

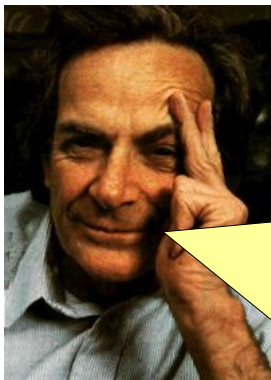
Nanomaterials

나노소재에 관한 개괄적인 소개

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I. Introduction of Nanotechnology

“There’s plenty of room at the bottom.”

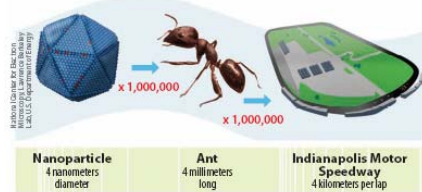
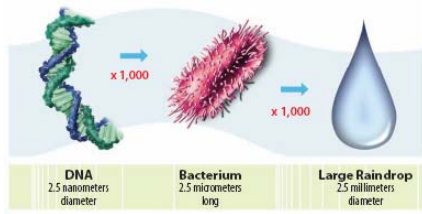


“I don’t know how to do this on a small scale in a practical way, but I do know that computing machines are very large; they fill rooms. Why can’t we make them very small, make them of little wires, little elements-and by little, I mean little. For instance, the wires should be 10 or 100 atoms in diameter, and the circuits should be a few thousand angstroms across...there is plenty of room to make them smaller. There is nothing that I can see in the physical laws that says the computer elements cannot be made enormously smaller than they are now. In fact, there may be certain advantages.”

- lectured by Feynman, R. (1959)

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Nanoscale 3 Examples



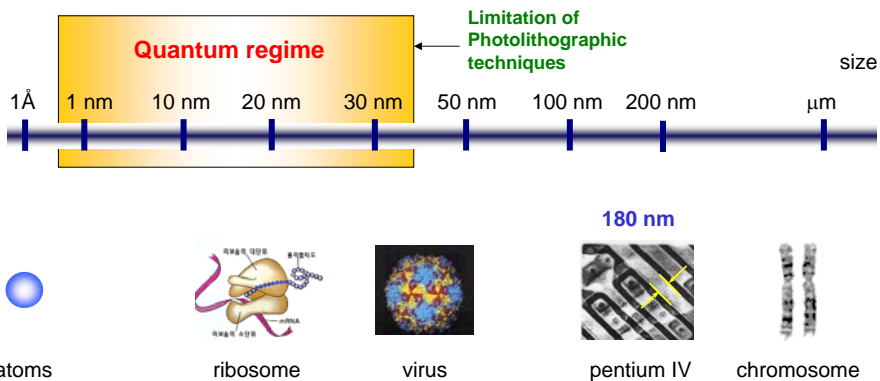
The Nanoscale in Perspective

How small is a nanometer? By definition, one nanometer is a billionth of a meter, but that's a hard concept for most of us to grasp. Here are some other ways to think about how small a nanometer is:

- A sheet of paper is about 100,000 nanometers thick.
- If you're a blond, your hair is probably 15,000 to 50,000 nanometers in diameter. If you have black hair, its diameter is likely to be between 50,000 and 180,000 nanometers.
- There are 25,400,000 nanometers per inch.
- A nanometer is a millionth of a millimeter.

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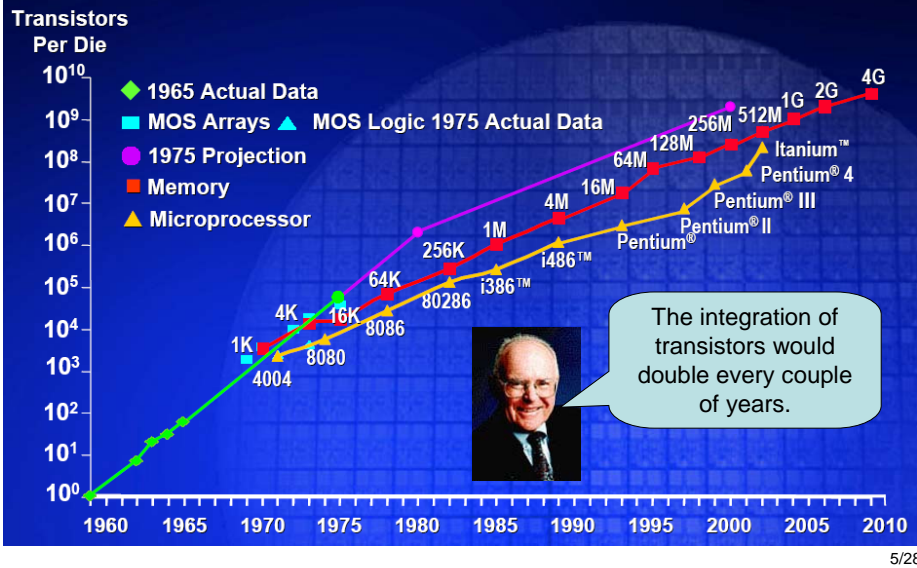
Paradigm Shift to the Nanosize



