Research on nanostructured materials for the energy and electronic

M.Ricardo Ibarra

Institute of Nanoscience of Aragón

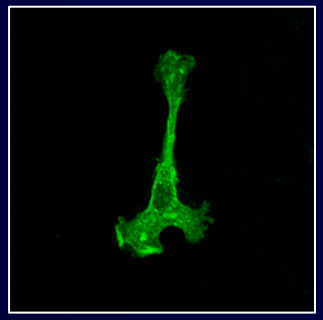
OUTLINE

-Presentation of the Institute of Nanoscience of Aragón

-Nanomaterials research in Aragón

INSTITUTE OF NANOSCIENCE OF ARAGON

RESEARCH LINES

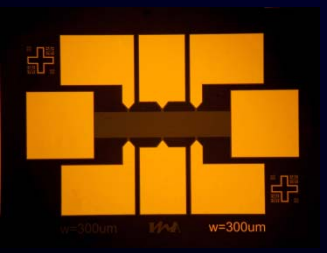


NANOBIOMEDICINE:

- Therapy:
  - Drug Delivery
  - Hyperthermy
- Diagnóstic:
  - Contrast agent (biomolecular and celular targeting)
  - Biosensors: Quantitative lateral flow.

NANOSTRUCTURED MATERIALS:

- Membranes and nanoporous films
- Carbon nanotubes
- Organic functionals materials (dendrimers, mesosocopic liquid crystals
- Core-shell magnetic nanoparticles



PHYSICS AT THE NANOSCALE:

- Thin films: magnetic heteroestructures, superlattices...
- Micro- Nanocircuits: Spintronics, quantum effects, nanowires, nanoconstrictions, MEMS&NEMS...

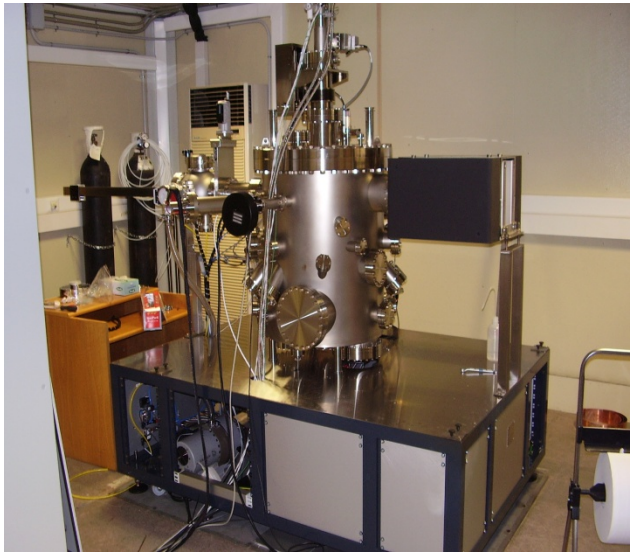
1. Laboratory of thin films growing

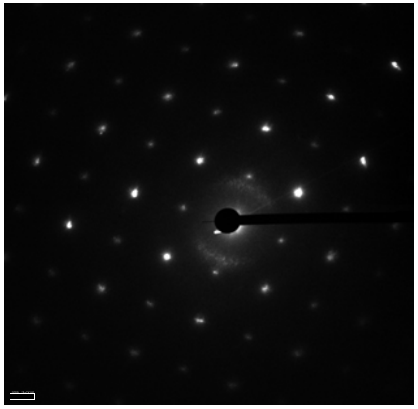
-LASER ABLATION

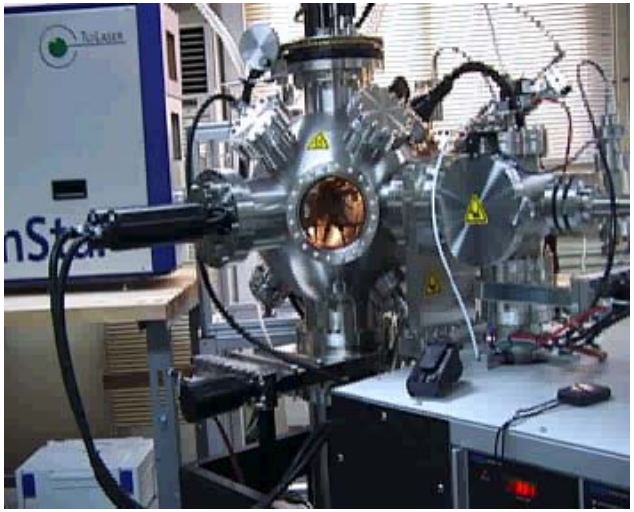
-SPUTTERING

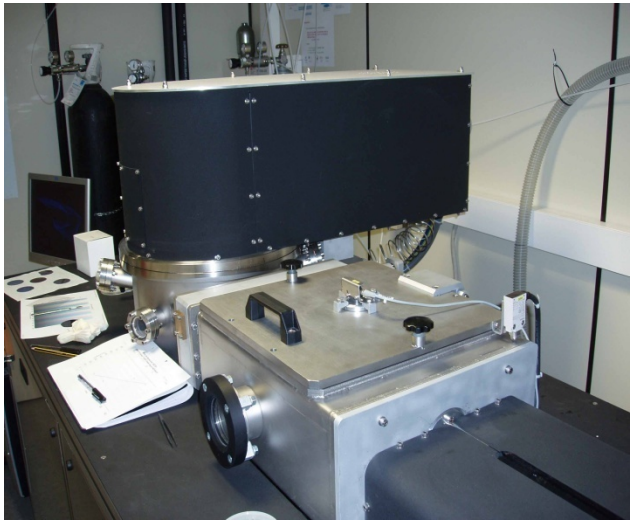
-MBE

-PECVD









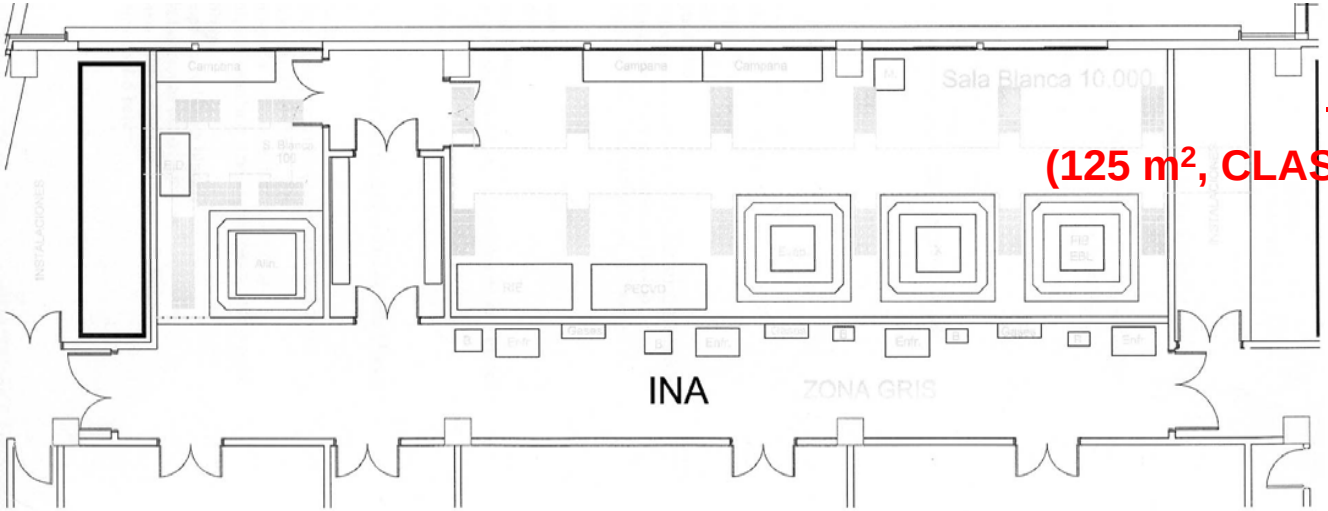
Fe_3O_4 / MgO epitaxial thin film

2. Laboratory of lithography

PRESENT

(20 m^2, CLASS 10.000)

- *Photoresist station*
- *mask aligner*
- *e-beam evaporator*
- *RIE / IBE*
- *PECVD*
- *μcontacts, optical microscope, saw*



NEW

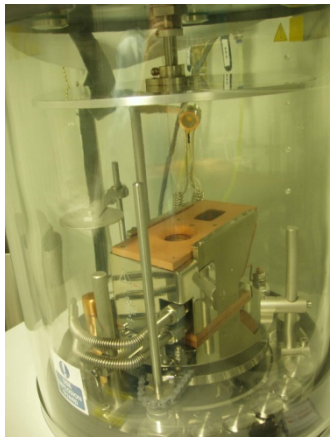
(125 m^2, CLASS 10.000 & CLASS 100)

