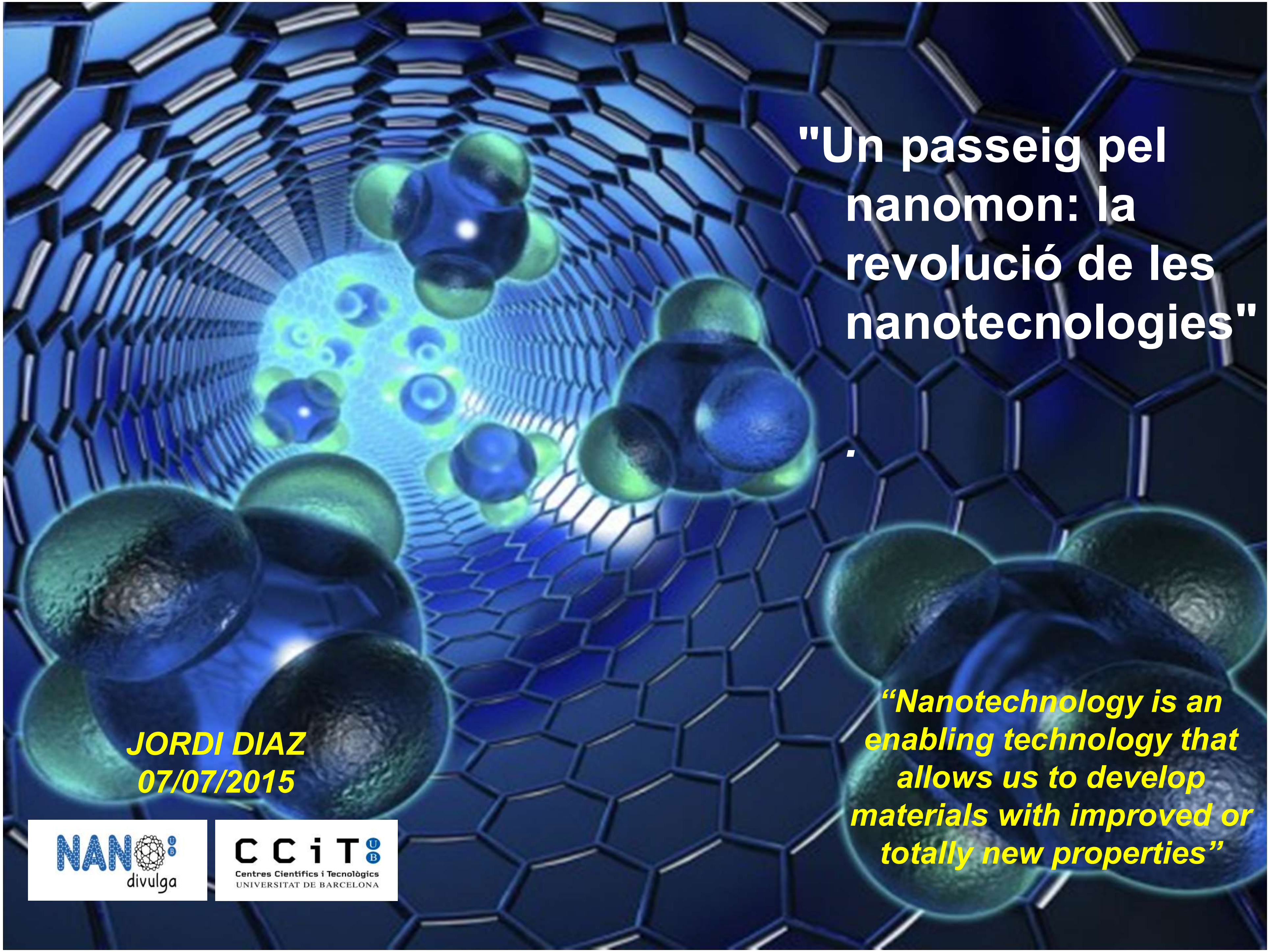


"Un passeig pel nanomon: la revolució de les nanotecnologies"

.

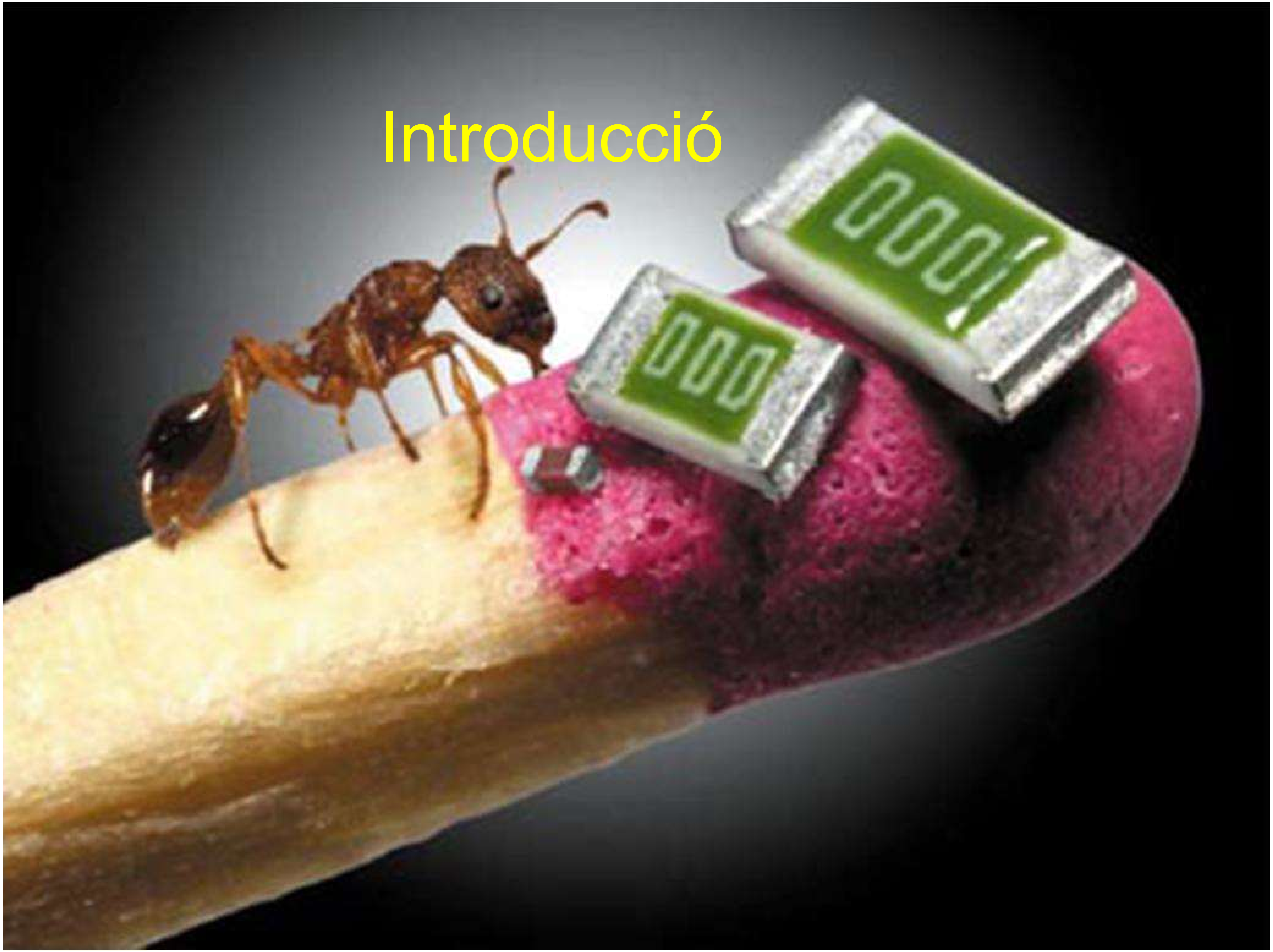
"Nanotechnology is an enabling technology that allows us to develop materials with improved or totally new properties"

JORDI DIAZ
07/07/2015

NANO UB divulga

CCiT UB
Centres Científics i Tecnològics
UNIVERSITAT DE BARCELONA

Introducció



Què és nano?

Per entendre la nanotecnologia, primer hem de pensar en l'escala

"NANO": UNA COSA MOLT, MOLT,MOLT PETITA……

QUANT SÓN MIL MILIONS

DISTÀNCIA:
1 peu -> Distància mitjana Terra-Lluna

TEMPS:
1 segon -> 30 anys!

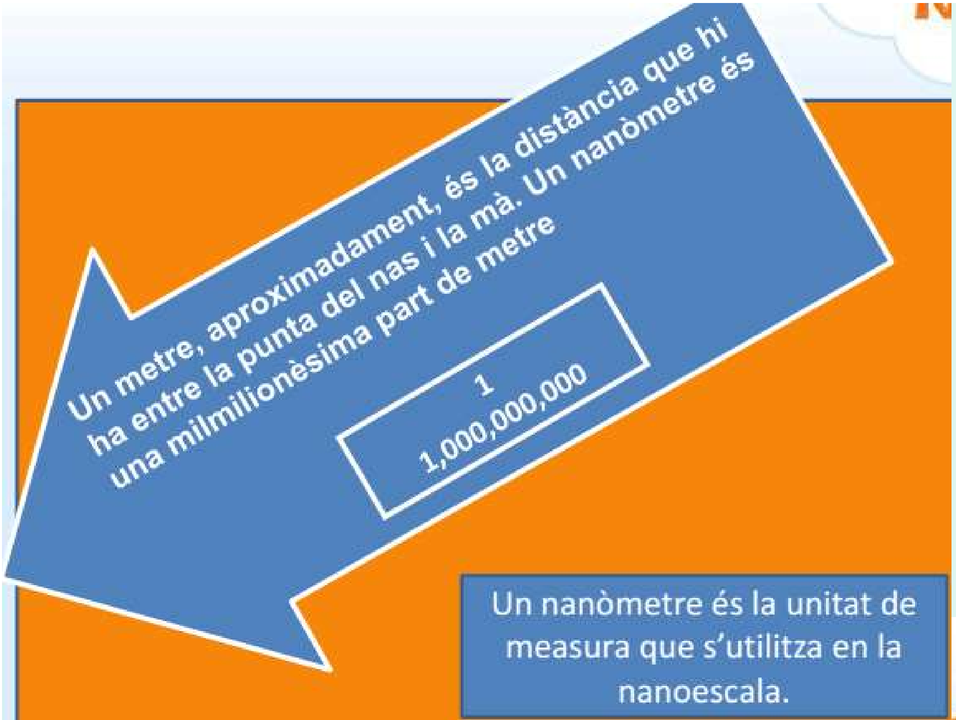
DINERS:
1 cèntim -> sou anual d'un futbolista de primer nivell.

$$1\ \text{nm} = 10^{-9}\ \text{m}$$

$$1\ \text{nm} = 0.000000001\text{m}$$

$$1\ \text{nm} = 0.000001\ \text{mm}$$

$$1\ \text{nm} = 0.001\ \mu\text{m}$$



https://www.youtube.com/watch?v=d6E-7Zr7lt4

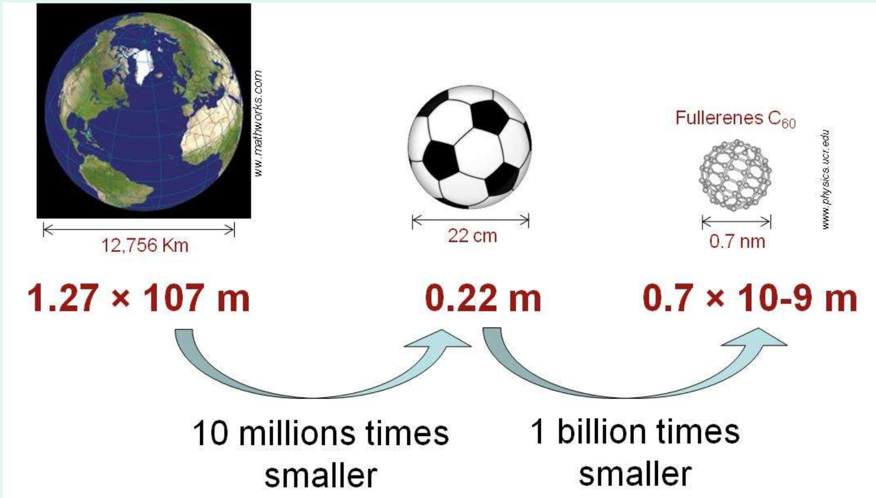
NANOCIENCIA I NANOTECNOLOGIA: QUÈ SÓN?

