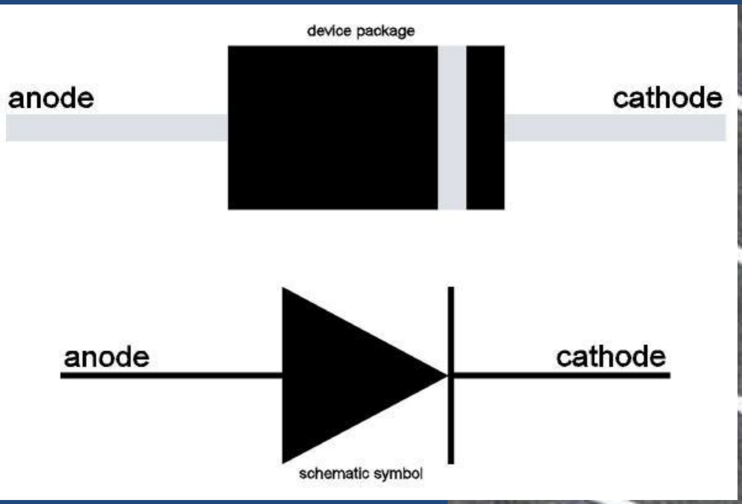
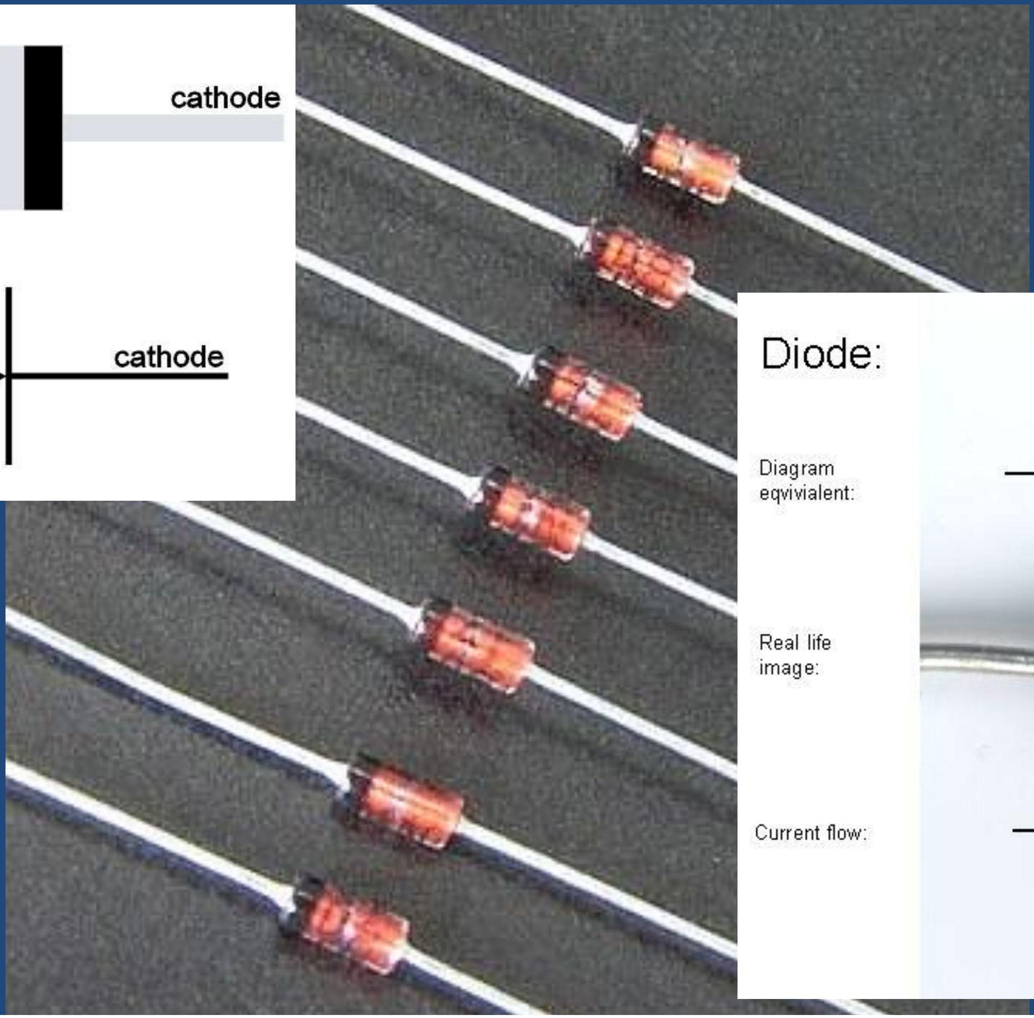
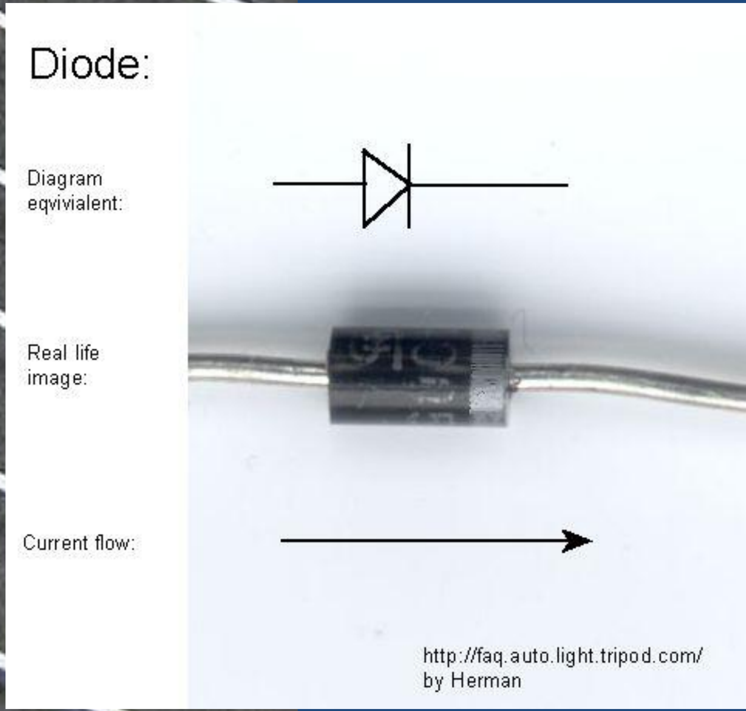
Al pensar en electrónica, pensamos en diodos…

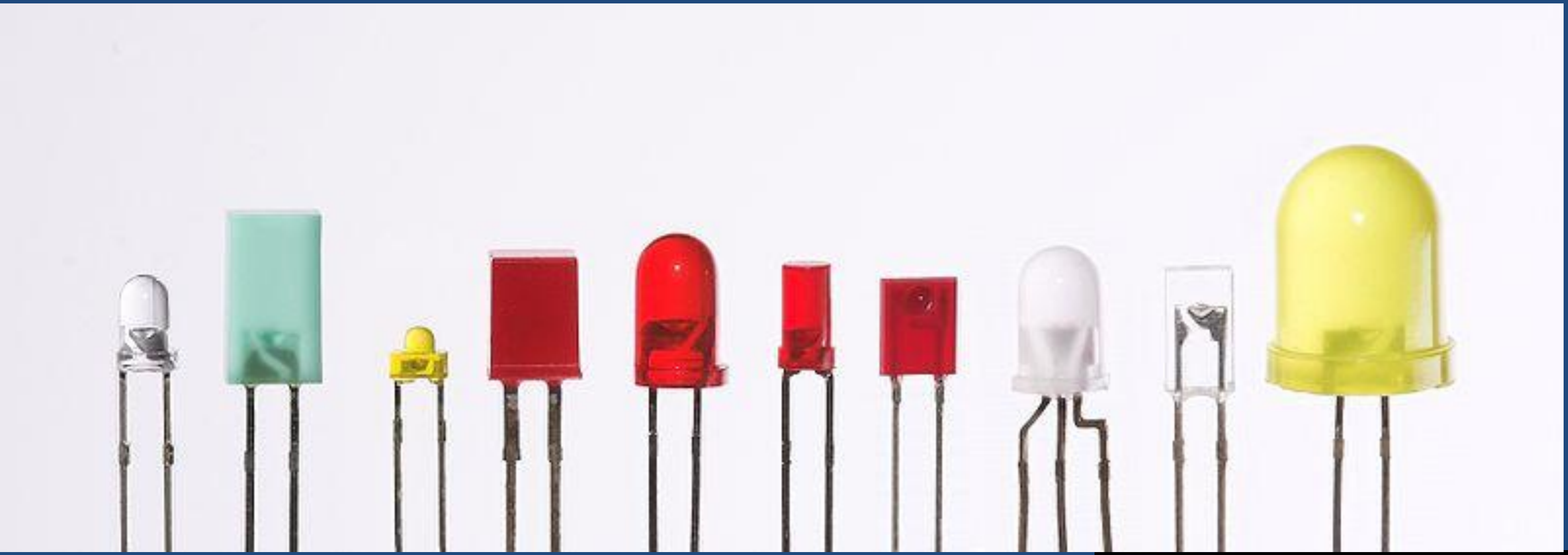






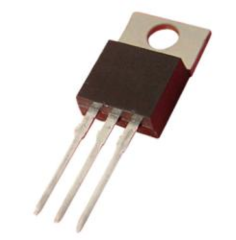
http://www.youtube.com/watch?v=AqzYsuTRVRc&feature=related

diodos emisores de Luz, LEDs…



http://www.youtube.com/watch?v=P3PDLsJQcGI&feature=channel

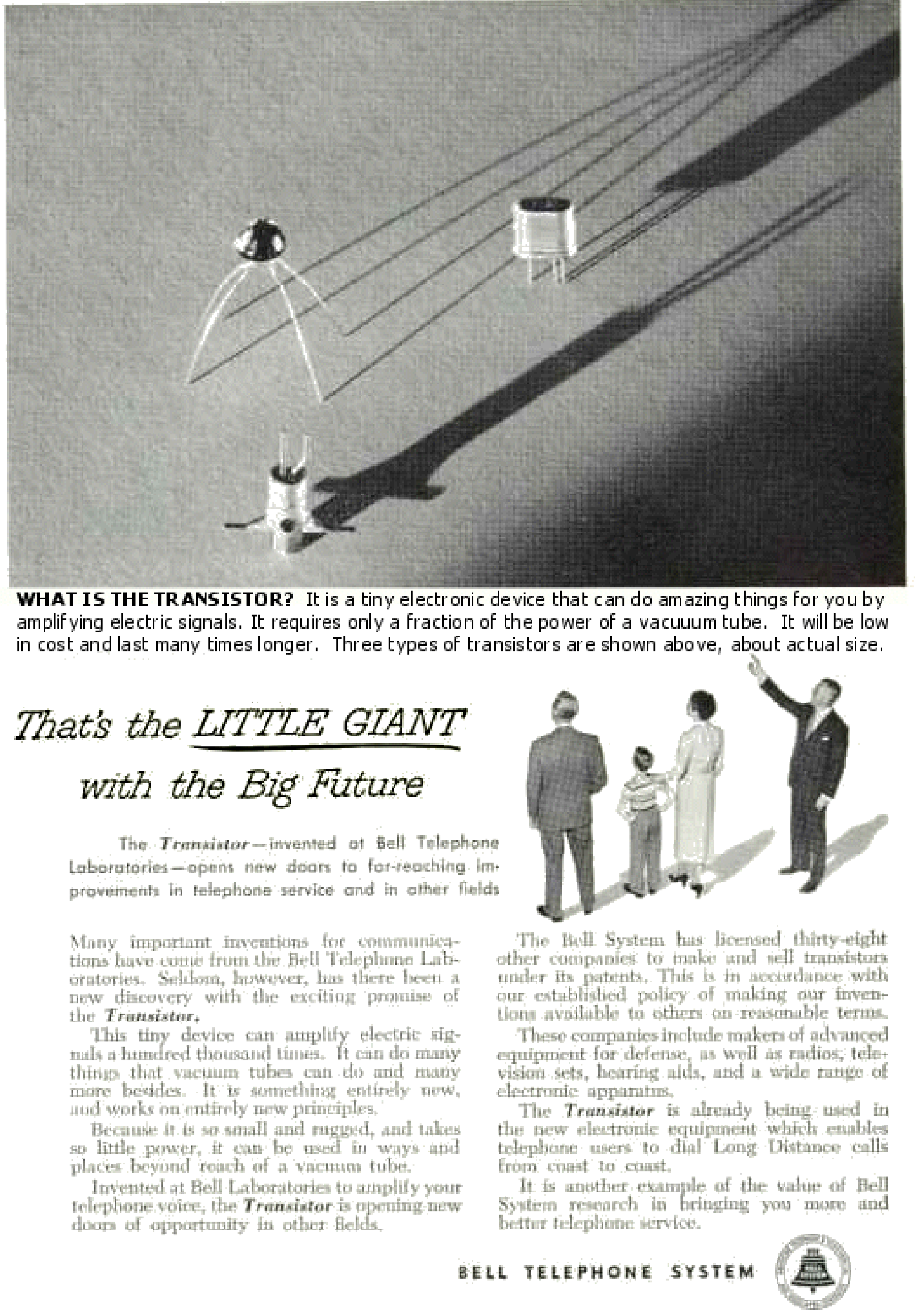
transistores...



