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INFLUENCE of γ-IRRADIATION ON PROPERTIES OF COMPOSITE STRUCTURE UHMWPE+α-SiO_2

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Abstract: UHMWPE/SiO_2 composites have been obtained from a homogeneous mixture of ultra-high-molecular-weight polyethylene (UHMWPE) and nanodisperse silica dioxide (α-SiO_2) powders by hot pressing method. Temperature dependence (20-170^{0}C) of their specific electrical conductivity σ_{dc} before and after γ-irradiation (D=200kGy), effect of absorbed dose on the value σ_{dc} (dose dependence), and also behavior of the function $\ln\sigma_{dc}=f(T)$ have been studied under heating-cooling conditions. It is shown that, the dependence $\ln\sigma_{dc}=f(T)$ in both cases has a complex character: there observed "breaks", associated with phase transitions. It has also been studied the frequency dependence (25-10^{6}Hz) of the real (M′) and imaginary (M″) parts of complex electric module. Analysis of these dependencies showed the relaxation character in nanocomposites UHMWPE+α-SiO_2 conditioned by interfacial polarization (Maxwell-Wagner effect) and that the dielectric properties of these composites and also their conductivity in high frequency range are determined by polymer matrix.

With increasing concentration of α-SiO_2 in the matrix there is observed a growth in the values ε' and ε'' (tgδ), and the dependence of these values on frequency corresponds to the exponential law.

Keywords: ultra-high-molecular-weight polyethylene (UHMWPE), composite UHMWPE+α-SiO_2, dielectric loss, dielectric permittivity, electrical conductivity, frequency, γ-irradiation, electric module.

1. Introduction

In recent years studies in the field of development of materials with special and practically important electrophysical properties based on polymer composites, containing metal nanoparticles and their oxides, have greatly expanded due to the use of such multi-functional materials in the development of new, more efficient electroactive elements of dielectronic devices. Despite the great advances, reached in this area, the ascertainment of interaction mechanisms between organic and inorganic phases in such nanocomposite systems remains an important and not fully studied question of developing new polymer composite materials (PCM), having a combination of various properties that allow using them in different applications [1,2].

In the past decade, ultra-high-molecular-weight polyethylene (UHMWPE) which belongs to a new generation of polymers are being used as a matrix by applying nanotechnology approaches modifying the base polymers with nanodisperse additives in order to improve the performance properties of PCM [3]. In this case it becomes possible to adjust the structure and properties of the materials in wide range due to nucleating and orientation effects, changes in conformation of macromolecules, their chemical binding to the surface of nanosize particles and "healing" of defects in the structure.

PCM have a number of promising electrophysical [4], electret [5] and optical [6] properties in applied approaching, that make them suitable for being used as base materials in development of new sensors, photovoltaic cells, various sensors, piezomaterials, etc. [7]. However, the expansion of practical application of PCM is limited by the lack of detailed information about adhesion between particles and matrix, and other possible interactions between phases, formation of boundary layer near the micro- and nanoparticles of the filler, charge carrier transport mechanism, role of the phase boundary, electron-ion and polarization processes in formation of their active properties.

It should be noted that, within the development of new PCM it is necessary to have information about temperature and frequency dispersion of the real (ε') and imaginary (ε'') parts of complex dielectric permittivity (ε), dielectric loss tangent (tgδ), conductivity on direct (σ_{dc}) and alternating (σ_{ac}) field and about the basic laws of structural relaxation within inclusion of micro- and nano filler into the polymer matrix [8]. Such kind of studies is attractive from the viewpoint of miniaturization of electronic cells and transition to technologies in molecular level. It is also known [9-11] that, one of the effective ways of modifying polyolefins is the application of ionizing radiation. Modification of composites by ionizing radiation is more universal. In this case it is possible both cumulative effect of modifying factors on polymers and their non-additive contribution. In this regard, the study of dielectric properties and electric conductivity of the composite system UHMWPE and nano-SiO_2 in a wide temperature and frequency range presents itself actual. Besides, the improvement of the properties of polymer nanocomposites is of interest in terms of expanding their application fields in micro- and nanodielectronics.

