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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

STRUCTURE FORMATION AND PROPERTIES INVESTIGATION OF THE POLYPROPYLENE, POLY-VİNYLIDENE FLUORIDE AND IRON NANOPARTICLES BASED NANOCOMPOSITES

Speciality:	2222.01 – Physics and Technology of Nanostructures
Field of science:	Physics
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GENERAL CHARACTERISTICS OF WORK

Relevance and degree of treatment of the topic: The features of the new class of materials such as universality, multi-functionality, effectiveness, extremely small size, and easy production technology define the main direction of modern scientific-technological investigations. From this perspective, in recent years, one of the most required research branches is the production and investigation of polymer nanocomposites. Furthermore, modern material science approaches to already known materials in nanoscale and luminesces the hidden potential and application areas of "classic" structures. One of the main progressive features of nanomaterials is their multi-functionality. They possess a large range of application areas including nanodevices, nanoelectronics, nanosensors, spintronics, bioengineering.

The magnetic phenomena and interactions play a vital role in obtaining a new class of electronic devices. Recent works are mostly related to the development of the device in which spin current takes place between individual parts. There is a growing interest in the realization of composite materials with room-temperature ferromagnetic properties for spintronic devices. Furthermore, it is known that the magnetic information in the hard disk is stored in ``bits" which are patterns of magnetization in a magnetic material to store data. Reducing the size of magnetic nanoparticles leads to increasing the capacity of the hard discs. Recent research suggests that Ferro- and ferrimagnetic polymer nanocomposites may be promising in this area. Looking at the numerous studies, it becomes clear that depending on the manufacturing technology of polymer-based magnetic nanocomposites they can be applied not only in nanoelectronics but also in aerospace engineering, medical technology, etc.

Research objects and subjects. The research objects were PP+Fe and PVDF+Fe nanocomposites based on Fe nanoparticle, and thermoplastic polymers of polypropylene (PP), polyvinylidene fluoride (PVDF). The structure, dielectric, magnetic, mechanical, and thermal properties of nanocomposites were studied. On the basis of the comparative analysis of theoretical and experimental results, the volume content of iron nanoparticles was selected for obtaining optimal physical parameters of nanocomposites.

Aims and purpose of the research. The essential purpose of the thesis is to develop PP+Fe and PVDF+Fe magnetic nanocomposites based on PP and PVDF polymer and Fe nanoparticles, to study the structure, dielectric, optical, magnetic, mechanical, and thermal properties of these nanocomposites depending on the volume content of Fe nanoparticles, to clarify the mechanism of physical processes taking place in these nanomaterials and identify opportunities for their practical application.

In order to achieve this purpose, the following problems are required to be solved:

1. To choose the optimal technological mode for the production of the PP+Fe and PVDF+Fe nanocomposites in different volume contents of Fe nanoparticles;

2. To study the composition and structure of PP+Fe and PVDF+Fe nanocomposites;

3. To investigate the dielectric properties of PP+Fe and PVDF+Fe nanocomposites depending on the volume content of Fe nanoparticles and to clarify the mechanism of change in dielectric permittivity;

4. To explore the mechanical and thermal properties of PP+Fe and PVDF+Fe nanocomposites depending on the concentration of Fe nanoparticles;

5. To study the optical properties of PP+Fe and PVDF+Fe nanocomposites depending on the concentration of Fe nanoparticles with the help of IR and UV spectroscopies and to determine the mechanism of optical absorption;

6. To examine the magnetic properties of PP+Fe nanocomposites depending on the concentration of Fe nanoparticles, to determine the nature of changes in magnetic resistance, and to compare the experimental results with theoretical calculations.

Research methods. For studying the structure and physical properties of obtained nanocomposites several experimental methods were used in the work: x-ray analysis, IR spectroscopy, UV spectroscopy, scanning electron microscopy (SEM), atomic force microscopy (AFM), magnetic force microscopy (MFM), thermogravimetric method of analysis (TGA), differential scanning calorimetry (DSC), methods for measuring electrophysical, mechanical strength and magnetic properties.

Basic provisions for defence:

1. The obtaining technology of new magnetic polymer nanocomposites characterized by unique magnetic, electrical, and optical properties was developed, the regulations of formation and distribution of nanoparticles in the polymer matrix were determined.

2. The amorphous/crystal phase ratio in polymers varies depending on the volume content of the Fe nanoparticles included in the PP and PVDF matrix.

