energy. At the same time, in works [21–23] it was shown that the use of optical UV spectroscopy methods

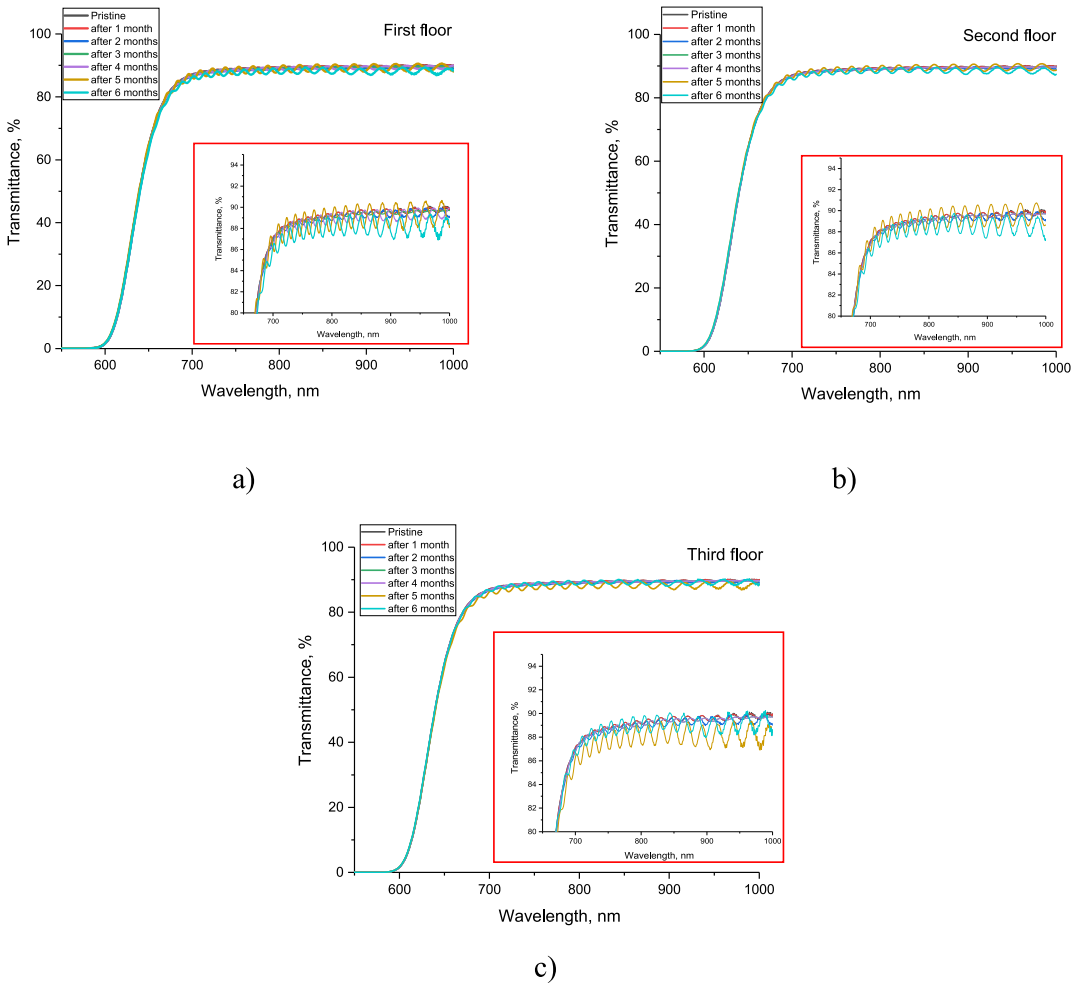

Fig. 2. Results of the optical transmission spectra of the studied film detectors depending on the exposure time (the insets show detailed spectra of the interference intensity change): a) first floor; b) second floor; c) third floor.

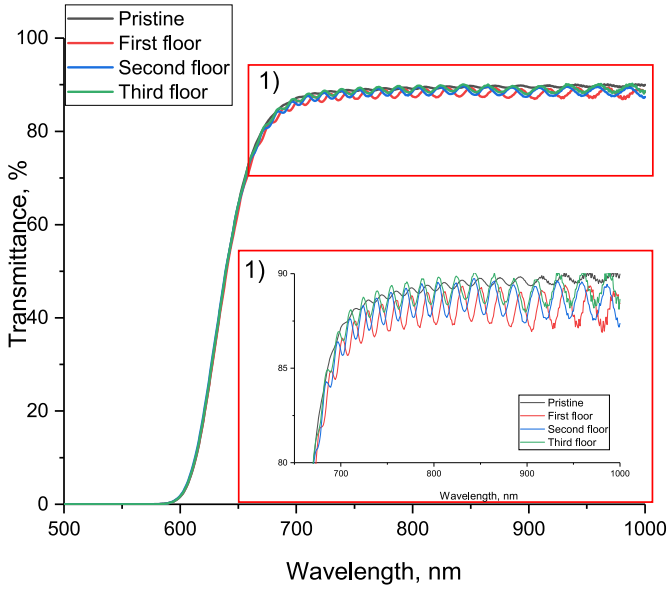

Fig. 3. Results of a comparative analysis of the optical spectra of film detectors after 6 months of exposure on different floors (the inset shows a scaled image of changes in the intensity of the optical spectra).

