Department of Biotechnology

2025-2026

Nanotechnology

Stage (Second)

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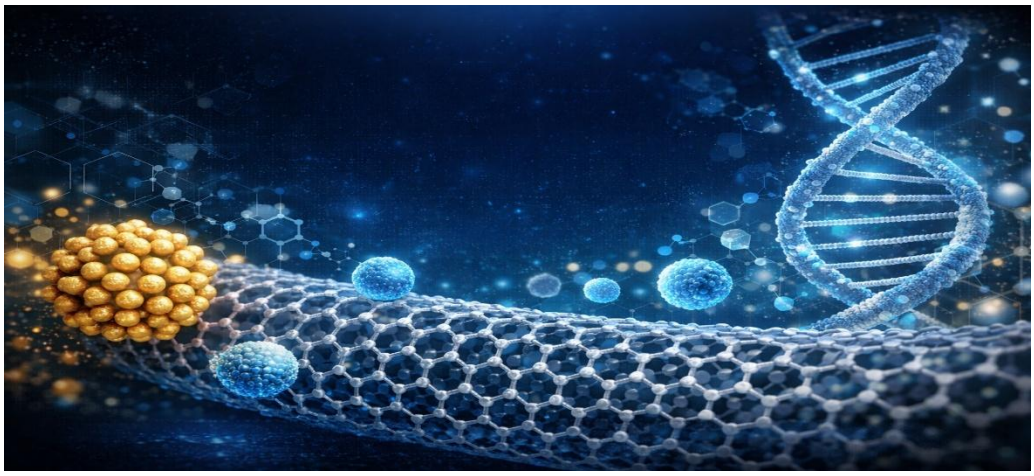

NANOTECHNOLOGY\ INTRODUCTION TO NANOTECHNOLOGY

By

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Introduction

Nanomaterials are cornerstones of nanoscience and nanotechnology. Nanostructure science and technology is a broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years. It has the potential for revolutionizing the ways in which materials and products are created and the range and nature of functionalities that can be accessed.

Where are nanomaterials found?

Some nanomaterials occur naturally, but of particular interest are engineered nanomaterials (EN), which are designed for, and already being used in many commercial products and processes. They can be found in such things as sunscreens, cosmetics, sporting goods, stain-resistant clothing, tires, electronics, as well as many other everyday items, and are used in medicine for purposes of diagnosis, imaging and drug delivery.

Engineered nanomaterials are resources designed at the molecular (nanometre) level to take advantage of their small size and novel properties which are generally not seen in their conventional, bulk counterparts. The two main reasons why materials at the nano scale can have different properties are increased relative surface area and new quantum effects.

Feynman's speech

The concept of nanotechnology is attributed to Nobel Prize winner Richard Feynman, who gave a very famous, visionary speech in 1959 (published in 1960) during one of his lectures, saying: "The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom".

At the time, Feynman's words were received as pure science fiction. Today, we have instruments that allow precisely what Feynman had predicted: creating structures by moving atoms individually.

What is nanotechnology?

Nanotechnology is the science of manipulating *atoms* and *molecules* to make *advanced nanomaterials*

Atom is the basic building block of all matter.

Atoms can combine with other atoms to form *molecules* but cannot be broken down into smaller pieces by ordinary chemical processes.

Molecule is a group of two or more atoms forming the smallest identifiable unit that retains the composition and chemical properties of that substance.

Advanced nanomaterials are new materials with enhanced properties designed to provide superior performance.

Nanotechnology is the understanding and manipulation of matter in sizes ranging from approximately 1 to 100 nanometers, where unique phenomena enable new applications

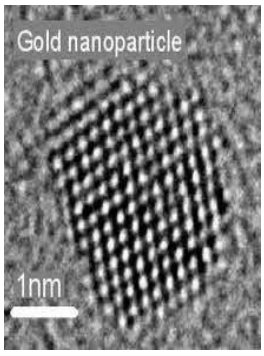
Nanotechnology is an emerging, interdisciplinary field involving: physics, chemistry, biology, engineering, materials science, computer science

