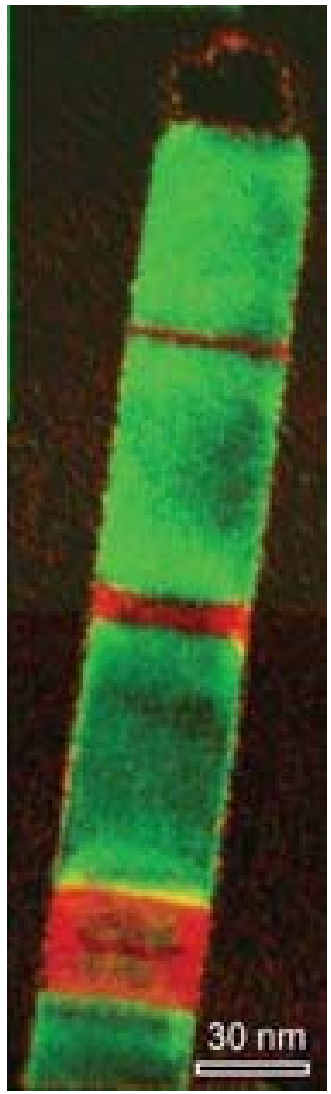
Questions…

- What is a nanowire? What is a nanotube?
- Why are they (scientifically) interesting?
- What are their potential applications?
- How are they made?
- ???

Q: What is a nanowire?

- A: Any solid material in the form of wire with diameter smaller than about 100 nm

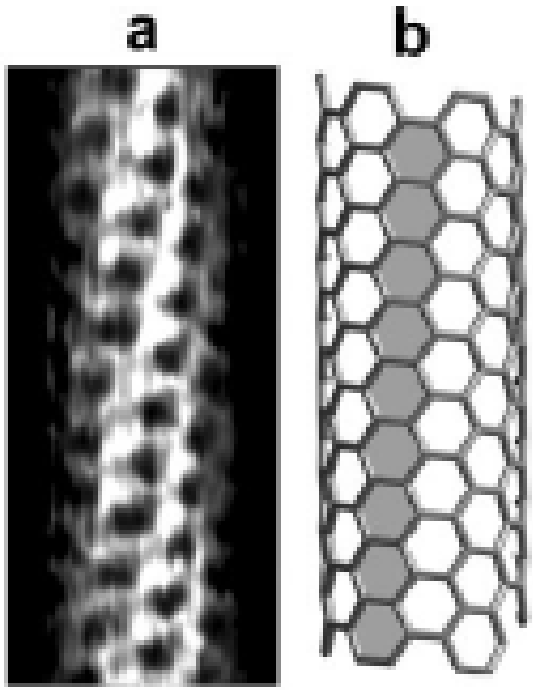


Transmission electron micrograph of an InP/InAs **nanowire**

(M.T. Bjork et. al., Nanoletters, 2:2 2002)

Q: What is a nanotube?

- A: A hollow nanowire, typically with a wall thickness on the order of molecular dimensions
- The smallest (and most interesting) nanotube is the single-walled carbon nanotube (SWNT) consisting of a single graphene sheet rolled up into a tube



Scanning Tunneling Micrograph of a single-walled carbon **nanotube** and corresponding model (Dekker)

Q: What makes nanowires and nanotubes (scientifically) interesting?

- **Electronic & optical properties**
  - Nanowires and nanotubes are the most confining electrical conductors - puts the squeeze on electrons
  - Can be defect free - electrons move “ballistically”
  - Quantum confinement - tunable optical properties
- **Mechanical properties**
  - Small enough to be defect-free, thus exhibiting ideal strength
- **Thermal properties**
  - Can be designed to conduct heat substantially better (or much worse) than nearly every bulk material
- **Chemical properties**
  - Dominated by large surface-to-volume ratio

Nanowires and Nanotubes are New Materials!

