Silica rod-shape capsules embedding superparamagnetic iron oxide nanoparticles

D. Carmona*, N. Miguel, A.G. Roca, F. Balas and J. Santamaria

*Aragon Nanoscience Institute (INA) and *International Iberian Nanotech. Lab. (INL)*

Zaragoza

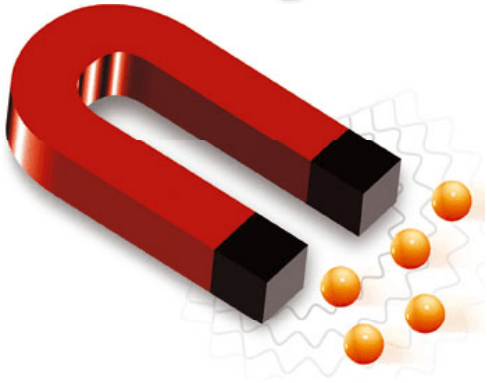
OUTLINE

- ***INTRODUCTION***
- ***PREPARATION OF SILICA COATED MAGNETIC NANOPARTICLES***
  - **Synthesis of magnetic nanoparticles**
  - **Silica coating**
- ***RESULTS***
  - **Structure and colloid characterization**
  - **Magnetic properties**
- **CONCLUSIONS**

INTRODUCTION

IRON OXIDE NANOPARTICLES

Magnetic properties

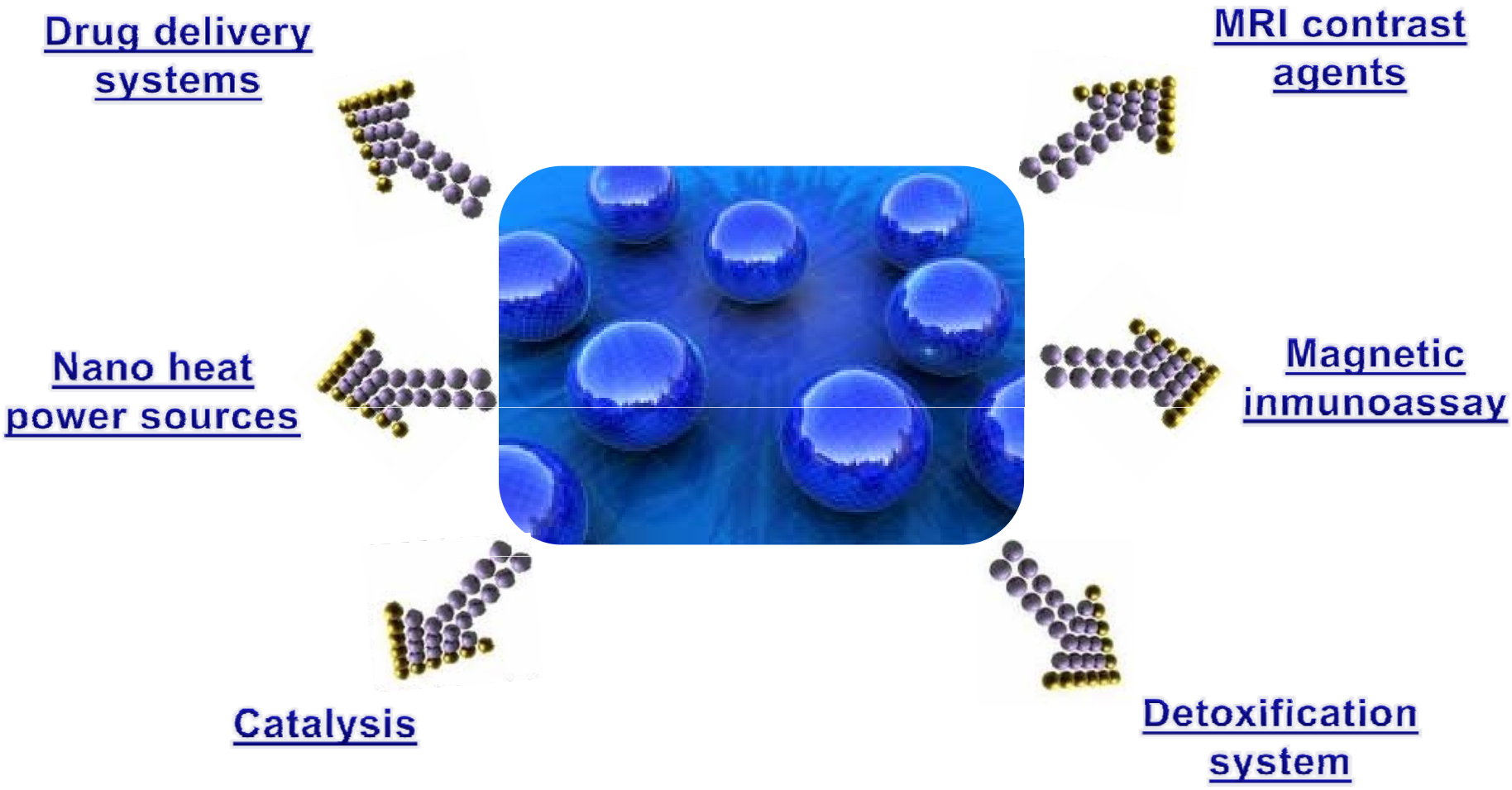


Biocompatibility

Optimum size

INTRODUCTION

A great versatility …



INTRODUCTION

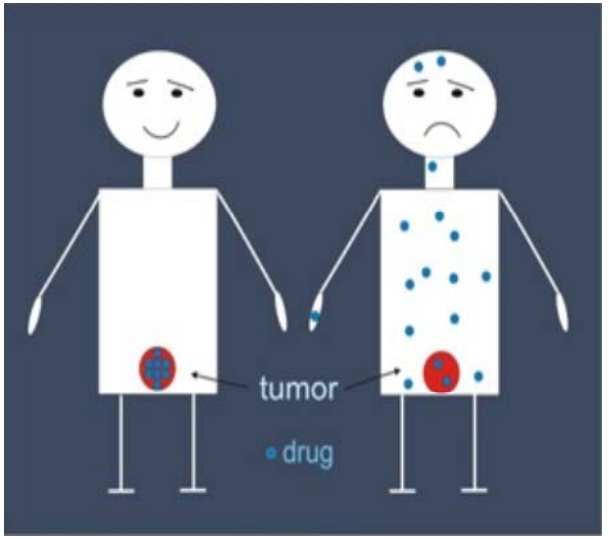
Most drugs are orally or parentherally administred

Conventional administration

Partial degradation of the drug before reaching its destination → Reduction of the potential effects of the drug

Immediate release of the drug → Probable side or adverse effects

Need to improve the therapeutic properties of drugs → **Directed system**



INTRODUCTION

However…

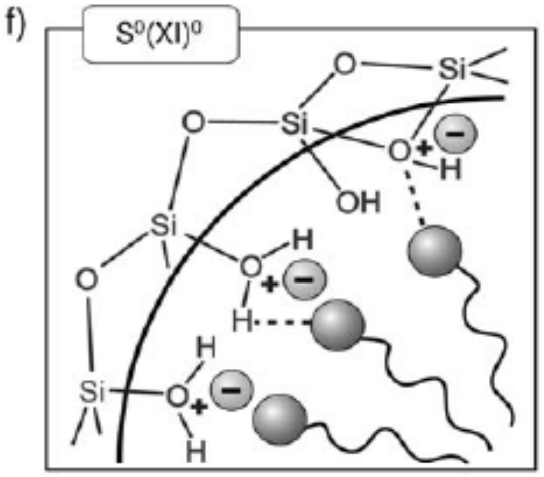
Low colloidal stability at physiological pH