In order to search the opportunities to adjust the properties of composite materials on the base of nanoparticles of amorphous α-SiO_2 dioxide in UHMWPE matrix, in the work it has been studied the temperature dependence of their conductivity σ_{dc} before and after γ-irradiation, influence of adsorbed dose on the value σ_{dc} (dose dependence), as well as the behavior of the function $\lg\sigma_{dc}=f(T)$ under heating-cooling conditions and frequency dependence of the real (ε') and imaginary (ε'') parts of the complex dielectric permittivity, also dielectric dispersion of UHMWPE+α-SiO_2 nanocomposites obtained by hot pressing method using the concept of electric module.

2. Experimental

As a polymer matrix it has been chosen powdered ultra-high-molecular-weight polyethylene (UHMWPE) with an average molecular weight of $1,55\cdot10^6$g/mole, crystallinity degree of 65%, melting point of 190 ^oC and density of 940kg/m^3. Selection of UHMWPE as a matrix is due to the fact that, it has a unique set of physical and mechanical properties, high wear properties and impact strength, stability in harsh environments. As a filler it has been used an amorphous silica dioxide α-SiO_2 (Sky Spring Nanomaterials, Inc.Hauston, USA) with 20nm size of spherical particles, specific surface area of S=160m^2/g and density of 2,65g/sm^3.

While producing film samples it was used the following scheme of powder technology [12]:

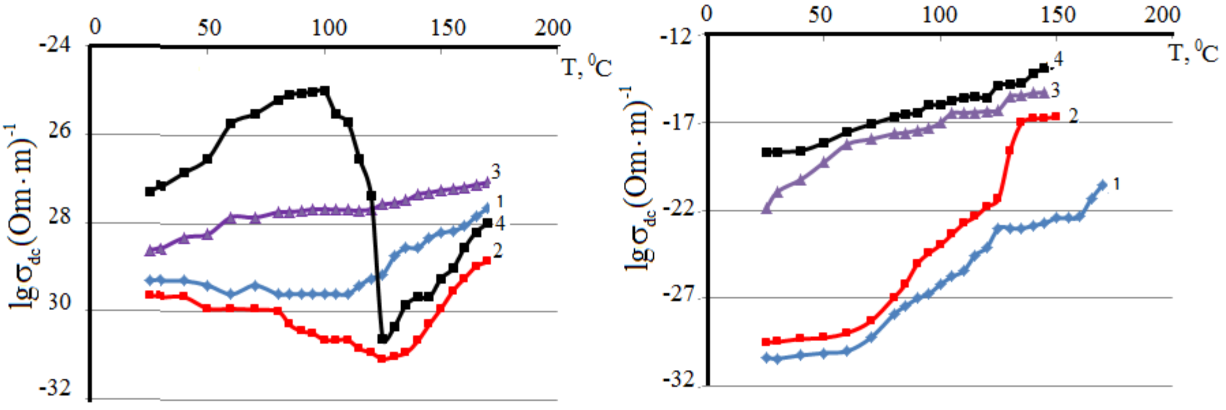
- mixing UHMWPE and α-SiO_2 powders in a porcelain mortar;
- pressing a homogenous mixture of powders of the components in hydraulic press with heated plates at the pressure of 15MPa at exposure 190^{o}C for 5 minutes and obtain of the composite samples in the form of discs with 20mm diameter and 80-100mkm thickness;
- pressing on both working surfaces of electrode samples of thin aluminum foil with 7mkm thickness with a subsequent cooling in ice-water mixture (quenching mode) for ensuring good electrical contact between sample and stainless steel electrodes.

The values ε' and tgδ were determined by two-electrode system within the frequency range from 25Hz to 10^6Hz and at voltage U=1V using a special shielded and grounded heated measuring cell of "sandwich" type having measuring system and potential electrodes with 15mm and 30mm diameters, respectively. The samples were placed in the measuring cell with clamping stainless steel electrodes. Measurement of capacitance C and tgδ of the samples was carried out by a broadband precision immitance meter of E7-20 type, and bulk resistance ρ_v by a teraohmmeter

E6-13A. Then, on the base of the measured values of the shown parameters and geometric dimensions of the samples it has been determined the values of the real ε' (ε' =C · d /ε_0 S, where S – the area of planar sample, d – density of the film, ε_0 – dielectric constant) and imaginary ε''(ε'' = ε' tgδ) parts of the complex dielectric permittivity by standard methods. Irradiation of the composite samples were carried out on γ-radiation ^{60}Co isotope source on the facility PX-γ-30. Radiation dose rate was -3,3·10^{3}Gy/h.

