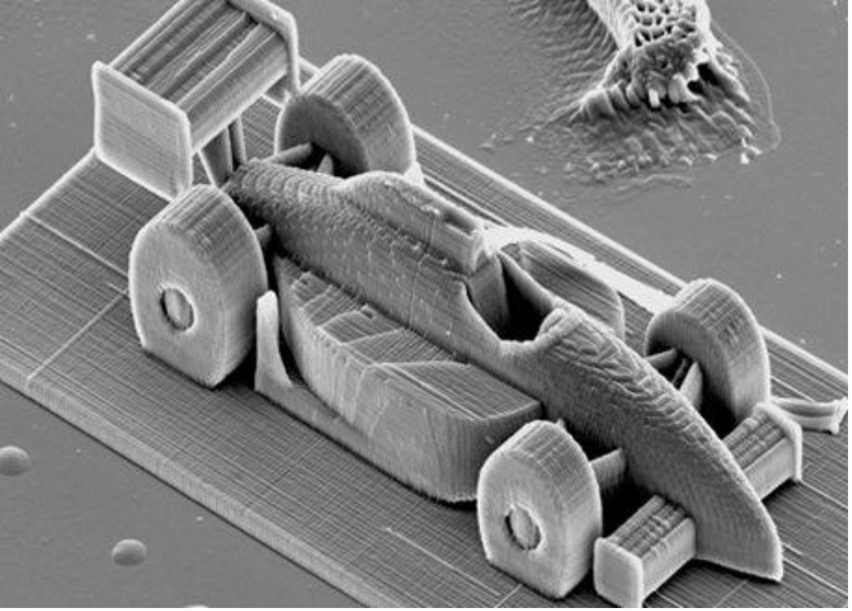
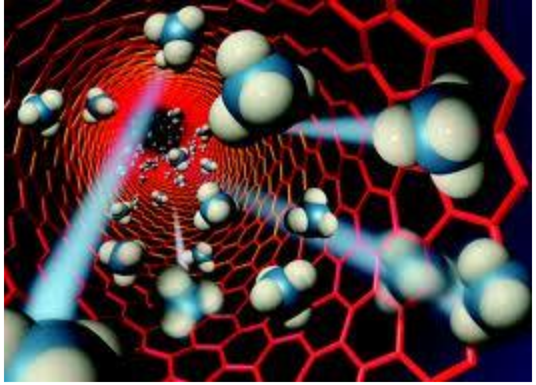
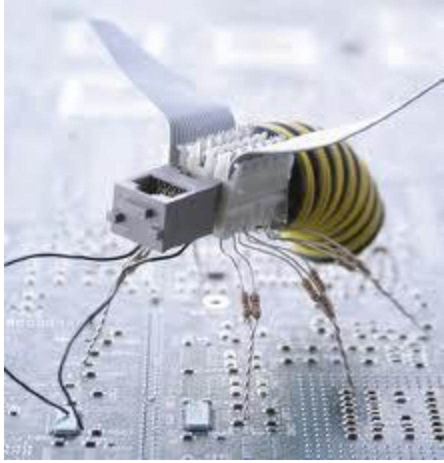
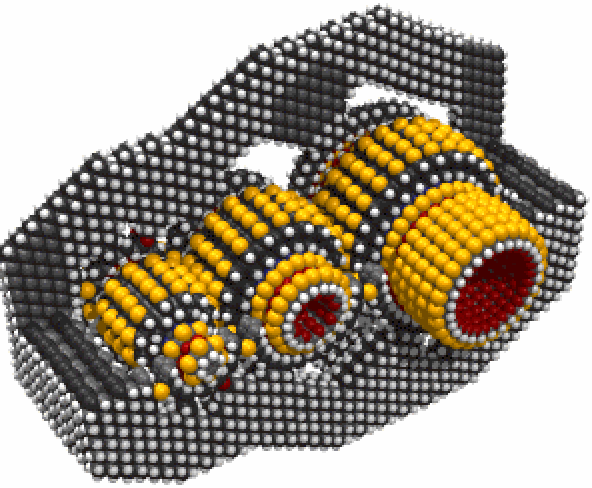
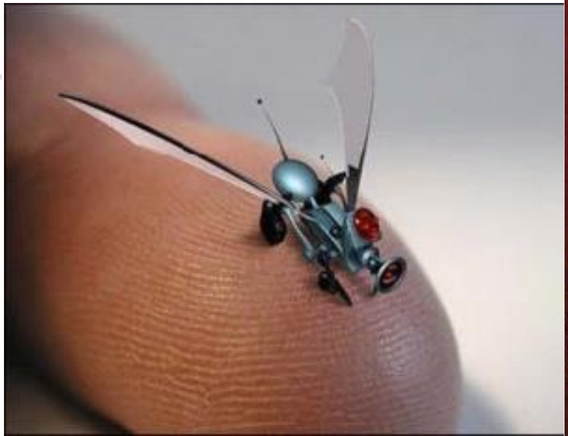
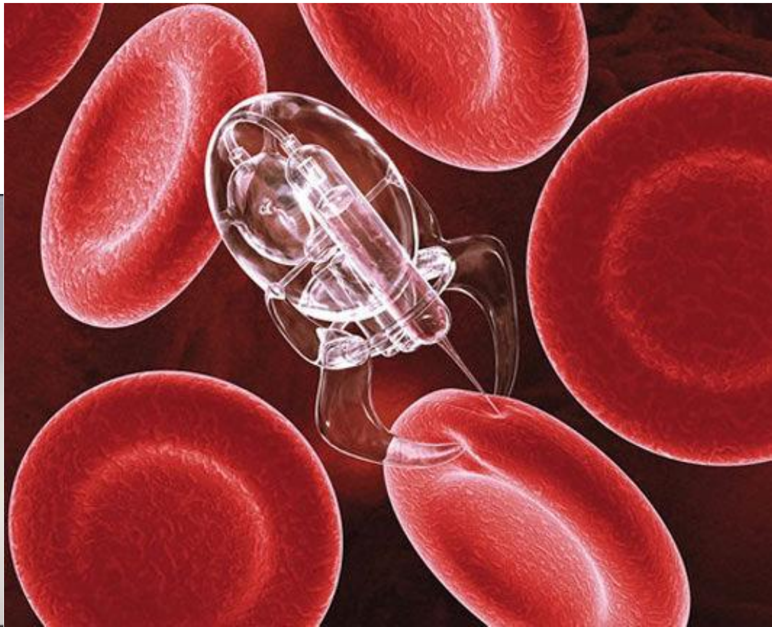




NANO TECHNOLOGY

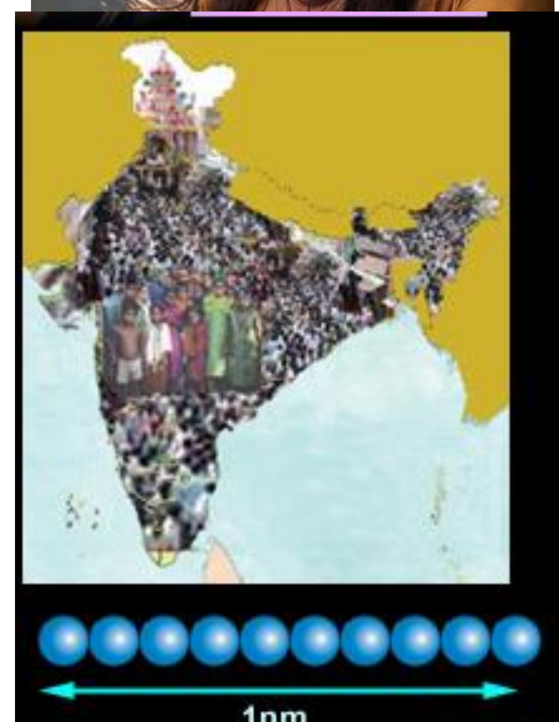
What is Nano??

- *Nano is the flavor of the day.*
- *Nano means one billionth or 10^{-9}*
- *Nano refers to the scale of nanometers.*
- *This is the scale of molecules, proteins, and other nano-objects that are the topics of this course.*
- *The Nanoscale involves the range from approximately 100 nm to 1 nm.*

A few more familiar examples may convince you of the difficult in imaging the size of nano-objects

