

Mechanism of the Effect of Gamma Irradiation on the Surface Properties of Polytetrafluoroethylene

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Abstract—Changes in the work of adhesion γ_{SL} of polar and nonpolar liquids, as well as the dispersion and polar components of the surface energy γ_S of suspension-polymerized polytetrafluoroethylene (PTFE) as a function of the gamma-radiation dose are analyzed quantitatively. A physicochemical model for increasing the work of adhesion γ_{SL} of a polar liquid is proposed. The model is based on the formation of a double electrostatic layer at the phase interface due to ion-dipole interaction.

Keywords: polytetrafluoroethylene, gamma irradiation, dielectric increment, surface energy, polar groups

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INTRODUCTION

Polytetrafluoroethylene (PTFE) possesses high antiadhesion properties and a low surface energy, which limits its compatibility with other materials. For this reason, in the design of composites where PTFE acts as a matrix, filler particles are subjected to modification in order to decrease their surface energy. In polymer-polymer composites where the filler is PTFE, unsintered PTFE powder particles are modified to increase their surface energy [1]. The increase in the surface energy of sintered block PTFE is a topical problem also in the design of adhesive joints and many other practical applications [2].

According to [3–5], the adhesive properties of unsintered PTFE powder improve after radiation exposure due to the emergence of polar groups on the surface of particles. In [6], the effects of gamma radiation on the contact angle of wetting, electric polarization, and dielectric increment $\Delta\epsilon$ for sintered and unsintered PTFEs were compared. Analysis of the obtained data showed that changes in the surface properties of sintered PTFE significantly exceed those anticipated in terms of enhancement in the dipole-dipole and donor-acceptor intermolecular interactions [6].

In order to reveal the mechanism of such considerable changes in the surface properties of irradiated PTFE, in the present work we quantitatively estimate the van der Waals interaction between a test liquid and the surface of PTFE based on the Lifshitz model.

THEORY

The work of adhesion in terms of molecular theory is conditionally divided into three components: dispersive (Lifshitz–van der Waals), acid-base (donor-acceptor), and electrostatic. The qualitative theory of adhesion is developed mainly for systems where adhesion is caused predominantly by dispersion forces [7–10].

The free energy of the dispersion interaction of two surfaces A and B at distance H is determined by the formula [9]:

$$G_{AmB}(H) = -\frac{A_{AmB}}{12\pi H^2},$$

where A_{AmB} is the Hamaker constant which is determined by the dielectric properties of materials A and B and by the medium dividing them. For different vacuum-divided dispersion surfaces A and B , the $G_{AmB}(H)$ values are equal to the work of adhesion of material B to material A .

According to the Lifshitz theory [7], for two differing vacuum-divided surfaces the Hamaker constant is calculated as follows:

$$A_{AmB} = \frac{3kT}{2} \times \left[\frac{1}{2} I_{AmB}(i\xi_0) + I_{AmB}(i\xi_1) + I_{AmB}(i\xi_2) + \dots \right], \quad (1)$$

where $A_{AmB}(i\xi)$ is the integral depending on the dielectric permittivity of materials A and B at the imaginary frequency $i\xi$. The summation in Eq. (1) is

performed over the Matsubara frequencies which are determined by the equation:

$$\xi_n = n \frac{2\pi k T}{\hbar}, \quad (2)$$

where k and \hbar are the Boltzmann and Planck constants, respectively, and $i\xi_n$ ($n = 0, 1, 2, 3, \dots$) are the Matsubara frequencies (a set of discrete imaginary frequencies for a specified temperature T). At room temperature, the Matsubara frequencies $i\xi_n$ change at a step of 2.44×10^{14} rad/s.

