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Magnetic Fabric: Development of Component Composition and Production Technology

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Abstract—The developed methods for mechanical dispersion of strontium ferrite and activation of the fiber base in low-temperature corona discharge plasma, as well as immobilization of high-coercivity nano- and microparticles in the fibrous material are fundamental technological processes for establishment of industrial production of anisotropic magnetic fabrics. Clothes made from magnetic fabrics, generating a magnetic field in the environment, ensure efficient protection of the human body under extreme conditions (activating adaptive-regenerating functions) and make it possible to perform magnetic therapy in the course of medical treatment and prevention of many diseases.

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INTRODUCTION

The technological order formed at the current state of development of the global economy is based on nanotechnologies and nanomaterials, the efficiency of which is at present reliably demonstrated. The most important task of modern nanoengineering is stabilization of nanosized formations in order to preserve their unique functional properties. Polymer-based nanocomposites are quite numerous and diverse, as polymers are used both as a matrix and a stabilizer for nanoparticles. A frequent case of polymer nanocomposite materials is fiber-based nanocomposites.

The greatest advantage of fiber-based nanocomposites is their adaptability to the human body, which makes it possible to use them for protection and medical treatment without applying special bulky installations, for example, using electromagnets creating a magnetic field. Feasibility and efficiency of the constant magnetic field application for medical prevention and treatment of almost all human systems is reliably demonstrated by the medical science and practice [1, 2].

The human body has a great number of structural formations, which are significantly and – in some cases – radically affected by a magnetic field, including moving electrons in atoms, blood ions and molecules of different nature, liquid crystals of membranes etc. Different processes take place in the structural formations of the human body under the influence of the magnetic field: electric charges appear, concentration changes and orientation processes take place, there are changes in the quasicrystalline structure and activation of ions, erythrocytes start forming chains etc. The processes and structural changes taking place in the human body under the influence of the magnetic field can cause changes in the activity of all body systems; the most significant of the changes are related to the nervous system activity (cerebral cortex, hypothalamus, midbrain, and peripheral nervous system).

In medical practice the modern magnetic therapy has been used for many decades. Efficiency of the magnetic therapy in medical treatment and prevention of almost all diseases, for example, strokes, kidney inflammations, cardiovascular diseases, metabolic disorders, radiculitis, musculoskeletal system inflammations, headaches etc. is justified.

One of the most important reasons restricting the magnetic field application is related to the magnetic field sources. Many of them can only be used in stationary conditions, as their weight ranges from several to hundreds of kilograms. Almost all magnets, including magnets manufactured on an elastic polymer base, do not adhere to the body surface, especially at sites with a complex geometrical surface, whereas an increase in the gap between the magnetic material and the body surface from 5 to 20 mm results in a 100-fold decrease in the magnetic field induction.

The solution to the problem can be to create a magnetic field source in the form of a nanostructured magnetic fabric. It will be possible to manufacture both outerwear and underwear elements from such fabrics using the sewing technology; application of such clothes will make it possible for people to receive magnetic therapy while carrying out different functional activities at work and at home. As more than a billion people need prevention and treatment of diseases with the use of magnetic therapy, the demand for magnetic fabric is substantial.

Magnetic therapy based on application of magnetic fabrics is the most relevant for people working under stressful conditions, during preparation for performance of works under such conditions, in the course of such works, and during the adaptation period following the completion of works. For example, it can be applied to such categories of people as staff members of the Ministry of Emergency Situations and security agencies, astronauts, sportsmen, and polar explorers. Also, magnetic fabrics can be used for creation of complex configuration magnetic fields in electronics and nanoelectronics, as well as for protection from electromagnetic and acoustic waves and vibration effects. The present work considers the component composition and the technology for production of magnetic fabrics, the functional purpose of which is to create magnetic fields in the environment.

