Electronic Supplementary Information

Mixing iron oxide nanoparticles with different shape and size for tunable magneto-heating performance

Jesus G. Ovejero[1], Federico Spizzo[2], M. Puerto Morales[1]*, Lucia Del Bianco[2]*

[1] *Dept. Energía, Medio Ambiente y Salud, Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, E-28049 Madrid, Spain*

[2] *Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, I-44122 Ferrara, Italy*

*****Corresponding authors. E-mail address: puerto@icmm.csic.es, lucia.delbianco@unife.it

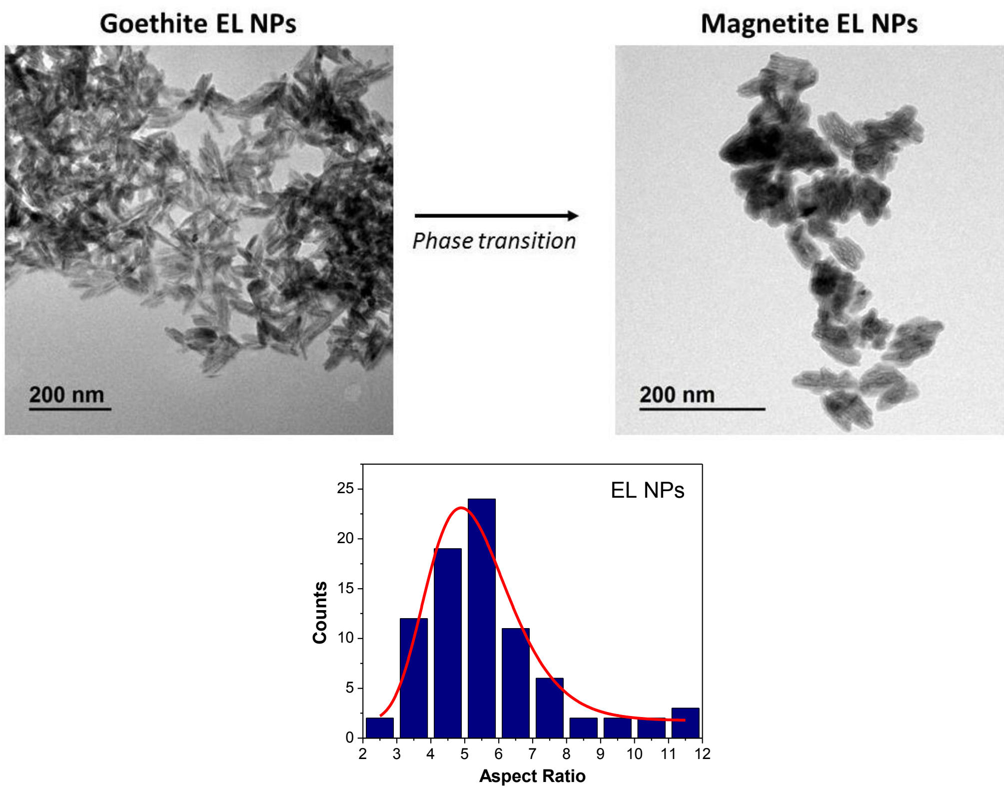

Fig. S1 High panel: TEM images showing the precursor elongated goethite NPs and the final magnetite EL NPs, prepared following the synthetic method described in the article (Scheme 1). Low panel: distribution for the aspect ratio of the core of EL NPs.

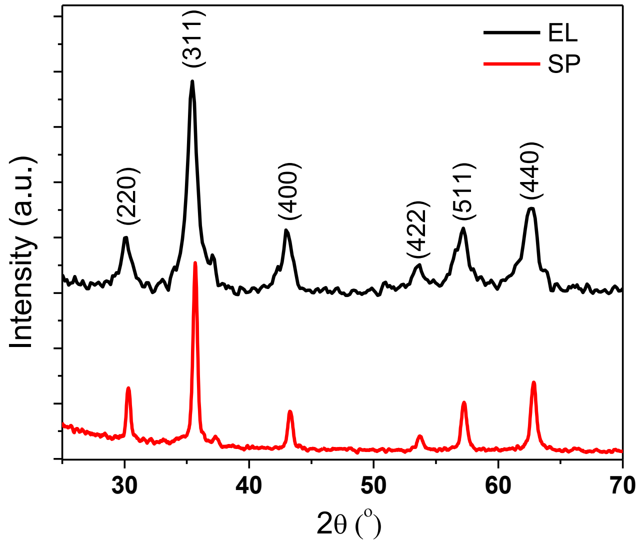

Fig. S2 X-ray diffraction patterns (smoothed for representation) for samples of EL and SP NPs in the powder forms. The diffraction peak positions match with the inverse spinel structure of the magnetite/maghemite iron oxide phases. The silica coating in EL NPs is amorphous and does not give rise to visible Bragg reflections.