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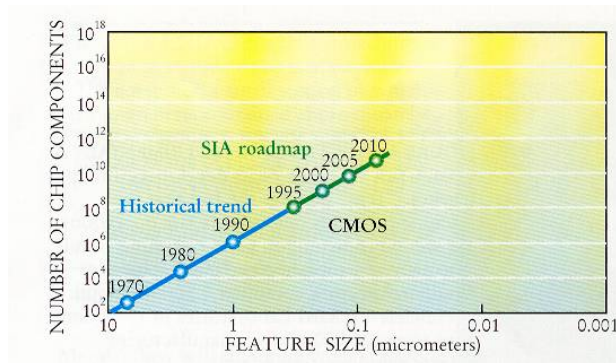
Moore's Law

Integrated Circuit Complexity



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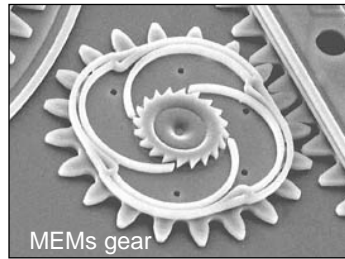
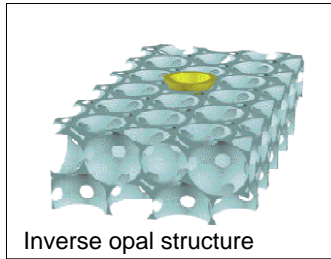
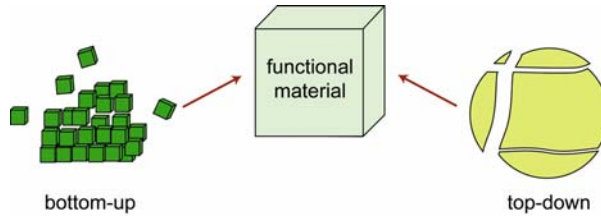
Physical Limitation of CMOS Structure



- Scaling of electron devices expects that only **8 electrons** are required for on/off by 2010 (1000 electron/bits today).
 - Manufacturing cost : **\$50 billion** / FAB
- } Limitation ??

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The Bottom-up Approach



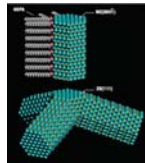
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II. Nano-Building Blocks

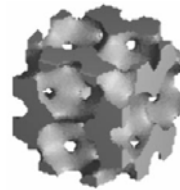
3. Carbon nanotubes



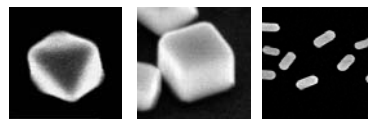
1. Quantum dots & wires



4. Silica nanostructures

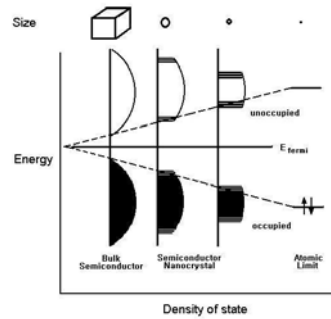
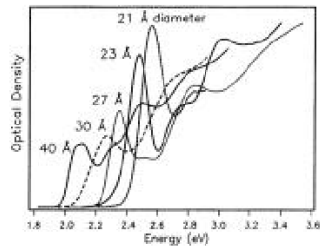


