Electronic Supplementary Material (ESI) for Nanoscale.

Electronic Supporting Information

Superparamagnetic-blocked state transition under alternating magnetic fields: towards determining the magnetic anisotropy in magnetic suspensions

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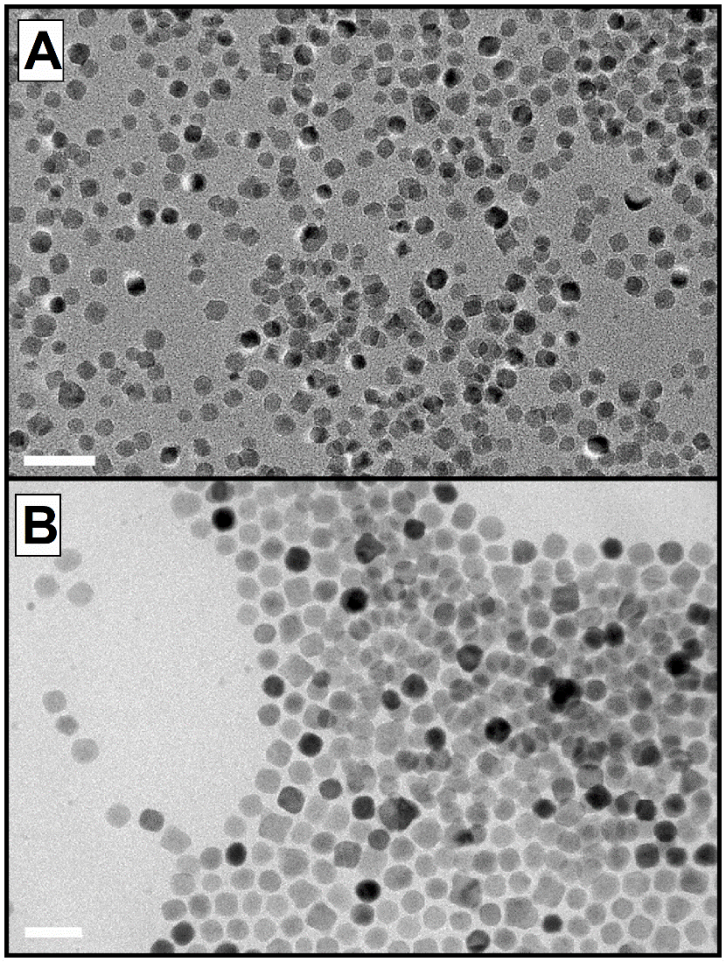

Figure S1. Representative TEM micrographs of (A) 12 and (B) 22 nm IONPs. Scale bar: 50 nm.