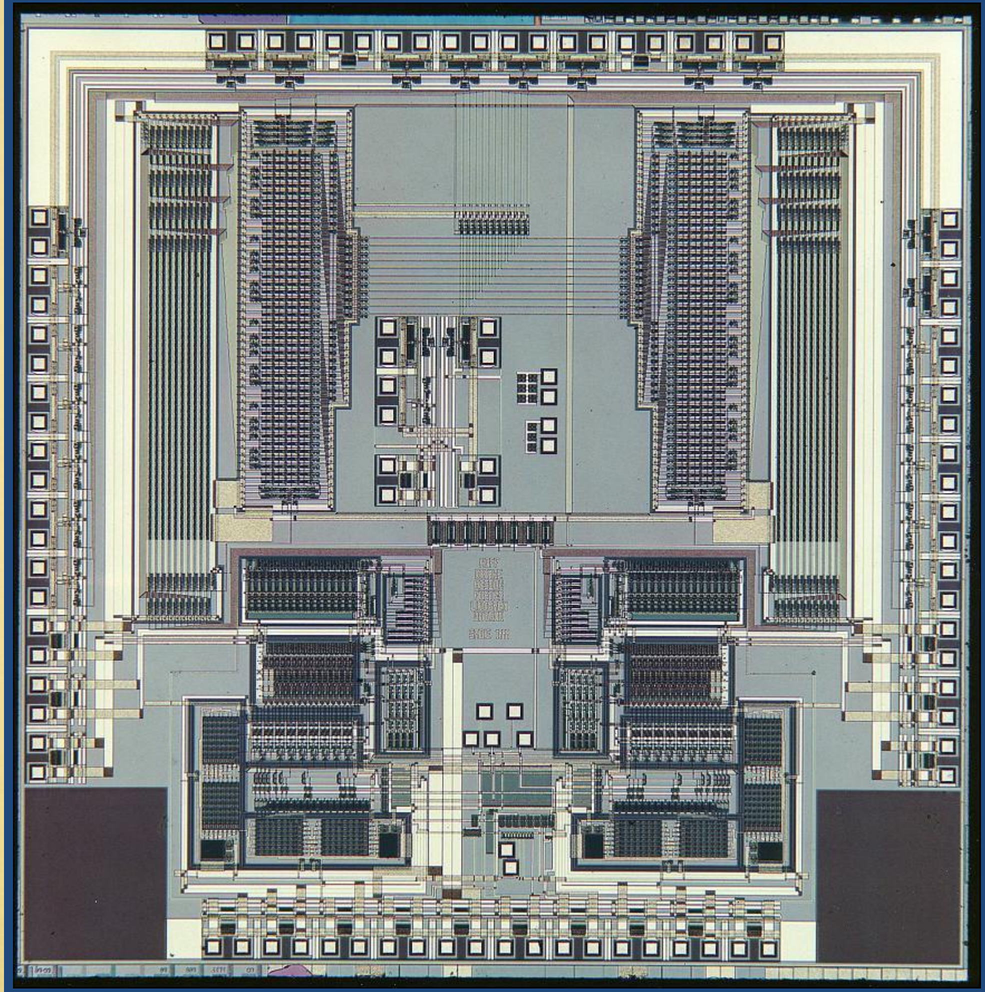
http://www.youtube.com/watch?v=-td7YT-Pums&feature=channel

http://www.youtube.com/watch?v=ZYH9dGl4gUE&feature=channel

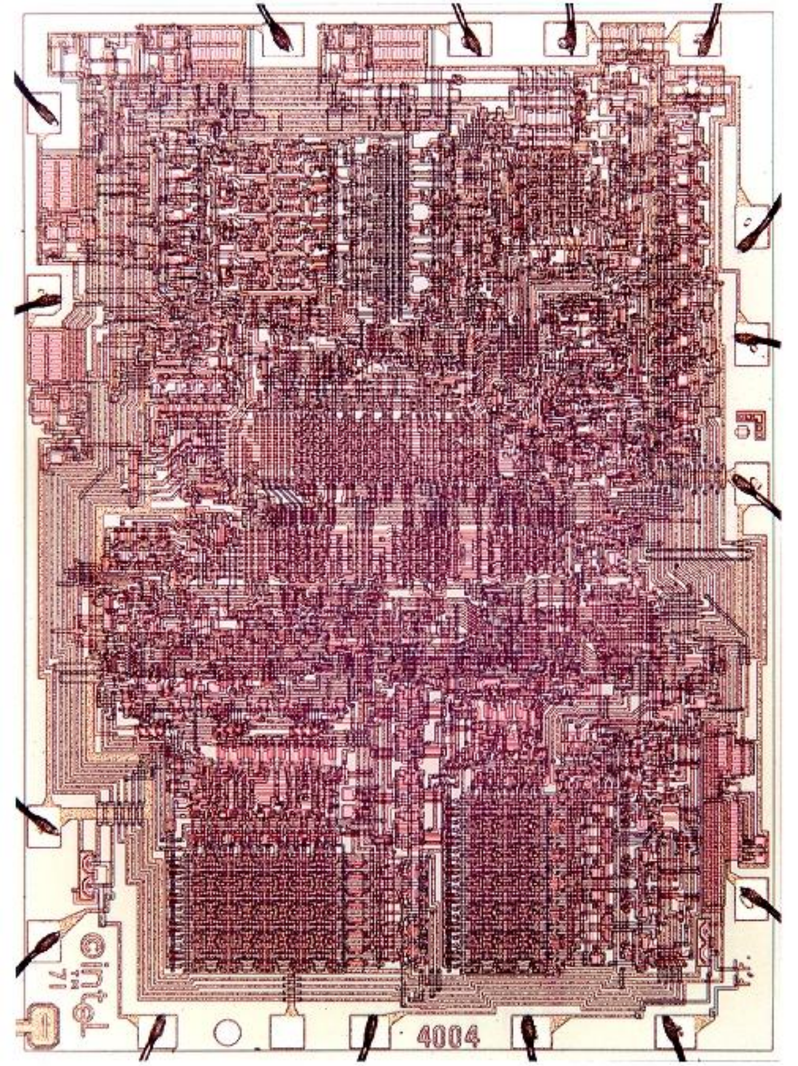
ores...


WHAT IS THE TRANSISTOR? It is a tiny electronic device that can do amazing things for you by amplifying electric signals. It requires only a fraction of the power of a vacuum tube. It will be low in cost and last many times longer. Three types of transistors are shown above, about actual size.
That's the LITTLE GIANT with the Big Future
The Transistor—invented at Bell Telephone Laboratories—opens new doors to far-reaching improvements in telephone service and in other fields
Many important inventions for communications have come from the Bell Telephone Laboratories. Seldom, however, has there been a new discovery with the exciting promise of the Transistor.
This tiny device can amplify electric signals a hundred thousand times. It can do many things that vacuum tubes can do and many more besides. It is something entirely new, and works on entirely new principles.
Because it is so small and rugged, and takes so little power, it can be used in ways and places beyond reach of a vacuum tube.
Invented at Bell Laboratories to amplify your telephone voice, the Transistor is opening new doors of opportunity in other fields.
The Bell System has licensed thirty-eight other companies to make and sell transistors under its patents. This is in accordance with our established policy of making our inventions available to others on reasonable terms.
These companies include makers of advanced equipment for defense, as well as radios, television sets, hearing aids, and a wide range of electronic apparatus.
The Transistor is already being used in the new electronic equipment which enables telephone users to dial Long Distance calls from coast to coast.
It is another example of the value of Bell System research in bringing you more and better telephone service.
BELL TELEPHONE SYSTEM

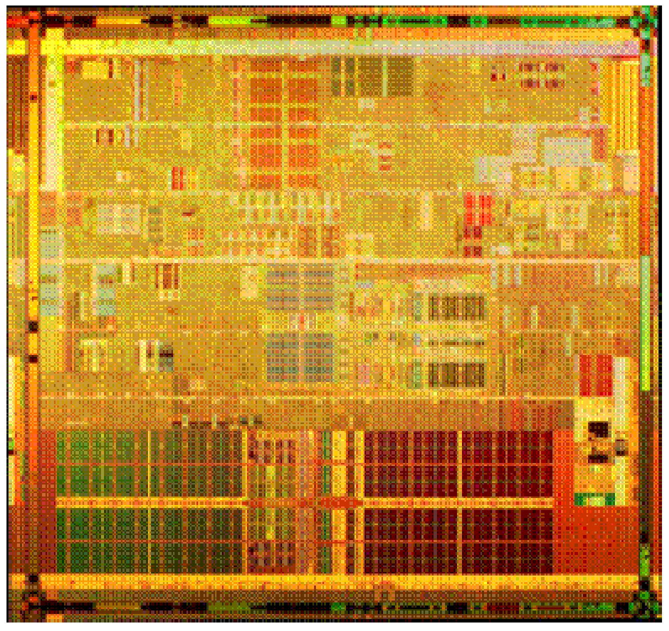
circuitos integrados (CI, *chips*)…



… cada vez más pequeños



1972. Pentium 4004, primer computador completo en un CI.



2000. Pentium 4. Cada cuadrito en el procesador es mas complejo que el viejo procesador 4004.

Ah, y en productos de uso masivo

Si, cada vez más pequeños…

más pequeños…

más pequeños…

más pequeños…

más pequeños…

ELECTRÓNICA DE HOY: CIRCUITOS INTEGRADOS, *CHIPS* EN MINIATURA

LOS CIRCUITOS INTEGRADOS POSIBILITARON LA EXISTENCIA DE TO
“JUGUETES” ELECTRÓNICOS QUE ESTÁN EN ESTA SALA.
¿CÓMO HACER CIRCUITOS INTEGRADOS MÁS RÁPIDOS Y MAS BARAT
TAN PEQUEÑOS PUEDEN LLEGAR A SER?

ELECTRÓNICA MOLECULAR

Walter Torres Hernández, PhD
Profesor Asociado Departamento de Química Universidad del Valle, Cali, Colombia
Correo: walter.torres@correounivalle.edu.co
Adjunct Associate Professor, Department of Chemical and Biomolecular Engineering, Clemson University, SC 29634, USA

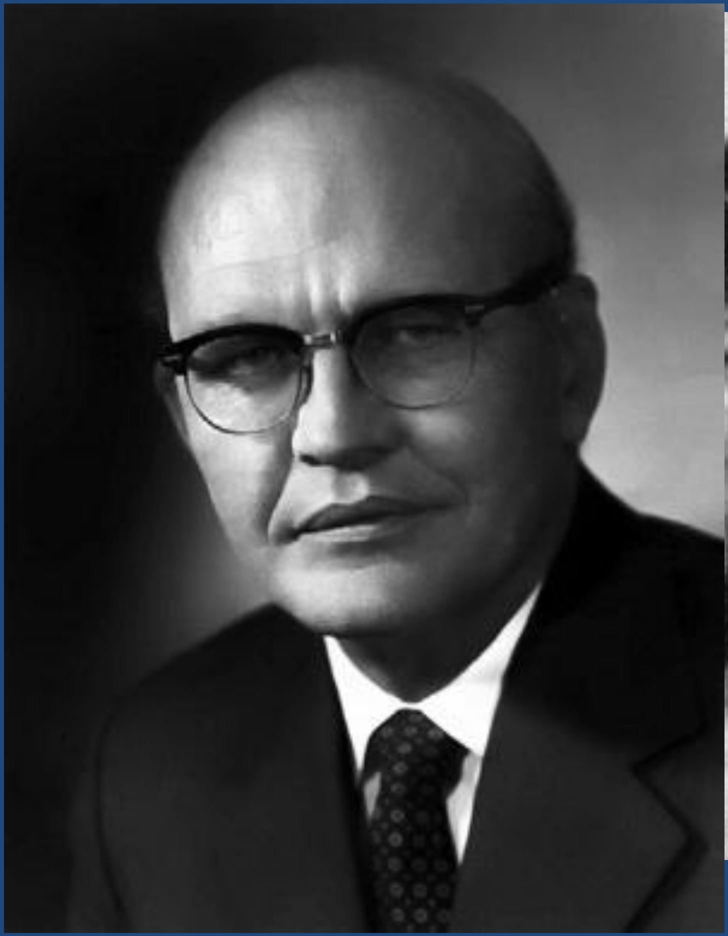
Nanociencias, 2010-10-19

Mucho empezó en esta tienda de mercado en Mountain View, California

En 1956, William Shockley fundó (en el 391 de la calle San Antonio) la compañía de semiconductores: Fairchild).

http://en.wikipedia.org/wiki/Shockley_Semiconductor_Laboratory

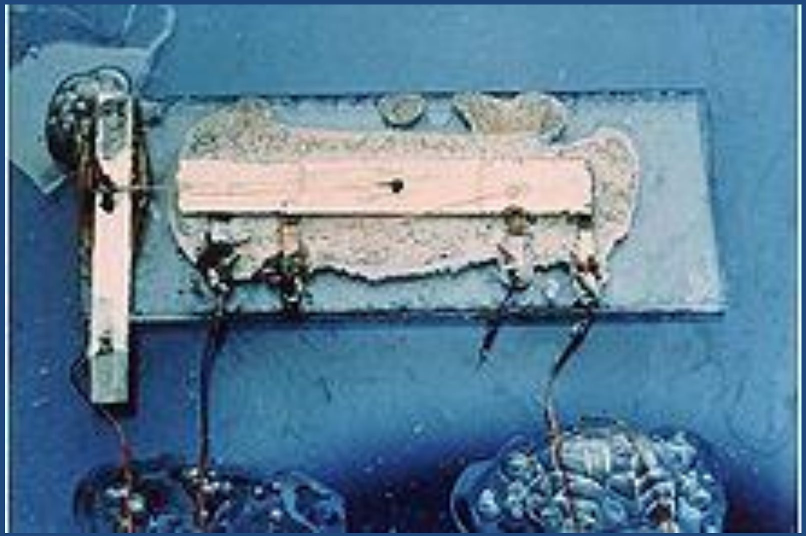
Primeros circuitos integrados: *Jack Kilby* y Robert Noyce



Texas Instruments, Dallas

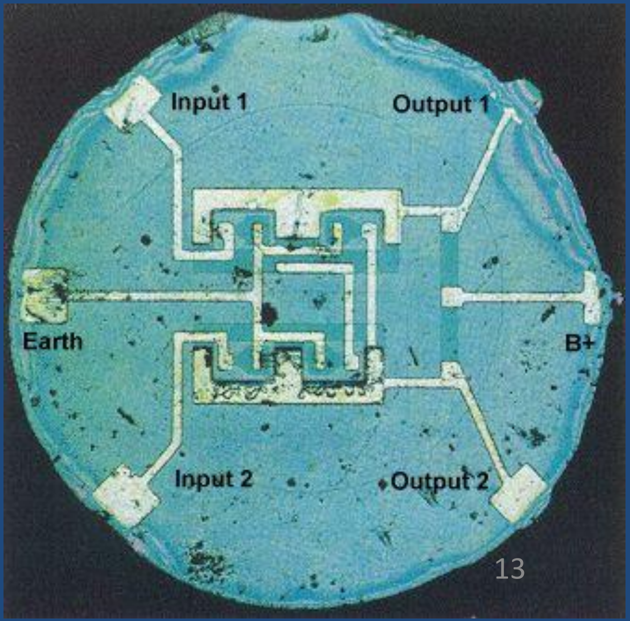
Fairchild, California

En el principio, todo era sencillo, grande



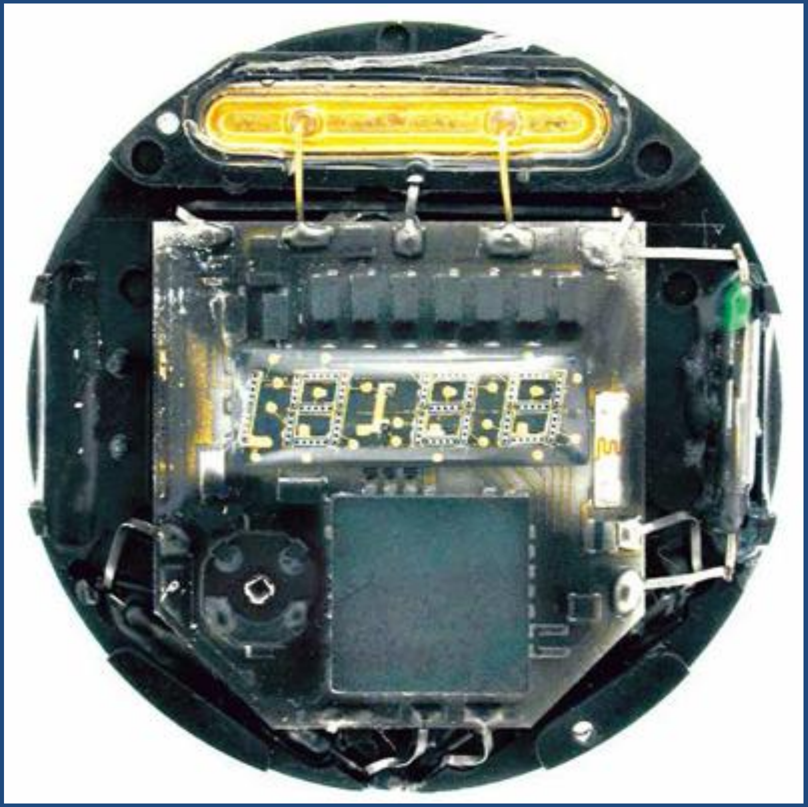
1959 J. Kilby. Chip de germanio, ancestro del actual chip de silicio

