Nano materials:

Nano scale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. A nanometer is one millionth of a millimeter – approximately 100,000 times smaller than the diameter of a human hair. Nano materials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge. These emergent properties have the potential for great impacts in electronics, medicine, and other fields.

Nanotechnologies involve designing and producing objects or structures at a very small scale, on the level of 100 **nanometres** (100 millionth of a millimetre) or less.

Nanomaterials are one of the main products of **nanotechnologies** – as nano-scale particles, tubes, rods, or fibres. **Nanoparticles** are normally defined as being smaller that 100 **nanometres** in at least one dimension.

As **nanotechnology** develops, **nanomaterials** are finding uses in healthcare, electronics, cosmetics, textiles, information technology and environmental protection.

Descriptions of **nanomaterials** ought to include the average particle size, allowing for clumping and the size of the individual particles and a description of the particle number size distribution (range from the smallest to the largest particle present in the preparation).

Detailed assessments may include the following:

1. Physical properties:

- Size, shape, **specific surface area**, and ratio of width and height

2. Chemical properties:

- Molecular structure
- Composition, including purity, and known impurities or additives

Type of Nanomaterials : there are four type of nanomaterials :

1- Carbon Based Materials

These nanomaterials are composed mostly of carbon, most commonly taking the form of a hollow spheres, ellipsoids, or tubes. Spherical and ellipsoidal carbon nanomaterials are referred to as fullerenes, while cylindrical ones are called nanotubes. These particles have many potential applications, including improved films and coatings, stronger and lighter materials, and applications in electronics.

2- Metal Based Materials

These nanomaterials include quantum dots, nanogold, nanosilver and metal oxides, such as titanium dioxide. A quantum dot is a closely packed semiconductor crystal comprised of hundreds or thousands of atoms, and whose size is on the order of a few nanometers to a few hundred nanometers. Changing the size of quantum dots changes their optical properties.

3- Dendrimers

These nanomaterials are nanosized polymers built from branched units. The surface of a dendrimer has numerous chain ends, which can be tailored to perform specific chemical functions. This property could also be useful for catalysis. Also, because three-dimensional dendrimers contain interior cavities into which other molecules could be placed, they may be useful for drug delivery.

4- Composites

Composites combine nanoparticles with other nanoparticles or with larger, bulk-type materials. Nanoparticles, such as nanosized clays, are already being added to products ranging from auto parts to packaging materials, to enhance mechanical, thermal, barrier, and flame-retardant properties.

Application of nanomaterials

❖ Nanomaterial Applications using Carbon Nanotubes

Researchers are improving dental implants by adding nanotubes to the surface of the implant material. They have shown that bone adheres better to titanium dioxide nanotubes than to the surface of standard titanium implants , Carbon nanotubes are being developed to clean up oil spills.

❖ Nanomaterial Applications using Graphene

Applications being developed for graphene include using graphene sheets as electodes in ultracapacitors which will have as much storage capacity as batteries, replacing indium in flat screen TVs and making high strenght composite materials.

❖ Nanomaterial Applications using Nanocomposites

Applications being developed for nanocomposites include a nanotube-polymer nanocomposite used to replacement of broken bones, making a graphene-epoxy nanocomposite with very high strenght-to-weight ratios, The anodes made of the **silicon-carbon nanocomposite** make closer contact with the lithium electrolyte, which allows faster charging or discharging of power.

❖ Nanomaterial Applications using Nanofibers

Applications being developed for nanofibers include stimulating the production of cartilage in damaged joints, piezoelectric nanofibers that can be woven into clothing to produce electricity for cell phones or other devices, carbon nanofibers that can improve the performance flame retandant in funiture

Nanomaterials with improvement of properties

Nanomaterial	Effect on Property
Nano-silica	Reduced CO_2-emissions, reduction in porosity/permeability, increased durability, crack resistance, high strength
Carbon nanotube	Improved compressive strength, tensile bending strength, flexural strength, durability, piezoelectric response, blast resistance, sensing ability
Polymer/clay nanocomposites	Increased tensile strength, reduced oxygen permeability, enhanced heat resistance
Nano-calcium carbonate	Improved hardness, compressive strength, shortening of C_3S hydration period
Nano-titania	Effective self-cleaning, degradation of NOx, corrosion resistance, flame resistance, abrasion resistance
Nano-alumina	Increased elastic modulus, compressive strength, thermal shock resistance, ability to withstand rapid temperature change
Nano-zinc oxide	Increased compressive strength, aging resistance
Nano-cellulose	Increased bonding strength, modulus of elasticity, reduced moisture absorption

Toxicity of Nanoparticles

Engineered nanoparticles (NPs) are commercially produced materials having at least one dimension less than 100 nm. Nano-technology has brought a great revolution in the industrial sector. Due to their distinctive physicochemical and electrical properties, nano-sized materials have gained considerable attraction in the field of electronics, biotechnology, and aerospace engineering. In the field of medicine NPs are being employed as a novel delivery system for drugs, proteins, DNA, and monoclonal antibodies. So far, NPs have been prepared from metal and non-metal, polymeric materials and bioceramics. The majority of NPs having medical applications are liposomes, polyethylene glycol, and dendrimers . Humans are exposed to various nano-scale materials since childhood, and the new emerging field of nanotechnology has become another threat to human life. Because of their small size, NPs find their way easily to enter the human body and cross the various biological barriers and may reach the most sensitive organs. Scientists have proposed that NPs of size less than 10 nm act similar to a gas and can enter human tissues easily and may disrupt the cell normal biochemical environment.