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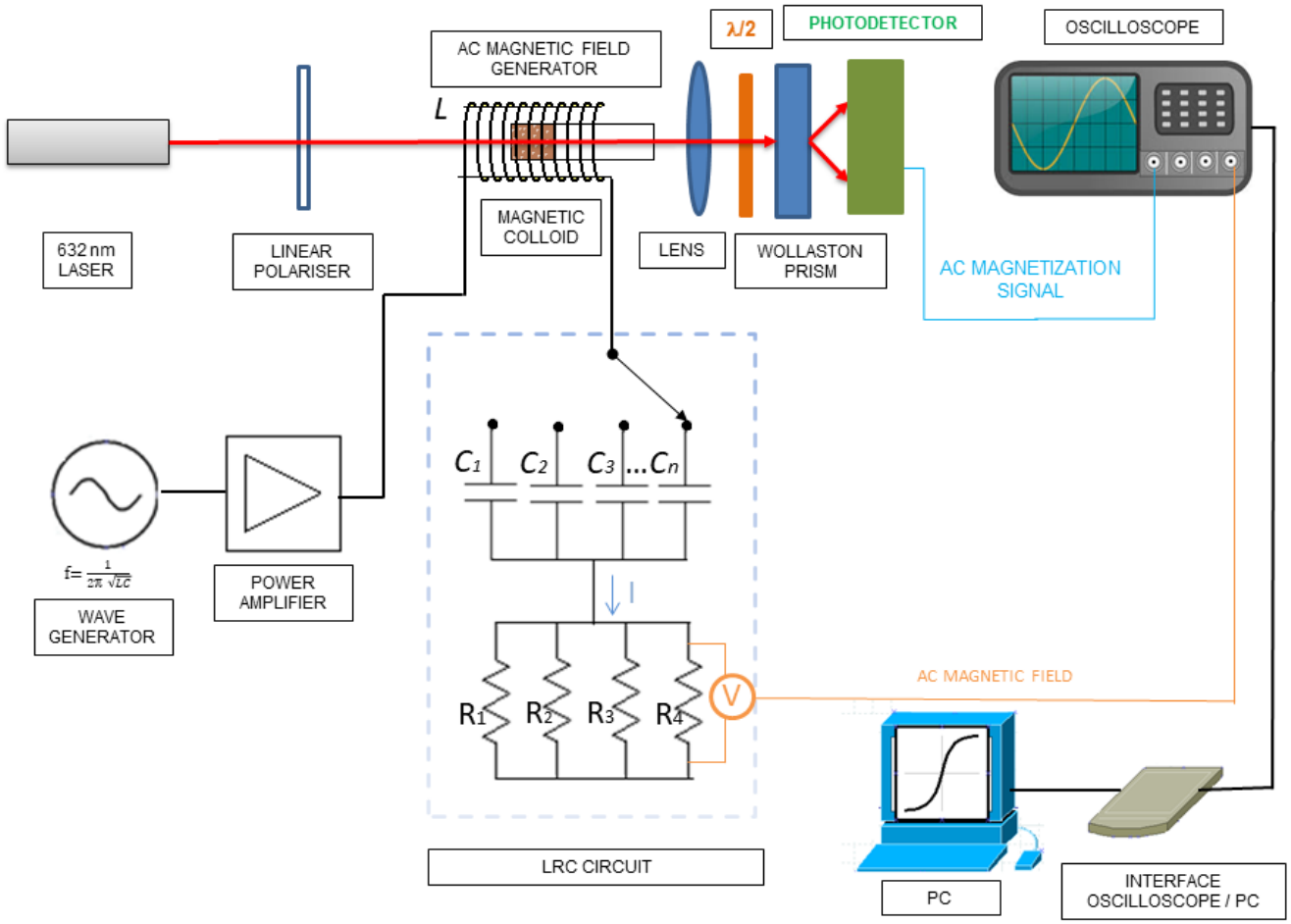

Figure S2. Schematic representation of magneto-optical Faraday effect magnetometer.

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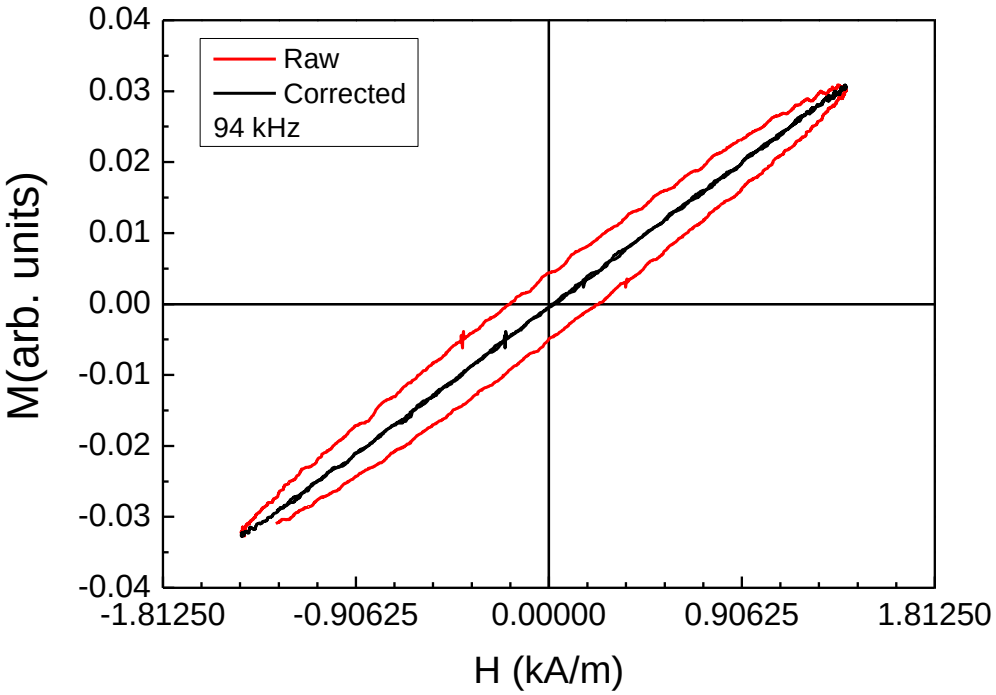

Figure S3. Representative MvH loops obtained in quartz crystal at 94 kHz and room temperature before and after corrections of artifacts in the input signal.

