NANOTECHNOLOGY: AN OVERVIEW AND ITS APPLICATIONS

1. Introduction

Nanotechnology offers the design, characterization, manufacturing, and alertness of systems, tools, and machines with the aid of using controlling length and form at the nanometre scale. Nanotechnology is the application of nanoscience, especially at an industrial level as at the industrial level materials and devices are made up of atoms and molecules thus, they all can be improved by using nanomaterials. Nanotechnology is a broad area emerging worldwide explosively in the last few years [1]. In industry, nanotechnology applications may include construction materials, military goods and nano-machining of nano-wires, nano-rods, a few layers of graphene, and so on. Nanotechnology may be taken into consideration as a thrilling low-fee approach in asphalt pavement engineering supplying novel views in making asphalt cloth extra durable. Nanotechnology is likewise being carried out to or advanced for software to a number of business and purification processes. Purification and environmental clean-up packages consist of the desalination of water, water filtration, wastewater remedy, groundwater remedy, and different nano-remediation. A crucial subfield of nanotechnology associated with power is nanofabrication. Nanofabrication is the manner of designing and growing gadgets at the nanoscale. Creating gadgets smaller than one hundred nanometres opens can also additionally doorways for the improvement of recent methods to capture, keep and switch power. The maximum outstanding software of nanotechnology withinside the family is "self-cleaning" or "easy-to-clean" surfaces on ceramics or glasses. Nano ceramic debris has progressed the smoothness and warmth resistance of not unusual place family gadget along with flat iron [2]. Nanomaterials are cornerstones of nanoscience and nanotechnology. Nanomaterials are described as systems having one or extra measurement of nanometre scale variety 10^{-9} m. Nanostructure substances obtained the researcher's interest because of their specific optical, digital, and magnetic houses as evaluated to bulk crystals of identical chemical composition. Nowadays, nanomaterials are utilized in numerous fields along with power garage gadgets (gas cells), detection of threats in defense, drug transport, and water purification. Nanomaterials are also used as catalysts in car catalytic converters and electricity-era systems, to react with poisonous gases along with carbon monoxide and nitrogen oxide, thereby stopping the environmental pollutants resulting from them. The optical houses of the nanomaterials are used to shape optical detectors, sensors, lasers, displays, and solar cells. This asset is likewise utilized in biomedicine and picture graph electrochemistry. In microbial gas cells, the electrodes are made of carbon nanotubes. Nanocrystalline zinc selenide is used withinside the show displays to grow the decision of the pixels forming High-Definition TV units and private computers [3-5, 12].

Nanotechnology has been associated with food enterprises for the beyond many years to enhance the quality, flavour, and texture of foods and extricate the food from bacterial infections [4,5,15,16]. By preventing microbial infections, nanomaterials used in food processing enhance the shelf-life of the food. Nanotechnology has turned out to be a vital part of meal processing and meal packaging with the arrival of the improvement of nano-polymers. Nano-sensors have been also used in the food processing industry for the detection of contaminants, microbes, and poisonous substances present in food [15].

In medicinal drugs, nanomaterials are designed in such a way that they have interaction at the cellular level. These nanomaterials and gadgets are vital merchandise of biomedical engineering, and they're utilized in medicinal drugs and physiology with very high precision. Manipulation of drugs, lively compounds, and gadgets at a nanometre scale, permits to manipulate and adjust the vital properties and bioactivity of the ingredients. Thus, they permit to manipulation of the solubility of drugs, managed release, and targeted drug delivery [17].

Water purification is one of the best applications of nanotechnology in which different nanoparticles are used to improve water quality by removing chemical and industrial waste from rivers and groundwater. The use of nanotechnology for cleaning water is very efficient and relatively cheaper [24].

In the past era, the automobile enterprise has seen a distinguishable shift. The car or bike models launch now and then, and work on extra-part technology. This is the application of nanotechnology visible in the automobile industry. Various polymer nanocomposites like Natural Rubber-Organoclay were utilized in tires to lead them abrasion-resistant. Furthermore, including nanoparticles like tungsten nanospheres in vehicle fluids has upgraded their mechanical properties [8].

2. Classification of nanostructures

Nanostructured materials are classified on the basis of their dimensions and pore dimensions.

2.1. Classification on the basis of dimensions

1. *Zero dimensional nanostructures:* In these structures, quantum dots and individual lies where the nanoparticles are isolated from each other [].

2. *One-dimensional nanostructure:* These structures are those where one of the dimensions goes in the range of nanoscale order and has versatile applications in nanodevice fabrication [].

3. *Two-dimensional nanostructure:* Thin nano films lie in two-dimensional structures and are studied extensively for the utilization of nanodevice applications [].

4. *Three-dimensional nanomaterials:* These structures include powders, fibrous, multilayer, and polycrystalline materials in which the 0D, 1D, and 2D structural elements are in close contact with each other and form interfaces. An example of dimensional nanomaterials is listed in **Figure 1**.

