

# Nanomateriales

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# INTRODUCCIÓN

A Nano-scale overview

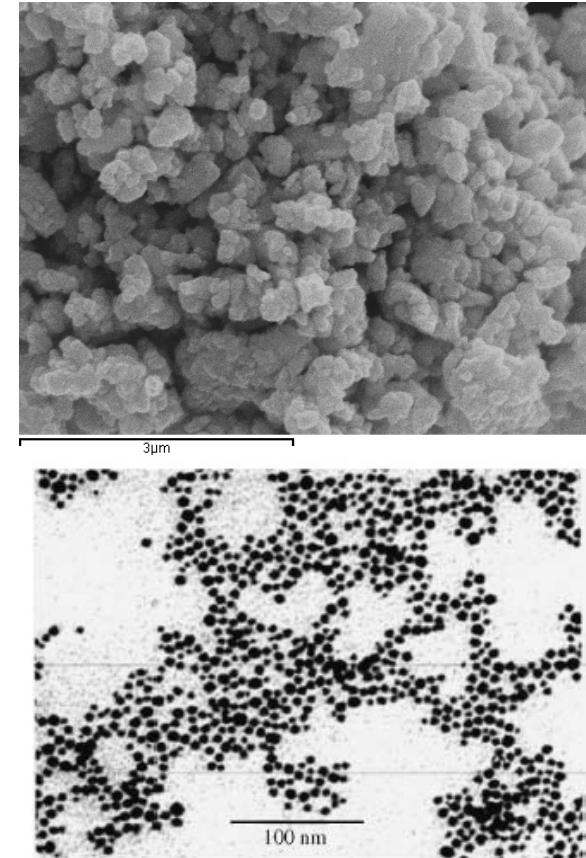
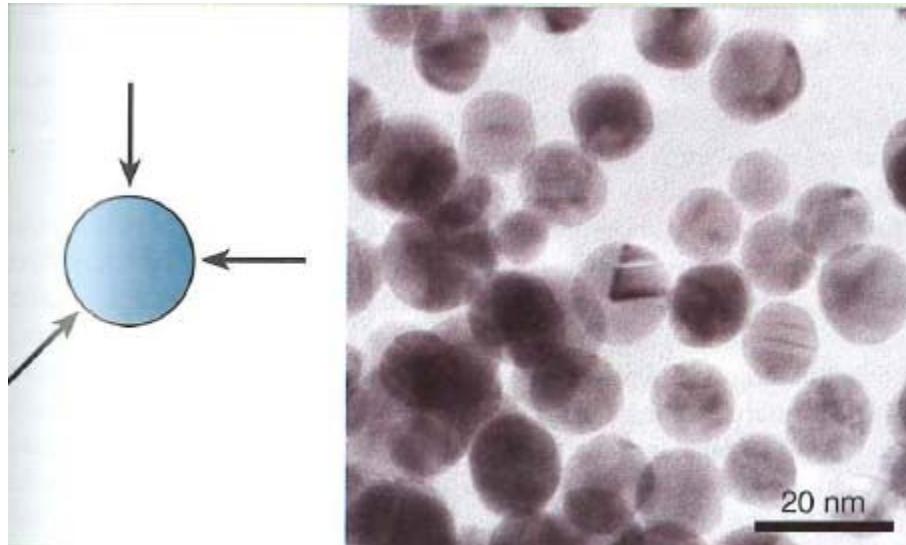
Scale	typical elements
<b>1 m</b>	1 m is 1.000.000.000 nanometers ( $10^9$ nm )
<b>200 µm</b>	About the size of the smallest letters you can write with a very very sharp pencil and a very very steady hand.
<b>100 µm</b>	Typical thick hair
<b>10-1000 µm</b>	Cells in living organisms can have many sizes, and neurons can be much longer. In frog embryos (Tadpoles) the initial embryo cells can be up to 1000µm.
<b>8 µm</b>	Red blood cell
<b>1 µm</b>	Bacteria
<b>100 nm</b>	Virus
<b>5-100 nm</b>	The range for nanotechnology systems built from atomic/molecular components (quantum dots, nanoparticles, diameter of nanotubes and nanowires, lipid membranes, nanopores...).
<b>10 nm</b>	Size of typical Antibody molecules in living organisms immune defence
<b>6-10 nm</b>	Thickness of a cell membrane, and typical pore size in membrane.
<b>2.5 nm</b>	The width of DNA (but it depends on the conditions)
<b>1 nm</b>	The size of a C60 buckyball molecule or glucose molecule.
<b>0.3 nm</b>	The size of a water molecule.
<b>1 Å = 0.1 nm</b>	Roughly the size of hydrogen atom.
<b>0.7 Å = 70 pm</b>	The best resolution in AFM achieved so far where they managed to image individual orbitals in an atom.

- Distances between objects can be measured with sub Å precision with STM, laser interferometry and its even done continuously in a standard airbag acceleration sensor chip that costs a few dollars and senses the vibrations of a micro-inertial mass element with femtometer precision ( $10^{-15}$  m).



# TIPOS DE NANOMATERIALES

## Partículas

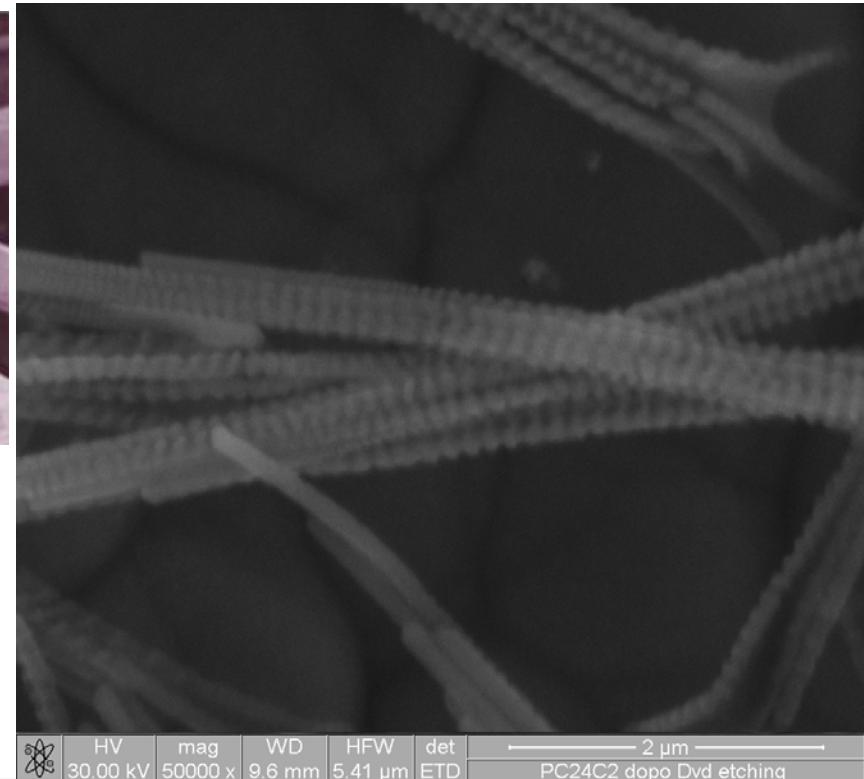
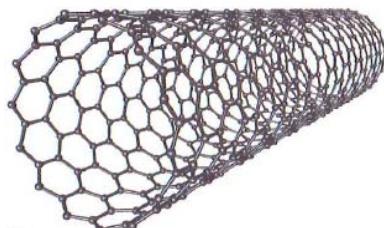
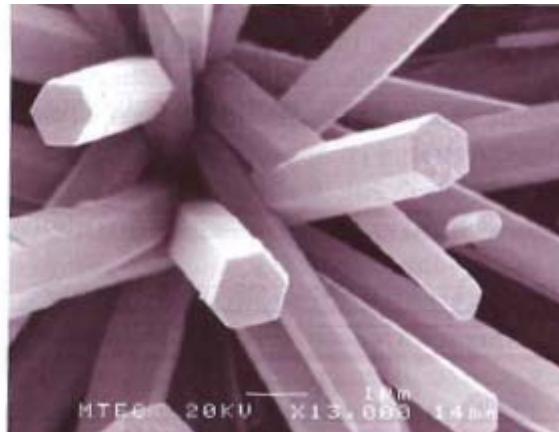
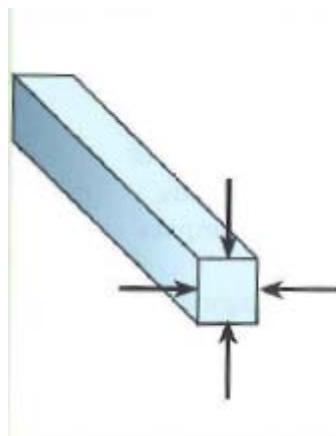