3. Quantitative and qualitative changes in the dielectric properties of polar and non-polar polymers by the influence of embedded magnetic nanoparticles are associated with interfacial polarization.

4. The stable and optimal value of the thermal and mechanical parameters of PP and PVDF polymers is determined by the volume content of the nanoparticles.

5. Complex experimental and theoretical calculations show that the magnetic parameters of nanocomposites depend on the volume content of the nanoparticles, the type of polymer, and the nature of the distribution of the nanoparticle in the polymer matrix.

6. The magnetoresistive effect observed in PP+Fe and PVDF+Fe nanocomposites is related to the tunnelling magnetoresistance mechanism.

7. The developed PP+Fe and PVDF +Fe nanocomposites can be used in the manufacture of magnetic heads for hard disks, structured information carriers, spintronics, and coatings that absorb high-frequency electromagnetic waves.

Scientific innovations. In the dissertation work, the following facts have been firstly identified:

1. The synthesis method of PP+Fe and PVDF+Fe polymer nanocomposites has been proposed.

2. Disperse Fe nanoparticles settle in the amorphous phase of polycrystalline polypropylene matrix, play the role of structure centering at particular concentrations and reduce the portion of the amorphous phase of the nanocomposite.

3. The thermostability of PP+Fe and PVDF+Fe nanocomposites is determined by the optimal value of the Fe nanoparticles concentration, as well as the interaction between the polymer and the filler (Fe) in the interfacial region.

4. A decrease in the dielectric permittivity depending on the concentration of Fe nanoparticles indicates a diminishing in the polarization ability of nanocomposites.

5. Disperse Fe nanoparticles distributed in the polymer matrix form magnetic domains in the local area, the magnetic field created by them, and the nanocomposite's magnetic morphology are controlled by the concentration of Fe.

6. It has been determined that the negative magnetoresistance is related to spin-dependent tunnelling of electrons between the isolated magnetic nanoparticles in the nanocomposite matrix.

7. The high-frequency electromagnetic waves absorption ability of PP+Fe and PVDF+Fe polymer nanocomposites is determined by complex dielectric permittivity, dielectric/magnetic losses, as well as interfacial relaxation between nanoparticles and polymers.

Theoretical and practical significance of the research. The practical significance of the work is as follows:

In this work, polymer nanocomposites based on PP+Fe and PVDF+Fe with unique physical properties were synthesized for the first time. PP+Fe and PVDF+Fe nanocomposites are characterized by magnetic tunnelling effect, which allows them to be used in the manufacture of magnetic sensors, as well as magnetic heads of hard disks, structured information carriers, and spintronics. It is also possible to produce coating materials based on PP+Fe nanocomposites that absorb high-frequency electromagnetic waves for radar systems, as well as in aviation.

Approbation and application. The main results of the PhD thesis have been presented at conferences:

– VIII Republican scientific conference "Physics and astronomy problems", Baku, 17 May 2013;

– Republican Scientific Conference “Actual problems of physics", Baku, 6 December, 2013;

– International Conference “Modern Trends in Physics”, 01-03 May, Baku, 2019;

– The applicant won the grant competition announced by the International Centre for Innovative Nanotechnology of the CIS countries (Russian Federation) in 2018. Within the framework of this project, she presented the topic of "Superparamagnetic nanocomposite materials based on thermoplastic polymers and iron particles for electronics" in the international seminar.

The main results of the PhD thesis have been published in 9 papers and 3 conference proceedings. 7 of them were published at journals released by Web of Science and SCOPUS bases.

Name of the organization where the dissertation work is executed. Dissertation work, completed in the Ecology Institute of National Space Agency, Ministry of Defence Industry of Azerbaijan.

Structure, volume and main content of dissertation work. Dissertation work including 69 figures, 20 tables, 4 chapters, a conclusion, practical recommendations is posted on 167 pages as a whole. It consists of an introduction, references include 34 works in Russian, 121 works in English and 8 works in Azerbaijani. The volume of the dissertation (with the exception of gaps and pictures in the text, tables, graphs, appendices and list of reference) – 205400 characters (introduction – 21846, chapter I –51595, chapter II –34393, chapter III – 45997, chapter IV – 45707, result –2305 characters).

The personal contribution of the applicant in the research. The applicant was fully involved in all stages of the dissertation. She participated in the process of reviewing the recent research literature related to the topic, synthesizing the nanocomposites, investigating the structure, dielectric, optical, magnetic, mechanical, and thermal properties of nanocomposites, summarizing and analysing the results, and also preparing scientific articles, and conference proceedings.

