Magnetization reversal mechanisms in electrodeposited nanowire arrays

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

LMB

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Outline

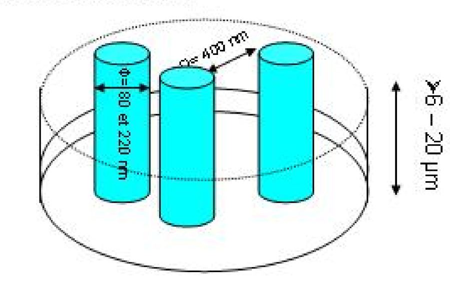
- ► Electrochemical fabrication of ferromagnetic nanowires
- ► Novel method for controlling the growth filling time in the pores
- ► Experimental study of the structural and magnetic properties of magnetic nanowires
- ► Comparison between theory and experiment, regarding reversal processes

Motivation

- ► Fundamental interest in the study of the magnetic behavior (dynamic of magnetization reversal) at the small scales
- ► Nano size effect: significant change in physical properties with reduced dimensionality.
- ► Potential applications (information technologies, sensors, microwaves…)

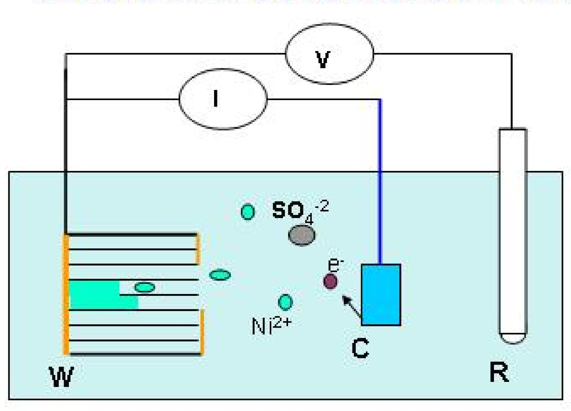
Samples

Ni - nanowires : synthesis by electrodeposition in porous polycarbonate membranes



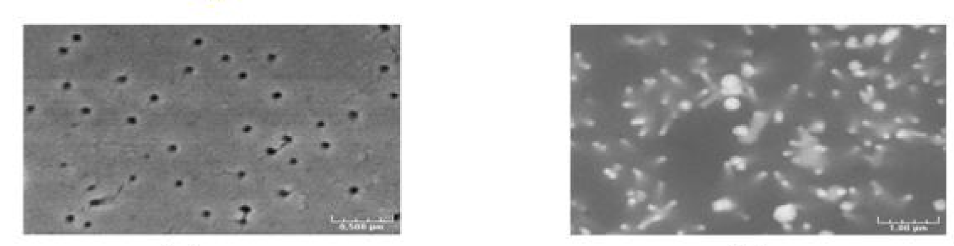
- ➢ Average diameter of the wire: 15 or 100 nm
- ➢ Pore density in the membranes: $10^9/cm^2$

Electrochemical cell



■ Electrochemical cell with three electrode set up

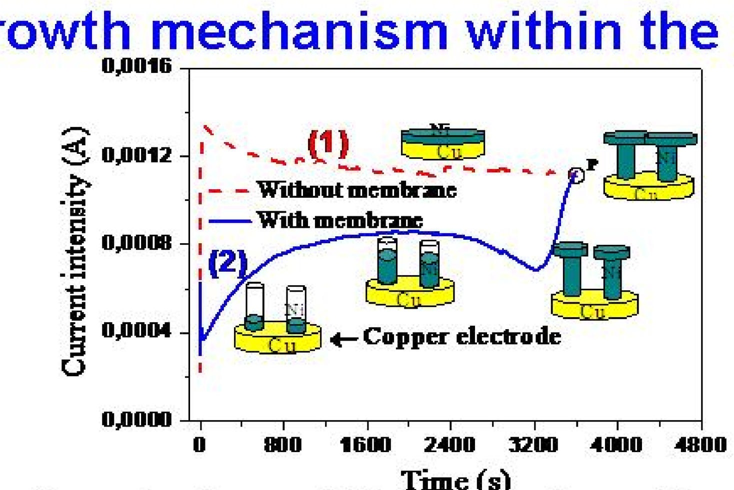
Polycarbonate membrane



(a) (b)

