EFFECT OF THE HOLLOW TOPOLOGY ON THE LOCAL SPIN DYNAMICS IN IRON OXIDE MAGNETIC NANOPARTICLES

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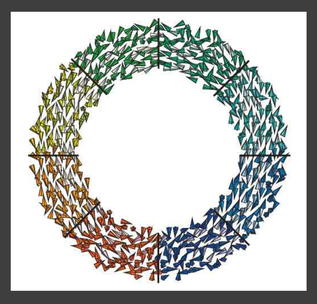
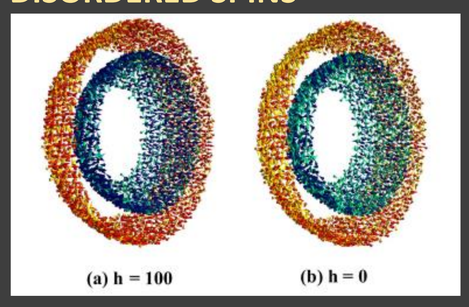
[2]

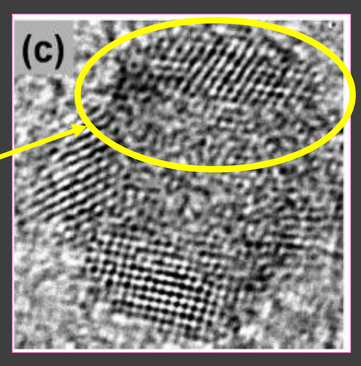


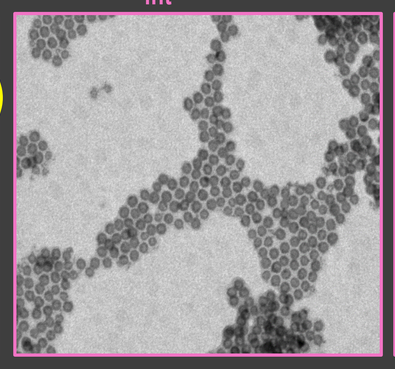
A LARGE NUMBER OF SURFACE DISORDERED SPINS

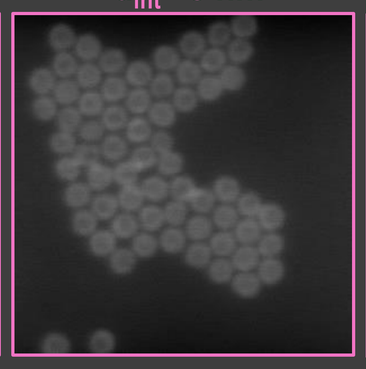
[3]

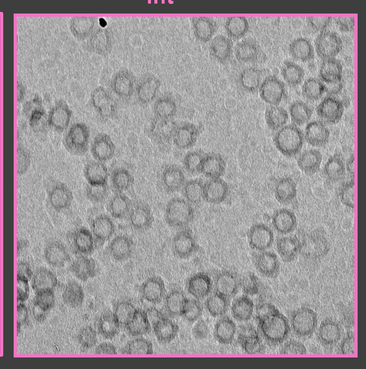


Multiple cryistallographic domains

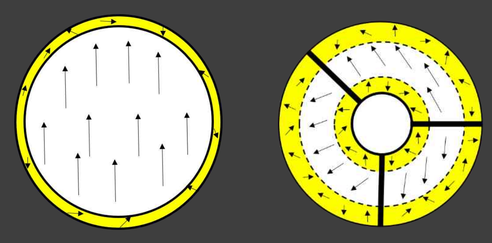






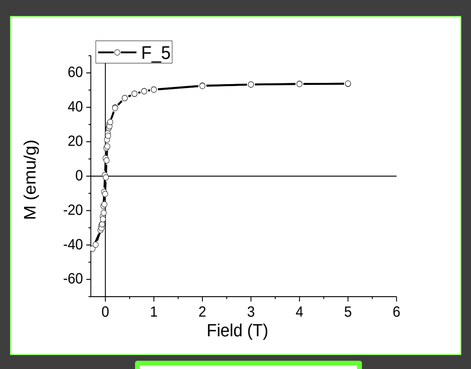


MORE CHANCE TO OBSERVE **THE SURFACE** WITH RESPECT TO A FULL NPs !!!