In the approximation of a tight gap H between interacting half-spaces, the integral $I_{AmB}(i\xi)$ transforms into:

$$I_{AmB}(i\xi) = \sum_{s=1}^{\infty} \frac{[\Delta_{Am}(i\xi)\Delta_{Bm}(i\xi)]^s}{s^3}, \quad (3)$$

where

$$\Delta_{Am}(i\xi) = \frac{\varepsilon_{Am}(i\xi) - 1}{\varepsilon_{Am}(i\xi) + 1}, \quad \Delta_{Bm}(i\xi) = \frac{\varepsilon_{Bm}(i\xi) - 1}{\varepsilon_{Bm}(i\xi) + 1}.$$

The $I_{AmB}(i\xi)$ values are determined for each Matsubara frequency. Summation continues until one of the ε_A or ε_B values at any frequency becomes equal to unity, then sum (3) becomes zero, which occurs approximately at X-ray frequencies.

Sum (3) is usually thought [8] to be approximately equal to its first summand:

$$I_{AmB}(i\xi) = \sum_{s=1}^{\infty} \frac{[\Delta_{Am}(i\xi)\Delta_{Bm}(i\xi)]^s}{s^3} \approx \Delta_{Am}(i\xi)\Delta_{Bm}(i\xi).$$

The maximum error of this approximation does not exceed 15% and emerges when $\Delta_{Am}(i\xi)$ and $\Delta_{Bm}(i\xi)$ reach maximum values.

In [11, 12], the irradiation of PTFE in the presence of molecular oxygen (in air) was shown to result in the appearance of additional polarizability (and an additional maximum of dielectric losses) with a typical relaxation time of 10–100 s at room temperature which corresponds to a radian frequency of $\sim 10^{-1}$ – 10^{-2} rad/s. This value is 15–16 orders of magnitude less than the Matsubara-frequency step at room temperature. Therefore, one can consider that in irradiated PTFE an additional polarizability changes the dielectric permittivity only at the zero Matsubara frequency $i\xi_0 = 0$. The dielectric permittivities at all other frequencies $\{i\xi_1, i\xi_n\}$ remain unchanged and the change in the Hamaker constant A_{AmB} upon irradiation is defined by a change in the first term in series (1).

For the change in the Hamaker constant ΔA_{AmB} resulting from irradiation, one can write:

$$\begin{aligned} \Delta A_{AmB} &= A_{AmB}^{\text{irr}} - A_{AmB}^{\text{unirr}} \\ &= \frac{3kT}{4} [I_{AmB}^{\text{irr}}(0) - I_{AmB}^{\text{unirr}}(0)], \\ I_{AmB}^{\text{irr}}(0) &= \frac{\varepsilon_0^{\text{irr}} - 1 \varepsilon_0^B - 1}{\varepsilon_0^{\text{irr}} + 1 \varepsilon_0^B + 1}, \\ I_{AmB}^{\text{unirr}}(0) &= \frac{\varepsilon_0^{\text{unirr}} - 1 \varepsilon_0^B - 1}{\varepsilon_0^{\text{unirr}} + 1 \varepsilon_0^B + 1}, \end{aligned} \quad (4)$$

where $\varepsilon_0^{\text{unirr}}$, $\varepsilon_0^{\text{irr}}$, and ε_0^B are the static dielectric permittivities of PTFE prior to and after irradiation and B is the test liquid, respectively.

At a constant spacing, it is convenient to use the relative change in the interaction energy which does not depend on H :

$$\frac{\Delta G_{AmB}}{G_{AmB}} = \frac{\Delta A_{AmB}}{A_{AmB}}. \quad (5)$$

The substitution of (4) into (5) allows one to determine the relative changes in the work of adhesion.

An additional factor of the increase in the intermolecular interaction can be an increase in the density ρ upon irradiation. According to the Clausius–Mossotti relation [7]:

$$\frac{1}{\rho} \frac{\varepsilon - 1}{\varepsilon + 2} = \frac{4\pi N_A \alpha}{3M} = \text{const},$$

where M is the molecular weight of the substance, ρ is its density, ε is the dielectric permittivity, α is the polarizability of a molecule, and N_A is Avogadro's number. For the case of one substance, if only ρ changes one can write:

$$\frac{1}{\rho} \frac{\varepsilon^{\rho} - 1}{\varepsilon^{\rho} + 2} = \frac{1}{\rho_{\text{ref}}} \frac{\varepsilon - 1}{\varepsilon + 2}, \quad (6)$$

where ε is the dielectric permittivity of the material at an initial density equal to ρ_{ref} , and ε^{ρ} is the new dielectric permittivity at the new density ρ . The change in the packing density is considered to be identical in the bulk of the substance and at the surface.