3. Results and discussion

The main results of the studies of temperature-frequency and dose dispersion of σ_{dc} conductivity, real and imaginary parts of complex dielectric permittivity of UHMWPE samples and composite materials based on it are depicted in fig.1-4. Figure 1 shows the dependence lnσ_{dc}=*f*(T) of composite materials based on UHMWPE on α-SiO_2 content before (a) and after (b) irradiation at dose of 200kGy. It is seen from figure that, by increasing the filler concentration to 5 vol.% the value of conductivity of nanocomposite samples increases by 5 orders. It can be assumed that, the increase in electric conductivity is due to the increase in the concentration of charge carrier.



a **b**

Fig.1. Temperature dependence of electrical conductivity of UHMWPE, containing 0(1), 1(2), 3(3), 5(4) α-SiO_2 microparticles before (a) and after (b) γ-irradiation at 200kGy

Type of dependence ln σ_{dc}=*f*(T) is complex, there are “breaks” associated with phase transitions. Conductivity of UHMWPE+α-SiO_2 system is greater than the base binder UHMWPE in all the studied temperature range. All samples have low conductivity ($\sigma \approx 10^{-13}$-10^{-9}Ohm^{-1}m^{-1}), characteristic for dielectrics. With increasing temperature the conductivity of UHMWPE and composite with a filler concentration of 1%vol. (curves 1,2) is somewhat reduced to the temperatures of 110 and 130°C, respectively (I region), reaches minimum and then increases to 170°C (II region). Within the insertion of -SiO_2 3%vol. nanoparticles with increasing temperature the conductivity of the composite (curve 3) increases by about an order till the end of temperature scale (170°C), and in the composite with a concentration of 5%vol. (curve 4) the conductivity strongly increases up to 100°C (I region), then decreasing sharply at the melting point (130°C) of the matrix crystallites reaches minimum (II region), after that increases again (III region). Above 135°C the course of the dependence lg σ_{dc} (10^3/T) is identical to the graphs of the samples of base UHMWPE and its composites with SiO_2 concentrations of 1 and 3%vol, respectively.

The effect of γ-radiation on electric conductivity of UHMWPE+α-SiO_2 system has been studied within the range of adsorbed dose up to 200kGy. The results of these studies are presented in fig.1b. The figure shows that, the temperature dependence of σ_{dc} conductivity of all samples undergoes major changes after influence of ionizing radiation, namely: 1) for pure UHMWPE (curve 1), unlike the non-irradiated samples, with a temperature increase σ_{dc} increases to 125°C, within the range (125-160°C) there is observed a "plateau", and after 160°C a slight increase; 2) with a temperature increase to 125°C the conductivity of the samples of UHMWPE+1%vol.α-SiO_2 composites (curve 2) increases and in the range (125-135°C) it sharply increases and then becomes stable; 3) temperature dependence of conductivity for the samples of UHMWPE+3%vol.α-SiO_2 composite (curve 3) remains unchanged after γ-irradiation, only the growth rate of σ_{dc} increases; 4) after γ-irradiation the region of sharp decay in conductivity of unirradiated UHMWPE+5%α-SiO_2 composite disappears in the range of 130°C, the conductivity of these samples gradually linearly increases till the end of temperature scale (curve 4). In all cases there is observed a general property-increase in conductivity with temperature increase.

Let's consider the possible reasons for the observed changes after γ-irradiation. It is known [7] that, within the accumulation of dose, firstly the radiation-chemical effects are becoming increasingly important (formation of radical and molecular products of radiolysis which leads to the change of energy distribution of traps due to appearance of radiation-generated traps), and then deep chemical conversions prevail in polymer (destruction, cross-linking, amorphization, gas emission, etc.) leading to the change in the nature of structurally modified layers of the polymer and enhancement of inconvertible dose effect.