CONTENT OF WORK

The introductory part of the dissertation reflects the relevance of the topic, the importance of research in this area, the purpose of the work, scientific innovation, the issues raised, the main provisions of the defence, the practical significance of the work.

The first chapter provides an overview of scientific and experimental research to determine the role of technological factors in the formation of the structure and properties of nanocomposites obtained by including ferromagnetic nanoparticles in the polymer matrix. Polymer-based magnetic nanocomposites are a class of materials that contains polymer matrix and nanoscale inorganic magnetic particles. The unique feature of these materials is related to the synergistic effect of components that make the final nanocomposite completely differ from individual components. Since the size of the magnetic filler is nanoscale, its properties vary from its bulk analogies. The polymer matrix ensures good processing of the obtained material and provides properties as effective mechanical, electrical, optical properties. Furthermore, polymer matrix plays the role of structure forming for distributed magnetic nanoparticles. The unique properties of polymer –based nanocomposites also depend on the nature of interface layer. From this point of view, magnetic nanocomposites based on polymers are very promising for obtaining materials with controlled magnetic properties. It is necessary to study the physical processes at the nanometre scale and develop their most effective obtaining method to produce such a class of materials. It became clear that the production technology of the polymer nanocomposites directly affects their characteristics such as the size of filler, distribution of the filler in the matrix, formation of supramolecular structure, the thickness of interphase layer between filler and matrix, etc. From this perspective, the ultra-small size and huge surface of nanofiller require the modification of the traditional methods and the introduction of new approaches to the production of composites. It is possible to control the magnetic properties of a new class of materials by just changing the size, shape, structure of the nanoparticles that they are based on. The properties of the polymer matrix depend on its supramolecular structure and the way of packaging structural elements. The size, configuration, and conformation of these structural elements define the supramolecular structure of the matrix and its properties. The continuous phase of polymer is filled by nanoparticles in order to produce nanocomposite. In this case, the adhesion between particle and filler directly depends on the size, structure, and shape of nanoparticles. The effect of technological conditions and external factors on properties of nanocomposites obtained by introducing of the ferromagnetic nanoparticles into the polymer matrix was investigated in this chapter.

In the second chapter, the choice of PP and PVDF polymers as a matrix and iron nanoparticles as fillers was substantiated, and important physical and chemical parameters were noted. The synthesis method of PP+Fe and PVDF+Fe nanocomposites is given, and the optimization of the production technology is discussed. Various modern and informative methods were used to identify and study the structure of the obtained nanocomposites. X-ray analysis, infrared and ultraviolet spectroscopy were used for the identification and structural investigation of polymer nanocomposites. Furthermore, scanning electron microscopy and atomic force microscopy were used to determine the nanoparticles distribution in the polymer matrix. Immittance meter E7-20 was used for studying the dielectric properties of obtained nanocomposites, namely, the dependence dielectric constant and dielectric loss tangent on frequency and temperature. Furthermore, the temperature dependence of resistivity was also investigated.

The third chapter describes the relation between structure and properties of the PP+Fe nanocomposites depending on Fe nanoparticles content in the polymer matrix.

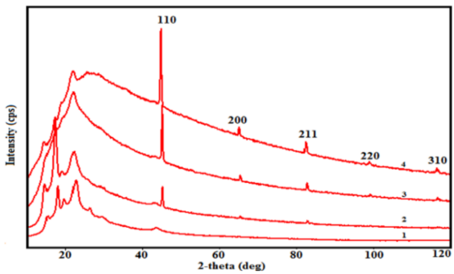

Figure 1. XRD pattern of PP polymer and PP+Fe nanocomposites: 1) PP, 2) PP+0.1%Fe, 3) PP+5%Fe, 4)PP+10%Fe

Figure 1 demonstrates the XRD patterns of PP+Fe nanocomposites. It is clear that with increasing the volume content of Fe nanoclusters in the PP matrix, the degree of crystallinity increases.

Fig. 2 shows AFM 3D images of nanocomposites based on PP+Fe with different volume content of iron. As it is seen with the addition of iron nanoparticles in the polymer matrix supramolecular structure varies greatly. This correlates well with the values of the average roughness of the surface of nanocomposites.

