THE STRUCTURE AND DIELECTRIC PROPERTIES OF NANOCOMPOSITES BASED ON ISOTACTIC POLYPROPYLENE AND IRON NANOPARTICLES

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Have been studied the structure and dielectric properties of polymer nanocomposites based on isotactic polypropylene and iron nanoparticles. It was shown that introduction of iron nanoparticles in the polypropylene matrix led to decreases of dielectric permittivity of nanocomposites. This is due to the fact that the increasing of the volume content of nanoparticle the sizes of formed particles increases and at the same time, the electrical conductivity of nanocomposites decreases. The reduction of the dielectric permittivity with the introduction of iron nanoparticles in a polymer matrix is explained by a decrease of the polarization ability of the nanocomposites. It is also found that the dielectric permittivity not changes at all frequencies. It is shown that increasing of the temperature up to 363 the dielectric permittivity decreases, first not significantly, then from temperature interval 363 K - 413 K the permittivity decreases sharply, and after 413 K the dielectric permittivity decreases slowly. The sharp decrease in the value of the dielectric permittivity at 373 K is due to the destruction of the crystalline phase of the polymer.

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1. Introduction

At the present time nanocomposite materials based on polymeric matrix with metals nanoparticles and their compounds, attracted much attention from researchers. One of the important directions of the development of nanotechnology is the creation and study of metal nanocomposites, representing two-phase system composed of metal nanoparticles in a dielectric matrix. Use of different polymers as a dielectric matrix led to the development of new scientific field - plastic electronics. Developed and continuously improved technology for producing and moulding the above materials, investigated the mechanical and electrical properties. Analyses of the researches demonstrate prospects of using these nanocomposites in acoustics to create a variety of waveguide structures. This is due to their low acoustic impedance and a low value of the permittivity [1].

It is now known that the properties of metal nanocomposite materials are critically dependent on the volume concentration of the metallic phase. When percolation concentration (concentration of filler) of metal nanoparticles in the matrix volume greater than the critical, in the nanocomposite form cluster, and the polymer becomes a conductor. Thus such a cluster is a structural network of contacting each other metallic particles ("conductive phase"). In the case of low concentration of filler, the metal clusters are spatially separated from each other, and the electrical conductivity of the nanocomposite represented by tunnelling of charge carriers between such clusters ("semiconductor or insulator phase"). Changing the concentration of metal nanoparticles filler of polymer matrix significantly influences the basic parameters of nanocomposite: conductivity, complex permittivity, the plasma frequency, etc.

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Thus, choosing the composition of the metal-dielectric matrix nanocomposites, type of metal, size of metal nanoparticles and their concentration in the matrix, it is possible to control the basic physical properties of the medium: electrical, optical, galvanomagnetic, etc.

This article is devoted to the experimental study of the structure and electrical properties of nanocomposites based on polypropylene and iron nanoparticles, as well as identifying the link between electrophysical parameters and the structures of nanocomposite.

2. Experimental part

2.1. Materials

The isotactic polypropylene (PP brand Sigma Aldrich P code 1001326963) has a density of 0,9 g / ml at 250C, refractive index- n20 / D 1.49, transition temp - Tg -26 ° C, mol wt-average Mw ~ 250,000 by GPC, autoignition temp -> 674 ° F, mp - 1890S.

Iron nanoparticles were prepared by electroexplosive technology.

2.2. Research methods

2.2.1 Method for measuring dielectric properties.

Measurement of the dielectric permittivity, dielectric loss tangent and resistivity nanocomposites conducted using immittance meter MNIPI E7-20. C by applying a broadband meter E7-20 immittance measured the frequency dependence of capacitance and dielectric loss at a temperature T = 293 K in the frequency range f = 25Hz-1MHz. Measurement of dielectric permittivity versus temperature was carried out at f = 1kHz using MNIPI meter E7-21. Measurement of specific resistance value depending on temperature was controlled by teraommeter E7-13 A.

