International week on MNT for space 2010
Session 7 : Nanotechnology roadmap and applications

Some contributions of nanomaterials to sensors, thermal control coatings and RADAR Absorbing Materials

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Plan

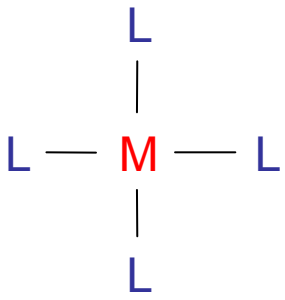
- State of the art of nanofillers synthesis in LCC
- Implementation of nanomaterials for space applications : possible benefits
  - Multifunctionnality
    - Passive thermal control coating with antistatic properties
  - Processability
    - RAM and EMI shielding materials
  - Enhanced detection and life span
    - Gas sensors

Plan

- **State of the art of nanofillers synthesis in LCC**

Laboratoire de Chimie de Coordination

- Important French laboratory in chemistry, depend on CNRS
  - 170 researchers, 300 workers
  - 150 publications / year



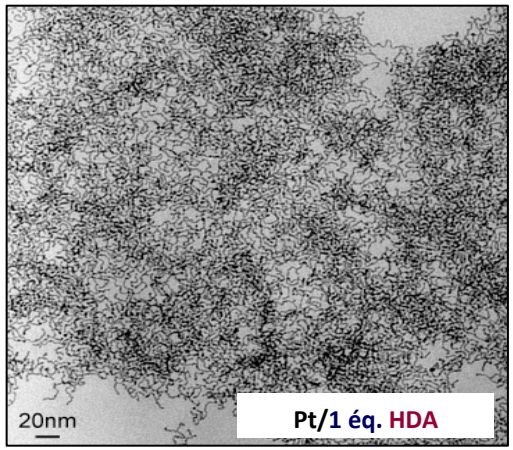
- Research in chemistry of metal complexes :
  molecules composed of metallic atoms and organic fragments

- Applications in catalysis, drugs, multifunctionnal organic materials, etc.

Metal complexes : precursors for organo- and water- soluble nanoparticles

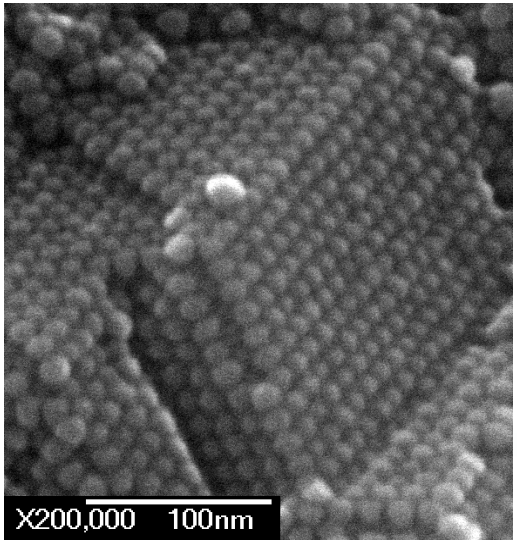
Nanoparticles synthesis

- Advantages of the approach developed in the LCC :



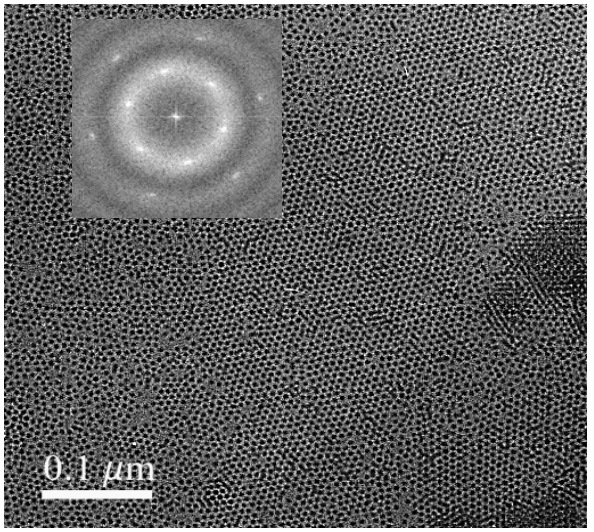
shape control :