To estimate the effect of the change in the sample density ρ on the dispersion component of the work of adhesion, upon calculation of the relative changes in the Hamaker constant the zero approximation in Eq. (4) cannot be used, since the changes occur at all Matsubara frequencies. Therefore, Eq. (6) for the dielectric permittivity $\varepsilon(i\xi)$ at each frequency $i\xi$ takes the form:

$$\frac{\varepsilon^{\rho}(i\xi) - 1}{\varepsilon^{\rho}(i\xi) + 2} = \frac{\rho}{\rho_{\text{ref}}} \frac{\varepsilon(i\xi) - 1}{\varepsilon(i\xi) + 2}.$$

Table 1. Dispersion and polar components of the surface energy of PTFE γ_S^{dis} and γ_S^{pol} (mJ/m²) and the works of adhesion of water and tetradecane $\gamma_{SL}^{\text{H}_2\text{O}}$ and $\gamma_{SL}^{\text{C}_{14}\text{H}_{30}}$ (mJ/m²) as a function of the absorbed radiation dose

Sample	γ_S^{dis}	γ_S^{pol}	$\gamma_{SL}^{\text{H}_2\text{O}}$	$\gamma_{SL}^{\text{C}_{14}\text{H}_{30}}$
F4PN-0	19.62	0.15	47.0	45.8
-100	20.71	0.31	50.4	47.1
-200	20.71	0.53	52.9	—
-500	21.11	0.83	55.9	47.5
F4-0	19.73	0.15	47.0	45.9
-100	20.36	0.54	52.6	47.6
-200	20.74	0.96	56.5	47.7
-500	21.34	3.12	68.4	47.7
F4RM-0	20.09	0.35	50.3	46.3
-100	20.58	1.04	56.9	46.6
-200	21.00	1.99	62.9	47.4
-500	21.34	4.56	73.9	47.7

Table 2. Relative changes (%) in the dispersion and polar components of the surface energy of PTFE (η_s^{dis} and η_s^{pol}) and in the work of adhesion for water $\eta(\text{H}_2\text{O})$ and tetradecane $\eta(\text{C}_{14}\text{H}_{30})$ as a function of the absorbed dose

Sample	η_s^{dis}	η_s^{pol}	$\eta(\text{H}_2\text{O})$	$\eta(\text{C}_{14}\text{H}_{30})$
F4PN-100	5.5	110	7.2	2.8
-200	5.5	250	13.0	2.8
-500	7.6	450	19.0	3.7
F4-100	3.2	260	12.0	3.7
-200	5.1	540	20.2	3.9
-500	8.2	1980	45.5	3.9
F4RM-100	2.4	200	13.1	0.6
-200	4.5	470	25.0	2.4
-500	6.2	1200	47.0	3.0

Hence one can express the dielectric permittivity as a function of the density change:

$$\epsilon_{Am}^p(i\xi) = \frac{1 + 2 \frac{\rho}{\rho_{\text{ref}}} \frac{\epsilon(i\xi) - 1}{\epsilon(i\xi) + 2}}{1 - \frac{\rho}{\rho_{\text{ref}}} \frac{\epsilon(i\xi) - 1}{\epsilon(i\xi) + 2}} \quad (7)$$

Substituting (7) in (3) we get:

$$I_{AmB}^p(i\xi) = \sum_{s=1}^{\infty} \frac{[\Delta_{Am}^p(i\xi) \Delta_{Bm}(i\xi)]^s}{s^3}, \quad (8)$$

where $\Delta_{Am}^p(i\xi) = \frac{\epsilon_{Am}^p(i\xi) - 1}{\epsilon_{Am}^p(i\xi) + 1}$. For the test liquid (material *B*), the parameter $\Delta_{Bm}(i\xi)$ remains unchanged.

