PHYSICAL ASPECTS OF MAGNETIC NANOPARTICLES METROLOGY

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Concepts “nanostructure”, “nanomaterial”, “nanoparticles” etc. unite objects of the various physical nature, terminologically fixing only their sizes, in difference, for example from the term "electronics" which contains instructions on the general nature of physical processes. Therefore in area “nanotechnology” there is a problem of the standard classification and certification of nanomaterials [1, 2]. Development of this direction demands the decision of variety of the new interconnected problems. Here it is possible to allocate problems of the general approach to classification nanoparticles and nanostructures on physical properties, methods of their reception, scopes, the geometrical sizes etc. For example, for the obvious reasons the division nanomaterials as conductivity loses sense habitual for massive bodies. It is obvious also, that in nanomaterials in comparison traditional against volume superficial effects should play the big role. At the same time superficial properties of nanoparticles practically are not studied now.

Studying of influence of the geometrical sizes on physical properties of nanoobjects should become one of research mainstreams in nanomaterials. However it is necessary to develop the certificated methods of measurement of the nanoparticles sizes, physically proved indicators of an average and dispersion about an average (i.e. physically proved statistics), that in turn demands search of corresponding properties and new physical effects.

In the present work distribution on the nanoparticle Fe_3O_4 size, received by a co-precipitation method from gel is considered. The given material represents the big interest for biomedical and of some other applications [3]. Besides, between nanoparticles strong enough magnetic interaction takes place, leading to formation of their conglomerates and, hence, to change of the sizes of particles operates. On Fig. 1 the kind of particles Fe_3O_4 besieged on mica, received by us by means of atomic force microscope JPK Nanowizard is presented. Nanoparticles have been placed in the focusing weak external magnetic field directed under a corner of 30 degrees to a vertical in a plane of a surface of a substrate. The typical sizes of particles makes from 2 to 10 nanometers. The same size is yielded by results of measurements by means of appearing through electronic microscopy. Laser correlation spectroscopy also confirms these results. The form of nanoparticles according to data of appearing through electronic microscopy and atomic force microscopy is not strictly spherical, and has poorly-ellipsoidal form. The carried out X-ray researches testifies to one-staging of a material and exclude presence of the second phase in received nanoparticles. X-ray spectra have allowed to estimate under Debue formula the size of the nanoparticles which also corresponds to the parameters resulted above.

As it was marked, for example in [4], distribution of nanoparticles (including magnetic Ni) in the sizes carries normal, or logarithmic-normal character with the expressed right-hand asymmetry. Thus all distributions are unimodal. For such distributions value of the average size and a deviation from it have quite certain sense: among set nanoparticles there is one most probable size defined both technology of reception, and conditions of a condition of this system.

The experimental data spent by us on appearing through electronic microscopy and atomic force microscopy have allowed to receive experimentally distribution of particles Fe_3O_4 in the sizes. All interval of possible values of the sizes (0 – 100 nanometers) broke into equal subintervals (0.5 nanometers), then was counted up on the basis of microscopy data n_i quantity of a nanoparticles which average sizes keep within corresponding intervals. Result in normalized form n_i/N, where N is the general number of particles, is presented in a Fig. 2.

The basic feature of distribution of nanoparticles Fe_3O_4 is bimodal form of size distribution with maxima for 4.5 and 8.75 nanometers. For single-phase system it means, that for the given particles is available two primary sizes. The form of the first peak with sharp recession above 4.5 nanometers testifies to presence of the mechanism interfering formation of particles with the sizes in the field of 6 – 7нм, however particles in the size more than 8 nanometers thus arise with frequency in 5 times smaller, than the most widespread. It is possible to assume, that the feature of distribution found out by us is caused by magnetic interactions in system.

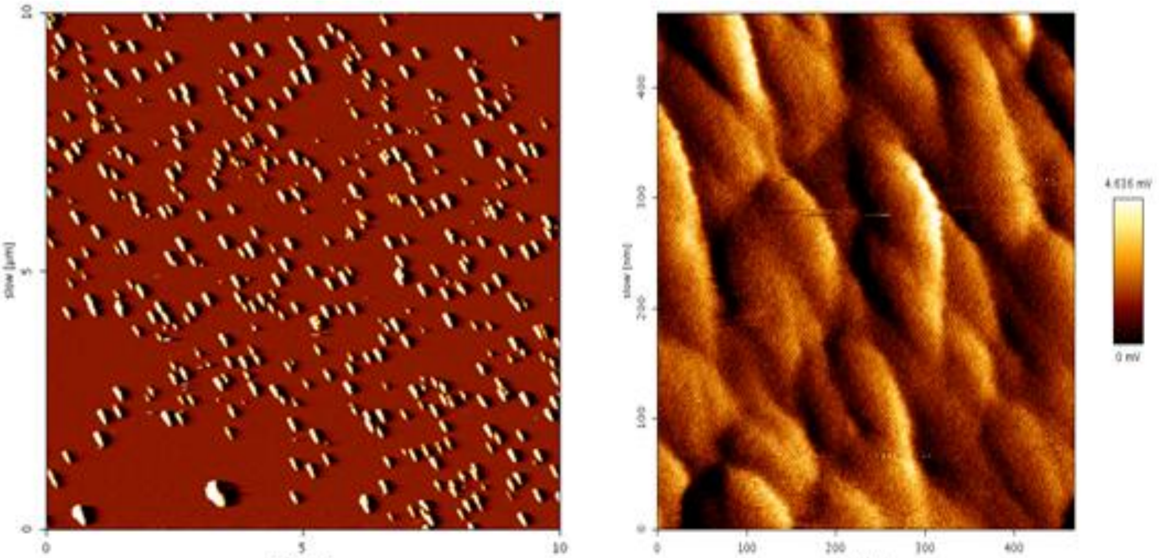
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Fig. 1. Atomic force JPK Nanowizard microscopy of nanoparticles Fe_3O_4, the sizes on a vertical and a horizontal scales are: A – 1x1 micron, B – 50x50 nanometer. Orientation of particles is set by an external magnetic field. The magnetic cantilevers with cobalt are used.

