Abstract—In this study, two types of ligands were introduced onto the surface of magnetite nanoparticles by hydrolysis and condensation of organosilicon reagents: organosilane-tetraethoxysilane (TEOS) and aminoorganosilane - aminopropyltriethoxysilane (APTES). It is shown that coatings based on SiO\textsubscript{2} solve a double problem: first, they prevent the aggregation of nanoparticles and the oxidation of magnetite; secondly, they allow the surface to be modified with various specific ligands for biomedical applications due to terminal groups. It was shown, that after the modification of TEOS and APTES (in argon and in air), the Fe\textsubscript{3}O\textsubscript{4} content decreases to 66, 42, and 36\%, respectively. The formation of a silicon framework on the magnetite surface due to Fe-O-Si and Si-O-Si bonds was determined by IR spectroscopy. The identification of surface amino groups is complicated due to the superposition of absorption bands of NH\textsubscript{2}- and OH-groups. This opens new prospective for creation of tailored nanocomposites containing magnetite nanoparticles. These materials can be further used as sorbents for various applications.

Keywords—Nanoparticles, core-shell, magnetite, silica.

I. INTRODUCTION

In order to solve possible problems with the introduction of magnetite nanoparticles into a living organism, such as instability under physiological conditions [1]-[12], the formation of free radicals dangerous for the body, as well as insufficient strong bond with ligands during targeted drug delivery, nanoparticles cover a protective a shell that should ensure their stability, reduce toxicity to a minimum, and have the ability to form strong bonds with various types of ligands that are used to functionalize the surface of nanoparticles [13]-[25]. Serious concern is also caused by the behavior of materials based on Fe\textsubscript{3}O\textsubscript{4} nanoparticles, which are widely used as detoxicants in the restoration of the environment, in particular, for the removal of chlorine-containing compounds, organic dyes, heavy metals from technogenic and natural aqueous media. Fe\textsubscript{3}O\textsubscript{4} nanoparticles are subject to oxidation in air and easily aggregate in aqueous systems. The necessary stabilization of iron oxide nanoparticles by surface modification should pursue a double goal: control of the size and polydispersity during synthesis and stabilization of nanoparticles against aggregation after synthesis [26]-[35].

Magnetite nanoparticles Fe\textsubscript{3}O\textsubscript{4} have a wide range of applications - from magnetic separation of universal technical media to the preparation of materials for biomedicine. The properties of magnetic nanoparticles are significantly affected by phase transformations as a result of their modification with various compounds, as a result of which the modified surface layer of magnetic nanoparticles can have completely different magnetic characteristics than the particle core [36]-[43]. In this regard, the methods of obtaining magnetic nanoparticles are combined with various methods of their stabilization, using protective shells of different nature [44]-[53]. Modification of the surface of nanoparticles allows not only to ensure their stability in biological media with high ionic strength, but also to control the nature of their interaction with objects, which determines the biocompatibility of nanoparticles [54]-[76]. In this case, already surface characteristics stand out as one of the most important, if not the main, determining factors of the bioactive properties of nanoparticles. For this purpose, magnetite nanoparticles of the "core-shell" type are widely used, which have an inner core of iron oxides (Fe\textsubscript{3}O\textsubscript{4}) with an outer protective shell made of silicon dioxide. The most
widely used are two types of silanol ligands: with terminal OH-groups and terminal NH₂-groups.

Modification of nanoparticles is carried out using various inorganic or organic compounds by their non-covalent or covalent immobilization on the surface of iron oxide nanoparticles, which leads to a change in their primary properties and allows expanding the areas of their potential application [36]-[45]. There is a wide range of substances capable of forming a protective shell on the surface of magnetite nanoparticles; among them, alkoxysilanes are of interest as inert, biocompatible, and functional inorganic ligands.

