

The Scale of Things – Nanometers and More

Things Natural

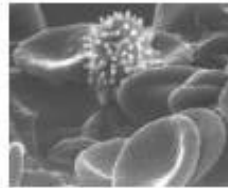


Dust mite
200 μm



Human hair
~ 60-120 μm wide

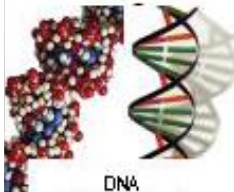
Red blood cells
with white cell
~ 2-5 μm



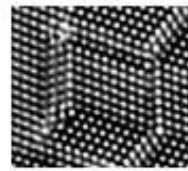
~ 10 nm diameter



ATP synthase



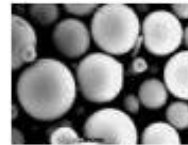
DNA
~ 2-12 nm diameter



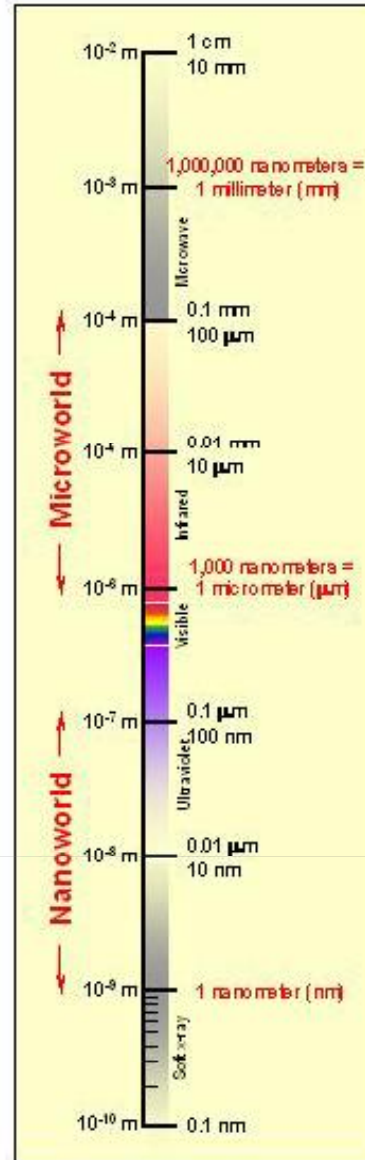
Atoms of silicon
spacing ~ tenths of nm



Ant
~ 5 mm



Fly ash
~ 10-20 μm



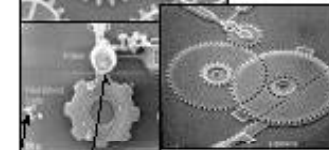
Things Manmade



Head of a pin
1-2 mm

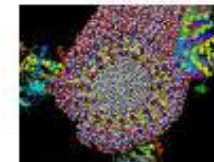


Micro Electro Mechanical (MEMS) devices
10 - 100 μm wide

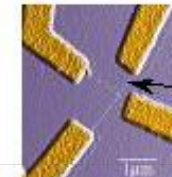


Pollen grain
Red blood cells

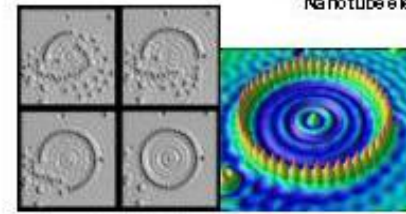
Zone plate x-ray "lens"
Outer ring spacing ~ 35 nm