A single strand of human hair is around 50,000 nm in diameter

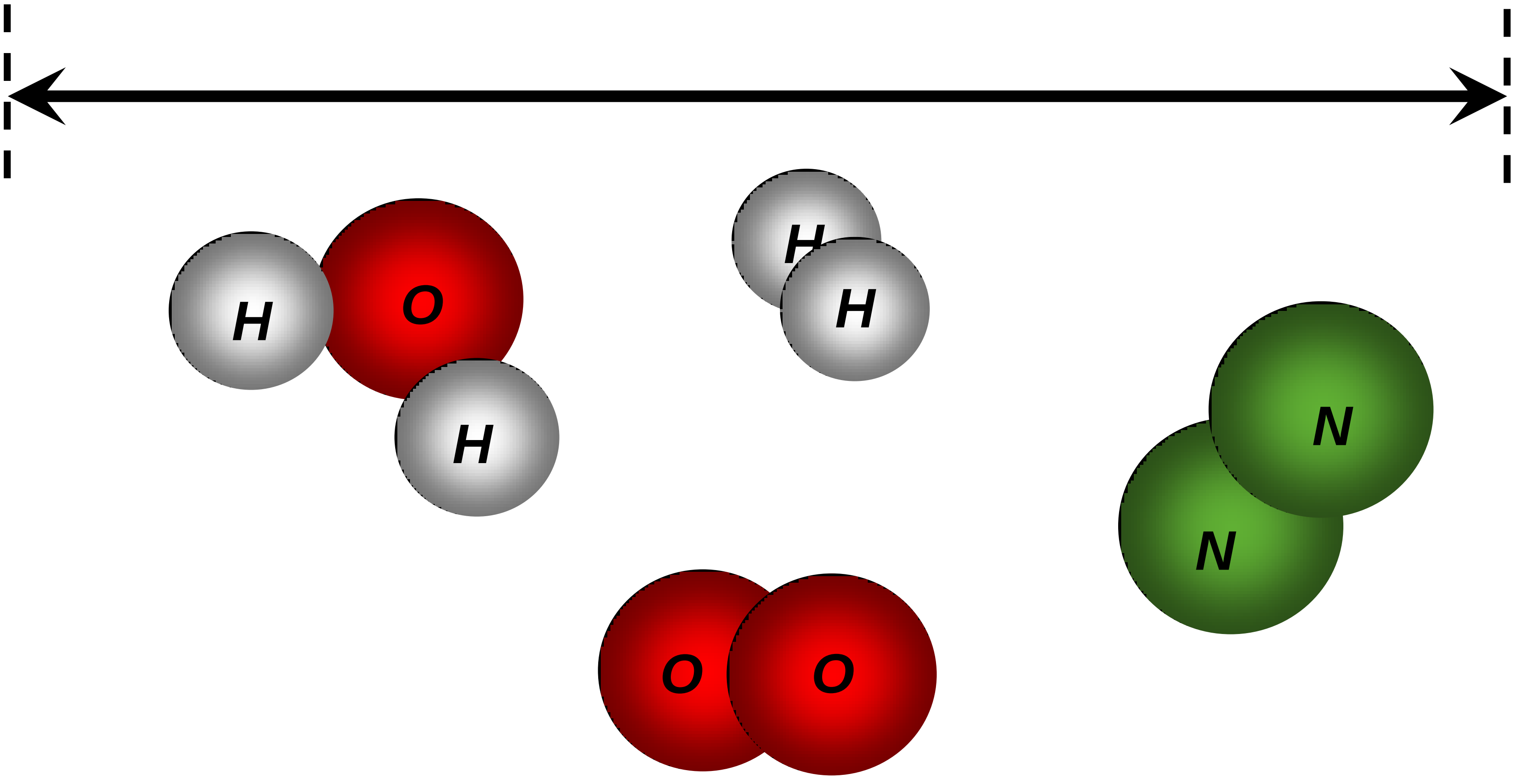
The population of India is one billion or >100 crore. Each Indian – you or me – is nano in comparison with population in India



10 Hydrogen atoms in line

Nanometer is the scale used to measure objects in the nanoworld

One Nanometer

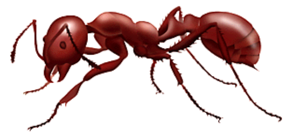


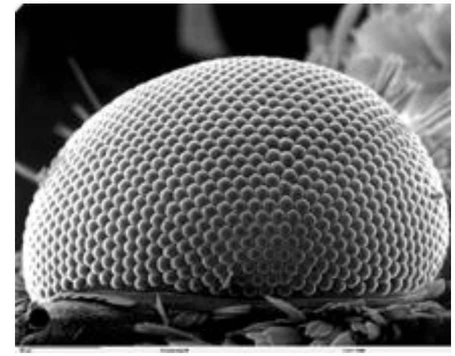
Also, 1 Angstrom (Å) = 0.1 nm

Distances between atoms in molecules are measure in Angstroms (Å)

