MACHINE SCIENCE

ISSN: 2227-6912
E-ISSN: 2790-0479

2024, № 2 Pages 77-83

PHASE ANALYSIS AND ELECTRICAL PROPERTIES OF COMPOSITES BASED ON HIGH PRESSURE POLYETHYLENE WITH Na^+-MONTMORILLONITE FILLER

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https://doi.org/10.61413/GMGO5334

Abstract. One of the promising areas in polymer science is the development of methods for obtaining and studying polymer composites and nanocomposites. An important advantage of composites is their higher functionality and electrical stability compared to polymer analogues. The functioning of composite structures as an active element is associated, in particular, with charge formation phenomena. Therefore, in the development of new dielectric composites, researcher's attention mainly focuses on their production and study of dielectric properties under effect of various factors (temperature, frequency). These studies can serve as a basis for selecting components of compositions for obtaining elements with predetermined parameters and assessing the possibility of their use as a dielectric. Analysis of literature data shows that fillers impart increased thermal and electrical conductivity, new magnetic properties to polymer materials, improve mechanical and electrical strength, etc. In the work presented the results of a study of surface microrelief and X-ray phase analysis of high pressure polyethylene with Na^+-montmorillonite filler **(**HPPE+x wt% Na^+-MMT) composites, the results of the study on the temperature dependences of dielectric permittivity and the tangent of the dielectric loss angle. It was found that with an increase in the filler content, the degree of crystallinity of the composites decreases, dielectric permittivity increases, and dielectric losses decrease. The results of the X-ray phase analysis of the composites show that with an increase in the filler content of Na^+MMT, the degree of crystallinity of the composites decreases from 50.5% (for 10 wt.%) to 62.1% (for 5 wt.%).

Keywords: *High pressure polyethylene, bentonite montmorillonite, surface microrelief, X-ray phase analysis, dielectric properties*

Introduction.

The development of technology is closely linked to advances in the creation of new materials such as semiconductors and polymers [1-5]. Polymer materials with a special properties are widely used in the fields of modern mechanical engineering, space technology, electrical engineering, radio engineering, etc. [6-9]. Controlling and varying the diverse properties of a new polymer material through modification allows for the creation of valuable industrial products. With a complex of physical properties, medium and highly crystalline polymer materials have specific features. Moreover, there is a vast raw material base for their production, their cost is relatively low, and their high chemical resistance is combined with excellent mechanical and dielectric properties. Based on this, high pressure polyethylene (HPPE) has secured a prominent position among other polymer materials of industrial significance. The production and application of HPPE in various fields of modern technology are steadily growing [10-14]. Therefore, it is not surprising that there is significant research interest in these materials, their structure, and the relationship between their structure and properties. Recent research dedicated to methods of evaluating the technological, physical-mechanical, and electrophysical characteristics of HPPE and the development of fundamentally new methods of regulating the properties of its melts and solid states, based on modern concepts of polymer structure and the ability to control their supramolecular structure and properties, is of certain importance. It should be noted that one of the most accessible methods for developing technology to obtain new dielectric materials with specified properties is the method of modifying ready-made polymers by introducing functional groups and various additives into their macromolecules. Based on this, the determination of the physicochemical basis for obtaining new polymer modifications based on HPPE with additives that improve their electrophysical properties is of great scientific and practical interest.

To obtain new composite materials, HPPE (grade M-150) was used as the matrix, and bentonite montmorillonite (Na^+-MMT) were used as fillers. The main feature of montmorillonite, determined by its structure and crystalline composition, is its ability to adsorb various ions and perform ion exchange. The presence of amorphous substitutions, a large specific surface area, and the ease of ion penetration into the interatomic space provide a significant capacity for cation exchange [15-17].

Experimental Methodology

The HPPE+x wt.% Na^+-MMT composites were obtained using the method described in [18-21]. The polyethylene and bentonite powders were pre-ground in a ball mill with porcelain balls to a particle size of no more than 60 μm. The surface microrelief of the HPPE+x wt.% Na^+-MMT composites was studied using a Solver Next AFM atomic force microscope in MD mode. The diagrams were obtained on a 'D2 Phaser' diffractometer (“Buker”).

