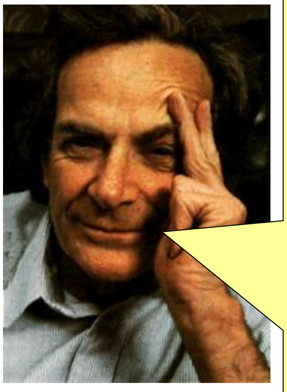
Nanomaterials

나노소재 에 관한 개괄적인 소개

1/28

I. Introduction of Nanotechnology

"There's plenty of room at the bottom."

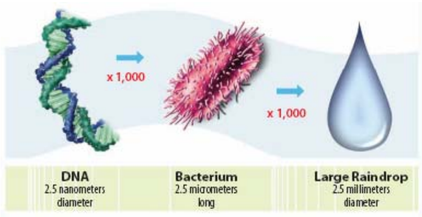


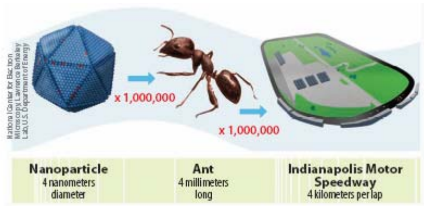
"I don't know how to do this on a small scale in a practical way, but I do know that computing machines are very large; they fill rooms. Why can't we make them very small, make them of little wires, little elements-and by little, I mean little. For instance, the wires should be 10 or 100 atoms in diameter, 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)

2/28

Nanoscale 3 Examples



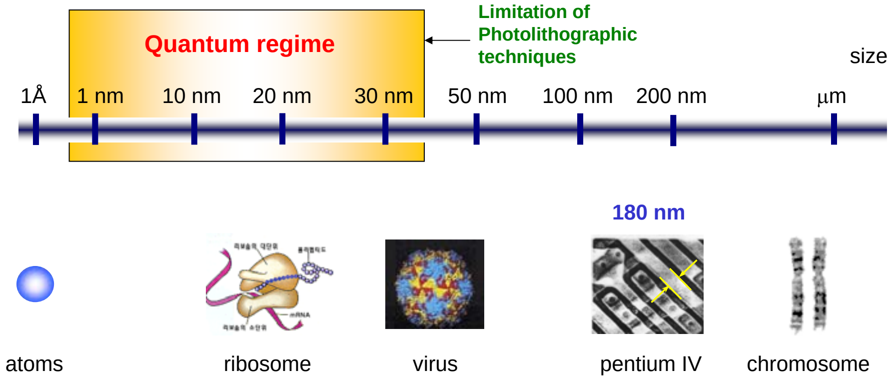


The Nanoscale in Perspective

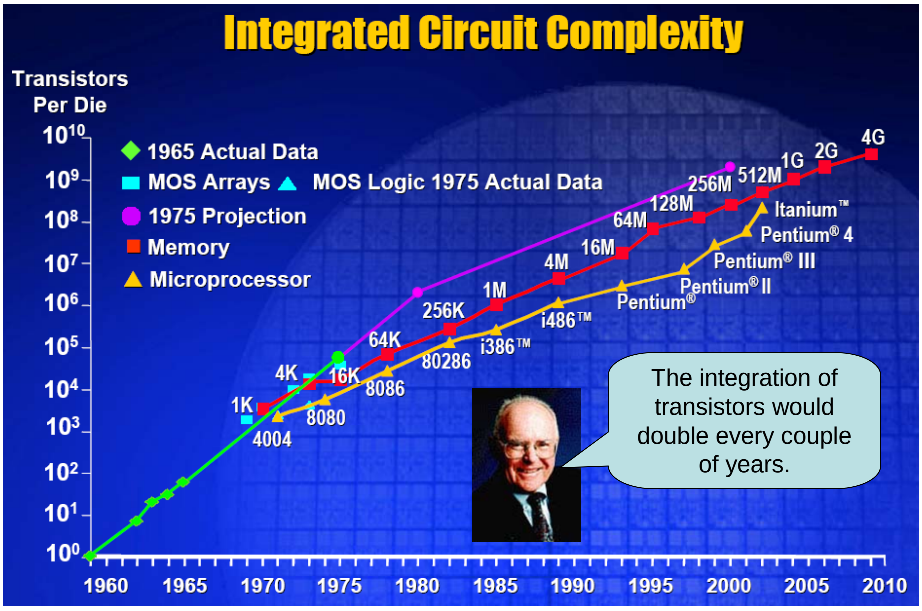
How small is a nanometer? By definition, one nanometer is a billionth of a meter, but that's a hard concept for most of us to grasp. Here are some other ways to think about how small a nanometer is:

- 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.

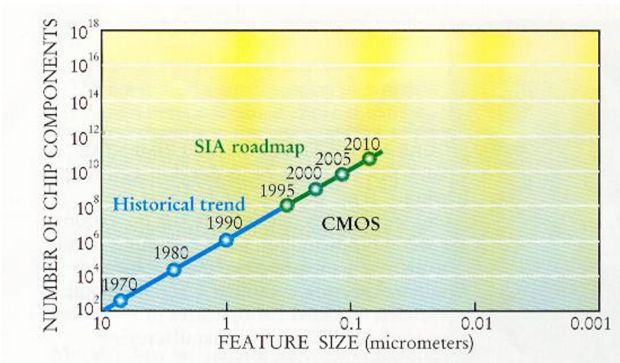
Paradigm Shift to the Nanosize



Moore's Law



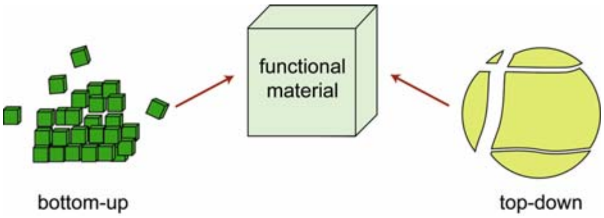
Physical Limitation of CMOS Structure

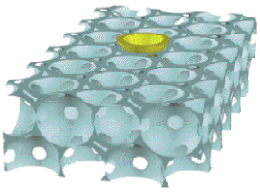


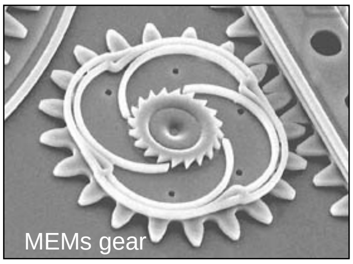
- Scaling of electron devices expects that only 8 electrons are required for on/off by 2010 (1000 electron/bits today).
- Manufacturing cost : $50 billion / FAB

} Limitation ??