In the irradiation process there also occurs the crystallite fracture (reduction of their size, increase of the efficient boundary surface), redistribution of traps in depth: decrease in density of interphase deep traps, but simultaneously the concentration of shallow electron traps, associated with carbonyl (C=O) groups (oxidation product) or with radiation-induced defects increases. Capture of charges, generated after γ-radiation occurs mainly at interphase boundaries of amorphous and crystal phases [9,11,15]. Carbonyl and various peroxide groups formed during γ-irradiation, provide small and interphase levels of capture lying at depths of up to 1eV. Within γ-irradiation the accumulation of the volume electric charge in UHMWPE correlates with the formation and accumulation of peroxide radicals which being electron acceptors determine the whole process of charge accumulation. Therefore, the majority of authors consider that, the dose effect, i.e. the impact of preliminary irradiation on electrical conductivity of the composites is due, most likely, to not change of the spectrum of molecular motions but to the accumulation of stabilized charge carriers in the irradiated material and to their irradiation effects [16].

Figure 2 shows the dependence of electrical conductivity on direct current on adsorbed dose (D) of γ-irradiation for UHMWPE (curve 1) and compositions based on it (curves 2-4).

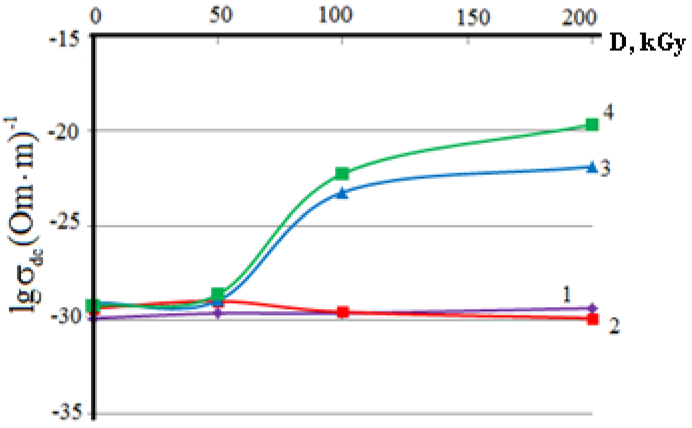


Fig.2. Dependence of electrical conductivity (σ) on irradiation dose (D) of UHMWPE+ α-SiO_2 composites: 1- pure UHMWPE; 2-1%; 3 - 3%; 4 - 5% α-SiO_2

As it is seen, increase in D up to 200 kGy practically does not influence on σ_{dc} of pure UHMWPE and films of UHMWPE+1%α-SiO_2 composite. We assume that, constancy of σ_{dc} of UHMWPE films and UHMWPE+1%α-SiO_2 composite with an increase in D in the studied range is due to the fact that, most of the electrons generated at each ionization event without going beyond the Coulomb field sphere of their ions recombine with them and cannot participate in conduction process. Within the transition from pure UHMWPE to the filled systems containing 3 and 5%vol. α-SiO_2 there is observed an increase in σ_{dc}. It should be noted that, the increase rate of σ_{dc} in UHMWPE+5%α-SiO_2 composite is more than in UHMWPE+3%α-SiO_2. Thus, these data show that, not the polymer but the filler is the donor of current carrier.

Figure 3 depicts the curves of temperature dependence of conductivity under heating-cooling in the coordinates of $\ln \sigma_{dc}=f(T)$ for UHMWPE+5% SiO_2. Curve 1 – forward (heating), 2 – reverse (cooling).

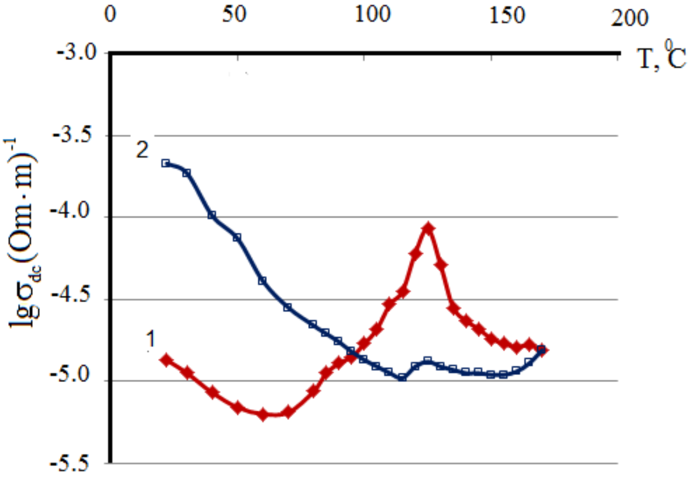


Fig.3. Temperature dependence of electrical conductivity for the sample of UHMWPE+5% α- SiO_2 composite under heating-cooling conditions

