MAGNETIC PROPERTIES AND HEATING PERFORMANCES OF MAGNETIC NANO AND MICRO MATERIALS SUBJECTED TO RADIOFREQUENCY FIELDS

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INTRODUCTION

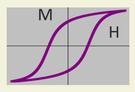
Superparamagnetic nanoparticles have been widely studied focusing on their ability to deliver localized heat on tumors when they are subjected to alternating magnetic fields. It is well stablished that their heating efficiency is due to hystheresis losses but in the case of magnetic microwires is not clear at all.

A better understanding of the dynamic magnetic behavior of iron oxide nanoparticles observing chain formation is presented in this work as well as a comprehensive study of the heating properties and mechanisms of Co-rich soft magnetic microwires with colossal heating efficiencies.

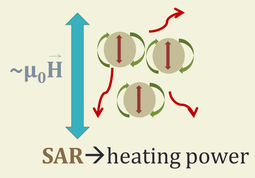
METHODS

The power delivered by the magnetic material via hystheresis losses can be obtained using:

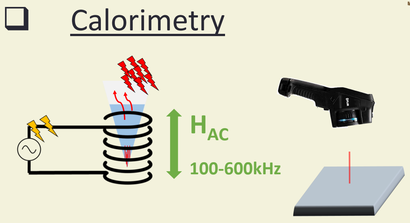
- Magnetometry



$SAR = A \cdot f$



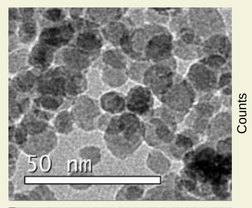
- Calorimetry

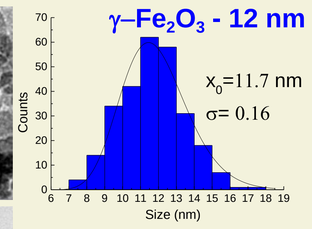


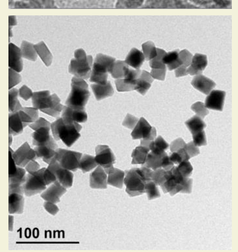
$$SAR = \frac{c_{water}}{m_{mag}} \cdot \left(\frac{\Delta T}{\Delta t}\right)$$