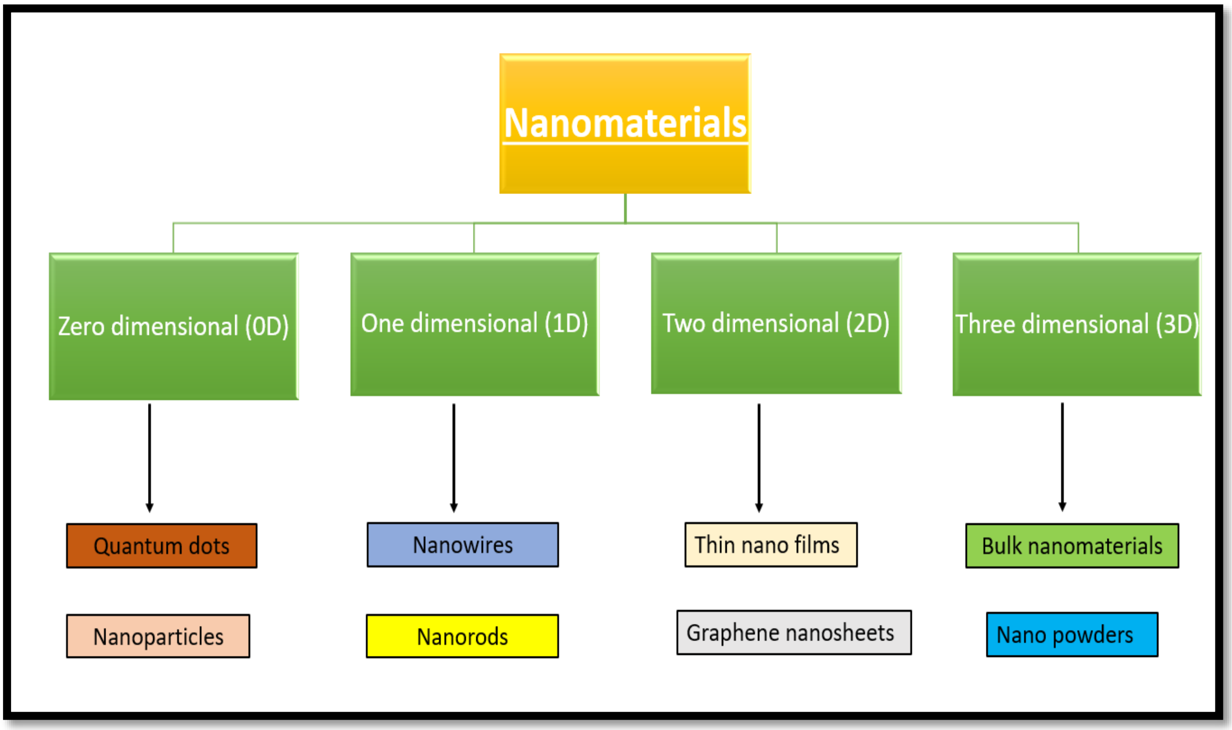

Fig 1: Classification of Nanomaterials on the basis of dimensions

2.2 Classification on the basis of pore size

I. Microporous materials (d<2nm) - These materials have very narrow pores. They can host only small molecules and show slow diffusion. The usage of these materials is generally in gas purification systems, and membrane filters. Example- Na-Y and naturally occurring clay materials.

II. Mesoporous materials (2<d<50 nm)- These materials can easily host some big molecules and diffusion kinetics of the adsorbed materials is with an initial interaction with the pore wall followed by pore filling. These materials can be used for polymerization. Example- MCM-41, SBA-15, and carbon mesoporous materials.

III. Macroporous materials (d>50nm)- The pores present in these materials can host very big molecules. These materials are used as matrices to store functional molecules. Example-Carbon microtubes, and porous gels (**Figure 2**).

