European Commission

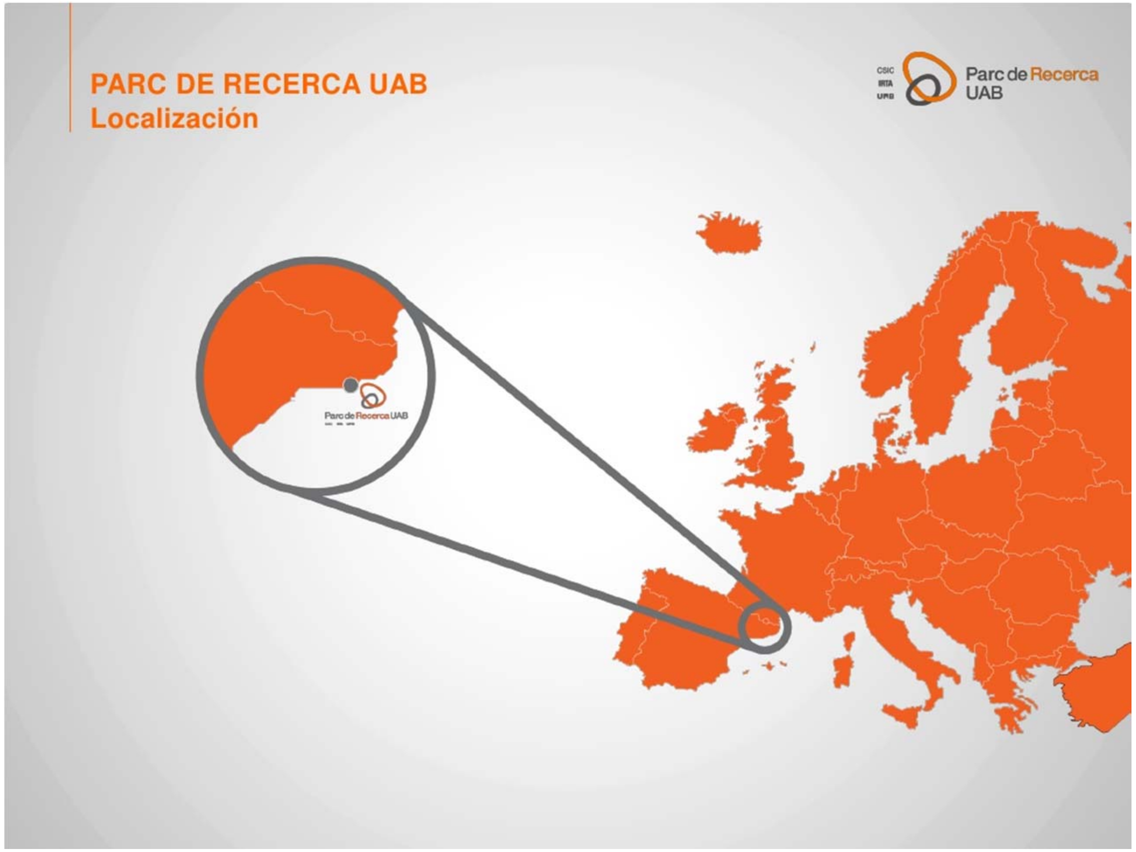
WIMB

Kick-off meeting

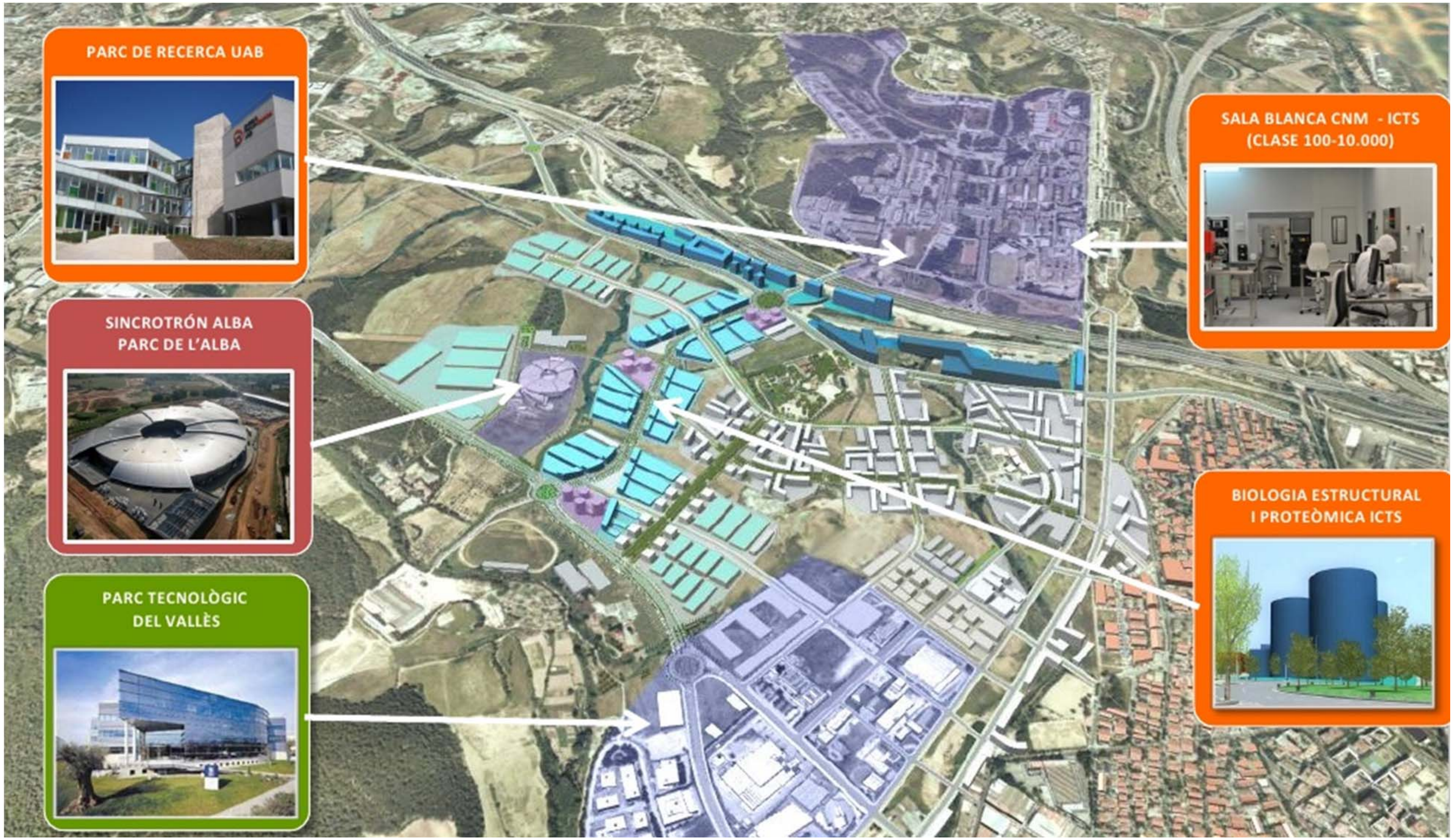
Barcelona, 3-5 March 2014

UAB Universitat Autònoma de Barcelona

University/institution - overview




UAB
Universitat Autònoma de Barcelona
UAB CEI
CAMPUS D'EXCEL·LÈNCIA INTERNACIONAL


PARC DE RECERCA UAB
SALA BLANCA CNM - ICTS
(CLASE 100-10.000)
SINCROTRÓN ALBA
PARC DE L'ALBA
BIOLOGIA ESTRUCTURAL
I PROTEÒMICA ICTS
PARC TECNOLÒGIC
DEL VALLÈS

University/institution - overview

40000 Students
4000 Researchers
57 Departments
520 Theses/year
3200 Research papers/year
50 Patents/year
30 Research Centers

Group/team – overview (I)

Prof. Dr. Maria Dolors Baró
Head of the Materials Physics II Group

Prof. Dr. Santiago Suriñach
Director of the Physics Department

Prof. Dr. Jordi Sort

Dr. Eva Pellicer

Group/team – overview (II)