**Figure 1.1.2**  
Transmission electron microscope picture of gold nanoparticles.



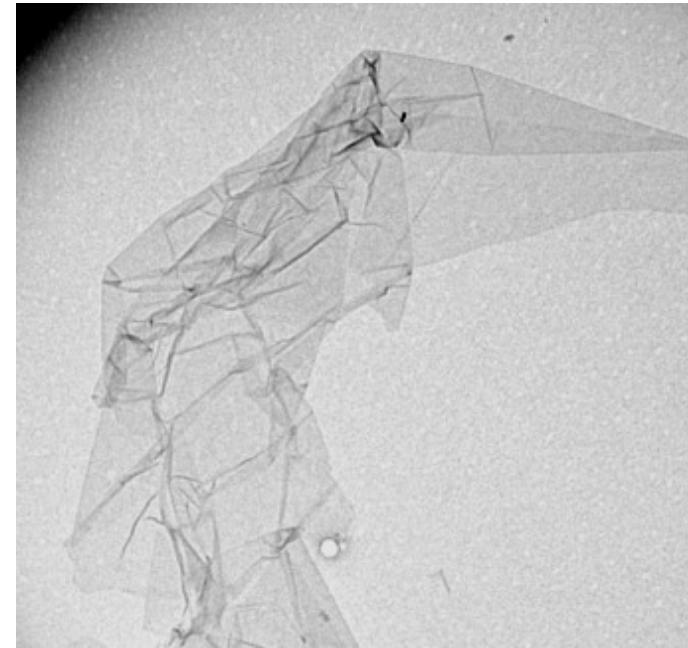
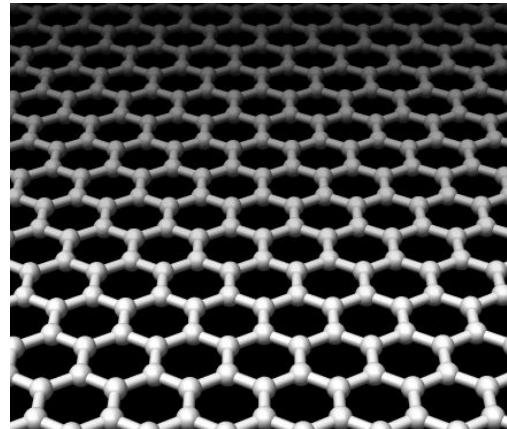
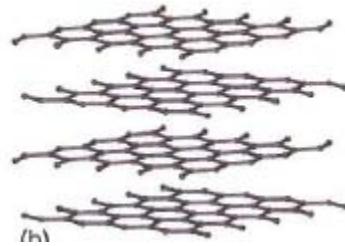
# TIPOS DE NANOMATERIALES

## Monodimensionales



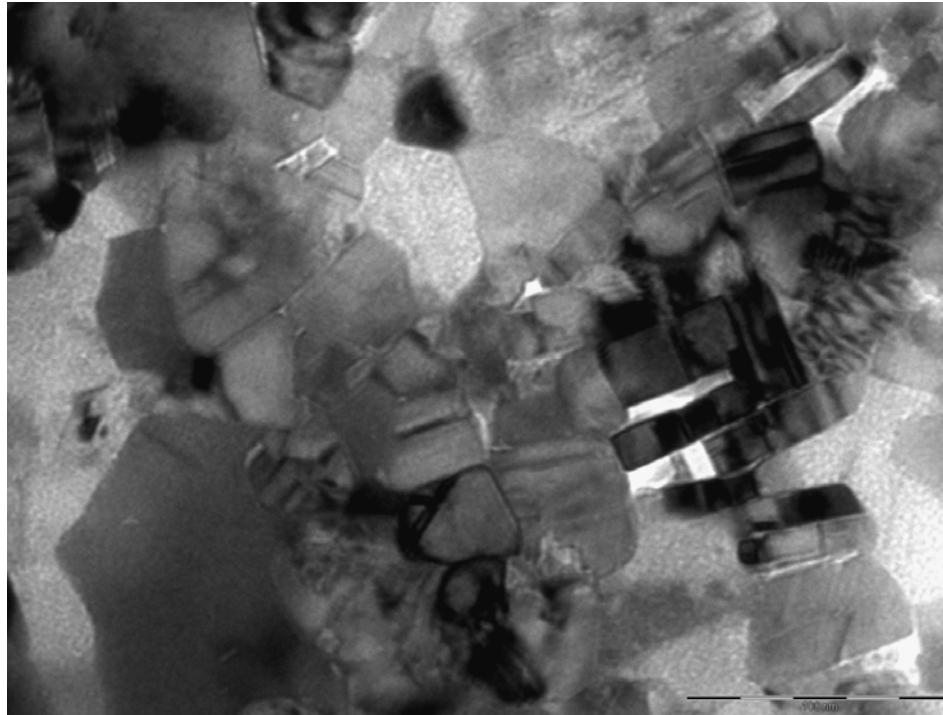
# TIPOS DE NANOMATERIALES

## Bidimensionales



# TIPOS DE NANOMATERIALES

## Tridimensionales



# ¿POR QUÉ TAN ESPECIALES?

## Features of nanoparticles:

*As materials are micronized, they tend to be affected by the behavior of atoms or the molecules themselves and to show different properties from those of the bulk solid of the same material.*