Nanomaterials of different substances and their toxicity

NPs of metallic substances

Aluminum oxide

Aluminum-based NPs contribute 20% to all nano-sized chemicals. aluminum-based NPs are being used in many areas such as fuel cells, polymers, paints, coatings, textiles, biomaterials etc .

The aluminum oxide NPs, at concentrations of 10, 50,100, 200, and 400 µg/mL possess no significant toxic effect on viability of mammalian cells. Balasubramanyam *et al* have reported that aluminum oxide NPs (30-40 nm) possess dose-dependent genotoxic properties. They assessed genotoxicity with comet assay and micronucleus test using rat blood cells. The result of another study using mouse lymphoma cells line also suggest that aluminum oxide NPs (<50 nm) cause genotoxic effects in the form of DNA damage without any mutagenic effects. There are very few *in vivo* studies which have reflected on this aspect of NPs.

Gold

Gold NPs have very unique physicochemical properties. They have the capability of easy functionalization; binding to amine and thiol groups. All these characteristics possessed by gold NPs pave the way for surface modification, and are being investigated as drug carriers in cancer and thermal therapy, and as contrast agents. Gold NPs are considered to be relatively safe, as its core is inert and non-toxic. In one experimental study, several gold NPs (4, 12, and 18 nm) with different caping agents have been investigated for any cytotoxicity against leukemia cells line. The results of this report suggest that spherical gold NPs enter the cell and are non-toxic to cellular function. The variation in toxicity with respect to different cell lines has been observed in human lung and liver cancer cell line.

Copper oxide

Copper oxide NPs are used in semiconductors, anti-microbial reagents, heat transfer fluids, and intrauterine contraceptive devices. Experimentally, copper nano-materials have been documented to possess toxic effects on the liver and kidney. Nano-copper has resulted severe impairment in liver, kidney, and spleen in experimental animals. After oral administration and interacting with gastric juice, highly reactive ionic copper is formed, which is then accumulated in the kidney of exposed animals. In one *in vitro* study, copper oxide NPs (50 nm), have been reported as being **genotoxic and cytotoxic** along with disturbing cell membrane integrity and inducing oxidative stress.

Silver

silver has long been known as an anti-bacterial substance. Its NPs are being used in a wide range of commercial products. Silver NPs are used in the form of wound dressings, coating of surgical instruments and prostheses. They enter human body via different ways and accumulate in different organs. Experimentally, silver NPs have been detected in various organs, including lungs, spleen, kidney, liver, and brain after exposing the rats to silver-based NPs either via inhalation or by subcutaneous injection.

Zinc oxide

NPs produced from zinc oxide have many applications and are being used in paints, wave filters, UV detectors, gas sensors, sunscreens, and many personal care products. On the basis of increased use in many areas, human exposure to zinc oxide NPs is imminent. Zinc oxide NPs have been studied for any possible toxic effects on bacteria and mammalian cells. Cytotoxicity, cell membrane damage, and increased oxidative stress have been reported in various mammalian cell lines as the most common toxic effect of zinc-based nanomaterials. *in vitro* study, zinc oxide NPs have been accounted for change in cell morphology, DNA damage, alteration in mitochondrial activity in human hepatocytes, and embryonic kidney cells.

Iron oxide

Iron oxide NPs have been used in biomedical, drug delivery, and diagnostic fields. These NPs bio accumulate in the liver and other reticuloendothelial system organs. *In vivo* studies have shown that after entering the cells, iron oxide NPs remain in cell organelles (endosomes/lysosomes), release into cytoplasm after decomposing, and contribut to cellular iron poll. Magnetic iron oxide NPs have been observed to accumulate in the liver, spleen, lungs, and brain after inhalation.

Titanium oxide

Titanium oxide is chemically an inert compound, but studies have shown that NPs of titanium dioxide possess some toxic health effects in experimental animals, including DNA damage as well as genotoxicity and lung inflammation· Titanium dioxide NPs (<100 nm) induce oxidative stress and form DNA adducts· Besides genotoxicity, titanium dioxide NPs (5-200 nm) possess toxic effects on immune function, liver, kidney, spleen, myocardium, glucose, and lipids homeostasis in experimental animals·