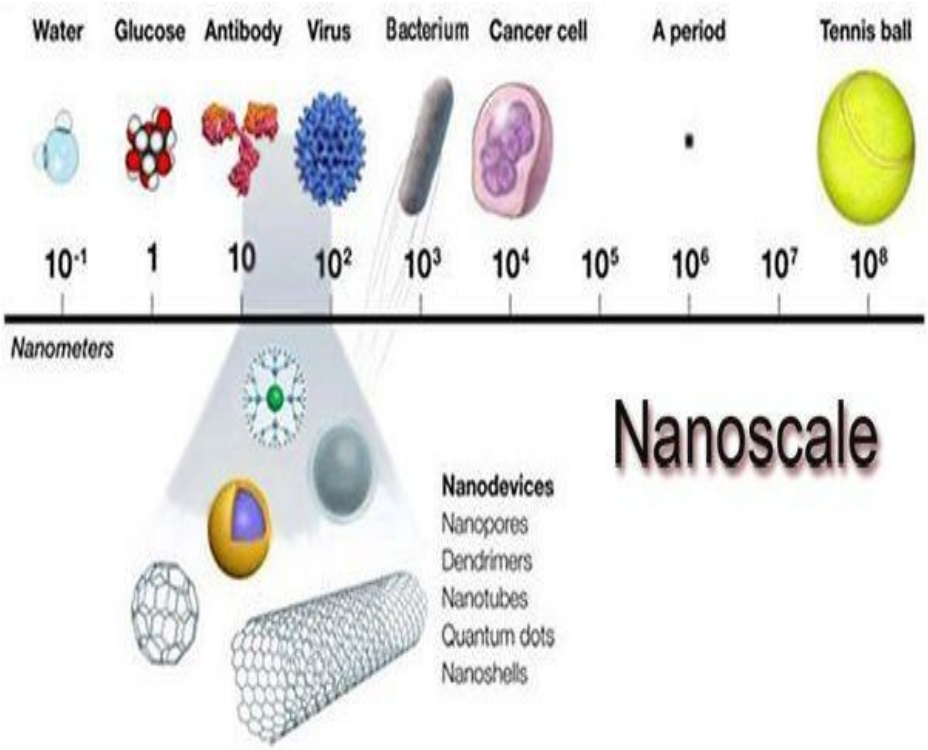
One of the major scientific advances of the 21st century laid the foundation for advanced nanomaterials.

Nano

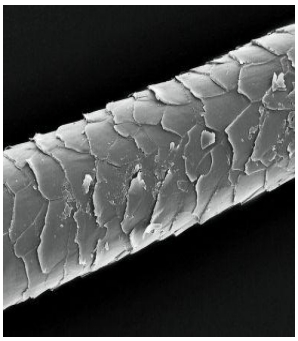
Na is a millionth of a millimeter or a billionth of a

*Ato*is about 0.1 nanometer - 10 atoms side by side





5,000–100,000 nm in



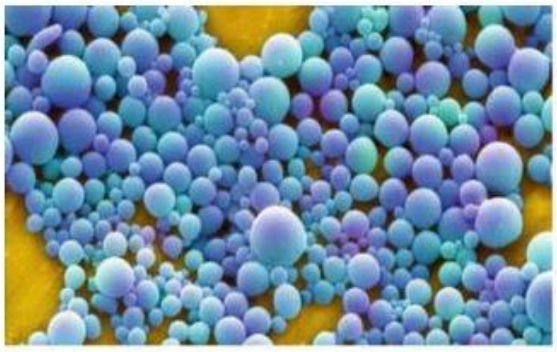
Human hair:

Nanomaterials

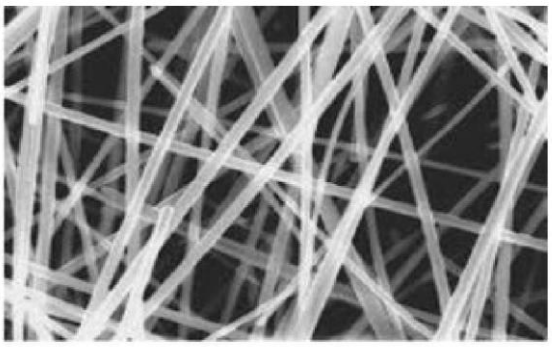
in the range of 1-100 nanometers in at least one dimension.

Classification: based on the number of free dimensions

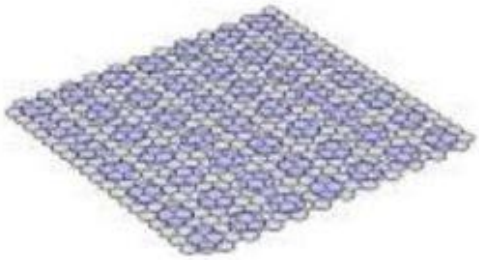
0D nanomaterial:- all three dimensions are in the nanoscale
(Nanoparticles, Colloids, Quantum dots).
1D *nanomaterial:-* one dimension beyond the nanoscale and two other dimensions in the nanoscale.
(Nanowires, Nanorods, Nanotubes & Biopolymers)
2D ***nanomaterial :-*** any two dimensions can be outside of the nanoscale and one dimension in the nanoscale
(Plate-like shapes - nanolayers, surface coatings and thin films).
3D nanomaterial:- all three dimensions can be outside of the nanoscale. Made of a nanomaterials.
(nanoparticle dispersions, nanowire/ nanotube bundles & multiple nanolayers).