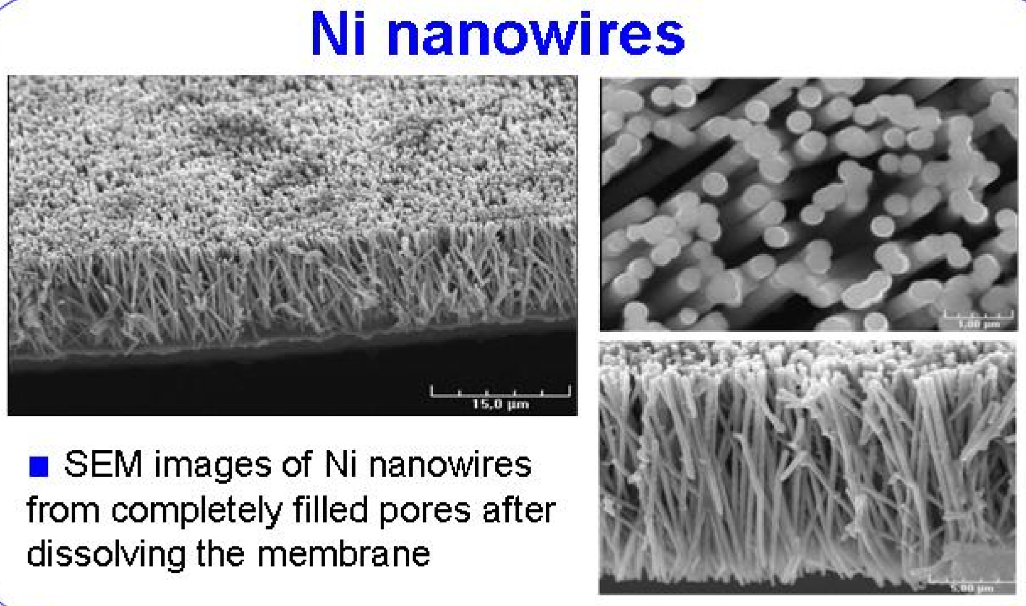
■ SEM images of polycarbonate membrane with pores 80 nm in diameter (a) before metal electrodeposition (b) after Ni electrodeposition with the wires emerging from the surface

Growth mechanism within the pores



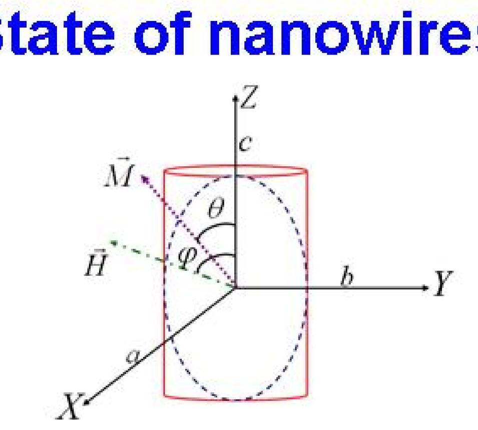
■ Growth mechanism and filling time values of the pores for Ni nanowires, (1) Ni deposit on copper electrode with membrane (2) Ni deposit on copper electrode with membrane

Ni nanowires



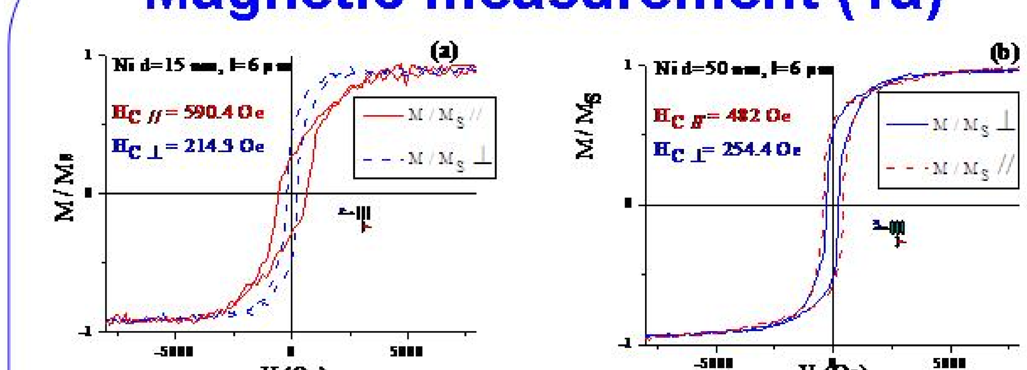
■ SEM images of Ni nanowires from completely filled pores after dissolving the membrane

