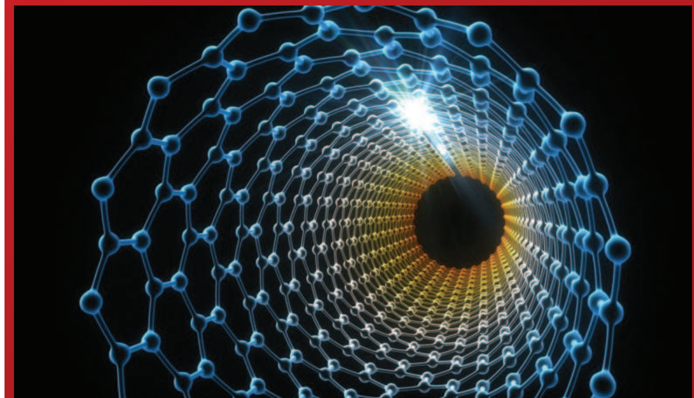
DE LA RECHERCHE À L'INDUSTRIE

nano SAFE'14

Nanoparticles properties & interest for industrial applications

Francois TARDIF, Olivier PONCELET and Pascal TIQUET

Univ. Grenoble Alpes, PNS, CEA, France



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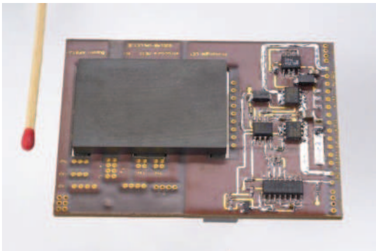
NANOTECHNOLOGIES: MATERIALS VS DEVICES

Nanotechnologies

Nano-devices

Micro-nano electronics

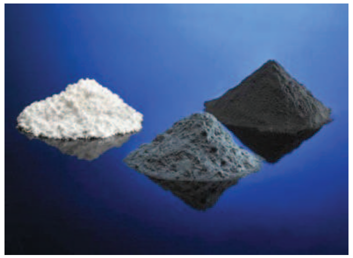


Nanorobots

Societal concerns: individual freedom, transhumanism

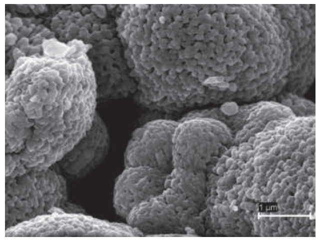
Nano-materials

Nano-powders



Nano-colloids

Nanostructured materials



Health concerns: nano toxicity

NANOMATERIALS: HISTORY

- 1959 : Richard Feynmann « There's Plenty Room at the Bottom »
- 1974 : Norio Tamiguchi invent the word « Nanotechnology »

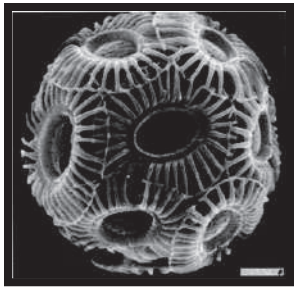
- 1982-1988 : K. Eric Drexler creates the concept of the bottom-up nanotechnologies and invent the «molecular nanomaterials »

- 1981 : Gerd Bining and Henrich Roher invent the Scanning Tunneling Microscope (STM)
- 1991 : Invention of the Carbon Nanotubes (CNT) by Bethune et Sumio Ligima

NANOMATERIALS: WHAT'S NEW?

- Mother nature fabricate nanoparticles e.g.:
  Aerosols in the air >10 nm: 10,000/cm^3

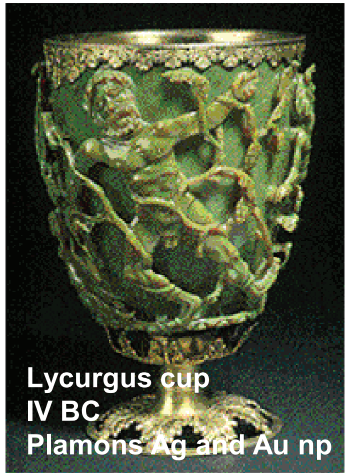
- The living synthesizes nano structured materials e.g.:



  - the bones
  - mother of pearl
  - wood
  - skeletons of micro-organisms

- Many industrial materials nano before we call nano e.g.:

  - Gold nanoparticles (plasmon) in stained glass
  - Silver nano particules for coloration
  - Titanium oxide in paints
  - Alumina for neons, paints
  - Silver for B&W photography
  - Etc.



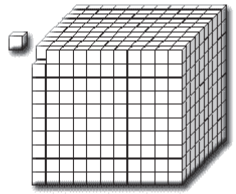
New: access to sophisticated nanostructured materials available at industrial scale

NANOMATERIALS: WHAT INTEREST?

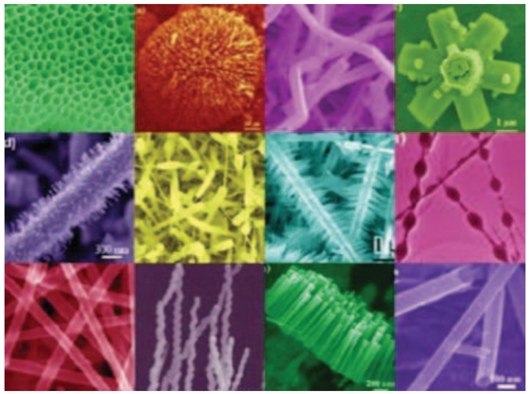
1. The <u>raw material more efficient</u>: the earth natural resources shared by the largest number of people

✓ The ratio surface/volume increases in 1/R when the particle radius decreases:

➔ Chemical reactivity, catalyze



✓ When assembling very small elementary units (nano crystallites: nanoparticles) we can use the minimum quantity of matter necessary to ensure the function like mother Nature does



ZnS

NANOMATERIALS: WHAT INTEREST?

2. Incremental improvement of some particular properties:

Optical properties

- ✓ **Lighting** (nano phosphors)
- ✓ **Coloration** (interferential, plasmon, etc.)
- ✓ **Authentication** (nanotag)
- ✓ **Anti-UV,** etc.

