Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Supporting Information

Magnetic properties of nanoparticles as a function of the spatial distribution on liposomes and cells

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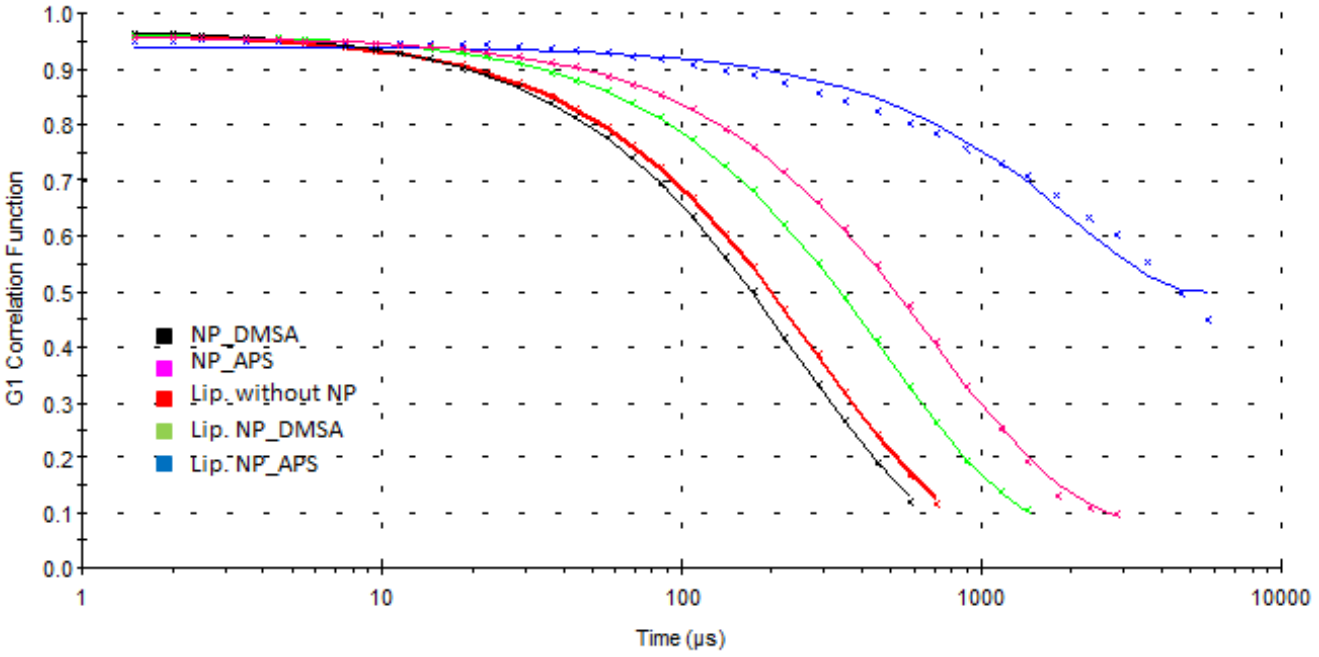

Figure S1: DLS correlation function measured for nanoparticles samples coated by DMSA (black curve) or APS (pink curve), liposomes without nanoparticles encapsulated (red curve) or with encapsulated nanoparticles NP_DMSA (green curve) or NP_APS (blue curve).

Table S1. Comparison of structural and magnetic properties for all samples described on the manuscript. DLS stands for Dynamic Light Scattering, T_B = Blocking temperature; M_S = Saturation magnetization; H_C = Coercive field; χ"= imaginary component of the AC susceptibility.