For calculation of the Hamaker constant with a new density, Eq. (1) will take the form:

$$A_{AmB}^p = \frac{3kT}{2} \times \left[\frac{1}{2} I_{AmB}^p(i\xi_0) + I_{AmB}^p(i\xi_1) + I_{AmB}^p(i\xi_2) + \dots \right] \quad (9)$$

The change in the Hamaker constant will be determined by the equation:

$$\Delta A(\rho)_{AmB} = A_{AmB}^p - A_{AmB}^{\text{p.ref}}, \quad (10)$$

where A_{AmB}^p is the Hamaker constant for the new density calculated by Eq. (9) and $A_{AmB}^{\text{p.ref}}$ is the Hamaker constant for the initial density calculated from Eq. (1). The substitution of (10) in Eq. (5) allows one to determine the relative change in the work of adhesion taking into account the change in density.

RESULTS AND DISCUSSION

The qualitative analysis of the intermolecular interaction between the test liquid and the irradiated PTFE surface was performed in terms of the Lifshitz model for unsintered (F4PN) and sintered (F4 and F4RM) suspension-polymerized PTFE samples (MW $\sim 5 \times 10^6$) for which we obtained earlier experimental data on the effect of gamma irradiation on the surface energy and the work of adhesion [6].

Table 1 gives experimental values of the dispersion and polar components of the surface energy (γ_S^{dis} and γ_S^{pol}) of PTFE calculated by the Owens–Wendt method, as well as the works of adhesion of water and tetradecane ($\gamma_{SL}^{\text{H}_2\text{O}}$ and $\gamma_{SL}^{\text{C}_{14}\text{H}_{30}}$) as a function of the radiation dose. From the data of Table 1, the relative changes in the works of adhesion of water $\eta(\text{H}_2\text{O}) = \Delta\gamma_{SL}^{\text{H}_2\text{O}} / \gamma_{SL}^{\text{H}_2\text{O}}$ and tetradecane $\eta(\text{C}_{14}\text{H}_{30}) = \Delta\gamma_{SL}^{\text{C}_{14}\text{H}_{30}} / \gamma_{SL}^{\text{C}_{14}\text{H}_{30}}$, as well as the relative changes in the dispersion and polar components of the surface energy ($\eta_s^{\text{dis}} = \Delta\gamma_s^{\text{dis}} / \gamma_s^{\text{dis}}$ and $\eta_s^{\text{pol}} = \Delta\gamma_s^{\text{pol}} / \gamma_s^{\text{pol}}$) at doses of 100, 200, and 500 kGy were calculated (Table 2).

It is seen from Table 2 that the changes in the work of adhesion of water $\eta(\text{H}_2\text{O})$ for F4PN, F4, and F4RM are very high and are 19, 45.5, and 47% at a dose of 500 kGy, respectively. For tetradecane, these changes are less: 3.7, 3.9, and 3.0%. The changes in the polar component of the surface energy of PTFE are still more dramatic: at a dose of 500 kGy η_s^{pol} increases

about 4.5-fold for the unsintered F4PN and 20- and 12-fold for the sintered F4 and F4RM samples, respectively. The dispersion component η_s^{dis} changes within due limits: by 6–8%.

In [6], the authors considered a possible relationship between such considerable changes in the work of adhesion of water to the irradiated PTFE surface and the radiation-dielectric effect (RDE) which is quite specific in nature and caused according to [11, 12] by the formation of long-living electron-hole pairs. The experimental data confirmed the presence of a correlation in the behavior of the dielectric increment $\Delta\epsilon$ and the surface characteristics $\gamma_{SL}^{\text{H}_2\text{O}}$ and γ_s^{pol} . The increase in the absorbed radiation dose, as well as annealing of the samples after irradiation resulting, respectively, in a dramatic increase and a dramatic decrease in $\Delta\epsilon$ were accompanied by symbate changes in $\gamma_{SL}^{\text{H}_2\text{O}}$ and γ_s^{pol} [6].

In the Lifshitz model, the changes in the dielectric permittivity are directly related to the Hamaker constant. Therefore, the qualitative analysis of its changes for the PTFE–water and PTFE–tetradecane systems is interesting in terms of the mechanism of correlation between the RDE and the surface properties.

