Nanotechnology

Lecture 1

Introduction to Nanoscience

Al-Mustaqbal University Department of Medical Physics

4nd stage

Second Course

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Metric System

▪Metric system is a decimal measuring system based on the metre, litre, and gram as units of length, capacity, and weight or mass .

▪The system was first proposed by the French astronomer and mathematician Gabriel Mouton 1618, and was standardized in Republican France in the 1790s.

▪It’s a system of measurement that standardises a set of base units and a nomenclature for describing relatively large and small quantities using decimal-based multiplicative unit prefixes .

▪Though the rules governing the metric system have changed over time, the modern definition, the International System of Units (SI), defines the metric prefixes and seven base units: metre (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol)، and candela (cd).

Quantity	Base Unit	Abbreviation
length	meter	m
Mass	gram	g
volume	Liter	L
time	second	s
force	Newton	N
energy	Joule	J
temperature	Kelvin	K
electric charge	Coulomb	C

Metric system and Measuring instruments

Nano & nanometre (nm)

The meaning of the term nano can be summarized as follows:

▪Nano is a term derived from the Greek word nanos, meaning "dwarf”

▪In the world of science and measurement, "nano" is a prefix that means one-billionth.

▪It is a scale that measure units at an infinitesimal level To give you some perspective:

The Scale of Nano, in the International System of Units (SI) the nanometer means:

▪A unit of units used in the International System of Units

▪One nanometer is one-billionth of a meter (1Nano = 10−9 meter)

▪It's difficult to imagine just how small that is.

▪A sheet of paper is about 100,000 nanometers thick.

▪ A strand of human DNA is about 2.5 nanometers in diameter.

The metre (or meter in US spelling; symbol: m) is the base unit of length in the International System of Units (SI). Since 2019, the metre has been defined as the length of the path travelled by light in vacuum during a time interval of 1/299792458 of a second, where the second is defined by a hyperfine transition frequency of caesium

The relationship between nanometers and meters can be illustrated in the table below.

1	kilometer	(km)	$=10^{3}$m
1	decimeter	(dm)	$=10^{-1}$m
1	centimeter	(cm)	$=10^{-2}$m
1	millimeter	(mm)	$=10^{-3}$m
1	micrometer	(µm)	$=10^{-6}$m
1	nanometer	(nm)	$=10^{-9}$m
1	angstrom	(Å)	$=10^{-10}$m
1	picometer	(pm)	$=10^{-12}$m
1	femtometer	(fm)	$=10^{-15}$m

Nano-Material

▪Nano materials are defined as a set of substances where at least one dimension is less than

100 nanometers.

▪Nano materials defined as the "length range approximately from 1 nm to 100 nm".

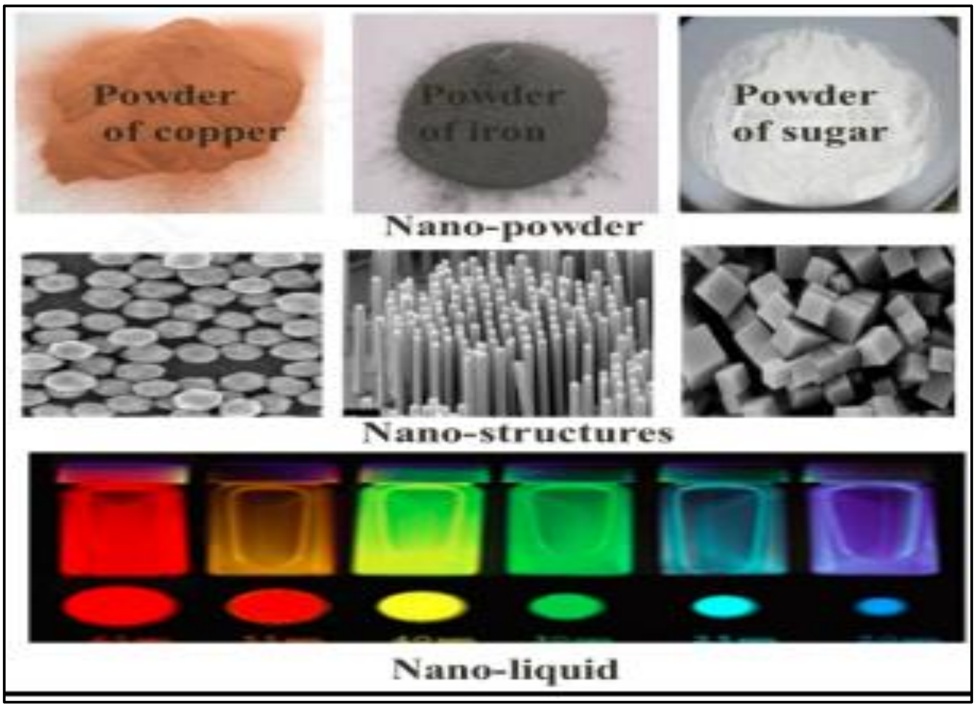
-Nano materials have attracted much attention because of their unique mechanical ، electrical and optical properties compared with those of big size or bulk phases

-Nano materials are of interest because at this scale unique (superior) optical, magnetic ،electrical, and other properties emerge.

