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NEW TECHNOLOGIES FOR OBTAINING AND PROCESSING MATERIALS

Formation of Hydrophobic Coatings on the Surface of Track Etched Membranes Using Magnetron Sputtering of Polymers in Vacuum

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Abstract—The surface properties and chemical structure of nanosized coatings deposited on the surface of polyethylene terephthalate track-etched membranes by magnetron sputtering of ultrahigh molecular weight polyethylene and polytetrafluoroethylene in a vacuum have been studied. Application of coatings leads to hydrophobization of surface of the original membranes, the degree of which depends on the type of polymer used for sputtering and the coating thickness. The use of this modification method causes smoothing of structural inhomogeneities of the surface layer of membranes, which is explained by the deposition of coatings in the pore channels at a certain depth from the inlet and the overlap of pores on the surface of modified membranes. In addition, the deposition of coatings on the surface of track-etched membranes leads to a change in the shape of pores. The pore diameter decreases significantly on the modified side and remains unchanged on the untreated side of the membrane, while the membrane pores acquire an asymmetrical (conical) shape. The study of chemical structure of coatings using X-ray photoelectron spectroscopy showed that they contain oxygen-containing functional groups owing to oxidation of the polymer matrix. The developed composite membranes can be used in membrane distillation processes for seawater desalination.

Keywords: polyethylene terephthalate track-etched membranes, magnetron sputtering of polymers in vacuum, polytetrafluoroethylene, ultrahigh molecular weight polyethylene, hydrophobization, composite membranes

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INTRODUCTION

Modification of polymer materials, including polymer membranes, is a universal approach that allows their physicochemical, mechanical, and operational properties to be varied over a wide range. There are various methods for modifying the properties of polymer materials on the basis of physical and chemical influences [1]. In most cases, to give polymer membranes greater polarity, surface hydrophilization is carried out, during which a radical interference occurs in the nature of the polymer surface layer. This treatment leads to an improvement in the bio- and hemocompatibility of the membrane surface, which makes it possible to use hydrophilized membranes for the purification and concentration of biological products, vaccines, etc. [2], as well as to use modified membranes in medicine, for example, as a highly effective biocompatible explant drainage in the surgical treatment of refractory glaucoma [3] and as implants in the surgical treatment of bullous keratopathy [4].

The most commonly used methods of hydrophilization include the treatment of polymers with etching solutions or reagent vapors, thermal (in particular, laser-chemical) treatment, and plasma or flame treatment. One of the simplest and most frequently used methods of surface hydrophilization is treatment with chemical reagents [5]. Etching of polymers usually leads to the formation of a thin surface modified layer with a large number of functional groups. Among physical methods of treatment for hydrophilization of polymer surface, the most widely used is the method of treatment in plasma of nonpolymerizing gases [6, 7], the advantage of which is the change in the surface layer of material insignificant in size owing to the small depth of penetration of active plasma particles into its volume. The bulk of polymer does not change, which is extremely important from the point of view of preserving the mechanical and physicochemical properties of the modified materials. In order to modify the properties, the influence of plasma on polymer membranes was studied [8, 9], including track-etched membranes [10, 11].

However, in some membrane processes, such as membrane distillation and hydrophobic pervaporation, and in processes using gas-liquid membrane contactors, it is necessary for their surface to be hydrophobic to prevent water from penetrating into the membrane pores. Since the production of membranes based on highly hydrophobic polymers from polyvinylidene fluoride (PVDF), polytetrafluoroethylene (PTFE), and polypropylene (PP) is difficult, a current approach to creating hydrophobic membranes is hydrophobization of the surface of membranes made on the basis of hydrophilic polymers. To obtain membranes with a hydrophobic surface, the method of applying thin polymer coatings to the surface can be used. This modification leads to the formation of composite membranes (CMs) consisting of a porous substrate—the original membrane and a deposited polymer layer. Of greatest interest is the development of methods for creating bilayer composite membranes (BCMs), in which one of the layers is a hydrophilic base, and the second thin layer has hydrophobic properties. Membranes of this structure, along with the traditionally used hydrophobic membranes made of PVDF, PTFE, and PP, are used in membrane distillation processes for seawater desalination. The use of a thin hydrophobic layer in combination with a thick hydrophilic base makes it possible to increase the productivity of this process by reducing the resistance to mass transfer [12, 13].