Surface properties

- ✓ **Barrier properties**
- ✓ **Functionalized surfaces**
  - Hardness
  - Gloss
  - Self cleaning
  - Anti-bacterial

Thermal properties

- ✓ **Thermal conduction** (liquid and polymers)
- ✓ **Phase shift materials**
- ✓ **Thermal insulation**

Electrical properties

- ✓ **Charge dissipation** (varnish, polymer)
- ✓ **Electrical conduction**
  - Polymers
  - Power cables (CNT
  - Transparent conductive film (TCO)

Catalysis

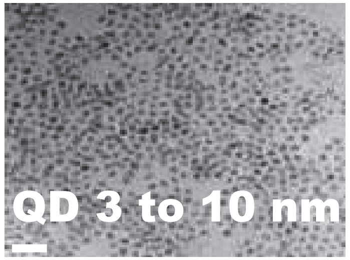
- ✓ **Chemical conversion**
- ✓ **Air purification, exhaust pipes**

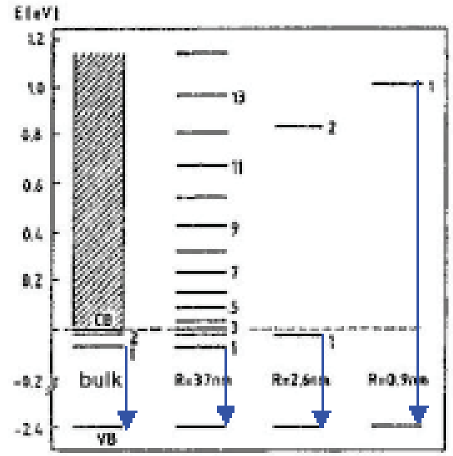
NANOMATERIALS: WHAT INTERESTS?

3. New properties and applications (nano enabled products):

- **Due to small size**
  - . **Transparency** (< 60 nm) : active materials invisible even theoretically when using thick thickness (cm, m) e.g. aerogel
  - . Insertion of active fillers **without any mechanical modification of the matrix**
  - . **Process-ability** of materials by inkjet (nozzle sizes)
  - . **Quantum effects:** light absorption and emission (super network, nanowires, quantum dots, plasmon effects, interferences)

1 material (CdTe), continuous adjustable colors according to the size

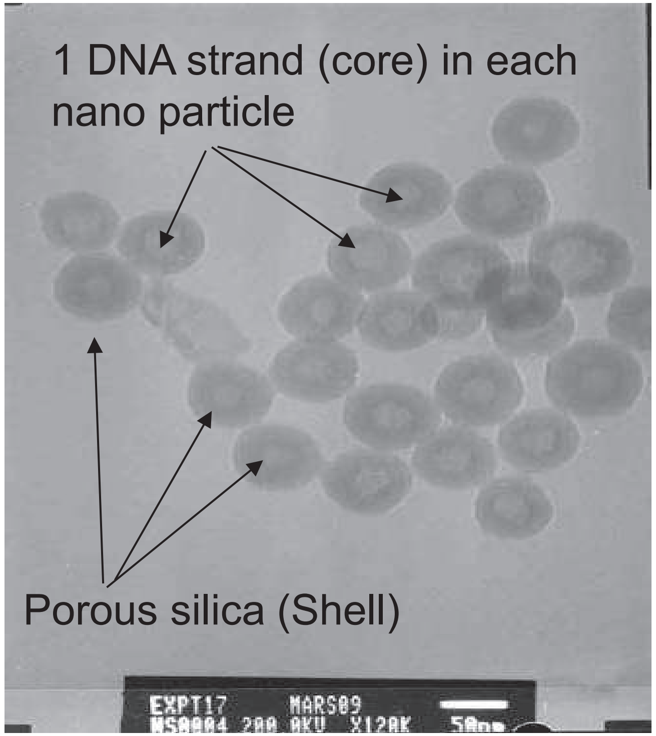


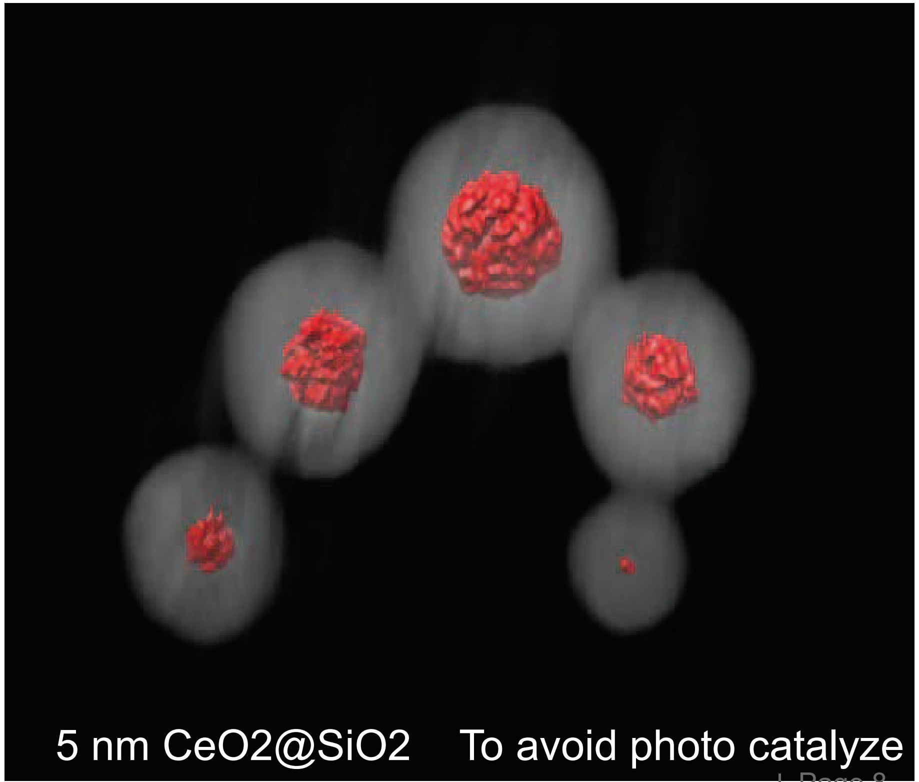


Discrétisation des niveaux d'énergie en fonction de la taille dans CdS

NANOMATERIALS: WHAT INTERESTS?

- **Possibility to embed molecules or other nano particles in nanoparticles <u>(core/shell)</u>**
  - . Chemical compatibilization organic/aqueous
  - . UV, temperature, chemicals - resistant
  - . Selective drug delivery
  - . Smart particles e.g. sensors, release of chemicals according to temperature



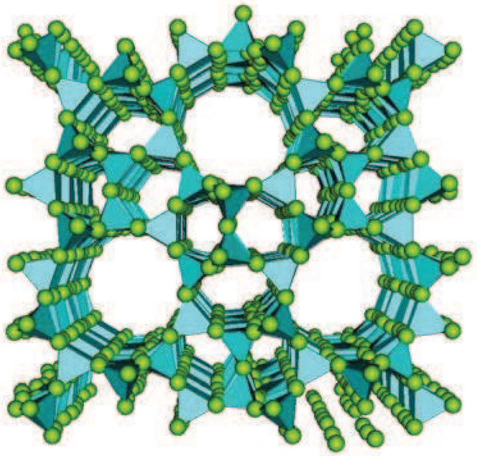


NANOMATERIALS: WHAT IT LOOKS LIKE?