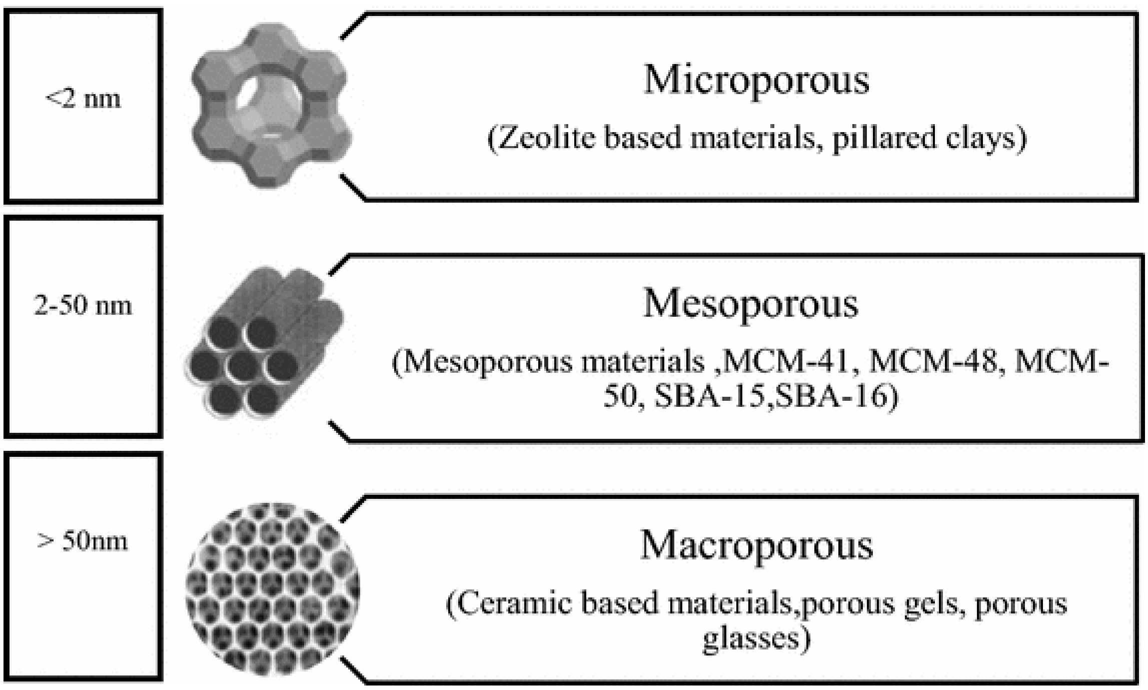

Fig 2: Classification of nanomaterials on the basis of pore size

2.3 Classification based on the structure and shape of the nanomaterials

I. Carbon Nanomaterials: Nanomaterials having carbon are known as Carbon nanomaterials. Different shapes of carbon nanomaterials such as hollow spheres and tubes are also synthesized. Carbon nanotubes, graphene, carbon black, fullerene and carbon nanofibers are also classified as Carbon nanomaterials (**Figure 3**).

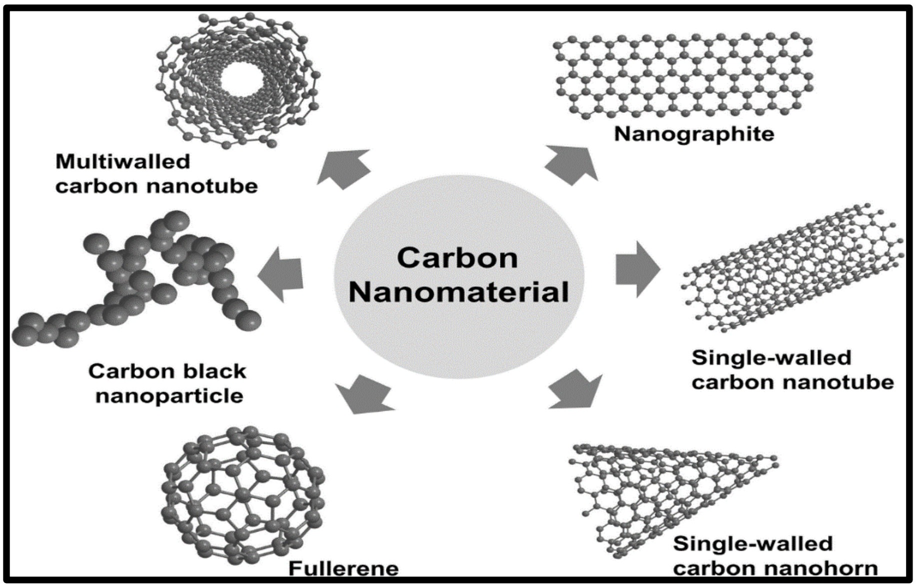

Fig 3: Some of examples of carbon nanomaterials

II. Metal/metal-oxide nanomaterials: In these nanomaterials, metal or metal oxide is used to synthesize nanomaterials which are known as metal or metal-oxide nanomaterials. They are also known as inorganic nanomaterials. Some example of metal nanomaterials is gold (Au) and Silver (Ag) nanomaterials and metal-oxide-based nanomaterials are zinc oxide (ZnO) nanomaterials and iron oxide (Fe_3O_4) nanomaterials.

III. Organic Nanomaterials: This type of organic nanomaterials contains organic matter (no carbon) or inorganic-based nanomaterials. Organic nanomaterials possess non-covalent bonds which means they are weak in nature and can be modified to produce different shapes of nanomaterials such as dendrimers.

IV. Nanocomposites: The formation of composite by combining one nanomaterial with another comes under nanocomposites. This combination could be of metal-based, organic-based nanomaterial with some other metals or polymer-based materials.