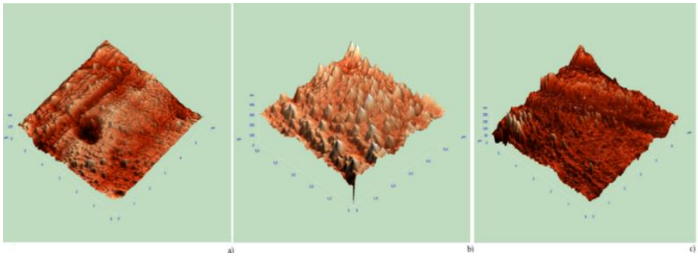

Figure 2. AFM 3D images of nanocomposites based on PP + Fe with different volume content of iron a) PP; b) PP+0,5%Fe;

Fig. 3. shows an AFM and MFM topography of nanocomposite PP + 5% Fe in the scanning area of 18 × 18 microns. MFM images were made in the dynamic mode, using the IMS needles coated with ferromagnetic material. Figure 3 (b) clearly shows the distribution of magnetic signals on the entire surface of the nanocomposite. MFM analysis has shown that dispersed nanoparticles of iron create around themselves a magnetic field, which leads to a change in the morphology of magnetic nanocomposites.

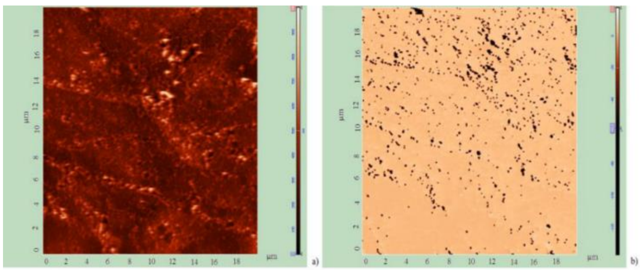

Figure 3. AFM (a)and MFM (b)topography of nanocomposite PP+5%Fe

During investigation of the dielectric properties of nanocomposites it became clear that, with increasing concentration of the nanoparticles in polymer matrix the conductivity of nanocomposite increases. The posistor effect is observed for PP+Fe nanocomposites in the temperature interval of 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.

Using SEM images, approximately 50 particle sizes were taken for statistical parameters calculation. Calculations show that the size distribution of Fe particles in the polymer matrix is fairly good and can be described by a lognormal distribution function[1].

$$f(x) = \frac{1}{\sqrt{2\pi\sigma \cdot x}} \cdot exp\left(-\frac{\left(ln\, x - \overline{ln\, x}\right)^2}{2\sigma^2}\right).$$

Figure 4 shows the lognormal distribution of Fe nanoparticles in the PP matrix at different filler contents.

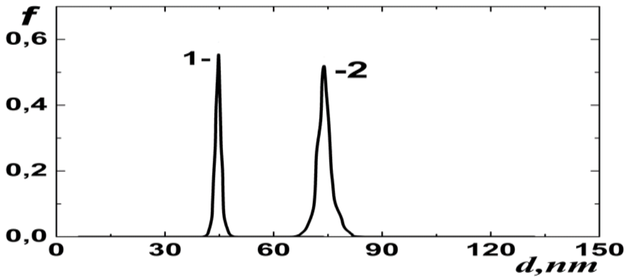

Figure 4. The log-normal size distribution function of Fe nanoparticles in the PP polymer matrix: a) PP+0.1% Fe, b) PP+10%Fe

The dependence of the average size of the nanoparticles in a polymer matrix on their concentration was investigated. According to figure 5, it is clear that the size of the Fe nanoparticle depends more sharply on its concentration. However, at high concentrations, such dependence is no longer observed, the dependence is weakened. It is directly related to the properties of the polymer matrix and nanoparticles.

The magnetic properties of PP+Fe nanocomposites were also studied experimentally, and the obtained results were compared with the theoretical calculations.

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[1]Awschalom, D.D., McCord, M.A., Grinstein, G. Observation of macroscopic spin phenomena in nanometer-scale magnets // Physical Review Letters, - 1990 65 (6),-p. 783-786.

