Synthesis and Properties of Magnetic Nanoparticles with Potential Applications in Cancer Diagnostic

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ABSTRACT

In this paper we prepared three types of magnetic nanoparticles with potential applications in cancer diagnosis: cobalt nanoparticles, cobalt-nickel alloy nanoparticles and mixed oxide particles, i.e. magnetite nanoparticles. For cobalt nanoparticles we have used the reverse micelles technique as "nanoreactors" inside which salt reduction and particle growth occurs. Particles of cobalt-nickel alloy have been prepared by co-reducing the corresponding salts. The reduction methods yield a dispersion of nanocrystals in liquids and involve the need for a ligand shell or a capping layer to prevent aggregation. The particles of magnetite were prepared by boiling in reflux of a mixture formed by γ-Fe_2O_3 and Fe(II) salt (citrate or sulphate). The magnetic behavior of Co nanoparticles NiCo nanoparticles and magnetite nanoparticles reveals as the obtained magnetic nanoparticles can be used to enhance the signal from magnetic resonance imaging examinations, as diagnostic tools of cancer tumors and targeting treatment of diseases.

Keywords: magnetic, metal, nano, particles, diagnostic.

1. INTRODUCTION

The size, shape and composition of magnetic nanoparticles being trialed as biochemical probes depend of their intended application, as well as the method of fabrication. The magnetic nanoparticles are very attractive for diagnostic tools of cancer tumors and targeting treatment in cancer and HIV infection.

A possible method to create new magnetic nanoparticles with a very narrow size distribution is the preparation of self-assembled magnetic nanoparticles of cobalt, cobalt –nickel, or these particles encapsulated in an organic shell material [1, 2]. Many biomedical applications, as targeting treatment, require the use of iron oxide particles (usually Fe_2O_3 or Fe_3O_4) with diameters ranging from 10 nm to 300 nm [3]. They exhibit super-paramagnetic or ferromagnetic behavior, magnetizing strongly under an applied field, but retaining no permanent magnetism once the field is removed. The cobalt or nickel-cobalt nanoparticles which form the magnetic dipoles also produce a collective magnetic state. In biomedical application magnetic nanoparticles placed at the side of the solution beaker induces a magnetic moment in each of the freely floating beads and sets up a field gradient across the solution [4].

The goal of our work is: 1) the new soft chemical preparation routes for Co, NiCo nanoparticles and iron oxide particles; 2) show the magnetic properties in correlation with microstructural properties of nanoparticles, which establish the capability of magnetic nanoparticles as diagnostic tools in cancer, as well as smart treatment agents.

2. EXPERIMENTAL

2.1 Preparation of Metallic Nanoparticles

We prepared two types of magnetic metallic particles: cobalt nanoparticles and cobalt-nickel alloy nanoparticles. The technique of reverse micelles acting as "nanoreactors" inside which salt reduction and particle growth occurs, has allowed to obtain monodisperse particles which may display a define shape. For the dispersion and to prevent aggregation in other reducing methods are used typical ligands or capping agents like: sodium citrate, polymers, long chain thiols or amines [5, 6, 7].

In our paper the metallic and alloy particles have been obtained by reducing or co-reducing of the metallic salts using reverse micelles technique or dispersion in a capping agent. The mixed oxide or doped mixed oxide particles have been prepared by a sol-gel method.

The preparation of cobalt nanoparticles has made using cobalt nitrate reduction with sodium borohydride in sodium bis (2-ethylphenyl) sulfosuccinat / toluene inverse micelles system Cobalt nitrate hexahydrate, $Co(NO_3)_2.6\ H_2O$ in concentration 0.01M – 0.02 M is dissolved in 10 ml of sodium bis (2-ethylphenyl) sulfosuccinat / toluene solution. By addition of 5 ml from 10 M sodium borohydride aqueous solution results a stable black colloid at room temperature. The particles of cobalt nickel alloy with the composition $Co_{0.9}Ni_{0.1}$ have been obtained by boiling in reflux of an ethylene glycol solution of cobalt and nickel acetates. A mixture of 2 g of $Co(CH_3COO)_2.4\ H_2O$ and $Ni(CH_3COO)_2.4\ H_2O$ (in 9Co:1Ni molar ratio) dissolved in 10 ml of ethylene glycol was refluxed at 130^0C with continuous stirring. After 15 hours of boiling, 2g of sodium citrate was added at the hot solution and the reaction was kept up 2 hours at the same temperature. At the end of the reaction, the particles were precipitated by adding 20 ml water and isolated by centrifugation. The black particles of alloy were washed, with water several times and dried on P_4O_{10} in a desiccators.