Magnetic Materials and Fiber Base for Formation of Nanostructured Magnetic Fabrics

To ensure stability of a magnetic field formed near the surface of the fibrous material ferromagnetic particles has to possess high coercivity, depending on magnetic crystallographic anisotropy of the material particles, anisotropy of the particles themselves, and their distribution in the fibrous matrix, as well as on the particle size, the reduction of which to the critical single-domain size causes an increase in coercivity by a factor of tens, and on the ambient temperature, as in case of the temperature increase to the Curie point ferromagnetic particles undergo a transition into the paramagnetic state.

In case of necessity to change the magnetic field created by the fabric by an external magnetic field it is necessary to transfer magnetic particles into the superparamagnetic state, in which magnetic susceptibility can be significantly higher than in the paramagnetic state. It is possible to achieve superparamagnetism of particles changing the magnetic moment of their surface zone by varying the parameters of the mechanical dispersion technology, in particular, by decreasing their size to 10 nm and less. Such particles can be located in interfibrillar pores and pores of the fibers amorphous zones in the fiber base.

To achieve the required level of induction of the magnetic field created by the magnetic fabric in the environment it is necessary to ensure the corresponding value of remanence of the particles material, as well as to obtain magnetic texture by using particles of different shape and orientating the particles by an external magnetic field.

A fundamental factor determining both the magnetic properties of magnetic composites and nanocomposites and the technology for production of functional magnetic materials is the transition of the ferromagnetic multi-domain system into single-domain. Fragmentation of ferromagnetic particles results in a reduction in their total energy, consisting of magnetostatic energy proportional to the particle volume and the particle surface energy proportional to the square size of the particle. When the particle reaches a certain critical size, in case of spherical particles it is a single-domain diameter [3–7], it is energetically advantageous for the particle not to have domain boundaries.

Magnetic properties of single-domain particles (nanoparticles) and composites embracing such particles can be controlled by changing their composition, homogeneity, defectiveness, surface anisotropy, shape anisotropy, anisotropy of the particles distribution, and packing density of the matrix.

The dielectric capillary-porous fiber base is both a good stabilizer for ferromagnetic particles and a matrix for optimal distribution of nano- and microparticles of different size.

The most wide-spread nanosized single-domain ferromagnetic materials include [5] α- and g-Fe, amorphous iron, cobalt, nickel, wustite, hematite, maghemite, magnetite, goethite, alloys of Fe-Co, Fe-Ni, Fe-Pt, Co-Pt, Nd-Fe-B, $SmCo_5$, $BaO \cdot 6Fe_2O_3$, $SrO \cdot 6Fe_2O_3$, and $CoOFe_2O_3$.

Table 1. Magnetic characteristics of modern hard-magnetic materials and their costs [8, 9]

Production method, material grade	Remanence, T	Coercivity, kA/m	Energy characteristic $(BH)_{max}$, kJ/m^3	Working temperature, °C	Average cost, RUR/kg (2005)
Casting, UND	0.6	39	9.2	450	
Casting, UNDK	0.72–1.16	51–52	15.5–37.5	450–500	26
Casting, UNDKT	0.85–1.33	54–117	36–84	500–550	
Sintered ferrites of barium and strontium, FT	0.2–0.41	125–267	6.2–32.5	250	4.5
Rare-earth sintered materials $SmCo_5$ and Sm_2Co_{17}	0.78–0.97	550–700	112–185	230–300	110
Rare-earth sintered alloys of Nd-Fe-B composition	1.06–1.23	825–900	210–270	150–180	90

For selection of a high-coercivity material used as a component introduced into the fabric in order to create a magnetic field in the environment all groups of materials applied for production of permanent magnets, including cast permanent magnets, sintered ferrites, and rare-earth sintered magnets, were considered.

Table 1 provides grades, costs, and magnetic characteristics of materials from various groups.