There are various approaches to creating bilayer CMs, one of which is the deposition of a polymer layer synthesized in plasma onto a porous substrate [6, 7]. The use of plasma has great advantages: it allows one to regulate the thickness of deposited polymer layer, ensures its high adhesion, and is characterized by a short process time and the possibility of using a wide range of organic and organoelemental compounds as precursors. The surface properties of composite membranes obtained by plasma-chemical modification depend on the nature of plasma-forming compound. The use of this method in the case of polymerization of organic compounds containing functional groups made it possible to obtain polymer layers of a hydrophilic nature on the surface of membranes [14]. However, an attempt to use this method to obtain hydrophobic polymer coatings on the surface of membranes using compounds that do not contain functional groups as precursors did not lead to positive results [15, 16]. The studies have shown that the surface of deposited coatings contains oxygen-containing functional groups, including carboxyl functional groups, the formation of which is associated with oxidation when the samples are exposed to air, as well as with the presence of residual oxygen in the vacuum reaction chamber. It is with the formation of oxygen-containing groups in the surface layer of deposited polymer coatings that insufficiently high values of contact angles are associated. In this regard, the search for new methods for the synthesis of bilayer composite membranes (BCMs) in which one of the layers is of a hydrophobic nature is very relevant.

A number of modern modification methods can be used to apply hydrophobic polymer coatings to the surface of membranes. Of greatest interest are methods for forming coatings from the active gas phase obtained as a result of exposure to a target (polymer or oligomer) of a concentrated energy flow—electrons, ions, laser radiation [17]. These methods are high-tech and allow one to regulate the structure and composition of deposited layers. To obtain hydrophobic coatings, materials with low surface energy are used, primarily silicon- and fluorine-based compounds.

The purpose of this work is to study the surface properties and chemical structure of nanosized coatings of ultrahigh molecular weight polyethylene (UHMWPE) and polytetrafluoroethylene (PTFE) deposited on the surface of polyethylene terephthalate track-etched membranes (PET TM) by high-frequency (RF) magnetron sputtering (MS) of the original polymers in a vacuum.

EXPERIMENTAL

In the experiments, we used PET TM with an effective pore diameter of 95 nm (the number of pores was 1.3×10^9 cm^{-2}) and 65 nm (the number of pores was 3×10^9 cm^{-2}) obtained on the basis of a Lavsan polymer film (GOST 24234-80, Russia) with a density of 1.40 g/cm^3 and a nominal thickness of 10.0 μm. To obtain membranes, the initial film was irradiated with positively charged krypton ions accelerated on a cyclotron with an energy of ~3 MeV/nucleon. Chemical etching of irradiated films was carried out at a temperature of 75°C in an aqueous solution of sodium hydroxide with a concentration of 1 mol/L according to the method [18]. Before etching, to increase the selectivity of the track etching process, the irradiated film was exposed to UV radiation with a maximum wavelength of the emission spectrum of 310–320 nm.

Coatings of UHMWPE and PTFE were applied to the surface of membranes by deposition from the active gas phase using RF magnetron sputtering of polymers in a vacuum. Argon was used as the working gas, the flow rate of which was 100 cm^3/min. The residual air pressure in the vacuum chamber before the start of the process start was ~10^{-2} Pa; the working pressure of argon was 6.8×10^{-1} Pa. The deposition process was carried out at a discharge power of 50 W. The deposition rate of UHMWPE coating was 0.85 nm/min, and that of PTFE was 6.0 nm/min. The layout of the setup and the coating deposition technique are described in detail in [19].

The characteristics of the original and modified membranes were determined using a number of techniques. The effective pore diameter was calculated using the Knudsen formula [20] on the basis of the gas permeability values (air flow passing through the membrane) measured using a float flow meter at a given pressure drop. The membrane surface wettability was characterized by the values of contact angles with water (bidistillate) measured using an Easy Drop DSA100 setup (KRUSS, Germany) and Drop Shape Analysis V.1.90.0.14 software (error of ±1°).

The membrane surface morphology was studied by atomic force microscopy (AFM) using an NTEGRA Prima microscope (NT-MDT, Spectrum Instruments, Russia). Scanning was carried out in an intermittent contact mode using HA_FM silicon probes (Tipsnano, Estonia). The scanning field was 1×1 μm^2 with a resolution of 512×512 points per image. The main parameter being determined was the value of the standard deviation of surface heights from the average value (S_q) calculated for all scan points. In order to avoid the influence of pores when determining surface roughness, the scans of a smaller area that did not contain pores were also examined.

X-ray photoelectron spectroscopy (XPS) spectra were obtained using a Thermo Scientific K-Alpha instrument (United States) equipped with a hemispherical analyzer. To excite photoelectrons, X-ray radiation from an aluminum anode ($AlK_\alpha = 1486.6$ eV) was used at a tube voltage of 12 kV and an emission current of 3 mA. The positions of peaks were calibrated using the standard C1s peak (284.6 eV) [21]. Survey spectra were recorded at a transmission window of 100 eV with a spectral step of 0.5 eV, and regional spectra were recorded at a transmission window of 20 eV with a step of 0.05 eV. The spectra were recorded and processed using the Avantage program.