3. Properties of nanomaterials

When nanoscale materials are broken down, a significant alteration in their properties can be seen. The quantum size effect causes the electrical characteristics of materials to change as we move from the molecular level to the nanoscale level. The rise in surface area to volume ratio at the nanoscale level can be recognized as a change in the material's mechanical, thermal, and catalytic properties [6,9,10]. At their nanoscale size, many insulator materials begin to behave as conductors. Similar to this, other intriguing quantum and surface phenomena can be seen as we approach nanoscale dimensions. The physical and chemical characteristics of nanomaterials include their size, shape, chemical composition, crystal structure, stability, surface area, surface energy, and other characteristics. Nanomaterials' surfaces become increasingly reactive to one another and to other systems as their surface area to volume ratio rises. The pharmacological action of the nanomaterials is significantly influenced by their size. Nanomaterials can change their crystal structure in response to interactions with water or other dispersion media. The aggregation states of the nanomaterials depend on their size, composition, and surface charge. These materials' magnetic, physicochemical, and psychokinetic characteristics are impacted by surface coating. When oxygen, ozone, and transitional materials come into contact with these materials' surfaces, ROS are created. Strong polar or covalent bonds or van der Waal forces are responsible for particle interaction at the nanoscale [7,11]. Polyelectrolytes can be used to alter the surface characteristics of nanomaterials and their interactions with other substances and environments. Nanomaterials can be created artificially, happen accidentally, or come from nature. Humans create engineered nanomaterials with certain desired features. Nanomaterials made of titanium dioxide and carbon black are among them. Inadvertently, mechanical or industrial activities such as fuel heating, welding fumes, cooking, and vehicle exhausts can also produce nanoparticles. Ultrafine particles are another name for air nanomaterials that are unintentionally created. The nanomaterial created by burning biomass, such as a candle, is fullerene. Many of the natural processes, including forest fires, volcanic ash, ocean spray, metal weathering, etc., result in the formation of natural nanomaterials. Examples of nanomaterials found in biological systems include the structure of viruses, spider-mite silk, the blue colour of tarantula spiders, and butterfly wing scales. All-natural occurring organic nanomaterials include things like milk, blood, horn, teeth, skin, paper, corals, beaks, feathers, bone matrix, cotton, nails, etc. Clays are an example of an inorganic nanomaterial that occurs naturally because they grow as crystals under various chemical conditions in the earth's crust.

4. Synthesis of Nanomaterials

Nanomaterials are synthesized by different methods based on the types and nature of the nanomaterials. The two most common techniques for synthesizing nanomaterials are the "top-down" and "bottom-up" approach. The classification of synthesizing approaches is mentioned in **Figure 4**.

<u>Top-down approach</u>

In this approach, the bulk material is broken down into smaller particles using a physical process such as crushing, milling, and so on. However, evenly shaped nanomaterials don't form using this approach and also this method requires high energy usage as it is very difficult to form very small nanoparticles. In addition to this, this method causes crystal loss to the newly formed shapes of the nanoparticle.

1. Ball Milling- In this method, the bulk powder can be reduced to nanoparticles with the help of heavy balls and mechanical energy is applied. The balls containing high energy along with the bulk powder roll down on the surface of the container to reduce the particle size. Different energy mills such as attrition ball mill, planetary ball mill, and vibrating ball mill are used for particle reduction. This type of technique is used to synthesize amorphous alloys such as metal-metal, and metal-carbon systems for various applications. But the long time required and contamination of powder is still a major challenge.

2. Mechanochemical synthesis- This method requires deformation; welding of the bulk mixture and chemical modifications are done at the interface of nano-sized particles. This is a simple and efficient method to synthesize the nanoparticles. To synthesize the nanoparticle below 20nm size, this technique requires a long time.

3. Laser ablation- The size of the nanoparticles can be reduced by using laser irradiation. The bulk powder is placed under a thin layer and laser irradiation is passed through them so that bulk powder can be fragmented into nano powders. This technique is relatively simple to produce small size nanoparticles. But long laser ablation time leads to the formation of more nanoparticles which can block the laser path and decreases the ablation rate.

4. Ion Sputtering- The solid particles are reduced to nanoparticles by vaporization of the solid particle using sputtering with a beam of inert gas ions. The sputtering equipment used is less expensive and fewer impurities are produced as compared to other chemical techniques. The inert gases used can produce an effect on the surface morphology, and composition of the particles synthesized.