Modern composites have not only a wide range of physical and mechanical properties, but are also capable of directionally changing them, for example, increasing fracture toughness, regulating rigidity, strength, and other properties. These possibilities are expanded when fibers of different nature and geometry are used in composites, i.e., when creating hybrid composites. In addition, these materials are characterized by the appearance of a synergistic effect (coordinated joint action of several factors in one direction) [45]-[63].

The properties of the interface or interfacial zone, first of all, the adhesive interaction between the fiber and the matrix, determine the level of properties of composites and their retention during operation. Local stresses in the composite reach their maximum values just near or directly at the interface, where material destruction usually begins. The interface must have certain properties to ensure efficient transfer of the mechanical load from the matrix to the fiber. The adhesion bond at the interface should not be destroyed under the action of thermal and shrinkage stresses arising from the difference in the temperature coefficients of linear expansion of the matrix and fiber or as a result of chemical shrinkage of the binder during its curing.

When creating nanocomposites, the key tasks are the development of efficient, reliable, and affordable production technologies for mass production, which make it possible to obtain materials with stable characteristics. The hand lay technique, also called wet lay, is the simplest and most widely used process for producing flat reinforced composites. The process consists of laying layers of a polymer in successive layering using an epoxy matrix. Wet-laying is a molding process that combines layers of reinforced carbon fiber with epoxy to create a high-quality laminate. Before starting the installation process, you must prepare the appropriate form. This preparation consists of cleaning the table and applying a release agent to the surface. The manual laying process can be divided into four main steps: mold preparation, epoxy coating, laying, and curing. Form preparation is one of the most important steps in the installation process. This process requires dry reinforcement layers and the application of a wet epoxy matrix. They are connected together - reinforcing material, impregnated with a matrix

Coatings on nano and micro-sized particles can serve for many purposes. First of all, modification of the surface with coatings makes it possible to make the particles compatible with various matrices [14]-[30]. For medical purposes, the biocompatibility with the environments of a living organism is of crucial importance. It is equally important that coatings can significantly enhance or decrease the sorption properties of magnetically controlled sorbents. This provides prerequisites for the creation of magnetically controlled particles with specific sorption properties. It is also known that the coatings prevent the core from leaching out. The presence of a coating also often facilitates the stabilization of particles in an environment with an alkaline pH or significant salt concentration. For example, the isoelectric point of SiO₂ is reached at pH 2-3. Therefore, the particles coated with silica are negatively charged at the pH of the blood, which causes electrostatic repulsion, which avoids the formation of clumps.

The ability of the adsorbent to absorb the adsorbate is characterized by the amount of adsorption. The amount of adsorption is the excess mass of the adsorbate in the boundary layer over its mass in an equal volume of the environment, referred to the unit surface of the adsorbent.

Sometimes the adsorption value is expressed in moles of adsorbate per 1 m² (or 1 cm²) of the adsorbent surface. Since quite often the surface of the adsorbent is unknown, the value of adsorption is expressed in moles of adsorbate per 1 g of adsorbent (mol/g). It is customary to evaluate the process of toxin sorption by the adsorbing surface using the curves of Langmuir sorption isotherms.

Silanol binding agents are applied directly to the surface of Fe₃O₄ nanoparticles by copolymerization of monomers or by direct silanization. The developed surface of nanoparticles leads to a high density of surface functional groups [48]-[57], which can fix a large number of biologically active substances [32]. The most common way to obtain LF Fe₃O₄/SiO₂ with a core-shell structure is the sol-gel method (Stober method), which consists in hydrolysis and polycondensation under alkaline conditions in ethanol [33].

Analyzing the works where the authors provide data on the electrokinetic properties of magnetite nanoparticles coated with silanes, it can be noted that under various conditions for the preparation of nanoparticles (different sample preparation, temperature and time of preparation, drying conditions), the authors obtained samples identical in structure and composition according to the IR data and the method of electrophoretic light scattering. However, the lack of uniformity in the characteristic absorption bands and the position of isoelectric points for the same samples does not make it possible to correctly evaluate the physicochemical data and the success of the preparation.