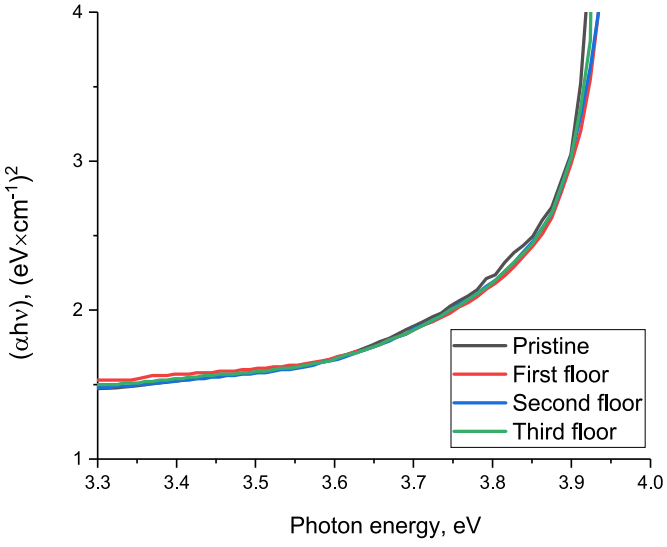

Fig. 4. Estimation results of the fundamental absorption edge shift depending on the location of film detectors.

makes it possible to accurately determine these changes, which are expressed in the optical transmission spectra as changes in the fundamental absorption edge, characterizing changes in the band gap, as well

Table 1
Optical characteristics data after six months of exposure.

Parameter	Locations		
	First floor	Second floor	Third floor
Band gap, eV	3.57[a]	3.58	3.58
Refractive index	2.26	2.26	2.25
$T_{optical}$	0.742	0.741	0.741
R_{loss}	0.149	0.148	0.148
Optical density	0.004	0.003	0.003

[a] In the case of the initial sample, the band gap was 3.60 eV.

as the transmittance value, the change in which is associated with a change in optical density due to the accumulation of structural defects. At the same time, in works [22,24] it was shown that the use of X-ray diffraction patterns makes it possible to determine the nature and degree of structural changes caused by irradiation, and taking into account the obtained changes, data on structural changes can be used to approximate and determine the dose or fluence of radiation in the case of high-dose radiation, for which classical methods of calculating the density of latent tracks are not applicable. Also, in works [25,26] the possibility of using UV spectroscopy and X-ray diffraction methods to detect α particles emitted by the model source Am – 241 as a result of nuclear decay reactions $^{241}Am \rightarrow {}^{237}Np + \alpha$ (5.6 MeV) was shown. During the experiments, the lower limits of the possibilities of using UV spectroscopy and X-ray diffraction methods in determining structural changes caused by the accumulation effect (density of detected α - particles) were determined, and the main parameters were determined, the combination of which most fully allows us to describe the observed changes associated with the interaction of α-particles with the polymer structure of the detector, as well as estimate the density of α-particles. At the same time, the use of a model source Am - 241 as a source generating α - particles made it possible to construct calibration curves that can be used to determine the density of α - particles - daughter products of radon decay without chemical etching of the polymer detector, which makes it possible to measure the time dependence of dose accumulation with the same film detector.

Based on the foregoing, the main purpose of this research is to study the prospects of using the proposed methods of optical UV spectroscopy and X-ray diffractometry to determine the radiation density of the daughter products of radon decay - α-particles recorded using polymer track detectors in real operating conditions, as well as to establish the dependence of the radon distribution on floors over a long period of time. The experiments were carried out in a three-story building in which LR-115 type 2 film detectors were placed on each floor and measurements were taken at equal intervals. The relevance of this study is in the possibility of developing alternative methods for determining the density of α-particles recorded by film detectors, eliminating chemical etching of the polymer, which makes it possible to reuse these detectors for further measurements.