Cast materials are characterized by increased values of the working temperature (450–550°C), remanence, and energy product as compared to ferrites. It is found that obtainment of UNDK-grade (AlNiCo) alloy powder using mechanical dispersion is associated with intensive deformation of the material, which causes a reduction in its coercivity to 25 kA m^{-1}. It is impossible to obtain powder in the form of nanosized particles from this alloy. The minimal size of particles obtained as a result of grinding of this alloy in the mill is 100 μm. Moreover, in the course of milling of UNDK-grade (AlNiCo) alloys oxidation of the material takes place; the share of the oxidized surface reaches 73%. In some cases, ignition of the material particles in the mill was observed. After grinding the magnetic properties of cast alloys are reduced as follows: coercivity by 27%, remanence by 7.6%, and energy product by 36%. It is impossible to improve the magnetic properties of such materials with reheat treatment as at homogenization in an inert atmosphere at 1240°C the powder particles coagulate to sizes exceeding 100 μm.

Powders of $SmCo_5$ and Sm_2Co_{17} alloys oxidize more intensively as compared to cast alloy powders. The powder of Nd-Fe-B cast alloy ignites even in case inert gas is supplied into the grinding zone: a negligible amount of oxygen penetrating into the mill from the material feeding zone is sufficient for this powder to ignite. In the process of grinding of strontium, barium, and cobalt ferrites to nanosized particles the powder neither ignites nor oxidizes; however, the values of all basic magnetic properties are reduced by (20–30)%, which is related to deformations of the material surface area and changes in the oxygen balance in the ferrite sublattices.

Mechanical dispersion of strontium ferrite to nanosized particles is possible, as the reduction in magnetic properties of this material in the course of grinding can be eliminated by additional thermomagnetic treatment of the strontium ferrite powder at temperatures of up to 1100°C. There is no coagulation of particles as a result of heating.

With regard to economic indicators strontium ferrite is the most preferable high-coercivity material for obtainment of nanosized particles.

Taking into account the data provided above, in our work we used strontium and cobalt ferrites for production of magnetic fabrics.

A possibility to obtain magnetic fabrics with acceptable indicators of magnetic and strength properties is largely determined by the structure of the fibrous matrix.

The fibrous matrix is a promising material for creation of functional and multifunctional nanocomposites. It stabilizes nonequilibrium nanoparticles, ensures physical and chemical interaction of nanoparticles with structural formations of the fibers at the molecular and supermolecular levels. Fibrous nanocomposites are characterized by flexibility, elasticity, crack resistance, and adaptability to the human body.

Table 2. Pore structure of certain fiber and fabric types

Fiber or fabric type	Share of pores (%) of specified size, nm									Specific volume of pores in material, cm^3 g^{-1}
	0.5–1.2	1.2–3	3–5	5–7	7–15	15–150	150–500	500–950	950–2200	
Cotton fiber	21.2	27.2	24.0	18.6	9.0	0	0	0	0	0.16
Cotton fabric	5.1	5.5	7.5	5.6	2.6	18.6	12.0	29.6	13.5	1.32
Aramid fiber	19.8	24.5	26.1	19.6	10.0	0	0	0	0	0.12
Aramid fabric	6.5	7.8	6.8	5.5	4.1	10.0	5.2	39.6	14.5	1.10

Fibrous materials belong to the group of capillary-porous bodies. For the formation of fiber-based nanocomposites it is possible to use the pores existing in the base; in this case the size and volume content of the pores are extremely important.

Parameters of the porous structure of fibrous materials are determined by changes in the moisture content of the fibers and fabrics at drying and humidifying [10, 11]. Within the framework of the present work the moisture content of the fibrous material was measured on the basis of the steaming method, which made it possible to fill the pores of the fibers with water molecules in the form of steam more fully; moreover, in this case it was possible to provide more accurate judgment on the mechanism of interaction of water molecules with the fibers.

With a number of simplifications adopted, the methodology presented in works [10, 11] was used to calculate the parameters of the porous structure of aramid and cotton fibers, as well as of cotton and aramid fabrics (Table 2).

Pores below 15 nm in size are intrafiber pores of the molecular and supermolecular levels. In cotton fibers there are almost 30% more pores of this size than in aramid fibers. In cotton and aramid fabrics the specific volume of pores exceeds similar indicator for the fibers by a factor of 8 and 9, respectively, i.e. interfiber and interfilament pores account for the major share of pores in these fabrics.