The Bottom-up Approach



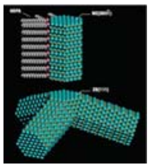

Inverse opal structure

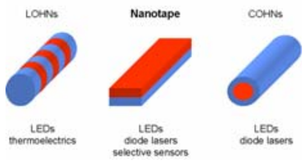

MEMs gear

II. Nano-Building Blocks

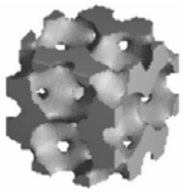
3. Carbon nanotubes

1. Quantum dots & wires

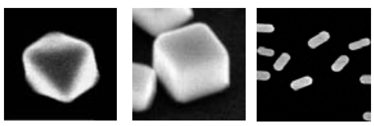




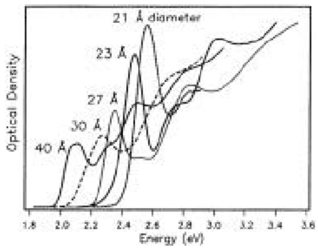
4. Silica nanostructures

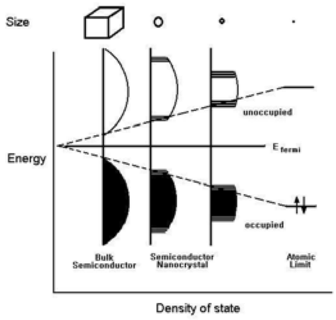


2. Metal nanoparticles



1. Quantum Dots & Wires





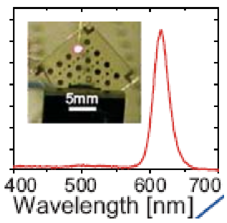
- The band gap in CdSe can be tuned from 2.6 (blue) to 1.7 eV (deep red) as the size is varied from 20 to 200 Å.

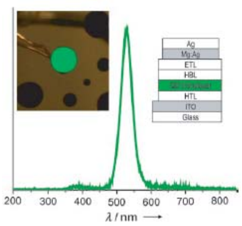
Bawendi, M. G. *et al. J. Am. Chem. Soc.* **1993**, *115*, 8706.

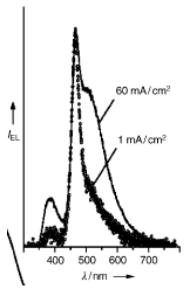
9/28

RGB-Emitting QD-LEDs

- Red-emitting LED: (CdSe)ZnS core-shell NCs, 615 nm, η_{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



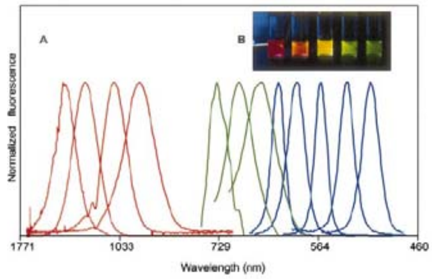


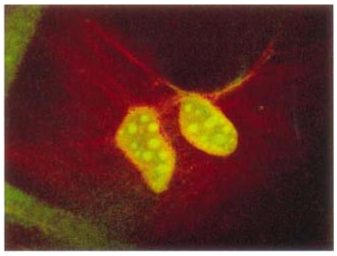


Bawendi group

10/28

Fluorescent Biological Labels





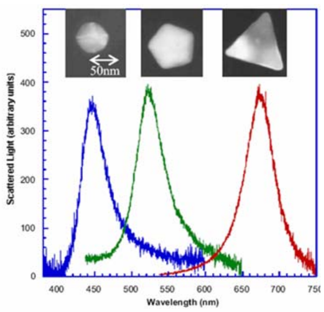
- Compared with conventional fluorophores, the nanocrystals have a narrow, tunable, symmetric emission spectrum and are photochemically stable.
- The CdSe-CdS core-shell nanocrystals enclosed in a silica shell were tailored to interact with the biological sample through a strong interaction.

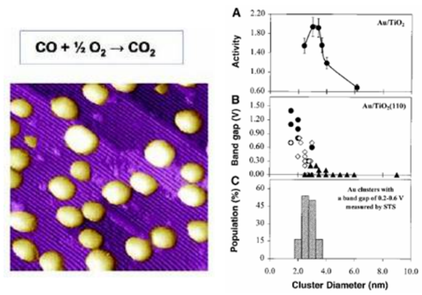
Alivisatos, A. P. *et al. Science* **1998**, *281*, 2013.

11/28

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)



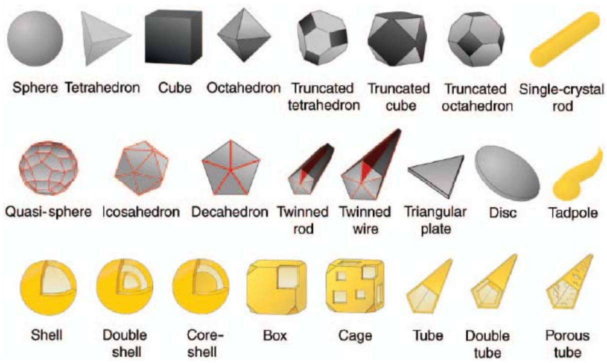


Schultz, S. *et al*. *J. Chem. Phys.* **2002**, *116*, 6755. Goodman, D. W. *et al*. *Science* **1998**, *281*, 1647.