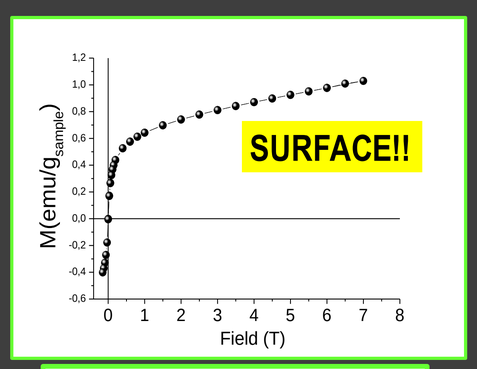
STATIC INVESTIGATION vs FIELD

FULL



$M(H) = M_s\, L(x)$

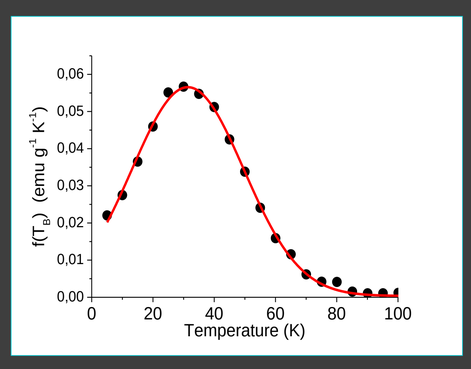
HOLLOW



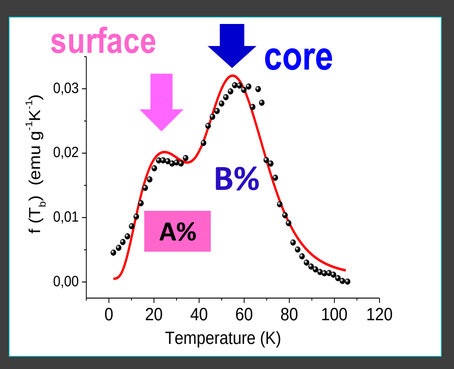
$M(H) = M_s\, L(x) + \chi^{PM} H$

STATIC INVESTIGATION vs TEMPERATURE

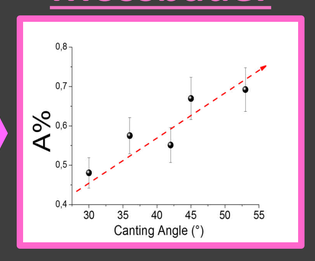
FULL



HOLLOW



Mössbauer



LOCAL SPIN DYNAMICS INVESTIGATION

SPIN DYNAMICS INVESTIGATION VS FIELD
Nuclear Magnetic Resonance (NMR)

HEURISTIC MODEL FOR FULL SUPERPARAMAGNETIC NPs (A. Roch et. al, 1999, [1])

$$\frac{1}{T_1^{SPM,heu}} = \frac{32\pi}{35000}\mu_{SPM}^2 Y_I^2 \left(\frac{N_A C}{r_d D}\right)\left\{7P\frac{L(x)}{x}J^F(\omega_S,\tau_D,\tau_N) + \left[7(1-P)\frac{L(x)}{x} + 3\left(1 - L^2(x) - \frac{2L(x)}{x}\right)\right]\cdot J^F(\omega_I,\tau_D,\tau_N) + 3L^2(x)J^A\left(\sqrt{2\omega_I\tau_D}\right)\right\} \quad (1)$$

