بسم الله الرحمن الرحيم

In the name of Allah

Nano chemistry- 4th stage

Lecture No. 1
History of nanotechnology

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Nano chemistry-4th stage Syllabus

-CH1: History of nanotechnology

-Introduction and important concepts in nanotechnology and nanoscience, Stages of nanotechnology history.

Nanomaterials, Nanomaterial hazards

Applications & Implication (Nano electronics, Nano biology, Nano chemistry Application)..

-CH2: Nanotechnology, principles, synthesis and application

Principles, types of nanomaterials, Quantum size effects, Classification of nanomaterials according to number of Nano size dimensions, Nanoscale materials are divided into three category (according to Siegel).

-Approaches of Nanotechnology (growth methods), Bottom-Up, Top – Down, Mechanical Milling: a Top Down Approach for the Synthesis of Nanomaterials and Nanocomposites, advantages and disadvantages.

- Method of nanomaterials synthesis, Laser ablation Method, Chemical vapor deposition (CVD) (Types and mechanism for CVD), Sol-Gel method (steps, mechanism, advantages and disadvantages).

Physical Deposition Approaches.

- Some properties and applications
- Physical properties of nanomaterials
- Semiconductor
- Metal nanoparticles.

-CH3: Carbon nanotubes

- Carbon types, Buckyballs (Fullerene), Carbon Nanotubes, types of carbon nanotubes that depended on the number of layers, Comparison between SWNT and MWNT, Other types of CNT.
- Special properties of carbon nanotubes.
- Methods for synthesis of CNT
- Growth mechanism
- Purification of Carbon Nanotubes
- Chemical methods for preparation of Graphene oxide, from graphite
- Applications of CNTs

-CH4: Nanotechnology instruments

- XRD, A Brief History of XRD, Bragg Diffraction Law, Derivation of Bragg's law, Generation of X-Ray, Uses of X-ray Powder Diffraction, Important advantages and uses of powder diffraction. Scherrer's Formula, Data Analysis.
- SPM, STM and AFM. History of Electron Microscopy.
- Scanning Probe Microscopes (SPM),basic , advantages.
- Scanning Tunneling Electron Microscope (STM), basic, advantages and disadvantages.
- Atomic Force Microscope (AFM), basic, advantages and disadvantages.
- Scanning Electron Microscopes (SEM), basic, advantages and disadvantages.
- Transmission Electron Microscope (TEM), basic, advantages and disadvantages.

What is Nanotechnology?

Nanotechnology deals with small structures or small-sized materials.

The science of manipulating atoms and molecules to make new materials and devices.

- One nanometer is 10^{-9} meters or about 3 atoms long. For comparison, a human hair is about 60-80,000 nanometers wide.

SIZE

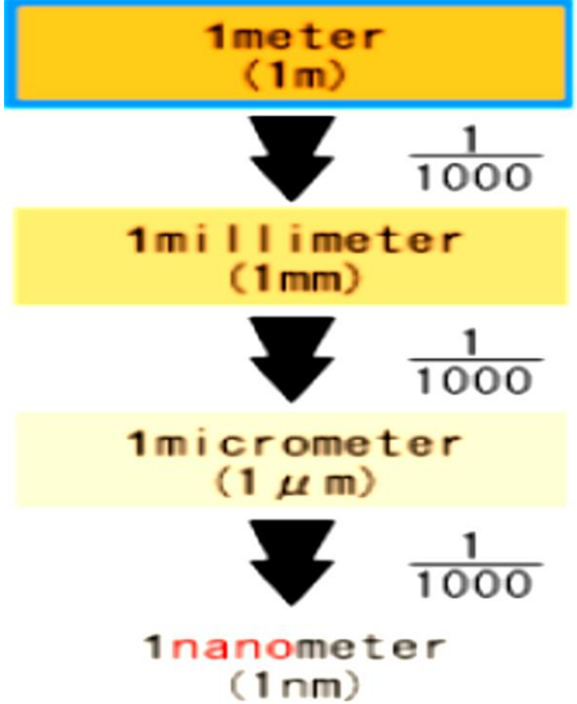
A **meter** is about the distance from the tip of your nose to the end of your hand (1 meter = 3.28 feet).