2.2.2 Study of nanocomposites using scanning electron microscopy (SEM).

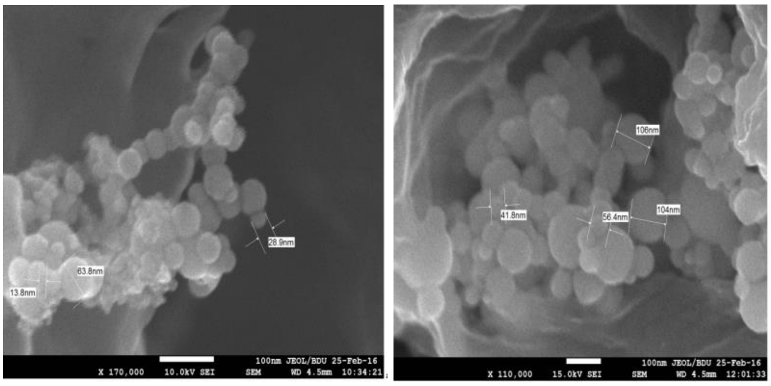
Distribution of iron nanoparticles in the polymer matrix depth studied by scanning electron microscopy (SEM, Jeol JSM-7600 F). Scanning was conducted in the SEI mode at an accelerating voltage of 15 kV and a working distance of 4.5 mm.

2.3. The synthesis of nanocomposites.

The polymer nanocomposite materials were prepared as follows: isotactic polypropylene was solved in toluene solvent, at a temperature of 120^0C. Iron nanoparticles were added to the polymer solution at various iron volume contents (0.1; 0.3; 0.5; 1; 2; 5%) and stirred for an hour to obtain a homogeneous mixture. The mixture was transferred to a petri dish and dried during the day. Nanocomposites have also been dried in a vacuum oven for 3-4 hours to completely remove the solvent. From these samples were obtained thin film of nanocomposite by hot-pressing at the melting temperature of polypropylene and a pressure of 10 MPa. Cooling the film after hot pressing was carried out in water and the cooling rate was 200 dg/min. It was also found that the threshold for nanocomposites PP + Fe occur at 5% volume content of iron nanoparticles.

3. Results and discussion

In the article the surface morphology of nanocomposites PP + Fe was studied using scanning electron microscopy. Fig.1 shows SEM image of nanocomposites PP + Fe. As can be seen from the figure 1 with increasing of the volume content of nanoparticles in the polymer matrix the number of aggregates and agglomerates of nanoparticles in the matrix increase. Thus, when the volume content of iron nanoparticles is 0.3% in the matrix the size of nanoparticles is 28-65 nm, at the 5% - the size of nanoparticles is 40-105 nm [2,3].



a) *b)*

Fig. 1. SEM images of nanocompositions PP+Fe a) PP+0,3%Fe b) PP+5%Fe

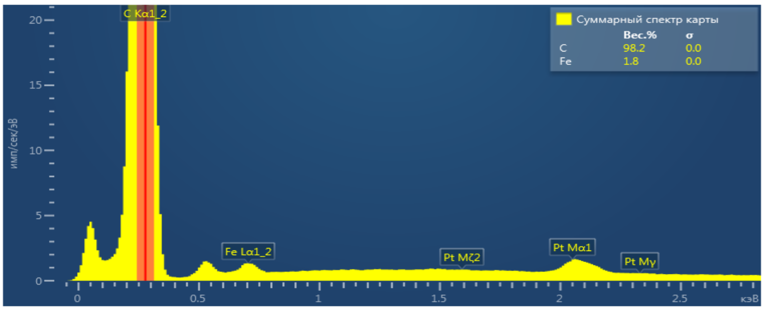


Fig.2. Energy dispersive spectrum of nanocomposites based on PP + Fe.

Fig. 2 shows energy dispersive spectrum of nanocomposites PP + Fe and as seen in the polymer matrix prevails mainly iron nanoparticles. Figure 3 shows the mapping of the elements of nanocomposites based on PP + Fe. Mapping also clear that the nanocomposite comprises essentially of iron and carbon components, platinum is detected as a result of deposition of Pt on the nanocomposite surface in order to eliminate charging nanocomposite films.