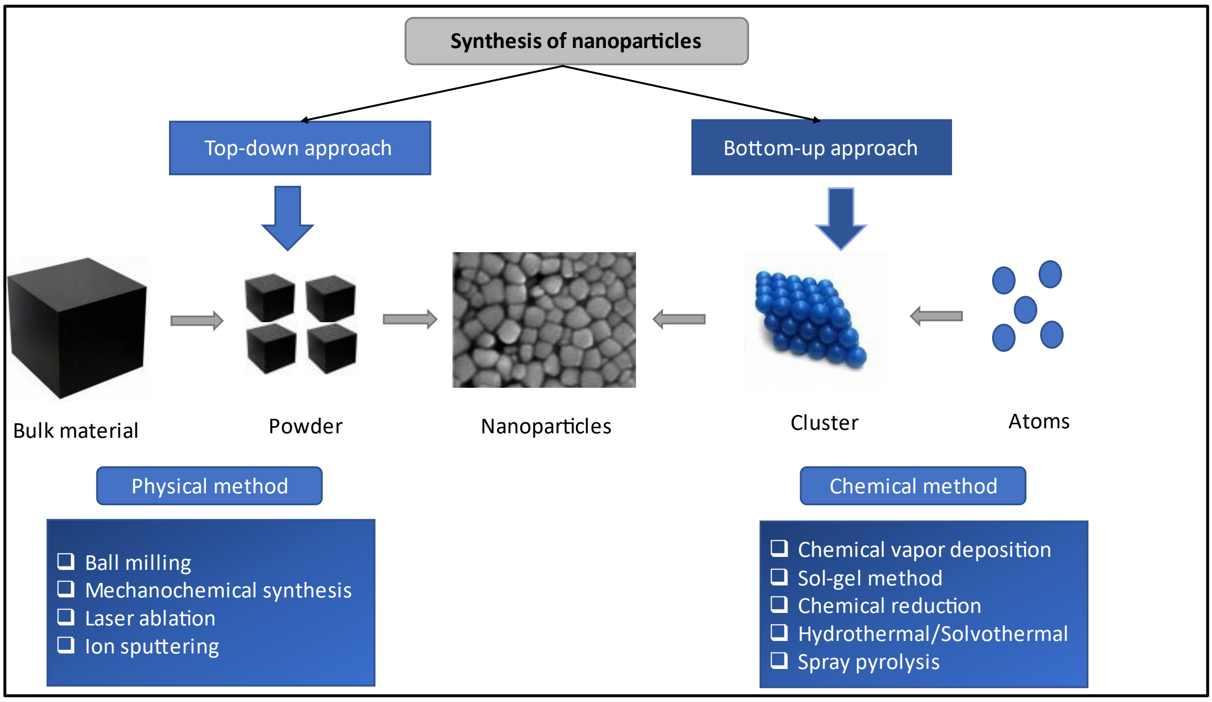

Fig 4: Approaches for Synthesis of nanomaterials

Bottom-up approach

This approach uses atom-by-atom or molecule-by-molecule to form larger particles. A nanoparticle of uniform shape and size is formed using this approach. By controlling the synthesis, this approach helps in to prevent the formation of growth of unwanted particles. Also, this approach is environmentally friendly and economical.

1. Chemical vapor deposition method- This technique uses a thin film of target material which gets deposited on the surface through the chemical reaction of atoms for the formation of films. Thermally active chemical vapor deposition, Plasma enhanced chemical vapor deposition, and photo-initiated chemical vapor deposition is used for the deposition of the target material. For temperature-sensitive materials, thermally active chemical vapor deposition is not suitable. The scale-up issues are arising in the case of plasma-enhanced chemical vapor deposition due to its high operating requirements. Whereas, the photo-initiated chemical vapor deposition has low energy requirements and does not require any equipment to control temperature and pressure. The chemical vapor deposition technique synthesizes nanoparticles with controlled morphology and crystal structure. The use of toxic and explosive gases in this technique causes chemical hazards. The synthesis of SnO2 nanorods using aerosol and deposition of single-layer graphene on copper metal are a few examples in which the chemical vapor deposition method is used.

2. Sol-gel method- The solid particles are formed using the small molecules. This method converts small molecules to a colloidal solution (sol) that is the precursor for integrated matrix forming species which then forms a gel. Generally, metal alkoxides are used as a precursor to form a colloid. Hydrolysis, condensation, particle growth, and agglomeration of particles are four steps involved in the sol-gel technique. This is a simple technique and particle size and morphology can be easily controlled by altering the process parameters. The thin film formation and ZnO_2 nanoparticle synthesis are done using the sol-gel technique.

3. Chemical Reduction method- The ionic salts are reduced using reducing agents in the presence of surfactants in an appropriate medium. Reducing agents such as sodium borohydride, and hydrazine hydrate is used to synthesize metal nanoparticles. This is the simplest technique to synthesize metal nanoparticles. Toxicity, poor reducing ability, and high cost are several limitations of the chemical reduction method. The copper nanoparticles are synthesized using potassium borohydride as a reducing agent.

4. Hydrothermal method- The nanoparticles are formed by the reaction of an aqueous solution containing solid particles at high temperatures and pressure. In this method, hydroxides are formed and then get dehydrated accelerating the formation of metal oxides. High crystallinity, desired shape, and size of nanoparticles are formed using the hydrothermal method. Reliability and reproducibility are the factors that can prohibit the use of hydrothermal techniques.

5. Solvothermal method- This method utilizes water or other solvents (mainly alcohol) as a solvent to synthesize the nanoparticles. The solvents are heated above their boiling points in the reaction. The crystallized monodispersed nanocrystals are synthesized by the solvothermal method.

6. Spray pyrolysis- The precursor in vapor form is delivered in the hot reactor using a nebulizer. Acetates, nitrates, and chloride precursors are generally used. This technique is relatively simple and is less expensive. Synthesis of ZnO nanoparticles using zinc acetate as a precursor and synthesis of TiO_2 are a few applications of spray pyrolysis.