Nano: The Middle Ground

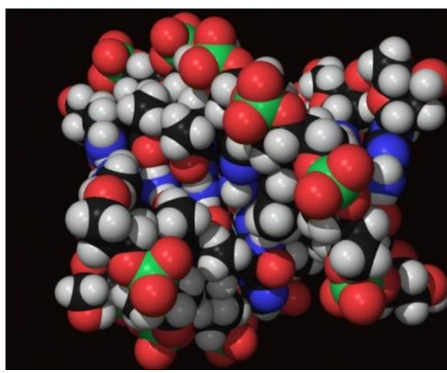
Galactic Scale

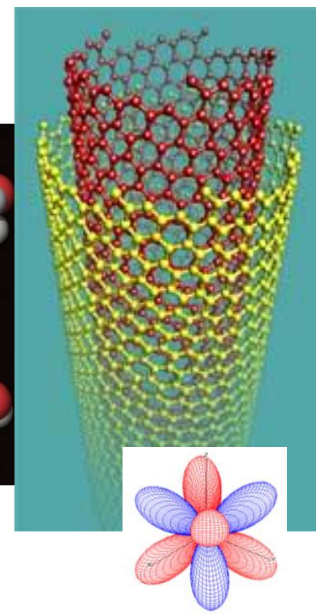


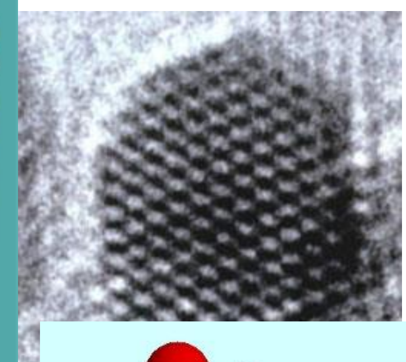


"Macroscopic" Scale

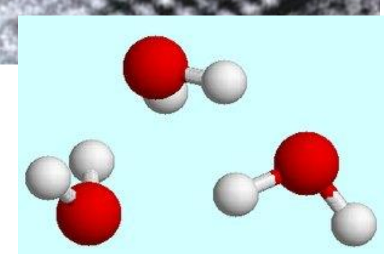
"Microscopic" Scale







Nanoscale



Subatomic scale:
Nuclear Physics

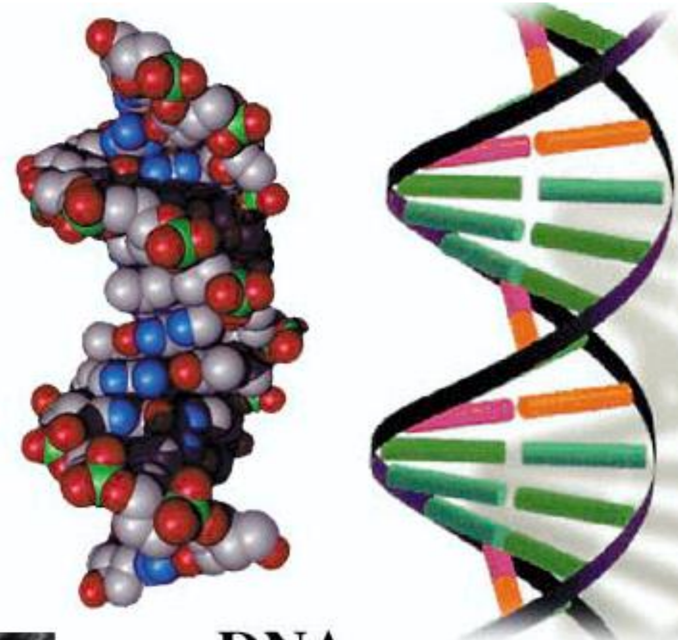
Partical Physics

atoms

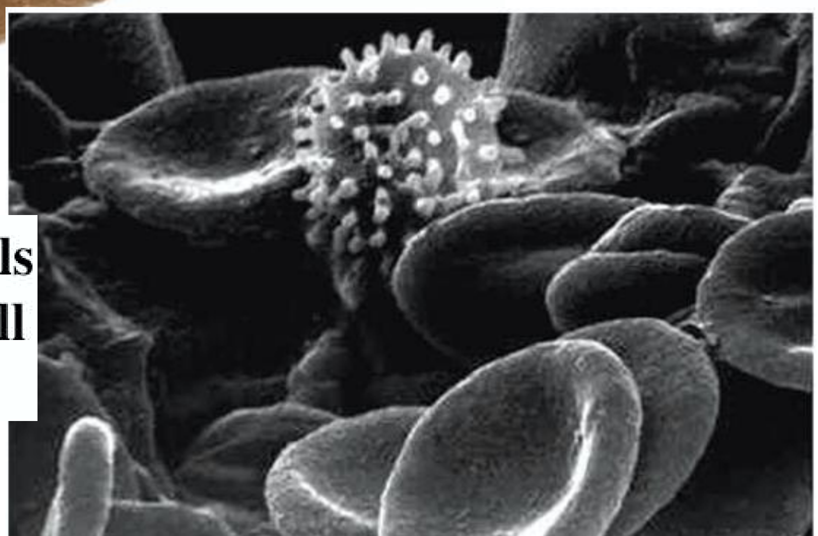
Molecular / Atomic Scale

Examples of Nanoscale Structures

Human hair
~50–150 μm wide



DNA
~2.5 nm diameter



Red blood cells with white cell
~2–5 μm

Carbon nanotube
~2 nm in diameter

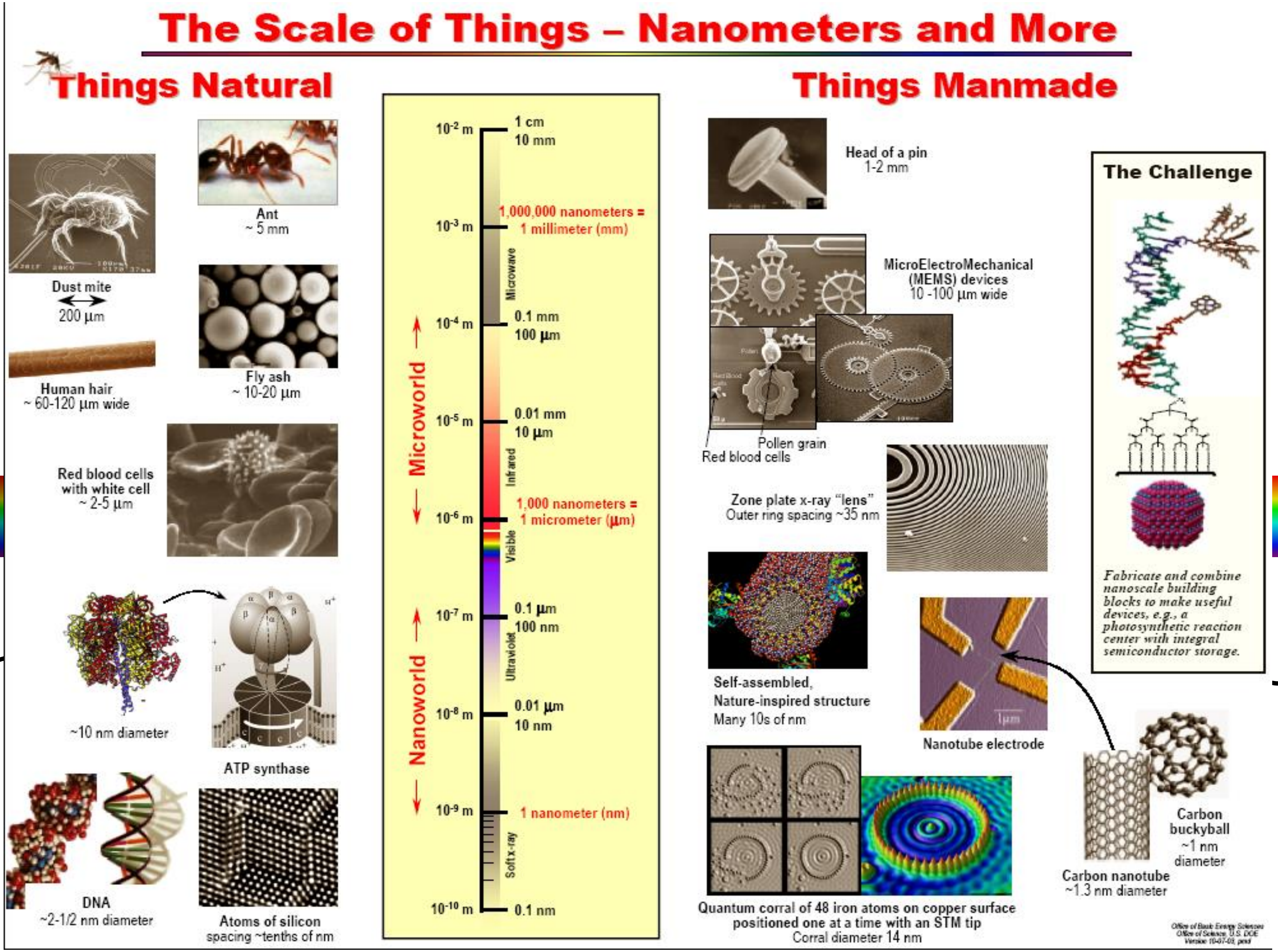


Figure 10.3: The Scale of Things Natural and Manmade. Source: DOE

Above the line:

We can still use light-based "Micro-fabrication" techniques

And even though they were developed for electronics,

they are now also applied to making all sorts of micro things!

Below the line:

NO longer able to use Micro-fabrication

Replacement would be called "Nanofabrication" or "Nanotechnology"

What is Nano Science??

- Synthesis the novel nano materials

- Study the all the properties (chemical, physical and electrical etc,)

- Characterize in different ways

“So where does Nanotechnology fit in the curriculum?

On one hand, it is not Physics, Biology, or Chemistry.

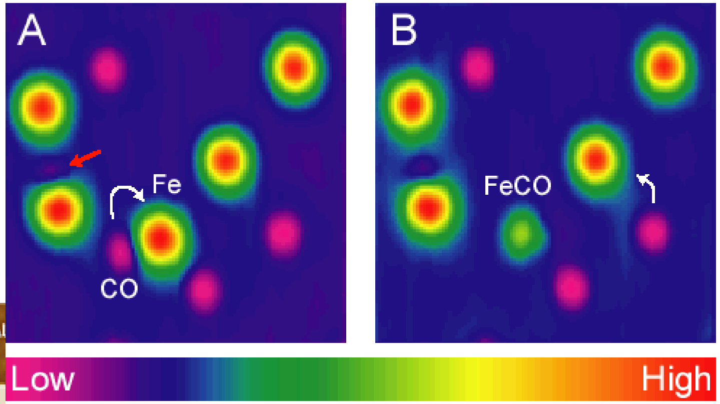
On the other hand, it is all of them !

Is nanotechnology a subject of its own, or is it just a way of thinking about other subjects?”

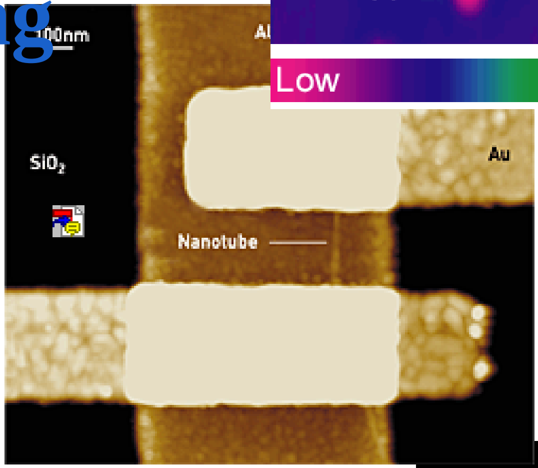
What is Nanotechnology?

- *It is science and engineering performed at the nanoscale, i.e., at the molecular and atomic scale.*
- *The result is that materials have different properties and behave in unique ways at this small scale.*
- *At this small scale, the effects of quantum physics become more prominent than classical physics.*
- *Nanotechnology provides mankind the ability to make things the way nature has been doing it for eons; atom by atom from the bottom up.*

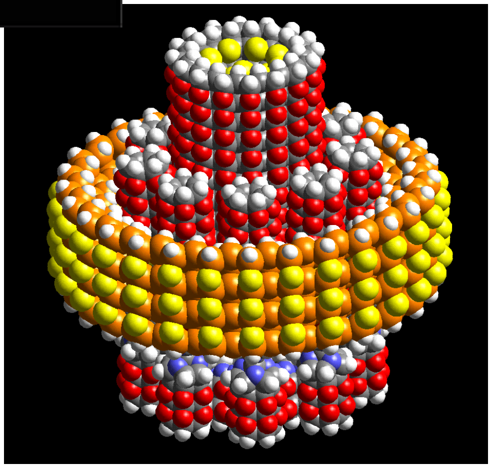
Nanoscience vs. Nanotechnology



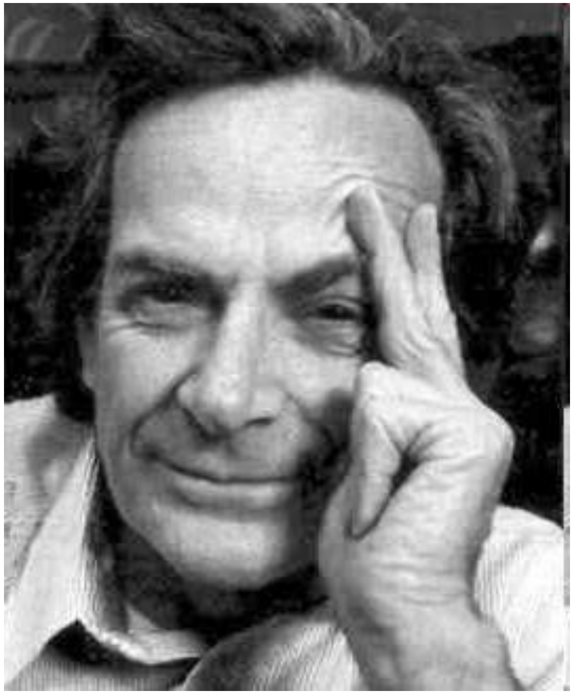
Nanoscience: exploring and studying the properties of the nanoscale



Applying the unique properties of the nanoscale to technology



ORIGIN OF NANOSCIENCE



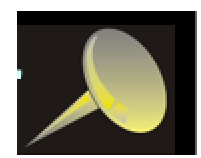
Richard P. Feynman

"There is a plenty of room at the bottom"

(Lecture in 1959 at the annual meeting of the American Physical Society)

"I would like to describe a field in which little has been done but in which an enormous amount can be done in principle"

“Why cannot we write the entire 24 volumes of the Encyclopaedia Brittanica on the head of a pin ?”