nanowires (left) and arrows (right) of platinum



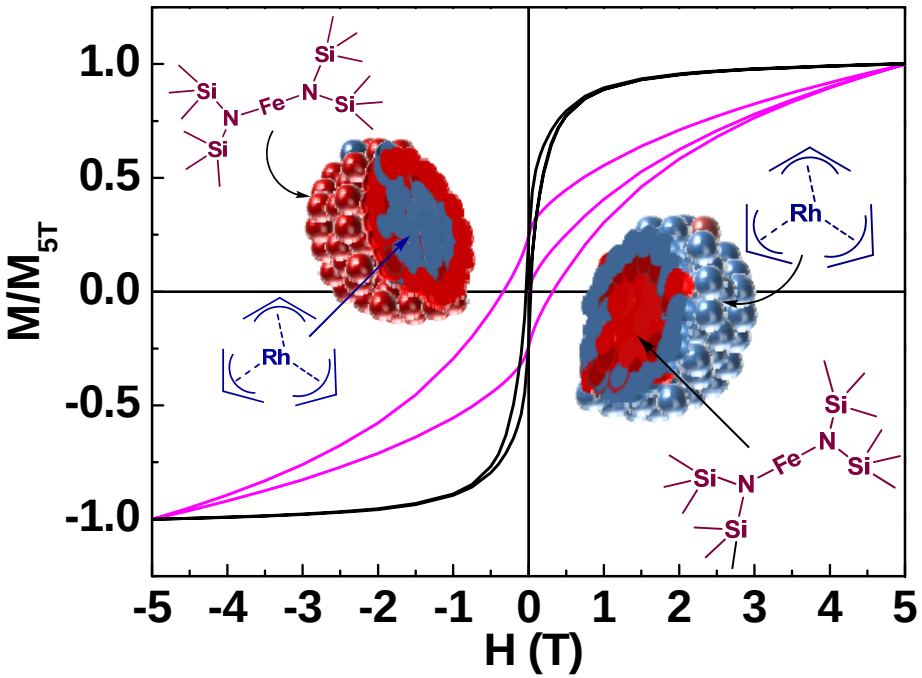
2D and 3D organization :

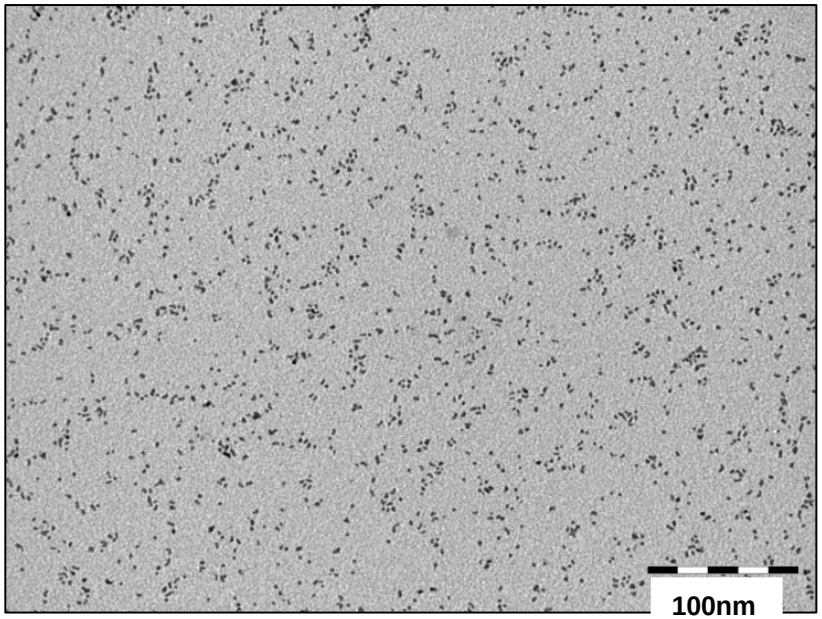
FeCo nanoparticles (left)
ZnO nanoparticles (rigth)



Nanoparticles synthesis

- Advantages of the approach developed in the LCC : adaptability
  - access to advance nanostructures





  - provides access to molecular material nanoparticles with original properties (photochromism, thermochromism, spin transition, etc.)