From the presented dependences it is seen that, the conductivity of reverse motion $\ln \sigma_{dc}=f(T)$ to 95°C is lower than the forward one, here the curves of forward and reverse motions intersect and the difference between the values of σ_{dc} intensifies: at T< 100°C the value of σ_{dc} for the same temperature is less at heating than at cooling of the sample.

According to [16], the behavior of $\sigma_{dc}(T)$ at heating-cooling can be explained in two ways: either by restructuring the structure of fractal chains near the melting point, or by the effects of “asymmetry” of temperature evolution of electrically active defects at heating and cooling. The lack of clearly defined hysteresis processes for the composite medium of UHMWPE+α-SiO_2 gives reason to believe that the main mechanism in our case is the “asymmetry” effect of temperature evolution of electrically active defects. The value of conductivity of the samples gets a new value in the result of heating-cooling, composite material turns into a new state with an increased conductivity that persists for some time (at least for ten days). Such behavior of UHMWPE+5% SiO_2 composites is, apparently, due to the thermally stimulated processes of charge redistribution on the boundary of nanoparticle – polymer matrix and percolation of slow relaxation processes.

On the other hand, according to the conclusions [17], such behavior of the dependence $\lg\sigma_{dc}=f(T)$ under heating-cooling can be explained by the fact that, solid particles of active nano-SiO_2 within cooling of UHMWPE melt contribute to conversing its crystalline part into more equilibrium, and amorphous (disordered) into less equilibrium state. In both cases it leads to stabilization of structure and properties of the polymer at γ-irradiation, but on different mechanisms. Structure and property of UHMWPE are determined by dispersion degree, nature and value of specific surface of silicon dioxide particles.

The study results of frequency dependences ε′ (a) and ε″ (b) of PCM based on UHMWPE with different volume contents of the filler α-SiO_2 (not represented as a separate figure), showed that, with increasing filler concentration to 5%vol. α-SiO_2 the real (ε′) and imaginary (ε″) parts of dielectric permittivity at the frequency of 10^2Hz increases by about 1,74 and 21,1 times, respectively, in comparison with the polymer matrix and within the frequency change of the external electric field from 10^2 to 10^6 Hz, the values ε′ and ε″ of the composites with volume content of filler to 1% slightly depends on frequency. With increasing concentration of the filler to 5%vol. the rate of change (decrease) of the value ε′ increases and in the case of UHMWPE+5%α-SiO_2 composite the value ε′ decreases by about 1,50 times, but the parameter $\Delta\varepsilon$ =(ε_c- ε_∞), where ε_c and ε_∞ - are low-frequency and high-frequency dielectric permittivity, respectively, describing the full width of dispersion, equals to 1,61. Absence of dielectric loss peak in frequency dependence of the studied composites indicates a weak relaxation polarization in these samples [15]. In the studied frequency range ε′ and ε″ of the base UHMWPE remains practically constant, within transition to composites, the functions ε′ (ν) and ε″ (ν)decrease to 10^4 Hz and 10^5Hz, respectively with frequency increase, and then the reduction rate is getting slow. In this case, with increasing α-SiO_2 concentration the reduction degree increases. In the case of UHMWPE+5%α-SiO_2 composite within the frequency range (10^2-10^3) Hz there is observed a “plateau”. Dielectric loss factor ε″ of UHMWPE+5%α-SiO_2 composite decreases by about 9 times with frequency increasing from 25 to 10^6 Hz.

In accordance with the obtained experimental results, the dielectric permittivity increases with increase of α-SiO_2 content in the base mixture and of measurement temperature. At the temperatures above 353K the real component of dielectric permittivity decreases (for UHMWPE+5% SiO_2 full width of dispersion from 293 to 353K is Δ ε′ =0,63). The observed character of the dependence indicates the existence of dielectric relaxation in these composites. However, dielectric loss peaks associated with this relaxation, are not detected. Growth in dielectric permittivity of the composites with increasing volume fraction of α-SiO_2 is consistent with our other experimental data on study of electrophysical properties of similar structures [18-19]. According to [1], a gradual increase in dielectric permittivity may be associated with the increase of segmental mobility of polymer molecules.