2. Laboratory of lithography

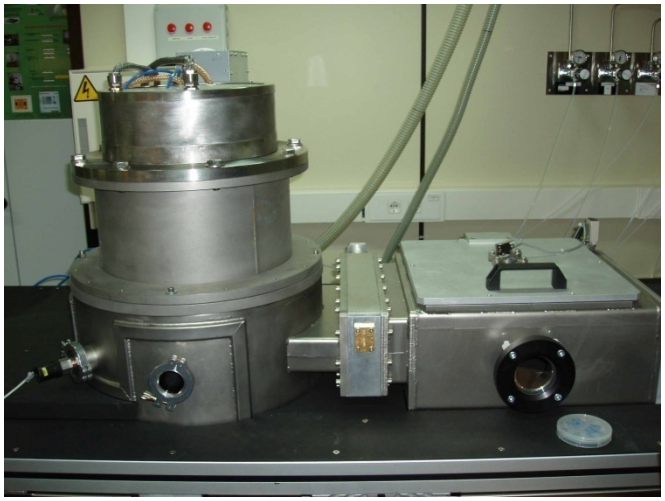
MASK ALIGNER

PHOTORESIST STATION

MICROCONTACTS



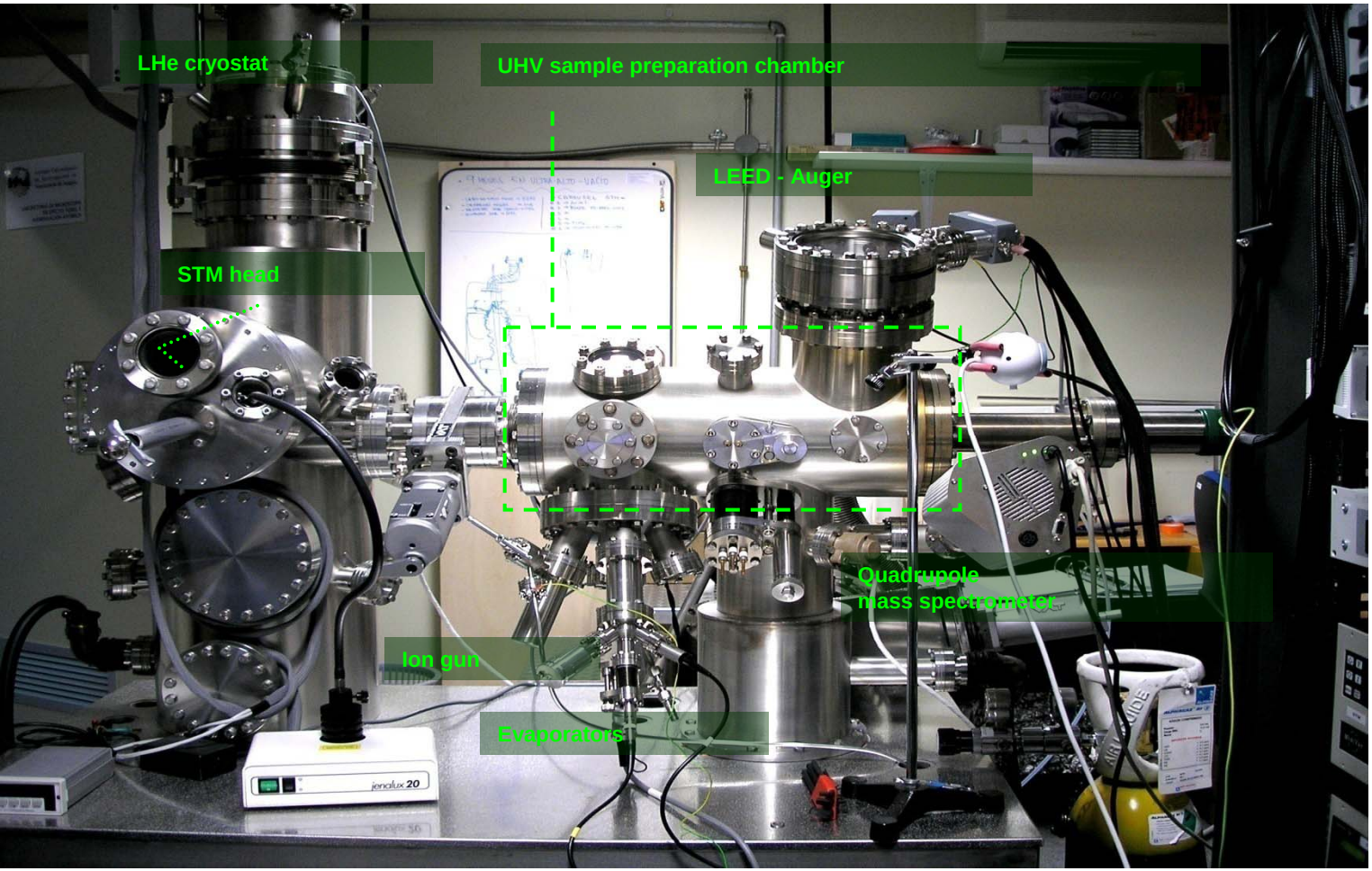
ELECTRON BEAM EVAPORATOR

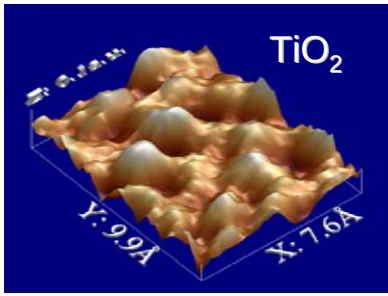


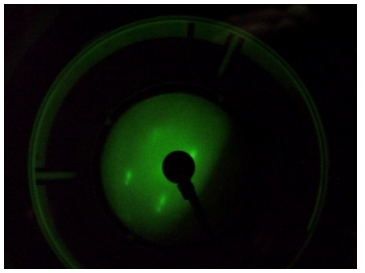
DRY ETCHING

RIE/IBE

3. Laboratory of scanning probe microscopy (SPM)





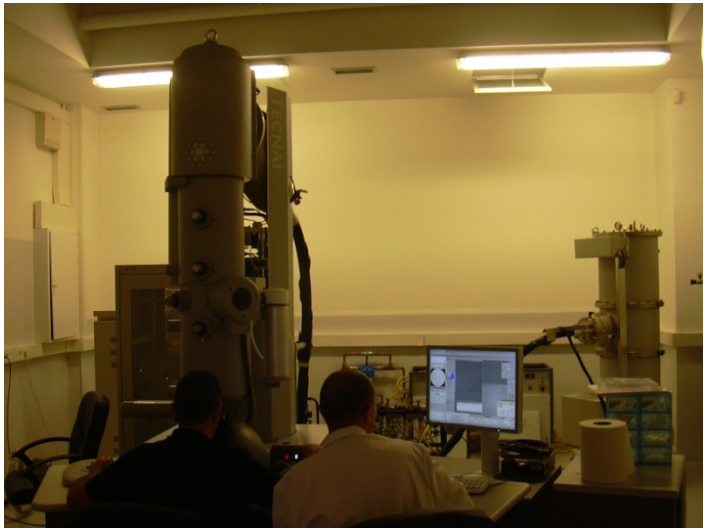


LEED pattern from a Cu (1 1 13) surface (regular array of steps)

Low Temperature UHV - STM

4. Laboratory of electron microscopy: TEM, SEM

HRTEM: FEI TECNAI G2 F30

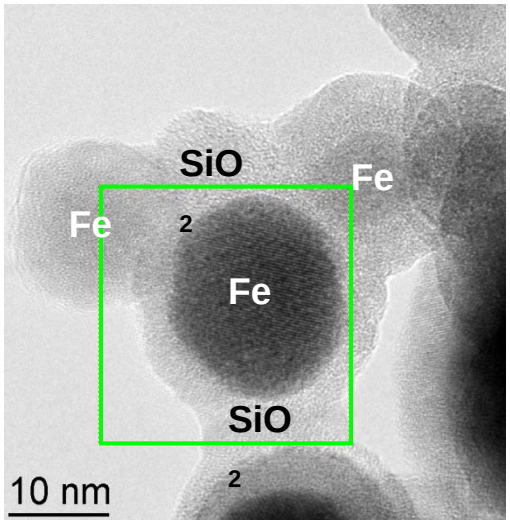


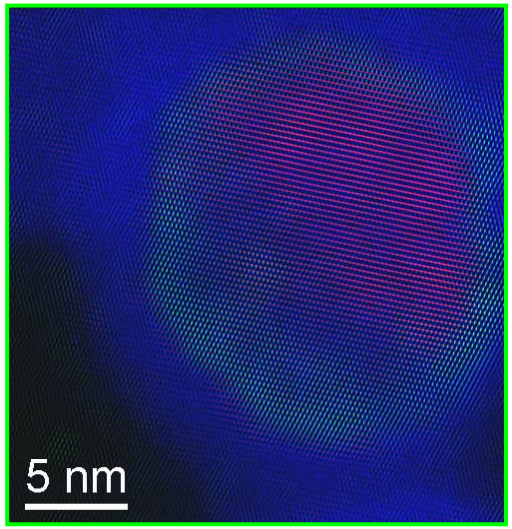
UHRTEM:

Cs correctors

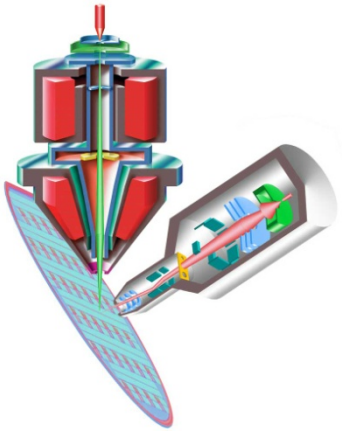
(Future project)

-Field Emission 80keV-300keV
-Gatan Energy Filter (TRIDIEM)
-STEM (EELS)
-HAADF, Z-contrast
-Tomography, 3D image
-Lorentz Lens