1961 R. Noyce. Primer circuito integrado de silicio



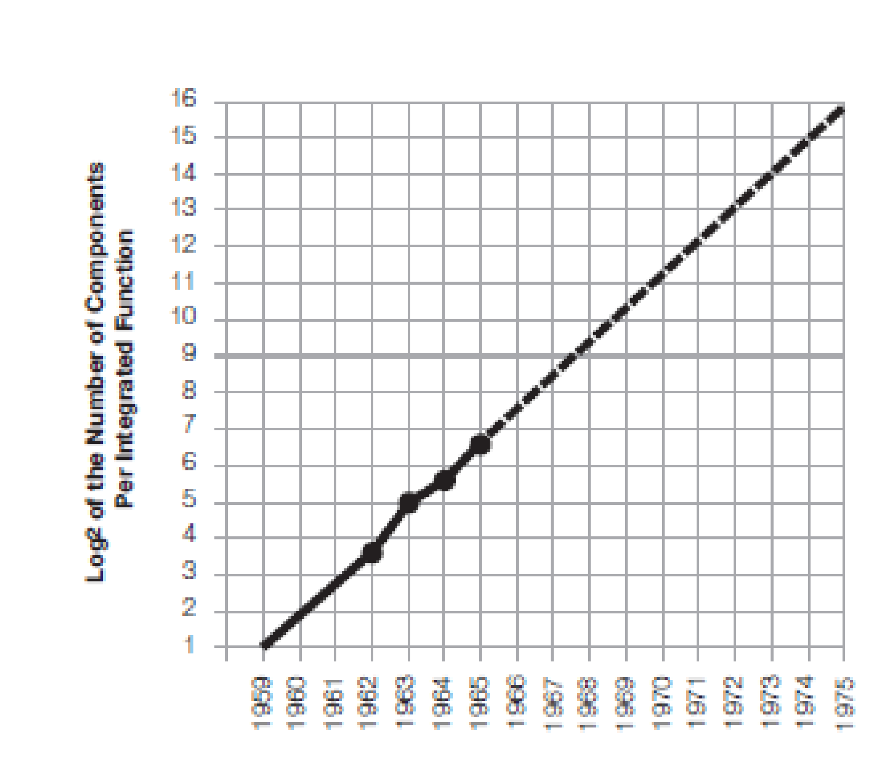
www.computerhistory.org

Después, todo empezó a reducirse de tamaño



1974 Microma. “Display” de cristal líquido.

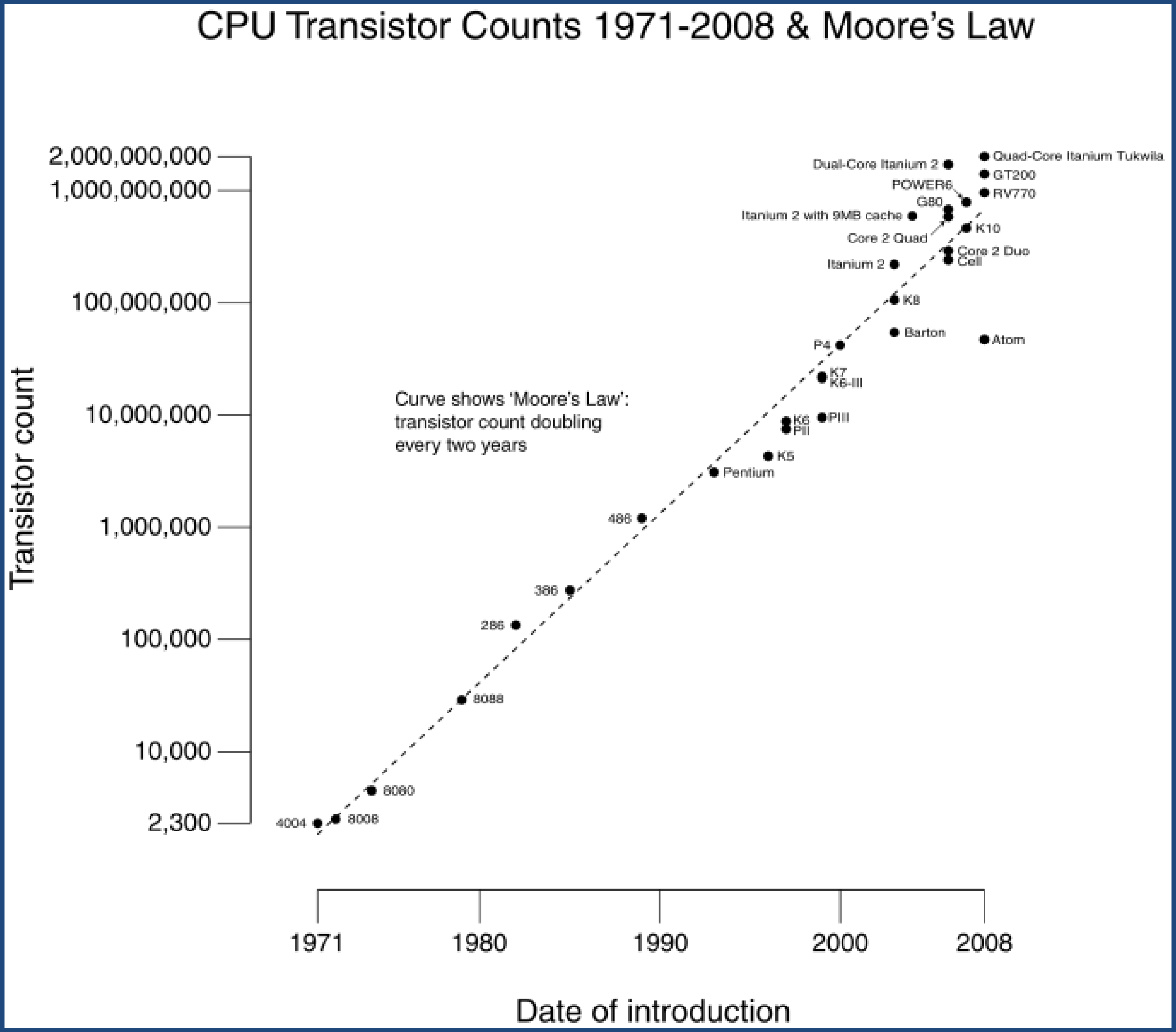
Mi nombre es Moore…Gordon Moore



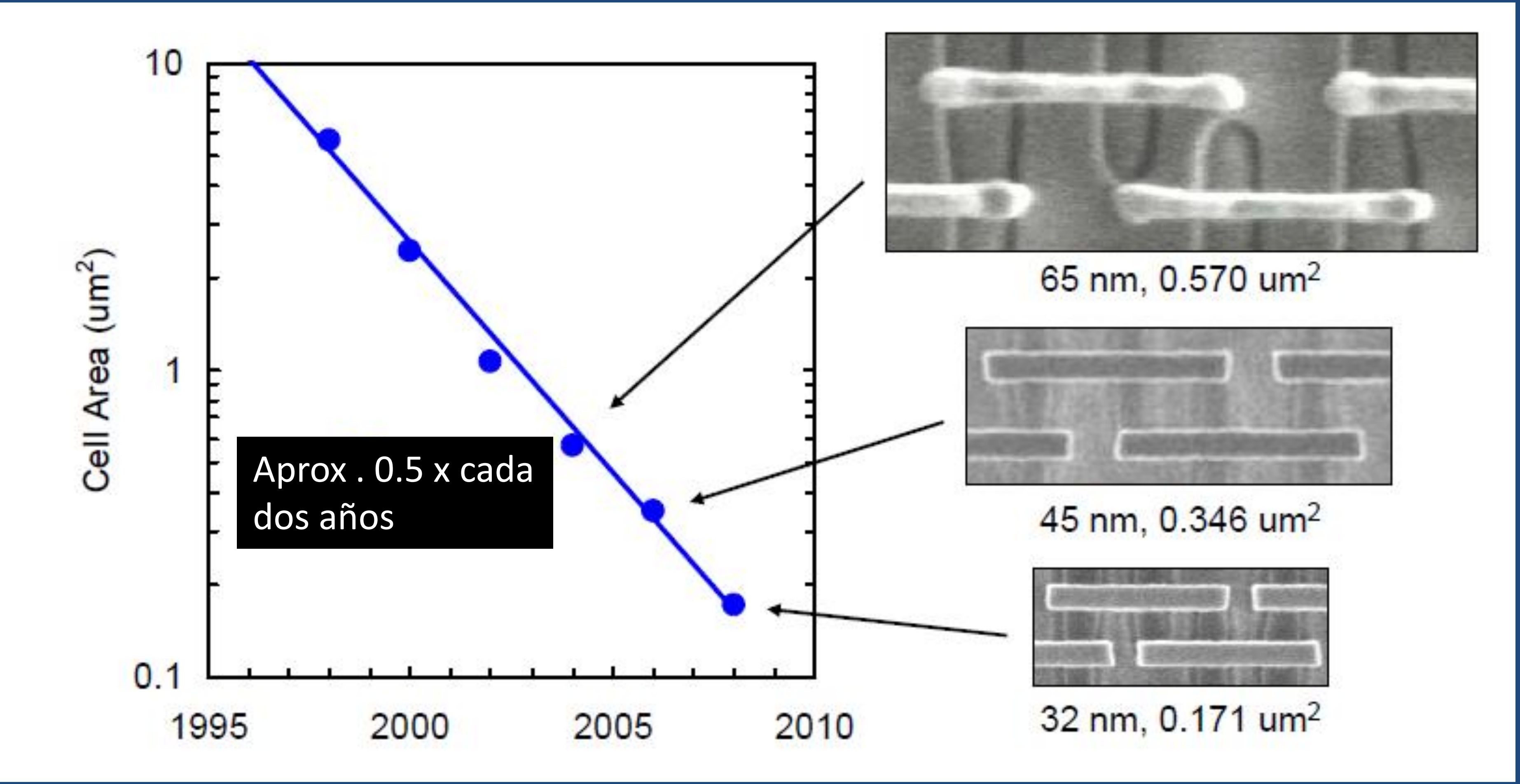
ftp://download.intel.com/museum/Moores_Law/Articles-Press_Releases/Gordon_Moore_1965_Article.pdf

Moore, G. E. *Electronics* **1965**, *38*(8)

Todo será más pequeño…



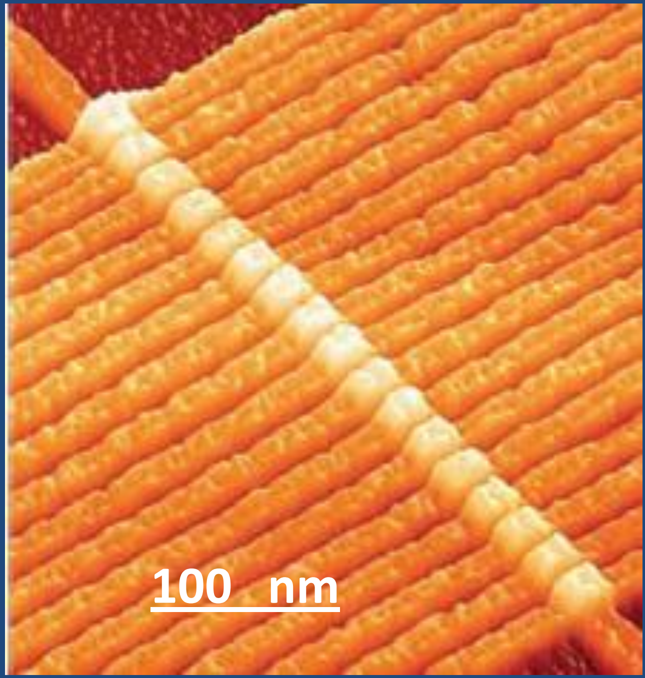
Disminución de tamaños de celdas SRAM de INTEL (1998-2009)



Pero cuando los elementos de circuito estén en la escala de unos pocos nanómetros…

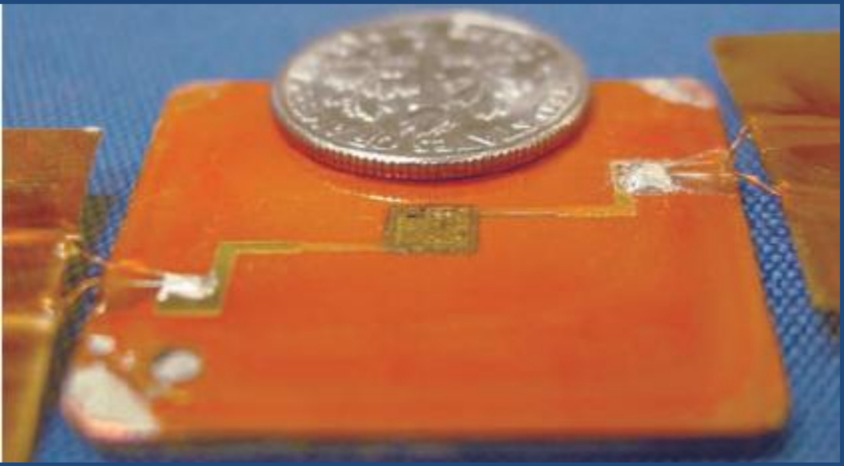
Serán casi tan pequeños como moléculas individuales…

Diseño de barras cruzadas: nanoalambres paralelos en un plano que cruzan sobre un segundo grupo de alambres en ángulos rectos. Entre los dos, hay una monocapa molecular. Cada intersección puede actuar como switches (memristors). Tambien sirven para almacenar información. Cada memristor puede hacer el trabajo de 10 transistores.