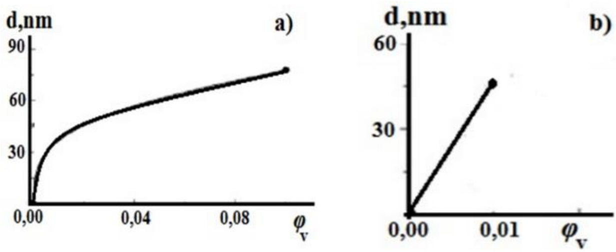

Figure 5. The dependence of the average size of the Fe nanoparticles in PP matrix on their concentration: a) Fe high concentration b) low concentration

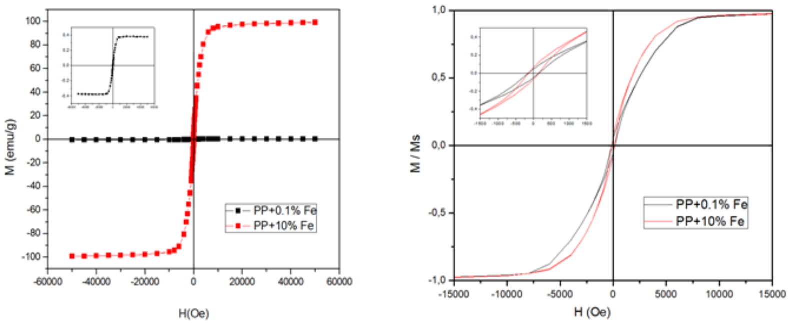

Figure 6. Magnetization versus magnetic field curves of PP+Fe based nanocomposites at 300 K: (a) magnetization versus magnetic field, (b) normalized magnetization versus magnetic field.

According to magnetization measurements, the saturation magnetization value Ms is 0.38 emu/g and 99.30 emu/g for PP+0.1%Fe and PP+10%Fe, respectively. Moreover, the value of the coercive field changes from 152 Oe to 143 Oe with increasing filler concentration.

The magnetoresistive effect was observed during the study of the magnetic field dependence of the electric resistance of PP + Fe nanocomposites (Figure 7).

The maximum value of magnetoresistance is observed when the Fe nanoparticles are isolated from each other by a dielectric layer of minimum thickness, and there is no interaction between them. The maximum value of magnetoresistance was observed for 5% of filler content. Further increase of the Fe nanoparticles in the composite leads to the ferromagnetic regulation of the magnetic moments of the nanoparticles and a decrease in the value of the magnetic resistance. The occurrence of the magnetoresistive effect in PP+Fe nanocomposites is associated with the tunnelling of electrons. This is explained by the morphology of such systems and the spin tunnelling of nanoparticle electrons through the potential barrier created by the polymer.

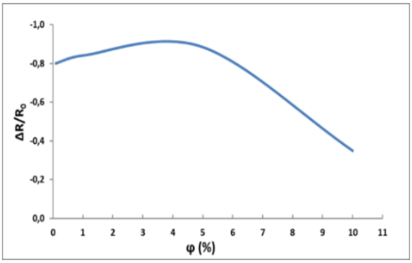

Figure 7. The dependence of magnetoresistance of PP+Fe based nanocomposite on filler concentration

The fourth chapter is devoted to the structure, physical properties of PVDF and Fe-based nanocomposites. Furthermore, the role of the interphase interaction and filler concentration in the formation of properties of PVDF+Fe nanocomposites were investigated. It was investigated that the characteristics of the interphase layer depend on the size, shape, distribution, concentration of the nano-size filler in the polymer matrix.

There are not any absorption maxima on the UV spectrum of Pure PVDF. However, the inclusion of the even low amount ((0.3 and 0.5 %) of the Fe nanoparticles into the PVDF matrix lead to the observation of new absorption maxima at 250, 265, 280 nm. With increasing of the iron nanoparticles concentration in the polymer matrix (1 və 5 %), the intensity of these maxima also increases (Fig 8). The raising of the maxima intensity by raising filler concentration shows the homogenous distribution of fillers in the matrix. Furthermore, it is also shown that at the 5% filler concentration, a new maximum appears on the UV spectrum of nanocomposite at 340 nm. It can be explained by the fact that at higher concentrations of the filler, agglomeration is occurring, which leads to the change in morphology of nanocomposite.

The morphology of the PVDF+Fe-based nanocomposites was studied by scanning electron microscope (Fig 9). The number and size of the iron agglomerates increase by raising filler concentration in the polymer matrix. However, for a given concentration the size of iron nanoparticles is relatively higher in the PVDF matrix compared with PP. Thus, while the size of iron nanoparticles for their 0,1% concentration in pp matrix is 24-42 nm, in PVDF for the same amount is 44-84 nm.