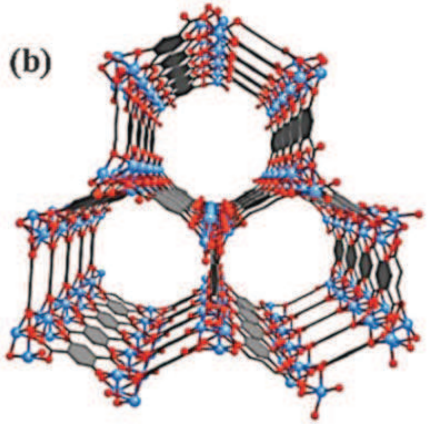
Large specific area

Nanoporous, mesoporous, hollow

Ex. CO_2 storage



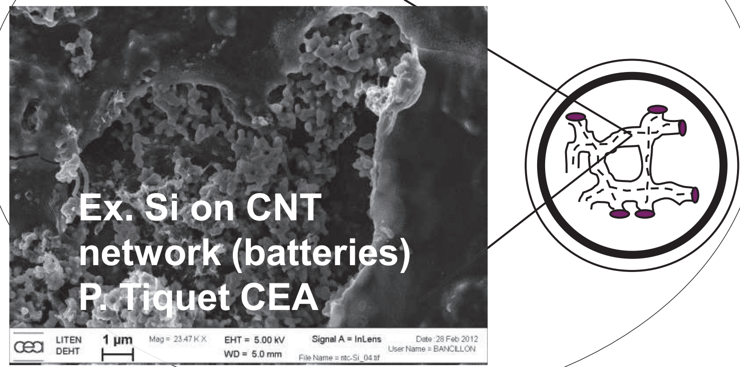
Zeolite



Metal Organic Framework

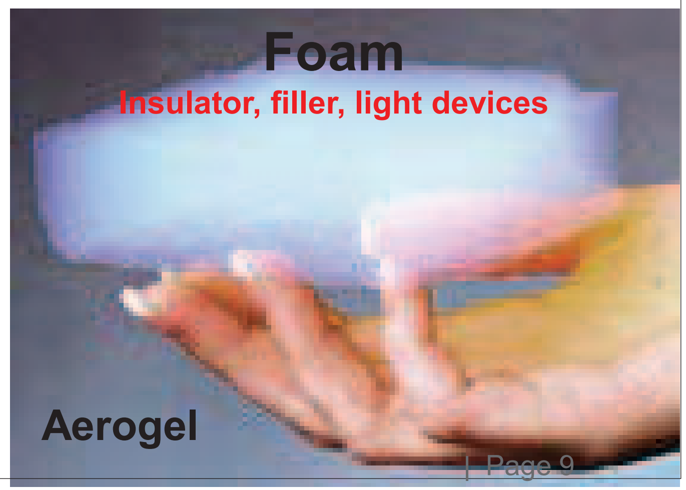
Skeleton

To maintain, to connect electrically, etc.



Foam

Insulator, filler, light devices

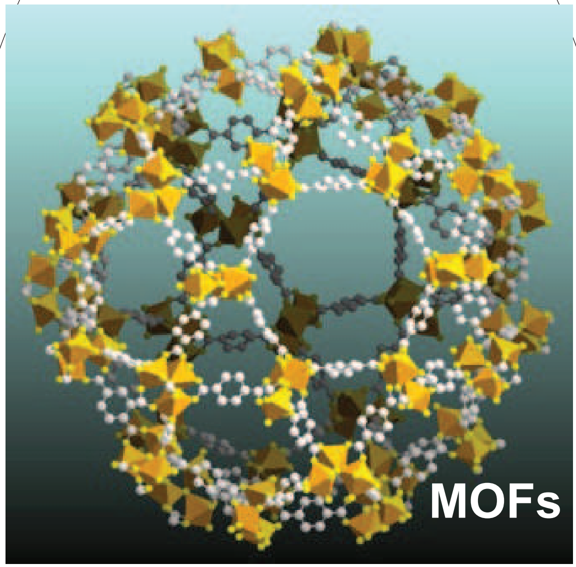


Aerogel

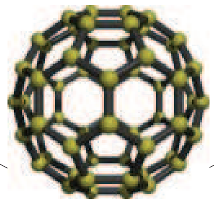
NANOMATERIALS: WHAT IT LOOKS LIKE?

Cage

To confine, release atoms , molecules, etc.

