INTRODUCCION A NANOCIENCA

Conceptos básicos y aplicaciones en Nanociencia y Nanotecnología

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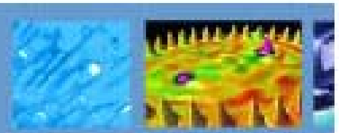
Director Centro de Excelencia en Nuevos Materiales CENM

Universidad del Valle

CENM

Centro de Excelencia en Nuevos Materiales



abc abc A A A

- Que somos
- Motivación
- Lineas de investigación
- Miembros participantes
- Sectores de aplicación
- Grupos científicos
- Artículos Científicos
- Bibliografia adquirida
- Convocatorias
- Marco legal
- Formatos
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- Equipo adquirido
- Financiación
- Prospectiva y vigilancia
- Informes
- Eventos
- Contáctenos
- Inicio

intro...

FP 7 Program :

CORDIS 2007 - 2013

European Union and American Ti, Oxides, Nanostructures - EUL Project 2007

FP7-NMP-2007-2007-(

Sub-Scheme CSA-CA

Información....

CENTER OF EXCELLENCE FOR NOVEL MATERIALS

- 19 research groups Researchers: 80 PhDs
- Sponsorship: PhD and Msc. students:
- Publications: 238

- High-tech robust equipment:

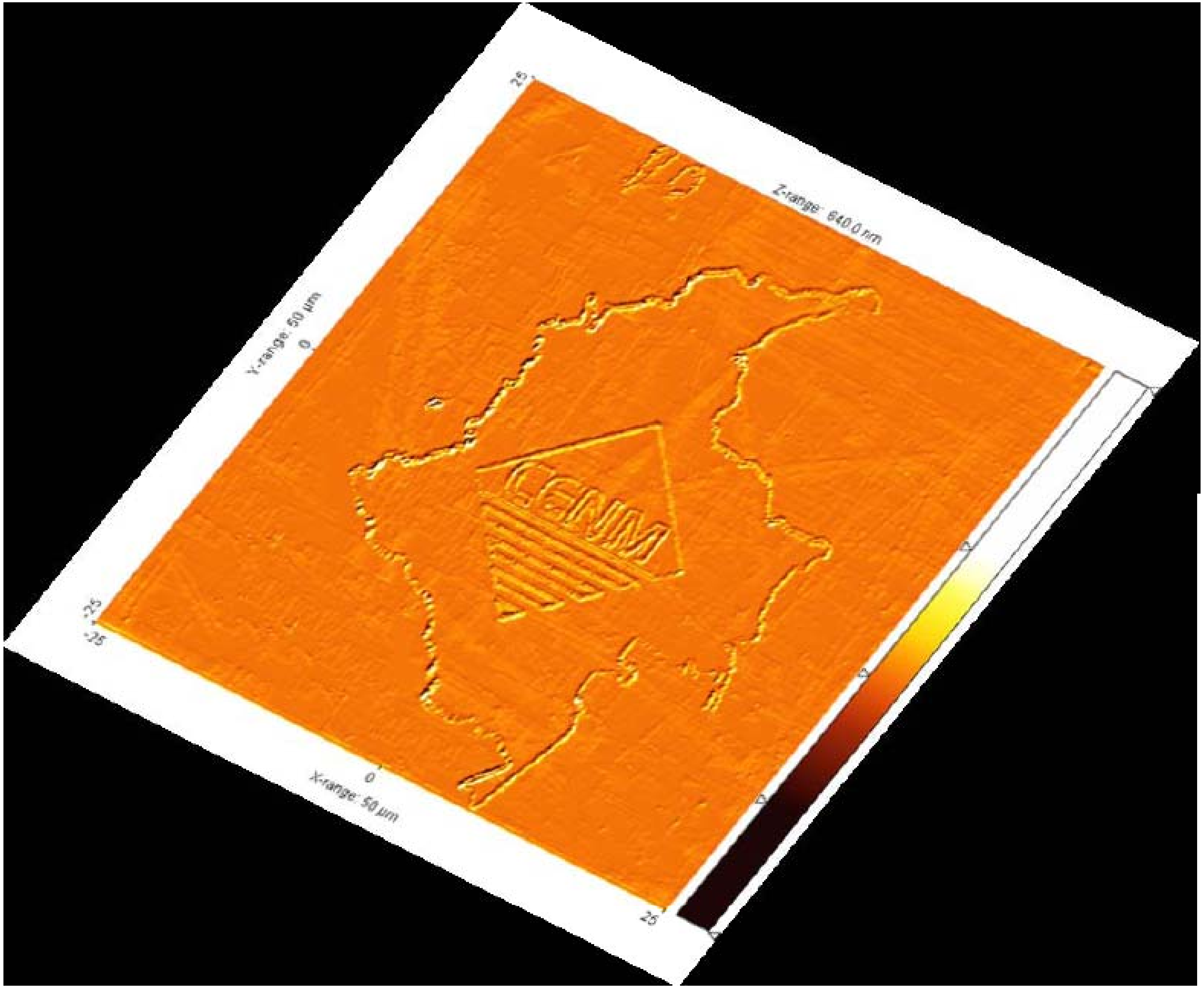
  PPMS (Physical Property Measurement System)

  AFM Atomic Force microscope

  Microraman

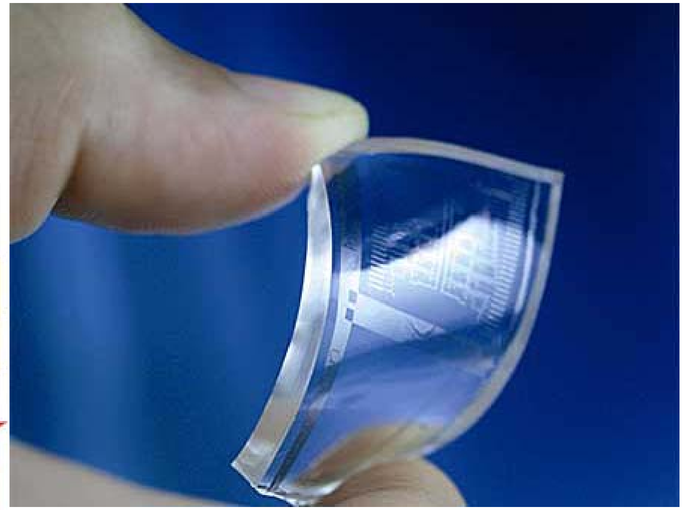
  Spectrophotometers

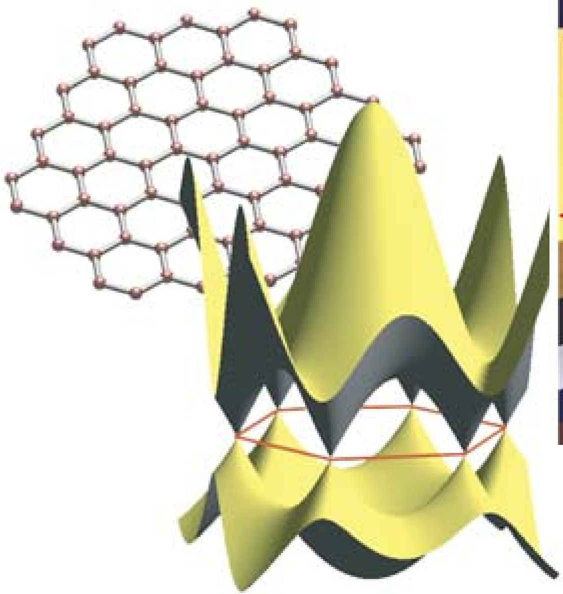
  SEM Scanning Electron Microscope

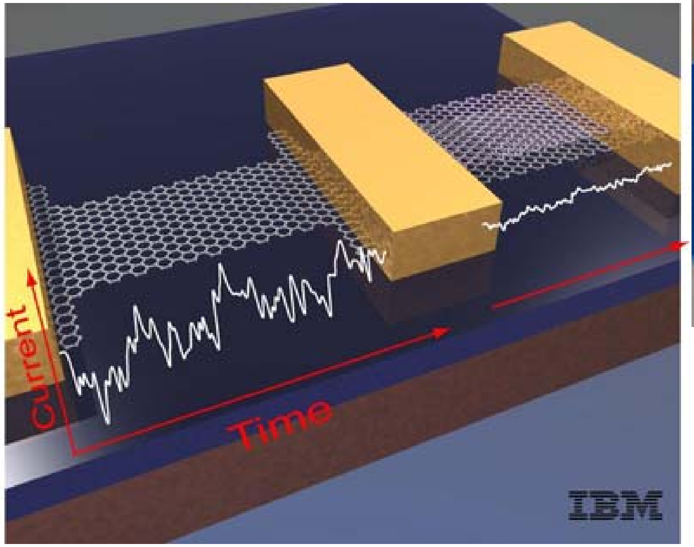

Z-range: 640.0 nm
Y-range: 50 µm
X-range: 50 µm
25
0
-25
-25
0
25

The 2010 Nobel Prize for physics was awarded Professor Andrei Geim (left) and Professor Konstantin Novoselov for their work with graphene at Manchester University.

A nano-material called GRAPHENE







Contenido

✓Conceptos básicos y aplicaciones en Nanociencia y Nanotecnología

✓La mecánica cuántica y la naturaleza a la nanoescala

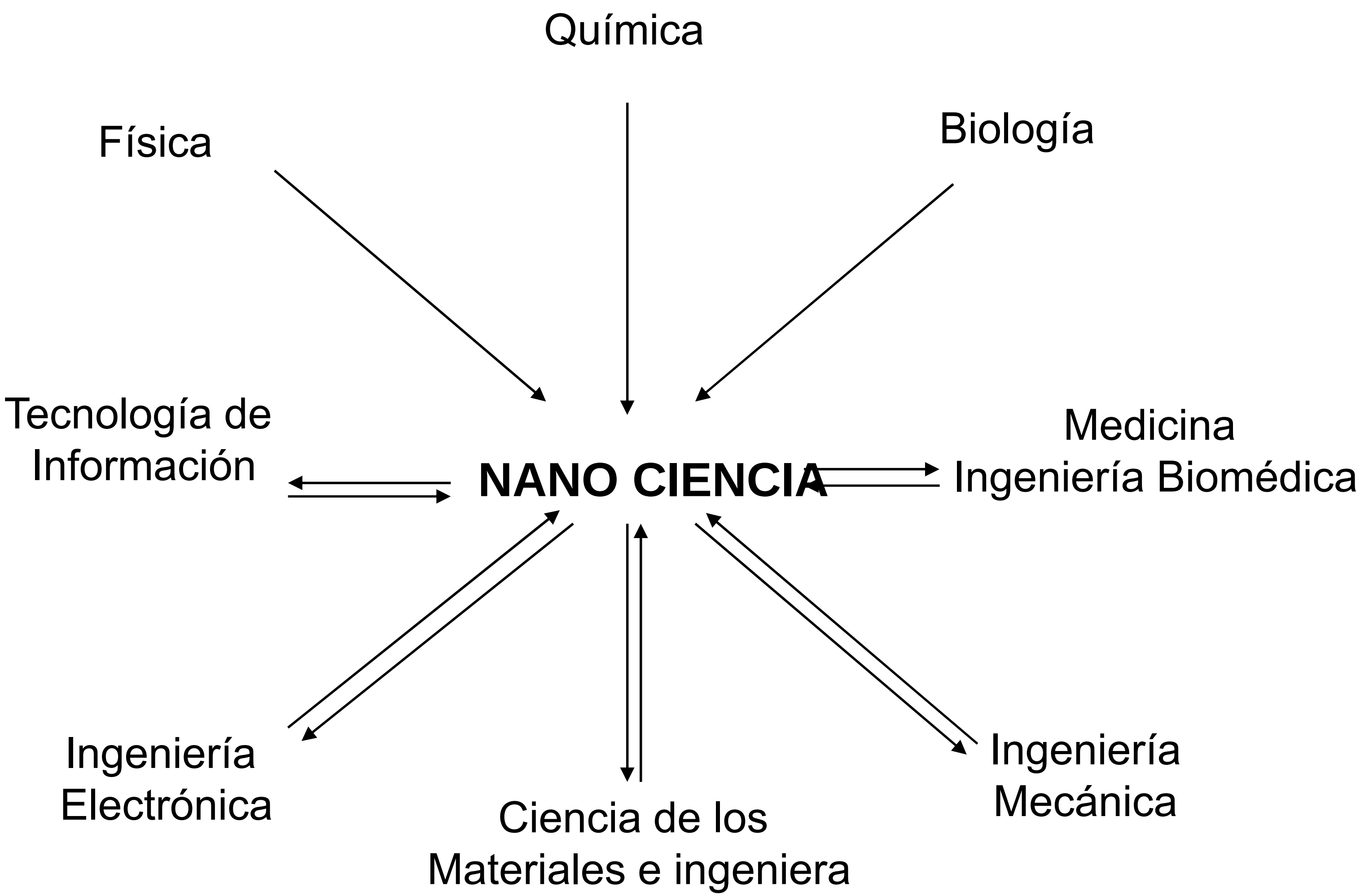
✓Propiedades de materiales nanoestructurados

✓Tecnicas Top-Down para preparación de nanostructuras

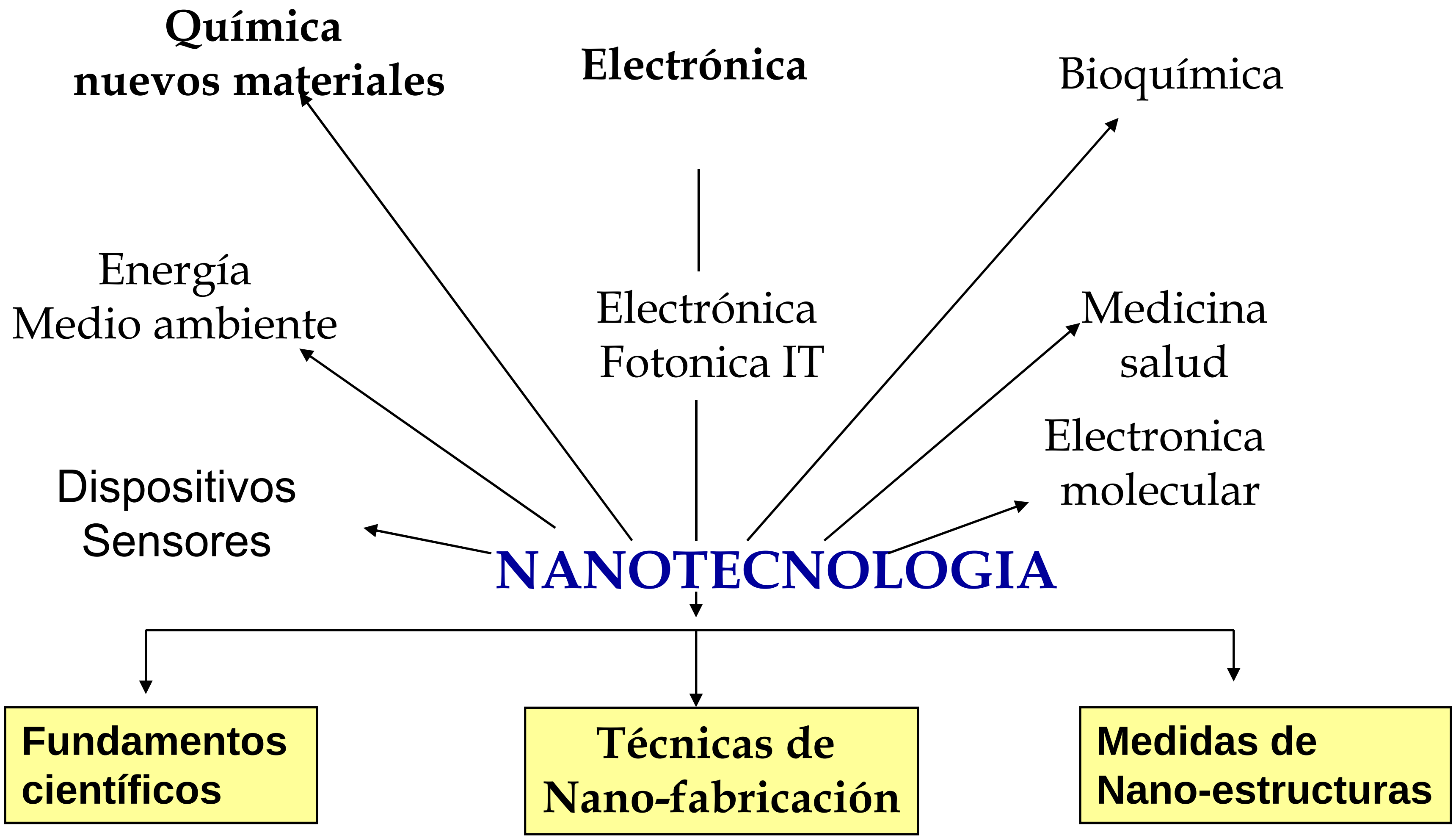
✓Metodos de fabricación Bottom-up

✓Autoensamblaje de nanostructuras

CIENCIA MULTIDISCIPLINARIA



AREAS DE INFLUENCIA DE LA NANOTECNOLOGIA



Antecedentes

“There's Plenty of Room at the Bottom”

Richard Feynman, December 29th 1959

Now, the name of this talk is ``There is Plenty of Room at the Bottom'' - not just ``There is Room at the Bottom.'' What I have demonstrated is that there is room - that you can decrease the size of things in a practical way. I now want to show that there is plenty of room. I will not now discuss how we are going to do it, but only what is possible in principle - in other words, what is possible according to the laws of physics. I am not inventing anti-gravity, which is possible someday only if the laws are not what we think. I am telling you what could be done if the laws are what we think; we are not doing it simply because we haven't yet gotten around to it.

Feynman propone que no hay límites teóricos para la miniaturización

Antecedentes

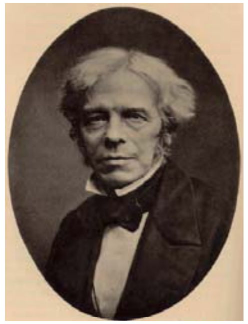
Durante 1856-7 Michael Faraday fue el primero en preparar oro coloidal mediante la reducción de cloruro de oro con fósforo para obtener una solución color “rubí”. Faraday mostró mediante ensayos químicos que el oro ya no permanecía en forma iónica y que los reactantes que disolvían el metal eran capaces de eliminar el color.

Su conclusión fue que el oro era dispersado en el líquido de forma finamente dividida, y su presencia podía ser detectada mediante la opalescencia azulada cuando un intenso y estrecho haz de luz atravesaba el líquido.

Opalescencia en el líquido con NP de Au Faraday, 1856

Opalescencia en el atardecer de Emberger Alm, Austria

Cuandro de una clase de Faraday, tomado de las ilustraciones de London News en 1856.

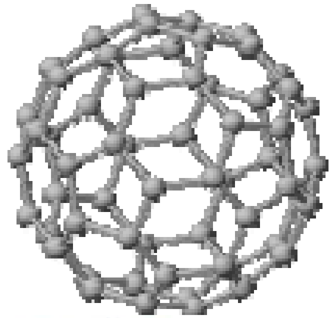


Michael Faraday
1791-1867

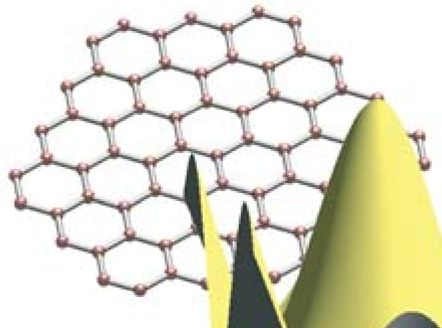
M. Faraday, 'The Bakerian lecture: experimental relations of gold (and other metals) to light', *Philosophical Transactions of the Royal Society of London, Vol. 147* (1847), 145-181, p. 159

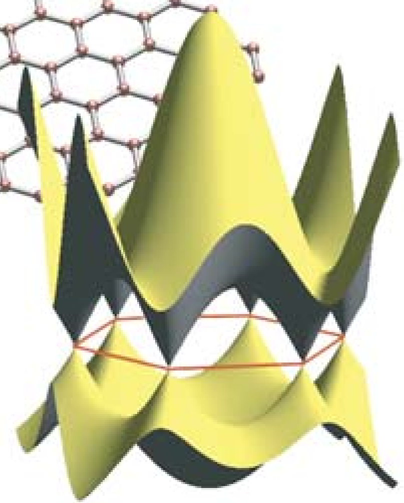
Antecedentes

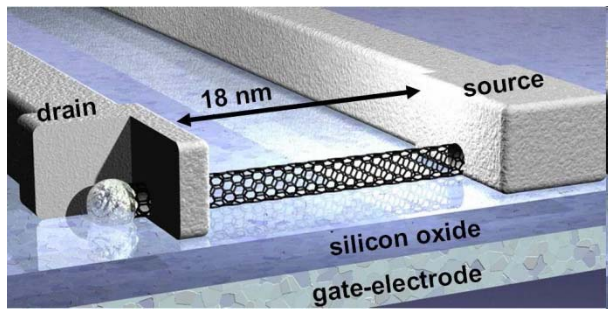
Cronología:



1959: R.P: . Feynmann: “There's Plenty of Room at the Bottom
1974: N. Taniguchi: “Nantechnology” (d = 100 nm)
1981: Binning y Rorher: Microscopio de efecto túnel.
1986: H.W.Kroto, J.R.Heath, S.C. O’Brien, R.F.Curl, R.E. Smalley: estructura de los fullerenos.
1986: Quate and Gerber: Microscopio de Fuerza Atómica (AFM).
1989: IBM: Litografía atómica
1991: S. Lijima: nanotubos de carbono
1996: G. Whitesides: electrónica molecular
1998: C. Dekker: nano-transistor
1999: J. Tour y M. Reed: interruptor molecular
2000: D. Eigler (IBM): corral cuántico
2007 P Grumberg A. Fert GMR Sensor
2010 A. Geim Professor K. Novoselov Grafeno



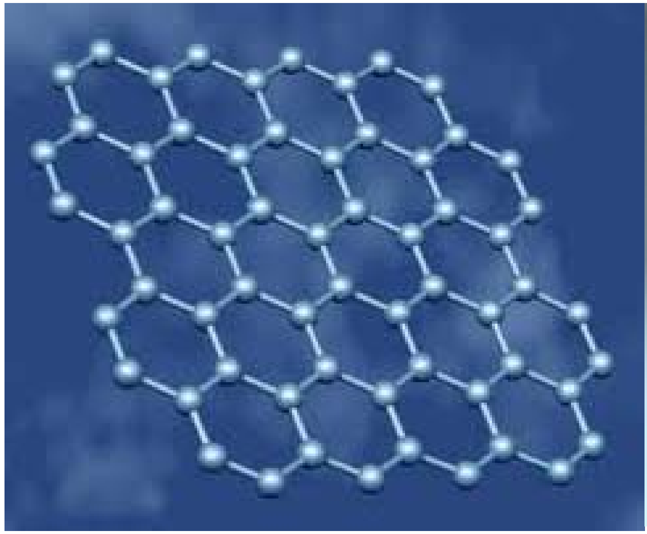


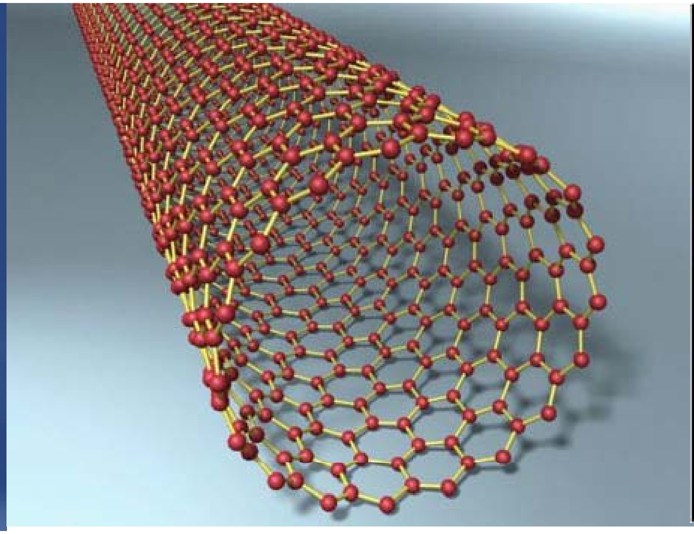


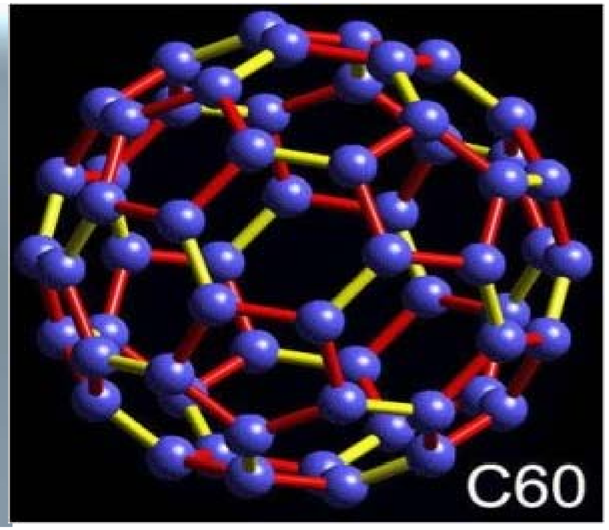
Que es Nanociencia?

Cuando se comienza a hablar de Nanociencia se empiezan a describir cosas

Los Físicos y los ingenieros en materiales apuntan a cosas tales como los nanomateriales basados en carbón







Graphene

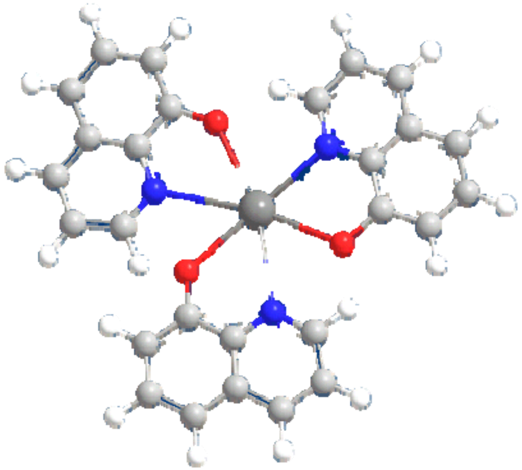
Carbon Nanotube

C60 Buckminster Fullerene

Los Biólogos responden que el nano-carbón es un descubrimiento reciente

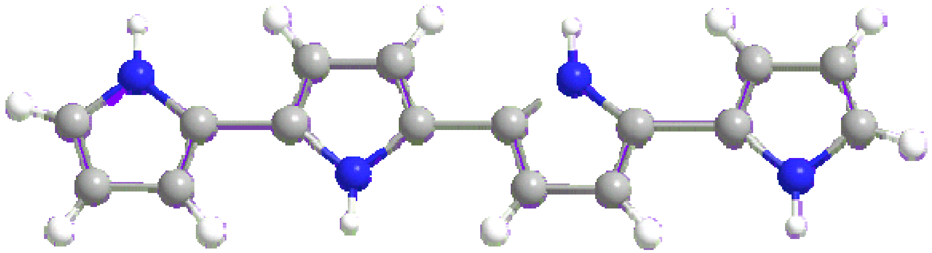
Ellos han estado estudiando el DNA y el RNA por mucho mas tiempo

Los Químicos responden Hemos estado sintetizando moléculas por siglos!!!

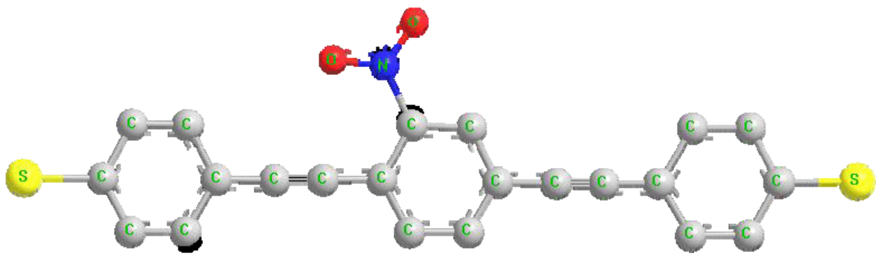


Primer Material para OLED:
tris 8-hydroxyquinoline aluminum

(OLED = Organic Light Emitting Diode)

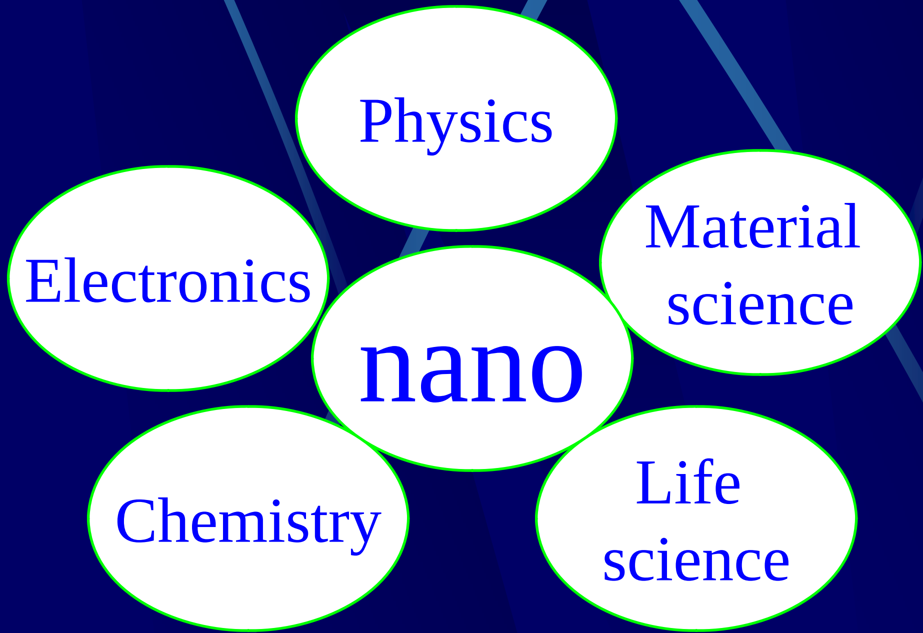


Material para OLED Comerciales:
Polypyrrole

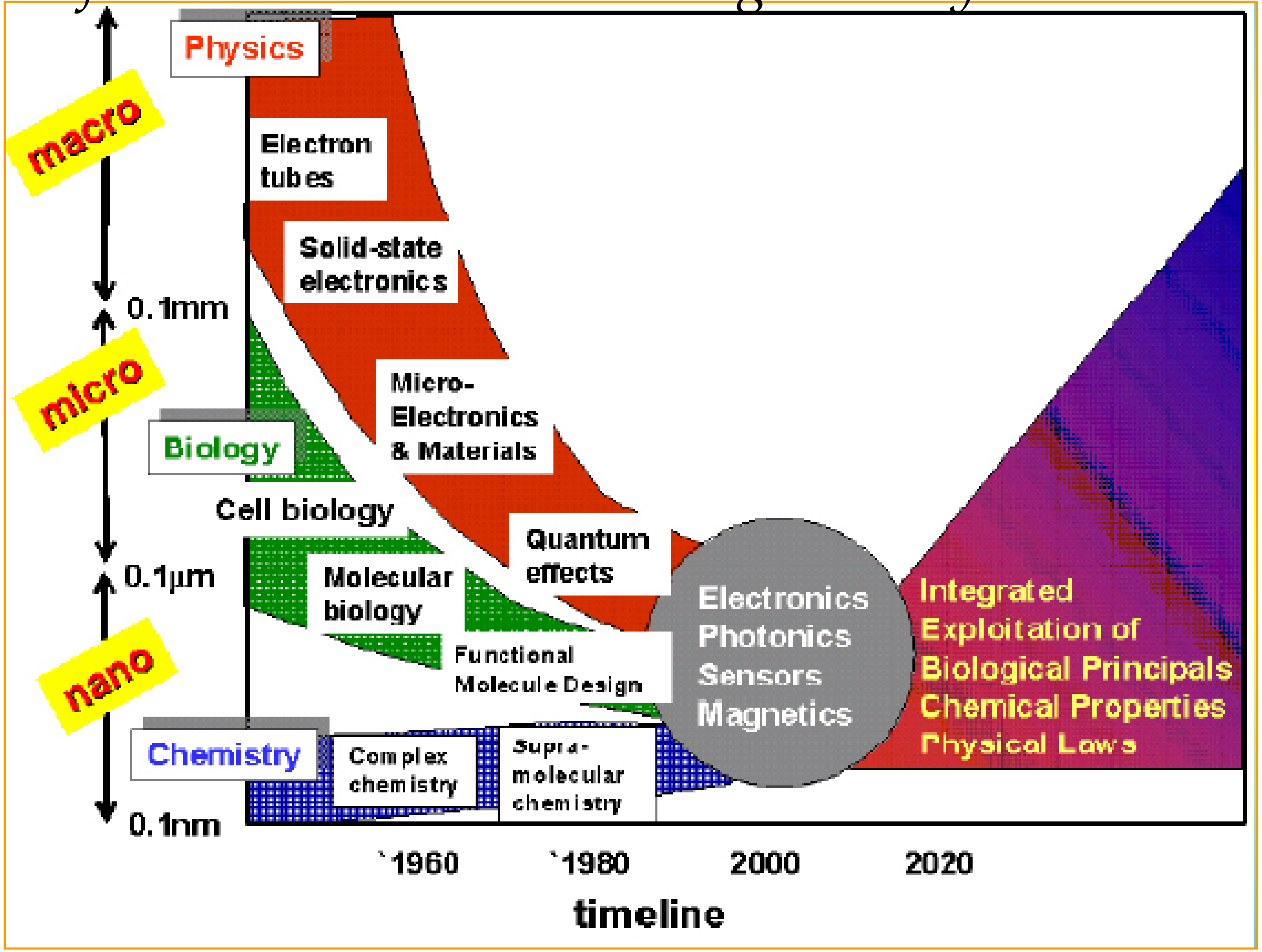


El Material más ampliamente investigado para interruptores en electrónica molecular :
Nitro oligo phenylene ethynylene

Nanotechnology is multi-disciplinary

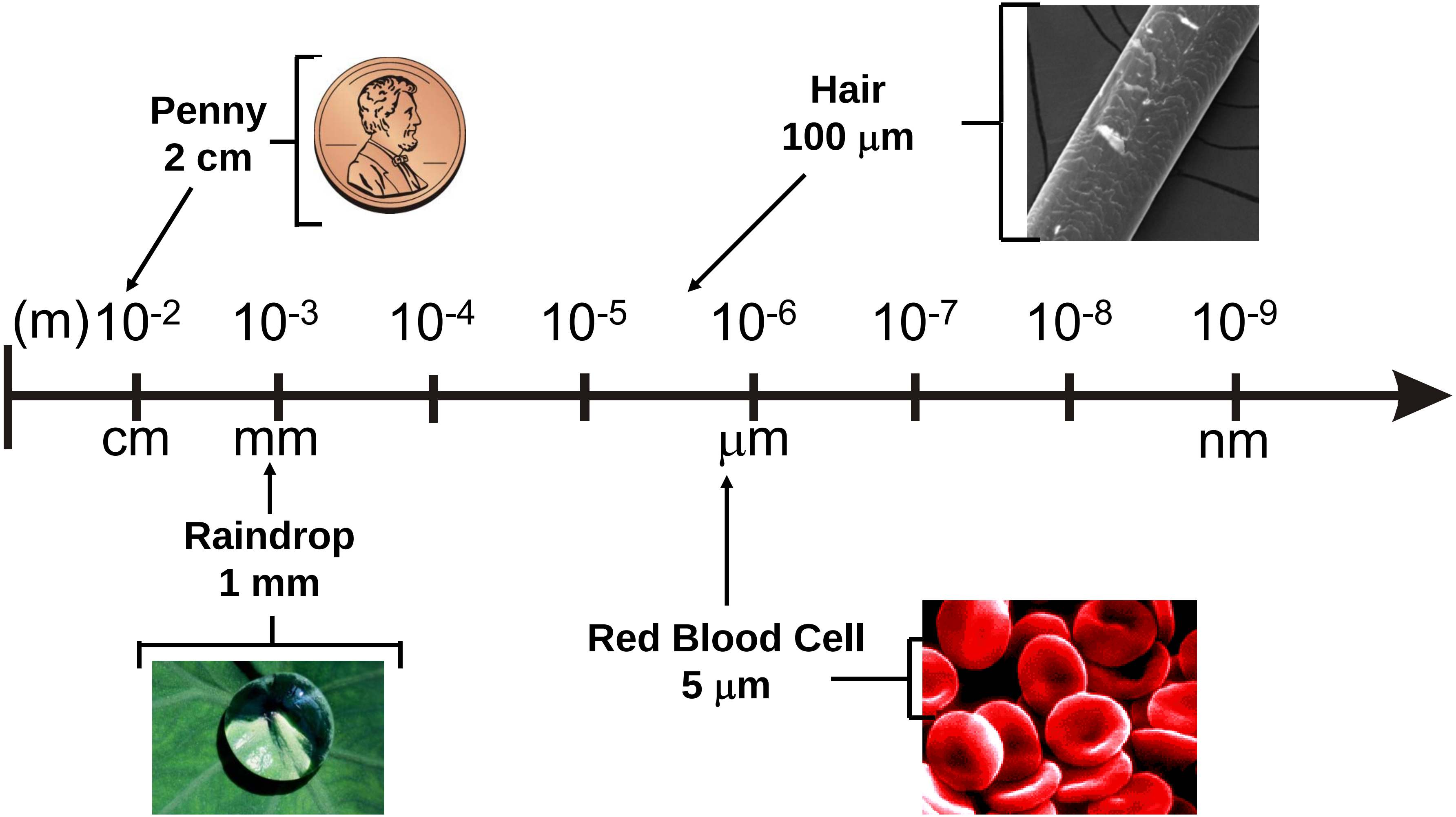


El Nanómetro como escala de longitud fundamental en Ciencia Ingeniería y medicina

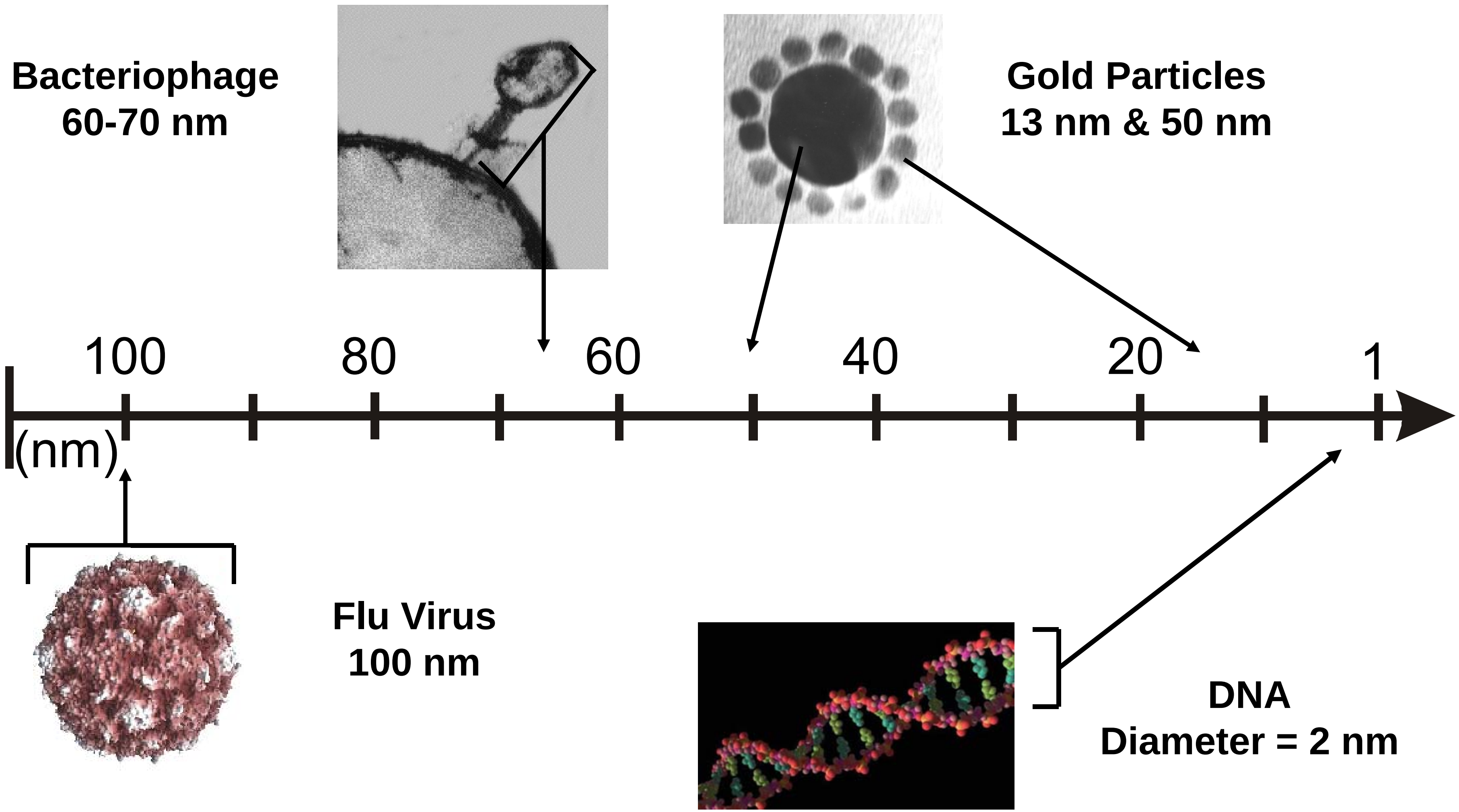


Adapted from the Asia-Pacific Economic Cooperation on Nanotechnology (http://www.apectf.nstda.or.th/html/nano.html).

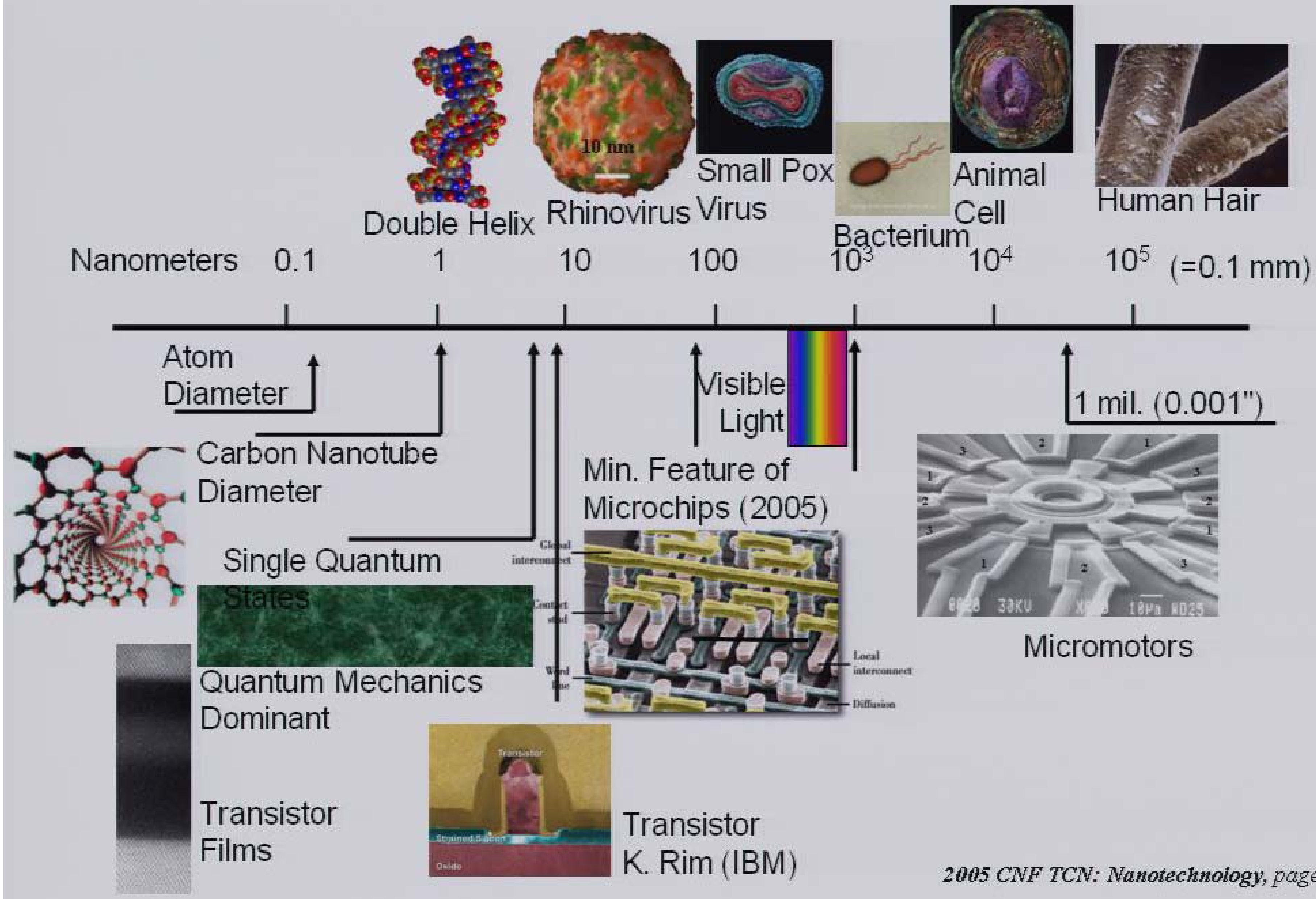
What Is A Nanometer?