Immobilization of Strontium Ferrite Particles in Fiber Base

Before the magnetic fabric production based on the immobilization method it is necessary to perform three technological operations: preparation of the fiber base, dispersion of the strontium ferrite particles, and obtainment of the metal-polymer composition. Let us consider these operations.

Preparation of the fabric involves activation of fibers under the influence of an environment containing ions and molecules in the excited state, electrons, and electromagnetic radiation quanta. Low-temperature plasma is usually used to form such an environment [12–15]. It is obtained in a low-pressure environment. The efficiency of its modifying effects on fibers is caused by a great length of the free path of ions and electrons (10^{-1}–10^{-5} m) and their great energy of 100 and 350 eV, respectively. The disadvantage of low-pressure plasma is great energy consumption for vacuum creation and the necessity to use precision equipment. An alternative to low-pressure plasma is corona discharge plasma created at atmospheric pressure, i.e. in this case there is no necessity for vacuum and complex equipment. The temperature and velocity of electrons and ions in corona discharge plasma are nearly the same as in low-pressure plasma, while the energy consumed in case of applying corona discharge plasma is approximately three orders of magnitude lower than the energy spent in case low-pressure plasma is used. However, in corona discharge plasma the length of the free path of particles causing the fibers activation is by 2–5 orders of magnitude smaller. It is possible to raise the efficiency of corona discharge plasma by increasing the length of the free path of electrons, ions, and molecules in the excited state.

In order to identify the factors influencing the free path length that can be altered the model of the corona discharge from the needle was developed (see figure). The following assumptions were made [12, 14]. The corona discharge is stationary, including its initial phase. Differences in the filed intensity at different time intervals are minor and it is possible to use average values of the electric charge volume density in calculations. In connection with the fact that the ionization zone is many orders of magnitude smaller than the outer zone where the fiber is located, it is possible to assume that ions enter the interelectrode space directly from the needle. The critical intensity of the electric field is equal to the intensity at the corona needle surface at the moment of the corona discharge formation.

Within the framework of this model it is possible to find the density of the electric charges in the outer zone of the corona discharge (in A and B zones) by solving the equation:

$$\partial\rho/\partial t + \upsilon\,\mathrm{grad}\rho = D\Delta\rho - B\rho^2, \tag{1}$$

where ρ is a volume charge density; υ is a charge velocity; D is a diffusion coefficient; Δ is aLaplace operator; B is a ion mobility coefficient; and t is a time.

As the density of molecules in the environment under consideration is high, it is possible to neglect diffusion of ions as compared to their directional movement under the influence of the electric field. With some more simplifications adopted, as a result we obtain the following equation:

$$\partial\rho/\partial t = -B\rho^2. \tag{2}$$

Let us apply this equation to A and B zones and express the coefficients as follows: B_A and B_B, respectively, are values determined by the mobility of ions in the air and in the air–fiber mixture:

$$B_\mathrm{A} = \frac{k_\mathrm{A}}{\varepsilon_\mathrm{A}\varepsilon_0};\ B_\mathrm{B} = \frac{k_\mathrm{B}}{\varepsilon_\mathrm{B}\varepsilon_0}, \tag{3}$$

