Impact of the ferrogel fine structure on magnetic heating efficiency

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Agarose gel with nanoparticles of Fe_3O_4 was used as a tissue-mimicking material (TMM) for hyperthermia study, e.g. in [1]. Magnetisation of clustered nanoparticles is generally lower than spatially separated magnetic nanoparticles, cf. [2]. The goal of this study was to show how the nanoparticle are clustering inside the agarose gel structure and to relate it with the heating efficiency of ferrogel. To this end, two types of ferrogels were studied, with bare and PEG-coated nanoparticles. XRD patterns revealed the spinel structure and mean crystal diametr c/a $d = 8.9$nm. TEM images confirmed these results. FTIR confirmed the PEG content in PEG-coated nanoparticles. SQUID measurements revealed the superparamagnetic properties at room temperature, and besides, lower magnetization values of PEG-coated nanoparticles than bare ones. A comparison of the temperature increase under the influence of the same alternating magnetic field in both gels indicated a bit faster temperature rise for a gel containing PEG-coated nanoparticles although the magnetic saturation of the PEG-coated superpapramagnetic nanoparticles was 15% lower than for bare nanoparticles. The measured specific heat of both gels was indistinguishable. So, the Specific Absorption Rate (SAR) of the ferrogel with PEG-coated nanoparticles was greater than with bare nanoparticles. This result confirmed the influence of the fine structure of the nano-composite gel on the heating efficiency of the composite. The fine structure of two types of nanocomposites differed firstly in the spatial nanoparticle distributions and their locations. Secondly, they differed also in the strength and type of bonds between nanoparticles and the gel. For the first time, it was possible to observe in TEM images chiral clusters of nanoparticles, evenly densely packed and located inside agarose double helices. We underline that such clusters, probably bonded by electrostatic and van der Waals forces were stable under the action of the AC magnetic field, we observed only in the ferrogel with bare nanoparticles. PEG-coated nanoparticles did not form such clusters, they were more uniformly distributed and located outside double helices, rather inside the ice structure of water, and bonded to this structure by weak hydrogen bonds. We concluded that these differences in nanostructures were responsible for differences in heating efficiency.

References:

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