Field dependent transition to the non-linear regime in magnetic hyperthermia experiments of distinct ferrite-based nanoparticles

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Further advances in magnetic hyperthermia might be limited by biological constraints, such as using sufficiently low frequencies and low field amplitudes to inhibit harmful eddy currents inside the patient's body. These incite the need to optimize the heating efficiency of the nanoparticles, referred to as the specific absorption rate (SAR). Among the several properties currently under research, one of particular importance is the transition from the linear to the non-linear regime that takes place as the field amplitude is increased. In this work we investigate the heating properties of cobalt, copper, iron and nickel ferrite nanoparticles at a large particle size range (3-15nm) under the influence of a 500 kHz sinusoidal magnetic field with varying amplitude, up to 134Oe. The particles were characterized by XRD, FMR and VSM, from which most relevant morphological, structural and magnetic properties were inferred. From magnetic hyperthermia experiments we found that, while at low fields soft ferrites are the best nanomaterial for hyperthermia applications, above a critical field, close to the transition from the linear to the non-linear regime, hard-like ones (cobalt ferrite) becomes more efficient. The results were also analyzed with respect to the energy conversion efficiency and compared with dynamic hysteresis simulations. The later revealed deviations from the elliptic-like hysteresis above a critical magnetic field. Finally, our experimental data and simulation results proved that out of phase coherent spin rotation show distinct field exponents at the non-linear regime highly dependent upon the magnetic anisotropy.

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