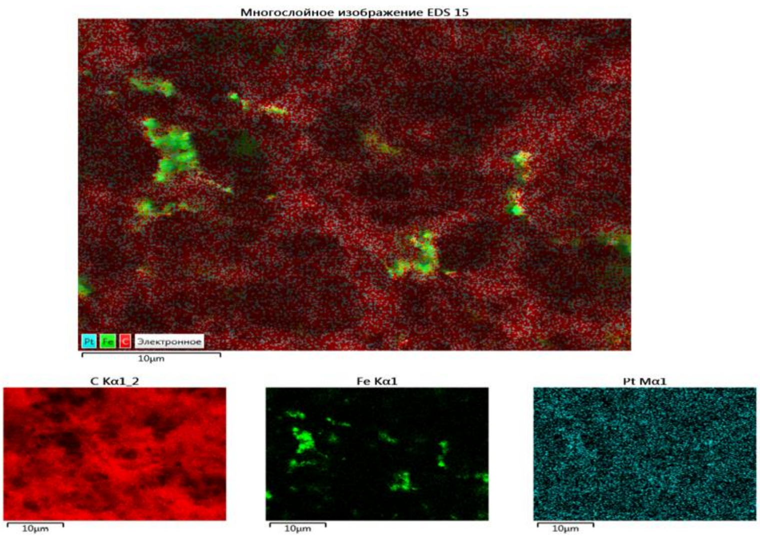


Fig. 3. Mapping of the elements of nanocomposites based on PP + Fe.

We studied the dielectric properties (ε, tgδ and ρ_v) of nanocomposites based on PP + Fe.

It investigated the value of the dielectric permittivity and dielectric loss tangent magnetic nanocomposites based on PP + Fe with different contents of iron nanoparticles depending from the measurement frequency.

Fig. 4 and 5 illustrate the dependence of dielectric permittivity and dielectric loss tangent of nanocomposites based on PP + Fe frequency. As can be seen from Fig. 4 with the addition of iron nanoparticles in the dielectric matrix of polypropylene PP the dielectric permittivity of nanocomposites decreases. With the increase of the volume content of iron nanoparticles the dielectric permittivity of nanocomposites also continues to decrease. This is due to the fact that by increasing of the volume content of nanoparticle the sizes of particles increases and at the same time, the electrical conductivity of nanocomposites reduces. Reducing of the dielectric permittivity of nanocomposites, depending on the volume content shows a decrease polarized ability of nanocomposites. Figure 4 also shows that the dielectric permittivity at low and high frequencies, almost no change [4.5].

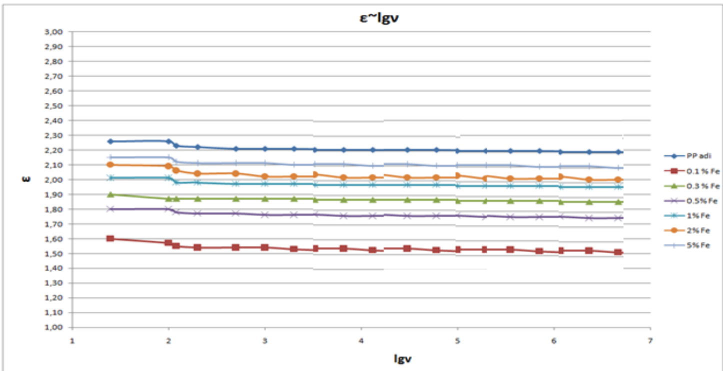


Fig. 4. Dependence of the value of the dielectric permittivity nanocomposites PP + Fe from the frequency

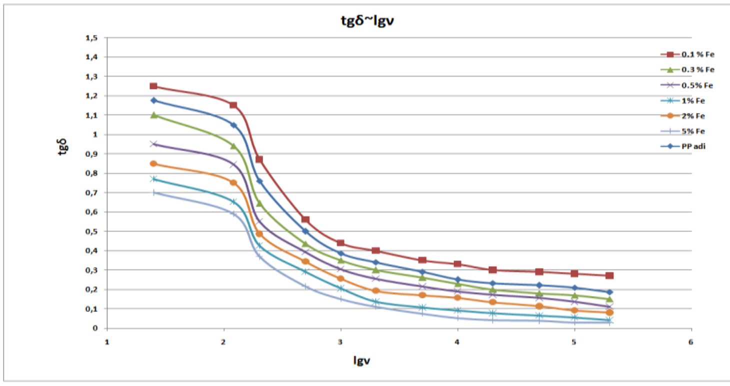


Fig. 5. The dependence of the dielectric loss tangent values of nanocomposites PP + Fe from the frequency

Fig. 6 shows the dependence of the dielectric permittivity of nanocomposites based on PP + Fe from the temperature, measured at a frequency 1 KHz. As can be seen the increasing of the temperature, the dielectric permittivity at 363 K first decreases a little, and then from 363 K to 413 K temperature dielectric permittivity falls sharply, after 413 K dielectric permittivity begins to increase. The sharp decrease of the dielectric permittivity value at 373 K is due to the destruction of the crystalline phase of the polymer. Further reduction of the dielectric permittivity at high temperature is explained with increasing electrical conductivity of nanocomposites.