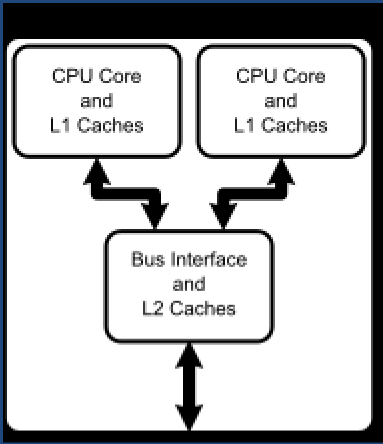


Puede haber problemas

Disipación de energía…



Superlattice de teluro de bismuto en el empaquetamiento de un chip. El material termoeléctrico convierte los gradientes de temperatura en electricidad mientras refrigera el chip.



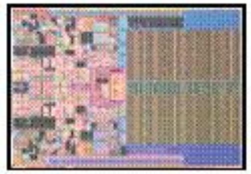
Soluciones creativas. Procesadores multi-core en paralelo. Pueden procesar mas datos/tiempo y consumir menos electricidad produciendo menos “calor”.

Necesitan programación en paralelo.

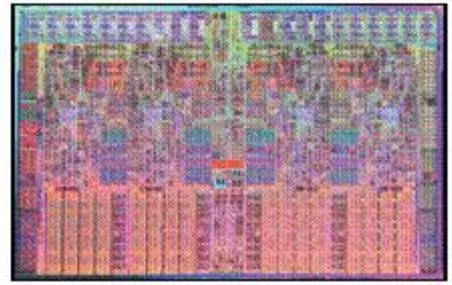
45 nm Microprocessor Products

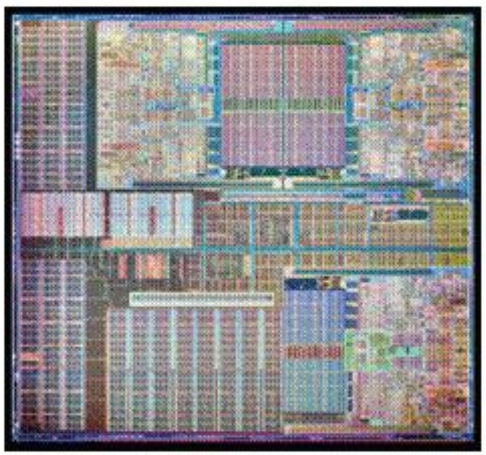
Single Core

Dual Core

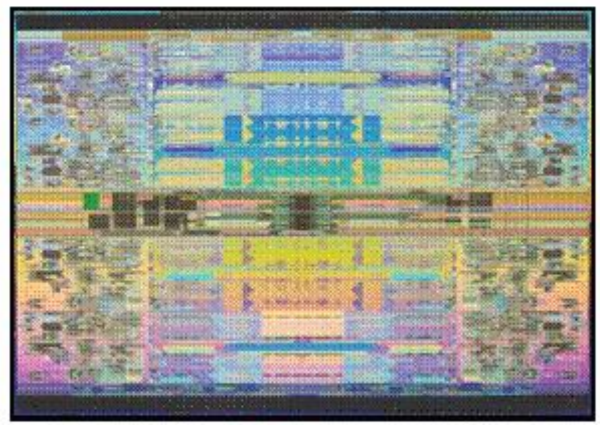


Quad Core





6 Core



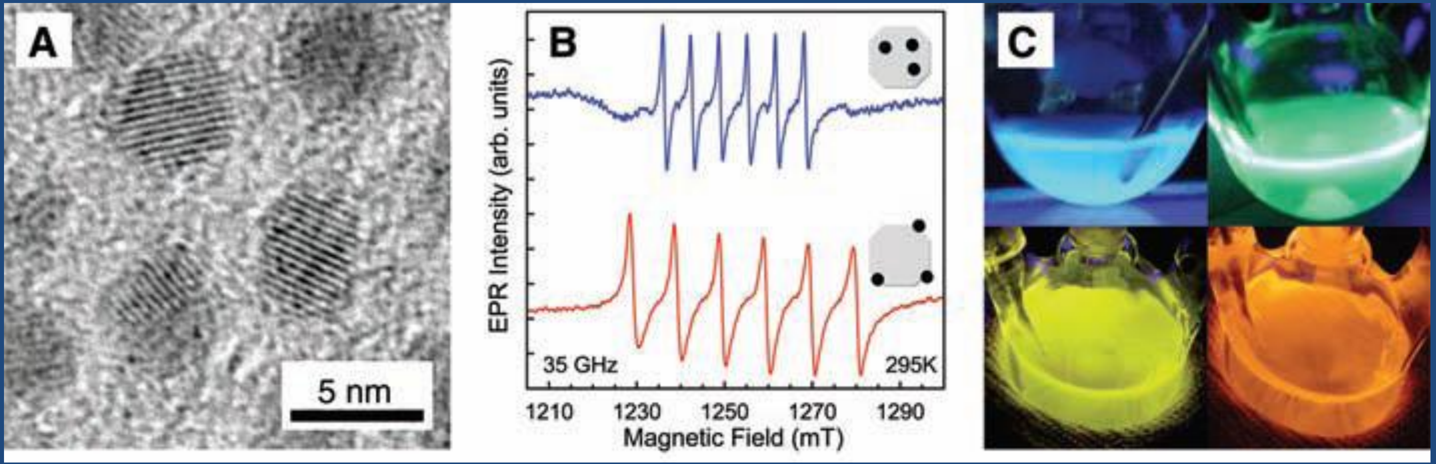
8 Core

>200 million 45 nm CPUs shipped to date

IDF2009
INTEL DEVELOPER FORUM

Y más problemas

Proceso de dopado: Irreproducible?



Nanocristales de ZNSe (5 nm) dopados con Mn. (A) Micrografía de transmisión electrónica. (B) Espectro de resonancia paramagnética. Mn dentro (azul) y en la superficie (rojo) de los nanocristales. (C) Fluorescencia de nanocristales dopados con Cu (arriba) y Mn (abajo) . La posición de las impurezas cambia el color de la fluorescencia.

Norris, D. J.; Efros, A. L.; Erwin, S. C. Science 2008, 319, 1776.

Y más

Fugas de corriente…
Efectos cuánticos

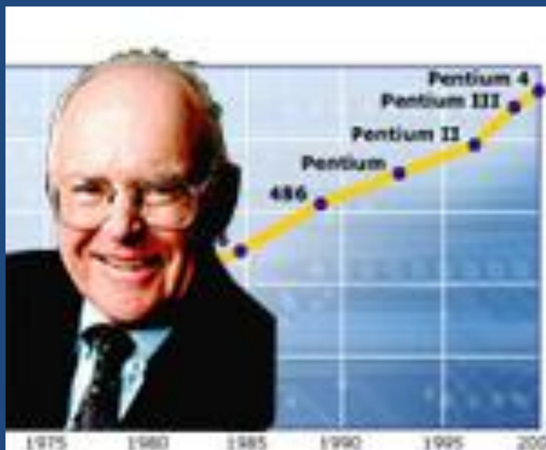
EN TEORÍA, UNO PODRÍA HACER DISPOSITIVOS ELECTRÓNICOS CON MOLÉCULAS INDIVIDUALES

Pero…

La electrónica es asunto de los físicos y los ingenieros, las moléculas son asunto de los químicos.

¿Cómo organizar y ensamblar moléculas para hacer electrónica?

Nunca digas nunca jamás



Abril 1965. La densidad de transistores en un circuito integrado dobla aprox. cada año

Abril 2005. *“No puede continuar para siempre. La naturaleza de los exponenciales es que … eventualmente ocurre un desastre”*

“..del tamaño [de los transistores] … estamos aproximando el tamaño de los átomos, la barrera fundamental. Tenemos 10 o 20 años para llegar al límite fundamental.“

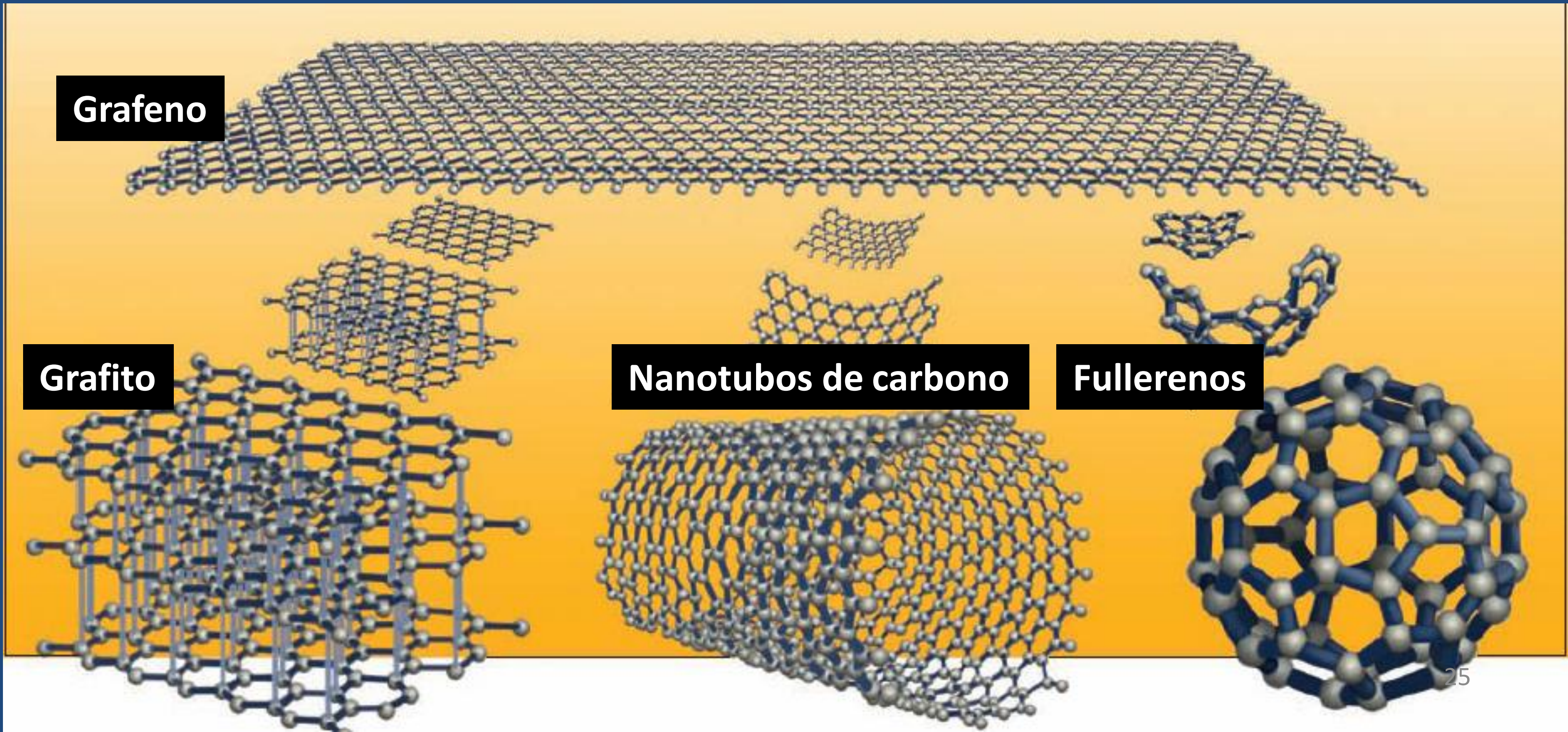
“Los CIs … reemplazarlos completamente es poco probable”

“Estamos operando muy debajo de los 100 nm lo que es visto como el comienzo de la nanotecnología, asi que ya estamos allá”

“La construcción de abajo hacia arriba, átomo por átomo … no está reemplazando los CIs”

¿Reinará el silicio por siempre?

Moléculas/macromoléculas para hacer electrónica a escala nano y sub-nano (molecular)

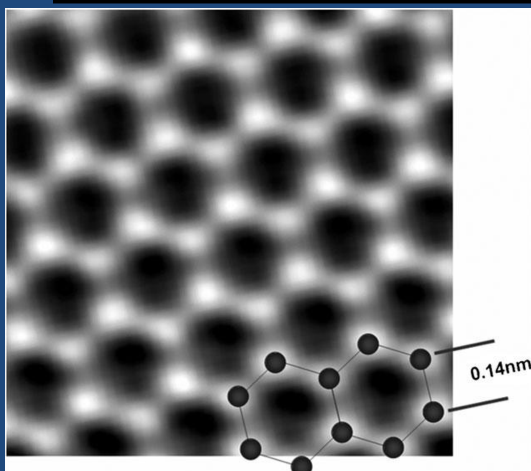


Moléculas/macromoléculas para

hacer electrónica a escala nano y molecular

Grafeno, el sólido mas delgado

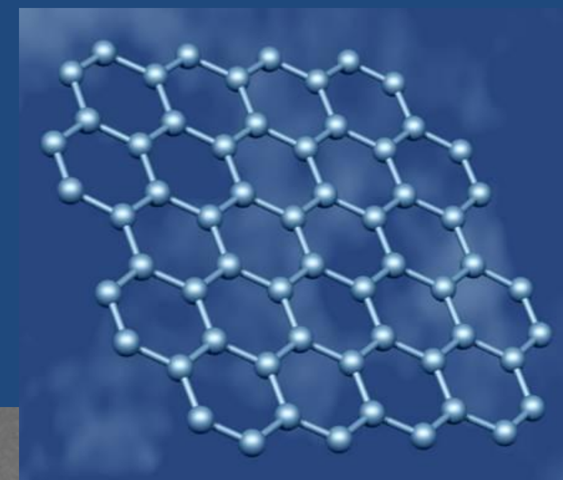
Enorme capacidad de almacenar carga.