Structural and magnetic parameters	NP_DMSA	Liposome NP_DMSA	NP_APS	Liposome NP_APS	Cells			
					Pan02 NP_DMSA 24h	Pan02 NP_APS 0.5h	Pan02 NP_APS 24h	Jurkat NP_APS 2h
DLS Diameter Intensity (nm)	80	880	220	400	-	-	-	-
DLS Diameter Number (nm)	53	119	45	105	-	-	-	-
M_S at 5 K ($Am^2/kgFe$)	117	114	125	117	105	119	122	128
M_S at RT ($Am^2/kgFe$)	106	99	120	109	104	108	120	123
H_C at 5 K (10^4 A/m)	2.38	2.68	2.37	2.55	2.68	2.60	2.48	2.45
H_C at RT (10^4 A/m)	0.21	0.18	0.23	0.19	0.12	0.19	0.22	0.20
T_B (K)	283	273	273	277	297	296	303	300
χ" peak (Hz)	1285	243	754	16	-	-	-	-
Hydrodynamic size ACS (nm)	68	118	82	986	-	-	-	-

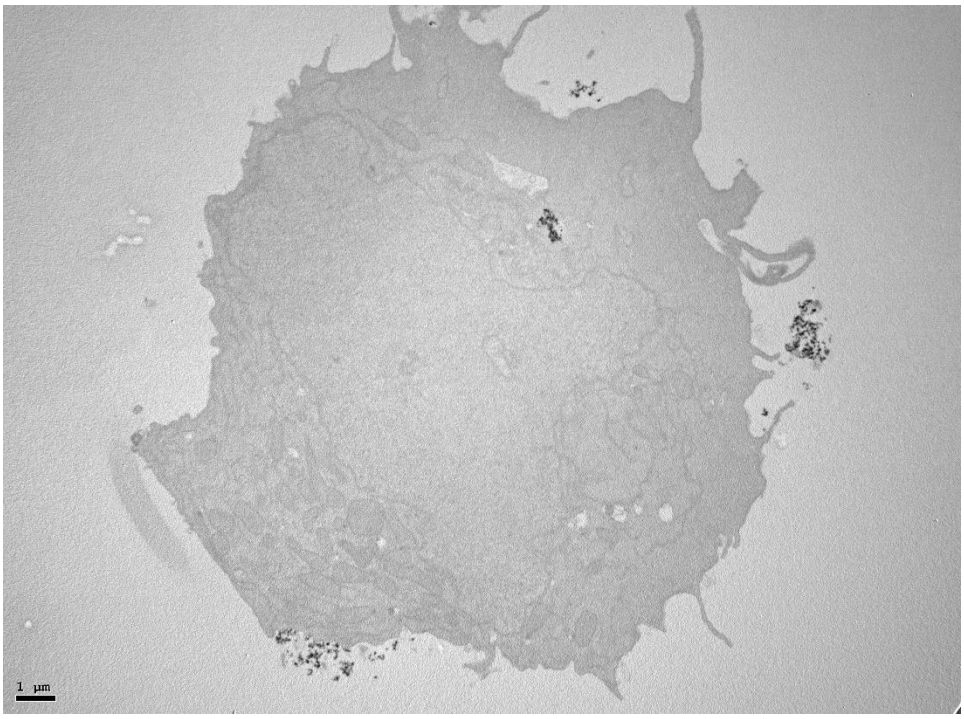

Figure S2. TEM microscopy of a Jurkat cell at 2 h incubation time where can be observed some nanoparticle internalization.

Table S2. Mass of iron per cell determined by ICP-OES.

NP	Cell line	Incubation time (h)	pg Fe/cell
NP_APS	Pan02	0.5	40±22
		24	39±6
	Jurkat	2	10±4
NP_DMSA	Pan02	24	2.5±0.5