**It is attributable to the change of the bonding state of the atoms or the molecules constructing the particles.**

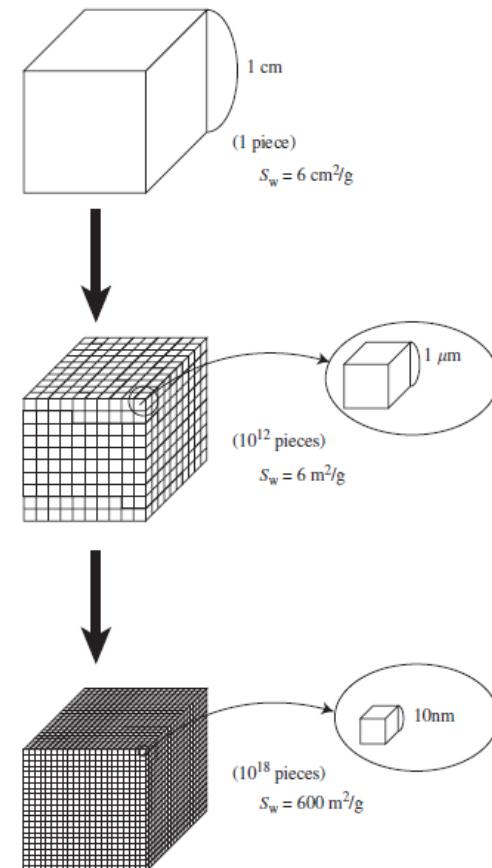
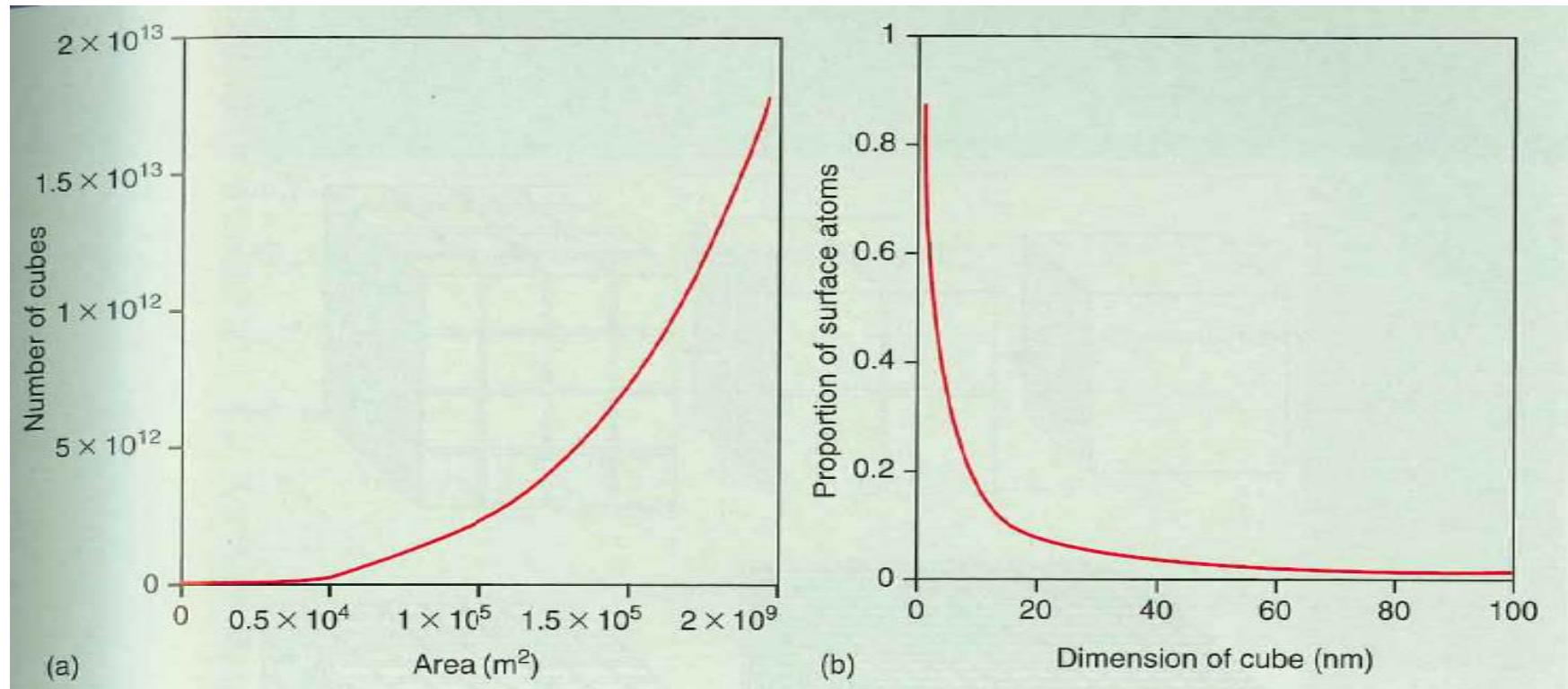


Figure 1.1.3  
Change of specific surface area by miniaturization of a solid cube assuming the solid density of 1 g/cm<sup>3</sup>.