Dr. Jordina Fornell

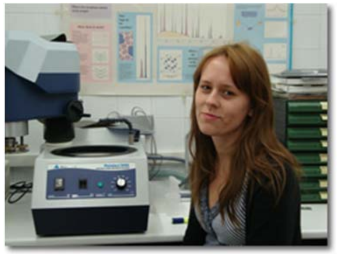
Dr. Pau Solsona

Dr. Sebastià Agramunt

Dr. Miguel Guerrero

Irati Golvano

Jin Zhang

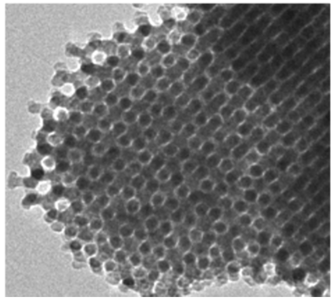


Anna Hynowska

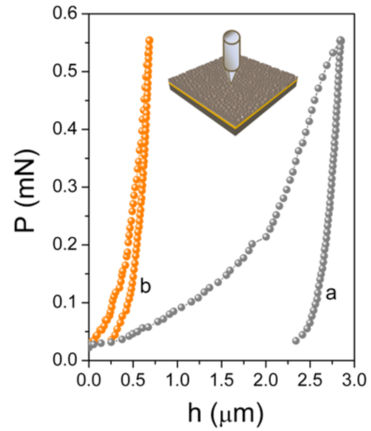
Roger Domingo

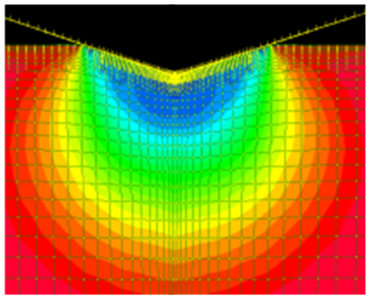
Alberto Quintana

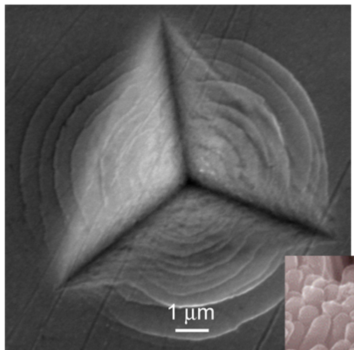
Fields of expertise

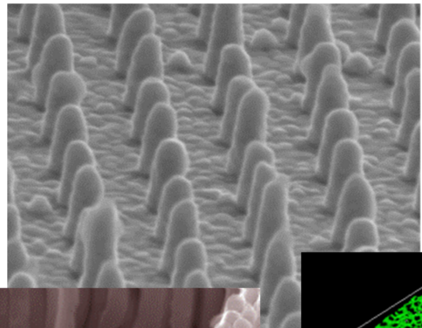


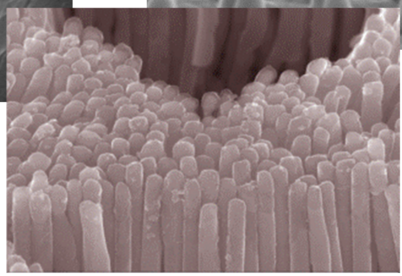
1. Metallic glasses and bulk nanocomposite materials
2. Thin Films, Foams and Micro/Nanostructures by Electrochemical Methods
3. Magnetic patterning
4. Permanent and Biodegradable Biomaterials
5. Mesoporous materials

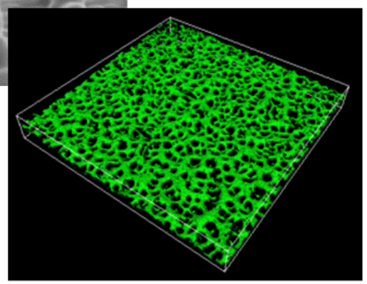












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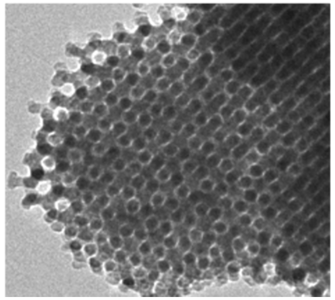
Fields of expertise



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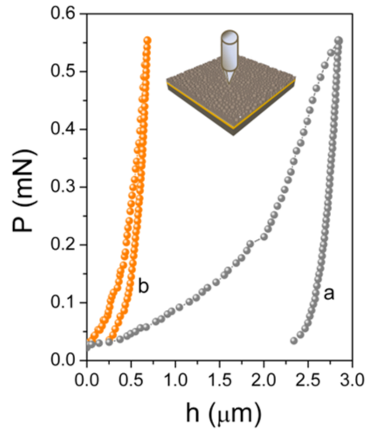

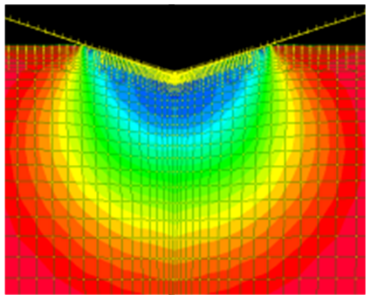

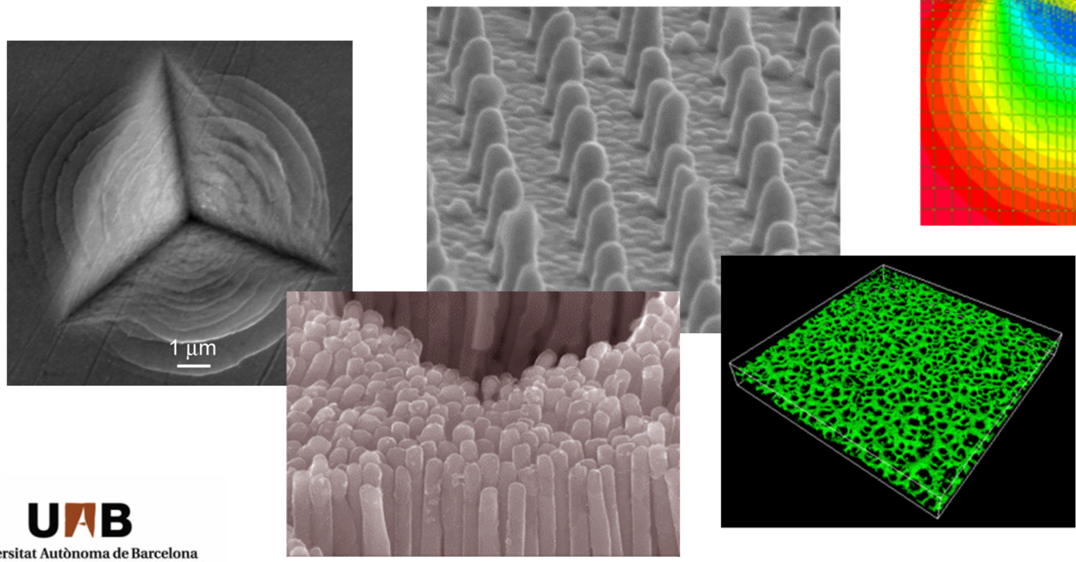

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1. Metallic glasses and bulk nanocomposite materials

- Metallic glasses (MGs) are amorphous metallic alloys, i.e. do not exhibit long-range order.

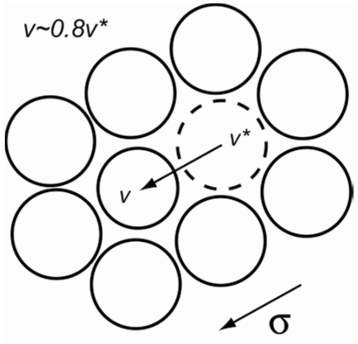
- Consequently, they offer unique properties compared to other materials:

  - Typically, high strength and large elasticity.
  - Good corrosion resistance.
  - Good microformability within the supercooled liquid region (similar to polymers).
  - Low plasticity in compression and NO plasticity in tension.

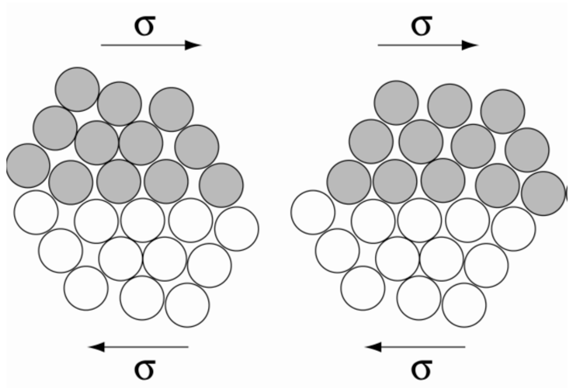
- Widespread applications, including medical and electronic devices, sporting goods or advanced defence and aerospace technologies.

1. Metallic glasses and bulk nanocomposite materials

- Plastic flow in metallic glasses (MGs) is accompanied by dilatation (i.e., creation of excess free volume).



Single atomic jumps
Spaepen, Acta Metall. 1977;25:407.



Shear transformation zones
Argon, Acta Metall. 1979;27:47
Falk and Langer . Phys. Rev. E 1998;57:7192.

Plastic flow equation:

$$\dot{\gamma} = 2\Delta f c_f k_f \left(\frac{\varepsilon_0 v_0}{\Omega}\right) \sinh\left(\frac{\tau \varepsilon_0 v_0}{2 k_B T}\right)$$

$\dot{\gamma}$: is the shear strain rate τ: is the shear stress

$c_f = \exp(-\gamma v^*/\langle v_f \rangle)$ flow defect concentration

k_B Boltzmann constant

k_f temperature-dependent rate constant

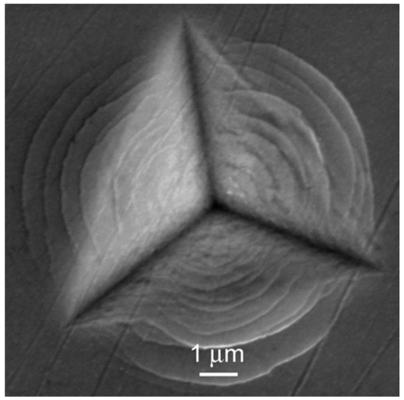
Δf volume fraction of potential flow units

$\varepsilon_0 v_0$: activation volume for a flow event and Ω: atomic volume.

1. Metallic glasses and bulk nanocomposite materials

- At room temperature, the excess free volume tends to coalesce into shear bands, leading to a local temperature increase.