Self-assembled,
Nature-inspired structure
Many 10s of nm

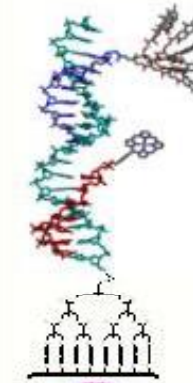


Nanotube electrode

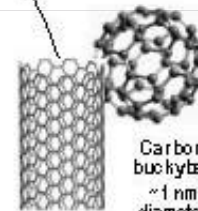


Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm

The Challenge



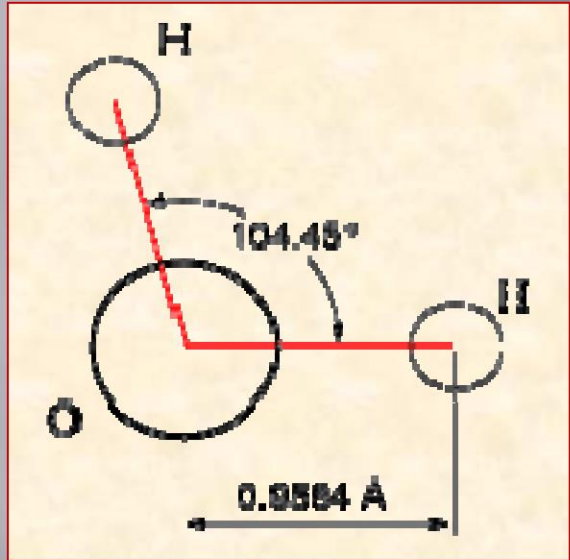
*Fabricate and combine
nanoscale building
blocks to make useful
devices, e.g., a
photosynthetic reaction
center with integral
semiconductor storage.*