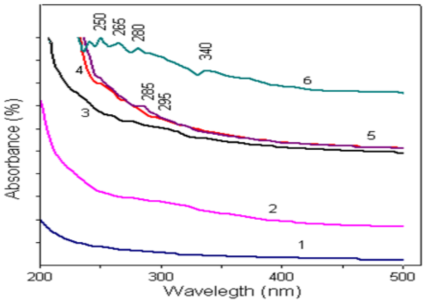

Figure 8. UV spectrum of the PVDF and PVDF+Fe based nanocomposites: 1) PVDF, 2) PVDF+0.1%Fe, 3) PVDF+0.3%Fe, 4) PVDF+0.5%Fe, 5) PVDF+1%Fe, 6) PVDF+5%Fe

The dielectric permittivity of PVDF+Fe nanocomposite depends on the iron concentration in the polymer matrix. The study of dielectric permittivity at the low-frequency region shows that for the high concentration (5 and 10 %) of filler by contrast to PP+Fe samples, the dielectric permittivity of PVDF+Fe composites is relatively higher. This difference is related to the polar nature of the PVDF matrix and high interphase polarization in PVDF+Fe nanocomposites.

The theoretical calculation of the size distribution of magnetic nanoparticles in polymer matrix and its influence on magnetic properties were also studied for PVDF+Fe nanocomposite. It is known that the size of filler depends on the concentration in the polymer matrix. It was investigated that the size of iron nanoparticles in the PVFD matrix for both low and high concentrations is bigger than that of in the PP matrix. This result demonstrates good agreement with the SEM investigation. Apart from some factors mentioned previously, the distribution of magnetic nanoparticles in the polymer matrix also depends on the polarity of the medium.

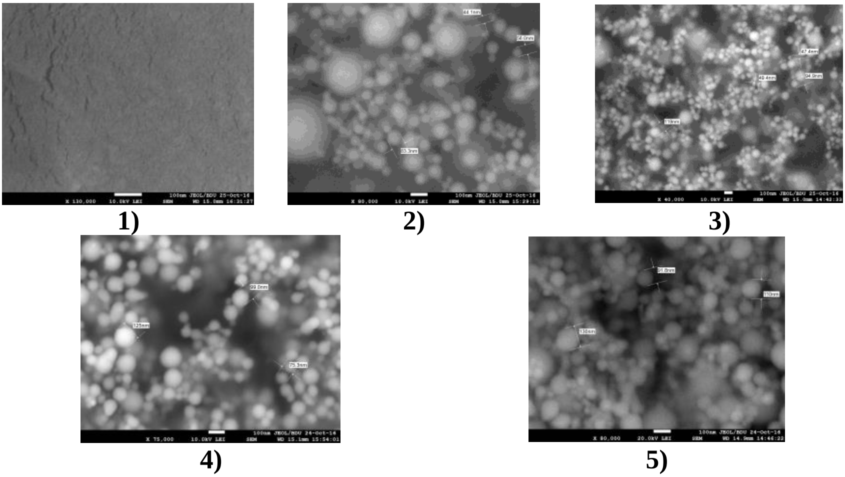

Figure 9. SEM images of the PVDF+Fe –based nanocomposites 1) PVDF, 2)PVDF+0.3%Fe, 3)PVDF+2%Fe, 4)PVDF+7%Fe, 5)PVDF+10%Fe

Furthermore, as can be seen from the distribution curves (Figure 10), the size of nanoparticles in the nanocomposite with 0.1%, 5%, 10% Fe content in the PVDF matrix varies between 45-60 nm, 75-90 nm, and 90-115 nm, respectively.

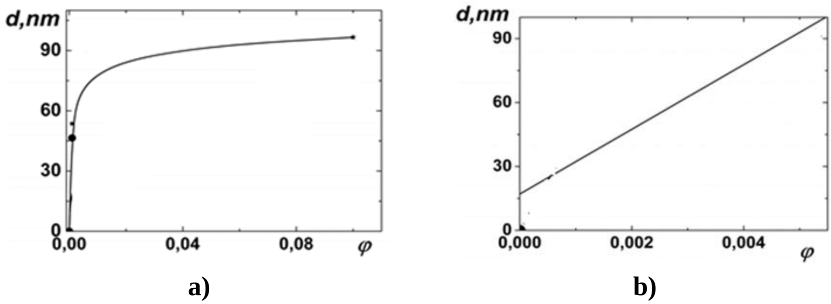

Figure 10. The dependence of the average size of the Fe nanoparticles in PVDF matrix on their concentration: a) Fe high concentration b) low concentration