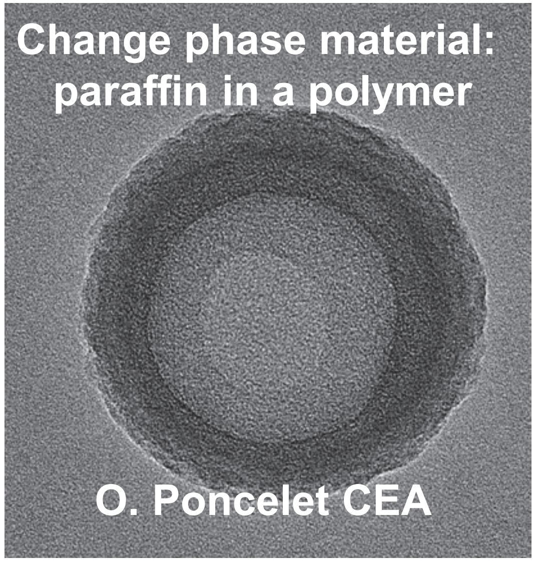


C60

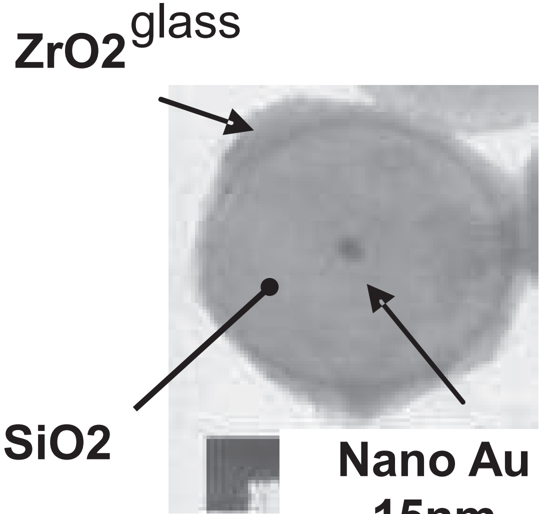


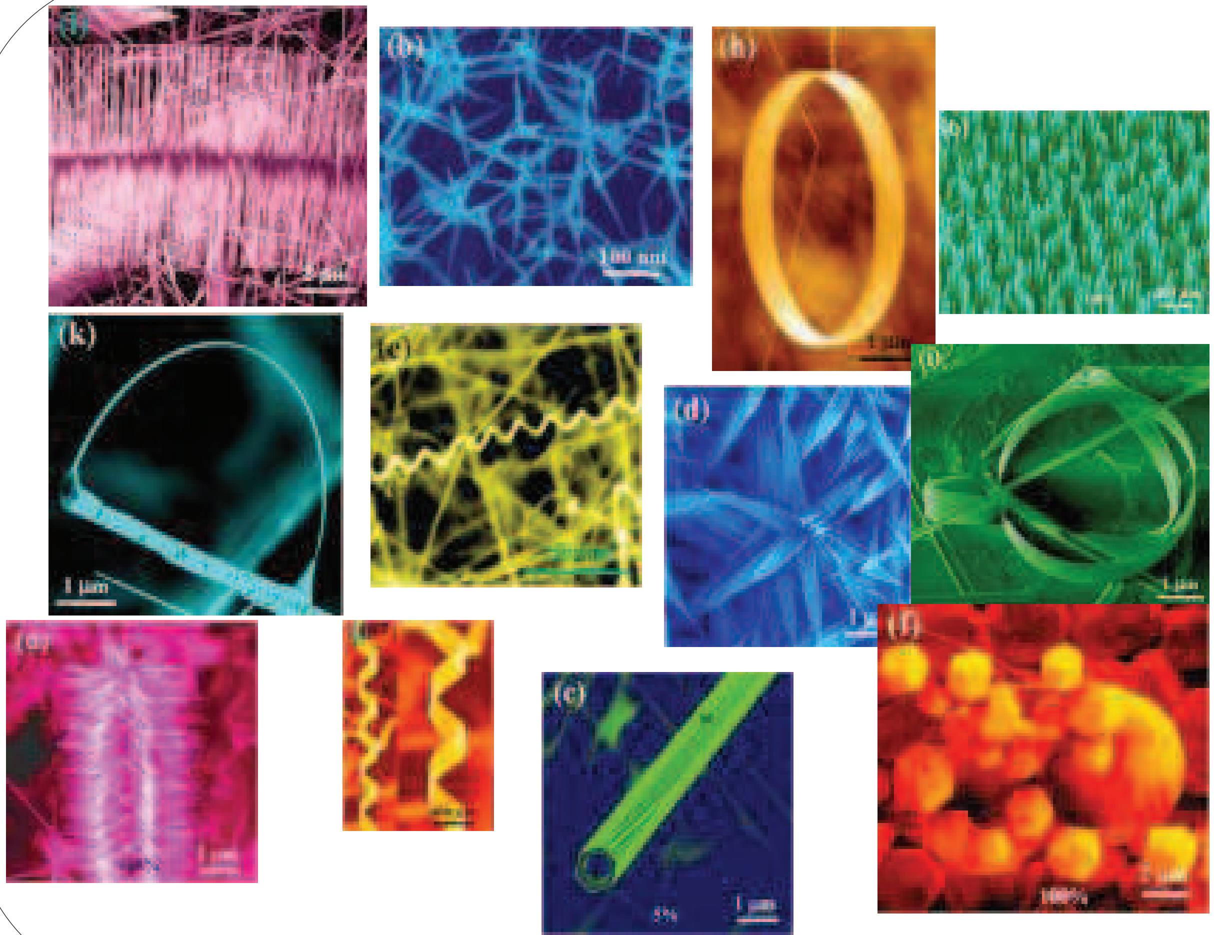
Core/Shell

To protect (°C, chemicals, mechanical, UV, etc.)



Plasmon nano gold for coloration in cristal glass





Complex shape

Specific properties due to the shape: Electrical, thermal, optical, mechanical, etc.

Nano-ZnO: One chemistry, many shapes, Courtesy of Prof. Z.L. Wang, Georgia Tech

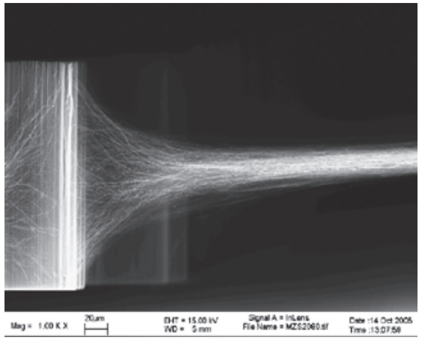
NANOMATERIALS: WHAT IT LOOKS LIKE?

Novel properties, transparency, impression, protection, compatibilization, matter efficiency, etc.

Fibers

To maintain (composites, wearing), to conduct heat, electricity, etc.

CNT



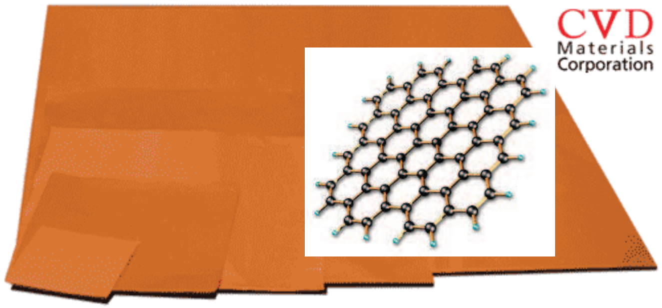
Starting from a carpet of CNT: electrical conductor lightweight without Cu (mm)

Nano fibers of cellulose amorphous + crystalline

Cellulose whiskers L > µm

Single leafs

Transparent Conductive Layers, Surface passivation, sealing, etc.

