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Temperature-Frequency Characteristics of Dielectric Properties of Compositions LDPE + *x*vol%Bi_2Te_3

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Abstract

In the paper, the results of investigations of temperature and frequency dependences of dielectric permeability and dielectric loss of compositions LDPE + *x*vol%Bi_2Te_3 are stated. The investigations were carried out at frequency 10 - 10^5 Hz and temperature 20˚C - 150˚C intervals, respectively. It was revealed that increase of percentage of the filler Bi_2Te_3 in the matrix, reduces to increase of dielectric permeability and dielectric loss of composites LDPE + *x*vol%Bi_2Te_3 in connection with the change reducing to Maxwell-Wagner's volume polarization and emergence of comparative strong inner field in semiconductor clusters.

Keywords

Composites LDPE + *x*vol%Bi_2Te_3, Dielectric Permeability, Dielectric Loss, Semiconductor Clusters

1. Introduction

Creation of composite materials is one of the basic directions in development of new prospective materials. Filling of polymers reduces to changes in characteristics of supramolecular structuration and in density of packaging as solid high-dispersive fillers may serve as builders of nucleus of crystals or their imperfections [1]. The fillers have considerable influence on mobility of different kinetic units of a polymer and on spectrum of its relaxation time. The filler particles play the role of a structuration, and the boundary layer of a polymer with filler has a special saturation structure. These are trapping cites with different values of energy of activation where the electrons are stabilized and as a result, electroactive properties of polymers are improved. It should be noted that depending on the nature, size, form and distribution character of filler, the obtained polymeric composition may

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be electro conducting, antistatic or dielectric [2]-[4].

Recently, in place of a filler semi-conductor compounds are frequently used, and the materials of scientific-practical interest have already been obtained [5]. It was revealed that with use of a filler of threefold compounds as $A^{III}B^{III}C_2^{VI}$ based on polyethylene, one can obtain a new class of electret materials with record time of life [6].

In the present paper, we give the results of investigations of dielectric properties of composite materials based on lower density polyethylene (LDPE) filled with semiconductor compound Bi_2Te_3.

2. Experimental Technique

Composition samples were obtained by mechanical mixing of powder Bi_2Te_3 with powder of LDPE in a porcelain motor. The mixing is continued up to receiving homogeneous mixture. The mixture some time is maintained at melting temperature of polymer under pressure 5 MPa. At the same temperature, by pressing the homogeneous mixture, the pressure slowly increases to 15 MPa. At this pressure, the sample is maintained within 5 minutes, and then is cooled in water. Herewith the sizes of the samples are: the thickness is about 80 - 120 mkm, diameter of the obtained samples 35 mm. In order to provide reliable electric contact between the samples and electrodes made of the stainless steel, the electrodes made of a thin aluminum foil of 7 mkm in thickness pressed on both working faces of the samples, are used.

Dielectric permeability and dielectric loss of LDPE + *x*vol%Bi_2Te_3 were measured in the range of 296 - 520 K at linear growth of temperature with velocity 2.5 degree/min and in frequency range 1 by the technique described in the paper [6].

The reliable electric contact of electrodes made of stainless steel of diameter 15 mm was provided by using pressed electrodes made of aluminum foil of 7 mkm in thickness. The value of electric capacitance (C) and tangent of dielectric loss angle $(\text{tg}\delta)$ of the investigated sandwich structures were determined by means of the device of the brand E7−20. The samples were located into a measuring cell with pressing electrodes that in its turn was located into the heating system. Measuring of capacity and $\text{tg}\delta$ was carried out in freshly prepared samples, and the quantity of the modulus of the complex of dielectric permeability (ε) were determined by the known formula

$$\varepsilon = \frac{Cd}{\varepsilon_0 S}$$

where, C is the measured electrical capacitance of the sample, F; electrical constant $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m; d—thickness of the sample, m; S—area of the sample. In experiments, frequency of the given electric field changed from 10^2 to 10^6 Hz, and temperature range 20˚C - 140˚C. Measuring voltage amplitude is 1 B. The temperature was determined by means of a standard thermocouple copper-constantan.

3. Experimental Results and Discussions

Temperature dependences of dielectric permeability and dielectric losses of composite materials LDPE + *x*vol%Bi_2Te_3 at temperature range 20˚C - 160˚C were studied. The results of investigations are given in **Figures 1-4**. As it follows from **Figure 1** for the composite 5 vol%Bi_2Te_3 in the investigated temperature range in $\varepsilon(T)$ dependence at 50˚C and 130˚C weak maxima are observed, and on the whole ε decreases due to temperature growth.