Earlier we have found out [19] that, in polymer – metal oxide composites there are dielectric relaxations, i.e. they can be polarized in the applied electric field. Dielectric relaxations are the results of voltages obtained by various polar segments of structure, formed in the result of partial thermal oxidation of polymer and after stabilization therein particles of nanodispersed fillers make a turn towards the applied alternating current. Existence of surface section in these structures causes interfacial polarization or Maxwell-Wagner effect, conditioned by charge accumulation on the surface of interface. Dielectric relaxation is observed in polymer composites at low frequencies and is the slowest of all manifested dielectric processes.

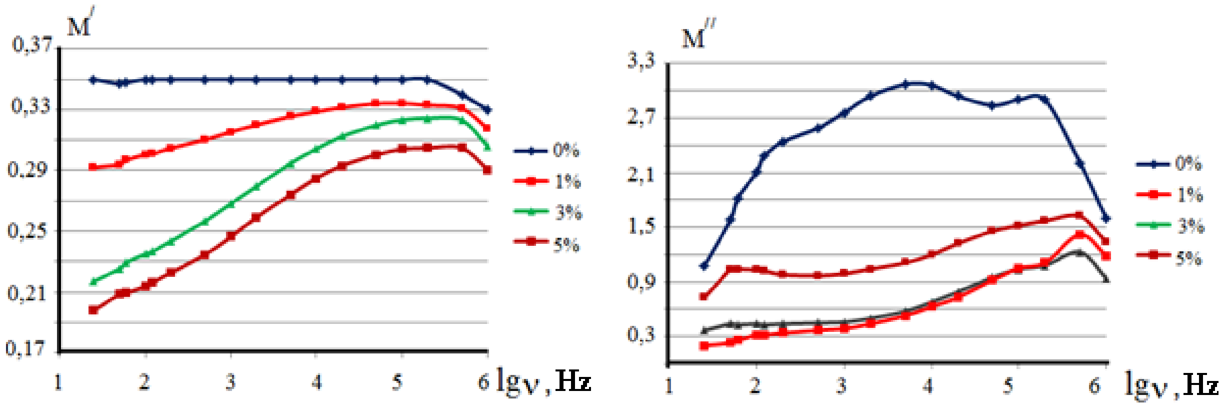
Analysis of behavior of the complex electric module was used for obtaining additional information and solution of usual difficulties associated with the influence of nature of electrodes, ohmic contact and effects of space charge injection which according to [20], “hide” relaxation in frequency dependence of real and imaginary parts of dielectric permittivity. Complex electric module M^* is determined by the equation

$$M^*=\frac{1}{\varepsilon}=\frac{1}{\varepsilon^{/}-j\varepsilon^{//}}=\frac{\varepsilon^{/}}{\varepsilon^{/2}+\varepsilon^{//2}}+\frac{\varepsilon^{//}}{\varepsilon^{/2}+\varepsilon^{//2}}=M^{/}+jM^{//},$$

Where M′ and M″ are the real and imaginary components of M^*, respectively.

In figures 4 and 5 it is shown the isothermal dependence of electric module components of the studied polymer structures on frequency. The obtained results show that, M′ and M″ are characterized by a small value in the range of initial measurement frequencies. With increasing frequency the behavior of dispersion charactetristics of M′ (*f*) corresponds to increasing function which is associated with the mobility of charge carrier within short distance.