Millimeter- One *thousandth* of meter.(10^{-3}m)

Micron: a *micron is a millionth of a meter (or) one thousandth of millimeter (10^{-6}m)*

Nanometer:

A nanometer is one thousandth of a micron (10^{-9}m) (or) a billionth of a meter. ie.,*one **billion** nanometers in a meter*.



'Nano' is the unit prefix representing 10^{-9}.

prefix	symbol	meaning
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

Nanoscale Materials Categorizations

Naturally occurring "ultrafine particles"

- Virus – 10 to 60 nm
- Bacteria – 30 to 10 µm
- Dust from deserts - ~ 100 nm
- Volcanic ash, Forest fire smoke

"Ultrafine particles" from established technologies or by products of conventional Processes

- Combustion soot – 10 to 80 nm
- Paint pigments – 80 to 100 nm
- Welding fumes – 10 to 50 nm
- Diesel exhaust particles – (Small mode) 7 to 40 nm
- Carbon black for photocopier toner – 10 to 400 nm

Engineered nanoscale materials – "nanomaterials"

- Fullerenes – buckyballs – 1 nm: nanotubes – 1 to 5 nm x 10 µm
- Quantum dots for medical diagnosis– 5 to 20 nm
- Semiconductor wires for sensors – 10 to 100 nm diam. x 1 µm

Introduction

The Greek word "nano" (meaning dwarf) refers to a reduction of size, or time, by 10^{-9}, which is one thousand times smaller than a micron.

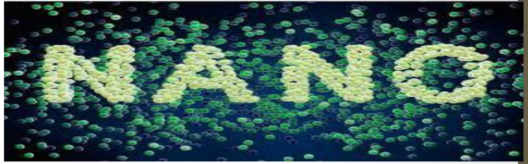
One nanometer (*nm*) is one billionth of a meter and it is also equivalent to ten Angstroms.

As such a nanometer is 10^{-9} meter and it is 10,000 times smaller than the diameter of a human hair.

Historical aspects of nanotechnology are introduced starting with the famous **1959** lecture by R.P. **Feynman**. It is suggested to name the nanometer scale the *Feynman* (ϕ nman) *scale*

$$\text{One } \textit{Feynman}\ (\phi) \equiv 1\ \textit{Nanometer}\ (nm) = 10\ \textit{Angstroms}\ (\mathring{A}) = 10^{-3}\ \textit{Micron}\ (\mu) = 10^{-9}\ \textit{Meter}\ (m)$$

concepts in nanoscience



- ***Nanoscience*** → the study of the phenomena at 1-100 nm
- ***Nanomaterials*** → *those which have structured components with at least one dimension less than 100 nm*

Nanomaterials can be of two types:

- '**non-intentionally-made nanomaterials**', which refers to nano-sized particles or materials that belong naturally to the environment (e.g. proteins, viruses, nanoparticles produced during volcanic eruptions, etc.) or that are produced by human activity without intention (e.g. nano-particles produced from diesel combustion);
- '**intentionally-made**' nanomaterials, which refers to nanomaterials produced deliberately through a defined fabrication process.

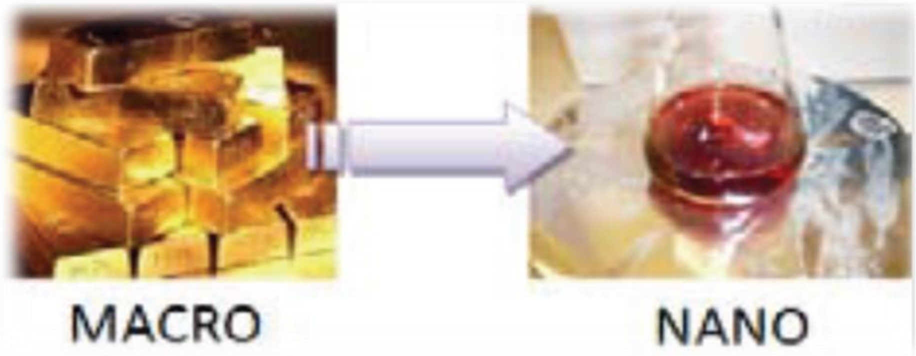
Nanoparticles are nanosized structures in which at least one of its phases has one or more dimensions (length, width or thickness) in the nanometer size range (1 to 100 nm)

- A solid particle in the 1-100 nm range that could be noncrystalline, an aggregate of crystallites or a single crystallite

- Nanocrystal
  - A solid particle that is a single crystal in the nanometer range 1-100 nm
- Cluster
  - A collection of units (atoms or reactive molecules) of up to about 50 units
- Colloids **(Sol)**
  - A stable liquid phase containing particles in the 1-1000 nm range. A colloid particle is one such 1-1000 nm particle.