La nanociència es dedica a l'estudi de les propietats dels objectes i fenòmens a escala nanométrica (un nanómetre és la mil milionèsima part d'un metre).

La nanotecnologia és l'estudi, disseny, creació, síntesi, manipulació i aplicació de materials, aparells i sistemes funcionals a través del control de la matèria a la nanoescala, i l'explotació de fenòmens i propietats de la matèria a la nanoescala (‹100nm)

The current recommendation for the definition of a **nanomaterial**
European Commission
(18 October, 2011)

"natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in **the number size distribution**, one or more external dimensions is in the size range **1 nm-100 nm**"



Some 'Nano' Definitions

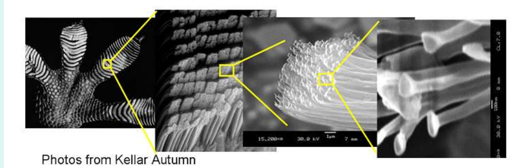
Cluster
Máximo de 50 moléculas o átomos

Coloïde
Líquido estable que contiene partículas (coloidales) entre 1-1000 nm

Nanopartícula
Partícula entre 1-100 nm q puede ser no-cristalina, un agregado o un monocristal

Nanocristal
Partícula que es un monocristal entre 1-100nm

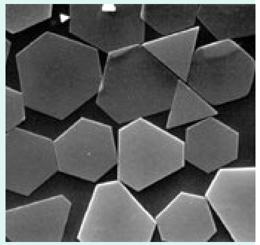
HISTORIA



La nanotecnologia ha existit des de sempre a la natura:
Partícules volcàniques, cristalls de sal a les brises marines, terpens (resina arbre), Dragó

640AD, The "Lycurgus Cup" is a Roman artifact from before
It is dichroic, changing colour when illuminated from the inside. This effect is caused by gold and silver nanoparticles, and was likely produced by accident.

500AD Glass artisans were making stained glass windows with vibrant reds and yellows .These colours were much more luminous and durable than dyes could produce. They were the products of "coinage metal" NPs imbedded in the glass.



1827, Joeph Niépse was able to stabilise silver halide nanocrystals in a gelatin that hardened with exposure to light. The silver halides decomposed to silver metal,producing black. The crystal grains were too small to be discerned, and so black-and-white photography gave excellently resolved photos.

1857, Nanoparticles "stay in solution", leading to one of the most enduring images of nanotechnology:The rainbow array of solutions made by the suspension of a variety of sizes of nanoparticles.This was discovered by Michael Faraday.

El salt cap a la Nanotecnología:

Una posibilitat fascinant.

Richard P. Feynman (Premio Nobel en 1965)
There's Plenty of Room at the Bottom
29 de diciembre de 1959
(Publicada en 1960, Caltech Science and Technology)

"The principles of Physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big".

http://www.zyvex.com/nanotech/feynman.html

El salt cap a la Nanotecnología:

Una posibilitat fascinant.

Norio Taniguchi,
profesor de la Universidad de Ciencias de Tokio

•***On the Basic Concept of 'Nano-Technology'," Proc. Intl. Conf. Prod. Eng. Tokyo, Part II, Japan Society of Precision Engineering, 1974.***

•***Nanotechnology: Integrated Processing Systems for Ultra-precision and Ultra-fine products, Edited by Norio Taniguchi. Associate Editors: Tsuguo Kohno, Kazuo Maruyama, Kiyoshi Iizuka, Iwao Miyamoto and Toshio Dohi.***

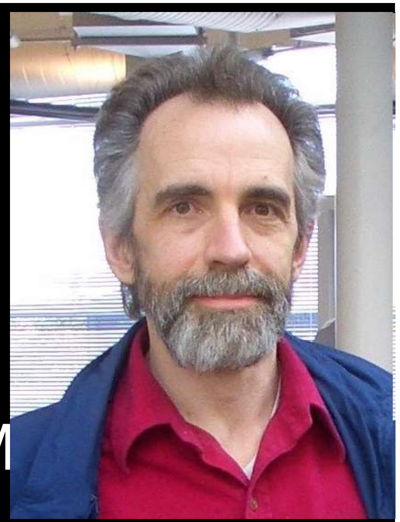
MICROSCOPI D'EFECTE TÚNEL (STM)

H. Rohrer y G. Binnig desarrollan a principios de los años 80 una herramienta que cambia la 'metodología' y la forma de abordar el estudio de los sistemas nanométricos: el Microscopio de Barrido Túnel (STM). Ambos recibieron el Premio Nobel de Física en 1986.

Del 'nanocontrol' han surgido poderosas herramientas como el Microscopio de Fuerzas Atómicas (AFM) (1985, Binnig, Quate, Gerber).

El salt cap a la Nanotecnología:

Una posibilitat fascinant.

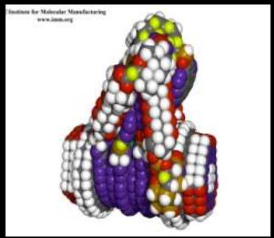


K. Eric Drexler
Fundador del Foresight Institute, invetigador en el M

"Molecular engineering: An approach to the development of general capabilities for molecular manipulation" (Proc. Natl. Acad. Sci. USA , Vol. 78, No. 9, pp. 5275-5278, September 1981).

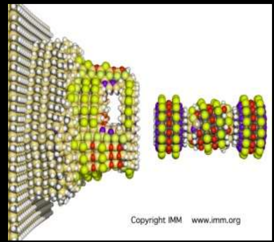
Engines of Creation: The Coming Era of Nanotechnology (Anchor Books, 1986)

Ensamblador molecular



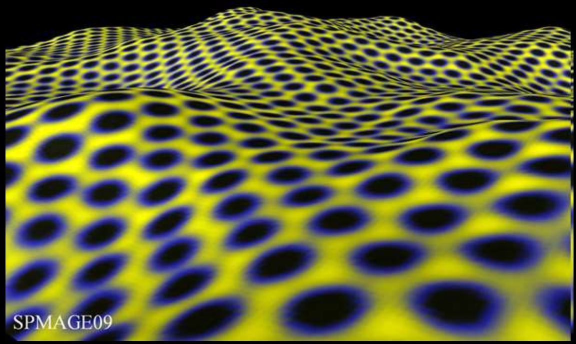
Engranaje molecular

Bomba molecular



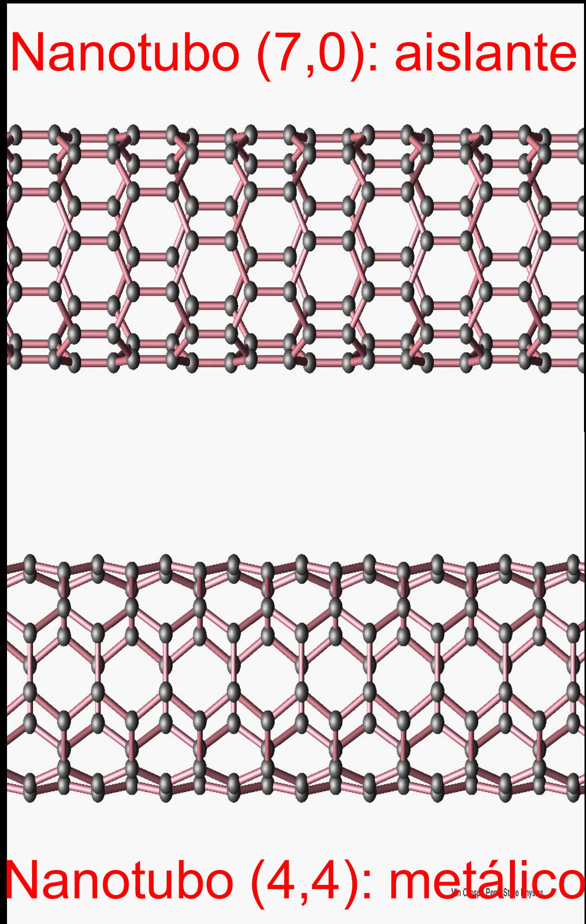
LO "NANO" ES DIFERENTE: FULLERENO, GRAFENO, NANOTUBOS DE CARBONO,

Grafeno
(Geim, Novoselov)
(2004)

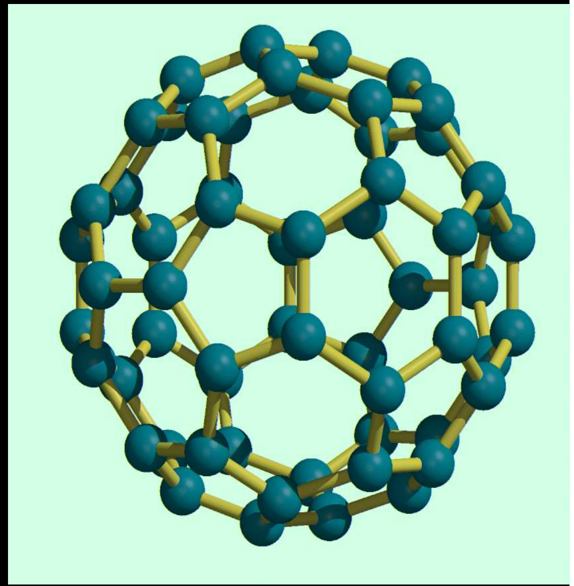


"intrinsic rippling of monolayer graphene"
Mr. Torge Mashoff. RWTH Aachen University (Germany)
.

Nanotubos
(Ijima @NEC)
(1991)



Fullereno C_{60}
(Smalley, Curl y Kroto)
(1989)



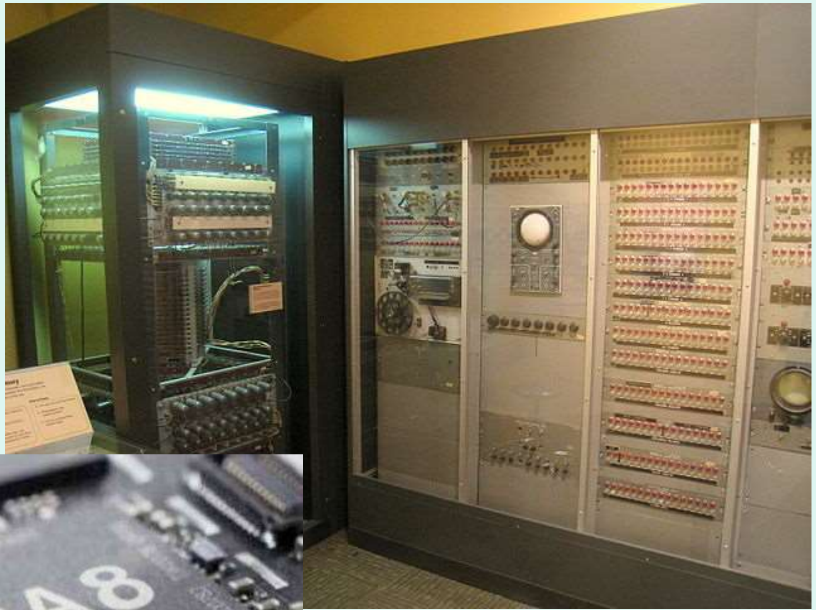
Página WEB del Prof. Smalley
http://cnst.rice.edu/

La conferència de Feynman obre la porta a plantejar-nos la manipulació atòmica i la miniaturització de les estructures tecnològiques.

El camí de la miniaturització te un llarg camí per recórrer:

1958: Whirlwind II – defensa aèria EEUU.

- 13.000 transistors
- 1.000.000W consum energètic.



2015: Iphone 6 – smartphone.

- 2.000.000.000 transistors
- 2W consum energètic.

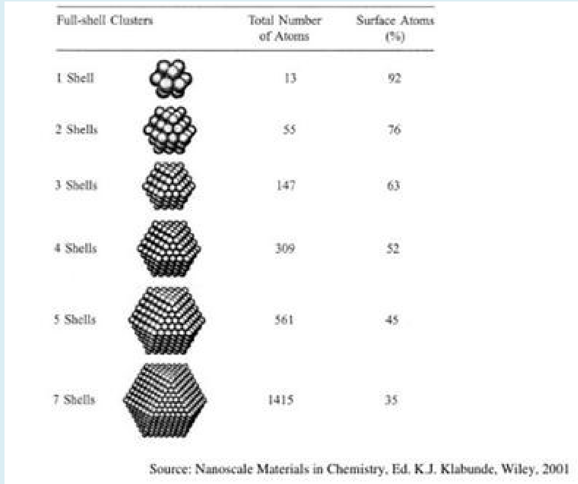
Alguna de les implicacions de ser “tan petit”…

El coneixement dels estats d’una partícula té un límit: no pots conéixer la posició i el moment d’una partícula alhora.

