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Obtaining of magnetic polymeric fibers with additives of magnetite nanoparticle

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Abstract

Nanotechnology in recent years has become one of the most promising and fastest growing areas of science. As a result of availability, high adaptability to processes for obtaining and low toxicity to the human body iron oxide nanoparticles are promising materials for industry and medicine. Many uses of magnetite nanoparticles due to its special physical and chemical properties. Thus the use of magnetite as an additive to create a shielding material against electromagnetic radiation is of great interest of scientists. Using electrospinning method for the introduction of magnetic nanoparticles into the structure of polymer fibers opens up new possibilities for creating shielding materials from electromagnetic radiation. Electrospinning method allows the use of almost any soluble or fusible polymer. Due to this it will be possible to create protective clothing from electromagnetic radiation. Shielding clothing is also important for people with implanted (implanted) pacemakers - devices for controlling heart rate, because the operation of pacemakers may be disturbed by external electromagnetic radiation.

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Keywords: magnetic nanoparticles; polymethylmethacrylate (PMMA); nanocomposite; electrospinning

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1. Introduction

Magnetic nanoparticles are widely distributed in nature and encountered in many biological objects. Magnetic nano-materials used in the recording systems and storage of information in the new permanent magnet in a magnetic refrigeration system [1] as the magnetic sensors, etc. All this explains the great interest of specialists in various fields to such systems. As a result of availability, high adaptability to processes for obtaining and low toxicity to the human body iron oxide nanoparticles are promising materials for industry and medicine.

The most common method of producing nanoparticles of magnetite - a liquid phase chemical condensation method proposed by Elmore [2], which is based on the deposition of salts and ferric iron with concentrated aqueous ammonia. Magnetite belongs to class spinel ferrites, which have crystal lattice noble spinel $MgAl_2O_4$ [3] of the general formula $MeFe_2O_4$. Many uses of magnetite nanoparticles due to its special physical and chemical properties. Thus the use of magnetite as an additive to create a shielding material against electromagnetic radiation is of great interest of scientists. Radio frequency energy, formed by the radio electronic means, different from the natural background on their frequency and power characteristics, and further contributes to the response of biological objects. Often the response of biological objects are difficult to predict and are complex [4,5]. There are three shielding mechanisms that could result in attenuation of EMI viz. reflection (R), absorption (A), and multiple reflections (B). The main mechanism for shielding in highly electrically conductive structures, such as metals, is reflection. Reflection relies on mobile charge carriers, such as electrons, being present within the material. [6] Therefore, the shielding material tends to be electrically conductive, although this is not an essential requirement for shielding [7]. Electrical conduction requires connectivity in the conduction path, whereas shielding does not [7]. Thus, high electrical conductivity is not typically a requirement for shielding, but shielding was found to be enhanced by connectivity [7] [8].

At the present time for the protection of the body is used clothing from metallized textiles and radar absorbing materials. Metallic fabric is made of cotton or nylon yarn entwined with, or combined with a thin metal wire. The fabric becomes similar to the metal shield grid [9]. These clothes is very uncomfortable and conducts electricity, which does not allow the use of any conditions for repair and adjustment work in emergency situations. Using electrospinning method for the introduction of magnetic nanoparticles into the structure of polymer fibers opens up new possibilities for creating shielding materials from electromagnetic radiation. Electrospinning method allows the use of almost any soluble or fusible polymer. Due to this it will be possible to create protective clothing from electromagnetic radiation. Shielding clothing is also important for people with implanted (implanted) pacemakers - devices for controlling heart rate, because the operation of pacemakers may be disturbed by external electromagnetic radiation.

2. Experimental part

Synthesis of Magnetite Nanoparticles by liquid phase chemical condensation method is the most promising, due to the simplicity and efficiency of the method, the ability to control particle dispersion obtained by varying the temperature and concentration of the initial reactants. In the paper for the synthesis of magnetite iron sulphate $FeSO_4 \cdot 7H_2O$ was used, iron trichloride $FeCl_3 \cdot 6H_2O$, and 25% aqueous ammonia solution. During the synthesis 1.806 g of $FeSO_4 \cdot 7H_2O$ and 2.811 g of $FeCl_3 \cdot 6H_2O$ was dissolved in 75 ml of distilled water and placed in an ultrasonic bath. The further synthesis was carried out at constant application of ultrasound while the temperature of the solution of iron salt is maintained at 50 ° C. In the iron salt solution with a rate of one drop per second, 20 ml of aqueous NH_4OH solution. The resulting precipitate was filtered and washed with distilled water to neutral pH and dried to completely remove water. The resulting magnetite nanoparticles were used as an additive in forming ultrafine fibers by electrospinning.