2.2 Synthesis of Magnetite Nanoparticles

The particles of magnetite were prepared by boiling in reflux of a mixture formed by γ-Fe_2O_3 and Fe(II) salt (citrate or sulphate). 20 ml of an aqueous solution of γ- Fe_2O_3 and FeC_2O_4 (1 Fe_2O_3 : 1 FeC_2O_4 molar ratio) was boiling in reflux for two hours with continuous stirring. After this time, a new quantity of water (150 ml) was added and the boiling was proceeded up 20 hours. After the cooling the solution, the particles filtered, washed with water and dried in air.

From the last type of magnetic particles, by passivation with gold, a nanocomposite magnetite-gold with the potential use in drug delivery has also obtained.

3. RESULTS AND DISSCUSION

Magnetic measurements of magnetic metal and oxides nanoparticles were performed at room temperature using Vibrating Sample Magnetometer (VSM) Lake Shore 7300.

Magnetic NiCo nanoparticles (Figure 1) have soft ferromagnetic behavior, with high saturation magnetization: 58 emu/g at relative high magnetic field (H_S) of 3000 Oe; the coercivity (H_c) is 24.5 Oe.

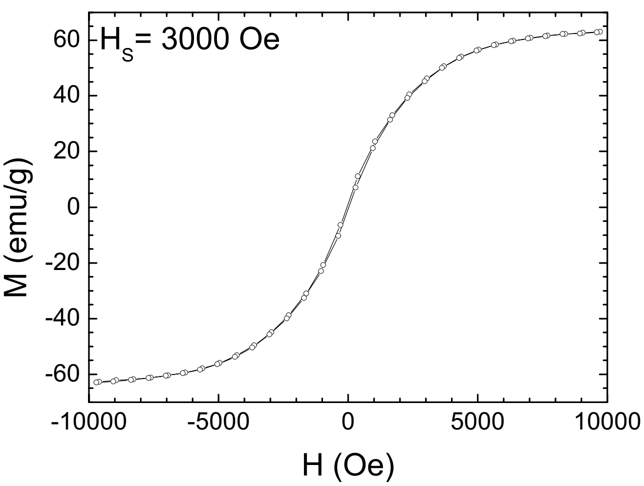

Figure 1: VSM hysteresis loop of NiCo nanoparticles, measured at room temperature.

Figure 2 shows the hysteresis loop of Co nanoparticles. This sample has small ferromagnetic behavior at room temperature: saturation magnetization of 0.6 emu/g, saturation magnetic field (H_S) of 4500 Oe and the coercivity (H_c) is 174 Oe. Magnetic behavior of Co particles sample suggests that cobalt particles are covered with cobalt oxide. Co oxide is antiferromagnetic at room temperature.

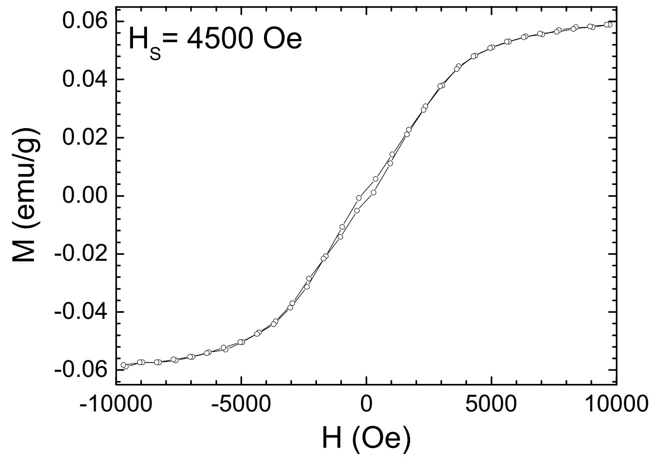

Figure 2: VSM hysteresis loop of Co nanoparticles, measured at room temperature.

Figure 3 shows the hysteresis loop of Fe_3O_4 nanoparticles. This sample has ferromagnetic behavior at room temperature: saturation magnetization of 23 emu/g , saturation magnetic field (H_S) of 3500 Oe, the coercivity (H_c) of 140 Oe and squareness ratio of 0,145. Magnetic behavior of Fe_3O_4 nanoparticles suggest that assemblies of magnetic multi-domains have been formed. Electronic microscopy reveals spheroidal morphology of Fe_3O_4 particles.

