Nanomaterials

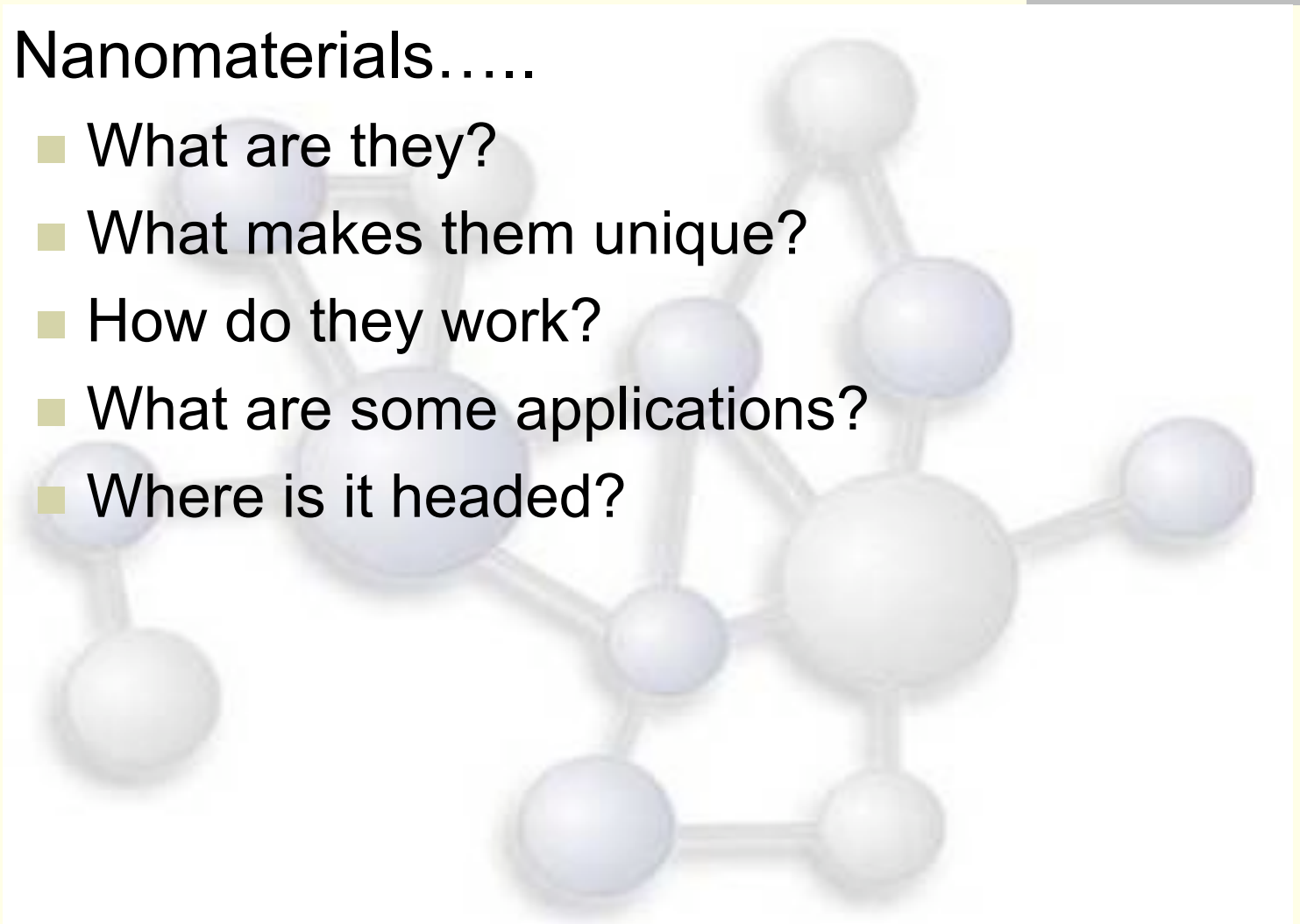
Brent Augustine

STS 201

1/25/05

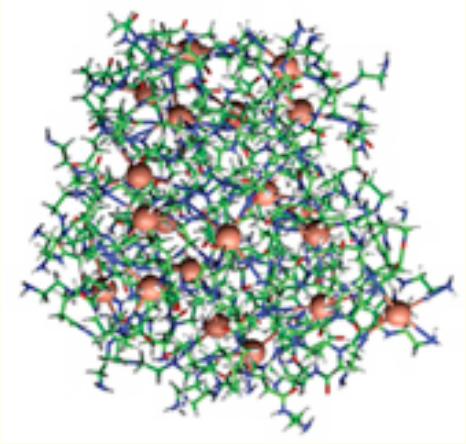
Questions to be answered…

- Nanomaterials…..
  - What are they?
  - What makes them unique?
  - How do they work?
  - What are some applications?
  - Where is it headed?



What are Nanomaterials?

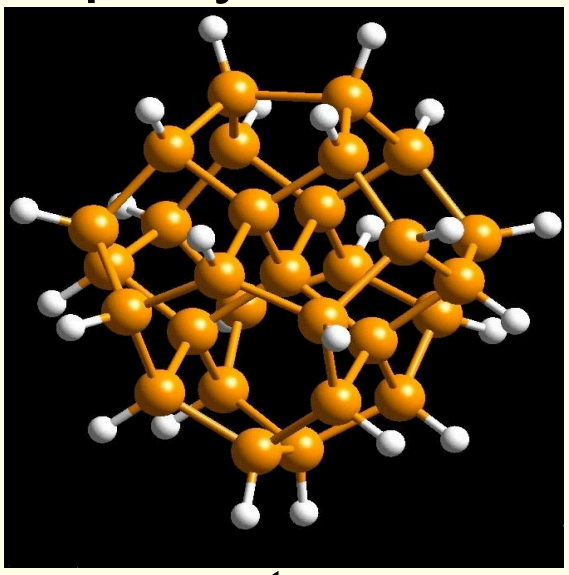
- Nanomaterials are any bulk material that contain embedded nano-sized particles that are no larger than 100 nm in any one direction.



COURTESY OF STEVE KENIATH, MICHIGAN MOLECULAR INSTITUTE

What makes them unique?

