

Introduction to Nanotechnology:

Insights into a Nano-Sized World

What is nanotechnology?

Definition 1:

Nanotechnology is the creation of functional **materials**, **devices**, and **systems** through **control of matter** on the **nanometer length scale**, exploiting **novel** phenomena and properties (physical, chemical, biological) present **only** at that length scale.

Definition 2:

Nanotechnology is the engineering of functional systems at the **molecular scale**. **It** refers to the projected ability to construct items **from the bottom up**, using techniques and tools being developed today to make complete, highly **advanced** products.

What is nanotechnology?

Some questions need to be answered...

- What is the nano length scale?
- Is nanotechnology new?
- What “novel” and “exciting” phenomena are at this scale?
- How do we use this to our advantage?

What does nano *really* mean?



mountain

1 km

1000 m

0.001 km = 1 m



child

1 m

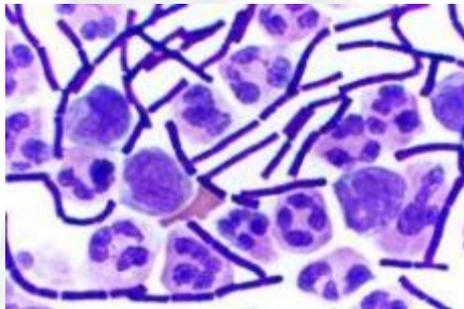


ant

1 mm

0.001 m

1,000 mm = 1 m

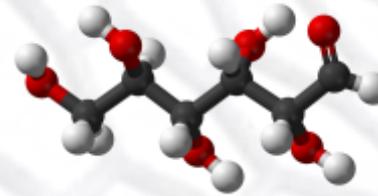


bacteria

1 μm

0.000001 m

1,000,000 μm = 1 m



sugar molecule

1 nm

0.000000001 m

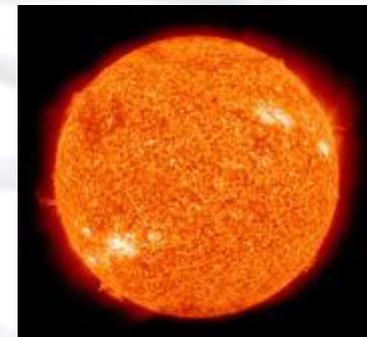
1,000,000,000 nm = 1 m



1 m = 1 **BILLION** nm



1 km = Saturn to Sun



How old is nanotechnology?

1965 Ferromagnetic fluids patented by S. Papel

1974 The word "nanotechnology" used

Early 1980s Quantum dots discovered by Alexei Ekimov

1985 Buckyball discovered

1991 Carbon nanotubes discovered

1997 Gold nanoshells discovered

1999 Doxil receives FDA approval

2008 Gold nanoshells therapy in human clinical trials

1687 Isaac Newton published "Principia," laws of motion

1769 Watt invented steam engine

1839 Goodyear invented vulcanized rubber.

1885 Hertz discovered photoelectric effect

1916 Einstein published theory of relativity

1905-1925 Birth of Quantum Mechanics

1938 Electron microscope

1981 Scanning electron microscope

How old is nanotechnology?

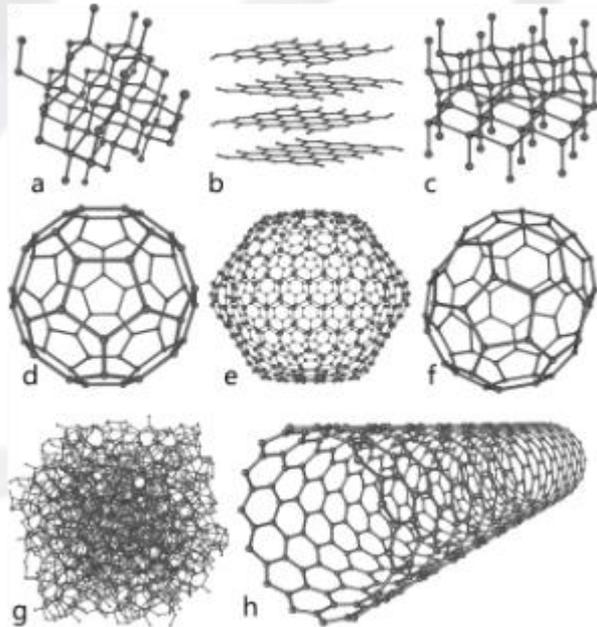
In comparison, nanotechnology is fairly young.