Carbon
buckyball
~ 1 nm
diameter

Carbon nanotube
~ 1.3 nm diameter

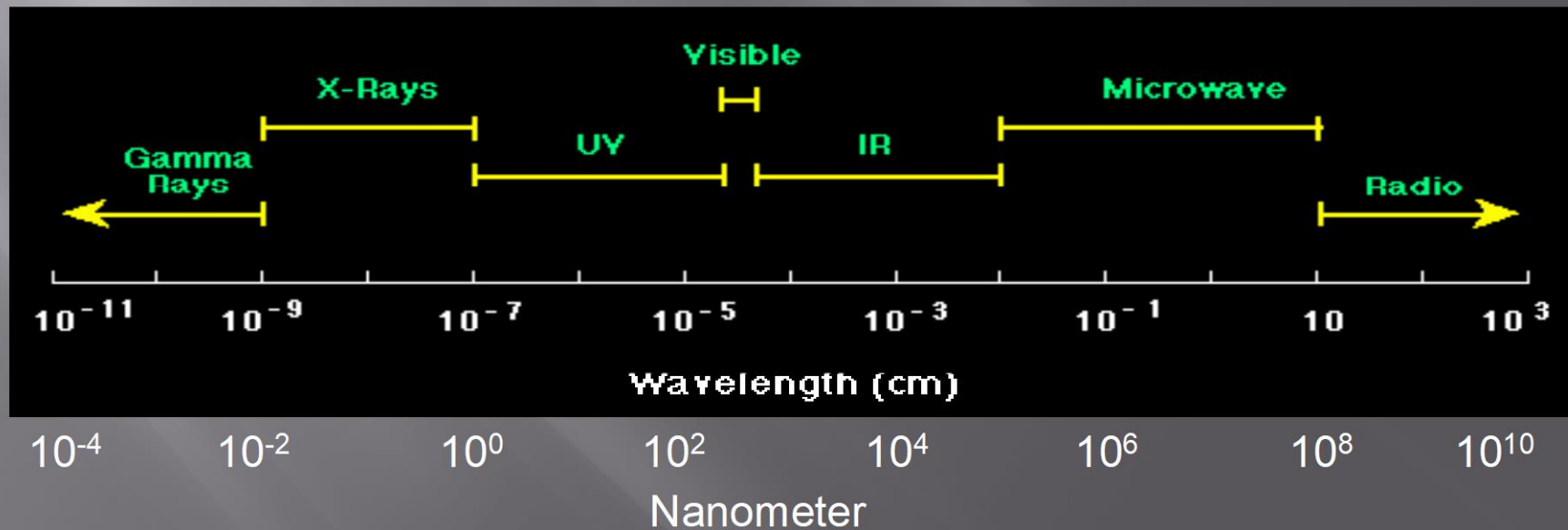
Scale of things



C-C bond – 1.5 angstroms

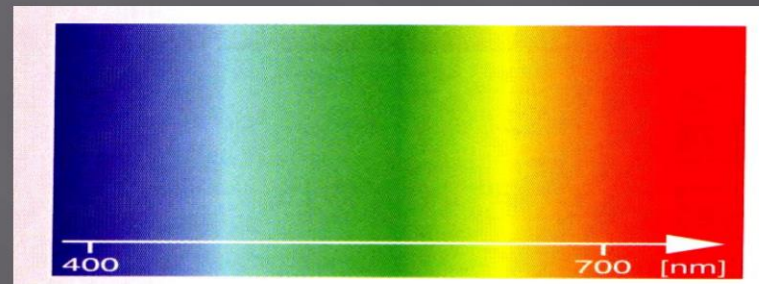
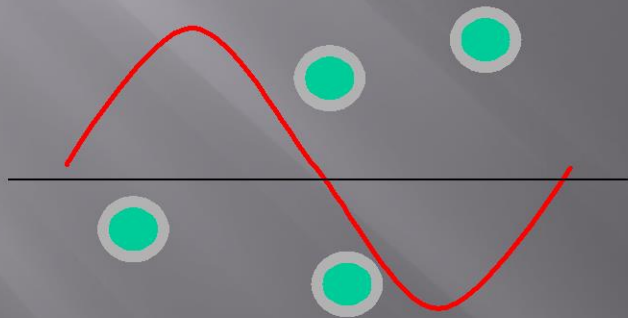
C-H bond – 1.1 angstroms

Ethanol: CH₃-CH₂OH



Nanocomposites: Optical Clarity

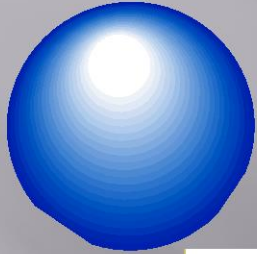
- ▣ **Size** and **refractive index** of particles are important
- ▣ Nanoparticles are smaller than the wavelength of visible light; reduces chance of light scattering



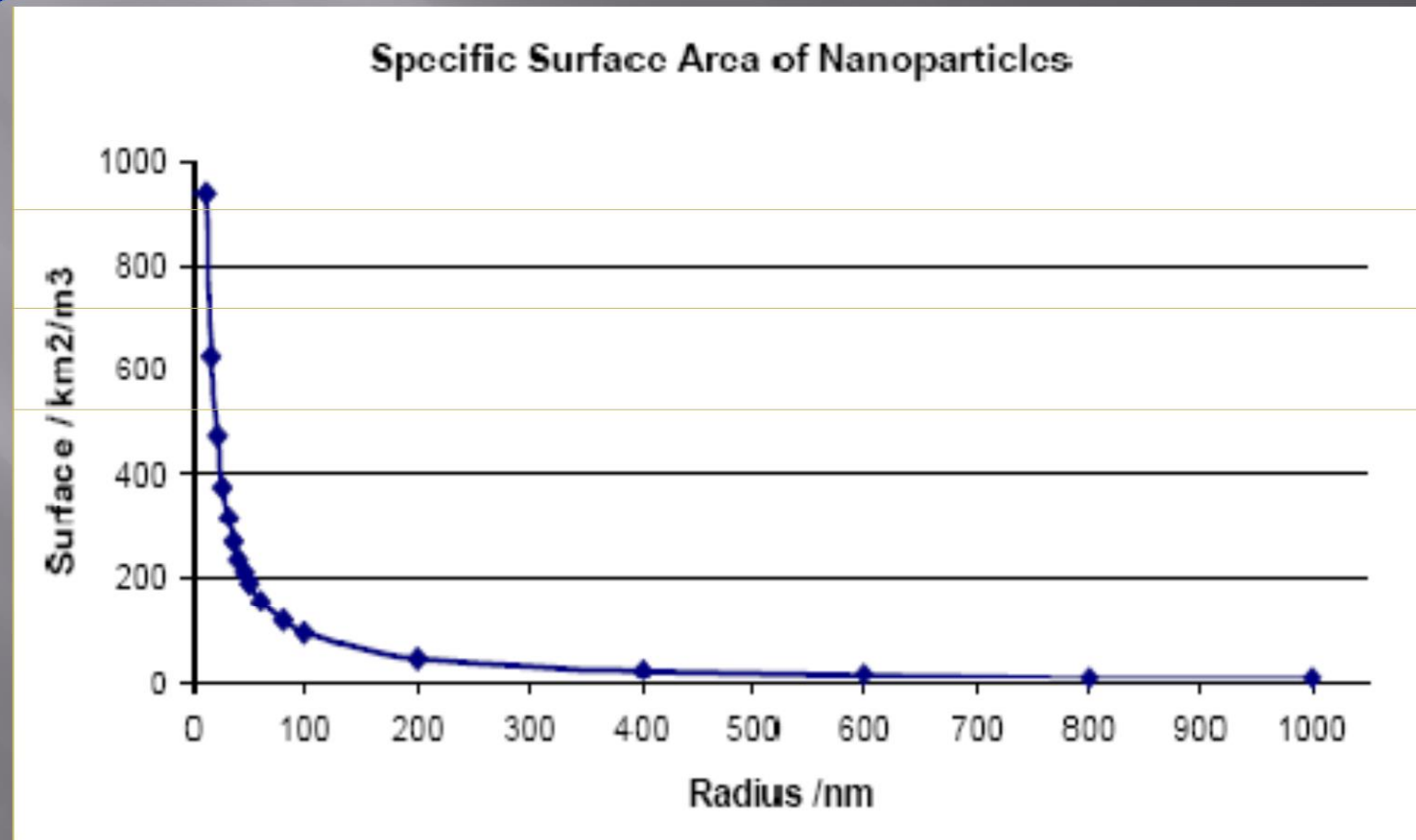
Nano-Scale & Conventional Polymeric Coatings