In this regard, in this work, we performed a comparative analysis of the microstructure of magnetite nanoparticles synthesized by various methods before and after their modification with 3-aminopropyltriethoxysilane under various reaction conditions (in argon and during oxidation).
II. PREPARATION AND STUDY OF THE PROPERTIES OF MAGNETITE NANOPARTICLES COATED WITH SILICON DIOXIDE

By studying the processes that occur during the interaction of ligands with nanoparticles, it is possible to understand the stabilization mechanism, and most importantly, the nature of the bond at the forming interface [32]-[38]. It is also necessary to take into account the fact that the processes of nanoparticle enlargement and the adsorption of macromolecules on the surface of both initial and formed particles proceed in parallel and, accordingly, influence each other. The size and polydispersity can be controlled within a fairly short nucleation period, because the end of the nucleation process means a finite number of particles. Nucleation, i.e. nucleation is the key to the crystallization process by controlling crystal shape and nanoparticle size distribution.

The first stage of modification of the surface of silica using APTES in an aqueous medium consists in the hydrolysis of alkoxysilyl groups with the formation of silanol groups Si-OH. Further, the silanol groups of the modifier react with OH-groups on the silica surface, releasing water, with the formation of an anchor bond Si-O-Si-C. The introduction of APTES on the surface of Fe₃O₄ nanoparticles in our case is justified by the presence of reactive amino groups, which can subsequently interact with any classes of compounds in order to obtain functional and hybrid materials. The disadvantages of the method for modifying the surface of silicas with organosilanes in an aqueous medium include the possibility of a side process of polymerization of functional organosilanes.

III. RESULTS AND DISCUSSION

To study the crystal structure and lattice parameters of the synthesized powder, X-ray phase analysis (XRF) and analysis of the X-ray line profile were carried out on a DRON-UM-2 diffractometer in the Bragg-Brentano geometry using CrKα radiation. The values of the current and voltage across the X-ray tube were 20 mA and 40 kV, respectively. The set of spectra was carried out in the continuous scanning mode at a detector movement speed of 1 rpm. The analysis of the phase composition was carried out in a platinum cell, in two modes of temperature control and a set of X-ray spectra. Consider the diffraction patterns of the obtained samples. From the Fig. 1 it is seen that distinguished peaks of magnetite as well as silica can be observed, this proves the creation of nanocomposite material.

In accordance with the values of the Miller indices hkl and interplanar distances d obtained from the Match! Program, the crystal lattice parameters were calculated:

\[ a: \frac{1}{d^2} = \frac{(h^2+k^2+l^2)}{a^2} \]

where \( a \) – unit cell parameter, angstrom, hkl – Miller indices, d – interplanar distance, angstroms. The interplanar spacing and Miller indices were obtained from the data of the Match! when processing spectra.

Magnetite can have a range of oxidation states depending on the amount of structural Fe²⁺, which is the stoichiometry of magnetite (\( x = \frac{Fe^{2+}}{Fe^{3+}} \)). For magnetite with an ideal Fe²⁺ content (formula Fe₃O₄) stoichiometric parameter is \( x = 0.50 \). As magnetite oxidizes, the \( Fe^{2+} / Fe^{3+} \) ratio decreases (\( x <0.50 \)), and this form is either nonstoichiometric or partially oxidized magnetite. Fully oxidized magnetite (\( x = 0 \)) is maghemite (\( \gamma-Fe₂O₃ \)). For nonstoichiometric magnetite, the structural formula is often written as Fe₃₋δO₄, where \( \delta \) can vary from zero (stoichiometric magnetite) to 1/₃ (completely oxidized). Stoichiometric parameters can be calculated from the following relationship:

\[ x = \frac{Fe^{2+}}{Fe^{3+}} = \frac{1-3\delta}{2+2\delta} \]

The \( x \) value is found from linear interpolation between two extreme points - magnetite and maghemite. For magnetite \( X=0.5, a=8.396-8.400 \) Å. For magnetite \( X=0 a=8.33-8.34 \) Å. The lattice parameters obtained in this work are less than those known for magnetite 8.396–8.400 Å.