Correction: Nano-sized objects have been around for centuries, but the ability to see, understand and control them is recent

Why?

- **Quantum mechanics** is needed to understand physics ←for modeling
 - atomic properties
 - wave properties
- **Tools** are needed to see length scale ←for imaging
 - transmission electron microscope
 - scanning electron microscope
 - atomic force microscope
- **Processing technology** is needed to control size, chemistry, shape, etc. ←for manipulation & fabrication
 - scanning tunneling microscope
 - atomic force microscope
 - evaporation techniques
 - self assembly (utilizing surface tension)
 - wet chemistry techniques

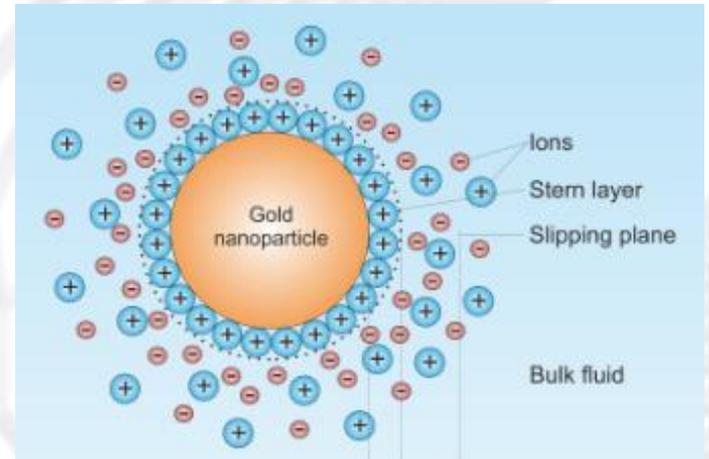
Types of Nano Phenomena