2. Materials and research methods

The detectors used were polymer detectors of the type LR-115 type 2 manufactured by Dosirad (France), consisting of a 12-μm layer of nitrocellulose, which is a detection film in which α-particles are inhibited, as well as a 100-μm layer of polyester, which is a substrate that holds a layer of nitrocellulose and protects it from mechanical stress. The thickness of the detecting layer of nitrocellulose is selected a priori, based on the depth of penetration of α - particles with an energy of about 5.5 MeV in the polymer, the result of which is a structurally altered region, with deformed molecular chains as a result of elastic and inelastic collisions of α - particles with the polymer along the trajectory of the particle [25,26]. Moreover, due to the dielectric nature of polymer films, the deformation distortions caused by collisions along the trajectory of particle motion are of an almost irreversible nature (especially

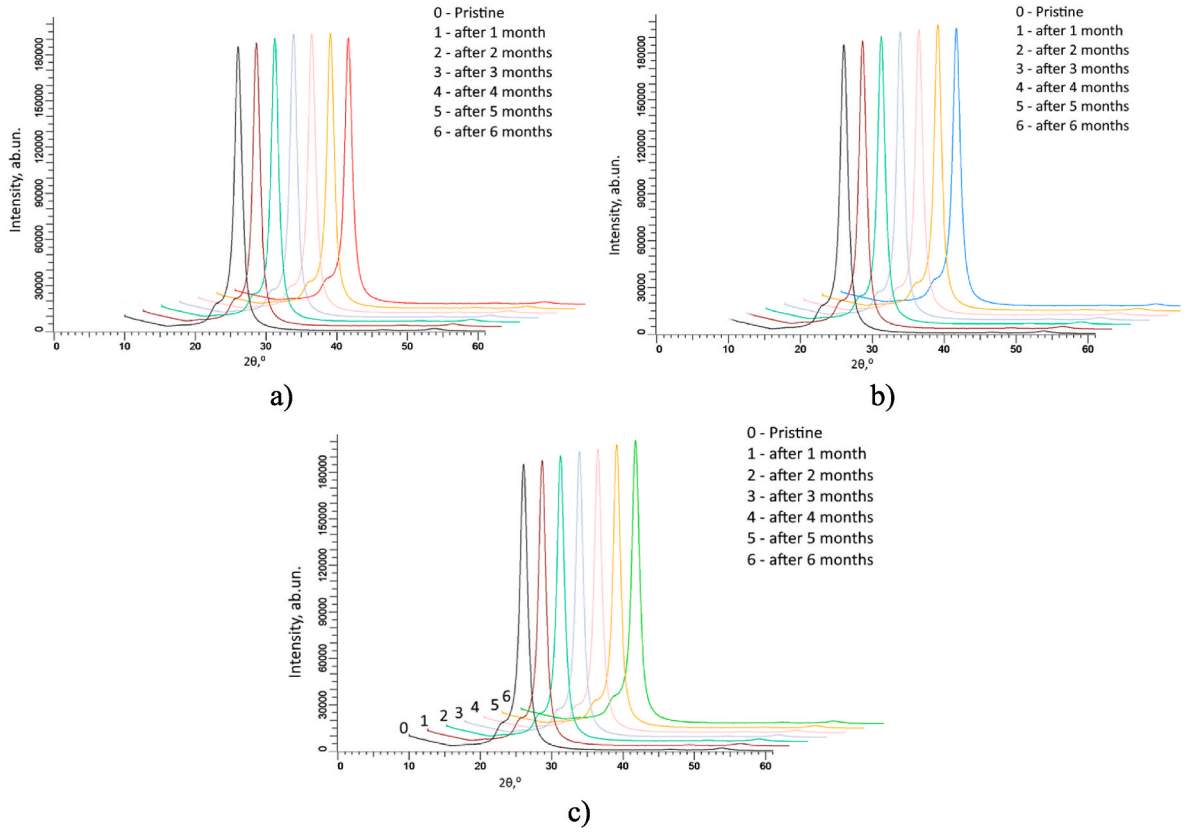

Fig. 5. Results of changes in X-ray diffraction patterns of the film detectors under study depending on the exposure time: a) first floor; b) second floor; c) third floor.

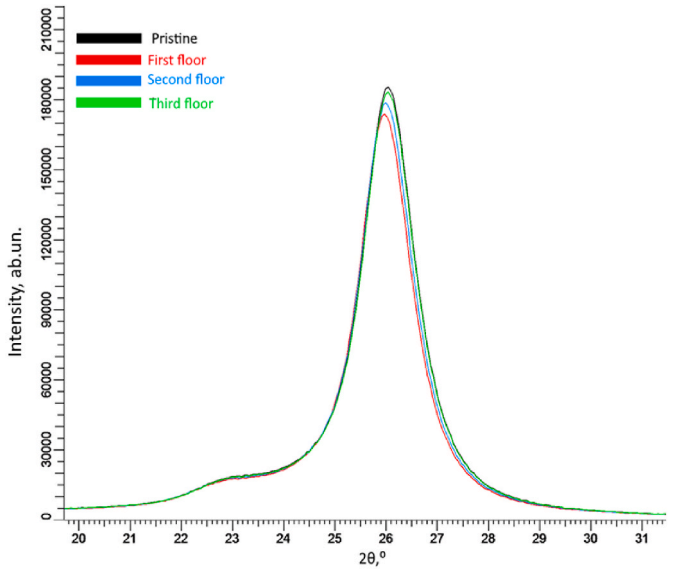

Fig. 6. Results of comparison of X-ray diffraction patterns after 6 months of exposure of film detectors on different floors.