Taking into account Eq. (4), we calculated the relative changes in the Hamaker constants as a function of the difference between the dielectric permittivities of PTFE prior to and after irradiation for the PTFE–water and PTFE–tetradecane contact surfaces (Fig. 1). Values of the static dielectric permittivity for the sintered suspension-polymerized PTFE at different absorbed doses obtained in [6, 13] were used in calculations.

As Fig. 1 shows, the studied dependences have the shape of curves approaching a plateau. The maximum change in the Hamaker constant does not exceed 6% for PTFE–water and 2% for PTFE–tetradecane at an arbitrarily high increase in the static dielectric permittivity (Fig. 1). This means that the experimental relative changes in the work of adhesion of water $\eta(\text{H}_2\text{O})$ to the irradiated PTFE surface are considerably higher than the relative changes in the Hamaker constant in the Lifshitz model. For the dispersion liquid, the experimental $\eta(\text{C}_{14}\text{H}_{30})$ and calculated $\Delta A/A$ values for the sintered PTFE have the same order of magnitude.

The increase in the density of PTFE upon irradiation can be an additional factor for an increase in the energy of intermolecular interactions. It is known [6] that, at a dose of 500 kGy, the density of F4 and F4RM increases from 2.148 to 2.225 g/cm³ (3.6%) and from 2.190 to 2.203 g/cm³ (0.6%), respectively.

The dependence of the relative changes in the Hamaker constant on the density calculated using Eq. (10) is close to linear. Therefore, the changes for each of the absorbed doses are equal with good accuracy to the corresponding change in density $\Delta\rho/\rho$.

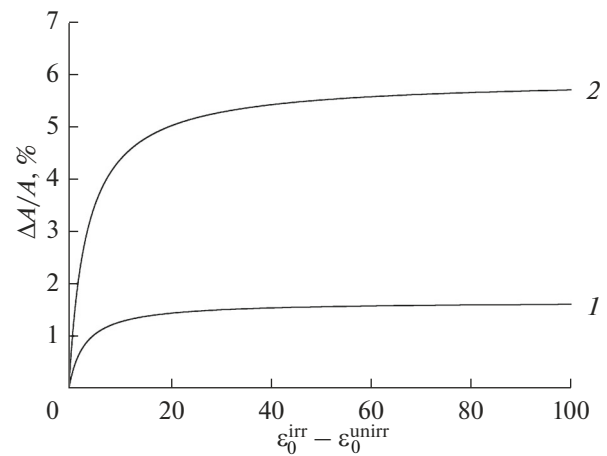


Fig. 1. Relative changes in the Hamaker constant as a function of the difference between the dielectric permittivities of PTFE prior to and after irradiation for the PTFE–tetradecane (1) and PTFE–water (2) contact surfaces.

Table 3 summarizes the calculated relative changes in the Hamaker constant and those obtained using Eqs. (4) and (10), taking into account the RDE and the density changes at different absorbed doses.

It is seen from Table 3 that the total changes in the energy of intermolecular interactions $\eta_{\text{e,p}}^{\text{dis}}(\text{H}_2\text{O})$ at the PTFE–water interface at the highest dose of 500 kGy are 0.01, 9.20, and 6.37% for F4PN, F4, and F4RM, respectively. Under the same conditions, the experimental $\eta(\text{H}_2\text{O})$ values are considerably higher: 19, 45.5, and 47% (Table 2). Consequently, the increase in $\eta(\text{H}_2\text{O})$ cannot be explained by enhancement of the dispersion interaction at the PTFE–water interface despite a considerable increase in the dielectric increment upon irradiation (by more than three orders of magnitude).

Conversely, the closeness of the calculated $\eta_{\text{e,p}}^{\text{dis}}(\text{C}_{14}\text{H}_{30})$ and experimental $\eta(\text{C}_{14}\text{H}_{30})$ values (Tables 2 and 3) for the dispersion liquid at the interfaces of the sintered F4 and F4RM samples allow their assignment to an increase in the energy of the dispersion interaction. An exception is the unsintered F4PN for which the $\eta_{\text{e,p}}^{\text{dis}}(\text{C}_{14}\text{H}_{30})$ values remain close to zero throughout the range of absorbed doses (Table 3), while the experimental $\eta(\text{C}_{14}\text{H}_{30})$ values vary in the range of 2.8–3.7% (Table 2). This fact suggests the existence of an additional contribution to the work of adhesion and dispersion interaction at the F4PN–tetradecane interface.