RESULTS AND DISCUSSION

The results of measuring the characteristics of original PET TM and membranes after coating by magnetron sputtering of UHMWPE and PTFE in vacuum are presented in Table 1. From the above data, it follows that the deposition of a polymer layer causes a decrease in the effective pore diameter of membranes; that is, the pore diameter in the deposited polymer layer is less than the pore diameter in the original PET TM. Formation of polymer coatings on the surface of track-etched membranes is illustrated in Fig. 1, which shows images of the surface layer of modified membranes obtained by AFM. It can be seen that the application of coatings causes a decrease in the pore diameter on the surface of the resulting composite membranes. However, the membrane pores on the surface are not completely closed by the polymer layer. Histograms obtained using the SPIP program to determine the distribution of membrane pore surface area after deposition of a polymer layer are shown in Fig. 2, from which one can determine the number of pores, as well as their area. Thus, for a membrane with a deposited PTFE layer 60 nm thick, the largest number of pores has a surface area in the range from 10^{-3} to 2×10^{-3} μm^2, and their diameter varies from 36 to 50 nm (Fig. 2a). The membrane surface porosity is 3.1%, while for the original membrane with a pore diameter of 95 nm, the pore area is 7.2×10^{-3} μm^2, and its porosity is 9.2%. An application of a polymer layer with a thickness of 180 nm leads to greater closure of pores on the membrane surface. The proportion of pores with a diameter from 36 to 50 nm decreases slightly, and the proportion of pores with a diameter less than 36 nm increases (Fig. 2b). The surface porosity of membranes in this case is reduced to 2.9%.

From the AFM data, it follows that the pore diameter on the back side of the composite membranes remains unchanged. This indicates that polymer deposition occurs only on the modified side of the membrane. Applying a layer of polymers to the surface of PET TM using magnetron sputtering leads to the formation of BCMs with an asymmetrical pore shape—the pore diameter on the untreated side of the membrane does not change, but on the modified side, it decreases. This result correlates with the data obtained in the study of PET TM modification by plasma polymerization [14].

Study of the surface layer of composite membranes by AFM shows that the deposition of a film of polymers on the surface of PET TM leads to a change in its roughness. Thus, for an initial membrane with a pore diameter of 65 nm, the value of S_q calculated over all scan points with an area of 1×1 μm^2 is equal to 23.2 nm. This relatively high value is due to both the presence of pores on the membrane surface and the method of manufacturing of TM, including chemical etching. The presence of pores has a more noticeable effect on the roughness value. This is indicated by the determination of such parameters as the maximum height of the roughness peak S_p and the maximum depth of the valley S_v. Estimation of these parameters for the original membrane leads to the following results. The S_v value is 129.5 nm, while the S_p value is 25.8 nm, which is significantly lower. To avoid the influence of pores when determining surface roughness, the scans with a smaller area that did not contain pores were processed. For the original TM with a pore

Table 1. Variation of characteristics of PET track-etched membranes when polymer coatings of different thicknesses are applied on their surface

Deposited polymer	Deposited polymer layer thickness, nm	Effective membrane pore diameter, nm		Surface roughness, nm		Contact angle, deg
		initial	after treatment	scanning area 1×1 μm^2	area without pores	
UHMWPE	50	65	62	13.8	4.0	78
UHMWPE	75	65	60	8.0	2.8	82
UHMWPE	100	65	57	5.2	3.5	94
PTFE	60	95	90	8.9	4.2	112
PTFE	120	95	80	6.4	4.5	111
PTFE	180	95	70	5.0	4.2	110

diameter of 65 nm, the value of S_q in this case is 5.4 nm, which is significantly less than when choosing a larger scanning field.

The deposition of coatings on the track-etched membrane surface leads to smoothing of irregularities. The S_q value for modified membrane samples calculated over all scan points with an area of 1×1 μm^2 noticeably decreases with an increase in deposition time (Table 1). This result is explained by the polymer deposition in the pore channels at a certain depth from the entrance and the overlap of pores on the surface of modified membranes. At the same time, the deposition of coatings on the surface of membranes without pores causes less noticeable changes in the value of S_q (Table 1). For example, when depositing a UHMWPE coating with a thickness of 50 nm, the value of S_q when choosing a scanning field of 1×1 μm^2 decreases by 9.4 nm, while on a surface without pores the standard deviation of surface height from the average value decreases by only 1.4 nm. A decrease in the S_q value on the surface without pores during the deposition process also indicates that the polymer coatings have a smoother surface compared to the original membrane surface and the value of its surface roughness depends little on the duration of the deposition process.

The observed difference in the morphology of the surface layer of composite membranes obtained by deposition onto the surface of track-etched membranes used for modifying polymers may be due, first of all, to the size of the deposited nanoparticles. Nanoparticles obtained by magnetron sputtering of PTFE are significantly larger in size (Figs. 1d–1f) than nanoparticles obtained by UHMWPE sputtering (Figs. 1a–1c). This difference is due to the peculiarities of the impact of particle flows falling on the target, under the influence of which polymers are destroyed. Decomposition of materials during magnetron sputtering is achieved by bombardment with an Ar$^+$ ions. When UHMWPE is used as a target, the reaction chamber contains atoms, ions, and radicals based on the C and H atoms that make up this polymer. When PTFE is used for sputtering, atoms, ions, and radicals based on C and F atoms are present in the reaction chamber. That is, the growth of coatings on the surface of track-etched membranes occurs from various polymer fragments.