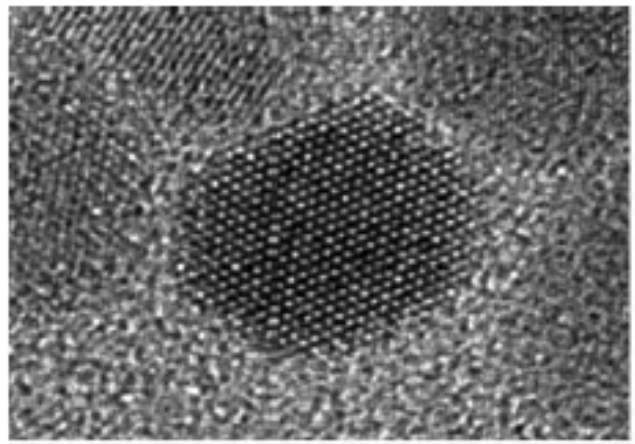
Optical properties

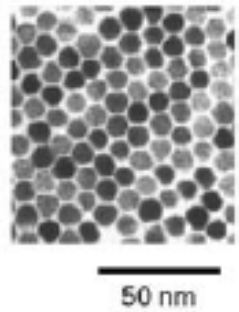
- Decreasing the size of a nanostructured material increases the energy difference, ΔE, between allowed electron energy levels
- When an electron drops from a higher energy state to a lower energy state, a quantum of light ("photon") with wavelength, $\lambda = hc/\Delta E$ may be emitted
- Larger ΔE implies shorter wavelength ("blue shifted")

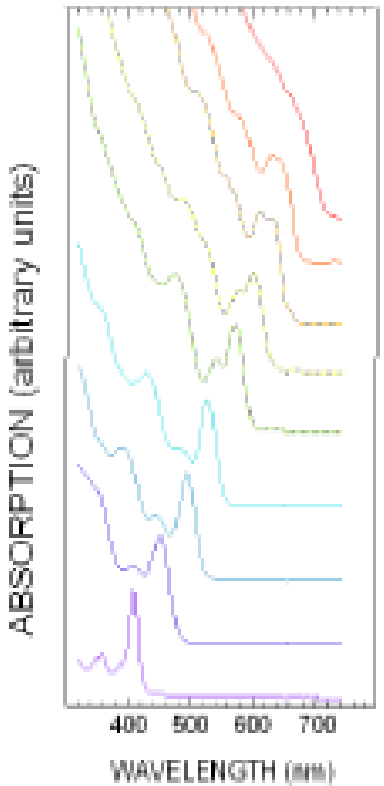
h is Planck's constant; c is the speed of light

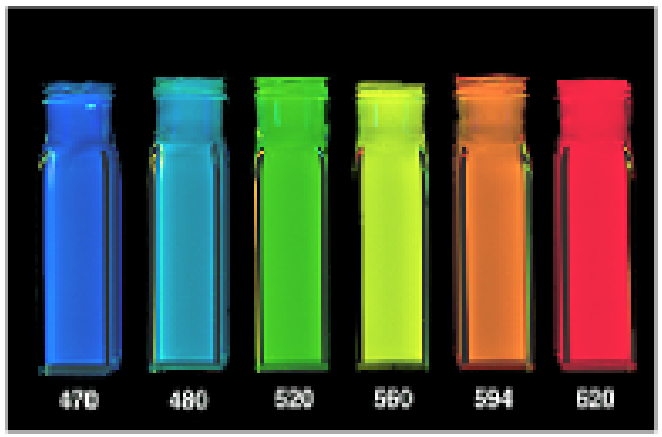
Example: Quantum Dots

CdSe nanocrystals; Manna, Scher and Alivisatos, J. Cluster Sci. 13 (2002)521









Left- absorption spectra of semiconductor nanparticles of different diameter (Murray, MIT). Right- nanoparticles suspended in solution (Frankel, MIT) - National Science Foundation Report, “Societal Implications of Nanotechnology” March 2001