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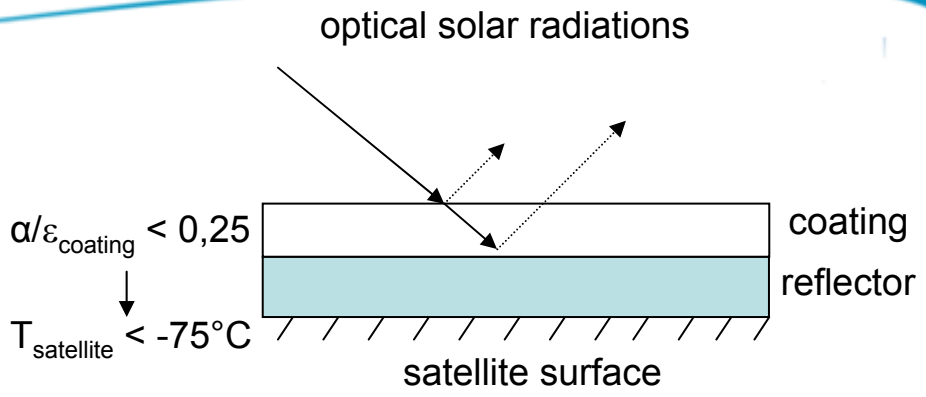
- Implementation of nanomaterials for space applications : possible benefits
  - **Multifunctionnality**
    - **Passive thermal control coating with antistatic properties**

Multifonctionnal materials

- Passive thermal control coatings :
  - minimal solar absorbtion (α)
  - maximal emissivity (ε)



- Current solutions : high surface resistivity, ESD may occure

  Cold coatings thermo-optical properties + antistatic properties ?

  ↳ Loading coatings with conducting or semi-conducting fillers

<u>Limits of conventional composites</u>

- High loading ratio required
- Diffusion enhances absorption

<u>Expected benefits of nanocomposites</u>

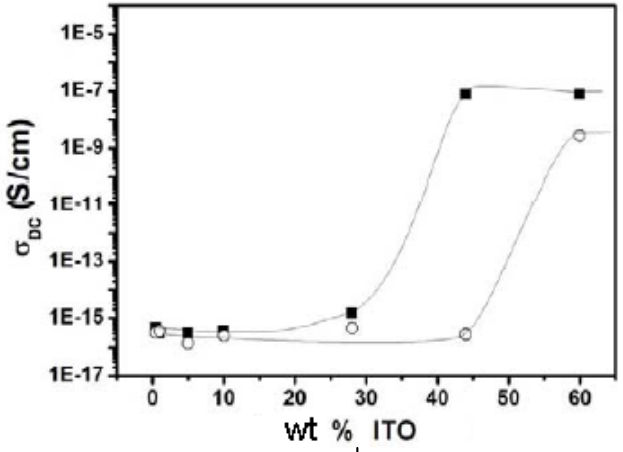
- Pseudo Tunnel effects
- Lower diffusion with decreasing size

(Rayleigh : $\frac{I}{I_0} = e^{-\left[\frac{3\phi_p x r^3}{4\lambda^4}\left(\frac{n_p}{n_m}-1\right)\right]}$)

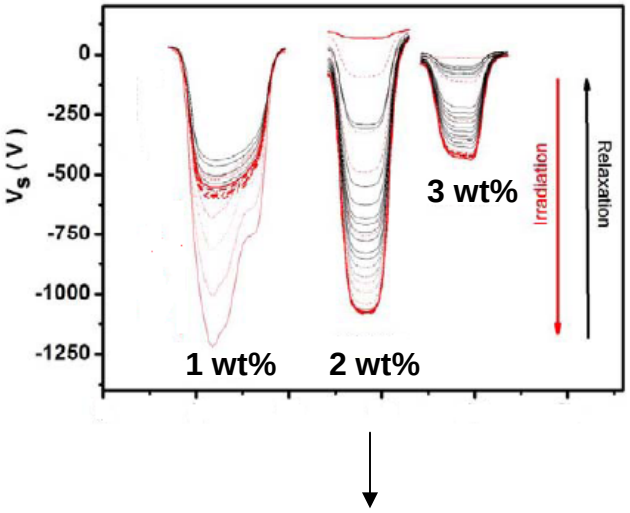
Multifonctionnal materials

J. Beigbeder, P. Nabarra, S. Rémaury, Centre National d'Etudes Spatiales

- Dispersion of nanofillers by sonication :
  - Carbon nanotubes : low content percolation (0,03 wt%), high α
  - Metal oxide nanoparticles : conductivity rises when submited to electron flow
    - ITO : $\alpha/\varepsilon < 0{,}25$ for 40 µm deposits while $\eta < 4$ wt %