Electric polarization in irradiated PTFE is known [11–13] to be determined by the kinetic mobility of holes in the field of immobile (localized) electrons. A part of the mobile holes near the PTFE surface which escaped from the Coulomb interaction area as a result

Table 3. Relative changes (%) in the dispersion (η^{dis}) component of the work of adhesion for water and tetradecane calculated using the Lifshitz model at different radiation doses

Sample	$\eta_{\epsilon}^{\text{dis}}(\text{H}_2\text{O})$	$\eta_{\epsilon}^{\text{dis}}(\text{C}_{14}\text{H}_{30})$	η_{ρ}^{dis}	$\eta_{\epsilon,\rho}^{\text{dis}}(\text{H}_2\text{O})^1)$	$\eta_{\epsilon,\rho}^{\text{dis}}(\text{C}_{14}\text{H}_{30})^2)$
F4PN-100	0	0	0	0	0
-200	0	0	0	0	0
-500	0.010	0.003	~0	0.010	0.003
F4-100	5.43	1.53	2.7	8.13	4.23
-200	5.65	1.60	3.0	8.65	4.60
-500	5.70	1.60	3.5	9.20	5.10
F4RM-100	5.50	1.60	0.3	5.80	1.90
-200	5.70	1.60	0.4	6.10	2.00
-500	5.77	1.60	0.6	6.37	2.20

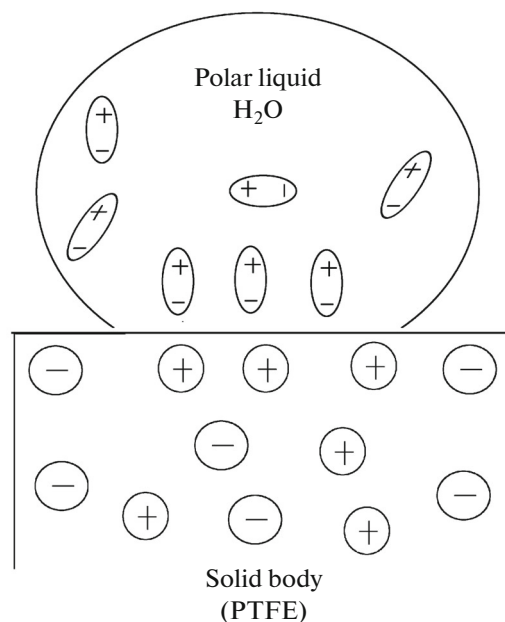
$$1) \eta_{\epsilon,\rho}^{\text{dis}}(\text{H}_2\text{O}) = \eta_{\epsilon}^{\text{dis}}(\text{H}_2\text{O}) + \eta_{\rho}^{\text{dis}}; \quad 2) \eta_{\epsilon,\rho}^{\text{dis}}(\text{C}_{14}\text{H}_{30}) = \eta_{\epsilon}^{\text{dis}}(\text{C}_{14}\text{H}_{30}) + \eta_{\rho}^{\text{dis}}.$$

of interaction with water dipoles can have an orienting influence on them and thereby can form a double electrostatic layer (Fig. 2). The energy of the ion-dipole interaction is about three orders of magnitude higher than that of the dipole-dipole interaction [7]. Therefore, upon implementation of the ion-dipole mechanism one should expect quite a dramatic increase in the work of adhesion of the polar liquid, which likely occurs at the interfaces of the irradiated, sintered F4 and F4RM samples. This mechanism allows one to explain the correlation between the dependences of the dielectric increment $\Delta\epsilon$ and the surface characteristics $\gamma_{SL}^{\text{H}_2\text{O}}$ and γ_S^{pol} by the fact that the bulk dielectric and surface characteristics are related to the same parameter: the concentration of stabilized electron-hole pairs. The accumulation of charged particles upon irradiation, as well as their recombination upon annealing lead to a correlated change in the parameters $\Delta\epsilon$, $\gamma_{SL}^{\text{H}_2\text{O}}$, and γ_S^{pol} .