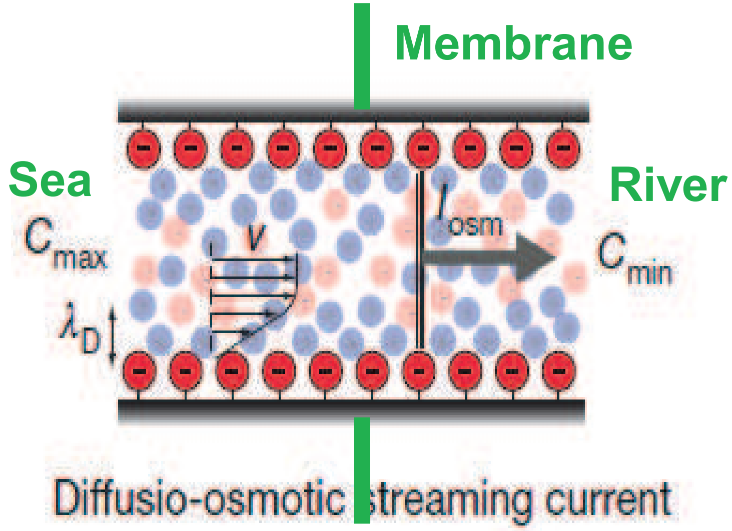


Passivation of a Cu sheet with one monolayer of graphene

Tubes

Molecular filters, reinforcement, osmotic energy harvesting, etc.

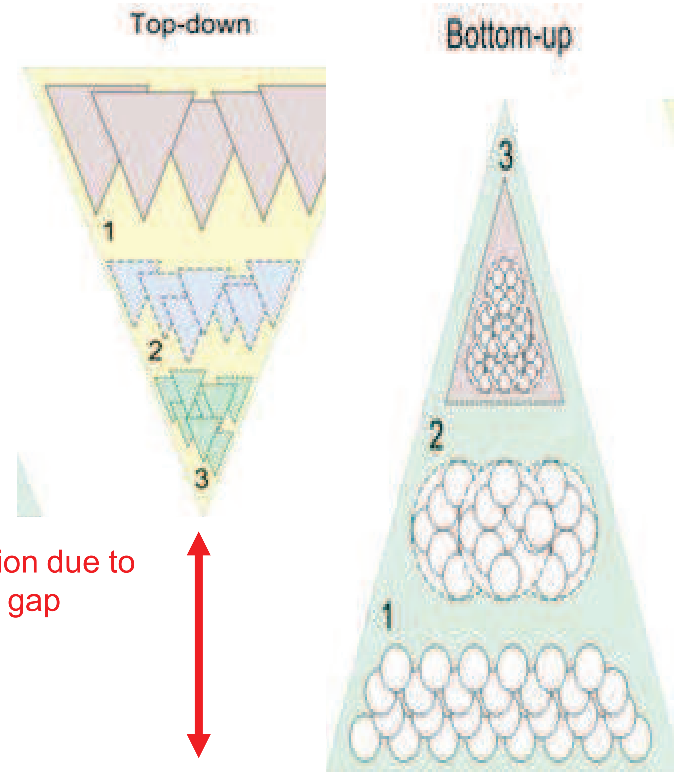
Imogolite (silico aluminates) tubes for energy storage or bumper (CEA)



Selective membrane: using BN nanotubes
L. Boquet et al.

Nanoparticles: how it is fabricated?

Two approaches: Bottom-Up and Top-Down



Limitation due to energy gap

Two process types: Physical and chemical routes

Milling
(Top-down)

Pyrolyse
(Bottom up)

Réacteur de pyrolyse pour la synthèse des poudres céramiques

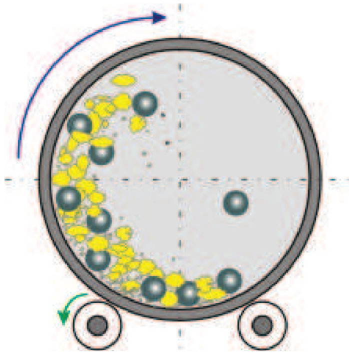
Soft chemistry:
(Bottom up)

Nanoparticles: how it is fabricated?

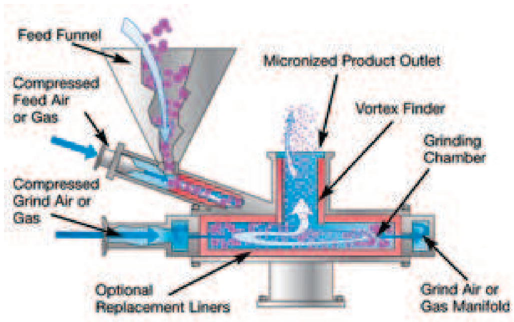
Examples:

Physical route

Milling

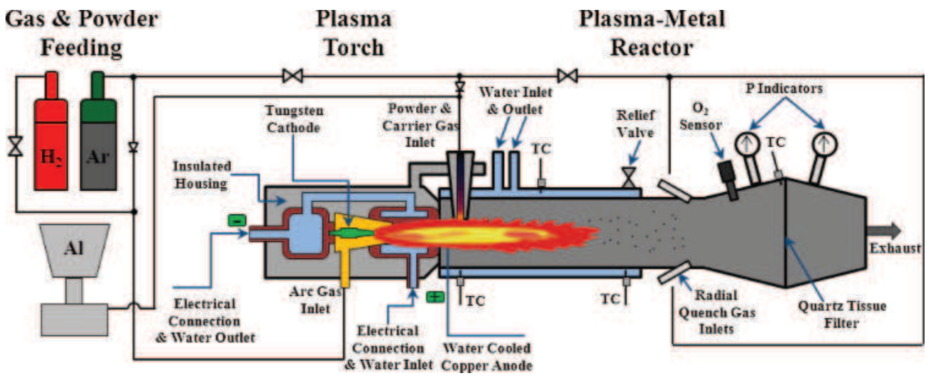


Ball milling



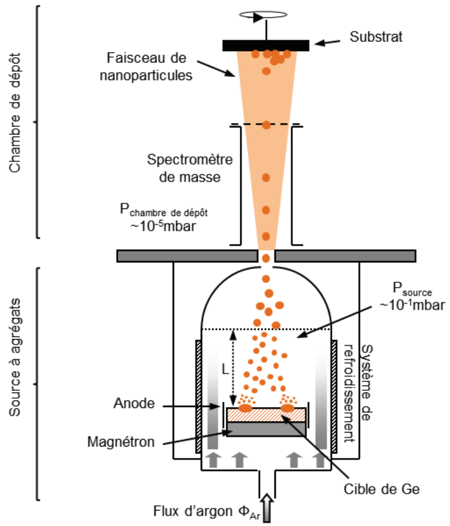
Jet milling

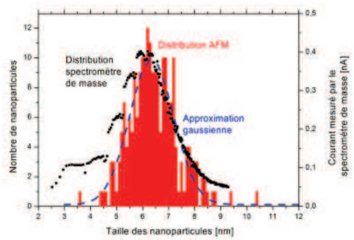
Plasma reactor (flame, laser pyrolysis: same)