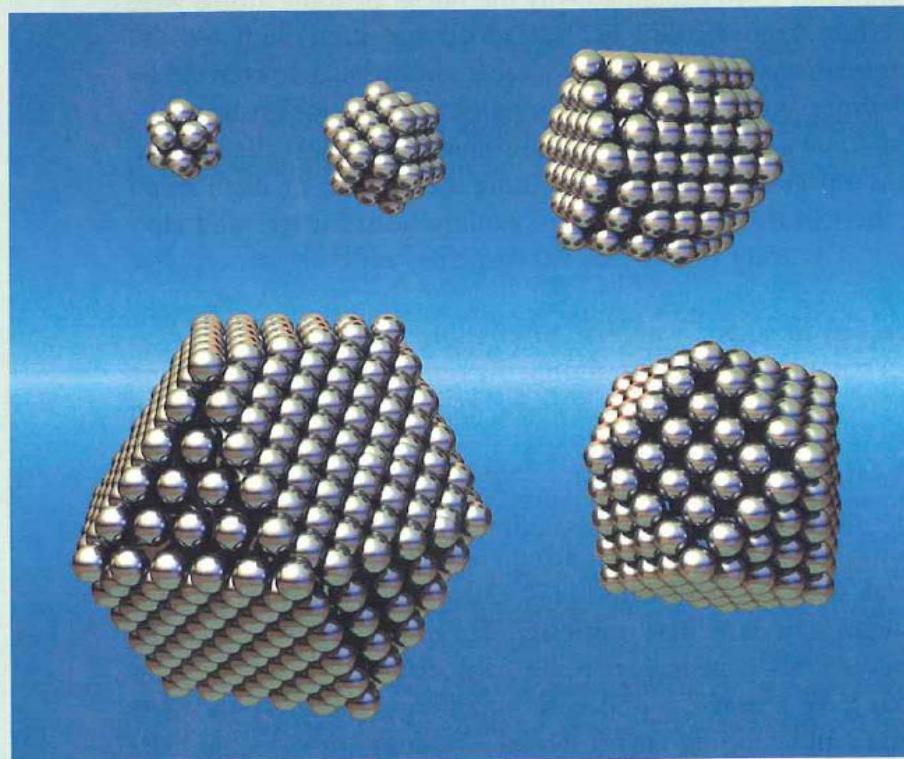
# ELEVADA RATIO SUPERFICIE/VOLUMEN



# ELEVADA RATIO SUPERFICIE/VOLUMEN

**FIG. 5.13**

Cuboctahedral gold clusters are shown. The progression represents a geometric series based on magic numbers: 13, 55, 147, 309, and 561. Notice how the faces retain their integrity regardless of the size of the cluster. As the cluster becomes larger, this figure also illustrates the concept of surface-to-volume ratio: The larger the cluster is, the more volume atoms seem to overwhelm the number of surface atoms.



Source: Courtesy of Professor Anil K. Rao, Department of Biology, the Metropolitan State College of Denver.



# ELEVADA RATIO SUPERFICIE/VOLUMEN

## Increase of surface area

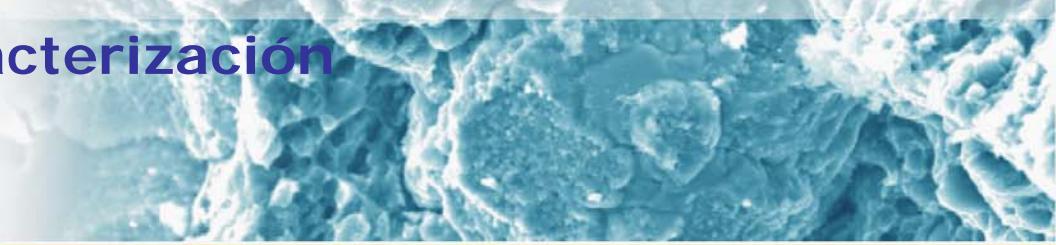
***As the micronization of solid particles, the specific surface area increases generally in reversal proportion to the particle size.***

*In the above-mentioned case, when the particle of 1cm is micronized to 1 micron and 10nm, the specific surface area becomes ten thousand times and million times, respectively.*

**As the increase in the specific surface area directly influences such properties like the solution and reaction rates of the particles**

It is one of major reasons for the unique properties of the nanoparticles different from the bulk material together with the change in the surface properties of the particles itself.





## Size measurement (1):

The most basic method to measure the size of nanoparticles is the size analysis from the picture image using the **transmission electron microscope**, which could also give the particle size distribution. For this analysis, preparation of the well-dispersed particles on the sample mount is the key issue.

The grain size of the particles can be obtained from peak width at half height in the **X-ray diffraction** analysis and it is regarded as an average primary particle size of particles.

Then the **BET (Brunauer-Emmett-Teller)** specific surface measurement based on the gas adsorption is often applied as a simple method to evaluate the size of nanosized primary particles.



# PROPIEDADES

## Properties of nanoparticle and size effect

*With the decreasing particle size, the solid particles generally tend to show different properties from the bulk material*

*These changes in the fundamental properties with the particle size is called "size effect" in a narrower sense.*

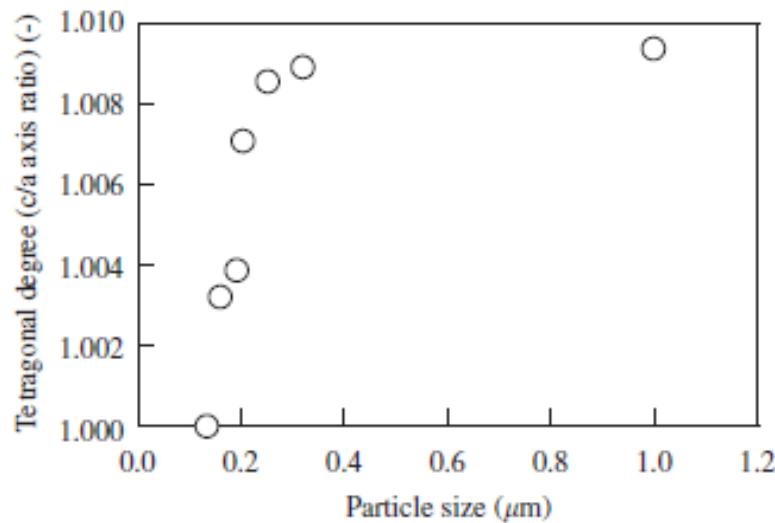
The nanoparticles have various unique features in the:

- morphological/structural properties
- thermal properties
- electromagnetic properties
- optical properties
- mechanical properties



# PROPIEDADES

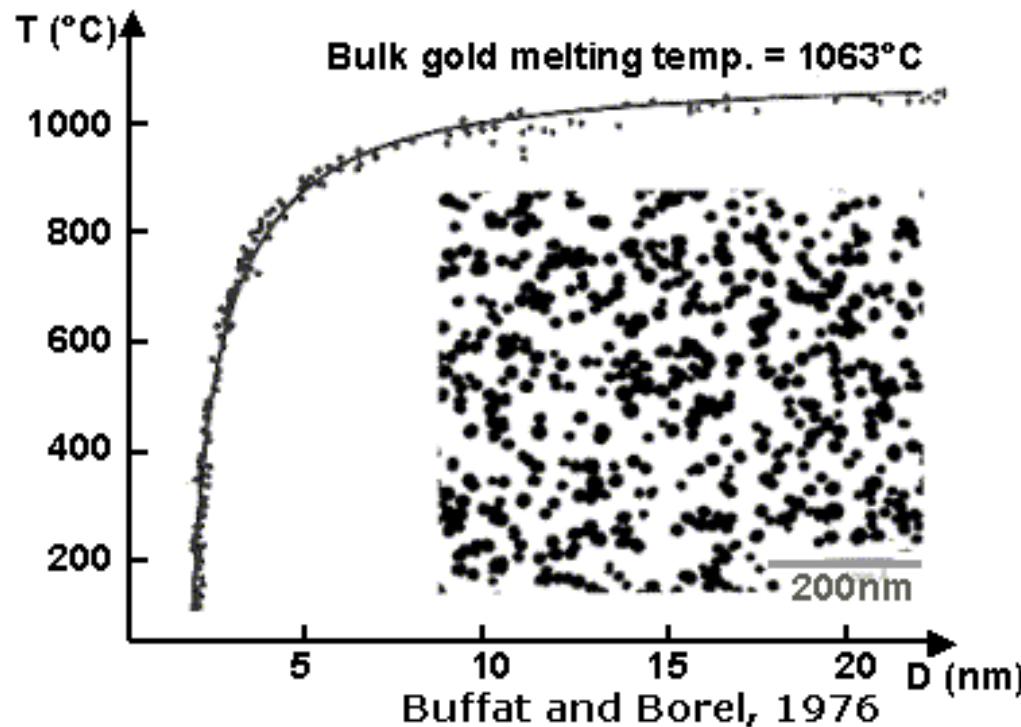
## (1) Morphological/structural properties



**Figure 1.1.4**  
Relationship between particle size and tetragonal degree ( $c/a$  axis ratio) of  $\text{BaTiO}_3$  powder.

