



# Nano-Technology: A Bright Concept still to get explored

**Abhishek Pandey<sup>1\*</sup>, Vashvi Tiwari<sup>2</sup>**

<sup>1</sup>Student, Department of Pharmacy, Pranveer Singh Institute of Technology.

<sup>2</sup>Research Scholar, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj

## Abstract

Nanotechnology, the science of manipulating and engineering materials at the nanoscale, has emerged as a revolutionary field with profound implications for various industries and applications. This abstract provides a concise overview of the key aspects of nanotechnology, its current status, and the potential it holds for the future. Nanotechnology operates at the nanometer scale, typically defined as one to one hundred nanometers, enabling scientists and engineers to harness unique properties that arise at this level. At this scale, quantum effects and surface area dominance become prominent, allowing for the creation of novel materials, structures, and devices. Nanotechnology has already made significant contributions in diverse fields, including electronics, medicine, energy, and materials science.

This abstract delves into the progress and future prospects of nanotechnology. It highlights recent developments such as the fabrication of nanomaterials with tailored properties, the advent of nanoelectronics, and the potential for drug delivery and medical diagnostics at the nanoscale. Moreover, the integration of nanotechnology in renewable energy sources, such as solar cells and energy storage systems, promises a sustainable future. Despite its remarkable progress, nanotechnology faces challenges related to safety, ethics, and regulation. The potential risks associated with nanomaterials necessitate responsible development and rigorous safety assessments. Ethical considerations include issues related to privacy, security, and the equitable distribution of benefits and risks. Striking a balance between technological advancement and ethical responsibility is essential for the continued success of nanotechnology.

In conclusion, nanotechnology offers a promising future with limitless possibilities. Harnessing the potential of this technology will require responsible research, ethical considerations, and international collaboration. As the field continues to evolve, nanotechnology will shape various industries and pave the way for innovative solutions to some of the world's most pressing challenges.

**Keywords:** Nanotechnology, Nanometers, Nanoscale etc.

## **Introduction:**

Nowadays, nanotechnology is not a science; rather, it has become a way of thinking that has profoundly impacted scientific advancement. Indeed, the majority of talks, seminars, research projects, and inventions these days centre around nanotechnology; nevertheless, surprisingly, the field of nanotechnology study has only recently—the last 20 years or so—begun to flourish. By using nanostructure and nanophases, nanotechnology actually overcomes every barrier in the realm of biological and physiological sciences. The Canadian Programme on Genomics and Global Health (CPGGH) study assessed the use of nanotechnology in the building industry at 8 out of 10 for expected impact on developing countries.

A simple definition of nanotechnology is any technology that operates on the nanoscale and has practical applications. Alternatively, it can be defined as the phenomenon of the alteration of particle size at their Atomic, Molecular, or Supramolecular (nanoscale) level of structure. The phrase "nanoscale" is frequently used in conjunction with the word "nanotechnology," as was previously noted. Consequently, we cannot define nanotechnology until we have a clear understanding of what is meant by the term "nanoscale," which is simply the scale that encompasses particles with sizes between 1-100 nm. I.e. Facts are offered throughout the essay to highlight the distinction between bulk amount and nanoscale material qualities. Particle performance improves when employed at the nanoscale in comparison to bulk quantity material.

As a byproduct of nanotechnology, nanoparticles can be thought of as the fundamental building block of the entire nanosystem. A wide range of particulate matter particles with at least one dimension make up nanoparticles. NPs can be classified as 0D, 1D, 2D, or 3D according on the shapes of them. It wasn't until the discovery that a substance's size is directly correlated with its physico-chemical characteristics that the significance of nanoparticles became apparent. For instance, Au NPs can be categorised as "Nanorods (50 nm)," "Nanoshells (140 nm)," and "Nanocages (50 nm)" based on their shape. NPs can be categorised into three levels based on their structural makeup, which are:

- The Surface layer
- The Shell layer
- The Core

NPs can be used for drug delivery, biological sensing, energy harvesting, the cosmceutical industry, and many more applications due to their vast features.

## **Categorization of Nanoparticles:**

Based on their diverse applications across multiple industries, nanoparticles can be categorised into multiple groups. Based on the physical and chemical characteristics of the nanoparticles, they can be categorised as follows:

### **1. Carbon-Based Nanoparticles:**

The two main categories of Carbon-Based Nanoparticles are Fullerene and Carbon Nanotubes(CNTs).