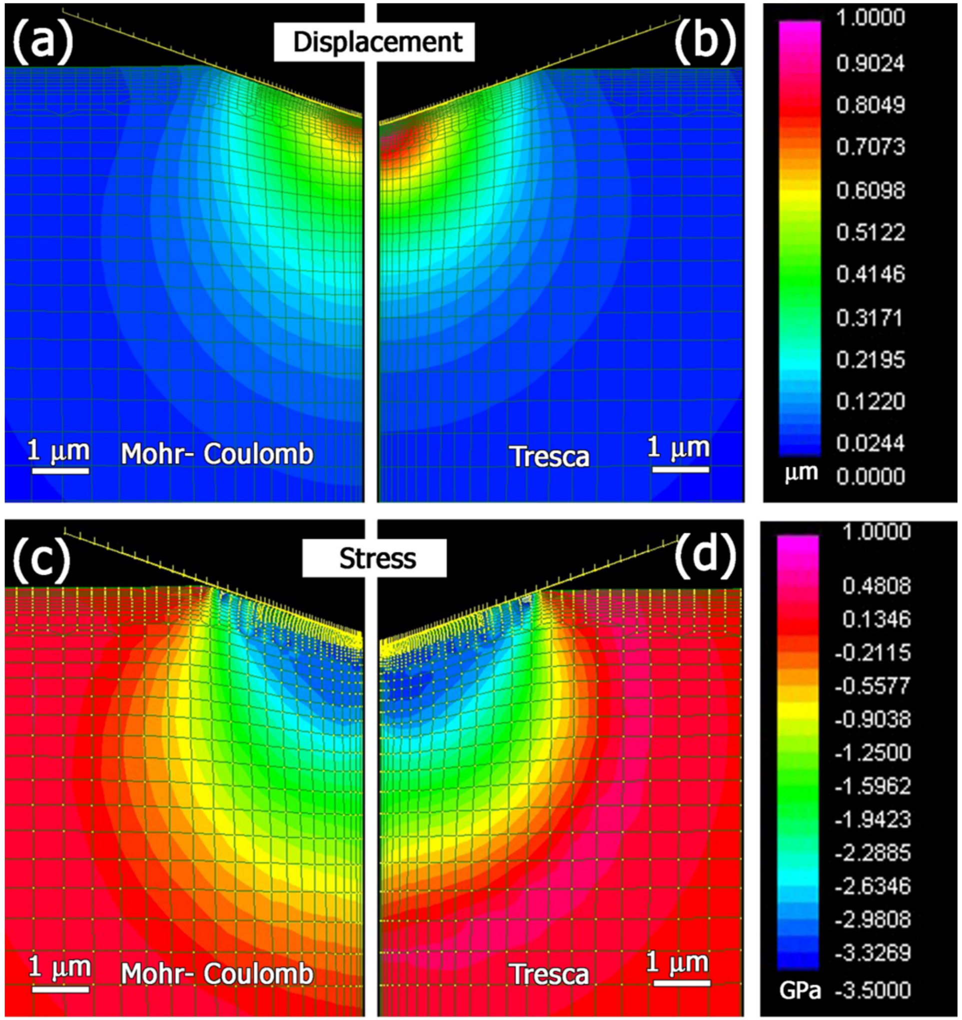
- As a consequence, viscosity locally drops , atomic mobility is enhanced and, **eventually, nanocrystallization occurs.**



Shear bands inside and around an indent performed on a Zr-based MG

- Consequence: serrations (pop-in events) in the loading curves typically observed.

1. Metallic glasses and bulk nanocomposite materials



- Application of the Mohr-Coulomb yield criterion results in an extended plastic zone beneath the indenter

  In agreement with:

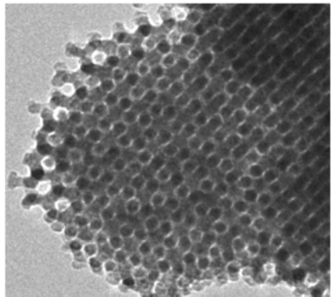
  Narashiman Mech. Mater. 36 (2004) 633

- Similar conclusions about yielding of metallic glasses (obtained from simulations) by:

  Vaidyanathan et al., Acta Mater. 49 (2001) 3781
  Anand and Su, J. Mech. Phys. Solids, 53 (2005) 1362
  Schuh et al. Acta Mater. 55 (2007) 4067

Displacement and Circumferential stress (s_{qq}) contour mappings

Fields of expertise



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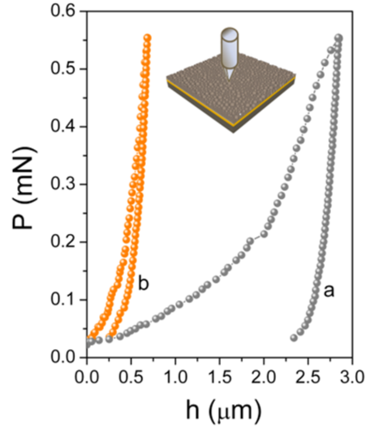