Professor Norio Taniguchi was the first person to use the term 'nanotechnology' in 1974.

"'Nano-technology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule."

Moore’s Law

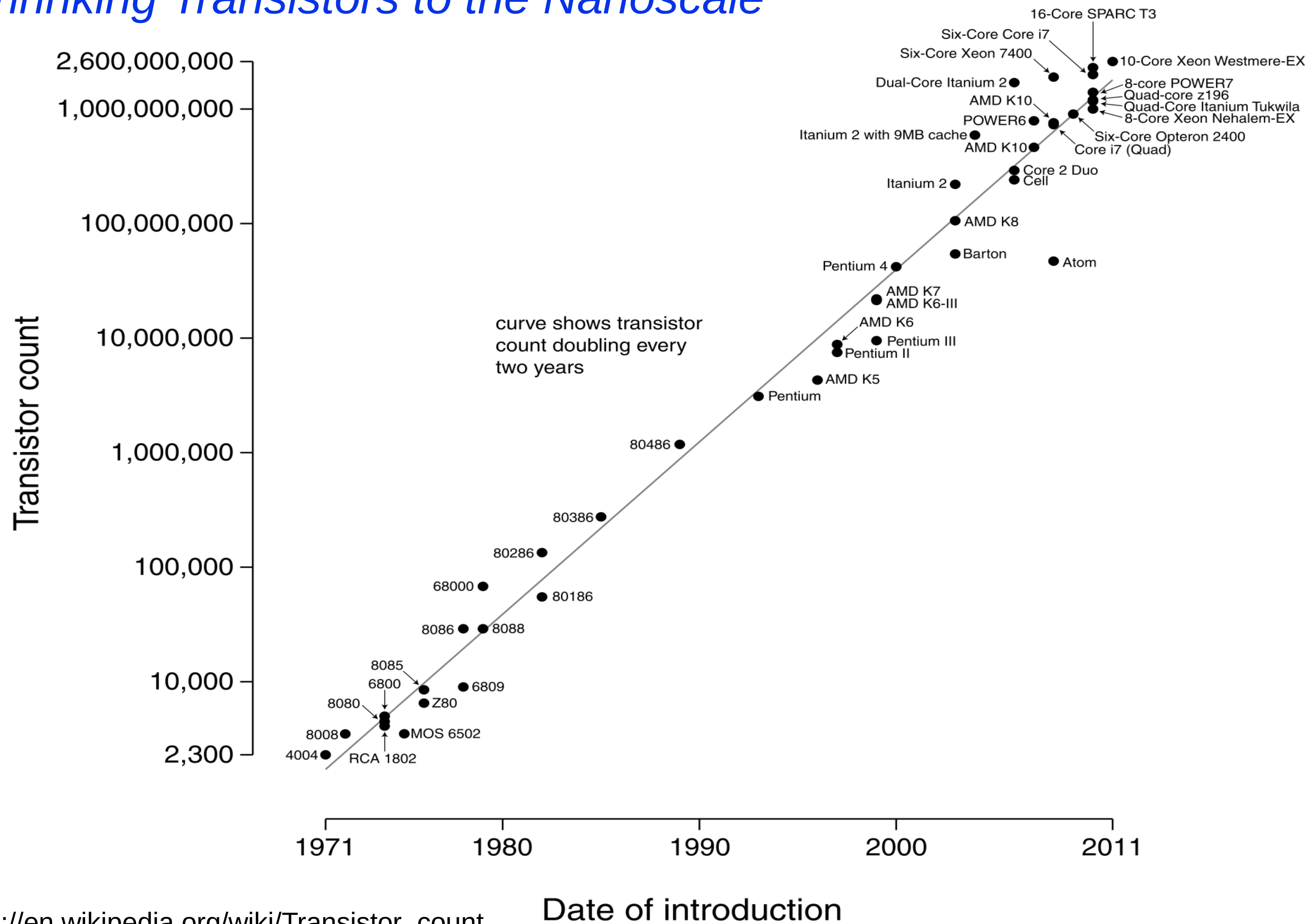
Garden Moore, one of the founder of Intel, made the observation in 1965 that the number of transistors per circuit would double every year, through the decade following that year. Later he changed this to 24 months. There where only 30 transistors on an integrated circuit at that time

We must, however, remember that Moore’s law is neither a scientific law nor a law of nature. It is only a prophetic statement.

Moore’s law has been the name given to everything that change exponentially

Microprocessor Transistor Counts 1971-2011 & Moore's Law

Shrinking Transistors to the Nanoscale



http://en.wikipedia.org/wiki/Transistor_count

Nanotechnology is <u>interdisciplinary</u> and impacts many <u>application</u>

- Physics
- Chemistry
- Biology
- Materials Science
- Polymer Science
- Electrical Engineering
- Chemical Engineering
- Mechanical Engineering
- Medicine

- Electronics
- Materials
- Health/Biotech
- Chemical
- Environmental
- Energy
- Aerospace
- Automotive
- Security
- Forest products

INTRODUCTION TO NANOMATERIALS

Richard P. Feynman

The Lycurgus Cup, when illuminated from outside, it appears green and when illuminated from within the cup, it glows red (glass; British Museum; 4th century A. D. From the site, http://www.thebritishmuseum.ac.uk)

Nano Structure and Device

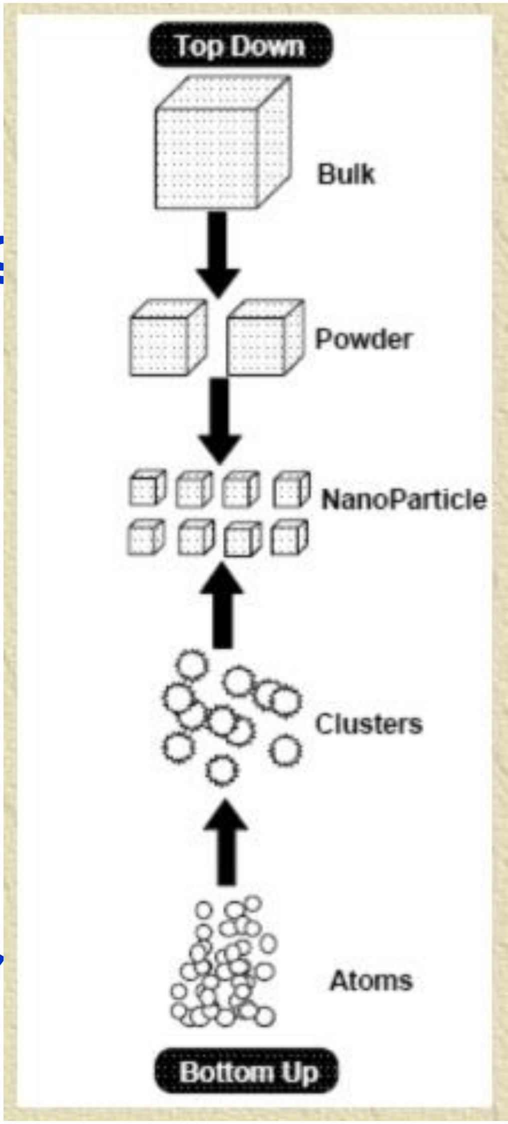
- Nano structure and device can be accomplished by two approaches.

-- "Bottom Up" method where small building blocks are produced and assembled into larger structures.

examples: chemical synthesis, laser trapping, self assembly, colloidal aggregation, etc

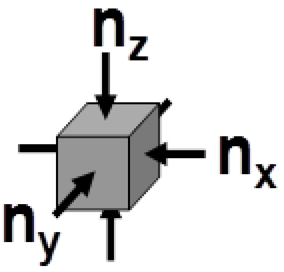
-- "Top Down" method where Large object are modified to give smaller features.

examples: film deposition and growth, nano imprint / lithography, etching technology, mechanical polishing



Different types of Nanomaterials

QUANTUM DOT (Zero-dimensional objects)



Nanoparticles or nanocrystals

Small nanoparticles are often called quantum dots

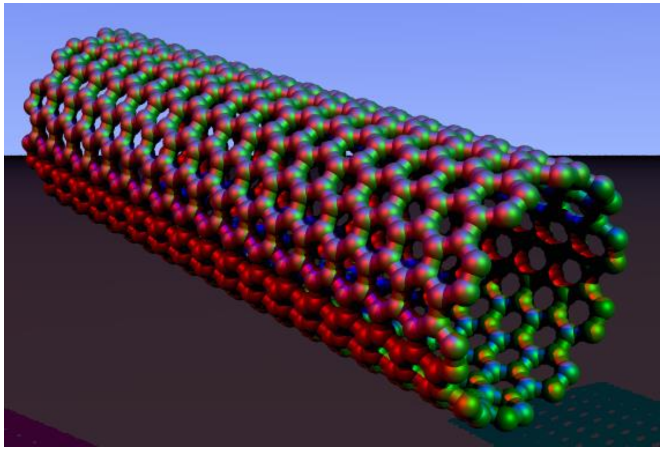
Nanodimensions ~ 1-50 nm in size

In this systems where the electrons are confined in their motion in all three directions