Nano aggregats

PVD gas condensation nanocluster source





Nano colloids synthesis

Chemical route

Supercritical H2O reactor CEA

Solgel deposition

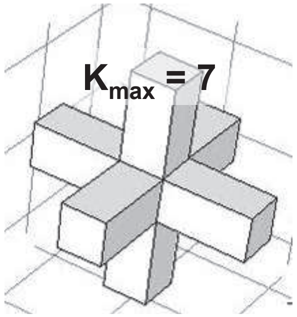
Continuous double cavity micro waves reactor CEA

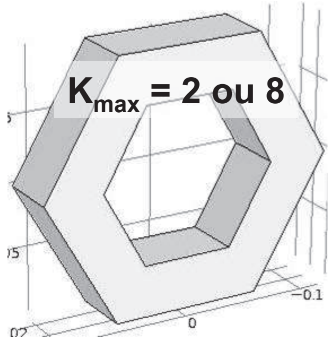
Few examples of promising applications

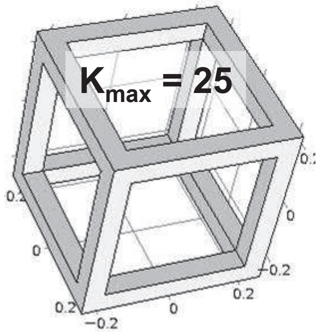
BREAKTHROUGH MATERIALS FOR THERMAL CONDUCTIVITY
"Nanofluids"

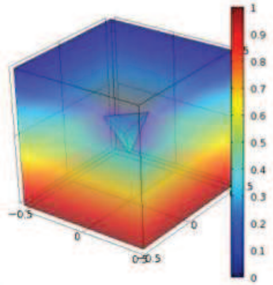
Cooling fluids for cars (lower consumption), solar plants, etc.

From modeling to material by design

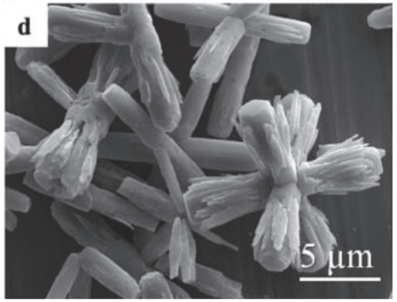




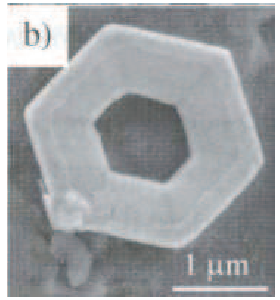




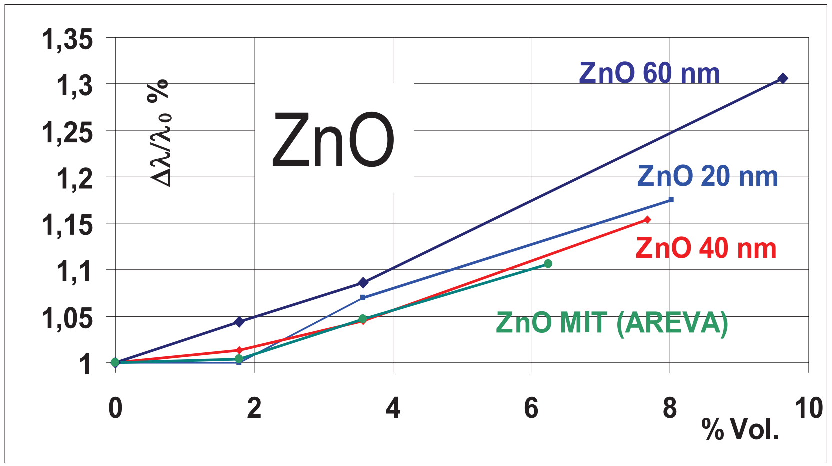
L. Zhang, Y.J. Zhu, Applied Physics A, 97, 2009



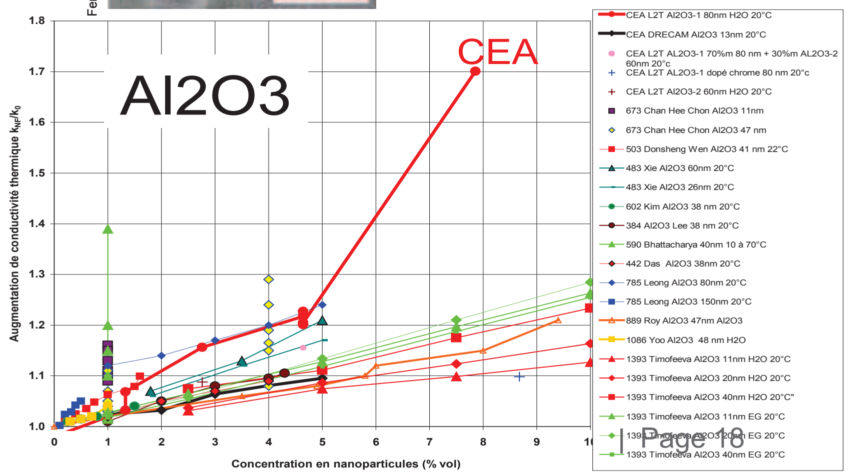
Feng li and coll., Angew. Chem. Int. Ed. 2004, 43,5228



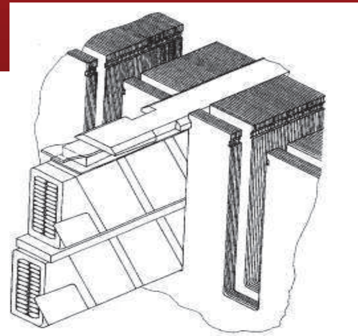
Help, anyone an idea??



CEA



BREAKTHROUGH MATERIALS FOR THERMAL CONDUCTIVITY
"Nanosolids"

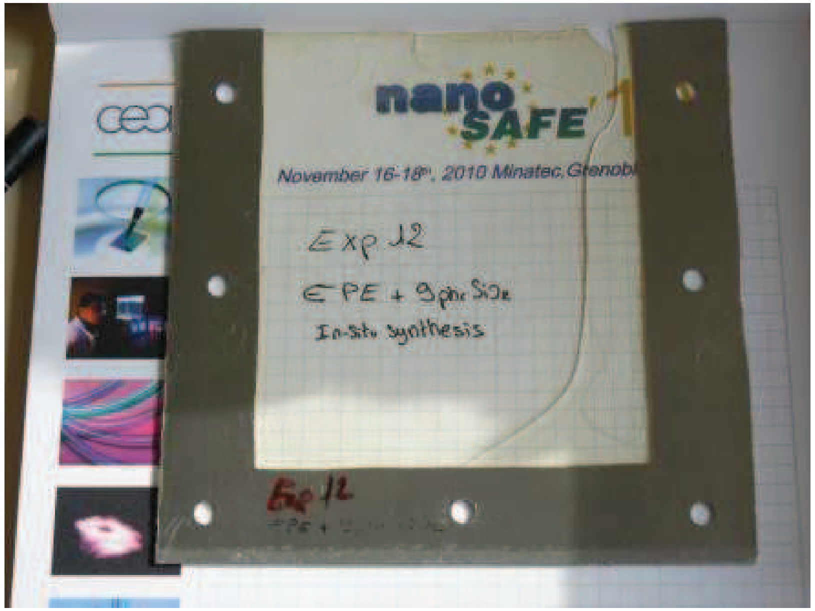


Insulator polymers for high voltage transformers, electrical motors, etc.

