Nanomaterials Research at Functional Materials Division

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Department of Materials and Nano-Physics

EULA-NETCERMAT Kick-off meeting
Brussels, March, 2013

Functional Materials Division

Electrum Laboratory

Largest Clean Room Facility in Sweden

Comprehensive National Facility

Nano and Microtechnology, STOCKHOLM

FNM Members

FACILITIES

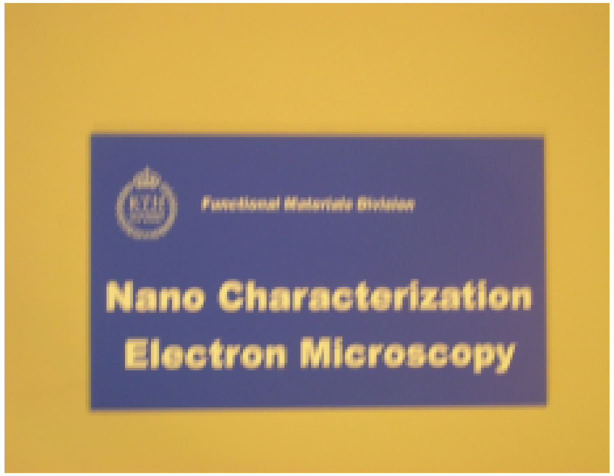
- Modern Chemistry Labs
- Comprehensive Nanoparticles Characterization
- High Resolution Electron Microscopy Facility

Nano Materials Synthesis Laboratory

Nano Materials Characterization Laboratory

Nano Characterization / Electron Microscopy

HRTEM



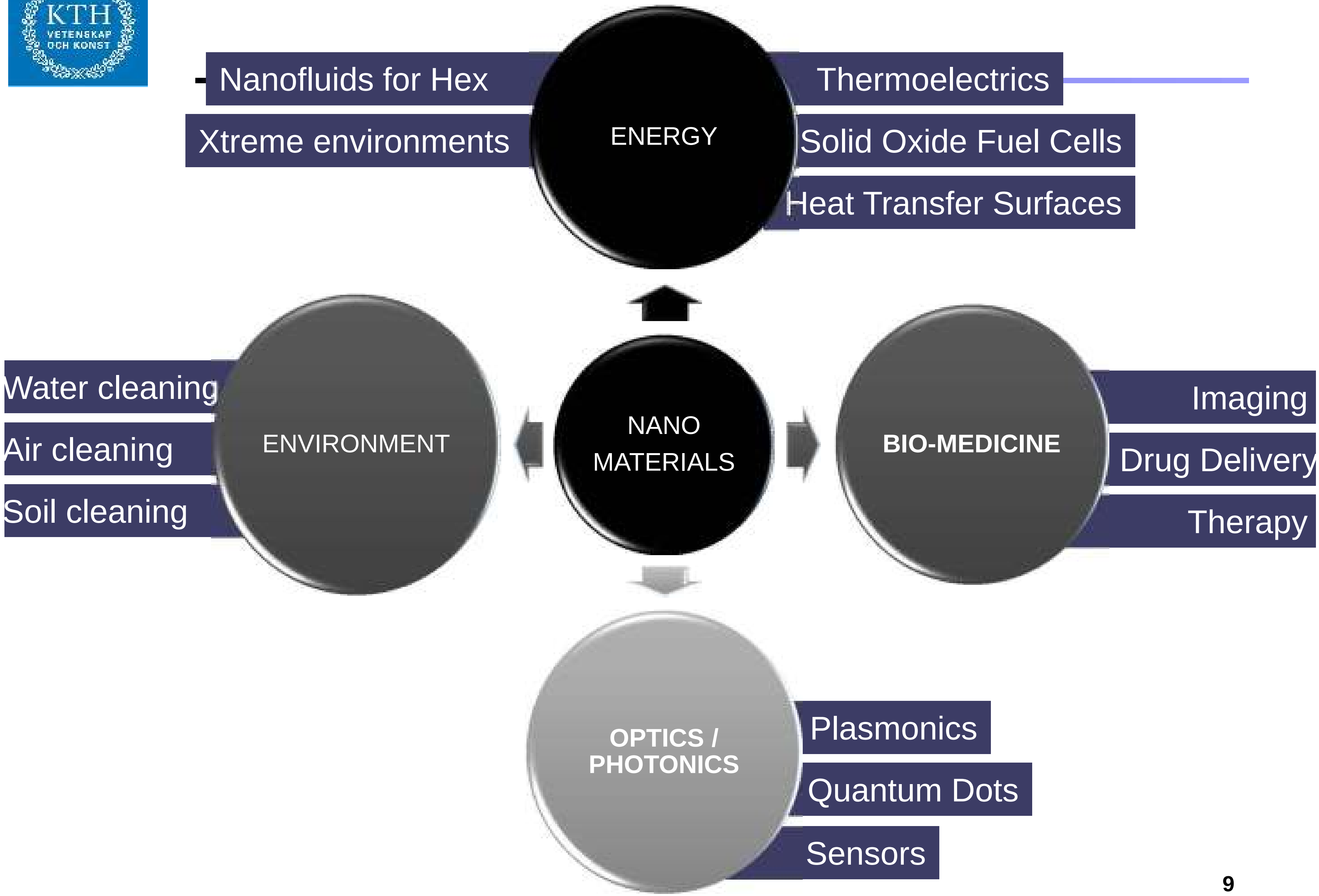
FEG-SEM

FIB/FEG -SEM

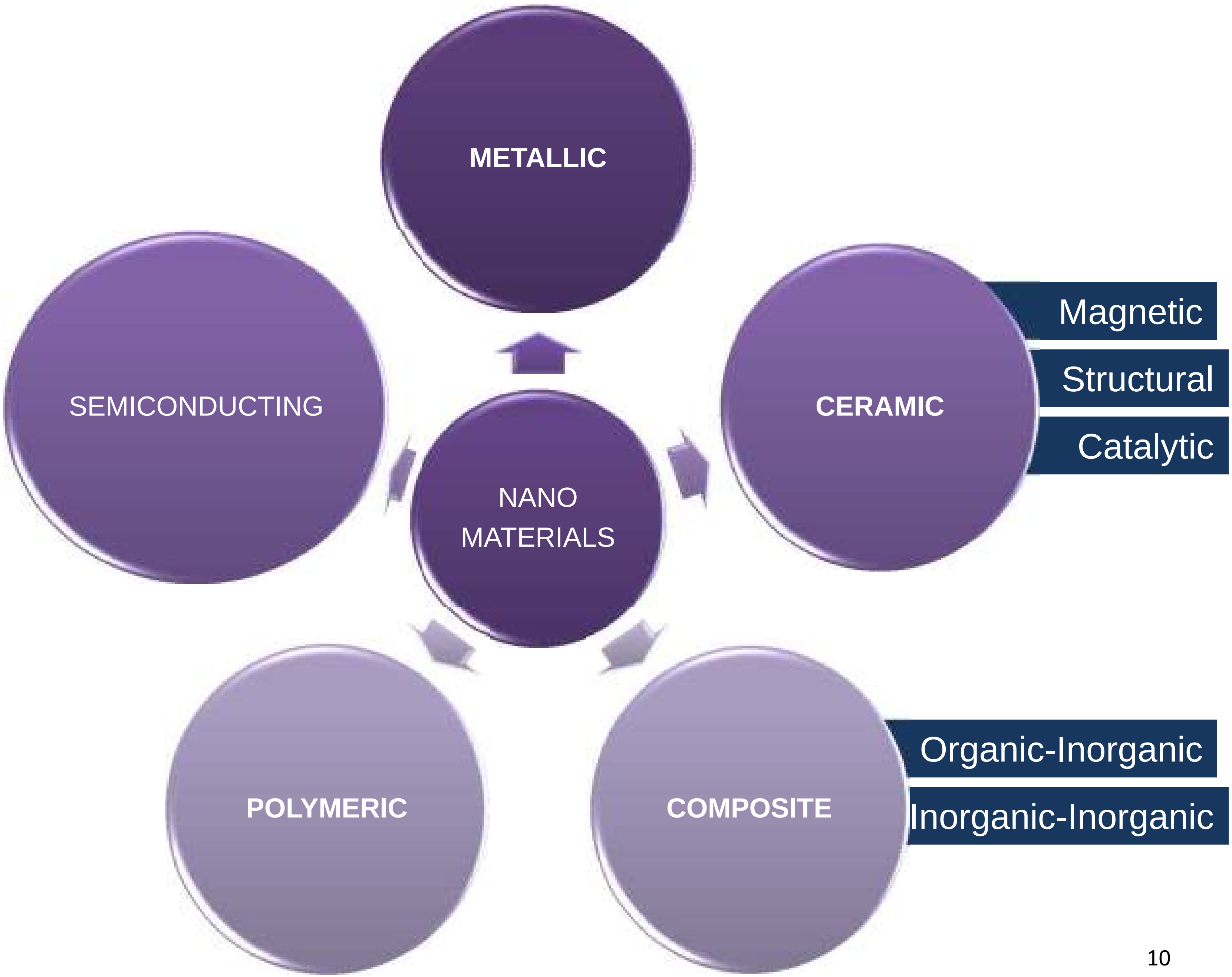
Improved Nano-Materials

Strategies

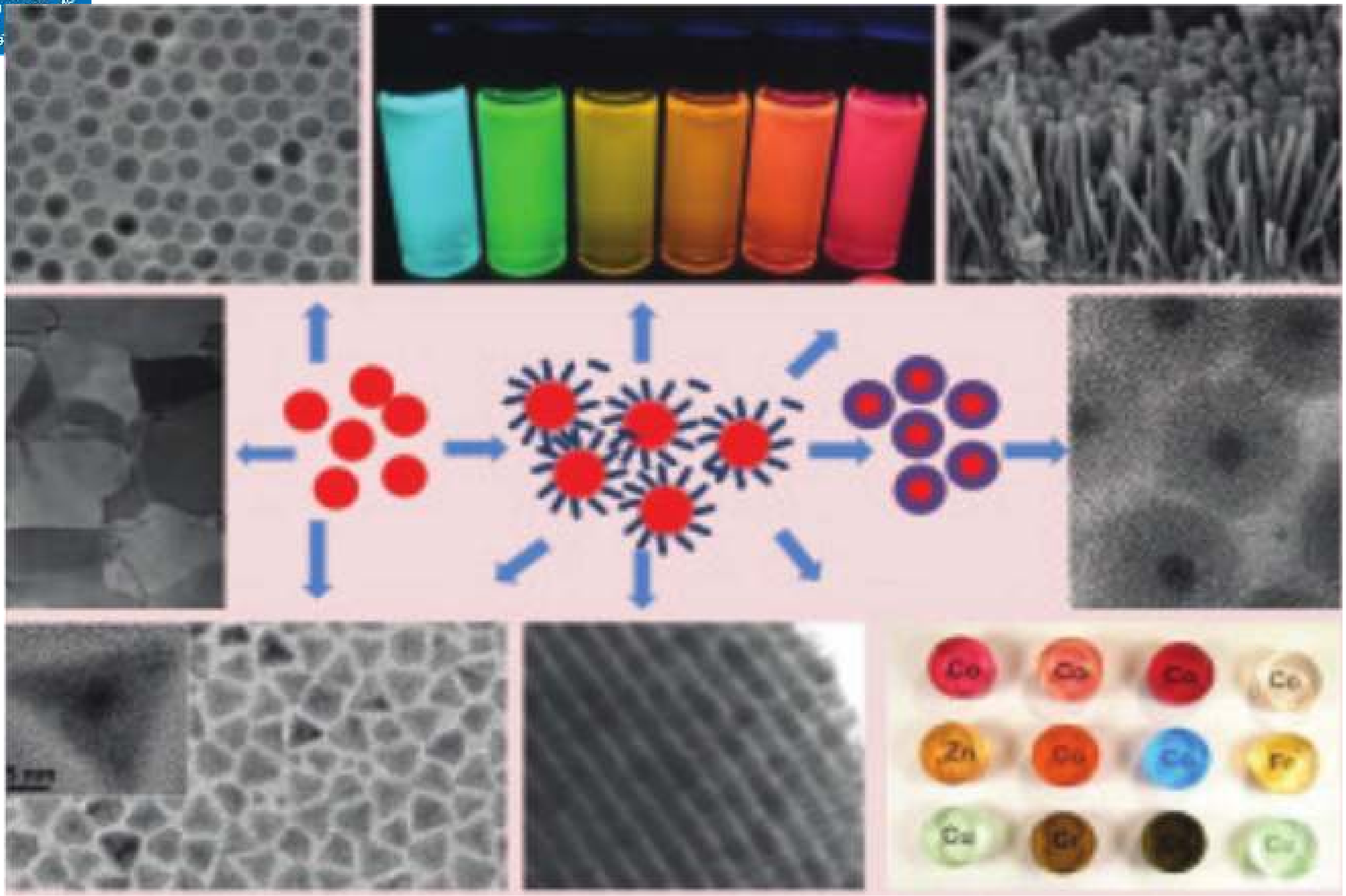
- Nano-structuring
  - Low Dimensionality: 0D, 1D, 2D
  - New Architectures: Mesocrystals, core-shell NCs, anisotropic NCs
- Interphase Engineering
  - Solid-solid
  - Solid-Liquid
  - Solid Gas


