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EFFECT OF GAMMA RADIATION ON THE ELECTROPHYSICAL PROPERTIES OF COMPOSITES BASED ON EPOXY-DIANE OLIGOMER AND ALUMINIUM HYDROXIDE

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Abstract: In this research, composite samples consisting of epoxy-diane oligomer ED-20 and 5–30 vol% aluminium hydroxide were prepared, and the effect of gamma radiation on their electrophysical properties was investigated. The real part of the dielectric permittivity and electrical conductivity of ED-20 and ED-20/ω$Al(OH)_3$ composites were studied at 303 K over the frequency range of 25 to 10^6 Hz, both before gamma irradiation and after exposure to absorbed doses of 50 to 800 kGy. For the composite samples, the frequency dependence shows a decrease in the real part of the dielectric permittivity (ε′) and an increase in electrical conductivity with increasing frequency. The high ε' value of the initial ED-20 and ED-20/ω$Al(OH)_3$ composite samples in the low-frequency region may be related to Maxwell-Wagner polarization at the interphase boundary formed in heterogeneous structures. The decrease in ε′ at high frequencies is caused by the rapid change of the electric field, causing a distortion of the orientation of the dipoles. The low values of conductivity (σ_{ac}) in the low-frequency region are attributed to interfacial polarization. At a certain critical frequency ($\nu_{c.}$), the real part of the conductivity follows the power law $\sigma_{ac}(\nu) \sim f^S$. For all samples, the exponent satisfies the condition $0 < s = 0.14–0.38 < 1$, indicating that σ_{ac} is governed by a hopping conduction mechanism. The electrical properties of the composite samples can be adjusted by using gamma radiation (up to a dose of 800 kGy) and changing the amount of filler used.

Keywords: epoxy-dian oligomer, composites, aluminium hydroxide, gamma radiation, absorption dose, electrophysical properties.

1. Introduction

In recent years, polymer composite materials based on epoxy diane oligomers have been widely used in electrical engineering, mechanical engineering, the construction industry, and other fields. This is due to the wide range of technological, physico-mechanical, thermophysical, and physicochemical properties of these composites, as well as the availability of a relatively favourable raw material base for their synthesis [1, 2, 3, 4]. Epoxy oligomers are used as binders in the production of various chemically resistant coatings, polymer solutions, and polymer concretes reinforced with coal, basalt, and glass fibres for the repair and reinforcement of building structures. Recently, stringent fire resistance requirements have been imposed on polymer materials used across various industrial sectors—including civil equipment, industrial facilities, and medicine—because polymers are generally flammable due to their organic chemical structure [5, 6, 7].

With the emergence of environmentally friendly flame retardants, some brominated flame retardants are being replaced by halogen-free alternatives, particularly magnesium hydroxide and aluminium hydroxide. These hydroxide flame retardants are among the most popular, safe, halogen-free, and smoke-suppressing flame retardants available. Other advantages include their low cost, absence of heavy metal contaminants (e.g., antimony oxide), and lack of toxic fume emissions. For fire-resistant epoxy materials, silicon dioxide, aluminium oxide, aluminium hydroxide, and magnesium hydroxide are commonly used. Both aluminium hydroxide and magnesium hydroxide are environmentally friendly inorganic flame retardants. When aluminium hydroxide is heated to 235 °C and magnesium hydroxide to 325 °C, water molecules are released, creating a cooling effect and eliminating smoke. The aluminium oxide and magnesium oxide formed during this process create a dense oxide layer that coats other materials, isolating them from oxygen. Aluminium hydroxide is less expensive than aluminium oxide. The effectiveness of hydroxides is directly proportional to their content in the polymer. [6, 8, 9].

It is known that in epoxy resins with a globular supramolecular structure, the epoxy ring opens under radiation exposure, leading to either recombination or destructive reactions. It is believed that the recombination reactions result from radicals formed at the central atom of units containing di- or methyl groups. Epoxy groups do not participate in the recombination reactions because they are hydrated by hydrogen atoms during irradiation. At certain doses, radiation can enhance the physical and mechanical properties of composite materials containing epoxy oligomers [10].