4. Laboratory of "Dual beam" microscopy



Imaging

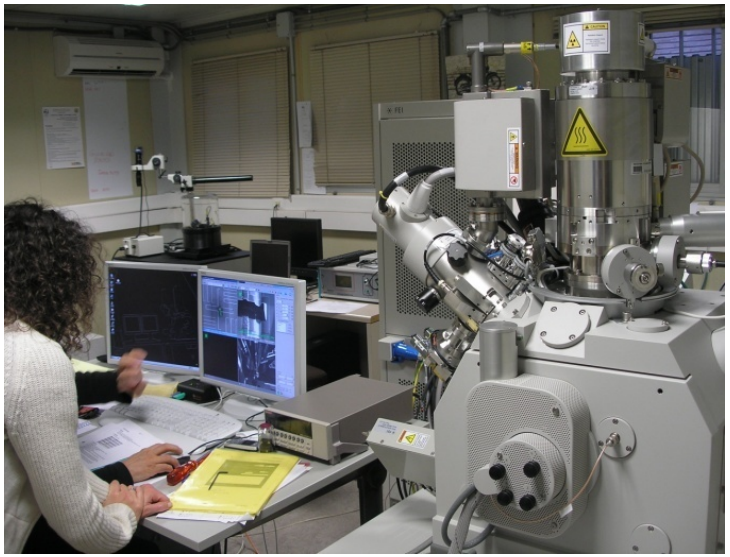
Ectching

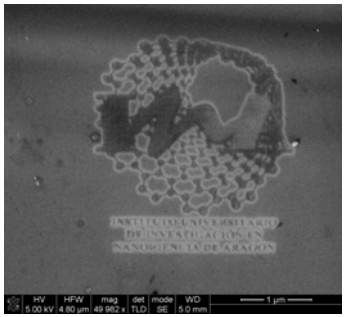
Deposition

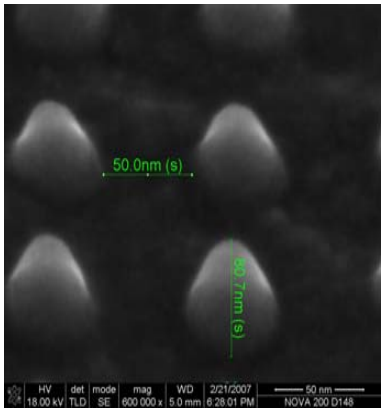
Analysis

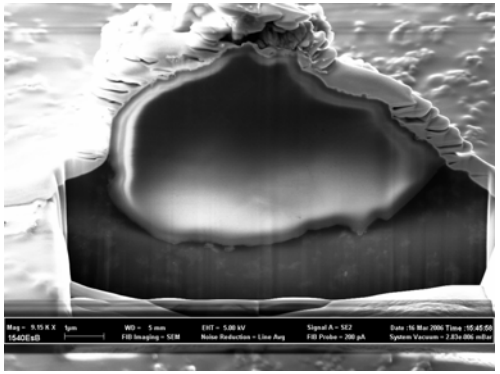
Nanopatterning

e-beam lithography









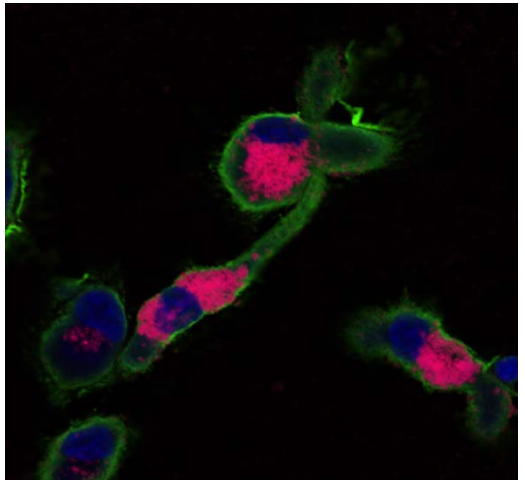
5. Laboratory of biomedical applications