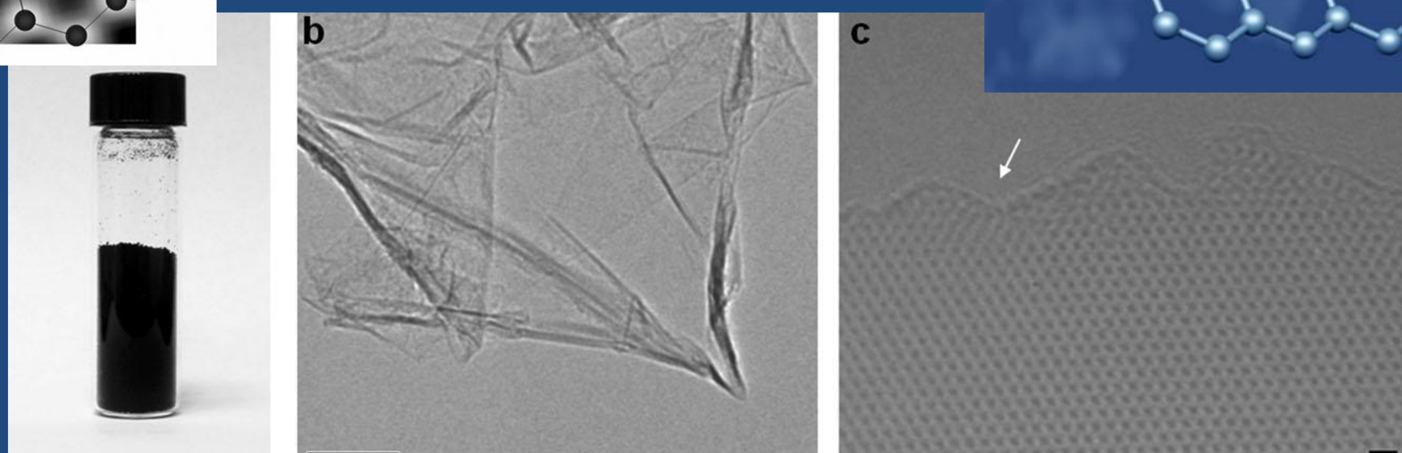


[Futuras aplicaciones]

[Futuras aplicaciones Samsung]

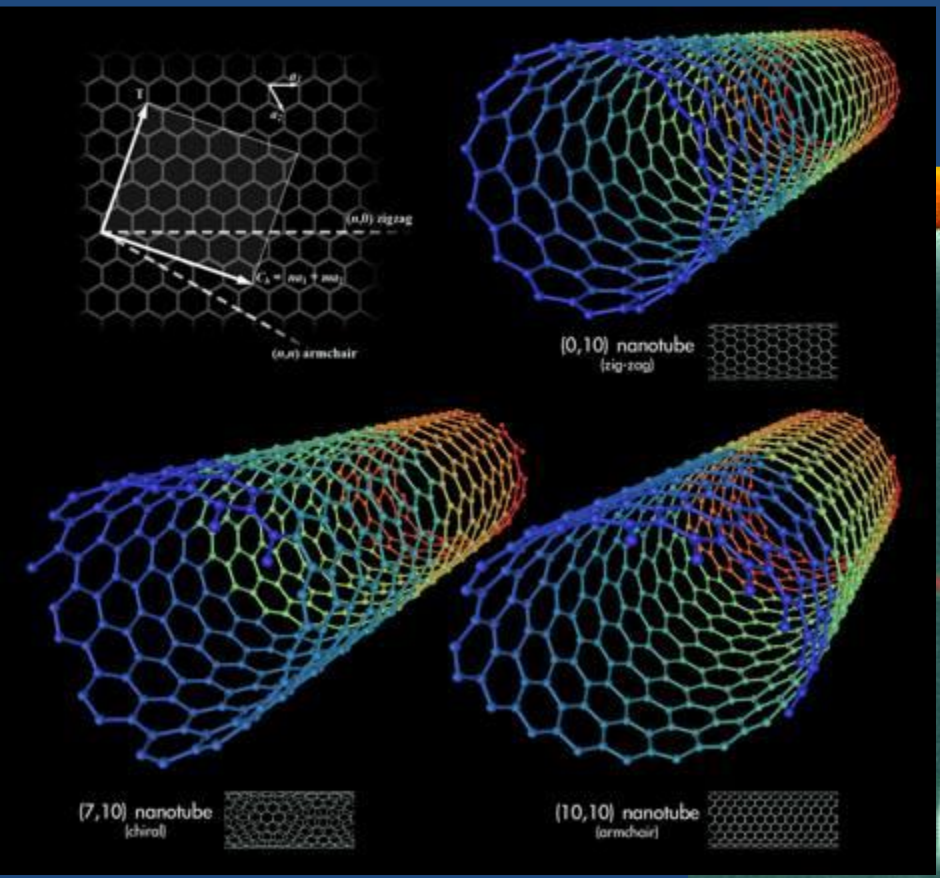
[Haciendo grafeno]

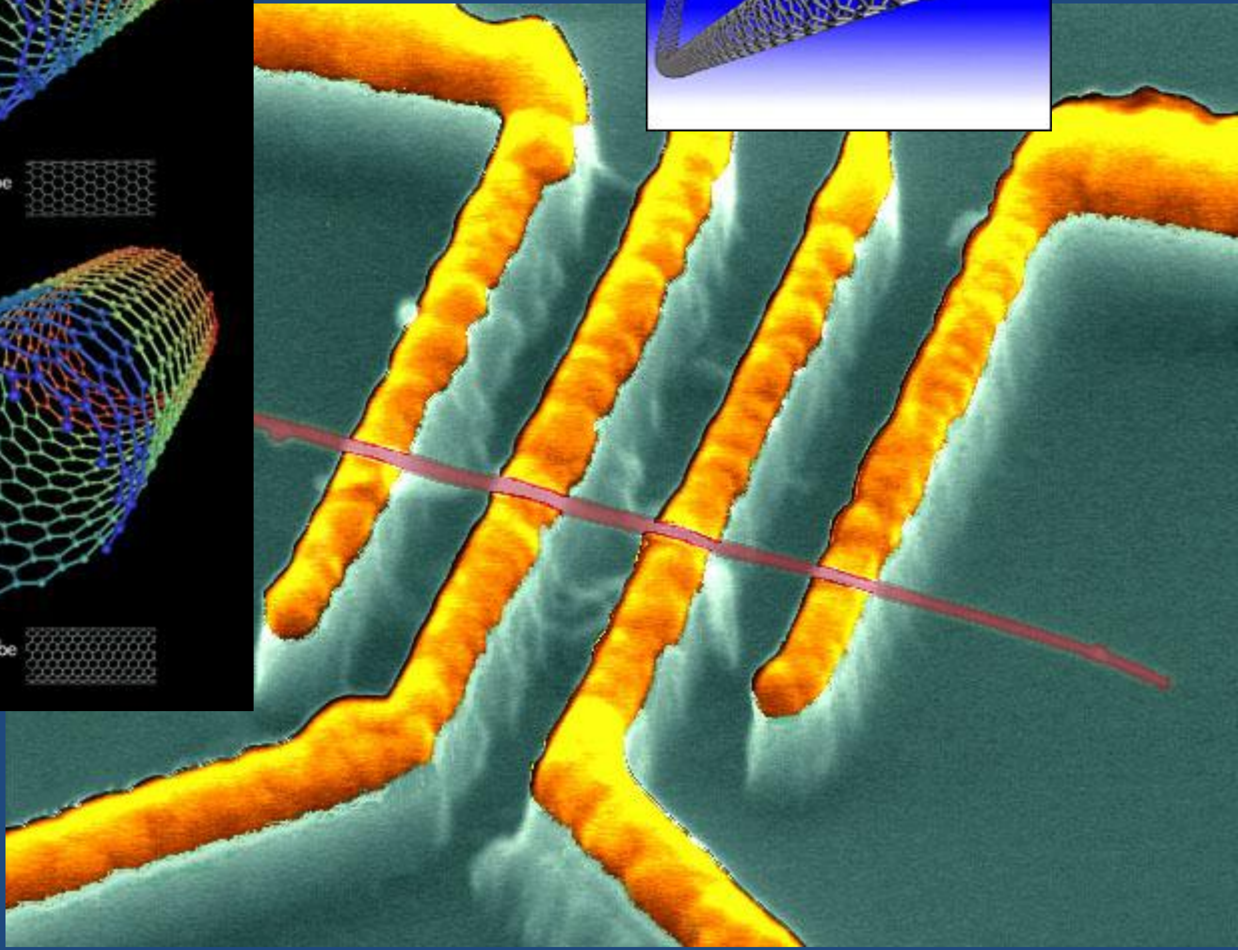


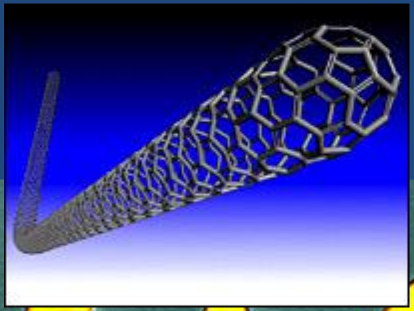


Dato, A.; Lee, Z.; Jeon, K. J.; Erni, R.; Radmilovic, V.; Richardson, T. J.; Frenklach, M. *Chemical Communications* **2009**, 6095-6097.

Nanotubos de carbono







Moléculas para hacer nano-electrónica

DNA Computing

DNA TRANSISTOR

ADN

Polímeros conductores

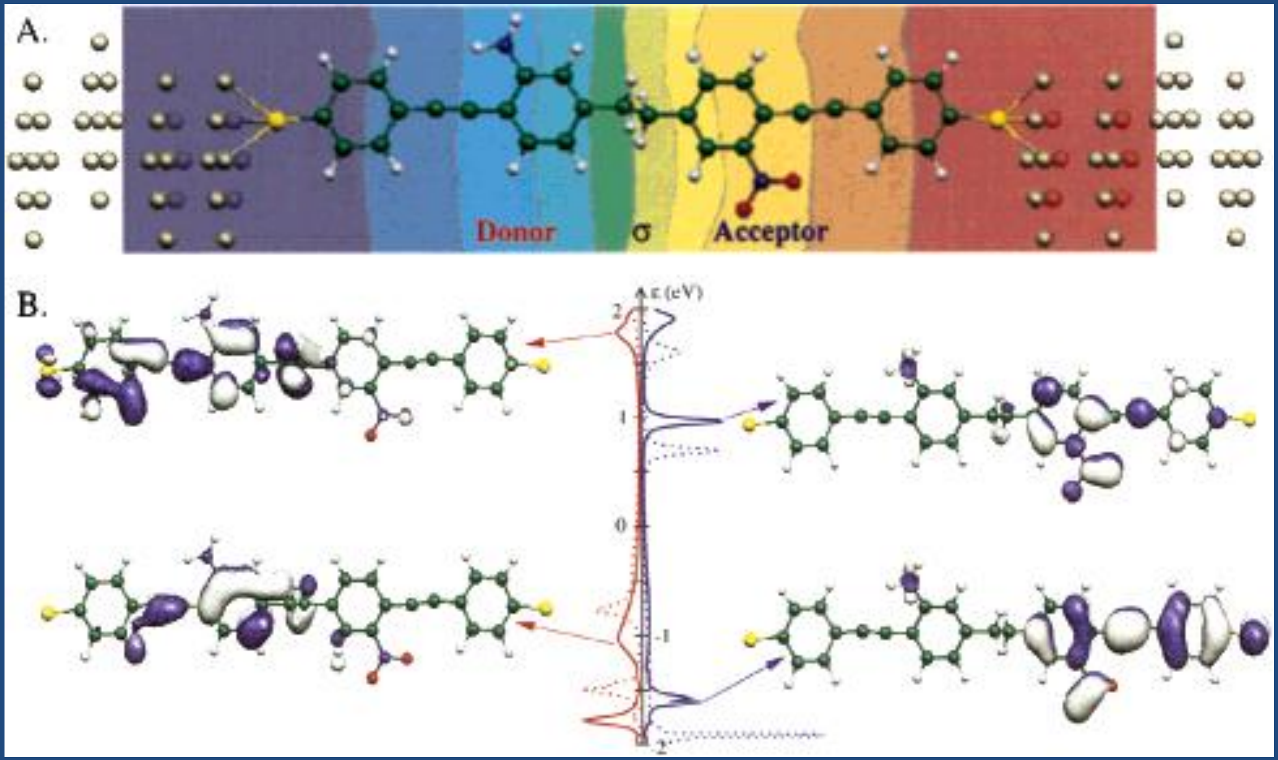
Moléculas para hacer nano-electrónica

Cristales Orgánicos
Complejos Donor Aceptor
TTF TCNQ

Cristales Líquidos

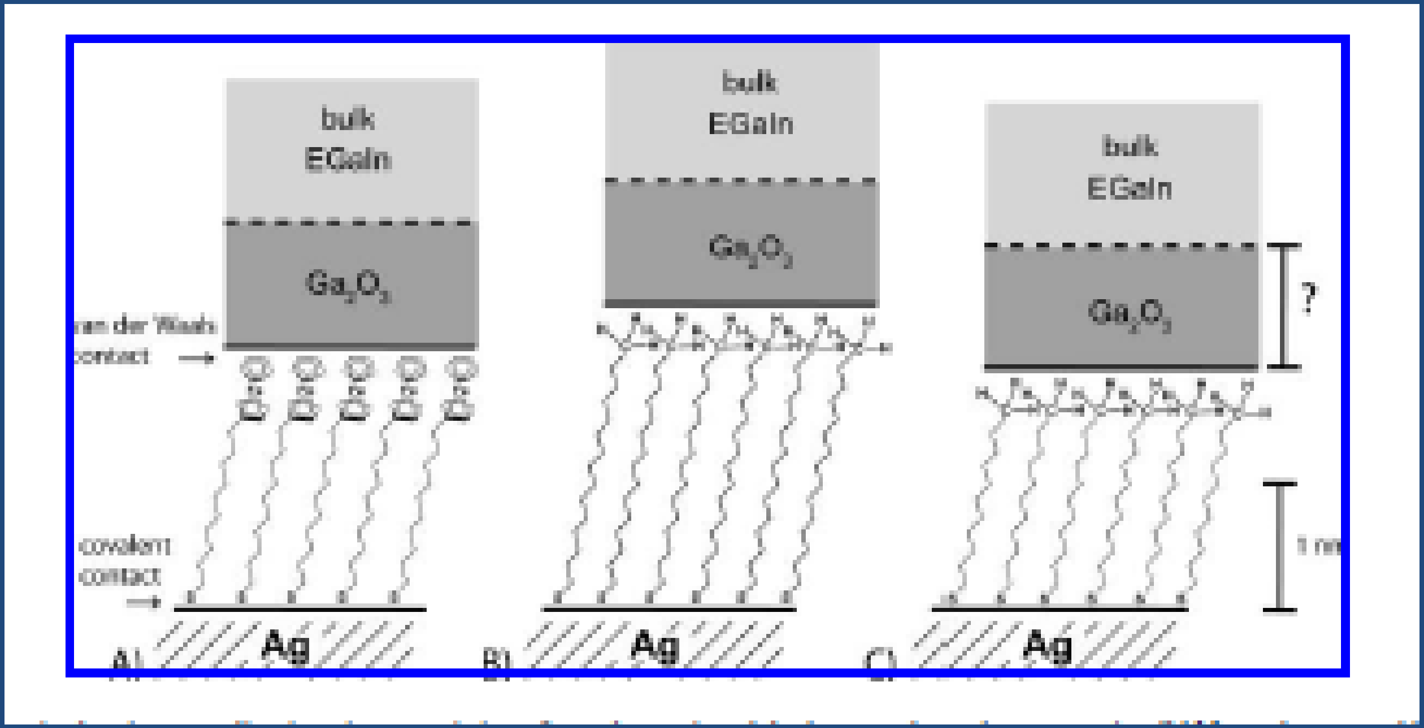
http://www.youtube.com/watch?v=msN1JfW4z7c