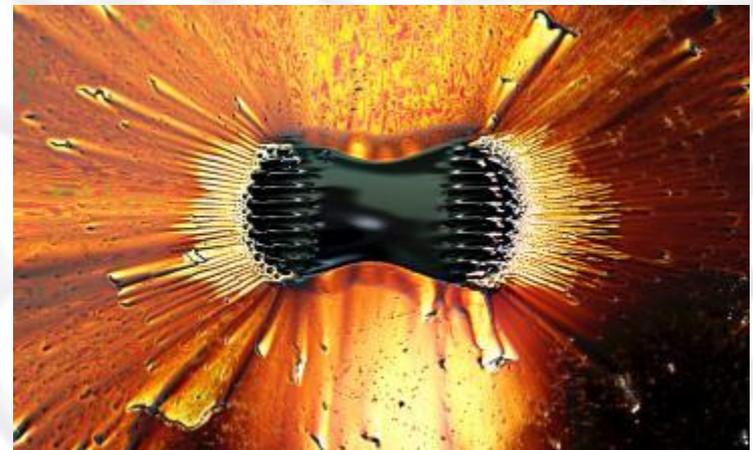
carbon allotropes



quantum dots

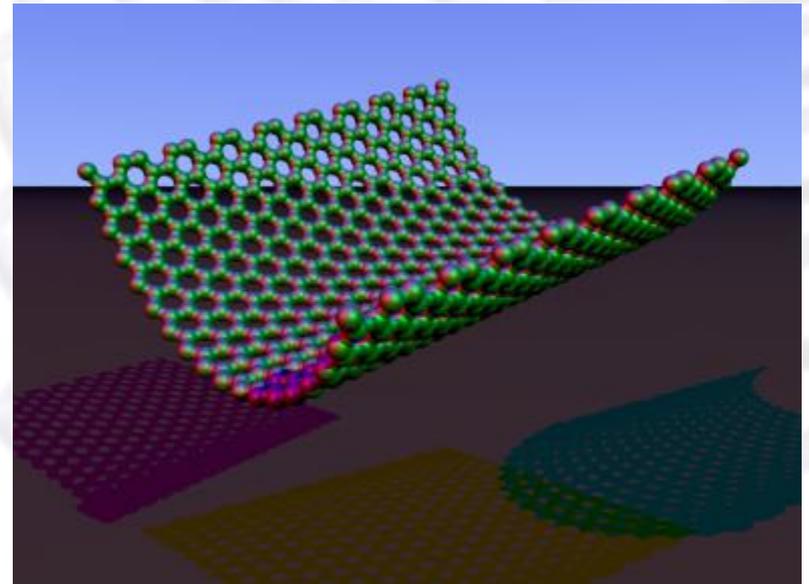
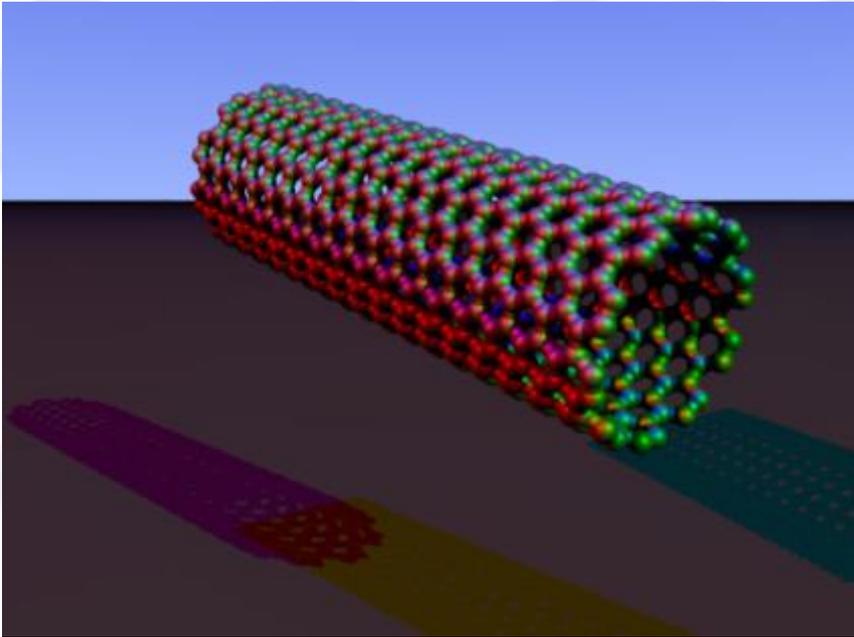


gold nanoshells



ferro fluids (magnetic)

Single-Walled Carbon Nanotubes



Graphene: a sheet of carbon atoms. →
Roll up the sheet up to form SWNTs.

SWNT Properties and Applications

- **Exceptional mechanical strength**

Tensile strength > **37 GPa** (steel 2 GPa)

Young's modulus ~**0.62 – 1.25 TPa** (steel 0.3 TPa)

- **Low density**

~**1.4 g/cm³**

- **Steel ~8 g/cm³**

- **Aluminum 2.7 g/cm³**

- **High-performance, lightweight fibers**

Sports equipment: tennis racquets, golf clubs, baseball bats

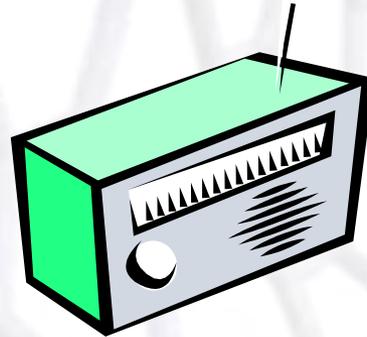
Body armor: replace Kevlar (PPTA) and Zylon (PBO)