Bulk Gold and Gold as nanoparticles

Bulk Gold	Gold as nanoparticles
1- Shiny surface when polished. 2-Alwayes gold in yellow colour when in a mass. 3-Heat and electronic conductor 4- High melting point (1080 º C). 5- Inert (unaffected by air and most reagents) metal.	1- A very good catalyst.. 2-Have different colours depended on size and shape of the nanoparticles (at 25 nm –red reflected, at 50 nm – green reflected). 3-Heat and electronic conductor 4- Relative low melting point (940 º C). 5- Not metal but semiconductor.



Common important properties of nanoparticles

- The changes in the properties of nanoparticles are driven mainly by three factors:

  1. The increase in the surface to volume ratio:

     -Atoms and molecules on surface and interface have different environment, hence exhibit different properties

     -As size reduced, relative number of atoms on surface increases inversely as particle size and appreciable in nm range.

  2. Quantum size effect:

     -When the size of the particle is comparable to phase coherent length of electrons, the energy spectrum is quantised into discrete levels with a energy spacing E_f/N.

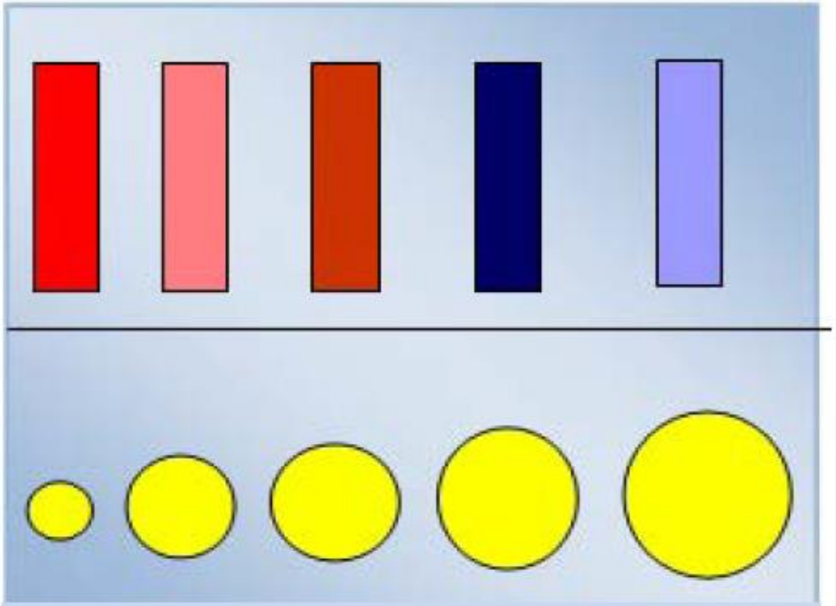
  3. Lattice contraction:

     -At very small sizes there are structural phase changes and decrease in lattice parameters

Quantum size effect

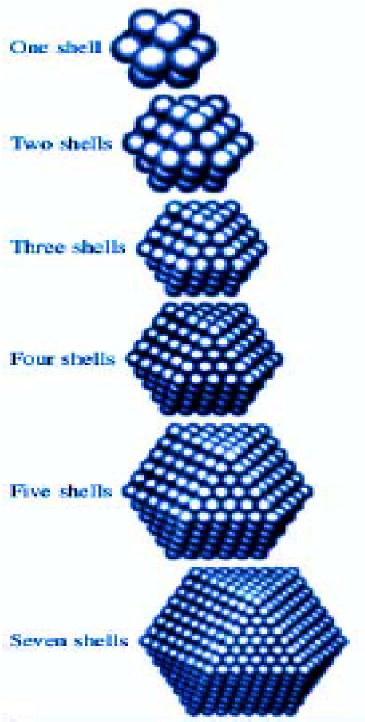
When the size of a nanocrystal (i.e. a single crystal nanoparticle) is smaller than the de Broglie wavelength, electrons and holes are spatially confined and electric dipoles are formed, and discrete electronic energy level would be formed in all materials. Similar to a particle in a box, the energy separation between adjacent levels increases with decreasing dimensions.