The tangent of the dielectric loss angle (tgδ) and the capacitance of the studied samples were measured using an AC bridge R-589 at a frequency of 1 kHz in the temperature range of 300-450 K, according to the method described in [22,23]. The measurement ranges for capacitance were 0.001 pF to 100 μF, and for the tangent of the loss angle, 10^{-5}-0,5. The bridge was powered by an AC network with a voltage of 220 V and a frequency of 50 Hz. The measuring electrodes were polished brass discs. The sample temperature was measured using copper-constantan thermocouples with an accuracy of ±1°C. The study was conducted on composites with filler contents of 3, 5, 7, and 10 wt. % Na^+-MMT.

Experimental Results and Their Discussion

The results of the study of the surface microrelief of the composites in 2D and 3D models and their histograms are shown in Fig. 1. From Fig. 1, it follows that with changes in the filler content of Na^+-MMT, the surface condition changes significantly. This is apparently due to changes in the interaction between the matrix and the filler in the boundary layer.

However, the intensities of the peaks on the X-ray diffraction patterns increase with an increase in the content of Na^+-MMT filler.

The results of the X-ray phase analysis of the composites, shown in Fig. 2, demonstrated that with an increase in the filler content, the degree of crystallinity of the composites decreases. Specifically, the degree of crystallinity with fillers of 5, 7, and 10 wt.% is 62.1%, 52.2%, and 50.5%, respectively. No significant changes occur in the X-ray diffraction patterns of the composites as the filler content increases.

The dielectric properties of the composites based on high pressure polyethylene (HPPE) with Na^+-MMT fillers were studied in the temperature range of 300-380 K. The studies were conducted on composites with fillers of 3, 5, 7, and 10 wt. % Na^+-MMT. Fig. 3 presents the temperature dependencies of the dielectric permittivity (ε), and Fig. 4 shows the tangent of the dielectric loss angle (tgδ) of these composites.

