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(RESEARCH ARTICLE)

Influence of organic additives on electret state of high pressure polyethylene

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Abstract

The paper presents the results of a study of the electret properties of *high-pressure polyethylene (hppe)* modified with organic additives as *phthalic-anhydride (pha)* and *orthophenylenediamine (ophd)*. Samples obtained and processed by extrusion on an industrial unit brand LRP-700m. Additives were introduced into HPPE by mechanical mixing. For polarization, the samples were placed on a grounded electrode and charged with a negative corona at a voltage of 7 kv. After polarization, the total surface charge of the samples was determined by the compensation method. The thermally stimulated current was recorded in the temperature range 290–520 K, provided that the heating increased linearly at a rate of 3.5 k / min. It is shown that after polarization of *hppe* composites modified with *pha* and *ophd* organic fillers, the depolarization process begins in connection with the resolution and release of trapped charge carriers from traps. After the complete destruction of the homo charges, the density of the surface charge of the *hppe* films and their optimal modification, reaching a certain value, in the future, depending on the duration of storage, does not change. It was also revealed that the introduction of the organic additive *pha* and *ophd* into *hppe* makes it possible to obtain an antistatic polymer material with improved technological and electrical properties.

Keywords: HPPE; Phthalic-Anhydride; Orthophenylenediamine; Additive; Thermostimulated depolarization; Electret Properties.

1. Introduction

Recently, interest in a new type of composite materials has grown significantly, in which the inclusion of a low molecular weight additive and nanoparticles in a polymer matrix leads to unusual electrophysical, electret, mechanical, and thermophysical properties. The properties of modified polymeric materials are largely determined by the compatibility and nature of the distribution of their components. The nature of the effect of additives on the supramolecular structure and physical properties of the polymer is due to the presence of both amorphous and crystalline phases. It is known that one of the main directions of the development of new electret materials based on composite materials is to give polyethylene high electret characteristics, which can be achieved by filling it with various fillers. The electret properties of polymer composite materials are widely used in electro-acoustic devices, in air-cleaning devices, in xerography, etc. [1-5]. The main characteristics of the electret material is the magnitude of the electric charge and its stability [6].

In light of the foregoing, in this paper we studied the effect of organic additives *pha* and *ophd* on the accumulation ability and stability of electric charges in *hppe* grade 10803-020 and their relationship with the electrical durability of the final polymer material.

2. Material and methods

In the feedstock of *hppe* by mechanical mixing were introduced *pha and ophd* in an amount of 0.1-0.5% (by weight). Processing of the developed *HPPE* modifications into films was carried out by extrusion on an industrial unit of the LRP-

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700M brand. Additives were introduced into *HPPE* by mechanical mixing. Before the introduction of the additive into *hppe*, they were dispersed using a sieve analysis on a device for determining the grain composition. In order to achieve a uniform distribution of *pha* and *ophd* additives in the composition of *hppe*, it was re-granulated again. Then, samples in the form of a disk 40 mm in diameter were cut from the films. The thickness of the samples was 50 μm. Before the experiment, the samples were thoroughly degreased. After that, they were placed on a grounded electrode and, at a voltage of 7 kv, charged with a negative corona 6×10^{-3} m from the surface of the sample. The choice of a negative crown is due to two circumstances:

Firstly, the negative corona is much less sensitive to the presence of water vapor than the ions formed with the positive corona. Secondly, the samples charged by the negative corona, when discharged, give a much higher current than when charged by the positive corona. In the case under consideration, the polarization time of the samples was 600 sec. immediately after polarization, the total surface charge of the samples was determined by the compensation method. In this case, the electrode on the surface of which the electret is applied is disconnected from the ground and a constant stabilized voltage is applied to it. The polarity of the applied voltage is chosen opposite to the polarity of the charge of the electret. By adjusting the magnitude of the applied voltage, the magnitude of the signal induced from the electret to the measuring electrode leads to zero. The surface charge density is calculated by the formula:

$$\sigma = \frac{\varepsilon\varepsilon_0 U_k}{d}$$

Where ε - *is the* dielectric constant of the polymer; ε_0 - electric constant; U_k – the value of the compensating voltage; *d* - is the thickness of the sample. After determining the charge of the samples, thermostimulated current (tsc) was recorded in them in the temperature range 293–523 k under the condition of a linear increase in heating at a rate of 3.5 k / min. When recording the tsd were used the U5-11 electrothermal amplifier and the H307 two-coordinate recorder. Determination of electrical durability of HPPE films and their modifications, i.e. the time after the application of the electric field to the breakdown of the sample at a given electric field strength was carried out according to the method described in [7].

3. Results and discussion

The paper presents experimental results on the study of the electret properties of *hppe* grade 1083-020 and its composition with additives *pha* and *ophd*. Analysis of the thermally stimulated depolarization current (tsd) depending on temperature (figure. 1) showed that *hppe* samples and its developed modifications, when exposed to a negative corona, accumulate charges and thereby acquire an electret state.