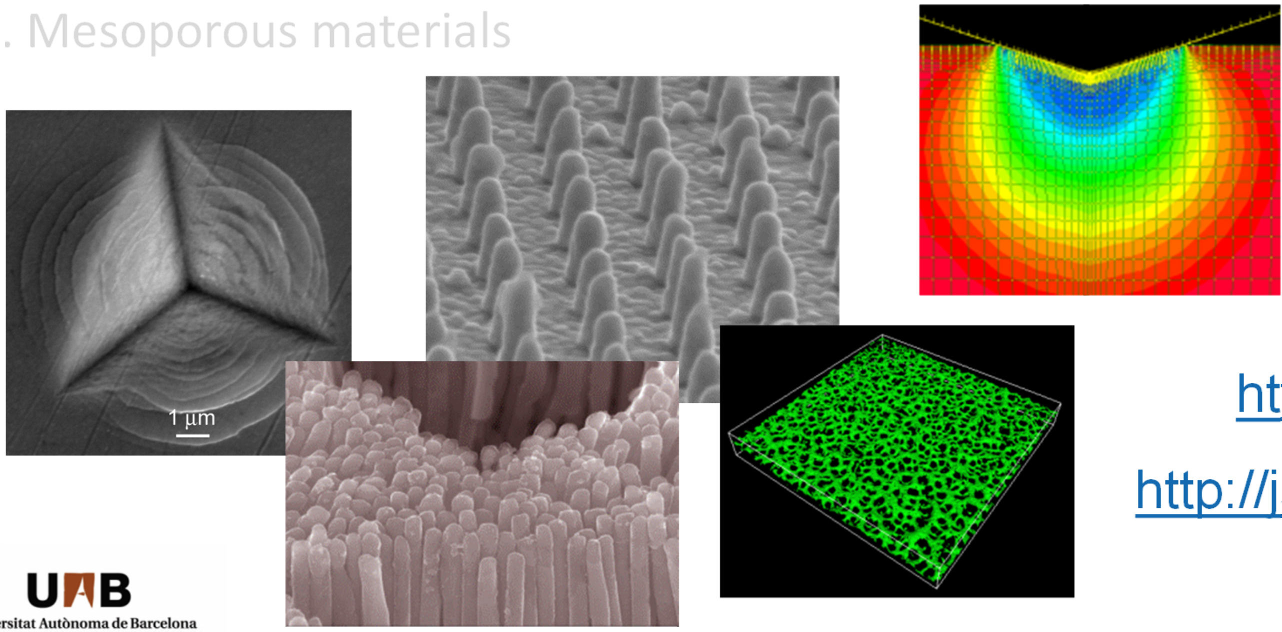

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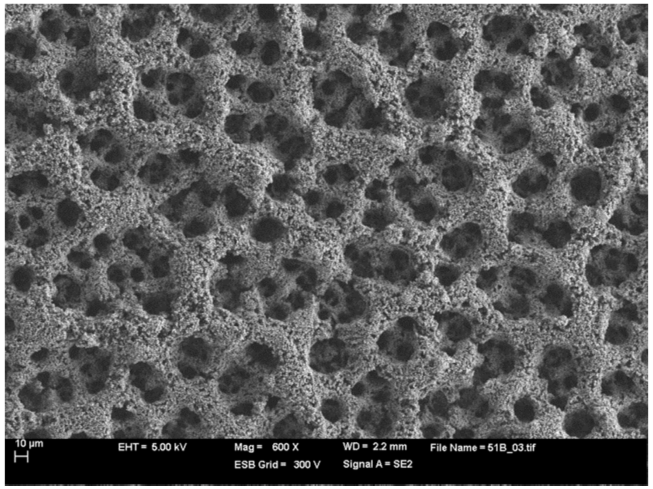
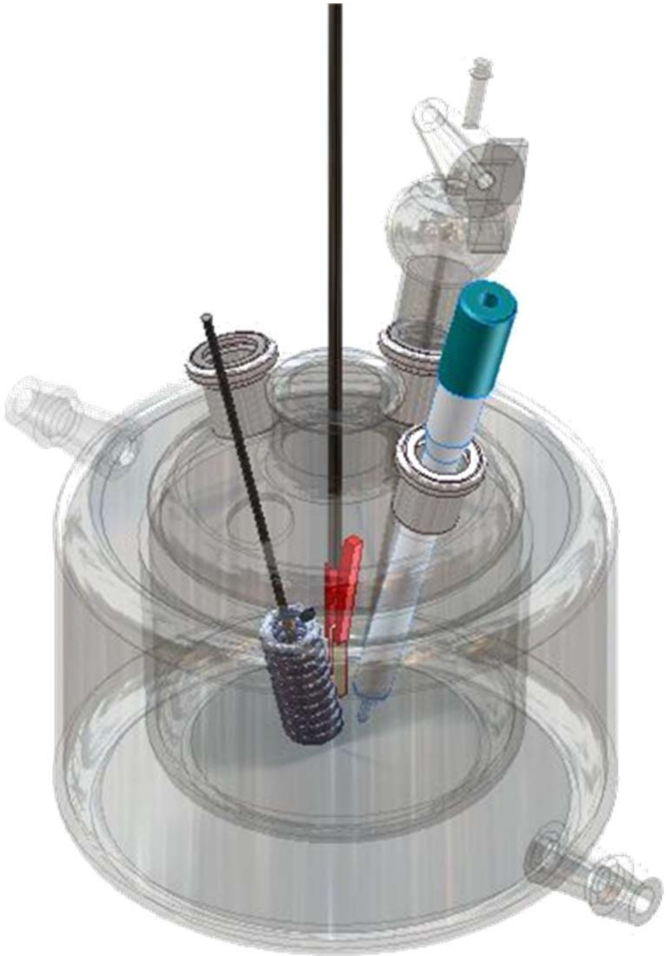
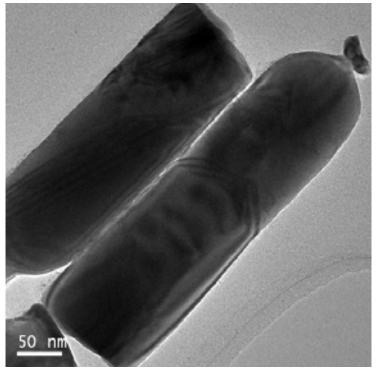
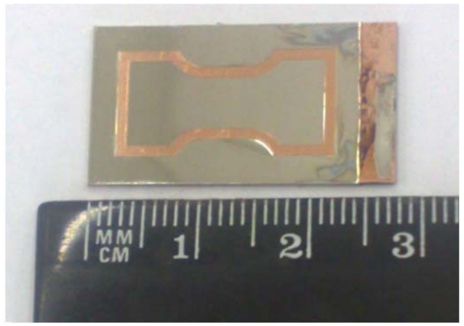
2. Thin films, foams and micro/nanostructures



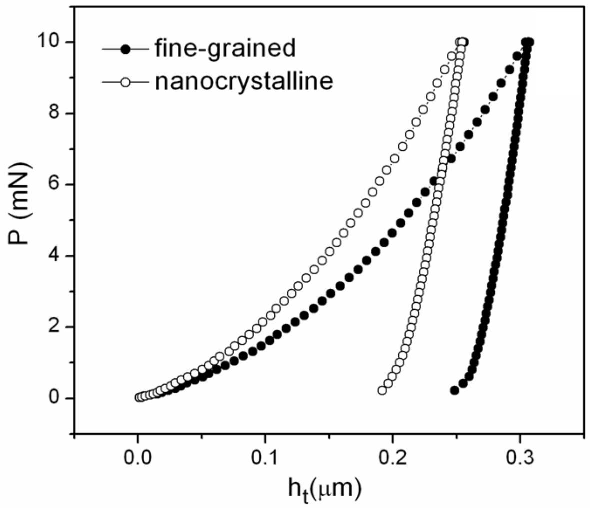




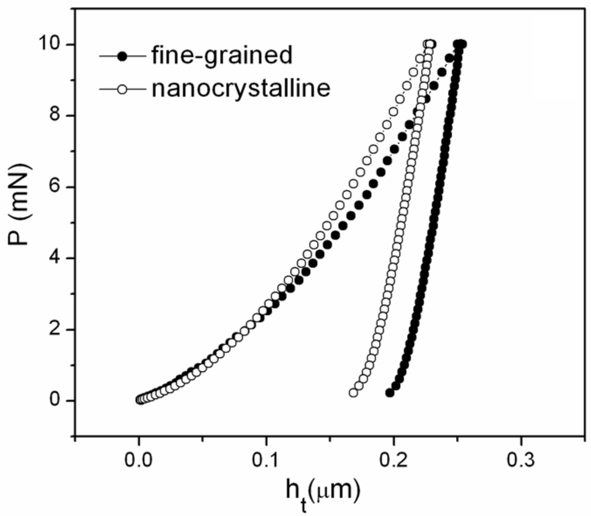


2. Thin films, foams and micro/nanostructures

Fine-grained versus nanocrystalline



- ● $Cu_{0.57}Ni_{0.43}$
- o $Cu_{0.55}Ni_{0.45}$



- ● $Cu_{0.14}Ni_{0.86}$
- o $Cu_{0.13}Ni_{0.87}$

Nanoindentation
P_{max} = 10 mN

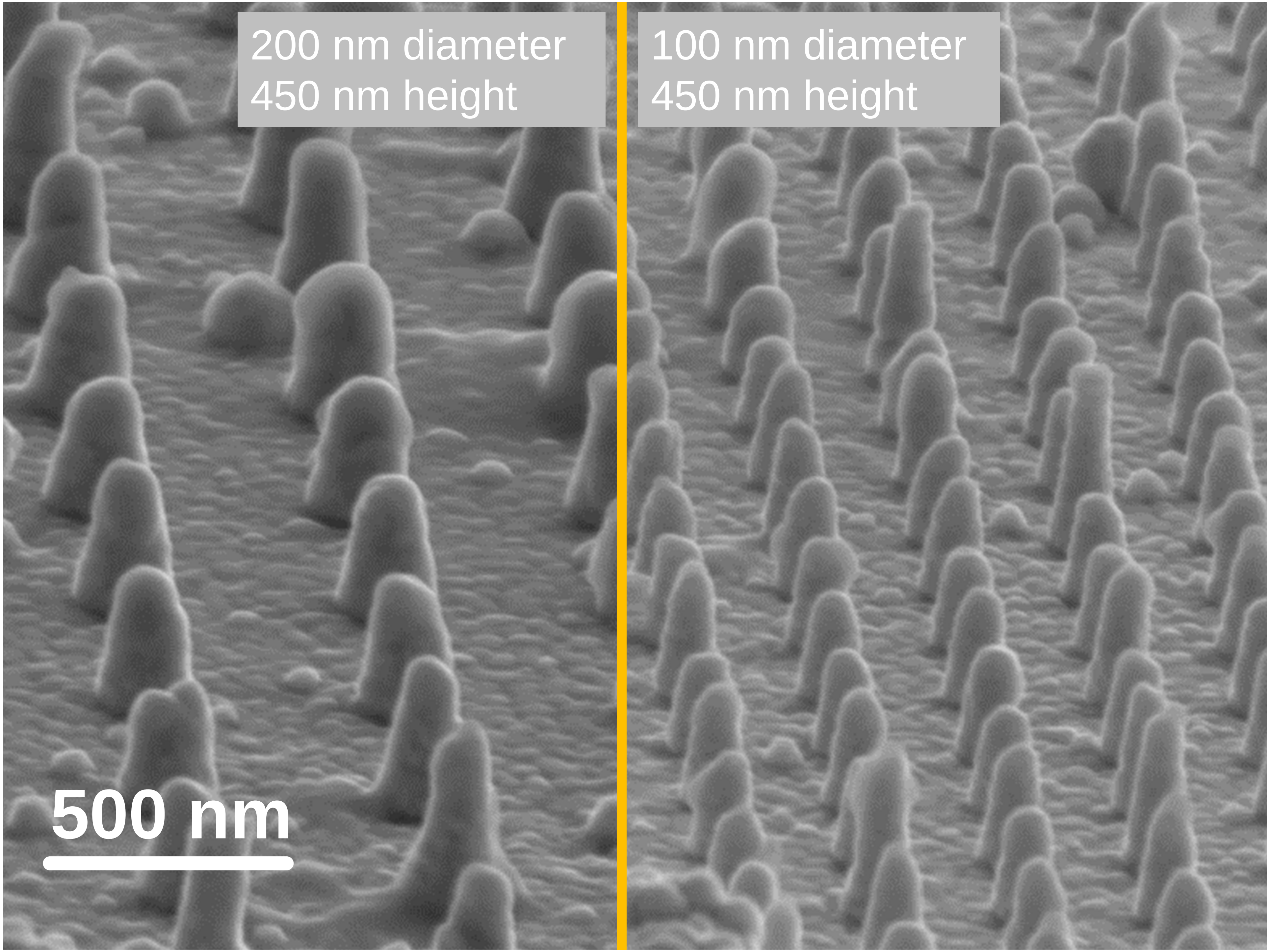
✓ Smaller crystallite sizes → Larger density of grain boundaries

✓ Intragranular nanotwins

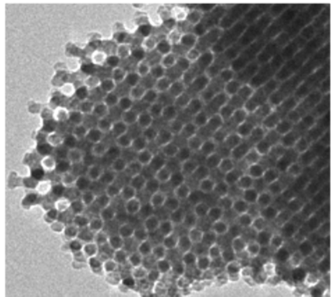
Effective disruption of dislocations propagation

