POLARIZATION PROCESSES AND ELECTRIC PROPERTIES IN POLYPROPYLENE / NANOCLAY COMPOSITIONS OF Na^+ MONTHMORILLONITE TYPE

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The work investigates the electret properties and the process of polarization of nanocomposites based on polypropylene (PP) and nanoclays of the Na^+ montmorillonite type. Knowing the magnitude of the compensation voltage of the electret, found from the experiment, according to the known formula, the values of the surface density of charges σ accumulated on the surface of electrets during electrothermopolarization are calculated. Due to the fact that polyolefins containing nanoclay additives have electret properties, it is of scientific and practical interest.

Key words: polypropylene, nanoclay, composite materials, electret properties
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1. INTRODUCTION

At the present time, an urgent task is to apply the results obtained by the phenomenological theory to specific electrets and to calculate the parameters characterizing relaxation processes.

As a rule, electrets are obtained from dielectrics. Dielectrics that retain the induced charges and polarization state for a long time are called active. Polymer electrets are their outstanding representatives. Scientists from all over the world are intensively studying polymer electrets [1-6]. This makes it necessary to obtain new and further in-depth study of the nature of the electret state of polymer dielectrics, as well as the promising use of electrets in electronic engineering makes the problem of obtaining new composite materials with improved electret properties urgent [8-10]. Electrets are made only from dielectrics with spontaneous polarization.

The electret properties of polymer compositions are widely used in electroacoustic devices, air-cleaning devices, xerography, etc. The main characteristics of electret materials are the magnitude of the electric charge and its stability. Another important performance characteristic of an electret is the lifetime of the electret charges, which characterizes its stability. Composite materials obtained with organic and inorganic additives are widely used to expand the range of materials with electret properties [1].

The aim of this work is to study the effect of Na^+ montmorillonite on the electret characteristics of composite materials based on polypropylene.

The growth of interest in electrets is associated with the rapid development of physics and chemistry. Almost all electrets used in practice are made of polymer dielectrics. Electrets are amorphous and polycrystalline dielectrics that retain their polarized state for a long time after the removal of the external electric field that caused the polarization of the dielectric, and create electric fields in the surrounding space. It follows from this definition that an electret is behind a polarized dielectric, in the same way, for example, as a polarized piezoceramic [15]. To obtain electrets, a dielectric placed in an electric field is subjected to a certain external influence, which contributes to the migration of charged particles (electrons and ions). Such influences can be heating, lighting, magnetic field, mechanical stress, radioactive irradiation, etc. Electrets are the electrical analogue of permanent magnets. Currently, they are widely used in technology. The range of their use extends from household appliances (for example, high-quality electret microphones are widely known) to special-purpose equipment (electret dosimeters, electret hydrophones, etc.). Therefore, the practical need to obtain electrets with desired properties stimulates the expansion of physical research underlying the so-called electret state of dielectrics [3].

It is known that charge carriers in the process of polarization accumulate mainly at the interfaces between phases and at inhomogeneities. The accumulation of charge carriers at the interface changes the interphase interactions, and this can lead to a change in the electrical, strength and other properties of the composition [4]. The lack of consensus on the effect of the accumulated charge in the polarization process on the strength properties raises an increased interest in studying the effect of the polarization process on these properties, which in turn creates the electret state of the composition based on PP and nanoclay like Na^+ montmorillonite. It is shown that the nanocomposite of the composition PP+2.0vol% Na^+ montmorillonite has optimal thermoelectret characteristics. The physicochemical properties of filled polymers are determined by several factors: size, shape, texturing of filler particles and their relative position in the matrix, degree of filling, interaction between filler and binder, and characteristics of the polymer matrix. The particle size of commonly used fillers range from a few units to hundreds of micrometers. In the last 10-15 years, fillers began to be widely used, the size of which in at least one direction lies in the nanometer range. Nanocomposites have a number of advantages over microcomposites. Various types of layered clay minerals are promising fillers for polymer nanocomposites. They are widespread in nature and have a low cost [10-11].

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2. EXPERIMENTAL RESULTS AND THEIR DISCUSSION

Samples for research were prepared as follows: polypropylene powder was mixed with montmorillonite powder [7]. Then, films with a thickness of 100μm are pressed from the mixture at the melting temperature of the polymer matrix and a pressure of 10-15MPa between the aluminum foil. The obtained samples with foil are quickly cooled in water and then the foil is removed. The samples obtained in this way are suitable for studying electret properties.