State of nanowires



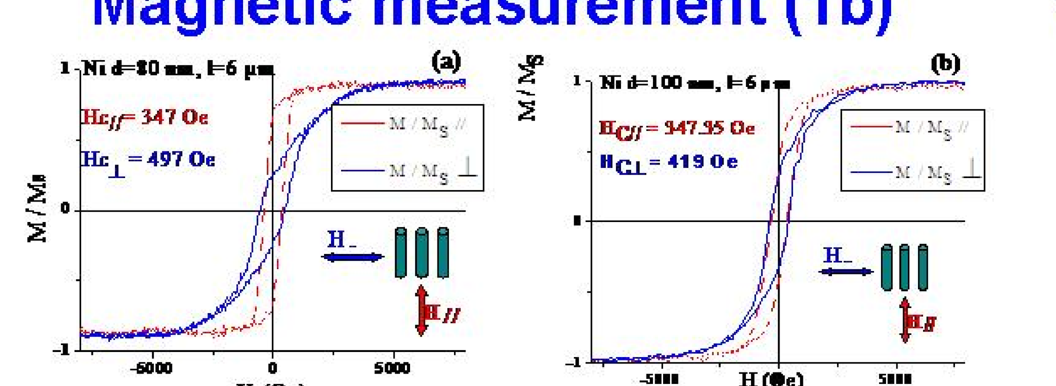
■ A single domain particle with uniaxial anisotropy in the présence of a external magnetic field H, showing angles, θ and φ that the magnetization M and the magnetic field H make with wire axis along Z, (a=b<c).

Magnetic measurement (1a)



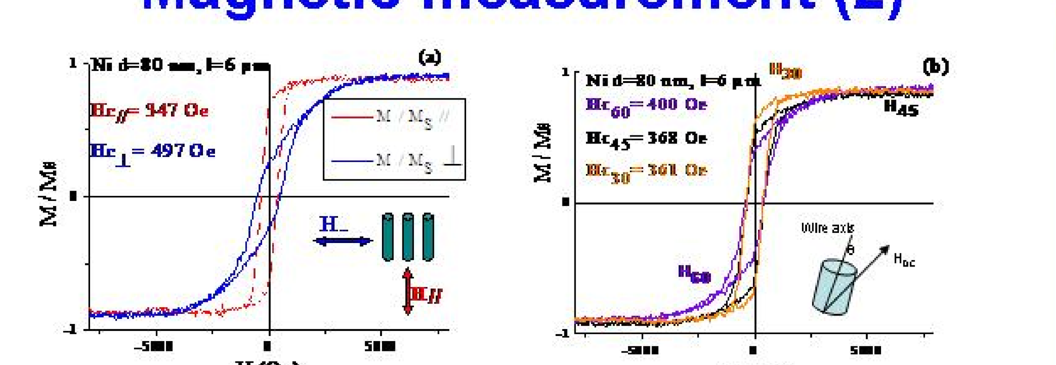
■ Hysteresis loop for an array of Ni nanowires (15 nm and 50 nm in diameter electrodeposited at -1V vs. Ag/AgCl) with the magnetic field applied respectively parallel and perpendicular ($H_{//}$ and $H_{\perp}$) to the axis of the wires

Magnetic measurement (1b)



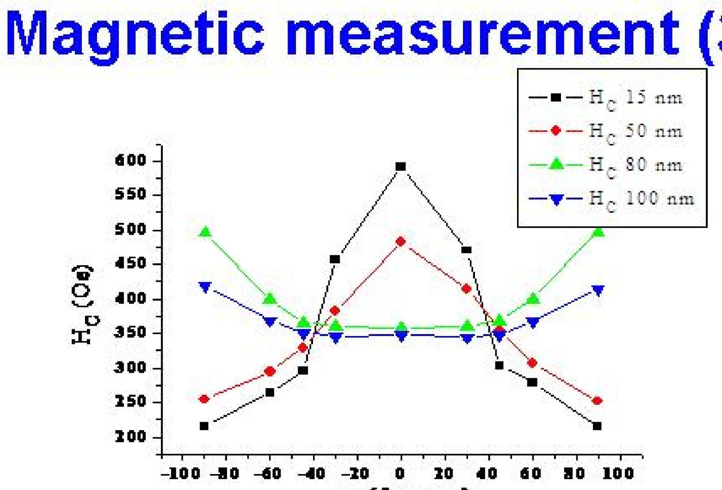
■ Hysteresis loop for an array of Ni nanowires (80 nm and 100 nm in diameter electrodeposited at -1V vs. Ag/AgCl) with the magnetic field applied respectively parallel and perpendicular ($H_{//}$ and $H_{\perp}$) to the axis of the wires

Magnetic measurement (2)