ENERGY
Nanofluids for Hex
Xtreme environments
Thermoelectrics
Solid Oxide Fuel Cells
Heat Transfer Surfaces
NANO
MATERIALS
ENVIRONMENT
Water cleaning
Air cleaning
Soil cleaning
BIO-MEDICINE
Imaging
Drug Delivery
Therapy
OPTICS /
PHOTONICS
Plasmonics
Quantum Dots
Sensors

Materials Systems



Types of Engineered Nanomaterials



Customers: **Companies** **SMEs** **Research** **FNM**

Applications:

Instrumentation
Imaging sensors
Global health
Aging societies
Biotechnology aimed at individuals
Personalized Medicine
Image processing
Bio sensors
Foundry services
Green technologies
Smart grids
Devices
Sensors
Tool manufacturing
Intelligent drug packaging
Homeland security
Process developmen

KTH Platforms:

Information and Communication Technology

Medical and Biomedical Technology

Energy ***Transport*** ***Materials***

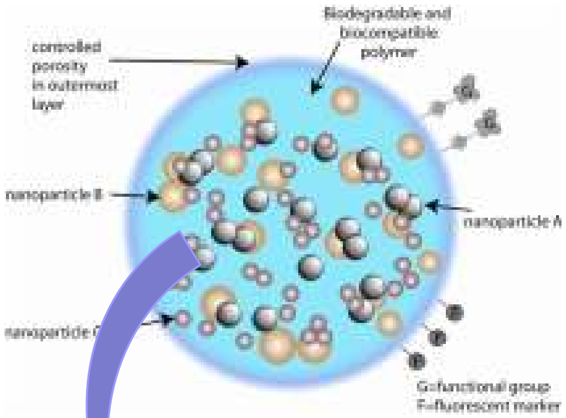
Technologies:

Polymers
SiC
Spintronics
Nanoelectronics
Silicon
Graphene
Collodial solutions
III-V:s
Opto
Mems
Electronics
II-VI:s
C-nanotubes
Microelectronics

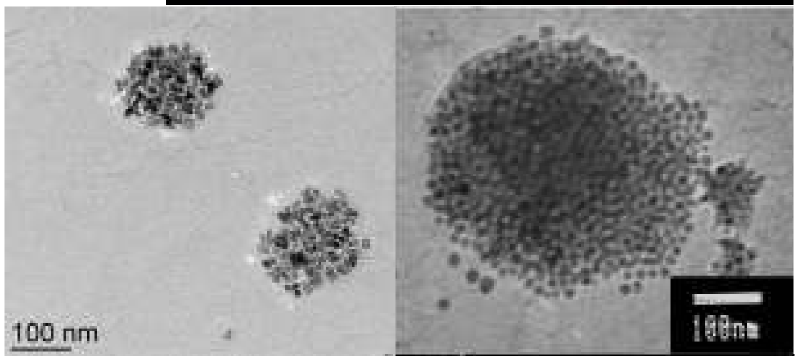
Nano-Bio Projects

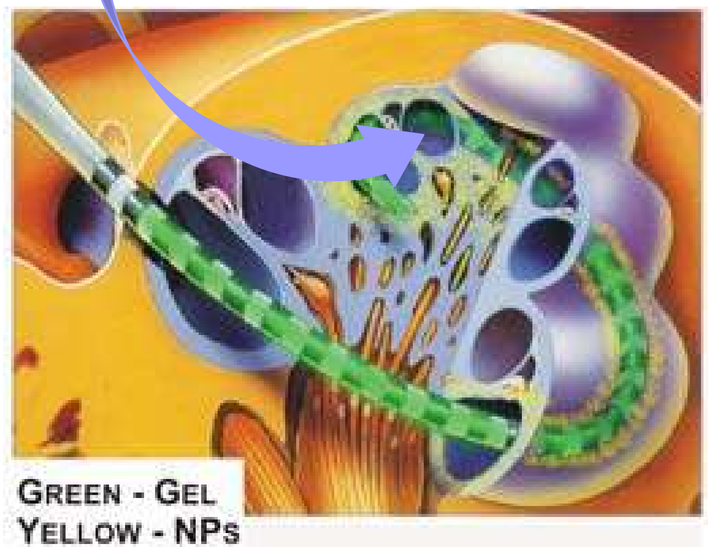
- NANOEAR – FP7
- NANOMMUNE – FP7
- BIODAIGNOSTICS – FP6
- NANO-IMMUNE - SSF

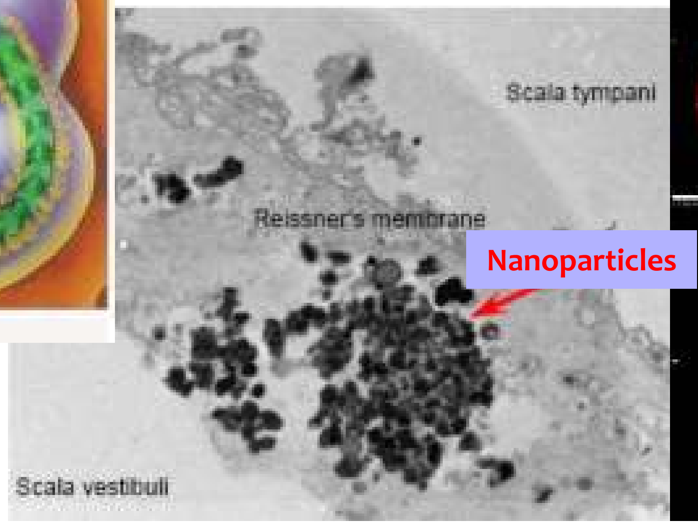
NANOEAR: Multifunctional Smart Nanoparticles for inner ear treatment

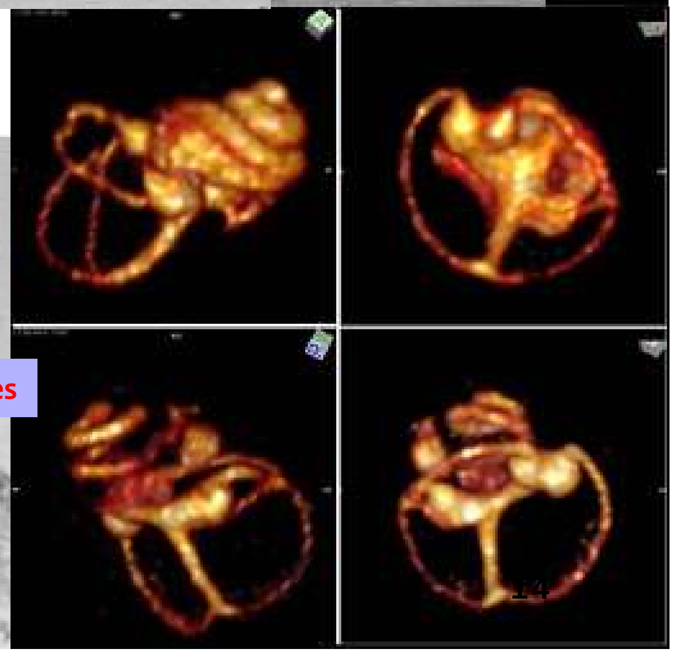


- Drug release
- Fluorescent imaging
- MRI contrast
- Inner ear localization



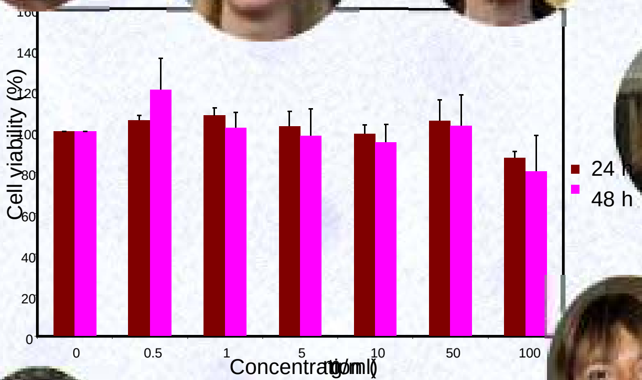






Core – shell nanoparticles for biomedical applications



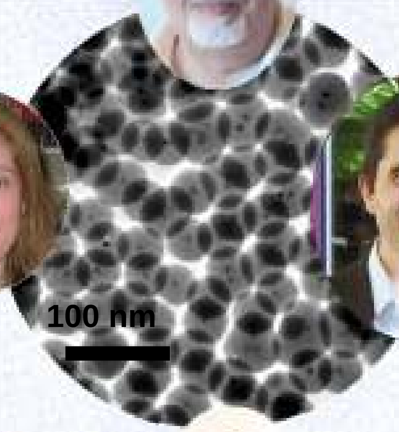



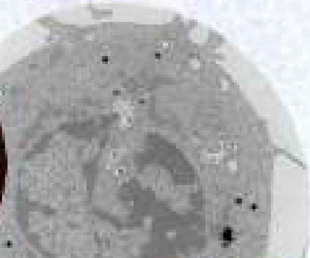


Cellular toxicity studies
KI

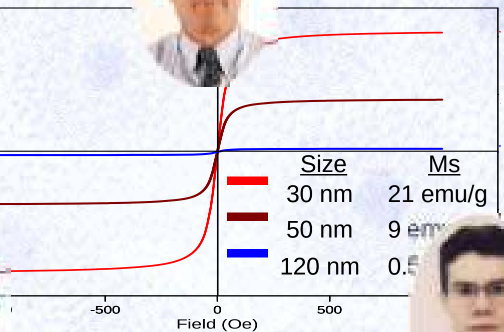
Nanoparticles synthesis

KTH


Cellular uptake studies
EMPA

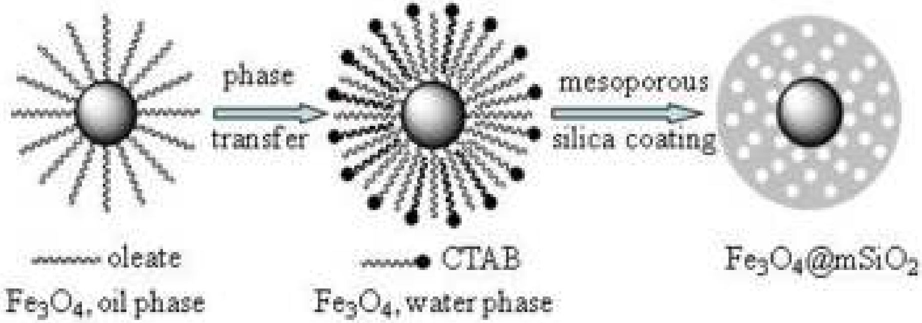


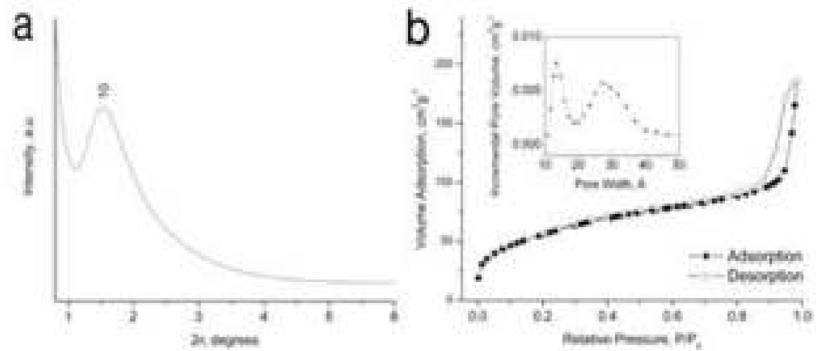

Magnetic characterisation

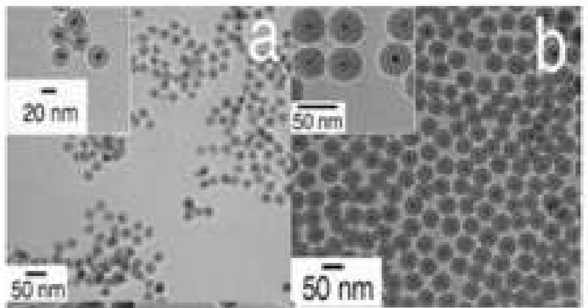
UMH

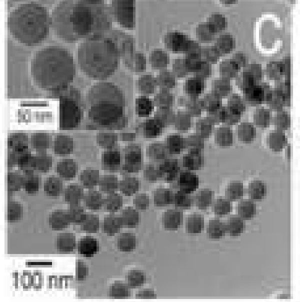
ROYAL INSTITUTE
OF TECHNOLOGY

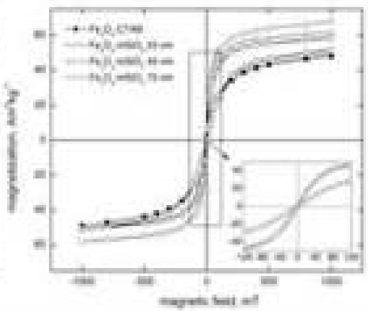
Uniform mesoporous silica coated superparamagnetic iron oxide nanoparticles for T_2-weighted magnetic resonance imaging