Diodos moleculares



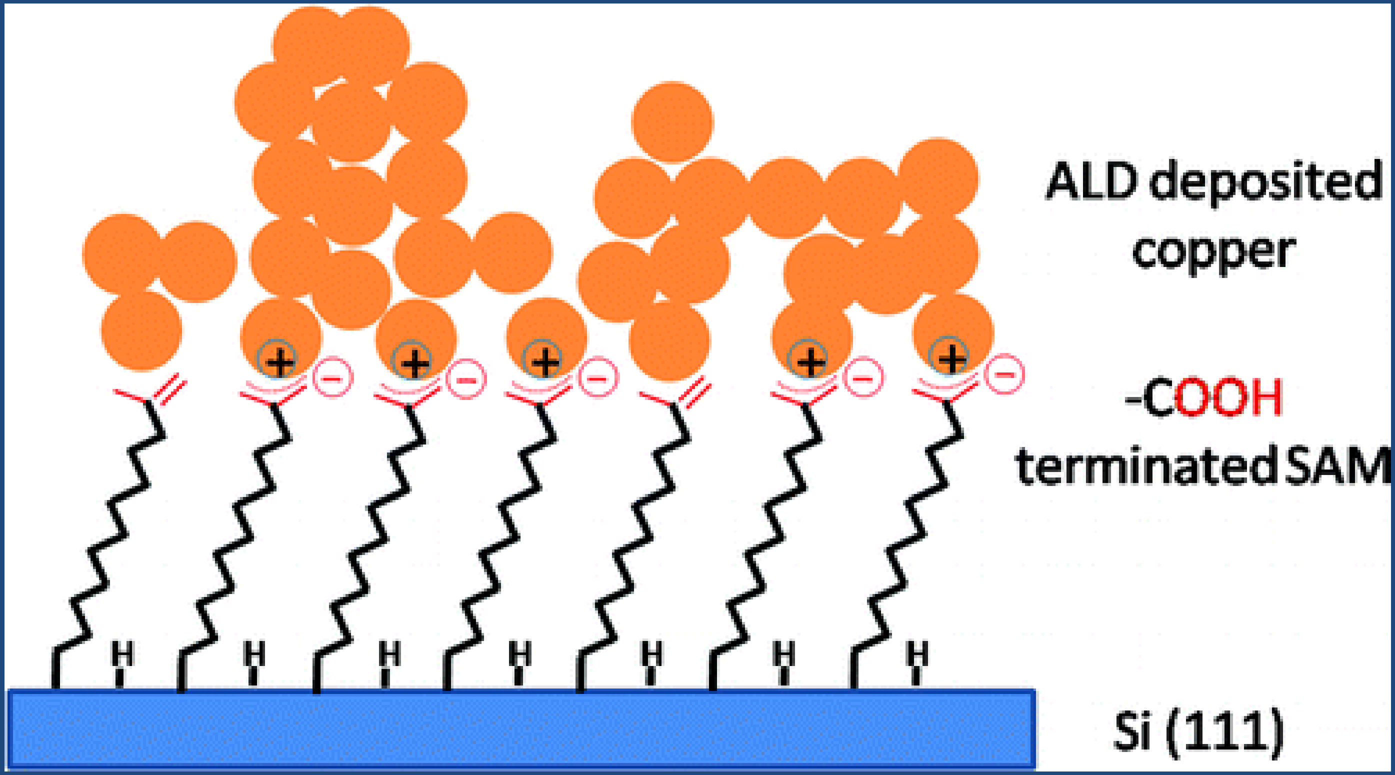
Stokbro, K.; Taylor, J.; Brandbyge, M. *Journal of The American Chemical Society* **2003**, *125*, 3674

Diodos moleculares



Nijhuis, C. A.; Reus, W. F.; Whitesides, G. M. *Journal of The American Chemical Society* **2009**, *131*, 17814

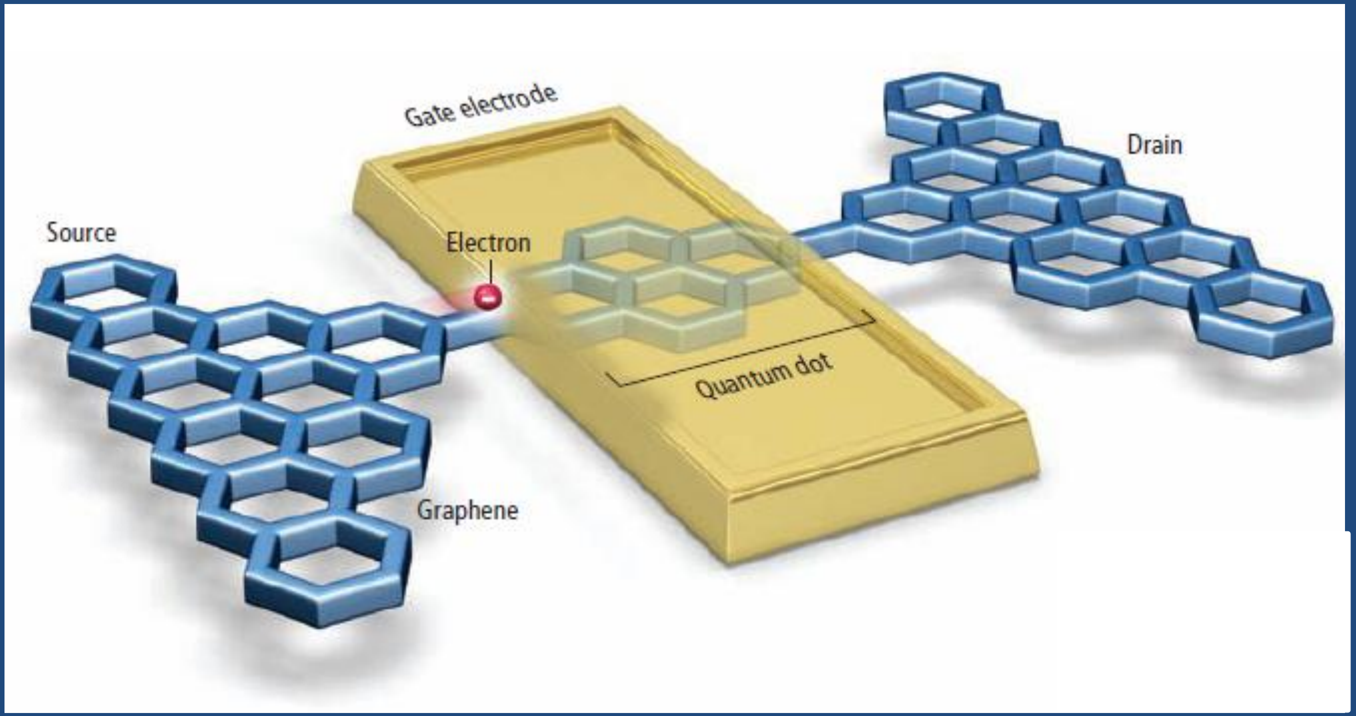
Diodos moleculares



Seitz, O.; Dai, M.; Aguirre-Tostado, F. S.; Wallace, R. M.; Chabal, Y. J. *Journal of The American Chemical Society* **2009**, *191*, 18159

Imaginemos un nanotransistor

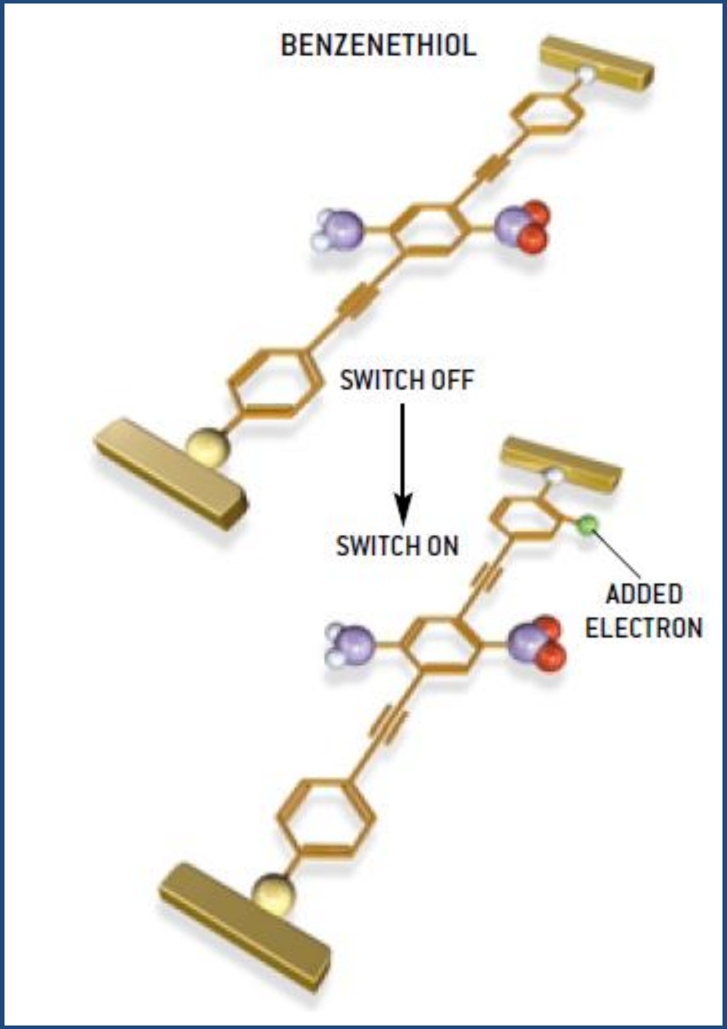
10 nm



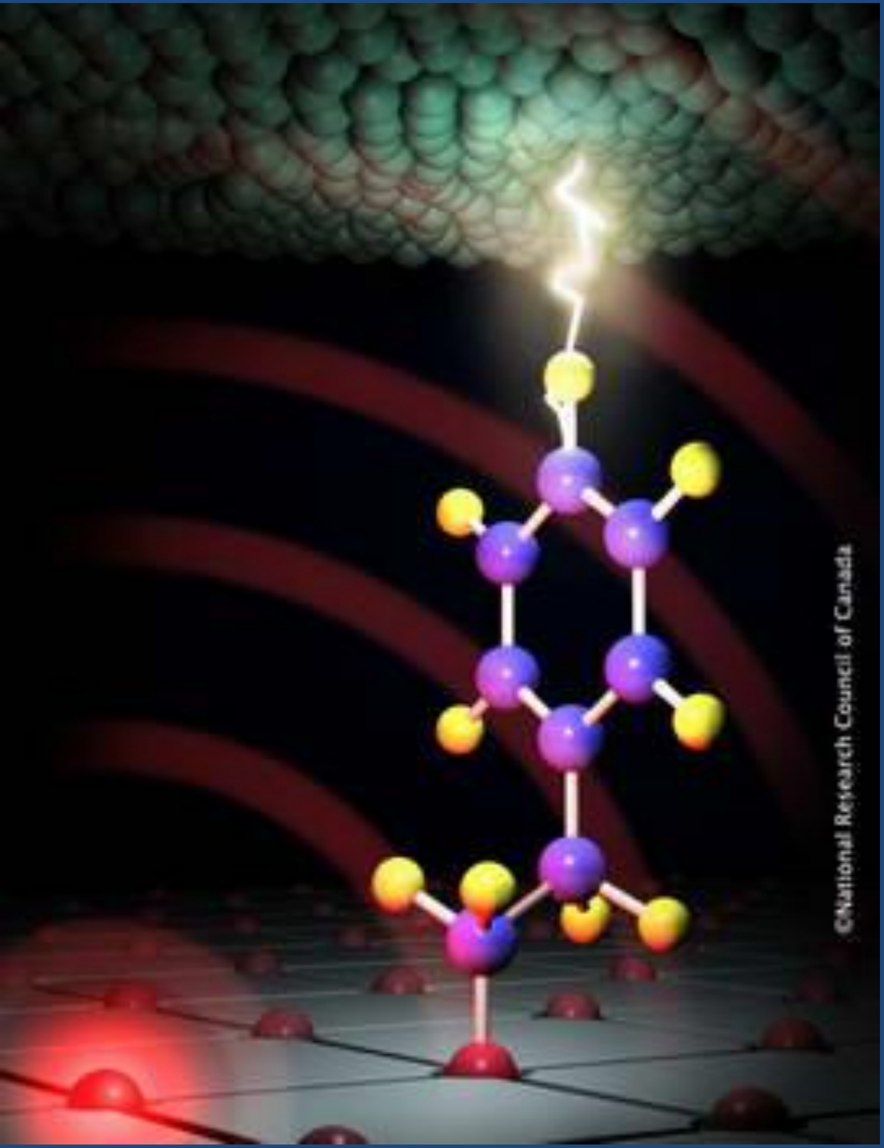
…hecho con hojas de grafeno y quantum dots (puntos cuánticos)

Scientific American **2010** (January), 83.