Una partícula només pot estar en una sèrie d’estats definits

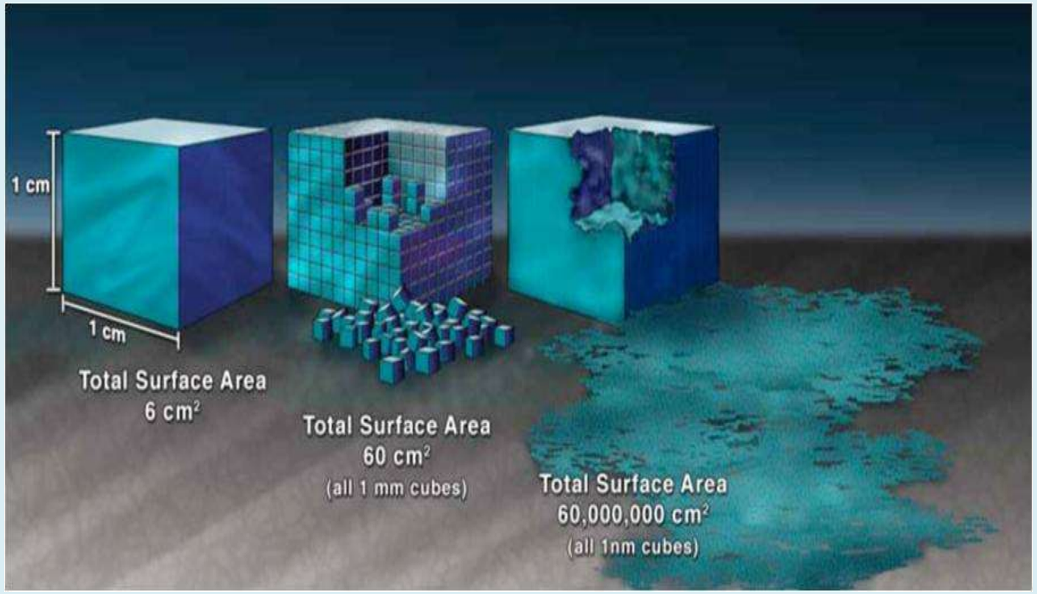
una partícula pot estar en una superposició d’estats propis

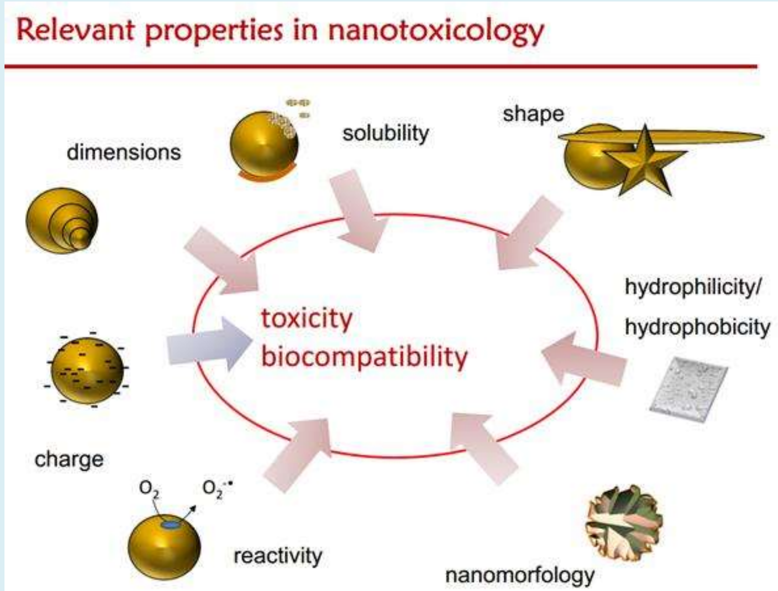
Alguna de les implicacions de ser “tan petit”…



Full-shell Clusters		Total Number of Atoms	Surface Atoms (%)
1 Shell		13	92
2 Shells		55	76
3 Shells		147	63
4 Shells		309	52
5 Shells		561	45
7 Shells		1415	35

Source: Nanoscale Materials in Chemistry, Ed. K.J. Klabunde, Wiley, 2001





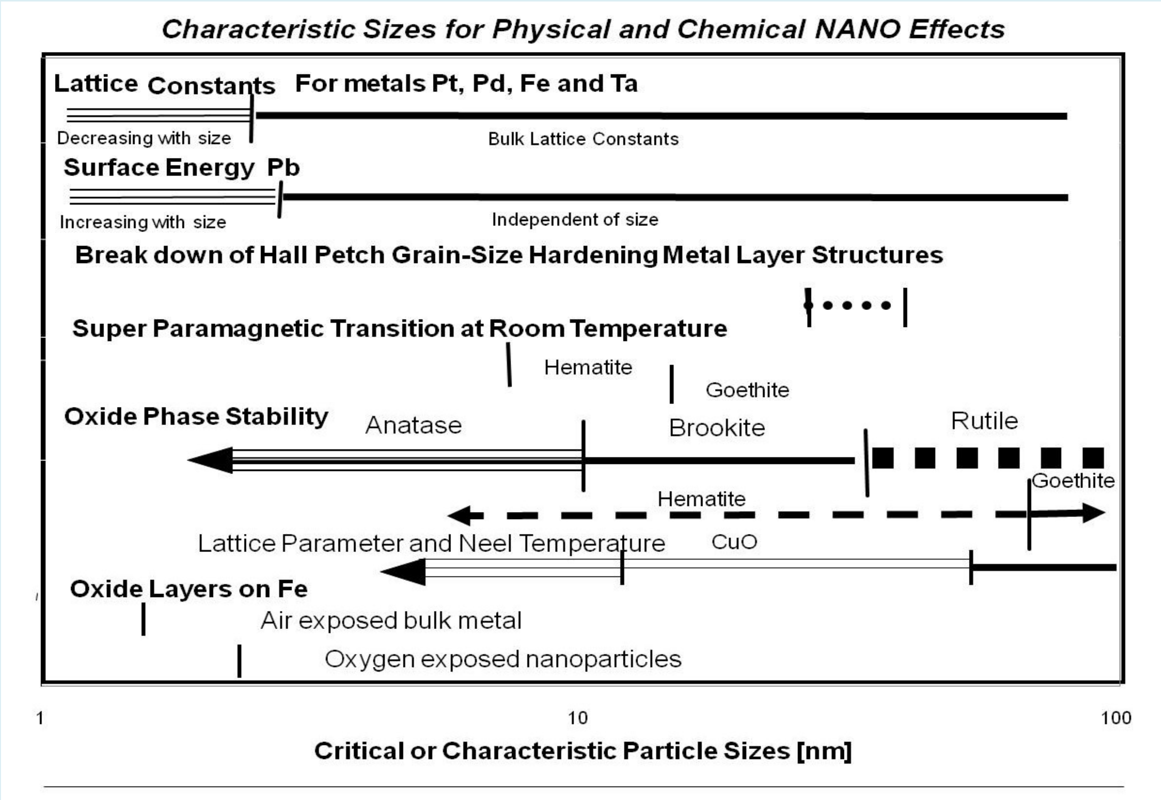
Alguna de les implicacions de ser “tan petit”…

Nano-scale Effects on Properties

Properties	Examples
Catalytic	Better catalytic efficiency through higher surface-to-volume ratio
Electrical	Increased electrical conductivity in ceramics and magnetic nanocomposites, increased electric resistance in metals
Magnetic	Increased magnetic coercivity up to a critical grain size, superparamagnetic behaviour
Mechanical	Improved hardness and toughness of metals and alloys, ductility and superplasticity of ceramic
Optical	Spectral shift of optical absorbtion and fluorescence properties, increased quantum efficiency of semiconductor crystals
Sterical	Increased selectivity, hollow spheres for specific drug transportation and controlled release
Biological	Increased permeability through biological barriers (membranes, blood-brain barrier, etc.), improved biocom-patibility

	Macroscale	Nanoscale
Copper	Opaque	Transparent
Platinum	Inert	Catalytic
Aluminium	Stable	Combustible
Gold	Solid at Room Temperature	Liquid at Room Temperature
Silicon	Insulator	Conductor

Alguna de les implicacions de ser "tan petit"…



- Per exemple, algunes vegades només canviant la grandària d'una partícula se'n pot alterar dràsticament el color.

Or

Tel·luri de cadmi

Augment grandària

Nanopartícules de CdTe.
A. Eychmüller , Technische Universität Dresden

Common Nanoparticle Sources

Industrial Process Emissions
May be harmful to workers and impossible to detect with standard monitoring instruments.

Vehicle Exhaust
Particulate emissions from vehicles are primarily in the nanoparticle size range.

Biomass Burning
The environmental implications of nanoparticle manufacturing are still largely unknown.

Emissions from Office Equipment
Some types of office equipment are known to generate large quantities of nanoparticles.

Candle and Incense Smoke
The indoor air quality effect from candles and indoor is frequently overlooked.

Engineered Nanoparticles
Engineered nanoparticles are the building blocks of some of the most innovative products.

Tobacco Smoke
Tobacco smoke and other indoor combustion sources are a known health hazard.

Stack Emissions
The environmental implications of nanoparticle manufacturing are still largely unknown.

Cooking Fumes
Can be dominant source of nanoparticles in indoor air in certain parts of the world.

Chemical Reactions
In the atmosphere and reactions from cleaning solvents or other household chemicals.

Eines a la nanoescala

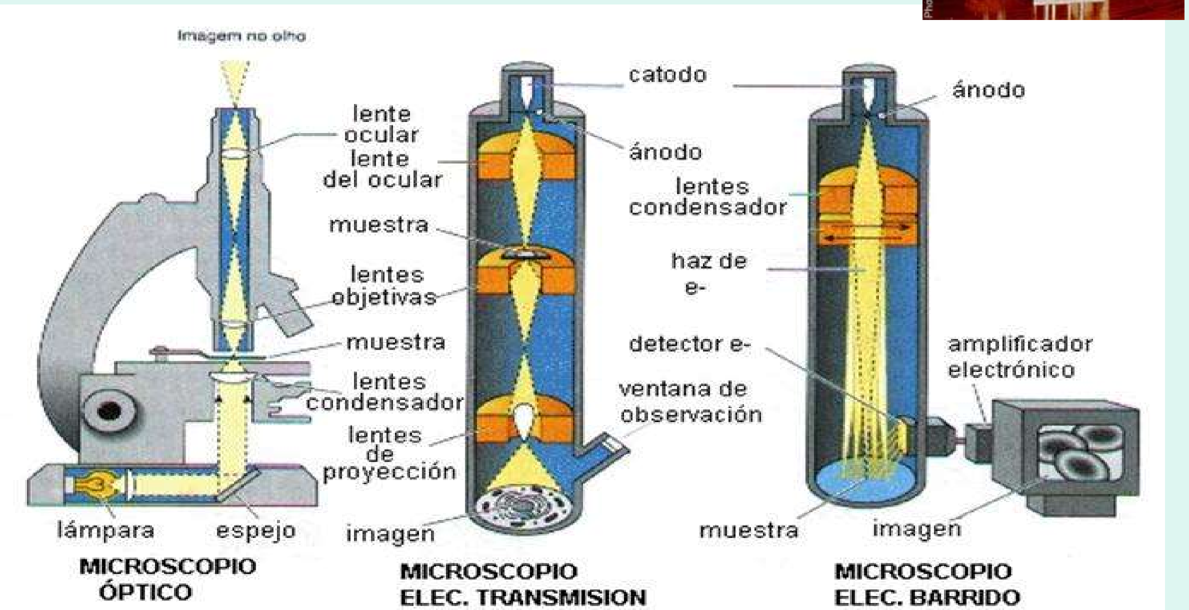
Per a poder manipular materials en la nanoescala, primer hem de desenvolupar les eines adequades.

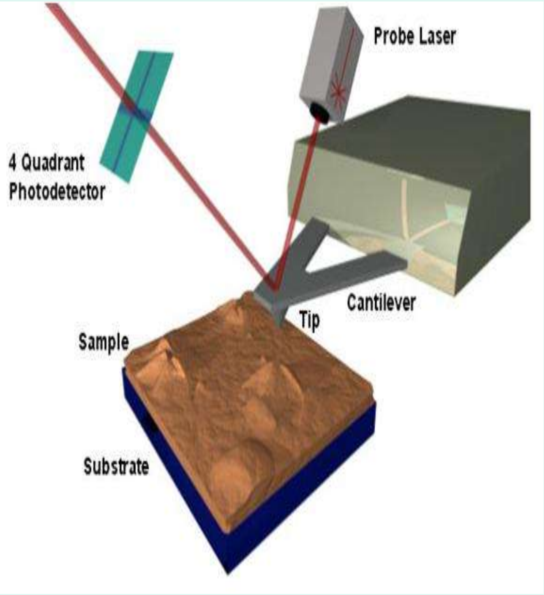
Observant la nanoescala

En la dècada dels 30 , els científics van ser capaços de veure en la nanoescala utilitzant instruments com el microscopi electrònic d'escombratge , de transmissió i el microscopi de camp iònic .

