What are Nanomaterials?

The term nanoscale refers to the dimension of 10^{-9} meters.
It is the one billionth part of a meter. So, the particles whose any of the external dimensions or internal structure dimension or surface structure dimension lies in the range of 1nm to 100nm are considered as Nanomaterials.
These materials are invisible to the naked eye. At this scale, these materials have unique optical, electronic, mechanical and quantum properties compared to their molecular-scale behavior.

Nanomaterials can be of natural existence, artificially manufactured or incidentally formed. With the advance in the research, nanomaterials are being commercialized and are being used as commodities.

Properties of Nanomaterials

A drastic change in the **properties of nanomaterials** can be observed when they are breakdown to the nanoscale level.
As we go towards the nanoscale level from the molecular level, the electronic properties of materials get modified due to the quantum size effect.
Change in the mechanical, thermal and catalytic properties of the materials can be seen with the increase in surface area to volume ratio at the nanoscale level.
Many of the insulator materials start behaving as conductors at their nanoscale dimensions.

Similarly, as we reach the nanoscale dimensions many interesting quantum and surface phenomena can be observed.

Particle size, shape, chemical composition, crystal structure, physicochemical stability, surface area, and surface energy, etc…attributes to the physicochemical properties of the nanomaterials.

As the surface area to volume ratio of the nanomaterials increases, their surface becomes more reactive on itself and other systems.

The size of the nanomaterials plays a significant role in their pharmacological behavior.

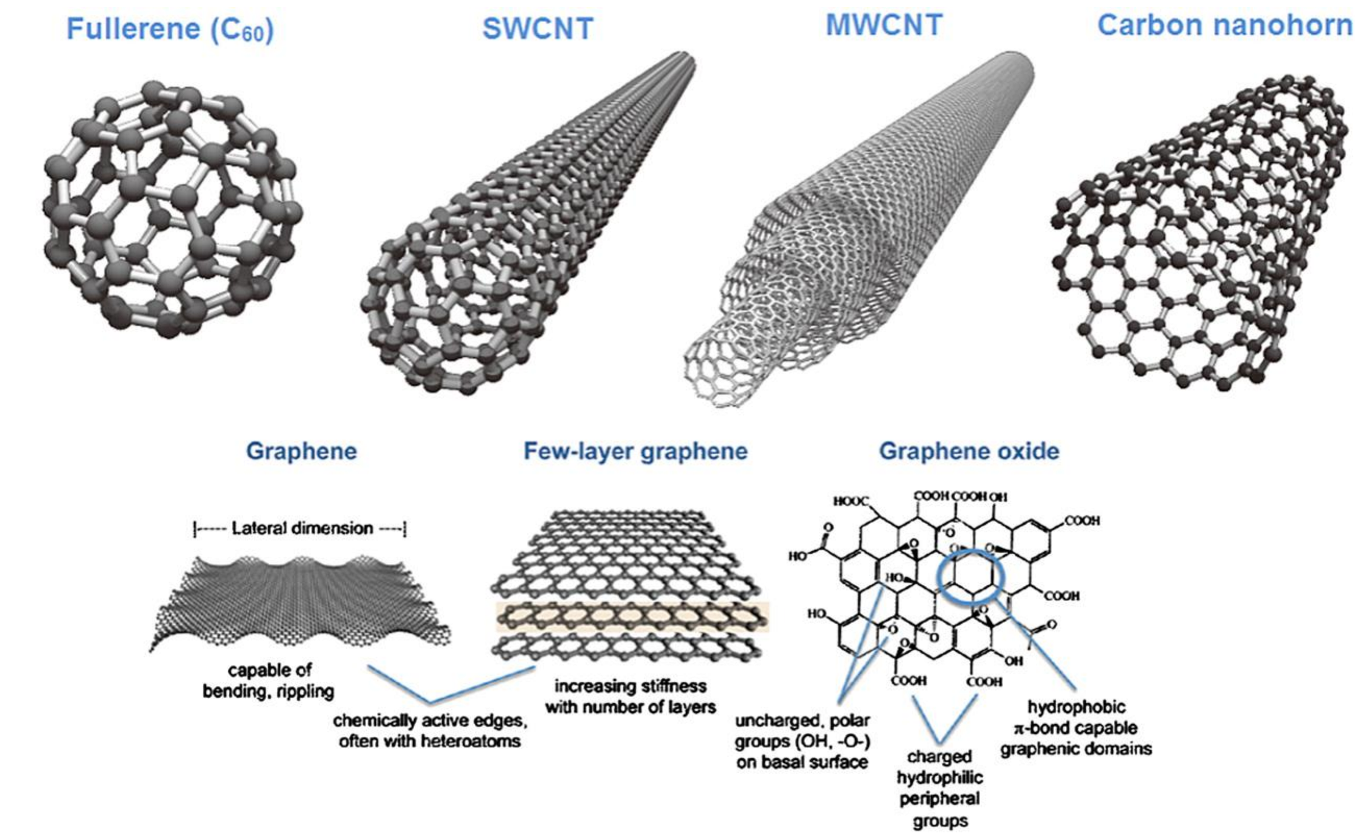
When nanomaterials interact with water or other dispersion media they can rearrange their crystal structure. The size, composition and surface charge of the nanomaterials affect their aggregation states. The magnetic, physicochemical and psychokinetic properties of these materials get affected by surface coating. These materials produce ROS when their surface reacts with oxygen, ozone, and transition materials.