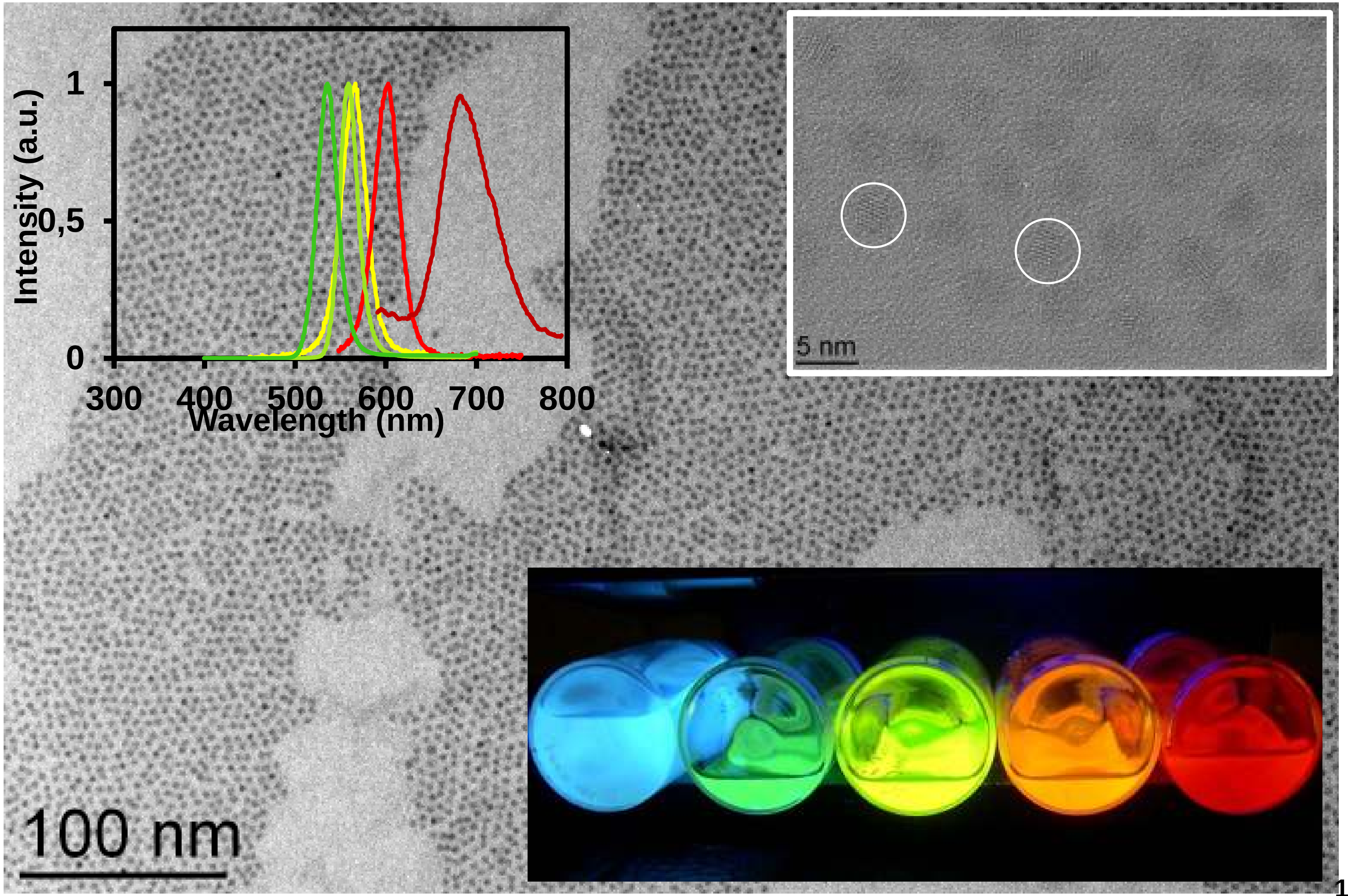




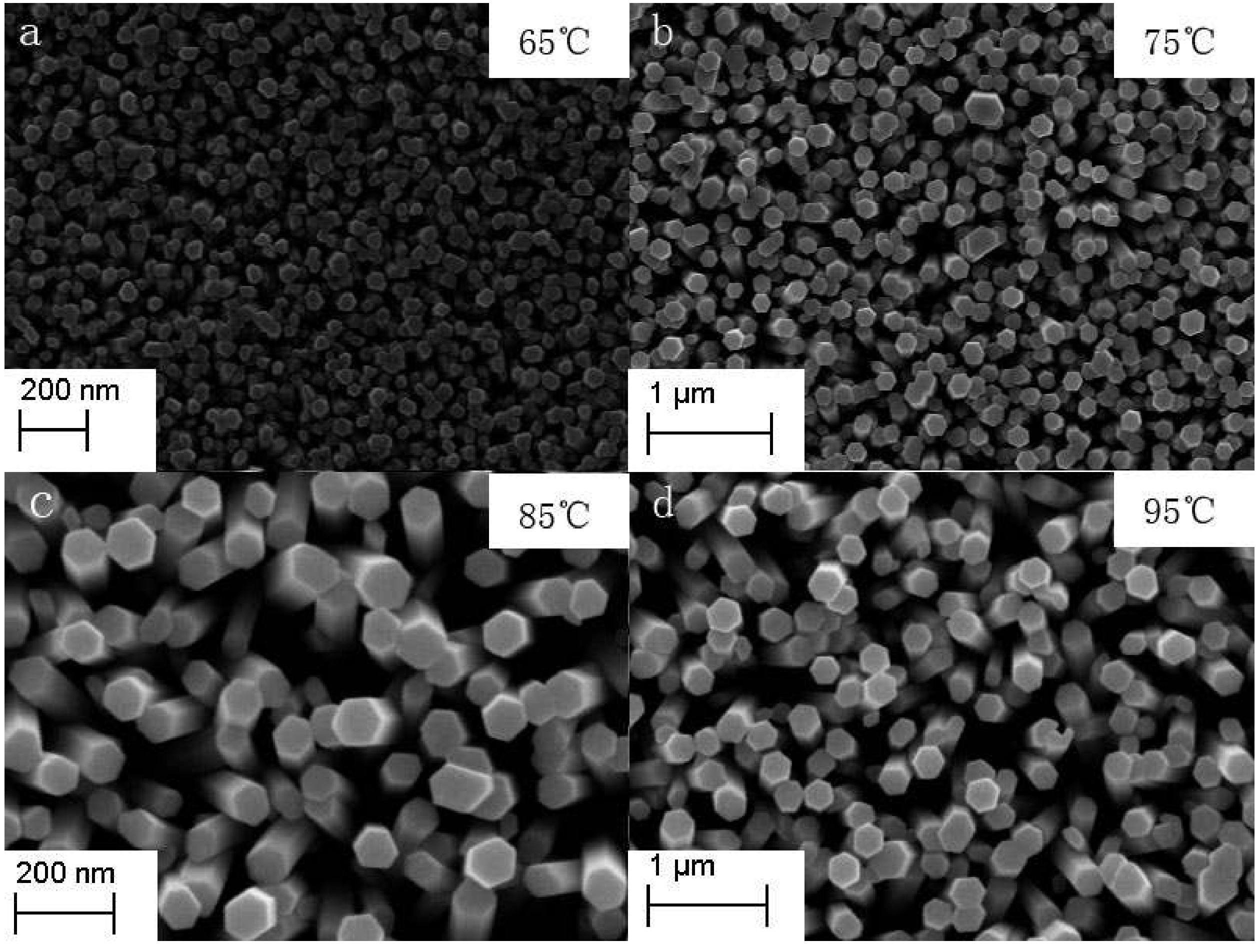
Sample name and surface coating	Mean hydrodynamic diameter [nm]	20 MHz			60 MHz		
		r_1	r_2	r_2/r_1	r_1	r_2	r_2/r_1
		$[s^{-1}mM^{-1}]$	$[s^{-1}mM^{-1}]$		$[s^{-1}mM^{-1}]$	$[s^{-1}mM^{-1}]$	
Fe_3O_4-CTAB	145	11.5	75.2	6.51	4.41	102	23.2
Fe_3O_4@$mSiO_2$_1	96	13.5	113	8.39	5.92	156	26.4
Fe_3O_4@$mSiO_2$_2	72	4.03	164	40.7	1.52	201	133
Fe_3O_4@$mSiO_2$_3	122	0.35	126	360	0.20	123	616
Resovist	65	25	164	6.2	–	–	–
Feridex*	72	40	160	4	–	–	–

Semi-conductor Nano-structures

CdSe Quantum Dots

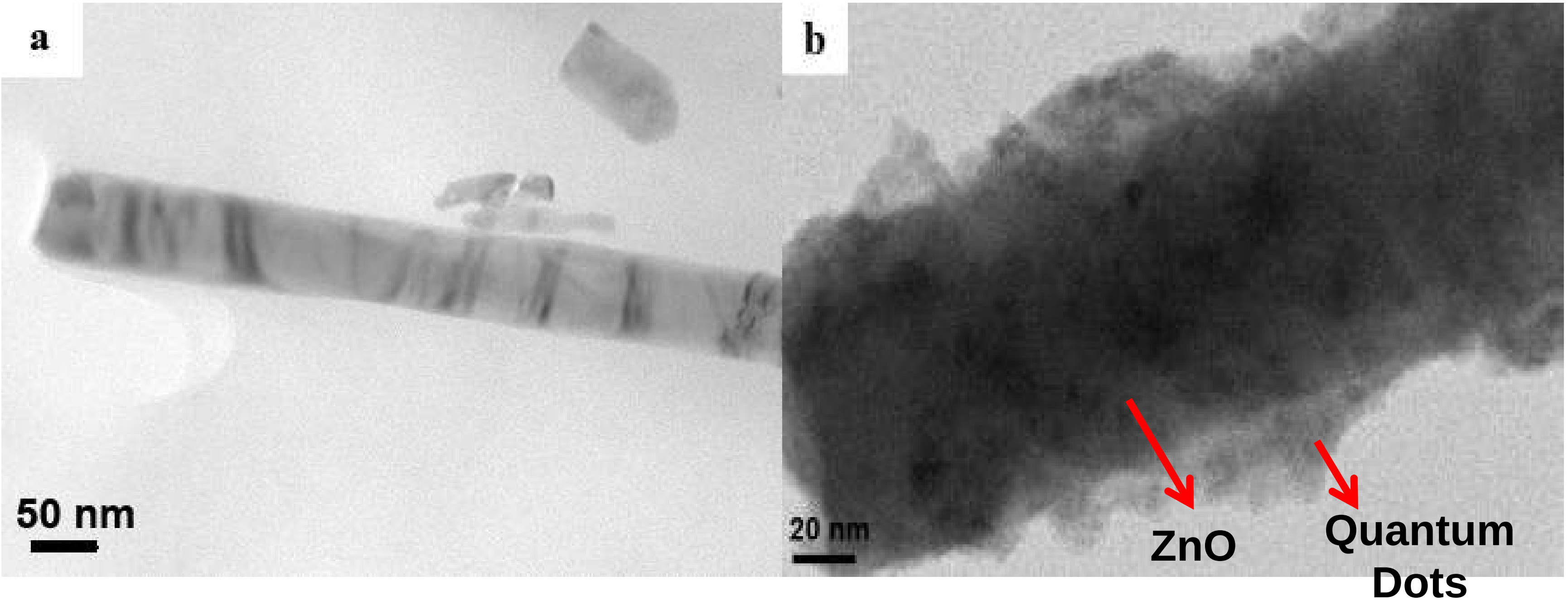


ZnO Nanorods



Optimized growth temperature: 95 ℃

ZnO nanowires with QDs



Coated ZnO nanowires with quantum dots

Nano-Energy

- Thermoelectric Materials
- Solid-Oxide Fuel Cells
- Materials for Harsh Environments
- QD solar cells
- Heat Transfer Surfaces
- Nano-fluids for Heat Exchange/transfer

Nano-Energy

- Thermoelectric (TE) Materials
  - Local cooling/heating via TEs
  - Waste heat recovery
- Nanofluids
  - Enhanced Heat transfer
  - Lubrication
- Solar Cells
  - Colloidal QDs
  - Flexible solar cells (conducting polymers + QDs)

NEXTEC

Next Generation Nano-engineered **Thermoelectric** Converters - from concept to industrial validation

European Framework 7 Programme

– NMP-2010-1.2-3Thermoelectric energy converters based on nanotechnology

€4million, 3 year long project

11 European Partners

NanoHex

Enhanced **Nano**fluid **H**eat **Ex**change

European Framework 7 Programme

– NMP-2008 NanoSciencies, NanoTechnologies, Materials and New Production Technologies.

