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Arranging at the nanoscale: Effect on magnetic particle hyperthermia

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Magnetic particle hyperthermia is a synergistic cancer treatment technique that takes advantage of heat released by magnetic nanoparticles (MNPs) when they are exposed in an alternating magnetic field and may lead cancer cells either to a severe thermal shock or even induce their death. The heating efficiency of MNPs is quantified by the specific loss power (SLP). The aim of this work is to provide a deeper understanding on the evolution of Fe_3O_4 nanoparticles field driven orientation within an agarose gel network and its consequences on magnetic hyperthermia efficiency. We examined a 10 nm and a 40 nm magnetite nanoparticle system with the former being superparamagnetic and the latter ferromagnetic and fully successful in chain array formation. For this purpose, specimens were prepared by dispersing nanoparticles in an agarose solution followed by a natural gelation procedure under static magnetic field. The success of chain formation for varying particle concentration and agarose gel content was evaluated by electron microscopy observations while molecular dynamics simulations successfully represented experimental findings (as shown in Figure 1). Eventually, chain formation results to increased heating efficiency as quantified experimentally in calorimetric experiments and theoretically correlated with magnetic features via Stoner-Wohlfarth model extended to include the temperature and frequency dependence of the coercive field. The chain formation due to dipolar interactions results to uniaxial anisotropy evolution and directly influences collective magnetic features as verified by VSM and FMR measurements. Magnetic heating efficiency strongly correlated with collective magnetic features. By adequate selection of nanoparticles and colloidal parameters, the formation of oriented arrangements may be easily achieved, fine-tuned and result to enhanced magnetic particle hyperthermia efficiency.

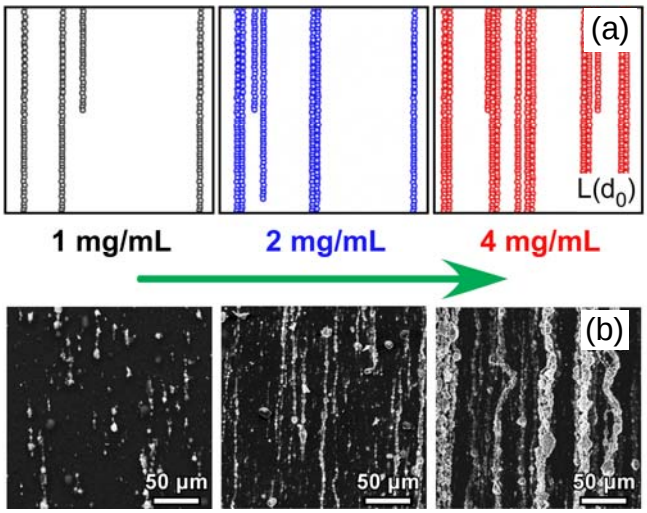

Figure 1: *Results from Molecular Dynamics simulations of chains formation of 40 nm MNPs for various concentration values. (a) Chain formation of MNPs in an external field of 40 mT. The dimensions of our 2D computational space were $L(d_0) \times L(d_0) = (80d_0)^2$ where d_0 is the MNPs diameter of 40 nm. The number of MNPs was set to 380, 760, 1520 for the concentrations of 1, 2 and 4 mg/mL, respectively. (b) Corresponding experimental SEM images for three MNPs concentrations.*