Determination of the size of polymer nanoparticles using the SPIP program shows that the average size of deposited PTFE nanoparticles for a coating 60 nm thick is ~50 nm, and their maximum size reaches 120 nm (Fig. 3a). With a longer deposition process, the average size of PTFE nanoparticles is ~60 nm, and their maximum value reaches 130 nm (Fig. 3b); that is, the size of nanoparticles changes slightly with an increase in the duration of the process. At the same time, the average size of deposited UHMWPE nanoparticles for a coating 50 nm thick is ~35 nm, and their maximum size reaches only 100 nm (Fig. 4a). During longer deposition, the average size of UHMWPE nanoparticles is ~50 nm, and their maximum value reaches 110 nm (Fig. 4b).

A study of the surface properties of composite membranes shows that the deposition of UHMWPE and PTFE coatings on the surface of PET TM leads to hydrophobization of its surface layer. If the original membrane is characterized by a water contact angle (Θ) equal to 65°, then for PET TM with a UHMWPE coating 50 nm thick the value of Θ is 78°. For a membrane with a UHMWPE layer 75 nm thick, $\Theta = 82°$. An increase in the thickness of applied polymer layer to 100 nm leads to an increase in the contact angle to 94°. The deposition of a polymer layer obtained by magnetron sputtering of PTFE leads to more noticeable hydrophobization of the original membrane surface. The BCM surface contact angle in this case is on average 111°. This is due to the lower surface energy of PTFE compared to UHMWPE. Thus, for PTFE, the surface energy is 18.3 mJ/m^2, and for UHMWPE, this value is 33.0 mJ/m^2. It should be noted that the values of the contact angle for these coatings are lower than for UHMWPE and PTFE coatings obtained by electron beam dispersion (EBD) [22]. Such changes are