2. Metal nanoparticles



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1. Quantum Dots & Wires



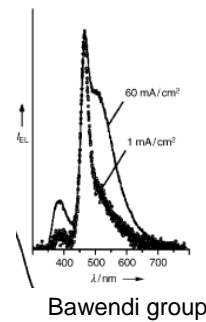
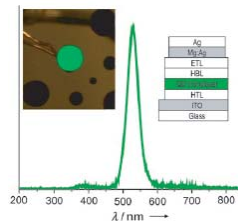
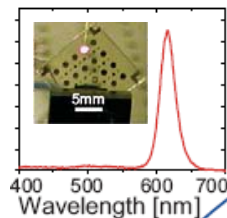
- The band gap in CdSe can be tuned from 2.6 (blue) to 1.7 eV (deep red) as the size is varied from 20 to 200 Å.

Bawendi, M. G. *et al. J. Am. Chem. Soc.* **1993**, 115, 8706.

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RGB-Emitting QD-LEDs

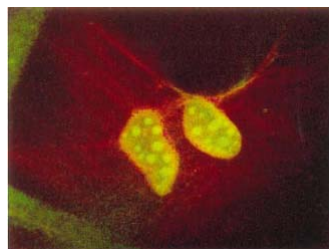
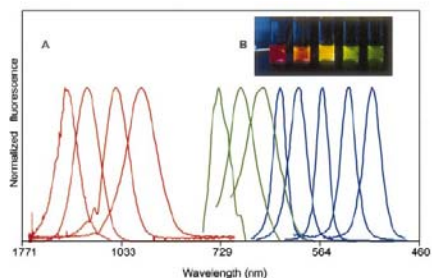
- **Red-emitting LED:** (CdSe)ZnS core-shell NCs, 615 nm, $\eta_{EX} > 2\%$
band gaps of CdSe = 1.94 eV
- **Green-emitting LED:** $(Cd_xZn_{1-x})Se$ $Cd_yZn_{1-y}S$ core-shell NCs, 527 nm,
 η_{EX} 0.5%; band gaps of ZnSe = 2.94 eV
- **Blue-emitting LED:** 4.7 nm (CdS)ZnS core-shell NCs, 459 nm, η_{EX} 0.1%
band gaps of CdS = 2.42 eV



Bawendi group

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Fluorescent Biological Labels



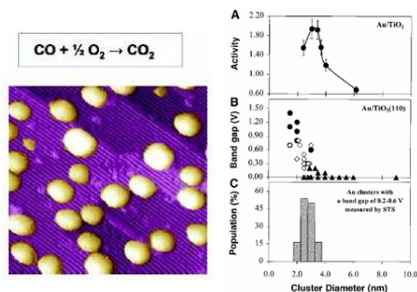
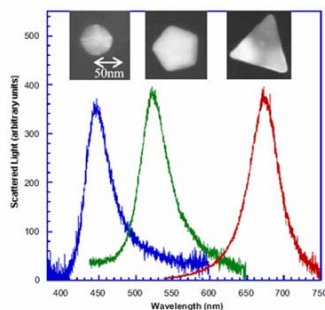
- Compared with conventional fluorophores, the nanocrystals have a **narrow, tunable, symmetric emission spectrum** and are photochemically **stable**.
- The **CdSe-CdS core-shell nanocrystals enclosed in a silica shell** were tailored to interact with the biological sample through a strong interaction.

Alivisatos, A. P. *et al. Science* **1998**, *281*, 1201.

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2. Metal Nanoparticles

- **Optical properties** – surface plasmon waveguide, sensors
surface enhanced Raman spectroscopy (SERS)
(Ag, Au, Cu)
- **Catalytic properties** – fuel cell, deNO_x, high performance catalysts,
(Au, Pt, Pd, Rh)



Schultz, S. *et al. J. Chem. Phys.* **2002**, *116*, 6755.

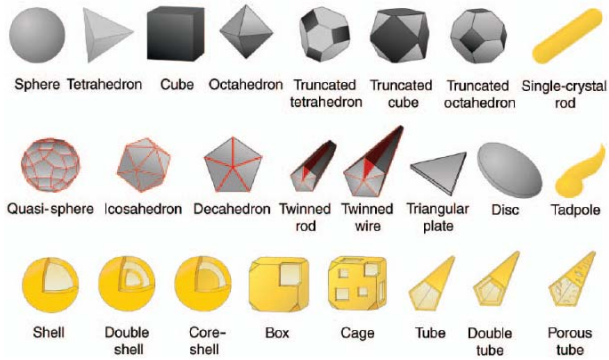
Goodman, D. W. *et al. Science* **1998**, *281*, 1647.