It should also be noted that up to 40% by volume was added to the PP/Na^+ montmorillonite nanocomposite. In other words, the addition of montmorillonite Na^+ acts as a filler. Then the compensation voltage U_c of the electret state of nanocomposite PP/Na^+ montmorillonite films with different component ratios was determined by the induction method.

Note that corona electrets are obtained in fields of lower strength in comparison with electroelectrets. For this, pointed electrodes are used, located at a certain distance from the surface of the charged dielectric. A corona discharge occurs between the tip and the surface, respectively, the ionization of air and the movement of charge carriers - electrons and ions - to the surface of the electret. Charge carriers remain mainly in the near-surface layer of the dielectric. The field strength in the polymer is low, below the breakdown strength of the polymer. The value of the charges is limited by the breakdown strength of the environment. The charging speed can be quite fast and the charges are evenly distributed over the surface.

Figure 1 shows the dependences of the surface charge density σ on the exposure time τ for PP/ montmorillonite Na^+ nanocomposites having different component ratios

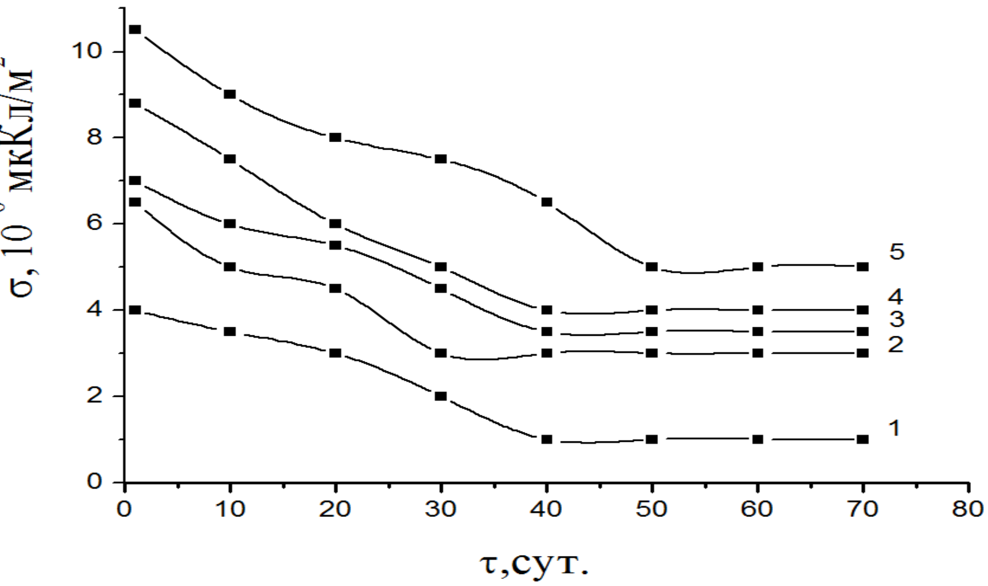

Fig. 1. Dependences of the surface charge density of electrets on the time of their exposure: 1. Na^+ montmorillonite – 10%; 2. Na^+ montmorillonite–0%; 3. Na^+ montmorillonite–30%; 4. Na^+ montmorillonite-40%; 5. Na^+ montmorillonite - 20%.

Figure 2 shows the TSD curves of PP / Na^+ montmorillonite compositions at different volumetric contents of Na^+ montmorillonite. Samples in the form of films with a thickness of 150-160 microns were polarized at $E_p = 5\cdot10^6$ V/m and T_n=393K for 1 hour. It can be seen that, depending on the filler content, the area under the TSD current curves, from which the number of charges was calculated, decreases. It can be seen that the dependence of the TSD current value on vol% Na^+ montmorillonite in the compositions is characterized by a curve with an extremum at high temperatures T=420-430K (curve 1). With an increase in the montmorillonite content due to agglomeration of filler particles, the TSD current decreases. It is known [3-4] that the surface density of charges accumulated on the surface of the electret during ETP is determined by the formula

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

where $\varepsilon_0=8{,}85\cdot10^{-12} C^2/N\cdot m^2$, ε=2.2, U_c is compensation voltage, d is the thickness of the nanocomposite film.

