Comparison of the influence of superparamagnetic nanoparticles concentration and coverage on the alternating magnetic field thermal effect

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Comparison of the influence of superparamagnetic nanoparticles concentration and coverage on the alternating magnetic field thermal effect. abstract The alternating magnetic field (AMF) causes the located in cancerous tissue magnetic nanoparticles (MNP) to dissipate heat, leaving the surrounding tissue intact, which is the basis for many biomedical technologies. One of them is magnetic fluid hyperthermia (MFH), a controlled technique of heating tissues to temperature from 41 to 46 °C exploiting magnetic fluids with Fe_3O_4 after injecting them directly into target tissues. The efficiency of MFH depends on the type of particles. The particles used in medical procedures must have high biocompatibility. For this purpose, they are usually coated with special coatings. Our goal was to investigate the effect of nanoparticle concentration and coverage in the tested samples on the efficiency of MFH.

The MNPs were produced by standard co-precipitation reaction of iron chlorides with ammonia water. To apply polyethylene glycol (PEG) coatings on the nanoparticles PEG was added during the process. For our research, two series of nanoparticles were produced: without (series 1) and with PEG coatings (series 2). Magnetic characterization, size, and composition of the nanoparticles produced were carried out based on X-ray diffraction (XRD), spectroscopy in Fourier transform infrared (FTIR), superconducting quantum interference device (SQUID), and transmission electron microscope (TEM). Magnetic fluids were prepared as oleic acid suspension of nanoparticles of the two series at concentrations of 5, 10, 20, 40 mg/ml. The volume of oleic acid in all samples was the same. Measurements of the temperature rise in all magnetic fluids were carried out within 3 minutes.

The results of the conducted experiments confirmed that the efficiency of MFH strongly depends on the concentration of fluids. The efficiency of the process increases with a higher amount of concentration. Besides, a fluid containing bare magnetic nanoparticles (series 1) had a greater temperature increase than those that contain particles with coatings PEG (series 2) in the concentration range from 5 to 40 mg/ml. To compare the heating properties of the Fe_3O_4 and Fe_3O_4-PEG nanoparticles, the specific absorption rate (SAR) was calculated for each sample $SAR = c_p \frac{\partial T}{\partial t}|_{t=0}$, where c_p is the specific heat of the sample and $\frac{\partial T}{\partial t}|_{t\approx 0}$ is the constant, i.e. the rate of temperature rise at the beginning of the process. The results indicate that the magnetic fluid containing nanoparticles with PEG heat up slower than fluids with bare nanoparticles. The reason for this is maybe the increase of "magnetic dead layer" width on the contact of nanoparticles with PEG, which was also confirmed by the worse magnetic properties of PEG-coated MNPs compared to bare MNPs.