The formation of charged particles (and neutral products) upon the irradiation of polymers, in particular, PTFE, is structurally dependent. The X-ray crystallinity is about 90–95% for the unsintered F4PN samples and significantly lower (65–70%) for the sintered F4 and F4RM samples. The increase in the crystallinity leads to a decrease in both the yield of neutral products and stabilized charges. According to [6], the $\Delta\epsilon$ change in unsintered F4PN upon irradiation is by four orders of magnitude lower than that in F4 and F4RM due to a decrease in the concentration of bound electron-hole pairs. Therefore, the calculated $\eta_{\epsilon,\rho}^{\text{dis}}(\text{H}_2\text{O})$ and $\eta_{\epsilon,\rho}^{\text{dis}}(\text{C}_{14}\text{H}_{30})$ values for F4PN and, correspondingly, the relative changes in the Hamaker constants are negligible compared to those for F4 and F4RM. At the same time, as judged by the change in $\eta(\text{H}_2\text{O})$ the contribution of the ion-dipole interaction to the work of adhesion of the polar liquid at the F4PN–water interface remains quite high, although it

decreases 2–3-fold compared to the sintered F4 and F4RM samples.

In the case of the dispersion liquid, the experimental increase in the work of adhesion $\eta(\text{C}_{14}\text{H}_{30})$ of the unsintered F4PN (at a level of 2.8–3.7%, Table 2) is likely due to an increase in the energy of the dispersion interaction at the F4PN–tetradecane interface due to neutral (uncharged) radiolysis products. At the surface of the unsintered samples, the concentration of such products (carbonyl, acid fluoride, and carboxyl ones) will be higher than that for sintered F4 and F4RM,

**Fig. 2.** Scheme for the formation of a double electrostatic layer at the PTFE–water interface due to the ion-dipole interaction between mobile charge carriers (holes) in the irradiated PTFE and dipoles of the polar liquid (water).

since the F4PN samples were obtained by preliminary irradiation of unsintered powder particles [6]. The powder particles have a more developed surface compared to block samples. Therefore, the bulk concentration of radiolysis products in a pressed plate made of them will be higher than that for the F4 and F4RM samples irradiated as blocks. The formation of radiolysis products in bulk is limited by oxygen diffusion. Thus, one can assume that the concentration of radiolysis products for the F4PN samples obtained by compression of the irradiated powder is sufficient for the observed slight changes in the work of adhesion $\eta(C_{14}H_{30})$, but is very low to effect the dielectric characteristics and the relative change in the Hamaker constant $\eta_{e,p}^{dis}(C_{14}H_{30})$. A more detailed analysis of the possible effect of radiolysis products on the dielectric behavior of PTFE was performed in [6].

CONCLUSIONS

The qualitative analysis of relative changes in the Hamaker constant at the PTFE–water and PTFE–tetradecan interfaces as a function of the PTFE gamma-irradiation dose shows that changes in the surface energy and the work of adhesion of polar and dispersion liquids are caused by different mechanisms. The main contribution to the change in the polar component of the surface energy γ_S^{pol} of PTFE irradiated in the presence of molecular oxygen is made by stabilized electron-hole pairs. The increase in the work of adhesion of the polar liquid $\gamma_{SL}^{H_2O}$ is due to the emergence of a double electrostatic layer resulting from the ion-dipole interaction between positive charges (holes) and dipoles of the polar liquid.

The change in the nonpolar component of the surface energy γ_S^{dis} of irradiated PTFE is due to an increase in the dielectric increment $\Delta\epsilon$ and the density of the polymer matrix in the case of sintered samples

and due to an increase in the concentration of neutral radiolysis products in the case of unsintered samples. A slight increase in the work of adhesion of the nonpolar liquid $\gamma_{SL}^{C_{14}H_{30}}$ in all cases is due to an increase in the energy of dispersion interaction at the PTFE–nonpolar liquid interface.

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