The aim of this work is to develop new environmentally safe, fire-resistant ED-20/ω$Al(OH)_3$ composite samples consisting of epoxy-diane resin (ED-20) and micro-sized aluminium hydroxide ($Al(OH)_3$) particles as a flame retardant and to investigate the effect of gamma radiation on their electrophysical properties (ε′ and σ).

2. Experiments

In the study, ED-20/ω$Al(OH)_3$ composite samples with varying filler content were prepared from epoxy-diane resin (ED-20) and micro-sized (200 μm) $Al(OH)_3$ particles as a flame retardant. The effect of gamma radiation on their electrophysical properties—the real part of the dielectric permittivity (ε′) and electrical conductivity (σ)—was investigated. The polymer was prepared from a liquid homogeneous mixture consisting of ED-20 epoxy-diane resin (GOST 10587-84), hardener - methyltetrahydrophthalic anhydride (MTHFA) (TU 38.103149-85), accelerator - UP-606/2 (TU 6-00209817.035-96), and plasticizer - Laprol 503 (TU 2226-009-10488057-94), all taken in stoichiometric amounts within the epoxy matrix. To prepare the test samples, micro-sized aluminium hydroxide powder of the AH-20 brand (CAS 21645-51-2, China) was separately introduced into the epoxy matrix at a temperature of 323–333 K in specified amounts (ω = 5, 10, 20, and 30 vol%) and mixed until a homogeneous system was obtained. The resulting liquid mixtures were poured into metal molds, and composite samples with a diameter of 54 mm and thickness of 900–1000 μm were cured in a SNOL-type muffle furnace using a stepwise heating mode at temperatures ranging from 353 to 453 K.

The frequency and dose dependencies of the electrophysical parameters of the studied composites were determined based on the relationships $\varepsilon' = f(\lg\nu)$, $\lg\sigma = f(\lg\nu)$, and $\varepsilon' = f(D)$, $\lg\sigma = f(D)$ before and after γ-irradiation. Capacitance (C) and active resistance (R) were measured using an alternating current with a measurement voltage amplitude of 1 V over the frequency range of $25–10^6$ Hz at 303 K. Measurements were performed in a two-electrode system using a broadband immittance meter (RLC) E7-20, equipped with a specially shielded, grounded, and heated "Sandwich"-type measuring cage. Based on the measured values of capacitance (C), active resistance (R), and the geometric dimensions of the samples, the real part of the dielectric permittivity (ε′) and electrical conductivity were calculated using standard methods.

ED-20/ωAl(OH)$_3$ composites were irradiated with γ-rays at room temperature using an MRX-γ-25 device equipped with a ^{60}Co radiation source to absorbed doses ranging from 50 to 800 kGy. The absorbed dose rate was 1.45 Gy/s.

3. Results and discussion

Figure 1 shows the frequency dependence of the real part of the dielectric permittivity (ε' = *f*(lgν)) for the initial ED-20 and ED-20/ωAl(OH)$_3$ composite samples at a temperature of 303 K over the frequency range of 25 to 10^6 Hz. The Al(OH)$_3$ filler content in the ED-20/ωAl(OH)$_3$ composite samples was ω = 5, 10, 20, and 30 vol%.