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Modified version of the Landau-Liftshitz-Gilbert (LLG) equations

The random torque $\vec{\Gamma}$ in Eq. (2) caused by thermal fluctuations satisfies the following equations:

$$\langle \Gamma_i(t) \rangle = 0, \quad \text{(S1)}$$

$$\langle \Gamma_i(t)\Gamma_j(t') \rangle = 2\delta_{ij}\delta(t-t'). \quad \text{(S2)}$$

Here, < > represents the average over an ensemble, *i* and *j* are Cartesian indices, δ_{ij} is the Kronecker delta function, and δ is the Dirac delta function.

Assuming a uniaxial magnetic anisotropy and neglecting magnetic dipolar interactions, the effective magnetic field $\vec{H}_{\text{eff}}$ in Eq. (3) is given by

$$\vec{H}_{\text{eff}} = \vec{H}_{\text{ex}} + \vec{H}_{\text{K}}, \quad \text{(S3)}$$

$$\vec{H}_{\text{K}} = \frac{2KV_c}{\mu_0 m_{NP}}(\vec{u}\cdot\vec{n})\vec{n}\,, \quad \text{(S4)}$$

where $\vec{H}_{\text{ex}}$ and $\vec{H}_{\text{K}}$ are the external and magnetic-anisotropy fields, respectively.

The fluctuating magnetic field, $\vec{H}_{\text{th}}$, due to thermal noise in Eq. (3) satisfies the following equations:

$$\langle H_{th,i}(t) \rangle = 0, \quad \text{(S5)}$$

$$\langle H_{th,i}(t)H_{th,j}(t') \rangle = \frac{2\lambda}{1+\lambda^2}\frac{k_B T}{\mu_0^2 \gamma m_{NP}}\delta_{ij}\delta(t-t'). \quad \text{(S6)}$$

Nanoparticle core volume utilised in simulations was estimated by TEM. Nanoparticle size (*d*) was determined through manual analysis of ensembles of over 300 particles found in randomly selected areas of the enlarged micrographs, with Imagetool software to obtain the mean size and standard deviation. For simulation purposes, nanoparticle volume (*V*) was calculated by simplifying nanoparticle shape as spherical:

$$V = \frac{\pi d^3}{6} \quad \text{(S7)}$$

In equations 2 and 3, damping coefficient λ was set to 0.1 and gyromagnetic ratio γ was calculated using the following relationship between τ_{N0} and γ :

$$\tau_{N0} = \frac{1}{2\gamma\lambda}\frac{M_S}{K} = 10^{-9}\ \text{s} \qquad \text{(S8)}$$

Here, M_s was determined fixed from the VSM magnetisation loops and only *K* was considered the adjustable parameter to fit the simulations to the experimental results. Otherwise, effective magnetic field is defined in Eqs. (S3) and (S4). Size distribution was not included into Brownian and effective relaxation times.

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Comparison of simulated and experimental MvH loops