Nanotransistor



O una unión híbrida



Metal-Molécula-Metal

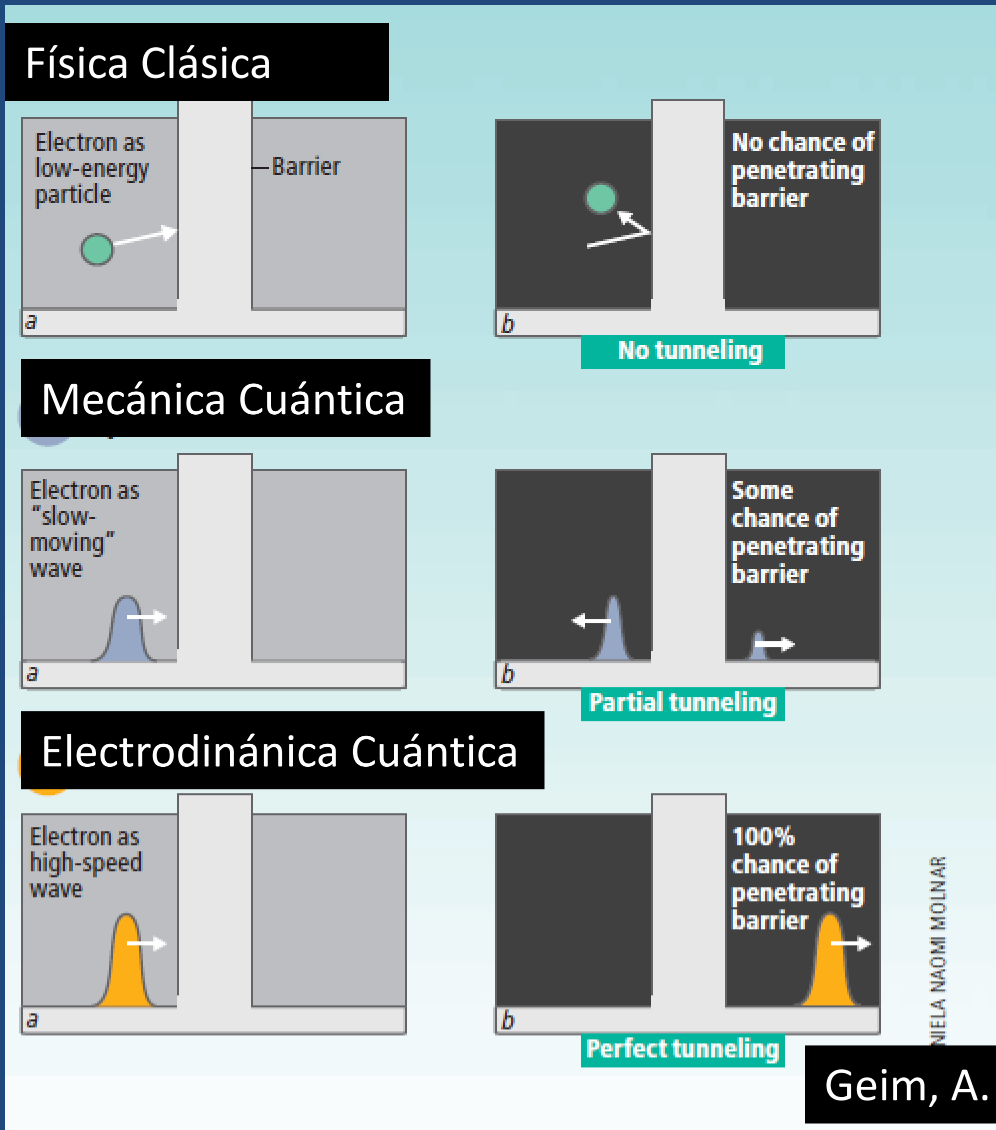
Metal-Molécula-Semiconductor

RETOS

¿Cómo pegar moléculas en la superficie de un metal o un semiconductor?

¿Cuáles son los mecanismos de transporte de un electrón a través de una interfase monomolecular?

Transporte de electrones a través de nano y subnano-barreras



MODELOS

Física clásica

Mecánica cuántica "ordinaria"

Electrodinámica cuántica

Geim, A. K.; Kim, P. *Scientific American* **2008** (April), 92

El reto

Poner todos estos componentes juntos

Lo que llevamos a la casa

Es necesario entender:

(i) La relación entre la conductancia y la temperatura.

(ii) ¿Es el ruido un punto crítico?

(iii) El efecto del calor en las propiedades de las interfases

(iv) Los cambios químicos provocados por la corriente.

(v) ¿Cómo el transporte electrónico modifica la geometría molecular?

Del Nero, J.; de Souza, F.; Capaz, R. B. *Journal of Computational and Theoretical Nanoscience* **2010**, *11*, 1–14.

http://www.quantrans.org/introduction/

Molecular Electronics :Key candidate to succeed the silicon based technology.

organic molecules in nanoscale nonlinear circuits offers many opportunities for new types of devices, which will differ in fabrication, functionality, and architecture.

But even the fundamental question how electrical current flows across a single molecule is not satisfactorily understood.

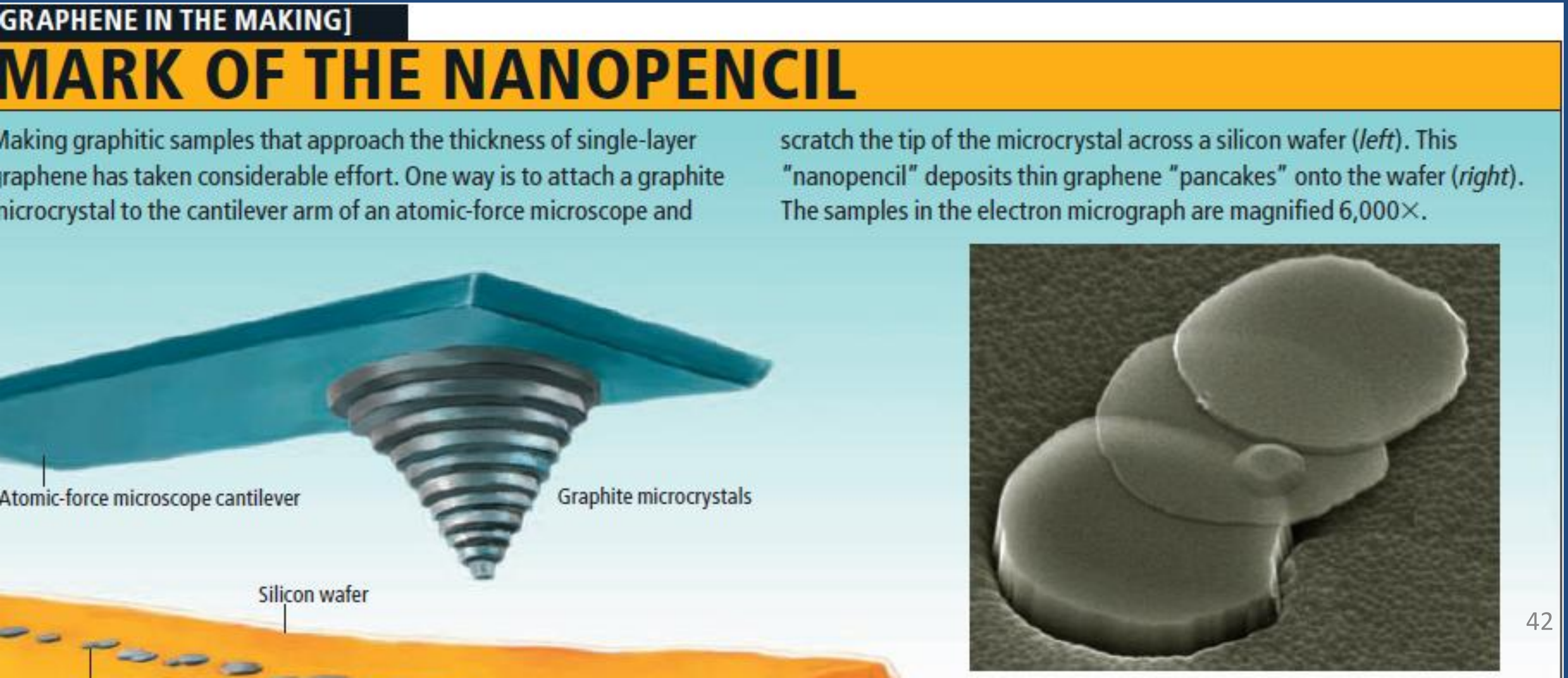
What is the full physical picture of molecular-scale charge transport?

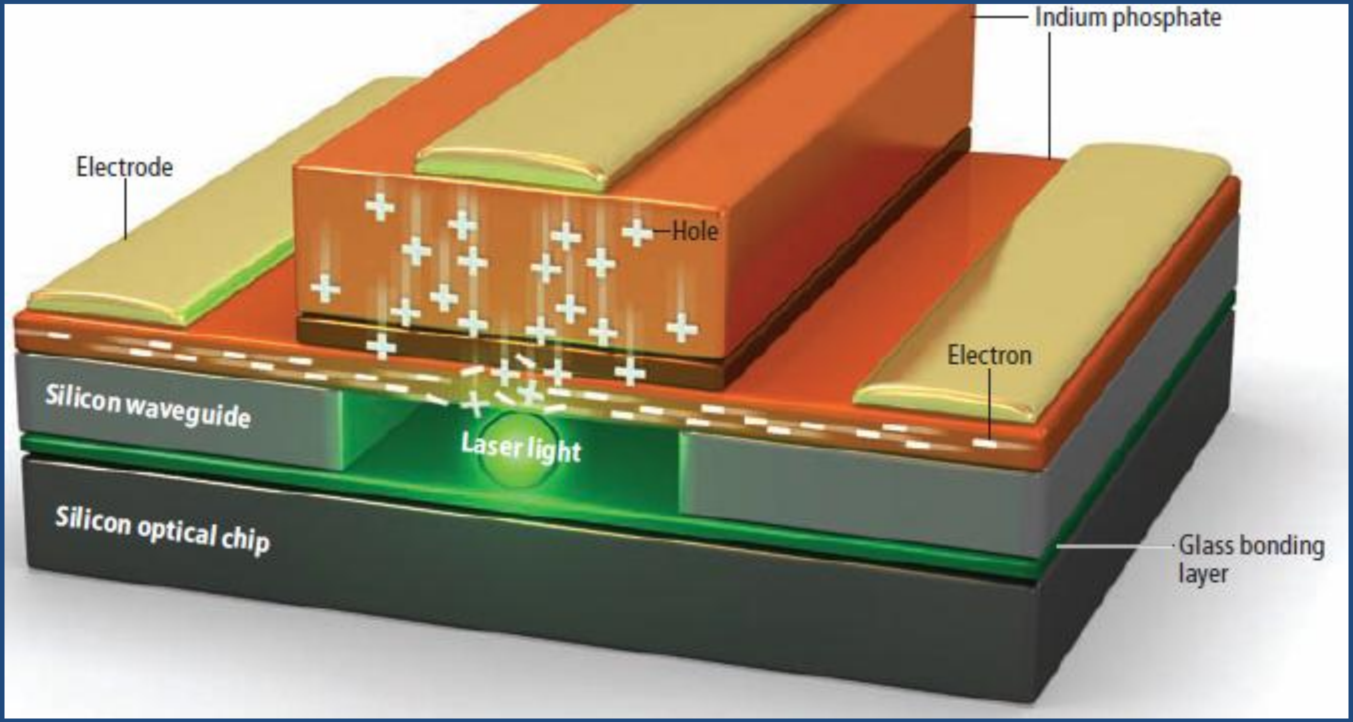
Molecular junction experiments: Different techniques to contact molecules have to be further developed, improved and calibrated. In addition to present charge transport measurements, new probes and additional control parameters are requested such as inelastic tunneling spectroscopy, the controlled treatment of environmental coupling, noise, and light-induced phenomena in transport.

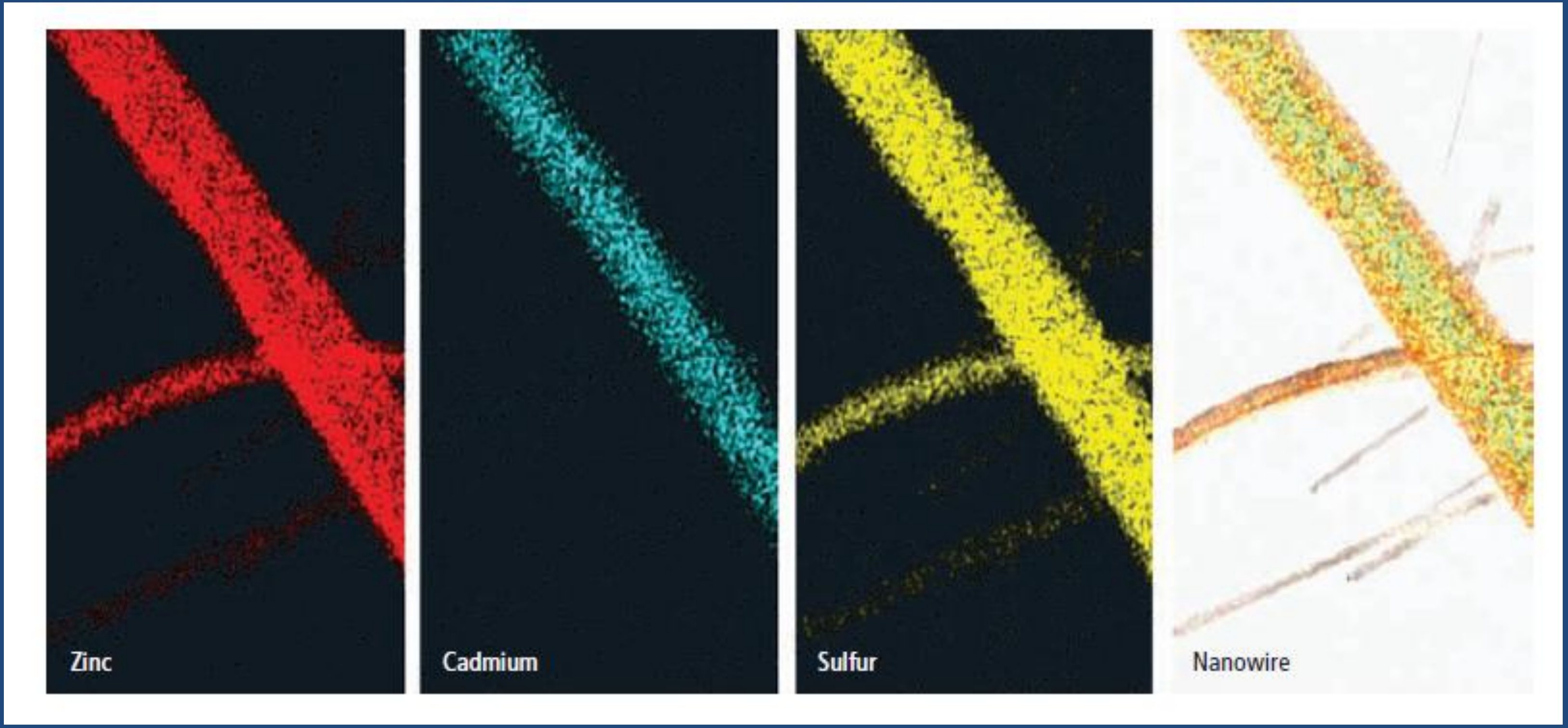
Scanning-probe experiments with molecules on surfaces: Experiments are requested, which correlate detailed spatial information (including engineering of the molecule-substrate coupling) with electronic transport properties. In addition, tip manipulations to achieve molecular junctions are supported. Purely structural information without the link to charge transport properties is disregarded.

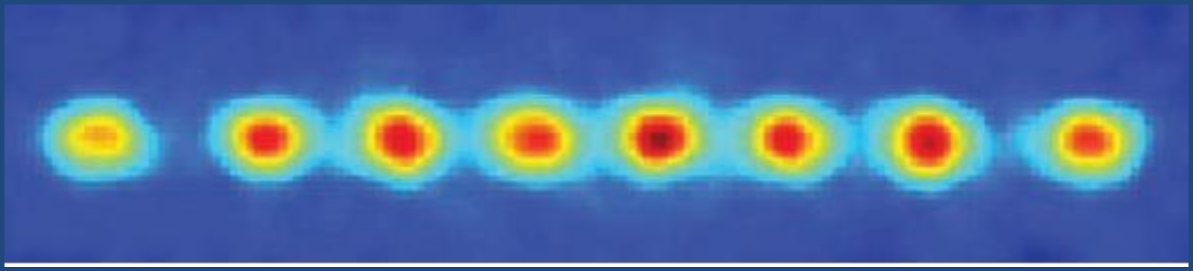
¿Haciendo grafeno

¿Pueden moléculas/macromoléculas orgánicas reemplazar al silicio como materiales en electrónica a escala nano y molecular?