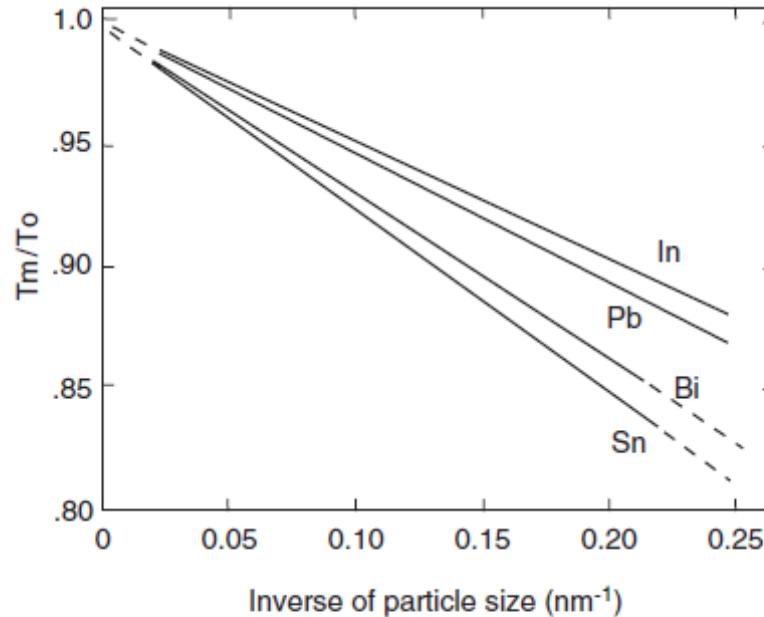


## (2) Thermal properties



# PROPIEDADES

## (2) Thermal properties



**Figure 1.5.2**

Relationship between inverse of particle size of various metal and  $T_m/T_0$  [19].  $T_m$ , measured melting point;  $T_0$ , melting point of bulk material.



# PROPIEDADES

## (3) Electromagnetic properties (bulk nanostructured materials)

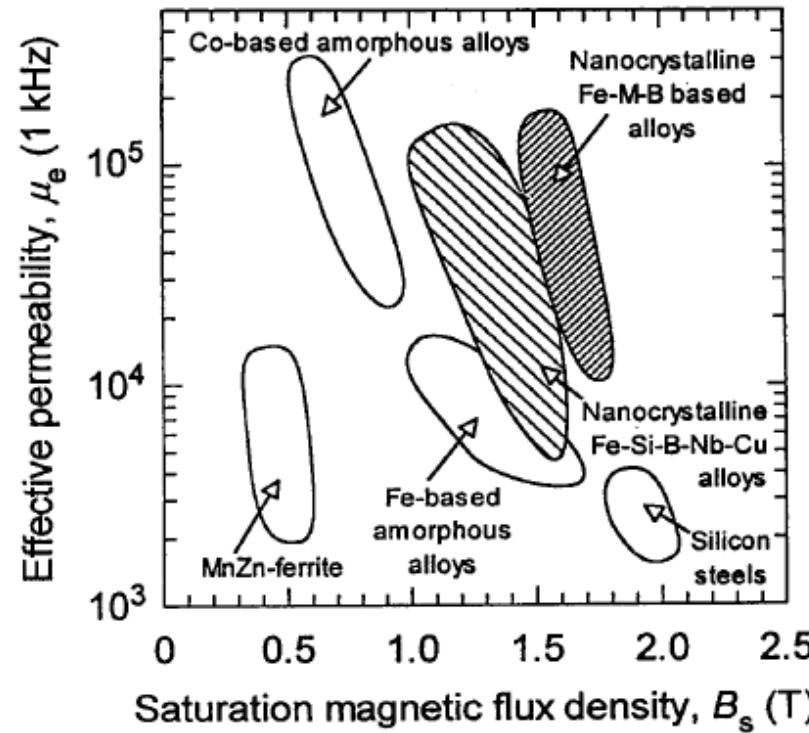
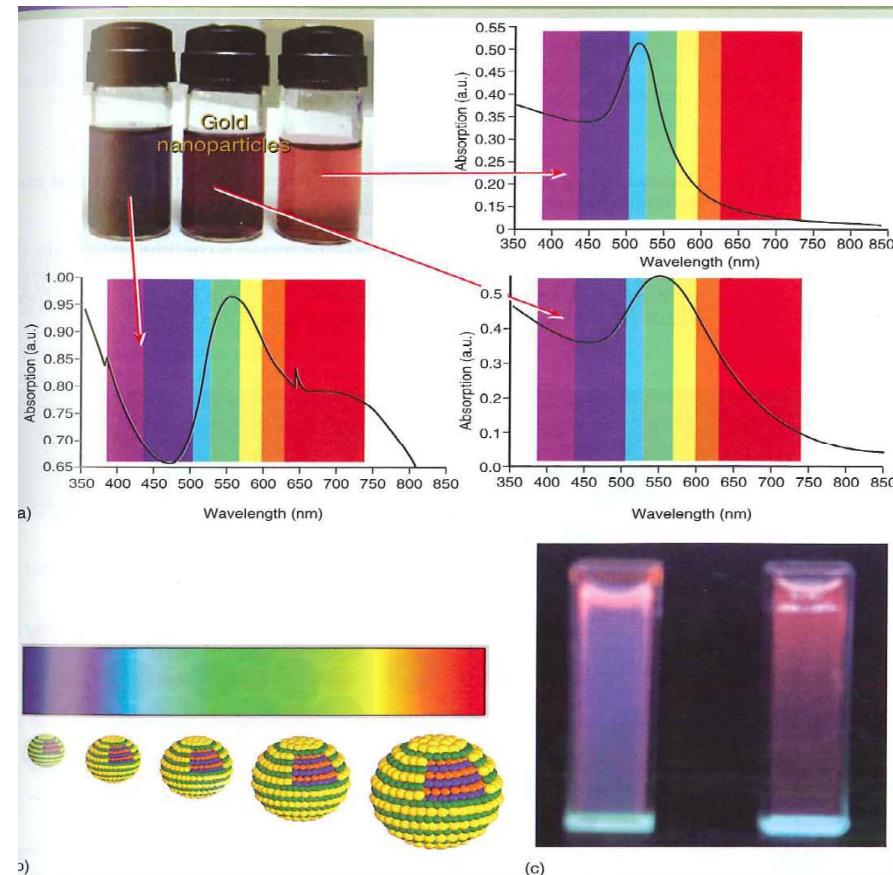


Figure 6.3. Effective permeability,  $\mu_0$ , vs. saturation magnetic flux density,  $B_s$ , for soft ferromagnetic materials (after A. Inoue 1997).