over a long time), which makes it possible to exclude the effect of self-healing of deformation distortions and changes in electron density in the material during long exposure times (in Ref. [27], structural changes caused by irradiation were identified after 10 years of storage).

Fig. 1 demonstrates a diagram of experiments to determine the use of optical spectroscopy and X-ray diffraction methods in detecting daughter products of radon decay in the form of α - particles using film detectors. This experiment involved placing film detectors on each floor of an office building in a three-story building. For this purpose, premises used as utility rooms with little ventilation were selected. Samples of film detectors were placed in special plastic containers (volume 50 ml) with perforations for ventilation and free access of air, and as a result, the possibility of radon penetrating into them along with air.

The exposure time of the samples was 6 months; after each month, optical spectra and X-ray diffraction patterns were measured in order to determine changes caused by the cumulative effects of α-particles on the polymer structure, which are expressed in a change in optical density (due to the accumulation of structural defects – changes in molecular chains associated with distortion of the electron density distribution), as well as deformation distortions associated with the accumulation of structurally changed areas (hidden latent tracks that appear along the trajectory of α - particles in the polymer). The frequency of measurements was carried out to verify not only the set of exposure doses, but also the establishment of detection limits for radon concentrations using the proposed methods.

For comparative analysis and control of the density of α - particles detected by the film detector, measurements of the density of latent tracks were made by chemical etching of films and counting visualized chemically etched latent tracks using the scanning electron microscopy method.

Optical spectra were obtained using a SPECORD 200/210/250 PLUS dual-beam spectrophotometer (Analytik Jena, Jena, Germany). The transmission spectra were recorded in the wavelength range from 550 to 1000 nm, with a step of 0.5 nm. The resulting spectra were analyzed for changes in transmittance, as well as characteristic changes in intensity due to changes in optical density due to the accumulation of structural changes. Also, based on determination of the fundamental absorption edge shift, the values of the band gap before and after testing were determined.

Determination of structural changes caused by the interaction of α-particles with the molecular structure of the polymer, as well as associated deformation structural distortions resulting from ionization and athermal effects, was carried out by analyzing the obtained X-ray diffraction patterns of film detector samples taken on a D8 ADVANCE ECO X-ray diffractometer (Bruker, Karlsruhe, Germany). The shooting of diffraction patterns was carried out in the Bragg–Brentano geometry in the angular range $2\theta = 10–60^{\circ}$, while all diffraction patterns were obtained from the same samples placed on each floor, which excluded differences in diffraction patterns associated with the molecular structure of the polymer film, as well as the measurement area.

Chemical etching of films for the purpose of etching latent tracks was carried out in an alkaline solution of 2.0 M NaOH. Etching was carried out at a solution temperature of 60 °C, heating and maintaining the temperature was carried out using a water bath. The chemical etching time was 60 min, after which the films were removed from the solution, washed in a solution of 0.1 M acetic acid and distilled water to neutralize the alkali residues.

The same film samples were used for measurements during all experiments, i.e. the same film was measured at the beginning of the experiment (in the initial state) and after being kept in the room for a specified period of time, which in turn made it possible to exclude effects associated with the influence of the thickness of the measured samples, given that the interference effect observed in the films is caused by the impact of radiation defects. The interference effect itself in this case can be caused by the following factors: when charged particles interact with the molecular structure of films along the trajectory of ion movement, effects of changes in the distribution of electron density arise, as well as structural distortions of the molecular structure caused by elastic and inelastic collisions. Moreover, as shown in work [27], changes in electron density as a result of irradiation are quite stable and can persist for a long time (on the order of several years), and in works [22,28–30] it is shown that structural changes are caused by distortions of the molecular structure, which in turn cause interference changes, as well as the formation of color centers in optical spectra. The works [25,26] present the assessment results of changes in the interference intensity from the accumulated dose of radiation damage, characterizing the concentration of defects in the damaged layer, which formed the basis of this work in assessing the optical spectra of samples used to determine the radon concentration.

3. Results and discussion

Fig. 2 reveals the results of changes in the optical transmission spectra of the films under study depending on the exposure time. Spectra are presented for each floor separately.