As shown in the figure, the ε'=*f*(lgν) dependencies for all samples exhibit a similar trend, with a linear decrease in ε′ values observed over the frequency range of (25 ÷ 5 × 10^5) Hz. In the frequency range of 5 × 10^5 ÷ 10^6 Hz, the ε′ values increase slightly. At low frequency (ν = 25 Hz), the ε′ values of the original ED-20 and ED-20/ωAl(OH)$_3$ composites vary differently. Thus, compared to the ED-20 composite (ε′ = 9.57), a decrease in dielectric permittivity is observed in the ED-20/5vol%Al(OH)$_3$ sample (ε′ = 6.84), while an increase is noted in composites with filler contents ω = 30 vol% (ε' = 14.39), ω = 10 vol% (ε' = 15.23), ω = 20 vol% (ε' = 17.41). In the studied frequency range (25 ÷ 5 × 10^5 Hz), no peaks were observed in the ε' = *f*(lgν) dependence, indicating no significant changes in intermolecular mobility. No clear correlation was found between changes in ε′ values and the increase in Al(OH)$_3$ filler content in the ED-20/ωAl(OH)$_3$ composite samples. In our opinion, the polar groups formed during the preparation of ED-20/5vol%Al(OH)$_3$ and ED-20/30vol%Al(OH)$_3$ composite samples—due to the curing temperature and partial oxidation—are poorly oriented in an alternating electric field. [11, 12].

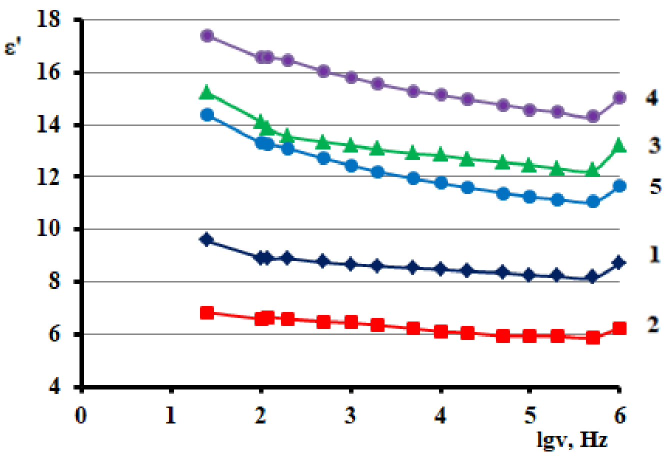

Fig. 1. Frequency dependence of the real part of the dielectric permittivity (ε'=f(lgν)) for the initial ED-20 (curve 1) and ED-20/ωAl(OH)$_3$ composite samples (curves 2–5) at T = 303 K. Al(OH)$_3$ filler contents: 2 – ω = 5 vol%; 3 – ω = 10 vol%; 4 – ω = 20 vol%; 5 – ω = 30 vol%.

The increase in ε′ values for the initial ED-20 (curve 1) and ED-20/ωAl(OH)$_3$ (curves 2–5) composite samples in the low-frequency region may be attributed to interfacial polarization (Maxwell-Wagner polarization). This phenomenon occurs in heterogeneous structures due to the accumulation of charges at the interface between the matrix and filler, which have different dielectric constants and permittivities [13]. The decrease in the value of ε' in the high-frequency region is attributed to the fact that the interphase polarization of the composites at high frequencies does not correspond to the applied electric field, i.e., at high frequencies the electric field changes so rapidly that polarization effects cannot manifest themselves. Furthermore, charges trapped at the interface between the composite sample and the electrodes create an additional capacitive element in the system, causing the ε′ values of all composite samples to decrease as the frequency of the applied electric field increases. [14].

Figure 2 shows the frequency dependence for the electrical conductivity (σ) of the initial ED-20 and ED-20/ωAl(OH)$_3$ composite samples on a double logarithmic scale (lgσ = *f*(lgν)) at a temperature of 303 K, over the frequency range of 25 to 10^6 Hz, with filler contents of ω = 5–30 vol%.