Now Entering The NANO-ZONE



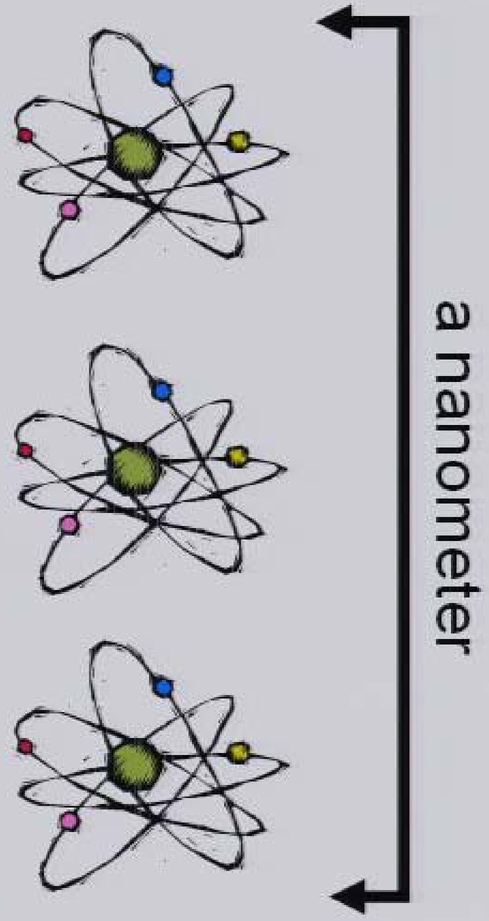
Nanostructure Size Scales

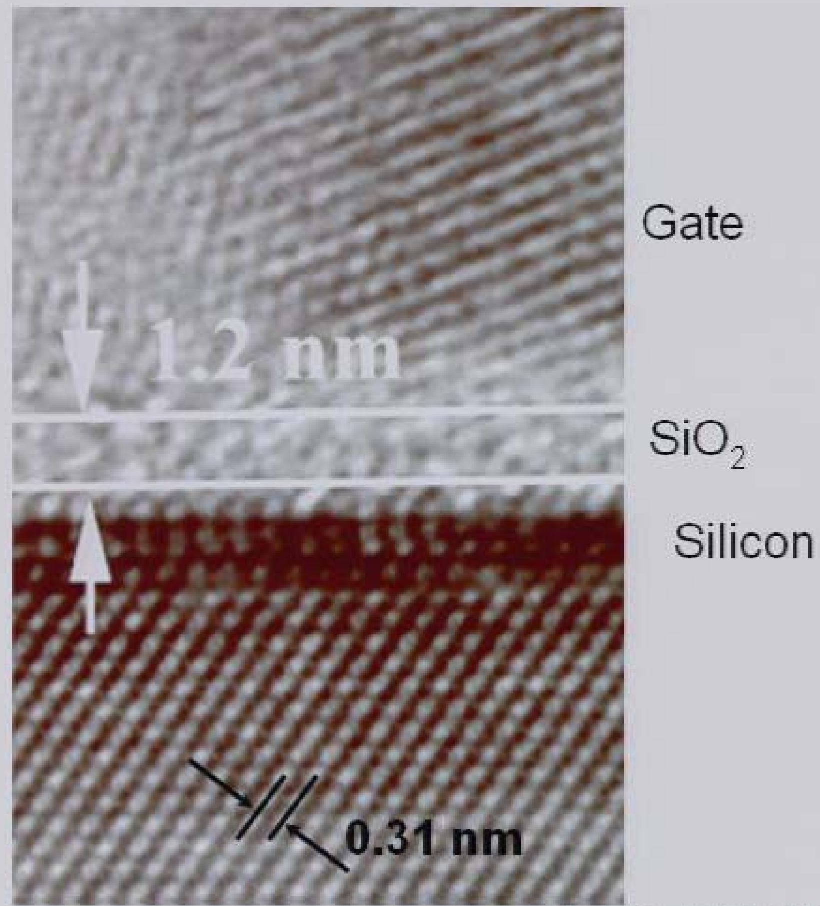


QUE ES NANO?: EL CONCEPTO DE LONGITUD

SI unit (abbreviation)	Description
meter (m)	About three feet
centimeter (cm)	1/100 of a meter
milimeter (mm)	1/1000 of a meter
micrometer (μm)	1/1,000,000 (10^{-6}) of a meter
nanometer (nm)	1/1,000,000,000 (10^{-9}) of a meter
Aångström (Å)	The smallest length unit (10^{-10} m), defined by Swedish physicist **Anders Jonas Ångström** (Aug. 13, 1814 - June 31, 1874)

What is a Nanometer?





Tiwari, MNE (1999)

- A nanometer is one-billionth of a meter.
- A stack of *three* silicon atoms is a nanometer high. This is approximately the thickness of the inversion layer – the conducting electron region of a transistor.

Nanociencia

“Today, at the beginning of the 21st century, research in the life sciences, the information technologies, and the materials sciences converges upon a commonality: the domain of the nanometer, and the manipulation of atoms and molecules. Continued technological progress becomes dependent upon achieving control of materials at the nano scale”

“Nanotechnology can not be defined in terms of dimension or geometry alone. In fact, it represents a convergence of the traditional disciplines of physics, chemistry and biology at a common research frontier”

EC Commissioner Busquin
Proceedings EC/NSF workshop Toulouse, Oct. 2001. Office for Official Publications, ISBN 92-894-0793-X

Que es la nanotecnología?

La Nanotecnología es la creación de Materiales Funcionales, Dispositivos y Sistemas a través del control de la materia a escalas de longitud de los nanómetros y la explicación de nuevos fenómenos y propiedades de los materiales (Físicas, Químicas y Biológicas) a estas escalas de longitud.

"If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering."

-Neal Lane Assistant to the President for S & T


ISSN 0957-4484
NANOTECHNOLOGY
Volume 18 Number 39 3 October 2007
200 nm
www.iop.org/journals/nano
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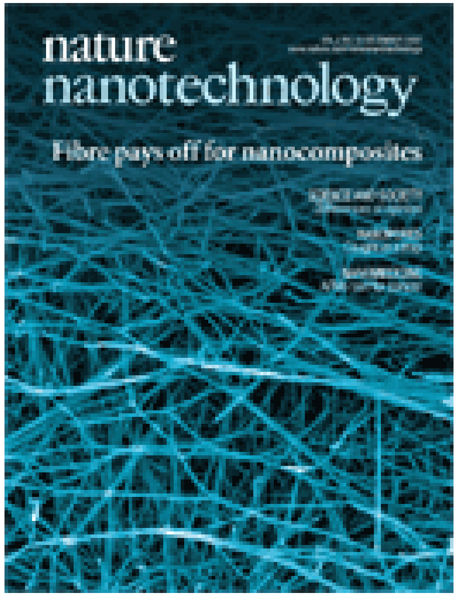
P Makaram, S Selvarasah, X Xiong, C-L Chen, A Busnaina, N Khanduja and M R Dokmeci
IOP Publishing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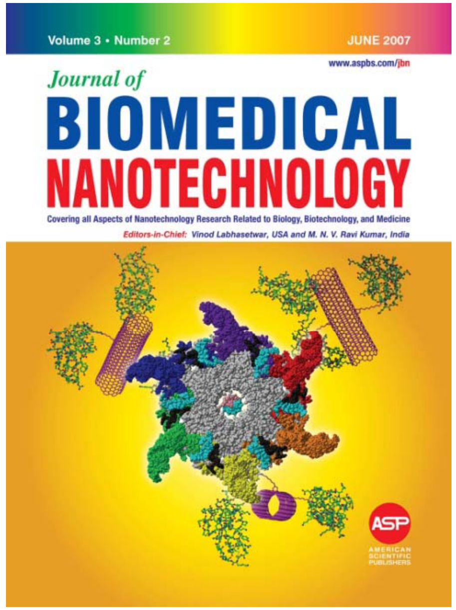
Volume 3 • Number 2
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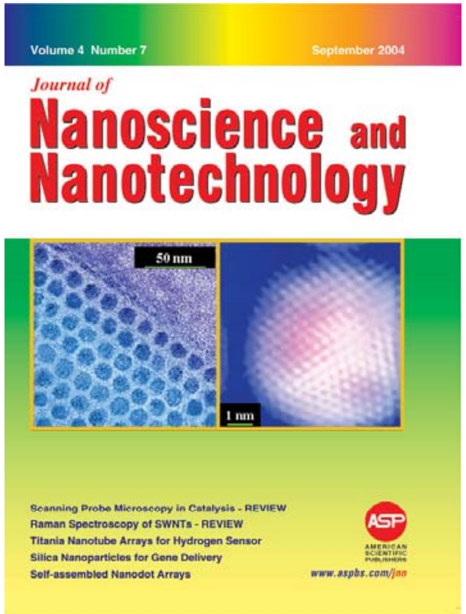
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1 nm
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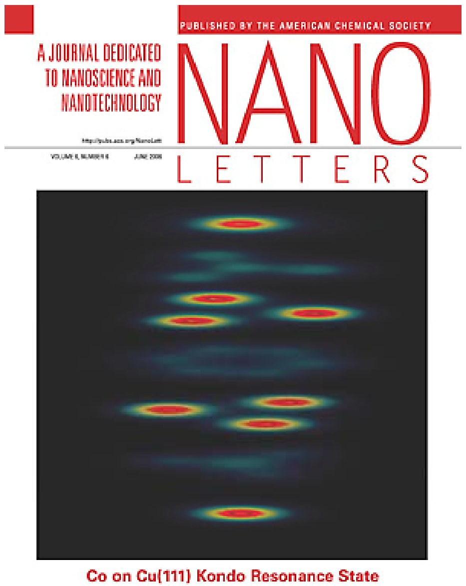
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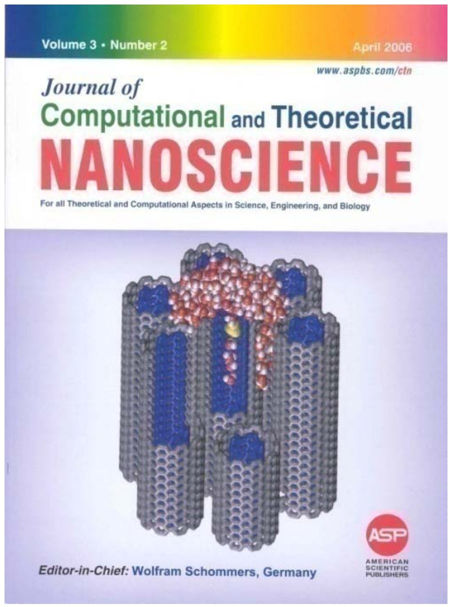
A JOURNAL DEDICATED TO NANOSCIENCE AND NANOTECHNOLOGY
NANO
LETTERS
Co on Cu(111) Kondo Resonance State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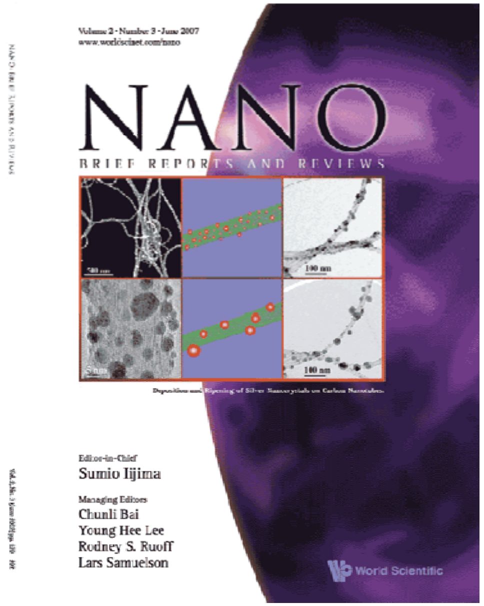
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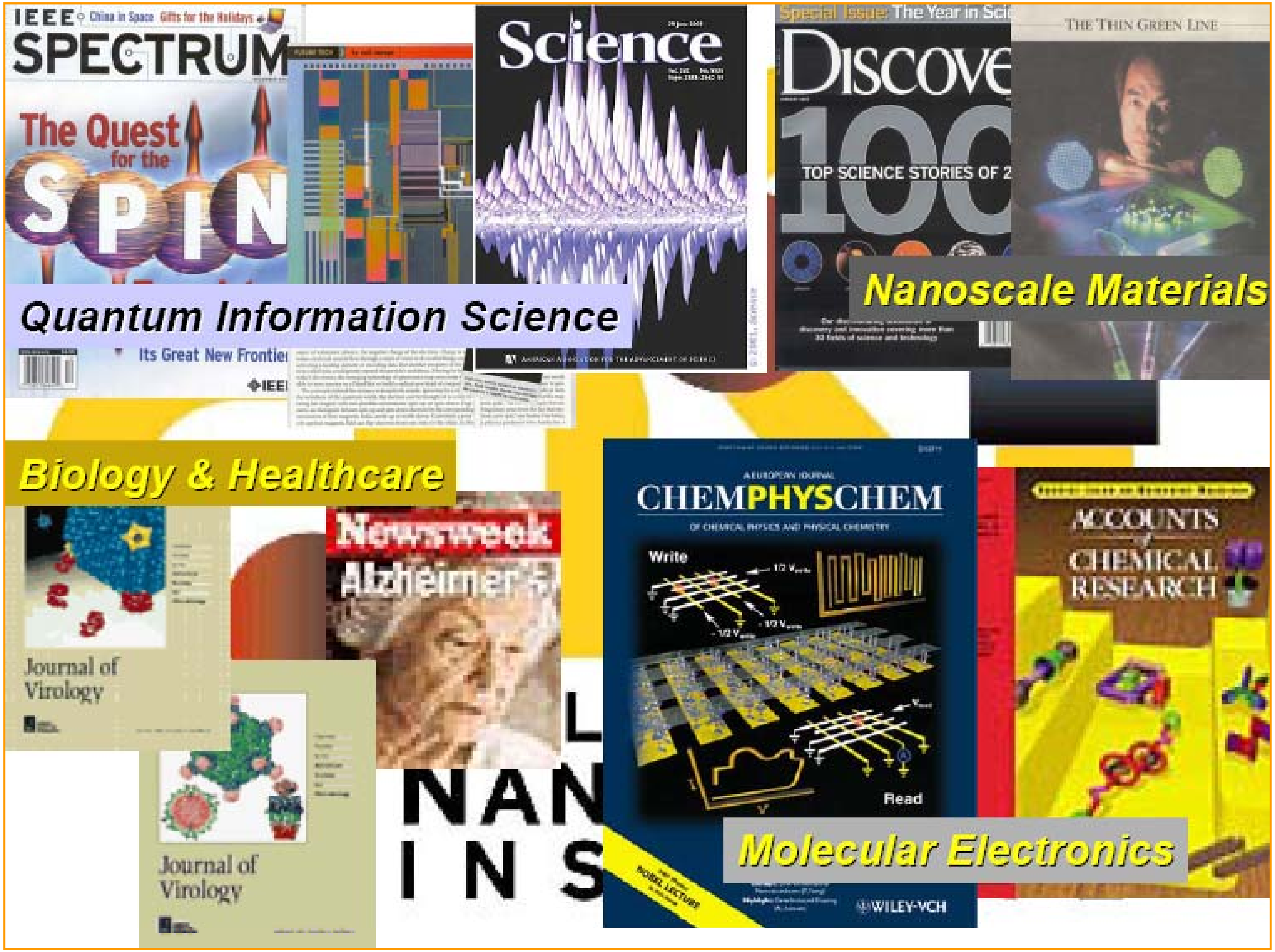
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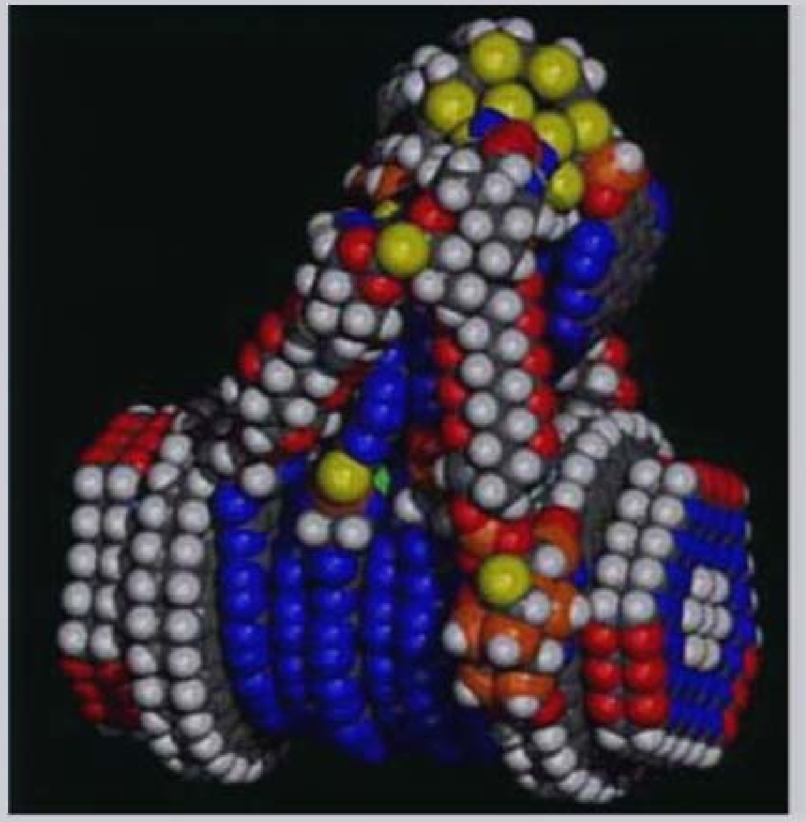
Fantasy (?)

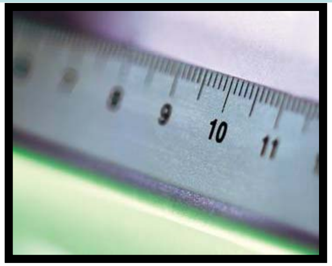

FOUR MEN AND ONE WOMAN ON
THE MOST FANTASTIC, SPECTACULAR
AND TERRIFYING JOURNEY
OF THEIR LIVES . . .
FANTASTIC VOYAGE
WILLIAM REDFIELD
ARTHUR KENNEDY
SAUL DAVID · RICHARD FLEISCHER
HARRY KLEINER · DAVID DUNCAN
OTTO KLEMENT · JAY LEWIS BIXBY



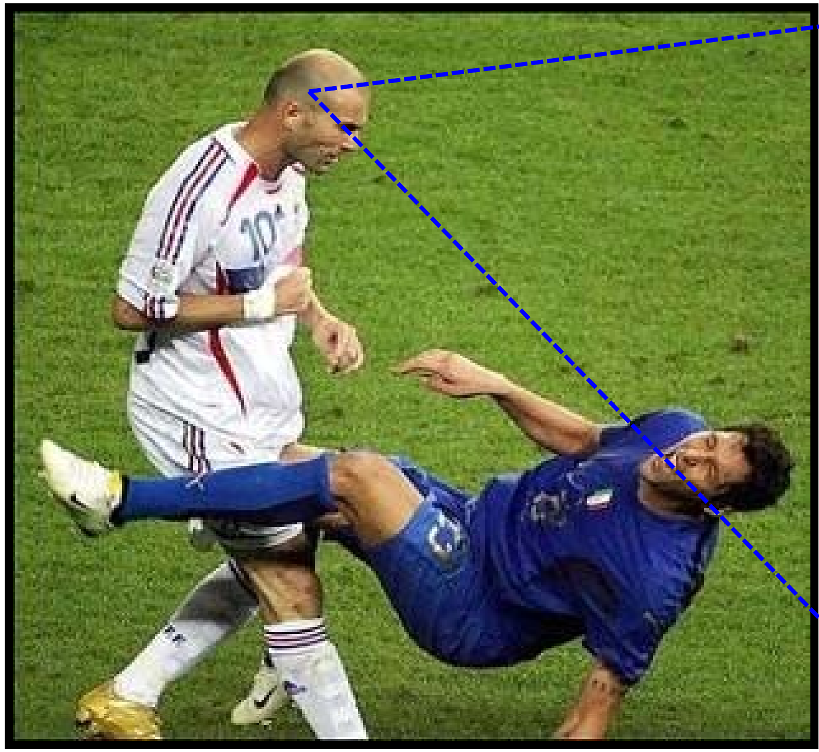
La escala de las cosas

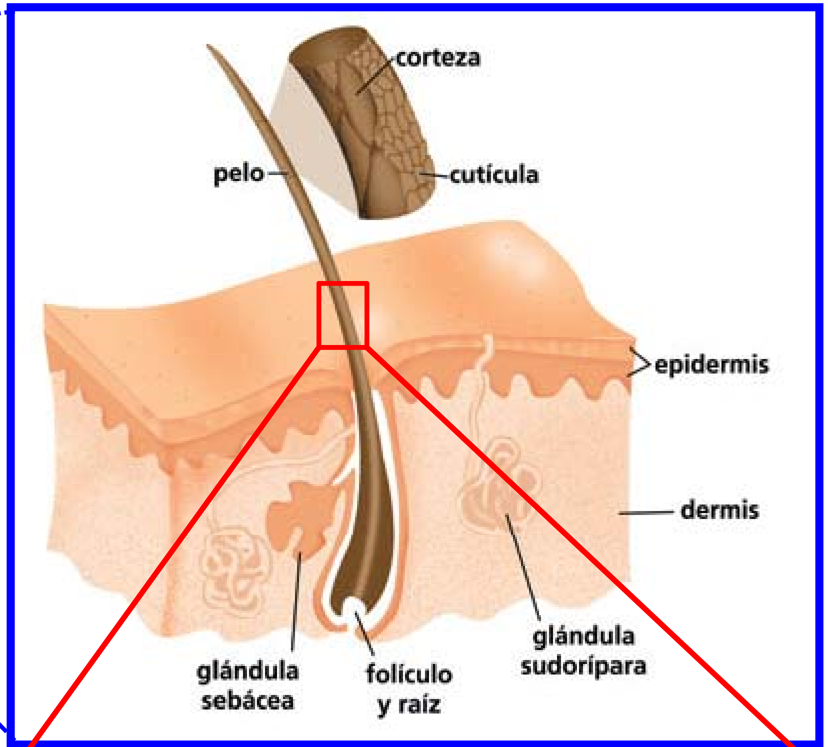
Ciencia y tecnología en la escala de los nanómetros (<100 nm).

1 metro = 1000’000.000 nm = 10^9 nm

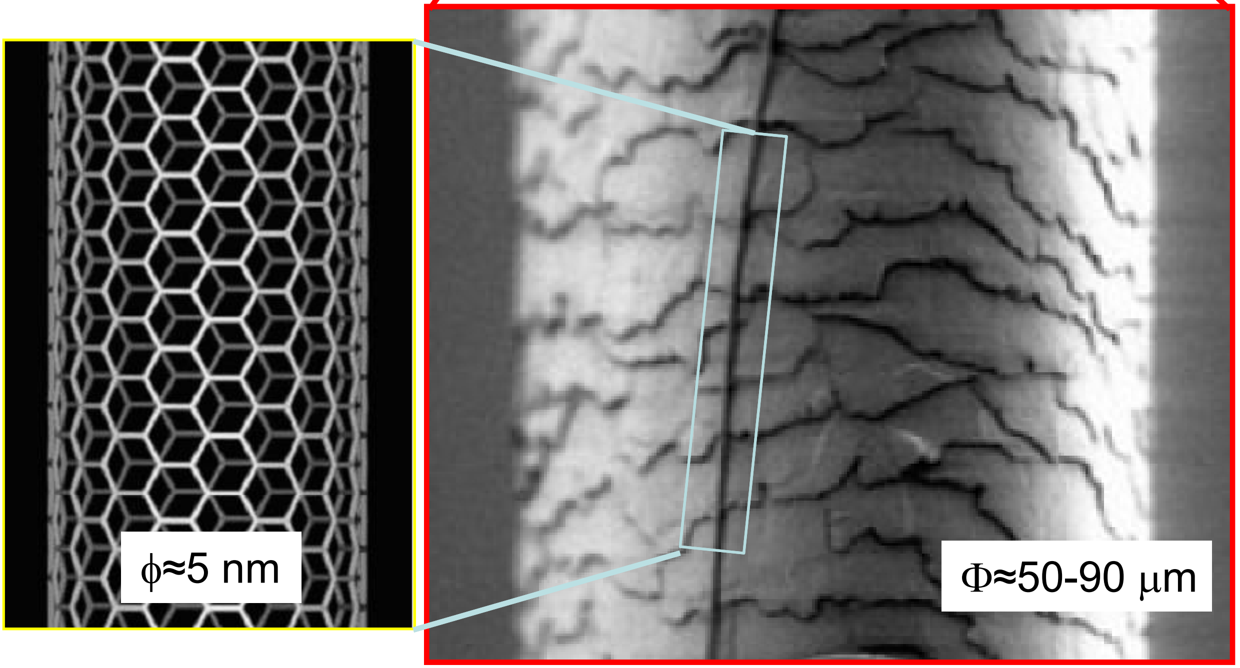


Cortesia J Restrepo UdeA



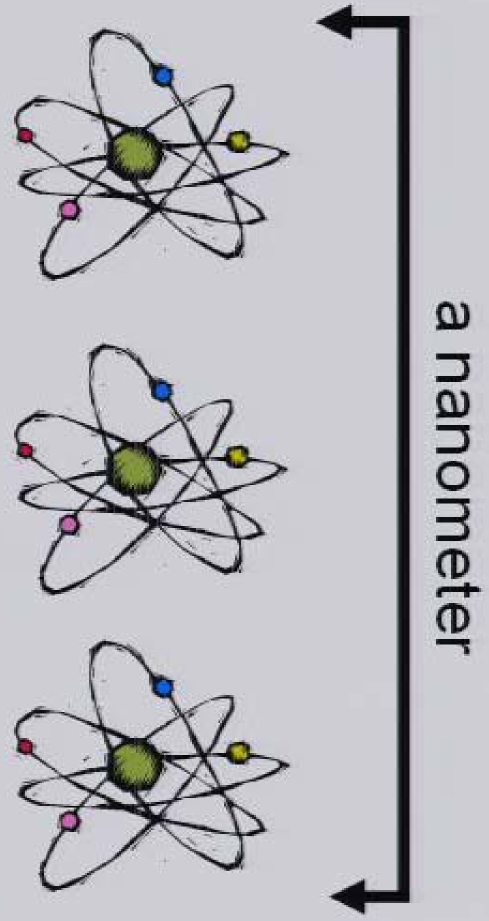


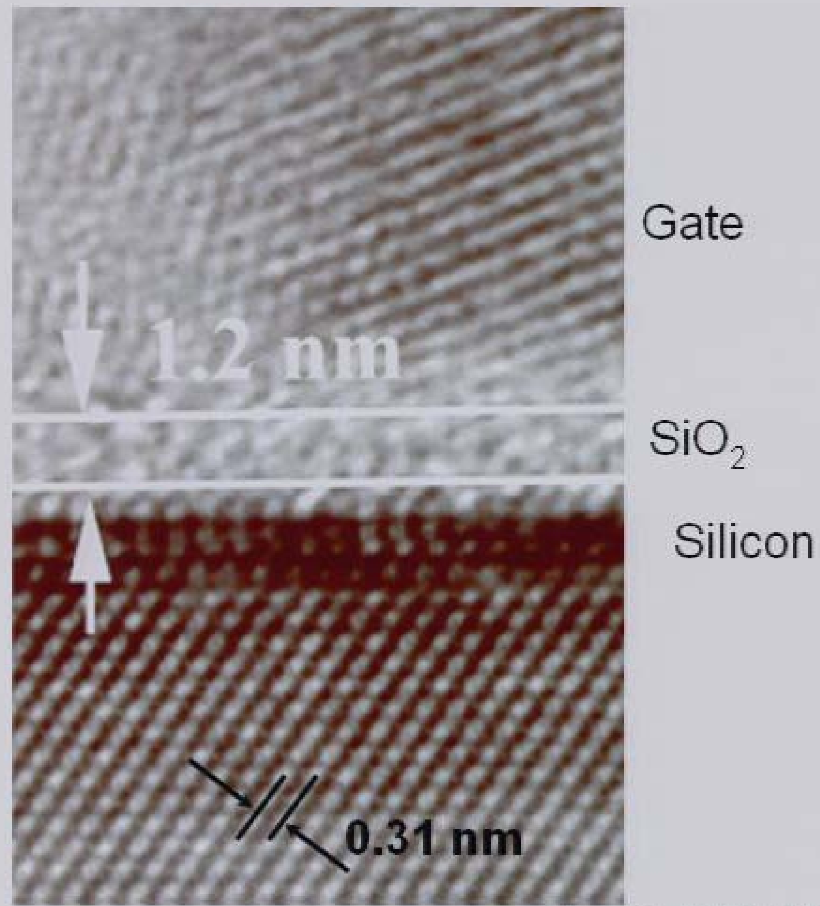
Sustancias opacas pasan a ser
transparentes
(el cobre); materiales inertes pasan
a ser catalizadores (el platino);
materiales
estables se tornan combustibles (el
aluminio); algunos sólidos se
vuelven
líquidos a temperatura ambiente (el
oro); y algunos materiales aislantes
llegan a
ser conductores (el silicio).



Cortesia J Restrepo UdeA

What is a Nanometer?

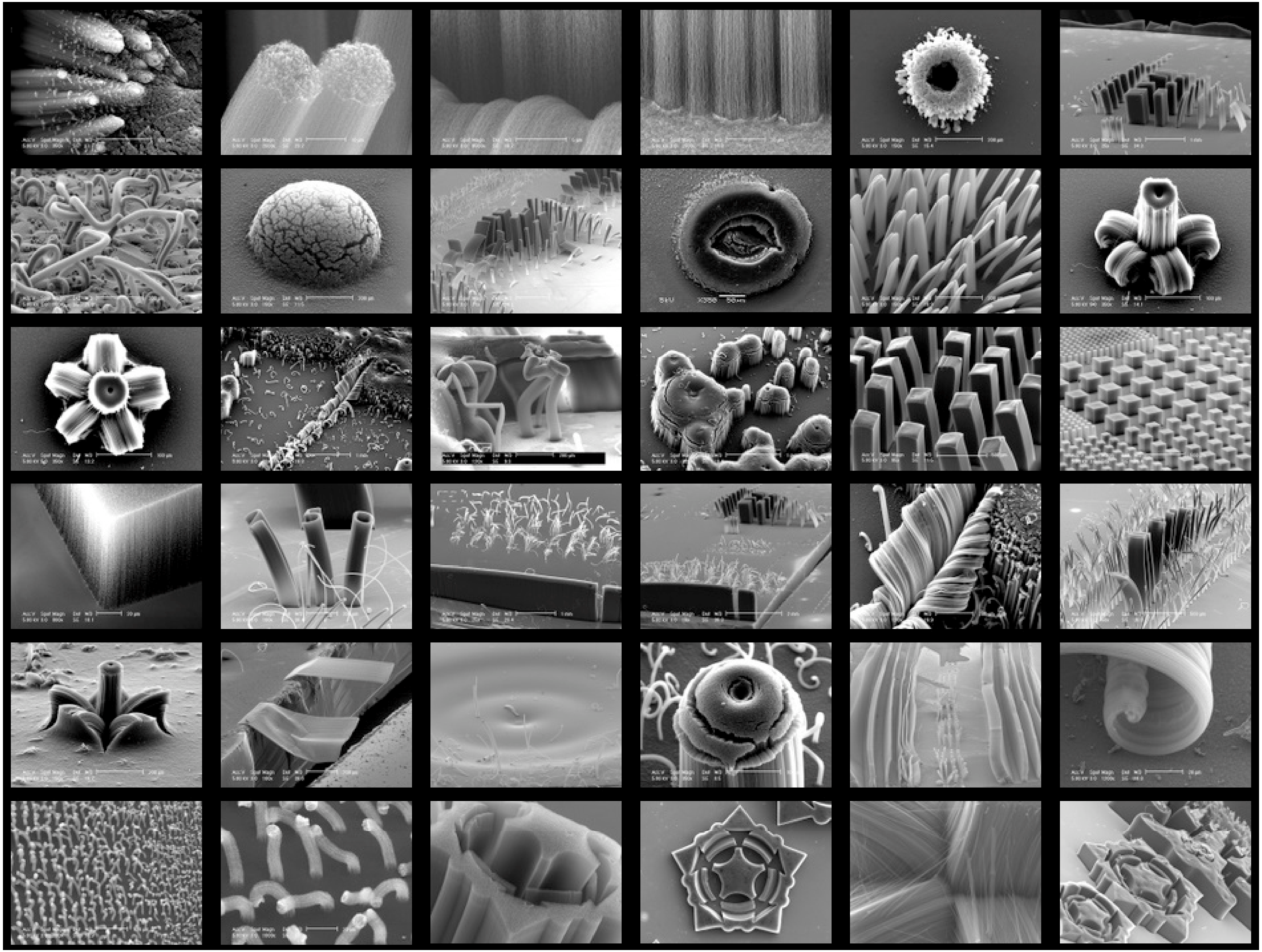


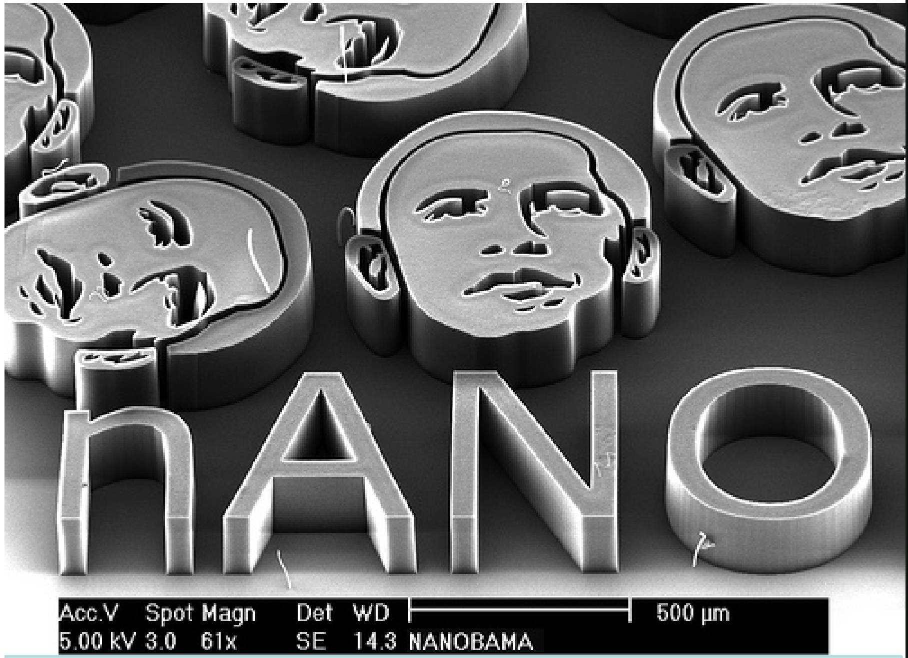


Tiwari, MNE (1999)

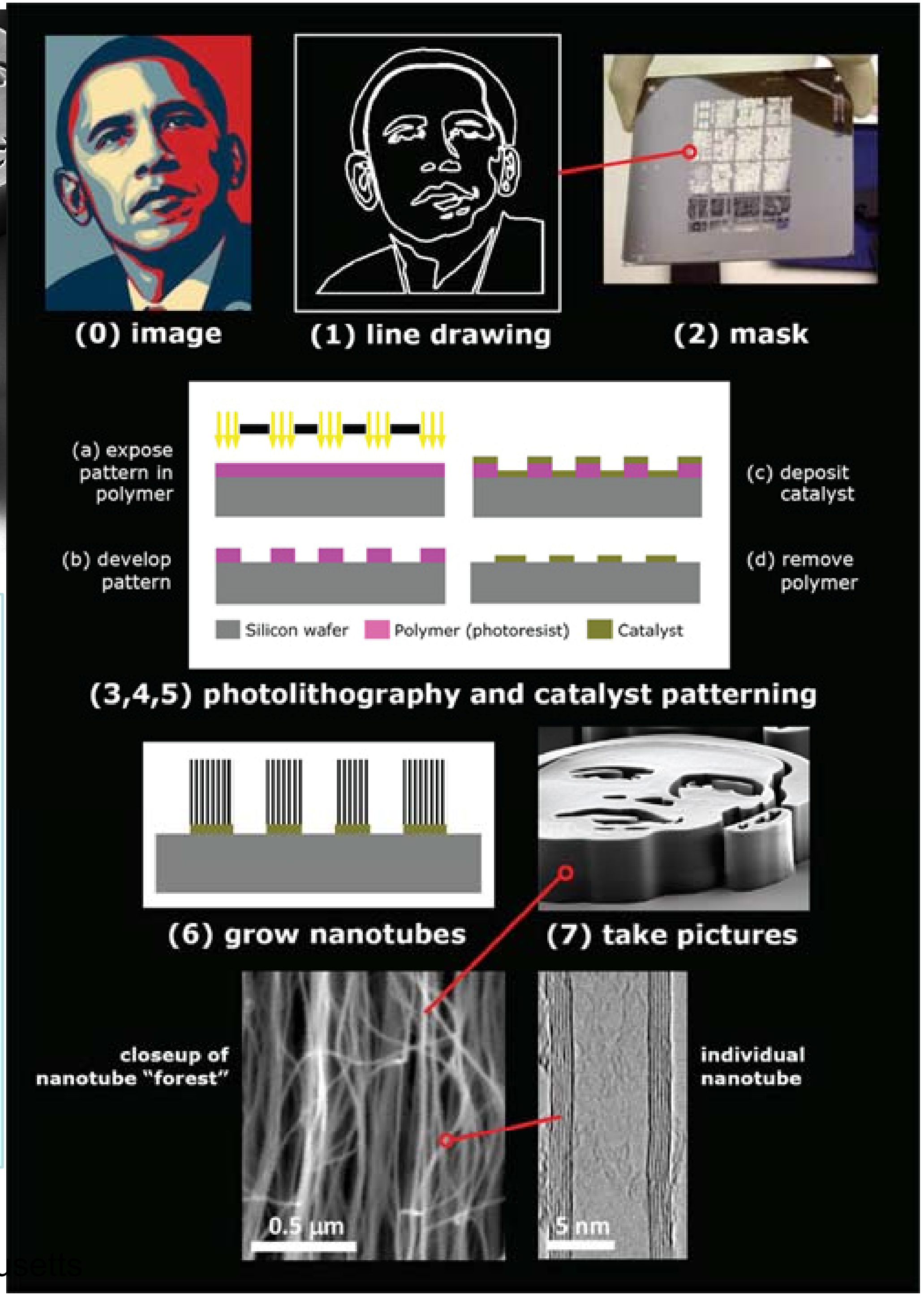
- A nanometer is one-billionth of a meter.
- A stack of *three* silicon atoms is a nanometer high. This is approximately the thickness of the inversion layer – the conducting electron region of a transistor.

CNF Cornell NanoScale Science and Technology Facility

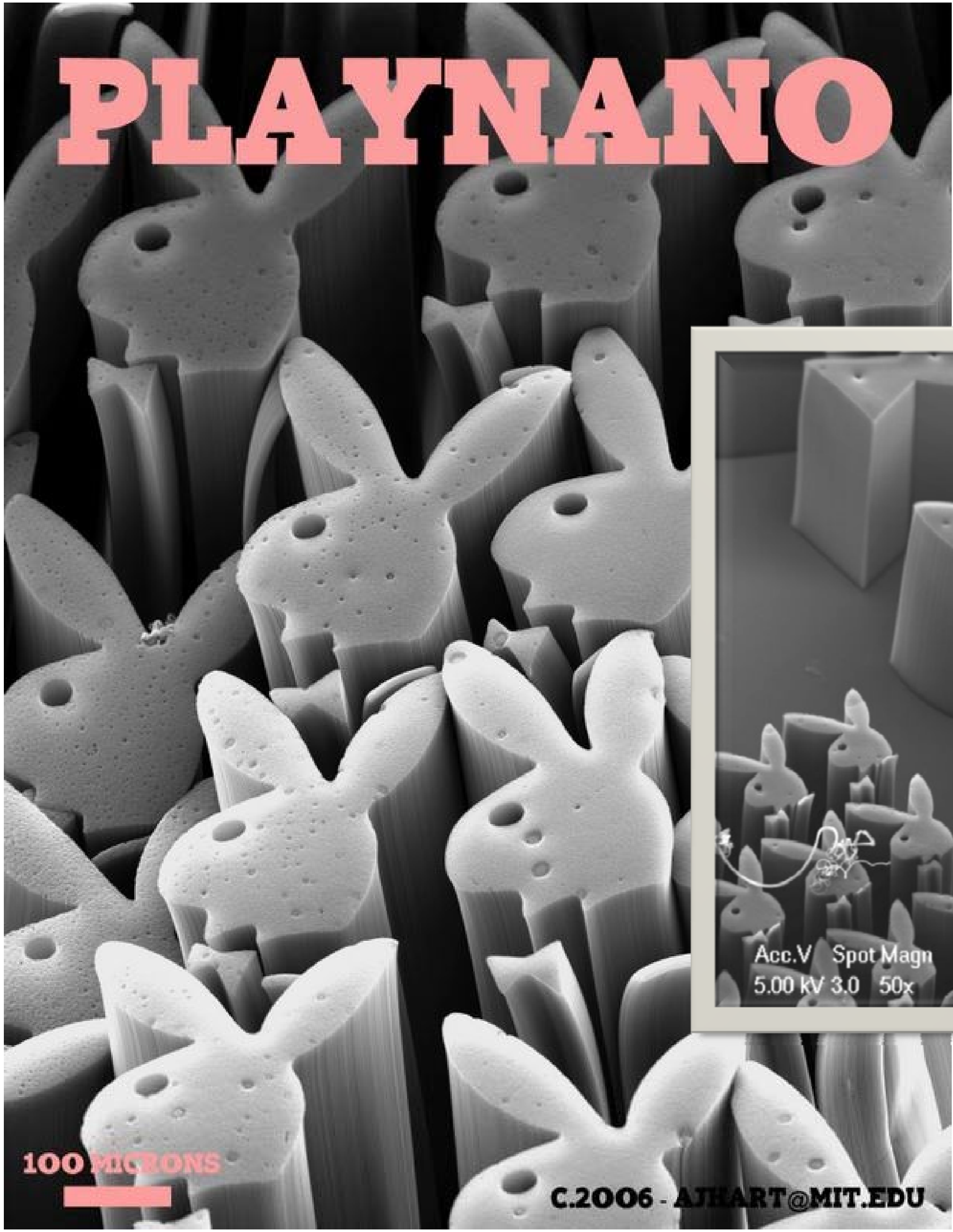


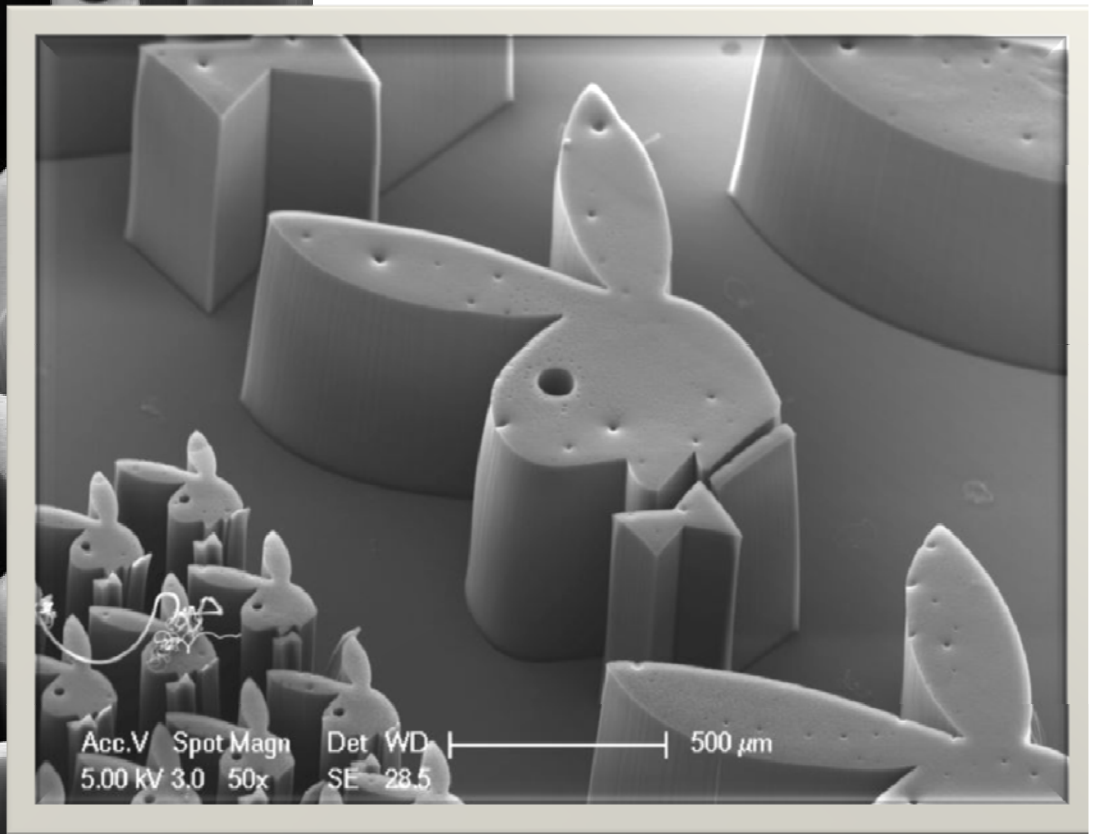


(1) Se convierte la imagen a una de líneas.
(2) Se encoje y se imprime sobre un substrato de vidrio (máscara) usando un sistema láser.
(3) Se ilumina con luz ultravioleta a través de la máscara una película delgada de polímero sobre un wafer de Si (Fotolitografía).
(4) Se recubre el wafer con una película delgada de nanopartículas catalíticas que funcionan como semillas para el crecimiento de los naotubos.
(5) Se remueve el polímero remanente y quedan las semillas en las formas de los nanobamas.
(6) Se crecen los CNTs colocando el wafer en un horno a alta temperatura y llenándolo con un gas rico en carbono.
(7) Se toman las fotografías de las estructuras mediante microscopía electrónica SEM.