▪These emergent properties have the potential for great impacts in electronics, medicine ، and other fields.

-Nano material is defined as the "material with any external dimension in the nanoscale or

having internal structure or surface structure in the nanoscale".



Different forms of nanomaterials

Basic Concepts of Nanomaterials

▪Moving material to the nanoscale isn't just about making reducing sizes

▪It represents the process of quantum laws advancing over classical physics laws.

▪When you reduce a material to the size of 1 to 100 nanometers (where a nanometer is one billionth of a meter), its fundamental properties—like color, strength, and conductivity_can change .

▪Changing in the chemical and physical properties nanomaterials due to of effects that are related to the size of material and surface state

▪ The dimensions and sizes of materials play an important role to determine their properties.

What is happen with convert the material to nano-size?

The shift in behavior happens primarily due to two factors:

One: Increased Surface-to-Volume Ratio

as particles get smaller, a much higher percentage of their atoms are located on the surface

rather than the interior.

Two: Reactivity

Because more atoms are "exposed," nanomaterials become incredibly reactive. A material

that is inert at a bulk level (like gold) can become a powerful catalyst at the nanoscale.

Three: Bonding

Surface atoms have fewer neighbors, making them more "eager" to interact with other substances

So, the reason why reducing the size of a material affects its properties can be

summarized as follows:

▪ The Reducing the size of materials leads to increase the surface area

▪ With increase the surface area leads to increase in the number of surface atoms .

▪ Where the surface atoms play an important role to determine their properties .

▪ These case leads to improves in the properties of the nanostructures.