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Metal Nanostructure Shapes

- Many techniques such as e-beam, focused ion-beam, and nanosphere lithography are available for fabricating metallic nanostructures on solid supports, but still have a lot of problems for high-throughput fabrication.

- Solution-based chemical synthesis of metallic nanostructures can generate various shapes and compositions with well-defined structures.

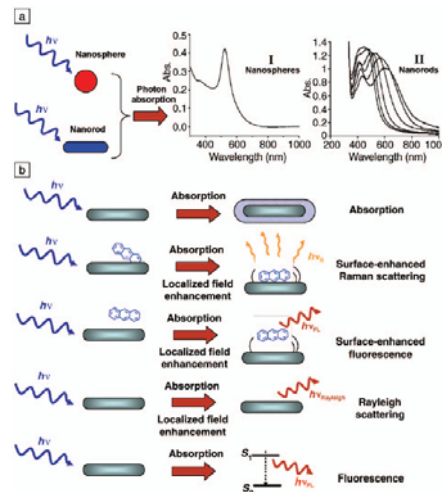


Xia, Y. *et al. MRS Bull.* **2005**, 30, 338.

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Optoelectric Behaviors of the Nanorods

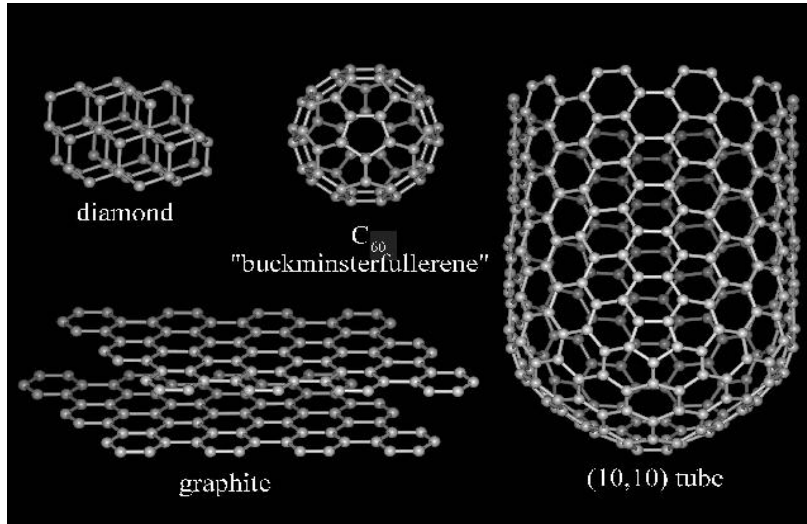
- LSPR excitation leads to **localized electromagnetic fields**, at the nanoparticle surface, and Rayleigh scattering.
- Local electromagnetic fields enhance signals in **surface-enhanced Raman spectroscopy (SERS)** and **fluorescence (SEF)**.



Murphy, C. J. *et al. MRS Bull.* **2005**, 30, 349.

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3. Carbon Nanotubes (Fullerenes)