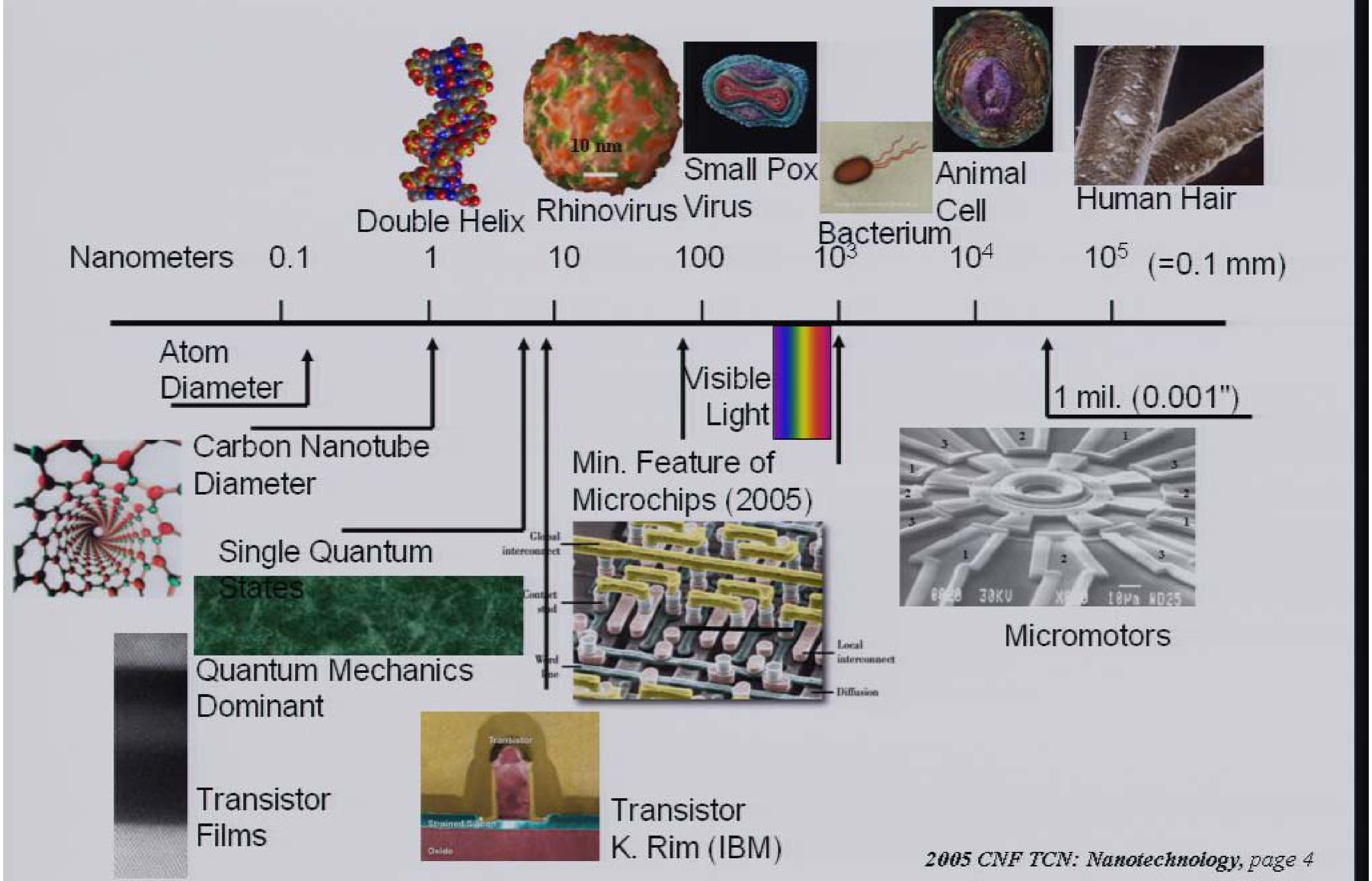


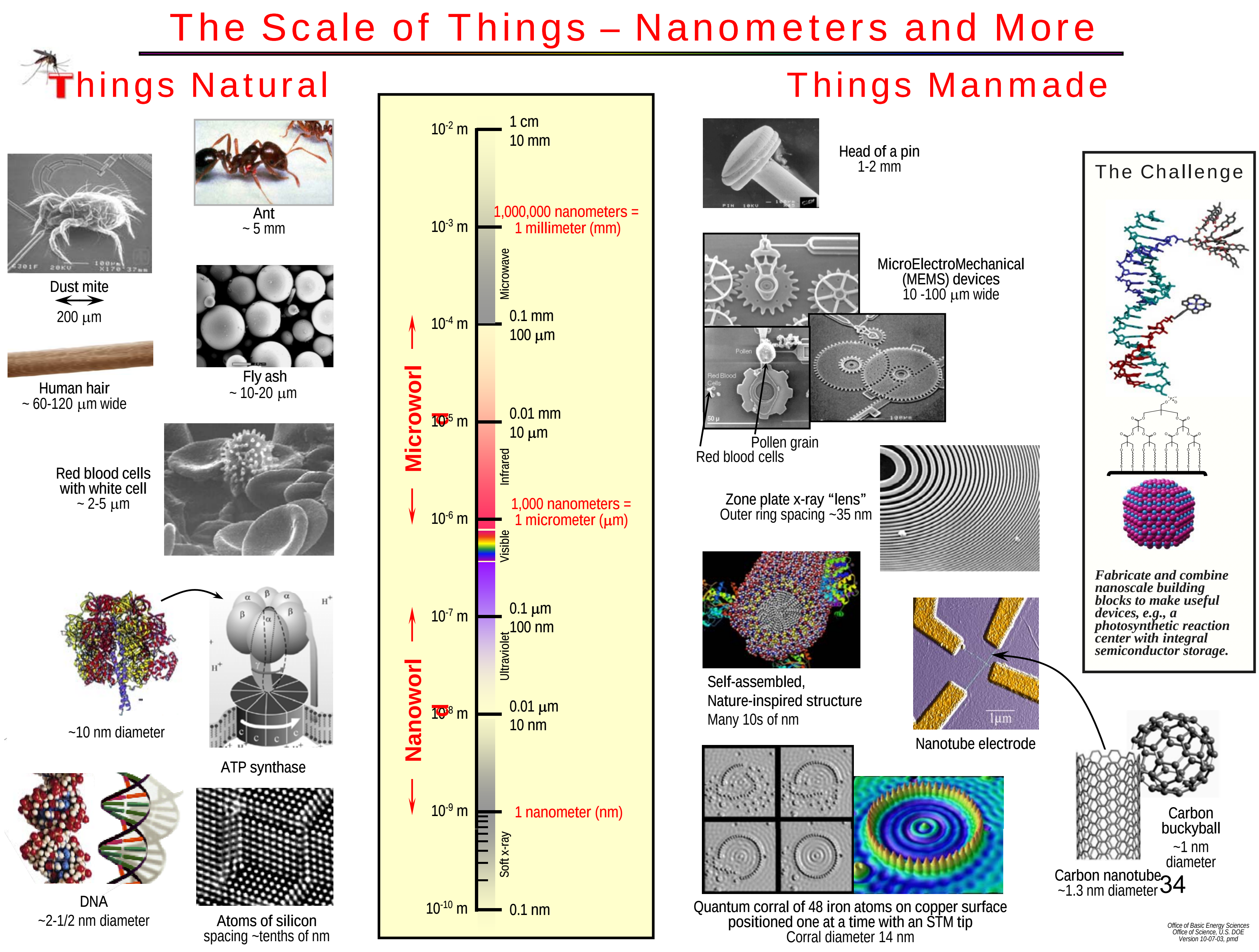
http://nanobliss.com/ John Hart. U. Miassachusetts


PLAYNANO
100 MICRONS
C.2006 - AJHART@MIT.EDU


Acc.V Spot Magn Det WD 500 µm
5.00 kV 3.0 50x SE 28.5

Nanostructure Size Scales

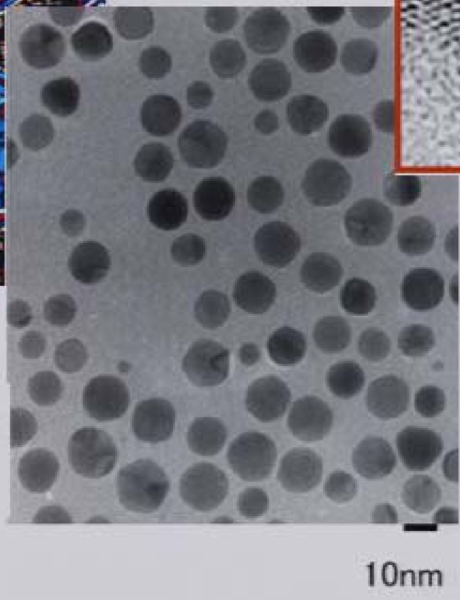



The Scale of Things – Nanometers and More
Things Natural
Things Manmade
Dust mite
200 µm
Ant
~ 5 mm
Human hair
~ 60-120 µm wide
Fly ash
~ 10-20 µm
Red blood cells
with white cell
~ 2-5 µm
~10 nm diameter
ATP synthase
DNA
~2-1/2 nm diameter
Atoms of silicon
spacing ~tenths of nm
10^{-2} m
1 cm
10 mm
10^{-3} m
1,000,000 nanometers =
1 millimeter (mm)
Microwave
10^{-4} m
0.1 mm
100 µm
Microworld
10^{-5} m
0.01 mm
10 µm
Infrared
10^{-6} m
1,000 nanometers =
1 micrometer (µm)
Visible
10^{-7} m
0.1 µm
100 nm
Ultraviolet
Nanoworld
10^{-8} m
0.01 µm
10 nm
10^{-9} m
1 nanometer (nm)
Soft x-ray
10^{-10} m
0.1 nm
Head of a pin
1-2 mm
MicroElectroMechanical
(MEMS) devices
10 -100 µm wide
Pollen
Red Blood Cells
Pollen grain
Red blood cells
Zone plate x-ray "lens"
Outer ring spacing ~35 nm
Self-assembled,
Nature-inspired structure
Many 10s of nm
Nanotube electrode
1µm
Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm
Carbon nanotube
~1.3 nm diameter
Carbon
buckyball
~1 nm
diameter
The Challenge
Fabricate and combine
nanoscale building
blocks to make useful
devices, e.g., a
photosynthetic reaction
center with integral
semiconductor storage.
Office of Basic Energy Sciences
Office of Science, U.S. DOE
Version 10-07-03, pmd

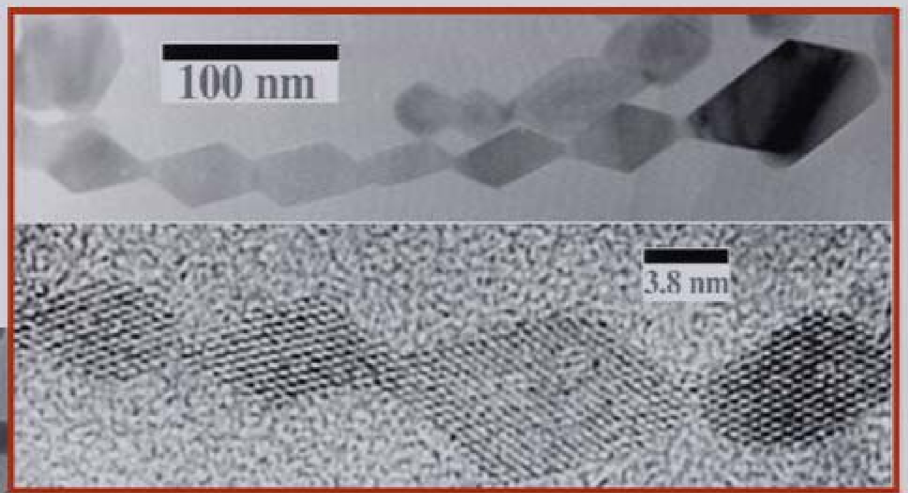
Is Nanotechnology Something New?

- Nanoscale components have been in use for thousands of years.
- Materials have been engineered at the nanoscale for many years.

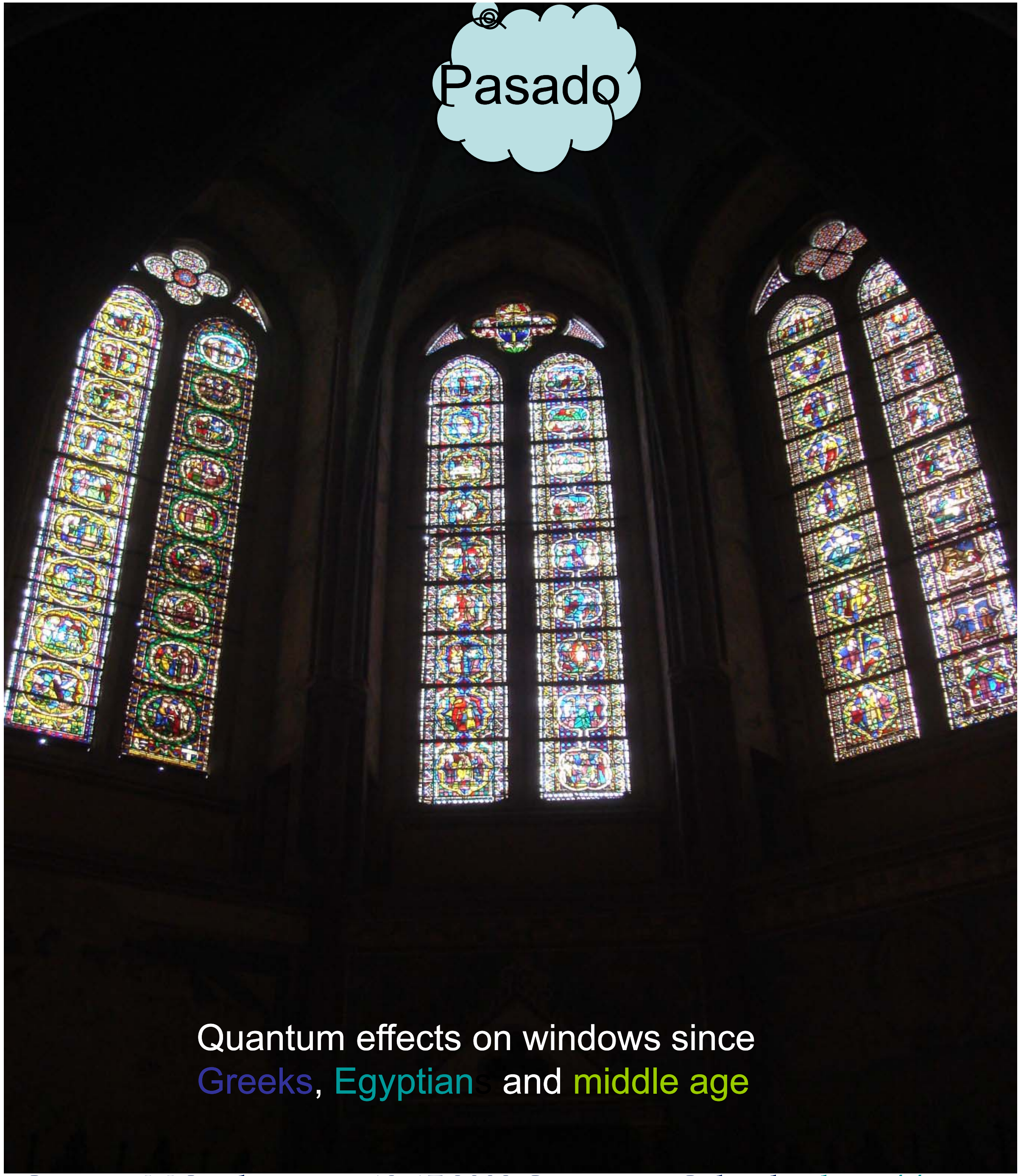
Stained Glass



Nanoscale gold particles in glass give red color

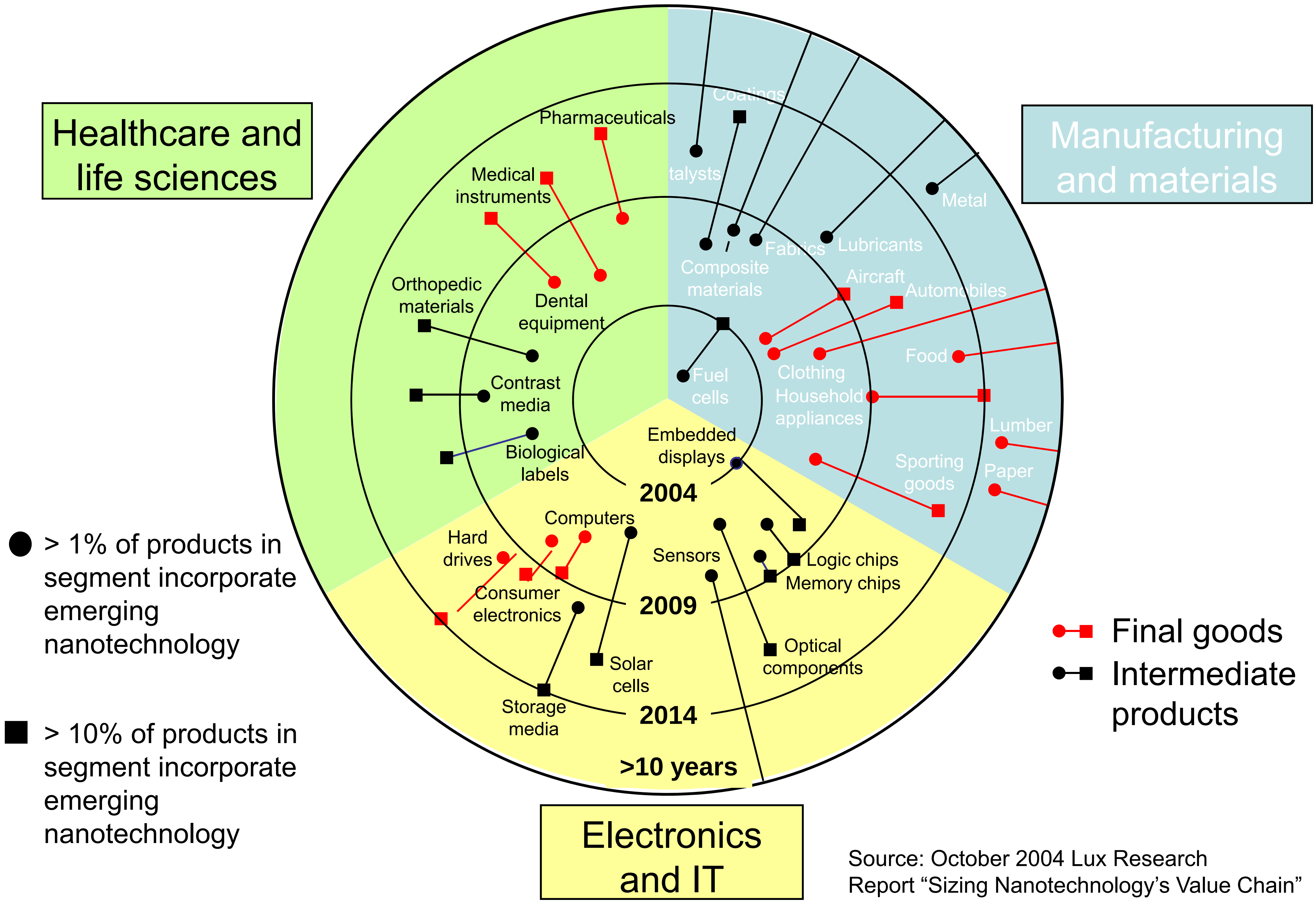


Grain size and grain boundaries have a strong effect on the *properties of materials*



Cortesia M Sacilotti oct. 13-17 2008 Cartagena-Colombia http://www.iberomet.org/

Potential and impact of Nanotechnology



Source: October 2004 Lux Research Report “Sizing Nanotechnology’s Value Chain”

The nanotechnology value chain

Nanomaterials

Nanoscale structures in unprocessed form

Nanoparticles, nanotubes, quantum dots, fullerenes, dendrimers, nanoporous materials…

Nanointermediates

Intermediate products with nanoscale features

Coatings, fabrics, memory and logic chips, contrast media, optical components, orthopedic materials, superconducting wire…

Nano-enabled products

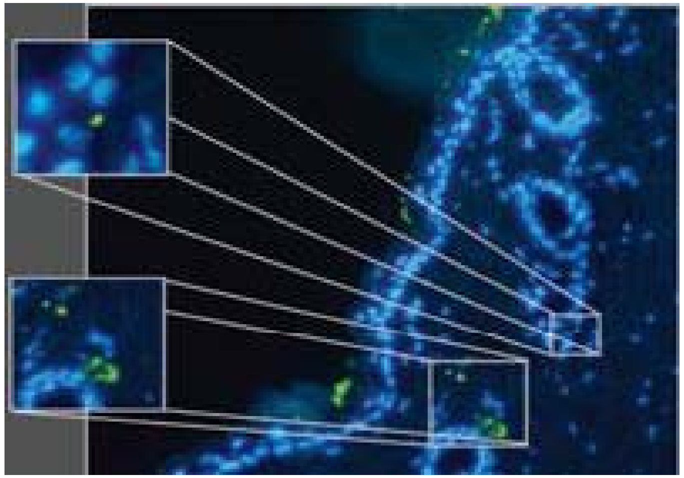
Finished goods incorporating nanotechnology

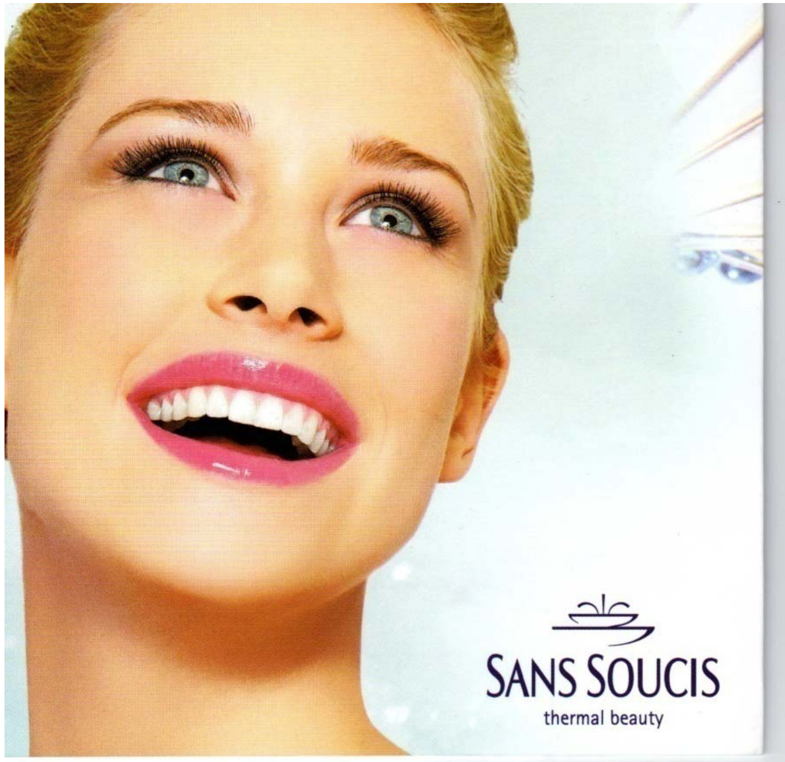
Cars, clothing, airplanes, computers, consumer electronics devices, pharmaceuticals, processed food, plastic containers, appliances…

Nanotools

Capital equipment and software used to visualize, manipulate, and model matter at the nanoscale

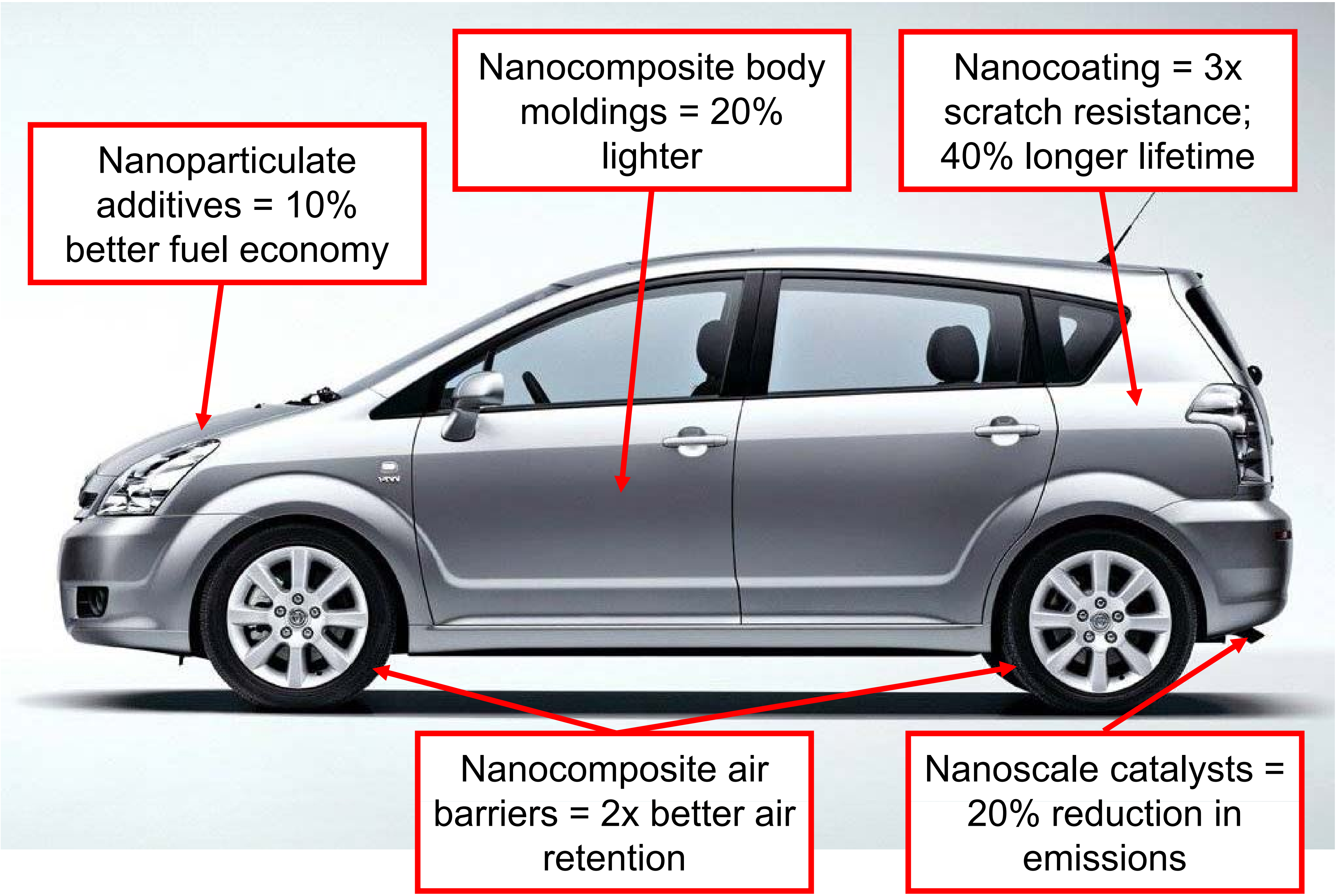
Atomic force microscopes, nanoimprint lithography equipment, nanomanipulators…





www.sanssoucisusa.com/

Skin penetration evidenced
Study of the penetration of nanoparticles known as quantum dots that fluoresce under some conditions, making them easier to see and track compared to other nanoparticles. The scientists looked at the distribution of quantum dots in mice whose skin had been exposed to about the same amount of ultraviolet light as might cause a slight sunburn on a person.
Do cosmetics, including mineral make-up, contain dangerous *nanoparticles?*
J. Mortensen, Oberdrster, P. Pentland,
A. DeLouise Nano Lett., 2008, 8 (9)

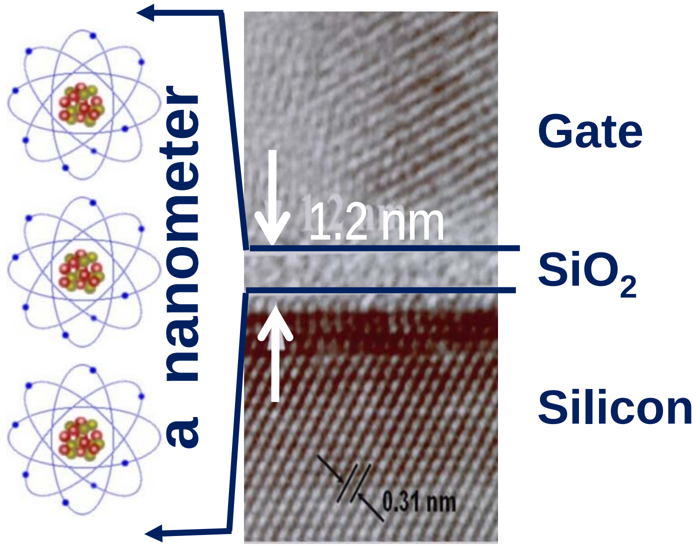

Nanoparticulate additives = 10% better fuel economy
Nanocomposite body moldings = 20% lighter
Nanocoating = 3x scratch resistance; 40% longer lifetime
Nanocomposite air barriers = 2x better air retention
Nanoscale catalysts = 20% reduction in emissions

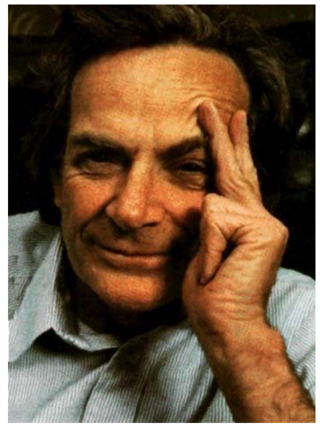
Nanotechnology and Novel Materials

Explore & exploit unique phenomena and effects at atomic, molecular, and supra-molecular dimensions to create materials, devices, and systems with fundamentally novel properties and functions. **Nanoscale** gathers multidisciplinary approaches: Physics, Chemistry, Biology, Mathematics, Materials Sciences, and TICs, all of great benefit to humanity.

Applications are exciting; scientific & engineering potential is vast.

Nanotechnology represent an open disposition by policy makers to exploit its full potential for the benefit of society.





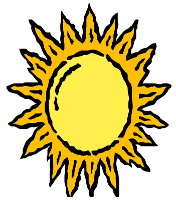
Feynman, 1959 *There's Plenty of Room at the Bottom*

K. Eric Drexler *Millennium Technology Conference14 June 2004*

Motivaciones para el estudio de materiales a escala nano/micrométrica (Ga, Al, In)N

Nasa satellite picture

20% total light economy



Light? may be LED is one of the solutions...

Cortesia M Sacilotti oct. 13-17 2008 Cartagena-Colombia
http://www.iberomet.org/

Presente

All ligthed by LED

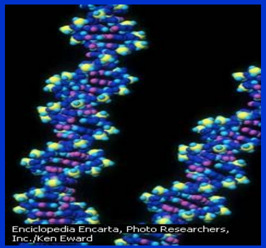
General lighting

(Ga, Al, In)N material's applications

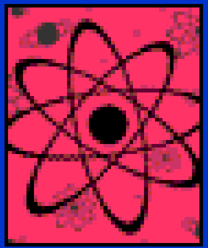
SIZE MATTER

Atomic nuclei ~ 10^{-15} meters= 10^{-6} nanometers
Atoms ~ 10^{-10} meters = 0.1 nanometers
Nanoscale ~ 1 to 100 nanometers
Everyday world ~ 1 meter = 10^{10} nanometers

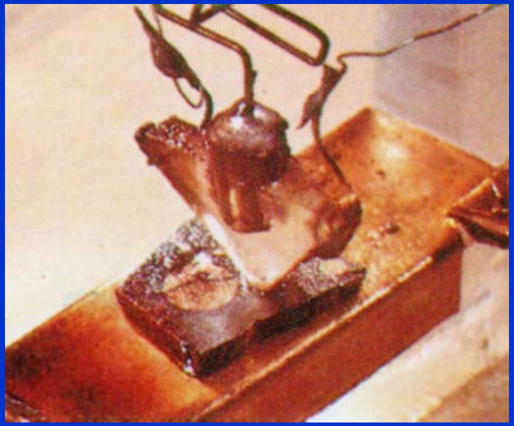
Célula ~1000 nm



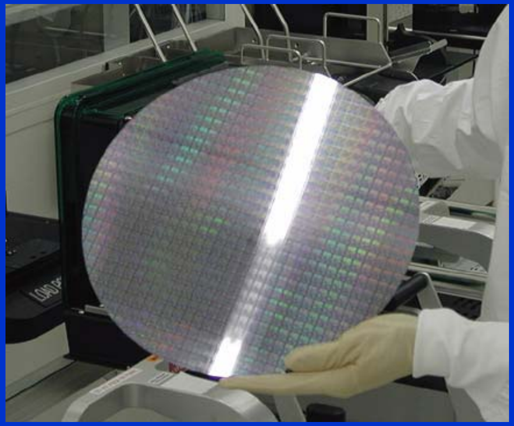
DNA ~2.5 nm



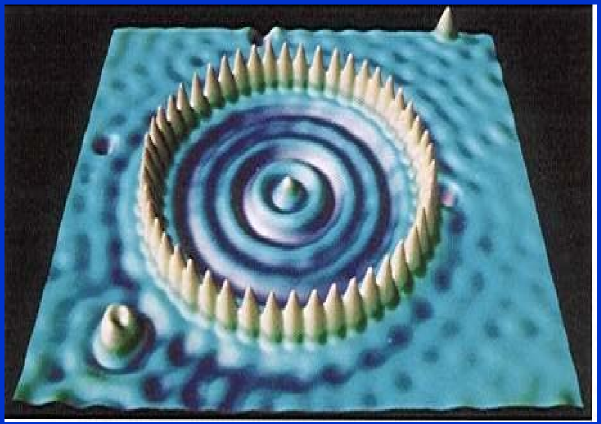
Atoms < 1 nm



Bell Labs, 1947: mm

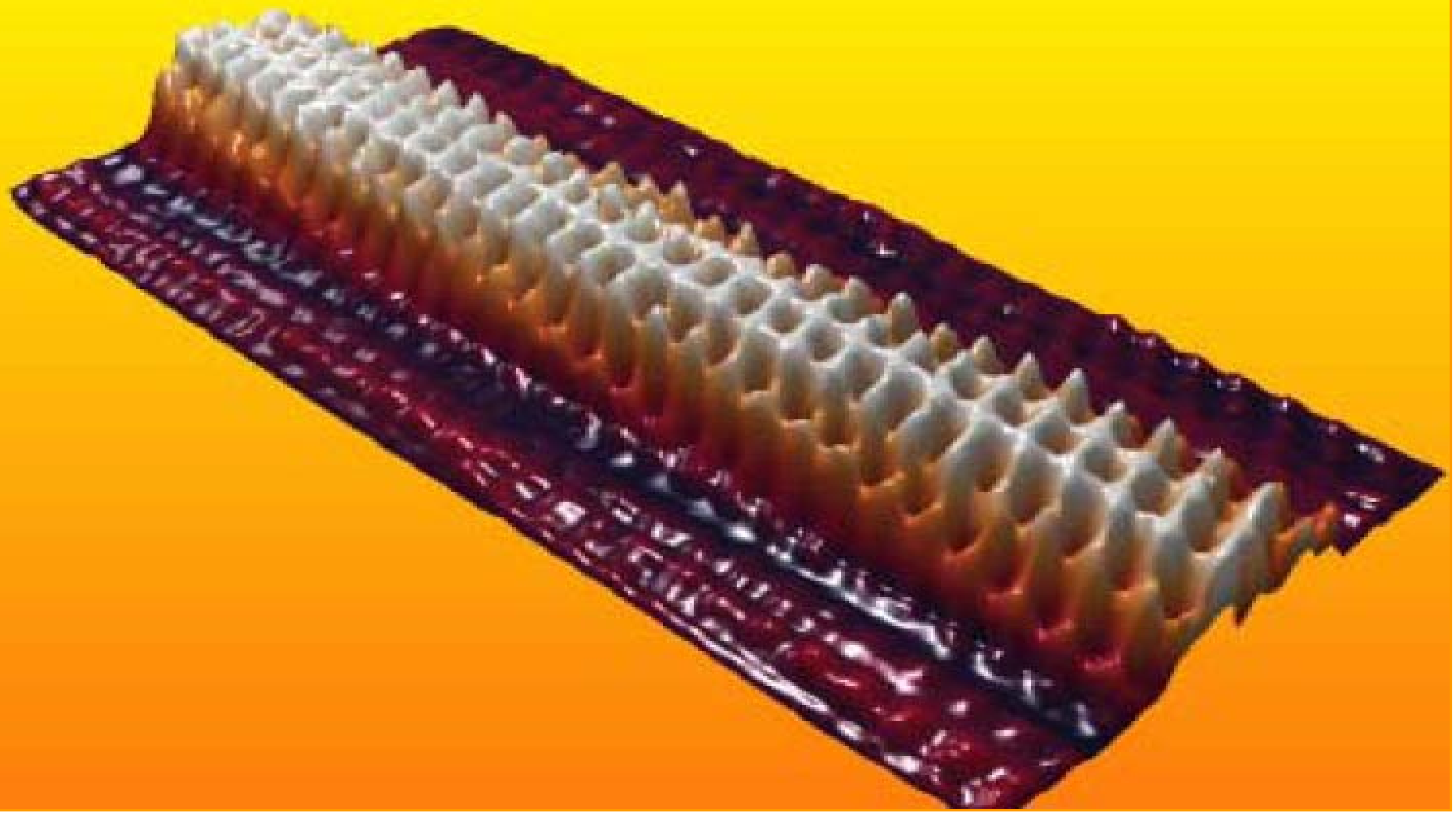


Intel 2004: μm



IBM 2002: nm

A scanning tunneling microscope image of a Single-Walled Carbon Nanotube
A symbol of the origins of Nanoscience & Nanotechnology



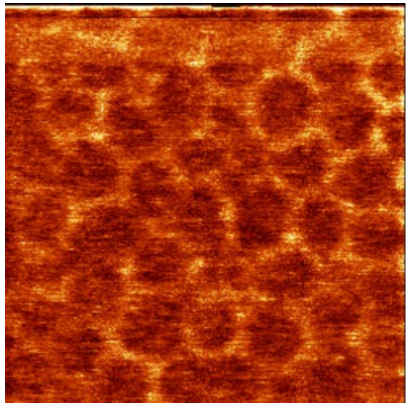
Propiedades de un material son de pendientes del tamaño y dimensión

- Una propiedad describe como un material se comporta bajo ciertas condiciones
- Tipo se propiedades
  - Ópticas (color, transparencia)
  - Eléctricas (conductividad)
  - Físicas (Dureza, punto de fusión etc.)
  - Químicas (reactividad tasas de reacción)
- La propiedades son usualmente medidas mirando un gran conglomerado de átomos o moléculas ($\sim 10^{23}$)

Sources: http://www.bc.pitt.edu/prism/prism-logo.gif
http://www.physics.umd.edu/lecdem/outreach/QOTW/pics/k3-06.gif

- El oro   tiene un color amarillo en bloque
- Nano partículas de oro aparecen de color rojo
  - Los electrones están confiados y no pueden moverse como en el bloque
  - Debido a este confinamiento los electrones reaccionan de una manera muy diferente con la luz.

“Bulk” gold looks yellow



12 nanometer gold particles look red

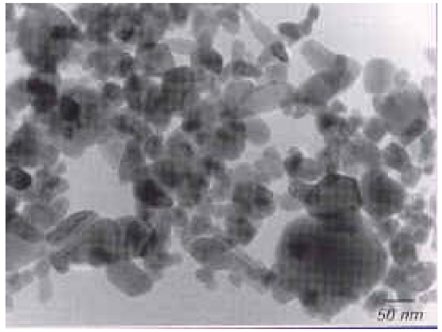
Sources: http://www.sharps-jewellers.co.uk/rings/images/bien-hccncsq5.jpg
http://www.foresight.org/Conferences/MNT7/Abstracts/Levi/

Propiedades ópticas del : Zinc Oxide (ZnO)

- Partículas macroscópicas de ZnO
  - Bloquen la luz UV
  - Dispersan la luz visible
  - Apariencia blanca
- Nano partículas de ZnO
  - Bloquen la luz UV
  - Su tamaño menor que la longitud de la luz visible que no dispersan la luz
  - Aparecen transparentes

"Traditional" ZnO sunscreen is white

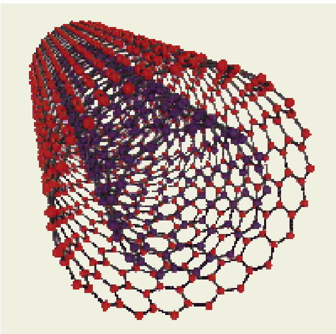
Nanoscale ZnO sunscreen is clear



Zinc oxide nanoparticles

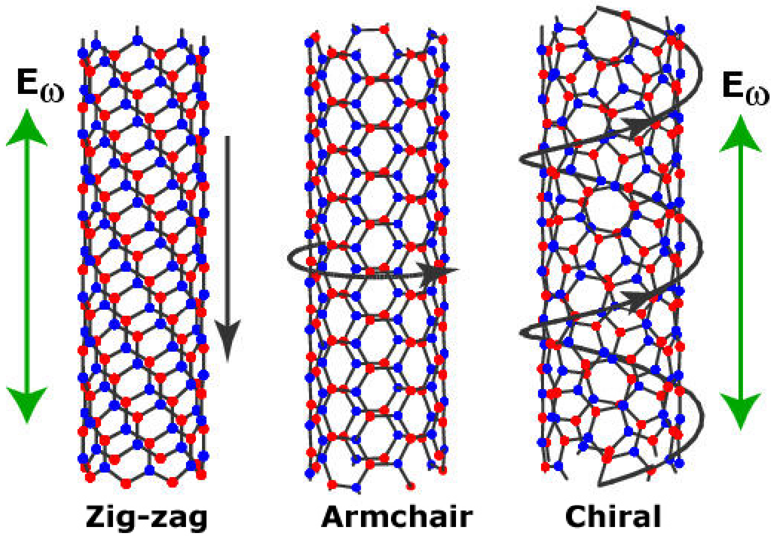
Sources: http://www.apt powders.com/images/zno/im_zinc_oxide_particles.jpg
http://www.abc.net.au/science/news/stories/s1165709.htm
http://www.4girls.gov/body/sunscreen.jpg

- Las propiedades eléctricas de CNT cambian con el diámetro la forma de “ arrollamiento” y el numero de paredes pudiendo ser conductores, o semiconductores.