For the composite 10 vol%Bi_2Te_3 in all temperature range, the dielectric permeability remains constant. With increasing the content of Bi_2Te_3 to 15 vol%, on temperature dependence of dielectric permeability weak maxima at 70˚C and 140˚C, minimum for 100˚C were revealed. Temperature dependences of dielectric loss of composites LDPE + *x*vol%Bi_2Te_3 were also studied. The investigations were carried out in temperature interval 20˚C - 150˚C. The results are given in **Figure 3**. As is seen from **Figure 4** for a composite with the filler LDPE + 5 vol%Bi_2Te_3 on the curve of $\text{tg}\delta(T)$ dependence for 80,102 and 116˚C the weakly expressed maxima are observed. On the whole, in the studied temperature range, $\text{tg}\delta$ increases due to temperature growth. With increasing the volumetric content of the filler to LDPE + 10vol%Bi_2Te_3 the curve smoothies out and maxima disappear. However, also for this composite $\text{tg}\delta$ increases according to temperature growth. For the composite LDPE + 15vol%Bi_2Te_3 the $\text{tg}\delta(T)$ dependence becomes linear and change of $\text{tg}\delta$ with temperature is slight.

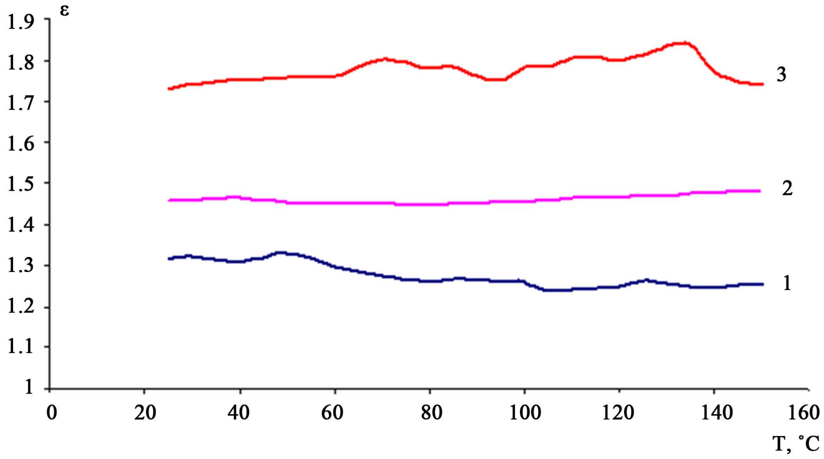

Figure 1. Temperature dependences of dielectric permeability of composite materials LDPE + *x*vol%Bi_2Te_3, 1 - 5, 2 - 10; 3 - 15.

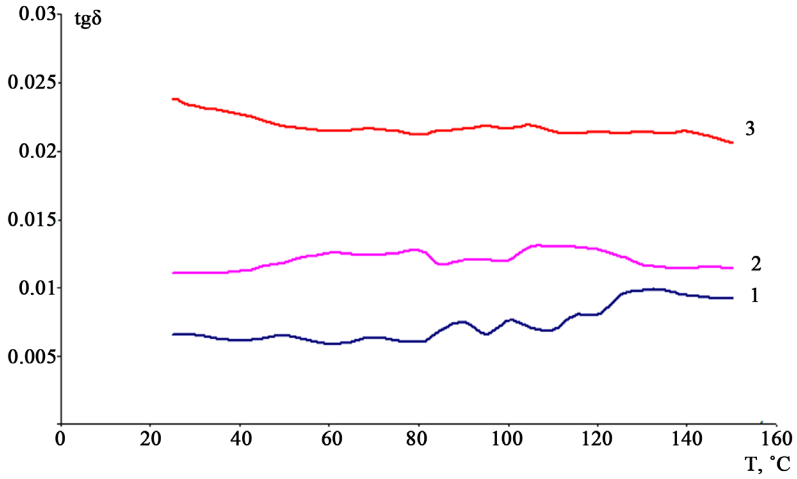

Figure 2. Temperature dependences of dielectric loss of composite materials LDPE + *x*vol%Bi_2Te_3, 1 - 5, 2 - 10; 3 - 15.

