Size of the single domain magnetite particles and MRI parameters

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Magnetic nanostructures are being increasingly used in medical diagnosis and treatment [1]. The properties of these structures depend on their size, shape and crystallographic structure. Among many kinds of nanoparticles that have magnetic properties, iron oxides form a large and diversified group and are of our research interest.

One of the representative of this group is magnetite that possesses the most interesting properties. Magnetite has two cations Fe^{3+} and Fe^{2+} that create the inverse spinel structure and have ferrimagnetic properties. Magnetite (Fe_3O_4) magnetic properties depend on the size of its magnetic structure. If we reduce the size of the magnetic particle to the nanoscale, the properties will change from ferrimagnetic to paramagnetic. That behavior is due to the creation of magnetic domain. If the size of a magnetic particle is small enough the probability of the domain walls creation is very low. As a result, single domain state is more energetically favorable compared to multi domain state. Such magnetite nanostructures have superparamagnetic properties. Superparamagnetic nanoparticle has a unique magnetic moment that significantly influences relaxivity in its closest environment.

The aim of the study was to examine the effect of the size of single domain magnetite structures on relaxivity of toluene as a selected solvent. The phenomenon is directly related to two different processes that influence the relaxation of the solvent. The first is concerned with the Brownian motion of SPIO (Superparamagnetic Iron Oxide) nanoparticles, the second one is associated with the Neel relaxation. The contribution of Neel and Brownian relaxation strongly depends on magnetite crystal radius [1,2,3]. In our experiment magnetic nanoparticles were suspended in organic solvents in presence of oleic acid (toluene) and polyethylene glycol (water).

The nanoparticles size distribution (fig.1) was examined using Transmition Electron Mictoscope (JEOL-*JEM* 1400, electron accelerating voltage 120kV and JEOL-*ARM* 200F, electron accelerating voltage 200kV). The chemical characterization of the particles was obtained using Energy Dispersive X-ray Spectroscopy (EDS). Proton relaxivity of toluene with magnetite particles of three different sizes: 5, 10 and 20 nm as well as 10 nm magnetite particles in water was measured using NMR techniques.

^1H spin-lattice (T_1) and spin-spin (T_2) relaxation times of toluene with magnetite particles of three different sizes were measured using pre-saturation and CPMG sequences respectively. For the particle sizes of 5 and 10 nm the increase of the T_1 relaxation time with increase of particle size was observed. We believe that this size effect is associated with the size of particles for Brownian and Neel processes which have influence on relaxation of the solvent to the same extent. Spin-spin relaxation time for the two smallest sizes behaves like T_1 i.e. the smaller size of particles, the shorter T_2. Spin-spin relaxation time for 20 nm particles is the shortest. We believe that either the 20 nm particles start to have the ferrimagnetic nature or spin-spin interaction is governed by Neel effect. Hence, NMR relaxation dispersion of magnetite nanoparticles was noticed.

References

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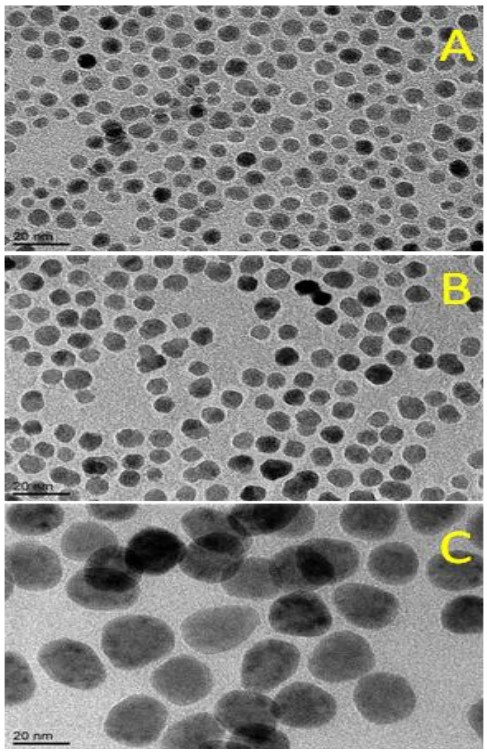

Fig.1 TEM images of magnetite particles. A: 5 nm particles, B: 10 nm particles, C: 20 nm particles.