The XRF data showed that the main phase formed during coprecipitation in the presence of TEOS is Fe₃O₄ (with a% content of 67%) in a γ-Fe₂O₃ shell with a% content from 33%). Upon functionalization of APTES%, the content of Fe₃O₄...
SiO confirms the formation of a silicon framework, which causes characteristic of the Fe bond -OH (Fig. 2). The appearance of stabilization and functionalization of Fe\textsubscript{3}O\textsubscript{4} nanoparticles. These materials can be further used as sorbents for creation of tailored nanocomposites containing magnetite (~ 3500 cm\textsuperscript{-1}) and Si-O-Si (1130 cm\textsuperscript{-1}) bonds was determined by IR spectroscopy. The identification of surface amino groups is complicated due to the superposition of absorption bands of NH\textsubscript{2}- and OH-groups (~ 3500 cm\textsuperscript{-1} and ~ 1650 cm\textsuperscript{-1}). This opens new prospective for creation of tailored nanocomposites containing magnetite nanoparticles. These materials can be further used as sorbents for various applications.

IV. CONCLUSION

Fe\textsubscript{3}O\textsubscript{4} nanoparticles functionalized with TEOS under conditions of acid and alkaline catalysis and APTES in different atmospheres were obtained. For the first time using the XRF method using the OriginPro and Match software! the effect of the ligand on the content of stoichiometric Fe\textsubscript{3}O\textsubscript{4} was determined. Thus, after the modification of TEOS and APTES (in argon and in air), the Fe\textsubscript{3}O\textsubscript{4} content decreases to 66, 42, and 36%, respectively. The formation of a silicon framework on the magnetite surface due to Fe-O-Si (760 cm\textsuperscript{-1}) and Si-O-Si (1130 cm\textsuperscript{-1}) bands was determined by IR spectroscopy. The identification of surface amino groups is complicated due to the superposition of absorption bands of NH\textsubscript{2}- and OH-groups (~ 3500 cm\textsuperscript{-1} and ~ 1650 cm\textsuperscript{-1}). This opens new prospective for creation of tailored nanocomposites containing magnetite nanoparticles. These materials can be further used as sorbents for various applications.

REFERENCES

[1] B. A. Antufev, E. L. Kuznetsova, L. N. Rabinskiy, O. V. Tushavina, "Investigation of a complex stress-strain state of a cylindrical shell with a dynamically collapsing internal elastic base under the influence of temperature fields of various physical nature," Asia Life Sciences, (2), pp. 689–696, 2019.

[2] B. A. Antufev, E. L. Kuznetsova, L. N. Rabinskiy, O. V. Tushavina, "Complex stressed deformed state of a cylindrical shell with a dynamically destructive internal elastic base under the action of temperature fields of various physical nature," Asia Life Sciences, (2), pp. 775–782, 2019.

[3] L. N. Rabinskiy, O. V. Tushavina, "Problems of land reclamation and heat protection of biological objects against contamination by the aviation and rocket launch site," Journal of Environmental Management and Tourism, 10(5), pp. 967–973, 2019.

[4] A. N. Astapov, I. P. Lifanov, L. N. Rabinskiy, "Perspective Heat-Resistant Coating for Protection of CF/SiC Composites in Air Plasma Hypersonic Flow," High Temperature, 57(5), pp. 744–752, 2019.
[5] V. N. Dobryanskiy, L. N. Rabinskiy, O. V. Tushavina, "Validation of methodology for modeling effects of loss of stability in thin-walled parts manufactured using SLM technology," Periodico Tche Quimica, 16(33), pp. 650–656, 2019.

[6] L. N. Rabinskiy, S. A. Sitnikov, "Development of technologies for obtaining composite material based on silicone binder for its further use in space electric rocket engines," Periodico Tche Quimica, 15(Special Issue 1), pp. 390–395, 2018.