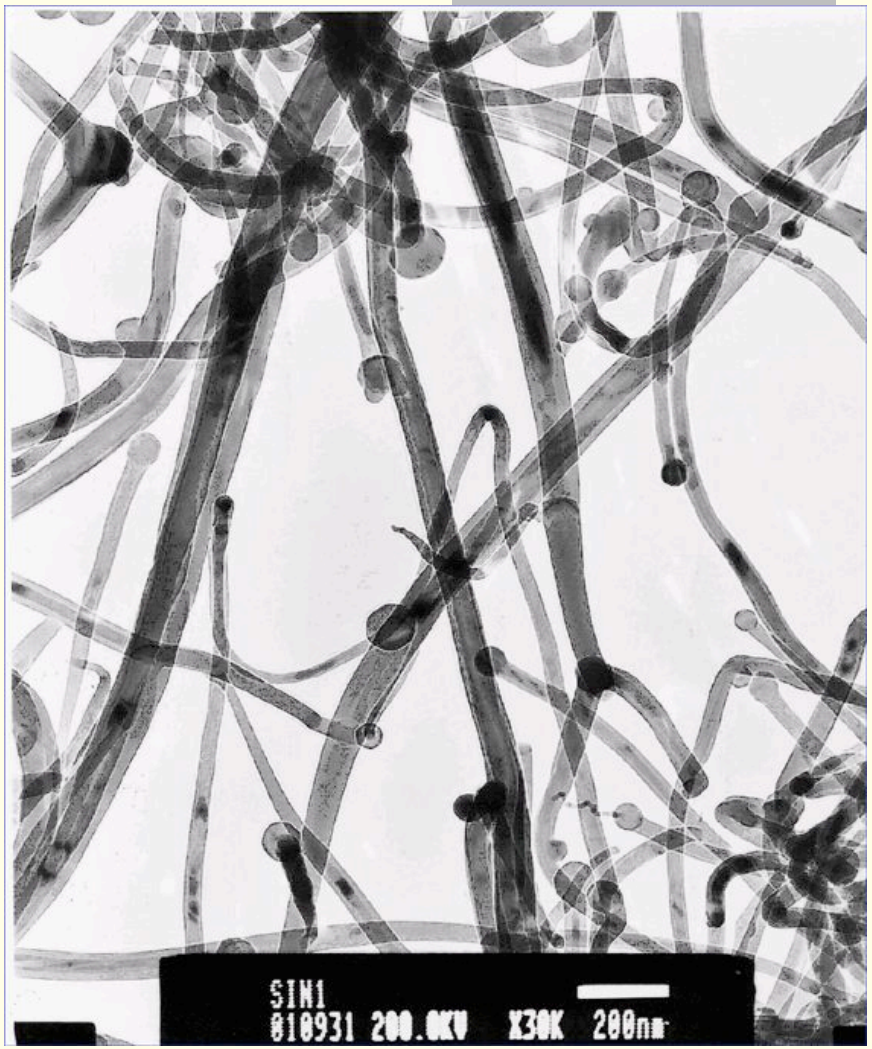
- When combined with nanoparticles, nanomaterials gain a slew of property enhancements such as…
  - Improved strength
  - Increased hardness
  - Improved ductility
  - Improved tensile properties
  - Resistance to tear
  - And many other material enhancement properties



altair.physics.ncsu.edu/ si29h24expl.html

What makes nanomaterials unique?

- Nanomaterials behave the way they do because when the nanoparticle grains overlap and reinforce the