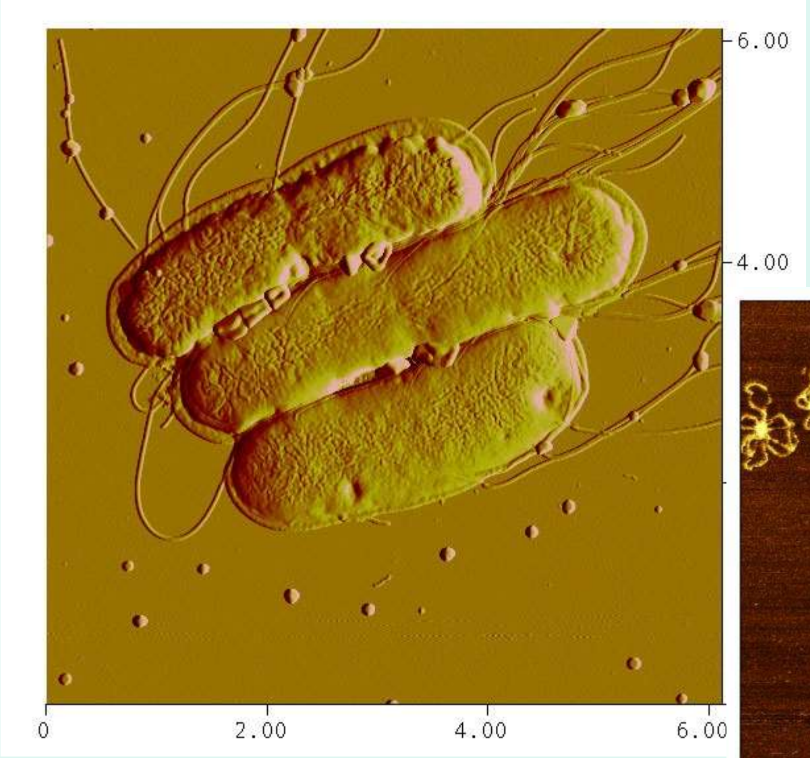
El microscopi electrònic , desenvolupat pels enginyers alemanys Ernst Ruska i Max Knoll , utilitza un feix de partícules d'electrons per il·luminar un espècimen i crear una imatge molt ampliada . Els microscopis electrònics tenen una resolució molt major que els microscopis òptics , podent-se obtenir augments de més 1 milió de vegades (fins a 100 vegades més que els millors òptics) .

Existeix una data clau en l'observació i desenvolupament de la nanotecnologia, al 1981, Heinrich Rohrer i Gerd Binnig creen el microscopi d'efecte túnel (STM), el qual és el primer d'una sèrie d'instruments que permeten veure i manipular partícules en la nanoescala. El seu desenvolupament va donar als seus inventors el Premi Nobel de Física en 1986. Una evolució del STM és l´AFM, desenvolupat pels mateixos científics juntament amb Calvin Quate i Christoph Gerber, en 1986.





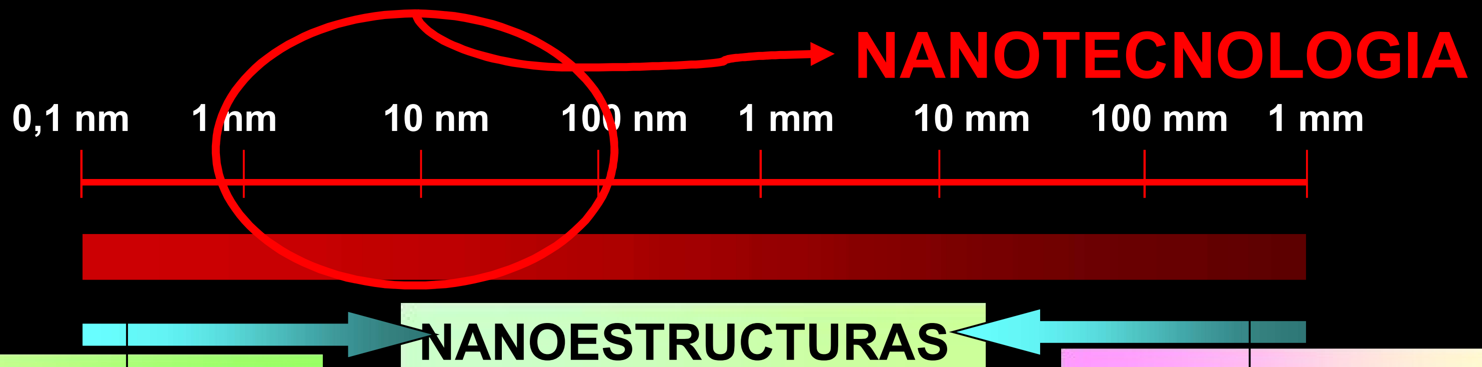
Atomic Force Microscope (AFM)



Biomaterials com cèl·lules o virus poden ser vistos en condicions in-vivo.

https://www.youtube.com/watch?feature=player_embedded&v=oSCX78-8-q0

DE LA NANOTECNOLOGÍA EXTREMA A LA REALISTA: DOS CAMINS CAP A LA “NANO”…



“BOTTOM-UP”

- Síntesis química
- Autoensamblado
- Autoorganización
- Deposición

NANOESTRUCTURAS

- Nanopartículas
- Nanotubos
- Nanohilos
- Puntos cuánticos
- Capas delgadas
- Multicapas
- Nanocomposites
- Dendrímeros
- Nanoporosos
- Zeolitas

“TOP-DOWN”

- Litografía óptica
- Nanolitografía electrónica
- Molienda
- Desgaste (FIB)

EL NANOBOOM:

DINERO-> ARTÍCLES -> PATENTS -> MERCAT

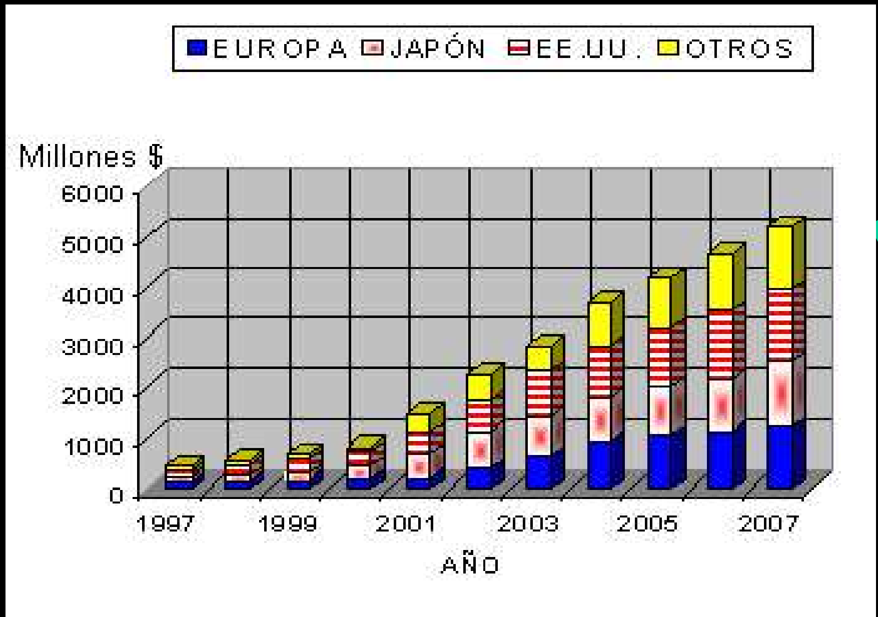
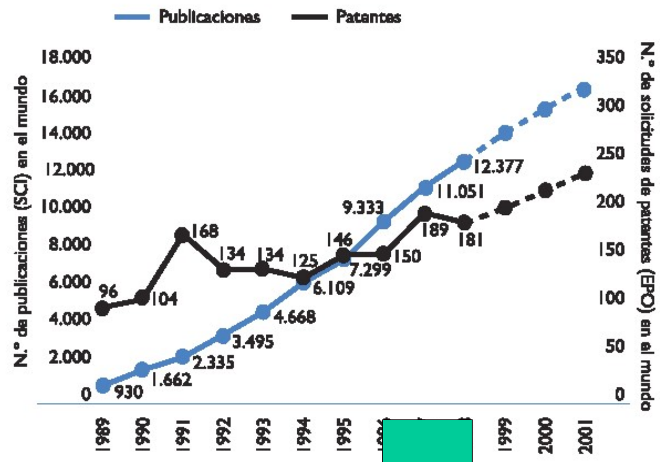
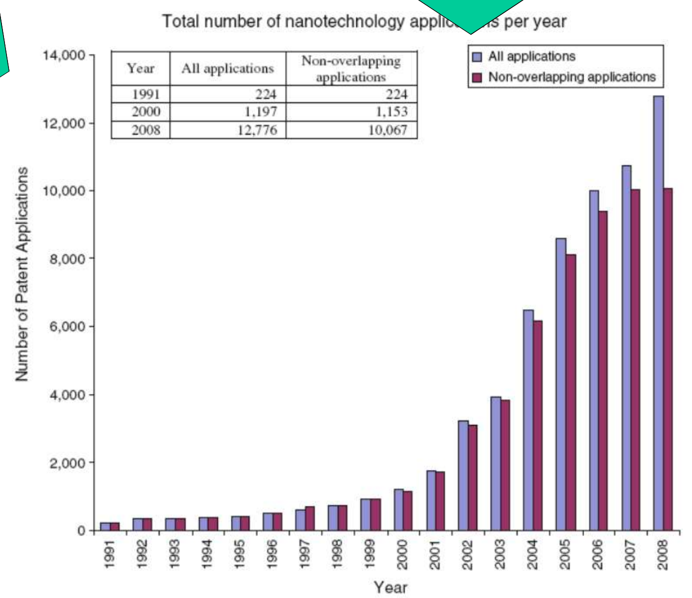


Gráfico 60. Nanociencia y nanotecnología: evolución del número de publicaciones (SCI) y del número de solicitudes patentes (EPO) en el mundo 1989-1998. Estimaciones 1999-2002



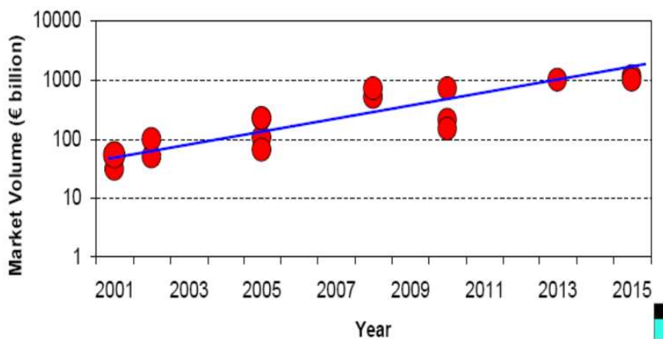
Fuente: «Third European Report on S&T Indicators». Eu... ...mission (2003).

Fi... evolution ... number of nan... patent applications in ... repositories per year (“... abstract,” 1991–2008)



Year	All applications	Non-overlapping applications
1991	224	224
2000	1,197	1,153
2008	12,776	10,067

- Analysts estimate that the market for products based on nanotechnology could rise to hundreds of billion by 2010 and exceed one trillion after



CLUSTERS DE CREACIÓN DE CONOCIMIENTO EN NC&NT

Cities With 1,000 or More Nanotechnology Publications

Source: Science Citation Index 1990 to Mid Year 2006

CATALUÑA

Plataforma de Nanotecnología del Parque Científico de Barcelona (UB)

http://www.pcb.ub.es/plataforma

Institut Catalá de Nanotecn

http://www.