[7] P. F. Pronina, O. V. Tushavina, E. I. Starovoitov, "Study of the radiation situation in moscow by investigating elastoplastic bodies in a neutron flux taking into account thermal effects," Periodico Tche Quimica, 17(35), pp. 753–764, 2020.

[8] A. A. Orekhov, Y. A. Utkin, P. F. Pronina, "Determination of deformation in mesh composite structure under the action of compressive loads," Periodico Tche Quimica, 17(35), pp. 599–608, 2020.

[9] V. F. Formalev, S. A. Kolesnik, B. A. Garibyan, "Mathematical modeling of heat transfer in anisotropic plate with internal sinks," AIP Conference Proceedings, 2181, 020003, 2019.

[10] I. P. Lifanov, A. N. Astapov, V. S. Terentieva, "Deposition of heat-resistant coatings based on the ZrSi2-MoSi2-ZrB2 system for protection of non-metallic composite materials in high-speed high-enthalpy gas flows," Journal of Physics: Conference Series, vol. 1713, no. 1, pp. 012025, 2020.

[11] O. A. Butusova, "Design and Properties of Magnetically Controlled Sorbents," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 515-519, 2021.

[12] O. A. Butusova, "Application of Magnetically Controlled Sorbents for Detoxication," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 520-524, 2021.

[13] M. O. Kaptakov, "Effect of Thin Polymer Layers on Mechanical Properties of Metal Surfaces," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 525-529, 2021.

[14] B. A. Garibyan, " Determination of the Elastic Modulus of the Coating Using a Spherical Indenter," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1594-1600, 2021.

[15] M. O. Kaptakov, "Modelling of Mechanical Properties of Metal Plates with Polymer Coatings," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 530-534, 2021.

[16] B. A. Garibyan, "Theoretical Estimations of Influence of Polymer Coatings on the Elastic Modulus and Ultimate Strength of Steel Samples," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1651-1656, 2021.

[17] M. O. Kaptakov, "Investigation of Effective Mechanical Characteristics of Nanomodified Carbon-Epoxy Composite by Numerical and Analytical Methods," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 535-541, 2021.

[18] M. O. Kaptakov, "Obtaining of Carbon Fibers Based Composite Materials and Study of Their Mechanical Properties," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1601-1605, 2021.

[19] I. P. Lifanov, A. A. Yurishcheva, A. N. Astapov, "High-temperature protective coatings on carbon composites," Russian Engineering Research, vol. 39, no. 9, pp. 804–808, 2019.

[20] A. N. Astapov, I. P. Lifanov, M. V. Prokofiev, "High-temperature interaction in the ZrSi2-ZrSiO4 system and its mechanism," Russian Metallurgy (Metally), no. 6. pp. 640–646, 2019.

[21] V. F. Formalev, S. A. Kolesnik, B. A. Garibyan, "Heat transfer with absorption in anisotropic thermal protection of high-temperature products," Herald of the Bauman Moscow State Technical University, Series Natural Sciences, (5), pp. 35–49, 2019.

[22] S. A. Kolesnik, N. A. Bulkevych, "Numerical analytic method for solving the inverse coefficient problem of heat conduction in anisotropic half-space," Journal of Physics: Conference Series, 1474(1), 012024, 2020.

[23] V. F. Formalev, N. A. Bulkevych, S. A. Kolesnik, M. A. Kazaryan, "Thermal state of the package of cooled gasdynamic microlasers," Proceedings of SPIE - The International Society for Optical Engineering, 11322, article number 113221B, 2019.

[24] O. A. Pashkov, "Influence of Polymer Coatings on the Mechanical Properties of Steel Samples in Tensile and Bending Tests," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 5, pp. 542-548, 2021.

[25] O. A. Pashkov, "Investigation of the Effect of Steel Plate Size and Elevated Temperature on Critical Load in Stability Tests," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1657-1663, 2021.