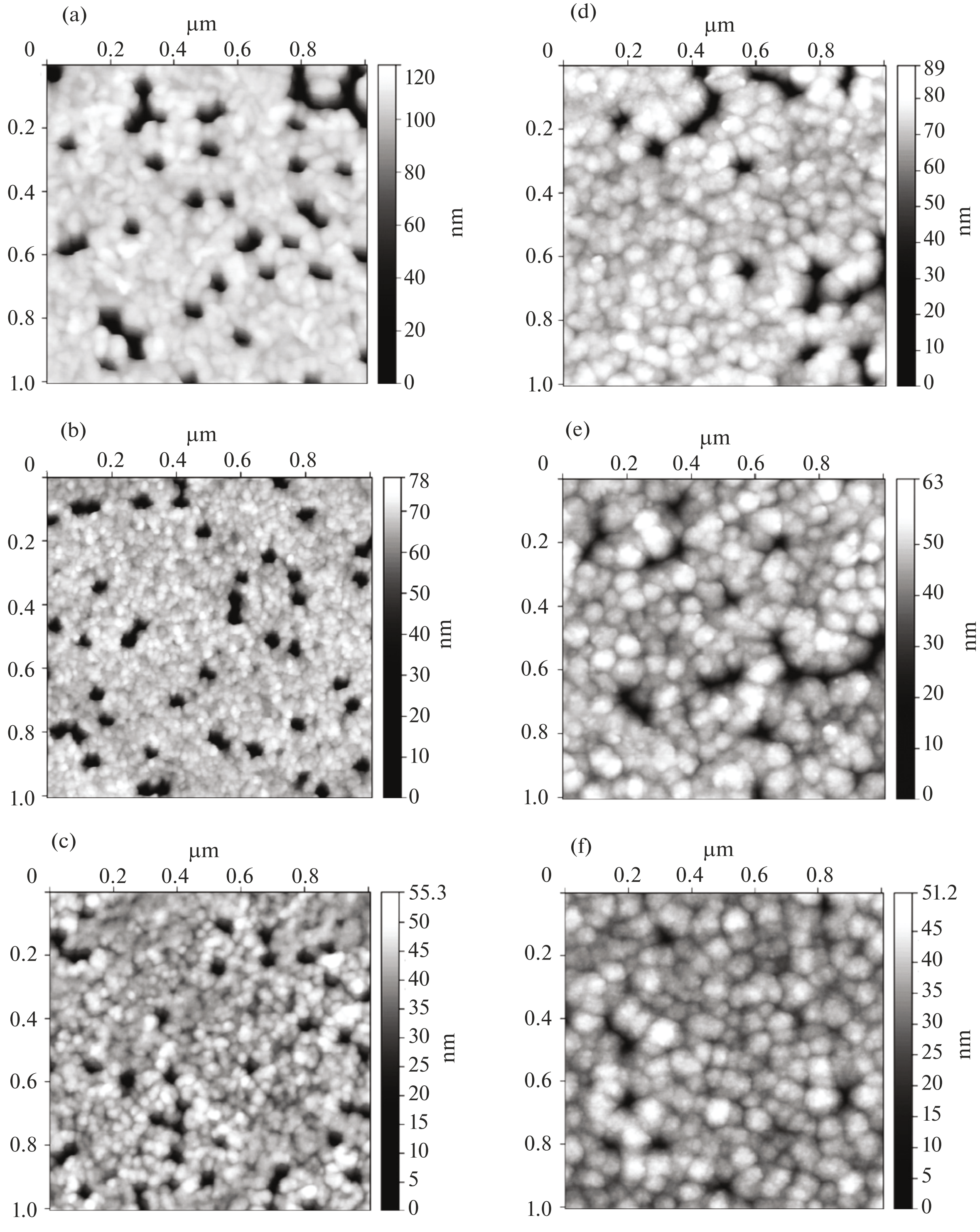

Fig. 1. AFM images of PET TM surface after applying UHMWPE coatings with a thickness of 50 (a), 75 (b), and 100 nm (c) and PTFE coatings with a thickness of 60 (d), 120 (e), and 180 nm (f) obtained by RF MS of initial polymers; scanning area is 1 × 1 μm^2.

most likely due to differences in the chemical structure of the resulting polymer coatings.

To obtain information about the chemical structure of BCM, XPS studies were carried out. Analysis of spectrum of the surface layer of original PET TM, as our studies have shown [22], is characterized by the presence of lines associated with carbon and oxygen atoms, the concentration of which is 74.5% and 25.5%, respectively. Decomposition of the C1s spectrum line of PET TM into components allowed us to

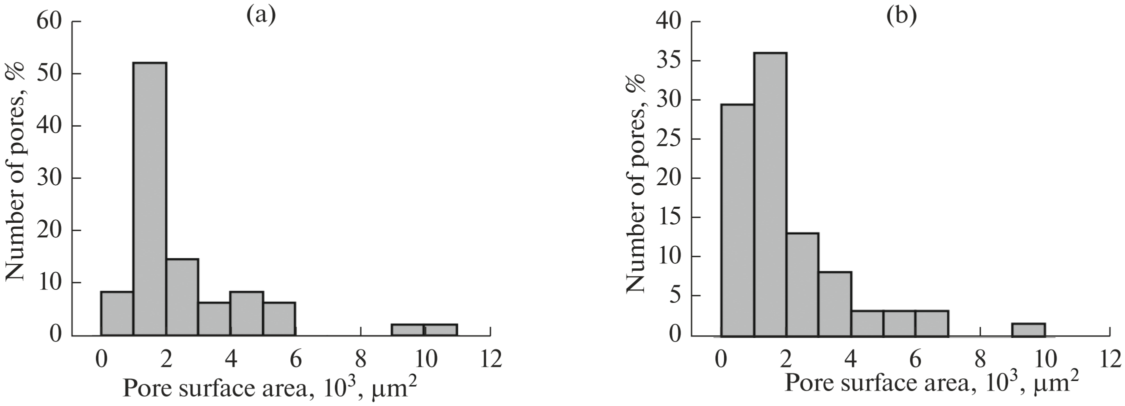

Fig. 2. Histograms of surface pore area distribution for PTFE coatings with a thickness of 60 (a) and 180 nm (b) deposited on the PET TM surface; scanning area is 2 × 2 μm^2.

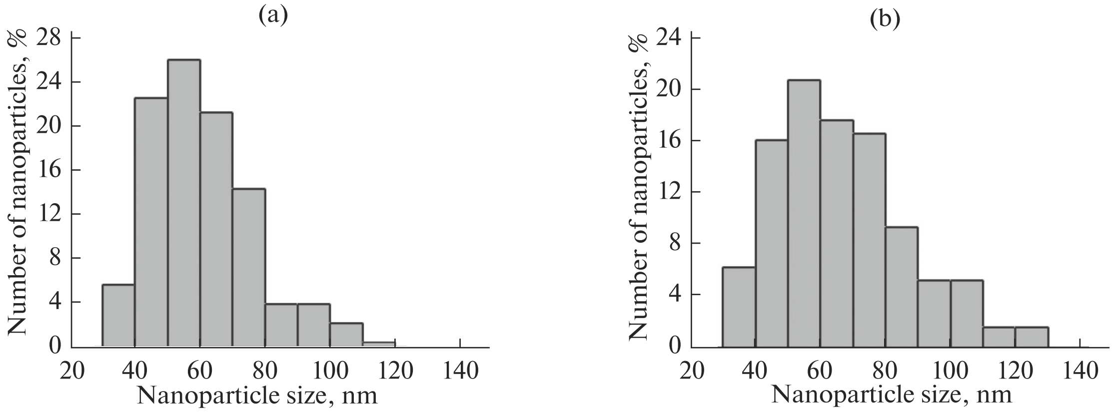

Fig. 3. Histograms of nanoparticle size distribution for PTFE coatings with a thickness of 60 (a) and 180 nm (b) deposited on the PET TM surface; scanning area is 5 × 5 μm^2.