Orbital shaker

Celules
and
bacterials
separation

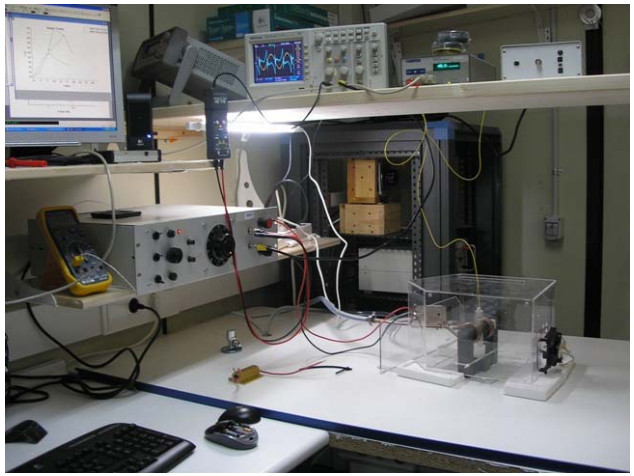
Peptide
chromatography

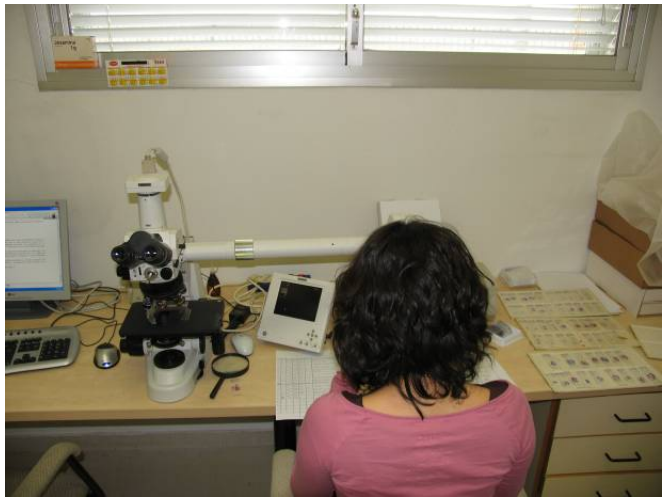
U-V spectrometer



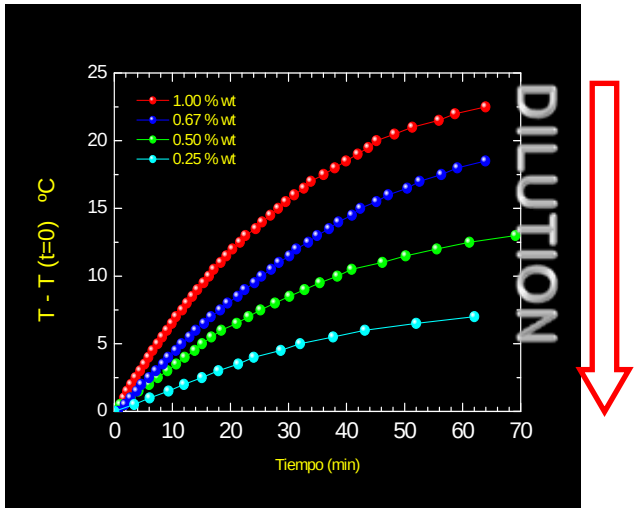
Cell culture&nanoparticles

5. Laboratory of biomedical applications ("in-vitro")

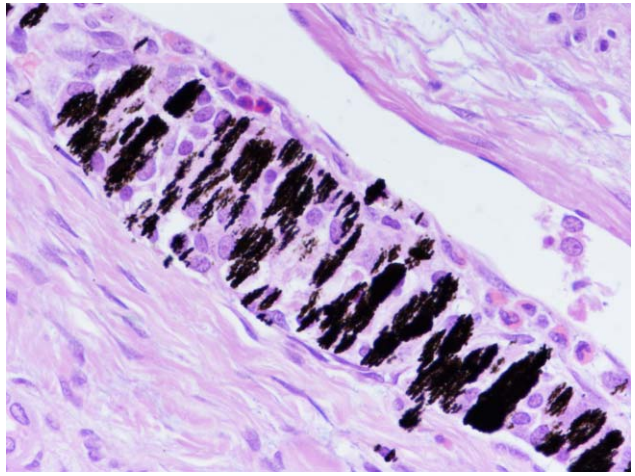




Magnetic Hyperthermy



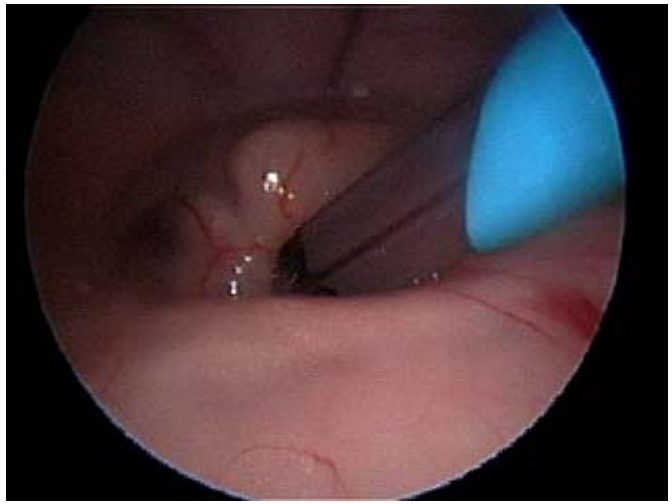
Anatomopatology



5. Laboratory of biomedical applications (“in-vivo”)

Veterinary Hospital Suregery room

Endoscopic surgery



6. Laboratory of synthesis and functionalización of nanosystems

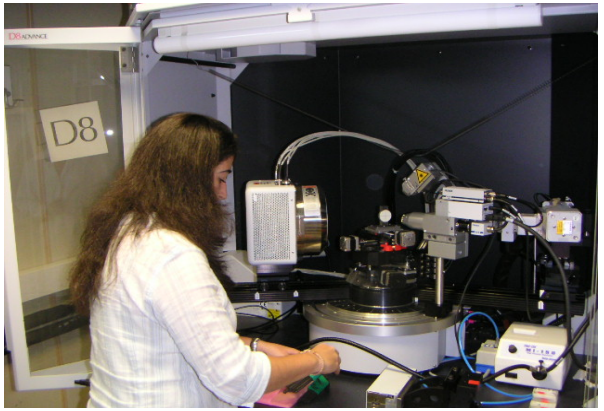
Nanoparticles

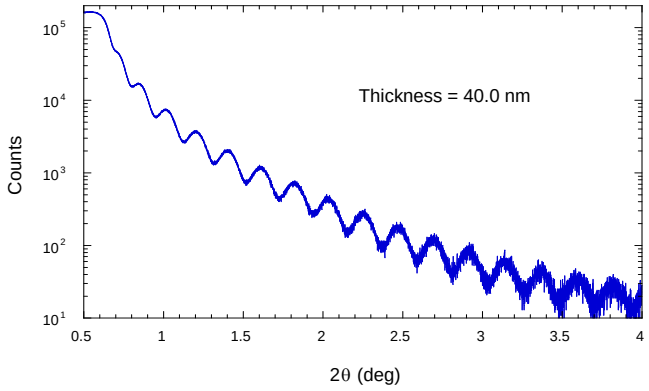
Optical microscopy

Laminar flow cabine

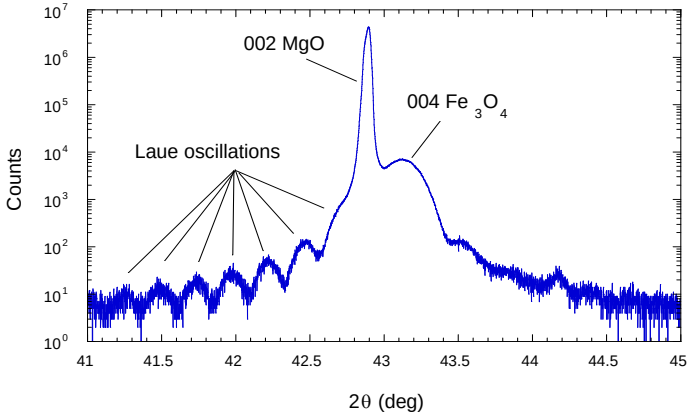
7. Laboratory of thin films characterization

X-RAY DIFFRACTION HIGH RESOLUTION D8 Brucker



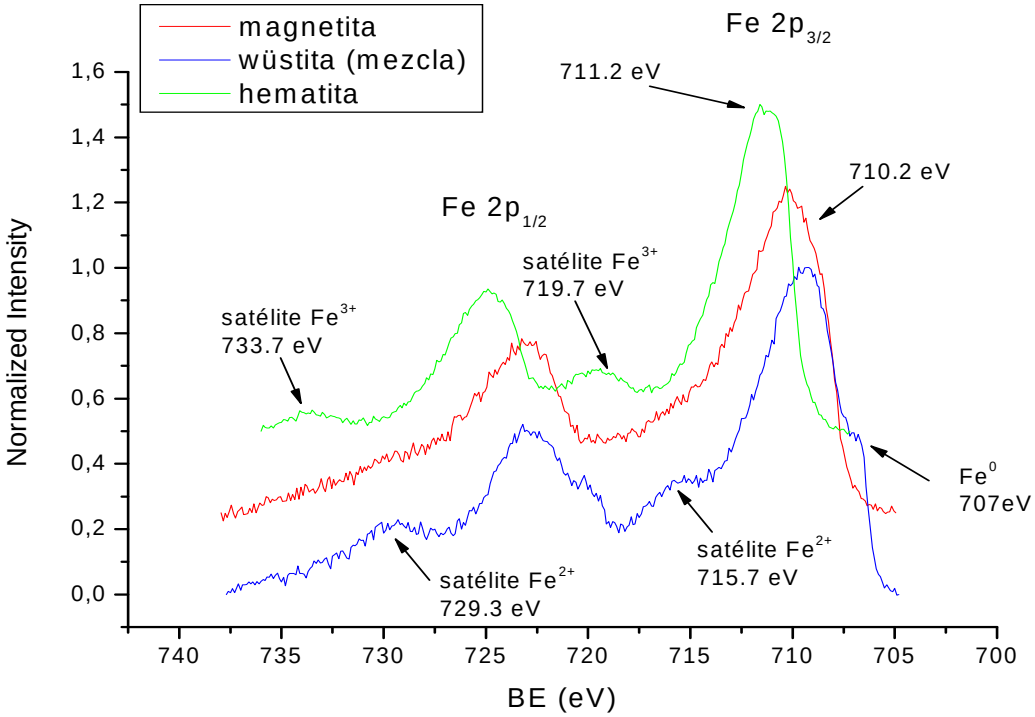


X-ray reflectivity



Laue oscillations high degree of coherency in the film

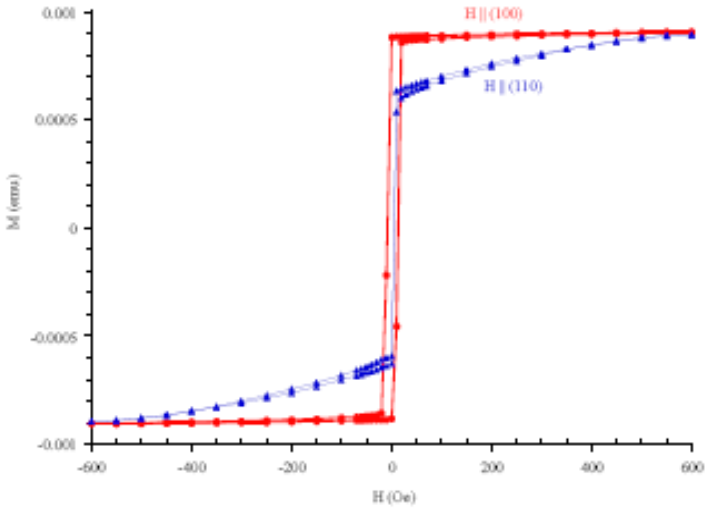
7. Laboratory of surface characterization (XPS &Auger)



Iron ionic states in different oxides

7. Laboratory of magnetic characterization VSM

Temperature range 100 K -800 K
High sensitivity (~10-6 emu).
Magnetic field up to 2 Tesla



Hystheresis loops of a epitaxial Fe thin film with the field applied along [100] y [110] directions

OUTLINE

-Presentation of the Institute of Nanoscience of Aragón

-Nanomaterials research in Aragón

NANOMATERIALS FOR THE ELECTRONICS

-Growth of Epitaxial Half-metal Oxides: Fe_3O_4, Sr_2CrReO_6

-Growth of Epitaxial Metals: Fe

-Epitaxial heterostructures for magnetic tunnel junctions and spin filtering

-Magnetoresistive granular materials: Fe/MgO

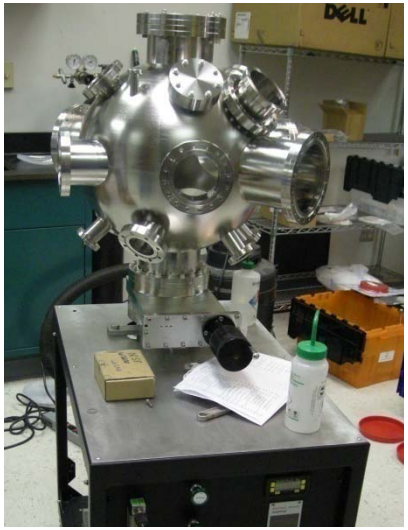
-Magnetic nanowires

-Magnetic nanoconstrictions

-Magnetic biosensors

-Superconducting nanowires

Thin-film epitaxial heterostructures for Spin Electronics



New chambers to be installed before June 2009: dedicated PLD + dedicated sputtering

The tool: UHV combined PLD-sputtering system

High-quality Thin Films / Heterostructures succesfully grown to date:

- MgO (001) // Fe_3O_4
- MgO (001) // Fe
- MgO (001) // Fe_3O_4/MgO/Fe
- CG // $[Fe/MgO]_N$
- $SrTiO_3$ (001) // Sr_2CrReO_6
- MgO (001) // $CoFe_2O_4$

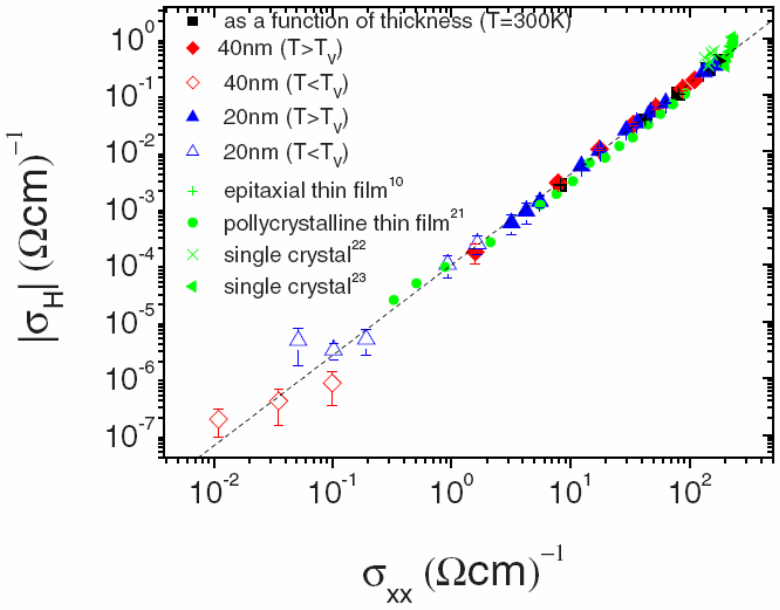
Thin-film epitaxial heterostructures for Spin Electronics

RAPID COMMUNICATIONS

PHYSICAL REVIEW B 77, 100403(R) (2008)