Surface treatment

Chemical stability

Reduced toxicity

Increased reactivity

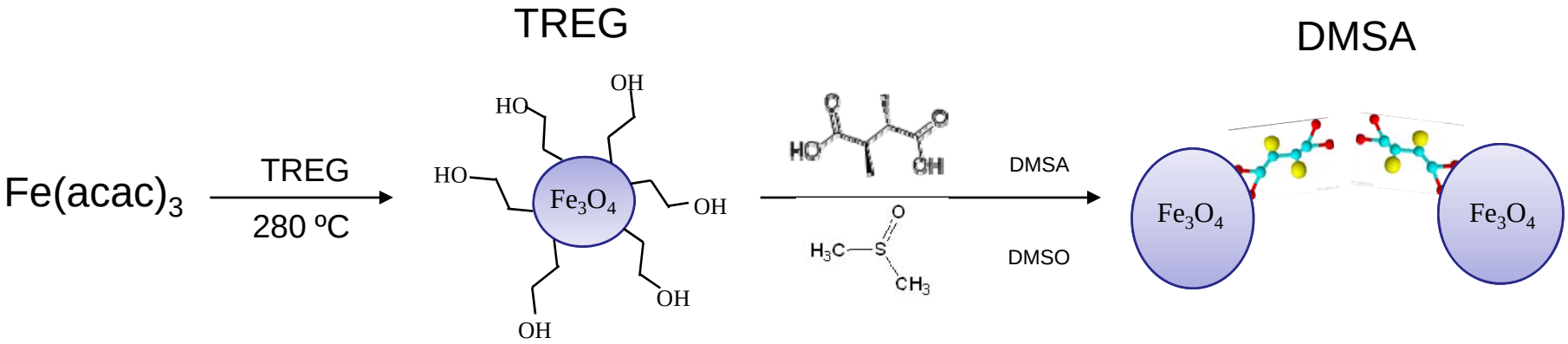


Hydrolysis and condensation of silica alcoxide precursors onto the particle surface provides several advantages