Enhanced hardness in nanocrystalline Cu-Ni films

Hall-Petch relationship


200 nm diameter
450 nm height
100 nm diameter
450 nm height
500 nm

Fields of expertise



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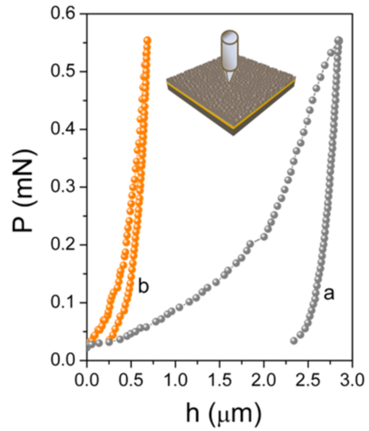

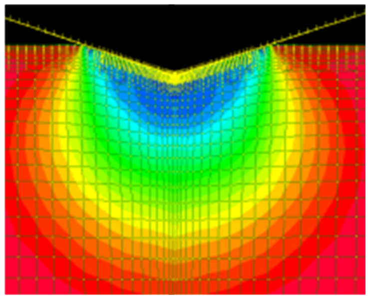

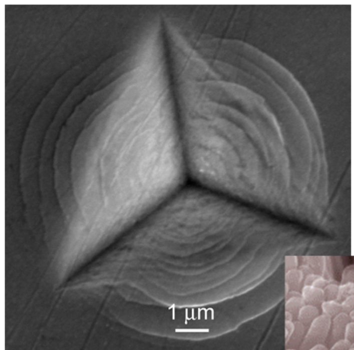

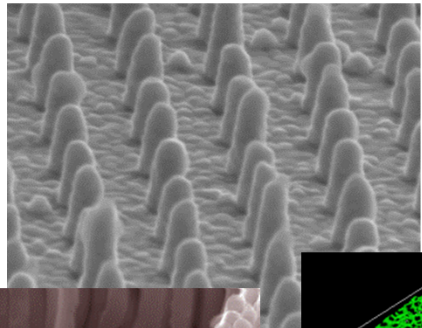

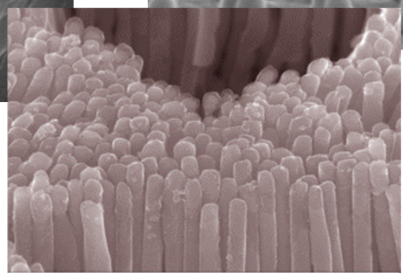

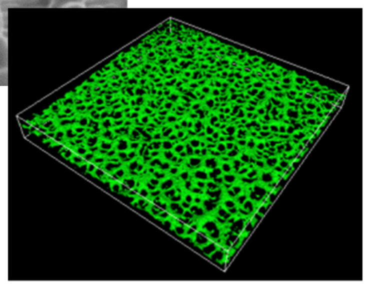

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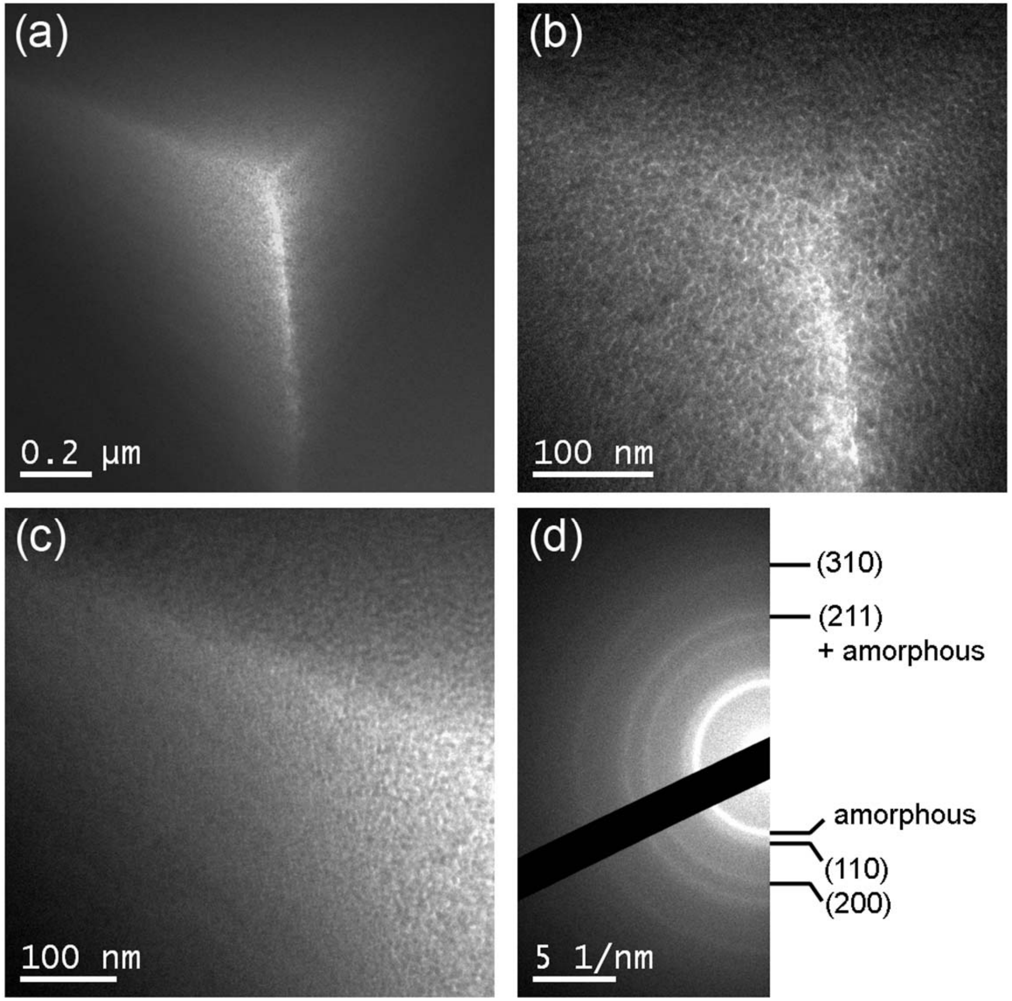
3. Magnetic patterning

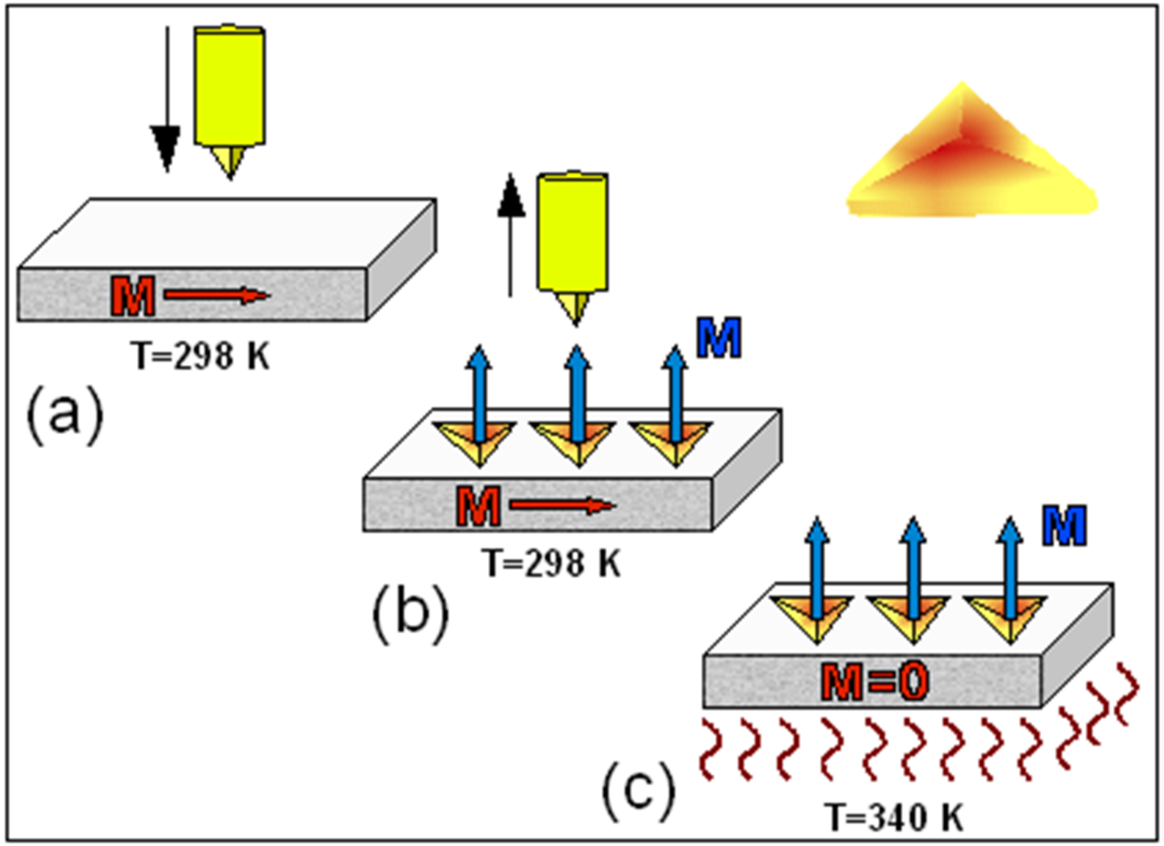


$Fe_{67.7}B_{20}Cr_{12}Nb_{0.3}$

- Nanoindentation induces crystallization of mainly α-Fe.