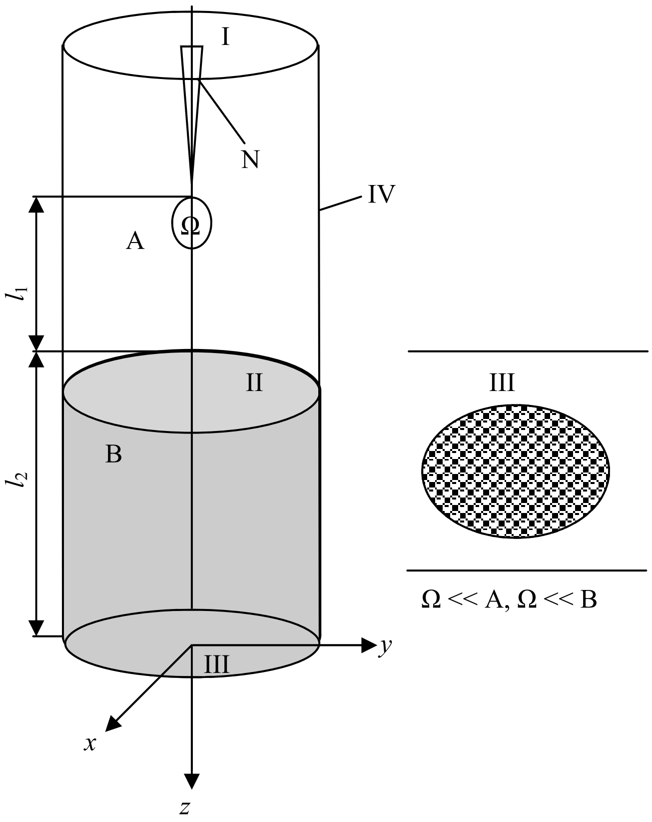
where k_A and k_B are ion mobility in the air and in the air–fiber mixture.

By integrating Eq. (2) within a range from 0 to t:

$$\rho^{-2}d\rho = -B\int_0^t dt, \tag{4}$$

we can find the value of volume density of charges – electrons and ions in different zones of the corona discharge. Knowing the volume charge density and applying Poisson's equation we can determine the electric field characteristics: intensity and potential.

Analysis of the obtained ratios leads to a conclusion that in order to increase the density of ions in the zone of the fibers location it is possible to change the two parameters: the distance from the corona needle to the fibers and the velocity of charges in A and B zones, which is equal to the velocity of the electric wind in the corona discharge of 0.2 m s^{-1}. In our experiments we used a perforated lower electrode, installing an air blower under the electrode, which made it possible to increase the charge velocity in A and B zones from 0.2 to 5.2 m s^{-1}. As a result of these measures and a decrease in the distance between the fabric and the corona needle to 5 mm the volume charge density in the zone of the fibers location increased approximately 40-fold.



Model of corona discharge from needle: (I) needle fastening plane; (II) plane of the fibers upper boundary; (III) perforated electrode, the fibers lower boundary; (IV) cylindrical surface limiting the corona zone in the air; (Ω) ionization zone (corona hood); (A) outer zone of the corona discharge in the air; (B) outer zone of the corona discharge in the fiber; (N) needle.

The IR spectroscopy method was used to determine intensification of the modifying effects of the corona discharge, created at the installation upgraded by us, on cotton fibers: at the molecular level an increase in the number of nonequivalent states of hydroxyl and methylene groups was observed, while at the microstructural level there was growth in the share of amorphous zones. A two-fold increase in the width of the zones of nematic methoxybenzylidene butylaniline with distorted homeotropic orientation upon contact with the surface of the fibers was also detected.

Dispersion of strontium ferrite particles, the original size of which amounted to 1–100 μm, was carried out in a three-stage mill (with the rotor speed reaching 10 000 rpm). The velocity of particles at each of the three stages amounts to 70, 100, and 160 m s^{-1}. Dispersion is performed through collisions of the particles with the rotor beaters and reflective panels of the mill, as well as through mutual collisions of the particles. The dispersion parameters and duration were determined experimentally. In order to evaluate applicability of the powder obtained as a result of the dispersion the powder particles were divided into the following groups: 0.5–15 nm; 15–500 nm; 500–950 nm; and 950–2200 nm.

Nanoparticles of the first group can fill the pores between между macromolecules, microfibrils, and fibrils. The share of such pores in fabrics is ~26%. Due to their small size particles of this group can be in the superparamagnetic state; however, in case of introduction into the fibers the surface areas of the particles interact with the activated functional groups of the fibers and Langen's fluctuations of their magnetic moments at room temperature are unlikely. According to the data [16, 17] particles of the second group are single-domain; they are located in pores, cracks, fractures, ruptures, and other microstructural defects of fibers, as well as in interfiber pores. The share of such pores in fabrics is 15–30%. Particles of the third group are also single-domain [16, 17]; they are located in interfiber and interfilament pores. The share of such pores in fabrics reaches 30–40%. Particles of the fourth group are more than 1 μm in size; their single-domain character is unlikely; the share of such particles should be minimal.