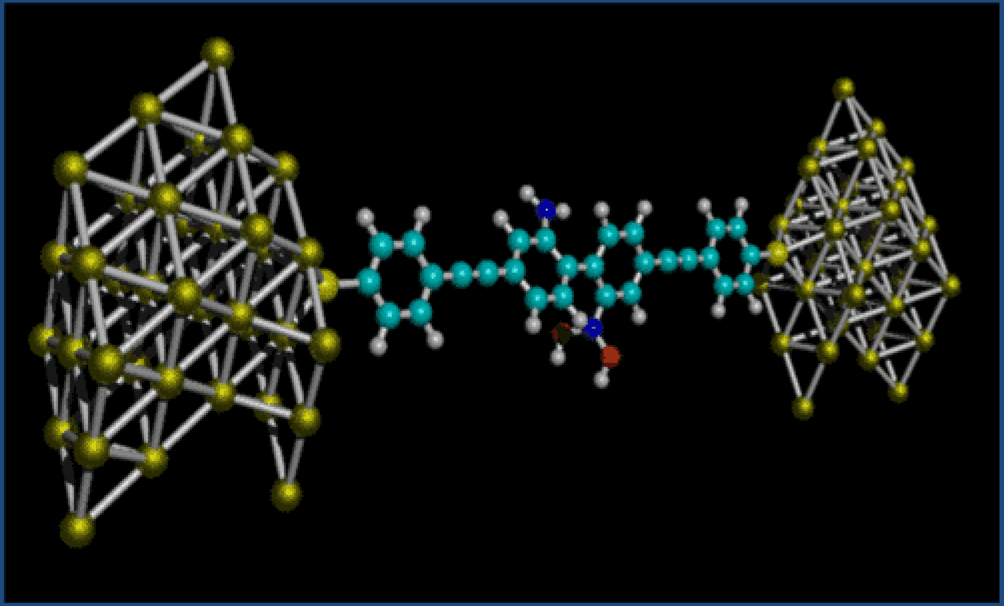



Indium phosphate
Electrode
Hole
Electron
Silicon waveguide
Laser light
Silicon optical chip
Glass bonding layer


Zinc
Cadmium
Sulfur
Nanowire



Transporte de corriente a escala…molecular



http://www.quantrans.org/introduction/

Molecular Electronics is recognized as a key candidate to succeed the silicon based technology once we have arrived at the end of the semiconductor roadmap. The use of organic molecules in nanoscale nonlinear circuits offers many opportunities for new types of devices, which will differ in fabrication, functionality, and architecture. But even the fundamental question how electrical current flows across a single molecule is not satisfactorily understood. The common goal of this SPP is to strengthen the obligatory fundamental research activity in the field by combining

Molecular Electronics

UNIONES MOLECULARES : Como mover cargas entre moleculas a voluntad?Molecular In addition to present charge transport measurements, new probes and additional control parameters are requested such as inelastic tunneling spectroscopy, the controlled treatment of environmental coupling, noise, and light-induced phenomena in transport.

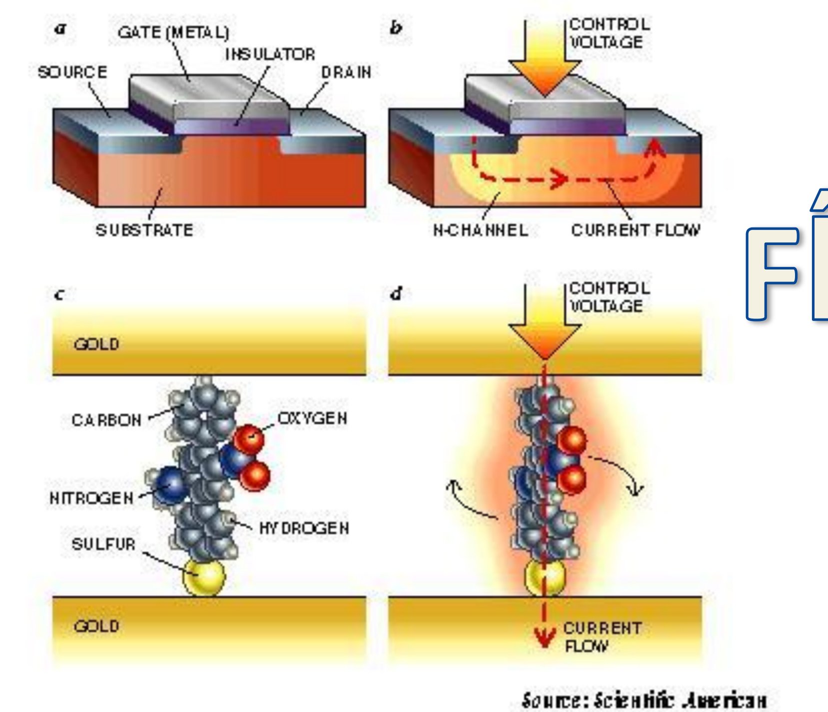
Correlacion entre la estructura molecular y el transporte de carga electrica entre las moleculas

Scanning-probe experiments with molecules on surfaces: Experiments are requested, which correlate detailed spatial information (including engineering of the molecule-substrate coupling) with electronic transport properties. In addition, tip manipulations to achieve molecular junctions are supported.

Estructuras hibridas y biomoleculas: Biorutas para autoensamblaje molecular y lograr funcionalidad electronica en DNA e hibridos de DNA This may include new concepts to control charge transport in DNA and in DNA hybrids. Carbon nanotubes might be employed as electrodes for molecular contacts.

Meta teorica is to devise new concepts and to design a computational machinery that allows for a **quantitative prediction of electronic transport properties** of individual molecules contacted to electrodes/substrates of a given

Electrónica Molecular



CONVENTIONAL MICROTRANSISTOR (a) has three terminals, known as the source, gate and drain. A positive voltage applied to the gate draws electrons to the insulator (b), enabling current to flow from the source to the drain. A molecule based on three benzene rings (c) was also used to switch an electric current. The center ring had asymmetric fragments, enabling it to be twisted by an electrical field (d). With a specific voltage applied, the electrical field twisted the molecule and permitted current to flow.

QUÍMICA

FÍSICA

INGENIERÍA

SISTEMAS A ESCAL MOLECULAR…LA BASE DE FUTUROS DISPOSITIVOS , CIRCUITOS Y SISTEMAS ELECTRONICOS?

Nanosensores,
Dispositivos optoelectronicos
Memorias
Switches (Interruptores)
Alambres.
?Como se inteconectarian estos sistemas electronicos molecualres?
Cadenas de polimeros conductores
Nanotubos de carbono

Nanoelectronic Devices: Challenges

http://www.youtube.com/watch?v=iNt8IdSi0q0&feature=PlayList&p=73D4BD6658E4E050&index=0&playnext=1

Surface to Bulk Atoms Ratio
Where the device ends and the system begins: the contacts intimately influence the properties of the system

Integration of hard and soft materials
Fabrication and synthesis

Fundamental challenges

http://www.youtube.com/watch?v=iNt8IdSi0q0&feature=PlayList&p=73D4BD6658E4E050&index=0&playnext=1

ADINA SCOTT

Device with advanced functionality by integrating semiconductors and organics

Organicos

Monocapas moleculares

Tintas Moleculas que emiten luz (fluorescencia)

Biomoleculas

Propiedades electronicas moleculares

Semiconductores

Microfabricacion

Transporte de electrones

Como depositar un metal en un sist

Modified Schotky diode

Highly doped semiconductor/mono

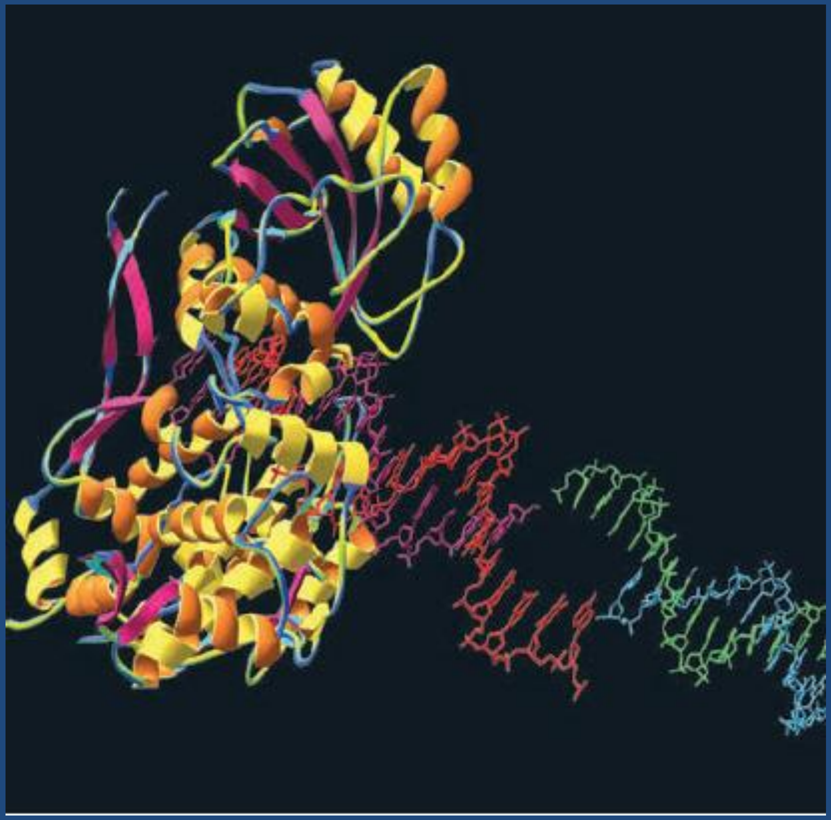
El pasado de La Electronica Molecular

Hacer mover electrones a traves de una o un paquete de moleculas unidas a un alambre metalico

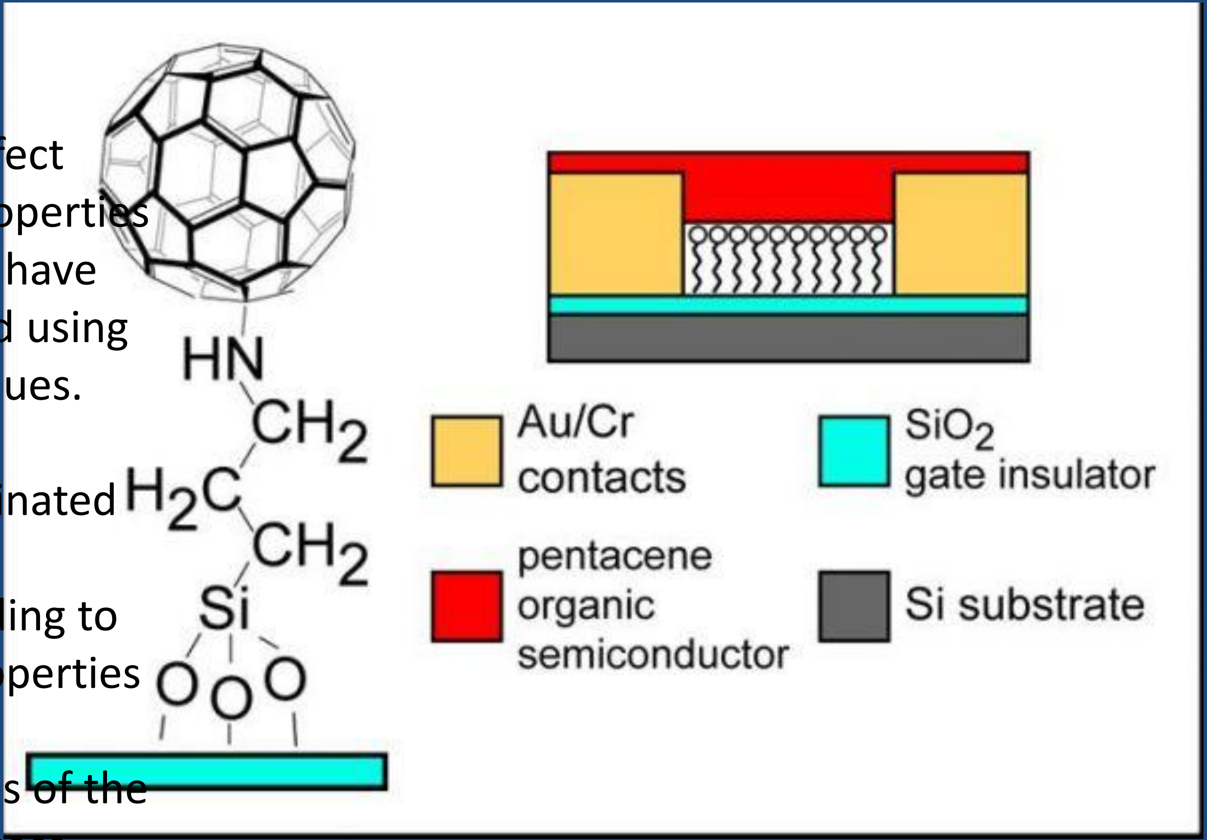
http://video.google.com/videoplay?docid=-2130436868883098726#

http://www.youtube.com/watch?v=YcqvJI8J6Lc&feature=related

Energía ~~del Futuro~~ de Ahora



Monocapas autoensambladas



The electronic behavior of field effect transistors (above) depends on properties of interfaces, including, Park et al. have found, electronic states introduced using self-assembled monolayer techniques.

States associated with a C60-terminated monolayer (at left) participate in photoinduced charge transfer leading to large changes in the electronic properties of a pentacene transistor.

The transistors are sensitive probes of the physics of the charge transfer process, which is the essential step in organic optoelectronic devices including light emitting diodes and solar cells. B. Park, et al., Adv. Mater. 19, 4353 (2007)

http://www.mrsec.wisc.edu/MR--Nugget.php?ID=16

Electricidad de Fuentes Renovables

Situación hipotética: Suministro de electricidad en California a partir de fuentes renovables durante un dia típico de verano.

Jacobson, M. *Scientific American* Noviembre 2009, 58-65.

Notas Finales

Overall, several properties on molecular devices must be investigated before a summary conclusion but it is
J. Comput. Theor. Nanosci. 7, 1–14, 2010 11
REVIEW
Molecular Electronics Devices: Short Review *Nero et al.*
possible stress out a few guidelines that deserve further analyses: (i) How is the behavior of conductance with temperature?; (ii) Is noise a critical point for molecular electronics?; (iii) How the heating process affects molecule/junction properties?; (iv) Are chemical changes in the molecule provoked by current? (v) How the molecular geometry is modified by the electronic transport?

Gracias por su tiempo

walter.torres@correounivalle.edu.co