Final properties will depend on the type of aggregate that they form

PREPARATION OF SILICA COATED NANOPARTICLES

- ***SYNTHESIS OF MAGNETIC NANOPARTICLES***

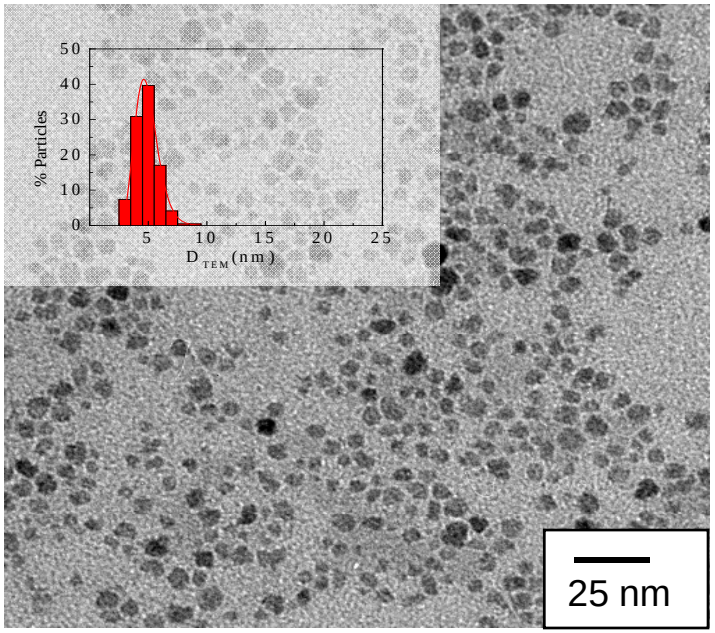


Wan, J.; W.Cai; Meng, X.; Liu, E. *Chem. Commun.* ***2007, 5004-5006***

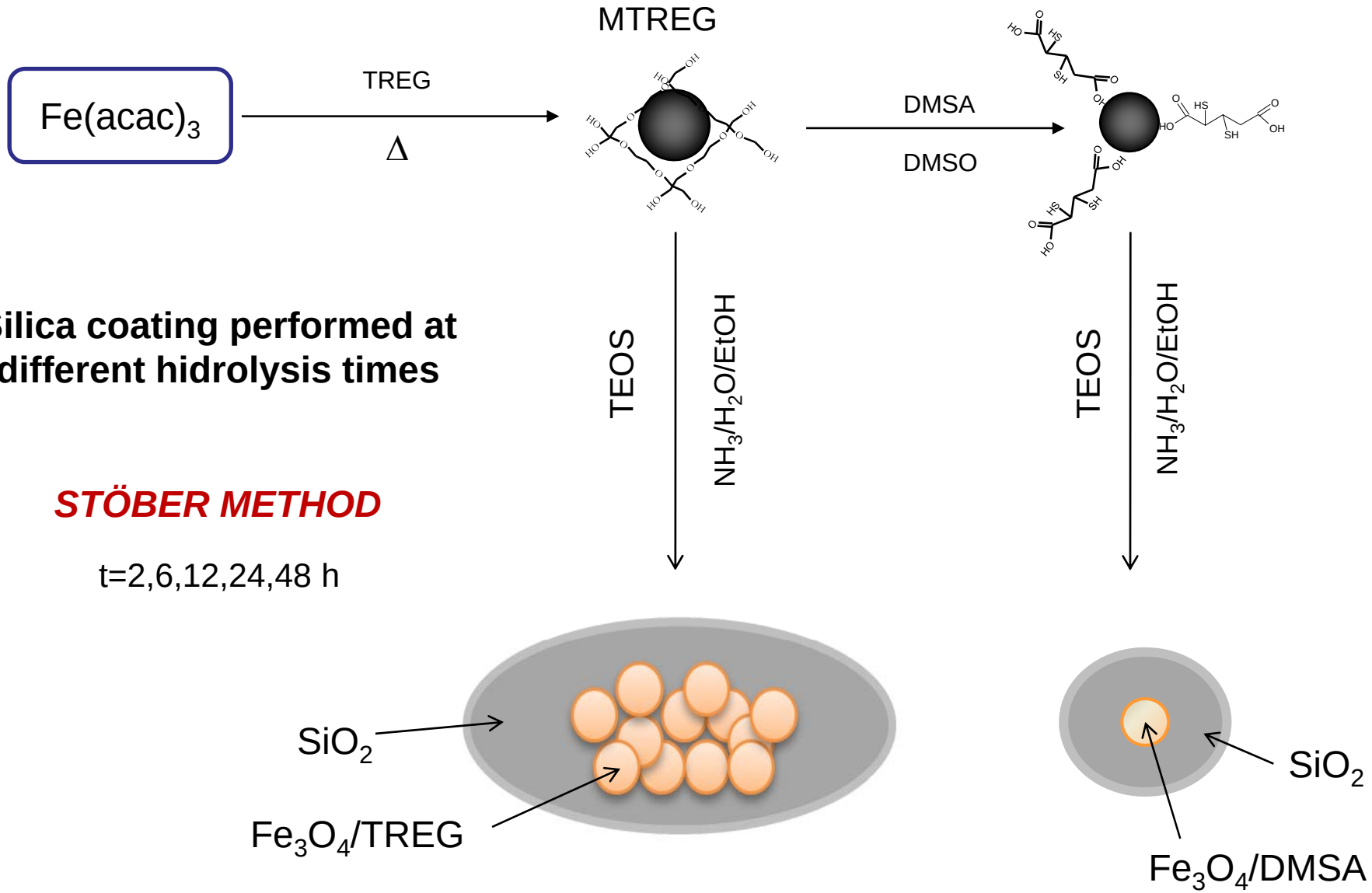
One-step synthesis

THERMAL DECOMPOSITION METHOD

D_{TEM}= 4.8 nm
W= 0.20



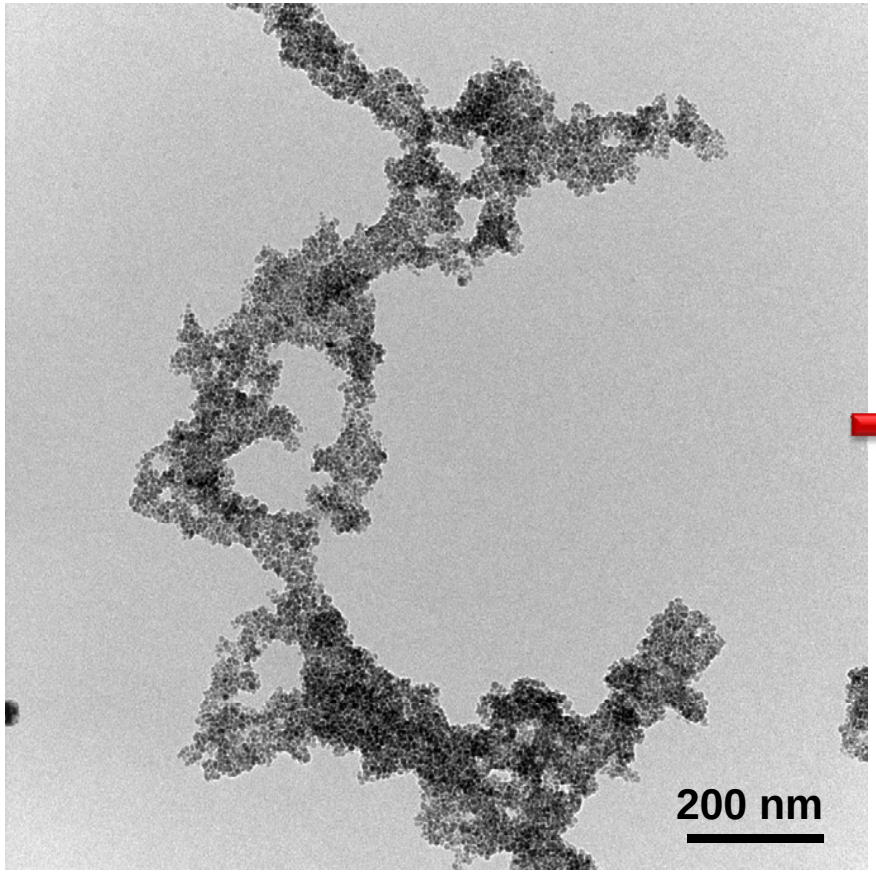
PREPARATION OF SILICA COATED NANOPARTICLES