Perfect dispersion as a prerequisite to avoid any electrical breakdown

↓

In-situ synthesis of SiO_2 nanoparticles in the polymer (epoxy) to avoid any aggregates (CEA)



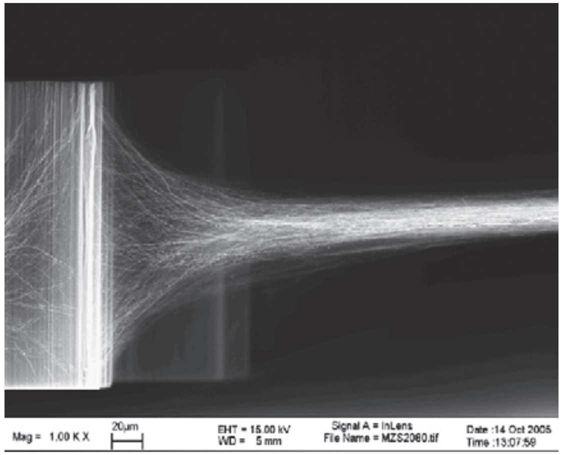
Thermal conductivity x 4
0.11 ➔ 0.48 m^2/s

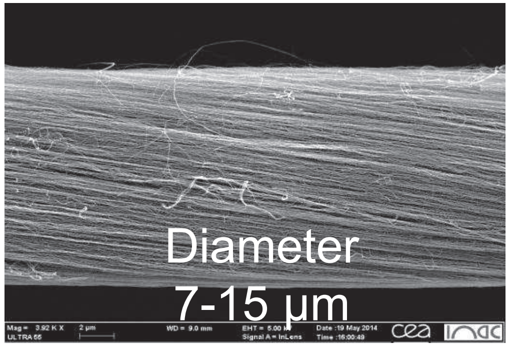
Perfectly transparent = perfectly dispersed

"Power cable of CNT"

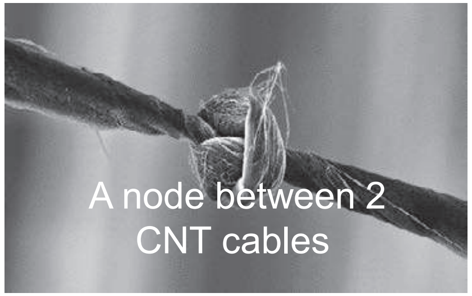
Electrical cables made of CNT to save Cu and energy for transportation (lightweight)

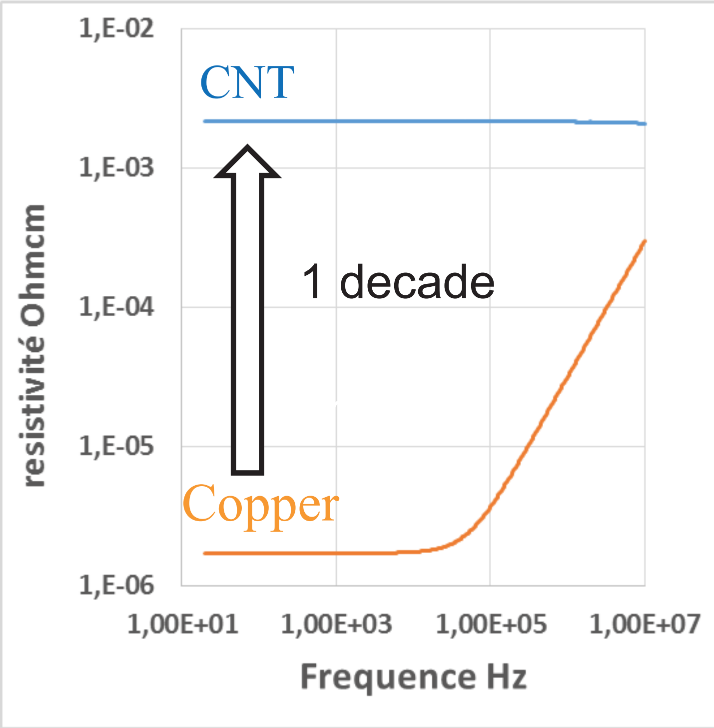
Spinning from a carpet of 1 µm long CNT





A simple connection!

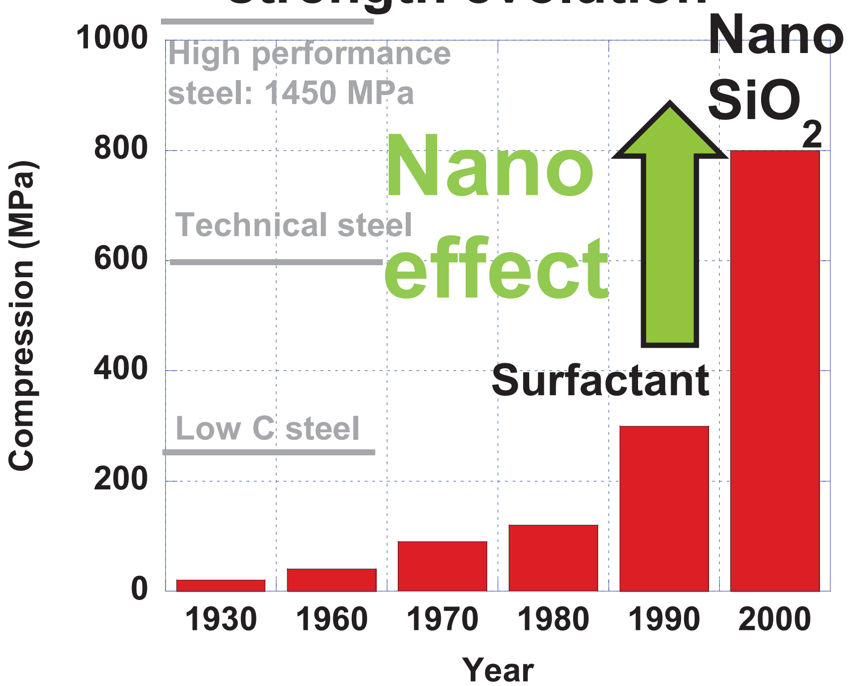




"Ultra high performance concrete"

Use of colloidal silica nanoparticles to fill up the inter-granular space (industrial by product)

Concrete compressive strength evolution



Density < 1/3 steel
Cost : < 1/10 steel

From A. Feylessoufi et al.