The quantum size effect is most pronounced for semiconductor nanoparticles, where the band gap increases with a decreasing size, resulting in the interband transition shifting to higher frequencies.

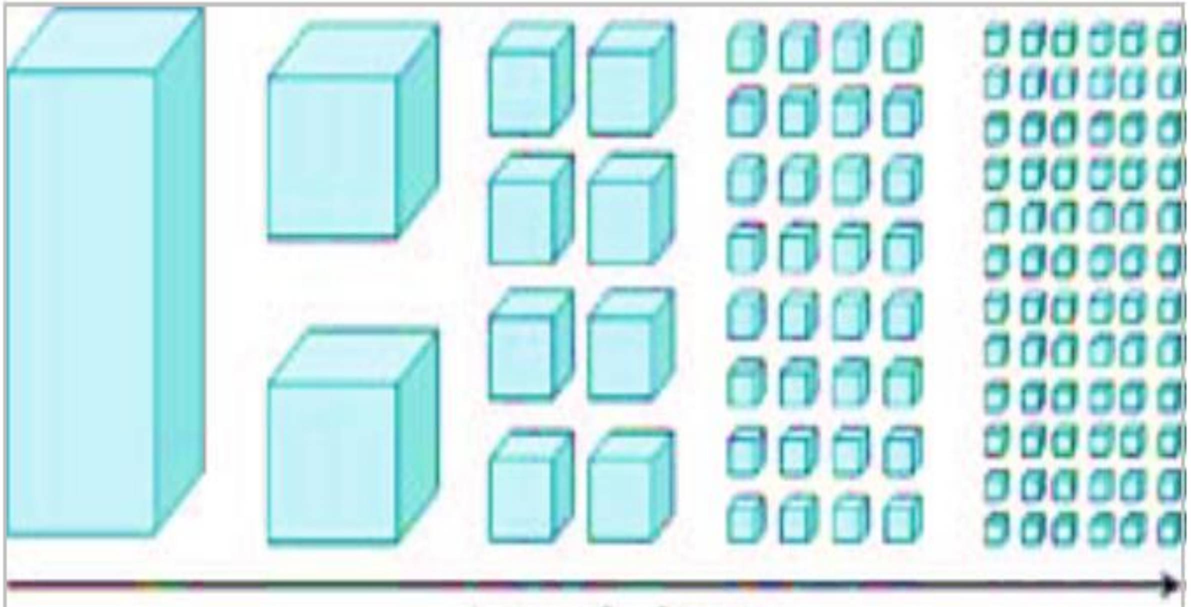


Gold particle of difference size producing different colour

- surface
  - The atoms on the surface play a dominant role for the physical and chemical properties that are controlled by surface exchanges
  - Contrary to classical materials, the proportion of atoms on the surface of the nanoclusters becomes non negligible.



Total number of atoms	Percentage of surface atoms
13	92 %
55	76 %
147	63 %
309	52 %
561	45 %
1415	35%



Increased in surface area

Figure 3: Schematic drawing showing how surface to volume increases as size is decreased (image not to scale)

Size of cube side	Number of cubes	Collective surface area
1 m	1	6 m^2
0.1 m	1 000	60 m^2
0.01 m = 1 cm	10^6 = 1 million	600 m^2
0.001 m = 1 mm	10^9 = 1 billion	6 000 m^2
10^{-9} m = 1 nm	10^{27}	6×10^9 = 6 000 km^2

QUANTUM DOTS

Quantum dot discovered by Louis E. **Brus**. It is nanoparticles that have a flash when excited it by UV light. The comment quantum dot crystals are ZnS, PbS, CdSd. The idea **quantum dot crystal has 100-100 000 atom in it hart and the diameter is 2-10 nm.**

Louis E. Brus
1943

Quantum dots have been used as a fluorescent labeling agents for both in vitro and in vivo studies for stem cell labeling, medical imaging, sensors, light-emitting diodes, in vivo imaging, 199 200 biological sensing, and multiplexing gene analysis.

- Recently, cytotoxicity of quantum dots (QDs) and deleterious effects of the labeling procedure on human mesenchymal stem cells has been reported.
- The cadmium-based quantum dots (QDs) showed cytotoxic effects.
- The CdTe quantum dots induce cell death by involving both Cd^{2+} and reactive oxygen species (ROS) accompanied by lysosomal enlargement and intracellular redistribution

Thank you For your Attention