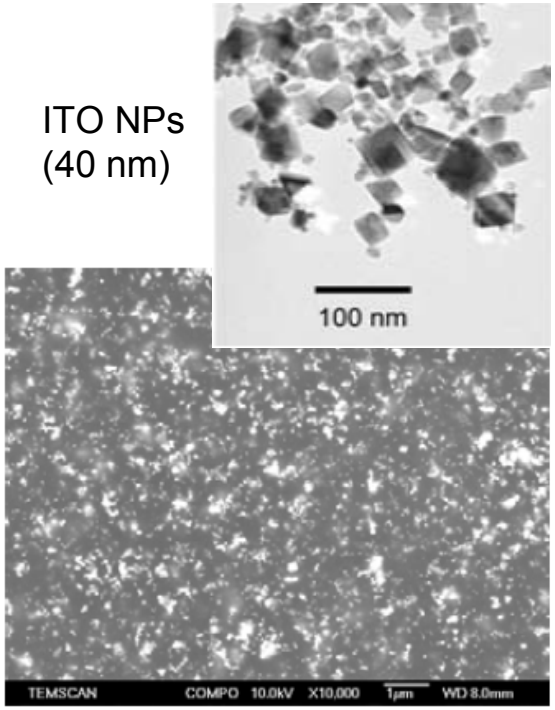


Isolating material
(Room Temperature, no irradiation)



$|V_s| < 500$ V for 3 wt%
Pass

ITO NPs
(40 nm)

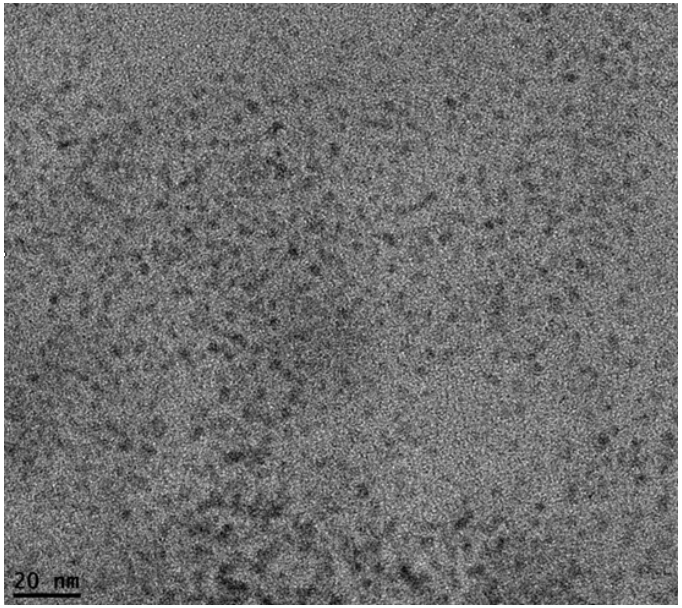


3 wt% ITO nanocomposite

Multifonctionnal materials

- Benefits withdrawn of the use of nanofillers
  - Induced conductivity under irradiation (doping process + percolation) at low filler contents
  - Conservation of thermo-optical properties fitting the application

- On-going : dispersion of ZnO nanoparticles using LCC methodology
  - improved dispersion
  - optical transparency
  - undergoing ESD tests



High Resolution Transmission Electron Micrography of a 80 nm thick slide of the composite

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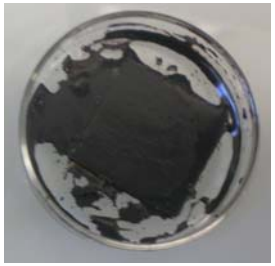
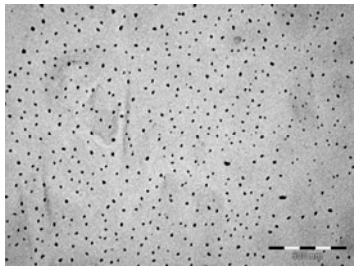
  - **Processability**
    - **RAM and EMI shielding materials**

Processability

- Colloïdal solutions : time stable solutions containing nanoparticles
  - Possibility to deposit thin layers of a wide variety of materials which are not soluble otherwise