material, many of the qualities of the nanoparticles are inherited by the material causing the additional property enhancements.



Applications of how they work…

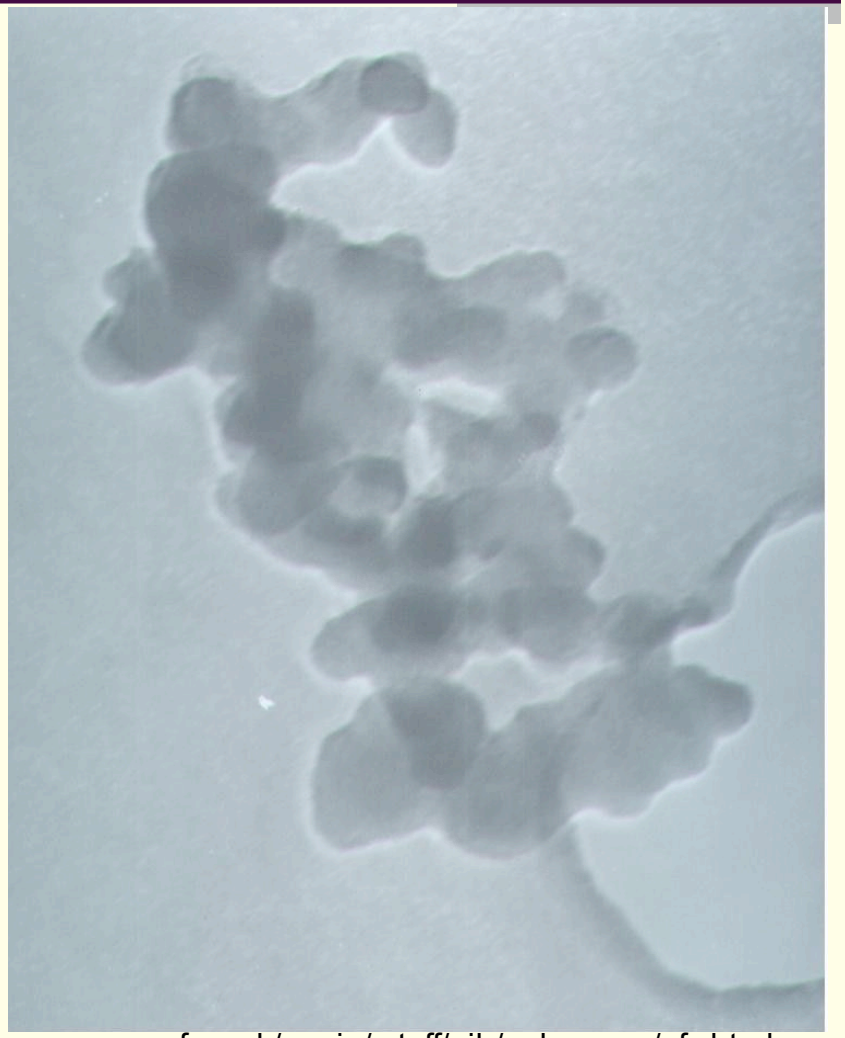
- The Hall-Petch model:
  - Inverse relationship between grain size and yield strength
  - Theorized with microparticles, proven to hold with nanoparticles as well
  - Nanocrystalline Fe powder grain size reduced from 33nm-8nm
  - Showed increase in hardness and decrease in fracture stress