Centre d'Investigacions

Nanotecnologia (CIN2) (

http://www.cin2.es/

InstituT de Ciencias Fotónicas (ICFO)

Gob. Catalán

http://www.icfo.es

ASTURIAS

tro de Investigación de

(CINN)

ias

PORTUGAL-ESPAÑA

Laboratorio Ibérico Internacional de Nanotecnología

Braga (Portugal)

MICINN (E) + MCTES (P)

http://www.iinl.org/

VALENCIA

gía Nanofotónica de

cia (NTC)

técnica de Valencia

upv.es/index.html

iencia Molecular

d de Valencia

http://www.icmol.es

e Nanotencología,

y Materiales Moleculares

(INAMOL)

sidad de Castilla-La Mancha

PAIS VASCO

CIC Nanogune

Gob. Vasco + Univ. País Vasco + MICINN

http://www.nanogune.eu

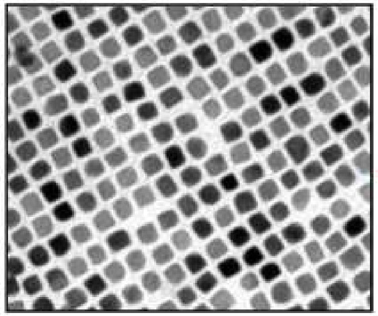
AN

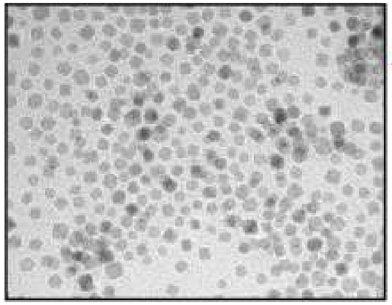
Centro Andaluz de Nanomedicina y Nanotecnología (BIONAND) de Málaga

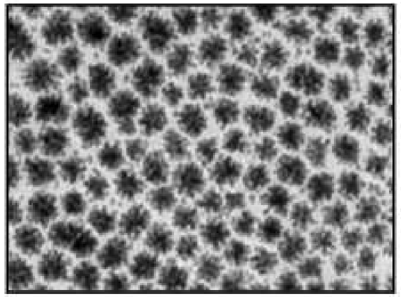
Junta de Andalucia

CENTROS DE INVESTIGACIÓN EN NANOTECNOLOGÍA

Size, Shape, Composition and Surface Coating Control by design







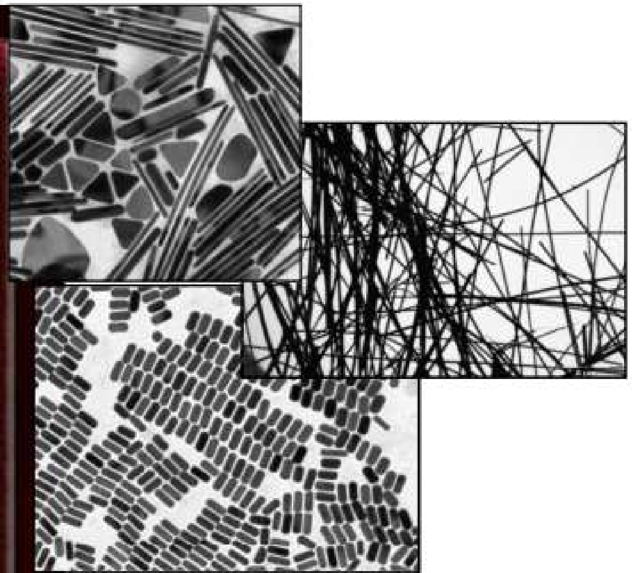
Au spheres (4 – 40 nm), rods, cubic boxes, tubes
Ag spheres, rods, cubes
Pt cubes, spheres, multipods
Pd cubic boxes

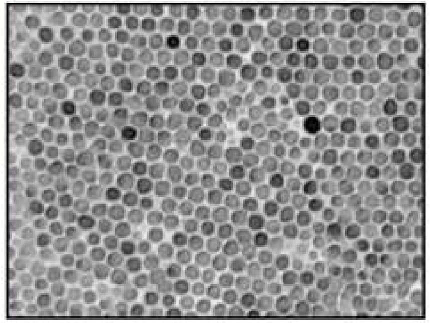
Fe spheres
Fe_3O_4 spheres
Fe_2O_3 spheres, hollow spheres

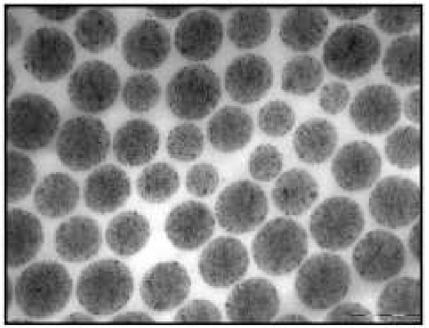
Co spheres, disks
CoO spheres, hollow spheres

CeO_2 spheres, belts
TiO_2 spheres
ZnO spheres

CoPt
Co-organic-Au

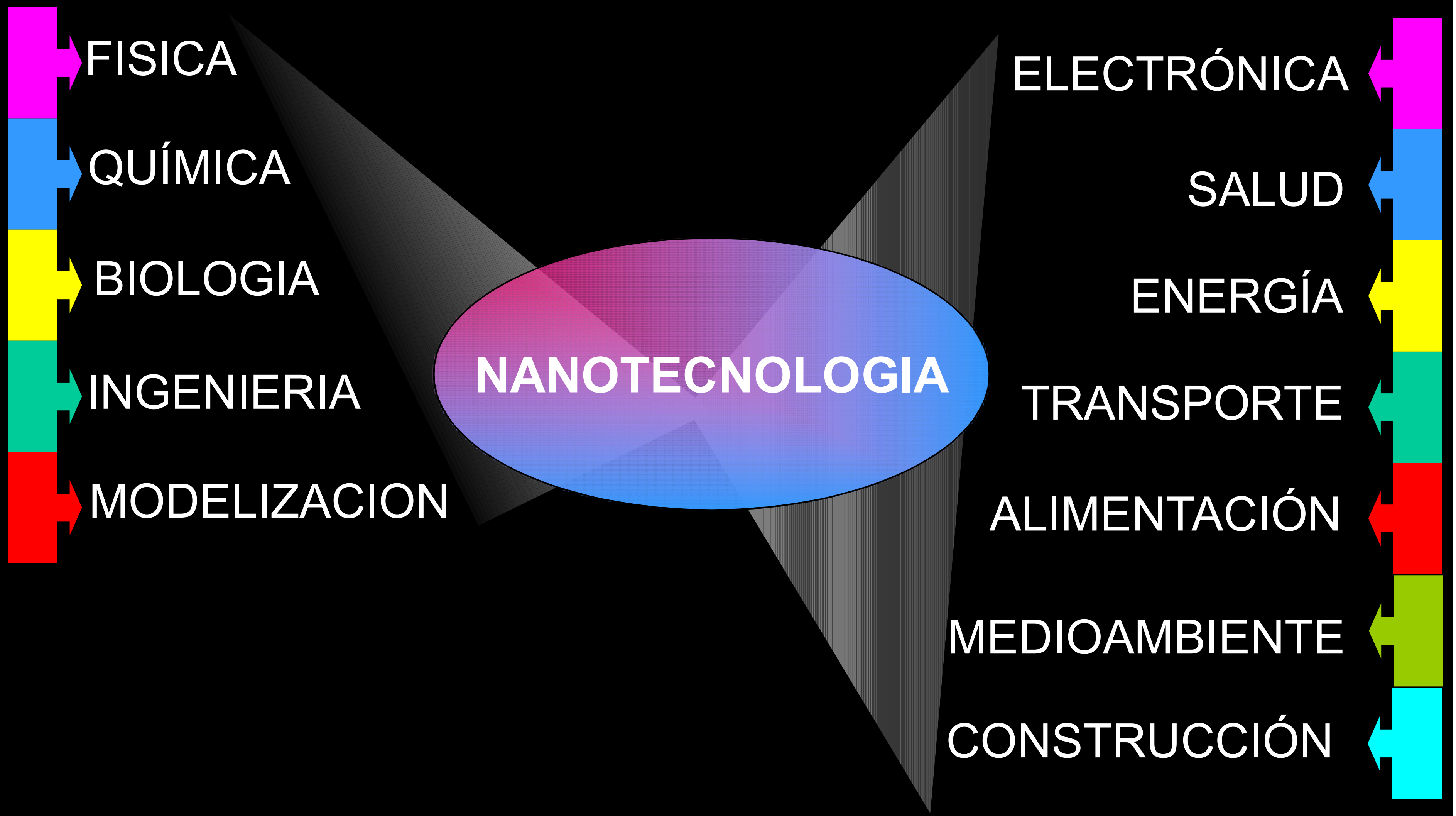


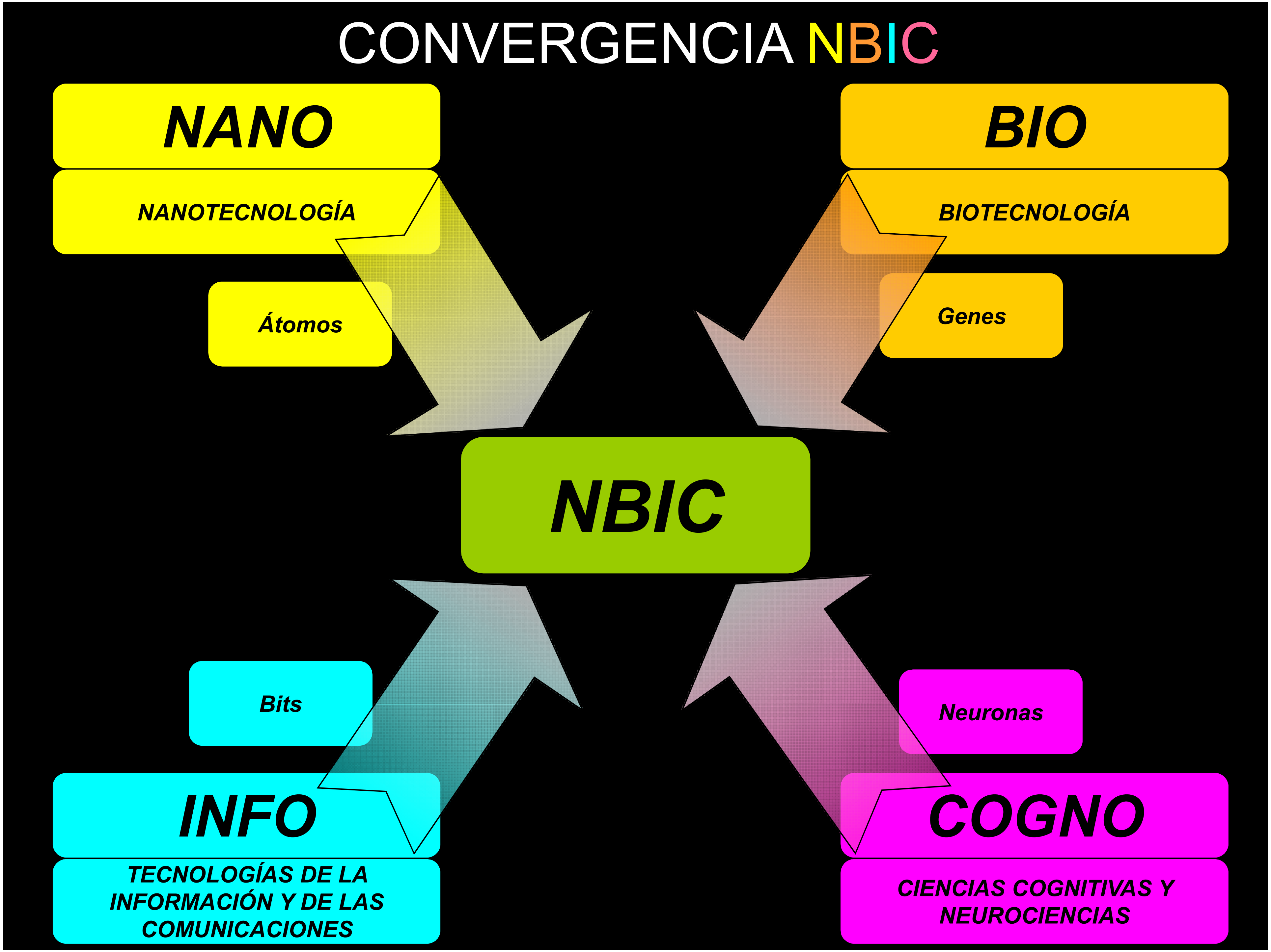




LA CONSEQÜÈNCIA DEL CARÀCTER MULTIDISCIPLINAR…

SECTORS MÚLTIPLES D’APLICACIÓ.