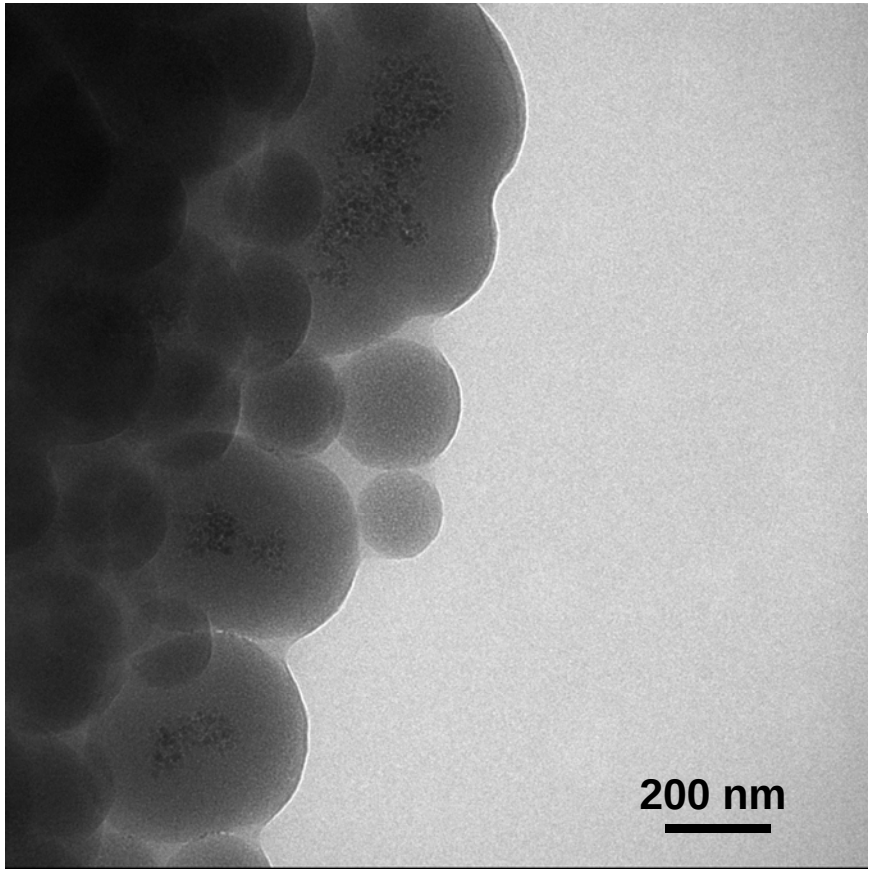
RESULTS

- ***STRUCTURAL CHARACTERIZATION***

Maghemite/TREG

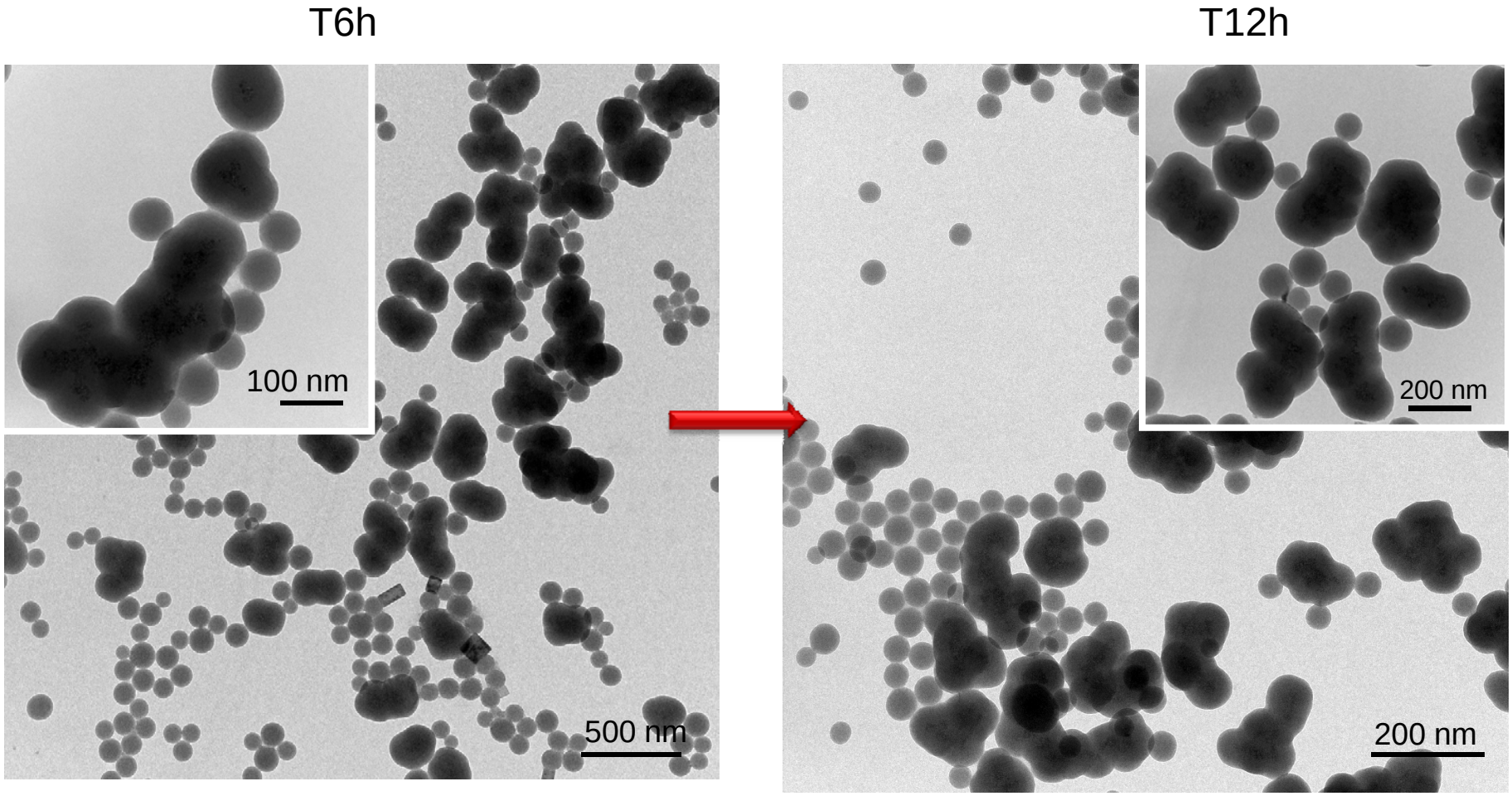


T2h



RESULTS

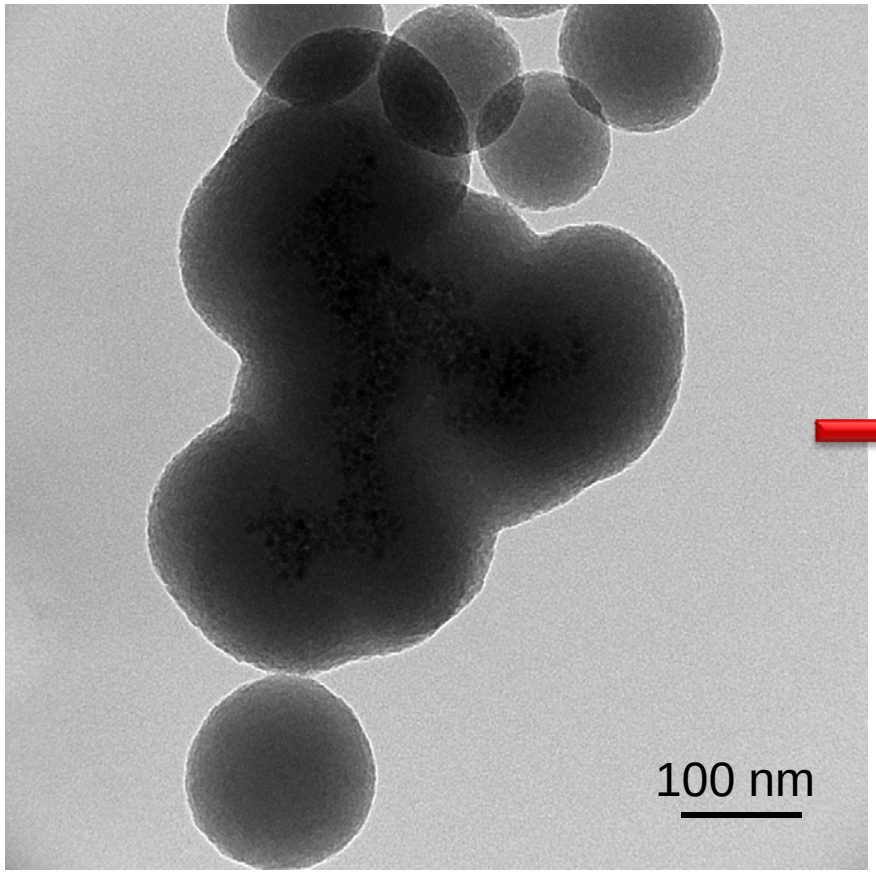
- ***STRUCTURAL CHARACTERIZATION***



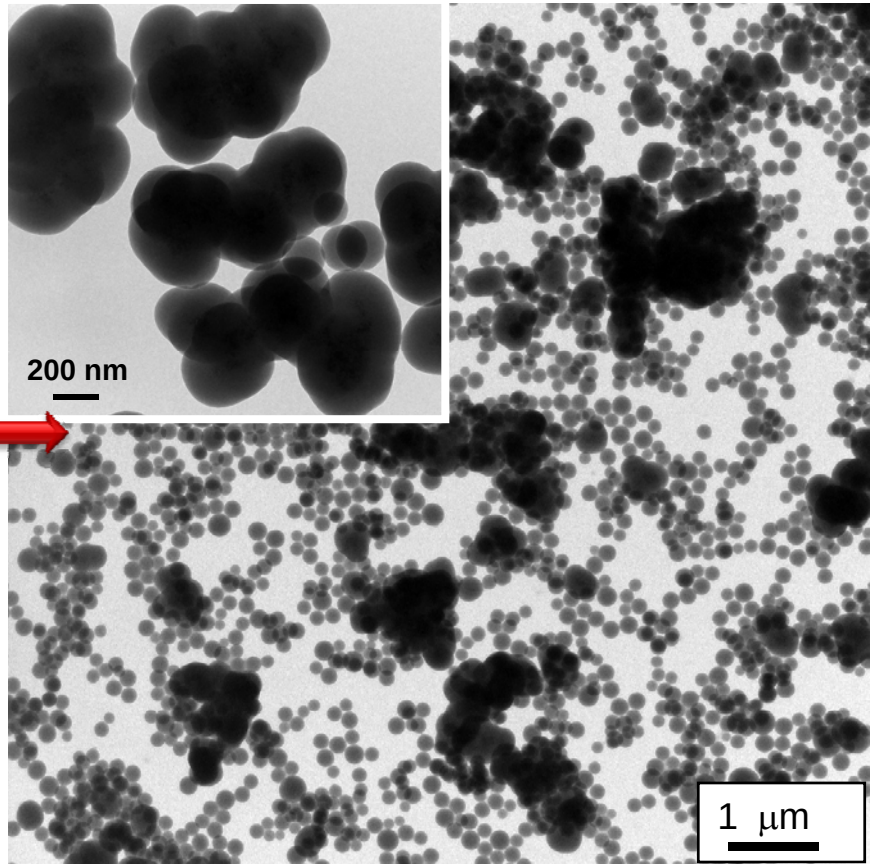
RESULTS

- ***STRUCTURAL CHARACTERIZATION***

T24h



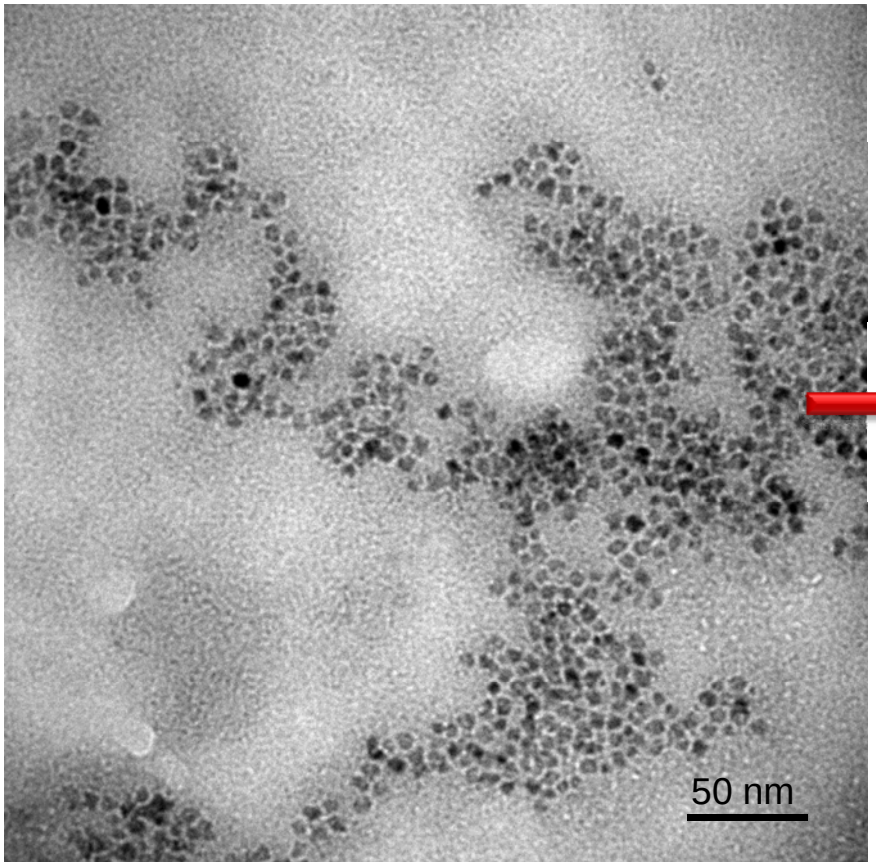
T48h



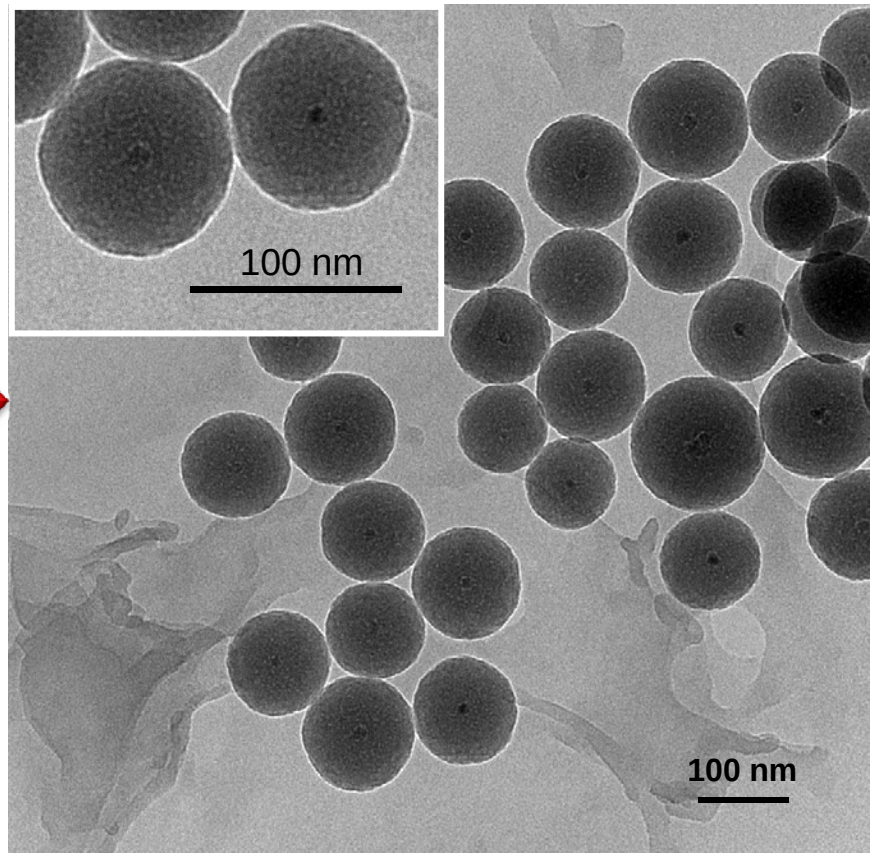
RESULTS

- ***STRUCTURAL CHARACTERIZATION***

Maghemite/DMSA