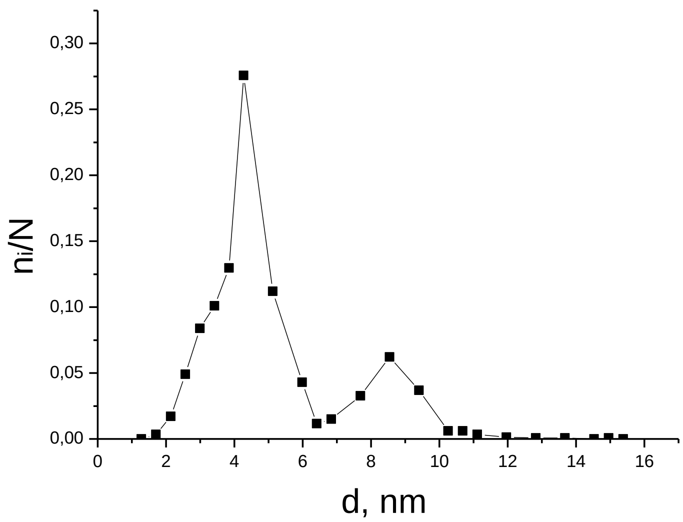
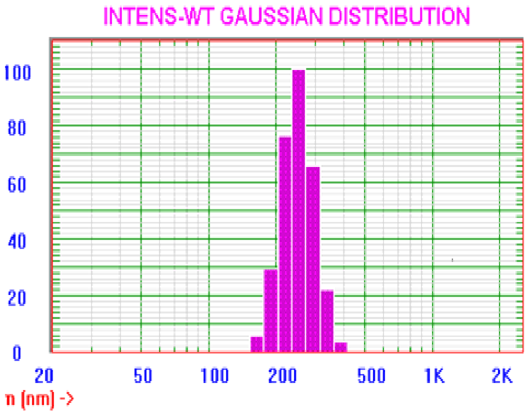


Fig. 2. Distribution of relative frequency of presence nanoparticles Fe_3O_4 from their size

For the purpose of studying of possible influence of superficial magnetic effects on a conglomeration of the magnetic nanoparticles, the investigation of the magnetic nanoparticles Fe_3O_4 is also carried out. Measurements were spent by a method of laser correlation spectroscopy on the Gaussian/Nicomp analyzer. The surface initial of the nanoparticles became covered by dextran (see A, Fig. 3), and also dextran – melphalan (B, Fig. 3) ones. The interval of diameters of particles for the first case (A) is (170 – 300 nm), and in the second one (B) consists of (70-190 nm). In case of dextran and melphalan covered Fe_3O_4 nanoparticles, the distribution of particles (see Fig. 3) became unimodal and close to normal. The given result can speak that the size of a covering much more exceeds the sizes of nanoparticles Fe_3O_4, therefore is considerable - on some usages, - one of conglomeration mechanisms,

- namely, - the mechanism of magnetic interaction наночастиц which falls down with distance under the law ~ r^{-6} [3] is weakened.



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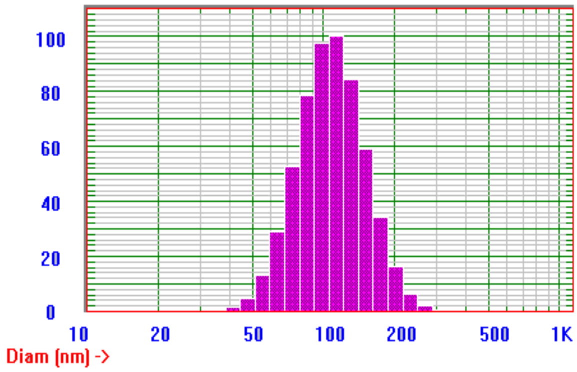

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Fig.3. Distribution in the sizes in dextran covered (A, a Fig. 3), and also dextran-melphalan covered (B, Fig. 3) nanoparticles Fe_3O_4.

It is necessary to draw a conclusion on necessity in metrological characterization and certification of magnetic nanoparticles to consider the factor of their strong magnetic interaction.

THE LITERATURE LIST

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