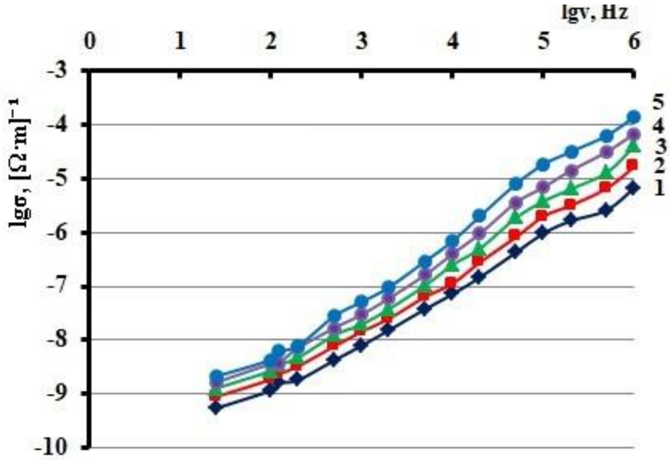

Fig. 2. Frequency dependences of logarithmic values of electrical conductivity of the initial ED-20 (1) and ED-20/ωAl(OH)$_3$ (2–5) composite samples lgσ = f(lgν), T = 303K; Al(OH)$_3$ content of the filler: 2 – ω = 5 vol%; 3 – ω = 10 vol%; 4 – ω = 20 vol%; 5 – ω = 30 vol%.

All lgσ = *f*(lgν) dependences exhibit a common behavior: electrical conductivity linearly increases with increasing frequency over the range of 25 to 10^6 Hz for filler contents of ω = 5–30 vol%. The electrical conductivity (σ) of the initial ED-20 composite (Fig. 2, curve 1) is lower than that of the ED-20/ωAl(OH)$_3$ composites, ranging from lg$\sigma_{1.4}$ = -9.26 to lgσ_6 = -5.17. The electrical conductivity values of the ED-20/ωAl(OH)$_3$ composites (Fig. 2, curves 2–5) increase with increasing filler content [14]. So, at ω = 5 vol% the range is (from lg$\sigma_{1.4}$ = -9.05 to lgσ_6 = -4.77), at ω = 10 vol% the range is (from lg$\sigma_{1.4}$ = -8.89 to lgσ_6 = -4.38), at ω = 20 vol% the range is (from lg$\sigma_{1.4}$ = -8.78 to lgσ_6 = -4.16) and at ω = 30 vol% the range is (from lg$\sigma_{1.4}$ = -8.67 to lgσ_6 = -3.84).

The decrease in conductivity (σ_{ac}) at low frequencies in an alternating current field is associated with interphase electronic polarization (Maxwell-Wagner polarization). This effect arises from the trapping of volume charges at the interphase boundary and the formation of polar substances due to partial oxidation during the thermal treatment in sample preparation. In this region, the applied voltage transports charge carriers over long distances within the sample, and σ_{ac} conductivity predominates. As the frequency increases, the average transport distance of charge carriers decreases. When the frequency reaches a certain critical value (ν_c), the real part of the electrical conductivity varies according to the power law $\sigma_{ac}(\nu) \sim f^S$, where *f* and *s* (0 < *s* < 1) are parameters that determine the mechanism of conductivity. [13, 14].

For the initial ED-20 composite, the range is 0.14< s <0.21; for the ED-20/5vol%Al(OH)$_3$ composite, it is 0.16 < s < 0.24; for the ED-10/10vol%Al(OH)$_3$ composite, it has the range of 0.17 < s < 0.34; for the ED-20/5vol%Al(OH)$_3$ composite, it exhibits the range of 0.18 < s < 0.35

and for the ED-20/30vol%Al(OH)$_3$ composite, it is 0.19 < s < 0.38; In all cases, the parameter *s* satisfies the condition 0 < *s* < 1, indicating a barrier-hopping mechanism of σ_{ac} conductivity—that is, electrons move via hopping transitions around the Fermi level [14].

Figure 3 shows the dose dependence ε′ = *f*(D) of the real part of the dielectric permittivity of initial ED-20, unirradiated D = 0, and for ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at absorbed doses ranging between D = 50–800 kGy, measured at T = 303 K and frequency ν = 1 kHz. Initial ED-20, unirradiated D = 0 and ED-20/ωAl(OH)$_3$ irradiated withγ-rays at absorbed doses of D = 50, 100, 200, 300, 400, 600 and 800 kGy.