Figure 4 shows that, with increasing frequency the value M′ of the composites increases and in dependence M′ (*f*) there is a broad peak in high frequencies, which is more notable in UHMWPE+3%SiO_2 and UHMWPE+5%SiO_2 samples. From figure it is also seen that, the real part of the electric module (M′) decreases with an increase in volume content of SiO_2 in the base mixture as a result of increase of the real part of the complex dielectric permittivity. For all the studied composite samples there is a transition from low values to high ones, which implies the relaxation process.



a **b**

Fig.4. Frequency dependence of the real (a) and imaginary (b) parts of the complex dielectric permittivity of the composite structure UHMWPE+ α-SiO_2

In the case of pure UHMWPE the value of M′ remains constant up to the frequency $2{\cdot}10^4$Hz, and then slightly decreases. On dispersion dependence M″ (*f*) of UHMWPE at low frequencies it is observed a relatively sharp increase in M″ up to the frequency $2{\cdot}10^3$Hz, and then such a sharp decline till the end of the frequency scale. The behavior of the functions M′ (*f*) and M″ (*f*) for composites are identical.

Figure 5a,b shows the functions M′ (*f*) and M″ (*f*) for composite structure UHMWPE+1%SiO_2 before (a) and after (b) γ-irradiation. It is evident that, after γ-irradiation at dose up to 200kGy there observed a decrease in the values M′ и M″.

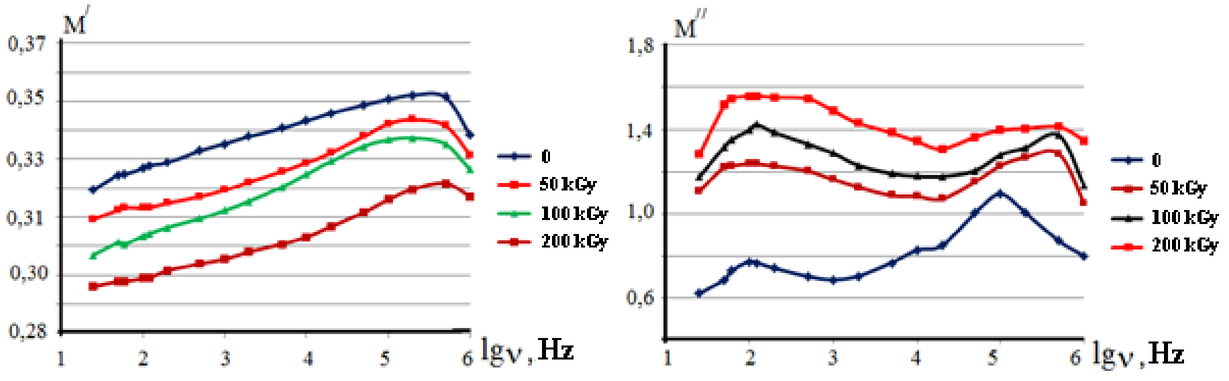


Fig.5. Frequency dependence of the real (a) and imaginary (b) parts of the complex dielectric permittivity of the composite structure UHMWPE+1%α-SiO_2 after γ - irradiation

The behavior of M′ (*f*) doesn't practically change after irradiation, but there occurs a slight decrease in the value $M^{/}$ at the frequency of 25Hz. As regards the behavior of M″ (*f*) it should be noted that, with increasing irradiation dose up to 200kGy the value M″ increases more than twice, and high-frequency maximum M″ shifts towards higher frequencies (from $1{\cdot}10^5$Hz to $5{\cdot}10^5$Hz). This behavior implies the slowest process- interfacial polarization, associated with the formation of surface charges by conduction electrons on interface boundaries, i.e. Maxwell-Wagner phenomenon, which is consistent with the theory [21] and our previous experimental results in similar structures [15,18].

It should be noted that, the presented experimental results don't allow to make a final conclusion on a particular electric conductivity mechanism in γ-modified composite materials yet. The issues relating to determination of transport and trapping mechanism of charge carrier depending on temperature, frequency and irradiation dose, requires further simulation studies.

4. Conclusions

1. It has been studied experimentally the temperature, frequency and dose dependencies of the properties of UHMWPE+α-SiO_2 nanocomposites and revealed the features of these relationships.
2. It is shown that, with increasing α-SiO_2 concentration in the matrix there occurs a decrease in ε′ and tgδ depending on frequency; it corresponds to the exponential law and is explained by the presence of a number of dipole elements which appear during addition of α-SiO_2 and obtain by thermal pressing method and material processing as a result of thermal oxidation and their ability to be guided by electric field.
3. It is established that, for UHMWPE composites with 5% concentration of α-SiO_2 at $T<100^0$C the value σ_{dc} is less at heating than at cooling for the same temperature.
4. The analysis of dependences $M^{/}$ (γ) and $M^{//}$(γ) showed that, the relaxation character in UHMWPE+α-SiO_2 nanocomposites is due to Maxwell-Wagner effect.