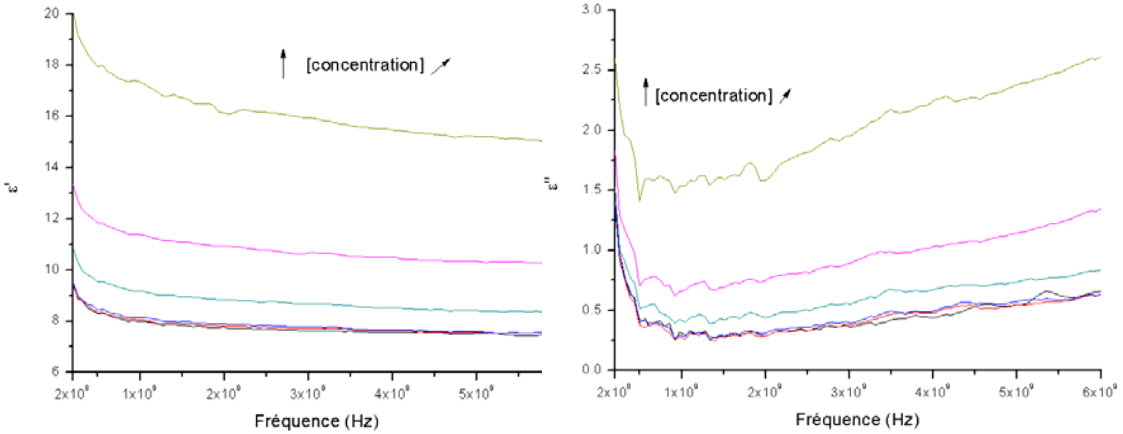


Deposition of an insoluble molecular conductor, σ_{DC}(nanodeposit) ~ σ_{DC} (powder)

  - Possibility to disperse homogeneously a material in a matrix and to control precisely its properties

Easy and precise tuning of a composite permittivity



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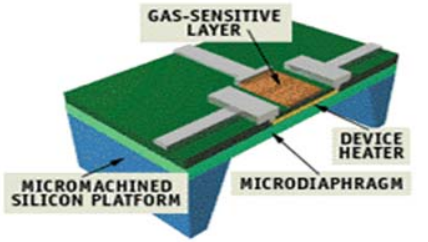
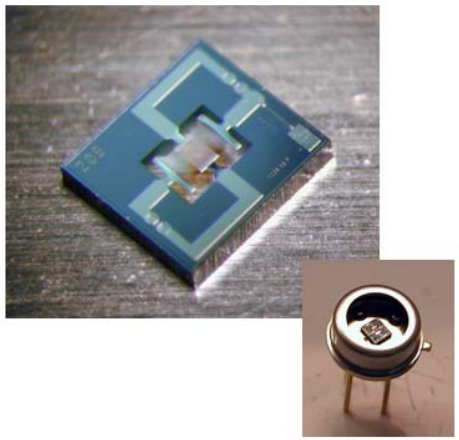
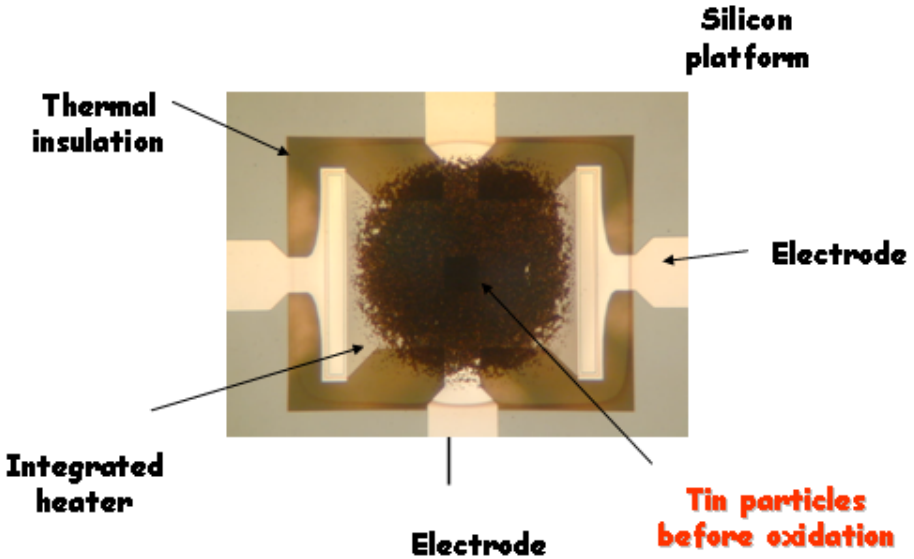
  - **Enhanced detection and life span**
    - **Gas sensors**