€8.34million, 3 year long project

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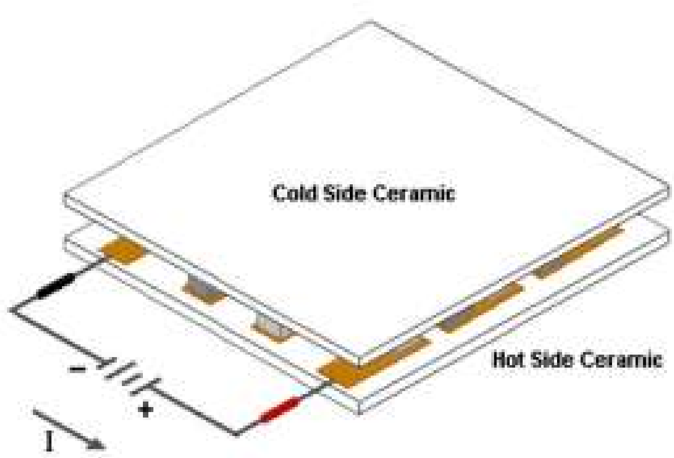
Thermoelectric Generation

Heat ⟲ **Electrical energy**

Seebeck Effect | Peltier effect cooler / heater



Materials with high electrical but low thermal conductivity needed!

Improved performance via nanostructuring:

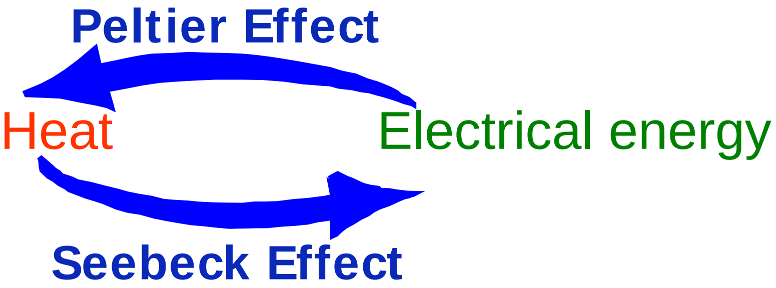
- Favourable carrier scattering mechanism
- Much lower thermal conductivity

$$ZT = \frac{S^2 \sigma}{\kappa} T$$

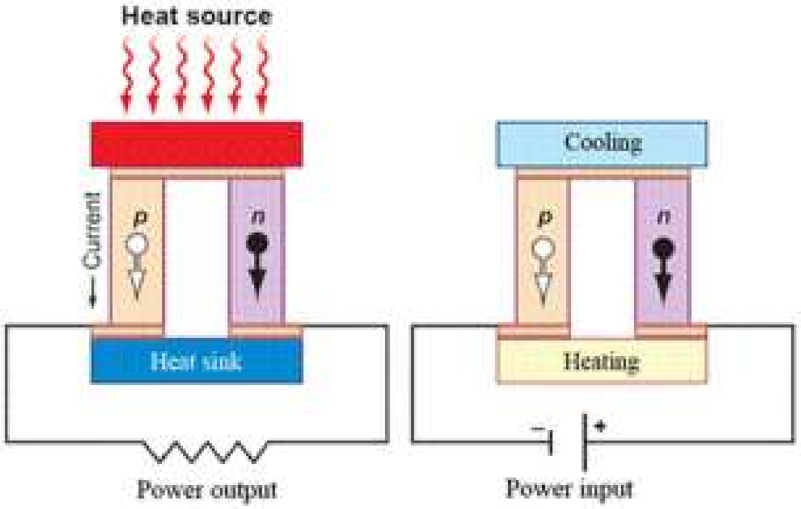
S Seebeck Coefficient,
σ electrical conductivity
κ thermal conductivity

Thermoelectric Materials

Thermoelectric (TE) phenomenon



TE device



Power generation Cooling

TE application

Advantages:

- Solid-state
- Zero-emission
- Long lifetime
- Vast scalability
- No maintenance
- Miniaturization

Low energy conversion efficiency!!!

FP7 Project

NEXTEC

Next Generation Nano-engineered Thermoelectric Converters - from concept to industrial validation

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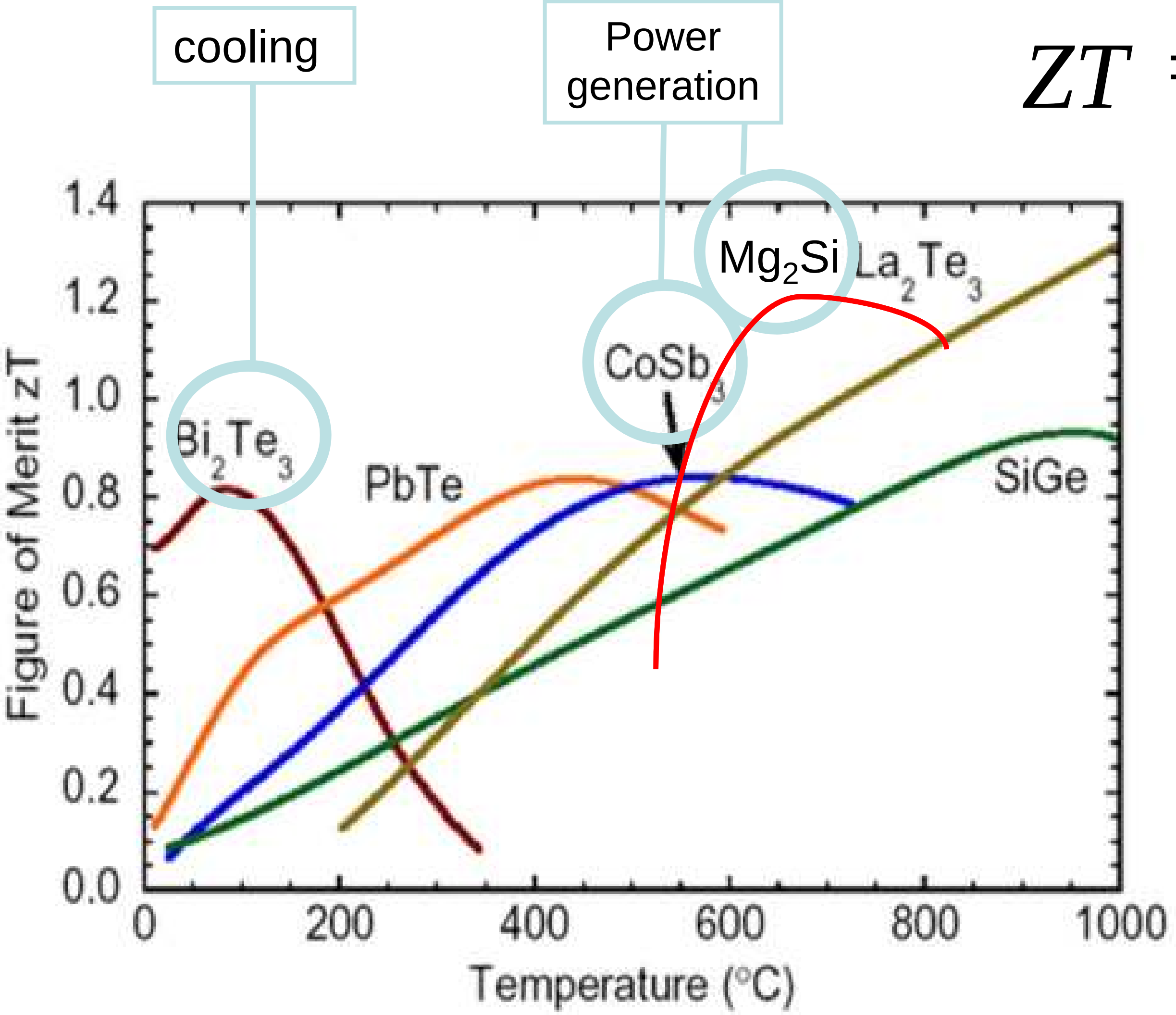
€6.3 MEuro (4 Meuro EC), 3 year long project

11 European Partners

Selection of TE Systems

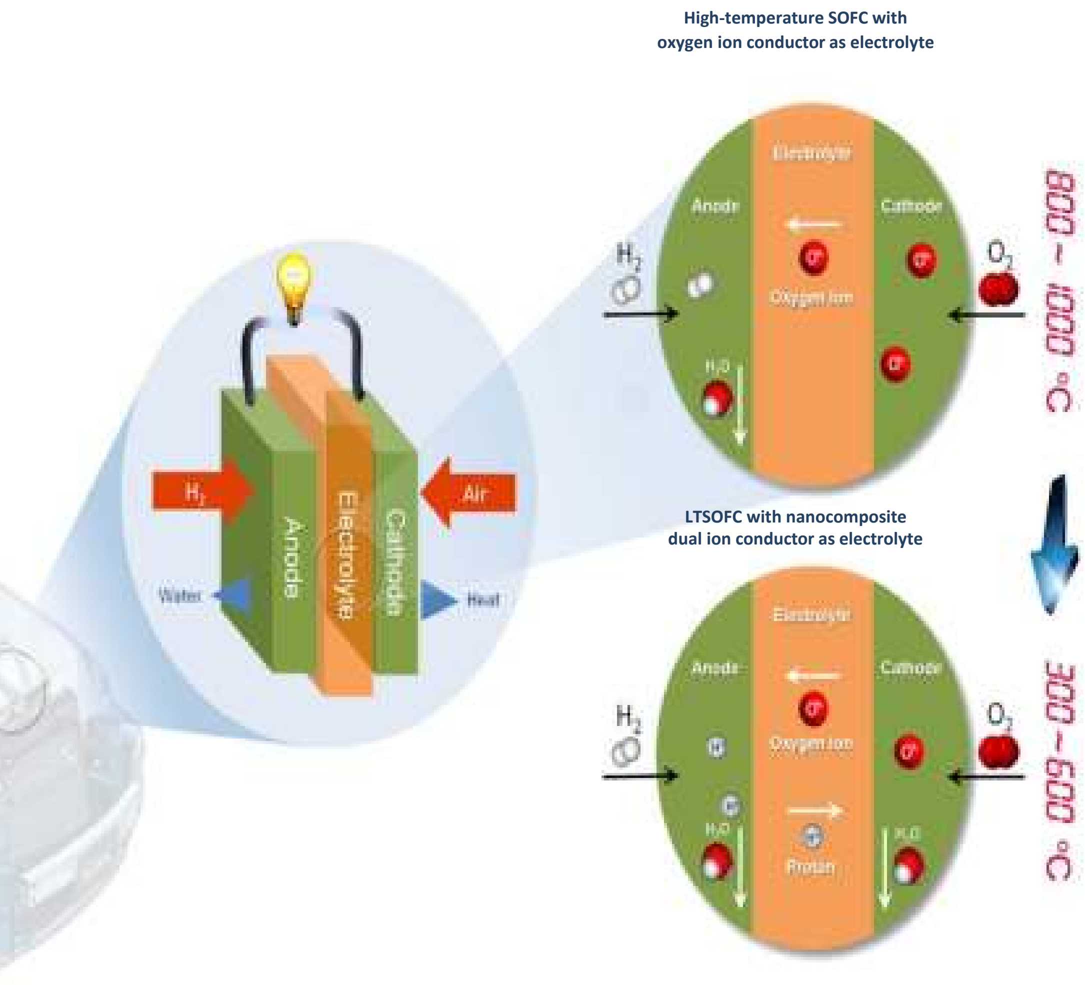
$$ZT = \frac{S^2\sigma}{k}T$$



L.D.Hicks and M.S. Dresselhuas et.al., Phy. Rev., Vol. B47,12727, (1993)

Nano-materials and Nano-technology for Innovative Solid Oxide Fuel Cells

Solid oxide fuel cells (SOFCs) are considered as promising power-generation technologies. However, the current SOFCs cannot be accepted for commercialization due to high operation temperature (800-1000 °C). Therefore, the development of low-temperature SOFCs (LTSOFCs, 300-600 °C) is now a world tendency. The discovery of new electrolytes materials for LTSOFCs is a grand challenge for the SOFC community.