12/28

Metal Nanostructure Shapes

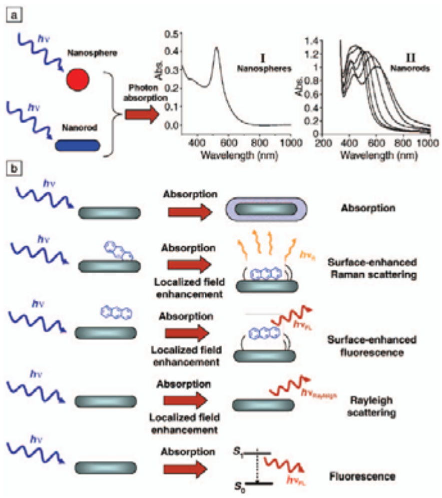
- Many techniques such as e-beam, focused ion-beam, and nanosphere lithography are available for fabricating metallic nanostructures on solid supports, but still have a lot of problems for high-throughput fabrication.
- Solution-based chemical synthesis of metallic nanostructures can generate various shapes and compositions with well-defined structures.



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

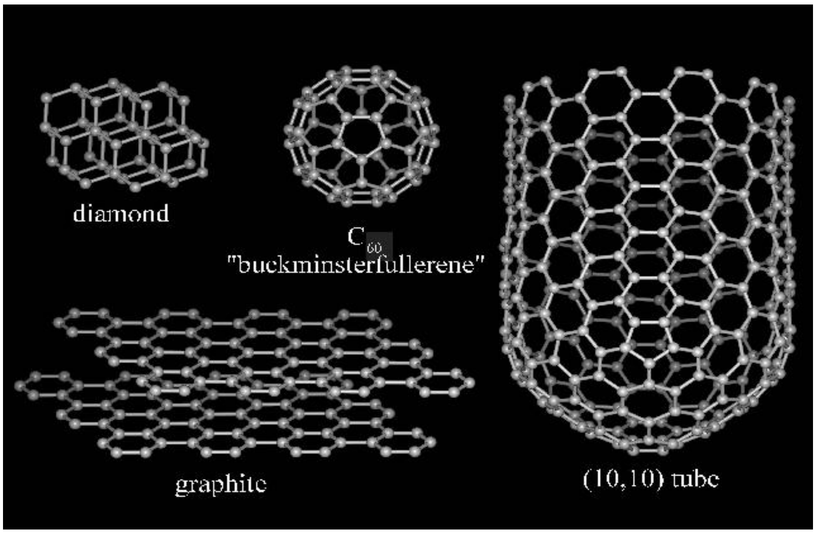
Optoelectric Behaviors of the Nanorods

- 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.