As the fiber-forming material used was a 3% by weight. polymethylmethacrylate (PMMA) was dissolved in dichloroethane additives previously synthesized nanoparticles of magnetite. This mixture was placed in a syringe with a needle, the needle was fed to a metal negative charge and a positive substrate. The voltage supplied by the source of constant voltage. Tension was - 9 - 16 kV. The interelectrode distance was 30 cm. The polymer solution flow was 60 l / s, corresponding to an optimum exit velocity of the solution in which the whole solution was drawn off into fibers. The morphology of the fiber composite PMMA / magnetite was investigated using scanning electron microscopy.

3. Results and discussion

To establish the structure and morphology of obtained magnetite nanoparticles were examined with a scanning and transmission electron microscopy, X-ray analysis and EDAX analysis. Results of XRD analysis shows that the sample is a single phase of Fe3O4 magnetite with cubic crystal system. The XRD pattern (Figure 1) of the sample has a great background, characteristic diffraction patterns of iron compounds obtained on copper radiation. The crystallite size of iron oxide found by Scherrer's formula equal = 130.0 Å.

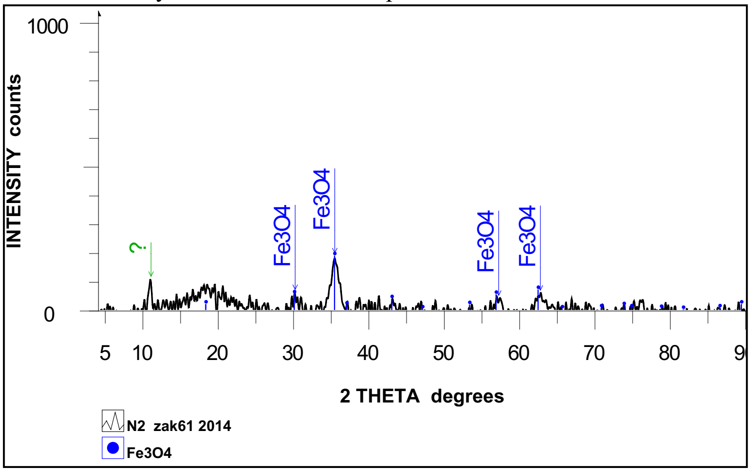


Figure 1 – XRD pattern of Fe_3O_4 magnetite

To determine the morphology and size of nanoparticles were studied by scanning and transmission electron microscopy (Figure 2).

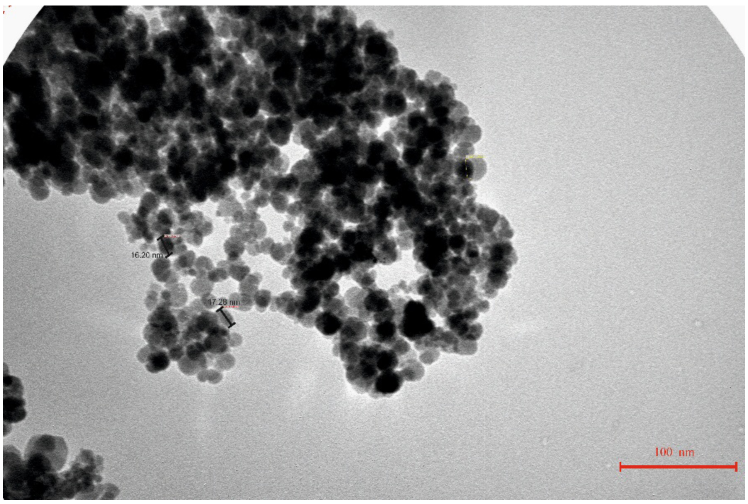
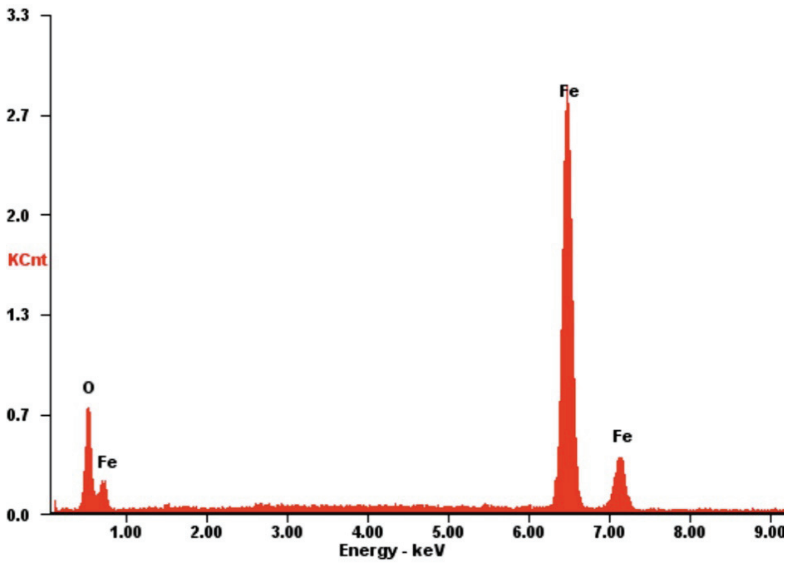


Fig. 2 - TEM image of magnetite nanoparticles

As seen from the SEM and TEM images obtained magnetite nanoparticles are a product with a homogeneous particle size range of 15-30 nm.