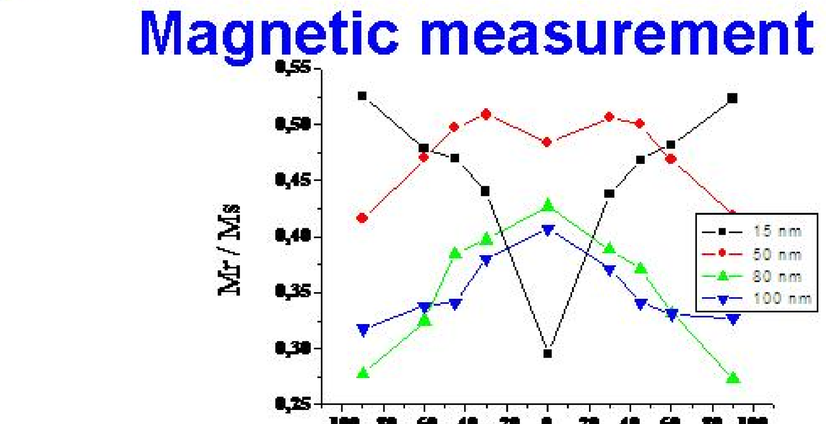
■ Hysteresis loops of the array of Ni nanowires. (a) for φ equal 0° and 90°, (b) for φ equal 30°, 45° and 60° (φ is the angle between the wire axis of the membrane and the applied magnetic field)

Magnetic measurement (3)



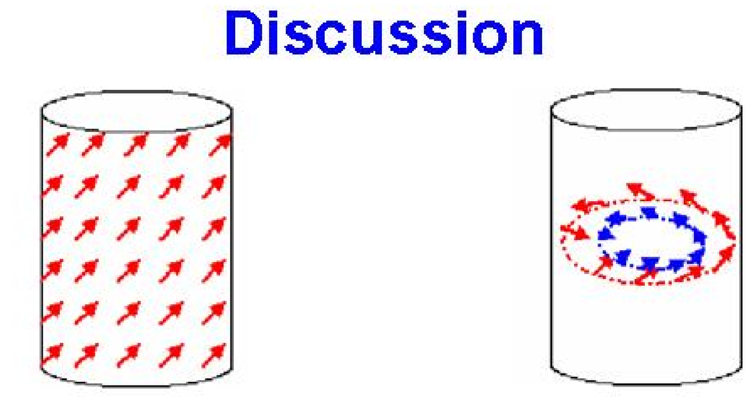
■ Coercive field for Ni nanowires 15, 50, 80, and 100 nm in diameter and electrodeposited at -1 V

Magnetic measurement (4)



■ Angular dependence of the squarness SQ= Mr/Ms of nanowires in PCTE membranes with different diameters of: 15, 50, 80, 100 nm and 6 µm length.

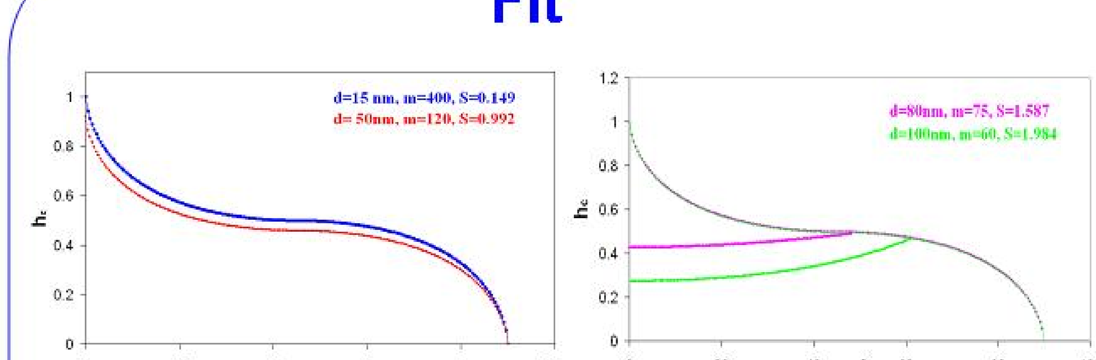
Discussion



SW (Stoner-Wohlfarth) coherent rotation

Curling incoherent rotation

Fit



■ Curves fit of the angular dependence of coercive fields for the nanowires of 15, 50, 80 and 100 nm diameters and 6 µm thick, using the two models SW and Curling.

Conclusion (1)

- ● The reproducibility of the measurements emphasizes the homogenous growth of the nanowires obtained by the electrodeposition method
- ● Electrodeposition is a very advantageous method: to fabricate nanoscale objects of different shapes with variable chemical composition
- ● The coercive field of Ni nanowires increases when the wire diameter decreases [1]

Conclusion (2)

- ● The effect of the nanowire size diameter shows that the magnetization reversal mechanism is strongly influenced by the nanowire diameter
- ● Comparison between coherent rotation and curling
- ● The coercive field is reduced when the magnetic field H is applied along the nanowire easy axis, this might indicate interacting among the nanowires. [2]

References

[1] R. Ferré, K. Ounadjela, J. M. George, L. Piraux and S. Dubois, Phys. Rev. B, **56** n° 21, 14066, (1997).

[2] M. Lederman et al, IEEE Trans. Magn. 31, 3793 (1995)