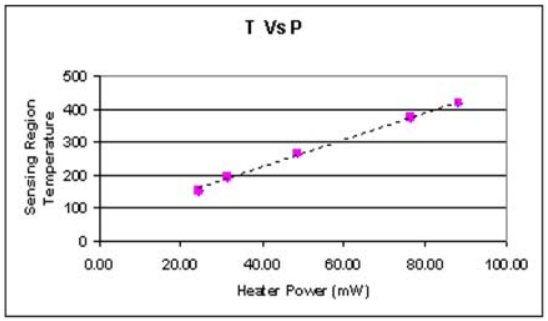
Sensibility and hardness

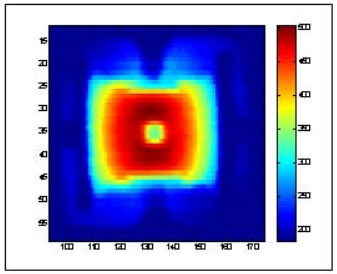
- Gas sensors devices :
  - Microhotplate architecture : micro-heater in a dielectric membrane







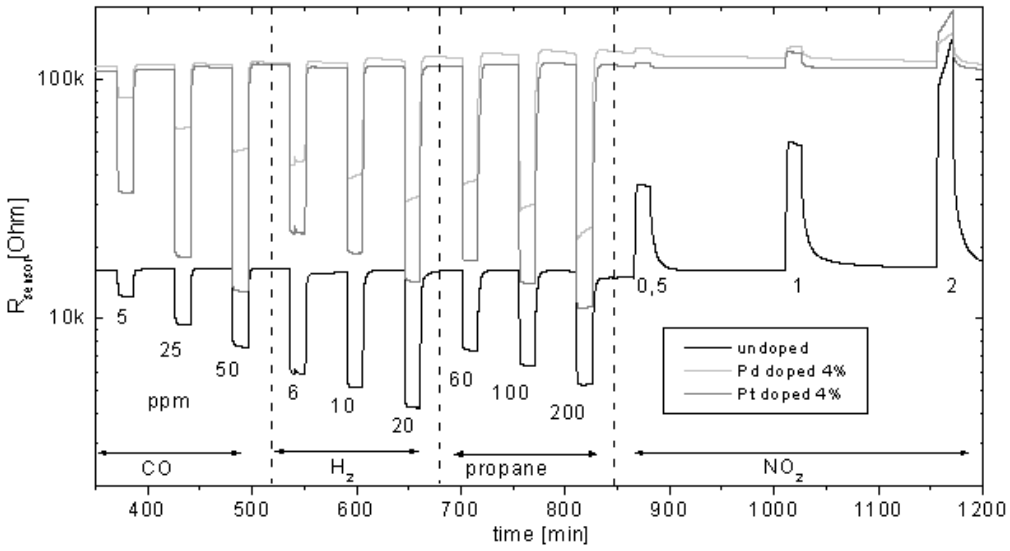


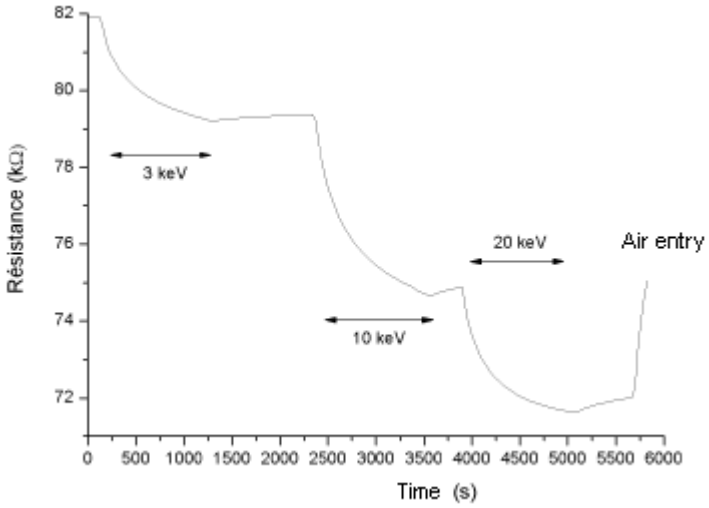


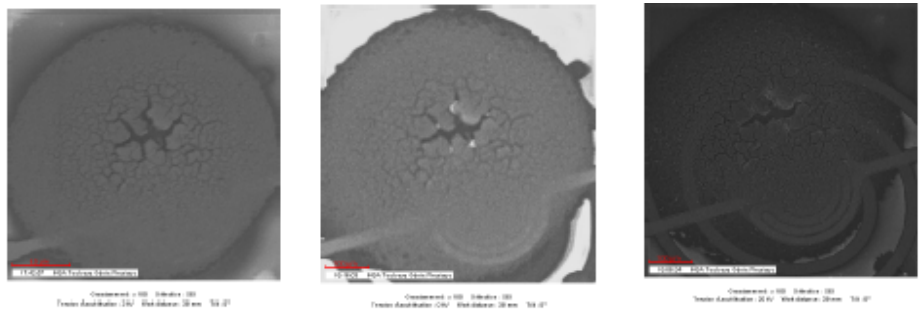
Sensibility and hardness

- Gas response of sensors
  - Quantitative