conclude that it has a complex nature. The most intense component with a maximum binding energy (E_{be}) at 284.6 eV, the relative contribution of which is 66.0%, corresponds to carbon in the C–C and C–H bonds. The components with maxima E_{be} at 286.3 and 288.7 eV correspond to carbon in the composition of

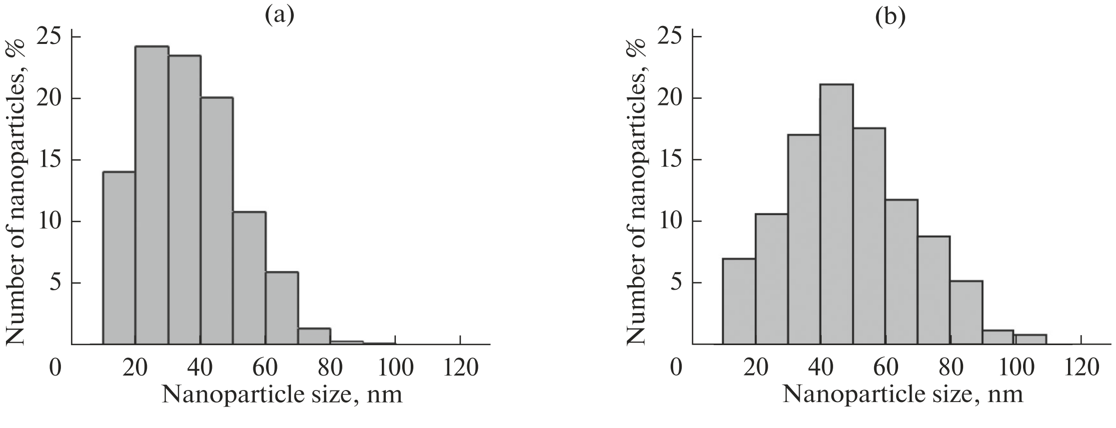

Fig. 4. Histograms of nanoparticle size distribution for UHMWPE coatings with a thickness of 50 (a) and 100 nm (b) deposited on the PET TM surface; scanning area is 5 × 5 μm^2.

Table 2. XPS data on the elemental composition of polymer coatings

Deposited polymer	Deposited polymer layer thickness, nm	Content of atoms, at %				Atomic ratio	
		F	C	O	N	O/C	F/C
UHMWPE	50	–	85.8	14.2	–	1.65×10^{-1}	–
UHMWPE	75	–	88.9	11.1	–	1.25×10^{-1}	–
UHMWPE	100	–	84.9	15.1	–	1.80×10^{-1}	–
PTFE	60	47.8	47.5	3.6	1.1	7.55×10^{-2}	1.0
PTFE	120	49.8	45.7	3.4	1.1	6.80×10^{-2}	1.1
PTFE	180	49.7	45.9	3.4	1.0	6.80×10^{-2}	1.1

oxygen-containing functional groups: C–O(H) with a concentration of 18.3% and O=C–O, the concentration of which is 15.7%. A significant concentration of oxygen-containing functional groups in the surface layer of original PET TM determines the hydrophilicity of its surface.

An XPS study of the chemical structure of UHMWPE coatings deposited by RF MS showed the presence of peaks associated with carbon and oxygen atoms (Table 2). A detailed analysis of the spectra of C1s atoms of UHMWPE coatings indicates some difference in the electron structure and chemical state of carbon in comparison with the original polymer. In the initial spectrum of the polymer (Fig. 5a), there is one intense peak with a maximum $E_{\text{be}} = 285.0$ eV, corresponding to the chemical state of carbon in the C–C and C–H bonds [21]. The spectrum of the coating obtained by the RF MS method of this polymer (Fig. 5b) contains four components: an intense one with a maximum $E_{\text{be}} = 285.0$ eV, corresponding to the chemical state of carbon in the C–C and C–H bonds, and components of lower intensity: with a maximum $E_{\text{be}} = 286.0$ eV, corresponding to carbon in the C–O(H) bonds; with a maximum $E_{\text{be}} = 287.5$ eV, corresponding to carbon in the C=O functional groups; and with a maximum $E_{\text{be}} = 289.1$ eV, corresponding to carbon in the O=C–O groups [23]. These data indicate the appearance of oxygen-containing groups on the surface of the UHMWPE layer. The ratio of the number of oxygen atoms to the number of carbon atoms in the deposited coatings is on average 1.6×10^{-1}, which is two times less than on the original PET TM surface, for which this ratio is 3.4×10^{-1}. This means that the concentration of ionic functional groups, in particular, oxygen-containing groups, on the surface of UHMWPE coatings is lower compared to the original membrane. According to experimental data, the concentration of oxygen-containing groups corresponding to different chemical states of carbon in UHMWPE coatings of various thicknesses varies slightly (Table 3).