Multi-walled

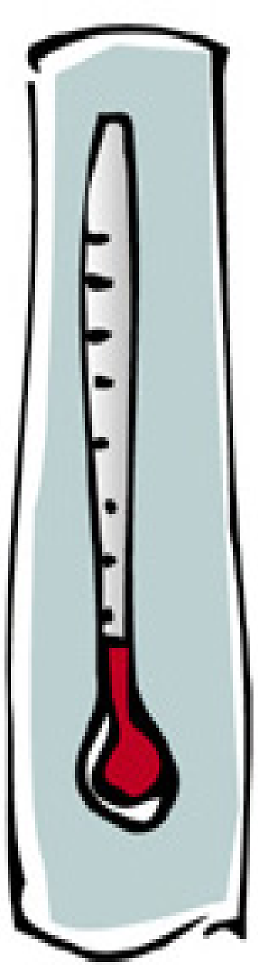
Electric current varies by tube structure

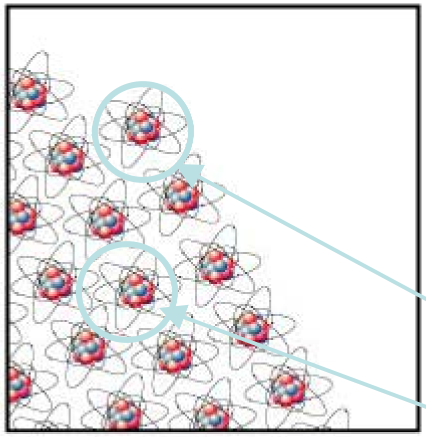


Source: http://www.weizmann.ac.il/chemphys/kral/nano2.jpg

Punto de fusión Temperatura a la cual los átomos o moléculas en una sustancia adquieren suficiente energía para superar las fuerzas intermoleculares que las mantienen " fijas" en un solido.

- Los átomos en la superficie requieren menos energía para " liberarse" debido a que están en contacto con menos átomos





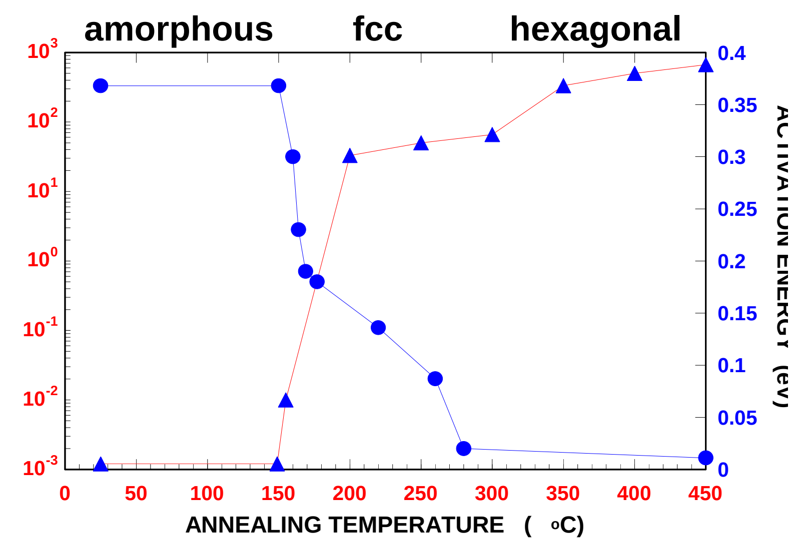
El Punto de fusión depende del tamaño

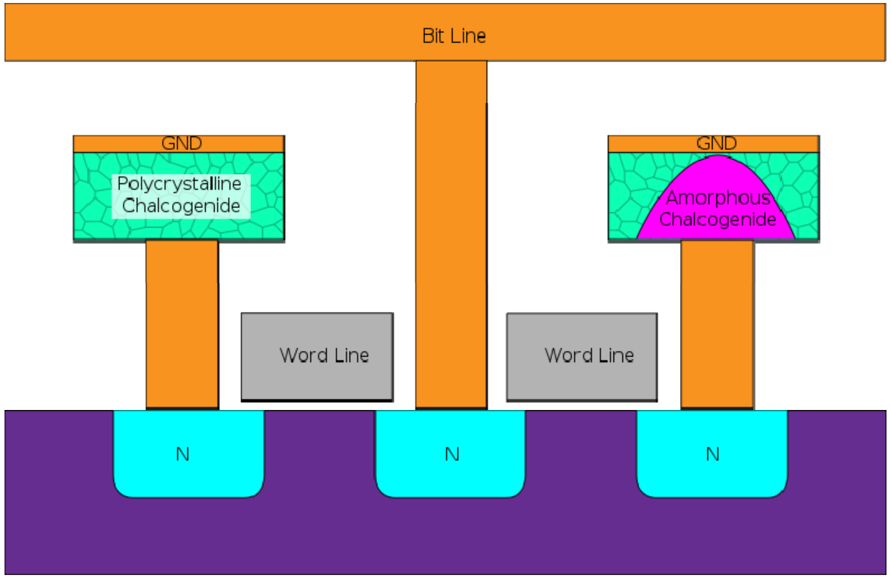
In contact with 3 atoms

In contact with 7 atoms

Sources: http://puffernet.tripod.com/thermometer.jpg and
image adapted from http://serc.carleton.edu/usingdata/nasaimages/index4.html

Phase-Change Memory PRAM uses the unique behavior of chalcogenide glass, which can be "switched" between two states, crystalline and amorphous, with the application of heat.





Samsung' unveiled a 512Mb multi chip package featuring PRAM , which is due to be available for use in mobile handsets later this quarter (May 6 2010)

http://www.telecoms.com/20183/samsung

A cross-section of two PRAM memory cells. One cell is in low resistance crystalline state, the other in high resistance amorphous state.

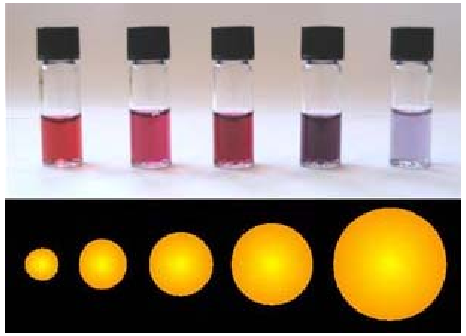
Efectos Cuánticos

- La mecánica clásica usada para entender la materia a escala macroscópica falla para..
  - Objetos a nanoscala

- La mecánica cuántica describe los fenómenos que no se entienden clásicamente …
  - Probabilidad (mejor que la certeza) de que un electrón sea encontrado en un solido.

Macrogold

Nanogold



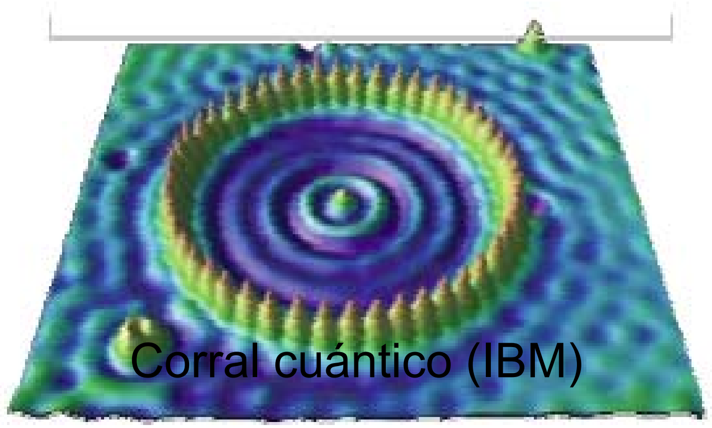
Por qué “Nano” es diferente?

Aspectos intrínsecos a la naturaleza cuántica de la materia:

Condensado de Bose-Einstein, transiciones conductor-aislante, confinamiento de cargas, QUANTUM DOTS, etc.

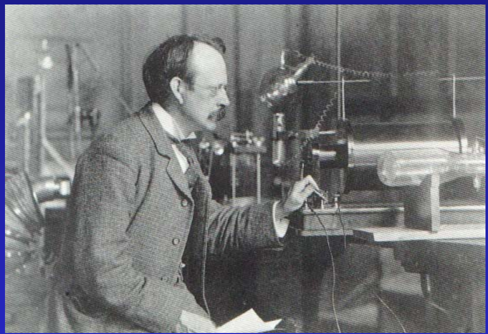
Aspectos intrínsecos a la aspectos (clásicos) estructurales y de escala:

Incremento de relación superficie/volumen, temperatura de fusión, transiciones de fase, modos vibracionales, etc.



Corral cuántico (IBM)

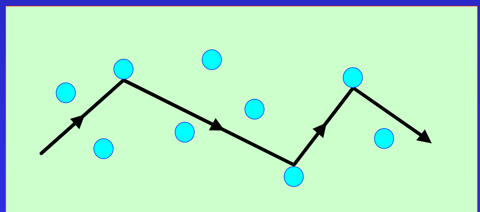
Los últimos años de la Era Clásica



1897 – Descubrimiento del electrón por J.J. Thomson

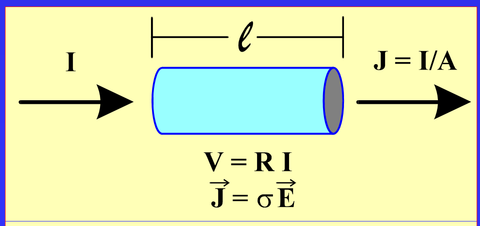
1900 –Modelo de Drude para electrones en metales

- **Gas de electrones libres $n \sim 10^{22}\ cm^{-3}$**
- **Interacción e-red despreciable**
- **Interacción e-e despreciable**
- **Colisiones con los iones**
- **$P(dt)=dt/\tau$**



$$\sigma = ne^2\tau/m \qquad \text{Ley de Ohm}$$

$$\sigma/\kappa = 3/2\ (k/e)^2 T \qquad \text{Widemann-Franz}$$

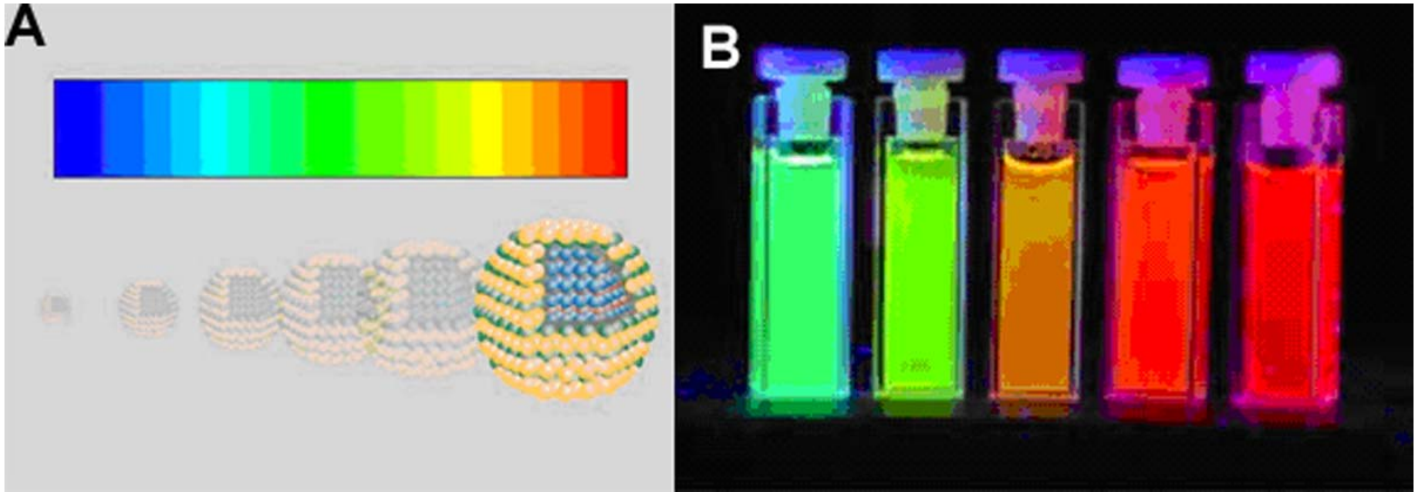


Fallas

- **C_v independiente de T**
- **χ dependiente de T**
- **ρ Independiente de T**

Quantum Mechanics

- Particle in a box $$E_1 = \frac{\hbar^2 \pi^2}{2mL^2}$$



(Courtesy of Dylan M. Spencer)

(Source: Philips)

ALGUNOS CONCEPTOS Y CANTIDADES

- *An electron:*

  $E = (\hbar k)^2/(2m_e)$; $P = \hbar k$; $\lambda_e = h/(2m_e E)^{1/2}$; 1eV $\rightarrow$ 12.3 Å.

  (de Broglie electron)

- *A photon:*

  $E = h\nu$; $P = E/c$; $\lambda_{\text{Photon}} = (hc)/E$; 1eV $\rightarrow$ 1.24 µm.

- *A photon (the energy quanta of lattice vibrations):*

  $E = \hbar\omega$; $P = \hbar q$; $\omega_{\text{Phonon}} = c_s/q$ (c_s=*the sound velocity*)

Plank constant: $h = 6.626 x 10^{-34}$ *J-s* $= 4.1357 x 10^{-15}$ *eV-s*

$\hbar = h/(2\pi) = 6.5822 x 10^{-16}$ *eV-s*

ALGUNOS CONCEPTOS Y CANTIDADES

- *Wave function:* $\Phi(\mathbf{r},t) = \psi(\mathbf{r})f(t) = A \cdot exp[-(\mathbf{k}\cdot\mathbf{r}-\omega t)]$

  $|\Phi(\mathbf{r},t)|^2$: the probability of finding an electron at point $\boldsymbol{r}$ and time t.

- *The Schrödinger wave equation,*

$$[-\frac{\hbar^2}{2m}\nabla^2 + U(\vec{r})]\Phi(\vec{r},t) = i\hbar\frac{\partial\ \Phi(\vec{r},t)}{\partial\ t}.$$

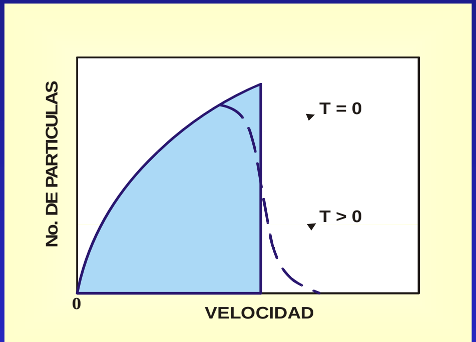
- *The time-independent Schrödinger wave equation,*

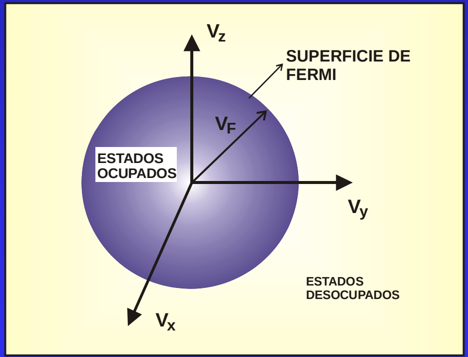
$$\hat{H}\psi(\vec{r}) = E\psi(\vec{r}),$$ *where* $$\hat{H} = -\frac{\hbar^2}{2m}\nabla^2\psi(\vec{r}) + U(\vec{r})$$

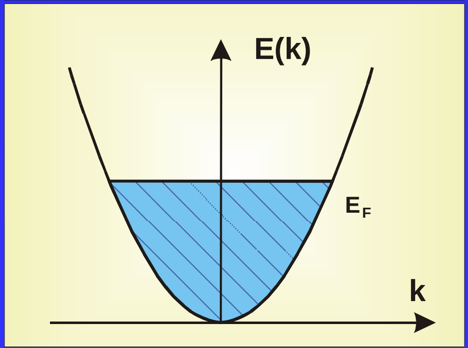
- *Uncertainty principle:*

  $\Delta P \Delta x > \hbar/2; \quad \Delta E \Delta t > \hbar/2.$

Primeros Impactos de la Mecánica Cuántica en la FMC







Modelo de Sommerfeld para electrones en metales

- Estadística de Fermi-Dirac a e

$$f(E_k) = \frac{1}{e^{(E_k-\mu)/k_B T} + 1}$$

$$\Psi(\bar{r}) = \frac{1}{\sqrt{V}} e^{i\bar{k}.\bar{r}} \qquad E(\bar{k}) = \frac{\hbar^2 k^2}{2m}$$

- E_F nivel más energético a T=0
- Superficie de Fermi esférica
- $C_v \sim T$
- χ independiente de T

❑ ¿Metales aislantes?

ELECTRONES

Electrones Libres:

In a free space, the potential $U = 0$,

$$-\frac{\hbar^2}{2m}\nabla^2\psi(\vec{r}) = E\psi(\vec{r})$$

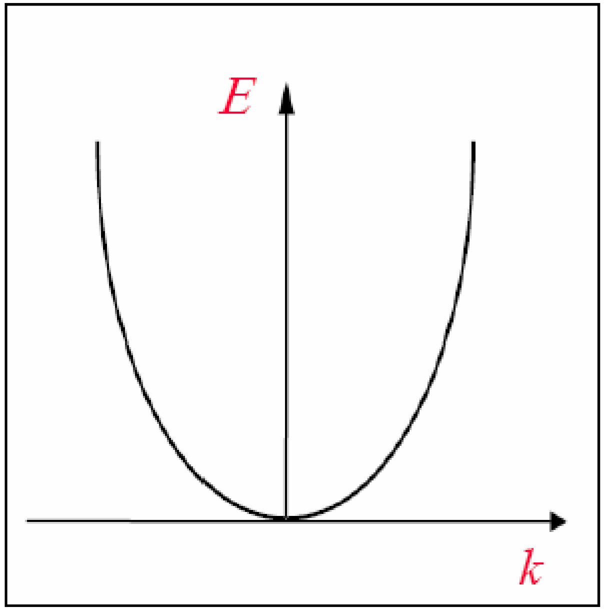
Solución de la función de onda

$$\psi(\vec{r}) = \frac{1}{\sqrt{L^3}}\exp(\pm i\vec{k}\cdot\vec{r}),$$

Donde $k = (2m_e E/\hbar^2)^{1/2}$. es el vector de onda.

Ej:

$$\boxed{E = (\hbar k)^2/(2m_e).}$$

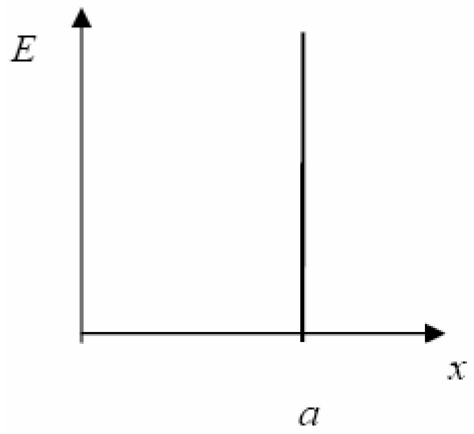


Los electrones libres tienen un comportamiento parabólico continuo de la energía con repecto al valor de K

ELECTRONES

Electrones en un pozo de potencial infinito 1-D

$$U(x)\begin{cases}\infty & x<0\\ 0 & 0<x<a\,.\\ \infty & x>a\end{cases}$$



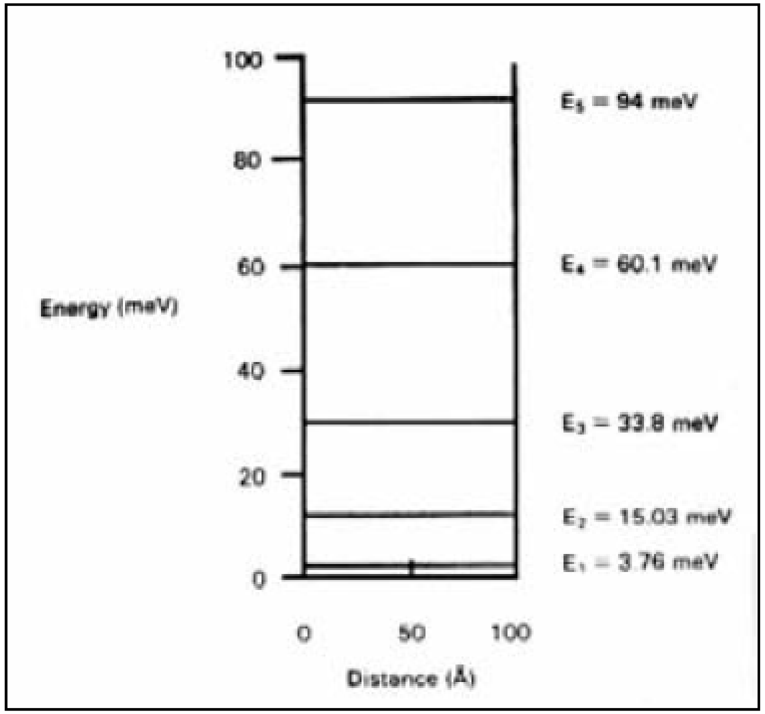
La ecuacion de onda de Schrodinger
Puede ser escrita como:

$$\frac{d^2\psi(x)}{dx^2}+k_x^2\psi(x)=0$$ Donde: $$k_x=(2m_e E/\hbar^2)^{1/2}.$$

ELECTRONES

Solución: E tiene valores discretos de energía $$E = E_n = \frac{\pi^2 \hbar^2 n^2}{2 m_e a^2}.$$

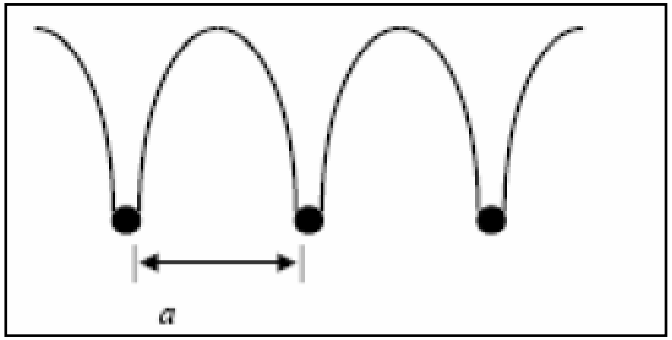
Ej:

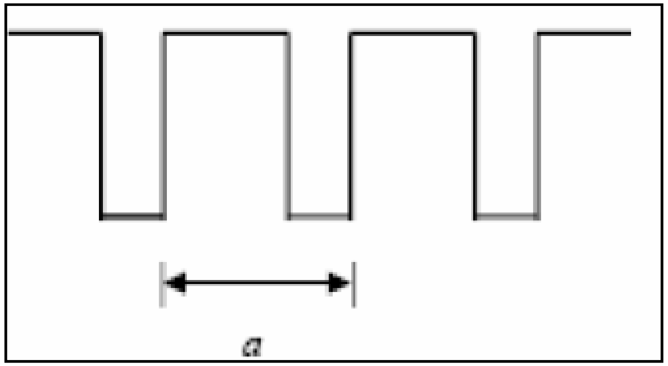


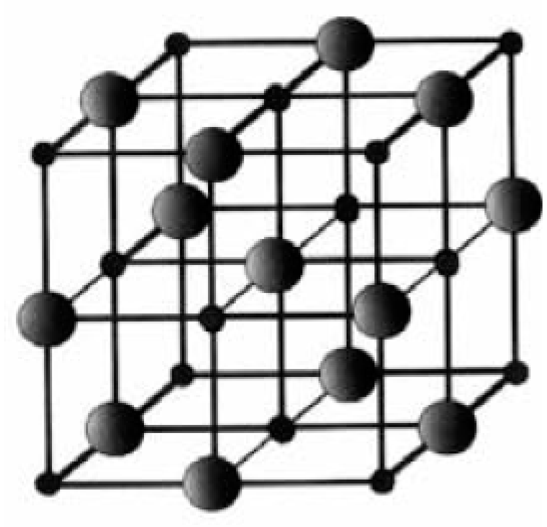
Los electrones en un pozo de potencial de tamaño limitado forman niveles de energía discretos

ATOMOS

CADENAS DE ATOMOS, REDES & ELECTRONES EN UN POTENCIAL PERIODICO





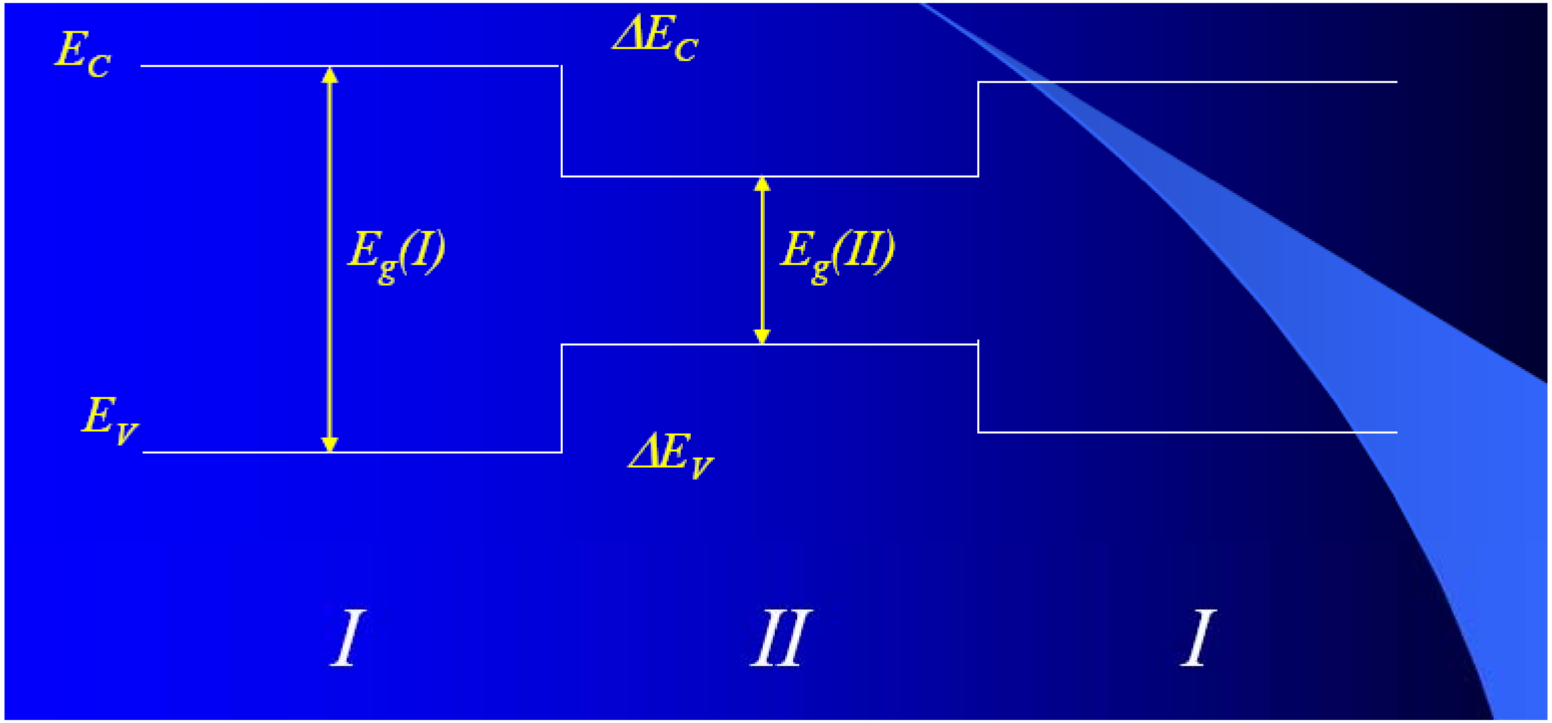


Red Cristalina

Resultando en un gap de energía prohibido

BANDAS DE ENERGIA

HETEROESTRUCTURAS SEMICONDUCTORAS & POZOS CUANTICO

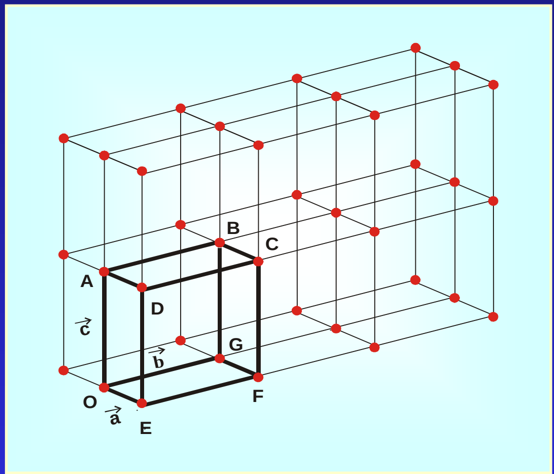


La diferencia de la banda gap

$$\boxed{\Delta E_g(I) = E_g(I) - E_g(II) = \Delta E_C + \Delta E_V}$$

Sólidos Cristalinos

Teorema de Bloch



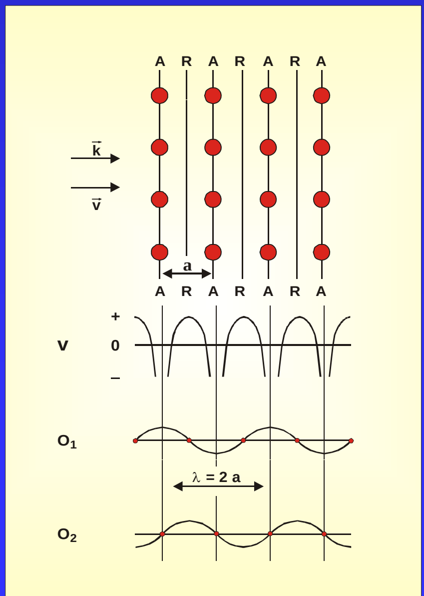
$$\bar{T}_n = n_1\bar{a} + n_2\bar{b} + n_3\bar{c}$$ **Simetría de Traslación**

$$U(\bar{r}) = U(\bar{r} + \bar{T}) \qquad H(\bar{r}) = H(\bar{r} + \bar{T})$$

$$\Psi(\bar{r}) = u_k(\bar{r})e^{i\bar{k}.\bar{r}}$$ **Función de Bloch**

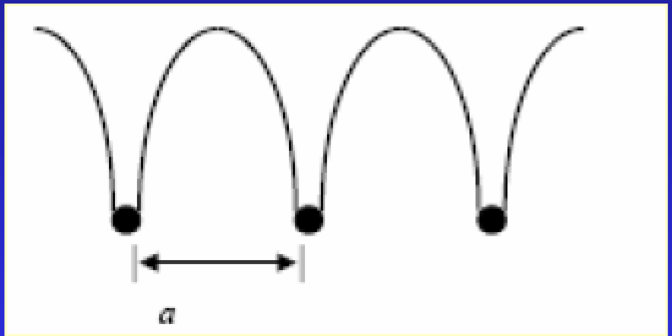
$$u_k(\bar{r}) = u_k(\bar{r} + \bar{T})$$

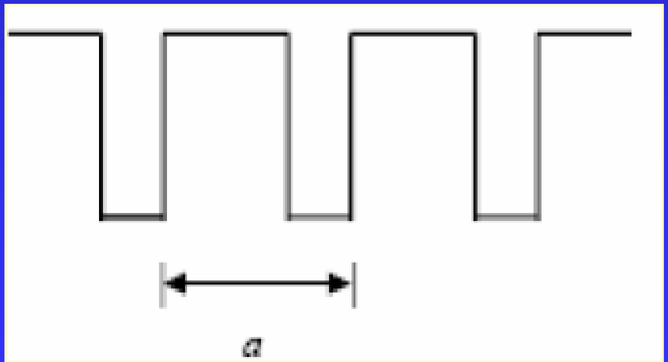
$$\Psi_k(\bar{r} + \bar{T}) = e^{i\bar{k}.\bar{T}}\Psi_k(\bar{r})$$

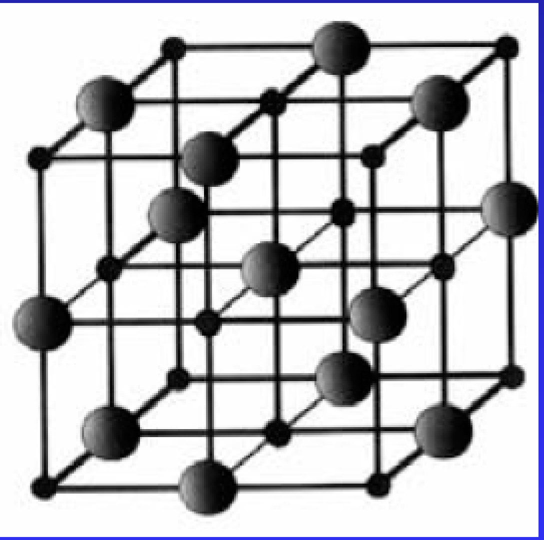


ATOMOS

CADENAS DE ATOMOS, REDES & ELECTRONES EN UN POTENCIAL PERIODICO



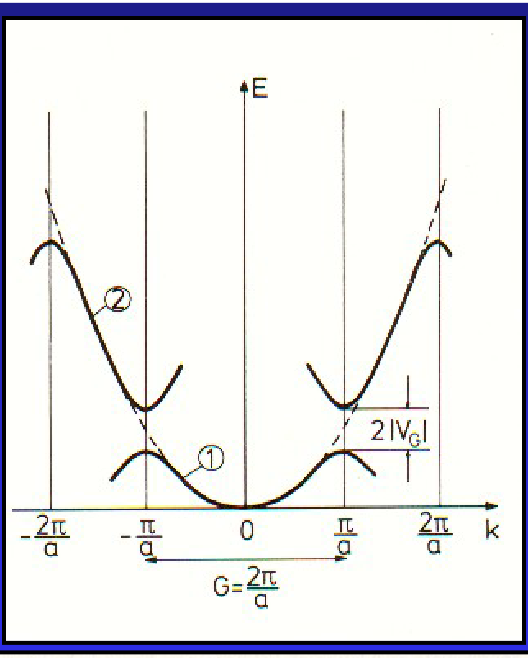


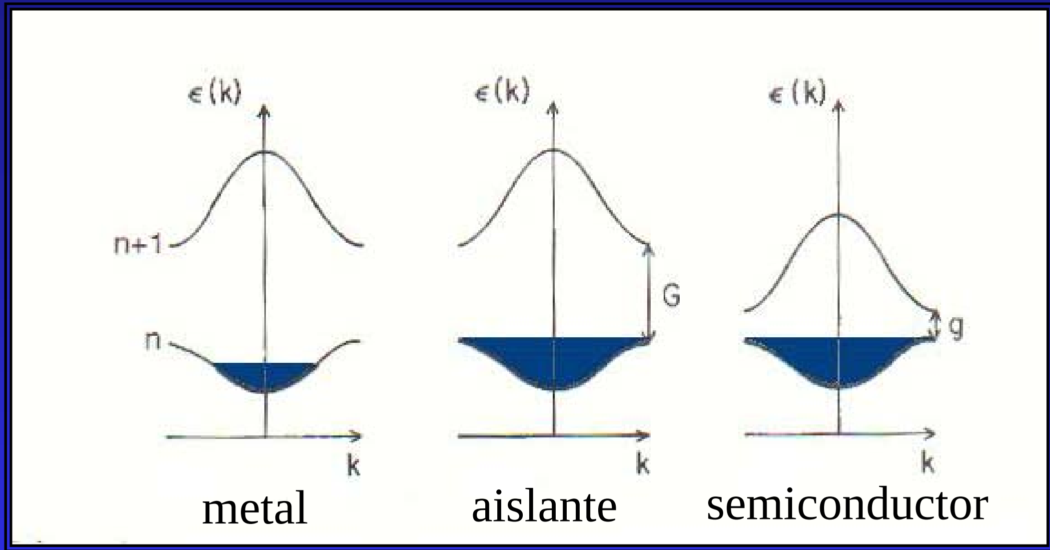


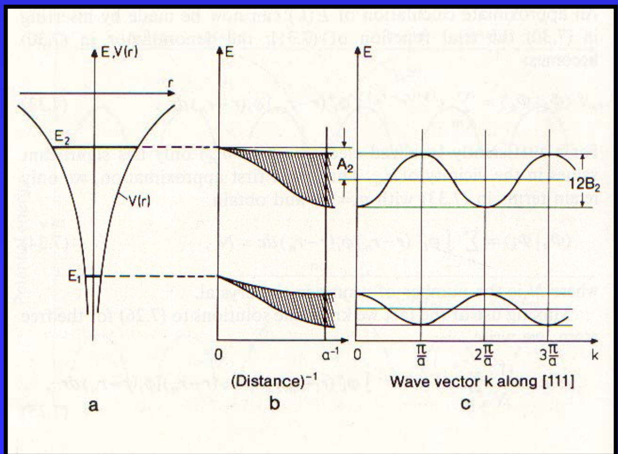
Red Cristalina

Resultando en un gap de energía prohibido

El Paradigma de la Estructura de Bandas







Modelo de electrón casi libre → $E_G \sim V_G$

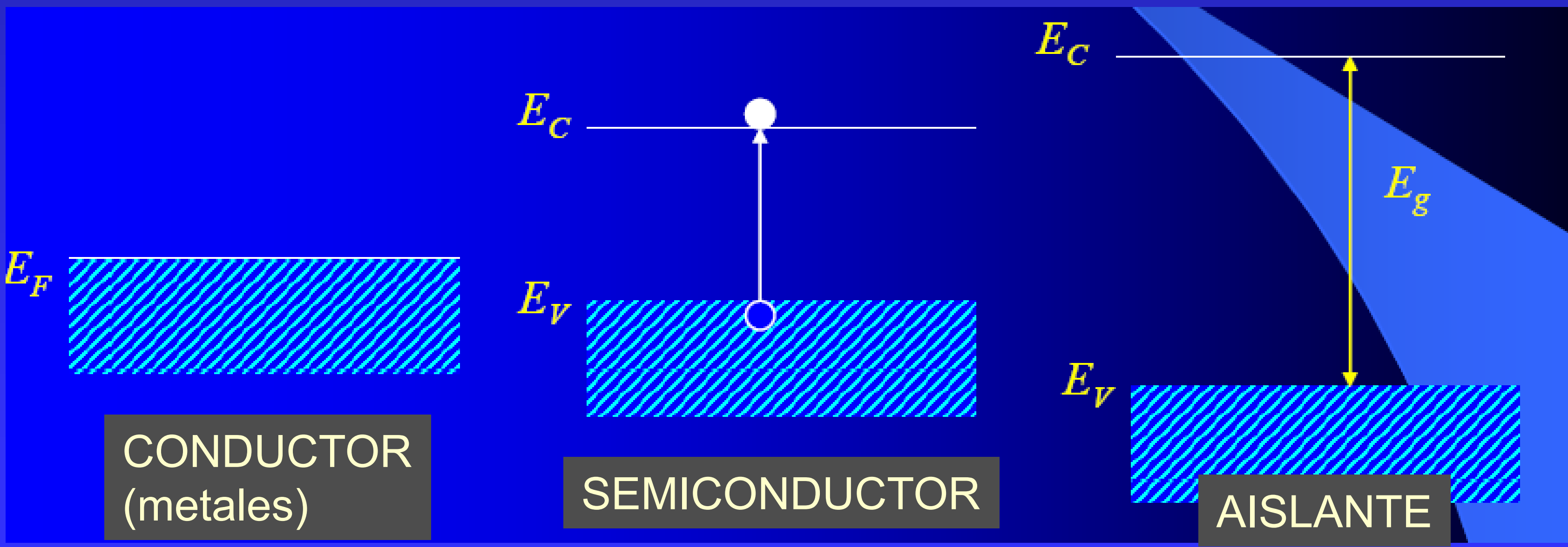
Modelo de enlace fuerte

ancho de banda ~ Integral de translapación

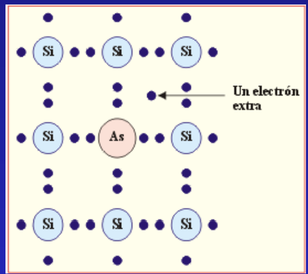
BANDAS DE ENERGIA

ESTRUCTURA DE BANDAS

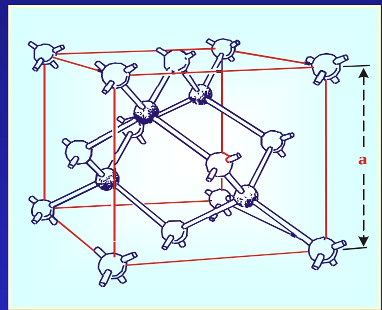
E_F: Energía del nivel de Fermi
E_V: Energía mínima de la banda de valencia.
E_C: Energía mínima de la banda de conducción.
E_g: Energía asociada con la banda prohibida (gap)