The magnetization curves of PVDF+0.1 % Fe, PVDF+5%Fe, PVDF+10% Fe polymer nanocomposites were given in figure 12. The dependences of the special magnetization for PVDF+Fe based nano-composites on the magnetic field intensity has been investigated. It has been revealed that, with increasing magnetic field intensity the magnetization for PVDF+5% Fe based nanocomposites increased up to the 20 emu/g, for PVDF+10%Fe based nanocomposites it increased up to the 90 emu/g and then saturation occurs. It has also been determined that, as the volume content of Fe nanoparticle increases in the polymer matrix, the saturation magnetization also increases.

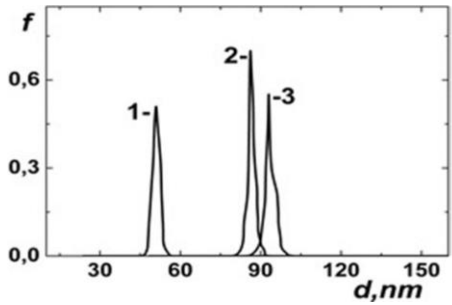

Figure 11. The log-normal size distribution function of Fe nanoparticles in the PVDF polymer matrix: a) PVDF+0.1% Fe b) PVDF+5%Fe c) PVDF+10%Fe

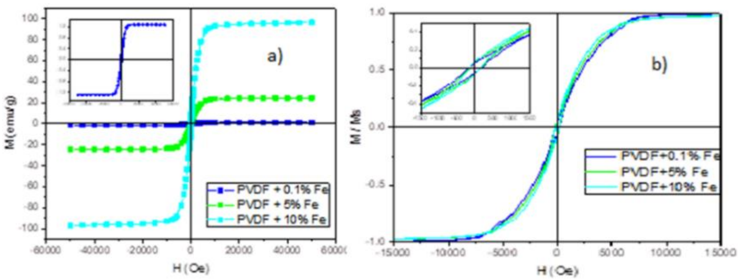

Figure 12. Magnetization versus magnetic field curves of PVDF+Fe based nanocomposites at 300 K: (a) magnetization versus magnetic field, (b) normalized magnetization versus magnetic field.

The shape of the magnetization curves suggests the presence of two magnetic phases: a soft one (iron) and a harder one responsible for the open loop observed at low field (inset of right panel). In the case of nanocomposite on the base PP+0.1%Fe, the magnetic content is so low, we arbitrary remove a diamagnetic contribution. It has been revealed that the volume content of Fe nanoparticle increases in the polymer matrix, coercivity increases till 5% volume content of Fe nanoparticles, then decrease is observed. As it is clear from m(H) curves of PVDF+Fe based nanocomposites, near to point zero remnant magnetization i.e. hysteresis has been observed. It can be related to the orientation of the surface spins with the increase in the volume content of nanoparticles in the polymer matrix. Furthermore, interface interaction between polymer and nanoparticles has a contribution to magnetic properties.

The magnetic resistance of PVDF+Fe nanocomposite increases with the increased iron content in the polymer matrix up to 1% of filler. With the incorporation of Fe nanoparticles into the PVDF matrix, the nanocomposite has multiferroic properties due to the formation of a magnetoelectric interaction at the PVDF/iron boundary. In this case, the polarized electric field changes the direction of magnetization of Fe nanoparticles, increasing the probability of transition depending on the interfacial spin. Further increase of the filler concentration leads to diminishing of the magnetoresistance effect. This is due to the increase in the size of magnetic nanoparticles in the polymer matrix with increasing volume.

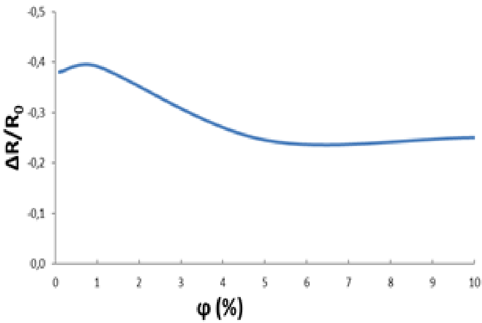

Figure 13. The dependence of magnetoresistance of PVDF+Fe based nanocomposite on filler concentration

It was investigated that the increasing filler concentration in the polymer matrix leads to enhancing the mechanical properties of the nanocomposite. The mechanical strength becomes maximum up to 1 % volume content of filler. Further, an increase in filler concentration causes a decrease in mechanical strength. An increase in the mechanical strength of PVDF+Fe nanocomposites at low filler concentrations is associated with good interfacial adhesion between Fe and the PVDF. This adhesion leads to the efficient transfer of stress from the polymer matrix to the nanoparticle. The mechanical stress efficiently distributes between the two phases. From this perspective, the interphase layer possesses a fundamental influence on the mechanical properties of the nanocomposite.