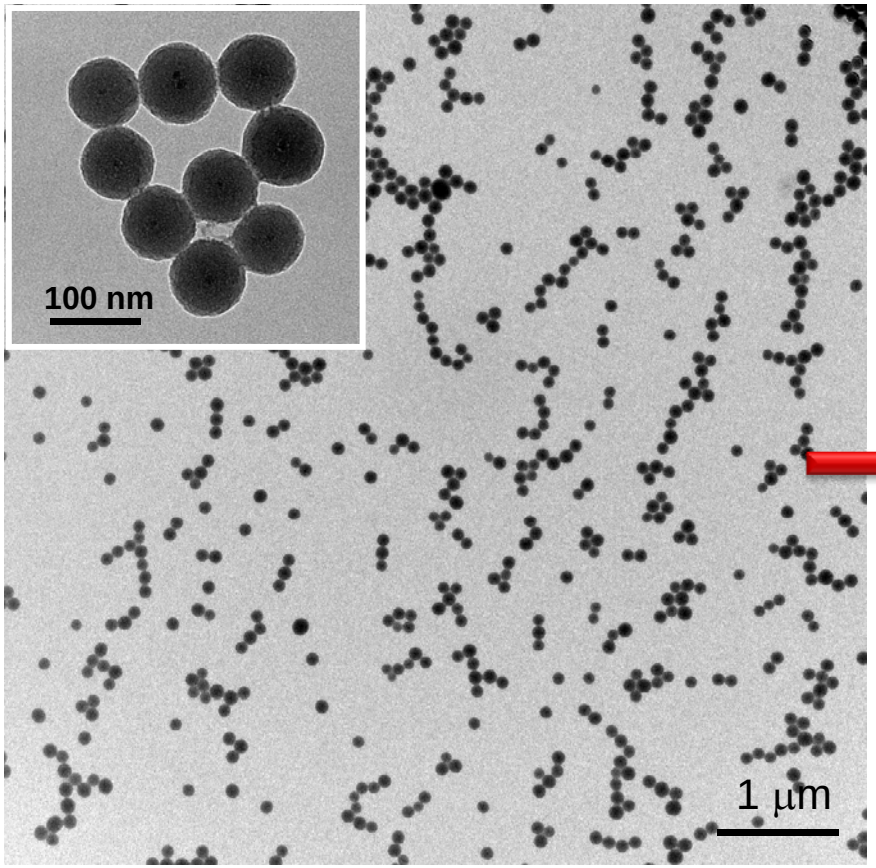
D2h



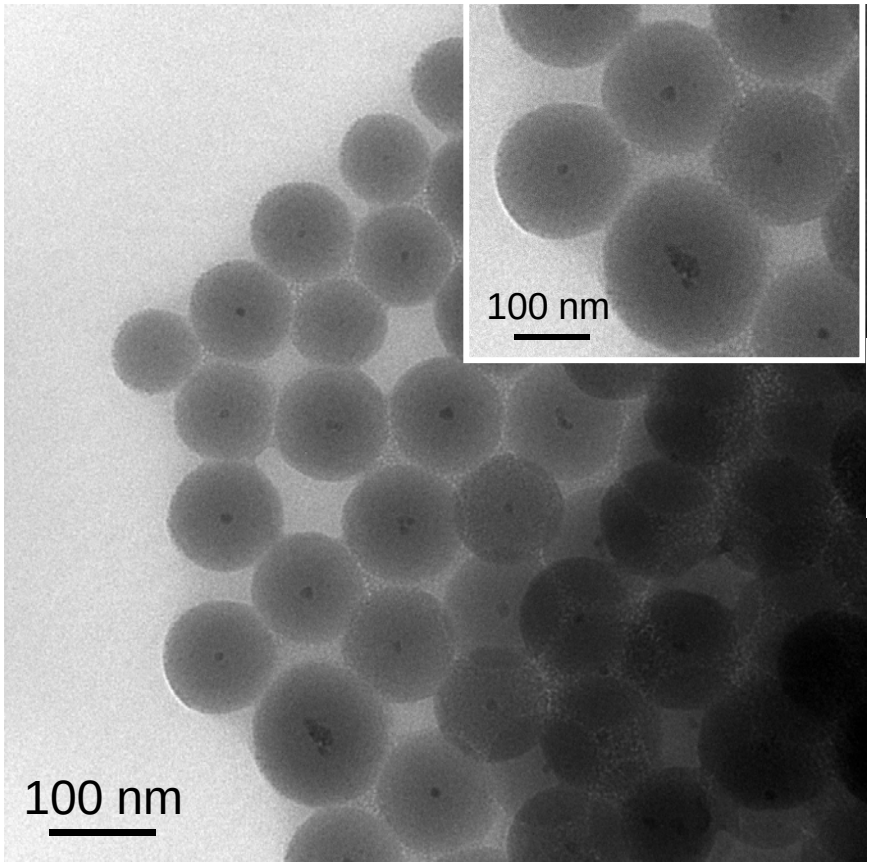
RESULTS

- ***STRUCTURAL CHARACTERIZATION***

D6h



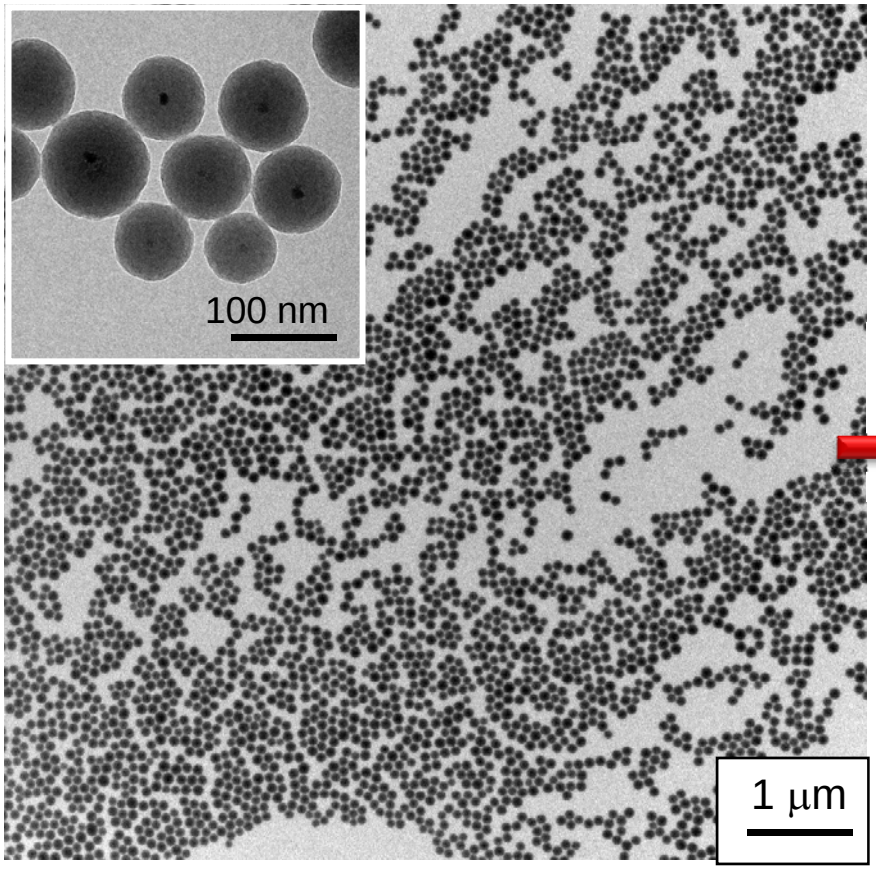
D12h



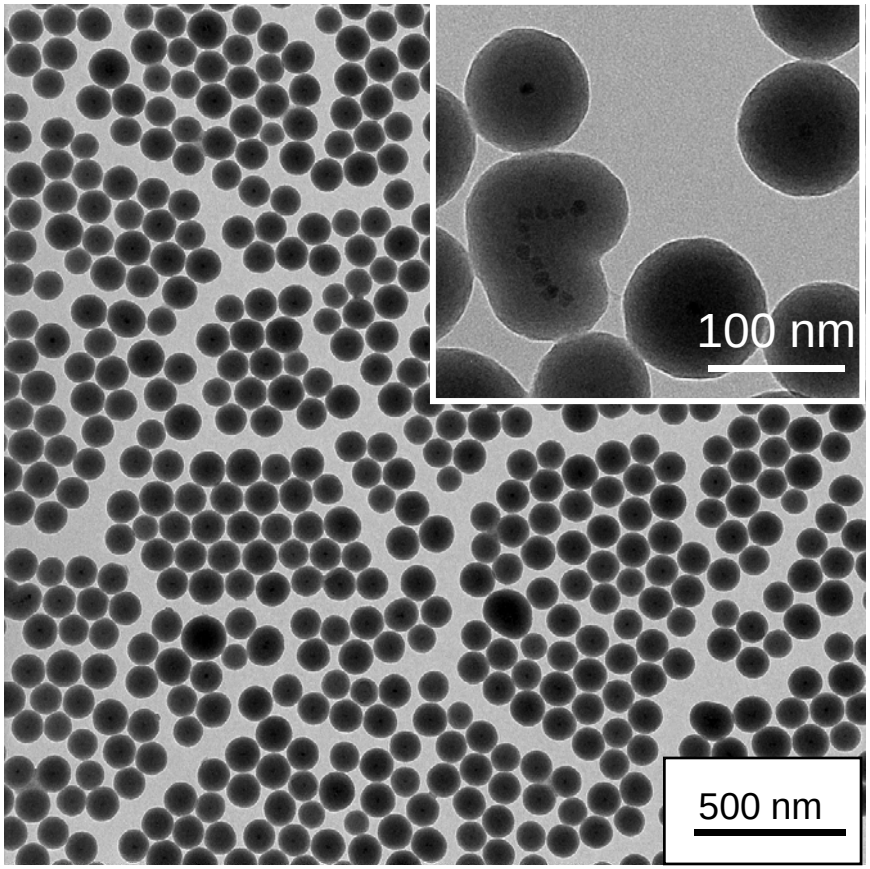
RESULTS

- ***STRUCTURAL CHARACTERIZATION***

D24h

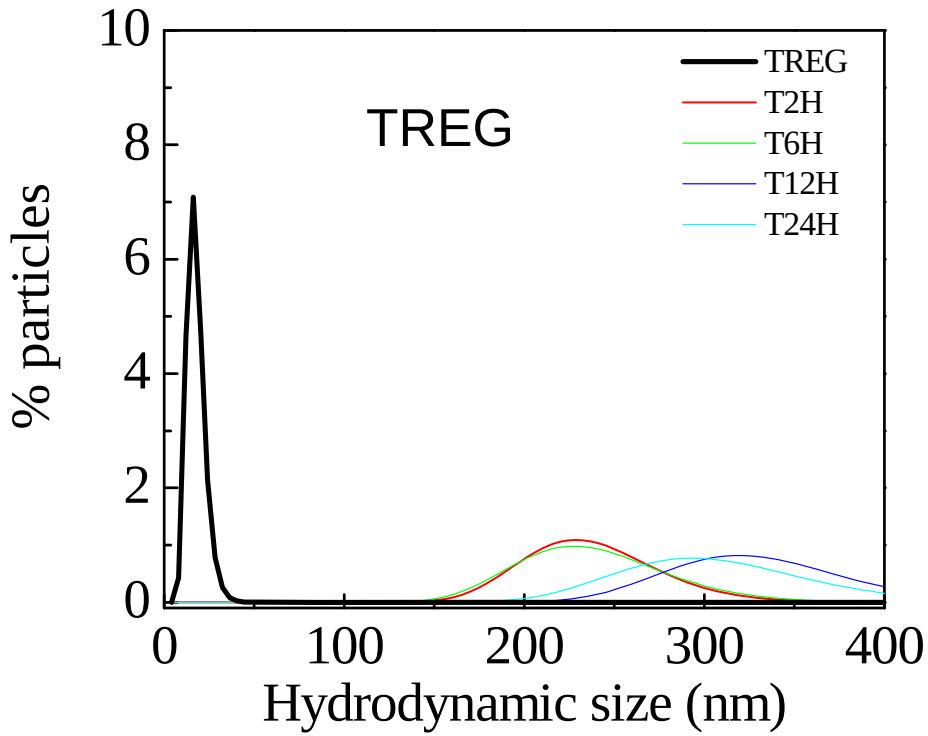


D48h

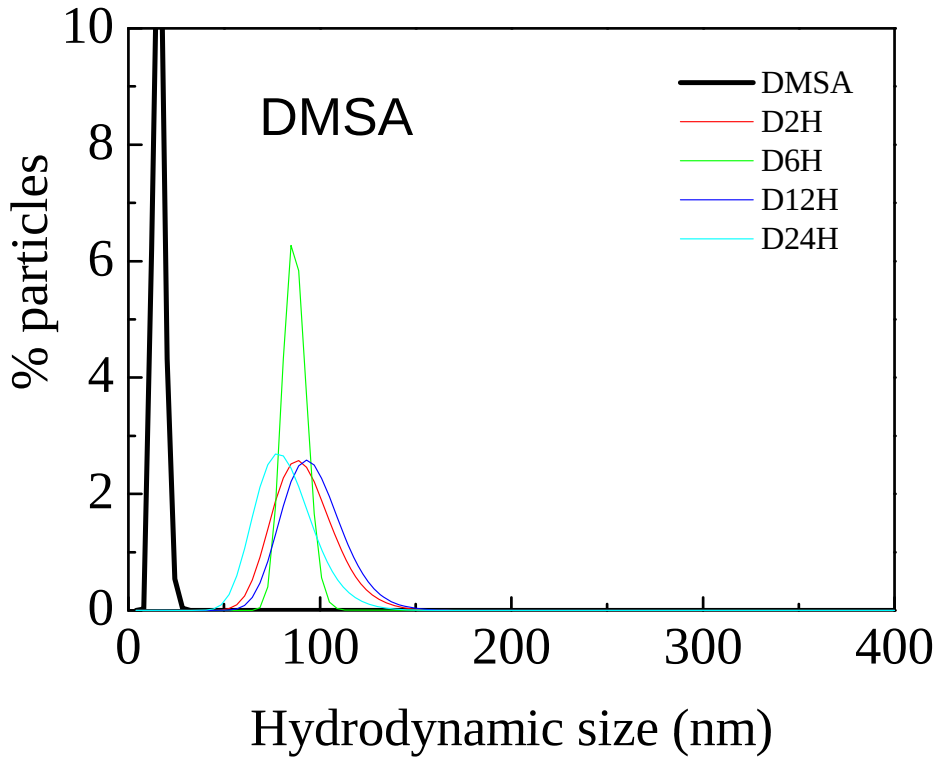


RESULTS

- ***COLLOIDAL CHARACTERIZATION***



Aggregation of the SiO_2 capsules with the hydrolysis time