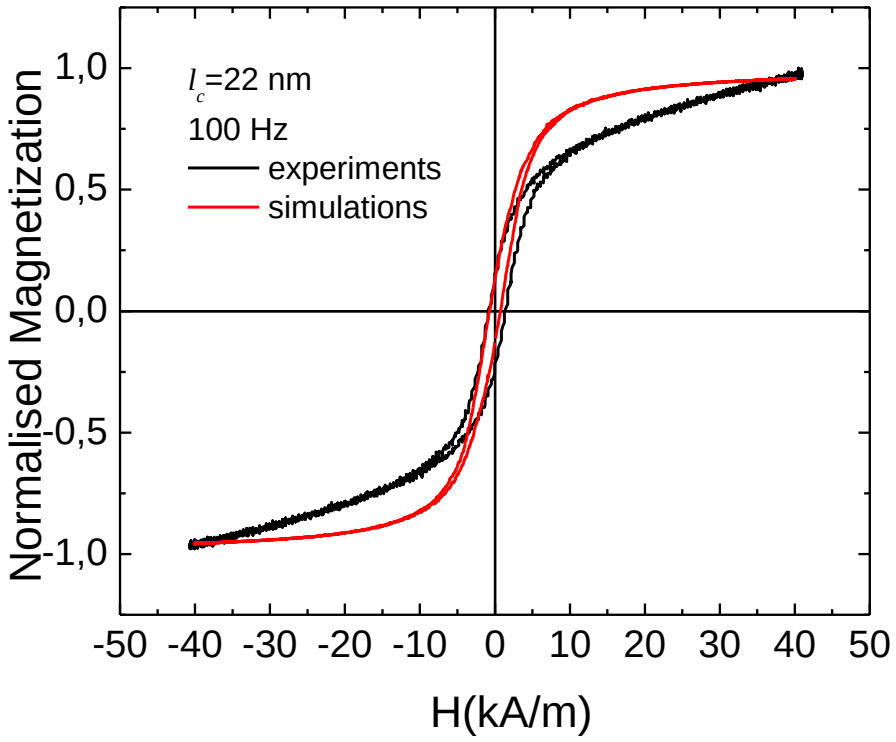

Figure S4. Comparison between experimental (black line) and LLG simulated (red line) AC hysteresis loops for 22 nm size IONPs dispersed in water at 0,4gFe/L, 100 Hz, and room temperature (298 K).

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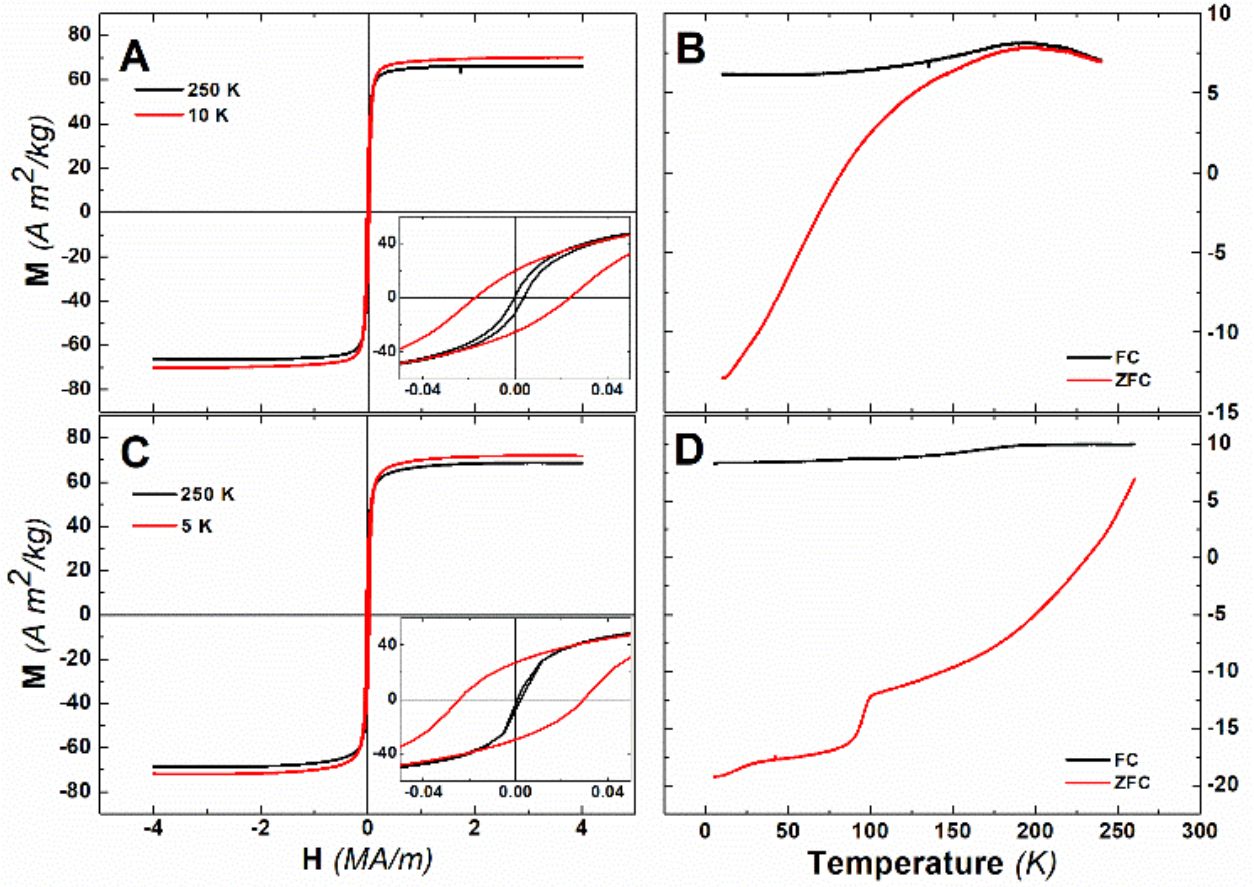

Figure S5.- Mass normalized magnetization cycles at different temperatures for (A) 12nm and (C) 22nm IONPs. Inset: Magnetization zoom at low magnetic fields. Zero field cooling- Field cooling measurements for (B) 12 and (D) 22 nm IONPs.