CONVERGENCIA NBIC
NANO
NANOTECNOLOGÍA
Átomos
BIO
BIOTECNOLOGÍA
Genes
NBIC
Bits
INFO
TECNOLOGÍAS DE LA INFORMACIÓN Y DE LAS COMUNICACIONES
Neuronas
COGNO
CIENCIAS COGNITIVAS Y NEUROCIENCIAS

IMPACTE EN ELCINEMA – TELEVISIÓ – JOCS - LITERATURA

Películas:

“The Hulk”, “Spiderman”, “Parque Jurásico”, “Inteligencia artificial”, “Yo robot”, “Minority report”, “Spy kids”, “Prey”, “Super agente Cody Banks”, “Terminator 3” , “The tuxedo”, “Batman”, “Transformers”, “G.I. JOE”, “Trascendence”

Series de televisión:

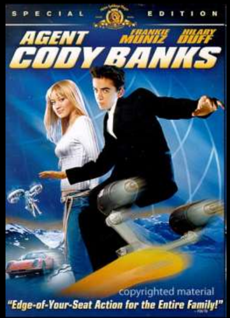
“Jake 2.0”, “Ben 10”

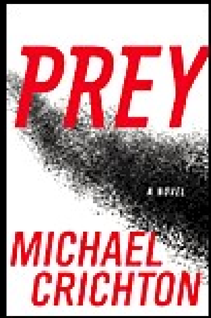
Juegos on-line:

“OGAME”

Libros:

“PREY” (M. Crichton, 2002)
“Nano” (J.R. Marlow, 2004)
The Diamond Age”
(N. Stephenson, 1995)





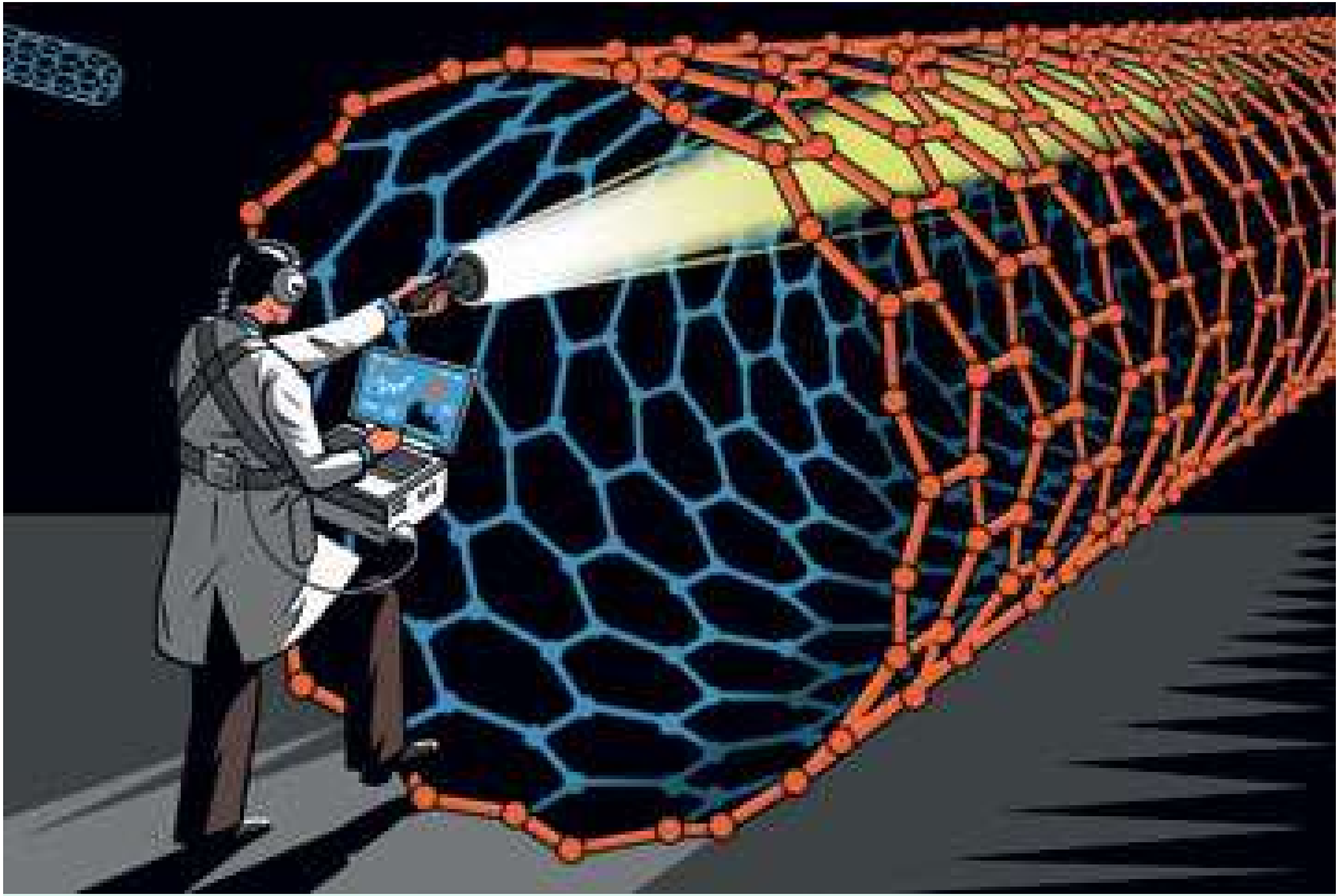
Camí del cel…o de l'infern

Mai abans el món havia encarat una oportunitat tan magnifica…

..però a la seva vegada,

mai abans els riscos

potencials havien estat tan grans.



Sobre els riscos encara hi ha molt desconeixement

VOCES DE ALARMA

QUE HEM DE FER?

QUE DIFERENTS COLECTIUS S'INVOLUCRIN (INFORMACIÓ / ENQUESTES)

COM SEGUIM?

EDUCACIÓ I DIVULGACIÓ

La nanotecnologia és el pas següent en el desenvolupament industrial o post-industrial de la humanitat. La nanotecnologia pot ajudar a resoldre reptes socials mitjançant productes millorats o solucions radicalment noves en l'àmbit de la transport, energia, medicina, alimentació, etc.

El desenvolupament de la nanotecnologia requereix :

-Ser realista i anar amb compte amb excessives promeses,

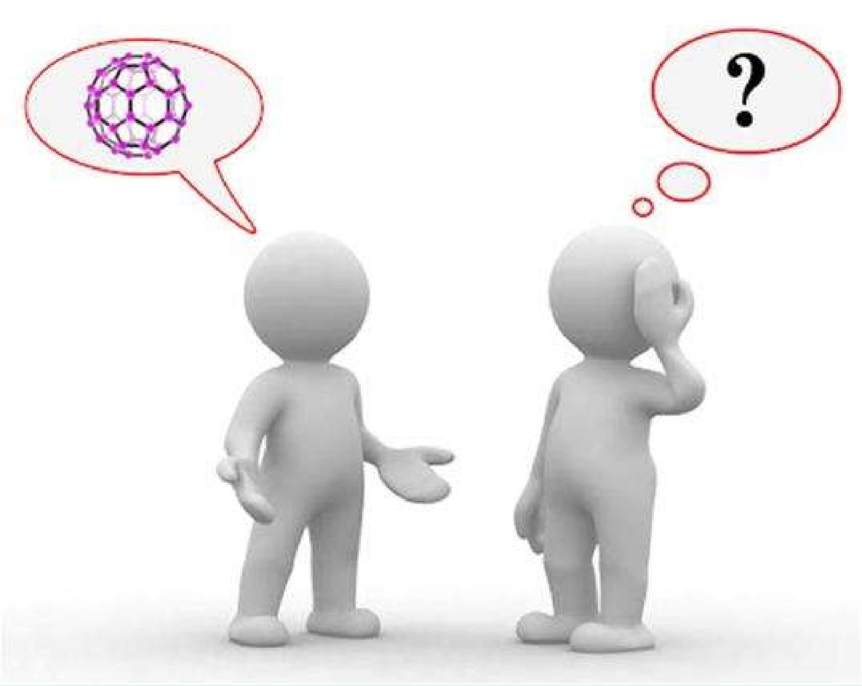
-estandarditzar productes, normativa sobre nanomaterials,

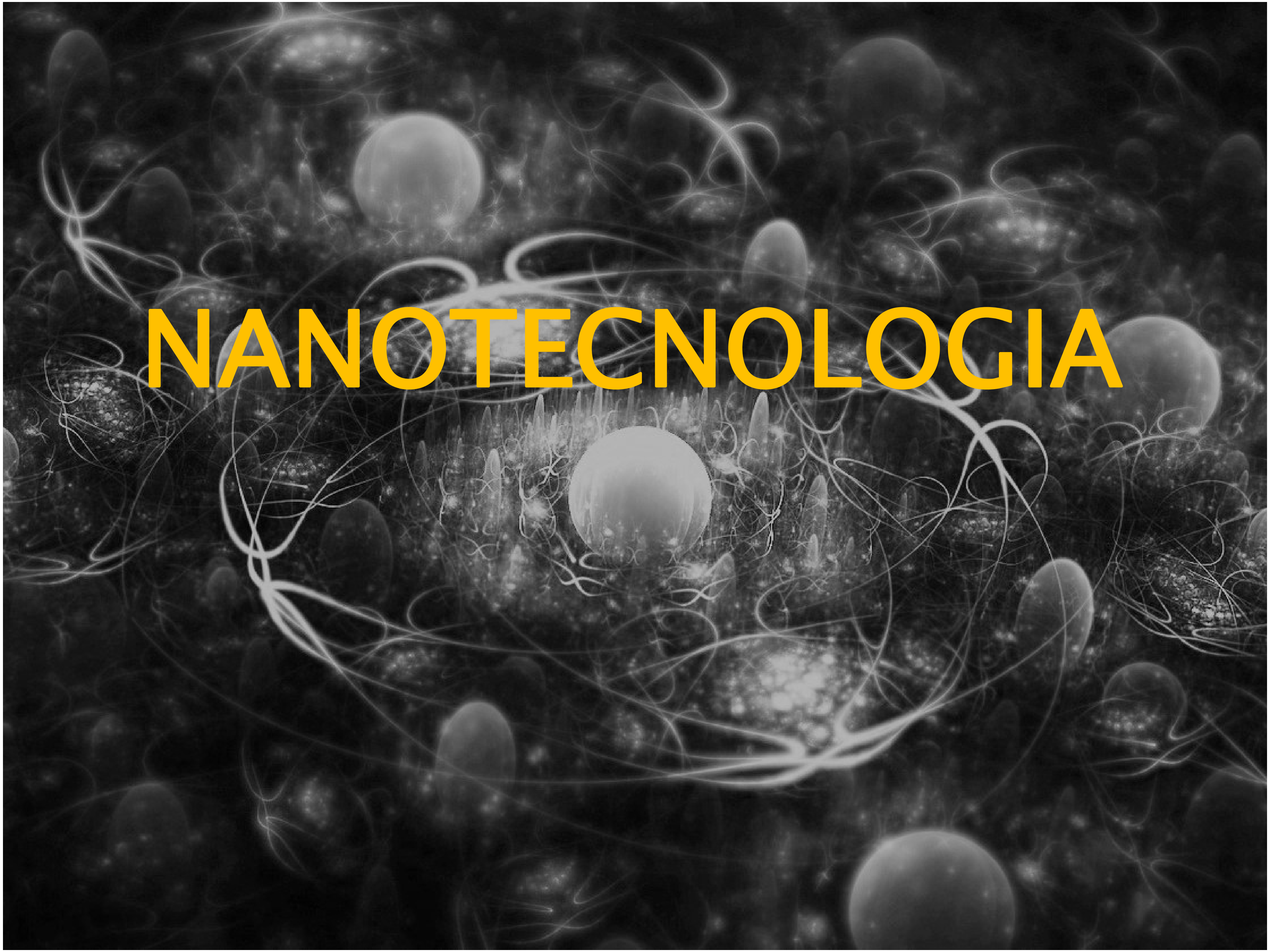
-tenir en compte la percepció del públic,

-realitzar activitats de divulgació i formació,

-recursos econòmics focalitzats

Preguntes, questions…..