Universal scaling of the anomalous Hall effect in Fe_3O_4 epitaxial thin films

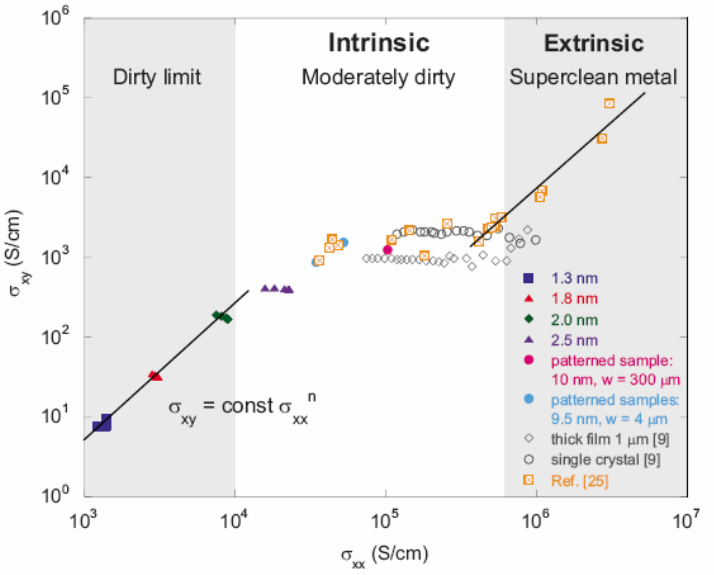
A. Fernández-Pacheco,[1,2] J. M. De Teresa,[2,*] J. Orna,[1,2] L. Morellon,[1,2] P. A. Algarabel,[2] J. A. Pardo,[1,3] and M. R. Ibarra[1,2]



PHYSICAL REVIEW B 79, 014431 (2009)

Anomalous Hall effect in Fe (001) epitaxial thin films over a wide range in conductivity

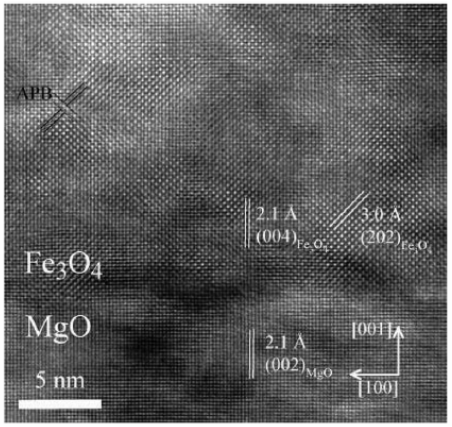
S. Sangiao,[1] L. Morellon,[1,2,*] G. Simon,[1] J. M. De Teresa,[2] J. A. Pardo,[3] J. Arbiol,[4] and M. R. Ibarra[1,2]

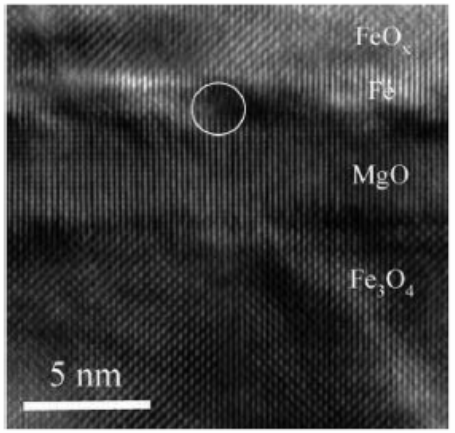


2662 IEEE TRANSACTIONS ON MAGNETICS, VOL. 44, NO. 11, NOVEMBER 2008

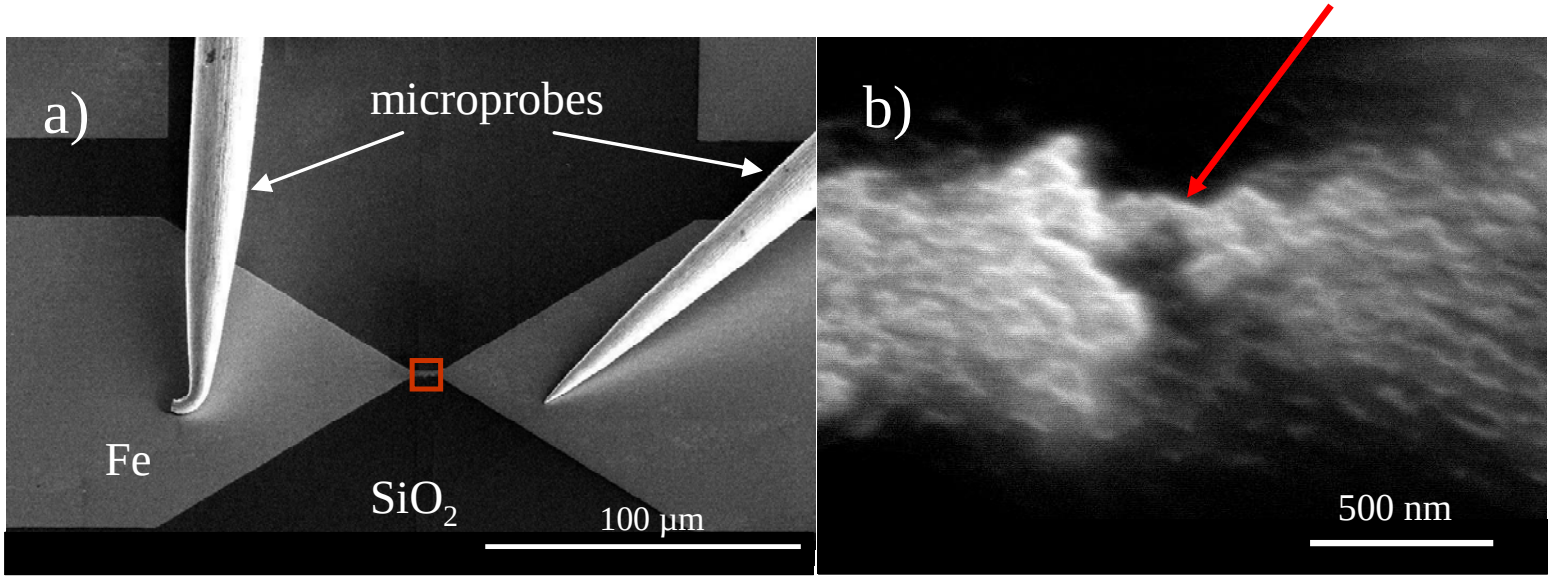
Fe_3O_4/MgO/Fe Heteroepitaxial Structures for Magnetic Tunnel Junctions

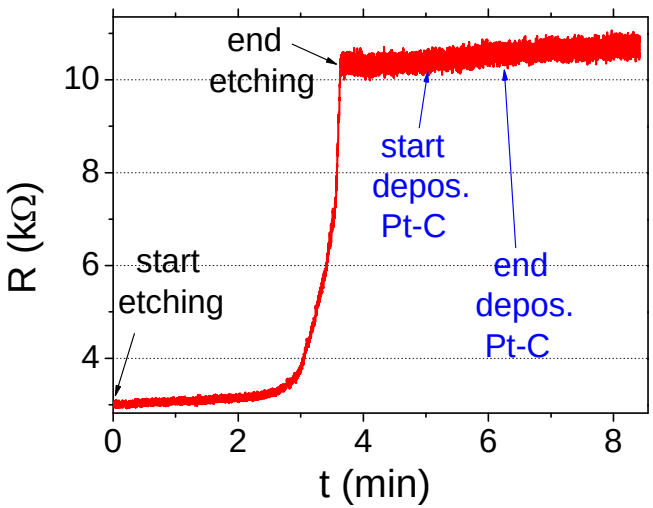
J. Orna[1,2], L. Morellon[1,2], P. A. Algarabel[2], J. A. Pardo[1,3], S. Sangiao[1], C. Magen[1,3], E. Snoeck[4], J. M. De Teresa[2], and M. R. Ibarra[1,2]

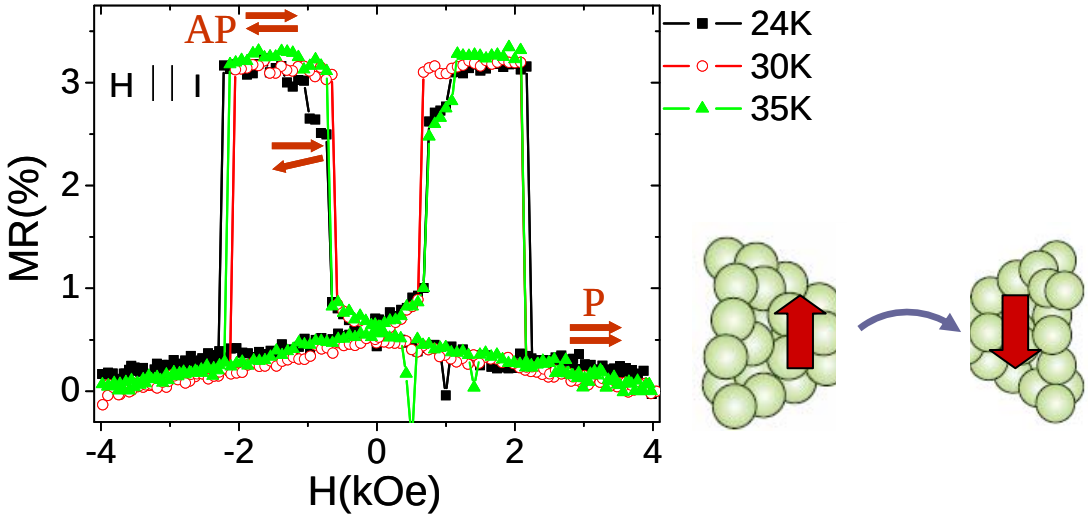




Transport measurements in Fe nanoconstrictions







NANOMATERIALS FOR THE ENERGY

-Polimer Electrolyte Membrane Fuel Cells (PEMFCs)

Two Polymer Families to withstand hight temperatures have been proposed:
Polyetherimides (PEI), polysulfones (PSU)

-Eutectic Ceramic

-Nanoeutectics

- Directionally solidified eutectics for catalysers

- Microtubular Solid Oxide Fuel Cells

-Nanotubes compsites

-Electroactive polymer/carbon nanotube composite materials

-Conducting polymer/carbon nanotube composite materials

-TiO2 nanotube:Hydrogen production & organic contaminants degradation

An Innovative Membrane for PEMFCs:

ZEOCELL PROJECT

(Nanostructured Electrolyte Membranes Based on Polymer/Ionic Liquids/Zeolite Composites For High Temperature PEM Fuel Cell)

INA. University of Zaragoza
(Spain)

ZEOCELL

ZEOCELL

GENERAL PROJECT OBJECTIVE

- **To develop nanostructured electrolyte membranes suitable for operating at 150º-200ºC in high temperature Polimer Electrolyte Membrane Fuel Cells (PEMFCs)**

WHY HIGH TEMPERATURE PEMFCs?