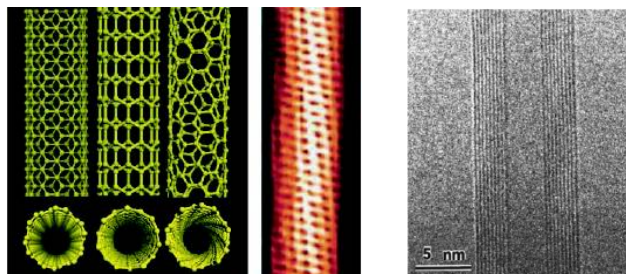


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Carbon Nanotubes

Carbon nanotubes : one of the purest carbon forms

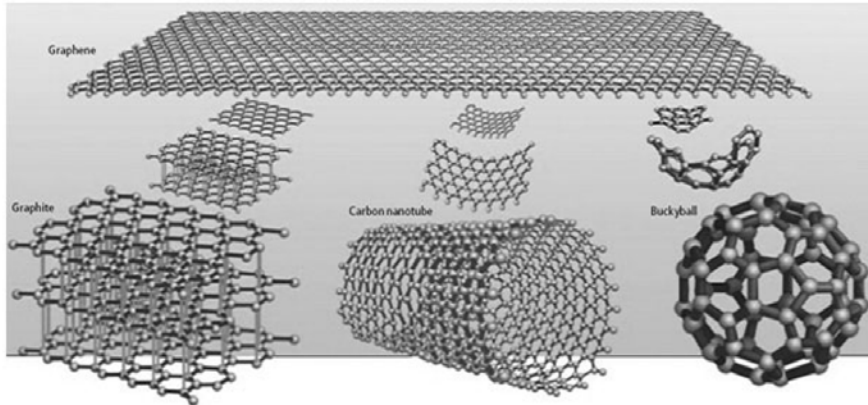
- Single-walled nanotubes (SWNTs)
 - a single graphite sheets wrapped into a cylindrical tube
- Multi-walled nanotubes (MWNTs)
 - an array of concentrically nested nanotubes



Baughman, R. H. *et al.* *Science* **2002**, 297, 787.

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Carbon Only Materials



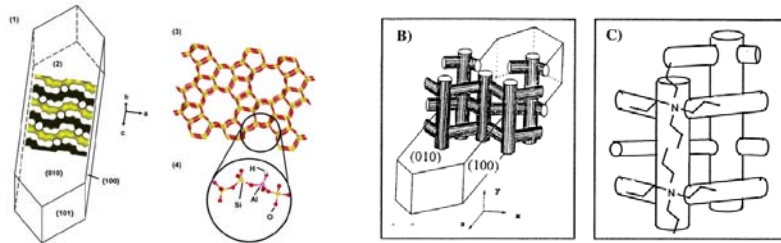
1985년 0차원, 1991년 1차원, 2004년 2차원 발견
탄소만으로 모든 차원을 다 구현할 수 있음!

신현석, *화학세계*, 2009 (2), 32-37.

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4. Silica Nanostructures

- **Zeolites**: crystalline aluminosilicates containing pores and cavities of molecular dimensions
- structures: porous with regular arrays of channels and cavities (ca. 3–15 Å) resulting from the periodic replacement of $[AlO_4]^-$ for $[SiO_4]$ i.e.) MFI type structure (with tetrapropylammonium cations as templates) two types of interconnected channels by 10 tetrahedral units



ZSM-5

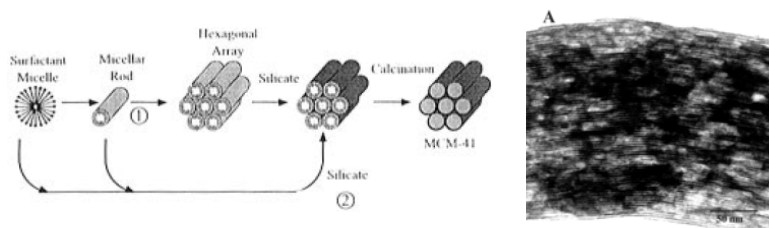
Silicalite-1

C. S. Cundy *et al.*, *Chem. Rev.* 2003, 103, 663.

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Mesoporous Materials

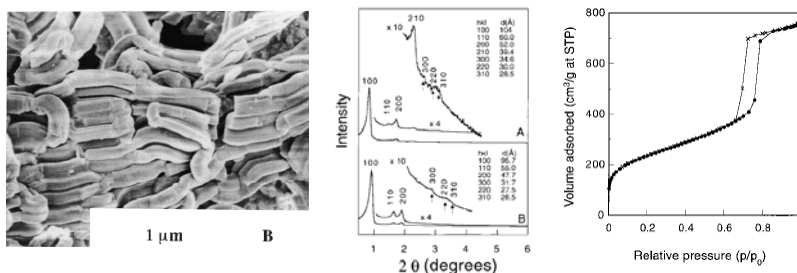
- The introduction of **supramolecular assemblies** (micellar aggregates, rather than molecular species) as templating agents permitted a new family of mesoporous silica and aluminosilicate compounds (**M41S**) to be obtained by Mobil research group in 1992.
- close relationship between **biology and chemistry of organized matter**: Nature employs macromolecules and microstructures to control the nucleation and growth of mineral compounds or organomineral hybrid composites.
- potential candidates in the fields of catalysis, optics, photonics, sensors, separation, drug delivery, sorption, acoustic or electrical insulation, etc.