## A)Fullerene

These are composed of the NPs, which are composed of the carbon's allotropic forms (globular hollow cage). A notable economic interest has been established in the modern period because of their electrical conductivity, high strength, structure, electron affinity, and adaptability. The following are a few of the Fullerenes' possessions:

- Have both pentagonal and hexagonal carbon units; additionally, they are all sp<sup>2</sup> hybridised.

### 1. Carbon nanotubes :

CNTs have a diameter of 1-2 nm and are extended (stretched) tubular structures [10]. Based purely on their structural makeup, they resemble a graphite sheet being folded up on itself. The rolled sheets are referred to as single-walled, double-walled, or multi-walled carbon nanotubes (CNTs) depending on how many walls they have.

### 2. Metal Nanoparticles:

As the name suggests, metal precursors make up the majority of Metal Nanoparticles. Typically, they exhibit Localised Surface Plasmon Resonance (LSPR), which gives them special optoelectrical characteristics. Alkali and noble metal nanoparticles (Au, Ag, and Cu) have a wide absorption band in the visible portion of the electromagnetic solar spectrum.

### 3. Ceramic nanoparticles:

Made by heating and then cooling, ceramic nanoparticles are regarded as inorganic, non-metallic solids. They are merely amorphous, polycrystalline, dense, porous, or hollow in nature if we base our analysis on their structural makeup. The nanotech applications are emphasising tiny particles because of all these characteristics.

### 4. Semiconductor Nanoparticles:

Because semiconductors have characteristics that fall somewhere between those of metals and non-metals, they are frequently employed in literature. Semiconductor nanoparticles (NPs) have large bandgaps and can change significantly in characteristics just by adjusting the bandgap. As a result, they are valued in the fields of electronics, photocatalysis, and photooptics. Furthermore, these semiconductor nanoparticles are discovered to be extraordinarily efficient in the energy harvesting sector (i.e., water harvesting) because of their wide and appropriate bandgap and bandedge position.

### 5. Polymeric nanoparticles (PNPs):

These NPs are commonly referred to as organic-based NPs in the literature and are referred to as such collectively. They are typically observed to have the structure of nanospheres or nanocapsules.

- **Nanospheres:** Generally composed of solid matter overall, these particles are classified as Matrix particles. At the outside edge of the spherical surface, additional molecules are absorbed.
- **Nanocapsules:** These particles have the solid mass entirely enclosed within them. These PNPs are frequently functionalized and found in many different applications.

## 6. Lipid-Based Nanoparticles:

These nanoparticles are widely used in numerous biomedical applications and are composed of lipid moieties. In most lipid-based nanoparticles, a spherical shape with a diameter ranging from 10 to 1000 nm is seen. Lipid nanoparticles are reported to have a solid core composed of lipid and a matrix comprising soluble lipophilic molecules, just like polymer nanoparticles. Emulsifiers and surfactants control the stabilisation of the NPs' outer core.

### B) Synthesis of the Nanoparticles:

There are numerous techniques for creating nanoparticles. These techniques for creating nanoparticles are typically thought to take a very long period in comparison to other procedures. Here, commonly used preparation techniques are separated into two primary groups:-

- Top-Down Approaches
  - Top-Down Methods
  - Bottom-up Methods
  - Hybrid Method

**1. Top-Down Methods:** These techniques are renowned for their destructive methodology. Using bigger externally controlled devices, this approach breaks down larger molecules into smaller ones that are then converted into appropriate nanoparticles. The microfabrication method is employed in externally controlled machines to cut, grind, and shape material into the required shape and order.

Crystallographic defects are frequently observed to be incorporated into the processing in Top-Down methods like lithography (e.g., surface imperfections, structural defects and impurities in the Nanowires generated by Lithography). The Top-Down technique is important in the synthesis and production of the nanoparticles, as opposed to having all these flaws.

**2. Bottom-Up Methods:** This involves the atom-by-atom, molecule-by-molecule, and cluster-by-cluster assembly of molecular components starting from the bottom growth of a crystal into more complicated assemblies. Techniques for sedimentation and reduction serve as examples of this approach.

**3. Hybrid methods:** In the field of nanotechnology, they are strategies that integrate various methods or approaches to accomplish particular goals or tackle difficulties in the field of nanoscience and nanotechnology. These techniques frequently combine several fields of study, resources, or equipment to produce inventive solutions for a range of uses.

