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Magnetophoresis of colloidal particles in a dispersion of superparamagnetic nanoparticles: Theory and Experiments

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Supplementary Information

MATERIALS AND METHODS

Synthesis of SDS-modified nanoparticles

The ferrofluid was prepared by conventional co-precipitation of iron oxide nanoparticles from an aqueous mixture of FeSO4 and FeCl3. (1:2 molar ratio) NH4OH was used as a precipitation agent. FeSO4·7H2O (0.5 mM, 1.4 g in 50 mL) and FeCl3·6H2O (1 mM, 2.7 g in 50 mL) were mixed and heated to 80ºC. In order to precipitated the iron hydroxides, the pH value was raised and maintained to pH=3 for 30 min. The solution was rigorously stirred at a constant temperature during all the process. Then, the pH value was increased to 10. [1,2]. 1 g of the as precipitated nanoparticles was dispersed in 50 ml of a 2g/l aqueous solution of SDS (Sodium Dodecyl Sulphate) followed by vigorous stirring for 2 hours. The pH was maintained at 10 to assure a stable suspension. The prepared suspension was washed with distilled water and magnetically separated for several times to remove the excess of SDS. Finally the NPs were dried and a suspension of 10g/l aqueous solution of the SDS-modified nanoparticles was prepared.

Characterization of SDS modified nanoparticles

A LEO 906E electron microscope operating at 100 KeV, was used for transmission electron microscopy. The samples were prepared by deposition of a droplet of particles solutions on a copper grid coated with carbon and allowed to dry. The as synthesised

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nanoparticles (NPs) were characterized by X-ray diffraction with a Bruker D8 Discover diffractometer using Cu Kα incident radiation. Hysteresis loop of the NPs at room temperature curves were measured with a superconducting quantum interference device (SQUID) magnetometer (Quantum Design MPMS5XL). A Nova^{TM} NanoSEM and Pegasus X4M (EDS/EBSD) were used for scanning electron microscope and elemental microanalysis, respectively.