# PROPIEDADES

## (4) Optical properties

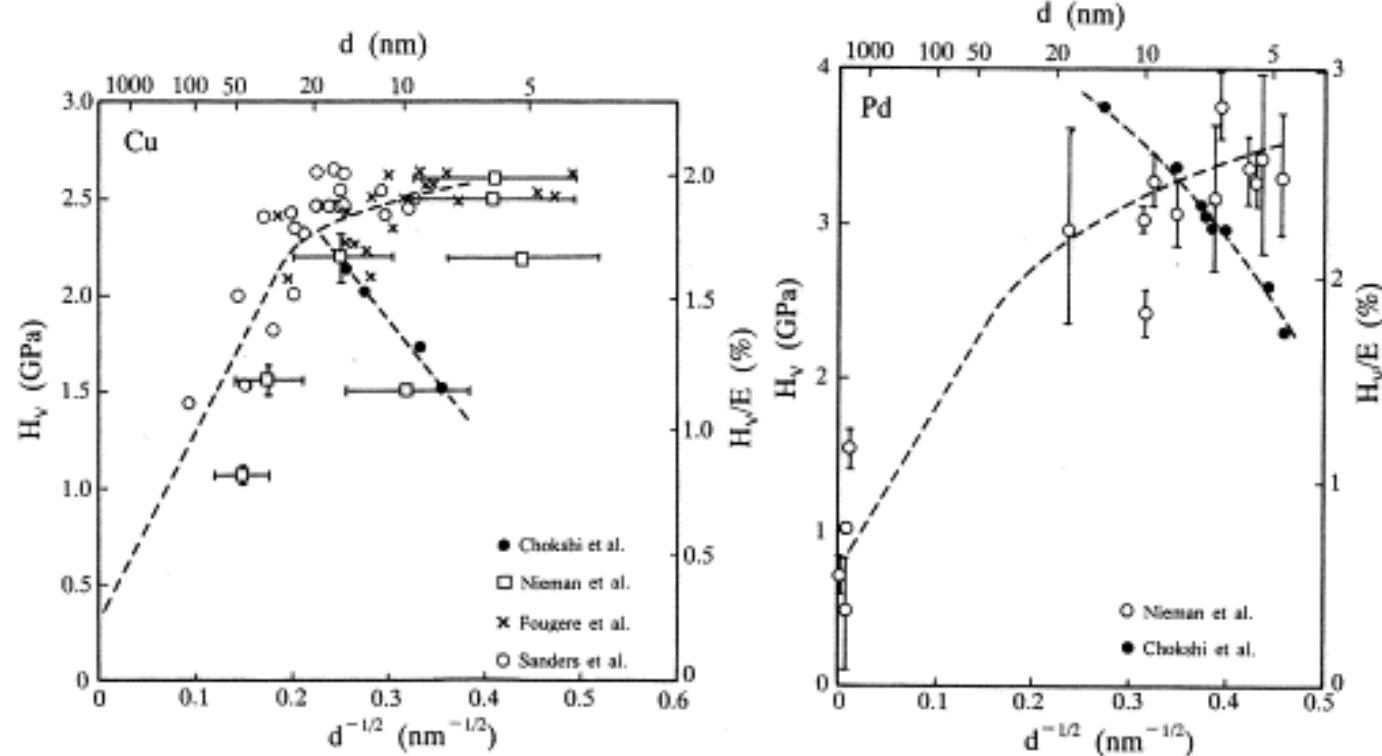


# PROPIEDADES



## (5) Mechanical properties

### (a) Elastic properties (Hall-Petch)



# PROPIEDADES



## (5) Mechanical properties (b) Hardness and strength

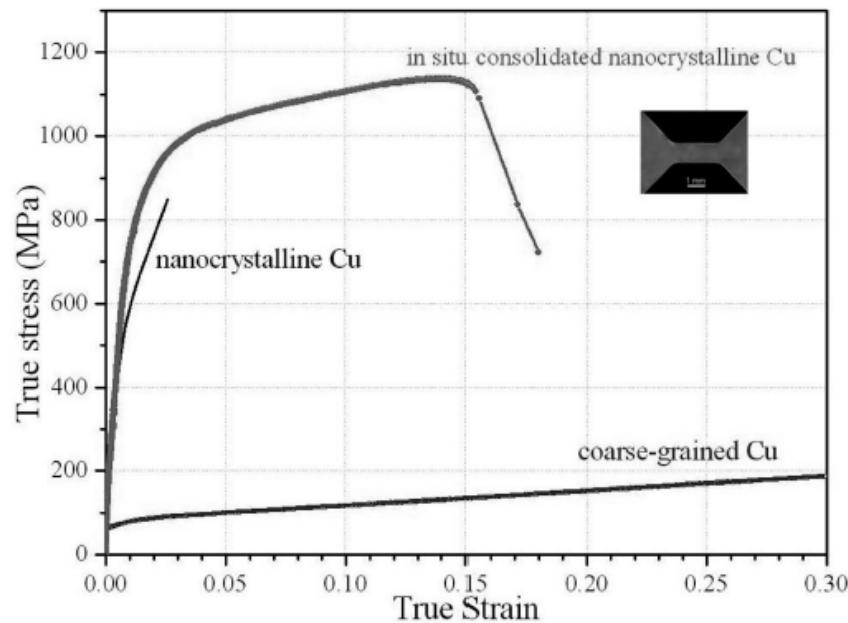
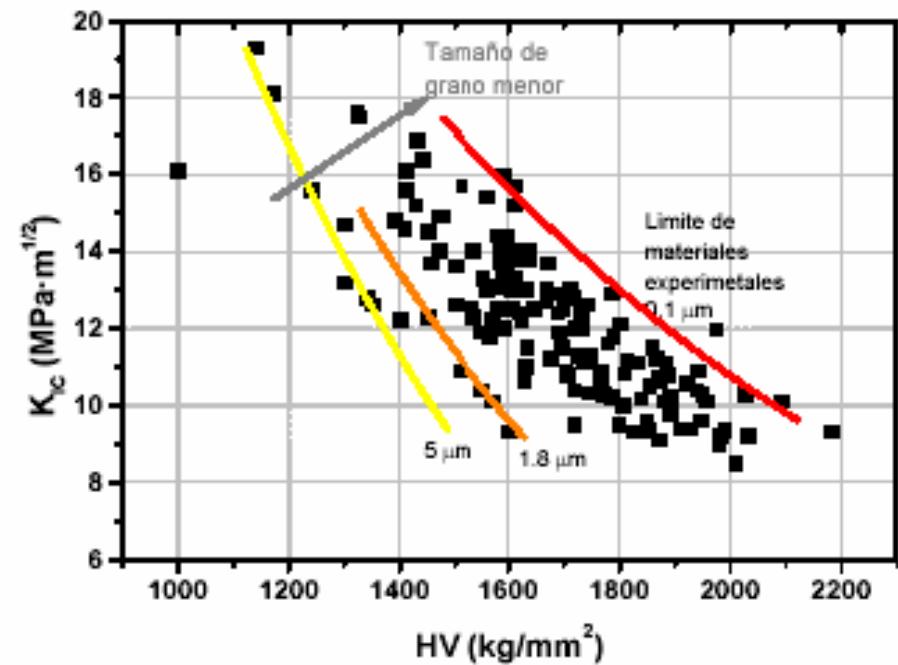
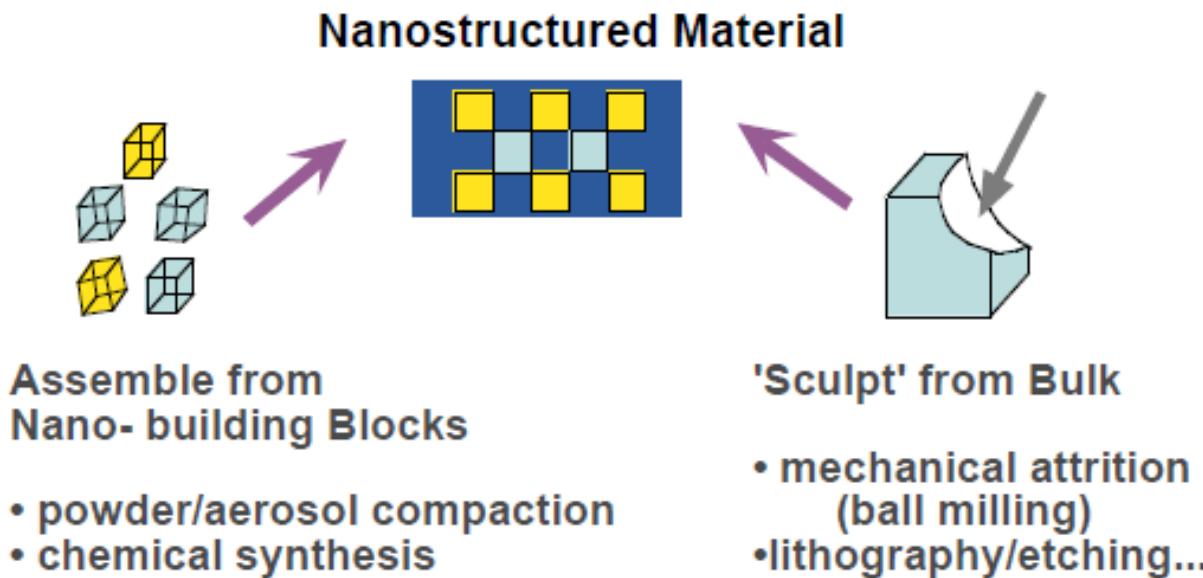