#### ▪ Applications of Nanotechnology:

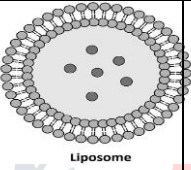
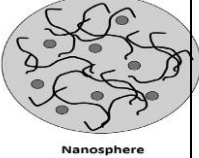
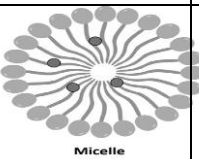
Over a long period of time, Nanotechnology has demonstrated its importance in the present day and in the advancement of technology. However, there is a severe scarcity or shortage of energy supplies in the world as a result of global warming and human resource mismanagement. These days, nanotechnology has emerged as a flexible platform with the ability to offer affordable, environmentally friendly solutions to the issues the world is currently experiencing. Not only has energy harvesting made significant advancements in recent years, but it has also created new avenues for the creation of pharmaceuticals, cosmoceuticals, targeted drug delivery systems, and medical diagnosis and therapy. The notion of nanotechnology first surfaced approximately fifty years ago, and it has since expanded to become a broad platform for both research and application. In actuality,

a survey claims that the U.S. National Nanotechnology Initiative (NNI) spends more than \$1 billion annually, with the President's Budget pushing that amount to \$1.5 billion in 2008.

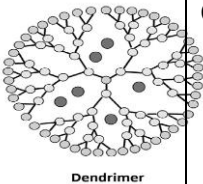
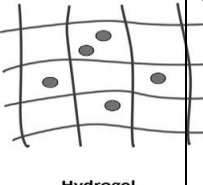
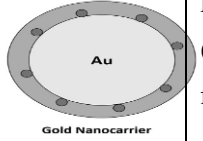
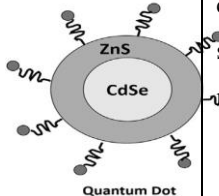
1. Target Drug Delivery System: Nanotechnology has several applications outside of medicine, including the therapeutics industry (disease prevention, diagnosis, and treatment). Of these, the study of nano-carriers is particularly useful in the target drug-oriented sector. When compared to the conventional method, the target drug delivery system is more advantageous since it delivers the drug directly to the site of injury, increasing therapeutic efficacy and lowering toxicity and side effects. The mechanism uses customised nano-carriers that can differ from patient to patient in order to protect drugs from biological and environmental factors (such as oxygen, light, and enzymes) and to achieve highly controlled and secure drug delivery to the target cell exclusively.

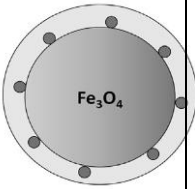
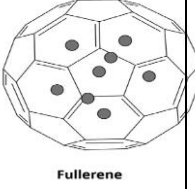
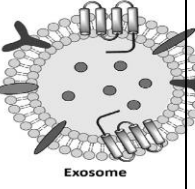
### Types of the Nano Technology

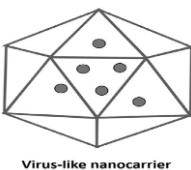
**Table 1: Detailed Overview of Nanocarriers**

Nanocarriers	Physical appearance	Diagrammatical Representation	Examples	Producing Company	Therapeutic Usage	FDA status
Liposomes	Spherical, self assembled artificial vesicle composed of lipid bilayer, enclosing an aqueous core		Marquibo (Vincristine Sulphate)	Talon Therapeutics Ltd.	To treat acute lymphoblastic leukemia	2012
			Onivyde (irinotecan)	Merrimack	In the treatment of Metastatic Pancreatic cancer	2015
Polymeric Nano-carriers	Submicron-sized colloidal carriers, Matrix type structure		Plegridy (Pegylated Interferon beta-1a)	Biogen	Multiple sclerosis treatment	2014
			Adynovate (Pegylated Antihemophilic Factor)	Baxalta	Hemophilia A treatment	2015
Micelles	Combination of water-soluble phosphor lipids or fatty acids, having a hydrophilic shell and hydrophobic		Estrasorb (Estradiol)	Novavax	Menopausal therapy	2003



	core					
Dendrimers	composed of various highly branched monomers that grow radially from the multifunctional central core, possess low polydispersity indexes		(VivaGel)	Stapharma	Microbicide that inhibits HIV, HSV-2, and HPV	Phase II
Hydrogels	based in hydrophilic polymers organized in 3D cross-linked Networks		(MuGard)	Access Pharmaceutical Inc.	Mucoadhesive oral wound rinse for the management of oralmucositis /stomatitis	Phase IV
Metallic Nano-carriers	Can be synthesized and tuned with several chemical functional groups		Ferrlecit (Sodium ferric gluconate)	SanofiAvertis	Iron deficiency anemia treatment	1999
			Venofer (Iron Sucrose)	Luitpold Pharmaceuticals	Iron deficiency anemia treatment	2000
Quantum Dots	high brightness, and antiphoto bleach features, constituted by an inorganic elemental core		cadmium sulfoselenide/zinc sulfide QDs	Lin et al	capable of molecular imaging and therapy and new opportunities in the area of cancer treatment	N/A