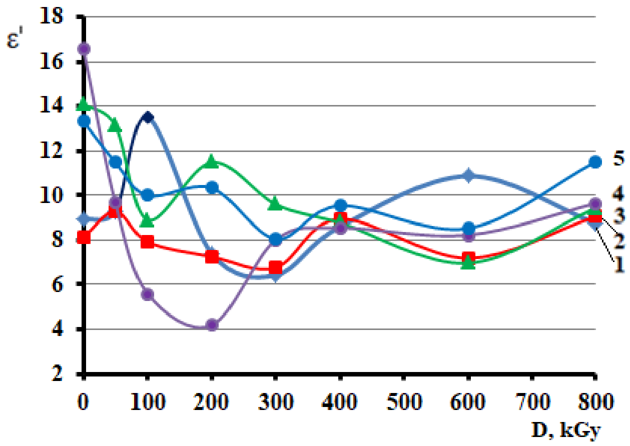

Fig. 3. Dose dependences of logarithmic values for electrical conductivity of initial ED-20 (1), unirradiated D = 0 and ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at D = 50–800 kGy absorbed doses ε′ = ƒ(D), T = 303K and ν = 1 kHz, Al(OH)$_3$ content of filler: 2 – ω = 5 vol%; 3 – ω = 10 vol%; 4 – ω = 20 vol%; 5 – ω = 30 vol%.

The values of ε′ in the ε′ = f(D) dependences of the composite samples are presented in Table 1. As can be seen, the ε′ values of the samples at D = 0 correspond to those presented in Table 1. As observed in Table 1, γ-radiation exhibits a distinct and individual effect on each composite sample.

Table 1

The ε' values of the real part of the dielectric permittivity for initial ED-20, unirradiated (D = 0) and ED-20/ωAl(OH)$_3$ composite samples measured at absorbed γ-ray doses ranging from 50 to 800 kGy.

Absorbed dose, kGy	**ε' values of the real part of the dielectric permittivity**				
	Amount of Al(OH)$_3$ filler, volume %				
	0	**5**	**10**	**20**	**30**
0	8.92	8.13	14.11	16.55	13.31
50	9.30	9.29	13.11	9.65	11.49
100	13.51	7.92	8.90	5.59	10.00
200	7.41	7.26	11.49	4.19	10.34
300	6.43	6.77	9.60	8.02	8.06
400	8.60	8.95	8.77	8.54	9.54
600	10.87	7.20	6.97	8.23	8.53
800	8.76	9.06	9.44	9.65	11.52

As can be seen from the ε' = f(D) dependences of the composite samples, ε' reaches a maximum value (ε'_{100} = 13.51) at an absorbed dose of 100 kGy for the irradiated ED-20 composite and a minimum value (ε'_{200} = 4.19) at an absorbed dose of 200 kGy for the ED-20/20vol%Al(OH)$_3$ composite. As is evident from the ε' = f(D) dependences, although the $\varepsilon'_{50\text{-}600}$ values of the composite samples at absorbed doses of D = 50–600 kGy are lower than the corresponding values of the unirradiated samples, they vary in the range of 8.76–11.52 at an absorbed dose of 800 kGy, i.e. they are in the range of the ε'_0 values of the samples. It should be noted that the ε'_{800} values of the composite samples at an absorbed dose of 800 kGy vary in accordance with the increasing filler content ω. The polar ED-20 oligomer and the ED-20/ωAl(OH)$_3$ composite samples (dielectrics) based on it undergo simultaneous destruction and recombination processes during radiolysis. The changing nature of the ε' = f(D) dependence indicates that from 50 kGy up to an absorbed dose of 300 kGy, destruction processes predominate in the epoxy matrix—such as breaking of the main molecular chain, formation of free radicals, oxidation in an oxygen environment, and separation of low-molecular-weight substances. However, with a further increase in dose, the recombination process becomes dominant, involving cross-linking between macromolecules due to radical recombination, leading to the formation of a three-dimensional network structure.

Fig. 4 shows the dose dependences lgσ = f(D) of the logarithmic values of the electrical conductivity of the initial ED-20, unirradiated D = 0, and the ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at D = 50-800 kGy absorbed doses.