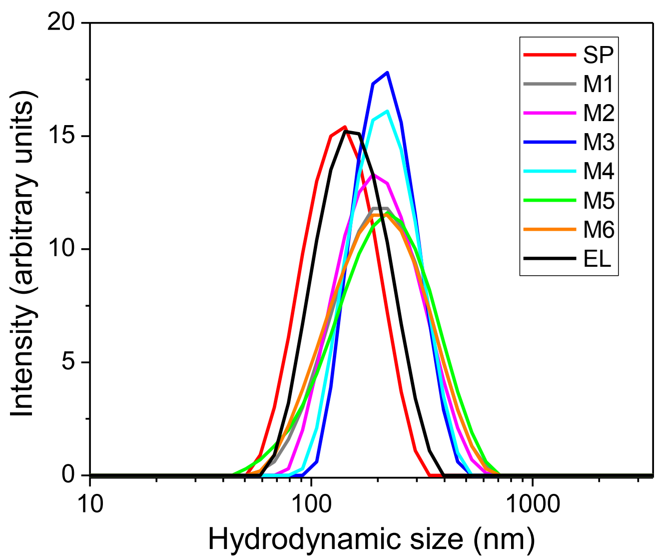

Fig. S3 Hydrodynamic size distributions measured by DLS on the parent EL and SP NPs and on the mixed samples.

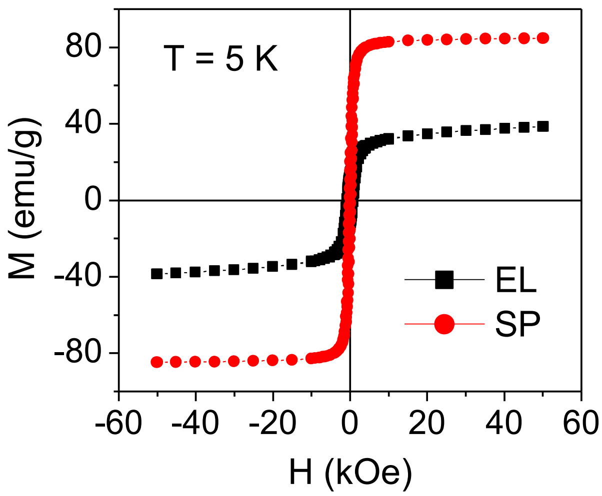

Fig. S4 Magnetization loops measured at T = 5 K on samples of EL and SP NPs in the powder form.

Table S1. Saturation magnetization values of the mixed samples

Sample	M_S (emu/g) T = 5 K	M_{S_calc} (emu/g) T = 5 K
M1	74 ± 4	74 ± 6
M2	69 ± 4	62 ± 5
M3	58 ± 3	56 ± 4
M4	48 ± 3	50 ± 4
M5	48 ± 3	44 ± 4
M6	43 ± 3	41 ± 3

The values of saturation magnetization M_S at T = 5 K are obtained by dividing the measured magnetic moment by the weight of the NPs dispersed in the solution absorbed by the cotton swab. M_{S_calc} is the saturation magnetization calculated considering the sample composition and M_S of EL and SP NPs (reported in the article).