Wang, X. and Y. Ma, et al. (2011). Journal of Power Sources 196 (5): 2754-2758.
Ma, Y. and X. Wang, et al. (2010). International Journal of Hydrogen Energy 35 (7): 2580-2585.


Mamoun Muhammed

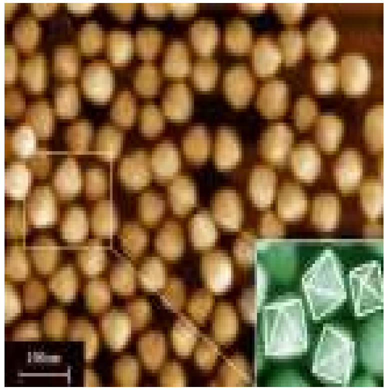

Xiaodi Wang


Ying Ma

Nano-materials and Nano-technology for Innovative Solid Oxide Fuel Cells

Nano Composite Strategy

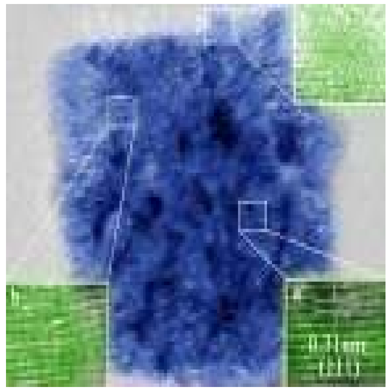
In this project , we are aiming at developing a novel nanocomposite approach to design and fabricate electrolyte materials for LTSOFC. The nanocomposite strategy combines advantages of nanotech-nology and composite approach, which will not only improve electrolyte performance but also contribute to the study of conduction mechanism.



Ceria mesocrystals with octahedron structure

Samarium-doped Ceria Nanowires

CeO_2 Nanoparticles with flower morphology



CeO_2 nano mesocrystals

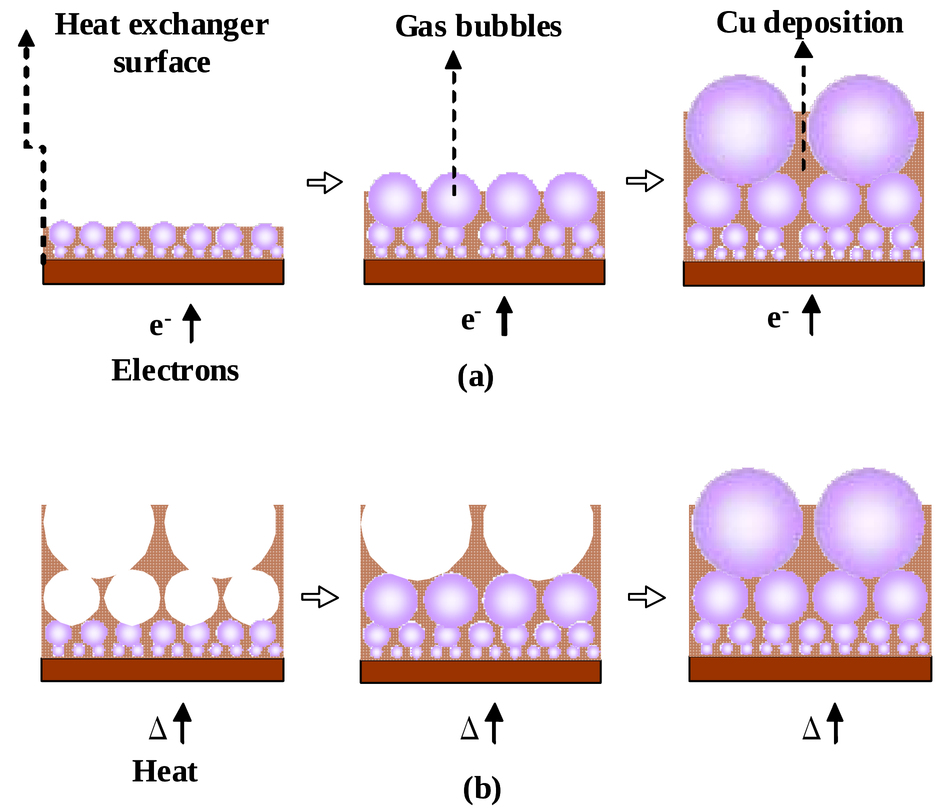
Ma, Y. and X. Wang, et al. (2010). Advanced Materials 22 (14): 1640-1644.
Wang, X. and Y. Ma, et al. (2008). Electrochemistry Communications 10 (10): 1617-1620.

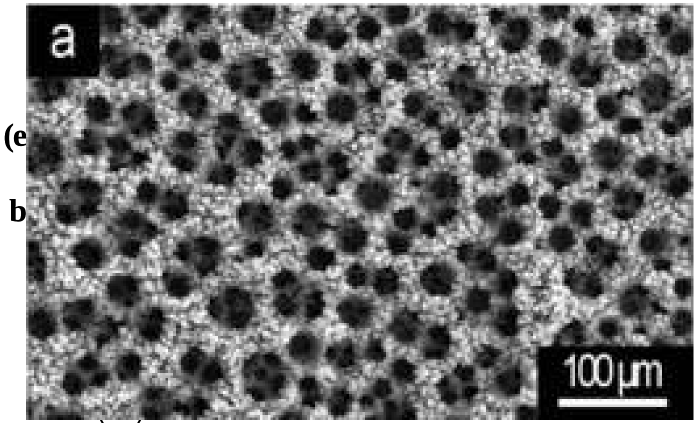
Mamoun Muhammed

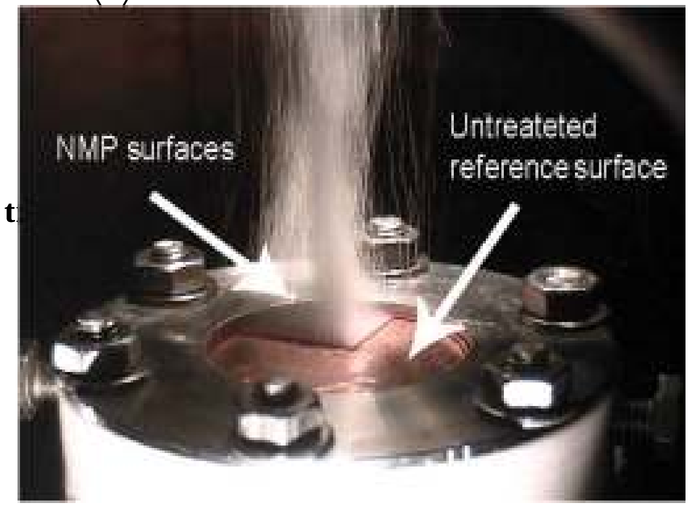
Xiaodi Wang

Ying Ma

Heat Transfer Surfaces







1700% HTC enhancement

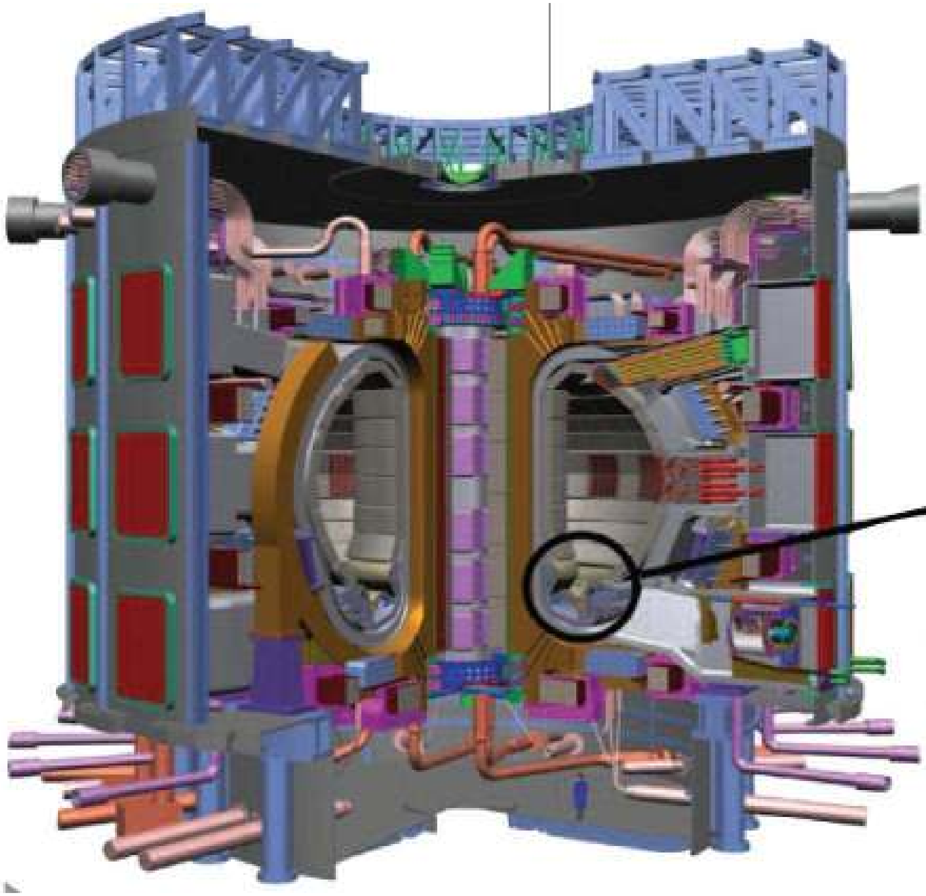
~20% device enhancement

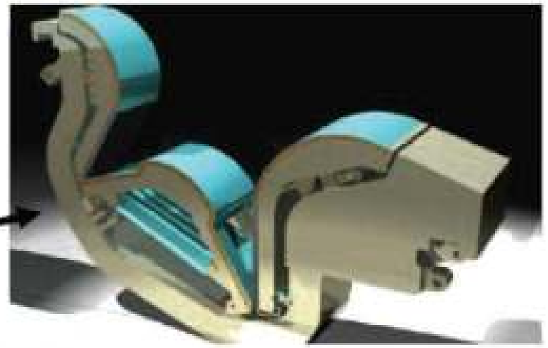
S. Li et al., *Adv. Func. Mater.* In press, Article No. adfm.200701405

Furberg, R. et al., *Proceedings of 13th International Heat Transfer Conference 2006*, NAN-07

W-based Materials for Energy

Fusion Energy





Schematic view of the International Thermonuclear Experimental Reactor (ITER); 100 t of tungsten will be used for the construction; the ITER divertor (black circle) is made up of 54 remotely-removable cassettes, each holding three plasma-facing components (the inner and outer vertical target and the dome) . The choice of the surface material is a crucial one as there are few materials to withstand temperatures up to 3000°C. (Courtesy of iter org.).