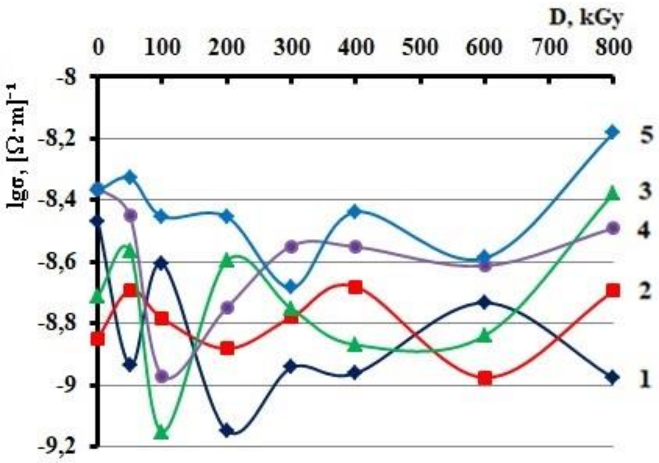

Fig. 4. Dose dependences of logarithmic values of electrical conductivity of initial ED-20 (1), unirradiated D = 0 and ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at D = 50–800 kGy absorbed doses, lgσ = f(D), T = 303K and ν = 1 kHz, Al(OH)$_3$ content of filler: 2 – ω=5 vol%; 3 – ω=10 vol%; 4 – ω=20 vol%; 5 – ω=30 vol%.

The lgσ values in the lgσ = f(D) dependences of the initial ED-20, unirradiated D = 0 and ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at D = 50, 100, 200, 300, 400, 600 and 800 kGy absorbed doses are shown in Table 2.

Table 2

lgσ values of the electrical conductivity of initial ED-20 unirradiated D = 0 and ED-20/ωAl(OH)$_3$ composite samples irradiated with γ-rays at D = (50–800) kGy absorbed doses.

Absorbed dose, kGy	**Logarithmic values of electrical conductivity, (Ω·m)$^{-1}$**				
	Amount of Al(OH)$_3$ filler, volume %				
	0	**5**	**10**	**20**	**30**
0	-8.47	-8.85	-8.71	-8.36	-8.37
50	-8.94	-8.69	-8.57	-8.45	-8.33
100	-8.61	-8.78	-9.15	-8.97	-8.45
200	-9.15	-8.88	-8.60	-8.75	-8.45
300	-8.94	-8.78	-8.75	-8.55	-8.68
400	-8.96	-8.68	-8.87	-8.55	-8.44
600	-8.73	-8.98	-8.84	-8.61	-8.59
800	-8.98	-8.70	-8.38	-8.49	-8.18

As can be seen from the electrical conductivity values of the composite samples given in Table 2, lgσ reaches a minimum at an absorbed dose of 100 kGy for the ED-20/10vol%Al(OH)$_3$ composite and at 200 kGy for the irradiated ED-20 composite (both having -9.15 (Ω·m)$^{-1}$). In contrast, the ED-20/30vol%Al(OH)$_3$ composite exhibits maximum conductivity values at absorbed doses of 50 kGy (lgσ = -8.33 (Ω·m)$^{-1}$) and 800 kGy (lgσ = -8.18 (Ω·m)$^{-1}$). The ED-20 composite exhibits lower dielectric permittivity within the absorbed dose range of 50 to 800 kGy. In ED-20/ωAl(OH)$_3$ composite samples, the values of electrical conductivity increase as the amount of filler increases (ω = 5→30vol%) in the dose range (50–800) kGy. At an absorbed dose of 800 kGy, the lgσ values of the composite samples change as follows: $lg\sigma_0$ <: $lg\sigma_{5\%}$ < $lg\sigma_{20\%}$ < $lg\sigma_{10\%}$ <: $lg\sigma_{30\%}$.