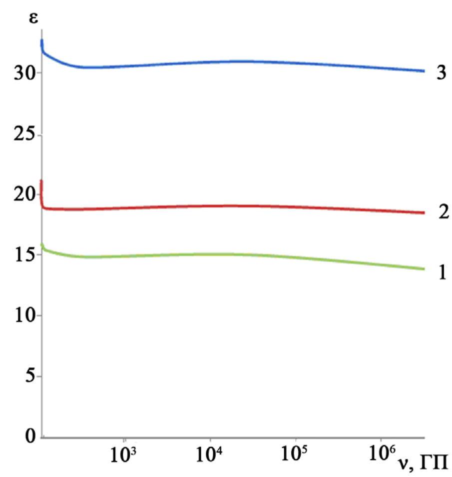

Figure 3. Frequency dependence of dielectric permeability of composite materials LDPE + *x*vol%Bi_2Te_3, 1 - 5, 2 - 10; 3 - 15.

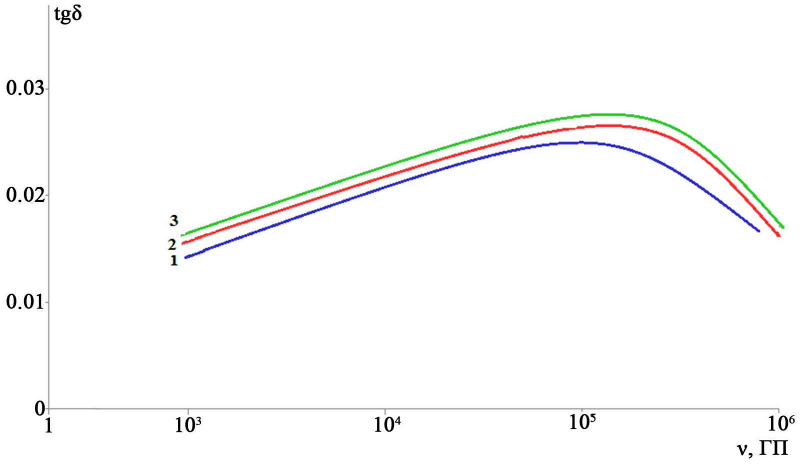

Figure 4. Frequency dependence of dielectric loss of composite materials LDPE + *x*vol%Bi_2Te_3, 1 - 5, 2 - 10; 3 - 15.

The results of investigation of frequency dependence of dielectric permeability of composites LDPE + *x*vol%Bi_2Te_3 are given in **Figure 3**. As it follows from **Figure 3**, in the frequency range 0 - 10^3 Hz, the dielectric permeability slightly decreases, and with further increase of frequency to 10^6 Hz remains practically constant. With increasing volumetric content of the filled, ε increases. Dispersions in $\varepsilon(\nu)$ dependence were not found.

The results of investigations of frequency dependence of dielectric loss of composites LDPE + *x*vol%Bi_2Te_3 are reduced in **Figure 4**. As it follows from **Figure 4**, in all the investigated composites in frequency range 10^3 - 10^5 Hz the typical is that dielectric loss increases, while in the range 10^5 - 10^6 Hz decreases. Dispersions in $\mathrm{tg}\delta(\nu)$ dependence were not found.

Thus, the analysis of the obtained results shows that with increasing the volumetric content of the filler Bi_2Te_3 dielectric permeability and dielectric loss increase. Apparently this is connected with the fact that increase of the volumetric content of the Bi_2Te_3 filler reduces to growth of the number of particles Bi_2Te_3 per cross sections of the composite, and this is equivalent to the part of Bi_2Te_3 in the general thickness of sample. The clusters closed with each other in the sample's thickness may be considered as pure resistance included between electrodes. Since Bi_2Te_3 has high conductivity compared with LDPE, we can assume that the composite's resistance will be especially determined between the particles Bi_2Te_3 on the boundaries of clusters (the clusters are surrounded with PE layers with small ε). Accumulation and redistribution of free electric charges that distort initial inner electric field, occurs in alternating current. At lower frequencies, the inner electric fields are distributed according to conductivities. Consequently, change of dielectric parameters due to increase of frequency and including temperature may be explained by emergence of a comparatively strong inner field in semi-conductor clusters.

4. Conclusion

By researches of temperature and frequency characteristics of dielectric permeability and dielectric loss of composites PELD + *x*vol%Bi_2Te_3, it was revealed that with a variation of the volume maintenance of a filler, temperature and frequency, it is possible to receive composites with the demanded dielectric parameters.

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