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SBA Silica Series

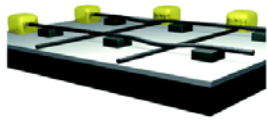
- Use of amphiphilic triblock copolymers has resulted in the preparation of well-ordered hexagonal mesoporous silica structures (SBA-15) with uniform pore sizes up to approximately 300 angstrom.
- The SBA -15 materials are synthesized in acidic media to produce highly ordered, two dimensional hexagonal silica-block copolymer mesophases.



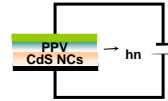
G. D. Stucky *et al.*, *Science* **1998**, 279, 548.

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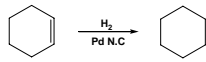
III. Applications of Nanomaterials



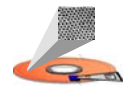
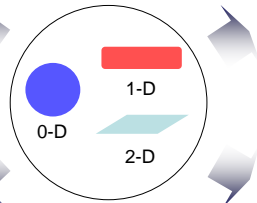
Electronic Devices



Light emitting diode or Photovoltaic devices



Nano-catalysts



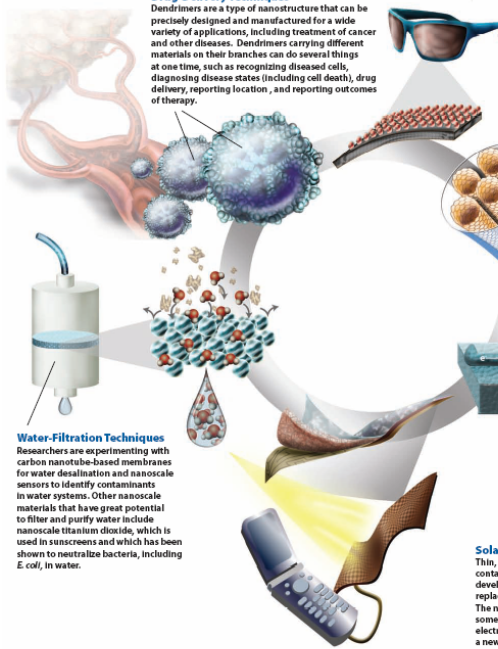
Magnetic bit



Biological imaging and detection

Drug-Delivery Techniques

Dendrimers are a type of nanostructure that can be precisely designed and manufactured for a wide variety of applications, including treatment of cancer and other diseases. Dendrimers carrying different materials on their branches can do several things at one time, such as recognizing diseased cells, diagnosing disease states (including cell death), drug delivery, reporting location, and reporting outcomes of therapy.



Nanofilms

Different nanoscale materials can be used in thin films to make them water-repellent, anti-reflective, self-cleaning, ultraviolet or infrared-resistant, anti-fog, anti-microbial, scratch-resistant, or electrically conductive. Nanofilms are used now on eyeglasses, computer displays, and cameras to protect or treat the surfaces.

Nanotubes

Carbon nanotubes (CNTs) are used in baseball bats, tennis racquets, and some car parts because of their greater mechanical strength at less weight per unit volume than that of conventional materials. Electronic properties of CNTs have made them a candidate for flat panel displays in TVs, batteries, and other electronics. Nanotubes for various uses can be made of materials other than carbon.

Nanoscale transistors

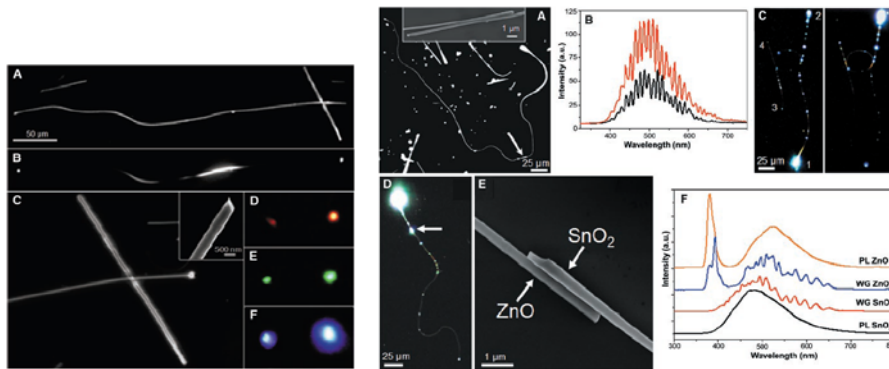
Transistors are electronic switching devices where a small amount of electricity is used like a gate to control the flow of larger amounts of electricity. In computers, the more transistors, the greater the power. Transistor sizes have been decreasing, so computers have become more powerful. Until recently, the industry's best commercial technology produced computer chips with transistors having 65-nanometer features. Recent announcements indicate that 45-nanometer feature technology soon will be here.