[26] Y. Sun, O. V. Egorova, E. L. Kuznetsova, "Identification of the front angle of a plane acoustic oblique pressure wave on convex surfaces with the use of analytical solution," Journal of the Balkan Tribological Association, 27(2), pp. 189–197, 2021.

[27] N. A. Kucheva, V. Kohlert, "Analytical solution of the problem of thermoelasticity for a plate heated by a source with a constant heat supply on one surface," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1622-1633, 2021.

[28] V. F. Formalev, S. A. Kolesnik, B. A. Garibyan, "Analytical solution of the problem of conjugate heat transfer between a gasdynamic boundary layer and anisotropic strip," Herald of the Bauman Moscow State Technical University, Series Natural Sciences, 5(92), pp. 44–59, 2020.

[29] Y. Sun, S. A. Kolesnik, E. L. Kuznetsova, "Mathematical modeling of coupled heat transfer on cooled gas turbine
blades," INCAS Bulletin, 12(Special Issue), pp. 193–200, 2020.

[30] I. Kurchatov, N. Bulychev, S. Kolesnik, E. Muravev, "Application of the direct matrix analysis method for calculating the parameters of the luminescence spectra of the iron ion in zinc sulfide crystals," AIP Conference Proceedings, 2181, 020015, 2019.

[31] A. V. Babaytsev, L. N. Rabinskiy, K. T. Aung, "Investigation of the contact zone of a cylindrical shell located between two parallel rigid plates with a gap," INCAS Bulletin, 12(Special Issue), pp. 43–52, 2020.

[32] O. A. Butusova, "Surface Modification of Titanium Dioxide Microparticles Under Ultrasonic Treatment," International Journal of Pharmaceutical Research, vol. 12, i. 4, pp. 2292-2296, 2020.

[33] O. A. Butusova, "Stabilization of Carbon Microparticles by High-Molecular Surfactants," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1147-1151, 2020.

[34] Yu. V. Ioni, A. Ethiraj, "New Tailor-Made Polymer Stabilizers for Aqueous Dispersions of Hydrophobic Carbon Nanoparticles," International Journal of Pharmaceutical Research, vol. 12, i. 4, pp. 3443-3446, 2020.

[35] Yu. V. Ioni, "Nanoparticles of noble metals on the surface of graphene flakes," Periodico Tche Quimica, vol. 17, no. 36, pp. 1199-1211, 2020.

[36] O. A. Butusova, "Vinyl Ether Copolymers as Stabilizers of Carbon Black Suspensions," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1152-1155, 2020.

[37] M. O. Kaptakov, "Catalytic Desulfuration of Oil Products under Ultrasonic Treatment," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1838-1843, 2020.

[38] A. A. Garibyan, "Enhancement of Mechanical Properties of Inorganic Glass under Ultrasonic Treatment," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1829-1832, 2020.

[39] M. O. Kaptakov, "Enhancement of Quality of Oil Products under Ultrasonic Treatment," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1851-1855, 2020.

[40] O. A. Butusova, "Adsorption Behaviour of Ethylhydroxyethyl Cellulose on the Surface of Microparticles of Titanium and Ferrous Oxides," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1156-1159, 2020.

[41] A. N. Tarasova, "Vibration-based Method for Mechanochemical Coating Metallic Surfaces," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1160-1168, 2020.

[42] A. A. Garibyan, "Mechanical Properties of Electroconductive Ceramics," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1825-1828, 2020.

[43] M. O. Kaptakov, "Effect of Ultrasonic Treatment on Stability of TiO2 Aqueous Dispersions in Presence of Water-Soluble Polymers," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1821-1824, 2020.

[44] Yu. V. Ioni, "Synthesis of Metal Oxide Nanoparticles and Formation of Nanostructured Layers on Surfaces under Ultrasonic Vibrations," International Journal of Pharmaceutical Research, vol. 12, i. 4, pp. 3432-3435, 2020.