Analysis of XPS spectra of PTFE coatings shows the presence of peaks associated with carbon and fluorine atoms, as well as minor nitrogen and oxygen contents. The appearance of the latter is possible both owing to the presence of residual oxygen in the vacuum reaction chamber and owing to subsequent oxidation of PTFE when the samples are exposed to air. For PTFE, the ratio of the number of fluorine atoms to carbon is 2. For polymers obtained by magnetron

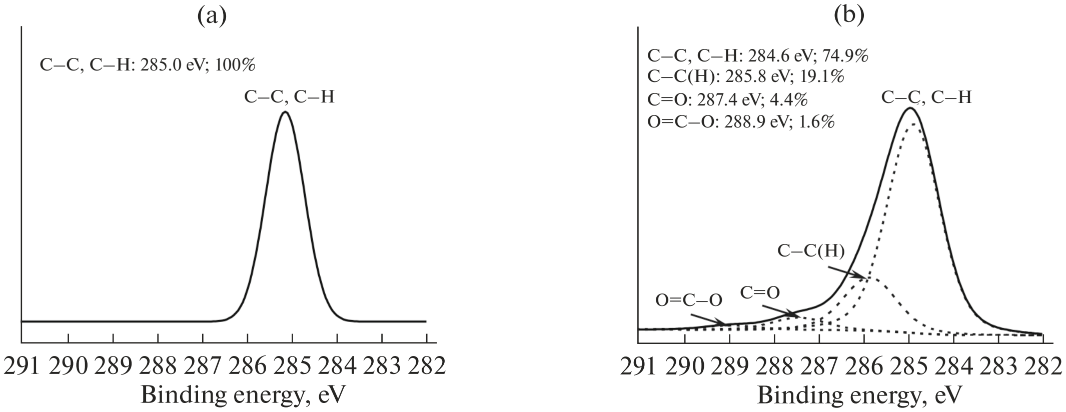

Fig. 5. XPS spectra of C1s atoms of the original UHMWPE (a) and UHMWPE coating 75 nm thick deposited by magnetron sputtering (b).

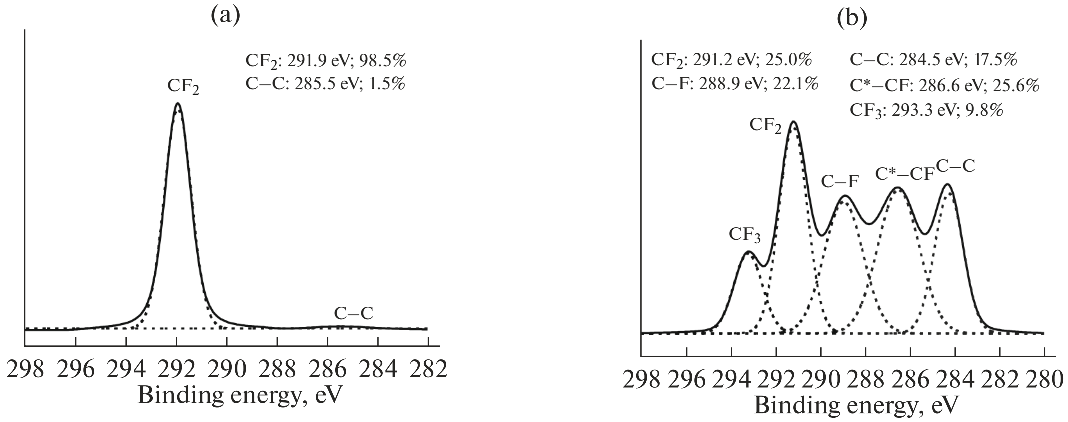

Fig. 6. XPS spectra of C1s atoms of the original PTFE (a) and PTFE coating 120 nm thick deposited by magnetron sputtering (b).

sputtering in a vacuum, this ratio is lower (Table 2), which indicates the removal of part of fluorine during the formation of coatings. A detailed analysis of the spectra of C1s atoms of PTFE coatings shows that, in contrast to the original PTFE spectrum, they are more complex. The original PTFE spectrum (Fig. 6a) contains two components: an intense one with a maximum binding energy of 292.1 eV, corresponding to the chemical state of carbon in the CF_2 groups, and a low-intensity component with a maximum $E_{be} = 284.5$ eV, corresponding to carbon in the C–C bonds [21]. The partial concentrations of these states are 98.5% and 1.5%, respectively. According to [24], the C1s spectrum of polytetrafluoroethylene contains one component corresponding to the CF_2 group with a maximum E_{be} at 292.1 eV. Apparently, the presence of a low-intensity peak (284.5 eV) in the spectrum may be due to the presence of a certain amount of hydrocarbon impurities in the polymer composition.