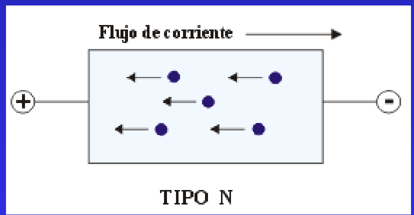
Materiales Semiconductores

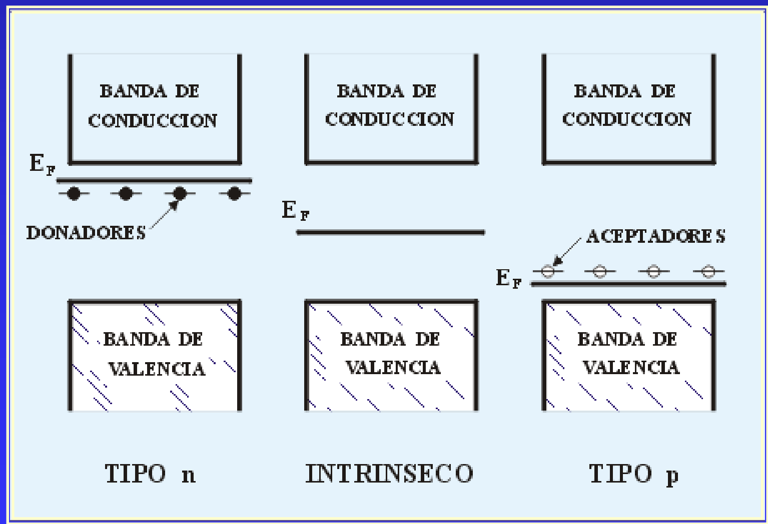


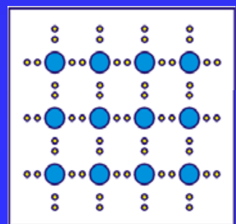
Si Tipo n

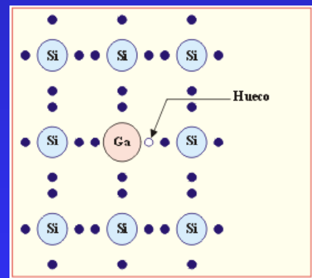


Si

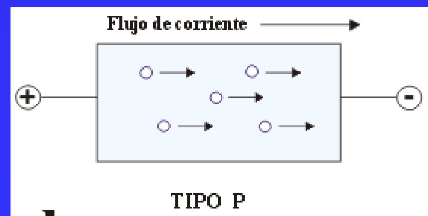




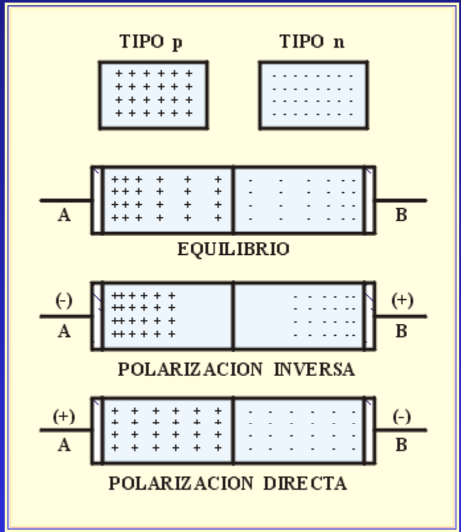




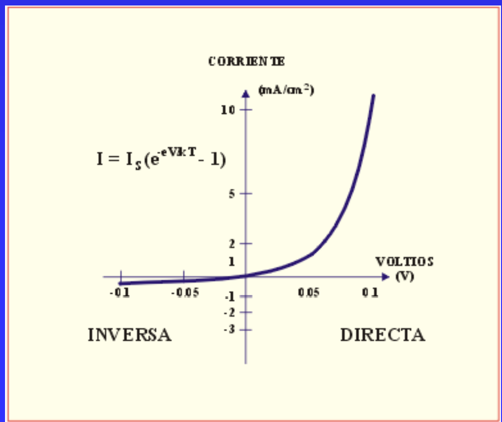
Si Tipo p

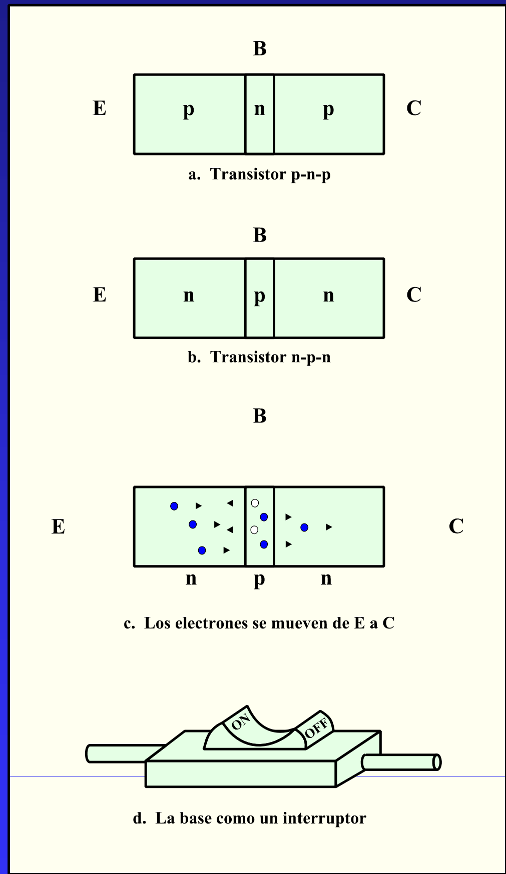


Dispositivos Semiconductores



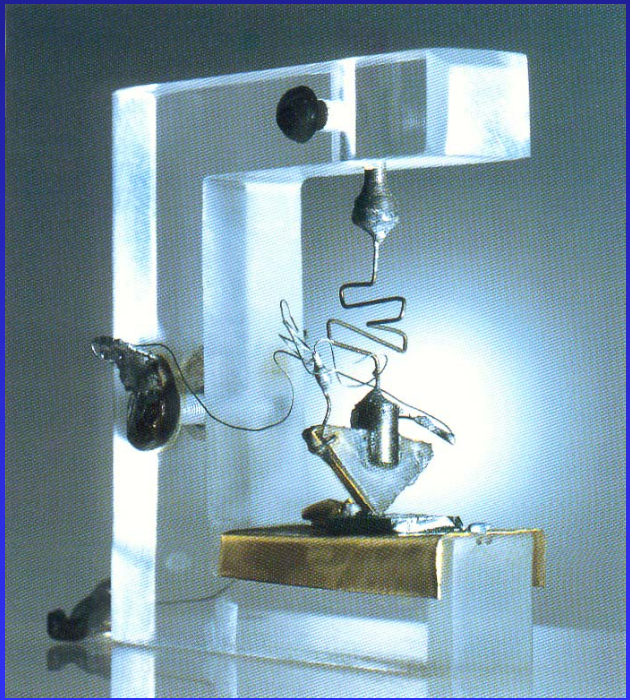
Diodo

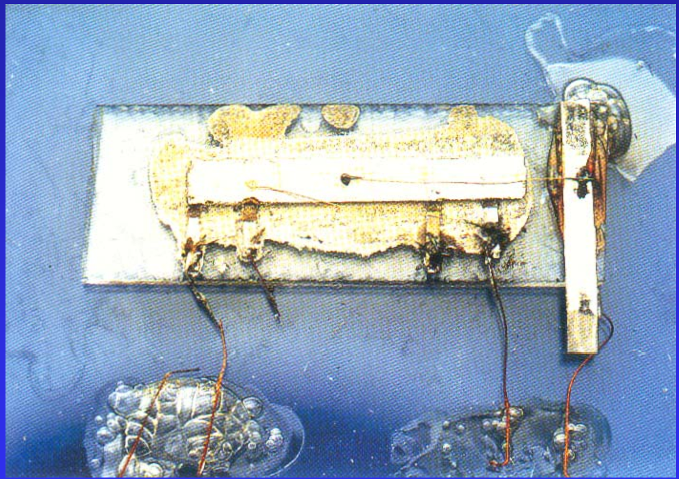


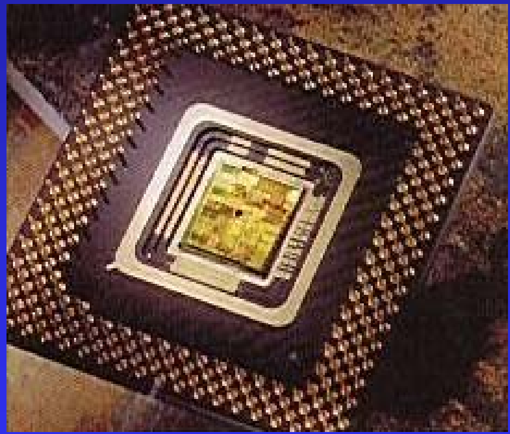


Transistor

Dispositivos Semiconductores







Transistor:
Bardeen, Shockley, Brattain
Bell Labs. 1947

Circuito Integrado:
Kilby.
Texas Instruments. 1958

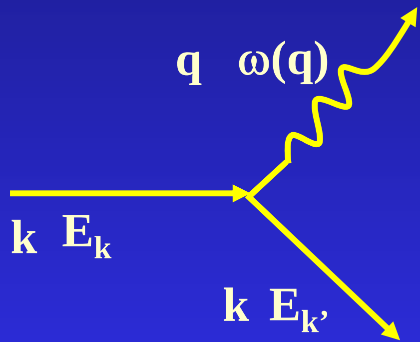
Chip Pentium :
Intel Corporation.
2000

Interacción e – fonón: Resistividad

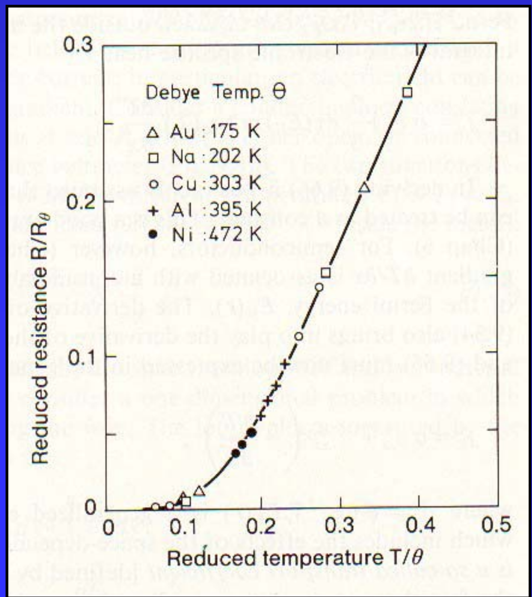
Aproximación adiabática $\mu_e >> \mu_i$

Oscilaciones de la red cuantizadas: fonones

$$H = \sum_l \frac{M_l}{2} \dot{u}_l^2 + \Phi(u_1, u_2, \ldots, u_N)$$



Relación de Bloch-Grüneisen

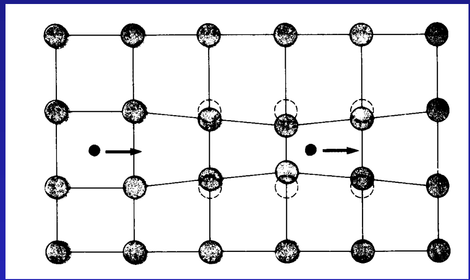


$$\rho = \frac{m^*}{ne^2}\frac{1}{\tau}$$

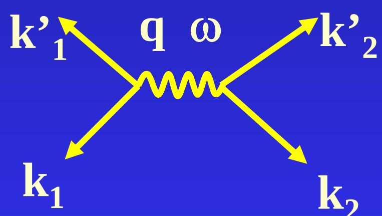
$$\rho_{ph}(T) = A(T/\Theta)^5 \int_0^{\Theta/T} \frac{x^5 dx}{(e^x - 1)(1 - e^{-x})}$$

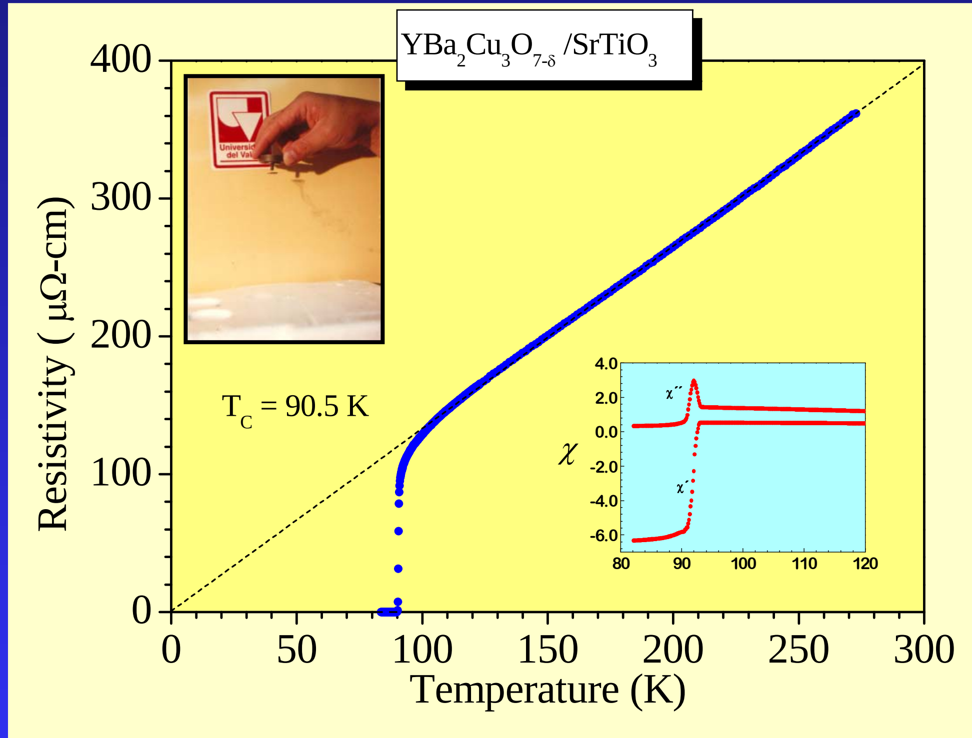
Interacción e – e : Superconductividad

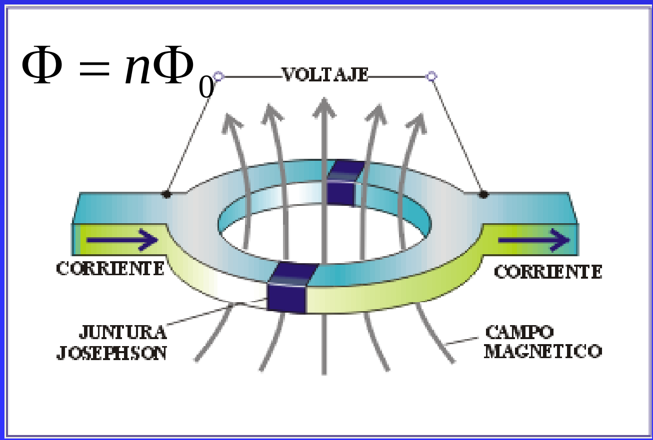
Teoría BCS



Par de Cooper



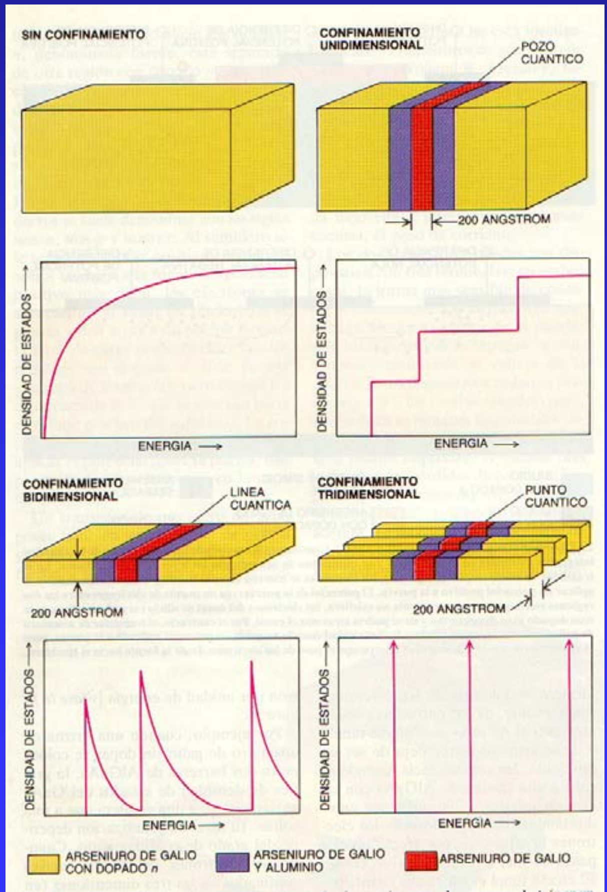


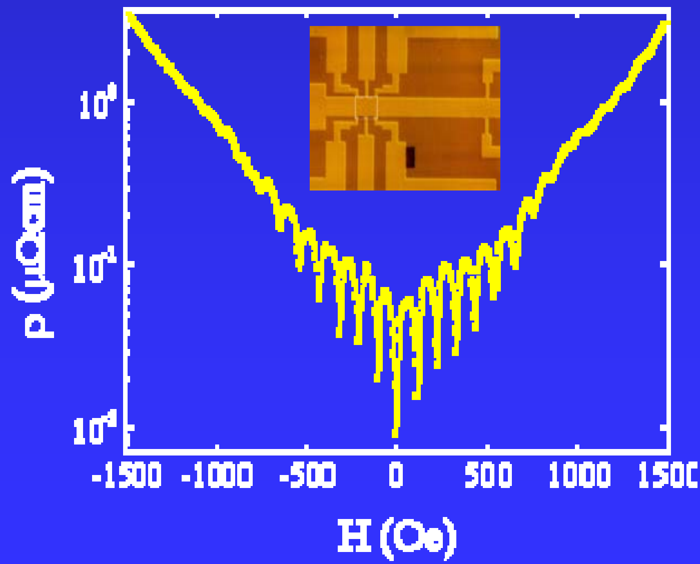


$$\Phi_0 = \frac{h}{2e} = 2.067x10^{-15}\,\frac{T}{m^2}$$

Confinamiento Cuántico

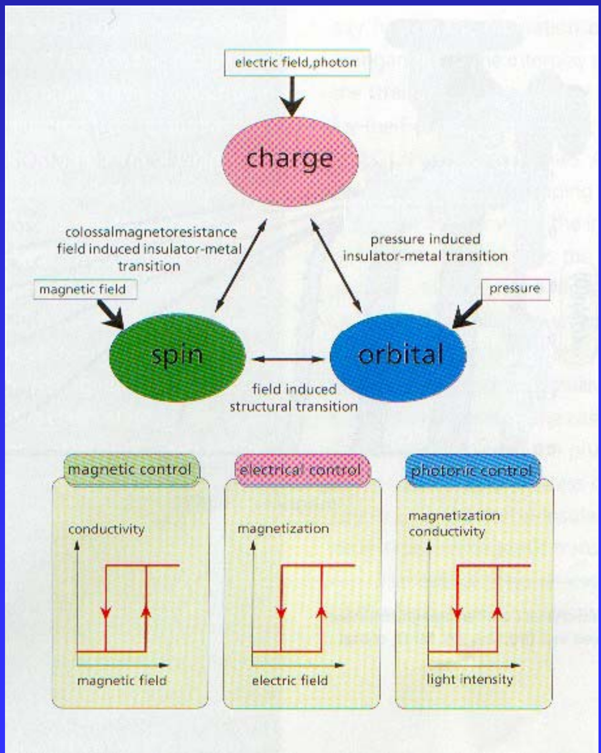
Física de baja dimensionalidad



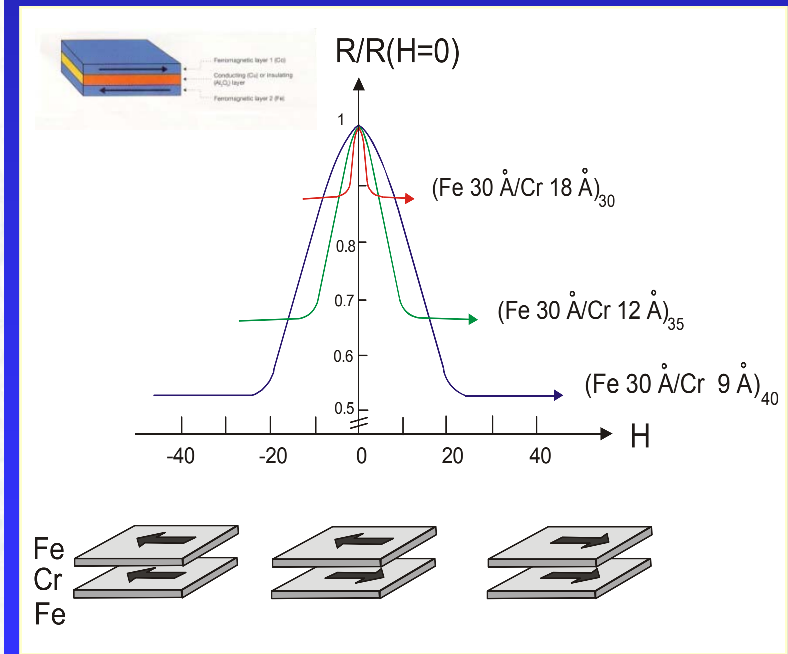


Spintronics

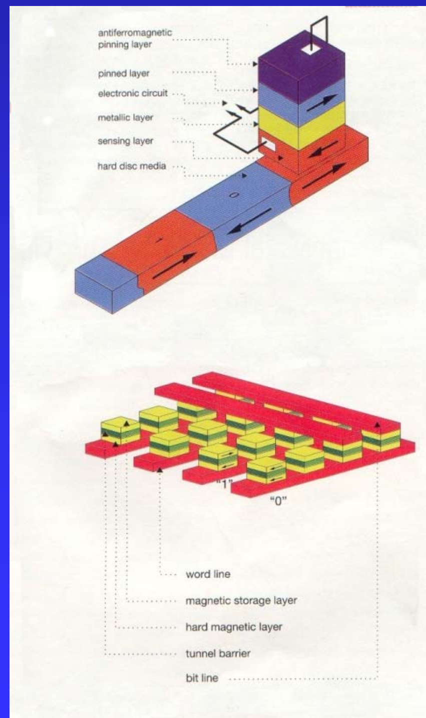
e:carga+spin



GMR

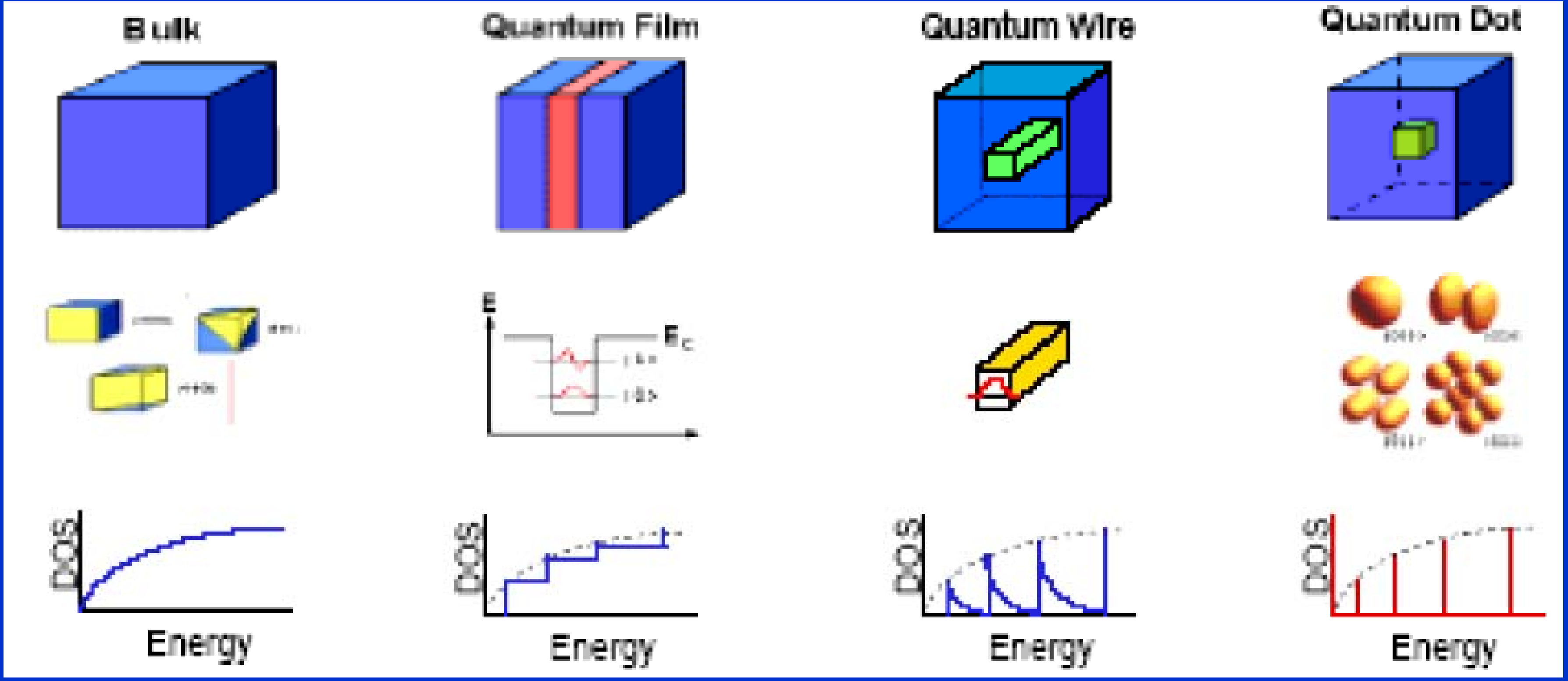


Dispositivos GMR



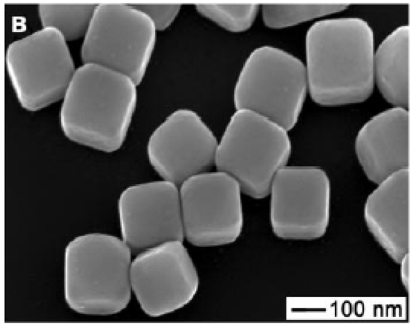
Efectos cuánticos de dimensionalidad

Cambios de los niveles de energía y al densidad electrónica
Cambiando de esta forma también las propiedades eléctricas, electrónicas, fotonicas y magnéticas

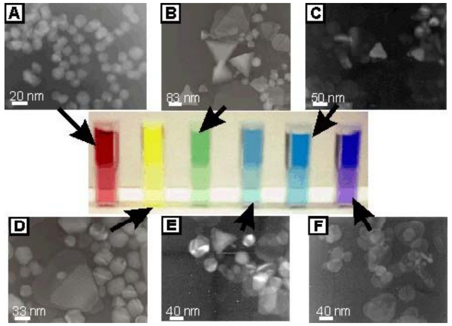


Nanostructures

Noble Metal Nanoparticles



Sun, Y.; Xia, Y. *Science* **2002**, 298, 2176.

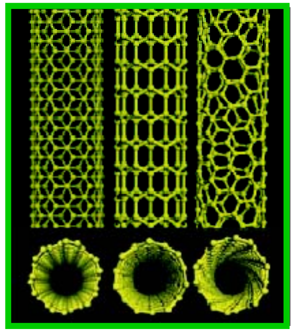


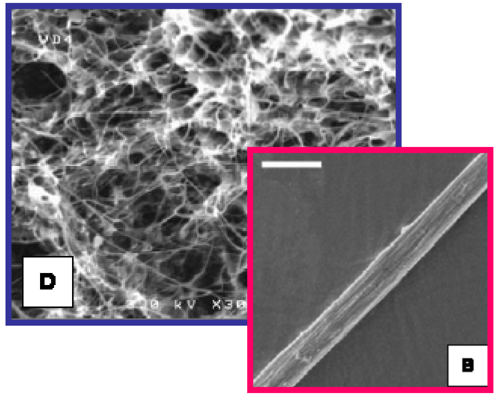
Courtesy of the Van Duyne group

CdSe Quantum Dots

Courtesy of Liza Babayon

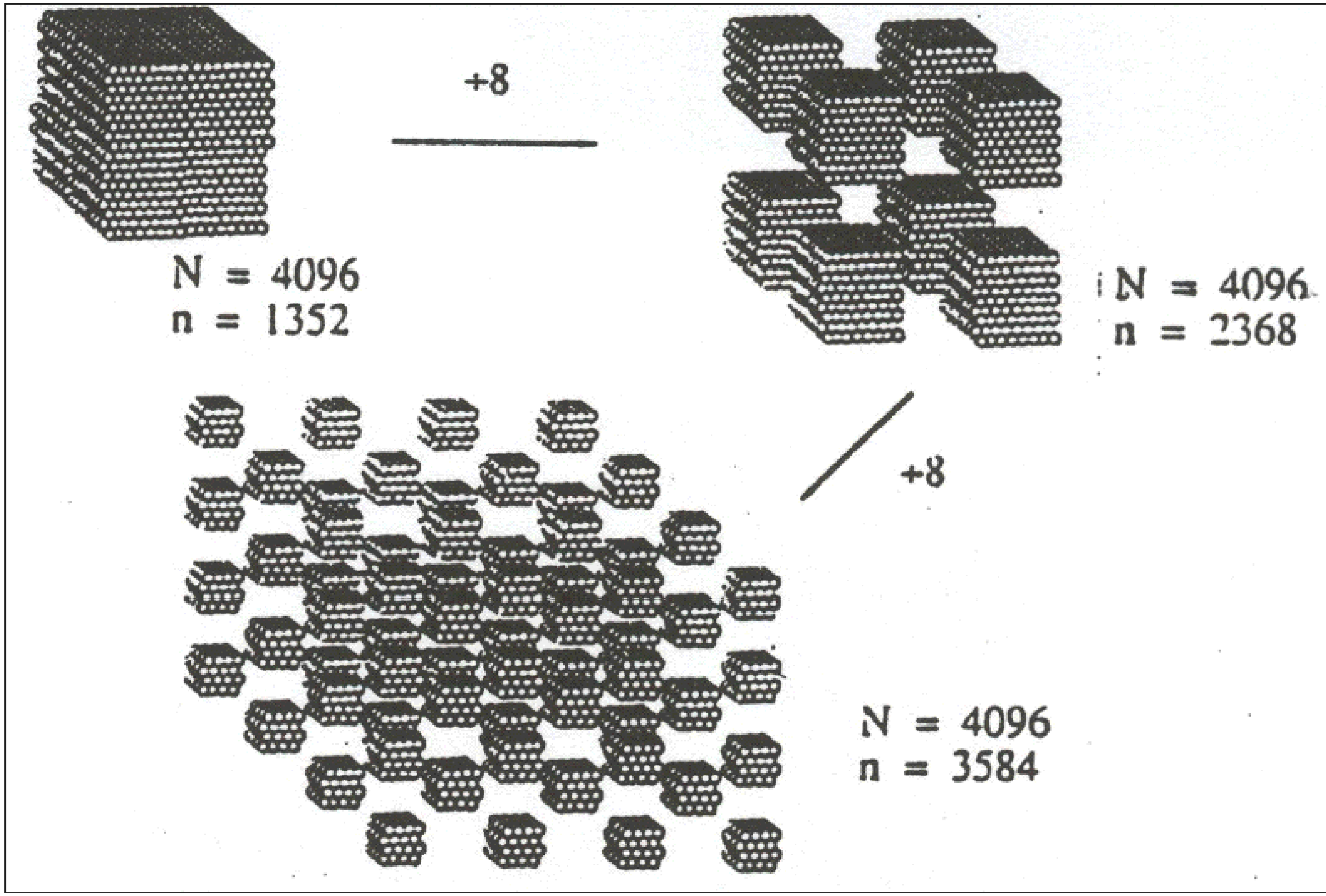
Carbon Nanotubes





Baughman, R. H.; Zakhidov, A. A.; de Heer, W. A. *Science* **2002**, 297, 787

Vigolo, B; Penicuad, A.; Coulon, C.; Sauder, C.; Pailler, R Journey, C.; Bernier, P. Poulin, P. *Science* **2000**, 290, 1331



Relación entre átomos en el volumen y sobre la superficie

Ostwald W. *Colloids – Zeitschrift*, 1907, 1, 291-331

TAMAÑO DE LA MATERIA

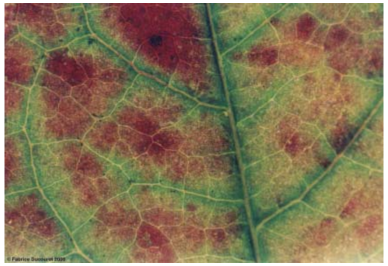
LOS EFECTOS SUPERFICIALES

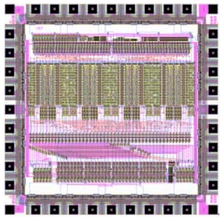
Cuando la razón superficie / bulk atómico es grande, entonces se presentan efecto en las propiedades mecánicas y químicas

Numero de átomos en el interior y en la superficie en la estructura BBC

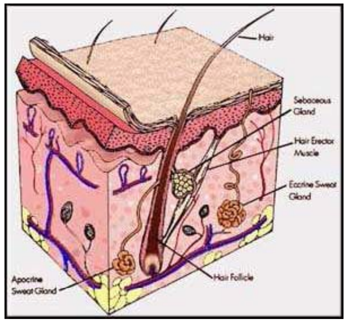
Number of unit cells in the cube	Surface (S) atoms	Interior (I) atoms	Ratio (S/I)
1	8	1	8
8 (2x2x2)	26	9	2.9
27 (3x3x3)	56	35	1.6
64 (4x4x4)	98	91	1.1
125 (5x5x5)	152	189	0.8
216 (6x6x6)	218	341	0.6
...			
1,000,000 (100x100x100)	60,002	1,970,299	0.03

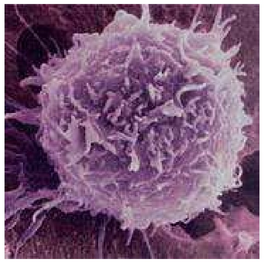
Los sistemas se vinculan a traves de su superficie (interfases)

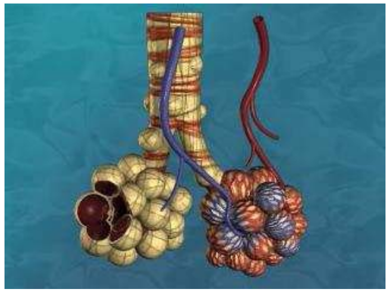




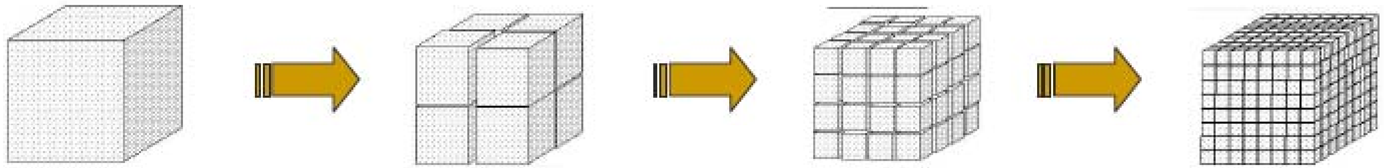
Numerosos procesos naturales y nonaturalesestán gobernados por interacciones en interfases







Efecto de la superficie:



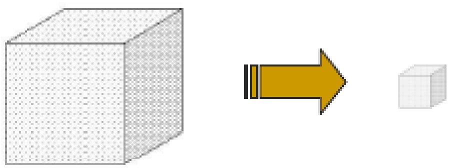
Lado = A
Sup = S

Lado = A/2
Sup = 2 x S

Lado = A/4
Sup = 4 x S

Lado = A/8
Sup = 8 x S

(1 mm = 1.000.000 nm)

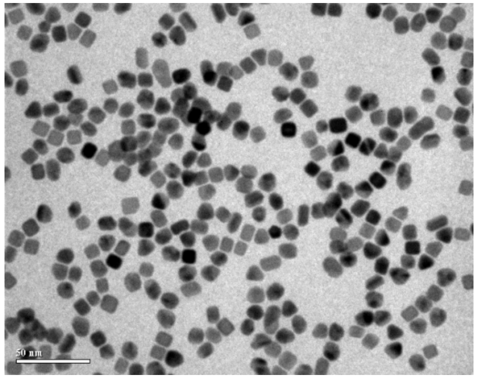


La superficie se amplificó 1 millón de vece

Lado = 1 mm
Sup = **6 mm²**

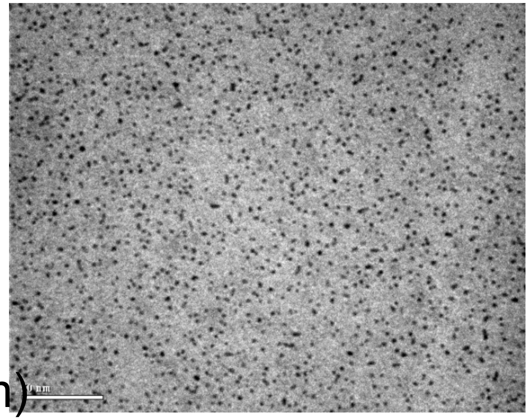
Lado = 1 nm
Sup = 6 nm²

Efecto de la superficie:



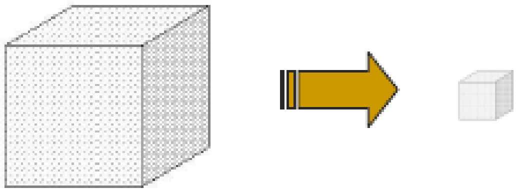
Nanopartículas cúbicas de Pt de 9 nm de arista

(1 mm = 1.000.000 nm)



Nanopartículas esféricas de Pt de 2 nm de diámetro

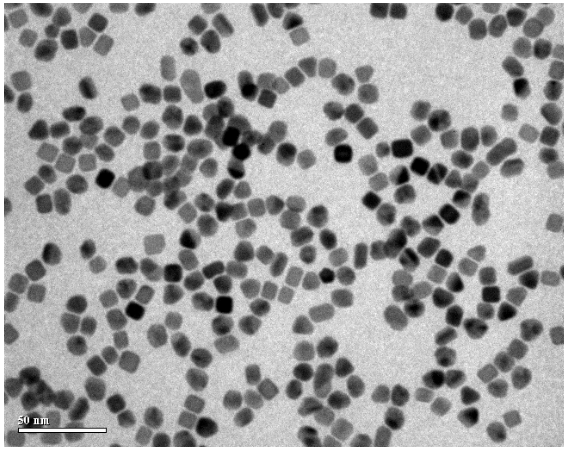
La superficie se amplificó 1 millón de veces



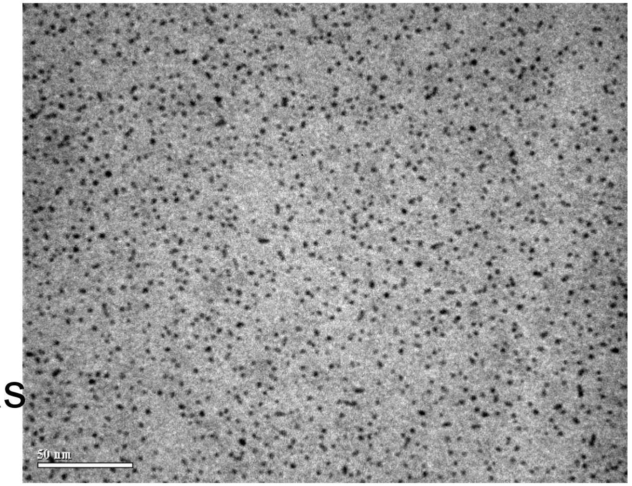
Lado = 1 mm
Sup = 6 mm^2

Lado = 1 nm
Sup = 6 nm2 x (106 x 106 x 106) = 6 x 10^{18} nm^2 = 6.000.000 mm^2

Efecto de la superficie:



Nanopartículas
cúbicas
de Pt de 9 nm de
arista



Nanopartículas esféricas
de Pt de 2 nm de
diámetro

La interaccion entre diferentes sistemas (o de un sistema con el medio) se da a través de su superficie.

La nano dimensión amplifica enormemente los efectos de superficie.

NANOPARTICULAS: ***LADRILLOS FUNDAMENTALES DE LA NANOTECNOLOGIA***

Influencia del espesor de capa

5 nm Plata

21 nm Oro

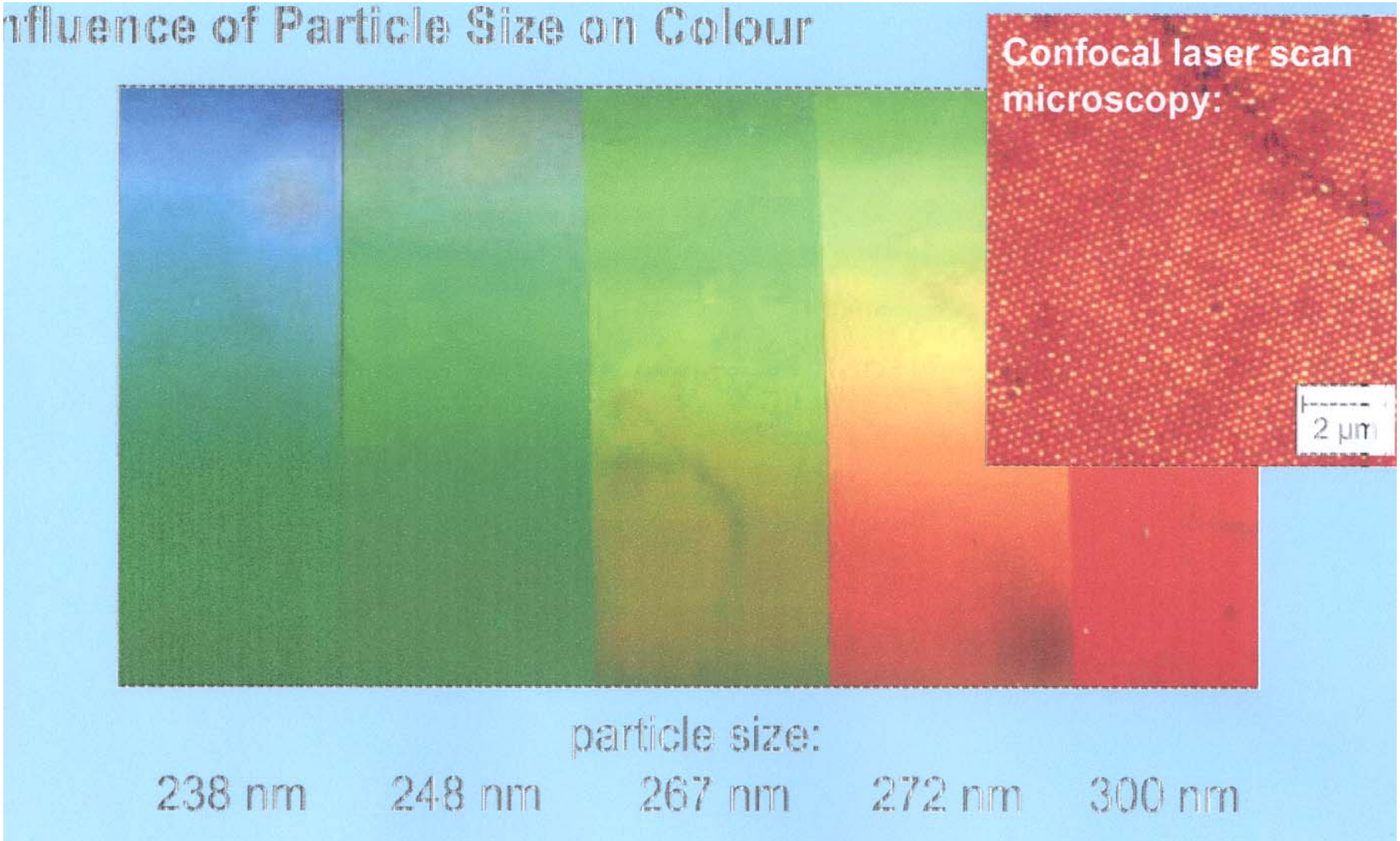
44 nm Violeta

122nm Rojo

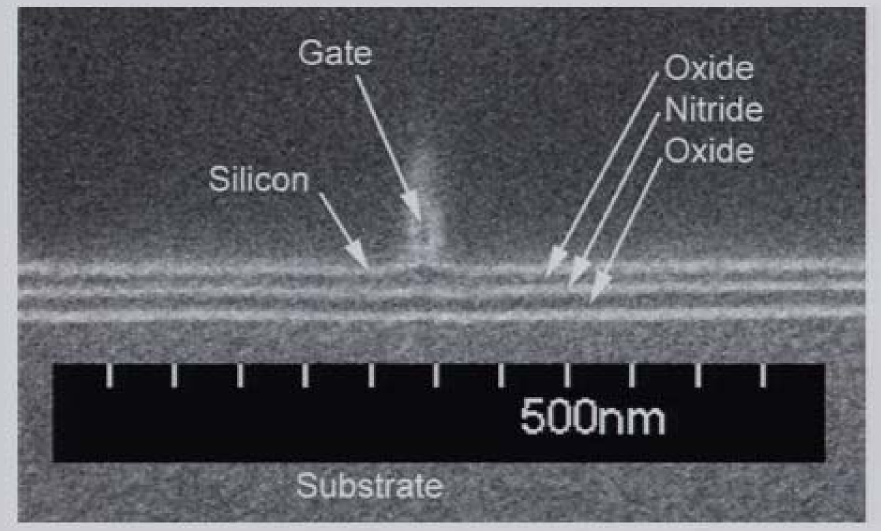
+ brillantes

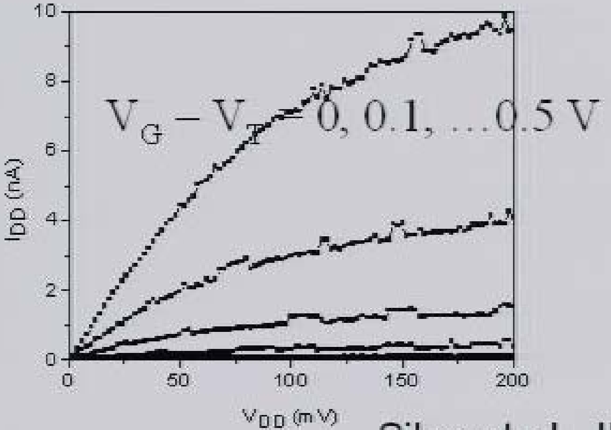
y opacidad

Influencia del tamaño de partícula en el color



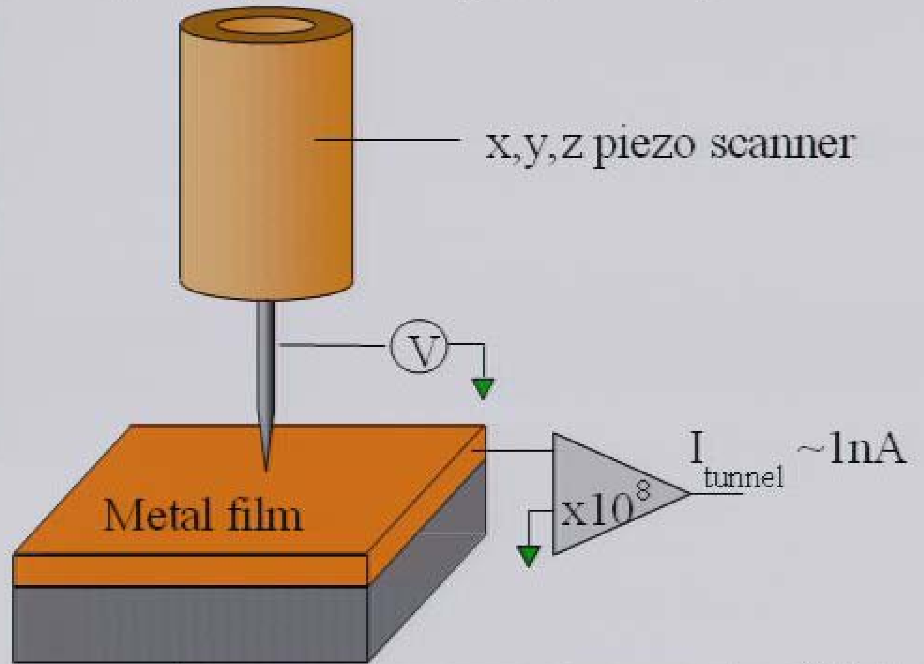
Nanoscale: Quantum Mechanical Effects





Silva et al., IEDM (2003)