Polymer latex particle size	50 - 500 nm
Hiding grade TiO₂ particle size	200 - 250 nm
Polyurethane Dispersion particle size	50 - 100 nm
Polymer molecular size in solution	2 - 100 nm

Nanomaterials: Surface Area Dependence on Size



$$A = 4\pi r^2$$



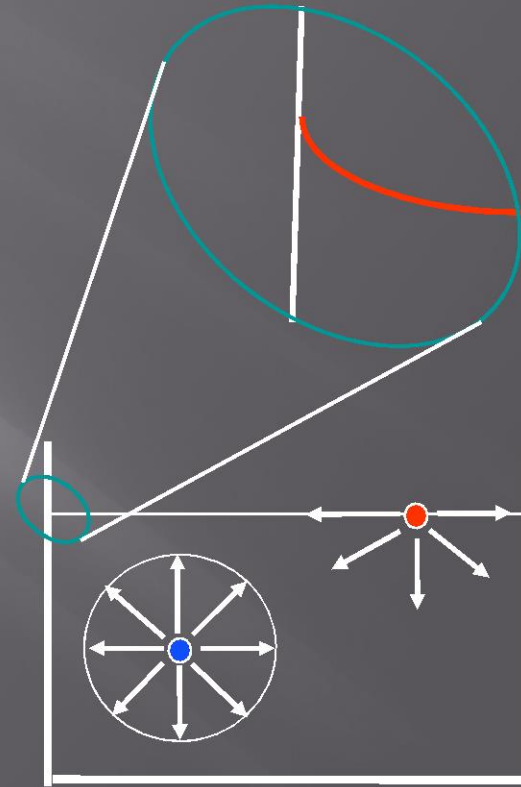
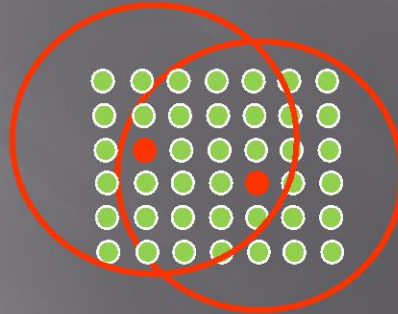
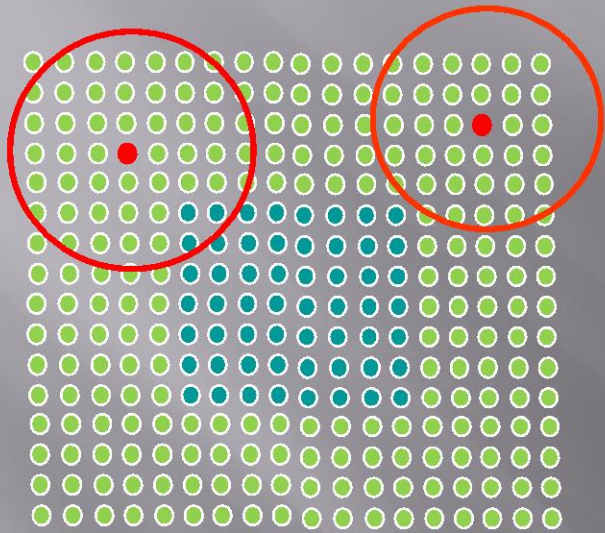
Surface Area