As can be seen from the presented data, the most pronounced changes in the optical spectra in the region above 650 nm are observed after exposure of the films for 5–6 months. At the same time, the main changes are associated with an increase in the amplitude of oscillations of interference fringes, which, as was previously established when exposing samples using a source of α-particles Am-241 [25,26], is associated with the formation of low-density latent tracks (10^4–10^5 track/cm^2). At the same time, the most pronounced changes in the interference amplitude are observed for samples of detectors exposed on the first floor, which indicates a higher concentration of radon in the room. This behavior of the optical spectra, as well as more pronounced changes in the amplitude of the interference fringes for samples exposed on the first floor, is due to the proximity to the surface, as well as possible routes of radon penetration through cracks in the floor or walls. For samples exposed on the second and third floors, the change in the interference amplitude is less pronounced than in the case of the first floor, which can be explained by the effect of distance from the surface and a large number of interfloor ceilings separating the rooms.

Fig. 3 demonstrates the results of a comparative analysis of optical transmission spectra after 6 months of exposure for different floors. This comparative analysis of the obtained spectra reflects the change in the optical characteristics of the films under study depending on the floor on

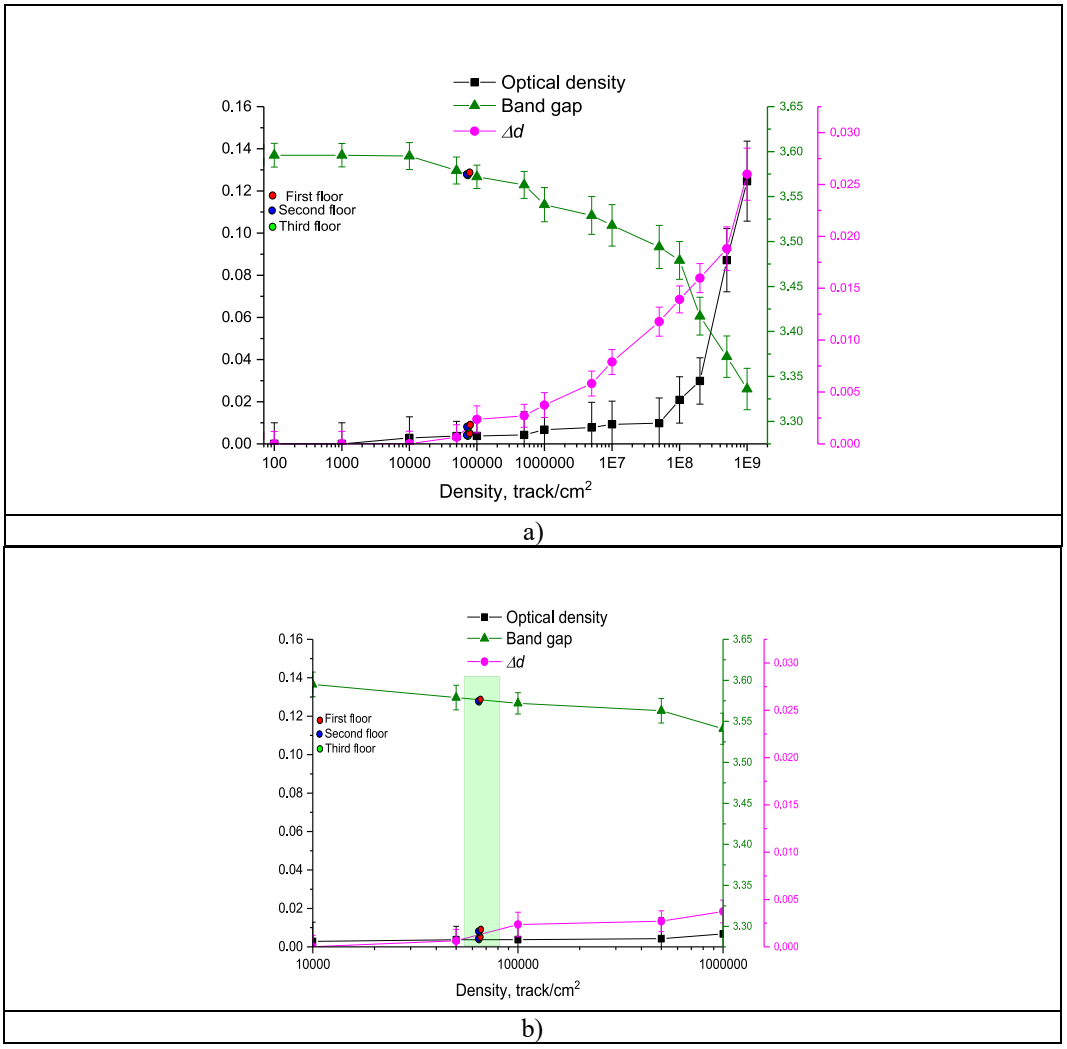

Fig. 7. a) Results of a comparative analysis of the optical and structural characteristics of the experimentally obtained values determined for various floors with the data obtained by measuring the density of α - particles during exposure to the Am-241 source (red, blue and green dots reflect the results of optical and structural characteristics obtained for each floor after 6 months of exposure); b) Detailing of the area of changes in measured values in the range from 10^4 to 10^6 track/cm^{-2}, the green area highlights the range in which the measured values are located for each floor.

which the measurements were made.