$$\sigma_y = \sigma_0 + \frac{K}{\sqrt{d}} \qquad \sigma_c = \sigma_0 + \frac{k_P}{\sqrt{l}}$$

http://www.matsci.ucdavis.edu/MatSciLT/EMS-174L/Files/HallPetch.pdf

Carbon Black

- Carbon Black in tires:
  - Carbon Black, produced by the partial combustion of natural gas, has long been used as a reinforcement in rubber tires
    - Improved strength and tensile properties, tear and abrasion resistance, and increased hardness



www.cf.ac.uk/engin/ staff/pjb/subpages/pfc.html

Carbon Black cont…

- Absolute strength of nanocomposite not linear
  - Initially increases with the addition of carbon because of the reinforcement from carbon grains
  - Then decreases due to the dillusion effect when too much carbon black is present

www.konimpex.com.pl/ phtml/sadza_techniczna.php

Courtesy of Bridgestone

Metal Nanocomposites

- Metals can be made into nanocrystalline materials that perform better than regular metals.
  - Roll copper at the temperature of liquid nitrogen
  - Then, heat to around 450 K
  - Results in ‘bimodal’ structure with micro-meter sized grains and nanocrystalline grains
  - Increases strength and hardness of metal because of the nanocrystalline grains
  - Shows high ductility as well, larger grains stabilize tensile deformation of material

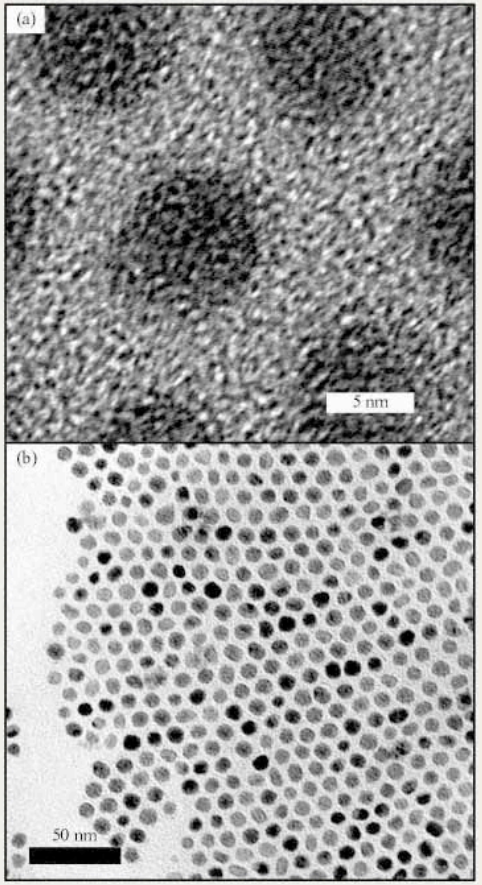


Figure 2

(a) High-resolution TEM image of 7-nm hcp Co NCs revealing subtle lattice imaging of the NCs. (b) Lower-resolution TEM images of an ensemble of 10-nm hcp Co NCs.