Materials that absorb electromagnetic waves are widely used in various fields of science and technology. It is primarily due to the demand to create different coatings that absorb electromagnetic waves in the microwave range. These classes of materials are usually obtained as a result of modification of non-absorbent (polymer, glass, ceramic) matrices with metallic or ferromagnetic ultra-disperse nanofillers. The absorption of electromagnetic waves by PP+Fe nanocomposites has been studied depending on the volume number of nanoparticles and the thickness of the sample. As noted, measurements were made in the 0.1 ÷ 30 GHz-high frequency electromagnetic waves range. With the introduction of Fe nanoparticles into the polymer matrix, its electromagnetic waves absorption ability relatively increases up to 20% concentration of the filler. It also was investigated that, for the same filler concentration the EM wave absorption was different for samples with various sample thicknesses. The absorption ability of the PP+30%Fe samples with 300 μm thickness is 2.7 %. However, the sample with the same percentage of filler and the thickness of 1mm demonstrates 2.5 times higher absorption ability- 6.9%. That is, as the thickness of the sample increases, the ability of nanocomposites to absorb EM waves increases. The increase in the EM-wave absorption ability of PP+Fe nanocomposites with the increasing iron concentration in the polymer can be explained by the raise in complex permittivity and the occurrence of suitable resistance characteristics as well as dielectric/magnetic losses. On the other hand, the relaxation processes in an interphase region between Fe nanoparticles and the polymer create fertile conditions for the energy losses, leading to the absorption of electromagnetic waves. Thus, PP + Fe nanocomposites are characterized by the absorption of electromagnetic waves at the radio wave region and are considered promising for various technological applications.

RESULTS

1. It was found that the increase in the intensity of the maximum in the X-ray spectra of PP+Fe and PVDF+Fe nanocomposites at certain values of the volume of Fe nanoparticles is associated with an increase in the degree of crystallization of nanocomposites. Disperse Fe nanoparticles settle in the amorphous phase of polycrystalline PP and play the role of structure centering, reducing the proportion of amorphous phase in the nanocomposite.

2. The nonlinear increase of the saturation magnetization in PP+Fe and PVDF+Fe nanocomposites depending on the Fe nanoparticles concentration is due to the orientation of surface spins in the polymer matrix as a result of dipole interactions and depends on the nature of the interfacial interaction between matrix and nanoparticles.

3. It has been found that increasing the concentration and size of Fe nanoparticles leads to an increase in the conductivity of nanocomposites. A decrease in the dielectric permittivity depending on the Fe nanoparticles concentration indicates the reduction in the polarization ability of nanocomposites.

4. Magnetoresistive effect was observed in nanocomposites with Fe nanoparticles. It was found that the negative magnetic resistance is related to the spin-dependent tunnelling of electrons between isolated magnetic nanoparticles through the polymer matrix.

5. Crystallization temperature of PP+Fe and PVDF+Fe nanocomposites rises by the increasing of the Fe nanoparticles concentration in polymer. Thermostability of nanocomposite is determined by the optimal value of the Fe nanoparticles concentration, as well as the interfacial interaction between the polymer and the filler (Fe).

6. It was found that the mechanical strength of PP+Fe and PVDF+Fe nanocomposites with 1% of Fe nanoparticles concentration is greater than that of pure polymers. The further increase in the concentration of Fe leads to a decrease in mechanical strength. The optimal mechanical parameters of the nanocomposites prove that at low concentrations, Fe nanoparticles play the role of nuclei for structure formation. However, at high concentrations, they play a destructive role in the nanocomposite.

7. The enhancement of the high-frequency electromagnetic waves absorption ability of PP+Fe nanocomposites by the increasing of the Fe nanoparticles concentration is determined by the rise of complex dielectric permittivity, dielectric/magnetic losses, and interfacial interaction between polymer and iron nanoparticles.

Author's publications on the subject of the PHD thesis

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