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Study of the adsorption of Immunoglobulinum humanum by functionalized - NH_2, - SH, - COOH groups on the surface of nanoscale magnetite

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Introduction / Objectives / Aims

Nanomaterials as substrates for targeted delivery of therapeutic or diagnostic agents are widely used in modern medicine. However, it remains important to study their interaction with both transported drugs and components of the biological environment. Compliance with the principles of biocompatibility, adsorption activity, residence time in the biological environment and the target zone, hydrophilicity / hydrophobicity etc. - the main requirements for the physico-chemical parameters of these materials.

Increasing biocompatibility through surface functionalization ensures the activity of the target system, the selectivity of the binding of nanoparticles to certain chemicals or cells. Therefore, it is important to understand the process and mechanism of interaction of biological substances with surfaces of different nature, the impact on the conformation and functional ability of protein substances. This interaction will be determined by the chemical nature of the active centers of the surface: physicochemical (surface charge, reactive groups, pH_{IIP}) and geometric (size, surface structure) properties of nanoparticles.

Since one of the forms of external stimulation of physical targeting of drug delivery to cells is the magnetic field, nanocomposites based on Fe_3O_4 with - NH_2, - SH, - COOH functional groups were synthesized for the study. Immunoglobulinum humanum (Ig), which has a wide range of opsonizing and neutralizing properties against bacteria, viruses and other pathogens, selected as a model protein. The main purpose of this work was to study the processes of adsorption immobilization of Ig on synthesized composites.

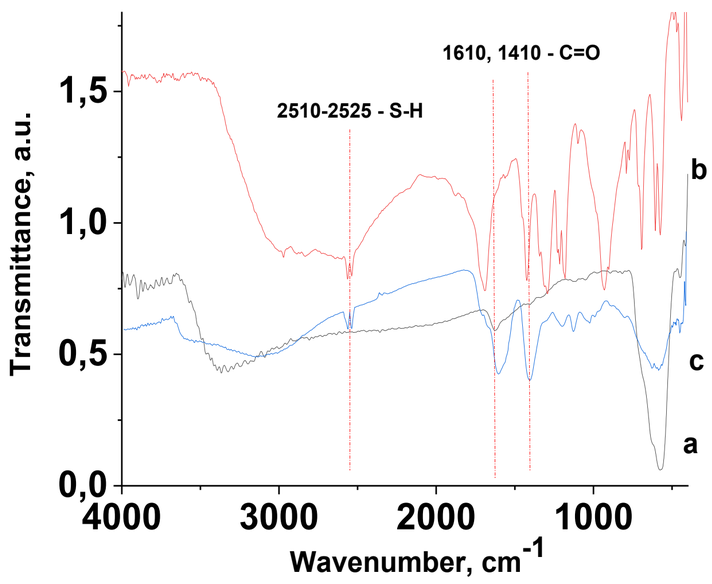
Metods

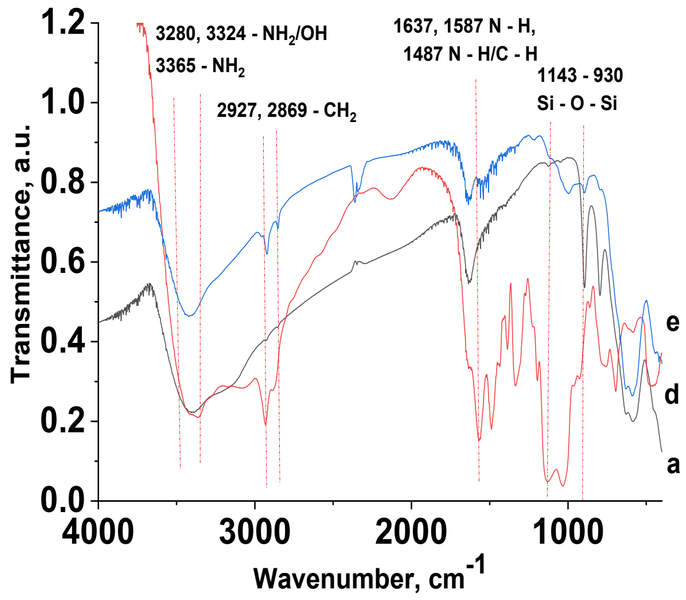
- The crystal structure of NPs was determinated by powder X-ray diffraction method (XRD). XRD measurements were perfomed using DRON-4-07 diffractometer with CoKα radiation and Fe filter, focusing on Bragg-Brentano.
- Infrared spectra were recorded on an FTIR (Fourier-transform infrared spectroscopy) Spectrometer Tensor 27 (Bruker Optik GmbH) in the range 4000–400 cm−1 using KBr pellets.
- The magnetization of the samples was measured using a vibrating magnetometer at a frequency of 228 Hz at room temperaure.
- The specific surface area of the samples was determined by the method of adsorption-desorption of nitrogen (KELVIN 1042 Sorptometer "COSTECH Instruments").
- The completeness of carbonization of the surface layer of the carbohydrate was evaluated by the method of TPD MS (MX-7304A (Sumy, Ukraine)) with electron impact ionization.
- The obtained samples were characterized by a scanning electron microscope MIRA 3 FE-SEM microscope (TESCAN, CR) equipped with an Energy-dispersive X-ray detector (EDX, UK).