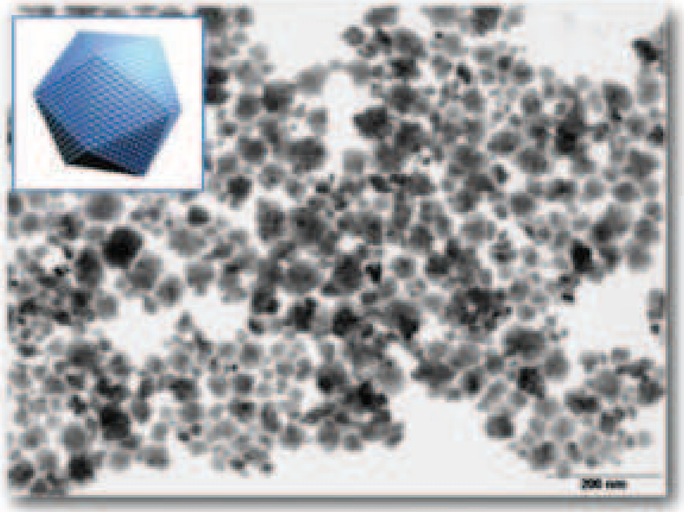
Roman concrete (pouzzoles)

2 000 years

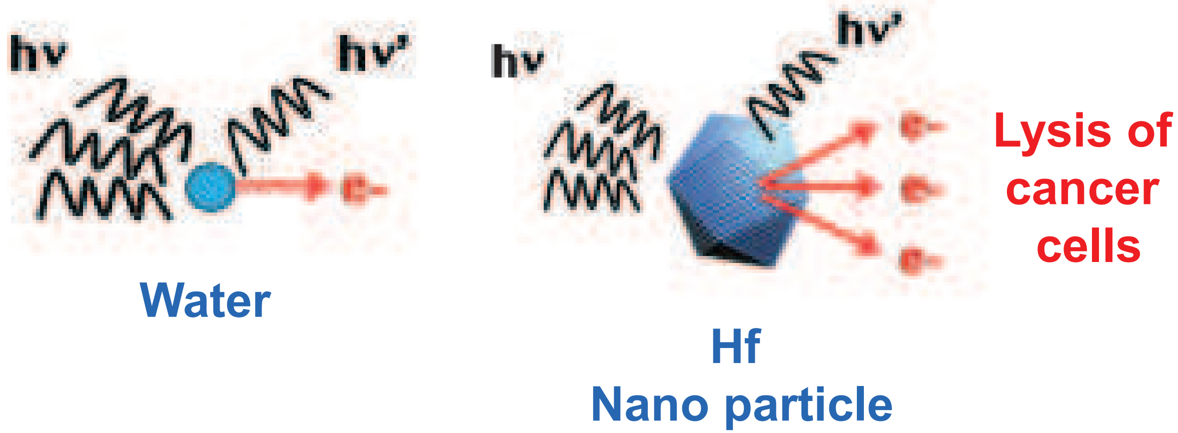
Ultra high performance concrete

"Selective radiotherapy"

Use of functionalized 50 nm Hf nanoparticles (high electron density)



1. The nanoparticles concentrate close to cancer cells thanks to the functionalization
2. The nanoparticles generate locally higher dose of active electrons able to destroy the sick cells when activated with X-rays



CONCLUSION

- Nanomaterials offer large possibilities of "real" improvement for humanity both for conventional products and brand new applications

- This is the responsibility and the exciting challenge of the Nanosafety community to bring data for the sustainable development of nanomaterials

Session 1:

Presentation of session 1:
New applications of nanomaterials

11:45-12:00 Nanoparticles: potential additives for sustainable **lubrication** Fabrice Dassenoy (Ecole Centrale de Lyon – Laboratoire de Tribologie et Dynamique des Systèmes, France)

12:00-12:15 Prospects and potential safety implications of nanoformulation of **agrochemicals in crops** production Cui Haixin, X. Zhao (Institute of Environment and Sustainable Development in Agriculture, The Chinese Academy of Agricultural Sciences, China)

12:15-12:30 Nanomaterials as a **New Approach to Fire,** Fiona Hewitt, D. Suleiman Eid Rbehat, A. Witkowski, A. Stec and T.R. Hull (University of Central Lancashire, U.K)

12:30-12:45 **Super-strong nano-composite materials** for bunker & command post in army Dalvinder Singh Grewal (Desh Bhagat University)

12:45-13:00 The in vivo activation of persistent **nanophosphors for optical imaging** of vascularization, tumours and grafted cells, Cyrille Richard, T. Maldiney , A. Bessière, J .Seguin, E.Teston, SK. Sharma, B. Viana, AJ. Bos, P. Dorenbos, M. Bessodes, D. Gourier, D. Scherman (Université Paris- Descartes, France)

Session 1:

Presentation of session 1:
New applications of nanomaterials

Afternoon: room B   Chairman: Olivier Poncelet (CEA PNS)

14:45-15:00 Exploration of Activation Energy and Electrical Applications of Synthesized Al Doped ZnO Nanomaterials as **Humidity/Gas Nanosensors,** Misra Suneet Kumar, N.K. Pandey and V. Shakya (Sensors and Materials Research Laboratory, University of Lucknow, India)

15:00-15:15 Application of carbon nano-tubes (CNTs)/alkyd resin composites as **anticorrosive coating** M. A Deyab (Egyptian Petroleum Research Institute, EPRI, Egypt)

15:15-15:30 In vivo study of novel nanocomposite for **prostate cancer treatment** Camila Silveira, A. J. Paula, L. M. Apolinário, W. J. Fávaro, N. Durán (Chemistry Institute, UNICAMP, Brazil)

15:30-15:45 Preparation, characterization and tests of incorporation in stem cells of **superparamagnetic iron oxide,** Haddad Paula, T.N. Britos, L. Min Li, L. D´Souza Li (Exact and Earth Sciences Department, Universidade Federal de São Paulo, Brazil)

+ many other very interesting presentations at the poster session!