MAIN CHALLENGES

BENEFITS OF T INCREASE	PROBLEMS/SPECIFIC CHALLENGES
• CO tolerance Increase (dirty H_2)	• Electrocatalysts sintering and recrystallization
• Reaction Rate Increase	• Fuel cross-over (Utility decrease)
• Polarization effect Reduction	• Electrolyte performance (dehydration)
• Operating Voltage Increase	• Durability (degradation/corrosion)
• Water management	
• Cogeneration possibilities	

MATERIALS TO BRIDGE THE GAP

ZEOLITES

Advantages

-High chemical and thermal stability
- Low price
- Hydrophilicity (gas humidification is not necessary for proton conduction)
-Well defined nanoporous structures, tailor made porosity and modulable adsorption properties (fuel-cross over)
- Catalytic properties (MEAs)

Disadvantages

-*Relative l*ow ionic conductivity
- *Mechanical properties* (f*ragility*)

IONIC LIQUIDS

Advantages

-Very high ionic conductivity
-Thermal stability
-Zero volatility
- Flexibility

Disadvantages

-Necessity to be confined into a matrix to be used as an electrolyte

POLYMERS

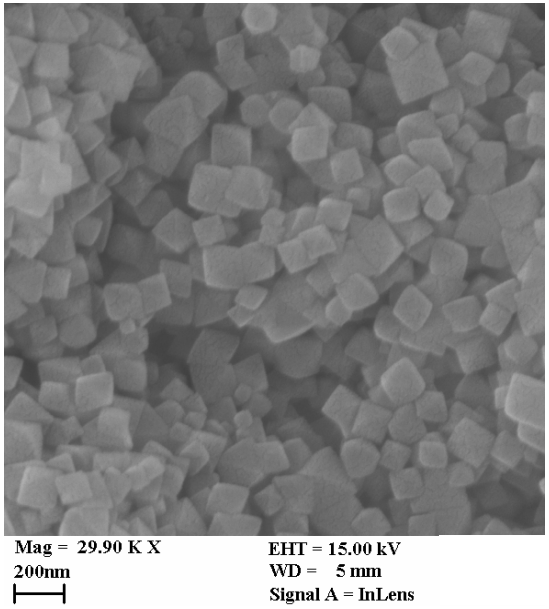
Advantages

- High ionic conductivity
-Elasticity, plasticity (non fragile)
-Procesability

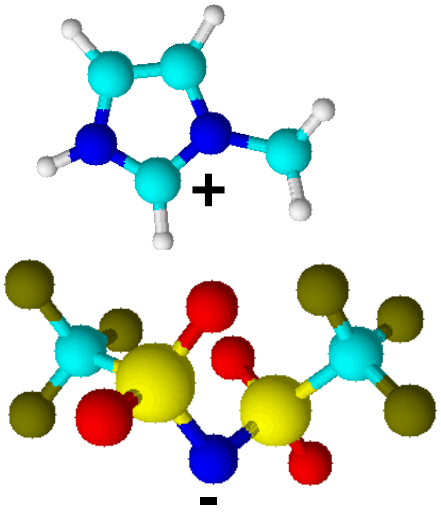
Disadvantages

- High fuel cross over
-Thermal stability

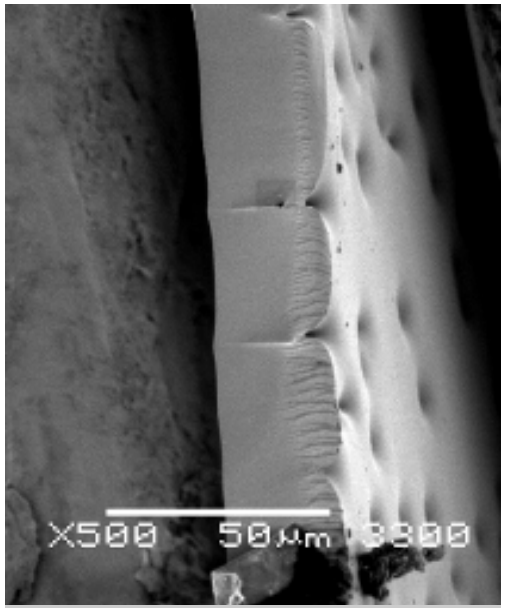
MATERIALS TO BRIDGE THE GAP



ZEOLITES & MICROPOROUS RELATED MATERIALS



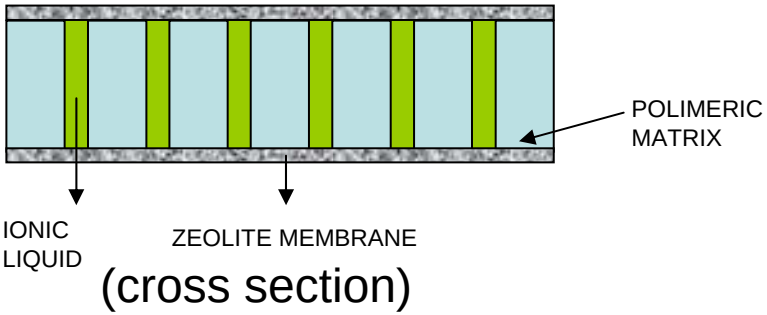
IMIDAZOLIUM/ AMMONIUM BASED IONIC LIQUIDS



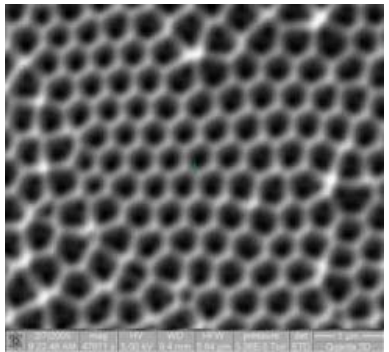
POLYMERS (PEI, PSU, s-PEEK, doped PBI)

2-D NANOSTRUCTURED COMPOSITE MEMBRANES

(ordered or randomly porous membranes)

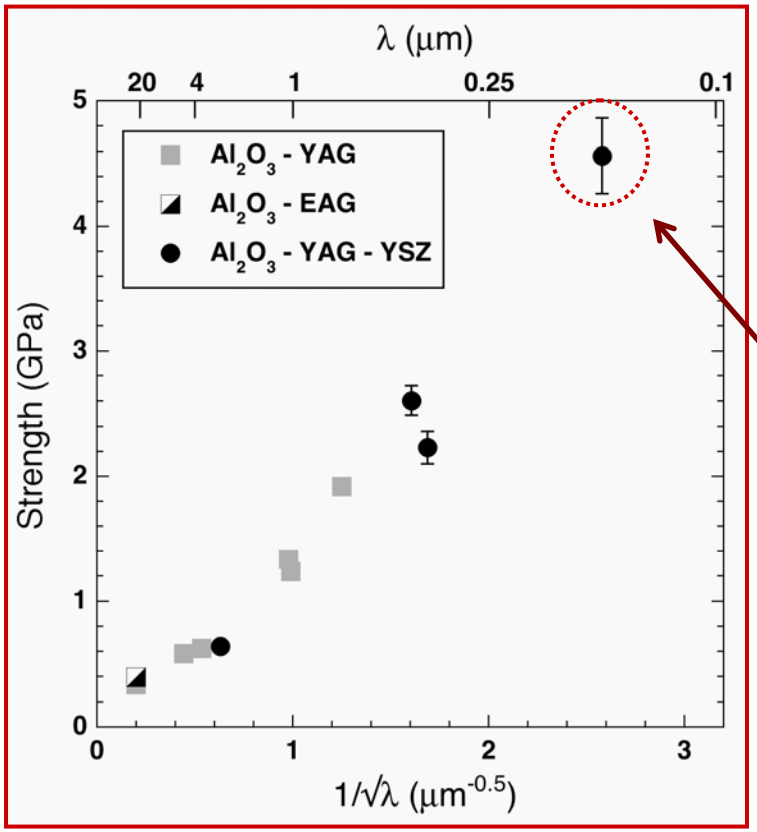


(cross section)



(top view)