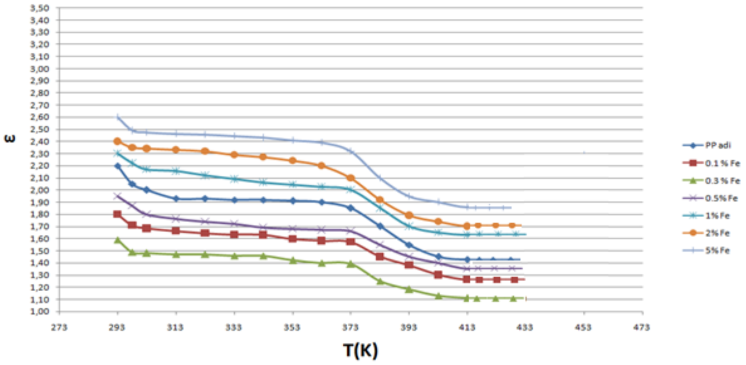


Fig. 6. Dependence of the dielectric permittivity value of the nanocomposites PP + Fe from temperature.

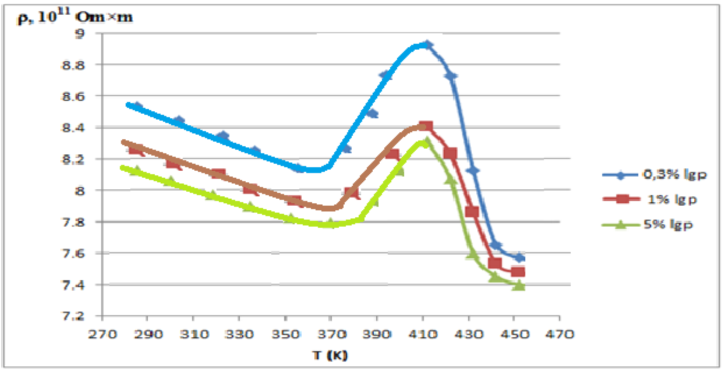


Fig. 7. Dependence of the specific resistivity of nanocomposites based on PP + Fe on temperature.

Fig. 7 shows the values of the specific resistance of nanocomposites based on PP + Fe on temperature. It is shown that the value of resistivity of nanocomposites PP + Fe with increasing temperature decreases gradually at 370 K and then observed an abrupt jump of specific resistivity at 410 K. Further increase of temperature leads to a sharp decrease in resistivity. Also from Figure 7 that the value of ρ_v at all temperatures for PP + 0,3% Fe + PP and 1% Fe greater than for PP + 5% Fe. It can be seen that the nanocomposite PP + 0,3% Fe, PP + 1% Fe, PP + 5% Fe posistor effect is observed in the temperature interval 370-430K. Observation of these nanocomposites posistor effect, in our opinion related to the destruction of the crystalline structure of the polypropylene. With the destruction of the crystalline polymer phase increases the average distance between the iron nanoparticles [6].

4. Conclusion

In this paper we studied the structure and dielectric properties of polymer nanocomposites based on isotactic polypropylene and iron nanoparticles. It was shown that introduction of iron nanoparticles in the polypropylene matrix led to decreases of dielectric permittivity of nanocomposites. This is due to the fact that the increasing of the volume content of nanoparticle the sizes of formed particles increases and at the same time, the electrical conductivity of nanocomposites decreases. The reduction of the dielectric permittivity with the introduction of iron nanoparticles in a polymer matrix is explained by a decrease of the polarization ability of the nanocomposites. It is also found that the dielectric permittivity not changes at all frequencies. It is shown that increasing of the temperature up to 363 the dielectric permittivity decreases, first not significantly, then from temperature interval 363 K - 413 K the permittivity decreases sharply, and after 413 K the dielectric permittivity decreases slowly. The sharp decrease in the value of the dielectric permittivity at 373 K is due to the destruction of the crystalline phase of the polymer.

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