In general, the dose dependences of ε' = f(D) and $lg\sigma_{ac}$ = f(D) for the studied composite samples exhibit regions with both maximum and minimum values of these parameters. It is known that irradiation not only induces structural changes in the composite—such as recombination and branching of intramolecular chains—but also enhances the interaction between phases by influencing the filler [15]. Low-dose radiation primarily activates recombination processes, with some degree of destructive effects. High doses of γ-radiation cause an increase in the conductivity σ_{ac} due to the products of the destruction process occurring in the epoxy matrix.

The effect of radiation on the conductivity (σ_{ac}) in the composite (dose-dependent effect) is not caused by changes in the mobility spectrum of polymer molecules, but rather by the accumulation of stabilized charge carriers in the irradiated polymer, as well as by radical or molecular agents formed during radiolysis that act as trapping centers [16]. On the other hand, the annealing of radiation-chemical effects—the formation of molecular and radical products during radiolysis—is highly specific to each polymer, making the determination of its role a distinct task. Moreover, irreversible effects on radiation-induced conductivity can be expected since once the generated radicals in the irradiated polymer are completely consumed, changes in its chemical and supramolecular structure will occur. The complex dependence of the conductivity σ_{ac} on the absorbed γ-radiation dose arises from radiation-induced changes in the polymer's structure and molecular mobility. The mechanism of the effect of dose on the transport of charge carriers is associated with a change in the molecular relaxation spectrum. [17].

4. Results

For unirradiated ED-20/ωAl(OH)$_3$ composite samples, no correlation is observed between the decrease in the real part of the dielectric permittivity (ε') with increasing frequency and the amount of filler in the frequency dependences ε' = *f*(lgν). During the preparation of ED-20/5vol%Al(OH)$_3$ and ED-20/30vol%Al(OH)$_3$ composite samples, the polar groups formed as a result of the curing temperature and partial oxidation exhibit poor orientation in an alternating electric field.

The increase in electrical conductivity (σ) with rising frequency, as observed in the dependence lgσ = *f*(lgν), is influenced by the chemical nature and concentration of the amphoteric Al(OH)$_3$ filler. The decrease in conductivity (σ_{ac}) at low frequencies in an alternating current field is attributed to Maxwell-Wagner polarization. The σ_{ac} values increase proportionally with the amount of Al(OH)$_3$ filler in the composite samples. The nature of the variation in the dependence lgσ = *f*(lgν) is consistent and characteristic of hopping conduction.

The changes observed in the electrophysical properties of ED-20/ωAl(OH)$_3$ composites under gamma radiation are attributed to the predominance of destructive processes in the epoxy matrix—such as main molecular chain, free radical formation, oxidation in an oxygen environment, and the release of low-molecular-weight substances—at absorbed doses from 50 to 300 kGy. However, at higher doses, recombination processes dominate, involving cross-linking between macromolecules due to radical recombination, leading to the formation of a three-dimensional network structure. During radiolysis, Al(OH)$_3$ particles located at the interphase boundary between the ED-20 matrix and the filler enhance the polarity of the composites by acting as additional sources for charge carrier regeneration.

The electrophysical properties of the studied composite samples can be effectively tuned by varying the gamma radiation dose and the filler content, up to an absorbed dose of 800 kGy.

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ВЛИЯНИЕ ГАММА-ИЗЛУЧЕНИЯ НА ЭЛЕКТРОФИЗИЧЕСКИЕ СВОЙСТВА КОМПОЗИТОВ НА ОСНОВЕ ЭПОКСИДНО-ДИАНОВОГО ОЛИГОМЕРА И ГИДРОЦИДА АЛЮМИНИЯ