[45] A. N. Tarasova, "Effect of Reagent Concentrations on Equilibria in Water-Soluble Complexes," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1169-1172, 2020.

[46] A. N. Tarasova, "Effect of Vibration on Physical Properties of Polymeric Latexes," International Journal of Pharmaceutical Research, vol. 12, Supplementary Issue 2, pp. 1173-1180, 2020.

[47] Yu. V. Ioni, A. Ethiraj, "Study of Microparticles Surface Modification by Electrokinetic Potential Measuring," International Journal of Pharmaceutical Research, vol. 12, i. 4, pp. 3436-3439, 2020.

[48] G. A. Kalugin, A. V. Ryapukhin, "Impact of the 2020 Pandemic on Russian Aviation," Russian Engineering Research, vol. 41. no. 7, pp. 627-630, 2021.

[49] R. N. Zaripov, I. M. Murakaev, A. V. Ryapukhin, "Development of the Organization’s Key Performance Indicators System in Order to Improve the Effectiveness of Its Human Capital and Risk Management," TEM Journal, vol. 10, no. 1, pp. 298-302, 2021.

[50] A. A. Kalugin, G. A. Kalugina, A. V. Ryapukhin, "Informational Support for the Sale of Passenger Aircraft," Russian Engineering Research, vol. 41, no. 2, pp. 183-187, 2021.

[51] R. N. Zaripov, I. M. Murakaev, S. V. Novikov, A. V. Ryapukhin, "Corporate Structure for Innovative Enterprises," Russian Engineering Research, vol. 40, no. 2, pp. 137-139, 2020.

[52] N. A. Bulychev, E. L. Kuznetsova, "Ultrasonic Application of Nanostructured Coatings on Metals," Russian Engineering Research, 39 (9), pp. 809–812, 2019.

[53] N. A. Bulychev, V. V. Bodryshev, L. N. Rabinskiy, "Analysis of geometric characteristics of two-phase polymer-solvent systems during the separation of solutions according to the intensity of the image of micrographs," Periodico Tche Quimica, 16(32), pp. 551–559, 2019.

[54] Ourida Ourahmoun, "Simulation of the electrical parameters of organic photovoltaic cells under QUCS and GPVDM software," WSEAS Transactions on Circuits and Systems, vol. 19, pp. 196-205, 2020.

[55] Vit Cerny, Rostislav Drochytka, "The Influence of Different Types of Siliceous Raw Materials on Tobermorite Formation in Lime-Silica Composite," WSEAS Transactions on Environment and Development, vol. 15, pp. 57-64, 2019.

[56] N. A. Bulychev, A. V. Ivanov, "Effect of vibration on structure and properties of polymeric membranes," International Journal of Nanotechnology, vol. 16, nos. 6/7/8/9/10, pp. 334 – 343, 2019.
[57] N. A. Bulychev, A. V. Ivanov, "Nanostructure of Organic-Inorganic Composite Materials Based on Polymer Hydrogels," International Journal of Nanotechnology, vol. 16, nos. 6/7/8/9/10, pp. 344 – 355, 2019.

[58] N. A. Bulychev, A. V. Ivanov, "Study of Nanostructure of Polymer Adsorption Layers on the Particles Surface of Titanium Dioxide," International Journal of Nanotechnology, vol. 16, nos. 6/7/8/9/10, pp. 356 – 365, 2019.

[59] N. A. Bulychev, L. N. Rabinskiy, O. V. Tushavina, "Effect of intense mechanical vibration of ultrasonic frequency on thermal unstable low-temperature plasma," Nanoscience and Technology: An International Journal, 11 (1), pp. 15–21, 2020.

[60] N. A. Bulychev, L. N. Rabinskiy, "Ceramic Nanostructures Obtained by Acoustoplasma Technique," Nanoscience and Technology: An International Journal, 10 (3), pp. 279–286, 2019.