Ceramic Based Nano-carriers	Porous in nature, great load ability, high stability, and easy integration into hydrophobic and hydrophilic systems	 Magnetic Nanocarrier	Quercetin	N/A	antiinflammatory, antioxidant, antihypertensive, antiobesity, and anticancer	N/A
Carbon Based Nano-Carriers	excellent optoelectronic, chemical, and mechanical properties, hexagonal hollow cylinders made of one single-walled (SWCNTs) or multiwalled (MWCNTs) sheets of grapheme	 Fullerene	Carbon Nanotubes (CNTs)	N/A	suited for drug delivery purposes, such as enhanced solubility, increased biocompatibility, and cellular responsiveness	N/A
			Fullerene	N/A	C60-fullerenes system for the delivery of docetaxel into breast cancer cells.	
			Nanodiamonds	N/A	In advanced tumor therapies, multidrug chemoresistant leukemia and have potential to improve cancer treatment, particularly against resistant strains.	
Exosomes	known as “natural nanocarriers”, present in almost all biological fluids, function	 Exosome	peptide-tagged exosome loaded with curcumin (PTX)	N/A	inflammatory response and cellular apoptosis in the lesion region was suppressed	N/A

	as natural transporters of cellular components, exhibit small size for penetration into deep tissues, being less likely to be immunogenic or cytotoxic than the other synthetic delivery systems, possessing slightly negative potential zeta for long circulation,				more effectively than when curcumin or exosomes that were administrated alone.	
Virus Based Nano-carriers	consist of regular arrays of virus coat protein molecules, which self-assemble to form a highly defined three-dimensional structure	 <p>Virus-like nanocarrier</p>	Glybera, an orphan medicine	N/A	treatment of rare disease lipoprotein lipase deficiency	approved by the European Medicine s Agency (EMA)

Source: Diana Sousa *et al.*, (2019).

- **Nanocarrier Targeting:** A medication must accumulate within a designated target area solely in order for a target drug delivery system to be successful [41]. In the past, first-generation nanocarriers relied on a passive targeting mechanism to outperform conventional free-drug formulations in terms of efficiency [42]. Eventually, after Active Targeting was discovered, it was able to surround the Nanocarriers with certain ligands, allowing them to act solely at the target sites with increased bioavailability, independent of lipophilic or lipophobic barriers (B.B.B.). While creating the nanocarriers, there are a few factors to consider, such as the type of ligand, the chemistry of the ligand conjugation, and the administration method.



**I. Passive Targetting:** The movement of the nanocarriers through convection or passive diffusion throughout the body is another way to describe passive targeting, commonly referred to as physical targeting. Here Convection, which is only a physical mechanism that permits the transportation of big molecules across the cell membrane with respect to the concentration difference and without the need for an energy input, is described as the movement of molecules with the flow of bodily fluids.

**II. Active Targeting:** Paul Ehrlich originated the idea of Active Targeting in 1906; at the time, it was referred to as the "magic bullet" because it targeted particular cells within the body. In order to facilitate active targeting and enable easy uptake of the nanocarriers by sick cells via ligand recognition, a targeted ligand is often applied to the surface of the nanocarriers. These ligands could be any kind of material, including nucleic acids, proteins, peptides, and antibodies. The target molecule is chosen based on a set of parameters that include its selective or overexpressive activity in diseased organs, cell surfaces, tissues, or even in subcellular domain.

- **Cosmeceuticals:**

It is common knowledge that the sole goal of the modern day is to look better, and the cosmetics industries are doing everything in their power to help people achieve this goal. And as time has gone on, this industry has emerged as a quickly expanding niche in the personal care sector for common ailments like wrinkles, hyperpigmentation, photoaging, and hair damage. "The articles intended to be applied to the Human Body or any part thereof for cleansing, beautifying, promoting attractiveness or altering the appearance" is how the FDA defines cosmeceuticals. Nevertheless, the FDA lacks the legal jurisdiction to approve medicines prior to their release on the market. Here, "cosmeceuticals" refers to both the intermediate drug and cosmetic product.