5. Benefits and demerits of nanomaterials

The electrical, magnetic, optical, and mechanical properties of 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 [12,13]. Some of the advantages of nanomaterials are as follows-

1. Semiconductor q-particles from nanomaterials exhibit luminescence due to quantum confinement effects.
2. Nanophase ceramics are more ductile at high temperatures compared to coarse-grained ceramics.
3. The ductility and cold-welding capabilities of the nanosized metallic powders are very helpful for connecting metal to metal.
4. Single nanosized magnetic particles provide superparamagnetic properties.
5. Nanostructured metal clusters of monometallic composition act as precursors for heterogeneous catalysts.
6. For solar cells, Nanocrystalline silicon films form a highly transparent contact.
7. Nanostructured titanium oxide porous films provide high transmission and high surface area enhancement.
8. Nanocrystalline materials can be used to overcome problems with the microelectronic industry's downsizing of circuits, such as poor heat dissipation from high-speed

microprocessors and low dependability. These offer strong resilience, excellent heat conductivity, and strong long-lasting interconnections.

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

1. The nanomaterials are highly unstable in nature, provide poor corrosion resistance, and are highly soluble in an aqueous solution.
2. When the nanomaterials with a high surface area come in direct contact with oxygen exothermic combustion takes place leading to an explosion.
3. Nanomaterials are considered to be biologically harmful and carcinogenic in nature. These have high toxicity which can lead to irritations.

6. Advancement in Nanotechnology

Since the 1980s, nanotechnology has been predicted to be the next big thing. However, it is now becoming a reality with numerous applications in nearly every industry, including food safety, computers, textiles, health, energy storage, information technology, water treatment (**Figure 5**), transportation, agriculture, tech-focused businesses, NASA, and even students pursuing a degree in nanotechnology.

6.1 Applications in Medicine

The use of nanotechnology in medicine is known as nanomedicine. It is the enhancement and maintenance of human health using molecular techniques. Nanotechnology is used in the medical field for things like gene therapy and diagnostic nanoparticles. Given that the human body is made up of molecules, molecular nanotechnology has the potential to advance medicine in innovative ways. In order to use molecular machine systems for treating complex medical illnesses like AIDS, cancer, and aging, it can help us understand how the biological machinery found inside live cells functions at the nanoscale. resulting in a major molecular improvement in the structure and function of the human body [11,12].

Nano diamonds, carbon nanoparticles, are being developed for use in medicinal applications by scientific communities. Bone development surrounding dental and joint implants can be accelerated using nanodiamonds with protein molecules attached. Scientists are experimenting with attaching chemotherapy medications to nanodiamonds to treat brain tumors. Other researchers are looking into using Nano diamonds connected to chemotherapeutic medicines to cure leukemia [13].

Carbon nanotube-based sensors that can be encapsulated in the gel have been created by researchers. These can be injected beneath the skin to check the blood's level of nitric oxide. Nitric oxide levels can signal inflammation, which greatly aids in the early identification of inflammatory disorders [14].

Additionally, scientists have developed a technique for using nanoparticles for the early identification of many viral disorders. Also being researched are tests for the early diagnosis of renal disease. This technique makes use of gold nanorods that are drawn to the proteins produced by injured kidneys [15].

Proteins and peptides used in biopharmaceuticals have a variety of biological effects on the human body, which indicates great potential for treating various ailments. A ground-breaking stage in nano biopharmaceutics is the controlled distribution of such macromolecules using nanomaterials, such as dendrimers and nanoparticles. These substances can be created as receptor-specific nano biopharmaceuticals. They can deliver peptides in the encapsulated form to postpone their degradation and can be resistant to unspecific degradation.

Nanoparticles have the potential to deliver chemotherapy medicines more successfully [16-22]. In recent research, scientists created a new nanoparticle that can deliver massive doses of medicine and won't leak the drug while it travels through the bloodstream to the target [23].