Futuristic applications: carbon nanotube rope from Earth to Moon

High-performance concrete

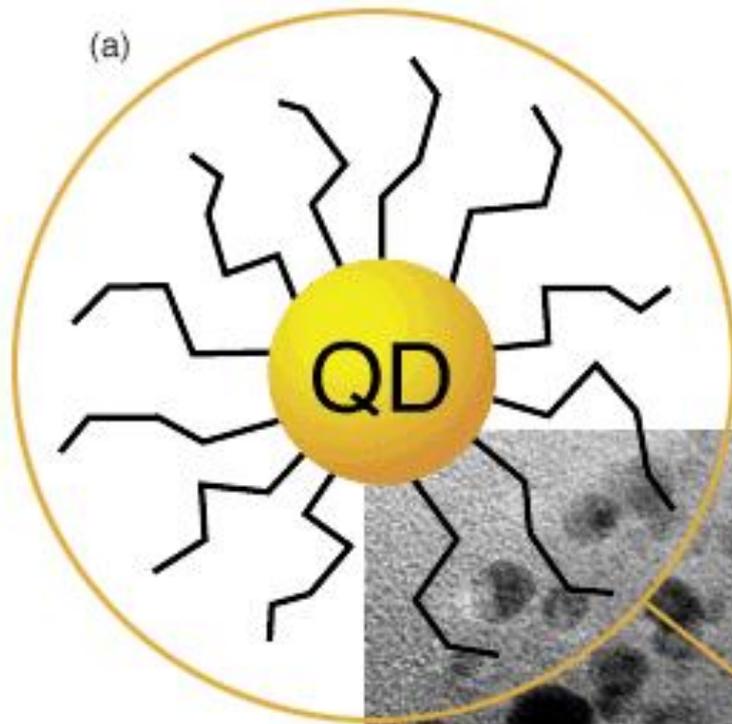
Road de-icing applications

The World's Smallest Radio

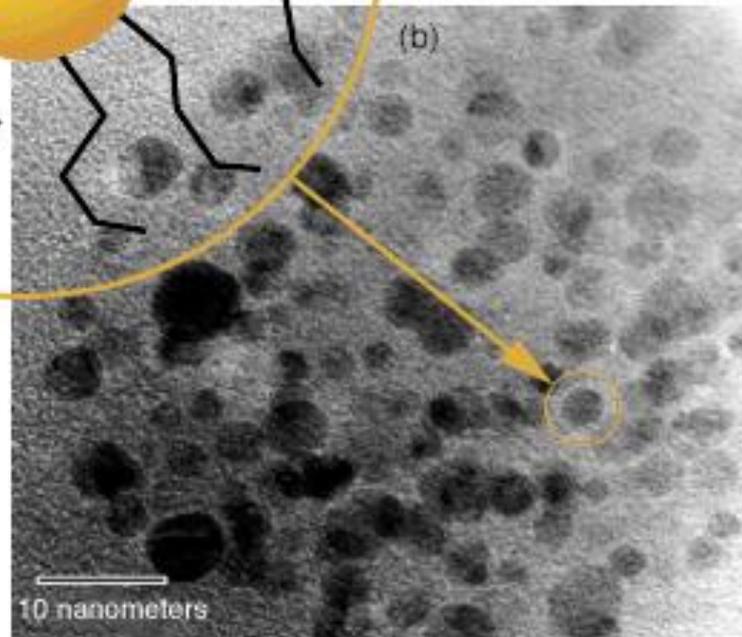


Star Wars theme song played from the world's smallest radio

Quantum Dots



(a) A nanometer-scale quantum ball, similar to the stringy Koosh Ball™, is made by bonding quantum wires to the surface of a quantum dot. (b) A high-resolution transmission electron microscopy image of quantum dots.



Quantum Dots

insert image here

http://www.onlineinvestingai.com/blog/wp-content/uploads/2009/02/quantum_dots-300x224.jpg

insert image here

<http://www.concepts.aero/system/files/quantum-dots.jpg>

Rotate image 90 degrees clockwise

Quantum Dot Applications

High-Performance Optical Properties

- **Optical beacons**
- **LEDs (light-emitting diodes)**
- **Solar cells**
- **Cancer detection**
- **Light bulbs**
- **Next-generation screens**

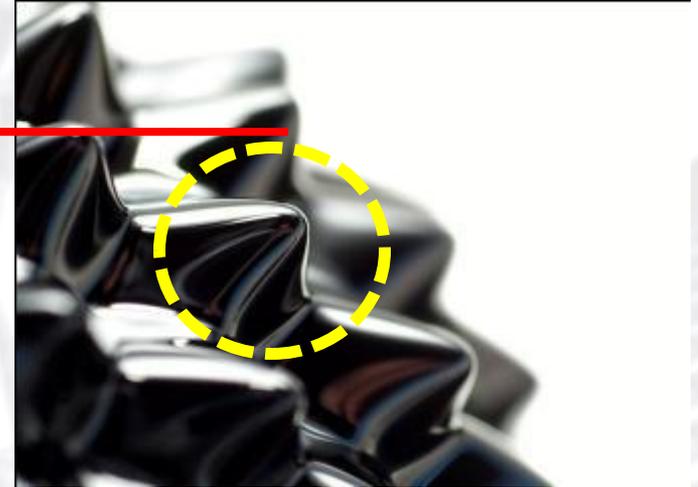
computers

cell phones

televisions



Ferrofluids (Magnetic Fluids)



insert image here

<http://www.ucl.ac.uk/~ucfbpmb/ferrofluid%20copy.jpg>

What makes up a ferrofluid?