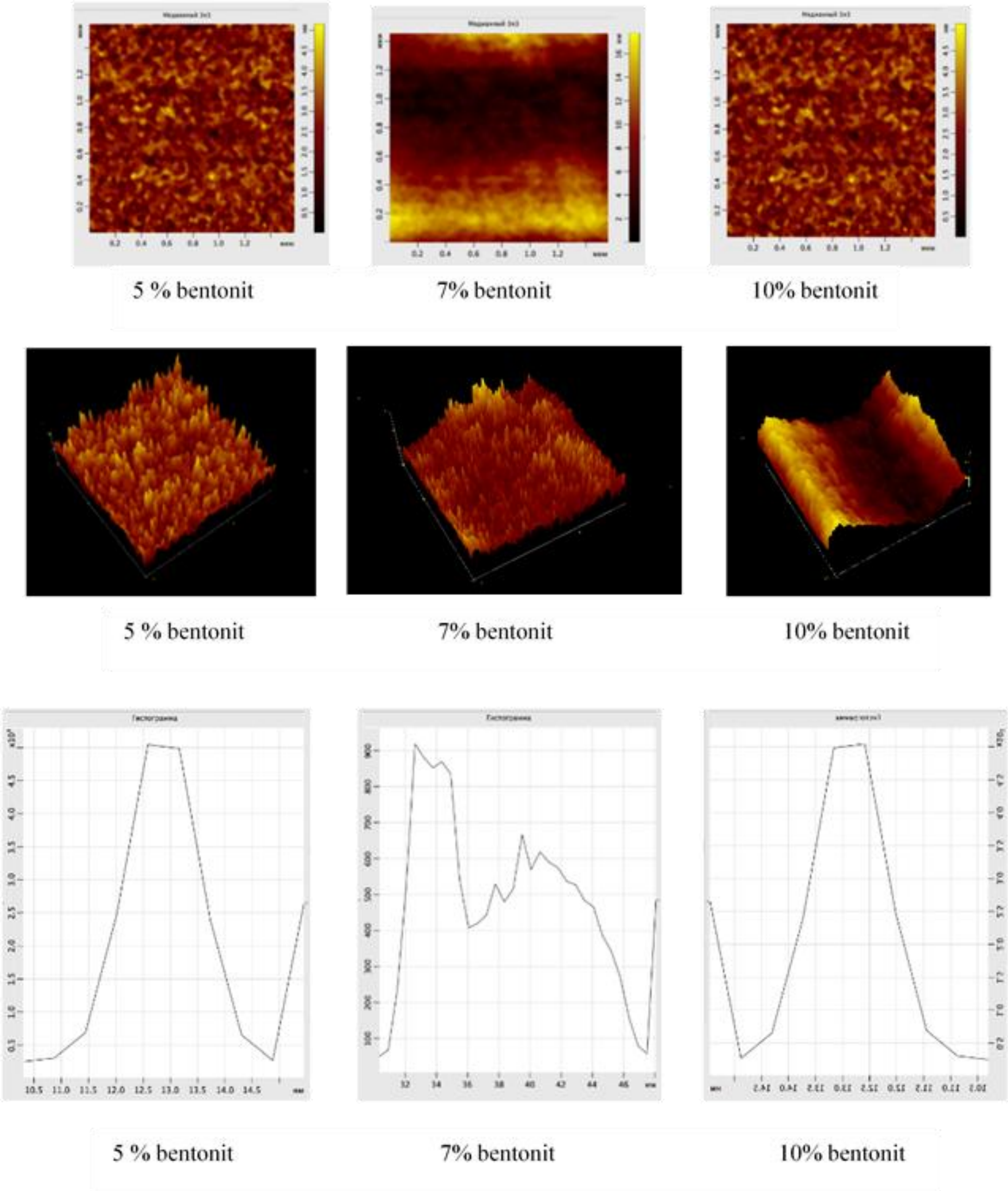

Figure 1 Results of the study of the surface microrelief of HPPE + x wt.% Na^+-MMT composites in 2D and 3D modes, 1 - x = 5; 2 - x = 7; 3 - x = 10, and their histograms.

As seen in Fig. 3, the dielectric permittivity increases linearly with rising temperature, and no specific responses were detected in the ε(T) dependency. The changes in the tangent of the dielectric loss angle with temperature variation are relatively complex. In the temperature range of 340-350 K, distinct maxima are observed on the tgδ(T) curves. Apparently, the appearance of maxima in tgδ(T) at high temperatures is the result of changes in the parameters of the interphase boundary layer. It should be noted that as the filler content of Na^+-MMT increases, the dielectric permittivity of the composites increases, while the tangent of the dielectric loss angle decreases.