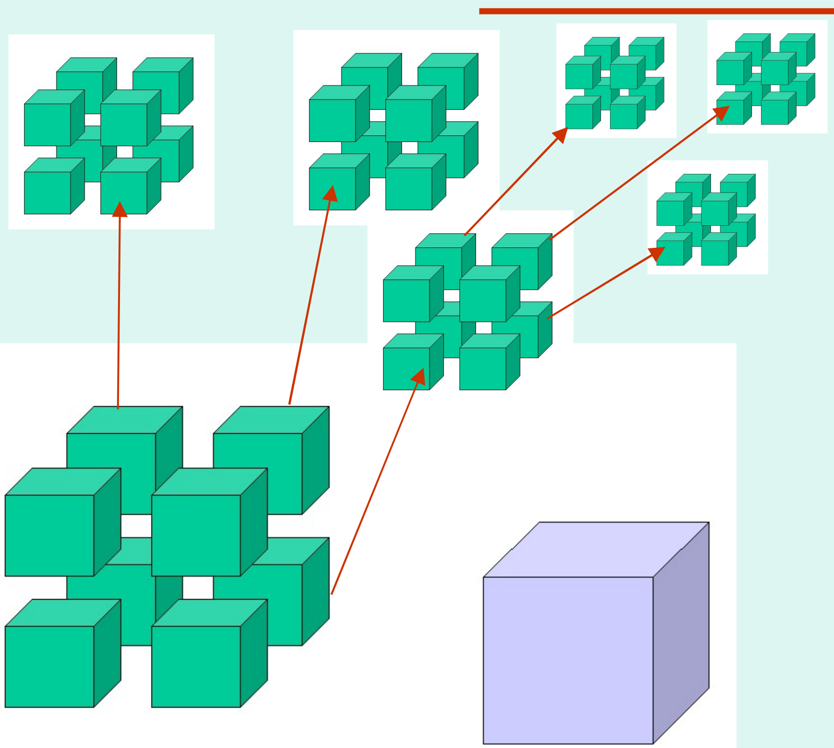



NANOTECNOLOGIA

NATIONAL NANOTECHNOLOGY INITIATIVE

Nanoscale = High Ratio of Surface Area to Vol.

Repeat 24 times



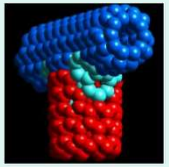
8 Cubes Side L
Each has Surface area $6L^2$
Total Surface Area $48 L^2$

1 Cube
Length of sides 2L
Surface area $24 L^2$

For example, 5 cubic centimeters - about 1.7 cm per side - of material divided 24 times will produce 1 nanometer cubes and spread in a single layer could cover a football field

Source: Clayton Teague, NNI

Size Dependence of Properties



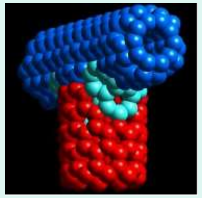
- In materials where strong chemical bonding is present, delocalization of valence electrons can be extensive. The extent of delocalization can vary with the size of the system.

- Structure also changes with size.

- The above two changes can lead to different physical and chemical properties, **depending on size**
  - Optical properties
  - Bandgap
  - Melting point
  - Specific heat
  - Surface reactivity
  -
  -

- Even when such nanoparticles are consolidated into macroscale solids, new properties of bulk materials are possible.
  - Example: enhanced plasticity

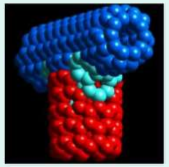
Some More Size-Dependent Properties



- For semiconductors such as ZnO, CdS, and Si, the bandgap changes with size
  - Bandgap is the energy needed to promote an electron from the valence band to the conduction band
  - When the bandgaps lie in the visible spectrum, a change in bandgap with size means a change in color

- For magnetic materials such as Fe, Co, Ni, Fe_3O_4, etc., magnetic properties are size dependent
  - The 'coercive force' (or magnetic memory) needed to reverse an internal magnetic field within the particle is size dependent
  - The strength of a particle's internal magnetic field can be size dependent

Color

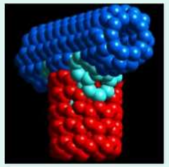


- In a classical sense, color is caused by the partial absorption of light by electrons in matter, resulting in the visibility of the complementary part of the light
- On most smooth metal surfaces, light is totally reflected by the high density of electrons → no color, just a mirror-like appearance.
- Small particles absorb, leading to some color. This is a size dependent property.

Example: Gold, which readily forms nanoparticles but not easily oxidized, exhibits different colors depending on particle size.

- Gold colloids have been used to color glasses since early days of glass making. Ruby-glass contains finely dispersed gold-colloids.
- Silver and copper also give attractive colors

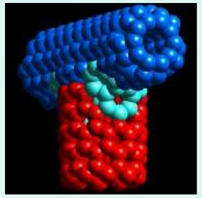
Specific Heat



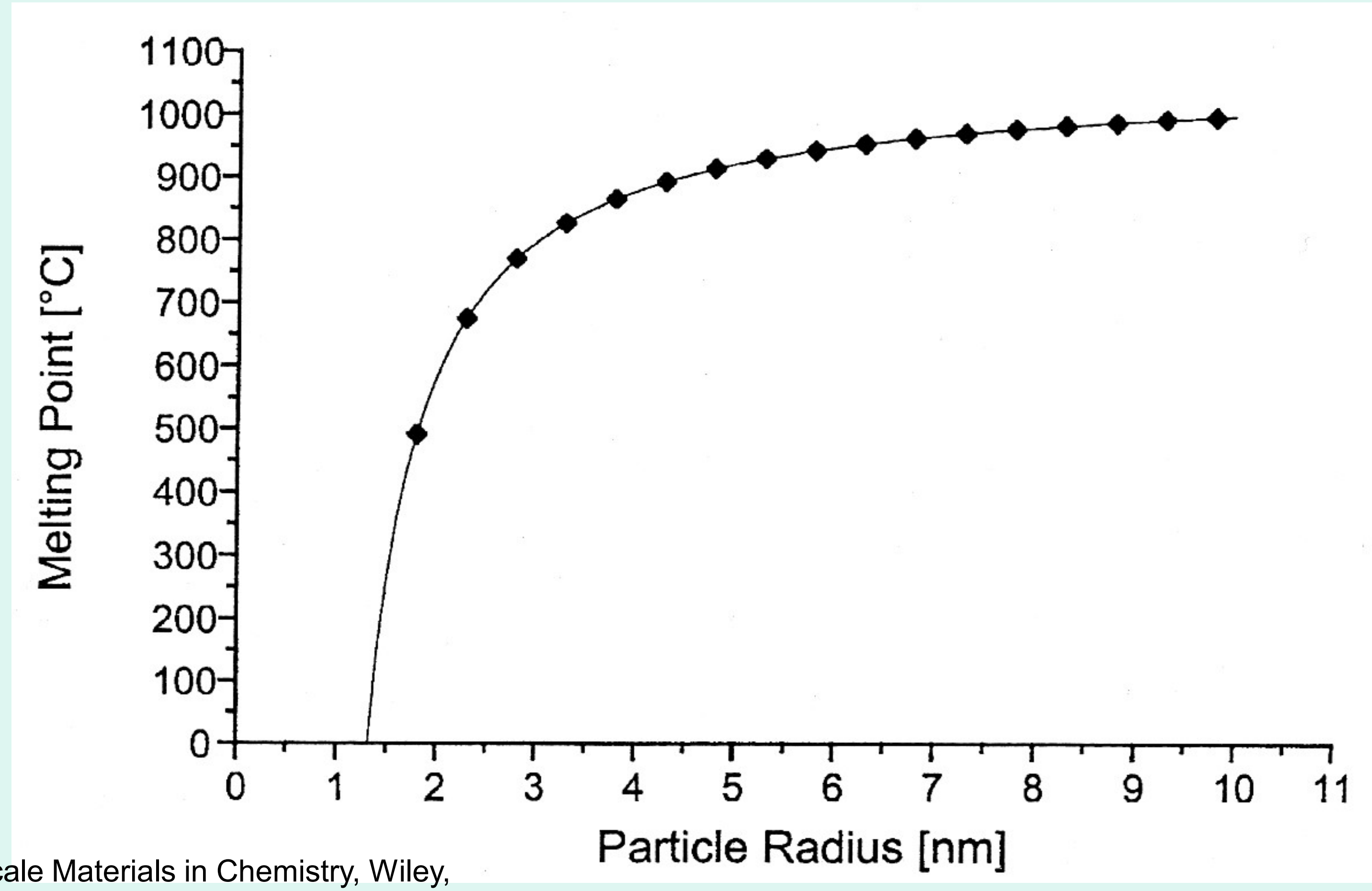
- $C = \Delta Q/m\Delta T$; the amount of heat ΔQ required to raise the temperature by ΔT of a sample of mass m
- J/kg ·K or cal/g ·K; 1 calorie is the heat needed to raise the temp. of 1 g of water by 1 degree.
- Specific heat of polycrystalline materials given by Dulong-Petit law
  - C of solids at room temp. (in J/kg ·k) differ widely from one to another; but the molar values (in J/moles ·k) are nearly the same, approaching 26 J/mol ·K; $C_v = 3$ Rg/M

    where M is molecular weight
- C_v of nanocrystalline materials are higher than their bulk counterparts. Example:
  - Pd: 48% ↑ from 25 to 37 J/mol.K at 250 K for 6 nm crystalline
  - Cu: 8.3% ↑ from 24 to 26 J/mol.K at 250 K for 8 nm
  - Ru: 22% ↑ from 23 to 28 J/mol.K at 250 K for 6 nm

Melting Point

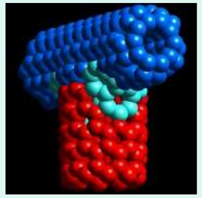


The melting point of gold particles decreases dramatically as the particle size gets below 5 nm



Source: Nanoscale Materials in Chemistry, Wiley,

Melting Point Dependence on Particle Size: Analytical Derivation

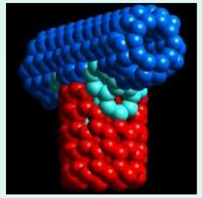


- Start from an energy balance; assume the change in internal energy (ΔU) and change in entropy per unit mass during melting are independent of temperature

$$\Delta\theta = 2T_o\sigma / \rho L r$$

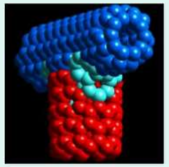
$\Delta\theta$ = Deviation of melting point from the bulk value
T_o = Bulk melting point
σ = Surface tension coefficient for a liquid-solid interface
ρ = Particle density
r = Particle radius
L = Latent heat of fusion

Melting Point Dependence on Particle Size



- Lowering of the melting point is proportional to 1/r
- $\Delta\theta$ can be as large as couple of hundred degrees when the particle size gets below 10 nm!
- Most of the time, σ the surface tension coefficient is unknown; by measuring the melting point as a function of radius, σ can be estimated.
- Note: For nanoparticles embedded in a matrix, melting point may be lower or higher, depending on the strength of the interaction between the particle and matrix.

Electrical Conductivity



- For metals, conductivity is based on their band structure. If the conduction band is only partially occupied by electrons, they can move in all directions without resistance (provided there is a perfect metallic crystal lattice). They are not scattered by the regular building blocks, due to the wave character of the electrons.