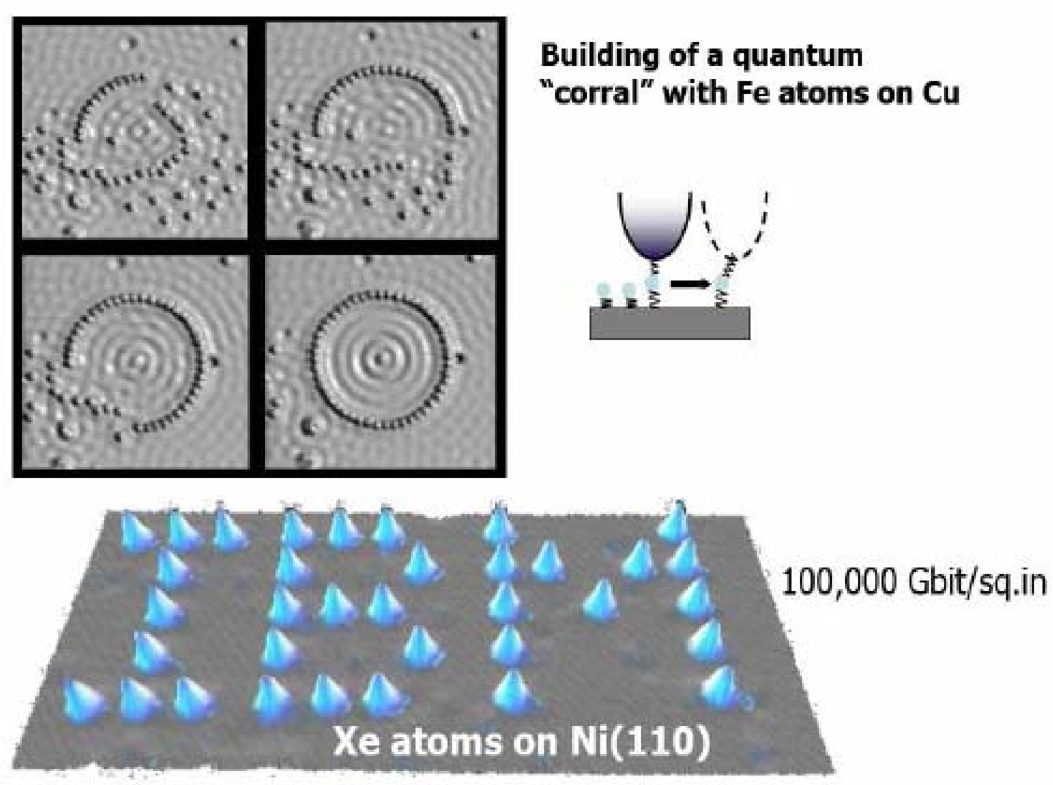
Scanning Tunneling Microscope



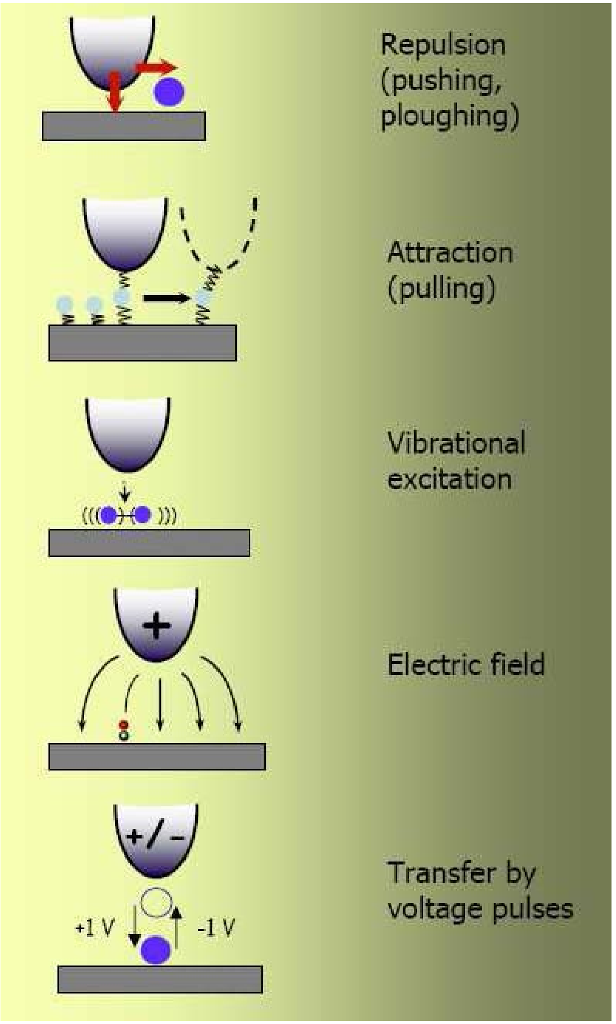
Fowler Nordheim tunneling makes Flash Memories possible
Tunneling makes scanning tunneling microscopes possible

Caracterización por imágenes

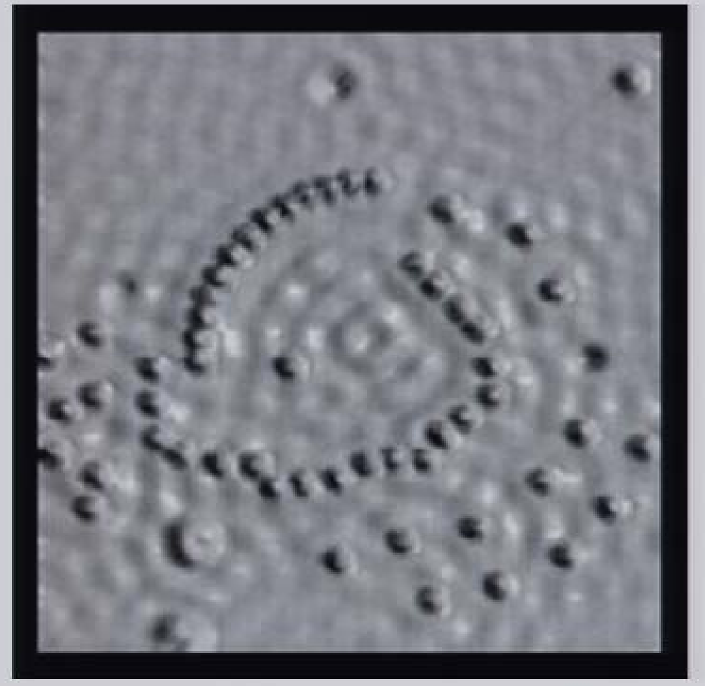
Manipulando átomos con STM



STM images courtesy of Don Eigler, IBM, San Jose

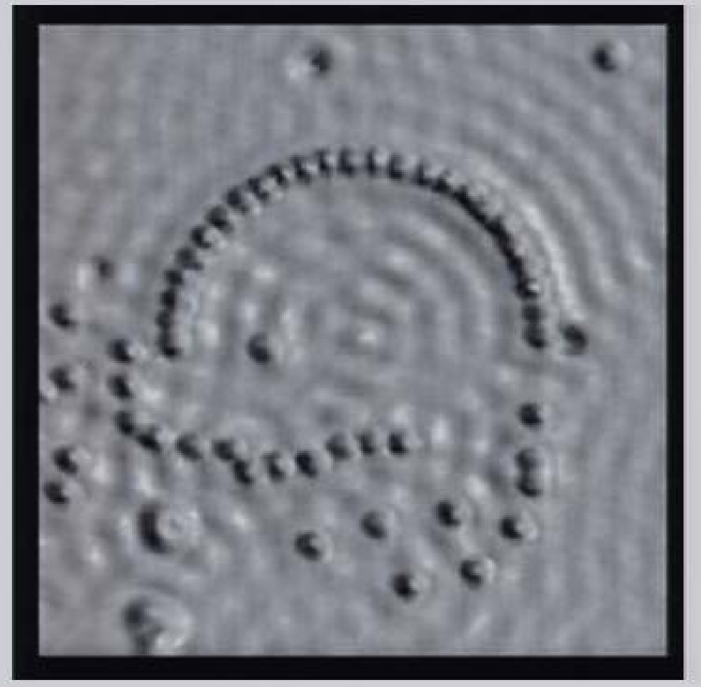


Atom by Atom



D. Eigler, IBM Almaden

Atom by Atom

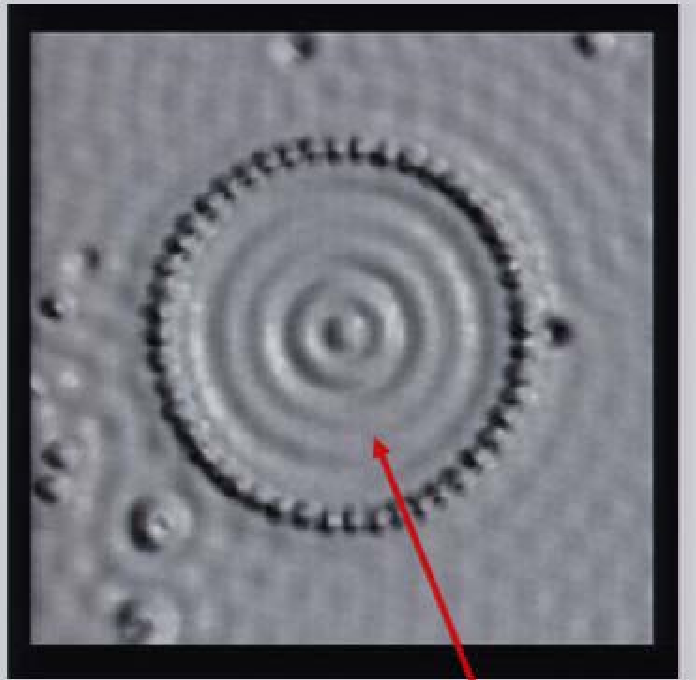


D. Eigler, IBM Almaden

Atom by Atom

D. Eigler, IBM Almaden

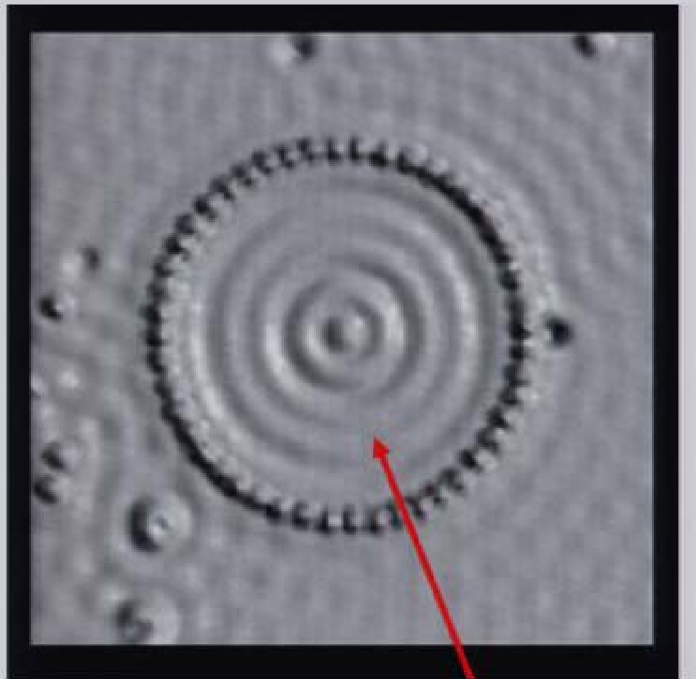
Atom by Atom

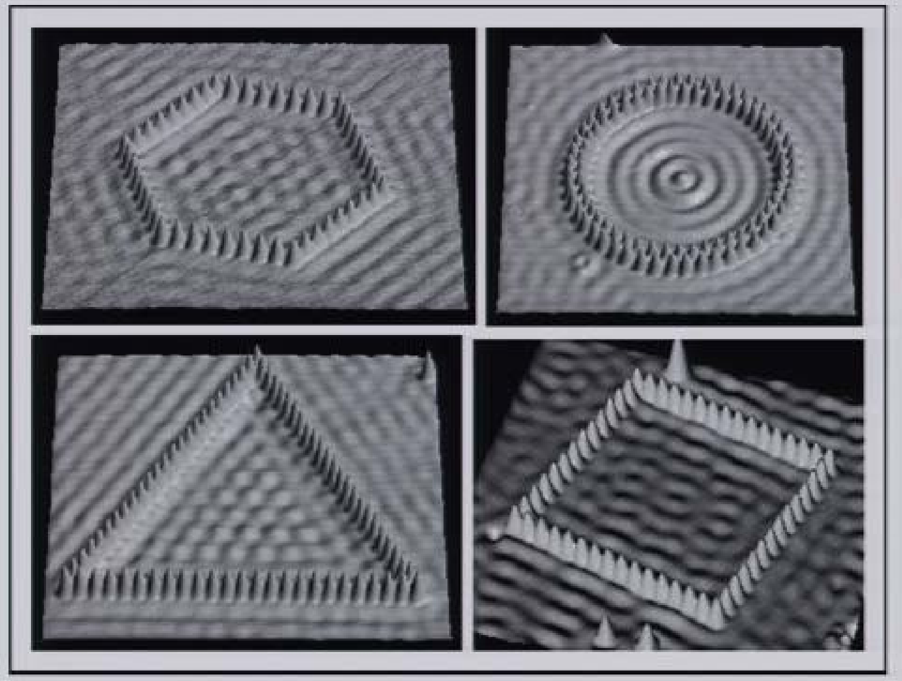


note waves

D. Eigler, IBM Almaden

Atom by Atom

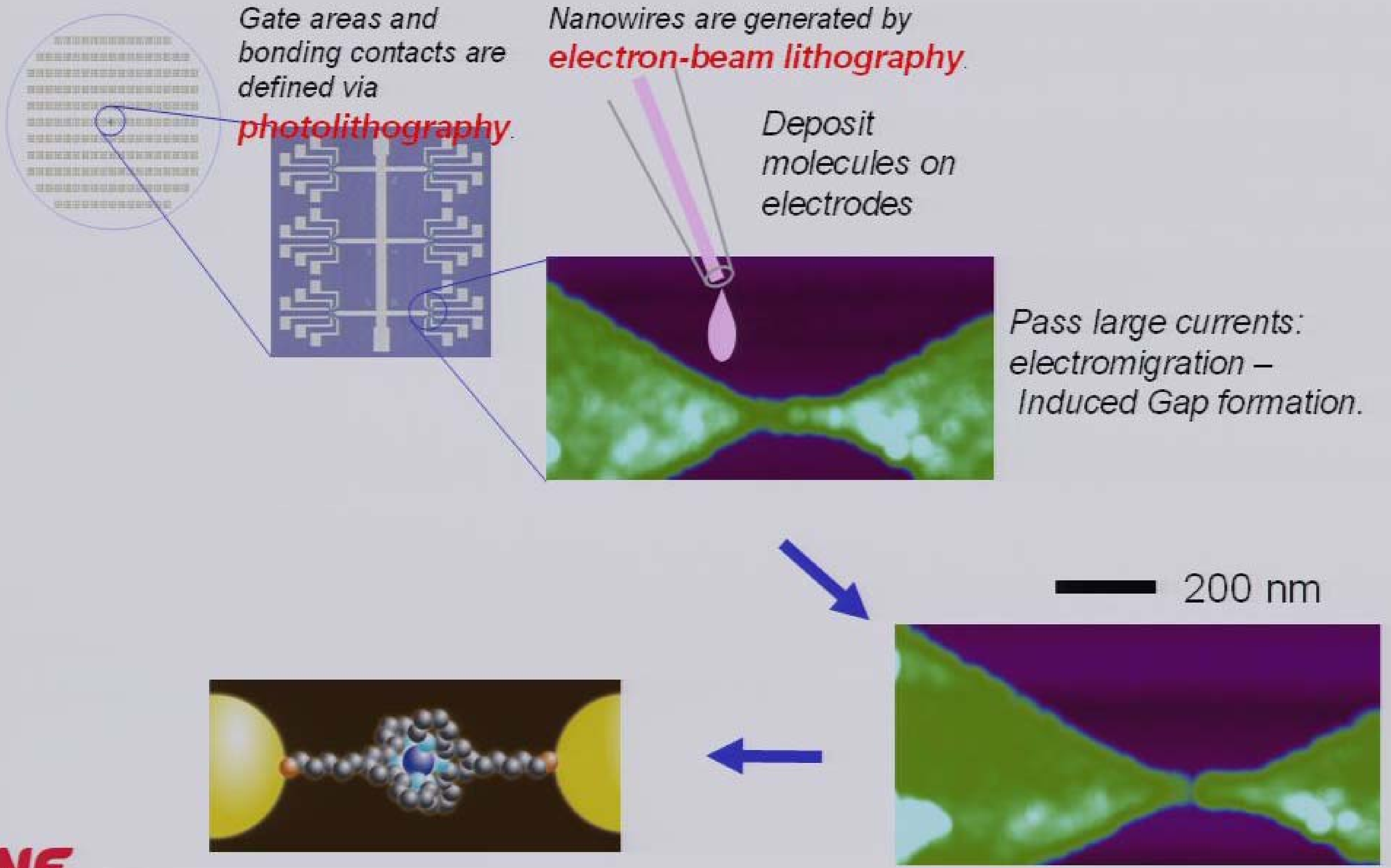




note waves

D. Eigler, IBM Almaden

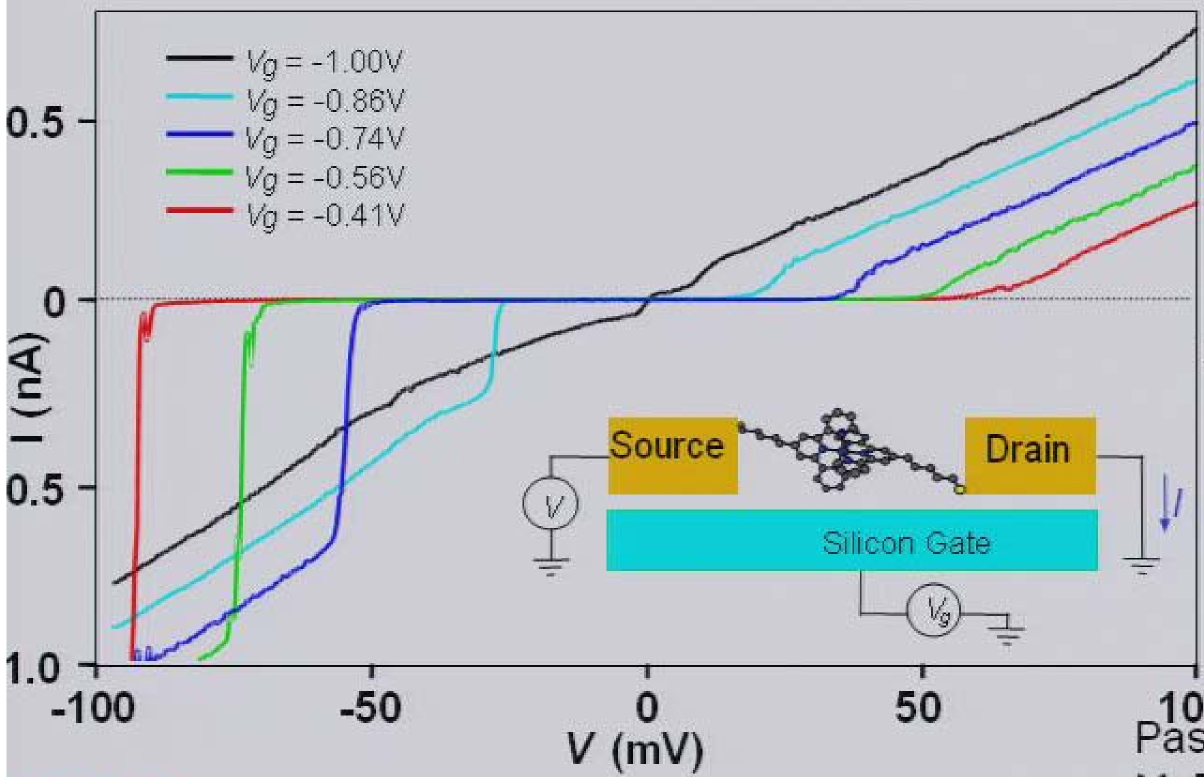
Creating Single-Molecule Transistors

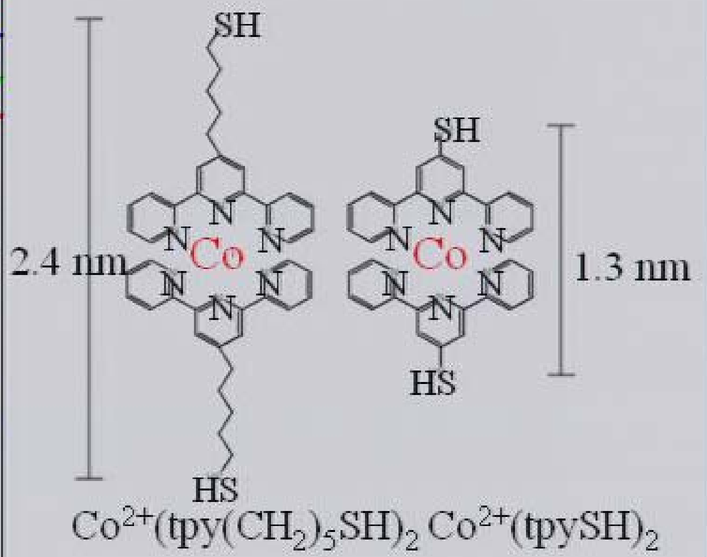


CNF Cornell NanoScale Science and Technology Facility

Transistor Action

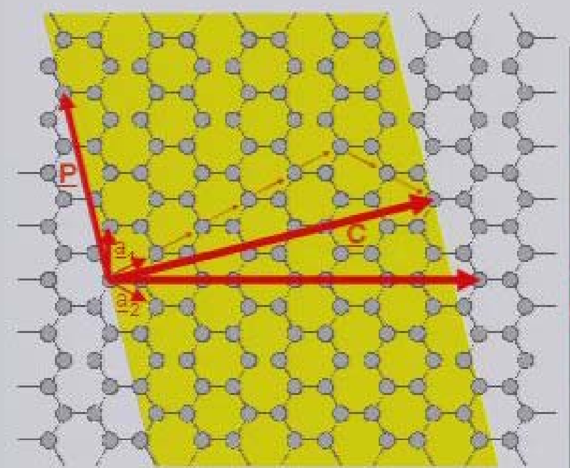
- Longer molecules: larger resistance
- Single molecule works as a single-electron transistor (though at low temperatures and no gain)



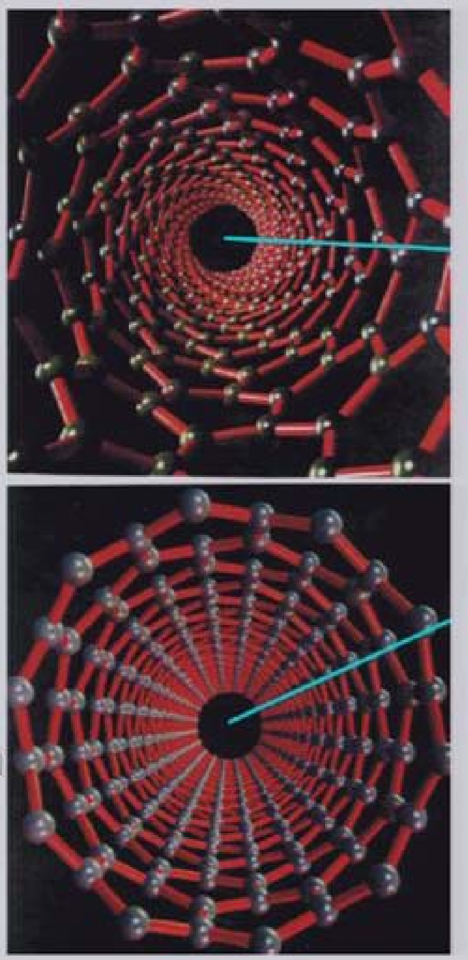


Pasupathy, Park, Goldsmith, Abruña, McEuen, Sethna, Ralph, Nature (2002)

Carbon Nanotubes

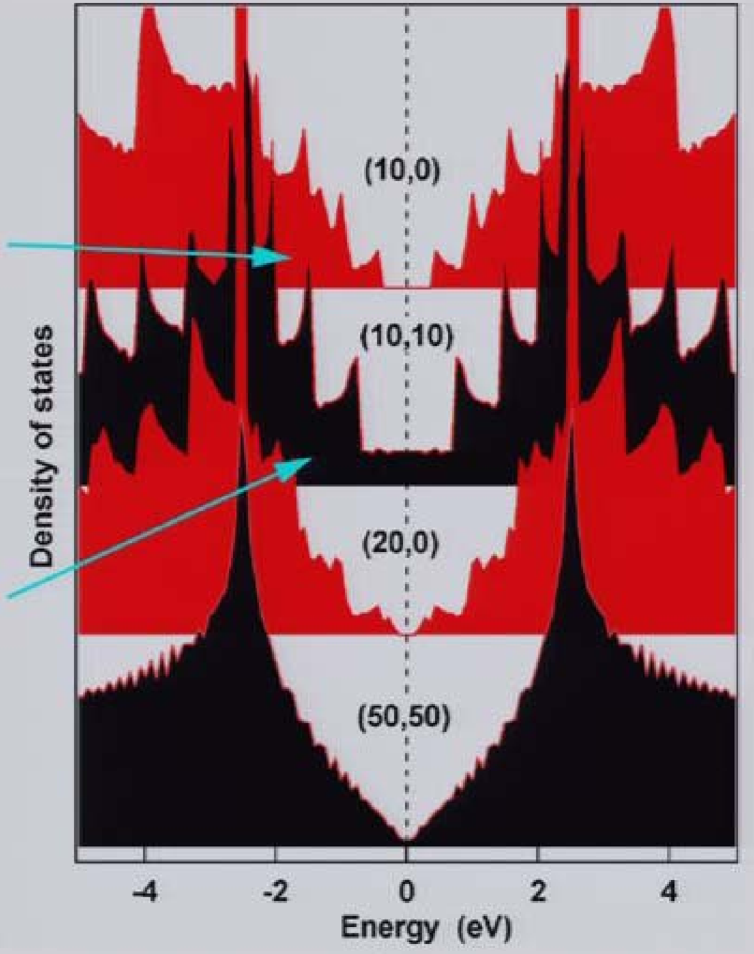


A nanotube (n,m) is a folded graphite sheet. Single wall tubes are 1 nm diameter



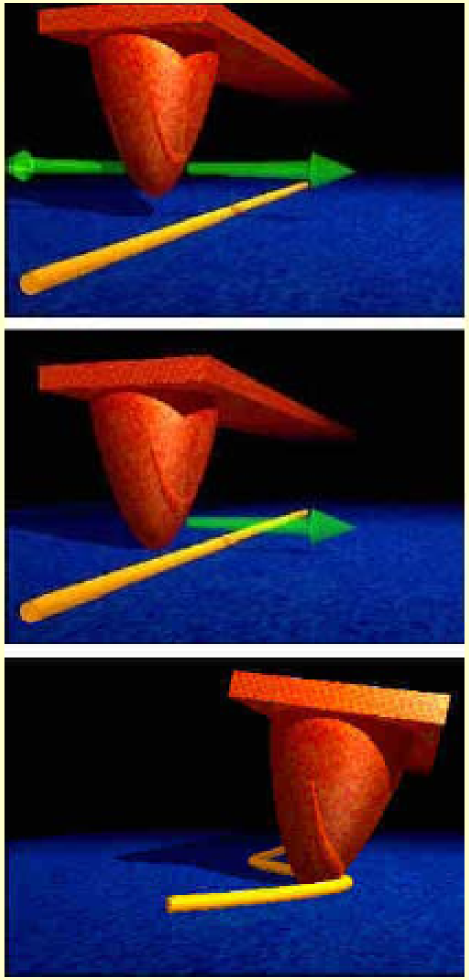
	Youngs Modulus (GPa)	Tensile Strength (GPa)
SWNT	1054	150
Steel	208	0.4

Peak Thermal Conductivity: 4×10^4 W/m.K



Semiconducting to metallic

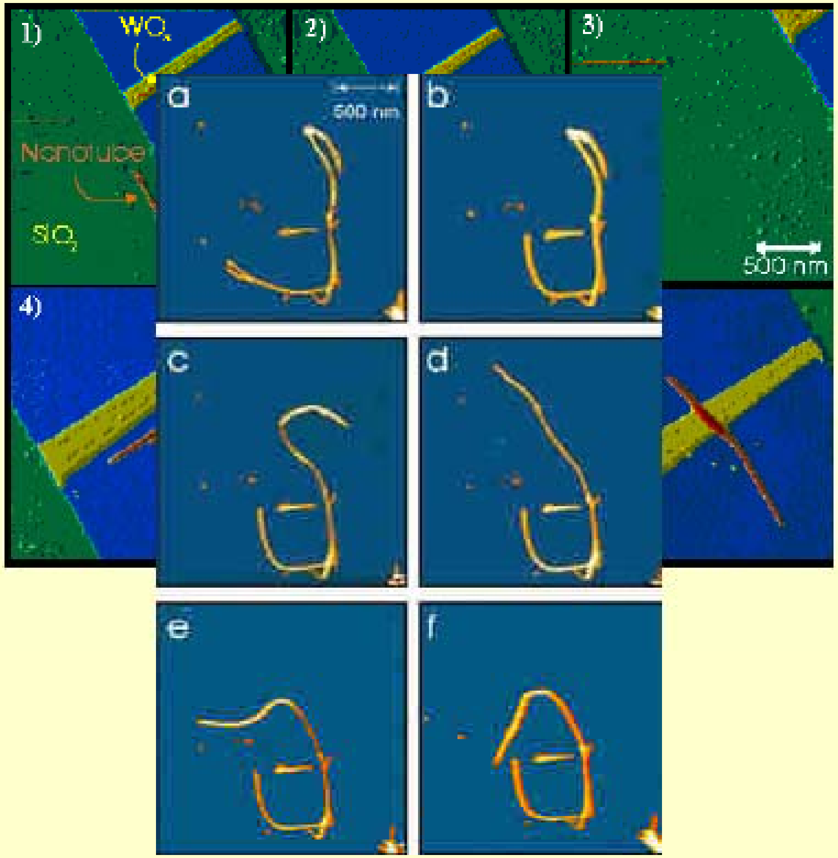
Carbon Nanotube Manipulation



AFM Scanning

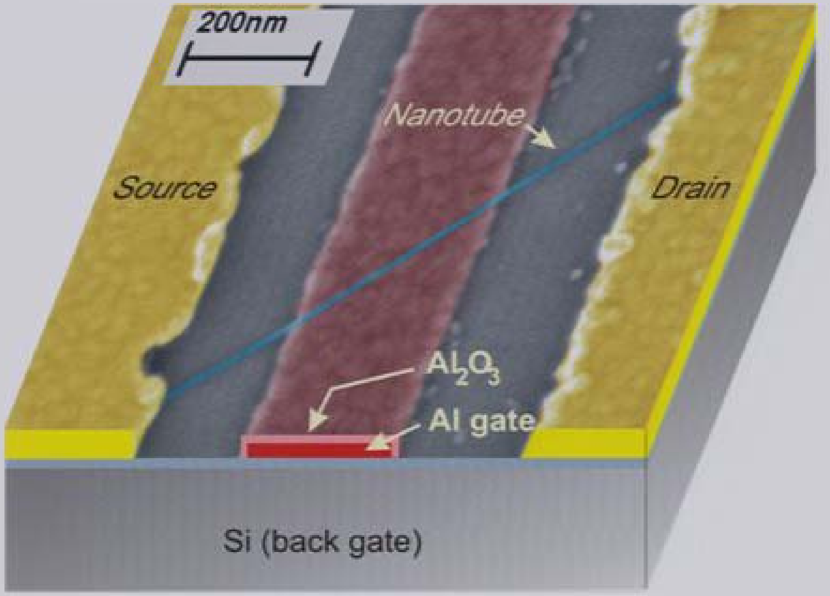
Lowering the tip and pushing

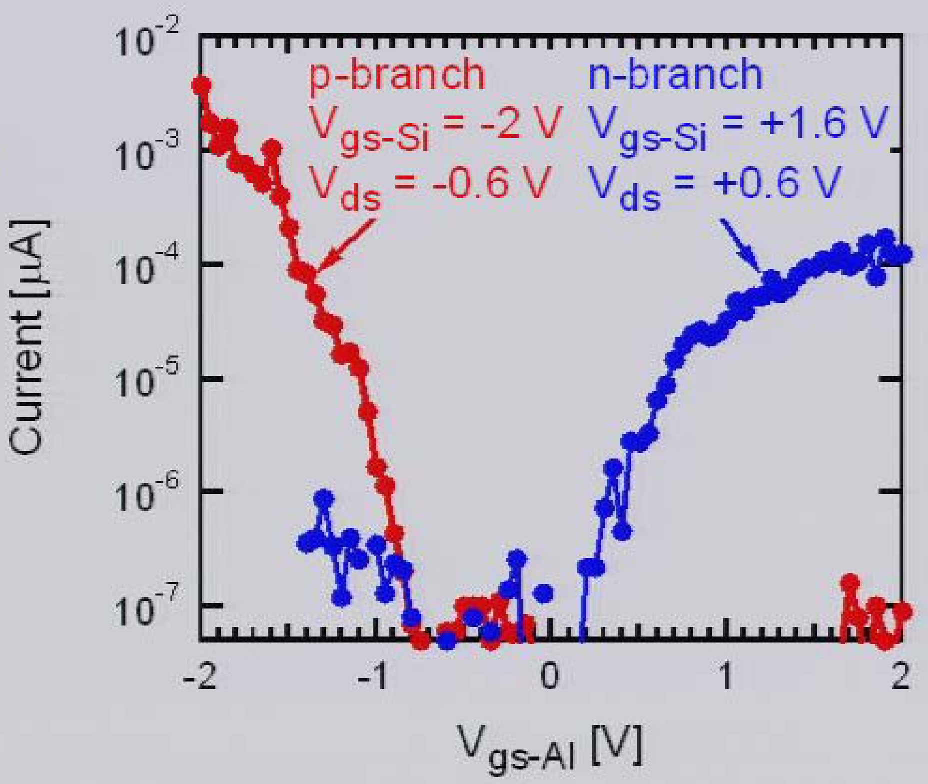
VDW forces hold the CNT



(Avouris *et al.* IBM)

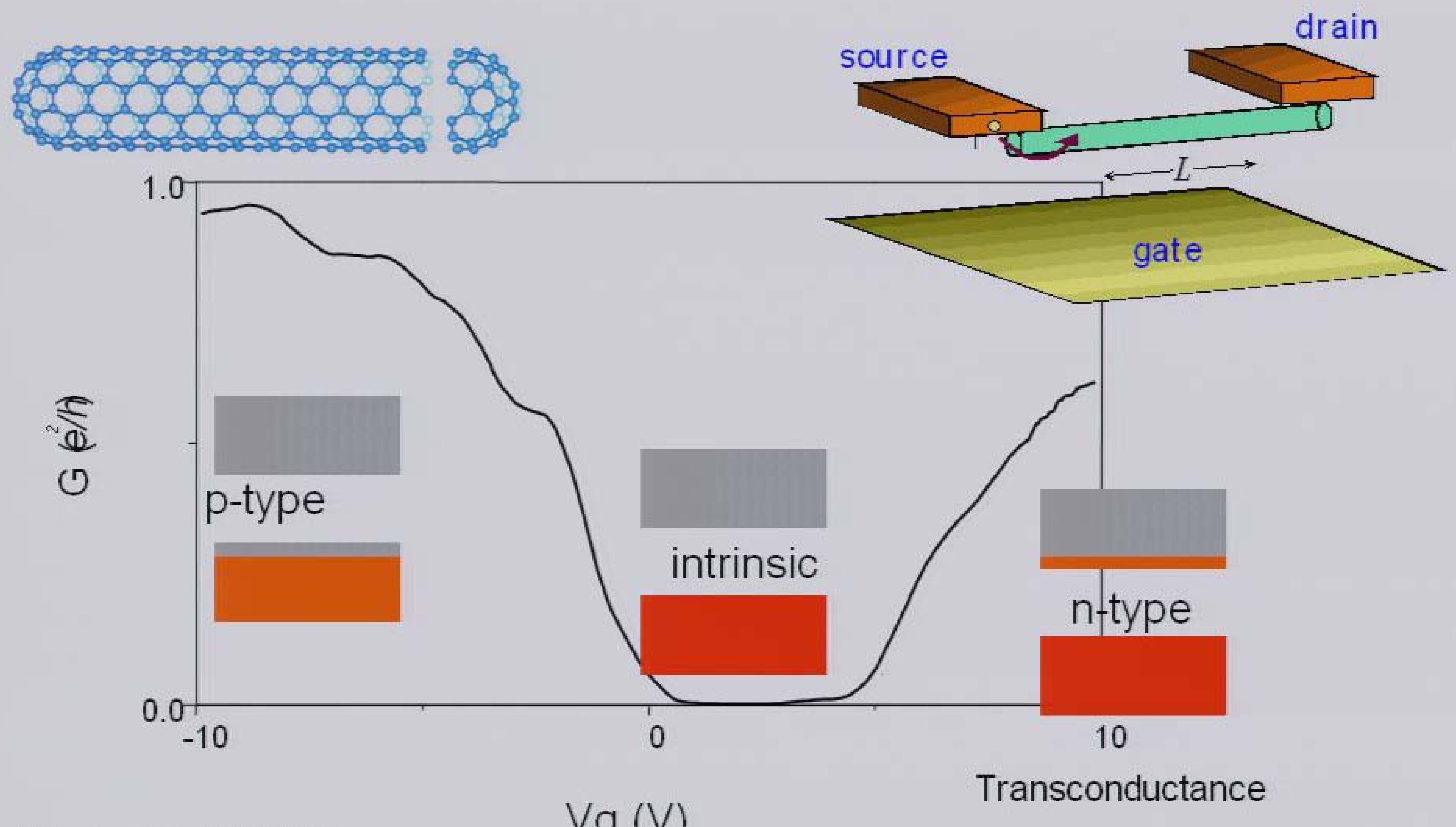
Carbon Nanotube Transistors





Y. M. Lin et al. (2005)

Ultimate Mobility of SWNT transistors

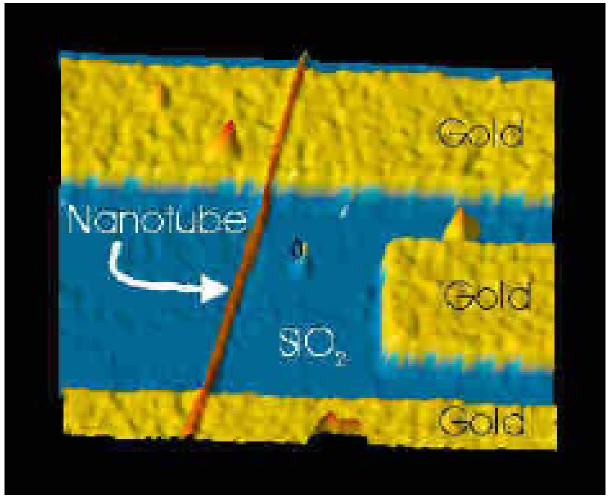


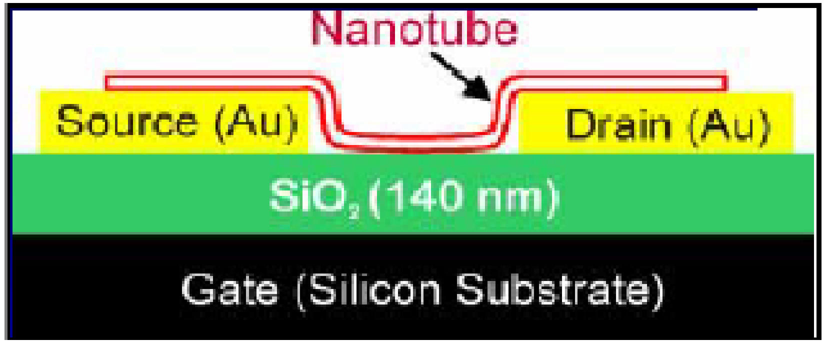
Maximum Mobility:
μ = 10,000 - 20,000 cm²/V-s