  - Selective
  - Long time stability

- Dose response of sensors





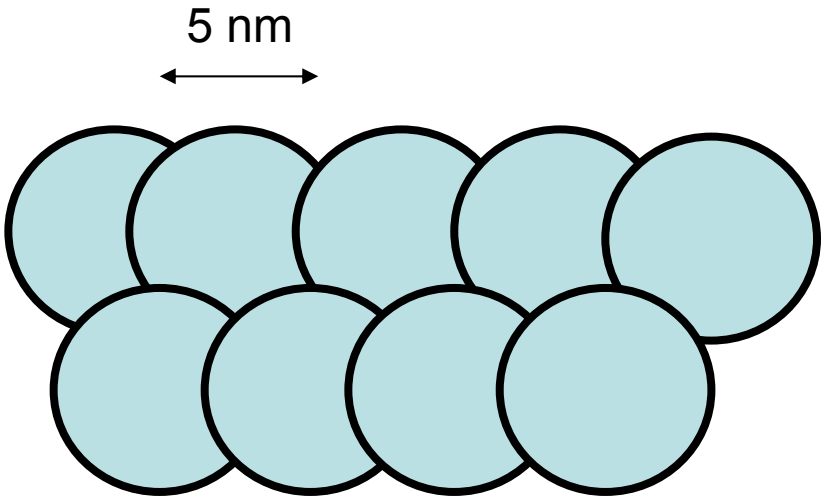


Reduction phenomenon under irradiation

Deposit morphology stable under irradiation

Sensibility and hardness

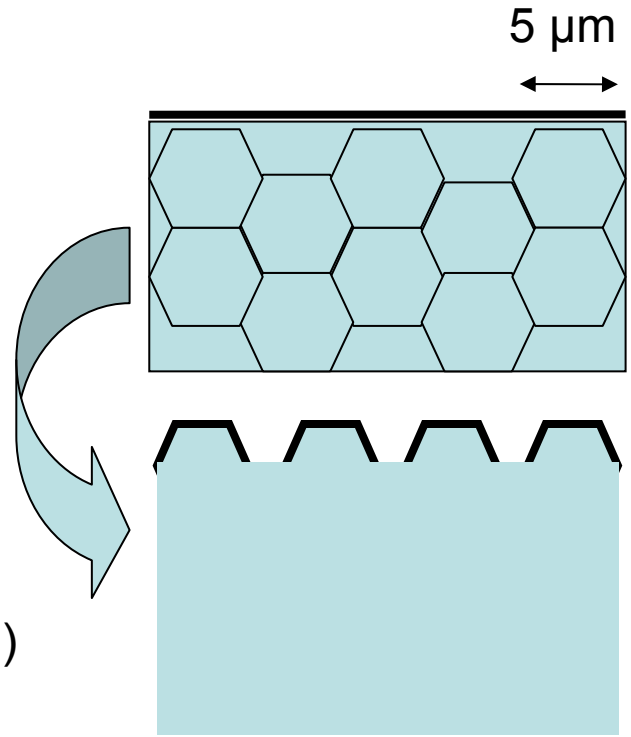
- Benefits in using nanoparticles deposits
  - Enhanced sensing due to higher surface area
  - Improved stability : assembly of nanosized monocristals