$$\text{Volume} = \frac{4}{3} \pi r^3 \quad \text{Surface area} = 4 \pi r^2$$

▣ 1 gram of $\text{TiO}_2 \rightarrow \text{Volume} = 0.25 \text{ cm}^3$

Particle diameter (nm)	Particles per gram	Surface area per gram (m^2)	Surface Area / Volume
200	6×10^{13}	7.5	1.8×10^{12}
20	6×10^{16}	75	1.8×10^{16}
2	6×10^{19}	750	1.8×10^{20}

Bulk Vs Surface Properties

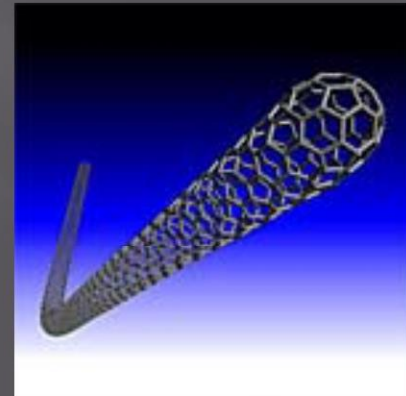


Bulk properties are not scalable to nanoscale

Surface Material Content

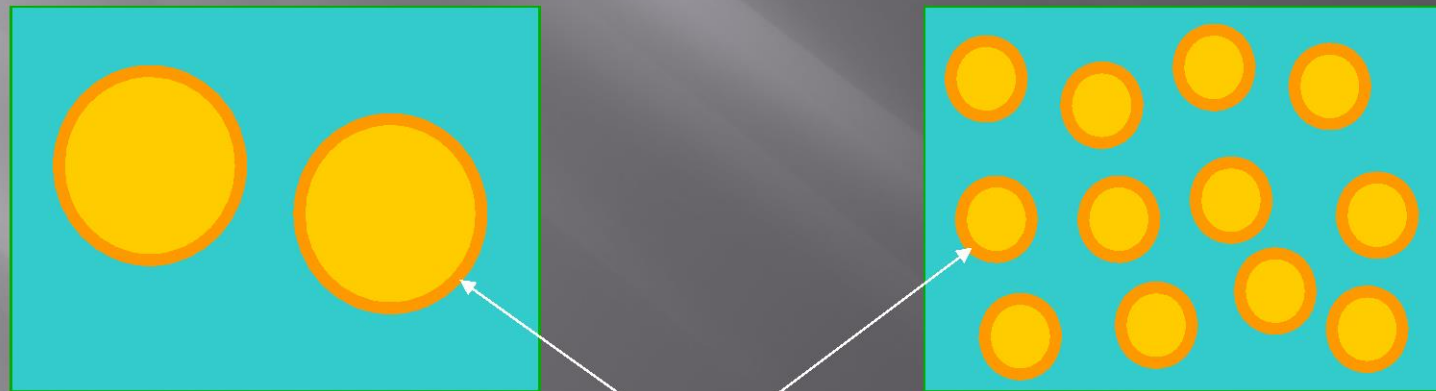
- ❑ A particle of 10nm diameter has 20% surface atoms
 - ❑ A particle of 2nm diameter has 80% surface atoms
 - ❑ A particle of 1nm diameter has 100% surface atoms
- Single wall Carbon nanotube

A capped single-wall carbon nanotube with a slight bend.
http://www.thomas-swan.co.uk/pages/nano_images.html



Interfacial Material Content

Particle Diameter (nm)	300	250	200	150	100	50
Interfacial Volume Fraction	0.03	0.04	0.05	0.06	0.10	0.22



10 nm Interfacial Layer

Dispersed particle volume fraction is 0.3 in all cases