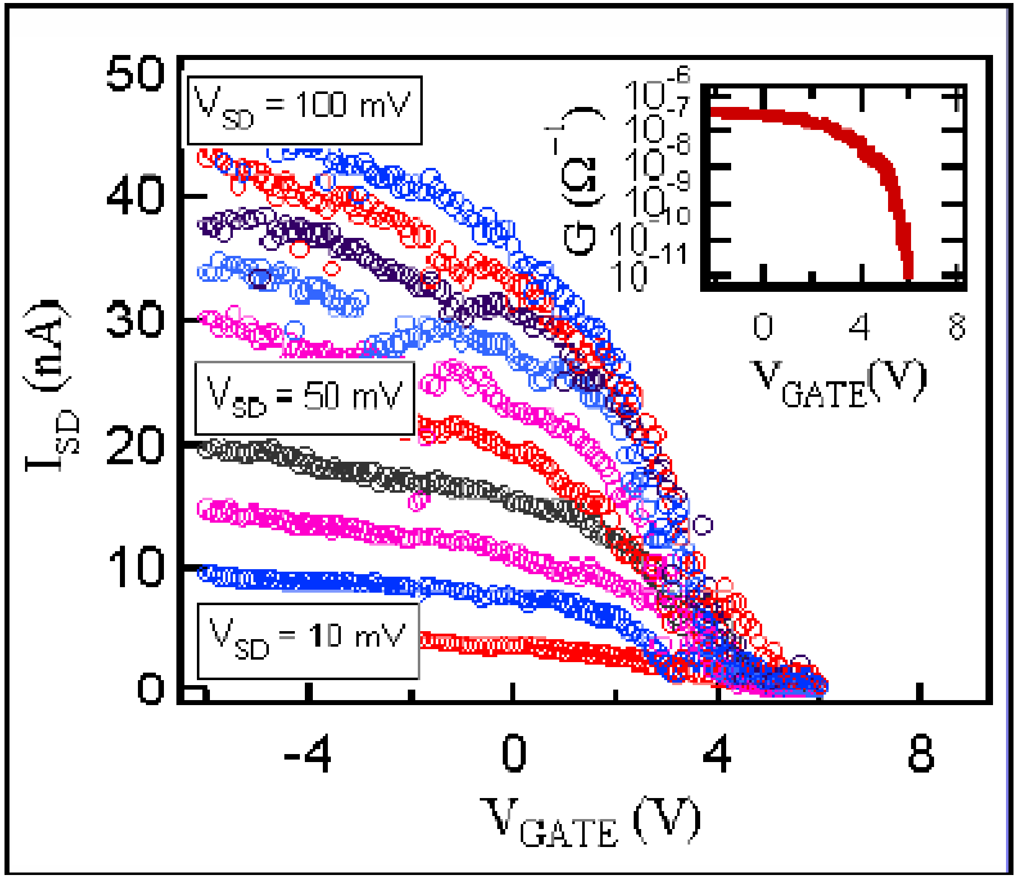
Limited by electron-phonon scattering

Zhao et al., unpublished

A Feld-Effect Transistor Made from a Single-Wall Carbon Nanotube

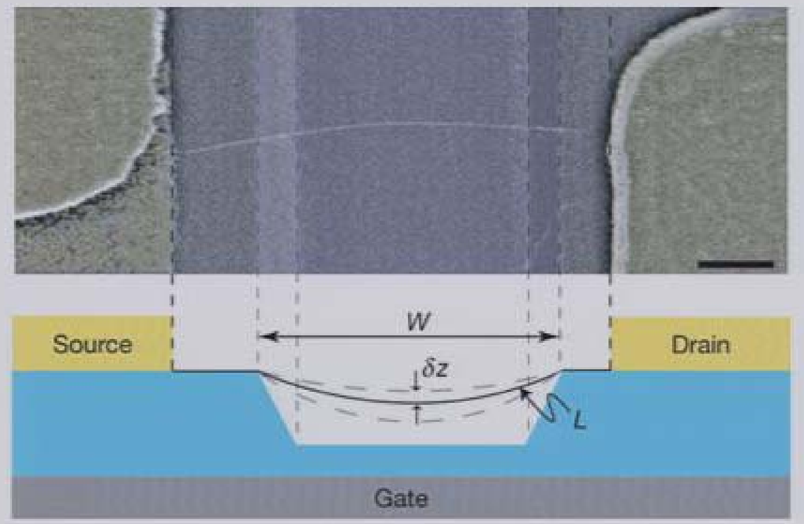


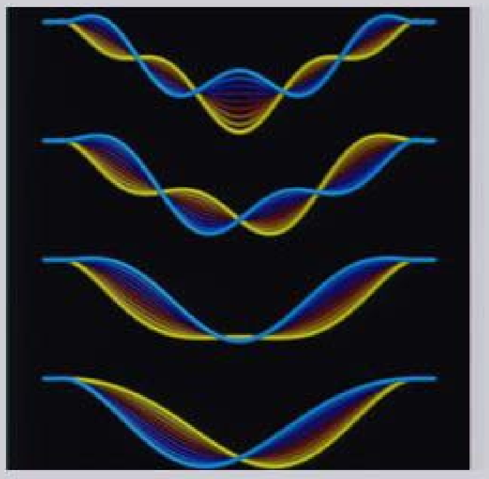


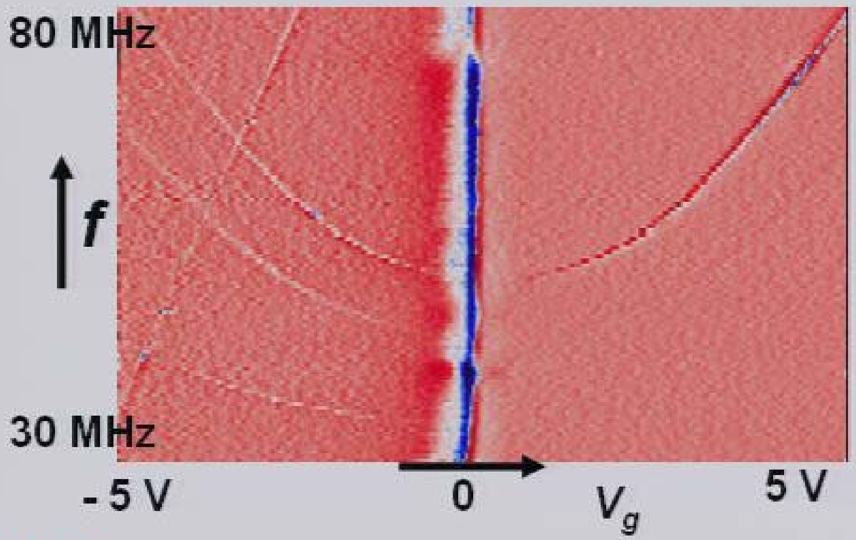


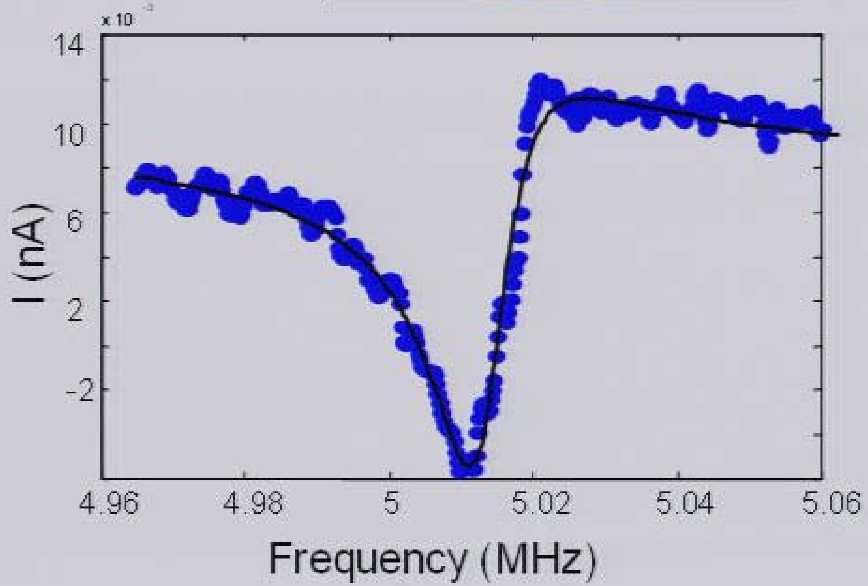
(Avouriset al. IBM)

Nanotube Mechanical Oscillator



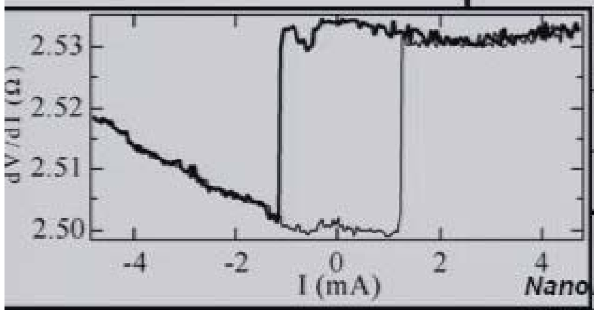


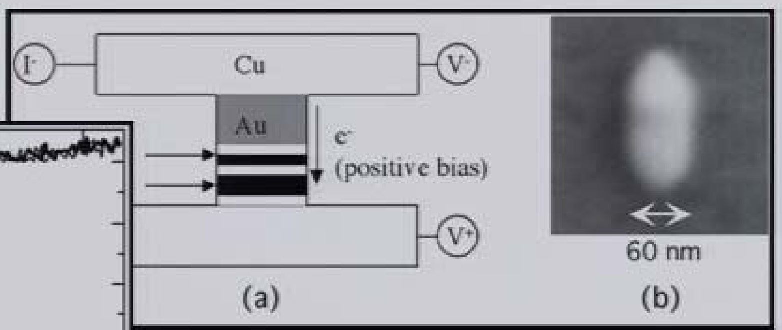




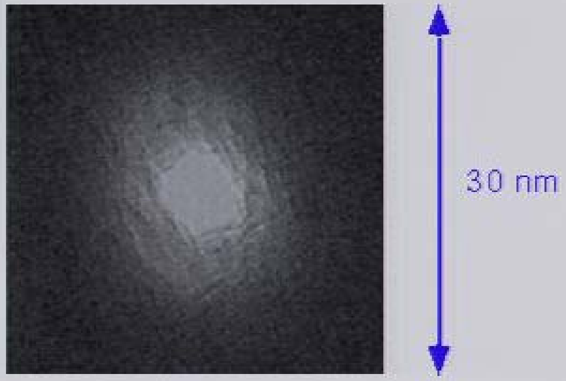
McEuen group, Nature (2004)

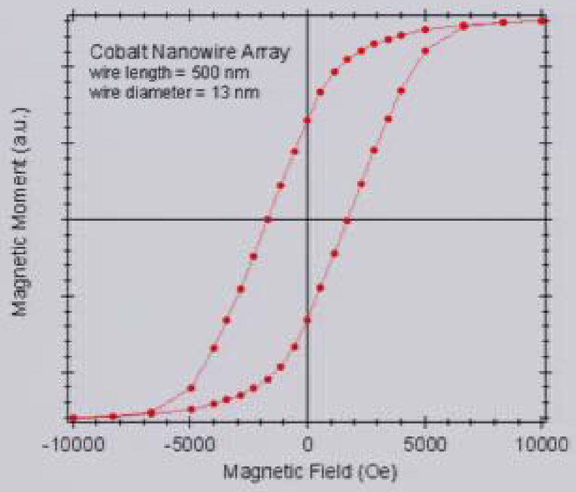
Nano-Magnetics



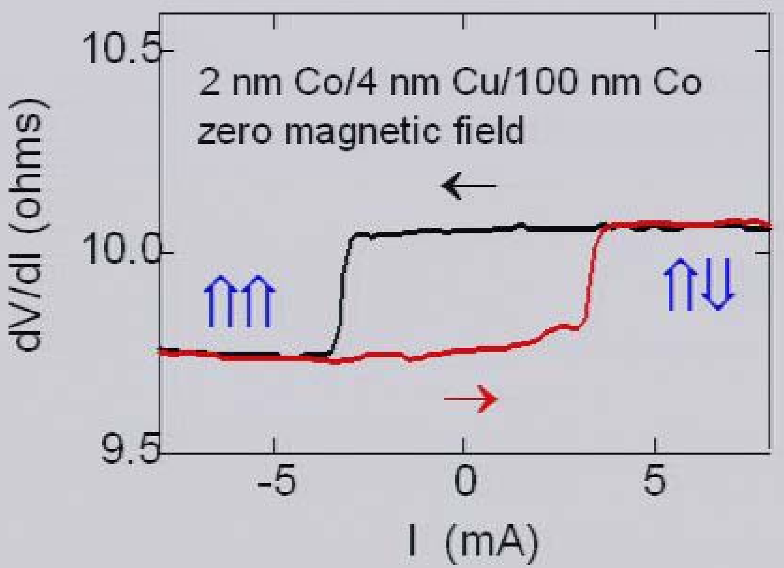


Nanomagnetic structures
http://www.cnf.cornell.edu/nnun/2002NNUNreports.html





A. Ursache, et al., Proc. Mat. Res.Soc (2002)

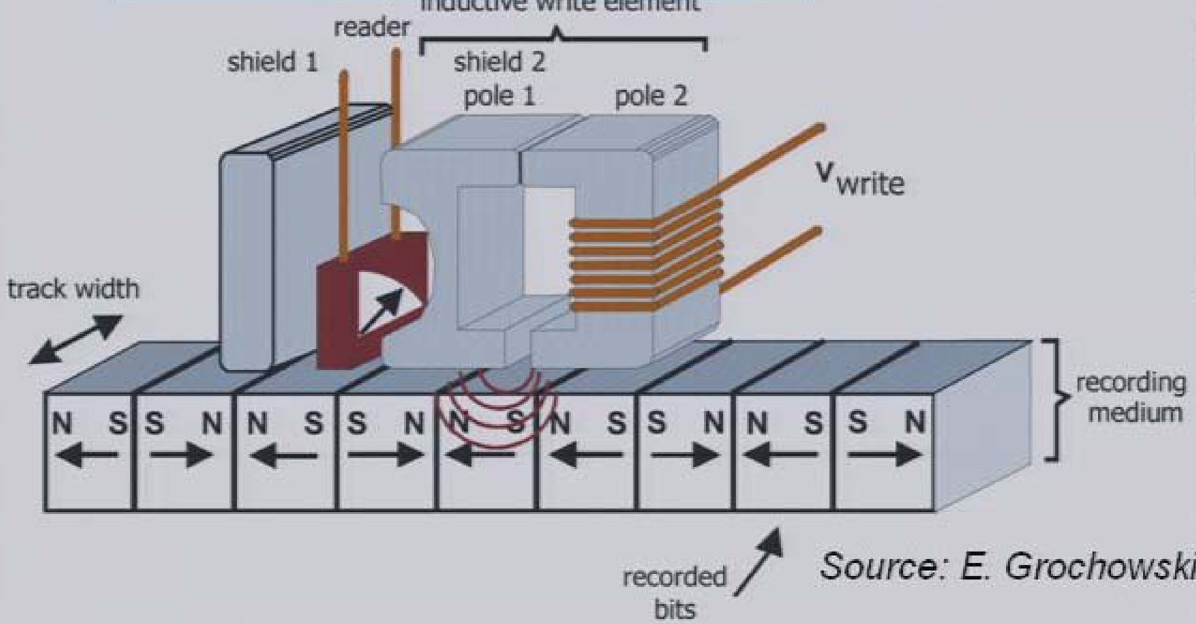


Ralph, Buhrman et al. (1999)

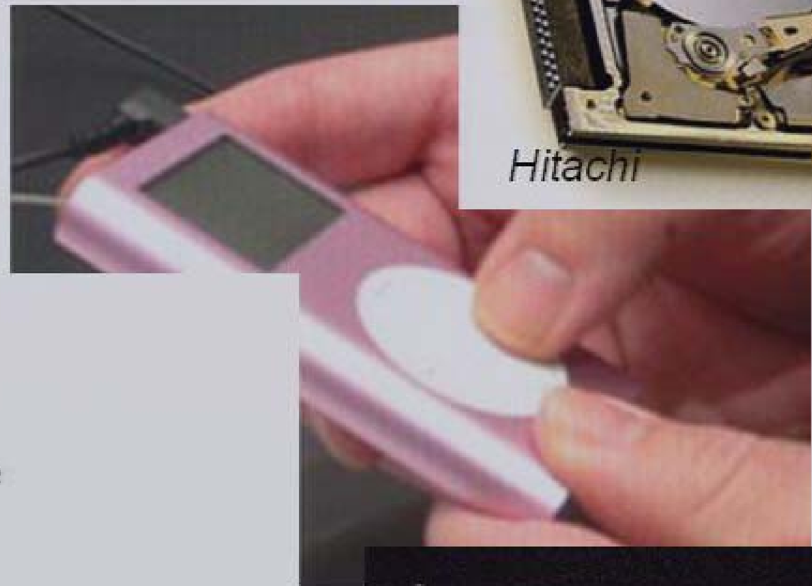
Hard Drives

Hitachi (4 GB, 1 inch micro-drive) in iPOD
Toshiba (4 GB, 0.85 inch micro-drive)

Ultra-sensitive read/write head
Small are magnetic storage
Horizontal recording -> Vertical



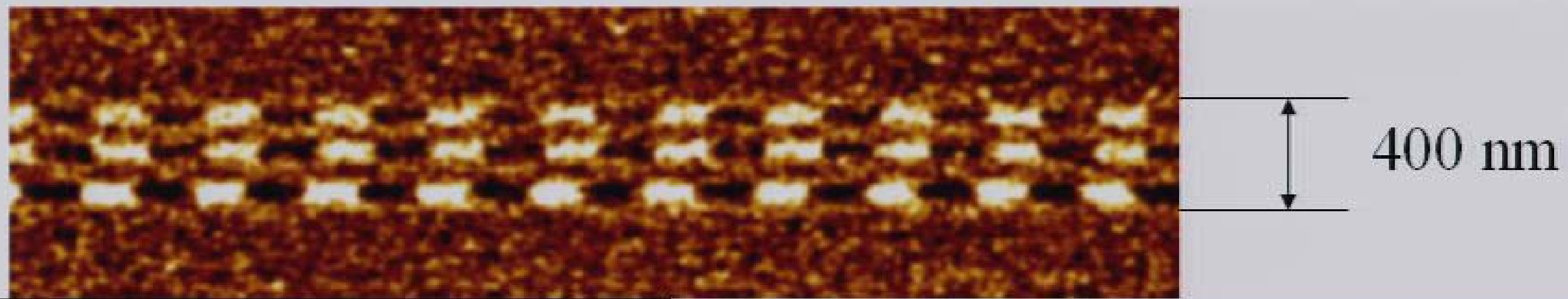
Source: E. Grochowski

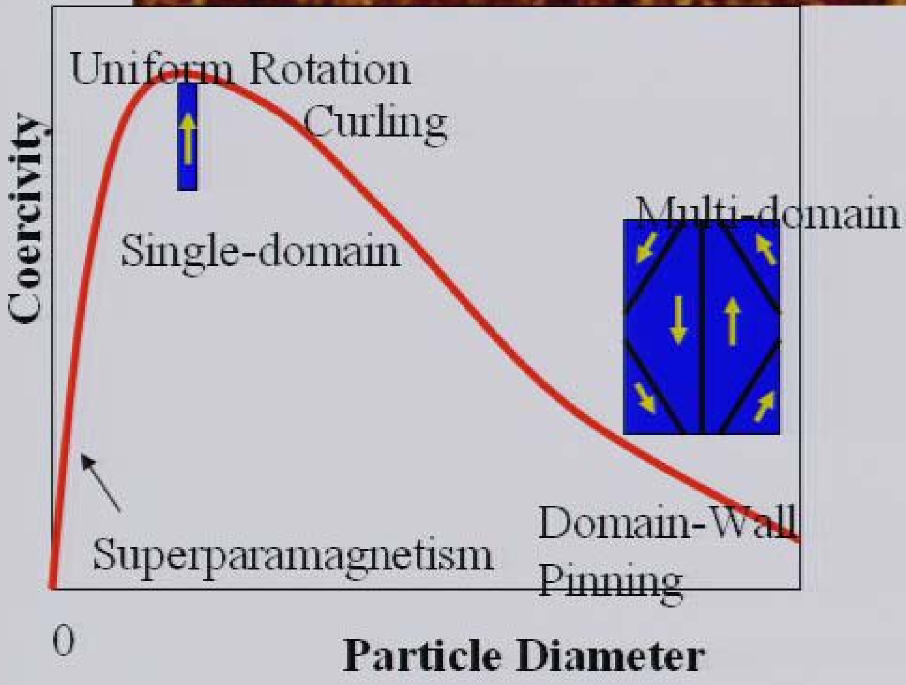


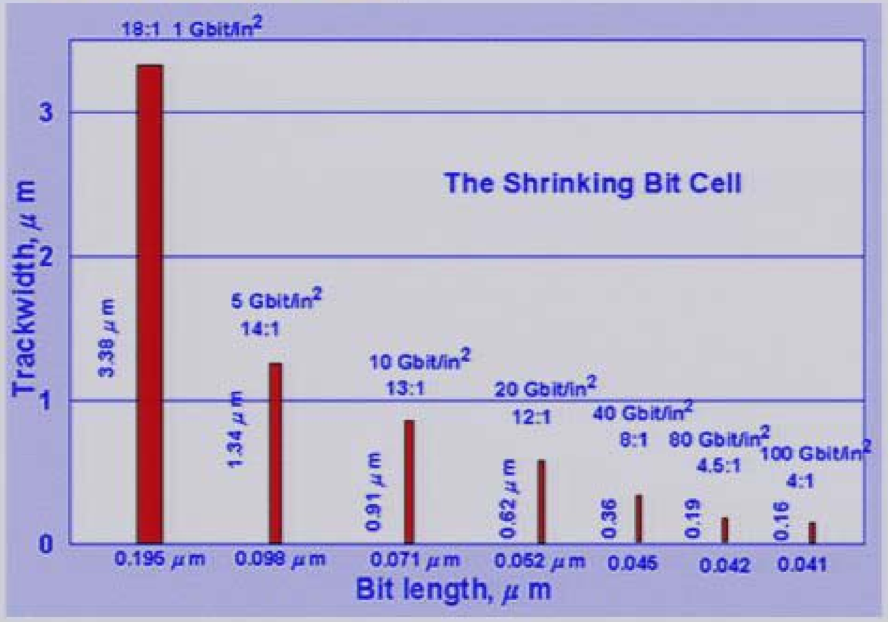
Hitachi

Toshiba

Magnetic Storage (Hard Disks)





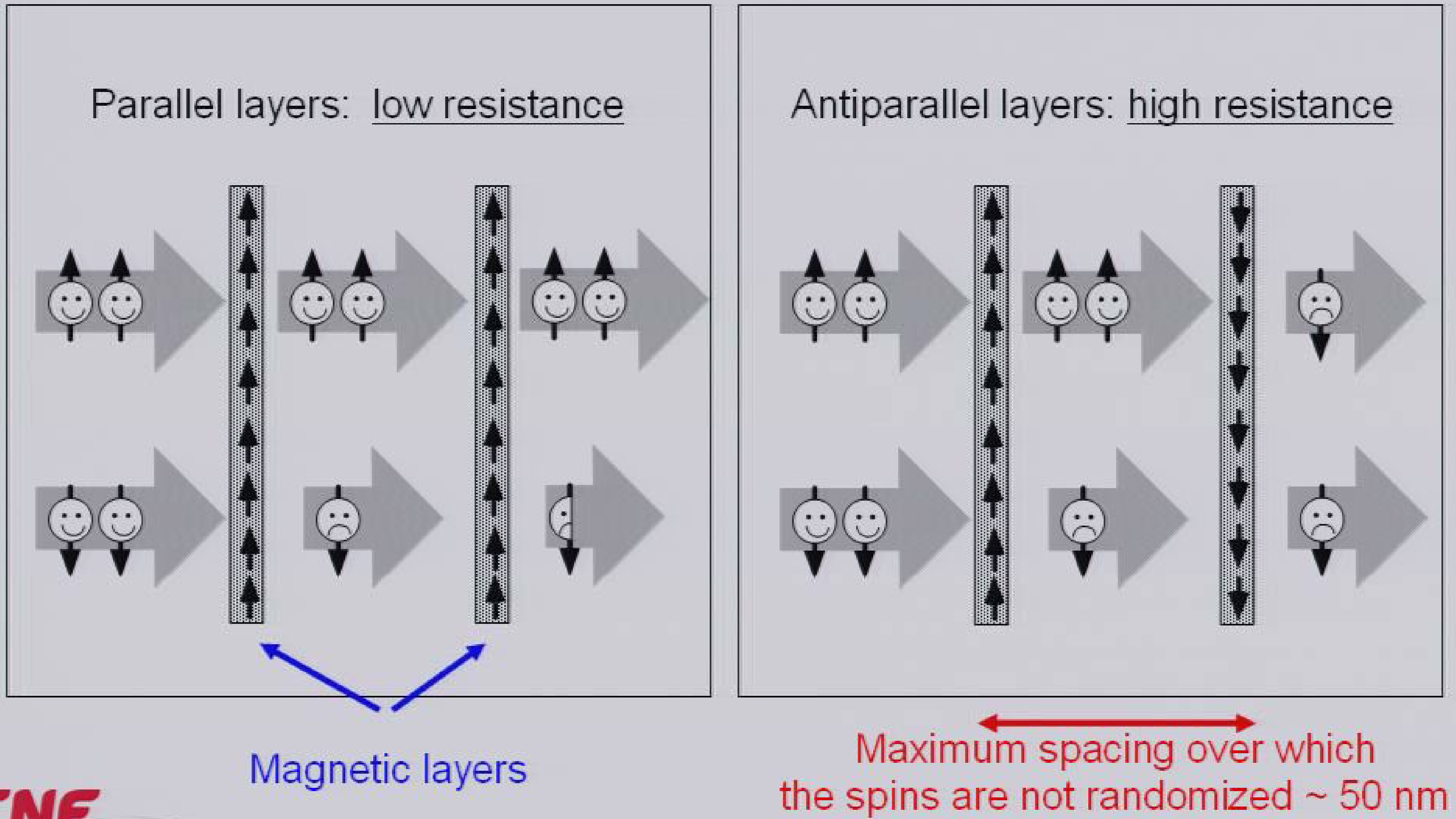


Tuominen, Khizroev, etc.

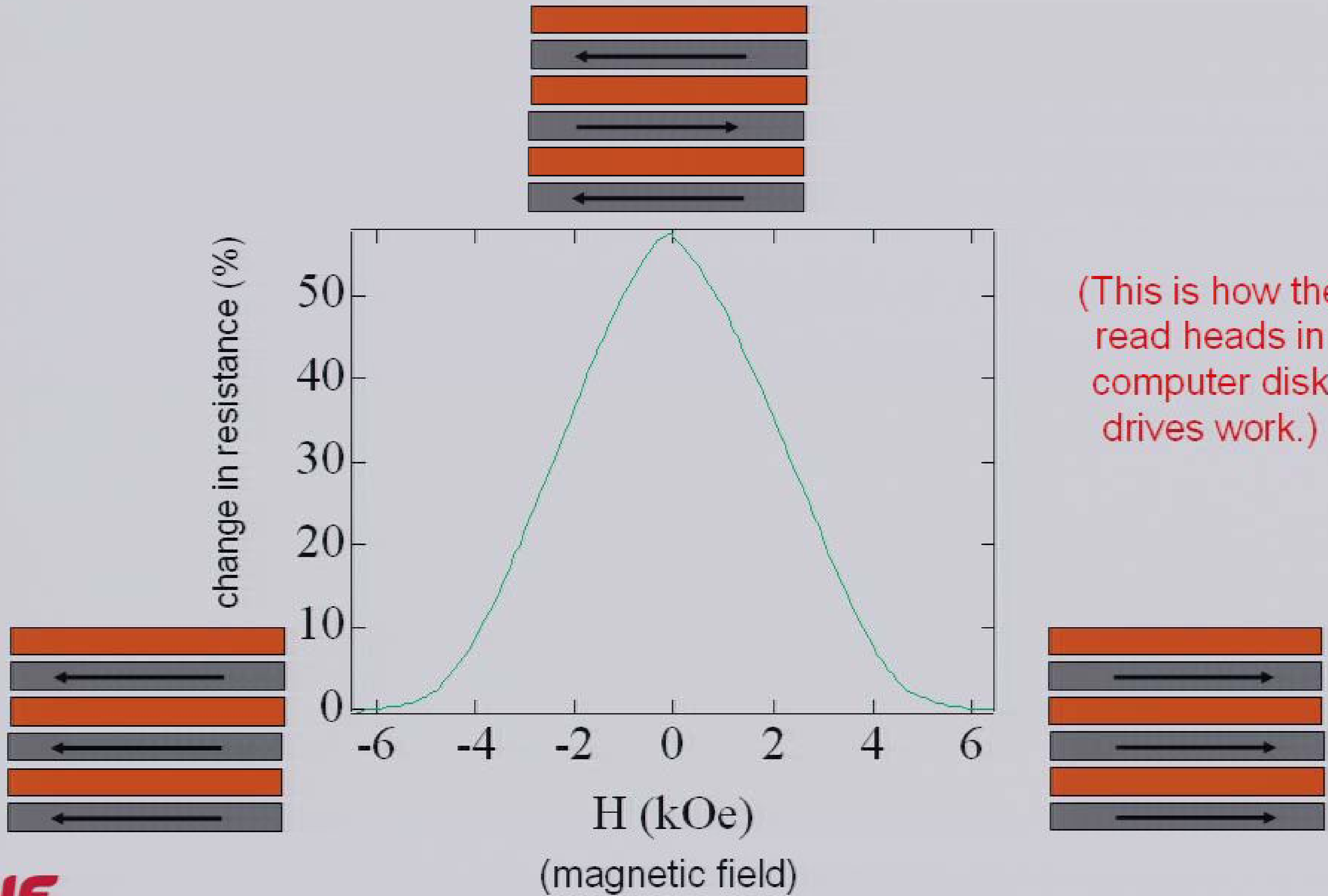
CNF Cornell NanoScale Science and Technology Facility

"Spintronics", or Nano-Magnetics

- Can get "giant" changes in resistance because magnetic layers filter spins.



These Resistance Changes Allow Magnetic-Field Sensing



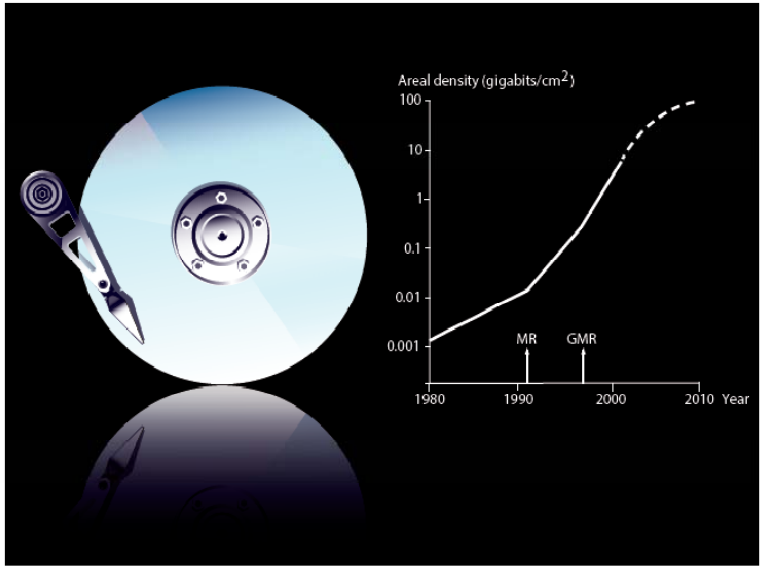
(This is how the read heads in computer disk drives work.)

The Nobel Prize in Physics 2007

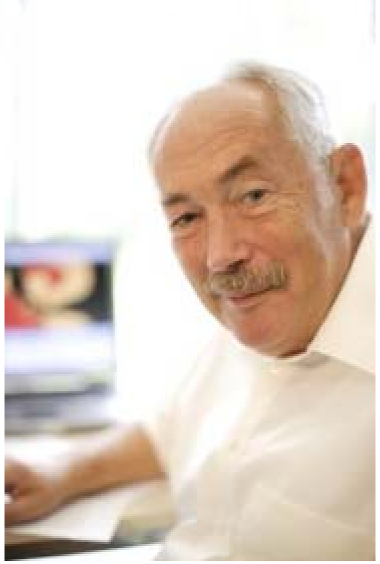
The discovery of Giant magnetoresistance

This year's Nobel Prize in Physics is awarded to **ALBERT FERT** *and* **PETER GRÜNBERG** *for their discovery of Giant Magnetoresistance. Applications of this phenomenon have revolutionized techniques for retrieving data from hard disks. The discovery also plays a major role in various magnetic sensors as well as for the development of a new generation of electronics. The use of Giant Magnetoresistance can be regarded as one of the first major applications of nanotechnology.*

Albert Fert
Unité Mixte de Physique
CNRS/THALES,
Université Paris-Sud,
Orsay, France,



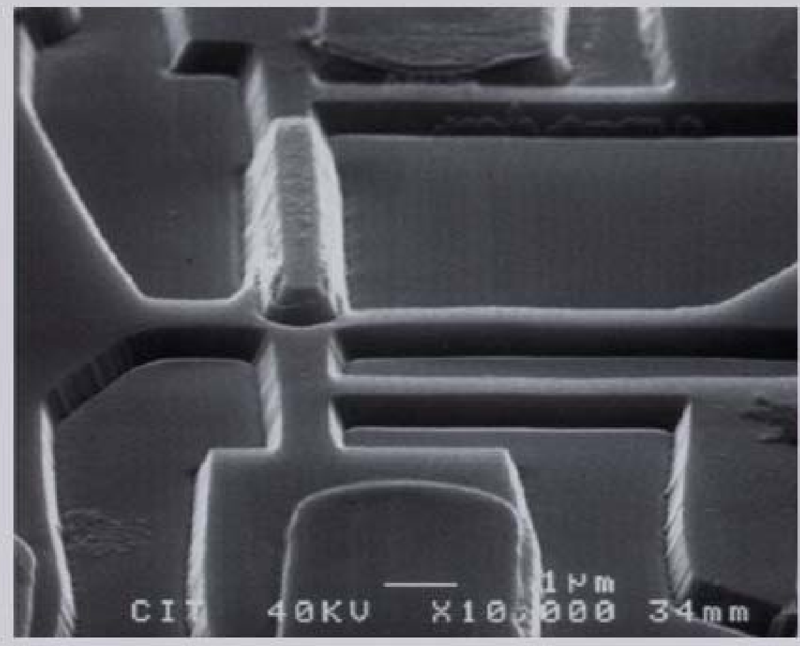
Diagrams showing the accelerating pace of miniaturization might give a false impression of simplicity – as if this development followed a law of nature. In actual fact, the ongoing IT-revolution depends on an intricate interplay between fundamental scientific progress and technical fine tuning. This is just what the Nobel Prize in Physics for the year 2007 is about.

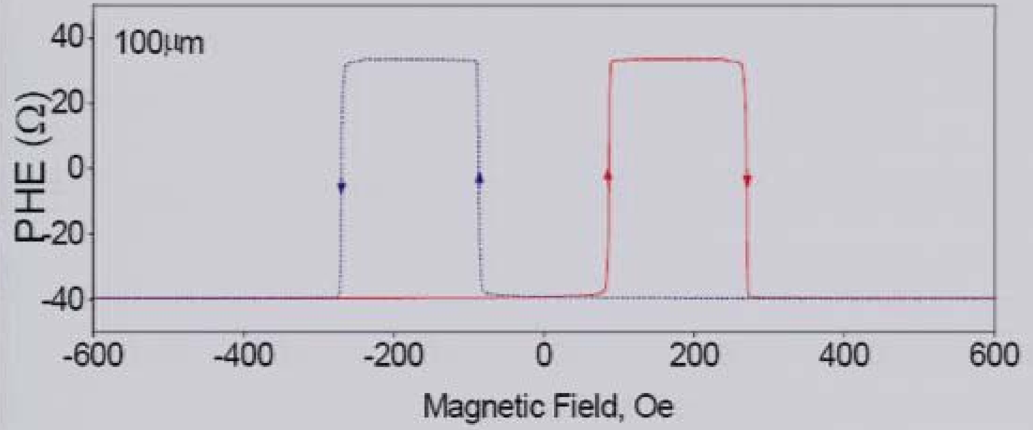


Peter Grünberg
Forschungszentrum
Jülich, Germany,

http://nobelprize.org/nobel_prizes/physics/laureates/2007/info.html)

Spintronics

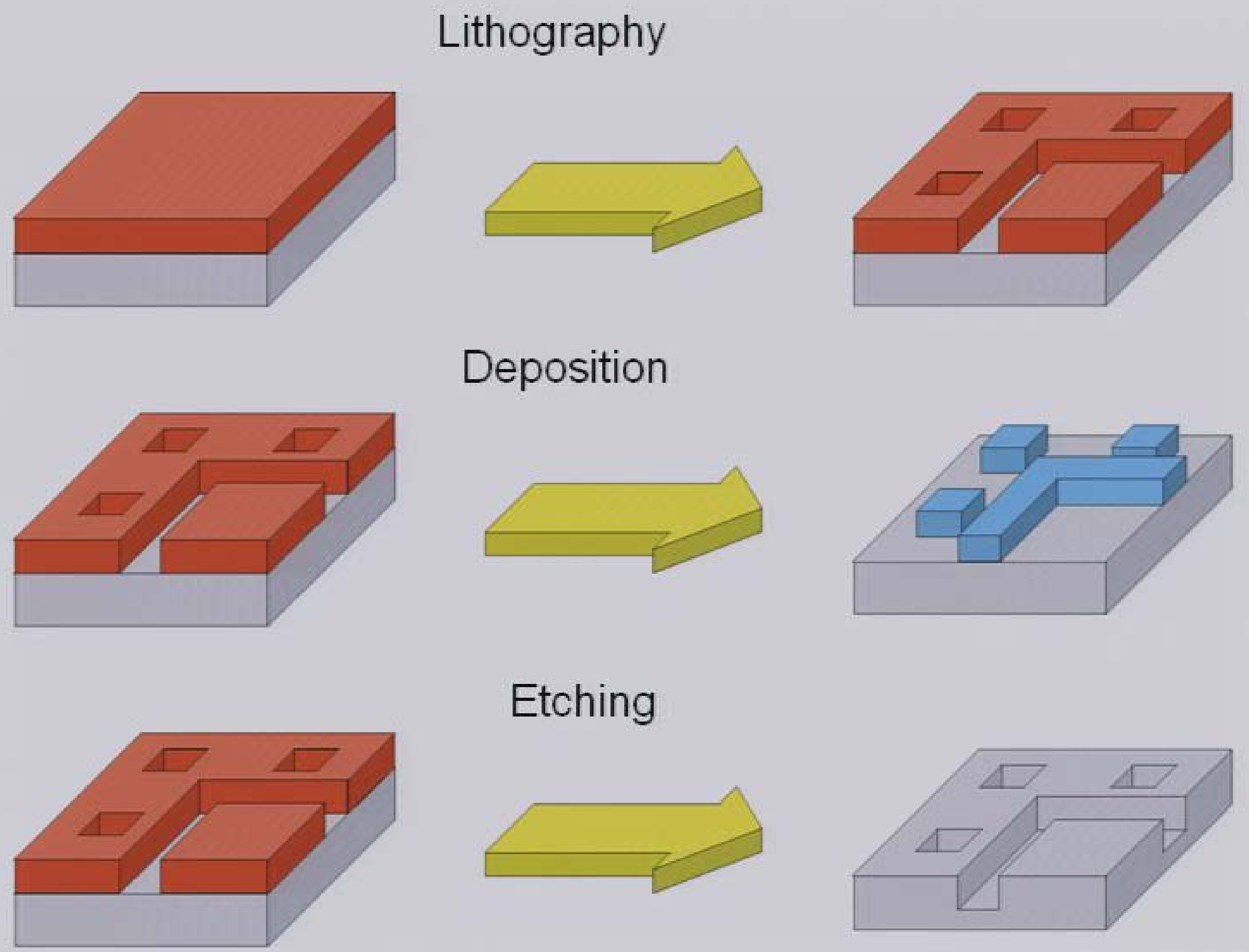




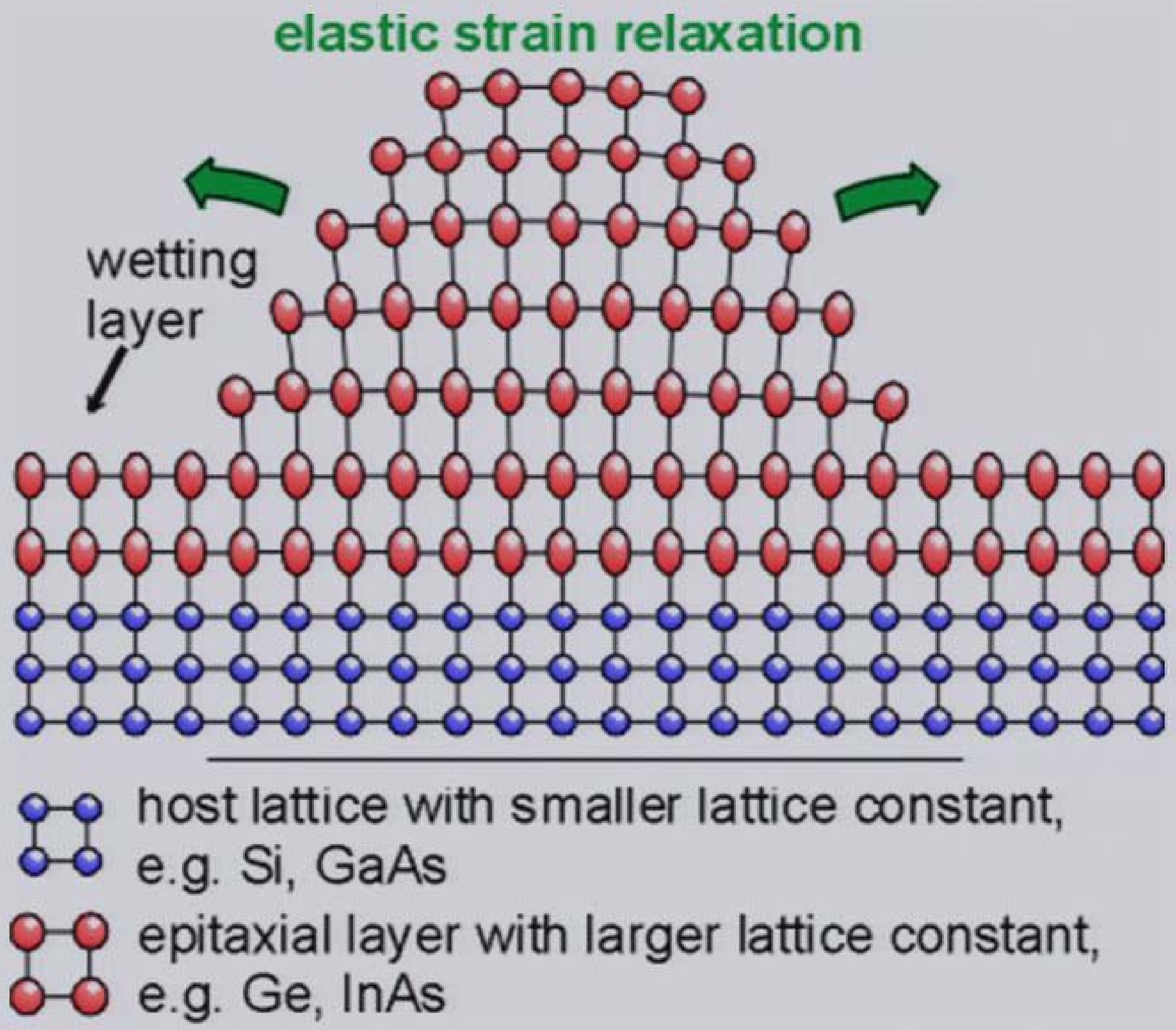
Awschalom et al., PRL (2003)

- Large spontaneous Hall effect in GeMnAs film that is 4 orders of magnitude larger than ferromagnetic films.
- Voltage control of domain walls

