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R. Müller

Heating by magnetic ac- field losses of iron oxide nanoparticles

Nanoscale ferrite particles are used in magnetic fluids. In such fluids rheological properties can be influenced by magnetic fields. Considerable heating effects can be achieved in ac-magnetic fields by remagnetisation losses or energy dissipation during particle rotation. They could be interesting as well for detection of biological binding reactions using their magnetic relaxation behaviour or for magnetic cell separation. In our investigation, we consider the suitability of magnetic nanoparticles for heating processes in biomedicine aiming at magnetic particle hyperthermia as a valuable tool for tumor therapy. Technical heating processes like heat assisted hardening of polymers and thermally mediated opening of drug capsules in order to allow the remote controlled drug delivery at a predetermined site within the gastrointestinal tract are possible applications as well. Enhancement of the specific loss power SLP would allow a reduction of the tissue load with magnetic material (iron oxide) and improve the reliability of a therapy. Moreover, due to technical limitations of the magnetic field amplitude achieved at the target site, on the one hand, and biomedical limitations on the other hand, the SLP should show high values even at relatively small field amplitudes (≤ 15 kA/m). During remagnetisation of magnetic nanoparticles in an ac-field several types of loss processes (hysteresis losses, Néel- or Brown relaxation) may appear which depend strongly on the mean particle size, the size distribution width and the anisotropy [1]. For iron oxide nanoparticles, a maximum of the SHP was found in the transition region from stable ferromagnetic single domains to superparamagnetism. The highest SHP value was reported for magnetosomes (mean size about 35 nm), i.e. magnetic particles produced by magnetotactic bacteria. Nearly 1 kW/g was measured at field parameters of 410 kHz and 10 kA/m [2]. Unfortunately, these particles are available only in very small amounts. Therefore, we have investigated precipitated particles in a range of mean diameters of 10 nm up to about 100 nm. To influence and improve the mean size as well as the size distribution new approaches in preparation are promising where nucleation and growth of particles can be influenced independently like in the case of crystallisation of glass or where a further growing is possible on small given particles without further nucleation. In our work the glass crystallisation method GCM and a modified wet chemical method is investigated with respect to preparation of nanoparticles with improved SLP.

At the preparation of magnetic iron oxide γ-Fe_2O_3 from CaO-Fe_2O_3-B_2O_3-glass avoiding non-magnetic iron oxides particles grow during annealing at 500°C - 750°C in a solid matrix and were leached out by dissolving the matrix. Their size is controlled by the annealing parameters. Experiments on a cyclic method (growth on given particles) based on „usual“ precipitation have shown an increasing mean particle size by XRD (from about 10 to 30nm) with increasing number of cycles. The coercivity increases with the size, whereas the hysteresis losses at small applied fields (11kA/m) reveal lower values again if the particles are magnetically too hard.

The measured ac-losses of both methods are in the order of 100 W/g for field parameters of 11 kA/m and 410 kHz which are suitable for hyperthermia therapy runs. However, they are nearly one order of magnitude lower than best values reported till now from magnetic bacteria and what seems necessary for future treatments like antibody targeting. Therefore, particle optimisation will be our goal also in future.

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