Interface stable upon heating and working

Heating and redox processes :

evolution of surface and properties (grains motion)

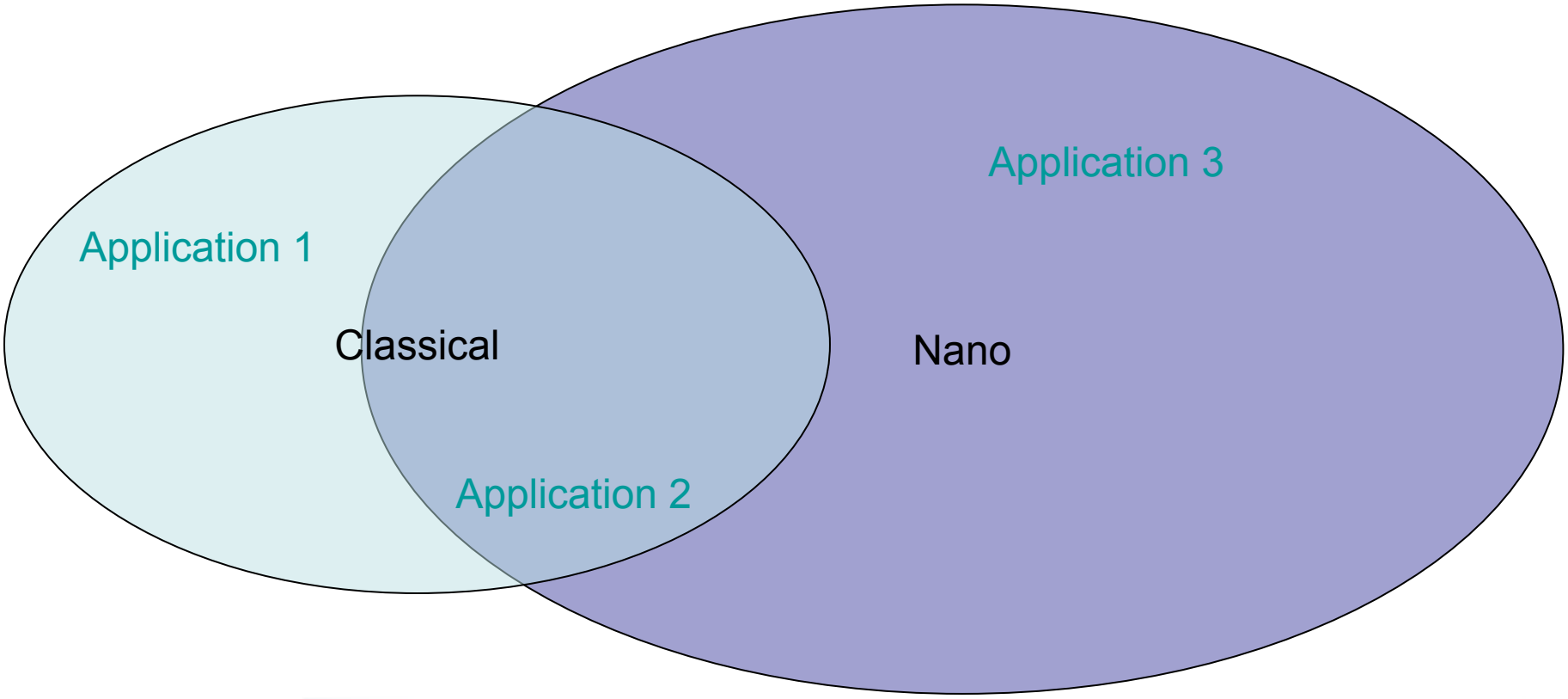


Conclusions

- Different technologic gaps associated with nanomaterials :
  - Processability of unsoluble materials as solutions
  - Access to a new class of composites with original and multiple properties
  - High surface area and hardness of nanostructured surfaces
- First applications for space technology :
  - Fruitful approach for multiple properties coatings, sensors

Conclusions

Different does not mean better : depending on specifications…



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