The values of the surface charge density σ were calculated using the above formula for nanocomposites having different ratios of components and held for different times.

The results obtained show that there is a certain relationship between the value of space charges and the values of the filler content and σ. These results show that there is a certain relationship between the value of space charges and the values of E_{pr} and σ. The density of stabilized charges in the compositions, depending on the concentration of nanoclay and polarization conditions, changes and allows you to choose the optimal mode, where the value of E_{pr} is the highest. These charges accumulated in the course of polarization can create a strong internal field with a strength of 10^8V/m, calculated as $E_к = \frac{Q}{\varepsilon\varepsilon_к}$, and thereby enhance changes in interfacial interactions between the components of the nanocomposition,

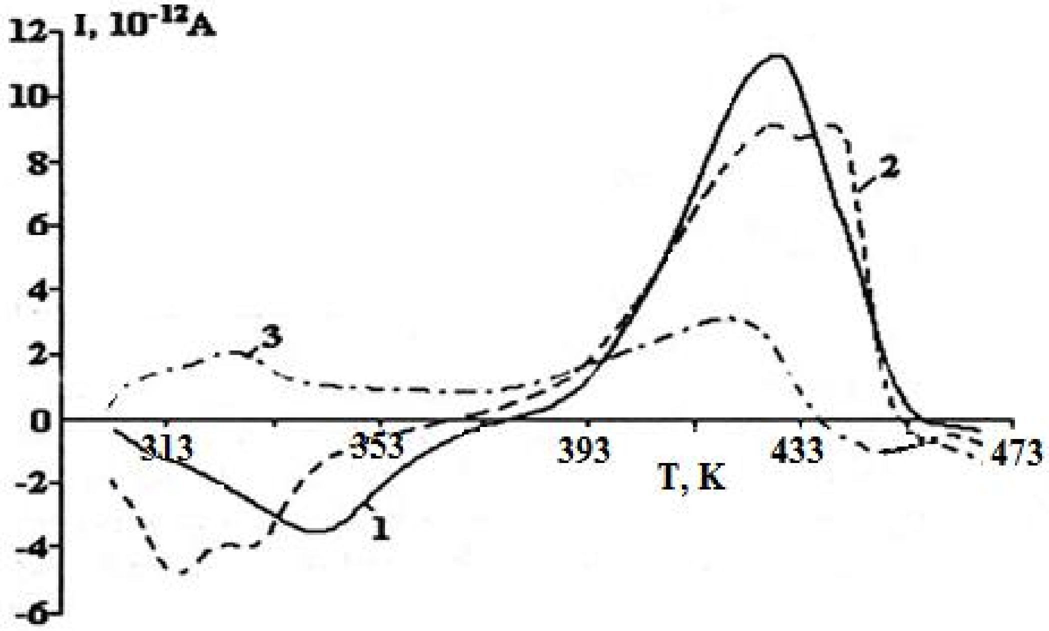

Fig. 2. TSD curves taken for the compositions PP + Na^+ montmorillonite, at various volumetric contents of Na^+ montmorillonite, previously subjected to electrothermopolarization at E_p=5×10^6 V/m and T_p=393K for an hour: 1- PP/Na^+ montmorillonite (96: four); 2 - PP / Na^+ montmorillonite (90:10); 3 - PP / Na^+ montmorillonite (80:20) vol%

It is known that charge carriers in the process of polarization accumulate at the interface and inhomogeneities. Some of them are captured by traps - electrically active material defects that can capture and hold a charge carrier. The accumulation of charge carriers at the phase interface changes the interfacial interaction, and this can lead to a change in the strength properties of the composition. The lack of consensus on the role of the accumulated charge in the polarization process on the strength properties arouses increased interest in studying the effect of the polarization process on these properties, which, in turn, creates the electret state of the composition [13-14].

3. CONCLUSION

The obtained experimental results show that the addition of Na^+ montmorillonite nanogel to the polypropylene polymer increases the concentration of centers of localization of electric charges, i.e. At the interface between the polymer and the nanogel, interphase layers are formed, which can act as traps for charges, as a result of which the density and stability of electret charges can increase. Changes in the interfacial interaction and the thickness of the boundary layer can affect the strength properties of the nanocomposite.

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