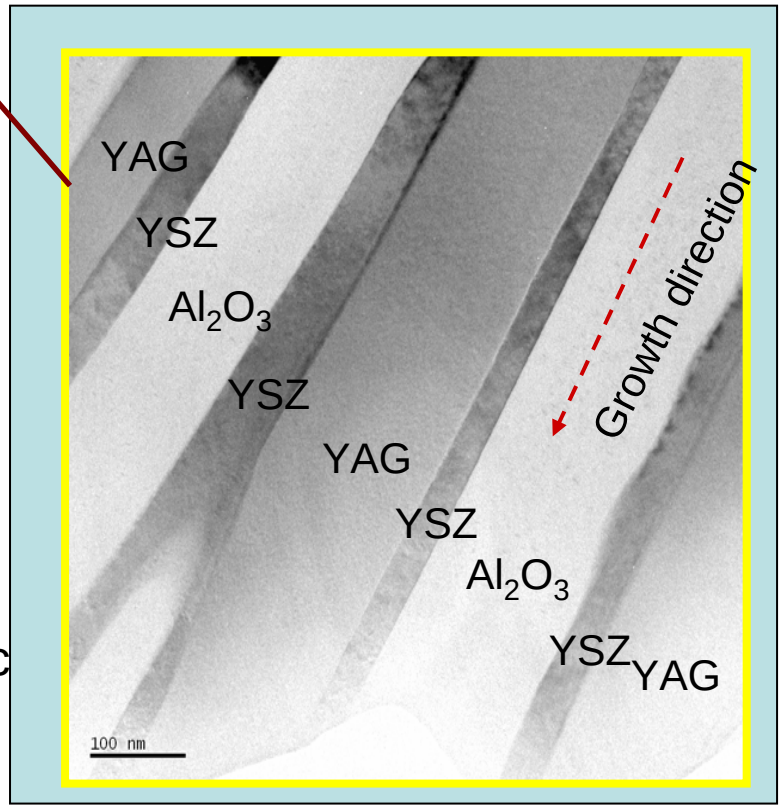
Nanoeutectics



PB Oliete et al. Adv. Mat (2007)

Eutectics are a paradigm for pattern structures of size scales down to submicron and nanometer with clean interfaces.

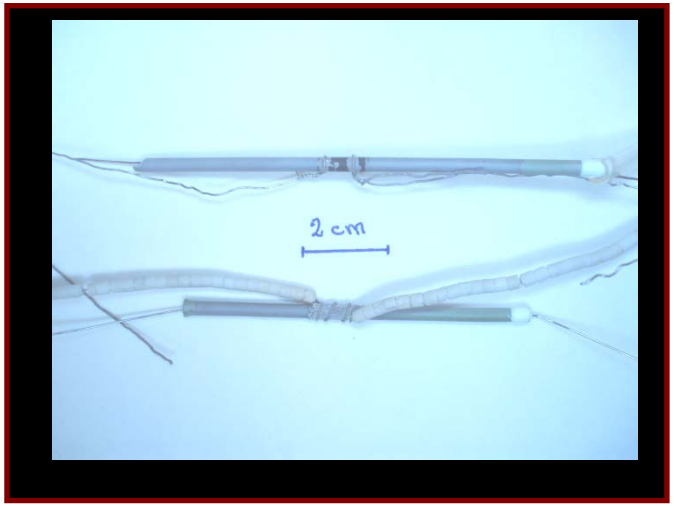
J. Llorca & V.M. Orera, Prog. Mat. Sci. 51(2006) 711-810

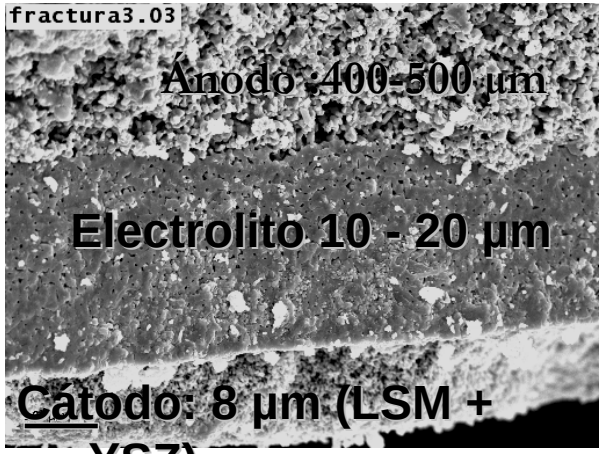


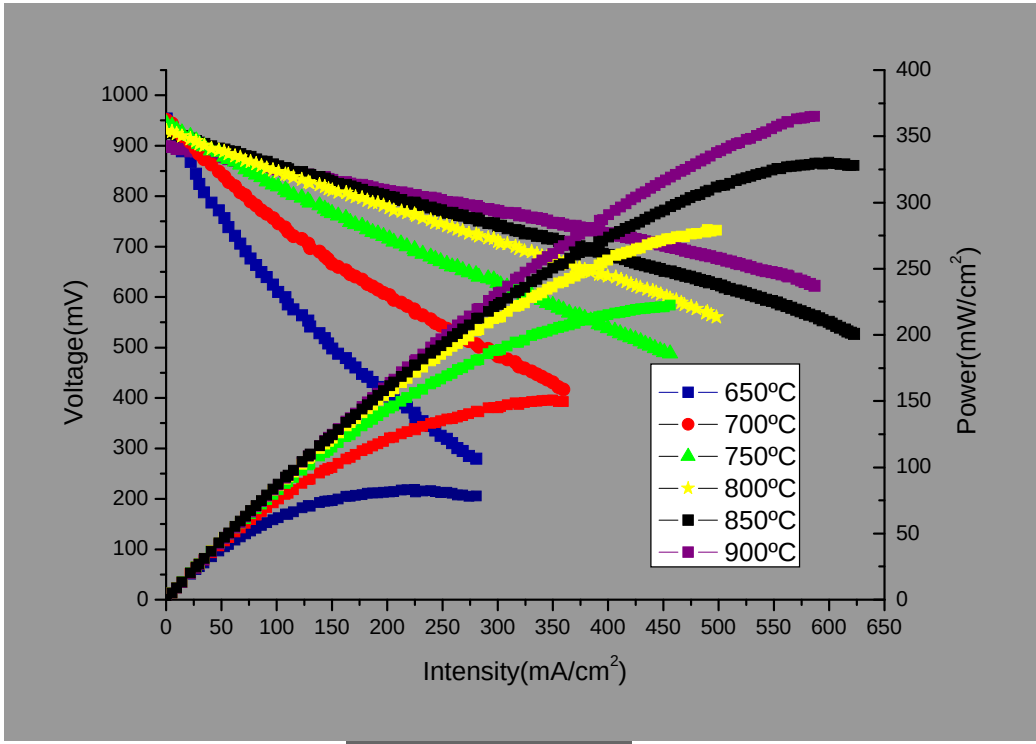
Microstructure of LFZ fabricated Al2O3-YAG-YSZ ternary eutectic