After single grinding the relative content of particles of the first, second, third, and fourth group was 7, 32, 46, and 15%, respectively. Particles of the first group were insufficient to fill the pores reaching 15 nm in size, while the share of large particles was as great as 15%. After double grinding the share of the first group particles increased to 24% and the share of the fourth group particles decreased to 7%, while the share of the second and third group particles amounted to 31 and 38%, respectively. As can be seen, after double grinding the ratio of the shares of pores and strontium ferrite particles is satisfactory. Thus, double ground ferromagnetic powder is required for production of magnetic fabrics.

After double grinding remanence and coercivity of the obtained powder are 25–30% lower. The reduction in the magnetic properties can be explained by plastic deformation of the surface areas, formation of additional amorphous zones, and breach of the ferromagnetic oxygen stoichiometry [3, 18]. Restoration of the magnetic properties at the previous level was achieved applying additional thermomagnetic treatment: at 450°C in a magnetic field (magnetic induction of ~1 T) and at 980°C for a period of 1 h with no magnetic field, which is in line with the data [18].

The metal-polymer composition, which was used for immobilization of the ferromagnetic component in the fabric, was obtained in compliance with the recommendations [19, 20]. The metal-polymer composition, consisting of an aqueous dispersion of acrylate latex, emulsifier, acrylic thickener, plasticizer, and strontium ferrite powder, ensured the formation of physico-chemical bonds between the ferromagnetic particles and the fiber base.

In order to obtain a homogeneous mixture all components were put into a paddle-blade mixer and mixed at a temperature of 45°C for 20 minutes at the angular velocity of the blade shaft rotation of 6.5 s^{-1}. The mixture quality was evaluated on the basis of the two criteria: the mixture viscosity and the particle distribution in the fabric pores. The mixture viscosity amounted to 20–25 Pa×s. Using the developed composition it is possible to achieve uniform distribution of strontium ferrite particles in the fabric pores, including intrafiber pores, and formation of strong bonds in the system of the fibrous matrix–polymer–ferromagnetic particles.

The sequence of operations for obtainment of the magnetic fabric is as follows:

– immobilization of the composition in the fabric;

– polymerization of the composition in the fabric, exposure at 100°C in the furnace for 20 minutes;

– magnetization of the fabric in a magnetic field with the induction of 2 T.

By changing the magnetic component content in the fabric it is possible to alter the induction of the magnetic field, created by the fabric near its surface, from 5 to 70 mT. The magnetic fabric possesses 20–30% higher deformation and strength properties as compared to the original fabric.

The obtained samples of the magnetic fabric were used for production of magnetic protective suits.

Efficiency of the suits application for activation of the adaptive-regenerating functions of the human body was tested in collaboration with specialists in physical therapy and disaster medicine. Tests with the participation of a group of 30 people working under conditions close to firefighters' real working conditions were performed. It was found that the experiment participants, who used the magnetic fabric protective suits, had a more optimal distribution of individual components of the vegetative support, an increased stability of the health index, and a reduced value of the biological age indicator.

Magnetic Fabric Production Based on Extraction-Pyrolysis Method

For introduction of functional components into the fibrous material it is possible to apply technological methods proven in the course of development of solution methods for production of thin films. These methods are highly efficient for formation of nanostructured thin films due to implementation of the self-organization and self-ordering processes. The film application process can be automated; it is possible to obtain layers of sufficient quality, controlled thickness, and required composition. Moreover, these methods are low-cost [21–23].

Among well-known methods of coating formation (thermal decomposition of aerosols, spray pyrolysis, sol-gel etc.) the extraction-pyrolysis method makes it possible to obtain nanostructured thin films of a given composition and high purity from low-purity source raw materials. It is a universal method, applicable for production of simple and complex functional oxide materials.

In relation to manufacturing of the magnetic fabric the extraction-pyrolysis method is based on obtainment of an organic extract containing components that can form ferromagnetic compounds (in particular, complex oxide) followed by pyrolysis of the extract on the textile material impregnated with the extract.