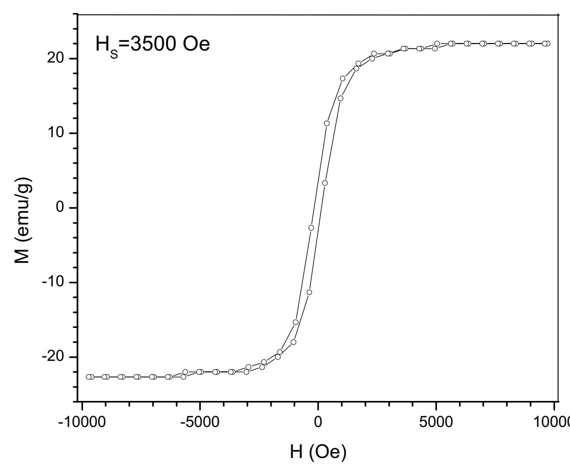

Figure 3: VSM hysteresis loop of iron oxide particles, measured at room temperature

Magnetic nanoparticles were characterized for microstructural properties by Transmission Electron Microscopy (TEM). Conventional TEM studies were performed using a JEOL JEM 200 CX at 200kV. To obtain specimens for microstructural and magnetic characterization, dispersions of nanocrystals in water (sols) were dropped onto carbon coated TEM Cu grids or glass or Si-substrates.

Figures 4 shows TEM image of NiCo nanoparticles, with average sizes of particles from 10-20 nm. The particles are spheroidal assemblies, because of magnetic interaction forces.

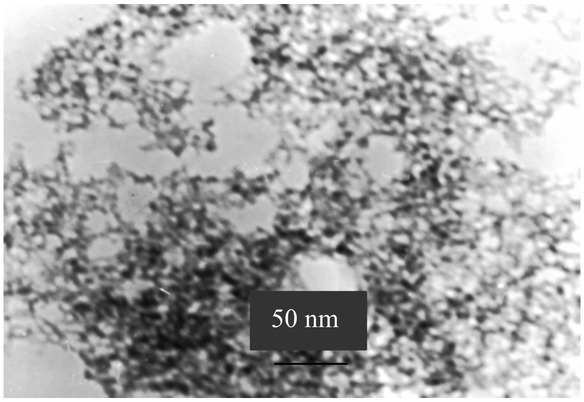

Figure 4: TEM image of sample NiCo nanoparticles, the average size of 10-20 nm

Figure 5 shows TEM image of Co nanoparticles, with average sizes of particles from 10-20 nm. The particles are spheroidal assemblies, as consequence of magnetic interaction forces, the coercivity of Co particles is relative bigger than the coercivity of NiCo particles .

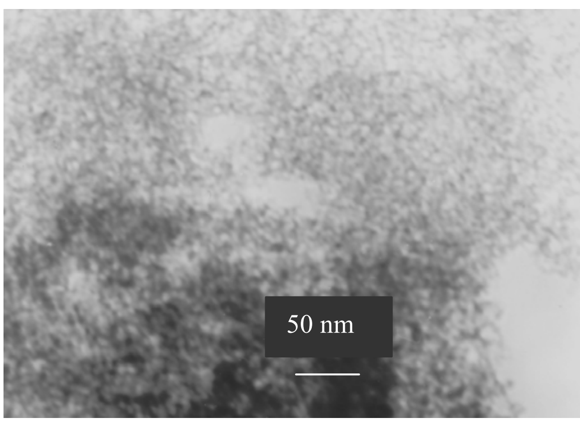

Figure 5: TEM image of Co nanoparticles, the average size of 10-20 nm

Figures 6 shows SEM image of Fe_3O_4 particles, with average sizes of particles from 100-300 nm. The particles are spheroidal assemblies, as consequence of magnetic interaction forces, the coercivity of Fe_3O_4 particles is relative bigger 140 Oe.

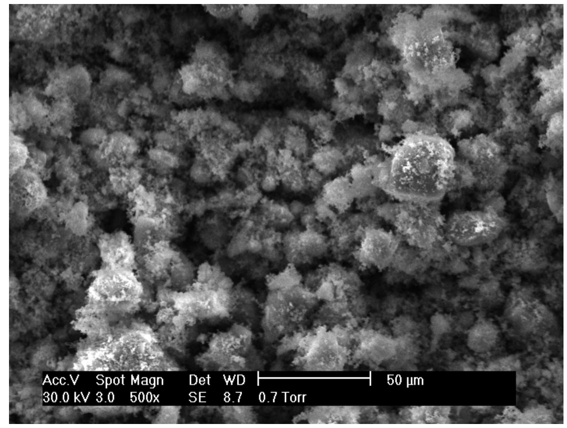

Figure 6: SEM image of Fe_3O_4 particles sample, the average sizes of 100-300 nm

4. CONCLUSION

Soft chemical methods are versatile techniques that can be used to prepare and organise any type of magnetic particles. The magnetic properties of magnetic nanoparticles have good quality for biomedical applications, as diagnostic tools and targeting treatment in cancer and other diseases. Magnetic properties obtained for metallic NiCo nanoparticles and for magnetite particles answer to magnetic field strengths required to manipulate nanoparticles have no deleterious impact on biological tissue. NiCo nanoparticles have a ferromagnetic behavior that magnetizing strongly under an applied field, but retaining no permanent magnetism once the field is removed. The spheroidal form of magnetic nanoparticles improves the removal in biological fluids for drug delivery and targeted detection of tumors.

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