Metal, metal oxides, semiconducting and magnetic materials can be prepared

QUANTUM WIRE

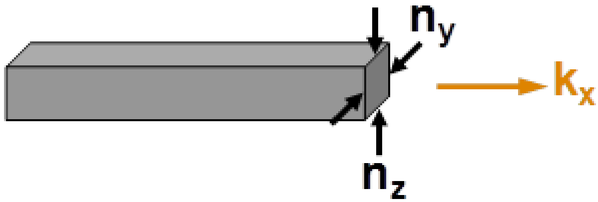
One dimensional materials

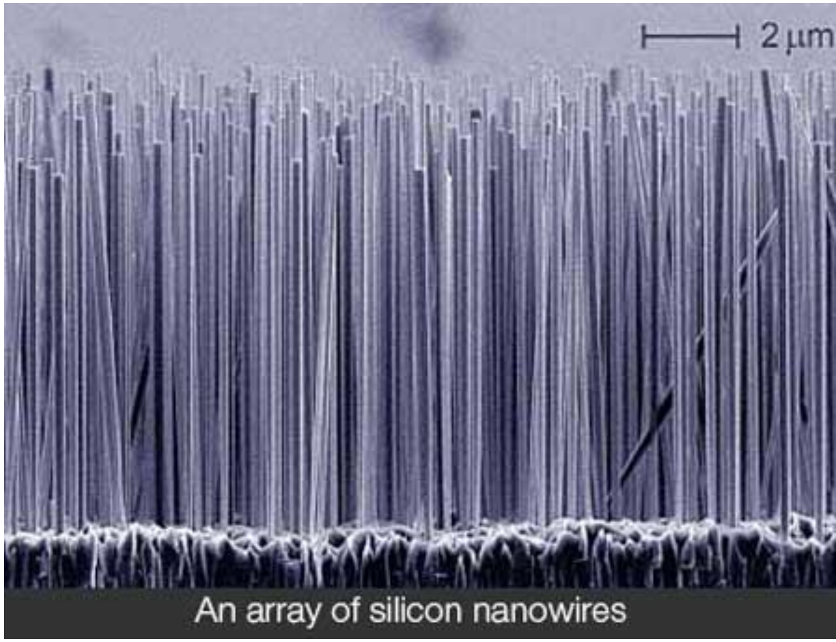


Long (several microns in length) but with diameters only a few nanometers

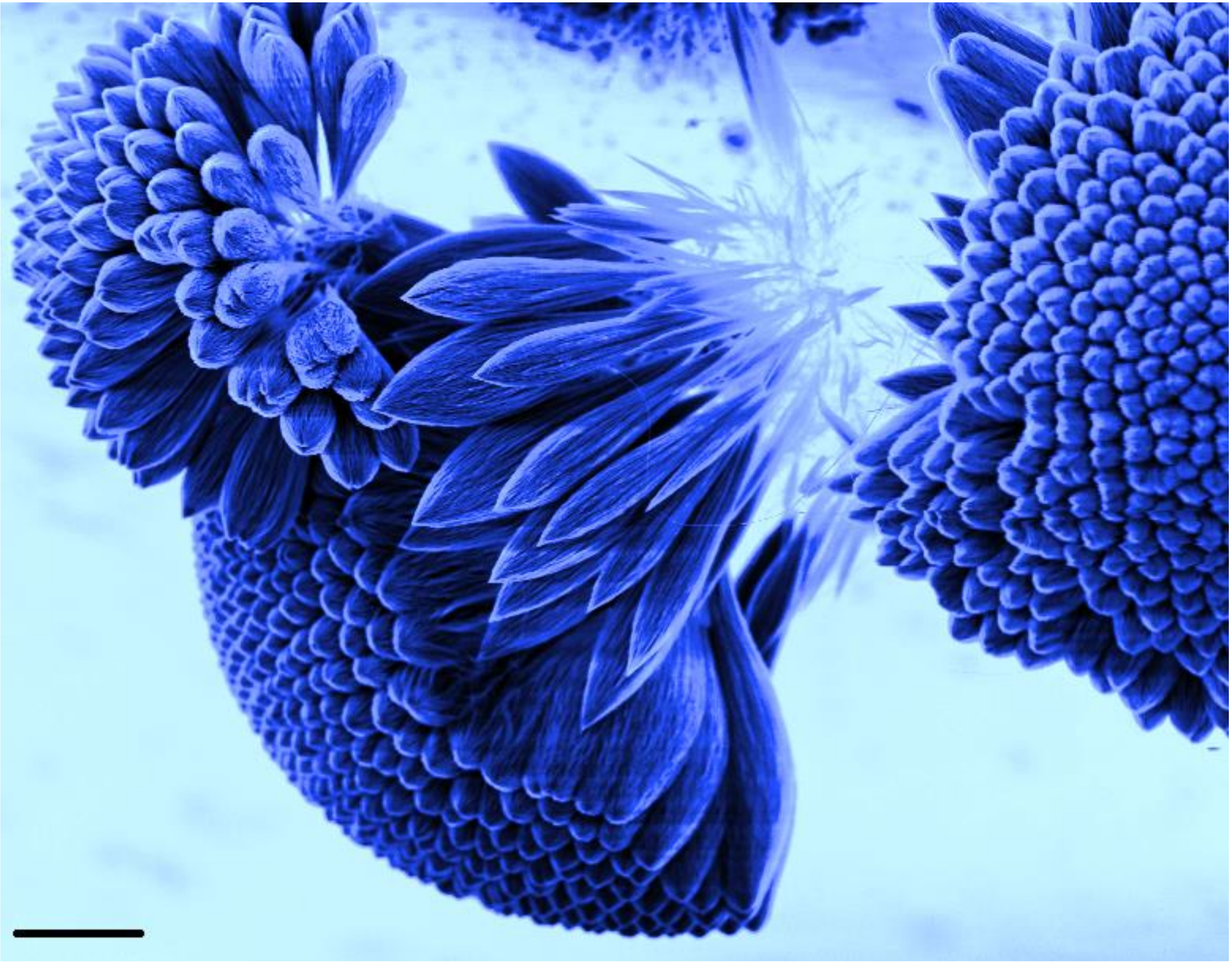
Nanowiires and nanotubes belong to this category

Metals, oxides and other materials



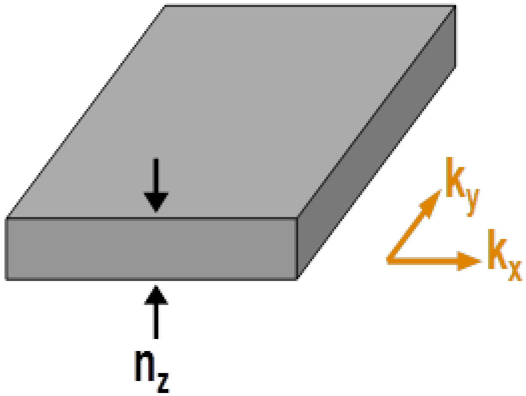


In this systems where electrons are free to move in one direction and confined in the other two directions.



Dr.K.JEGANATHAN, Associate Prof. and Coordinator
Center for NanoScience and NanoTechnology
Bharathidasan University, Trichy -24

QUANTUM WELL
(Two dimensional materials)

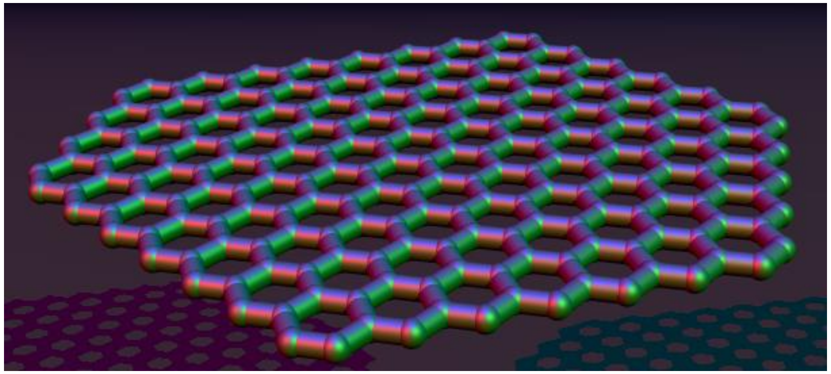


Area (several microns square) but with thickness only a few nanometers

Nanofilms and nanosheets or nanowall belong to this category

e.g. Graphite

In this type of systems the electron are confined in their motion in one direction while they move as in the corresponding bulk material in the other two directions.