MATERIALS

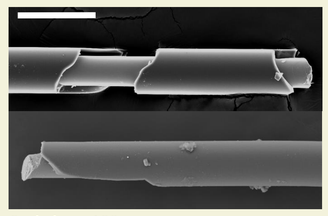
MAGNETIC NANOPARTICLES - MNP







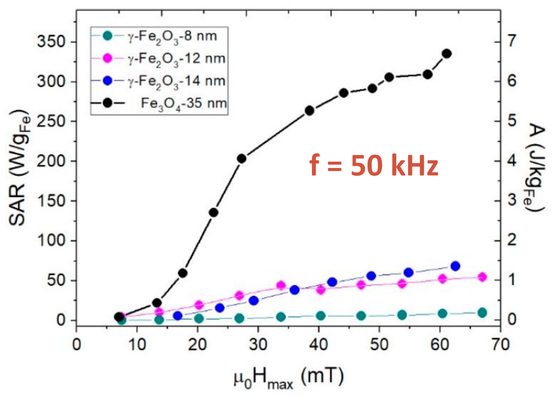
MAGNETIC MICROWIRES - MH



Scale bar= 100 μm

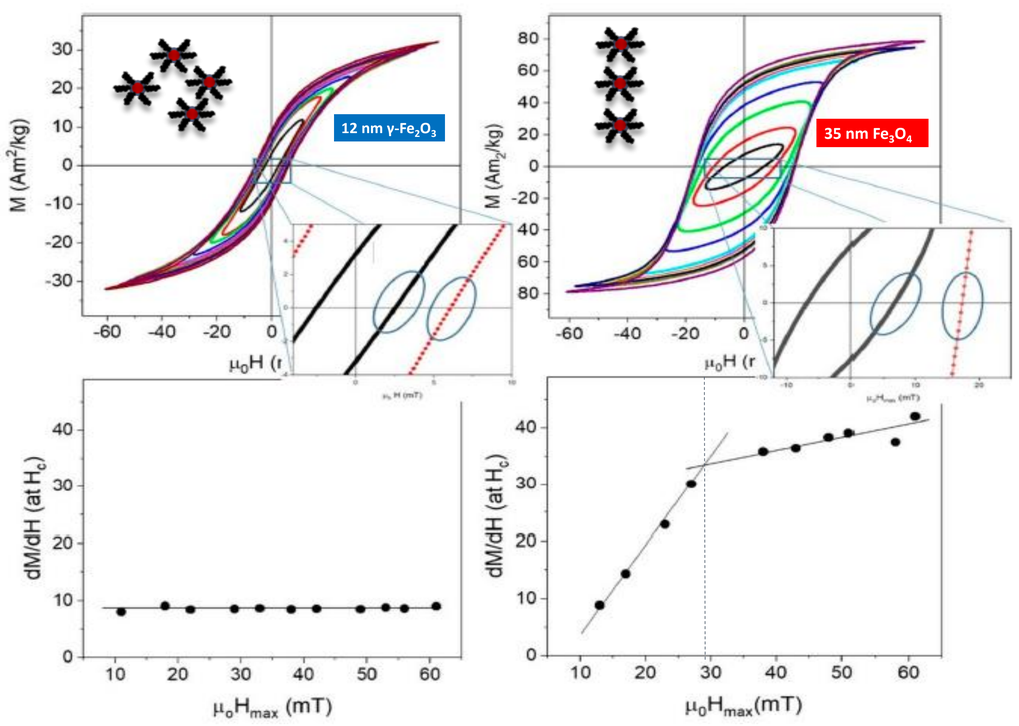
Co-rich amorphous soft magnetic microwires (MH) Ø=30μm

MAGNETIC NANOPARTICLES – CHAIN FORMATION



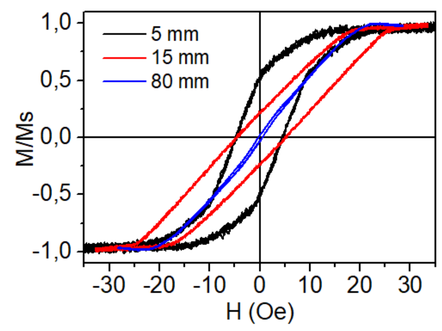
The application of high-frequency fields increases the magnetic susceptibility from 9 to 40 for 35 nm NPs, while in the case of smaller nanoparticles remains the same due to the competition between dipolar and thermal energy. Chain formation change the demagnetizing field and induced an easy axis in the direction of the field producing a larger squaring of the hysteresis loops

$\mu_0 H_{max}$ = 60 mT, f = 50 kHz



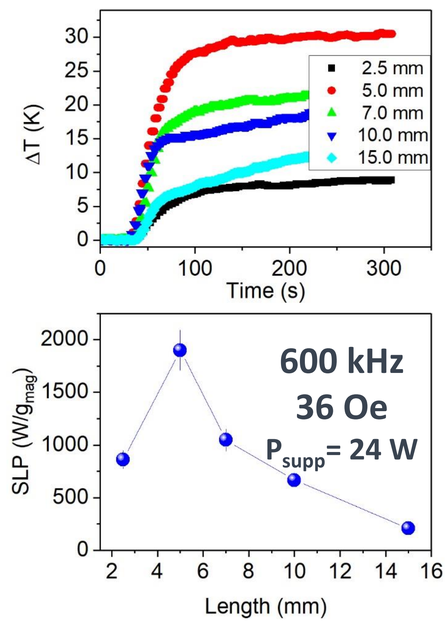
MH – HEATING EFFICIENCY AS A FUNCTION OF LENGTH

Hysteresis loops for **1MW** at **50 Hz**



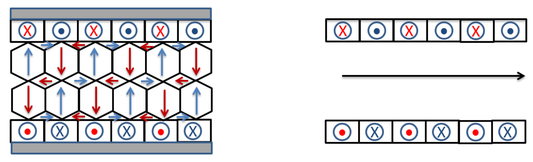
The cut of the wire produces a release of the stress induced by the glass-coating, increasing the heating efficiency.

Measurements for 20MWs in water



MAGNETIC DOMAIN STRUCTURE

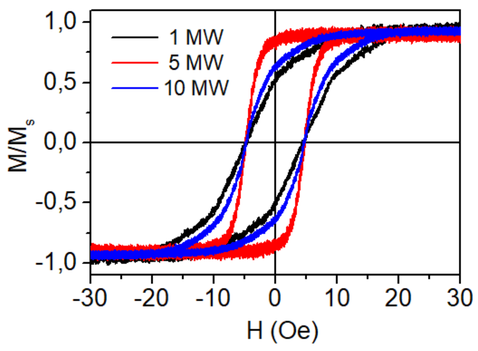
Before glass-coating removal (l=8cm)