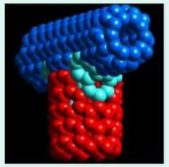
$$\mu = \frac{e\lambda}{4\pi\varepsilon_o m_e v}$$

v = electron speed
ε_o = dielectric constant in vacuum

τ, mean time between collisions, is λ/v

- For Cu, $v = 1.6 \times 10^6$ m/s at room temp.; $\lambda = 43$ nm, $\tau = 2.7 \times 10^{-14}$s

Electrical Conductivity (continued)



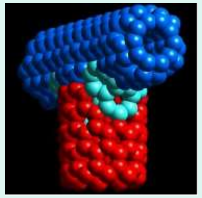
- Scattering mechanisms
  (1) By lattice defects (foreign atoms, vacancies, interstitial positions, grain boundaries, dislocations, stacking disorders)
  (2) Scattering at thermal vibration of the lattice (phonons)

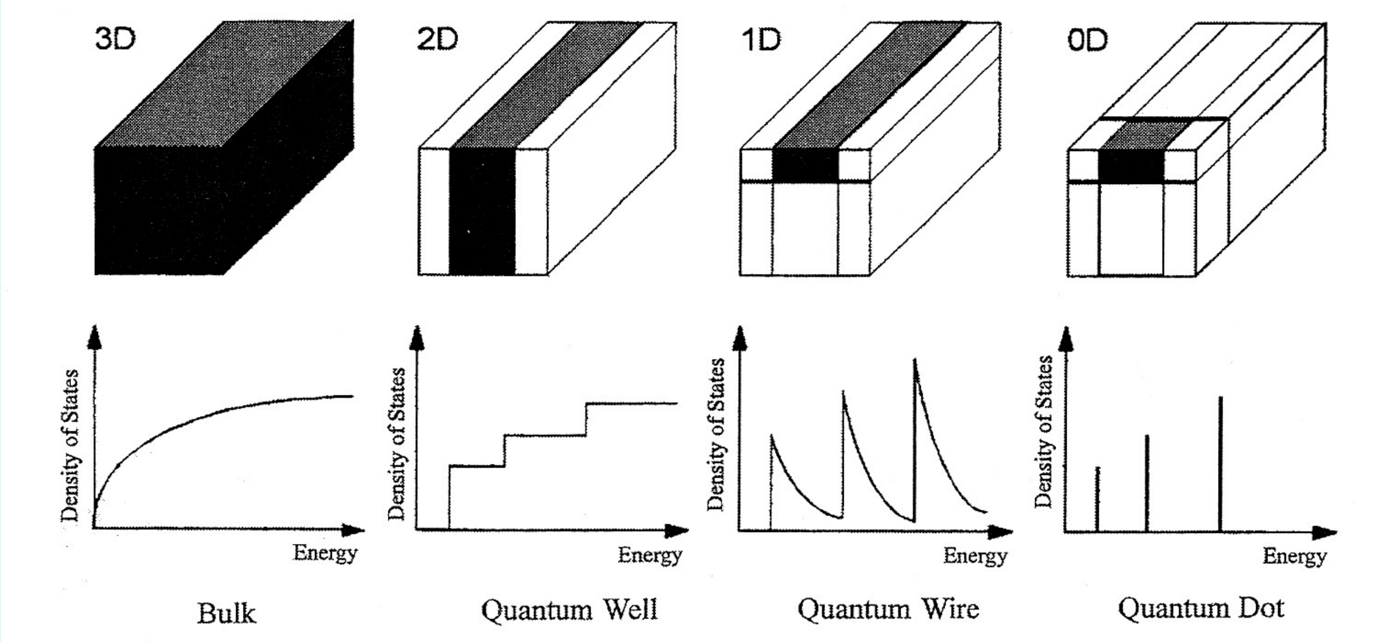
- Item (1) is more or less independent of temperature while item #2 is independent of lattice defects, but dependent on temperature.

- Electric current collective motion of electrons; in a bulk metal,
  Ohm's law: V = RI

- Band structure begins to change when metal particles become small. Discrete energy levels begin to dominate, and Ohm's law is no longer valid.

3D → 2D → 1D → 0D



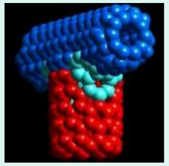


Source: Nanoscale Materials in Chemistry, Wiley, 2001

- If a bulk metal is made thinner and thinner, until the electrons can move only in two dimensions (instead of 3), then it is “2D quantum confinement.”
- Next level is ‘quantum wire
- Ultimately ‘quantum dot’

Ames Research Center

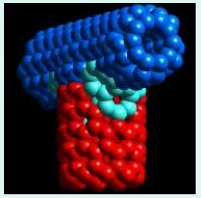
Adsorption: Some Background



- Adsorption is like absorption except the adsorbed material is held near the surface rather than inside

- In bulk solids, all molecules are surrounded by and bound to neighboring atoms and the forces are in balance. Surface atoms are bound only on one side, leaving unbalanced atomic and molecular forces on the surface. These forces attract gases and molecules $\Rightarrow$ Van der Waals force, $\Rightarrow$ physical adsorption or physisorption

- At high temperatures, unbalanced surface forces may be satisfied by electron sharing or valence bonding with gas atoms $\Rightarrow$ chemical adsorption or chemisorption
  - Basis for heterogeneous catalysis (key to production of fertilizers, pharmaceuticals, synthetic fibers, solvents, surfactants, gasoline, other fuels, automobile catalytic converters…)
  - High specific surface area (area per unit mass)



Fine Particle Technology

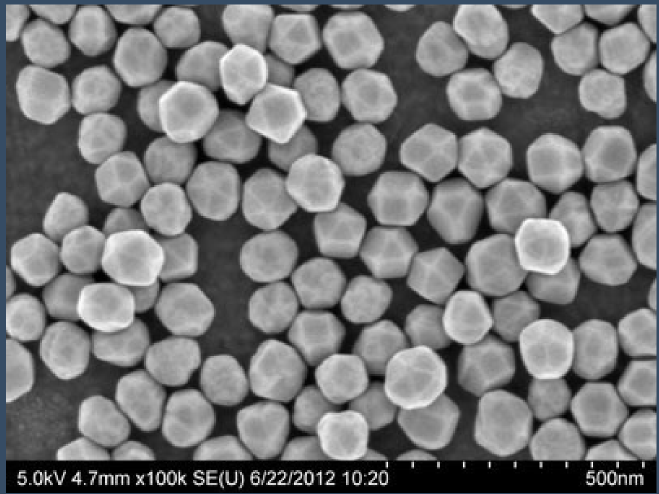
- Frequently encountered powders:
  - Cement, fertilizer, face powder, table salt, sugar, detergents, coffee creamer, baking soda…

- Some products in which powder incorporation is not obvious
  - Paint, tooth paste, lipstick, mascara, chewing gum, magnetic recording media, slick magazine covers, floor coverings, automobile tires…

- For most applications, there is an optimum particle size
  - Taste of peanut butter is affected by particle size
  - Extremely fine amorphous silica is added to control the ketchup flow
  - Medical tablets dissolve in our system at a rate controlled by particle size
  - Pigment size controls the saturation and brilliance of paints
  - Effectiveness of odor removers is controlled by the surface area of adsorbents.

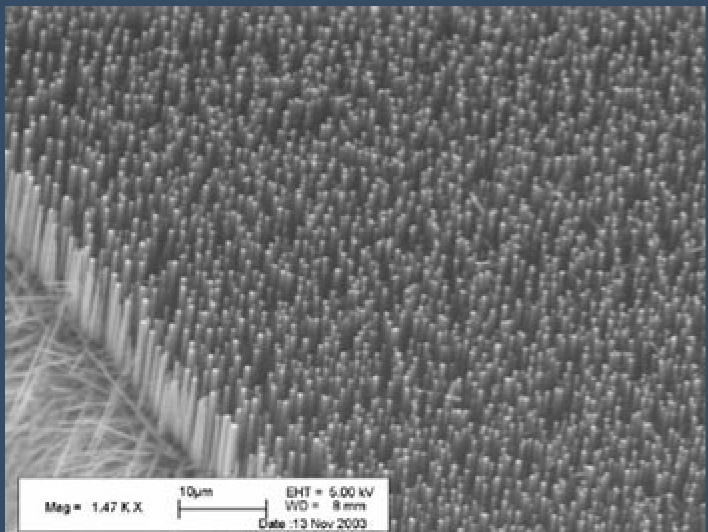
From: Analytical methods in Fine Particle Technology, Webb

Nanoestructures

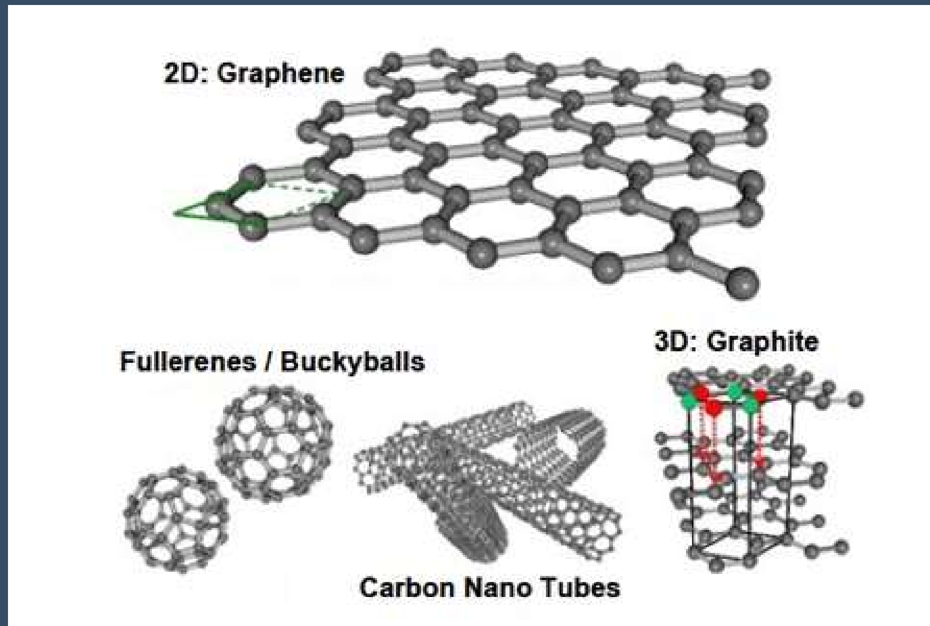


Nanopartícules d'Or. 100nm diàmetre.

Quantum dots: NP semiconductures (CdSe)

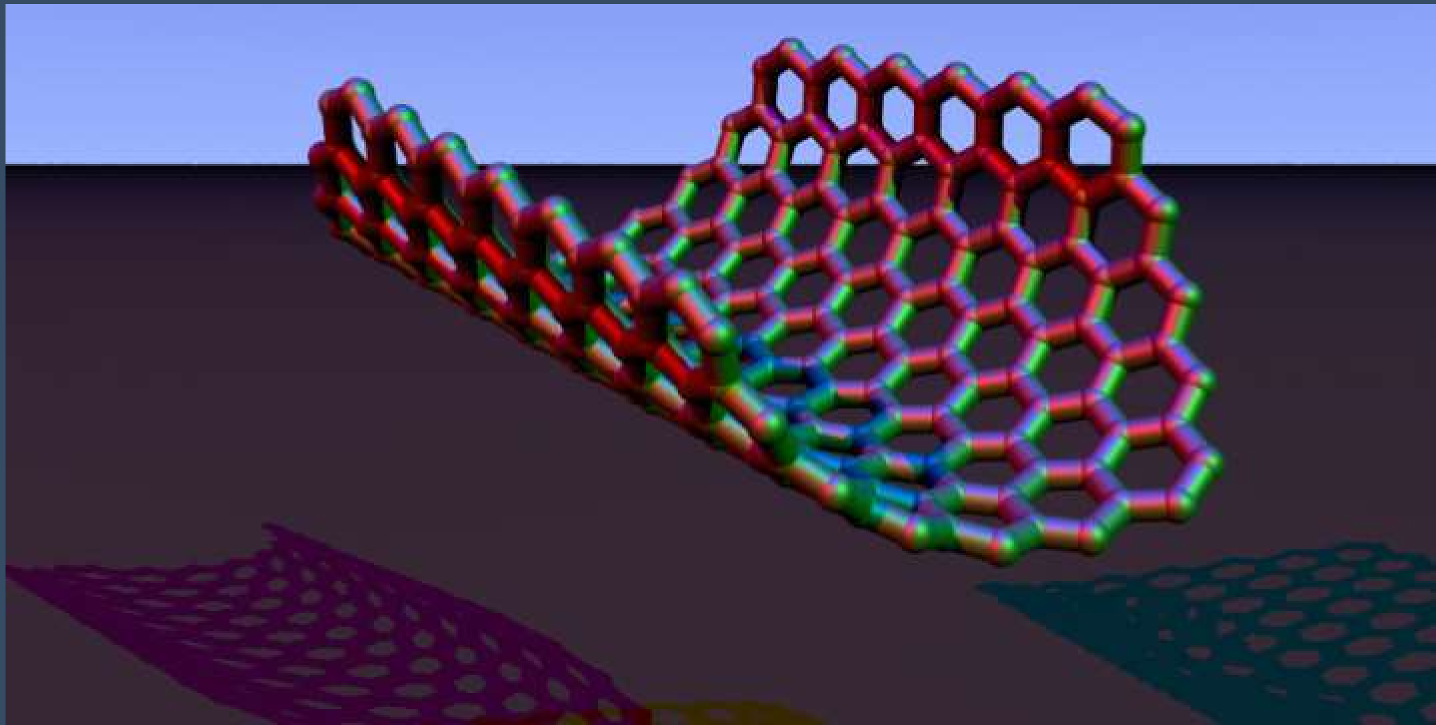


Nanofils de Silici.



Nanoestructures de Carboni

El GRAFÉ



As a Key Enabling Technology (KET), nanotechnology is receiving major funding under Horizon 2020's Industrial Leadership pillar. In addition to investing in the next generation of technologies and helping increase Europe's international competitiveness, the KETs will also help address Horizon 2020's Societal Challenges. El grafé, és un material descobert al 2004 format por àtomos de carboni, amb un espesor atòmic, de 0.34nm, que té unes propietats mai vistes fins ara. És el material més resistent a nivell atòmic, el millor conductor tèrmic i més alta movilitat electrònica conegut fins ara .