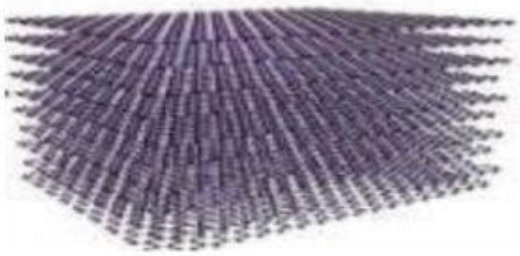
0D(Nanoparticle)



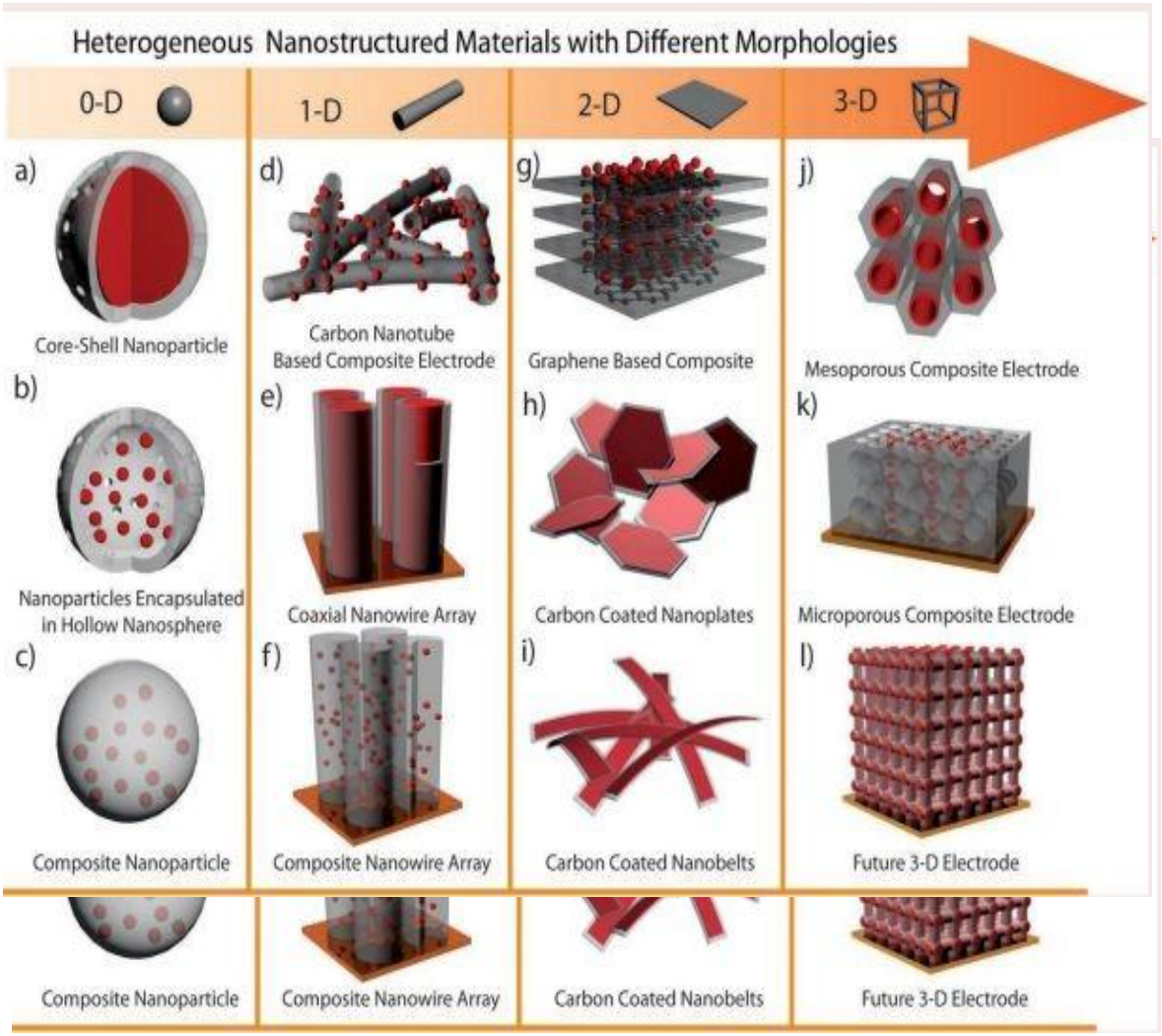
1D(Nanowire)