**Major Classes of the Cosmeceuticals:**

**I. Moisturisers:** Dehydration can result from excessive water loss or evaporation from the stratum corneum, the skin's primary barrier that keeps external substances out and internal substances in. In this instance, moisturisers are the products that are utilised to prevent dehydration while also giving the skin elasticity.

**II. Sunscreens:** The sun is a huge energy source and a necessary component of life as we know it on Earth. As it's been said that every coin has two sides, the Sun is equally responsible for supporting life on Earth as it is for emitting dangerous radiations, such as infrared and ultraviolet light, that are damaging to humans. Thus, zinc oxide (ZnO) and titanium dioxide (TiO<sub>2</sub>) are used to make sunscreen formulas in this instance, which aid in shielding the skin from the damaging effects of solar exposure. When these minerals are applied traditionally, a materialistic barrier is formed on the skin, which causes both UVA and UVB rays to be reflected.

**III. Antiaging Creams:** Abrasions, pollution exposure, infrared (IR) and ultraviolet (UV) radiation, and the usage of chemical products are some of the variables that contribute to skin ageing. Here, collagen plays a central role in the entire skin ageing process since it is the only substance that can rejuvenate the skin and reverse the effects of ageing. In addition, a decrease in collagen levels in the skin with age is the single factor contributing to skin ageing. Skin can become visibly apparent to the naked eye through a variety of processes, including drying out, losing elasticity and texture, thinning,

compromised barrier function, emergence of spots, modification of surface line isotropy, and wrinkles.

**IV. Hair Care:** Hair Care has emerged as the major industry for nanotechnology, alongside all other industries. Many companies use nanotechnology to create hair care formulas, and ongoing study is being done to find out how nanoparticles can help preserve the health, gloss, and silkiness of hair as well as prevent hair loss. The primary benefit of utilising nanoparticles in hair formulations is that, unlike regular hair straighteners, they do not damage the cuticles, the outer layer of hair fibres, allowing the particles to enter the hair strand.

**V. Skin Cleanser:** Depending on the body part, the skin is coated in a thin layer that is often hydrolipid in nature and is made up of different secretions from the sebaceous and apocrine glands, respectively. Cellular waste and stratum corneum lipids are also secreted and end up on the skin's surface. In other words, this hydrolipid coating essentially serves as a first line of defence (natural barrier) against viruses, but it also draws dirt and contaminants from the surroundings. Therefore, the majority of the time, when these skin-resident bacteria react with the hydrolipid film's constituents, unwanted compounds like poor body odour

**VI. Lip Care:** The different nanoparticles that are incorporated into the lipsticks help to soften and soothe lips by preventing water loss from the transepidermal layer. In the patent held by the Korea Research Institute of Bioscience and Biotechnology, it is stated that gold or silver nanoparticles can be used to create pigments of different hues by combining them in different compositional ratios [100]. Furthermore, silica nanoparticles are used into lipsticks to facilitate the uniform dispersion of pigments and inhibit their absorption through the delicate lip lining.

**VII. Nail care:** It has been demonstrated that nano-based nail care formulations are more advantageous than conventional ones. A study indicated that, in comparison to traditional formulations, mammalian nails painted with nanobased nail paints exhibited enhanced toughness, mar resistance, and impact resistance.

- **Plans of the Government for Nanotechnology:**

Recognising the importance of nanotechnology, the government has also launched a number of initiatives in this area.

- **Current Initiatives:**

1. IIT Bombay offers Nano Fabrication Prototyping Facilities for SMEs and Start-ups in the MEMS and NEMS fields.
2. At the Centre for Materials for Electronics Technology (C-MET), Pune, "Three-Dimensional Nanostructure based Miniaturised and Flexible rechargeable lithium batteries for flexible electronics"
3. Pulsed Laser Deposition (PLD) technology demonstration of LED at University of Delhi, New Delhi

## ▪ Finalised Projects:

1. NPL Delhi's general nanometrology development for nanotechnology
2. Quantum dot technology based on III/V compound semiconductors at IISc Bangalore
3. Synthesis of Noble and Transition Metal Nanoparticles for Use in Optoelectronics and Electronic Packaging at C-Bangalore
4. Production of Nanosized Metals, Oxides, and Nitrides on a Large Scale in a Transferred Arc Plasma Reactor at C-MET Pune.

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