www.research.ibm.com/journal/rd/451/murray.html

Reinforced Polymers

- One particular area of research has been the reinforcement of polymers coupled with Polyhedral Oligomeric Silsesquioxanes (POSS)
- Allows for greater mechanicals due to the entrainment with the polymer chains
- Connections with polymer chains:

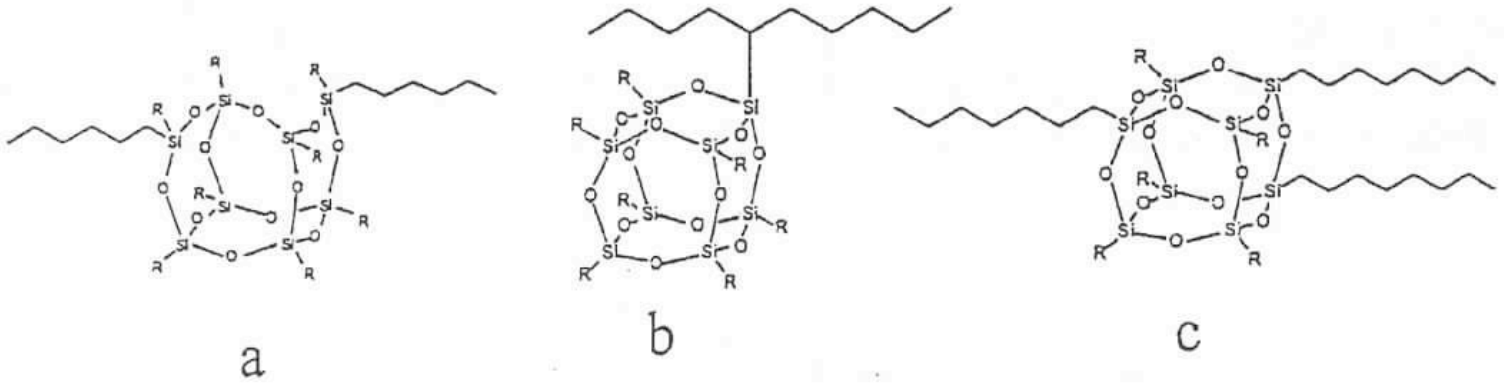


Figure 4. The most common type of POSS-polymers. (a) bead, (b) pendant and (c) cross-linked.

Current Industrial Applications

- Carbon black rubber filler in tires
  - $4 billion industry
- Hummer H2
  - Nanocomposites line the bed of the truck

GM's 2005 Hummer H2 cargo bed uses about 7 lb of molded-in-color TPO nanocomposite parts.

