SYNTHESIS OF SUPERPARAMAGNETIC ZINC-SUBSTITUTED MAGNETITE NANOPARTICLES

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At present a great experience has been accumulated in application of the magnetic field in medicine for treating a number of diseases. The application of medicines with a magnetic component – nanoparticles of ferrites – in their composition is a new step in further development of magnetic therapy.

Such medicines possess magnetic properties and are able to be managed by the external magnetic field, i.e. being magnetically managed. They can be widely applied for magnetic biodetection, sorting of cells, contrast increasing in magnetic resonance tomography, regeneration of tissues, hyperthermal treatment and the targeted drug delivery.

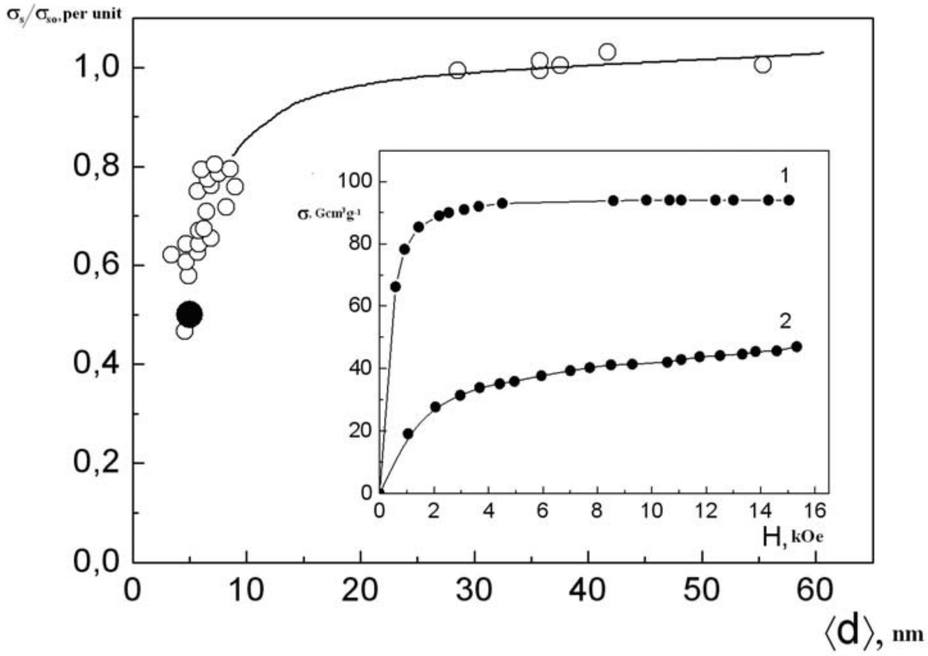
The main requirements to highly disperse ferrite materials for medical and biological purposes are: biocompatibility set by the chemical composition; the powder dispersity, which depends on the technology of obtaining; a great magnetic susceptibility set by a high magnetic saturation at a low value of the magnetic anisotropy field; superparamagnet (SPM) state determined by the particles volume, the magnetic anisotropy constant, temperature and the external magnetic field. Application of substituted ferrospinels gives the possibility to solve this rather complex multifactor task successfully.

To coordinate morphological and magnetic parameters of particles the physical and technological principle has been suggested and approved in this article, its essence is in choosing a chemical compound and using the technology that provides the given particles dispersity, as well as biochemical purity of the target product.

Comparing to the known analogue (magnetite - Fe_3O_4) used for a number of medical technologies, zinc-substituted magnetite ($Zn_x^{2+}Fe_{1-x}^{2+}Fe_2^{3+}O_4$) provides the increase of magnetization by 38 % at the zinc concentration of $x = 0.4$.

It has been experimentally found that in order to proceed the reaction and to form a black precipitate, which is characteristic to magnetite, the mixture obtained in the process of the reaction could be kept on the water bath for approximately 2 h at T = 80 °C while mixing constantly. Then the content is allowed to leave for 2 days (for complete “maturation” of the precipitate) with further multiple washing with distilled water to adjust pH = 7.5 – 8.0. To prevent a possible aggregation of ferrite particles the aqueous suspension obtained was placed in the ultrasonic dispersing agent for 2 – 3 min. A distinctive feature of the method used in this article is simplicity and a low price of the technological process, a high yield (~ 90 %) of the finished product, as well as a guaranty for performing of three main requirements of the target medical application – biochemical purity, nanoscale range of particles sizes and, as a result, their superparamagnet state.

As it is seen from figure (insertion), the value of the volume magnetic susceptibility of the given nanodisperse powder (2) comparing to its macroscopic analogue (1) – polycrystal prepared from this powder decreased almost twice. The effect is stipulated by a great contribution of the structural imperfect near surface area of particles with the "squinted" magnetic structure. The size effect mentioned is observed for all known oxide ferromagnetics. At first it was discovered by Berkovich. Figure demonstrates the dependence of magnetization obtained by him on dispersity of particles γ-Fe_2O_3. The value σ_s for the zinc-substituted magnetite studied in this article is marked there.



Demonstration of particles size influence on the value of powder magnetization in the fields reaching the anisotropy field value of macroscopic analogues of oxide ferromagnetics with a low anisotropy, γ-Fe_2O_3 (○), $Zn_{0,4}Fe_{2,6}O_4$ (●).

Insertion: the main magnetization curves at 300 K for the macroscopic analogue (1) and nanodisperse powder (2) of $Zn_{0,4}Fe_{2,6}O_4$.

To confirm the presence of the superparamagnetic state of the system of $Zn_{0,4}Fe_{2,6}O_4$ ferrite particles in the working range of temperatures for medical application, namely in the 300 K area, the study of the hysteresis loop in the fields H = 2 kOe, that are suitable for macroscopic analogue saturation has been conducted. The curves of magnetization and demagnetization coincide, i.e. the hysteresis-free behaviour of the magnetization process is observed: remnant magnetization σ_r and coercivity H_C are equal to zero.

Thus, the variant of technology suggested to the optimized composition of $Zn_{0,4}Fe_{2,6}O_4$ ferrite provided the chemical homogeneity of the powder required for medical and biological application, maximum small sizes and the superparamagnet state of the nanoparticles system at the room temperature.