2D Nanomaterials (plate)



3D Nanomaterials



Nanomaterials: compex form

Nanoscience

The most common working definition of nanoscience is:

'**Nanoscience** is the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale'

Bulk materials (the 'big' pieces of materials we see around us) possess continuous (macroscopic) physical properties.

The same applies to micron-sized materials (e.g. a grain of sand).

But when particles assume nanoscale dimensions, the principles of classic physics are no longer capable of describing their behavior (movement, energy, etc.): at these dimensions, the principles of quantum mechanics principles.

The same material (e.g.gold) at the nanoscale can have properties (e.g.optical, mechanical and electrical) which are very different from (and even opposite to!) the properties the material has at the macroscale (bulk). **Nanotechnologies are defined thus:**

'Nanotechnologies are the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale.

What is a nanomaterial?

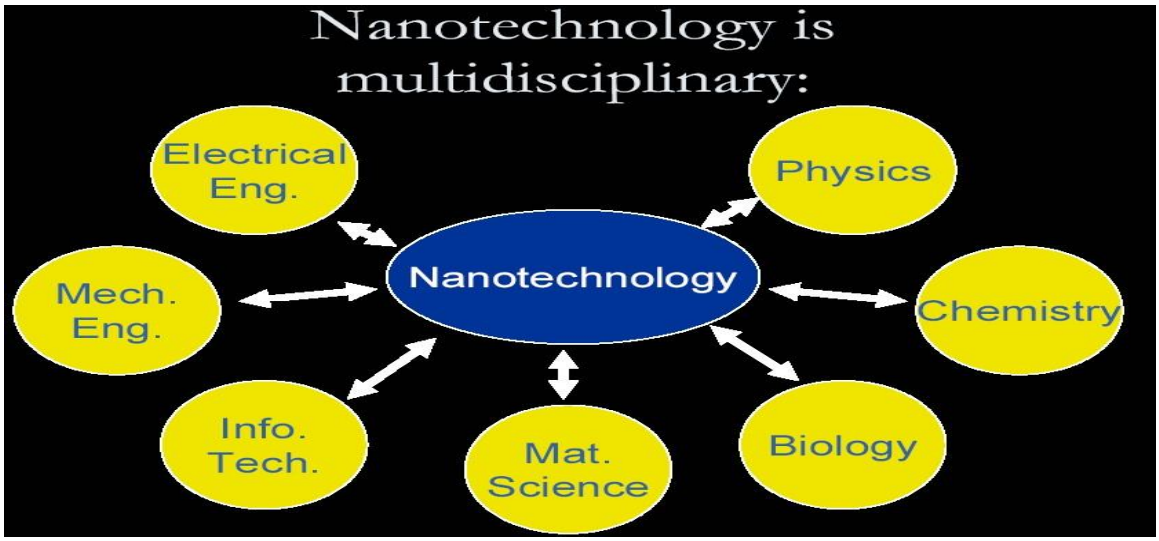
A nanomaterial is an object that has at least one dimension in the nanometre scale (approximately 1 to 100 nm).

Nanomaterials are categorised according to their dimensions.

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.



What makes 'nano' special

Nano' means small, very small; But why is this special? There are various reasons why nanoscience and nanotechnologies are so promising in materials, engineering and related sciences.

First, at the nanometer scale, the properties of matter, such as energy, change.

This is a direct consequence of the small size of nanomaterials, physically explained as quantum effects.

The consequence is that a material (e.g. a metal) when in a nano-sized form can assume properties which are very different from those when the same material is in a bulk form.