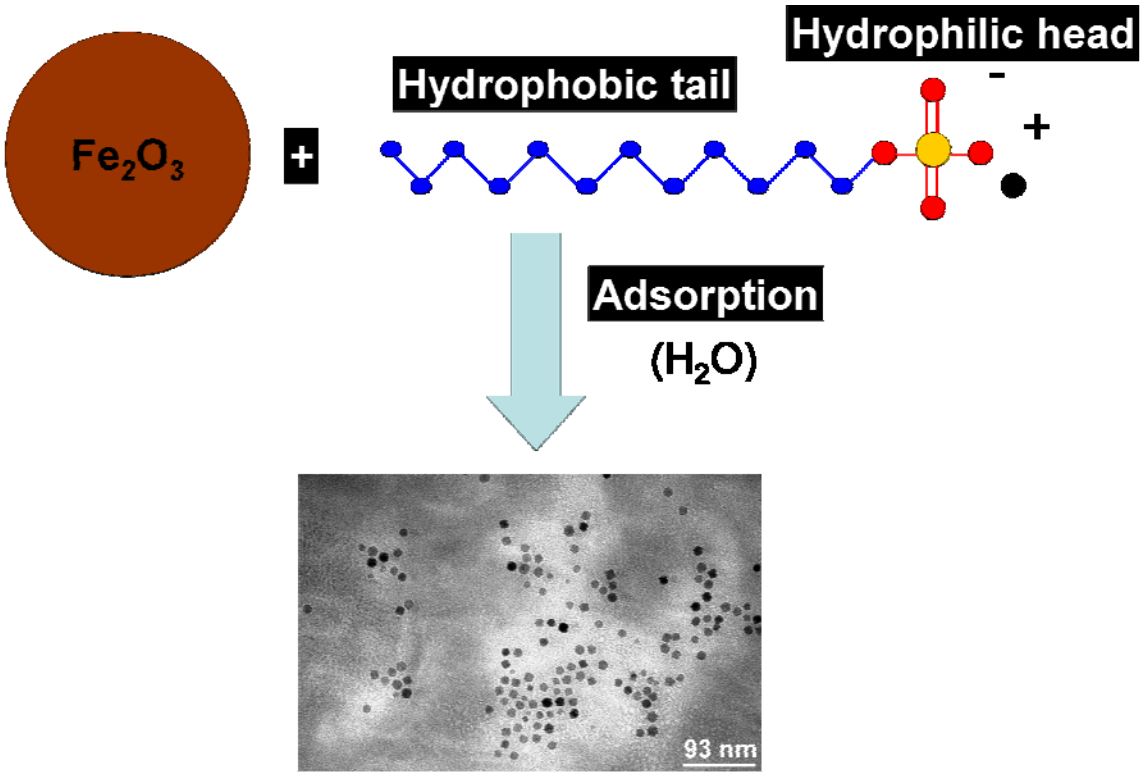

Figure S1. Scheme of the different steps of the preparation of the suspension and TEM image of SDS modified maghemite nanoparticles (SDS-NPs).

Transmission electron microscopy images of the SDS-modified nanoparticles show nanoparticles with average size of 12 nm **(Figure S1**). X- ray diffraction was performed on dry nanoparticles. Because of the modest amount of the available sample, the peaks of the diffractogram are not very well defined. They can be indexed either to maghemite or magnetite. Magnetic measurements of SDS-Modified nanoparticles show a magnetization saturation of 68 Am^2/Kg at about 0.1T (**Figure S2**).

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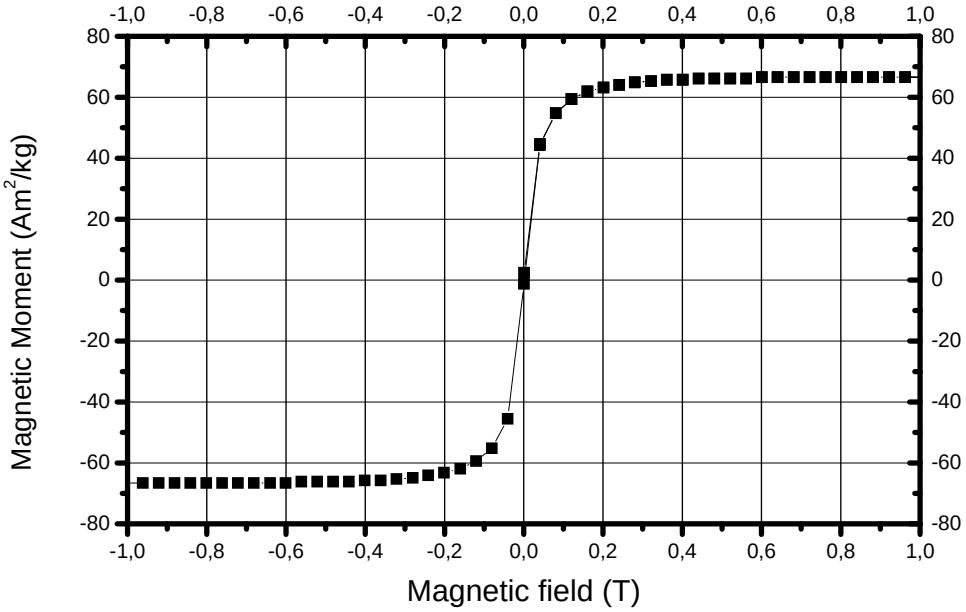