At the nanoscale level, the interaction between particles is either due to the van der Waal forces or strong polar or covalent bonds. The surface properties of the nanomaterials and their interactions with other elements and environments can be modified with the use of polyelectrolytes.

Examples

Nanomaterials can be found as either engineered nanomaterials, incidental or of natural existence.

Engineered nanomaterials are manufactured by humans with some desired properties. They include carbon black and titanium dioxide nanomaterials. The nanoparticles are also produced due to mechanical or industrial processes incidentally like during vehicle exhausts, welding fumes, cooking, and fuel heating. Incidentally produced atmospheric nanomaterials are also known as ultrafine particles. Fullerenes are the nanomaterial produced due to the burning of biomass, candle.



Natural existing nanomaterials are formed due to many of the natural processes such as forest fires, volcanic ash, ocean spray, weathering of metals, etc… Some of the **examples of nanomaterials** present in biological systems are the structure of wax crystals covering lotus, structure of viruses, spider-mite silk, blue hue of tarantula spiders, butterfly wing scales. Particles like milk, blood, horn, teeth, skin, paper, corals, beaks, feathers, bone matrix, cotton, nail, etc.. are all-natural occurring organic nanomaterials. Clays are the example of naturally occurring inorganic nanomaterial, as they are formed due to crystal growths in diverse chemical conditions on the earth's crust.

Classification

The classification of nanomaterials mainly depends on the morphology and their structure, they are classified into two major groups as Consolidated materials and Nanodispersions. Consolidated nanomaterials are further classified into several groups.

The one dimensional Nano dispersive systems are termed as Nanopowders and Nanoparticles. Here the nanoparticles are further classified as Nanocrystals, Nanoclusters, Nanotubes, supermolecules,etc..

For the nanomaterials, the size is an important physical attribute. Nanomaterials are often classified depending upon the number of their dimensions falls under nanoscale. The nanomaterial whose all the three dimensions are of nanoscale and the is significantly no difference between the longest and shortest axes, are called Nanoparticles. Materials with their two dimensions in the nanoscale are called Nanofibres. Hollow nanofibres are known as Nanotubes and the solid ones are known as Nanorods. Materials with one dimension in the nanoscale are known as Nanoplates. Nanoplates with two different longer dimensions are known as Nanoribbons.

Based on the phases of matter contained by the nanostructured materials they are classified as nanocomposite, nanofoam, nanoporous and nanocrystalline materials. Solid materials containing at least one physically or chemically distinct region with at least one region with dimensions in the nanoscale are called Nano Composites. Nanofoams contain a liquid or solid matrix, filled with a gaseous phase and one of the two phases has dimensions in the nanoscale.