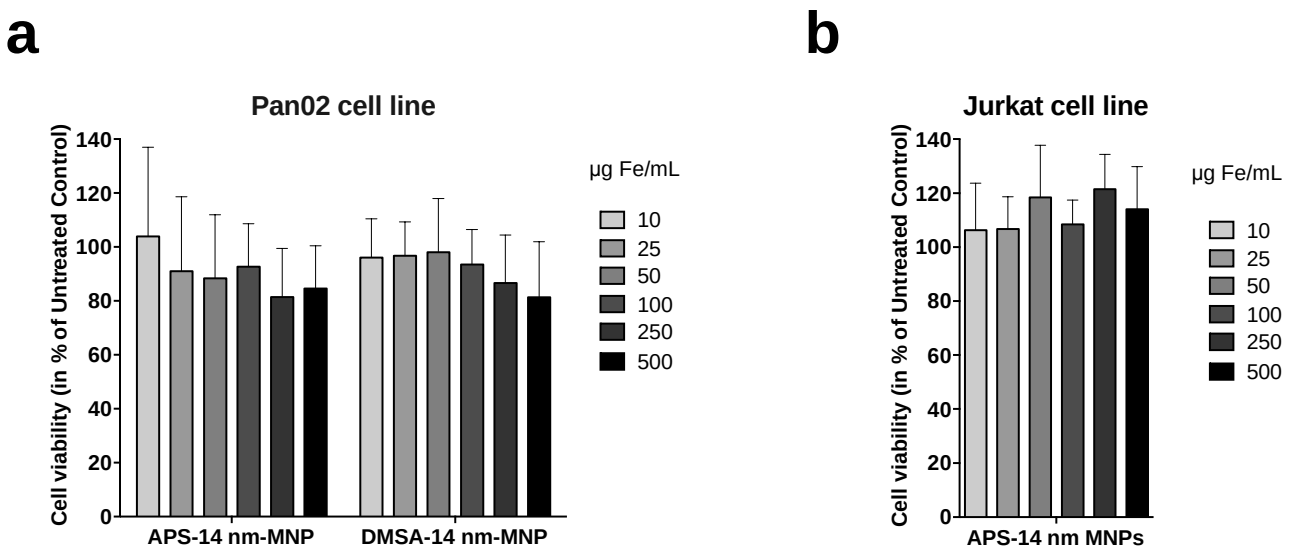

Figure S3: Magnetic nanoparticles cytotoxicity evaluation. Cell viability was determined in (a) Pan02 cells and (b) Jurkat cells, 24 h after treatment with different concentrations of MNP, using PrestoBlue Reagent. Untreated cells were used as control (100% viability). Data represent the mean (± standard deviation, SD) of three independent experiments; three replicates per experiment (one-way ANOVA followed by Bonferroni's multiple comparison post-test, (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).