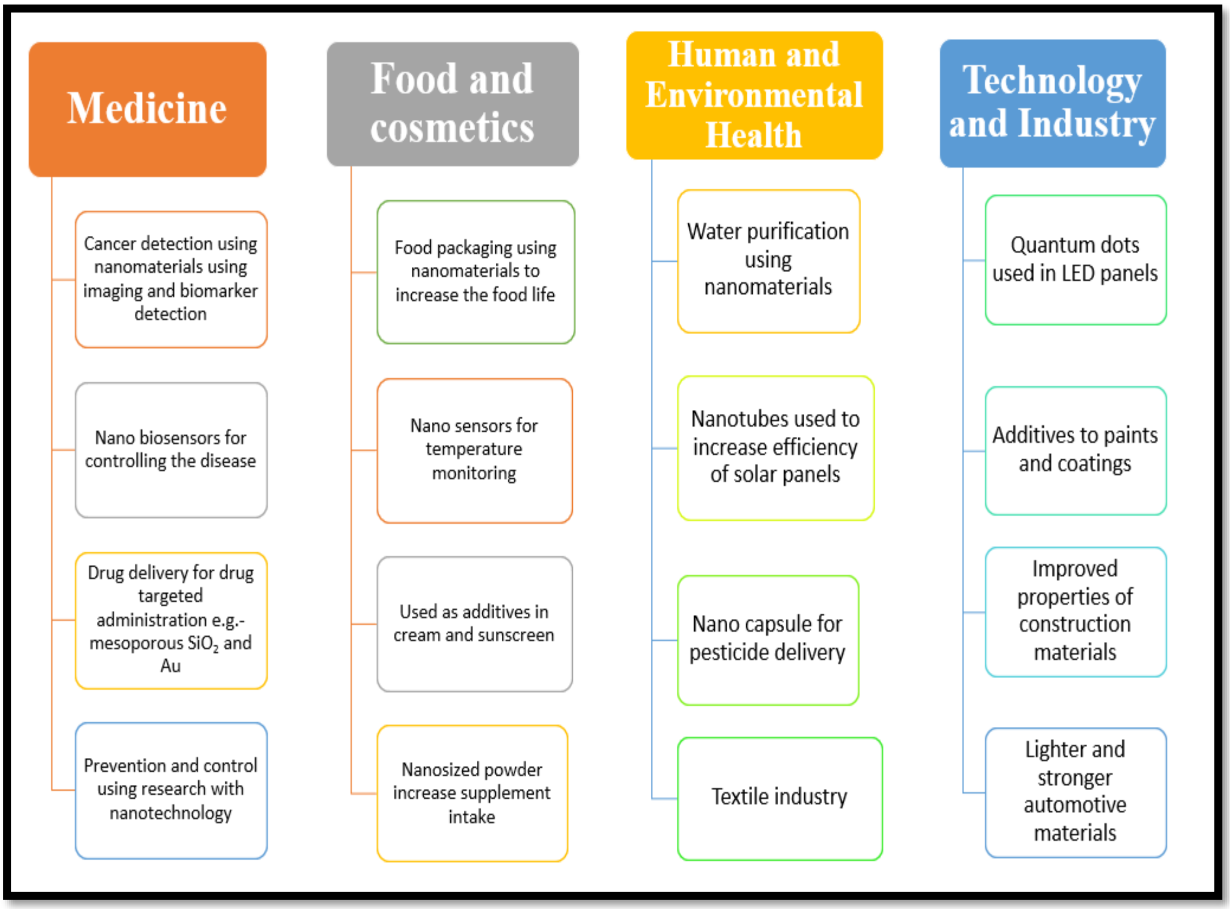

Fig 5: Applications of Nanotechnology

6.2 Energy applications

Both traditional energy sources (fossil and nuclear fuels) and renewable energy sources like geothermal energy, sun, wind, water, tides, or biomass can be significantly improved with the help of nanotechnologies. For example, nano-coated, wear-resistant drill probes enable cost-effective system longevity and efficiency enhancement for the exploitation of oil and natural gas resources or geothermal energy. Additional examples include wear and corrosion protection layers for mechanically stressed components as well as high-duty nanomaterials for lighter and more durable rotor blades of wind and tide power plants (bearings, gearboxes, etc.). Nanotechnologies will be crucial, particularly with the increased usage of solar energy through photovoltaic systems [9]. The layer design and shape of organic semiconductor mixes in component architectures may be improved with the help of nanotechnologies. Long-term use of nanostructures like quantum dots and wires could lead to solar cells with an efficiency of more than 60%. In order to make coal-fired power plants, an essential source of electricity, more ecologically friendly over the long term, nano-optimized membranes can expand the range of alternatives for separation and climate-neutral storage of carbon dioxide. Nanostructured electrodes, catalysts, and membranes can increase the energy yield from the conversion of chemical energy through fuel cells, opening up opportunities for cost-effective use in vehicles, structures, and mobile electronics [18]. There is optimism that the exceptional electric conductivity of nanomaterials like carbon nanotubes can be used for application in electric cables and power lines in order to reduce energy losses in current transmission. The improvement of superconductive materials for flawless current conduction is also possible using nanotechnological methods [21]. It turns out to be incredibly promising to use nanotechnologies to improve electrical energy storage devices like batteries and super-capacitors. The lithium-ion technology is seen to be the most promising kind of electrical energy storage because of the high cell voltage and the exceptional energy and power density [23]. Nanotechnologies have the potential to significantly increase the capacity and security of lithium-ion batteries, for instance by creating new ceramic, heat-resistant, yet flexible separators and high-performance electrode materials [16]. In addition to the efficient use of existing energy sources, increasing energy efficiency and reducing needless energy usage are required to establish a sustainable energy supply. Numerous strategies for energy conservation are offered by nanotechnologies. The optimization of fuel combustion through wear-resistant, lighter engine components and nanoparticular fuel additives or even nanoparticles for improved tyres with low rolling resistance are examples of how fuel consumption in automobiles can be reduced.