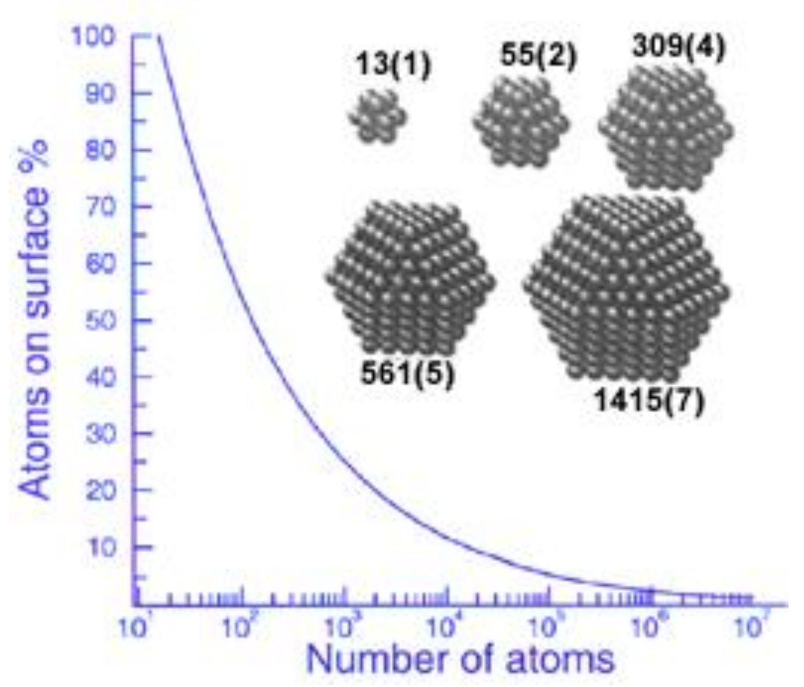
Physical properties of nanomaterials

Atoms on a small scale behave like nothing on a large scale

Main feature – size determines the properties of nanomaterials

In macro-scale – properties do not change much with size

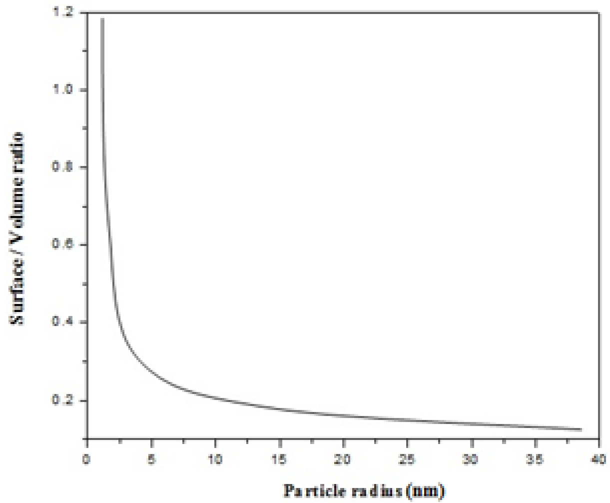
In nano-scale – enormous changes



The Surface Area - if you go on reducing the size of a material to a very very small particle, say 1 nm then all the atoms constituting the particle will be on the surface.

-if you increase the size 1 nm to 5 nm, the number of atoms on the surface will decrease.

SURFACE AREA TO VOLUME RATIO



In a nanoparticle, the amount of surface area the particle has larger compared to its volume.

This means there are more atoms on the surface of the particle than in the middle of it, and that makes them the most important.

Surface atoms act differently to atoms inside a particle, so when there are more surface atoms than inside atoms the way they behave dominates the whole behaviour of the particle.

The opposite is also true, when the particle is bigger it has a large volume compared to its surface area and the number of atoms inside the particle is much higher than the number of atoms on the outside (the surface) of the particle.
What the inside atoms are doing is the most important thing and the behaviour of the particle will be decided by them.

So what difference does it make?

How surface atoms and inside atoms behave can be very different.

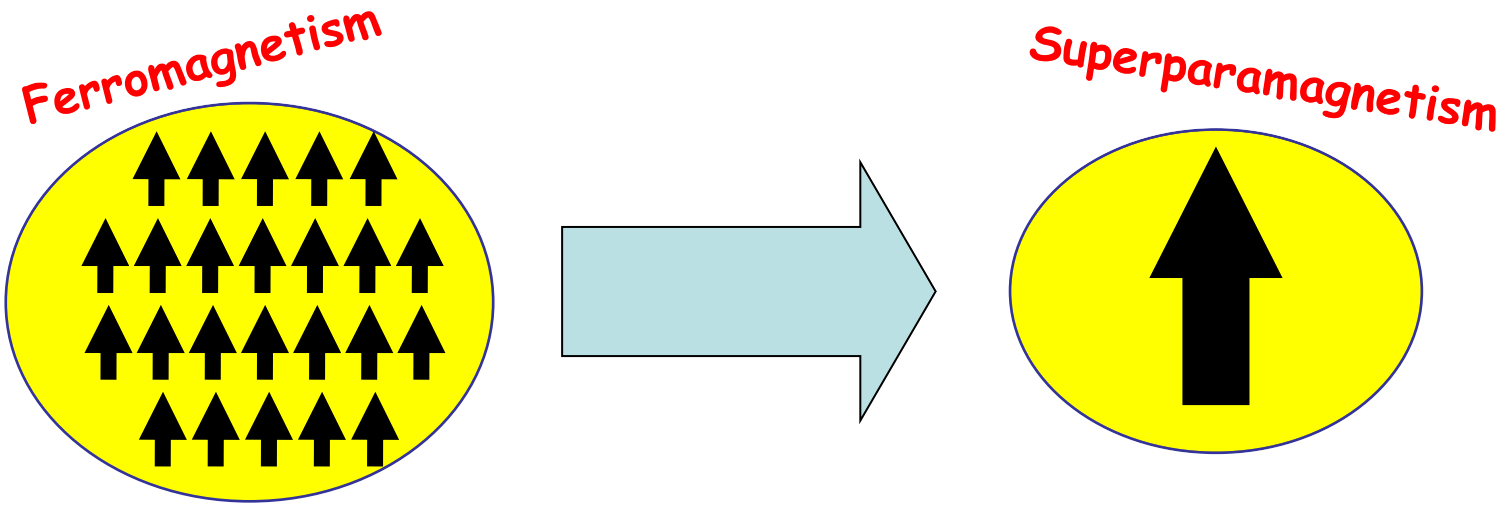
This means that when we get a very small piece of material, with comparatively large numbers of surface atoms, the material can act very differently to what we are used to (aluminium nanoparticles explode!).

In nanotechnology we are making use of particles with lots of surface atoms and the fact that this makes them behave differently – it allows us to do new and exciting things.

Changes in properties

Magnetic properties

Magnetic properties of nanostructured materials are distinctively different from that of bulk materials. Ferromagnetism of bulk materials disappears and transfers to superparamagnetism in the nanometer scale due to the huge surface energy.



N spins, each of moment μ

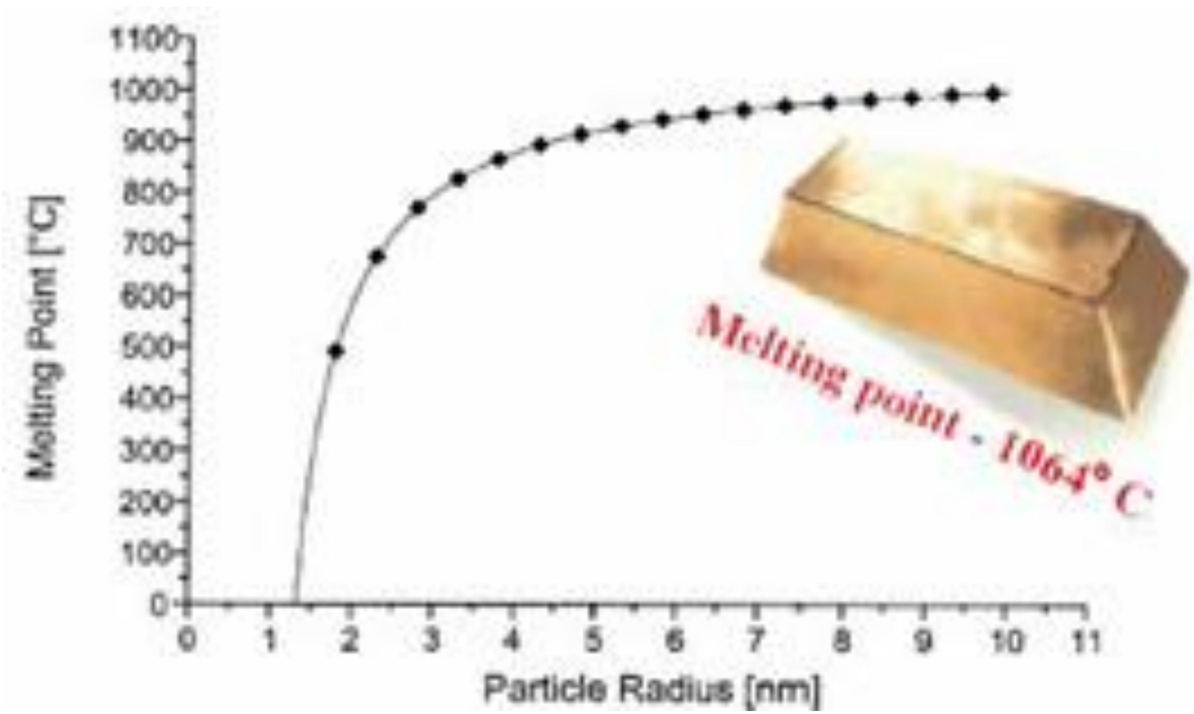
'Superspin' of moment $N\mu$

Optical properties of nanomaterials can be significantly different from bulk crystals. E.g. The optical absorption peak of a semiconductor nanoparticle shifts to short wavelength, due to an increased band gap. The colour of metallic nanoparticles may change with their sizes due to surface plasmon resonance.