3. Carbon Nanotubes (Fullerenes)

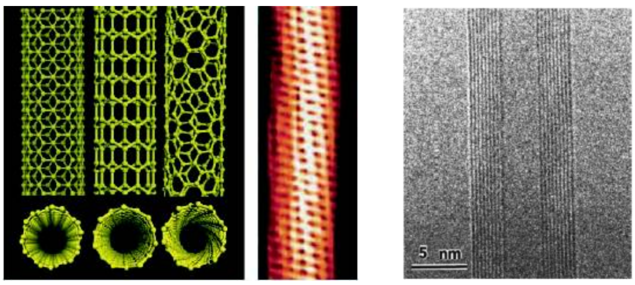


15/28

Carbon Nanotubes

Carbon nanotubes : one of the purest carbon forms

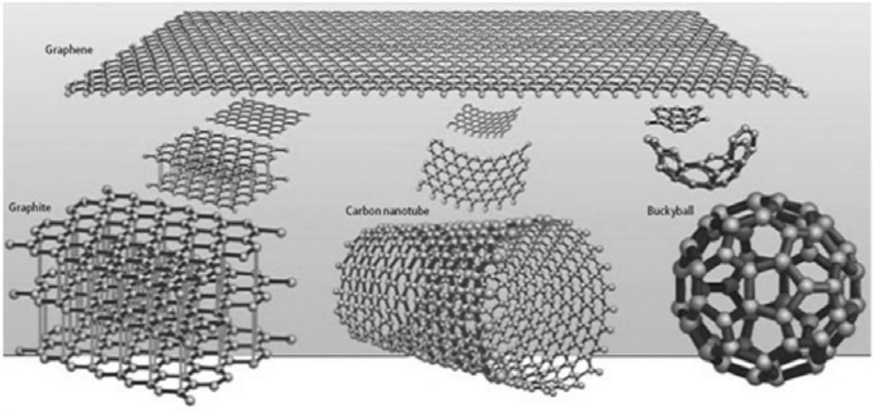
- Single-walled nanotubes (SWNTs)
    - a single graphite sheets wrapped into a cylindrical tube
- Multi-walled nanotubes (MWNTs)
    - an array of concentrically nested nanotubes



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

16/28

Carbon Only Materials



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

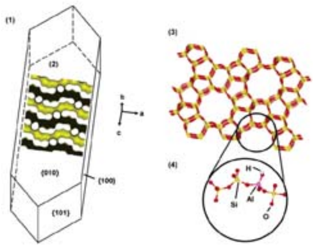
신현석, *화학세계*, **2009** (*2*), 32-37.

4. Silica Nanostructures

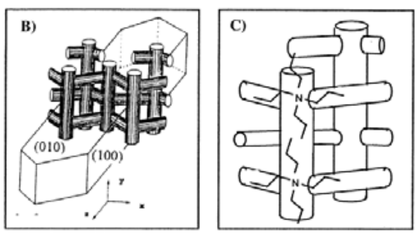
• **Zeolites**: crystalline aluminosilicates containing pores and cavities of molecular dimensions

- 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

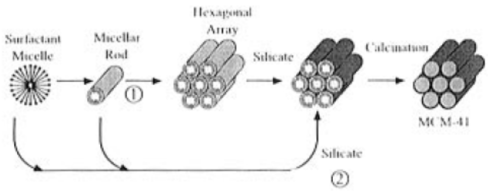


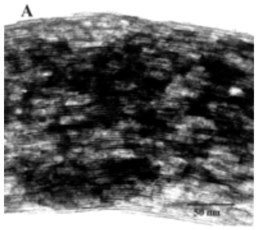
Silicalite-1

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

Mesoporous Materials

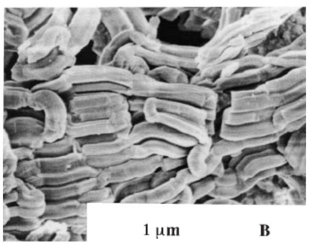
- The introduction of supramolecular assemblies (micellar aggregates, rather than molecular species) as templating agents permitted a new family of mesoporous silica and aluminosilicate compounds (M41S) to be obtained by Mobil research group in 1992.
- close relationship between biology and chemistry 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.

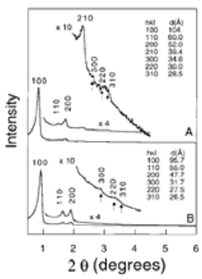


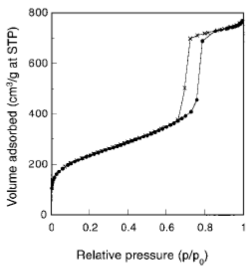


SBA Silica Series

- 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.