- Progressive decrease of the crystallite size towards the edge of the indents (crystallite size around 8 nm at the central part of the indents).

3. Magnetic patterning



J. Sort et al., Small 6 (2010) 1543

- **At T = 298 K:**

- *In-plane* magnetic anisotropy before indentation.

- *Perpendicular-to-plane* magnetic anisotropy after indentation. Kerr signal increases!

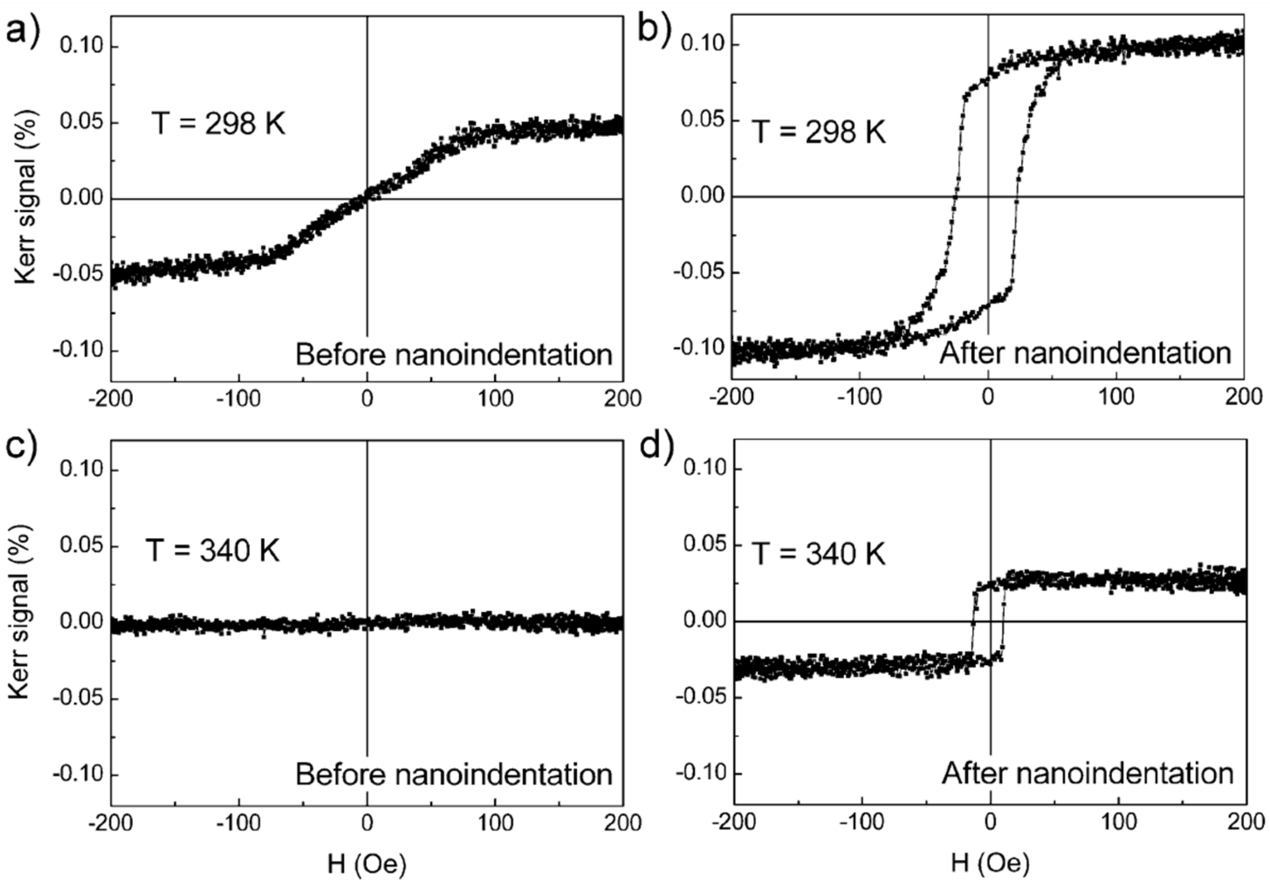
- **At T = 340 K:**

- *No ferromagnetism* before indentation

- *Perpendicular-to-plane* magnetic anisotropy after indentation

3. Magnetic patterning

Polar Hysteresis loops at room temperature and above $T_{C,am}$ ($T_{C,am}$ = 330 K)



- **At T = 298 K**:

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- *Perpendicular-to-plane* magnetic anisotropy after indentation. Kerr signal increases!

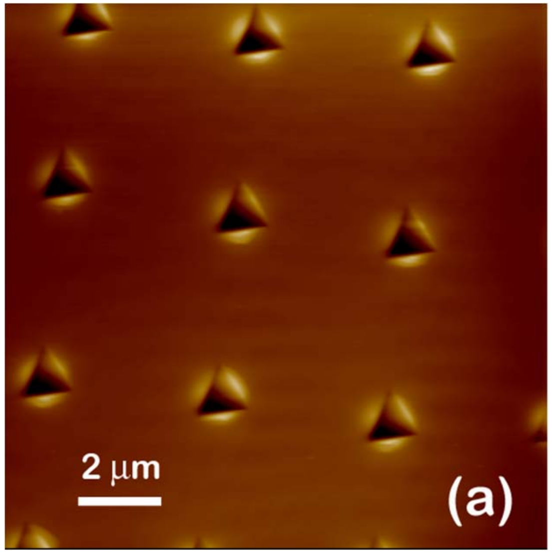
- **At T = 340 K**:

- *No ferromagnetism* before indentation

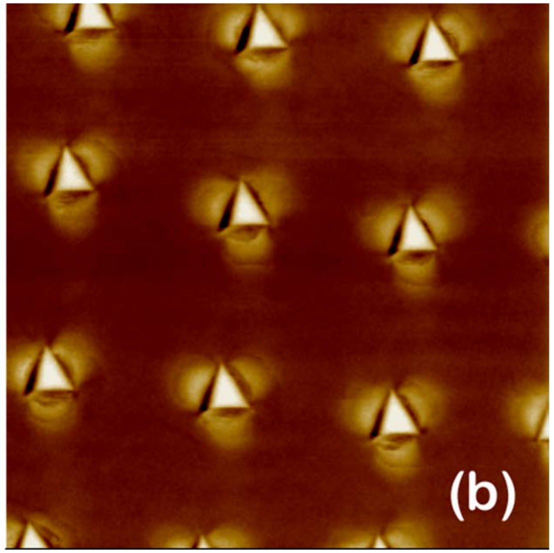
- *Perpendicular-to-plane* magnetic anisotropy after indentation

3. Magnetic patterning

Topological versus magnetic contrast: magnetic contrast expands towards the pile-up



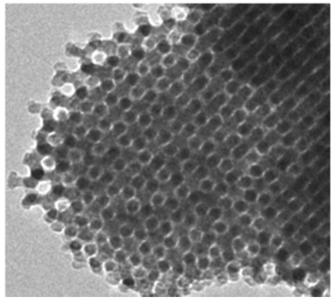
Atomic force microscopy



Magnetic force microscopy

- No magnetic domains around the indentations because the initial amorphous ribbon is very soft (i.e., with large domain sizes)

Fields of expertise



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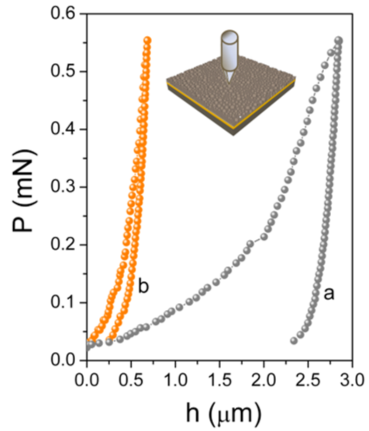

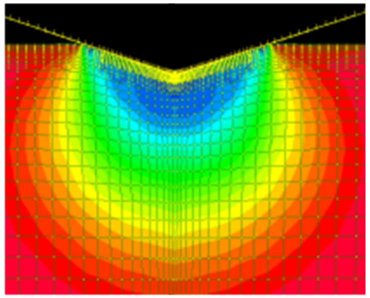

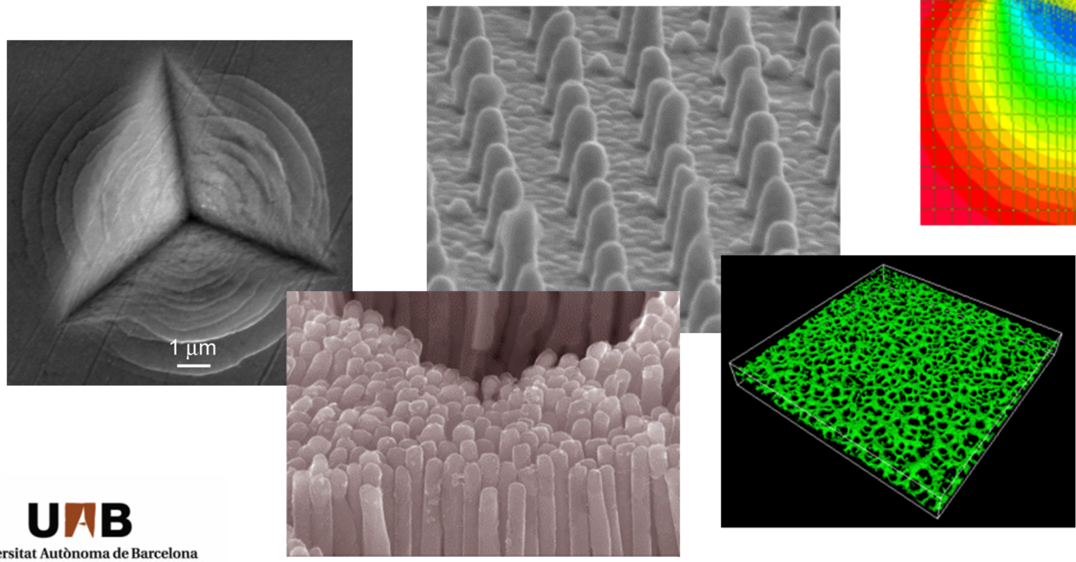

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4. Permanent and biodegradable materials

Conventional implant metallic alloys (steel, CoCr, TiAlV,…)

- ✗ Not biodegradable
- ✗ Relatively high Young's modulus (E ~100-200 GPa, larger than E_{bone} = 3-20 GPa (stress shielding effects).
- ✗ In some cases, revision surgery is required to remove the implant.