Bulk gold	small particle of gold
shine as a metal;	no metallic, don't shine
Chemically not reactive (make jewel)	Reactive

Thermal properties

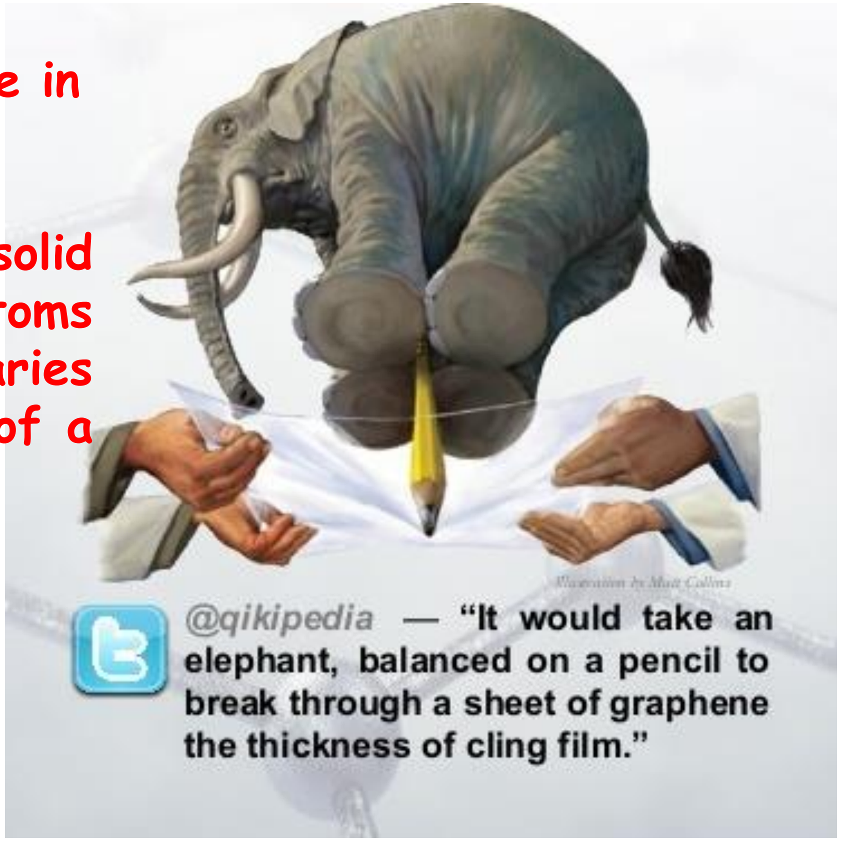
Nanomaterials may have a significantly lower melting point or phase transition temperature and appreciably reduced lattice constants, due to a huge fraction of surface atoms in the total amount of atoms



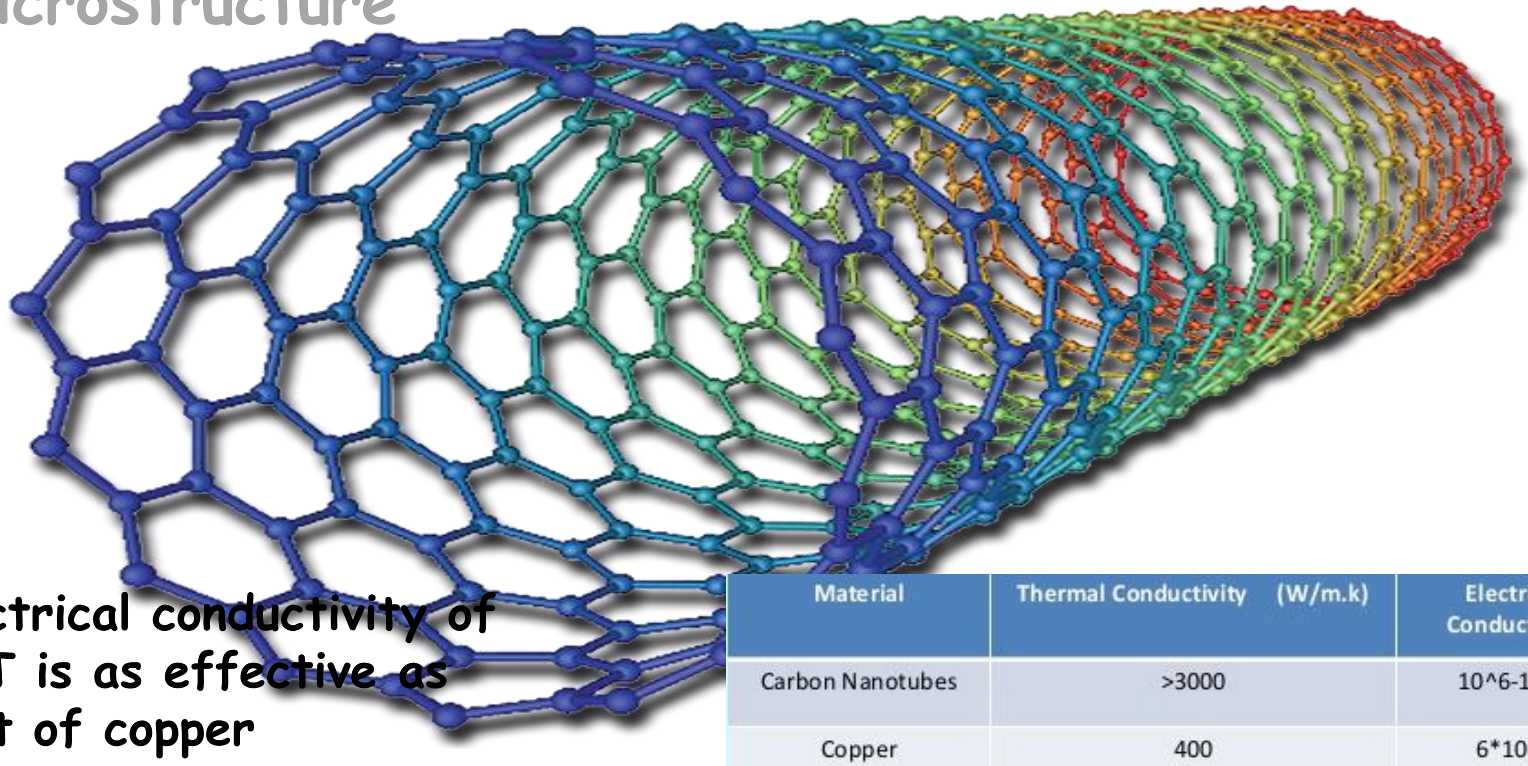
Mechanical properties of nanomaterials may reach the theoretical strength, which are **one or two** orders of magnitude **higher than** that of single crystals in the bulk form. The enhancement in mechanical strength is due to the **reduced probability of defects**.

Grain boundaries play a significant role in the materials properties

As the grain size d of the solid decreases, the proportion of atoms located at or near grain boundaries relative to those within the interior of a crystalline grain, scales as 1/d.



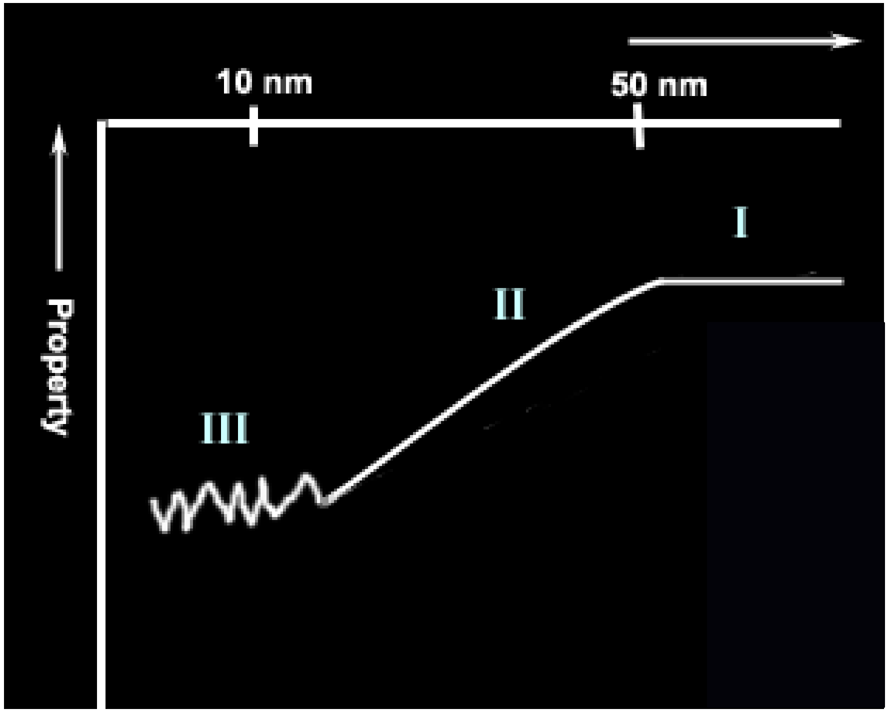
Electrical conductivity decreases with a reduced dimension due to increased surface scattering. However, electrical conductivity of nanomaterials could also be enhanced appreciably, due to the better ordering in microstructure



Electrical conductivity of CNT is as effective as that of copper

Very high current carrying capacity

Material	Thermal Conductivity (W/m.k)	Electrical Conductivity
Carbon Nanotubes	>3000	10^6-10^7
Copper	400	6*10^7
Carbon Fiber – Pitch	1000	2-8.5*10^6
Carbon Fiber – PAN	8-105	6.5-14*10^6



In region I (50 nm and above) ,
properties will be similar to those the bulk

II (10 – 50 nm),
their properties vary linearly with size

III (very small),
we get some unusual and new properties

These are due to quantum effects

Any heat treatment increases the diffusion of impurities, intrinsic structural defects and dislocations, and one can easily push them to the nearby surface. chemical stability would be enhanced.