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ВЛИЯНИЕ γ-ОБЛУЧЕНИЯ НА СВОЙСТВА КОМПОЗИТНОЙ СТРУКУТРЫ СВМПЭ+α-SiO_2

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Резюме: Из гомогенной смеси порошков сверхвысокомолекулярного полиэтилена (СВМПЭ) и нанодисперсного диоксида кремния (α-SiO_2) методом горячего прессования получены композиты СВМПЭ/ SiO_2. Изучена температурная зависимость (20-170^{0}С) их удельной электропроводности σ_{dc} до и после γ-облучения (D=200кГр), влияние поглощенной дозы на значение σ_{dc} (дозовая зависимость), а также поведение функции lnσ_{dc}=f(T) в условиях нагрев-охлаждение. Показано, что зависимость lnσ_{dc}=f(T) в обоих случаях имеет сложный характер: наблюдается «изломы», связанные с фазовыми переходами. Изучены также частотные зависимости (25-10^{6}Гц) вещественной (M′) и мнимой (M″) частей комплексного электрического модуля. Анализ этих зависимостей показал релаксационный характер в нанокомпозитах СВМПЭ+α-SiO_2 обусловленный межфазной поляризацией (эффект Максвелла-Вагнера) и то, что в высокочастотном диапазоне диэлектрические свойства этих композитов, как и их проводимость определяются полимерной матрицей. С увеличением концентрации α-SiO_2 в матрице наблюдается рост значений ε′ и ε″ (tgδ), а зависимости этих величин от частоты отвечает экспоненциальному закону.

Ключевые слова: сверхвысокомолекулярный полиэтилен (СВМПЭ), композит СВМПЭ+α-SiO_2, диэлектрические потери, диэлектрическая проницаемость, электропроводность, частота, γ-облучение, электрический модуль.

γ - ŞÜALANMANIN İYMPE+α-SIO₂ KOMPOZİT BİRLƏŞMƏSİNİN XÜSUSİYYƏTLƏRİNƏ TƏSİRİ

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Xülasə: İfrat yüksək molekullu polietilen (İYMPE) və nano dispers silisium dioksid (α-SiO_2) tozlarının homogen qarışığından isti presləmə üsulu ilə İYMPE+α-SiO_2 kompozitləri alınmışdır. γ - şüalanmadan əvvəl və şüalanmadan sonra (D-200kQr) onların σ_{dc} xüsusi elektrik keçiriciliyinin temperatur asılılığı (20-170^{0}C), σ_{dc}-nın qiymətinə udulma dozasının təsiri (doza asılılığı), həmçinin qızma-soyuma şəraitində lgσ_{dc}=f(T) funksiyasının gedişi öyrənilmişdir. Göstərilmişdir ki, iki halda lgσ_{dc}=f(T) asılılığı mürəkkəb xarakterə malikdir: faza keçidləri ilə bağlı olan “sınmalar” müşahidə olunur, həmçinin kompleks elektrik modulunun həqiqi M′ və xəyali M″ hissələrinin tezlik (25-10^{6}Hs) asılılıqları öyrənilmişdir. Bu asılılıqların analizi İYMPE+α-SiO_2 kompozitlərində fazalararası polyarizasiya (Maksvell-Vaqner effekti) ilə şərtlənən relaksasiya xarakterini və yüksək tezliklər diapazonunda bu kompozitlərin onların keçiriciliyi kimi dielektrik xassələrinin də polimer matrisa ilə müəyyən olunduğunu göstərdi. Matrisada α-SiO_2-nin konsentrasiyasının artması ilə ε′ və ε″(tgδ)-nin qiymətlərinin artması müşahidə olunur, bu kəmiyyətlərin tezlikdən asılılıqları eksponensial qanuna cavab olur.

Açar sözlər: ifrat yüksək molekullu polietilen (İYMPE), İYMPE+α-SiO_2 kompoziti, dielektrik itkisi, dielektrik nüfuzluğu, elektrik keçiriciliyi, tezlik, γ-şüalanma, elektrik modulu.