Fig. 1.6 True stress versus true strain for bulk *in-situ* consolidated Cu in comparison with that for coarse-grained Cu and nanocrystalline Cu made by the inert gas condensation and compaction technique. (reproduced with permission from Ref. [9], Fig. 2).



# FABRICATION METHODS

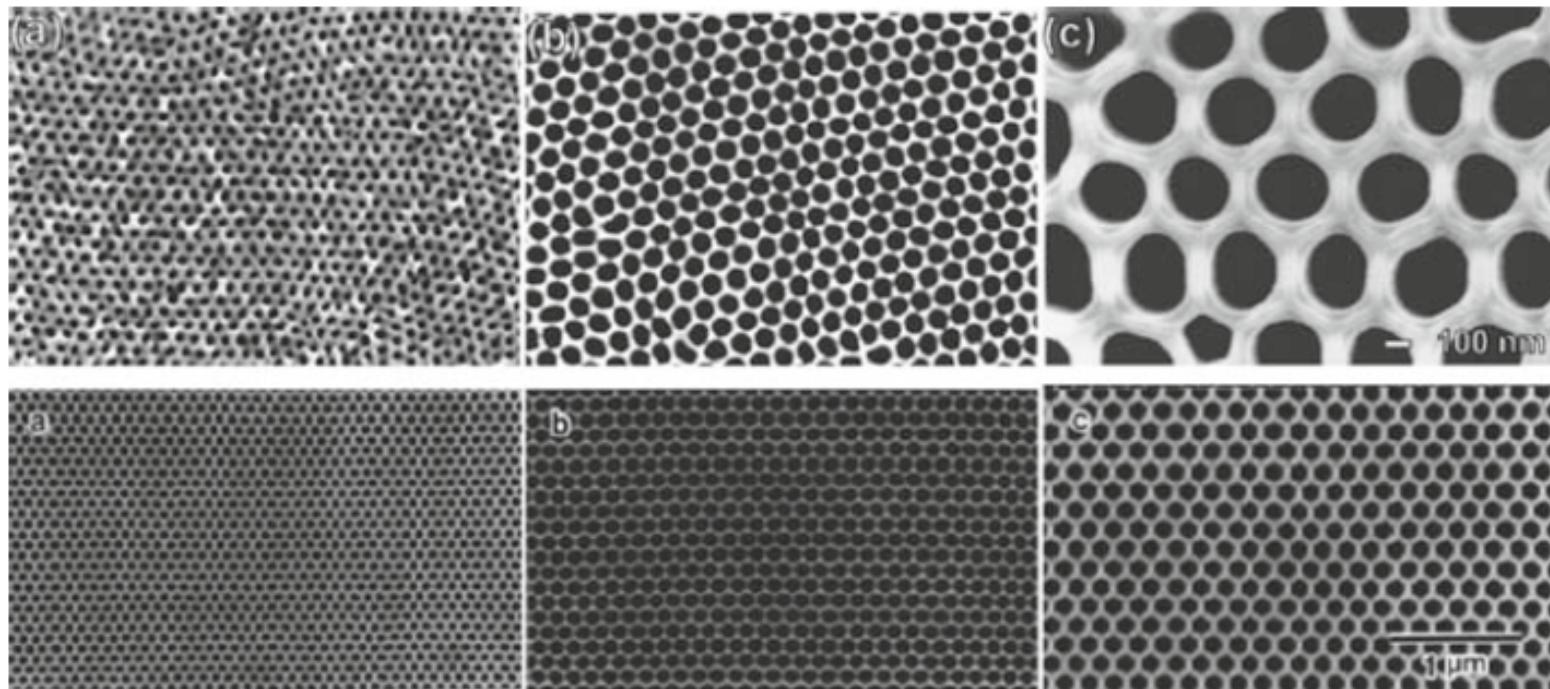
## General approaches



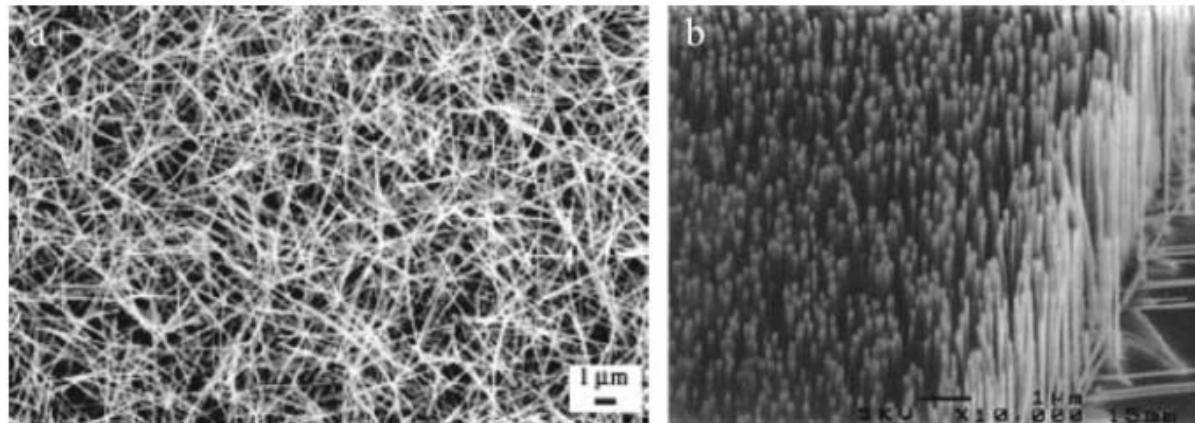
*Figure 2.1.* Schematic of variety of nanostructure synthesis and assembly approaches.



# TOP-DOWN FABRICATION METHODS



# BOTTOM-UP FABRICATION METHODS



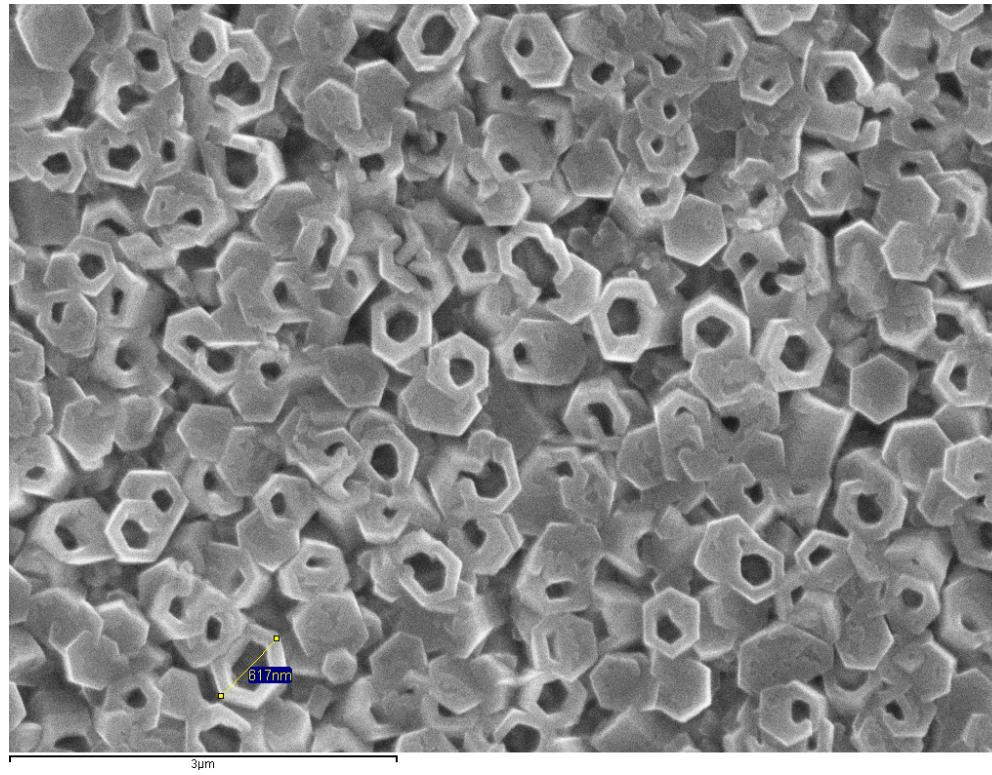
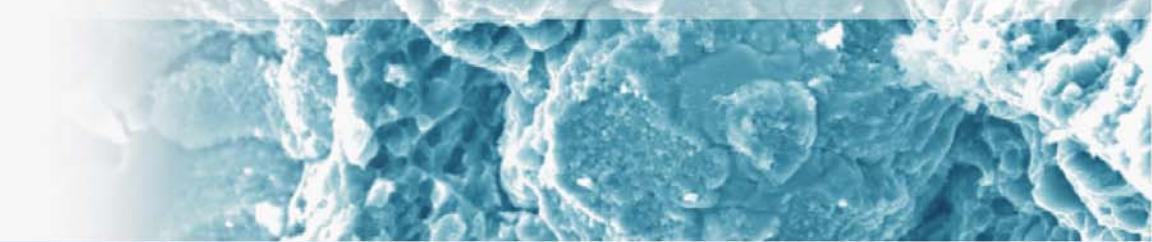
**Fig. 3.2** (a) Randomly ordered ZnO nanorods array (Huang et al. 2002b). (Reprinted by permission from Advanced Materials 13, 113 (2001), copyright 2001, Wiley.) (b) Aligned ZnO nanorod array (Yang et al. 2002) (Reprinted by permission from Advanced Functional Materials, 12, 323 (2002), copyright 2002, Wiley) fabricated through thermal vapor transport method





Instituto de Tecnología de Materiales

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# ENVIRONMENTAL IMPLICATIONS

## How nanomaterials impact the health

Some of the recently developed nanoparticle products may have unintended consequences. Researchers have discovered that silver nanoparticles used in socks only to reduce foot odor are being released in the wash with possible negative consequences.

*Silver nanoparticles, which are bacteriostatic, may then destroy beneficial bacteria which are important for breaking down organic matter in waste treatment plants or farms.*

A study at the University of Rochester found that when rats breathed in nanoparticles, the particles settled in the brain and lungs, which led to significant increases in biomarkers for inflammation and stress response

*A major study published more recently in Nature Nanotechnology suggests some forms of carbon nanotubes could be as harmful as asbestos if inhaled in sufficient quantities.*

**So those sorts of materials need to be handled very carefully!!!**



# ENVIRONMENTAL IMPLICATIONS

## How nanomaterials impact the environment

Nanopollution is a generic name for all waste generated by nanodevices or during the nanomaterials manufacturing process.

This kind of waste may be very dangerous because of its size.

It can float in the air and might easily penetrate animal and plant cells causing unknown effects.

Most human-made nanoparticles do not appear in nature, so living organisms may not have appropriate means to deal with nanowaste.

**It is probably one great challenge to nanotechnology: how to deal with its nanopollutants and nanowaste**