OUR NOVEL PHENOMENOLOGICAL MODEL FOR HOLLOW NPs (M. Basini et. al, 2017)

$$\frac{1}{T_1} = A_{\%}\, HF\frac{\tau_c}{(1+\omega^2\tau_c^2)} + (1-A_{\%})\frac{1}{T_1^{Heu}} \quad (2)$$

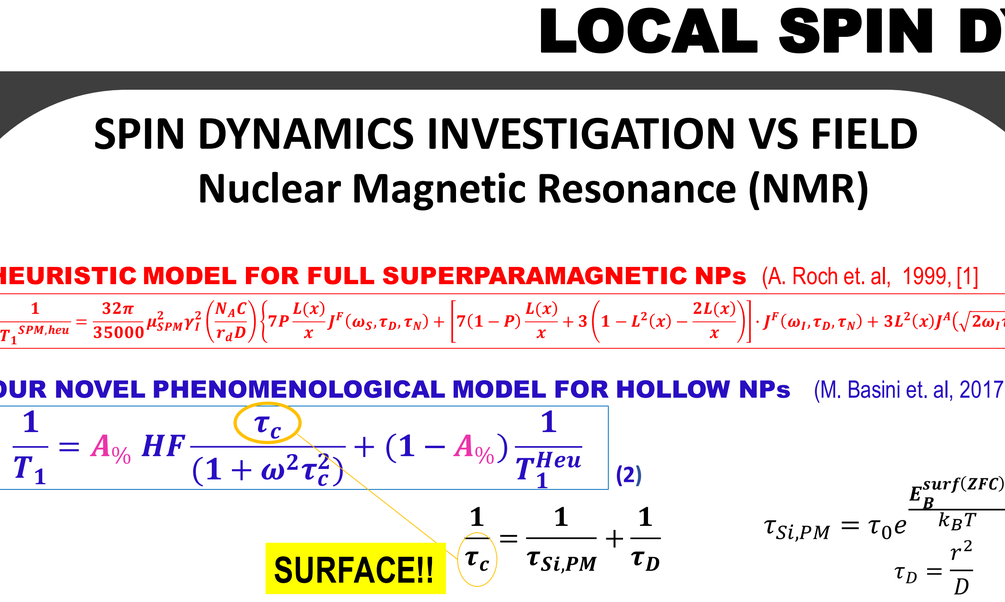
SURFACE!!

$$\frac{1}{\tau_c} = \frac{1}{\tau_{Si,PM}} + \frac{1}{\tau_D}$$

$$\tau_{Si,PM} = \tau_0 e^{\frac{E_B^{surf(ZFC)}}{k_B T}}$$

$$\tau_D = \frac{r^2}{D}$$

EXPERIMENTAL DATA + FIT by (1) and (2)

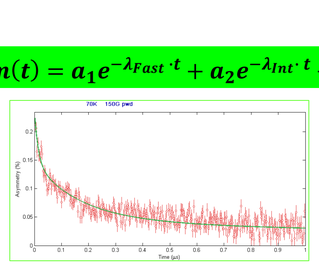


Conclusions:

- The heuristic model is not able to reproduce the experimental data
- The novel model wors for EVERY semple we measured
- The surface is paramagnetic-like (correlation time $\tau_{S,PM} \sim 10^{-14}\ s$)
- The core is superparamagnetic (correlation time $\tau_{c,SPM} \sim 10^{-9}\ s$)

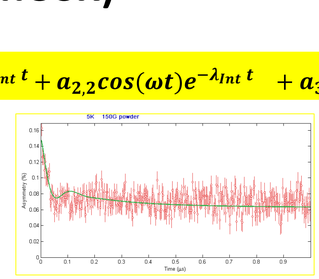
SPIN DYNAMICS INVESTIGATION VS TEMPERATURE
Muon Spin Resonance (MUSR)

$$Asym(t) = a_1 e^{-\lambda_{Fast}\cdot t} + a_2 e^{-\lambda_{Int}\cdot t} + a_3 e^{-(\lambda_{Slow}\cdot t)^{0.5}}$$