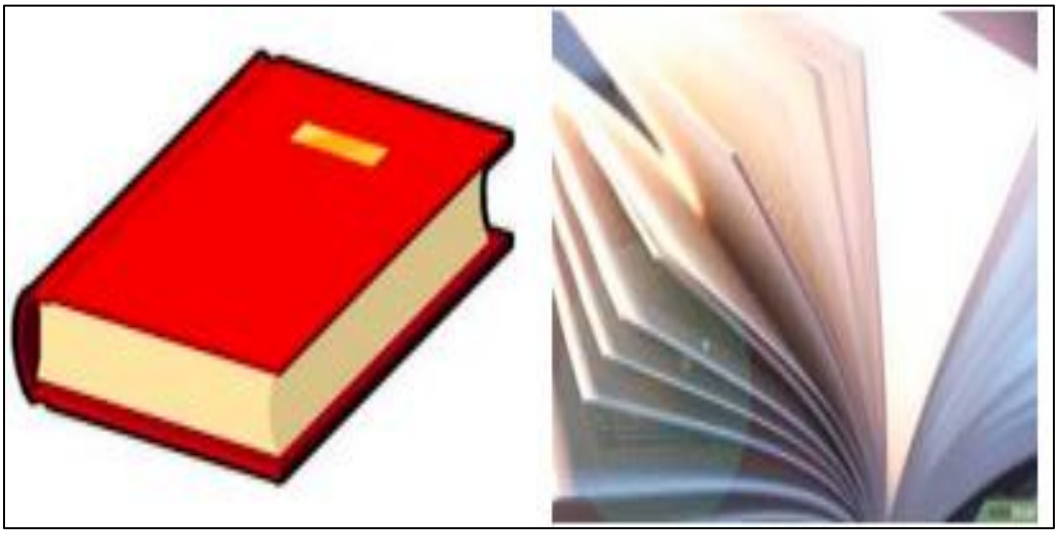


Diagram illustrating the difference in surface area

Nanoscience

Nanoscience is about the phenomena that occur in systems with nanometer dimensions. Some of the unique aspects of nano systems arise solely from the tiny size of the systems. Nano is about as small as it gets in the world of regular chemistry, materials science, and biology. The diameter of a hydrogen atom is about one-tenth of a nanometer, so the nanometer scale is the very smallest scale on which we might consider building machines on the basis of the principles we learn from everyday mechanics, using the 1000 or so hydrogen atoms we could pack into a cube of size 1 nm×1 nm×1 nm. If this is all that there was to nanoscience, it would still be remarkable because of the incredible difference in scale between the nano world and the regular macroscopic world around us. In 1959, Richard Feynman gave a talk to the American Physical Society in which he laid out some of the consequences of measuring and manipulating materials at the nanoscale. This talk, "There is plenty of room at the bottom," is reproduced in its entirety in Appendix B. It does a far better job than ever I could of laying out the consequences of a technology that allows us to carry out routine manipulations of materials at the nanoscale and if you have not already read it, you should interrupt this introduction to read it now. The remarkable technological implications laid out in Feynman's talk form the basis of most people's impression of Nanoscience. But there is more to Nanoscience than technology. Nanoscience is where atomic physics converges with the physics and chemistry of complex systems. Quantum mechanics dominates the world of the atom, but typical nanosystems may contain from hundreds to tens of thousands of atoms. In nanostructures, we have, layered on top of quantum mechanics, the statistical behavior of a large collection of interacting atoms. From this mixture of quantum behavior and statistical complexity, many phenomena emerge. They span the gamut from nanoscale physics to chemical reactions to biological processes. The value of this rich behavior is enhanced when one realizes that the total number of atoms in the systems is still small enough that many problems in Nanoscience are amenable to modern computational techniques. Thus studies at the nanometer scale have much in common, whether they are carried out in physics, materials science, chemistry, or biology. Just as important as the technological implications, in my view, is the unifying core of scientific ideas at the heart of Nanoscience. This book seeks to build this common core and to demonstrate its application in several disciplines. The nanoworld is the intermediary between the atom and the solid, from the large molecule or the small solid object to the strong relationship between surface and volume. Strictly speaking, the nanoworld has existed for a long time and it is up to chemists to study the structures and properties of molecules. They have learnt (with the help of physicists) to manipulate them and build more and more complex structures. Progress in observation tools (electron microscopes, scanning-tunneling microscopes and atomic force microscopes) as well as in analysis tools (particularly X-ray, neutron and mass spectometry) has been a decisive factor. The production of nanoscopic material is constantly improving, as is the case for the process of catalysis and surfaces used in the nanoworld. A substantial number of new materials with nano elements such as ceramics, glass, polymers and fibers are making their way onto the market and are present in all shapes and forms in everyday life, from washing machines to architecture.

Nanotechnology

Nanotechnology and nanoscience have gained remarkable interest since the last decade and played an important role in improving modern applications due to its unique combination of properties. The materials on a nanoscale-size show a dimension of less than 100 nm according to the dimensions nanomaterials. The nanostructures could be classified into zero-dimensional (0D) (such as quantum dot, and nanopartical), one-dimensional (1D) (such as nanowires, nanoneedle, nanorod, and nanotube), two-dimensional (2D) (such as nanoflak, nanoleave, -and -nanosheet), - and -three-dimensional -(3D) (such -as -tetrapod, -and nanosphere) Nanostructured materials have attracted much attention because of their unique mechanical, electrical and optical properties that differ from those of their bulk phases. The dimensions and sizes of materials play an important role to determine their properties, where the nanoscale-size of material allows to show greatly changed physical and chemical properties in comparison with same material in the micrometer scale. These variations are due to of effects that are related to the size of nanostructures and surface state. As the size of nanomaterial decreases, its surface area increases. Increment in the surface area will allow a greater population of its atoms/molecules to be displayed on the surface of nanomaterial rather than its interior. The large length-to-diameter ratio causes an increase in the surface-to-volume ratio. This condition in turn causes an increase in the number of surface atoms. Consequently, the surface atoms bond less with the partial surrounding interior atoms, which leads to change in the properties of the nanostructures. The surface area to volume ratio significantly increases to the level that the material properties are determined by the surface properties. This ratio offers unique characteristics that have extensive applications in various industrial sectors, including medical, electronics, and chemical sectors kinetic stability. Nanoscience and Nanotechnology are becoming the most interesting subjects because they have many applications in various fields. Nanoparticle is defined as a microscopic particle of matter that is measured on the nanoscale usually in the range of 1–100 nanometers. The properties of nanoparticles may be tuned by controlling the size of the nanoparticles. The size and surface characteristics of nanoparticles can be easily manipulated. Nanoparticle is unique because it has large surface area and large surface energy. It is highly reactive and can be used as an excellent catalyst. Nanoparticles often possess unexpected optical properties as they are small enough to confine their electrons and produce quantum size effects. We can reduce the dimension of nanoparticles to obtain thin films, quantum wires or quantum dots. These are the main reasons why we are using nanoparticles instead of bulk materials. Nanoparticles have extensive applications in biomedicine, optics and electronics. Nanoparticles are used in electrical batteries, filters, bio-labeling, optical receptors, sensors, drug delivery systems, detection of diseases, destruction of tumors, etc