- Ferromagnetic nanoparticles
- Surfactant (detergent)
- Carrier fluid (kerosene, vegetable oil)

Why Ferrofluids? Why Nano?

- Without magnetic field nanosuspension behaves as a fluid.
- Under controlled magnetic fields can manipulate properties
- Nanoparticles behave as permanent magnets.

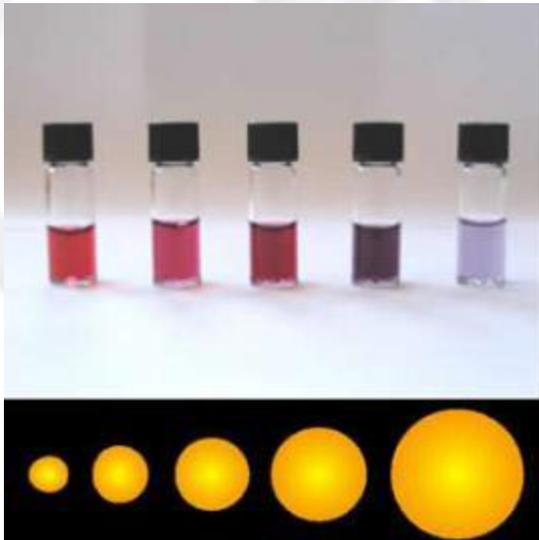
That's a lot of magnets in a little fluid!!!

Ferrofluid Applications

- Audio speakers
- Seals (engineering applications)
- Cancer treatments
(use magnetic field to heat particles and cook cancer cells)
- Drug delivery systems
(manipulate drugs through induced magnetic field)
- Toys

Nano Shells

- Metal nanoshells are excellent optical absorbers
 - Particularly gold, because of the strong optical absorption from the metal's response to light
 - Similar to quantum dots; shell diameter and thickness play a role in optical tuning
- Shells are comprised of gold or metal layer engineered to a particular thickness with a glass or dielectric core



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<http://www.nanotech-now.com/images/Nanospectra-logo-sm.jpg>

Gold Nanoshell Synthesis

insert image here

http://education.mrsec.wisc.edu/SlideShow/slides/nanoparticles/Au_nanoshell_synthesis.jpg

insert image here

http://education.mrsec.wisc.edu/Edetc/SlideShow/images/nanoparticles/Au_wavelength.jpg

- **Near infrared peak absorption characteristics with gold shells**
- **Wavelength that is not absorbed by skin**
- **Important features when considering cancer treatment applications.**

Nanoshell Applications

- **Optical imaging contrast agents**
- **Photothermal ablation (cooking) of cancerous cells**
- **Pharmaceutical delivery**
- **Optically controlled microfluidics valves**
- **Biosensing**

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<http://english.ipc.cas.cn/ns/es/201101/W020110121336809111199.jpg>

Misconceptions about Nanotechnology

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<http://www.flickr.com/photos/kt/8727693/>

This is science fiction!!!!

Consumer Uses and Projections

- **Motor vehicles**

Such as catalytic converters, interiors, coatings, adhesives, lighting

- **Electronics and computers**

Such as hardware, displays, recording media, batteries, electronic parts, lighting, ink and paper

- **Household products and improvements**

Such as packaging, cleaning products, coatings

- **Personal care**

Such as sunscreen cosmetics, over-the-counter health products, oral hygiene, eye glass coatings (anti-reflective, scratch resistant)

- **Sporting equipment**

- **Clothing**

- **Air and water filtration and purification**

- **And more...**



Nanoworld as a Whole

- Google “**nanotechnology**” and see ~**24,100,000*** results... and growing everyday
- Nanotechnology is in emerging technology that surrounds us:
 - Consumer products *contain it*
 - Advanced medical treatments, renewable energy methods and consumer products *use it*
 - Our job is to *understand, design, and control it*
- By 2015, nanotechnology revenues are estimated to reach \$2.5 trillion (\$2,500,000,000,000) worldwide
 - **This is the future!!!!**

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