2009

Microtubular SOFC







Fuel: 4% H_2

Channeled Metal-YSZ cermets for Solid Oxide Fuel Cells anodes

Directionally Solidified Eutectics

self-organized lamellar microstructure

&

Strong interphase bonding

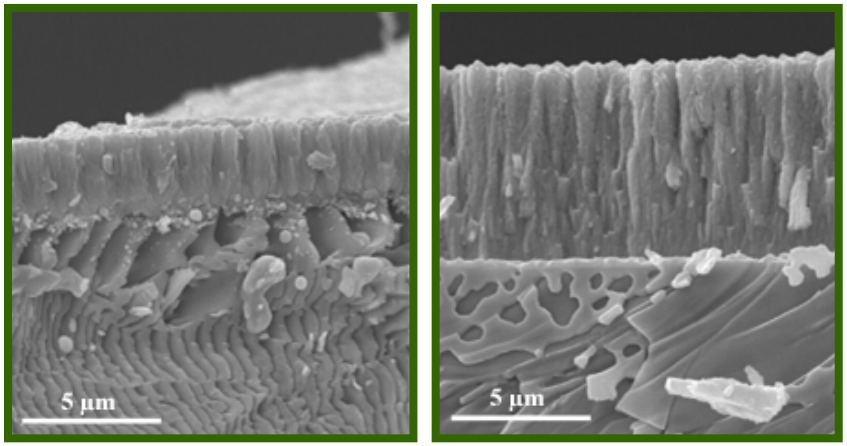
Channeled M-YSZ cermet

Easy gas flow

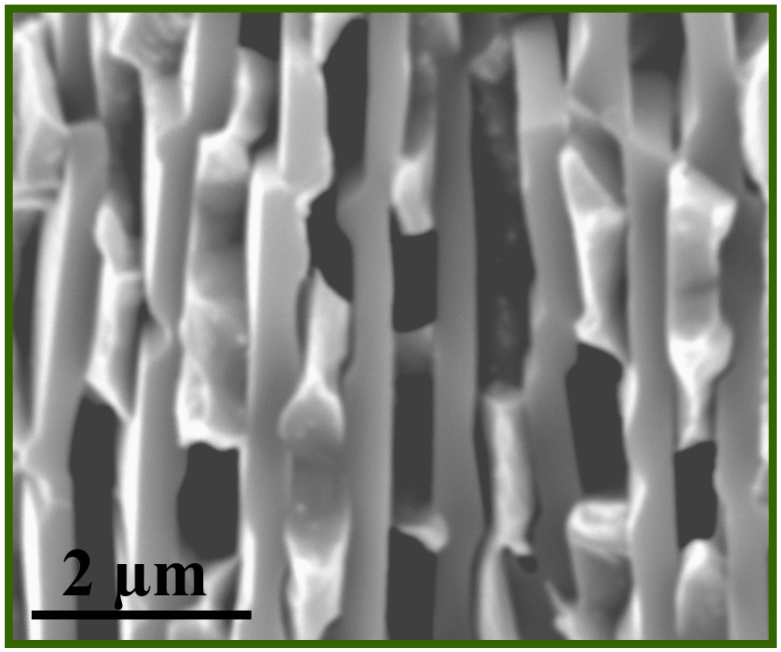
High electronic conductivity

Same CTE as YSZ

Microstructural stability



YSZ electrolyte deposited by CVD on a Ni-YSZ channeled cermet



Fracture of a Ni-YSZ channeled cermet

1 R.I. Merino *et al.*, *J. Eur.. Ceram. Soc.* 2005, 25, 1455-1462.

2 M.A. Laguna-Bercero *et al.*, *J. Eur.. Ceram. Soc.* 2004, 24, 1349-1353.

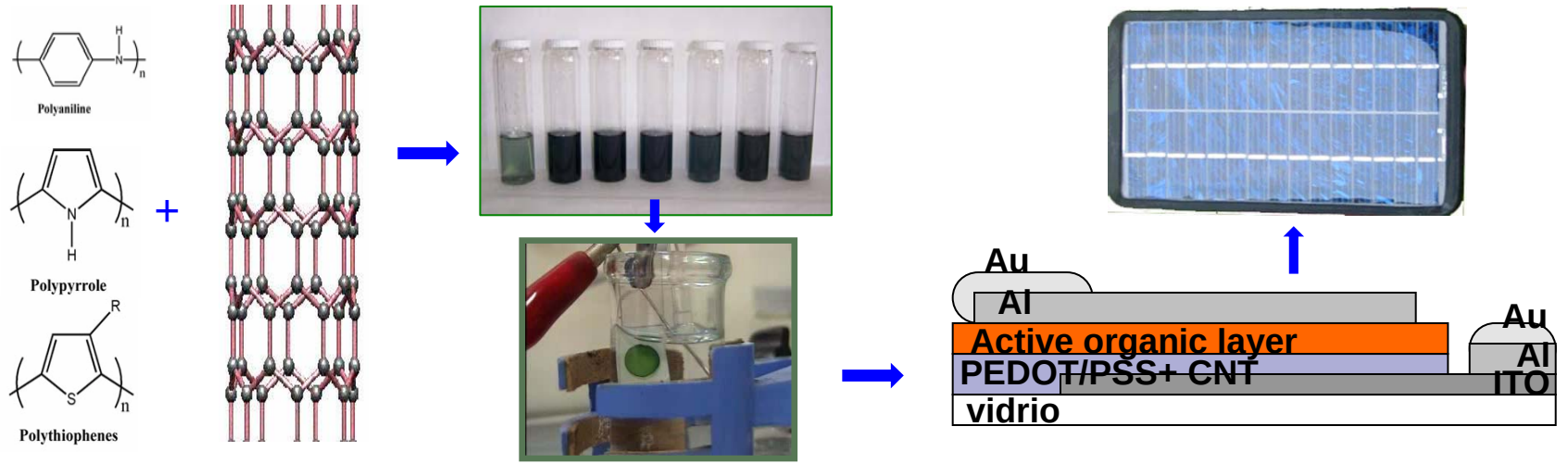
3 G. García *et al.*, *Chem. Vap. Deposition* 2004, 10(4), 242.

Carbon Nanotubes Nanocomposites for Photovoltaics

Development of novel electroactive polymer/nanotube composite materials
- With improved electrical, thermal and mechanical properties
- With improved processing properties

For use as
- Transparent flexible electrodes
- Flexible active layer
- Allowing improved electron-hole separation

TOWARDS
Flexible and efficient Photovoltaic Cells

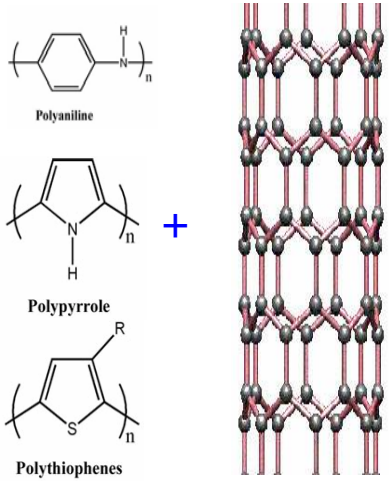


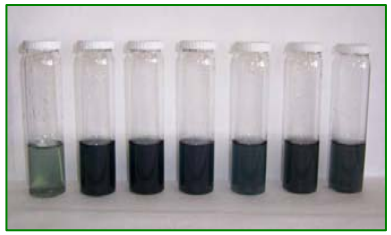
Patent: PCT/ES2009/070021

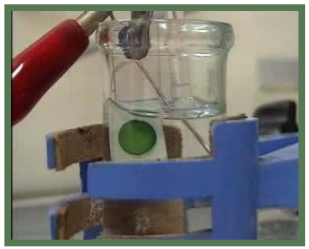
Carbon Nanotubes Nanocomposites for Improved Electochemical Devices

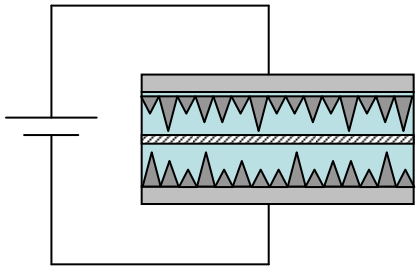
Development of novel conducting polymer/nanotube composite materials
- With improved electrical, thermal and mechanical properties and porosity
- With improved processing properties

For use as
-flexible and highly porous, highly conducting electrodes
In Supercapacitors and Batteries









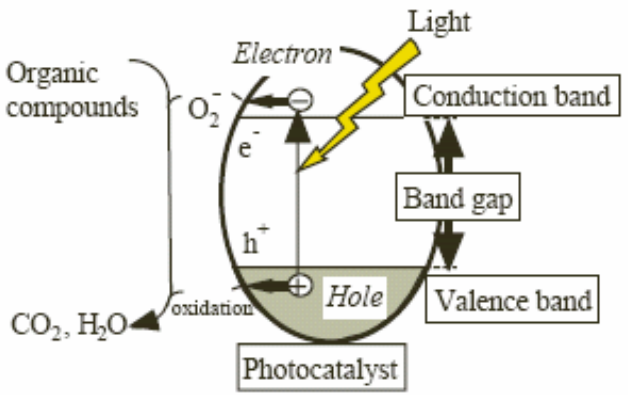
TOWARDS
Flexible and efficient electrochemical devices

Patent: PCT/ES2009/070021

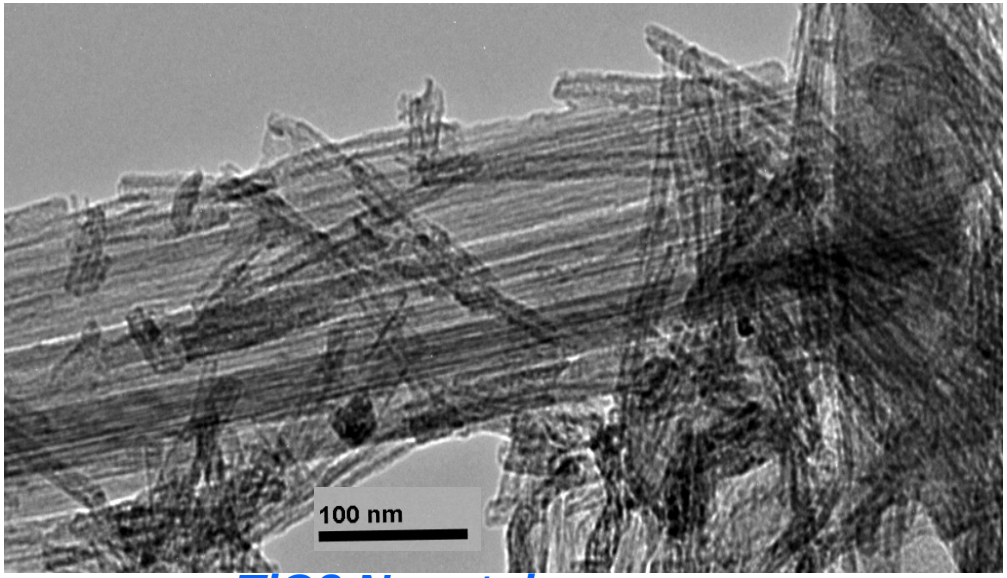
Nano Photoenergy Technology. TiO_2 Nanotubes

Production of TiO2 nanotubes
- Hydrothermal method
- Alumine template

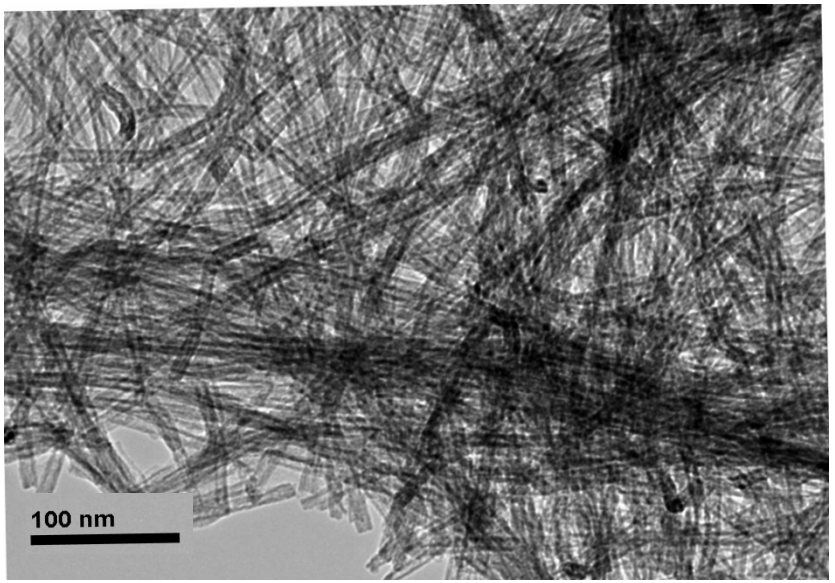
For use :
Hydrogen production
Organic contaminants degradation



Photacatalysis mechanism



TiO2 Nanotubes



TiO2 Nanotubes

Master in Nanotechnology