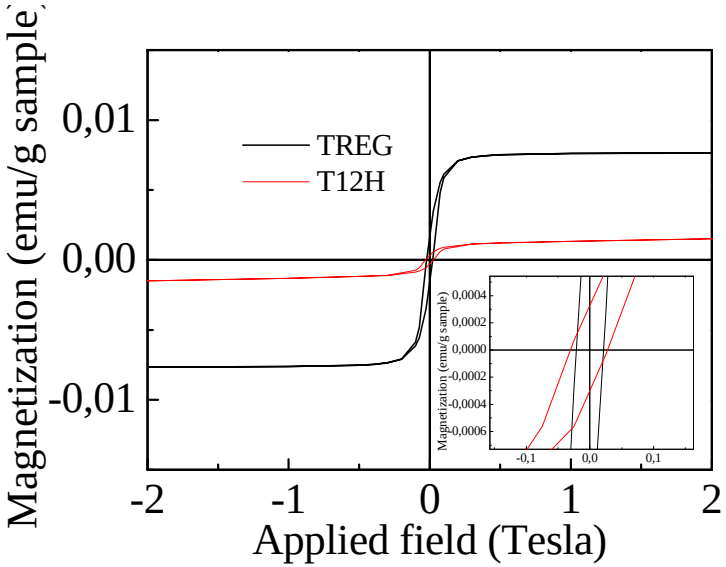


No variation of the hydrodynamic size with the hydrolysis time

RESULTS

- ***MAGNETIC PROPIERTIES***

MAGNETIZATION CURVES IN SUSPENSION COOLED TO 5 K

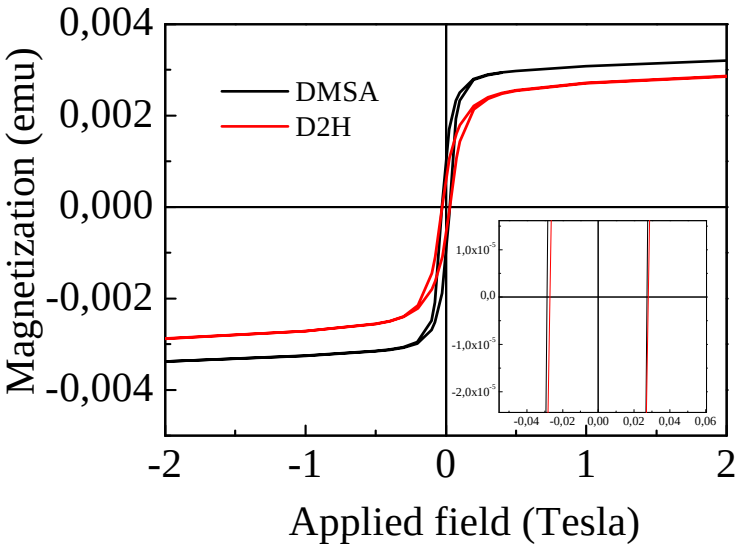


H_C(T12H)=300 Oe

H_C(TREG)=150 Oe

H_C(T12H)>> H_C(TREG)

Interactions between particles increase after silica coating

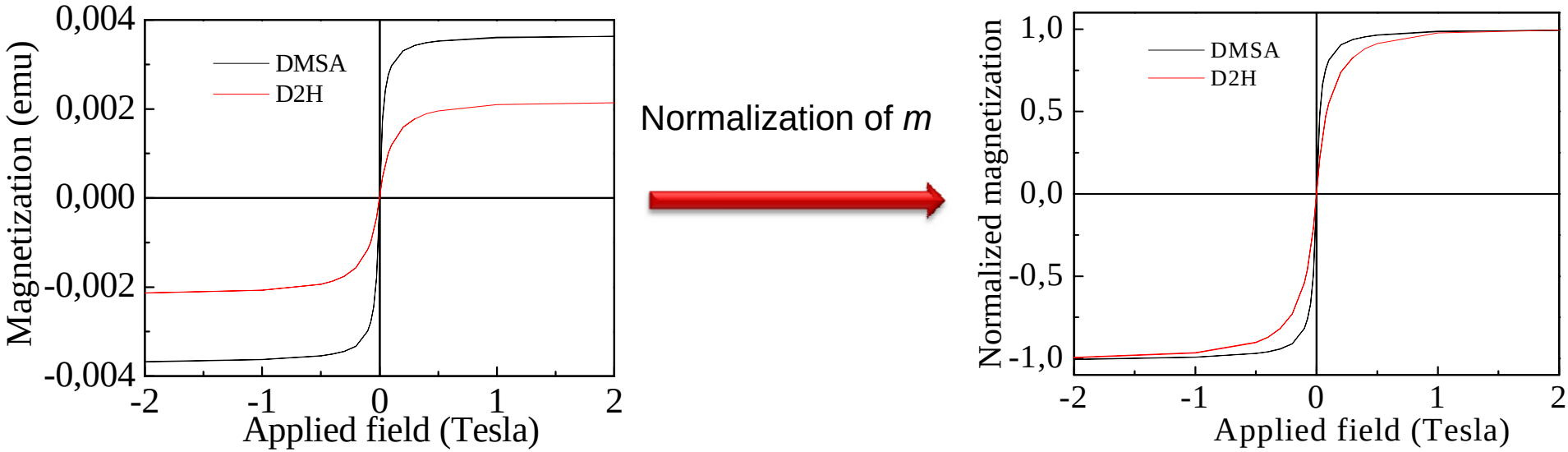


H_C(DMSA)~ H_C(D2H)=420 Oe

RESULTS

- ***MAGNETIC PROPIERTIES***