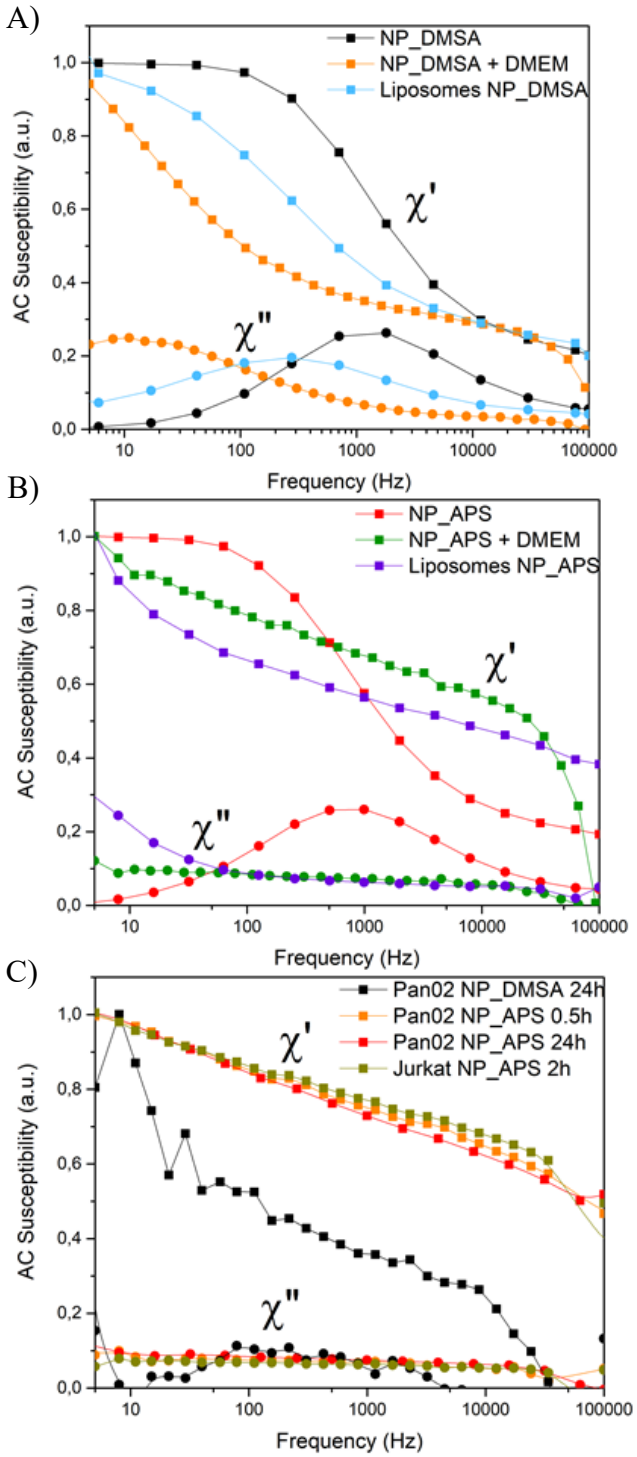

Figure S4. Frequency dependence of the low-field mass AC susceptibility showing the real part χ' and imaginary part χ" for the different systems. A) Nanoparticles coated with DMSA in water (black curve), in cell culture medium (orange curve) and encapsulated in liposomes (blue curve). B) Nanoparticles coated with APS in water (red curve), in cell culture medium (green curve) and encapsulated in liposomes (purple curve). C) Cells incubated with nanoparticles, coated by dimercaptosuccinic acid (DMSA) or aminopropyltrietoxisilane (APS), with different incubation times. For ease of visualization, data were normalized such that the maximum χ' values were unity in each case.

Calculations for the number of nanoparticles per liposome:

First starting with DPPC lipids molar mass used in this work and maghemite.

DPPC = 734.04 g/mol

Fe_2O_3 = 159.69 g/mol

$\rho_{Fe_2O_3}$ = 4.9 g/cm^3

For the quantities used in this work:

10 mg DPPC = 1.36 x 10^{-5} mol

5 mg Fe_2O_3 = 3.13 x 10^{-5} mol

Volume of one maghemite nanoparticle of 14 nm:

$V_{NP} = \frac{4\pi r^3}{3}$ = 1.436 x 10^{-18} cm^3

One nanoparticle of maghemite weights 7.03 x 10^{-15} mg;

Given the quantities used in this work there is a total of 7.1 x 10^{14} nanoparticles in the system.

As calculated in the text one liposome of 200 nm is formed by 336000 lipids. For 10 mg of DPPC there is 8.2 x 10^{18} molecules of lipids.

Given the quantities used in this work there is a total of 2.44 x 10^{13} liposomes in the system.

So, there is a total of 29 NP/liposome in this system, or in a different perspective there is more than 11000 lipids/NP.

Calculations for the Multi-core model fits used in ACS data.

$$\chi(\omega) = \chi_{0_B} \int \frac{1}{\left(1 + j\omega\tau_B(r_H)\right)} f(r_H) dr_H + \frac{\chi_{0_N}}{1 + (j\omega\tau_N)^{\alpha}} + \chi_{high}$$

where χ_{0b} is the DC susceptibility for the particles that undergoes Brownian relaxation, χ_{high} is the dynamic susceptibility at frequencies much higher than the Brownian relaxation frequency (due to single-domain crystals with fast Néel relaxation with respect to the Brownian relaxation), ω the angular frequency ($2\pi f$), r_H the hydrodynamic radius of the particles, $f(r_H)$ is the hydrodynamic radius distribution function, τ_B is the Brownian relaxation time, χ_{0N} is the DC susceptibility for the particles that undergoes Néel relaxation, τ_N is the Néel relaxation time.

$$\tau_B = \frac{3V_H\eta}{k_BT} = \frac{4\pi r_H^3\eta}{k_BT}$$

The log-normal distribution is used for the hydrodynamic radius distribution function, $f(r_H)$, and is expressed as:

$$f(r_H) \propto \frac{1}{r_H} e^{-\frac{1}{2\ln^2\sigma}\ln^2\left(\frac{r_H}{r_{mH}}\right)}$$

in which σ sets the width of the distribution.