Figure S2. Magnetization curve of SDS-NPs at room temperature

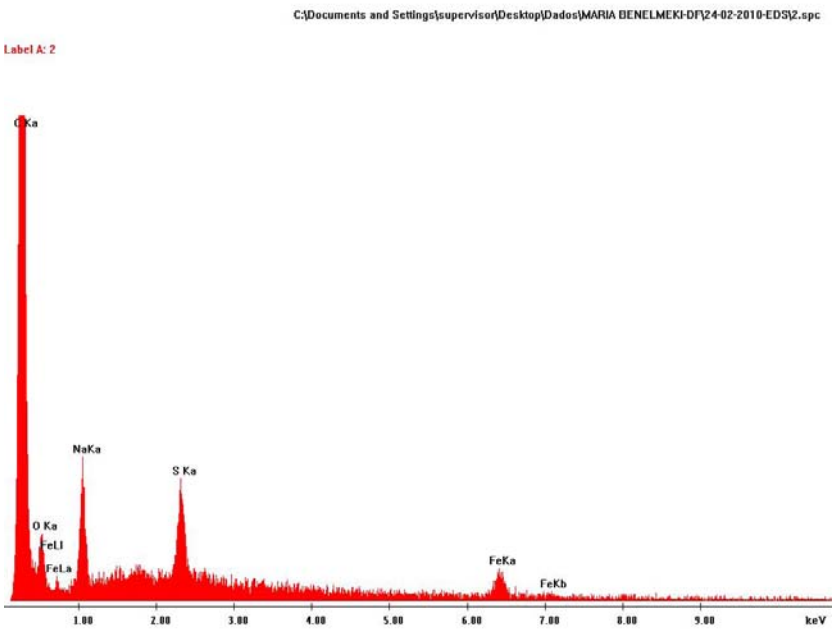

Figure S3. EDS spectrum of the mixture of latex particles and SDS-NPs

Table S1 show the composition of the sample of a 2.8% in weight of Fe (corresponding to about 3000 magnetic nanocrystal by latex particle). Other EDS measurements on

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others areas of the sample (not shown) show a content of 0.33- 0.44% in weight of Fe with an acceptable integration error value (about 10), this percentage correspond to about 400-500 magnetic nanocrytal by latex particle.

Element	*Wt %*	*At %*	*Integration Error*
C K	76.5	84.1	1.0
O K	14.7	12.1	5.1
NaK	3.6	2.1	3.7
S K	2.2	0.9	3.6
FeK	2.8	0.6	5.6

Table S1. EDS microanalysis in the case of 2.8% Fe weight content. Data are expressed as both weight and atomic percents.

Magnetophoresis experiments:

The magnetophoresis setups employed in our experiment are the SEPMAG LAB 1x25 ml 2042 and 2042 Plus systems, commercially available from SEPMAG company [3]. The systems consist of a cylindrical cavity containing a high permanent magnetic field with a uniform radial gradient magnetic field pointing toward the walls of the cylindrical vessel, and a vertical gradient magnetic field close the wall and pointing to the extremities of the cylinder walls. Opacity monitoring is performed using the external light source SEPMAG CBL Q250 ml, also available in SEPMAG company [3].

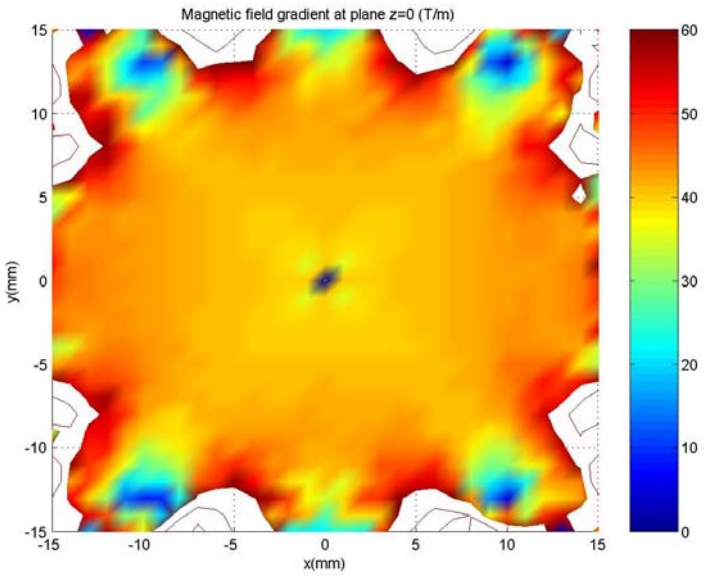

Figure S4. Distribution of the radial gradient magnetic field in the SEPMAG LAB 1x25 ml 2042 plus sytem (60T/m)