Courtesy of International Thermonuclear Experimental Reactor (www.iter.org)

The Project

NanoHex

Enhanced **Nano**fluid **H**eat **Ex**change

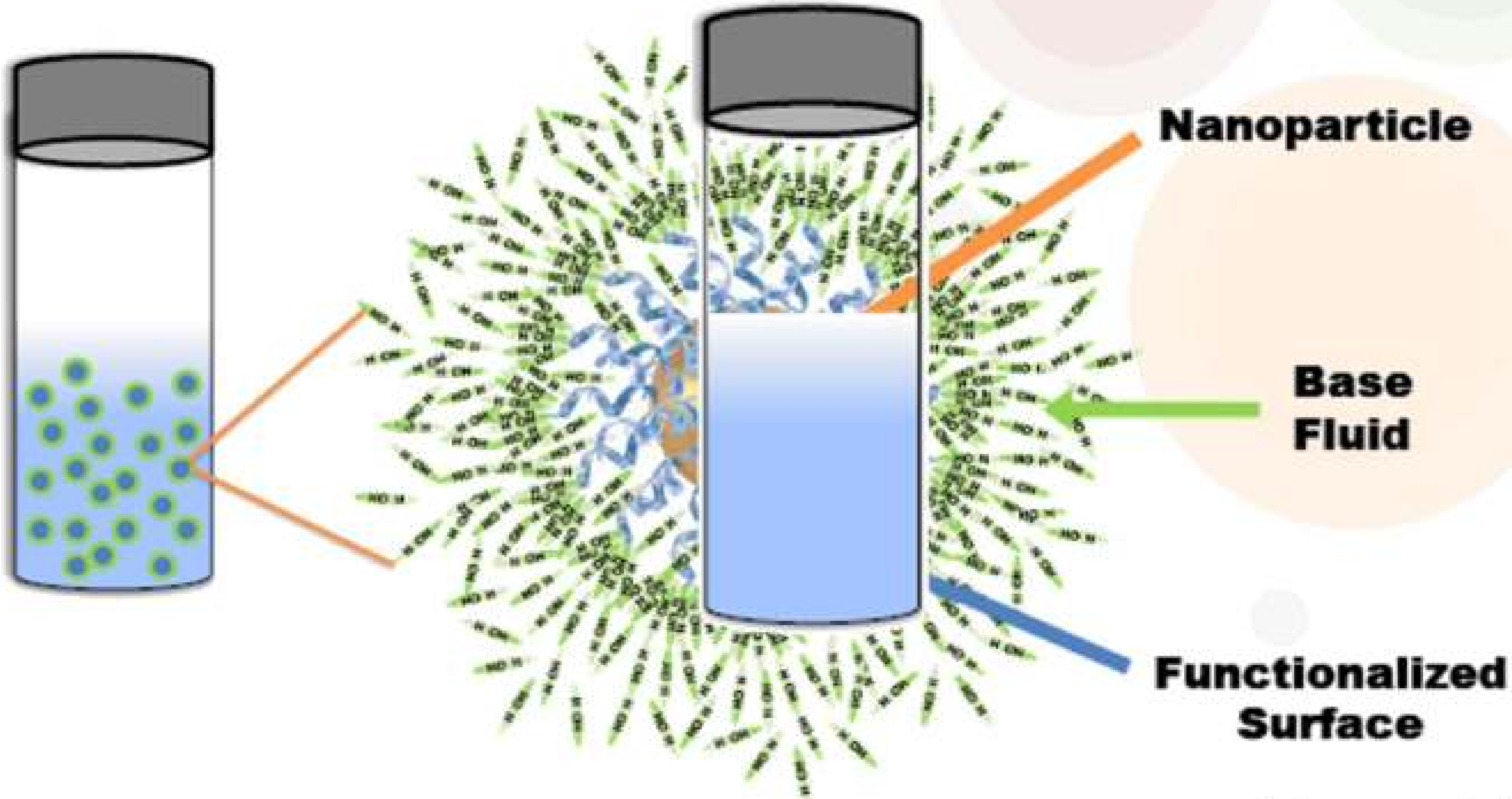
European Framework 7 Programme

– NMP-2008 NanoSciencies, NanoTechnologies, Materials and New Production Technologies.

€8.34million, 3 year long project

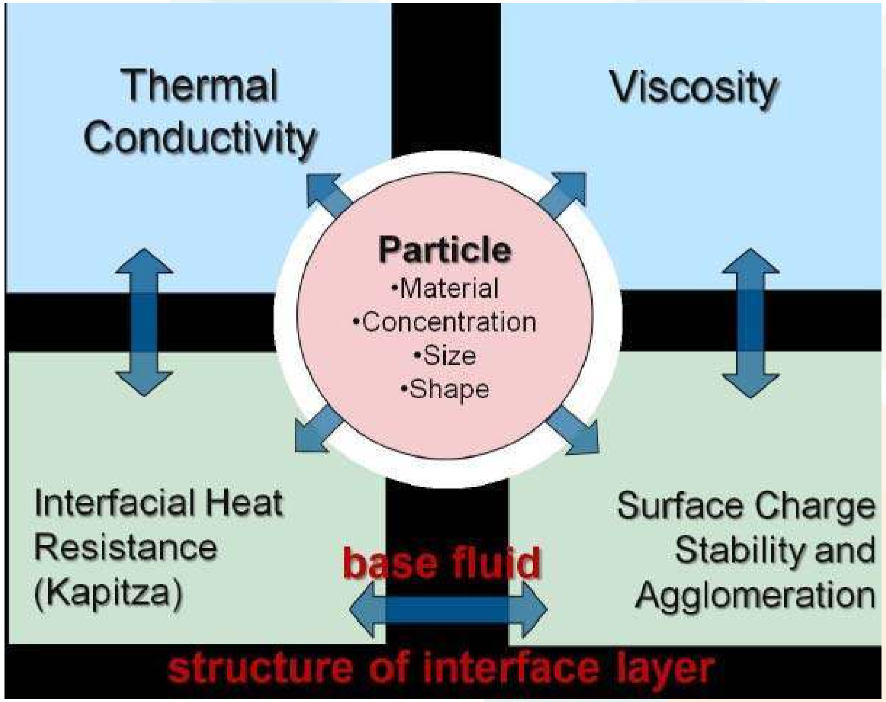
12 European Partners

Nanofluids



NanoHex
Enhanced Nano-Fluid Heat Exchange

What influences thermal performance?



Timofeeva et al. Nanoscale Research Letters 2011, 6:182

Attributes of the nanoparticles	**Attributes of the base fluid**	**Impact of the surfactants**	**Quality of the Dispersion**	**Manufacturing Process**	**Operating Conditions**

NanoHex
Enhanced Nano-Fluid Heat Exchange

Properties of nanofluids

Base fluid (C_P, TC)

Dispersion Process

Interfacial heat resistance

Viscosity

Impurities?

Stability

NPs

- Size (& distribution)
- Concentration
- Shape (AR)
- TC
- Density
- C_p
- Particle Type

Flow

- Laminar
- Turbulent

Additives

- Yes/No?
- Type?
- Amount?

Pumping Power?

NanoHex

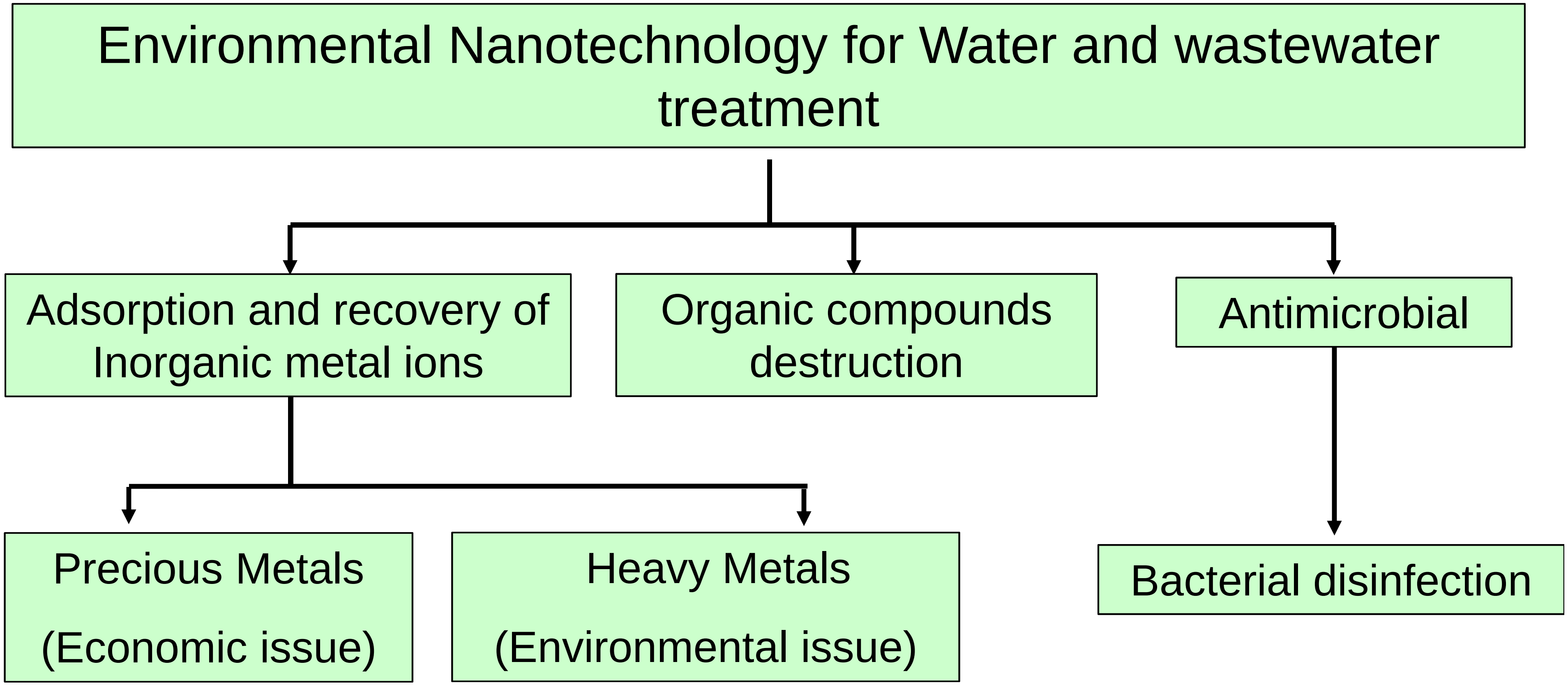
Enhanced Nano-Fluid Heat Exchange

Nano - Environment

Projects

1. SOWAEUMED
2. EULA-NETCERMAT
3. SUDSOE

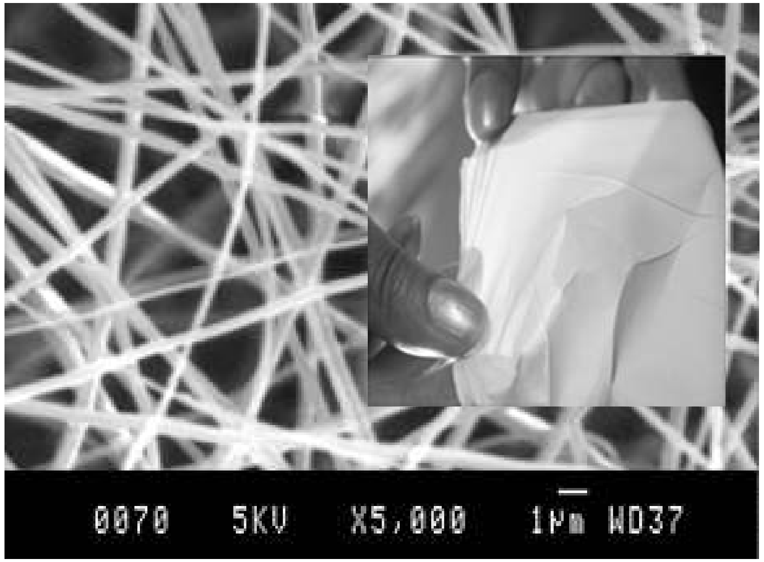
Nano - Environment

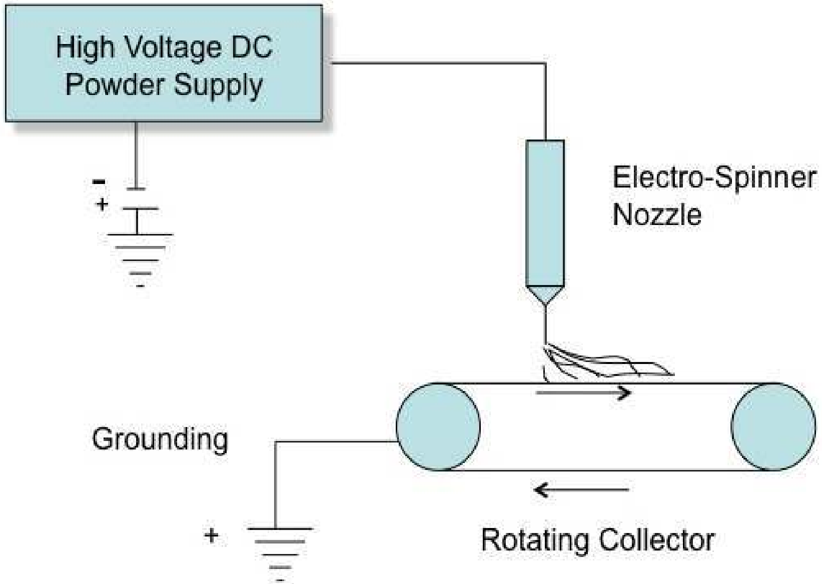


Jet initiation and extension

Bending instability and further elongation

Solidification of the jet into fibers





Electrospinning process

characteristics of Electrospun Nanofibers

- ❑ High porosity (permeability)
- ❑ large surface area to volume or weight ratio
- ❑flexibility in surface functionalities
- ❑superior mechanical performance