MAGNETIZATION CURVES IN SUSPENSION COOLED TO 250 K

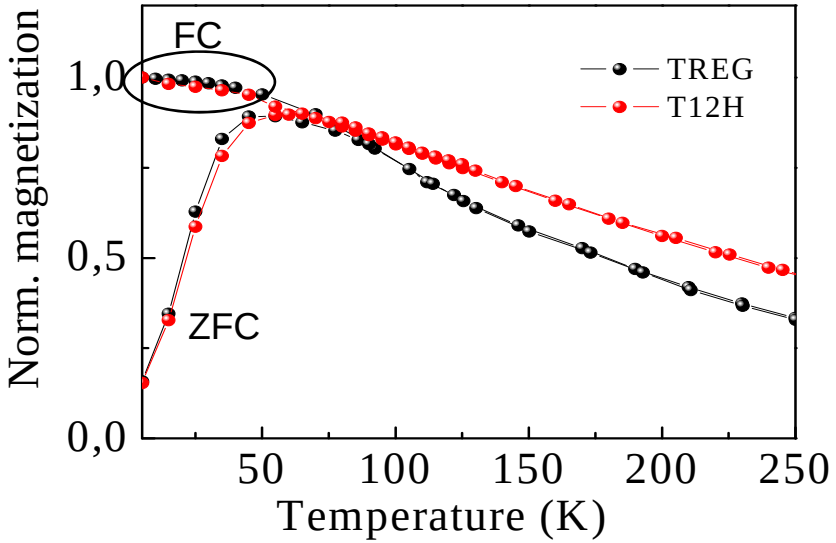


- Both samples have superparamagnetic behavior at 250 K
- Magnetization saturates at higher fields in D2H than DMSA due to the decrease of interactions

RESULTS

- ***MAGNETIC PROPIERTIES***

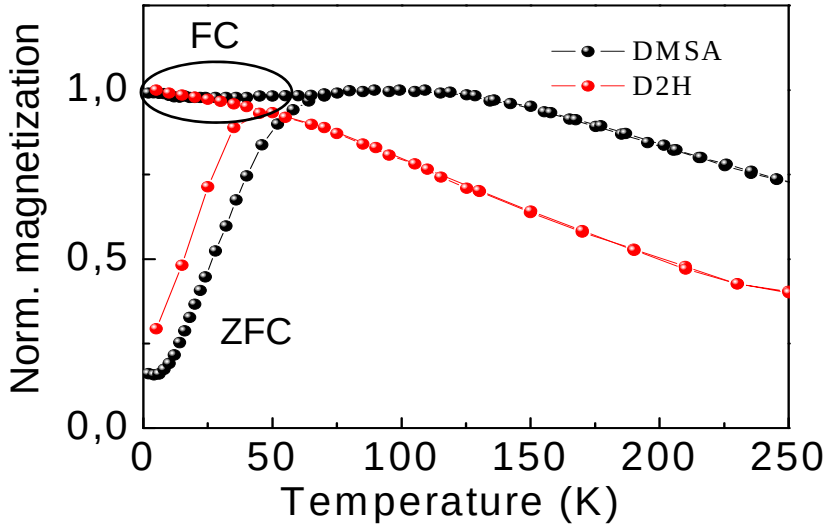
ZERO FIELD COOLING-FIELD COOLING



- Similar T_B for TREG and T12H

- Decrease in magnetization larger in TREG than T12H in the high-temperature region