According to the presented data on changes in the optical transmission spectra for samples exposed for 6 months, it was found that in the case of the exposed sample on the first floor, in addition to an increase in the amplitude of oscillations of the interference fringes, which indicates a change in the properties of the material, a decrease in transmission intensity is observed. Similar effects were observed for samples exposed on the second and third floors, but with a lower intensity of amplitude changes and a decrease in transmittance. Such a difference in changes in optical spectra indicates differences in the concentrations of recorded radon and its daughter decay products, changes in which may have a pronounced dependence on the floor of the building. Moreover, the recorded changes in the optical spectra after 6 months of exposure are due to the effect of accumulation of the density of latent tracks from α-particles interacting with the detector material. An analysis of the fundamental absorption edge shift depending on the floor on which the film detectors were located is shown in Fig. 4. An analysis of certain bandgap values shown in the inset in Fig. 4 indicates that the most pronounced changes in the bandgap, and as a consequence, changes in electron density, are observed for film samples exposed on the first floor. In the case of samples on the third floor, the change in the band gap compared to the same value for non-irradiated film is no more than 0.4 %, which is 1.5 times less than similar changes for samples exposed on the first floor.

The presented changes in the band gap values, as well as changes in the optical density (changes in this value are 0.003–0.004) for samples exposed for 6 months indicate that the density of the recorded latent tracks exceeds 10^4 track/cm^2, which is the sensitivity threshold for the optical spectroscopy method.

Table 1 presents the results of changes in the optical characteristics of film detectors depending on their location. For calculations, methods proposed in Refs. [25,26] were used to determine changes in the band gap, refractive index, and optical density, which characterizes the accumulation of structural defects in the samples.

The general appearance of the presented changes indicates the presence of a sufficient number of registered latent tracks, the density of which leads to the formation of anisotropic changes in the electron density in the structure, as well as the formation of structurally altered inclusions of molecular chains, leading to a change in the charge distribution. At the same time, these changes in optical characteristics, such as refractive index and reflection and absorption losses, indicate that the number of structurally changed areas in the exposed samples is quite small, the concentration of which cannot lead to large changes in optical absorption and a decrease in the throughput of film detectors, which is observed for high densities of latent tracks [21,22,25,26].