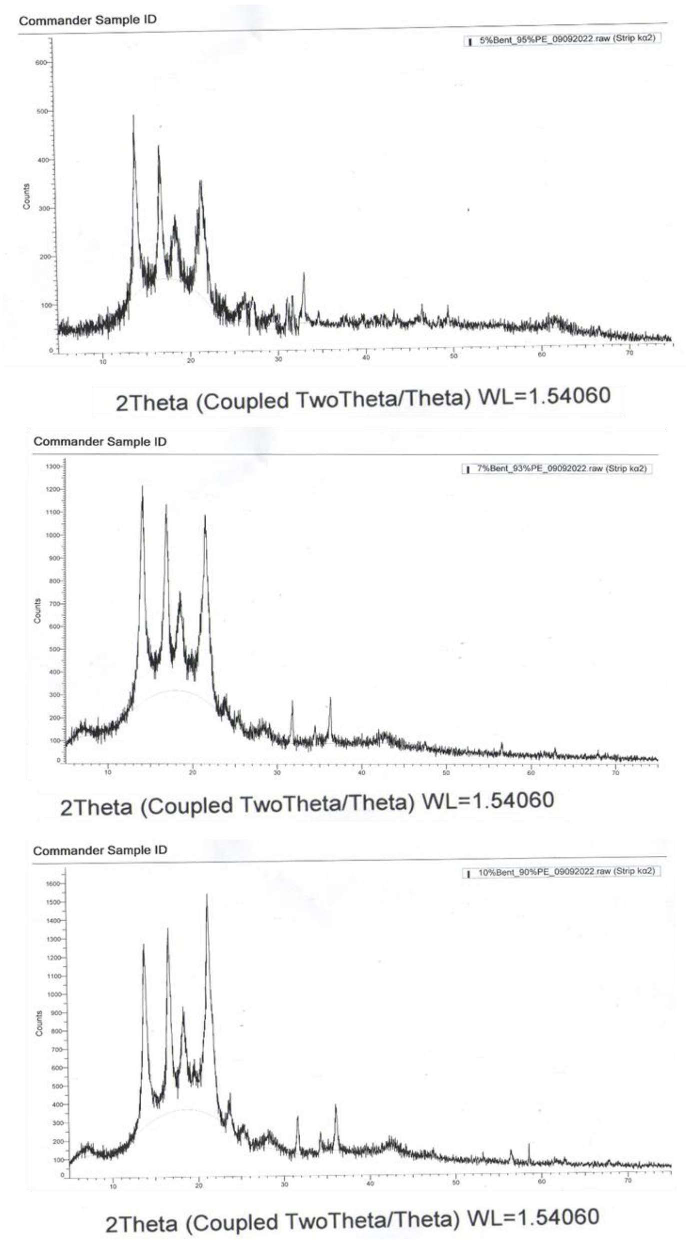

Figure 2. X-ray phase analysis of HPPE + x wt.% Na+-MMT composites with 5, 7, and 10 wt.%.

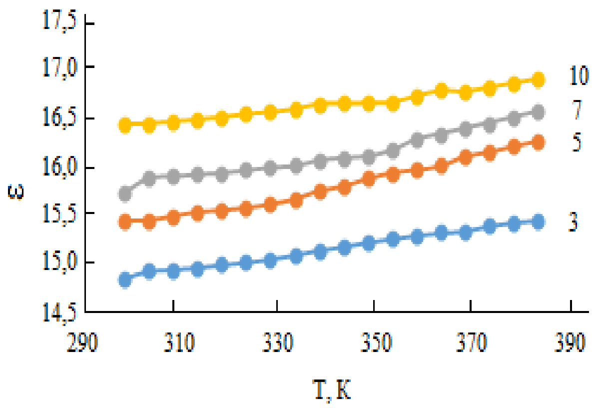

Figure 3 Temperature dependence of the dielectric permittivity of HPPE + x wt.% Na^+-MMT composites, where 1 - x = 3; 2 - x = 5; 3 - x = 7; 4 - x = 10

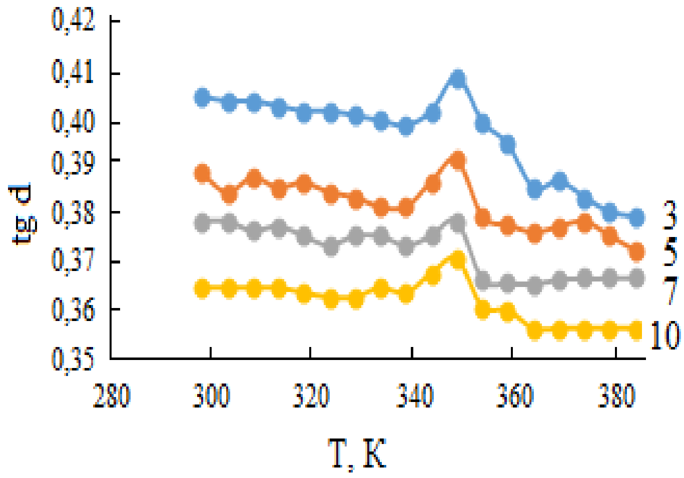

Figure 6. Temperature dependence of the tangent of the dielectric loss angle of HPPE + x wt.% Na^+-MMT composites.

Results and conclusions.

The surface microrelief and X-ray phase analysis of high pressure polyethylene composites with Na+-montmorillonite filler (HPPE+x vol.% Na+-MMT) were studied. The results of the study of temperature dependences of permittivity and dielectric loss tangent showed that with an increase in the volumetric filler content, the degree of crystallinity of the composites decreases, the permittivity increases, and dielectric losses decrease. According to the results of X-ray phase analysis of the composites, it was revealed that with an increase in the volumetric filler content Na+MMT, the degree of crystallinity of the composites decreases from 50.5% (for 10 vol.%) to 62.1% (for 5 vol.%).

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Received: 15.01.2024
Accepted: 22.09.2024