Potential Applications of Nanofibers

Defence & security
Chemical & biological protection
senseors

Environmental engineering & biotechnology
Membranes & filters

Applications

Healthcare
Tissue engineering & tissue repair

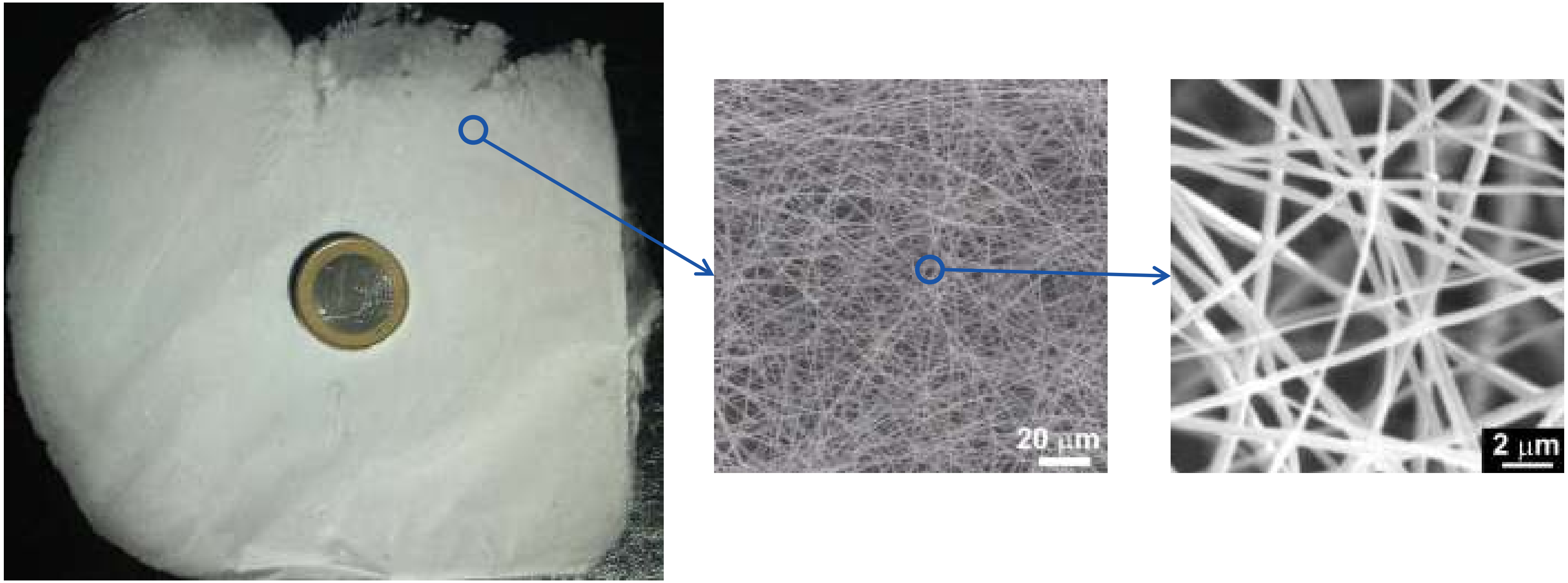
Energy
Solar cell & fuel cells

Photocatalysis - ZnO nanostructures

novel concepts

To obtain highly compact, yet high surface area structures… Similar to Nature's solution

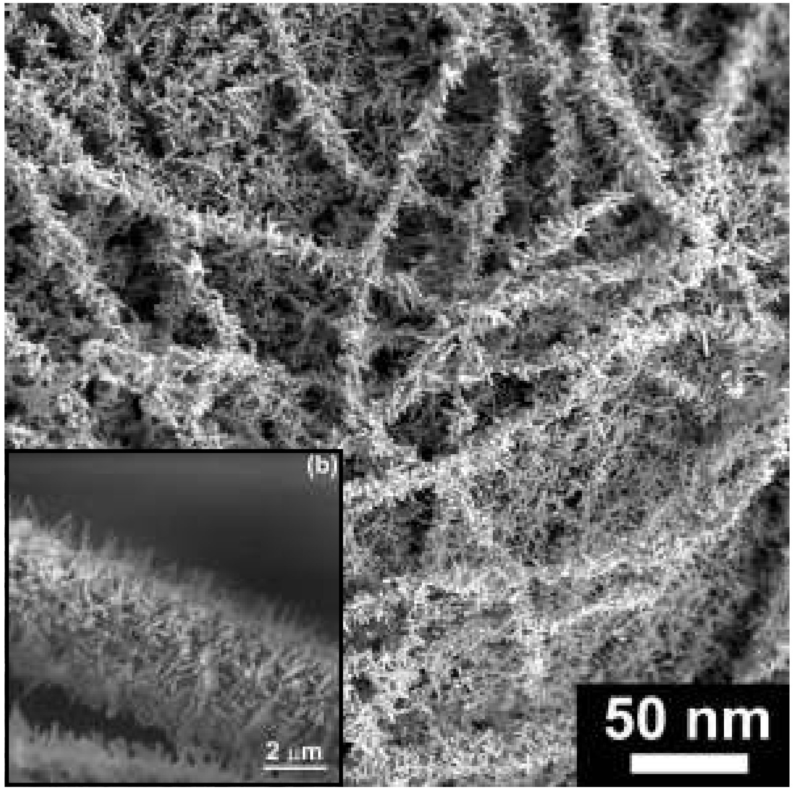
We produced nanofibers of poly-L-lactide (PLLA) by electrospinning:



High surface area, flexible, bio-compatible…

Hierarchical ZnO nanostructures

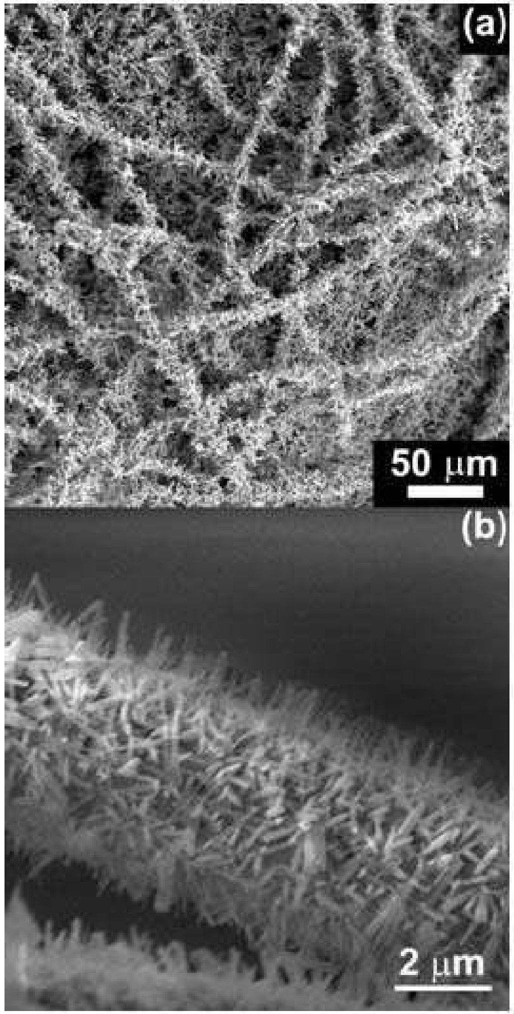
ZnO nanorods synthesized by chemical bath deposition using the nanofibers as a high surface area 'substrate'

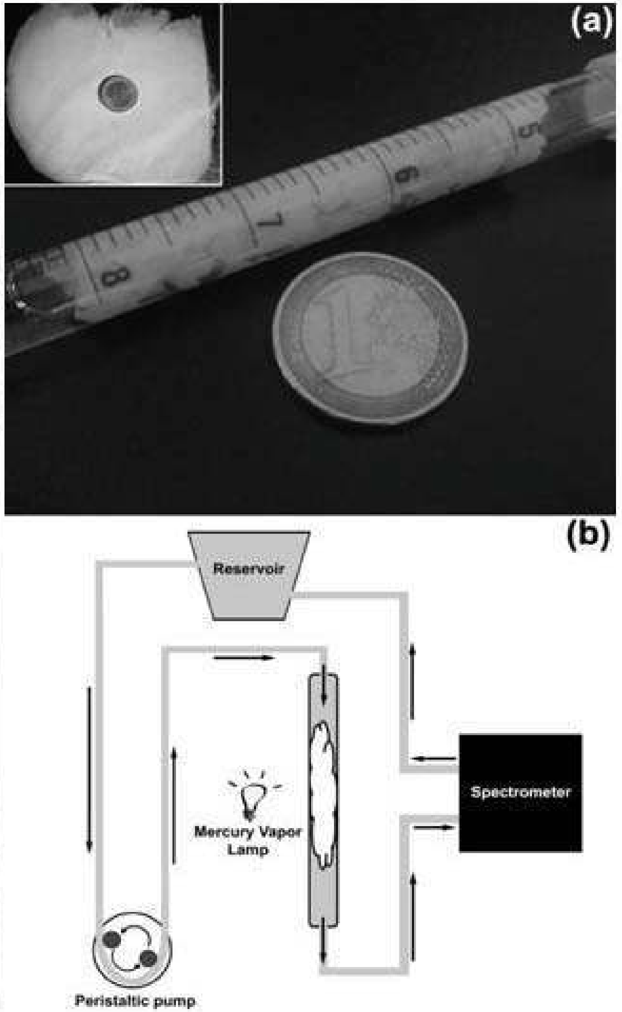


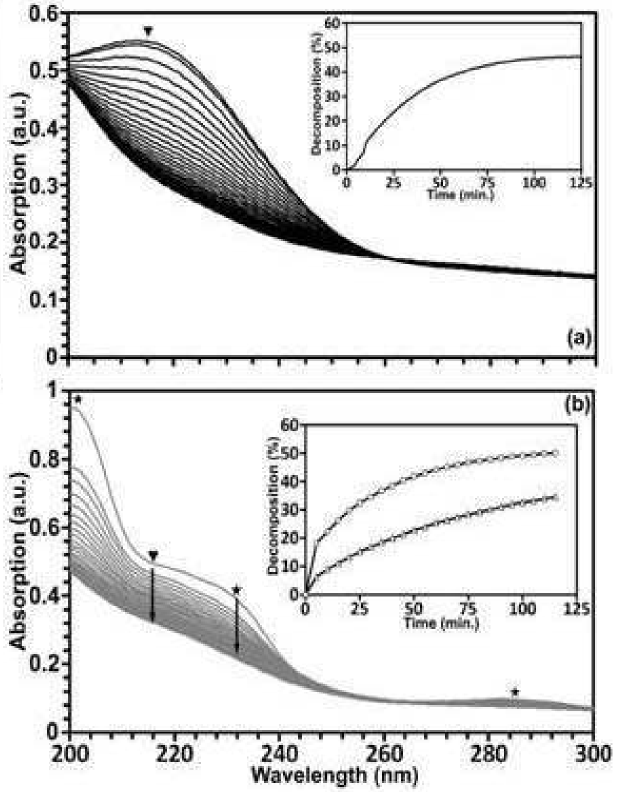
Obtaining highly compact, yet high surface area structures… Similar to Nature's solution