NPs of non-metallic substances

Carbon-based nanomaterials

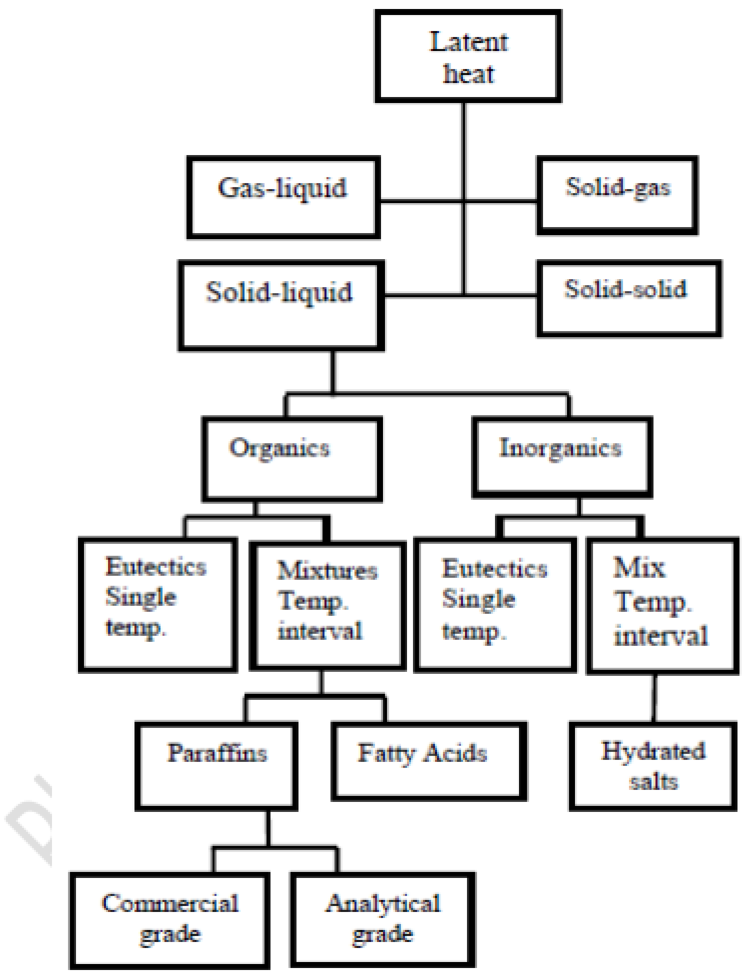
From application point of view, the carbon-based nanomaterials, such as carbon nanotubes, fullerenes, single and multi-walled carbon nanotubes are the most attractive and are widely used nanomaterials· Carbon-based nanomaterials have been reported in literature as cytotoxic agents. Magrez *et al.*· have reported that carbon-based nanomaterials possess size-dependent cytotoxicity. These investigators have tested various forms of carbon NPs on lung cancer cells

Silica

The uses of silica NPs have many advantages in drug delivery systems. silica NPs have been reported as easily functionalized drug carriers· Besides, having application in drug delivery systems, silicon dioxide NPs are also present in ambient air comprising of 8% of all air born NPs· Previously, nanosilica was thought as a highly biocompatible material in drug delivery systems, but according to recent reports, NPs of silica cause the generation of ROS and subsequent oxidative stress·

Phase Change Materials (PCMs) are ideal products for thermal energy storage & considered as one of perfect enhancement solutions in many fields. This is because they store and release thermal energy during the process of melting & freezing (changing from one phase to another) so it is called latent heat energy storage systems. They use chemical bonds to store and release heat. When such a material freezes, it releases large amounts of energy in the form of latent heat of fusion, or energy of crystallization. Conversely, when the material is melted, an equal amount of energy is absorbed from the immediate environment as it changes from solid to liquid.

Characteristics and classification



PCMs can broadly be arranged into three categories:

A - Organic PCMs:

Paraffin (CnH2n+2) and fatty acids (CH3 (CH2)2nCOOH) Organic Thermal Salt can be Aliphatic or Other Organics. Organic materials used as PCMs tend to be polymers with long chain molecules composed primarily of carbon and hydrogen. They tend to exhibit high orders of crystallinity when freezing and mostly change phase above 0°C (32°F). Examples of materials used as positive temperature organic PCMs include waxes, oils, fatty acids and polyglycols.

- **Advantages**

1. Freeze without much super cooling.2. Ability to melt congruently. 3. Compatibility with conventional material of construction. 4. Chemically stable. 5. Recyclable.

- **Disadvantages**

1. Low thermal conductivity in their solid state. 2. Volumetric latent heat storage capacity is low. 3. Flammable.

B - Inorganic PCMs:

Salt hydrates (MnH2O) Inorganic Thermal Salts are generally Hydrated Salt based materials. Academicians are likely to misguide you into using pure hydrated salts like Sodium Sulphate Decahydrate .

- **Advantages**

1. High volumetric latent heat storage capacity. 2. Availability and low cost. 3. Sharp melting point. 4. High thermal conductivity. 5. High heat of fusion. 6. Non-flammable.

- **Disadvantages**

1. Change of volume is very high. 2. Super cooling is major problem in solid–liquid transition. 3. Nucleating agents are needed and they often become inoperative after repeated cycling.

Application

Passive Cooling: A passive cooling energy storage application designed to work the natural difference between the cooler night and warmer day time ambient temperatures and by storing the cold energy over-night, the daily heat gains both internally and externally can be handled without any mechanical refrigeration, thereby providing maintenance free passive cooling system.