Bulk gold does not exhibit catalytic properties
Au nanocrystal is an excellent low temperature catalyst.

- Therefore, if we can control the processes that make a nanoscopic material, then we can control the material's properties.

Characteristics of nanomaterials that distinguish them from bulk materials

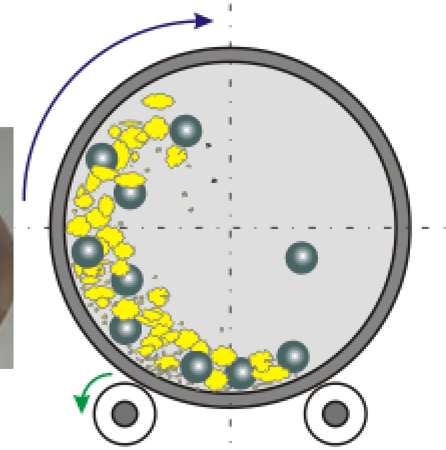
- **large fraction of surface atoms**
- **high surface energy**
- **spatial confinement**
- **reduced imperfections**

Methods of preparing nanomaterials

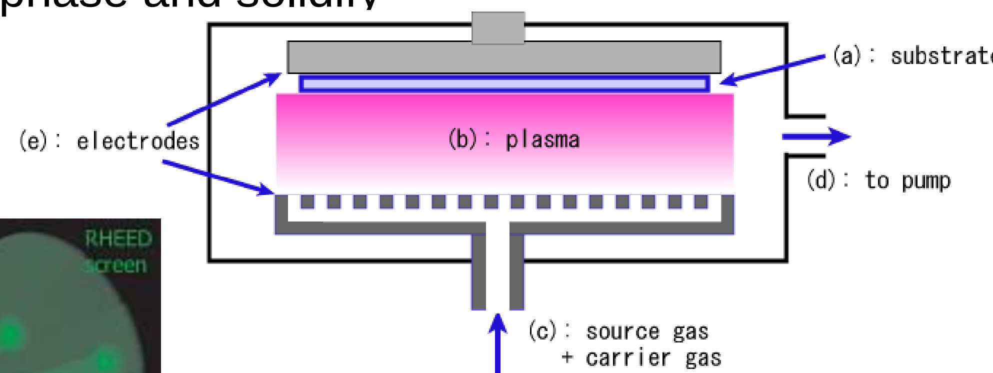
Physical and Chemical methods

Physical Method -

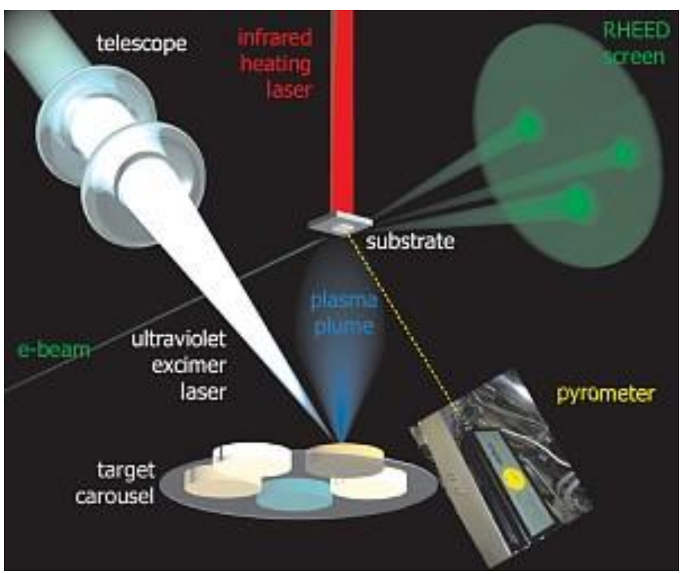
Grind materials Using ball milling



Evaporate materials to gas phase and solidify



Laser



Chemical methods (most powerful)

React a metal salt with a alcohol or
some other reducing agent

Metal compound along with a reagent
in a boiling solvent (sealed vessel)

Under this condition,
many kinds of nano-particles are formed

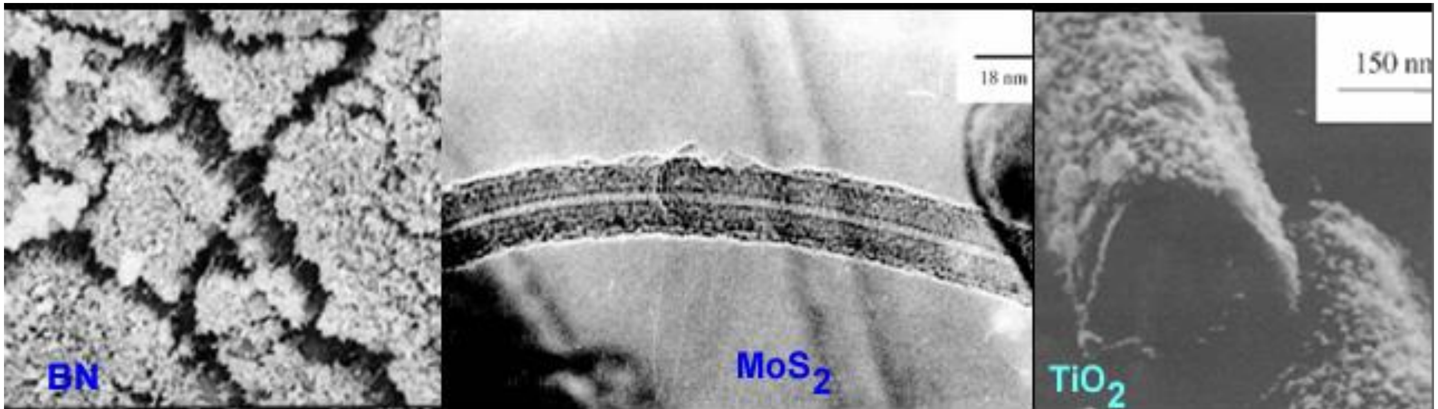
Hydrothermal and solvothermal methods

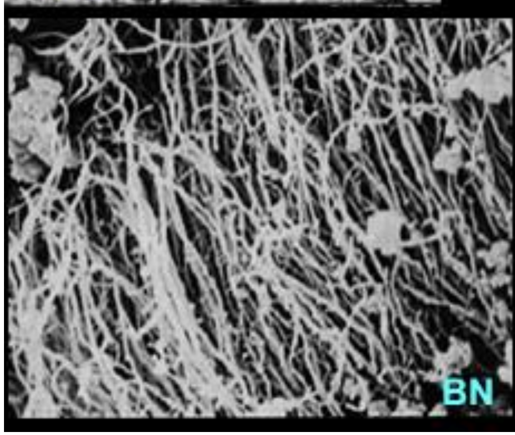
Water used as a boiling solvent - Hydrothermal

Organic boiling solvent like a hydrocarbon - solvothermal

For example, if we take a metal acetate and heat in a boiling hydrocarbon, we get metal or metal oxide nanoparticles

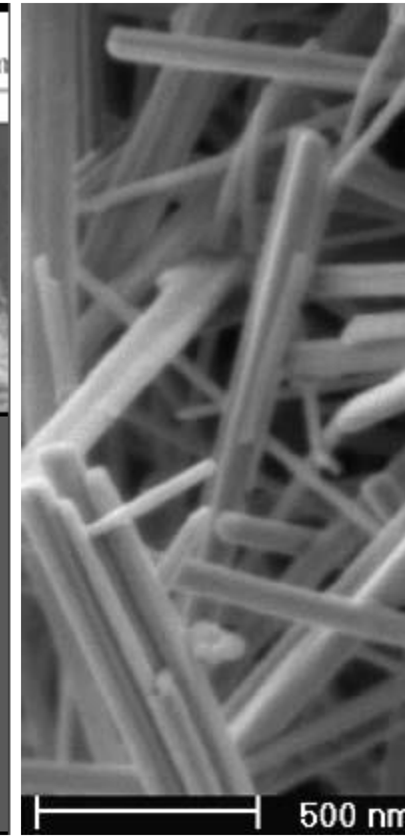
Today we have reached a level where can make nanomaterial of any compound in any shape we desired





Carbon nanotubes have been known since 1991.

Now it is possible to make nanotubes of metal sulfides, metal oxides and other materials



SEM image of WS_2 nanotubes

Nanotubes, therefore, need not be of carbon alone