Solar Plastics

Thin, flexible, lightweight rolls of plastics containing nanoscale materials are being developed that some people believe could replace traditional solar energy technologies. The nanoscale materials absorb sunlight and, in some cases, indoor light, which is converted into electrical energy. Thin-film solar cells paired with a new kind of rechargeable battery also are the subject of research today. This technology will be more widely used when researchers learn how to capture solar energy more efficiently.

Nanoribbon Waveguide

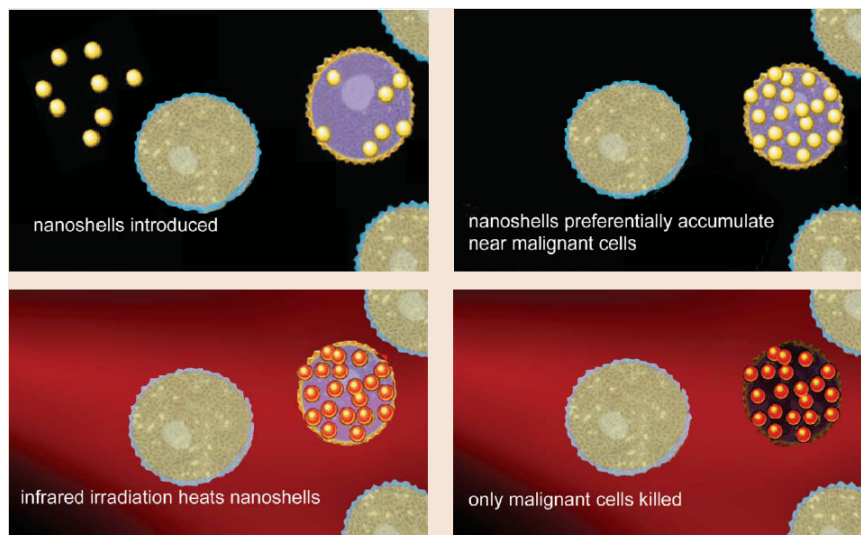
- Individual SnO₂ nanoribbons could act as **subwavelength optical waveguides**.
- Physical contact between nanowire light sources and ribbon waveguides demonstrated the assembly of **nanowire photonic circuitry**.



Yang, P. *et al. Science* **2004**, 305, 1269.

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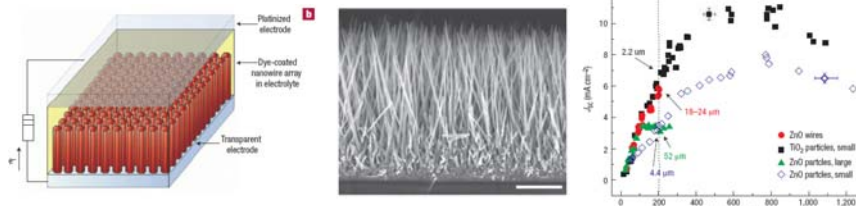
Cancer Treatment by Nanoshells



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Nanowire Dye-Sensitized Solar Cells