Figure 3 shows the energy-dispersive spectrum and the elemental composition of the nanoparticles.

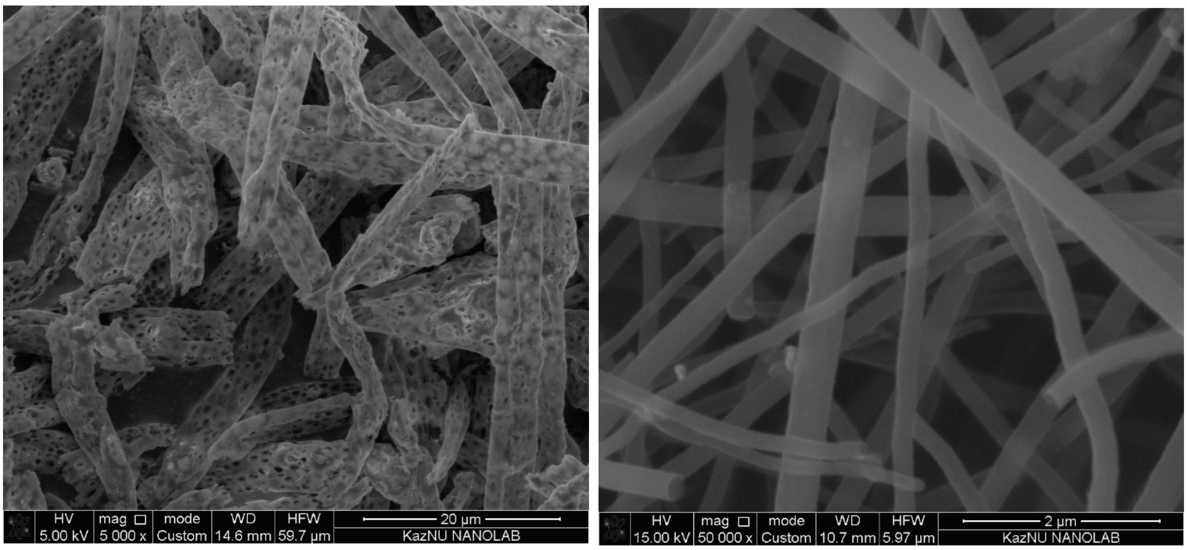
On the basis of magnetite nanoparticles were synthesized ultrafine composite fibers obtained PMMA / Fe3O4, which were examined with a scanning electron microscope (Figure 4). Also note the size of the nanoparticles have a small variation, which is important for the method of electrospinning. To compare and visual illustration the effect of Fe3O4 addition, Figure 4 shows the SEM images of PMMA fibers without additives (a) and with the addition of nanoparticles of magnetite (b).



Element	Wt%	At%
O	25.70	54.67
Fe	74.30	45.33

a b

Fig. 3 - Energy dispersive spectrum (a) and the elemental composition (b) of magnetite



a b

Fig. 4 - SEM images of PMMA fibers without additives (a) and adding (b) Magnetite nanoparticles

As seen from the SEM pictures, the addition of magnetite particles to a polymer precursor, largely affects the shape, size and structure of the obtained fibers. The diameter of the obtained composite PMMA / Fe3O4 fibers lies in the range 5-10 µm, and has a porous structure wherein the pores are evenly distributed across the surface of the composite fiber.

Production of polymer fibers with the addition of magnetite nanoparticles by electrospinning opens up new possibilities for the creation of polymers with magnetic properties. With their help, you can create a shield clothes against electromagnetic radiation are not only for clothing but also for everyday life. Polymer fibers with additives magnetite nanoparticles can be used as additives to concrete, to enhance the shielding properties. At the same time the magnetic properties of polymers can be used not only as the shielding material but also in various fields of science and technology.

CONCLUSION

Results of experiments shows that by method of liquid-phase condensation can be synthesized the Fe3O4-magnetic nanoparticles with diameter 15-30 nm. This method is easy to implement and effective even in mass production. These magnetite nanoparticles as additive for formation of PMMA-based electrospun-composite fibers were used. We successfully prepared PMMA-based multi-functional magnetic composite ultrathin fibers by a single-step electrospinning process. The fabrication technique was simple, and the materials used were inexpensive. Obtained PMMA/Fe3O4 composite fibers have porous structure and diameter 5-10 nm. The resulting composite fibers have perspective in use as catalysts and shielding materials from electromagnetic radiation.

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