Nano - Environment

Nanomaterials for water treatment

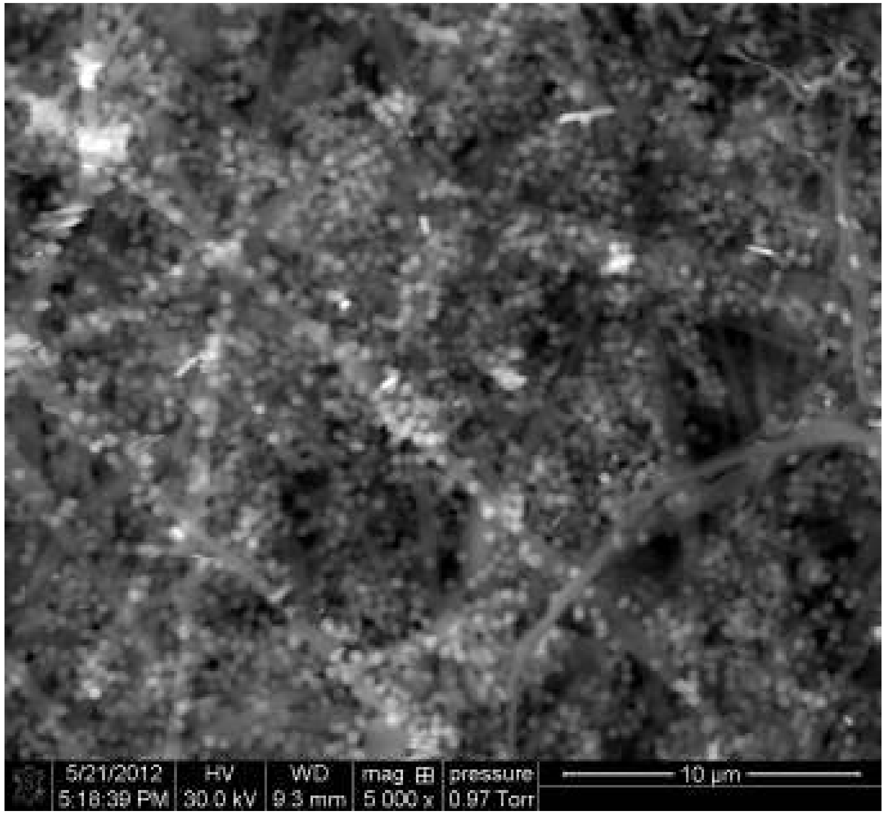


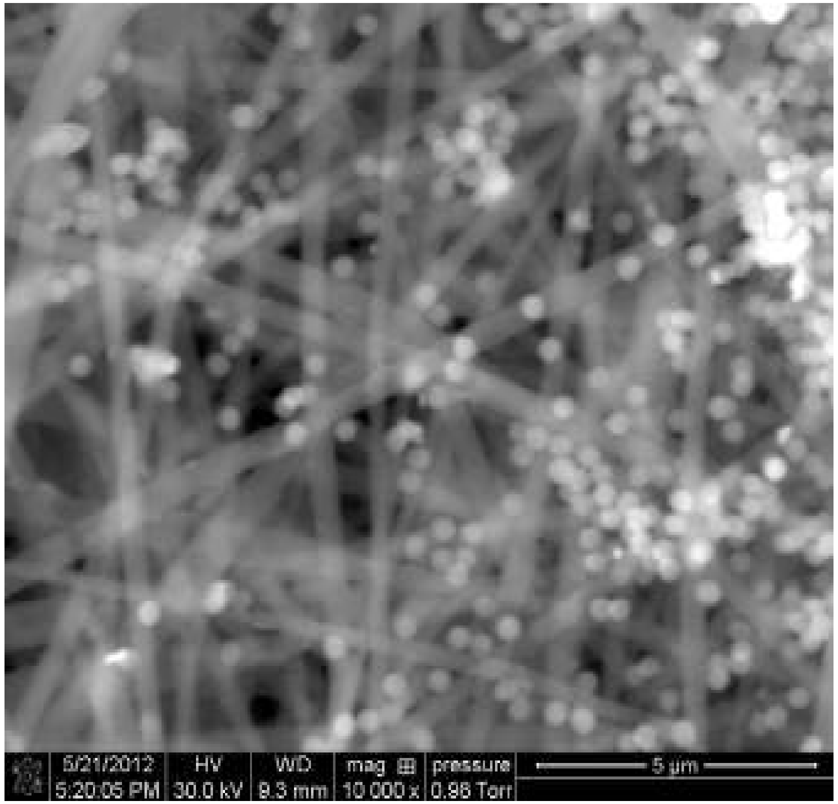




Pesticides: MCP & DPA

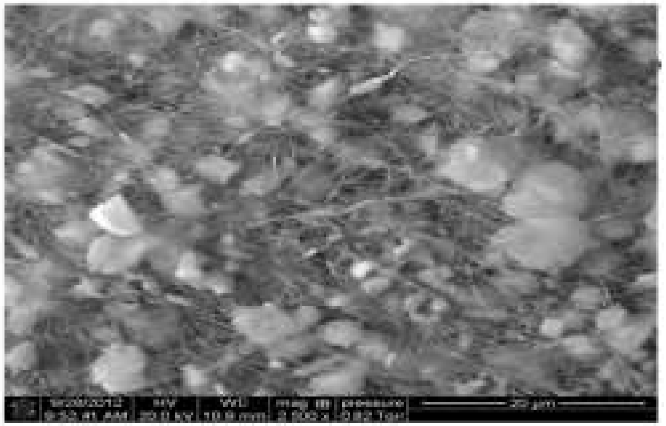
Sugunan A., Guduru V. K., **Uheida A.**, Toprak M. S., and Muhammed M. (2010) Journal of American Ceramic Society 93 (11), pp 3740-3744.

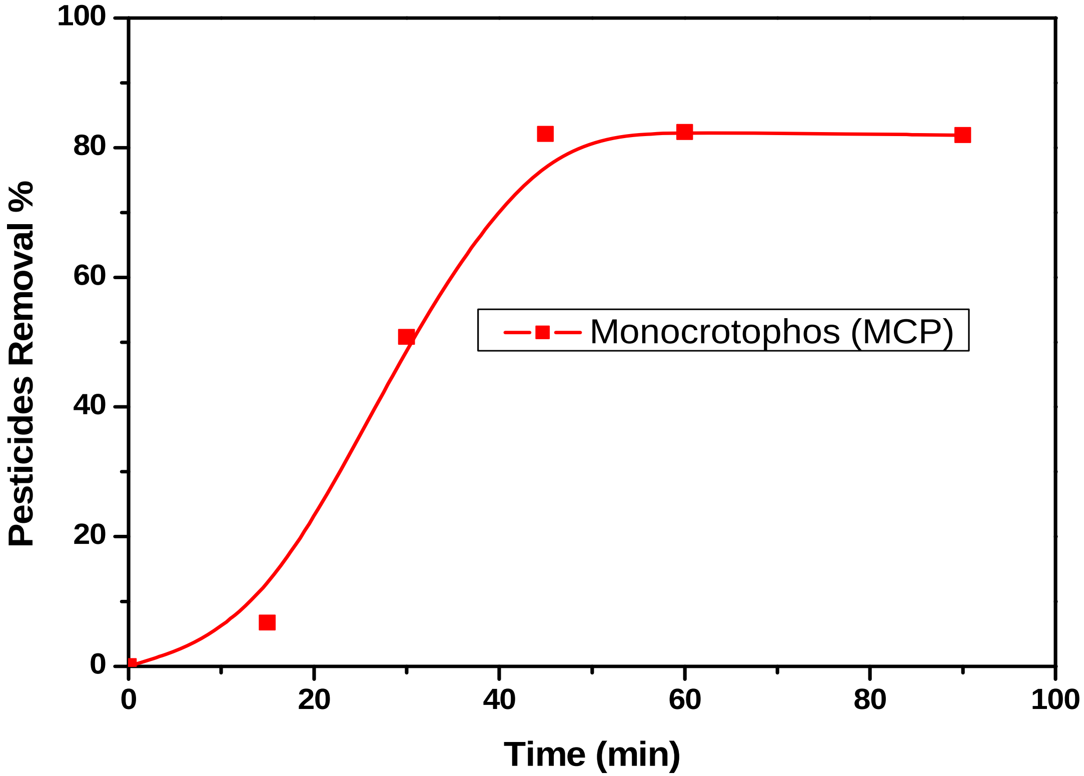




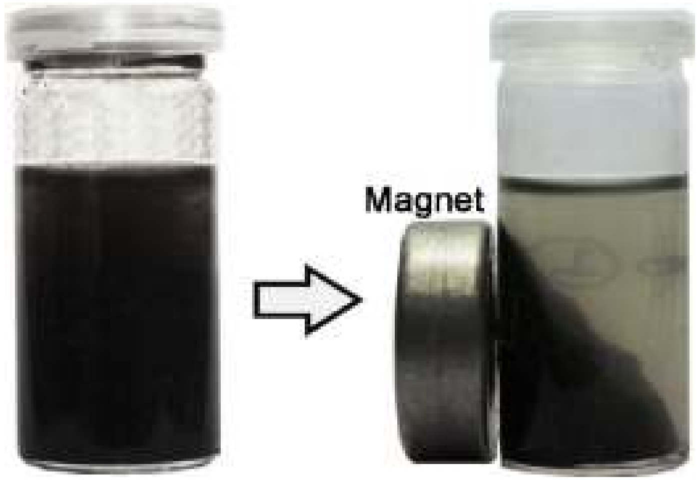
SEM Images of the nanocomposites

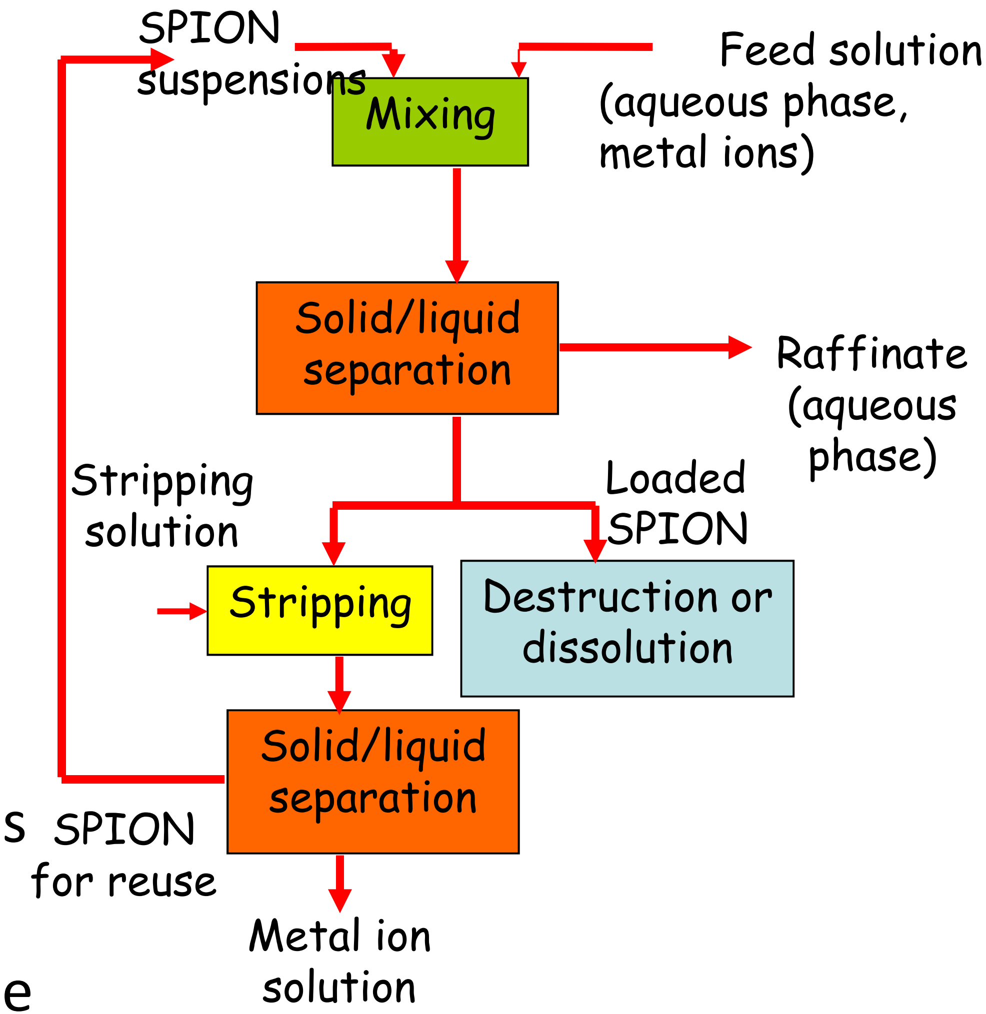
Photo-catalytic decomposition of pesticides using Natural Clay





Nano-Adsorbents





- Easy to re-disperse in aqueous solutions
- Easy to collect (facilitate phase separation)

Summary

➢ We have demonstrated that different nanostructured materials can be fabricated in our laboratory. These materials can be ceramic nanomaterials such as metal oxides, QDs, metal sulfides, nanocomposites (Nanofibers/Nanoparticles).

➢The fabricated ceramic nanomaterials were tested for different applications including Environment, Energy, and biomedical.

➢ Advanced techniques available in our department make it possible, the characterization of the fabricated engineered nanostructured materials.

Motilities within EULA-NETCERMAT Project

Instituto de Investigaciones en Ciencia y Tecnología
de Materiales (INTEMA) - Argentina

Dr. SERGIO A. PELLICE

Dr. Raúl Procaccini

sol-gel technique for Silver doped biocide coatings

Our bigger deficiencies are related to electronic microscopy techniques. Also the rheological study of sols and chemical analysis of lixiviated are our weakness.


Thank You!