→ Interactions



- D2H: Decrease of the T_B from 75 to 50 K

↓

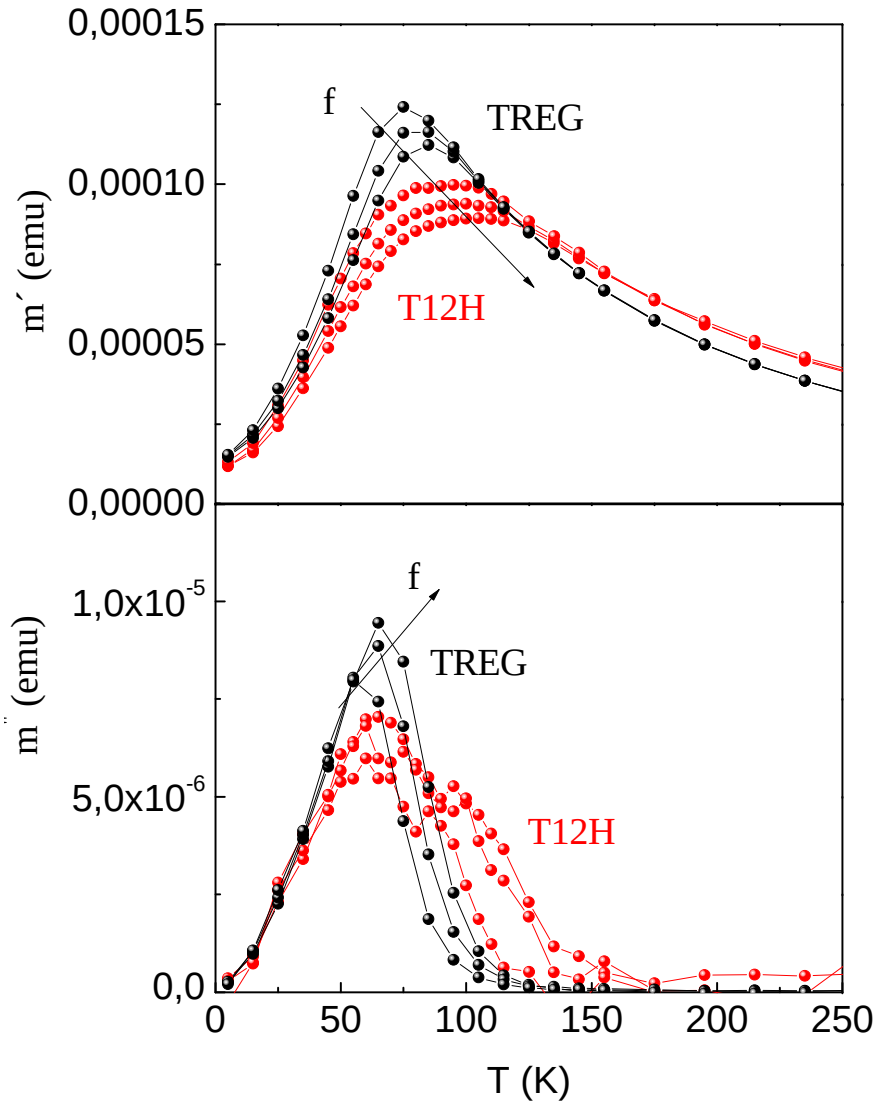
- Sharp magnetization decrease at low and high-temperature region in FC brench

→ Interactions

RESULTS

- ***MAGNETIC PROPIERTIES***

TREG & T12H



AC SUSCEPTIBILITY

χ_{ac} vs T f (5,50,240 Hz)

- Superparamagnetic behavior
- T_M increases with f

INTERACTION PARAMETER

RELATIVE SHIFT OF THE BLOCKING TEMPERATURE PER A FREQUENCY INTERVAL*

$$\phi = \frac{\Delta T_f}{T_f \Delta \log_{10}(f)}$$

ϕ(TREG) = 0,06

ϕ(T12H) = 0,04

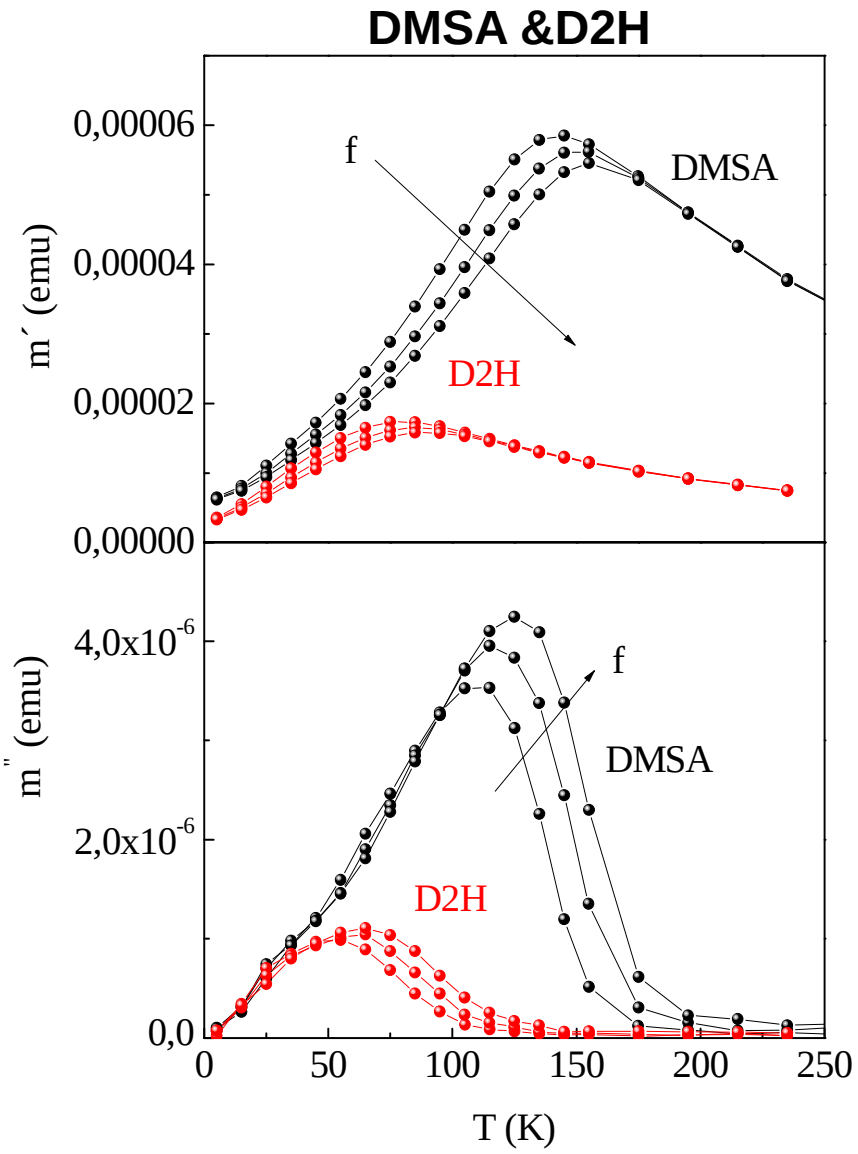
ϕ=0,1 for superparamagnetic systems
ϕ~0,01-0,03 for spin glass

Interactions increase after silica coating.
The aggregate size of the particles is larger

*G.F. Goya, T.S. Berquo, F.C. Fonseca, M.P. Morales, Journal of Appl. Phys. 94, 3520 (2003)

RESULTS

- ***MAGNETIC PROPIERTIES***



AC SUSCEPTIBILITY

χ_{ac} vs T f (5,50,240 Hz)

- Superparamagnetic behavior
- T_M decreases after the SiO_2 coating

ϕ(DMSA) = 0,04

ϕ(D2H) = 0,08

$$\phi = \frac{\Delta T_f}{T_f \Delta \log_{10}(f)}$$

LESS INTERACTIONS

D2H collective magnetic behavior is superparamagnetic due to the individual coating of the particles by silica

Opposite behavior than TREG sample!!!

CONCLUSIONS

- SiO_2-coated maghemite nanoparticles with spherical and rod-like nanostructures are synthesized using a reproducible method
- From TREG-coated maghemite nanoparticles, we obtained condensed SiO_2 spheres filled with magnetic nanoaggregates
- From DMSA-coated maghemite nanoparticles, we obtained isolated SiO_2 spheres filled with 1-5 magnetic nanoparticles
- The nature of the magnetic interactions between the Maghemite-coated SiO_2 particles depends on the molecule coating of the magnetic particles:
  - TREG-coated → Increasing interactions
  - DMSA-coated → Decreasing interactions

NANOPOROUS FILMS AND PARTICLES GROUP

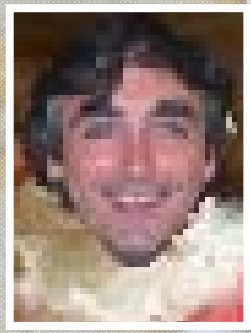
nanoporous films &particles

Nuria Miguel

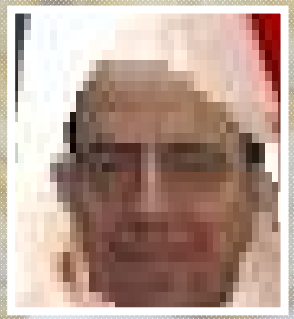
Daniel Carmona

Alejandro G. Roca

Francisco Balas



Jesús Santamaría



Thank you

Gracias

Obrigado