www.plasticstechnology.com/.../ 200411fa2.html

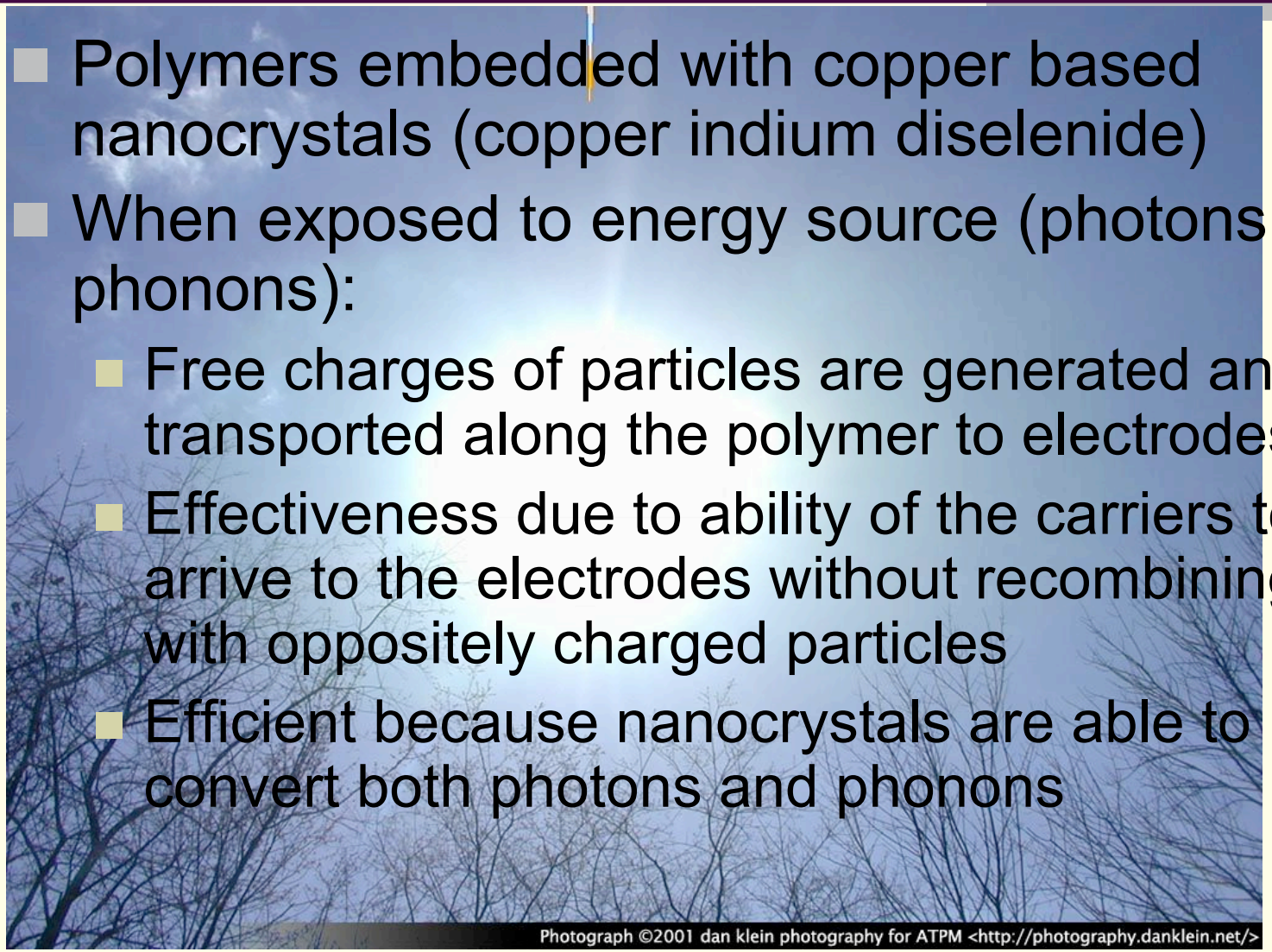
Industrial Applications

- Wilson Company
  - Have added nano-sized silicon dioxide crystals to rackets to increase their power
  - Also, coated tennis balls with a butyl-based nanoparticle that cuts air permeation in half and makes them last longer

http://www.tennis-warehouse.com/WilsonRacquets.html

Solar converting polymers

- Polymers embedded with copper based nanocrystals (copper indium diselenide)
- When exposed to energy source (photons or phonons):
  - Free charges of particles are generated and transported along the polymer to electrodes
  - Effectiveness due to ability of the carriers to arrive to the electrodes without recombining with oppositely charged particles
  - Efficient because nanocrystals are able to convert both photons and phonons



Future of nanomaterials

- Major influence on current industries
- Must ensure risk factors are eliminated when dealing with the unknown
- Technological Somnambulism

cnn.com