Non-toxic biodegradable implants

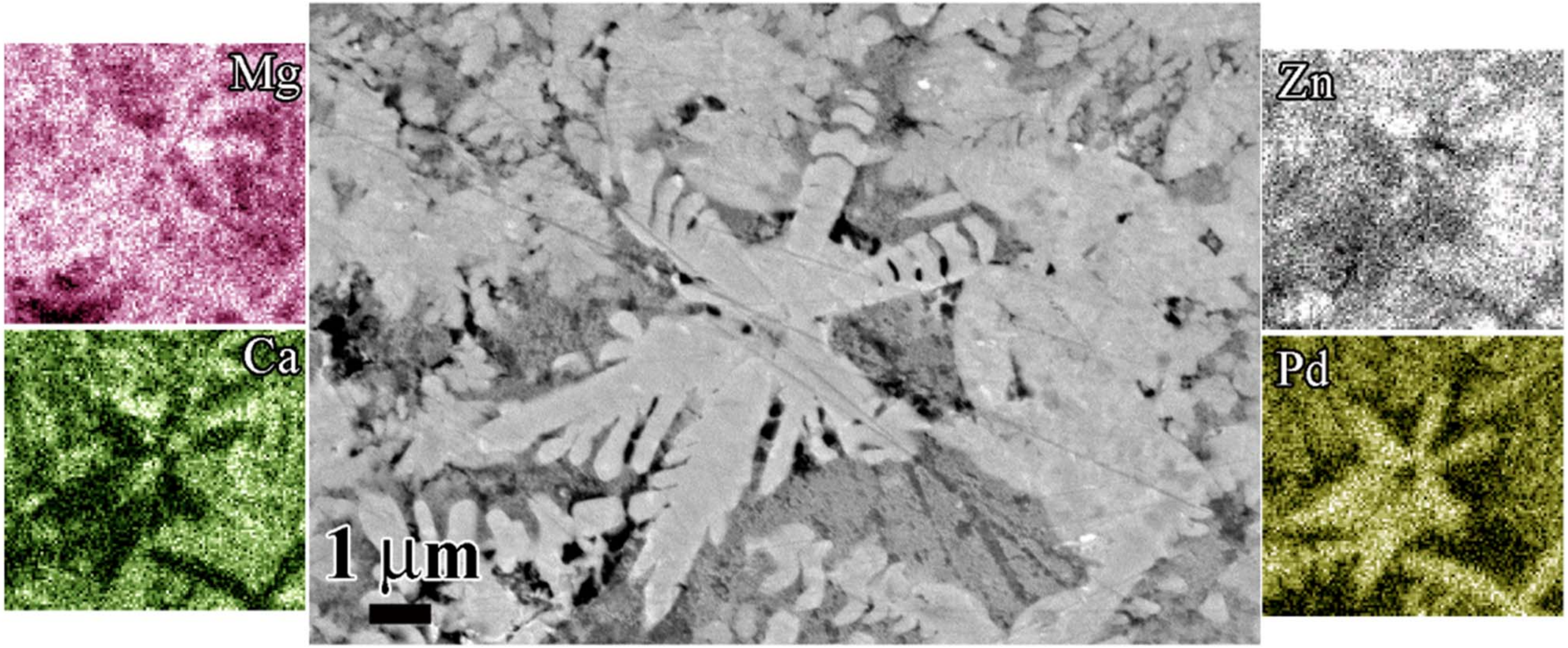
usually made of organic polymers: polyglycol acid, poly(dl-lactic acid), poly(p-dioxanone),…

- ✗ Too costly
- ✗ Strength and Young's modulus are exceedingly low

…What about metallic biodegradable implants?

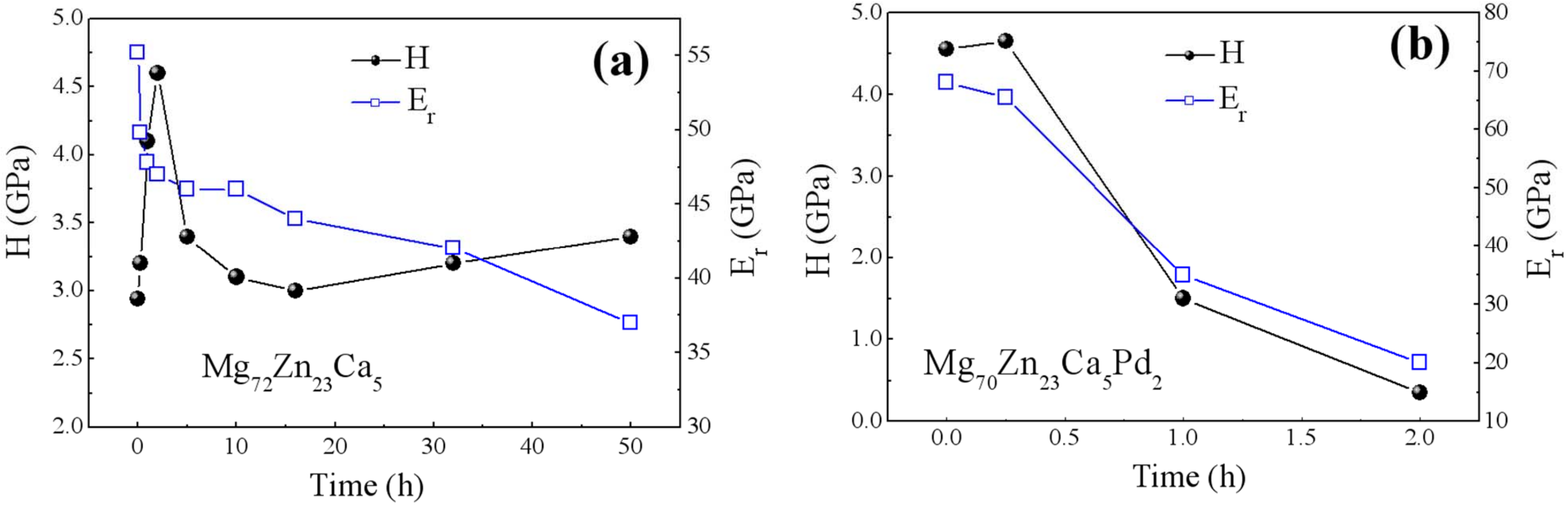
4. Permanent and biodegradable materials

$Mg_{70}Zn_{23}Ca_5Pd_2$

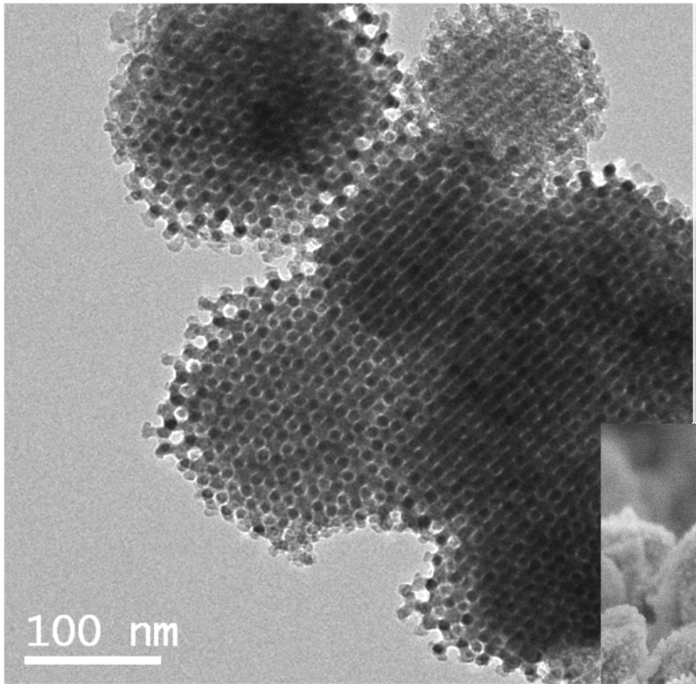


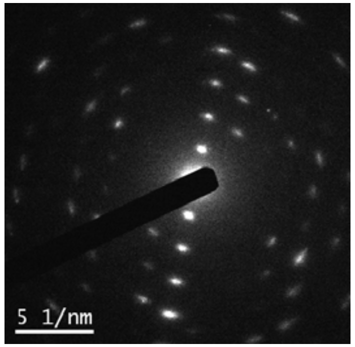
4. Permanent and biodegradable materials