Fig. 5 demonstrates the results of changes in the diffraction

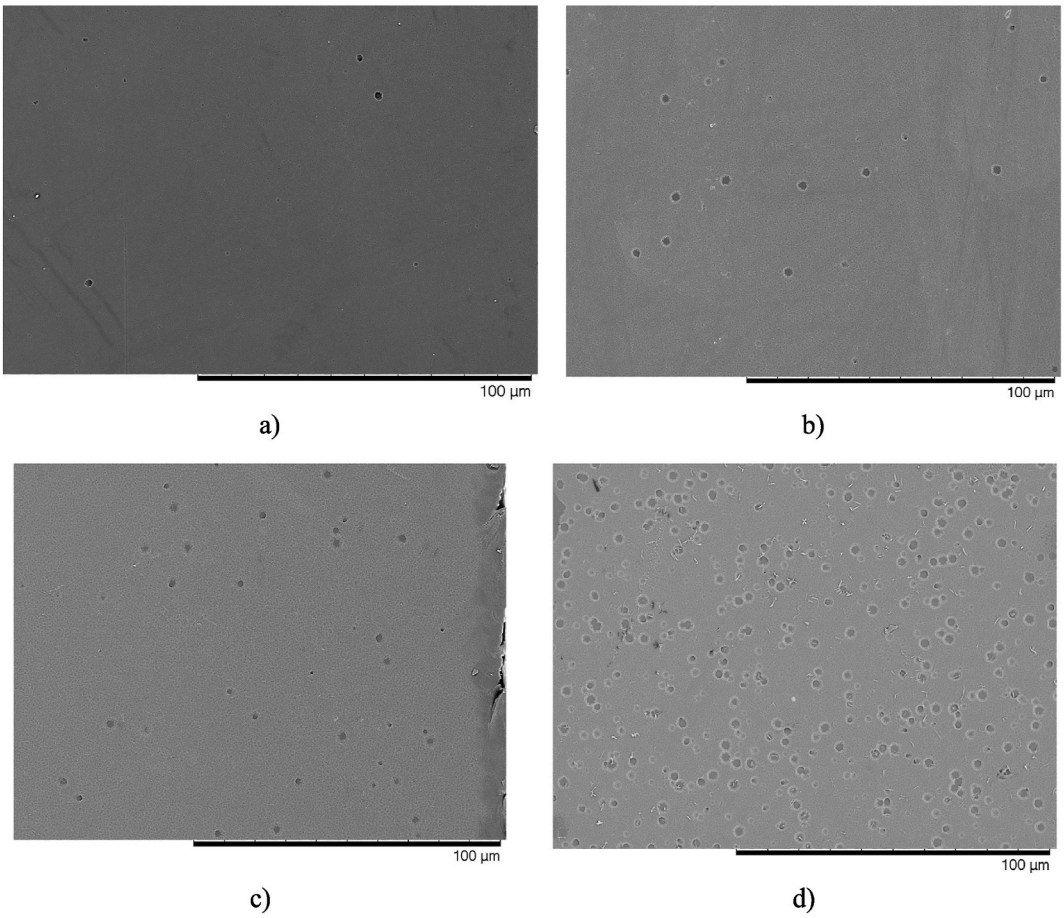

Fig. 8. Results of surface images of film detectors exposed for different times after chemical etching: a) after 1 month; b) after 2 months; c) after 3 months; d) after 6 months.

Table 2
Data on volumetric activity and equivalent equilibrium volumetric activity of radon and its daughter decay products.

Floor	Exposure time, day	Density of latent tracks, track/cm^2	Volume activity, Bq/m^3	Equivalent equilibrium volumetric activity, Bq/m^3
First floor	180	19342 ± 200	497.8	195.9[a]
Second floor		15432 ± 200	397.1	158.6
Third floor		10434 ± 200	268.6	107.5

[a] Within the permissible limits according to hygienic standards "Sanitary and epidemiological requirements for ensuring radiation safety".

reflections of the film detectors under study depending on the exposure time, as well as the floor on which the detector was placed.

As can be seen from the presented data of X-ray diffraction patterns depending on the exposure time, the most pronounced changes are observed after 4–5 months of successive measurements, which are expressed in a decrease in the intensity of reflections, as well as their slight shift to the region of small angles, which indicates deformation distortion of the molecular structure of the polymer. At the same time, these changes are most pronounced for film detectors that were placed on the first floor of an office building without constant ventilation, and the smallest changes are observed on the third floor, for which the main changes recorded by X-ray diffraction were established only after 5 months of consecutive measurements.

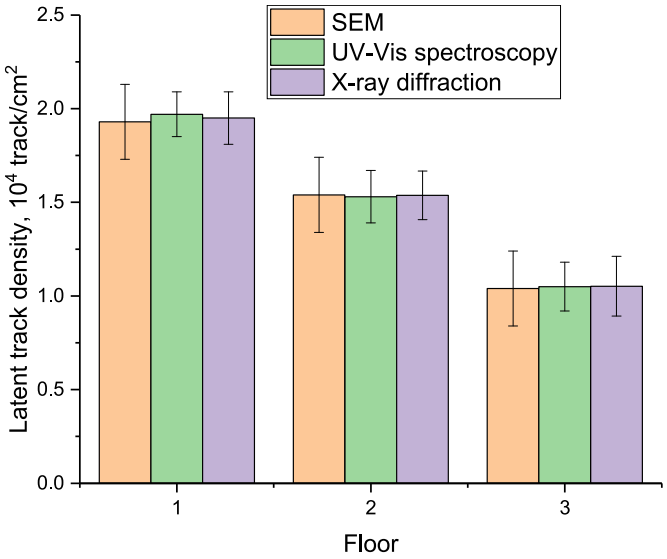

Fig. 9. Comparative diagram for determining latent track density using different methods.

For a comparative analysis of structural changes, X-ray diffraction patterns of samples were collected after 6 months of exposure when measuring the daughter products of radon decay on different floors. The results of the comparative analysis are presented in Fig. 6. The general appearance of the presented changes in the intensity of the diffraction

reflection at $2\theta = 25.8°$ and its FWHM indicate that for detector samples located on the second and third floors, the magnitude of structural distortions caused by the interaction of radon decay products is less than for samples located on the first floor. From this we can conclude that when detectors are placed on floors above the 1st, the concentration of radon and its products is somewhat lower than on the first floor, which is explained by the distance from the surface and the partial exclusion of the possibility of radon penetration from underground through microcracks in the floor.