[61] Yu. V. Ion, "Effect of Ultrasonic Treatment on Properties of Aqueous Dispersions of Inorganic and Organic Particles in Presence of Water-Soluble Polymers," International Journal of Pharmaceutical Research, vol. 12, i. 4, pp. 3440-3442, 2020.

[62] V. G. Dmitriev, O.V. Egorova, E. I. Starovoitov, "Particularities of mathematical modeling of deformation processes for arched and panel designs of composites with large displacements and rotation angles," INCAS Bulletin, 12(Special Issue), pp. 53–66, 2020.

[63] O. V. Egorova, E. I. Starovoitov, "Non-stationary diffraction problem of a plane oblique pressure wave on the shell in the form of a hyperbolic cylinder taking into account the dissipation effect," INCAS Bulletin, 12(Special Issue), pp. 67–77, 2020.

[64] O. A. Pashkov, "Theoretical calculation of the thickness of interphase zones in the Al-Al2O3 composite," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1672-1677, 2021.

[65] O. A. Pashkov, "Experimental and Theoretical Study of Mechanical Properties of Matrix Composite Materials," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1678-1684, 2021.

[66] N. A. Kucheva, V. Kohlert, "Mathematical modeling methods for estimation the thermophysical properties of heat-protective composite materials," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1606-1612, 2021.

[67] N. A. Kucheva, "Investigation of the mechanical properties of heat-protective highly porous composite materials using the effective medium model," Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 10, pp. 1613-1621, 2021.

[68] O. V. Tushavina, "Coupled heat transfer between a viscous shock gasdynamic layer and a transversely streamlined anisotropic half-space," INCAS Bulletin, 12 (Special Issue), pp. 211–220, 2020.

[69] V. A. Pogodin, L. N. Rabinskiy, S. A. Sitnikov, "3D Printing of Components for the Gas-Discharge Chamber of Electric Rocket Engines," Russian Engineering Research, vol. 39, no. 9, pp. 797-799, 2019.

[70] Y. K. Kyaw, E. L. Kuznetsova, A. V. Makarenko "Complex mathematical modelling of mechatronic modules of promising mobile objects," INCAS Bulletin, 12(Special Issue), pp. 91-98, 2020.

[71] L. E. Kuznetsova, V. G. Fedotenkov, "Dynamics of a spherical enclosure in a liquid during ultrasonic cavitation," Journal of Applied Engineering Science, 18(4), pp. 681 – 686, 2020.

[72] A. V. Makarenko, E. L. Kuznetsova, "Energy-Efficient Actuator for the Control System of Promising Vehicles," Russian Engineering Research, 39(9), pp. 776-779, 2019.

[73] E. L. Kuznetsova, A. V. Makarenko, "Mathematic simulation of energy-efficient power supply sources for mechatronic modules of promising mobile objects," Periodico Tche Quimica, 15(Special Issue 1), pp. 330-338, 2018.

[74] Y. Li, A. M. Arutjunian, E. L. Kuznetsova, G. V. Fedotenkov, "Method for solving plane unsteady contact problems for rigid stamp and elastic half-space with a cavity of arbitrary geometry and location," INCAS Bulletin, 12(Special Issue), pp. 99–113, 2020.

[75] E. L. Kuznetsova, G. V. Fedotenkov, E. I. Starovoitov, "Methods of diagnostic of pipe mechanical damage using functional analysis, neural networks and method of finite elements," INCAS Bulletin, 12(Special Issue), pp. 79–90, 2020.

[76] Y. K. Kyaw, P. F. Pronina, P. O. Polyakov, "Mathematical modelling of the effect of heat fluxes from external sources on the surface of spacecraft," Journal of Applied Engineering Science, 18(4), pp. 732–736, 2020.

Creative Commons Attribution License 4.0 (Attribution 4.0 International, CC BY 4.0)
This article is published under the terms of the Creative Commons Attribution License 4.0
https://creativecommons.org/licenses/by/4.0/deed.en_US