

**MAGNETITE NANOPARTICLES SURFACE MODIFICATION**

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Creation of new drugs with magnetic properties in different forms by the use of the magnetic component in their composition makes it possible to optimally combine pharmacological and magnetically controllable properties of the drug, which can be applied both in the traditional way and by using its special magnetic properties.

The conditions of stabilization of magnetic nanoparticles in such systems can be defined by structural - rheological properties of the dispersion medium. In the case of using of polar dispersion unstructured environment (such as water) stability of the systems can be achieved using electrostatic and steric stabilization factors. In a viscous base the stabilization of magnet particles is possible without using of surfactant, due to the forces of viscous resistance of the dispersion medium.

For the such systems the nature of interaction of adsorbent-adsorbat between the particles of magnetic phase and surfactant molecules (or environment) should be determined, that affects the state of the surface and subsurface layers of magnetic nanoparticles and thus on their magnetic properties and the magnitude of the magnetic interparticle interaction.

Considering the importance of these samples for biomedical applications and the fact that most applications require the use of this material in the form of aqueous colloidal suspensions, it is worth studying the magnetite surface chemistry and the stability of the particles in water. The aim of this work is to investigate the aggregation and sedimentation stability of the synthesized magnetite particles in various rheological dispersion medium, to determine the interaction of "adsorbent - adsorbat" between the particles of magnetic phase and the stabilizer molecules.

The samples of magnetite nanoparticles suspended in water-based (surfactant were sodium oleate, 0.5% aqueous solution of hydrochloric acid, 3% aqueous solution of pectin) and polyethylene-based (PEG1500: PEG 400 8:2) were investigated. Synthesis of magnetite particles was performed by chemical coprecipitation: average particle diameter  $\langle d \rangle = 20$  nm, X-ray density  $\rho = 5.2$  g·cm<sup>-3</sup>.

According to the type of carrier liquid, two types of ferrofluids are distinguished: an aqueous ionic ferrofluid and a surfactated organic-based one. Ionic ferrofluids demonstrate several specific phenomena as well as may be used as precursors for a wide class of surfactated ferrofluids. Surfactated ferrofluids based on low-evaporating non-polar liquids keep their fluid properties in a rather wide temperature range. This is important for practical applications. Synthesis of these two types of ferrofluids requires an elaboration of appropriate solubilisation procedures for magnetite particles.

The obtained values of electrokinetic potential of research systems and sedimentation results are presented in Table 1. It was found relatively high values of electrokinetic  $\zeta$ -potential for all experimental systems. Adding the stabilizer led to an increase in potential values on average by 45% and sedimentation stability constants

at 60%. The efficiency of the electrolyte can be explained with the formation of the electrical double layer on the surface of magnetite particles.

**Table**

Electrokinetic potential of dispersion, average size and aggregation degree of magnetic phase

The composition of dispersed systems	$\xi$ -potential, $10^2$ V	Average size of particles, nm / degree of aggregation, %		
		1 day	7 days	60 days
magnetite/water	4.28	120/40	120/40	120/40
magnetite/5% solution of HCl/water	6.28	60/10	60/10	60/10
magnetite/sodium oleate /water	6.95	80/20	80/20	80/20
magnetite/3% solution of pectin/water	7.08	80/20	80/20	80/20

The suspension with the pectin solution (anionic polyelectrolyte) seems to provide the best properties. On the surface of the micelle core (magnetite particles) the anions of D-galacturonic acid (the main component of pectin) were adsorbed. This increases the stability of the dispersion system and facilitates the spatial structuring of colloidal particles (granules).

For the magnetite particles in the PEG-based dispersed systems using Rebinder's effect and Deryagin's rule an algorithm was developed. It was founded, that the disperse system PEG/magnetite has the necessary condition for sedimentation stability: low sedimentation rate of the magnetic phase ( $2.15 \cdot 10^{-9} \text{ cm} \cdot \text{s}^{-1}$ ) and high value of the measures of kinetic stability ( $45 \cdot 10^5$ ).

The type of the interaction between the stabilizer molecules and the magnetite particles was determined using IR-spectra analysis. In the resulting spectra of the samples, a band exhibits in the range  $3200\text{-}3600 \text{ cm}^{-1}$ . Surfactant is covalently attached to the iron oxide surface and helps to isolate the nanoparticles. Chemical bonding of the surface atoms of the magnetic particles with the stabilizer molecules reduces the "magnetic size" of the particles. Besides excessive local concentration of the stabilizer molecules on the surface of the particles forms the paramagnetic layer. Thus, on the one hand due the presence of surfactant prevents aggregation of the particles in the medium with low structural and mechanical resistance on the other, the use of stabilizer (oleic acid and its salts) leads to decrease in the magnetic properties of such a system that should be considered.

Polyethylene glycol and PEG derivatives are the most effective and widely used polymer for improving nanomaterial stability. PEG with a uniform and ordered chain structure is easily absorbed at the surface of magnetite, and acts as a dispersion stabilizer. When the surface of the colloid adsorbs this type of polymer, the activities of the colloid greatly decrease. By using PEG as a surfactant, we prevented particle growth, decreased interparticle interactions, and controlled the morphology. PEG reduces the tendency of particles to aggregate by steric stabilization, thereby producing formulations with increased stability during storage and application.