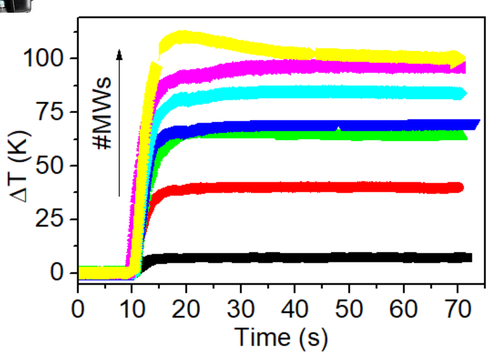
After glass-coating removal (l=5mm)

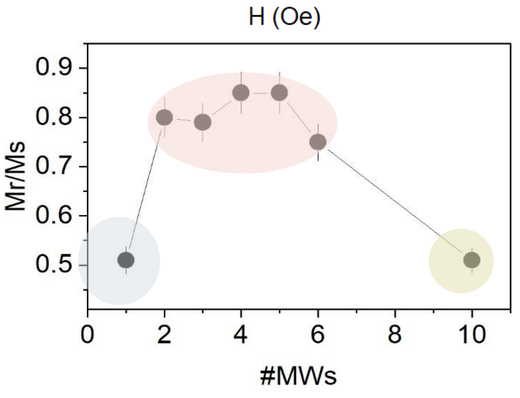
MH - HEATING EFFICIENCY AS A FUNCTION OF #MWS

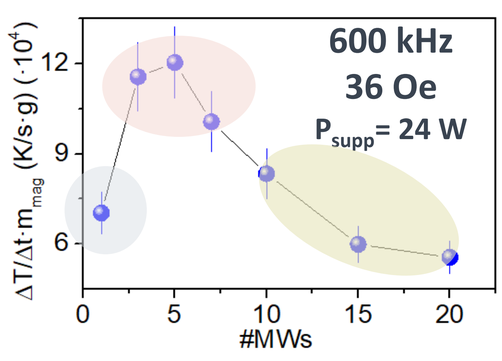
Hysteresis loops for **l=5mm** MWs at **50Hz**



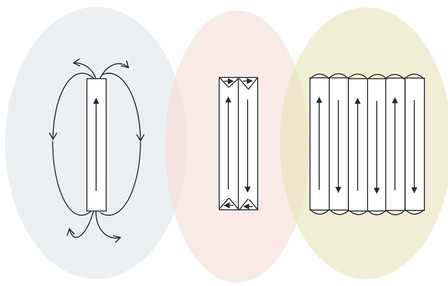
IR camera measurements







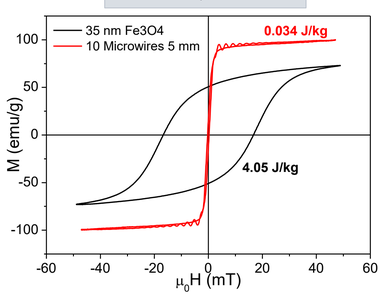
DOMAIN STRUCTURE DUE TO MAGNETOSTATIC INTERACTIONS



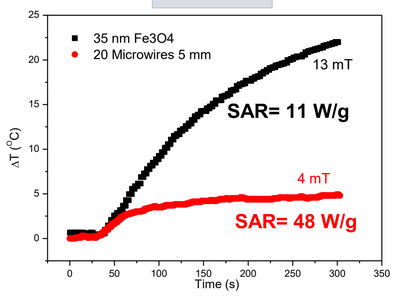
When around 5 MWs are put together, the remanence increases up to Mr/Ms≈0.8, suggesting the formation of closing domains in order to diminish the magnetostatic energy.

HEATING MECHANISM IN SOFT MAGNETIC MICROWIRES

50 kHz, 47 mT

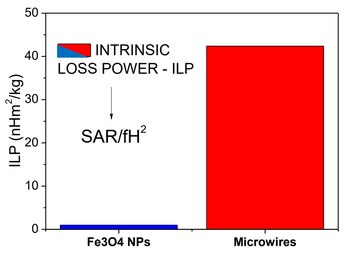


100 kHz



$$SAR = \frac{c_{water}}{m_{mag}} \cdot \left(\frac{\Delta T}{\Delta t}\right) = ILP \cdot f \cdot H^2$$

The heating in the case of the microwires can´t be fully explained via hystheresis losses. The heating is mainly due to the Eddy currents induced by ***B=M+χH.***



CONCLUSIONS

- The enhanced heating efficiency for the 35nm Fe3O4 was not only a consequence of the particle's intrinsic properties but by the kind of particle interactions. **The increase of the magnetic susceptibility at the coercive field could be considered as a magnetic stamp for chain formation.**
- Colossal heating efficiency is observed in Co-rich amorphous microwires.
- These microwires are very interesting for heating applications at a very low cost energy.