A comparative analysis of optical and structural changes with similar data on changes in the properties of film detectors exposed to a source of α - particles in order to determine the dose dependence of changes in the characteristics of films with the density of the formed latent tracks is shown in Fig. 7. Data presented in the form of curves of changes in optical density, band gap, and Δd (The value of $\Delta d = (d_{irr} - d_{pristine})$, d_{irr} is the value of the interplanar distance after irradiation; $d_{pristine}$ is the value of the interplanar distance for the initial sample), which characterizes the change in deformation of the molecular structure, determined based on the shifts of the diffraction maxima of X-ray diffraction patterns, were taken from works [25,26], in which the dependences of changes in the density of latent tracks of α - particles generated by the Am-241 source, used for model experiments to determine the daughter products of radon decay (due to the similarity of the energy of α - particles emitted as a result of nuclear reactions), were established. These curves are a kind of calibration curves for determining the density of latent tracks of α - particles formed in the nitrocellulose polymer film used as a detector.

The analysis was carried out by superimposing the obtained changes in optical (optical density and band gap) and structural (value Δd, reflecting the deformation distortion of the structure) onto the obtained dependences of changes in similar values depending on the density of latent tracks obtained during exposure to the Am-241 source. As can be seen from the presented changes, the experimentally obtained values of changes in optical and structural characteristics for samples exposed on different floors correspond to changes characteristic of samples with latent track densities exceeding 1.5–2.0 × 10^4 track/cm^2. At the same time, the analysis of the obtained values showed that the most pronounced changes correspond to the samples located on the first floor, for which all observed changes were more pronounced, which is due to the high densities of latent tracks of registered α - particles.

Fig. 8 shows the results of surface images of film detectors exposed for different times after chemical etching.

The presented data reflect changes in the density of latent tracks depending on the exposure time, an increase in the density of which indicates the accumulation of registered particles depending on time. As can be seen from the presented data, after 1 month of exposure, the density of recorded latent tracks is no more than 10^3 track/cm^2, which indicates that in order to register latent tracks it is necessary to etch the tracks to sufficiently large diameters (more than 5 μm) for detailed visualization at low magnifications and speed up the calculation of latent tracks. At the same time, the distance between the latent tracks is more than 50–70 μm, which may explain the lack of changes in the optical spectra and X-ray diffraction patterns.

Table 2 presents the assessment results of changes in volumetric activity (Bq/m^3) and equivalent equilibrium volumetric activity (Bq/m^3). The data were calculated based on changes in the density of latent tracks recorded from α particles.

Fig. 9 shows a comparative diagram for determining the latent track densities of registered α-particles when exposing samples after 6 months using various analysis methods. Determination of latent track density by comparative assessment of optical and structural changes was performed by overlaying the data on the calibration curves presented in Fig. 7.

According to the data obtained, there is good agreement in determining the density of latent tracks using various analysis methods, which indicates that the obtained calibration curves of changes in optical and structural characteristics when registering α - particles at the Am-241 source can also be used to evaluate real experimentally obtained data during temporary exposures to radon in various rooms.

It is also worth to highlight that the accuracy of determination of the density of latent tracks when recording them near the sensitivity threshold of optical spectroscopy and X-ray diffraction methods is no less than 90–95 %, in comparison with similar data obtained by directly calculating the density of latent tracks. Moreover, in contrast to traditional methods for estimating latent track densities using chemical etching of latent tracks for visualization, using optical spectroscopy and X-ray diffraction methods does not require the use of these procedures, and, as a consequence, allows film detectors to be reused to obtain time dependences of the concentration of radon and its daughter decay products.

4. Conclusion

The paper presents the assessment results of the use of optical UV spectroscopy and X-ray diffraction methods for conducting experiments on time exposure to detect daughter products of radon decay in the form of α - particles on various floors of a three-story building, in order to determine both the possibilities of using alternative registration methods (UV spectroscopy and X-ray diffraction method) and determining the accuracy of measurements. The time frame of the experiment was about 6 months, during which measurements of the optical spectra and X-ray diffraction patterns of the studied samples of film detectors used to detect α-particles were carried out.

During the research, it was found that the use of optical spectroscopy and X-ray diffraction methods makes it possible to accurately record the daughter products of radon decay using polymer film detectors. Moreover, in contrast to standard methods for determining traces of radon decay products, which require chemical etching of films to visualize latent tracks of α-particles, the use of optical spectroscopy and X-ray diffraction methods eliminates this procedure. During field experiments to determine the concentration of radon and its daughter decay products under real conditions when exposing samples indoors on different floors, good agreement was obtained between the obtained changes in optical and structural characteristics with the density of latent tracks, as well as the concentration of registered α - particles.

CRediT authorship contribution statement

Dana S. Yerimbetova: Writing – original draft, Visualization, Resources, Project administration, Formal analysis, Data curation, Conceptualization. **Marina Konuhova:** Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Artem L. Kozlovskiy:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Umitali N. Tuichiyev:** Resources, Project administration, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

No data was used for the research described in the article.

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