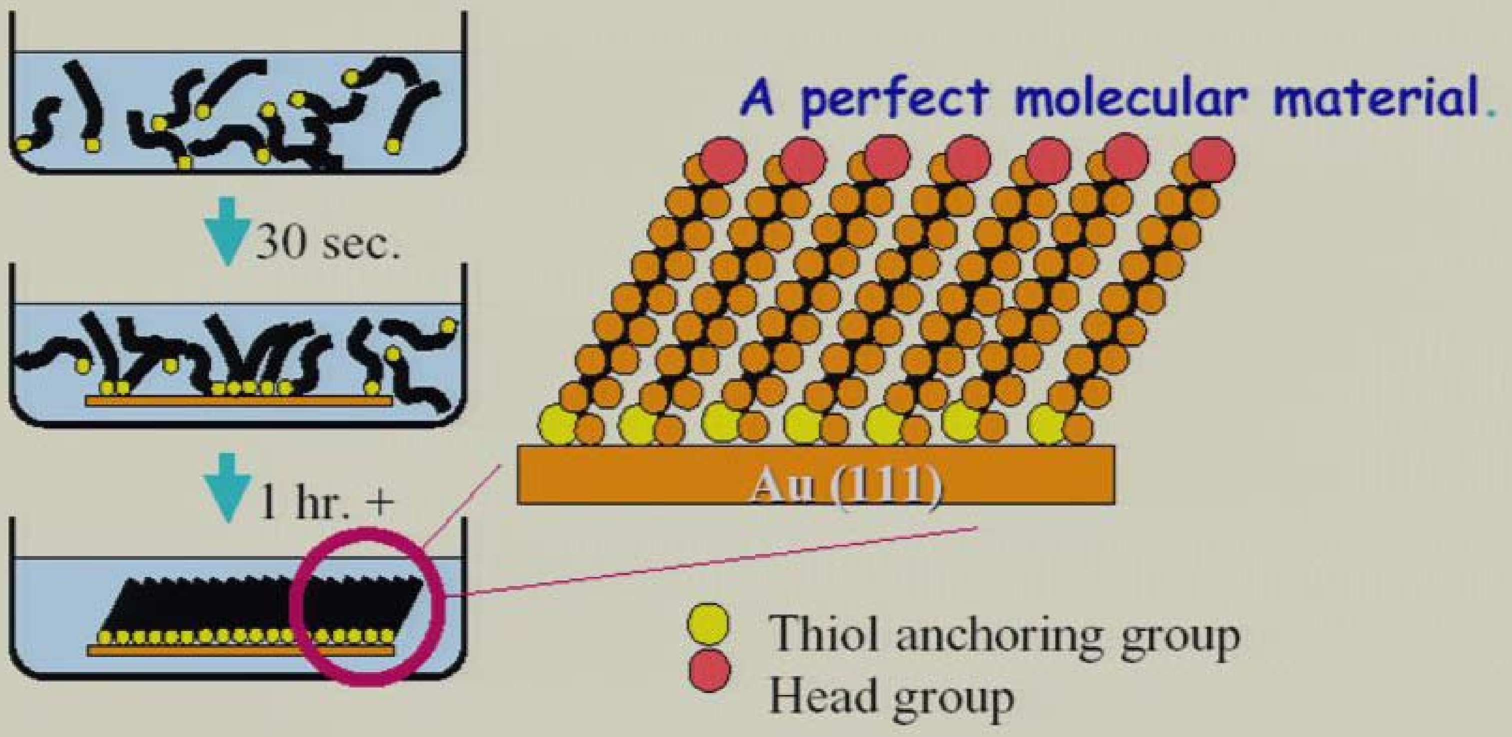
Top-Down



Bottom-Up: Growth as Self Assembly



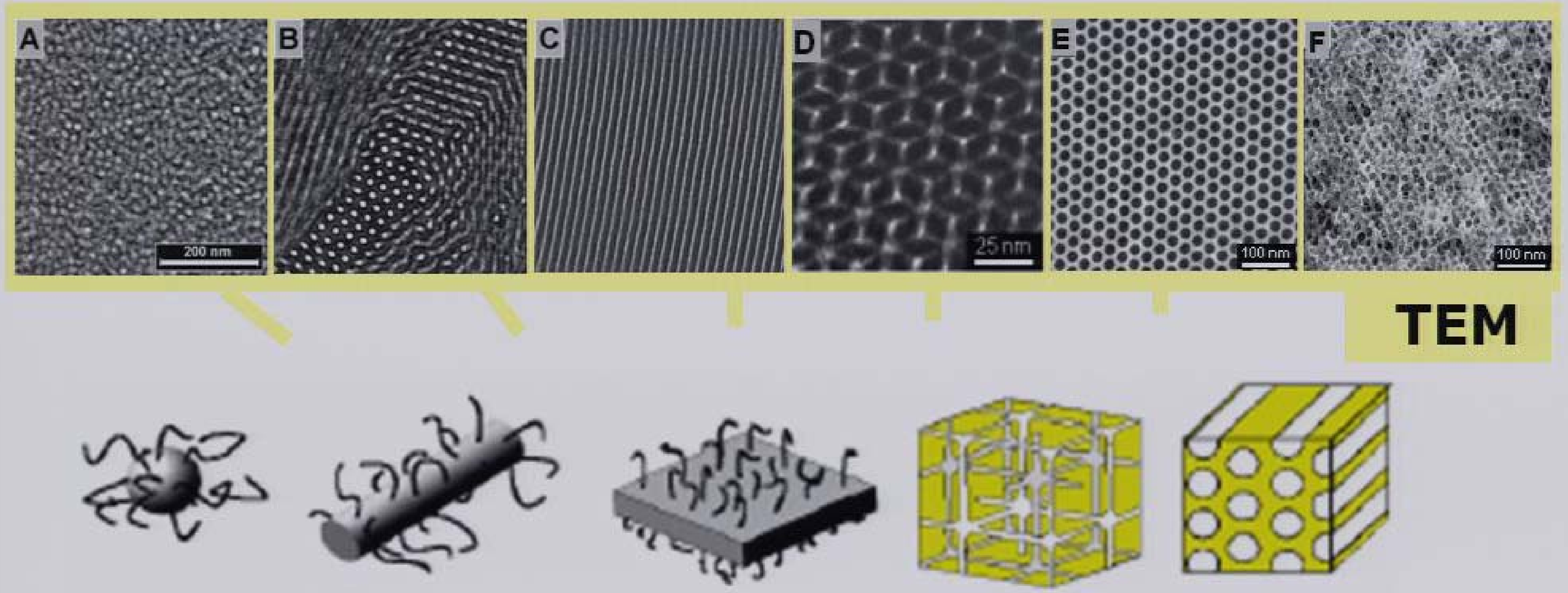
Self-Assembled Monolayers



Major discovery -- 1983

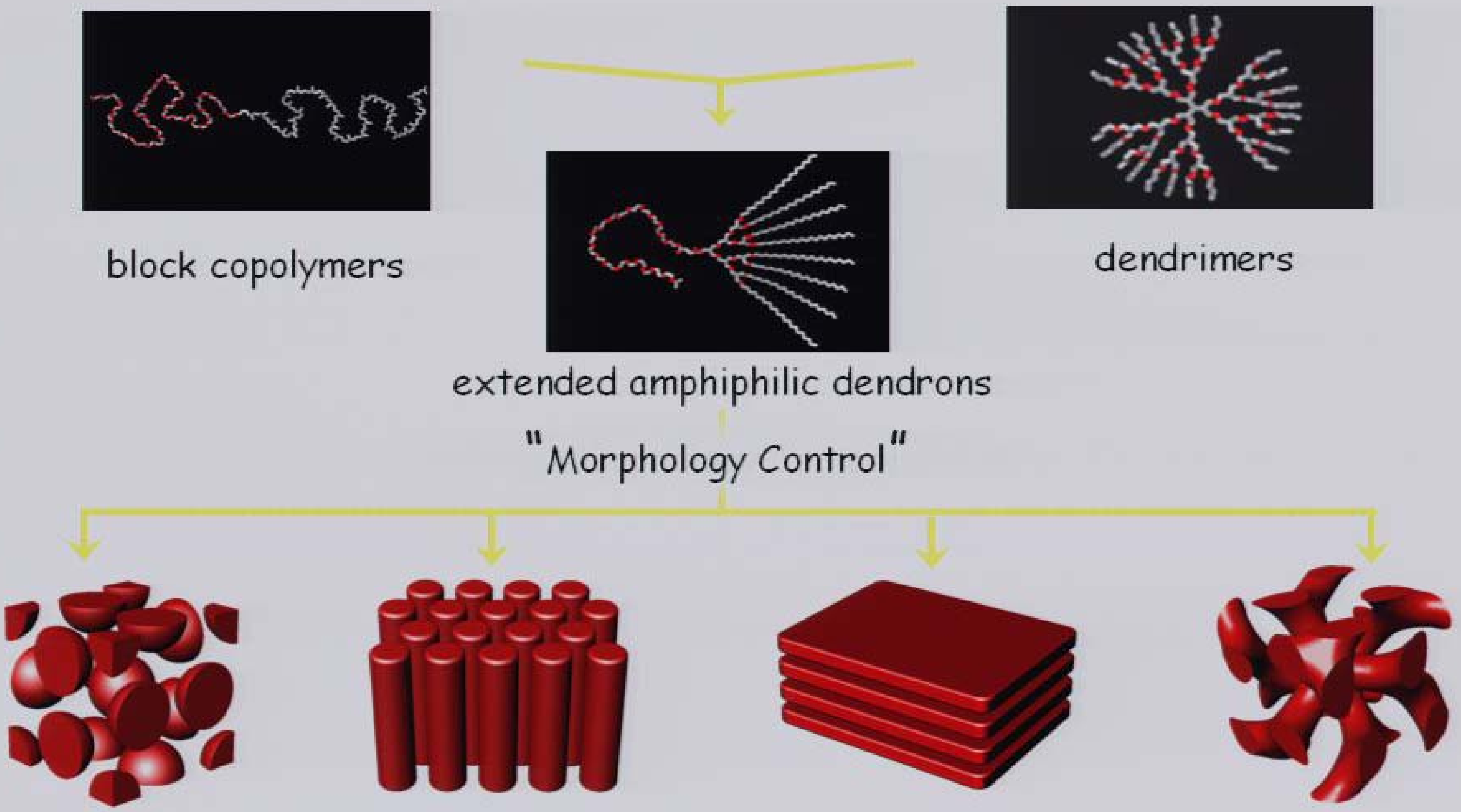
Nuzzo,RG; Allara,DL (1983): Adsorption of bifunctional organic disulfides on gold surfaces. J. Am. Chem. Soc. 105(13), 4481-4483.

Self-Assembly



Science 278, 1795 (1997)

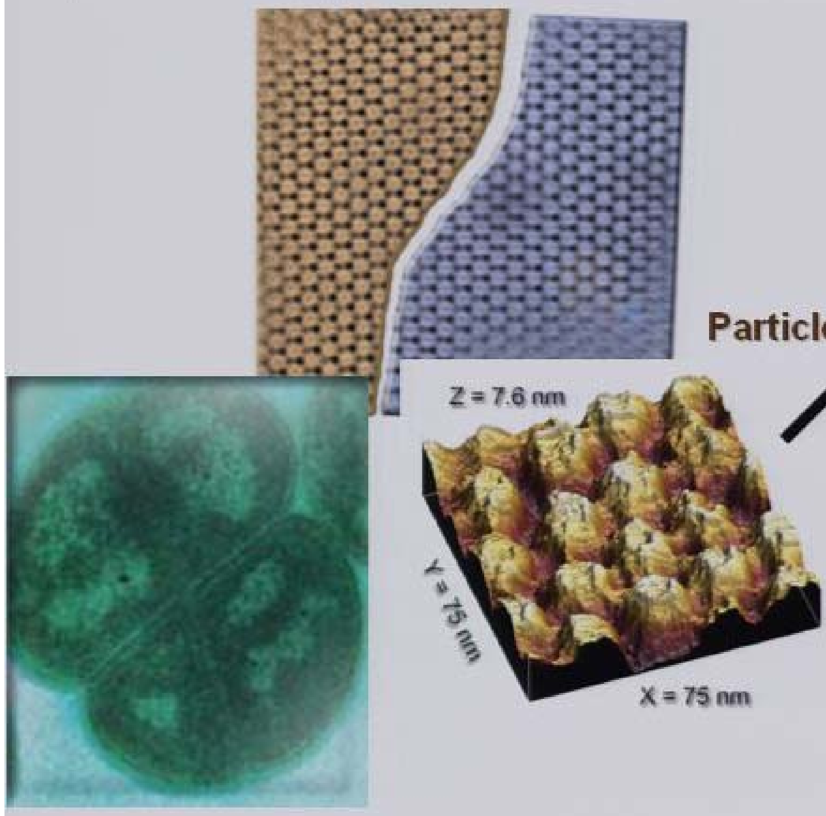
Utilizing Building Blocks



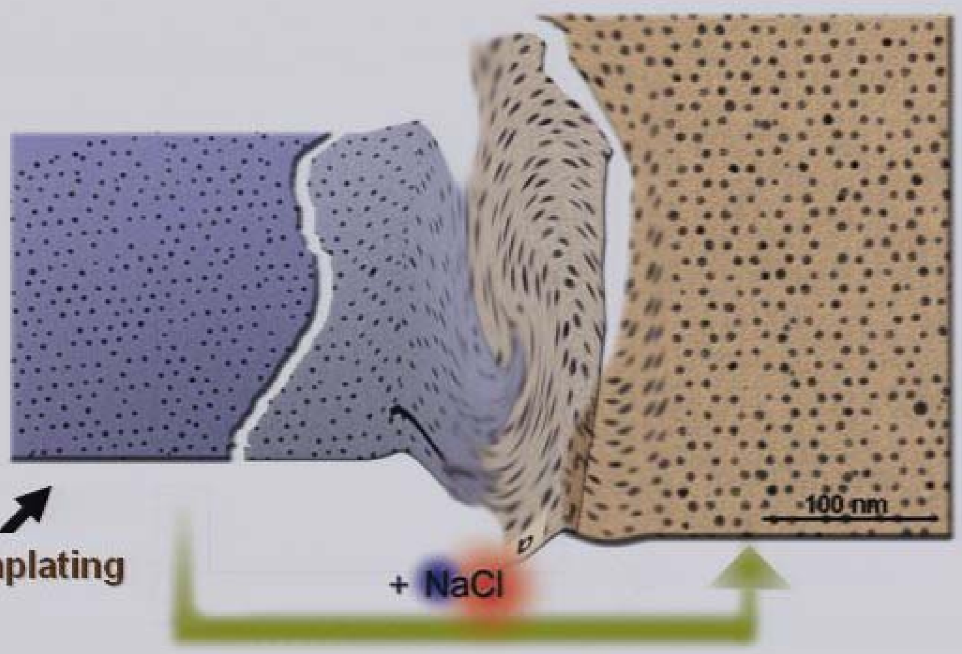
Science 305 (2004)

Bionanofabrication of Ordered Nanoparticle Arrays

S-layers are protein nanoscale arrays found on the surface of a number of bacteria.



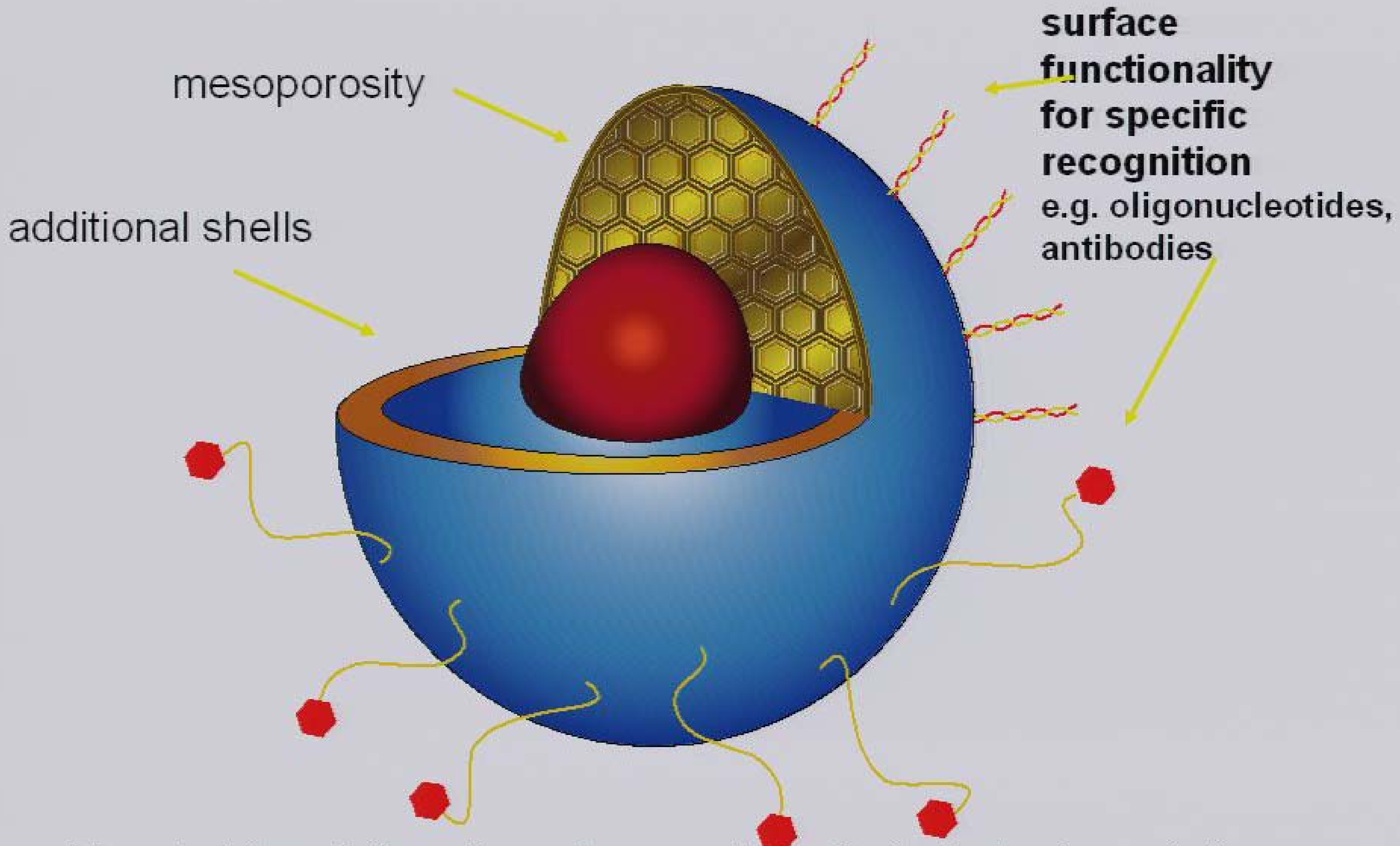
Particle Templating



Salt concentration influence pattern

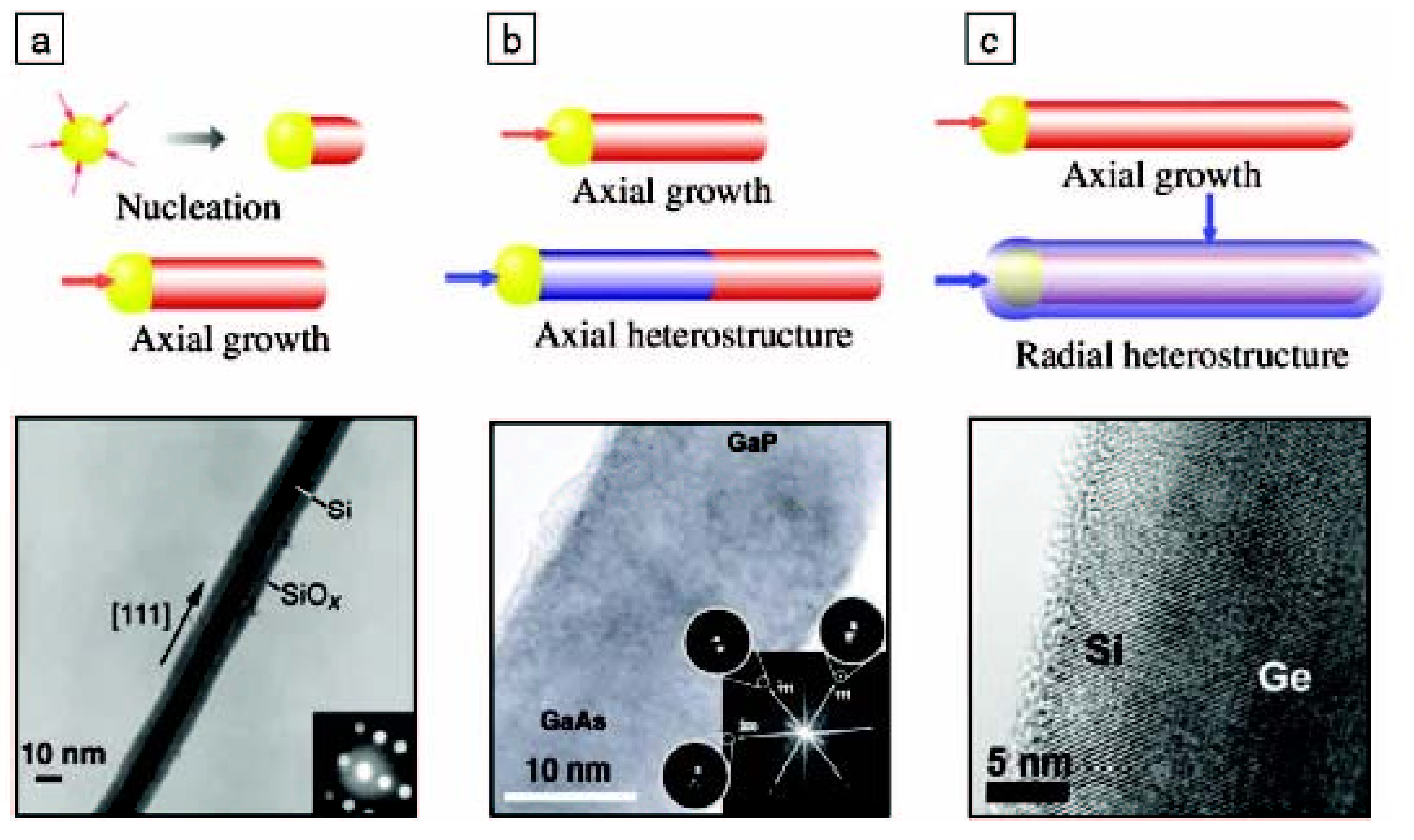
Bergkvist et al. J. Phys. Chem.: B (2004)

Built-In Multifunctionality



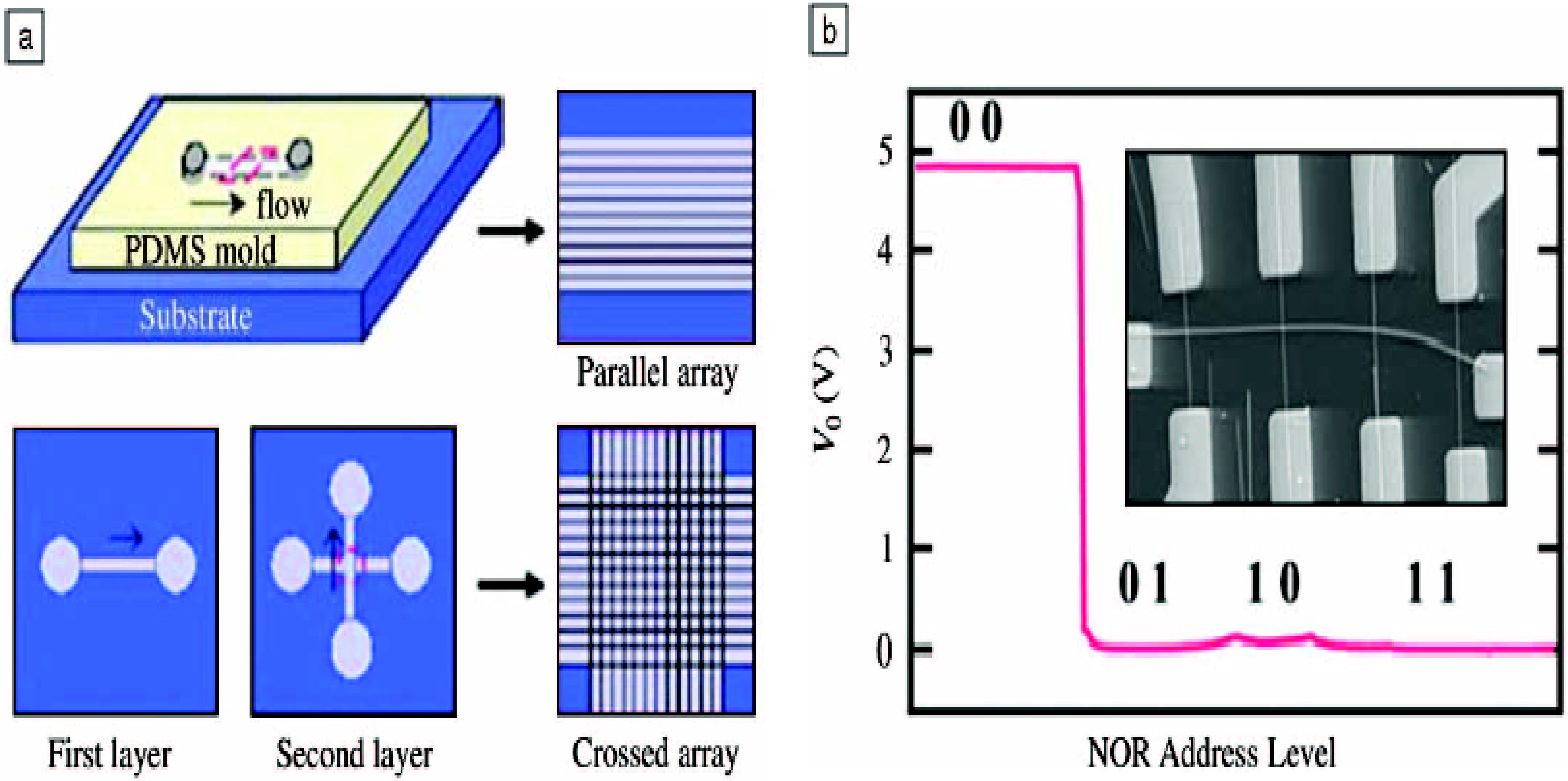
Targeted drug delivery through magnetic, optical, electronic, and other means for activation and control

SINGLE-CRYSTAL SEMICONDUCTOR NANOWIRES



C. Lieber MRS BULLETIN July 2003

INTEGRATED NANOWIRE ELECTRONICS



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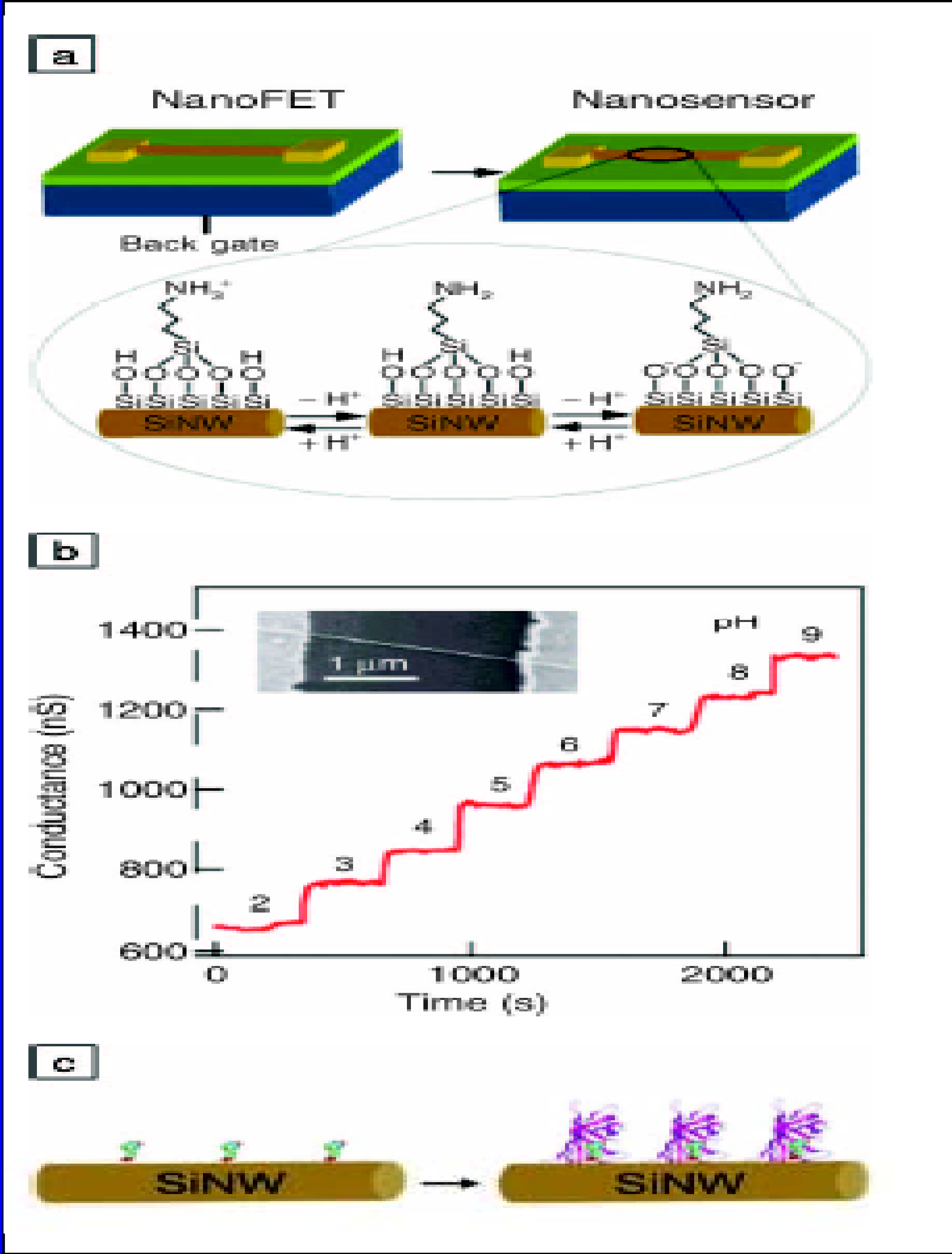
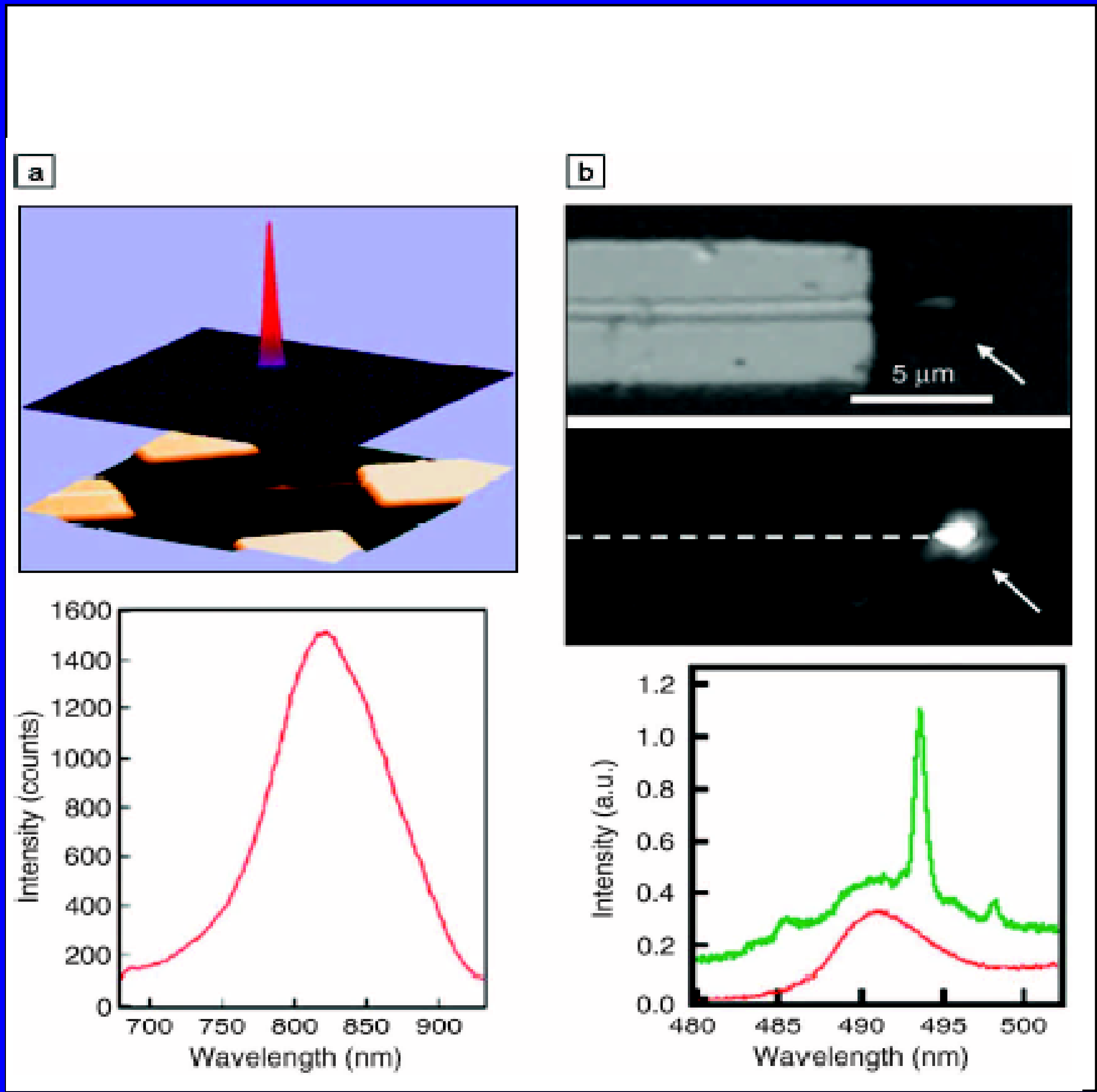
Silicon nanowire (SiNW) nanosensors



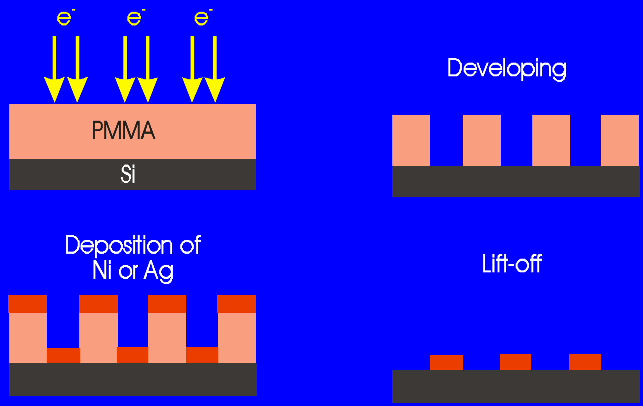
C. Lieber MRS BULLETIN July 2003

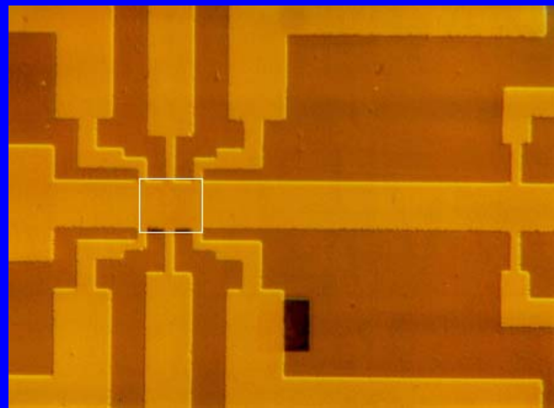
NANOWIRE PHOTONIC DEVICES

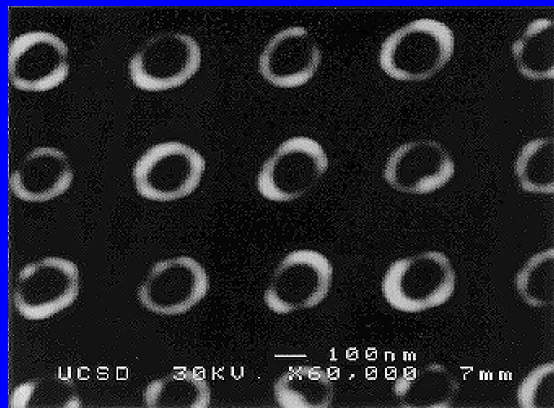


C. Lieber MRS BULLETIN July 2003

PUNTOS MAGNÉTICOS NANOMÉTRICOS

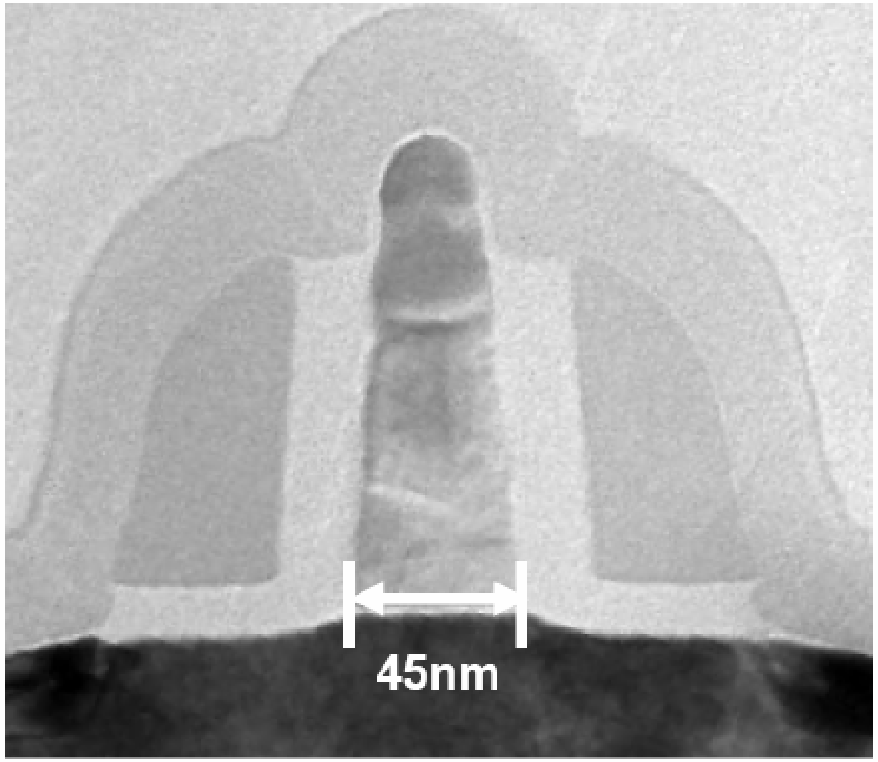






P. Prieto et al PRB 2000

BARRERAS DE 45 nm PARA DISPOSITIVOS MPU/CPU L-90nm

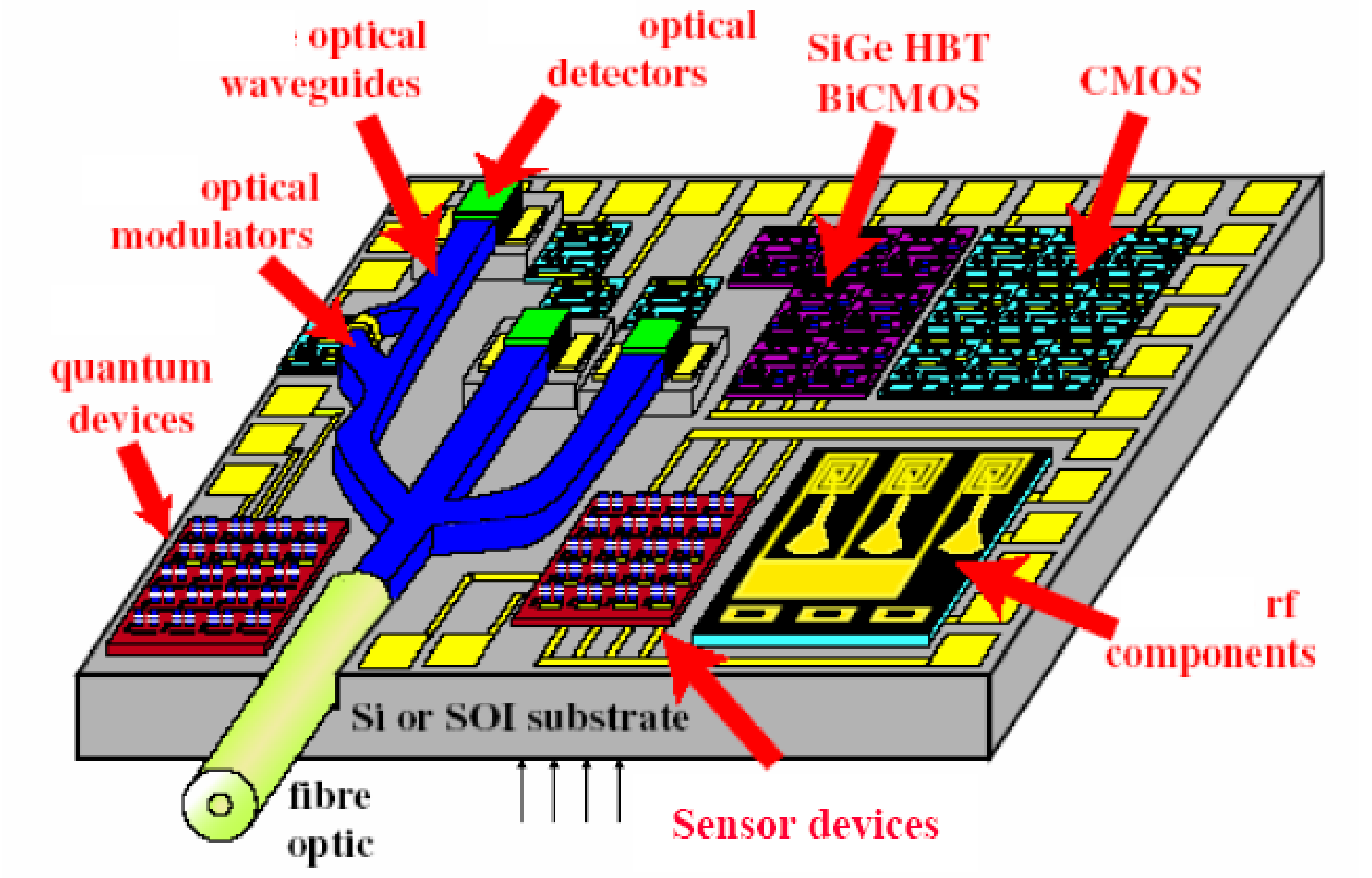


Parámetros de escalamiento de un dispositivo

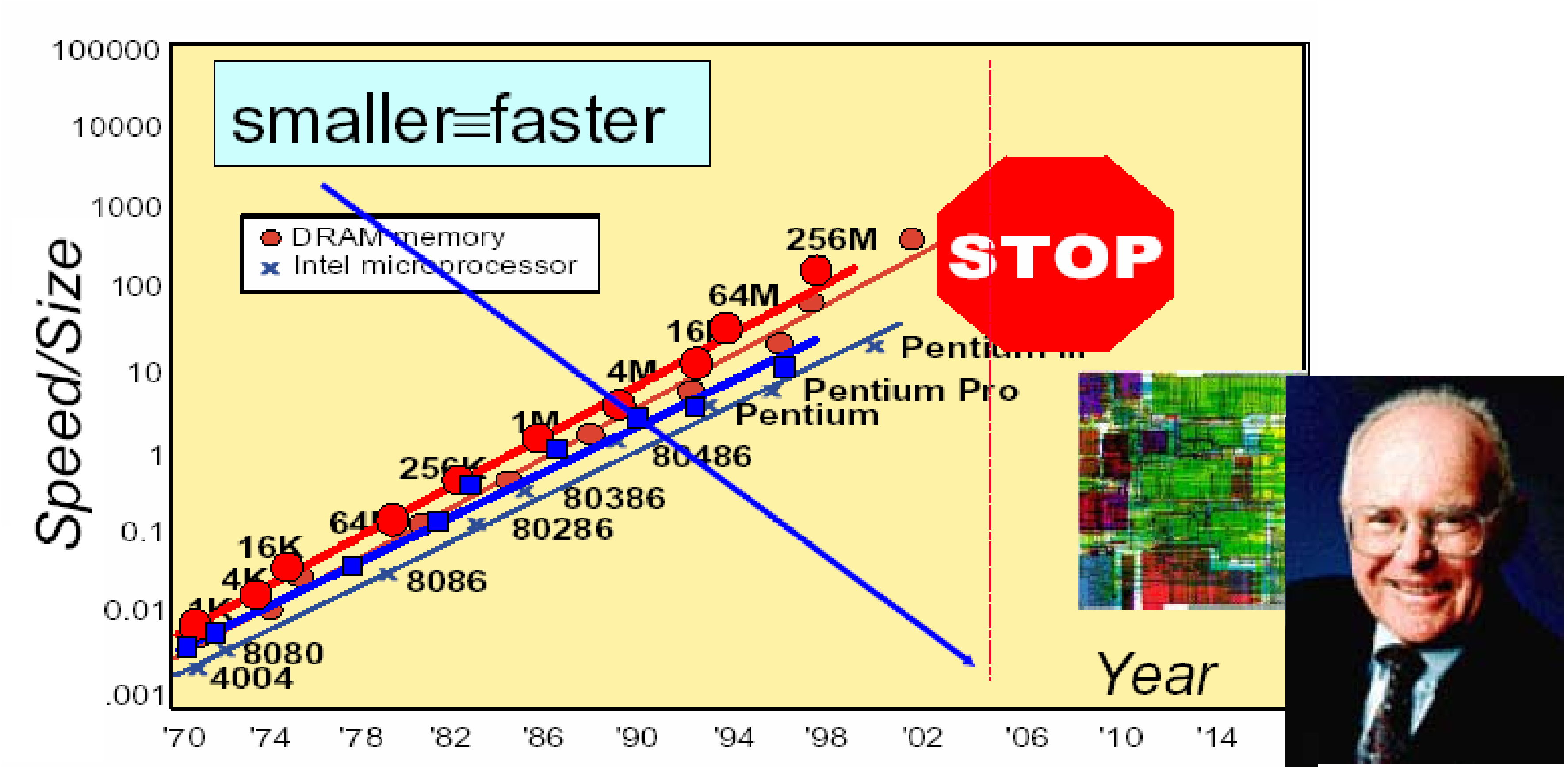
- Longitud de la barrera
- Voltaje aplicado
- Área del dispositivo
- tiempo de retrazo
- Consumo de potencia

La longitud de la barrar de un MOSFET: 90 nm definidos en la mascara. La longitud real es de 45 nm luego del proceso (143-330 átomos de Si)

Anatomía de un CHIP óptico



OTRO NANO-MUNDO: TECNOLOGIA DEL CHIP DE Si



✓**La ley de Moore**: el numero de transistores encapsulados en un chip se duplica cada 18 meses

✓Transistores mucho mas pequeños, mas rápidos, de alta densidad, bajo consumo de energía