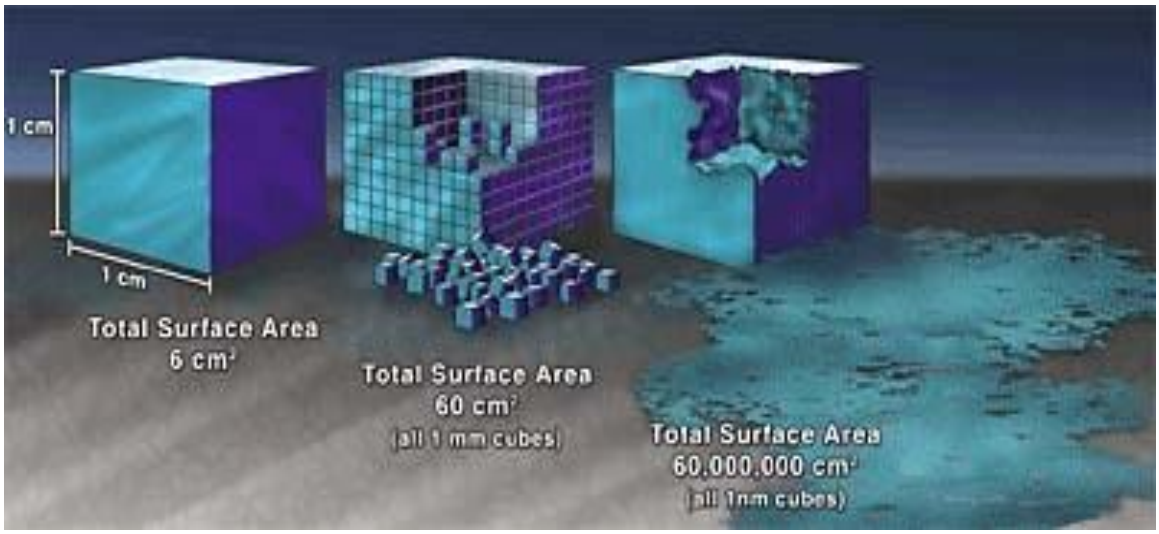
For instance, bulk silver is non-toxic, whereas silver nanoparticles are capable of killing viruses upon contact.

Properties like electrical conductivity, color, strength and weight change when the nanoscale level is reached.

The second exceptional property of nanomaterials is that they can be fabricated atom by atom by a process called bottom-up.

Finally, nanomaterials have an increased surface-to-volume ratio compared to bulk materials.

This has important consequences for all those processes that occur at the surface of a material, such as catalysis and detection.

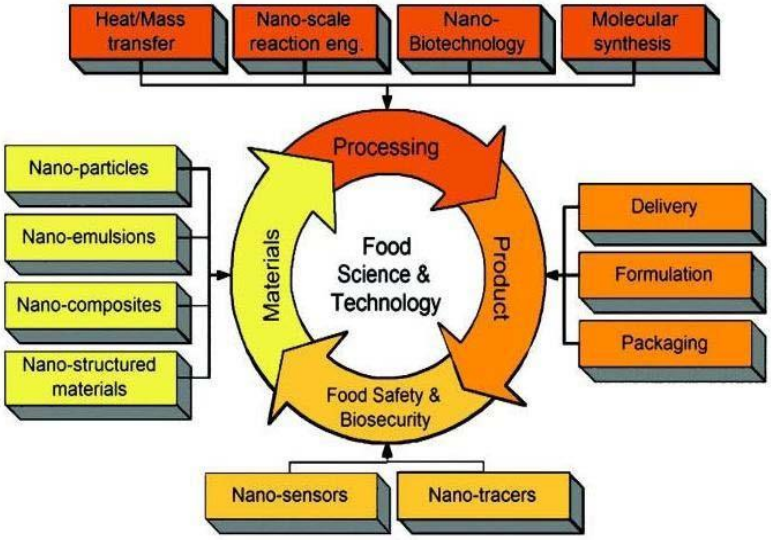


Nano structures generations

First Generation: passive nanostructures in coatings, nanoparticles, bulk materials (nanostructured metals, polymers, ceramics): **~ 2001 – Second Generation: active nanostructures** such as transistors, amplifiers, adaptive structures: **~ 2005 –**

Third Generation: 3D nanosystems with heterogeneous nanocomponents and various assembling techniques **~ 2010-**

Fourth Generation: molecular nanosystems with heterogeneous molecules, based on biomimetics and new design **~ 2020 (?)**



Risks of nanomaterial

Health Risks

• Ultrafine particles can catalyze chemical reactions in the body.

• Carbon nanotubes can cause infections of lungs.

• They could easily cross the blood-brain barrier, a membrane that protects the brain from harmful chemicals in the bloodstream.

Environmental Risks

Air pollution.

References

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2-An Introduction to Nanoscience and Nanotechnology. 2008

3-NANO: The Essentials Understanding Nanoscience and Nanotechnology. 2007