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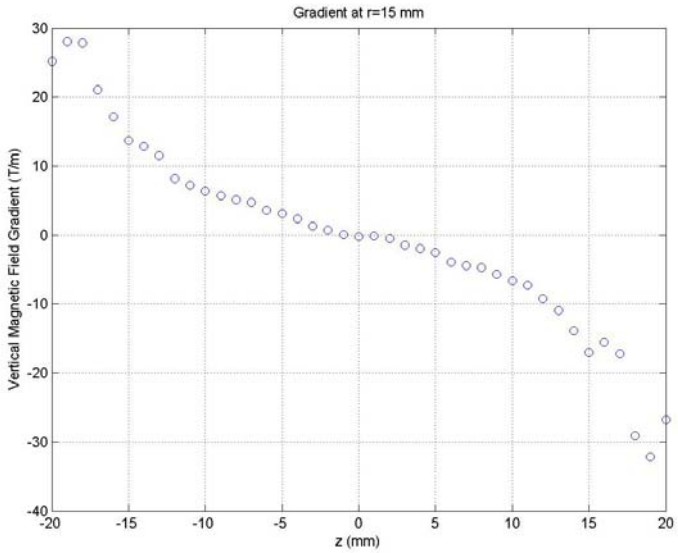

Figure S5. Distribution of the vertical gradient magnetic field in the cylindrical walls of the SEPMAG LAB 1x25 ml 2042 plus (60T/m).

Magnetophoresis behavior of the SDS-NPs:

The magnetoforesis experiment was performed by placing a glass bottle containing 15 ml of the synthesised ferrofluid (10g/l) inside the SEPMAG cylindrical cavity. The initial yellow-brown solution becomes transparent reaching a transparent final state with all particles close to the walls of the bottle. By applying 60T/m gradient the total time separation is about 20 hours. By applying 30T/m gradient the total time separation is about 55 hours (Figure S6).

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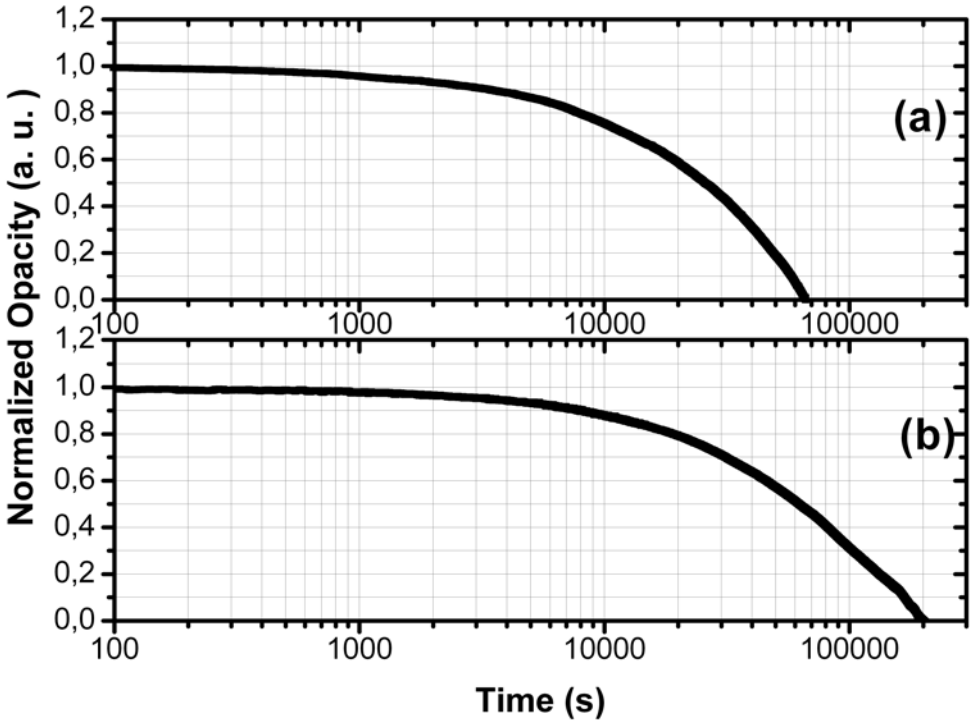

Figure S6. Magnetophoresis curves of the synthesised SDS-NPs core-shell at different magnetic field gradients: (a) 60 T/m and (b) 30T/m

References

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2. Zhang, Jing; Yu, Demei; Chen, Wei; Xie, Yunchuan; Wan, Weitao; Liang, Honglu; Min, Chao *Journal of Magnetism and Magnetic Materials* **2009,** *321*, 572-77

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