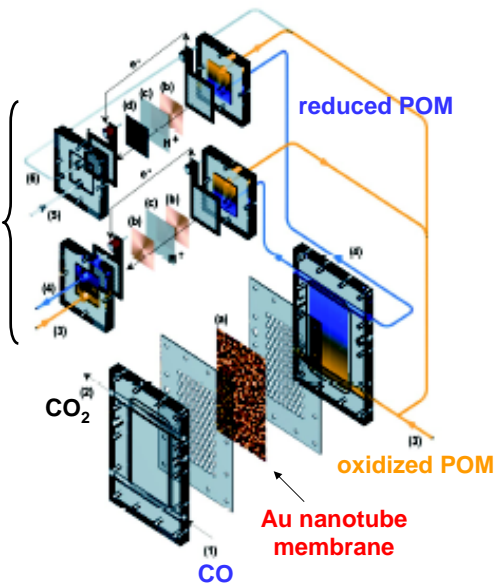
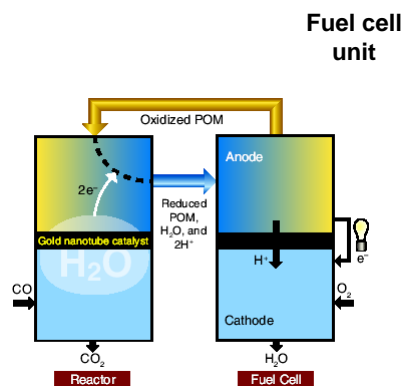
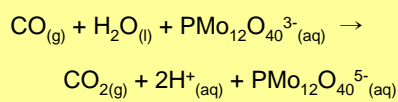
- The dye-sensitized solar cell in which a dense array of **oriented, crystalline ZnO nanowires** was employed.
- The direct electrical pathways provided by the nanowires ensure **the rapid collection of carriers**, and a full sun **efficiency of 1.5%** was demonstrated.



Yang, P. *et al. Nat. Mat.* **2005**, *4*, 455.

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Powering Fuel Cells with CO



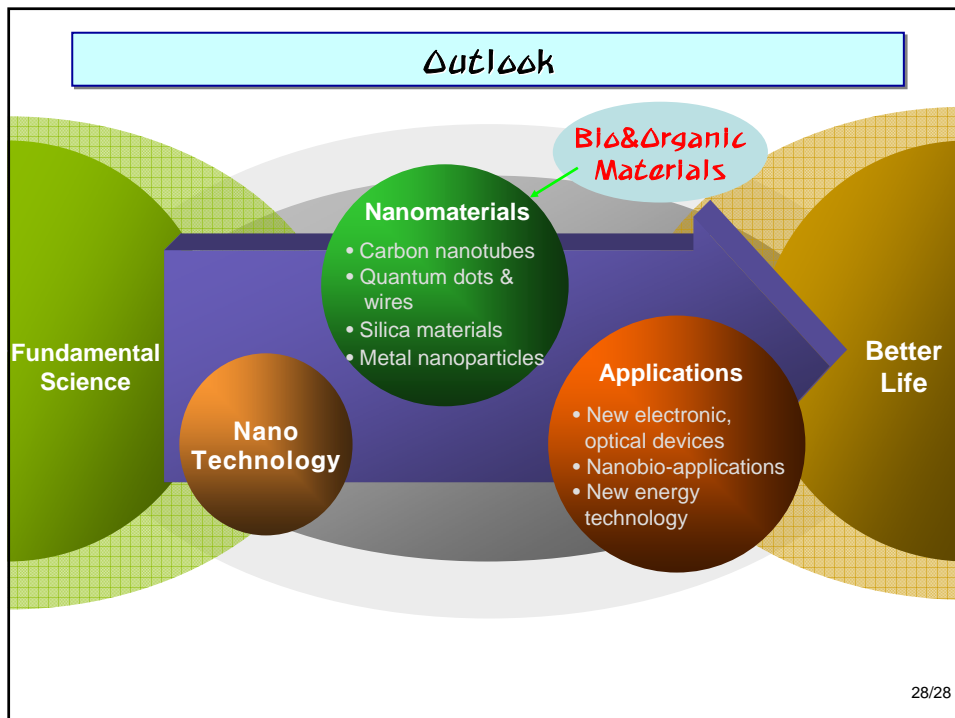
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Ripple Effects of Nanotechnology

	Market billion\$/yr	Commercialization	Application fields
Materials	340	less than 10 yrs	- materials with high performance and functions
Semiconductor	300~350	10~15 yrs	- semiconductors with terra-bit resolution
Pharmacy	180	10~15 yrs	- 50% Pharmaceuticals with nanotechnology
Chemicals Petroleum	100	10~15 yrs	- Nanostructured catalysts for petroleum and chemical plants
Transport	70	less than 10 yrs	- Nanomaterials and nanoparts for vehicles and airplanes

NSF, "National Nanotechnology Initiative", 2000. 7.

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