SYNTHESIS AND EVALUATION OF ZINCSUBSTITUTED MAGNETITE NANOPARTICLES FOR DRUG DELIVERY SYSTEMS

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Nanotechnology is one of the most interesting areas of modern science. One of the most promising of nanomaterials is the magnetic nanoparticles (MNPs) of different compositions. MNPs offer exciting opportunities in fundamental study and technological applications, such as biomedical applications, bioprocessing and catalysts among many others. Due to their unique properties, MNPs have been actively investigated as the component of targeted drug delivery systems.

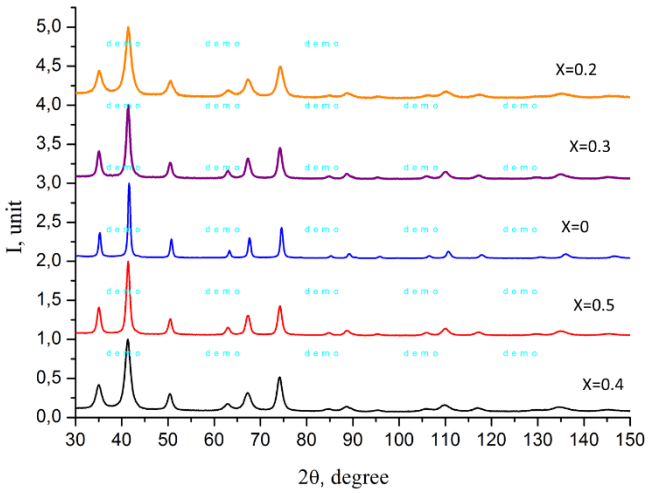
Nanoparticles of magnetite are the most widely used sources of magnetic materials. Doping magnetite with transition metal elements (zinc, copper, manganese) allows the modification of important quantities such as saturation magnetization, optical properties, electroconductivity. Zinc belongs to a class of microelements that is considered to play an important role in many vital biochemical reactions and physiological processes: growth and development of the cells, stimulation of the gene transcription and cell proliferation, slowing down the oxidation processes, optimization of the human immune system.

Zinc oxide nanoparticles are used as antimicrobial agent when incorporated into materials such as paints, textiles, plastics and personal care products, and can be added to the food to reduce the food poisoning effect by the various *Aspergillus sp*., which is legally approved. Zinc oxide nanoparticles have shown the best antibacterial behavior compared to copper (II) oxide and iron (III) oxide nanoparticles.

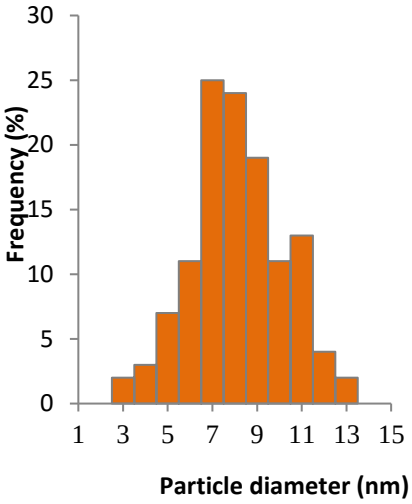
Therefore, to get more information about zinc ferrite nanoparticles ($ZnO \times Fe_2O_3$) and to improve their applications or develop new ones, careful studies related to their functionality, particle sizes and also their antimicrobial behavior are essential. In this work, zinc-doped magnetite nanoparticles are synthesized through co-precipitation method. This method may be the most promising one because of its simplicity and productivity. It is widely used for biomedical applications because of the ease of implementation and the need for less hazardous materials and procedures. The crystalline structure of the zinc-doped magnetite nanoparticles were studied by means of X-ray diffraction.

Ultrafine particles with the composition of $Zn_xFe_{3-x}O_4$ (x = 0; 0.2, 0.3, 0.4, 0.5) were prepared by co-precipitating aqueous solutions of the salts. In a typical procedure, 10 % by mass water solution of precursors ($FeSO_4$, $Zn(CH_3COO)_2$ and $FeCl_3$) freshly prepared were mixed together at heating. 0.1 M NaOH solution was added drop-wise with continuous stirring until complete precipitation of the black ferrite was achieved (pH 9–11). The reaction mixtures were maintained at 85 – 90 °C for 4 hrs. This time was sufficient for the hydroxides to transform into spinel ferrite. After the system was cooled to room temperature, the precipitates were collected using magnetic separation and washed with distilled water until pH neutral, producing thus samples ZnMNPs.

The crystalline structure, morphology and the magnetic properties of the ferrite particles were studied by means of X-ray diffraction (XRD), transmission electron microscopy (TEM) and vibrating sample magnetometer.



X-ray diffraction pattern of $Zn_xFe_{3-x}O_4$ composition



Particle size histogram of synthesized nanoparticles ZnMNPs40

The dependence of the crystalline lattice constants on the zinc ions concentration has been determined. Magnetic measurements at 300 K have demonstrated the superparamagnetic behaviour of ZnMNPs.

The antimicrobial activity of the ZnMNPs40 has been studied on strains belonging to common bacterial pathogens, that is, the Gram-negative, *Pseudomonas aeruginosa*, *Escherichia coli*, Gram-positive *Staphylococcus aureus*, *Bacillus subtilis* and fungus. The sample of ZnMNPs40 was found to be active against the test organisms with varying values of MIC.

Significant inhibitory effect was observed against *Escherichia coli* (gram negative), and *Staphylococcus aureus*, *Bacillus subtilis* (gram positive) bacteria and fungus. It was found that the ZnMNPs40 exhibited antibacterial activity against *E. coli*, *S. aureus*, *B. subtilis*and antifungal activity with MIC, 62.5 μg/ml, and MBC of 125.0 μg/ml. The nanoparticles was found to be bacteriostatic and fungistatic in action. Similar activity observations have been made for nanoparticles of zinc oxide. The probable mechanism of the antimicrobial action of ZnMNPs involves the binding of Zn^{2+} ions to functional groups of proteins and enzymes, which causes inactivation and inhibition in cell processes. Zinc ions cause destruction of the bacterial cell wall, degradation and lysis of the cytoplasma; leading to cell death. ZnMNPs with the size 9 nm have a large surface area, thus their bactericidal efficacy is enhanced compared to large sized particles.

Zinc oxide nanoparticles potentiate bactericidal efficacy of macrolides, tetracyclins and beta lactum antibiotics. Future studies should investigate the effect of ZnMNPs on the antibacterial activity of different antibiotics and the applicability of these nanoparticles for magnetic targeted drug delivery system will also be investigated.