For polymers obtained by RF MS of polytetrafluoroethylene, the broadening of spectra is observed (Fig. 6b), which indicates the superposition of several lines corresponding to different chemical states of a carbon atom. Spectral fitting revealed three additional peaks with E_{be} 286.6, 293.3, and 288.9 eV, which can be attributed to the C*–CF and CF_3 groups and C–F bond, respectively [25, 26]. This indicates the occurrence of PTFE destruction processes occurring during magnetron sputtering. The presence of CF_3 groups in a polymer indicates the presence of macromolecules with short chains [27]. The concentration of fluorine-containing groups corresponding to different chemical states of carbon in PTFE films of various thicknesses, as experimental data show, varies slightly (Table 4). It should be noted that the presence of a peak corresponding to $E_{be} = 286.6$ eV may indicate the presence of oxygen-containing chemical groups C–OH and C–OR in a polymer. This means that part of the carbon atoms are bound to oxygen, and the lower contact

Table 3. Distribution of carbon atoms by chemical state in the C1s spectra for UHMWPE coatings of different thicknesses

Coating thickness, nm	Relative content, %			
	C–C, C–H	C–O(H)	C=O	O=C–O
50	75.7	15.1	6.6	2.6
75	74.9	19.1	4.4	1.6
100	73.8	17.9	6.0	2.3

Table 4. Distribution of carbon atoms by chemical state in C1s spectra for PTFE coatings of different thicknesses

Coating thickness, nm	Relative content, %				
	CF_2	C–C	C–F	C*–CF	CF_3
60	20.0	20.4	23.4	26.2	10.0
120	25.0	17.5	22.1	25.6	9.8
180	22.2	14.6	24.5	27.9	10.8

angle (equal to 111° on average) compared to the initial PTFE, for which $\Theta = 120°$, is explained by the formation of some polar oxygen-containing groups.

CONCLUSIONS

Application of UHMWPE and PTFE coatings to the surface of PET TM by magnetron sputtering of polymers leads to the formation of bilayer composite membranes. The first layer is the original membrane, with terminal carboxyl groups on the surface and an average level of hydrophilicity. The water contact angle of this layer is 65°.

The second layer is hydrophobic in nature. The contact angle of this layer, depending on the thickness, varies for UHMWPE coatings from 78° to 94°, and for PTFE coatings from 110° to 112°. Insufficiently high values of water contact angles are associated with the formation of oxygen-containing groups in the surface layer of applied polymers.

A comparison of experimental data with the results of studying polymer coatings deposited by electron beam dispersion shows that polymers obtained by EBD are closer in chemical composition to the original ones. They exhibit higher concentrations of chemical bonds characteristic of UHMWPE and PTFE and significantly lower concentrations of oxygen-containing groups compared to polymers deposited by magnetron sputtering.

Coating the surface of track-etched membranes using magnetron sputtering of UHMWPE and PTFE leads to smoothing of structural inhomogeneities—the surface roughness of modified membranes is lower compared to the original PET TM. An application of UHMWPE and PTFE coatings on the surface of track-etched membranes made of polyethylene terephthalate leads to the formation of composite membranes with an asymmetric (conical) pore shape: the pore diameter is significantly reduced on the modified side, and on the untreated side, the membrane remains unchanged.

The developed composite membranes can be used in membrane distillation processes for seawater desalination. Work on the use of these membranes in the process of water desalination using membrane distillation is planned in the near future.

ABBREVIATIONS AND NOTATION

PVDF	Polyvinylidene fluoride
PTFE	Polytetrafluoroethylene
PP	Polypropylene
CMs	Composite membranes
BCMs	Bilayer composite membranes
UHMWPE	Ultra-high molecular weight polyethylene
MS	Magnetron sputtering
RF MS	Radio-frequency Magnetron sputtering
PET TM	Polyethylene terephthalate track-etched membranes
AFM	Atomic force microscopy
XPS	X-ray photoelectron spectroscopy
TM	track-etched membrane
EBD	Electron beam dispersion

PVDF	Polyvinylidene fluoride
PTFE	Polytetrafluoroethylene
PP	Polypropylene
CMs	Composite membranes
BCMs	Bilayer composite membranes
UHMWPE	Ultra-high molecular weight polyethylene
MS	Magnetron sputtering
RF MS	Radio-frequency Magnetron sputtering
PET TM	Polyethylene terephthalate track-etched membranes
AFM	Atomic force microscopy
XPS	X-ray photoelectron spectroscopy
TM	track-etched membrane
EBD	Electron beam dispersion

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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