T>T*

$$Asym(t) = a_{2,1} e^{-\lambda_{Int}\, t} + a_{2,2}\cos(\omega t) e^{-\lambda_{Int}\, t} + a_3 e^{-(\lambda_{Slow} t)^{0.5}}$$

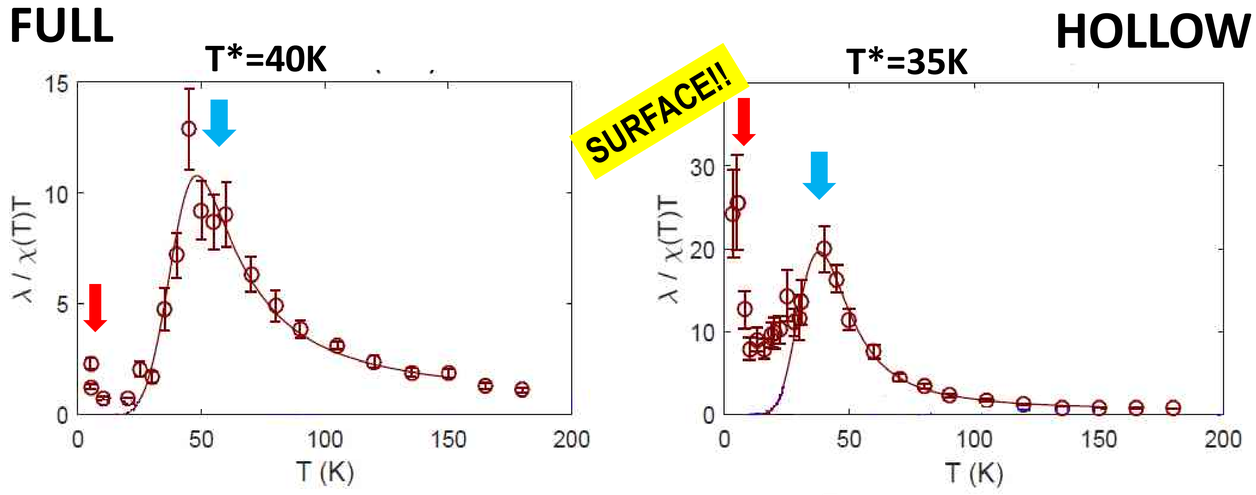


T<T*

T_2^{MAX}: $\omega_L \tau_c^{surf} \sim 1$

T_1^{MAX}: $\omega_L \tau_c^{core} \sim 1$

FULL **HOLLOW**



$A = (1.5 \pm 0.3)x10^{12}$

$\tau_0 = (1.2 \pm 0.3)x10^{-9}\ s$

$\Delta = 200 \pm 39\ \ K$

$$BPP: \quad \lambda(T) = A\chi(T)T\frac{\tau_N}{1+\tau_N^2\omega_L^2}$$

$$\tau_{c,SPM} = \tau_N = \tau_0 e^{\frac{\Delta}{k_B T}}$$

$A = (2.2 \pm 0.4)x10^{12}$

$\tau_0 = (0.3 \pm 0.1)x10^{-9}\ s$

$\Delta = 220 \pm 15\ \ K$

Conclusions:

- The anomaly at higher temperature (T_2^{MAX}) is ascribed to the surface spins
- The anomaly at higher temperature (T_1^{MAX}) is ascribed to the core spins
- The core is superparamagnetic (correlation time $\tau_{c,SPM} \sim 10^{-9}\ s$)
- The FIT ascribes an higher HF coupling between the hollow NP and the muon spin

[1] Gills P., Roch A. and Brooks R.A. Journal of Magnetic Resonance , **137**, 402 (1999)
[2] A. Cabot *et al.* Phys. Rev. B **79**, 094419 (2009)
[3] H. Khurshid *et al.* scientific reports **5**:15054 (2014)