$Mg_{70}Zn_{23}Ca_5Pd_2$

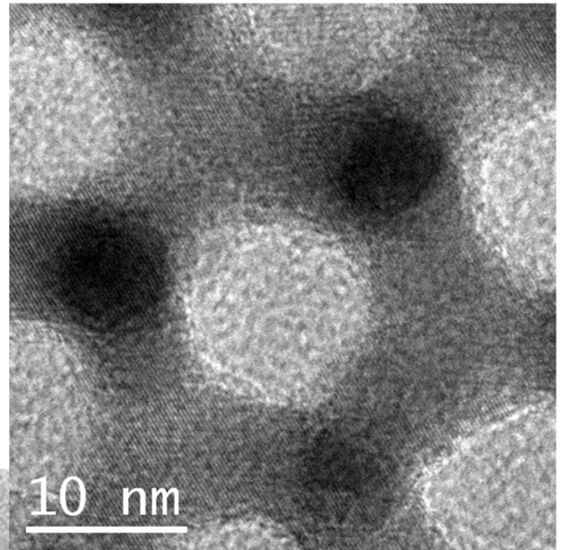


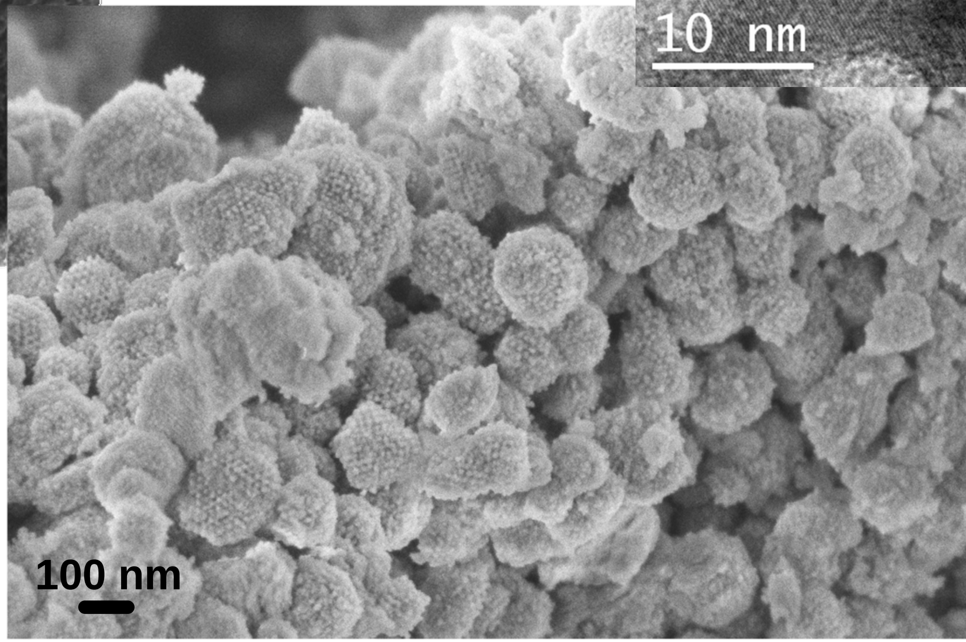
5. Mesoporous materials

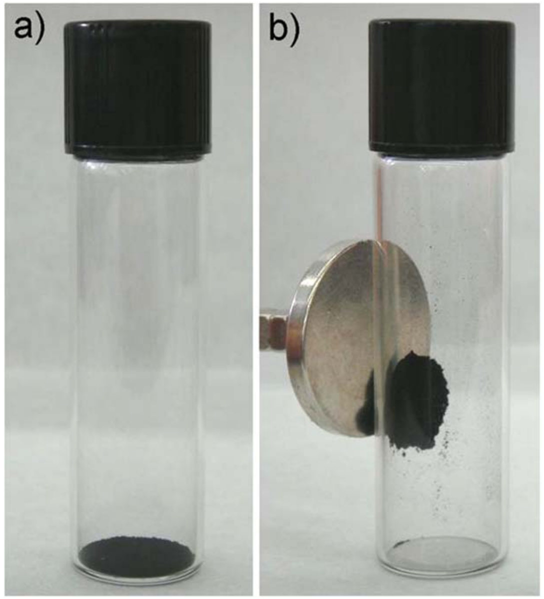


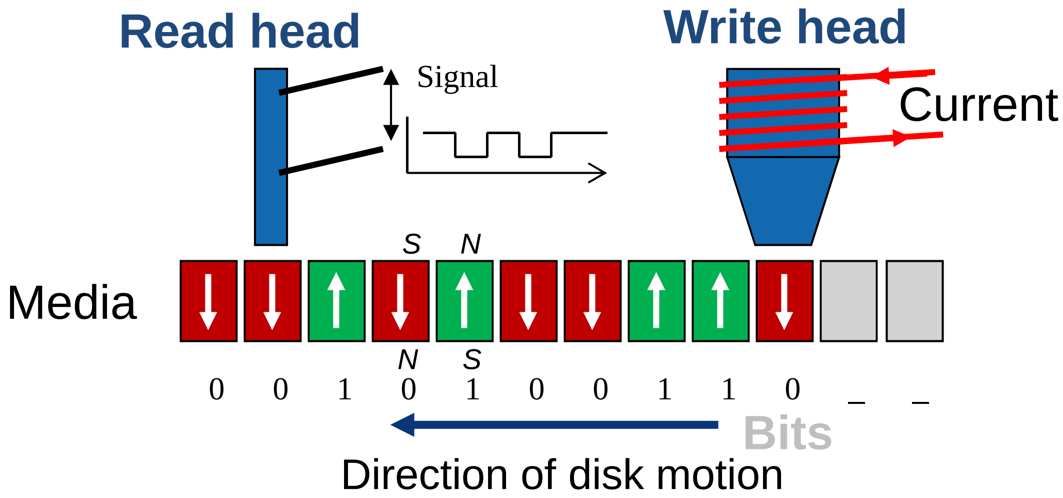


Co_3O_4 KIT-6









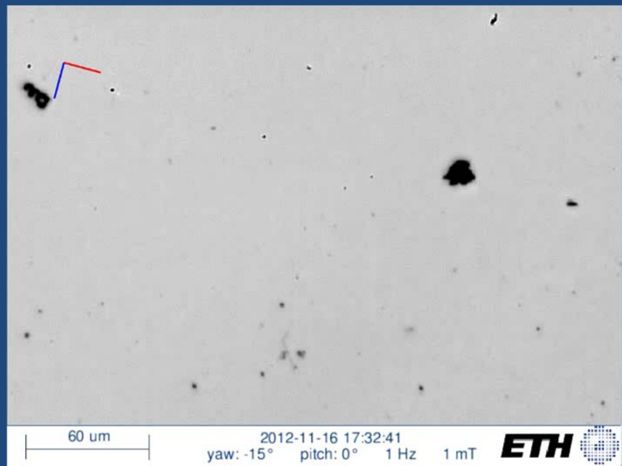
Adapted from Mark Tuominen, CHM

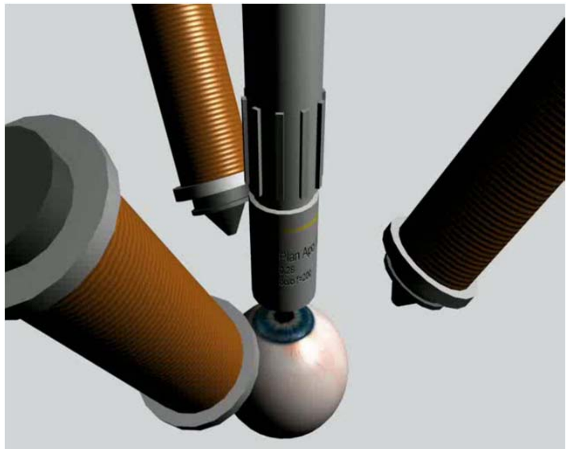
Nanotechnol. 22 (2011) 275713

Adv. Funct. Mater. 23 (2013) 823

Small 8 (2012) 1498

Small 2014, in press.





Role in the project

- *UAB – coordinating instituion : responsible for management and activities supervision*

Proposal of engagement in the following activities:

- 1. To identify current state of education, research and innovation in PC countries (Serbia, Bosnia, Montenegro) in nanotechnologies and advanced materials

    Case studies (per country project participant) of successful stories in nanotechnology and advanced materials innovation and their impact on the university, society and business communities

- 2. To establish the platform to support strong links of research with education and innovation and accelerating development to industry/clinic and market and modernise PC universities (Serbia, Bosnia, Montenegro)

    Analysis of key players, research & education gaps

- 3. To develop vocational training courses to address the market needs in nanotechnology and advanced materials innovation transfer

    manuals for vocational courses: 4) Biomedical applications of additive manufacturing; 5) From nano and biomaterials to innovative products

Role in the project

... We want the project to be a success!