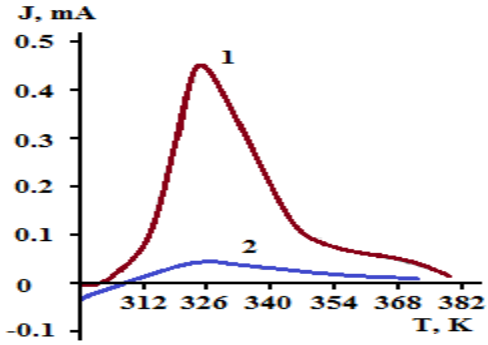

Figure 1 Current of thermally stimulated depolarization (tsd) of *hppe* films and its modifications charged with a negative corona: 1 - *hppe* (without additives); 2 - *hppe* + 0.05% *pha* + 0.05% *ophd* (by weight). Cooking mode U_k = 7 kV. J_k = 600 s. T = 293K.

As can be seen from the figure, ceteris paribus, the introduction of the optimal amount into *hppe* , i.e. 0.05% *pha* + 0.05% *ophd* (by mass) leads to a significant decrease (13.8 times) in the accumulation of surface charge calculated by the area of the tsd curve. The discovered effect of reducing the charge of *hppe* with the introduction of *pha* and *ophd* additives in

the optimal amount can be associated with the antistatic feature of the latter. This is also indicated by the fact that in the nature of the static electrification of polymeric materials and the mechanism of their charging in the field of the negative corona, it is basically the same and includes the injection of charge carriers on the surface layer of the polymer [8]. In polymers, various types of molecular relaxation processes are possible. At low temperatures, only local movements of molecular groups are possible, for example, rotation of side groups or internal movement in them. At high temperatures, mobility acquires main chain segments. In amorphous-crystalline polymers, relaxation processes occurring in the crystalline parts or in the interphase zone are possible.

The additives *pha* and *ophd,* possessing a fairly good technological compatibility with *hppe*, strongly prevent the formation of homo charges in them and, therefore, the conductivity current J due to thermal destruction of homo charges becomes insignificant. The contribution of the introduced additive to the process of charge accumulation at various depths of *hppe* films after their treatment with a negative corona is also quite clearly seen from the data on the dependence of the surface charge density on the storage duration (figure. 2).

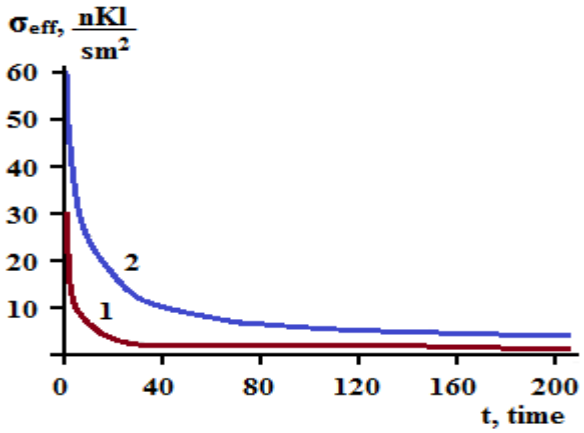

Figure 2 Dependence of the surface charge density on the storage duration of the electret from the films (by weight). 1 -pure *hppe*, 2 - optimally modified *hppe*.

From the data obtained it follows that after the polarization of *hppe* films and its optimal modification, the depolarization process begins, associated with the destruction and release of the captured charge carriers from traps located at different depths. At the same time, the initial value of the surface charge density (a) for an optimally modified *hppe* film (figure. 2, curve 2) becomes insignificant in comparison with the *hppe* film without additives (figure. 2, curve 1). After the complete destruction of the homo charges, the density of the surface charge of the *hppe* films and their optimal modification, reaching a certain value, in the future, depending on the duration of storage, does not change. However, in this case as well, the numerical value of the charge density of the optimally modified film turned out to be less than that of the *hppe* films without additives.

The ability of polymer materials to electrify and vice versa is closely related to their electrophysical properties. In strong electric fields, as a rule, the presence of surface and space charges in polymer dielectrics accelerates the breakdown process in them.

Comparison of the obtained experimental data showed that when the organic additives *pha* and *ophd* are added in *hppe* in the optimal amount, the minimum value of the charge accumulation density corresponds to the maximum value of the electrical durability of the electret. This essentially means that during the electrical destruction of polymer dielectrics, the degree of their electrical state plays one of the decisive roles.

Accumulated charges in polymer films on shallow and deep traps are the primary reason for the development of breakdown in strong electric fields. The use of *pha* and *ophd* additives, which are technologically compatible with *hppe* at its optimal content, strongly hinders the accumulation of charges in the final polymer material.

4. Conclusion

The results of the study indicate the possibility of using organic additives *pha* and *ophd* in *hppe* to obtain an antistatic polymer material with improved technological and electrical properties.

Compliance with ethical standards

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Disclosure of conflict of interest

We (Eldar Mekhraly Gojayev *, Sevinc Sarkar Osmanova, Shujayat Aman Zeynalov and Farhad Shamil Karimov) the authors of the article “Influence of organic additives on electret state of high pressure polyethylene” wish to state that there are no conflicts of interests in this our research article.

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