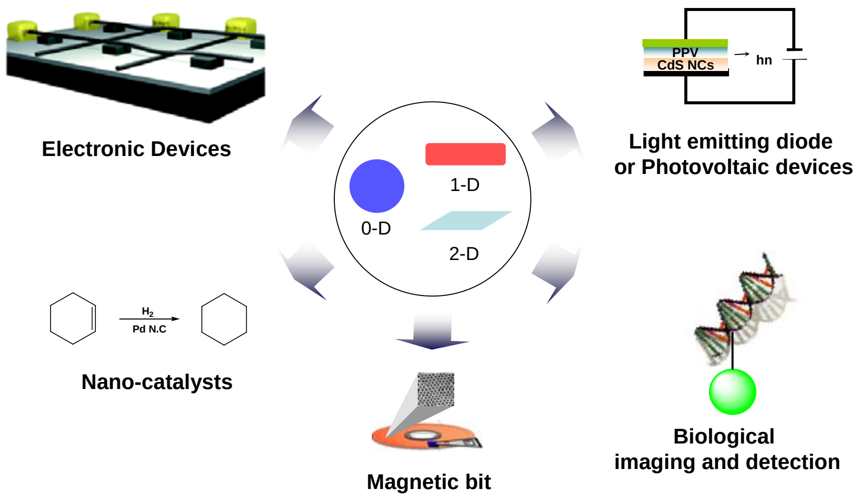




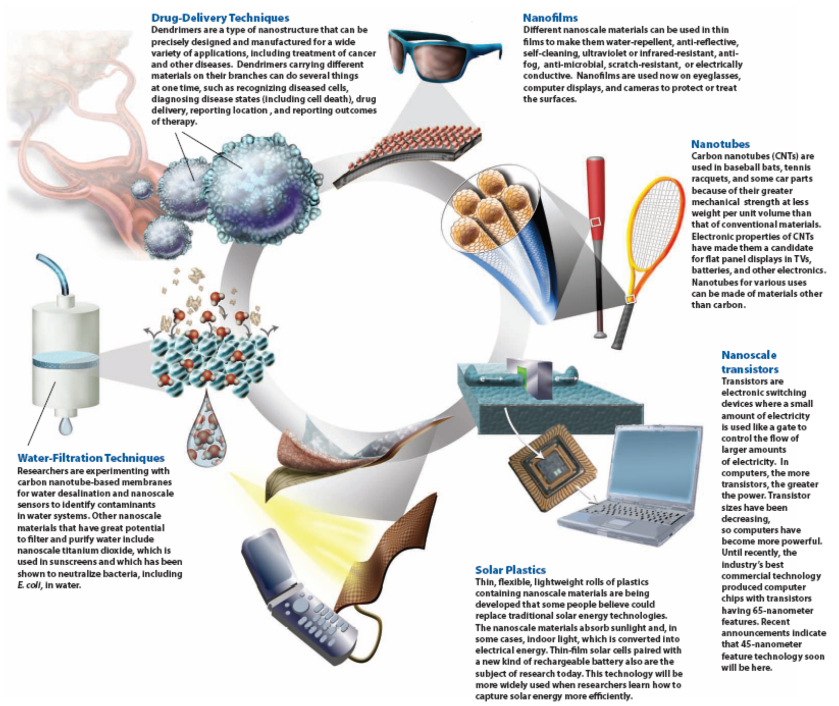


G. D. Stucky *et al.*, *Science* **1998**, *279,* 548.

III. Applications of Nanomaterials



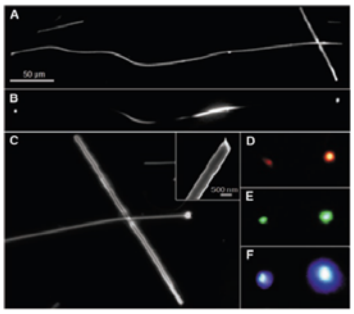
21/28

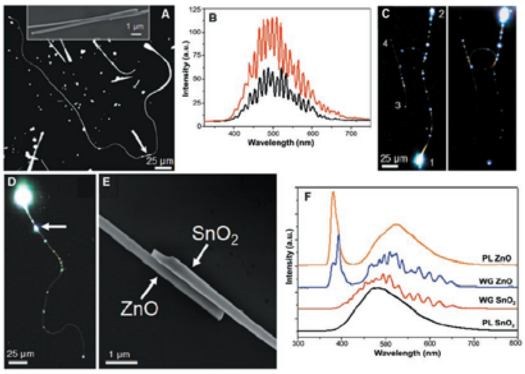


22/28

Nanoribbon Waveguide

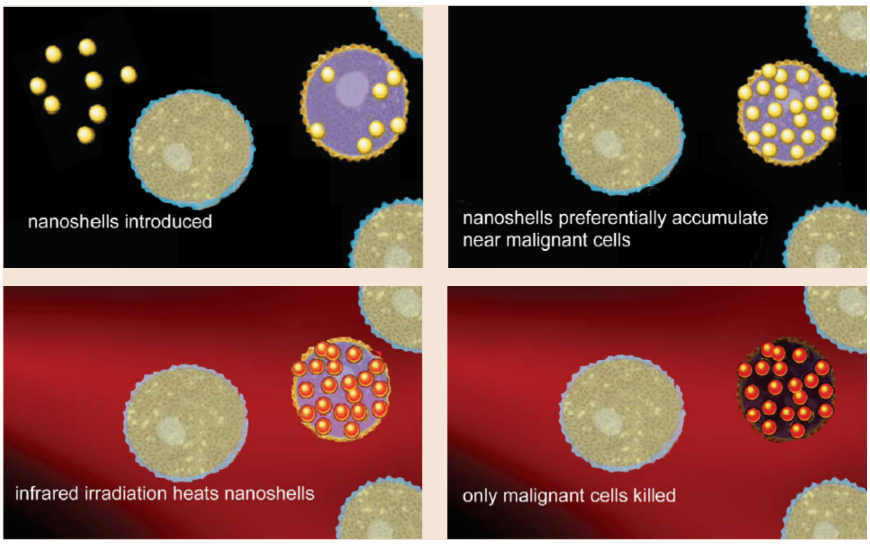
- Individual SnO_2 nanoribbons could act as subwavelength optical waveguides.
- Physical contact between nanowire light sources and ribbon waveguides demonstrated the assembly of nanowire photonic circuitry.





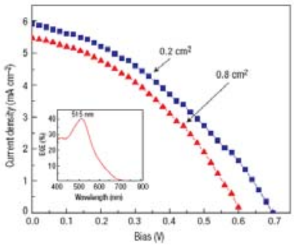
Yang, P. *et al. Science* **2004**, *305*, 1269.

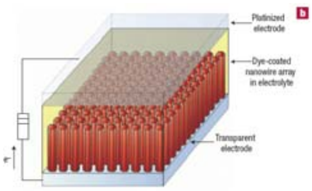
Cancer Treatment by Nanoshells

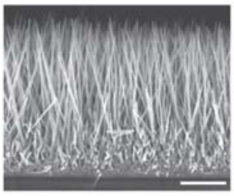


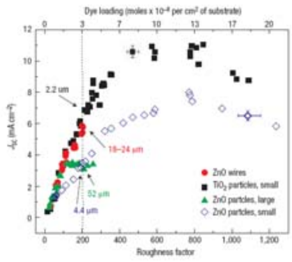
Nanowire Dye-Sensitized Solar Cells

- The dye-sensitized solar cell in which a dense array of oridented, 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.