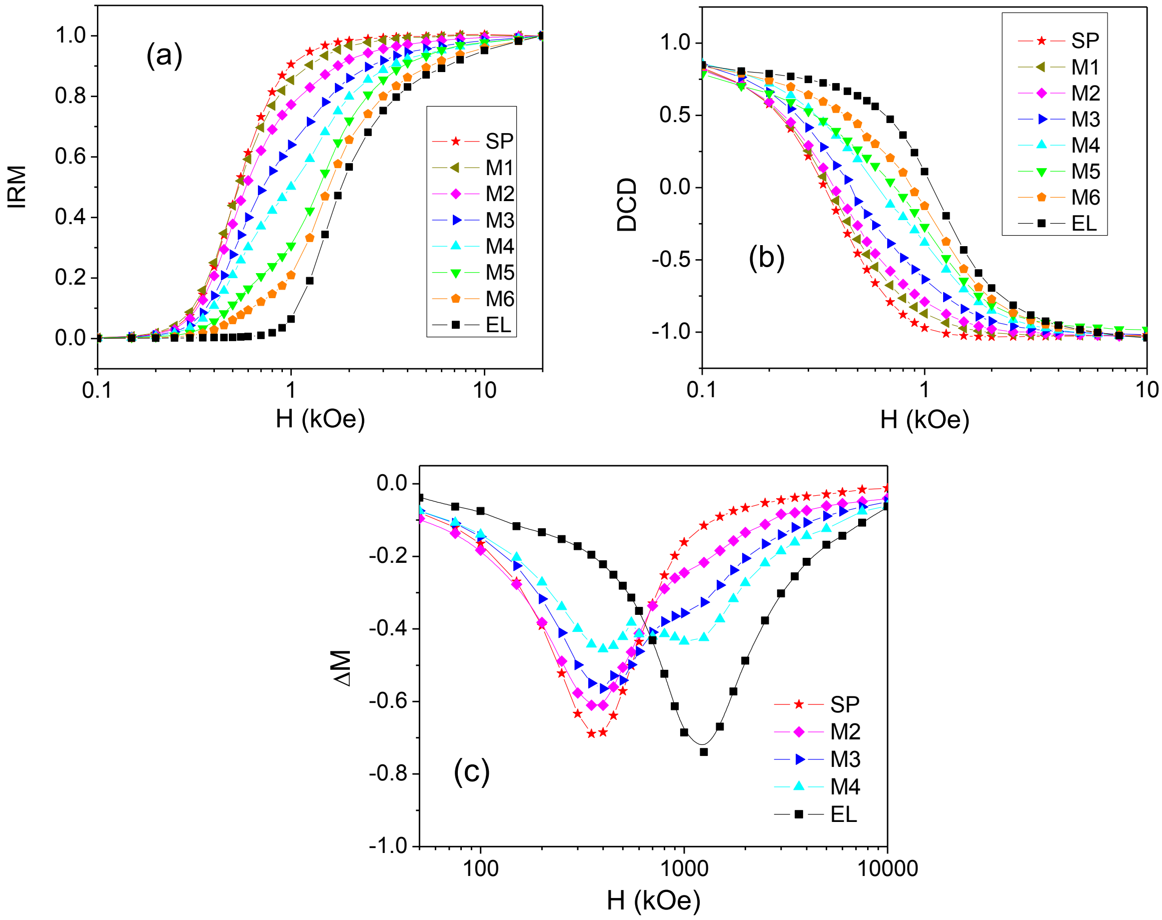

Fig. S5 (a) Isothermal remanent magnetization (IRM) and (b) dc demagnetization remanence (DCD) measured at T = 5 K on all the investigated samples. (c) ΔM-plots at T = 5 K for SP, EL and some representative mixed samples (M2, M3 and M4).

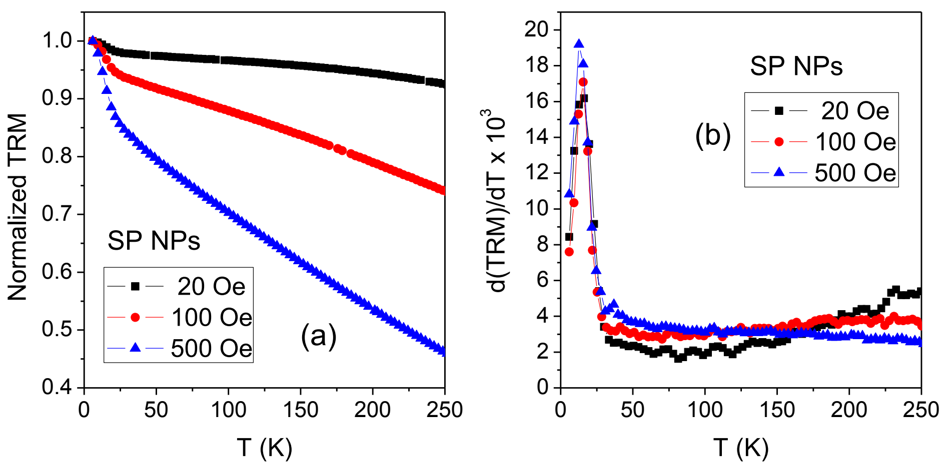

Fig. S6 Thermoremanent magnetization (TRM) vs. T measured on SP NPs for three different values of the magnetic field previously applied to the sample; the curves are normalized to their initial value at T = 5 K. (b) Temperature derivatives of the curves in (a).

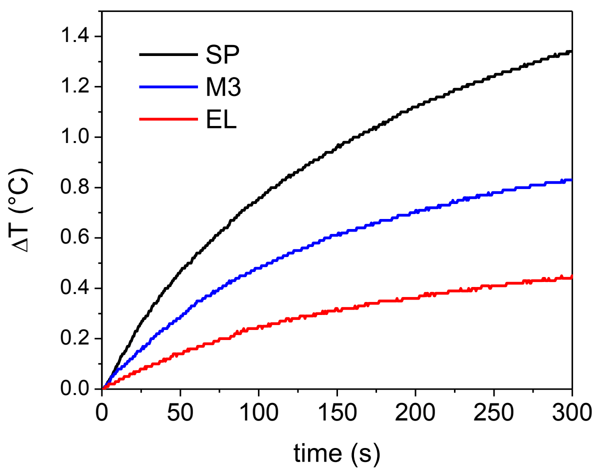

Fig. S7 (a) Heating curves for the indicated samples, subjected to an alternating magnetic field of amplitude H_{max} = 100 Oe and frequency f_m = 96 kHz.

ESTIMATION of T_{Squid}

We use the relation reported in the article as equation (2) to estimate the value of temperature T_{Squid} that, operating with a SQUID at f_m = 0.01 Hz (t_m = 100 s), corresponds to the same magnetic relaxing state probed at T = 294 K operating at f_m = 96 kHz ($t_m = 1\times10^{-5}$ s).

In fact, equation 2 can be reformulated in this way:

$\ln(t_m f_0)\, T = KV/k_B$

Considering constant KV/k_B, T_{Squid} is obtained from the relation:

$[\ln(1\times10^{-5} f_0)]\, 294 = [\ln(100\, f_0)]\, T_{Squid}$

As indicated in the article, f_0 is assumed equal to 10^9 Hz.