Currently used extraction agents can extract the majority of metals existing in aqueous solutions both in the cationic and anionic forms, as well as anions of inorganic acids. Efficient separation of the components with the use of extraction agents ensures fine purification of functional materials.

With regard to synthesis of ferromagnetic nanosized particles in the fabric the extraction-pyrolysis method possesses such advantages [21–23] as a possibility to use cheap raw materials, including industrial waste materials, extensive decontamination from impurities, and a possibility to produce materials with a varied content of target components.

In our work synthesis of cobalt ferrite magnetic nanoparticles in the fabric was implemented. This compound is characterized by an increased value of the magnetic crystallographic anisotropy constant (up to 10^6 erg/cm^3) and, correspondingly, an increased value of coercivity in the process of magnetization reversal of homogeneous nanosized particles. Apart from that, cobalt ferrite has a high Curie point and, consequently, an increased thermal stability.

The salts of $FeCl_3$ and $CoCl_2$ were used as starting materials for the synthesis of ferrite. On the basis of the cation-exchange extraction method using an organic extraction agent the cations of these salts passed from the aqueous solution into the organic phase.

The extraction agent consisted of a mixture of carboxylic acids, including caprylic, capric, enanthic, pelargonic, malonic, and succinic acids. Extracts containing iron and cobalt carboxylates were used as precursors for the complex oxide production.

The technology for synthesis of the complex oxide was developed on the basis of the data of thermogravimetric analysis of the carboxylates. When heated iron carboxylate decomposes in three stages. At the first stage (200–255°C) 35% of the compound mass is lost, at the second stage (255–380°C) the value reaches 40%, and at the third stage (380–465°C) it is 9%. It follows from the analysis of the thermogravimetric method data that the iron oxide is formed within a temperature range of 410–465°C.

Cobalt carboxylate also decomposes in several stages. At the first stage (170–300°C) there is evaporation of organic acids from the extract; within a temperature range of 300–410°C decomposition of carboxylates takes place. The cobalt oxide is formed at 410°C.

The thermal decomposition process of the carboxylates mixture is a two-stage process accompanied by exothermic effects at 200 and 430°C. Within a temperature range of 200–290°C there is evaporation of organic acids, which overlaps the processes of the carboxylates thermal decomposition. The reaction of the complex oxide formation starts at 430°C. As it is necessary to perform the complex iron-cobalt oxide synthesis at a temperature of around 500°C; glass fiber fabric was used as a fiber base.

The sequence of operations for obtainment of the magnetic fabric is as follows:

– removal of different formations from the surface of the fabric in order to enhance its hydrophobic properties (rinsing with isopropyl alcohol or toluene);

– impregnation of the fabric with the precursor;

– drying of the fabric for 90 s in the vertical position;

– pyrolysis in the quartz furnace at 500°C for 90 s;

– air cooling of the fabric for 120 s.

This cycle was repeated ten times. X-ray diffraction pattern was obtained for the magnetic fabric sample. Angles 2θ, amounting to 15°–40°, are in correspondence with peaks characteristic of ferrospinels. The increased half-width of the peaks is a consequence of the crystallites small sizes. It follows from the calculations that the sizes of the crystallites in different samples of the magnetic fabric amount to 15–25 nm.

The magnetic properties of the fabric produced using the extraction-pyrolysis method are as follows: coercivity of 85 kA m^{-1} and remanence of 0.19 T.

CONCLUSIONS

Obtainment of nanosized single-domain ferromagnetic particles in different phase magnetic states and of functional nanocomposites on the basis of such particles on fibrous material can be achieved with the use of the following technologically available methods: dispersion; variation of the component composition and defectiveness of the particles; implementation of different types of anisotropy of both the particles themselves and their distribution in the polymer matrix; influence of external magnetic and thermal fields etc. It is possible to control the state of ferromagnetic particles by changing the magnetic properties of the particles themselves and the characteristics of the magnetic field they create.

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