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Резюме: В ходе исследовательской работы были подготовлены образцы композитов, состоящих из эпоксидно-дианового олигомера ЭД-20 и (5–30) гидроксида алюминия в объемном процентном соотношении, изучено влияние гамма-излучения на их электрофизические свойства. Фактическая часть диэлектрического проникновения и электропроводность композитов ЭД-20 и ЭД-20/ωAl(OH)$_3$ исследована при температуре 303 К в диапазоне частот (25 ÷ 10^6) Гц, перед гамма-излучением и при дозах поглощения (50‒800) кГр. В частотных зависимостях для составных образцов наблюдается уменьшение действительной части диэлектрического проникновения (ε‘) с увеличением частоты, увеличение электропроводности. В низкочастотной области вязкость ε'-значения исходных композитных образцов ЭД-20 и ЭД-20/ωAl(OH)$_3$ может быть связана с поляризацией Максвелла-Вагнера на межфазной границе, возникающей в гетерогенных структурах. Снижение значения ε' в высокочастотной области быстрое изменение электрического поля на высоких частотах приводит к нарушению ориентации диполей. Получение малых значений проводимости в поле переменного тока низкой частоты (σ_{ac}) связан с межфазной поляризацией. Определение частоты C. фактическая часть электропроводности при ее критическом значении изменяется по закону $\sigma_{ac}(\nu) \sim f^S$, для всех образцов выполняется условие $0 < s = 0.14–0.38 < 1$, т. е. показывает скачкообразный механизм σ_{ac}-проводимости. Электрофизические свойства исследуемых композитных образцов можно регулировать с помощью гамма-лучей и количества наполнителя до дозы поглощения 800 кГр.

Ключевые слова: эпоксидно-диановый олигомер, композиты, гидроксид алюминия, гамма-излучение, доза поглощения, электрофизические свойства.

EPOKSİ-DİAN OLİQOMERİ VƏ ALÜMİNİUM HİDROKSİD ƏSASINDA KOMPOZİTLƏRİN ELEKTROFİZİKİ XÜSUSİYYƏTLƏRİNƏ QAMMA ŞÜALANMANIN TƏSİRİ

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Xülasə: Tədqiqat işində epoksi-dian oliqomeri ED-20 və (5‒30) həcm faizi miqdarında alüminium hidroksiddən ibarət kompozit nümunələri hazırlanmış, onların elektrofiziki xassələrinə qamma-şüalanmanın təsiri araşdırılmışdır. ED-20 və ED-20/ωAl(OH)$_3$ kompozitlərin dielektrik nüfuzluğunun həqiqi hissəsi və elektrik keçiriciliyi 303 K temperaturda (25 ÷ 10^6) Hz tezlik diapazonunda, qamma-şüalanmadan əvvəl və (50‒800) kQr udulma dozalarında tədqiq edilmişdir. Kompozit nümunələri üçün tezlik asılılıqlarında tezliyin artması ilə dielektrik nüfuzluğunun həqiqi hissəsinin (ε‘) azalması, elektrik keçiriciliyin artması müşahidə olunur. Aşağı tezlikli oblastında ilkin ED-20 və ED-20/ωAl(OH)$_3$ kompozit nümunələrinin ε' qiymətinin döyük olması heterogen strukturlarda yaranan fazalararası sərhəddə Maksvell-Vaqner polyarlaşması ilə əlaqəli ola bilər. Yuxarı tezlikli oblastında ε' qiymətinin azalması yüksək tezliklərdə elektrik sahəsinin sürətlə dəyişməsi, dipolların orientasiyasının pozulmasına səbəb olur. Aşağı tezlikdə dəyişən cərəyan sahəsində keçiriciliyin kiçik qiymətlər alması (σ_{ac}) fazalararası polyarlaşma ilə əlaqəlidir. Tezliyin müəyyən $\nu_{c.}$ kritik qiymətində elektrik keçiriciliyinin həqiqi hissəsi $\sigma_{ac}(\nu) \sim f^S$ qanunu ilə dəyişir, bütün nümunələr üçün $0 < s = 0.14–0.38 < 1$ şərti ödənilir, yəni, σ_{ac} keçiriciliyinin sıçrayışlı mexanizmini göstərir. Tədqiq olunan kompozit nümunələrin elektrofiziki xassələri 800 kQr udulma dozasına qədər qamma şüalar və doldurucunun miqdarı ilə tənzimlənə bilər.

Açar sözlər: epoksi-dian oliqomeri, kompozitlər, alüminium hidroksid, qamma-şüalanma, udulma dozasi, elektrofiziki xassələr.