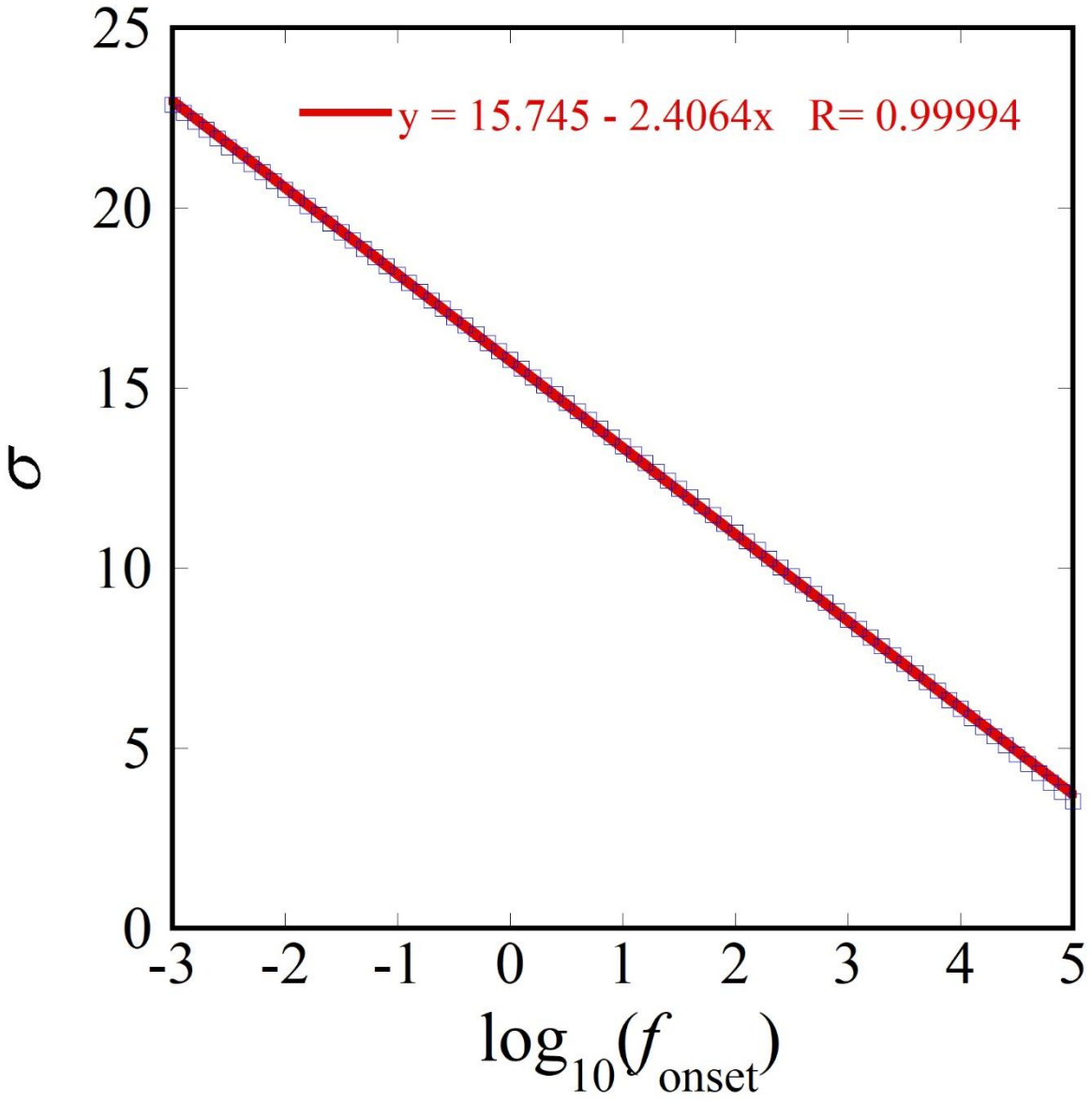

Figure S6. Correlation between f_{onset} and $\sigma = K_{eff}V/k_BT$.