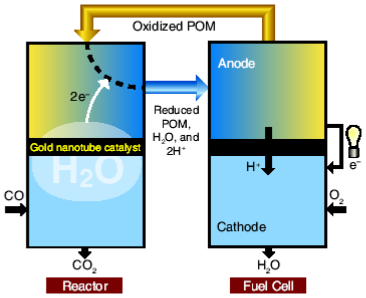
Yang, P. *et al. Nat. Mat.* **2005**, *4*, 455.

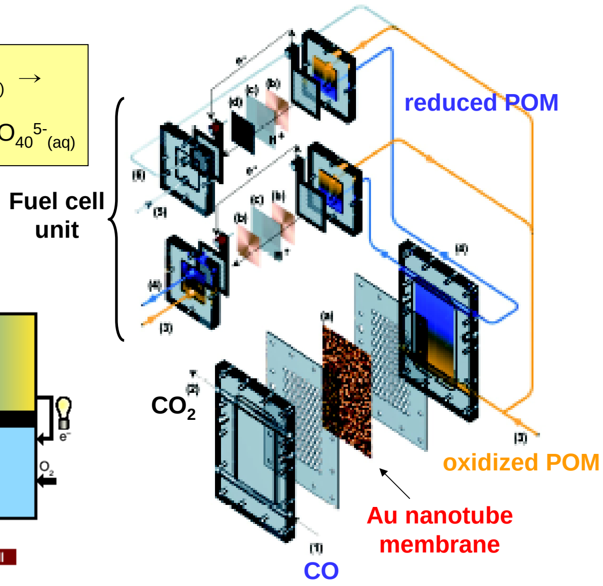
25/28

Powering Fuel Cells with CO

$CO_{(g)} + H_2O_{(l)} + PMo_{12}O_{40}{}^{3-}{}_{(aq)} \rightarrow$

$CO_{2(g)} + 2H^+_{(aq)} + PMo_{12}O_{40}{}^{5-}{}_{(aq)}$





26/28

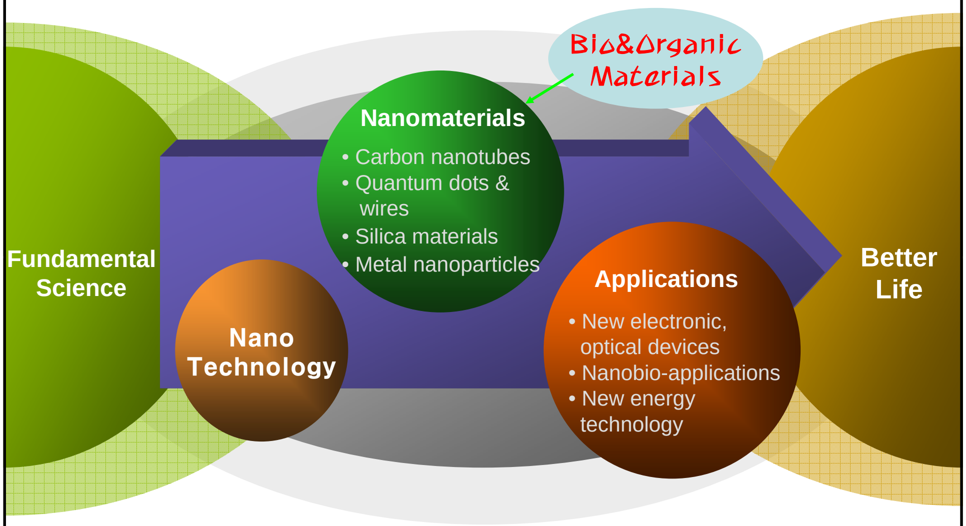
Ripple Effects of Nanotechnology

	Market billion$/yr	Commer-cialization	Application fields
Materials	340	less than 10 yrs	- materials with high performance and functions
Semicon-ductor	300~350	10~15 yrs	- semiconductors with terra-bit resolution
Pharmacy	180	10~15 yrs	- 50% Pharmaceticals 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 airplains

NSF, “National Nanotechnology Initiative”, 2000. 7.

27/28

Outlook



28/28