Synthesis of functionalized - NH_2, - SH, - COOH groups on the surface of nanoscale magnetite

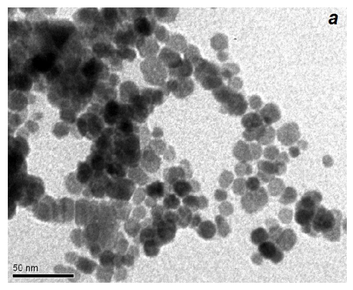
- $FeCl_2 \cdot 4H_2O$ and $FeCl_2 \cdot 6H_2O$ (Fe^{3+}: Fe^{2+} = 1:2 molar ratio) were dissolved in deionized water under nitrogen gas with vigorous stirring at 80^0C to prevent oxidation.
- Modification of a surface of magnetite nanoparticles with γ-APTES was carried out by the liquid-phase method; in toluene, γ-aminopropyltriethoxysilane (γ-APTES) was used as modifying agent. Oligomers were eliminated by distillation in vacuum. Before modification, magnetite was kept in 10 % solution of γ-APTES in toluene within 8 h for complete wetting of a surface.
- Modification of a surface of magnetite nanoparticles with DMSA was carried out by the liquid-phase method; in a suspension of nanodispersed Fe3O4 in toluene was added a solution of DMSA in Dimethyl sulfoxide (DMSO) (ratio 1: 1). The reaction was carried out at room temperature for 24 hours, the Fe3O4/DMSA precipitate was washed with ethanol and deionized H2O
- A MNC with a carbon surface was synthesized by the method of low-temperature pyrolysis of carbohydrate (sucrose). It was established that the used heat treatment mode does not lead to deterioration of the magnetic characteristics of magnetite under the condition of preliminary creation on its surface of a protective layer of alumina or silicon oxide.
- Differential thermal analysis (DTA) in combination with differential thermogravimetric analysis (DTGA) and programmed temperature desorption mass spectrometry showed that the carbonization of sucrose under these conditions was complete. The results of TEM studies and magnetic measurements indicated the formation of MNCs Fe3O4/Al2O3 or (SiO2) and Fe3O4/Al2O3 or (SiO2)/C by the type of core-shell.

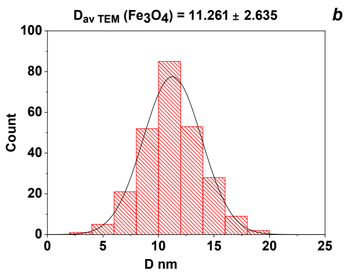
Characterization of of MNPs



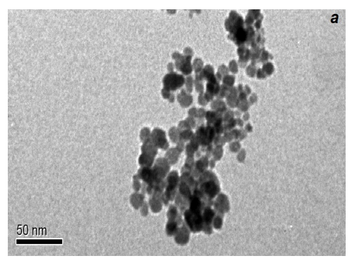


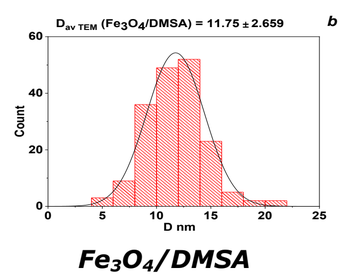
FT-IR spectra of Fe_3O_4 NPs (a), DMSA (b), γ-APTES (d) and modified NPs Fe_3O_4/DMSA (c), Fe_3O_4/γ-APTES (e)





Fe_3O_4





Fe_3O_4/DMSA

(a)TEM image of NPs; (b) particle size distribution