Solid materials with nanopores, cavities with dimensions on the nanoscale are considered as Nanoporous materials. Nanocrystalline materials have crystal grains in the nanoscale.

Applications of Nanomaterials

Graphene has one hundred times greater electron mobility than silicon, the most widely used material in semiconductors today. It is more durable than steel and has high heat conductibility as well as flexibility, which makes it the perfect material for use in flexible displays, wearables, and other next generation electronic devices.

Today nanomaterials are being highly commercialized. Some of the commercial nanomaterials available in the market are cosmetics, strain resistant textiles, electronics, sunscreens, paints, etc…

Nanocoatings and nanocomposites are being used in various consumer products such as sports equipment, windows, automobiles, etc..

To protect the damage caused to beverages from sunlight, glass bottles are being coated with nanocoating which blocks the UV rays. Using nano-clay composites longer-lasting tennis balls are being manufactured. Nanoscale silica is used as a filler in dental fillings.

The optical properties of the nanomaterials are used to form optical detectors, sensors, lasers, displays, solar cells. This property is also used in biomedicine and photoelectrochemistry. In microbial fuel cells, the electrodes are made up of carbon nanotubes.

Nanocrystalline zinc selenide is used in the display screens to increase the resolution of the pixels forming High Definition TV sets and personal computers. In the microelectronic industry, miniaturizing of circuits such as transistors, diodes, resistors, and capacitors is emphasized.

Nanowires are being used in forming junctionless transistors. Nanomaterials are also used as catalysts in automobile catalytic converters and power generation systems, to react with toxic gases such as carbon monoxide and nitrogen oxide, thereby preventing the environmental pollution caused by them.
To increase the sun protection factor (SPF) in the sunscreens nano-TiO2 is used. To provide a highly active surface to the sensors, engineered nanolayers are used.
Fullerenes are used in cancer to treat cancer cells such as melanoma. These have also found use as light-activated antimicrobial agents. Due to their optical and electrical properties, quantum dots, nanowires, and nanorods have highly opted for Optoelectronics. Nanomaterials are being tested for applications in tissue engineering, drug delivery, and biosensors. Nanozymes are the artificial enzymes used for biosensing, bioimaging, tumor detection.

Advantages and Disadvantages of Nanomaterials

The electrical, magnetic, optical and mechanical properties of the nanomaterials have provided many fascinating applications. Research is still in progress to know about these properties. Properties of the nanomaterials differ from that of their bulk size model. Some of the advantages of the nanomaterials are as follows-

- Nanomaterial semiconductor q-particles show quantum confinement effects, thereby giving them the luminescence property.
- Compared to coarse-grained ceramics, nanophase ceramics are more ductile at elevated temperatures.
- Cold welding property of the nanosized metallic powders along with their ductility is highly useful for metal-metal bonding.
- Single nanosized magnetic particles provide super paramagnetism property.

- Nanostructured metal clusters of monometallic composition act as precursors for heterogeneous catalysts.
- For solar cells, Nanocrystalline silicon films form a highly transparent contact.
- Nanostructured titanium oxide porous films provide high transmission and high surface area enhancement.
- Challenges faced by the microelectronic industry in the miniaturization of the circuits such as poor dissipation of heat generated by high-speed microprocessors, poor reliability can be overcome with the help of nanocrystalline materials. These provide high thermal conductivity, high durability, and durable long-lasting interconnections.

There are also some technological disadvantages found in the use of nanomaterials. Some of those disadvantages are as follows –

- Instability of the nanomaterials.
- Poor corrosion resistance.
- High solubility.
- When the nanomaterials with the high surface area come in direct contact with oxygen exothermic combustion takes place leading to an explosion.
- Impurity
- Nanomaterials are considered to be biologically harmful. These have high toxicity which can lead to irritations.
- Carcinogenic
- Difficult to synthesize
- No safe disposal available
- Hard to recycle