6.3 Applications in Food Packaging

An essential component of any product is its packaging, which should have the ideal strength, barrier, and performance properties. In comparison to traditional packaging techniques, nano-based packaging offers a number of benefits, including superior packaging material with increased strength and barrier. Food rotting by bacteria is a significant problem that the food industry is dealing with, and it is especially pertinent in light of the current global food scarcity. Metal and its oxides are frequently used in food and food packaging as antibacterial agents. Strong antibacterial action may be obtained in small quantities using inorganic nanoparticles of these metals and metal oxides, and they also offer greater stability in harsh environments. Because of the high surface-to-volume ratio, nanomaterials are much more reactive than their macroscale counterparts [25]. Antimicrobial packaging is essentially an active packaging type that prevents or delays potential microbial growth on food surfaces. Several nanoparticles, including carbon nanotubes, nano titanium dioxide, nano copper oxide, nano silver, and nano magnesium oxide, [26] can be employed in packaging as antibacterial agents. Nanocomposites are created by adding a variety of nanoparticles, including SiO_2, clay and silicate nanoplatelets, carbon nanotubes, and more, to the polymeric matrix. Because of the low permeability to gases that these nanocomposites offer, the packaging's barrier characteristics, temperature resistance, and moisture resistance are all improved. Utilizing carbon nanotubes makes it easier to absorb undesirable flavours or remove CO_2 [27]. The gas barrier properties of the nanocomposite, which is used to make drink bottles and other food packaging materials, are considerably improved by nano clay. This prevents oxygen and moisture from diffusing through, causing drink instability and food material spoiling. Nanoparticles are also utilized in the creation of nano sensors, which track physical, chemical, and biological changes made to food during processing and detect food pollutants [28]. Toxins, chemicals, and infections are detected using specially crafted nano sensors and nanodevices.

6.4 Applications in textiles and fabrics

These days, nanotechnology prospects have also been recognized by the textile sector. In order to engineer, synthesize, and alter the physical, chemical, and biological properties of the materials (individual atoms, molecules, and bulk matter) in order to create the next generation of better materials, devices, structures, and systems, we can define nanotechnology in textile as the understanding, manipulation, and control of matter at the above-stated length. It is employed to create textiles with the desired attributes, including high tensile strength, a distinct surface structure, a soft hand, durability, water repellence, fire retardancy, antimicrobial capabilities, and similar ones [29]. Most nanotechnology or nanofiber-based fibres are water-repellent. By covering the cloth with a coating of wax, the material becomes hydrophobic or unwettable. The layer of wax is added, creating a peach fuzz look that further reduces the likelihood of water absorption. Scuba divers, water navy, and swimmers frequently utilize these fibres to lessen their contact with water. Thus, one of the characteristics of nanofibers or smart fibres is their ability to reject water. There are several coating methods that can be used to add nanoparticles to textile fibres, including sol-gel, plasma polymerization, and layer-by-layer [30]. These methods can extend the fabric's lifespan and strengthen its resistance to harsh weather. The composition of nanocoating elements, such as surfactants and carrier media, can change the surface texture of fabrics. The textile sector has a huge potential for developing new materials, new products, and uses for currently available materials by realizing self-cleaning capabilities on textile surfaces. Self-cleaning clothing has been created using nature as a basis and the self-cleaning abilities of plant leaves and insects. The development of novel textile applications will usher in a new phase. Self-cleaning textiles will support the expansion of the technical textile industry's production, sales, and application sectors. The application of chemical finishing nanoparticles in textiles has received particular attention [31]. Different molecules or nanoparticles can be more effectively delivered to target areas on textile materials in a particular direction and trajectory using thermodynamic, electrostatic, or other technical methods. Spray coating or electroplating techniques can be used to design nanoparticles so that they attach to textile surfaces. Fabrics can become sensor-based materials by being coated with nanoparticles. Wearable fabrics that include nanocrystalline piezoceramic particles can be used to monitor body functions like heartbeat and pulse.

6.5 Applications in Electronics

The term "nanoelectronics" refers to the use of nanotechnology in electronic components. It has a wide range of uses in fields like computing and the production of electronic goods like iPod Nanos' Flash memory chips and mouse, keyboard, and cell phone castings with antimicrobial and antibacterial coatings. Organic light-emitting diodes, or OLEDs, are nanostructured polymer films that are utilized in many modern TVs, laptop computers, digital cameras, and cell phones [32]. OLED panels consume less power and have a longer lifespan than traditional LCD screens. With the help of conductive nanomaterials, data storage, quantum computing, printable and flexible electronics, and magnetic nanoparticles for data storage, nanotechnology in electronics enables quicker, smaller, and better handheld devices. It also enables new display technologies. By increasing the density of memory chips and reducing the size of the transistors used in integrated circuits, nanotechnology in electronics improves the capabilities of electronics devices while lowering their weight and power consumption.

7. Future of Nanotechnology

The development of cleaner, better, more affordable, and more intelligent products is the primary objective of nanotechnology research. Despite its appearance as a technology of the future, nanotechnology is currently used to make numerous conventional items. Nanotechnology is now present in a wide range of products, from pharmaceuticals and smartphones to tanning lotions and deodorants. One billionth of a metre is a nanometre. For production on a small scale, nanotechnology is a trustworthy technique. Materials can now be made stronger, lighter, more resilient, responsive, more mesh-like, or have greater electrical conductivity, among many other improvements thanks to the usage of nanotechnology materials. Because of the involvement of cosmetic firms in nanotech products, this sector is now incredibly lucrative and expanding. In fact, it is among the pioneers in introducing a technology that frequently incorporates nanoscale components. The applications of nanotechnology have been named as one of the six important technologies by the European Commission that would propel the expansion of numerous industrial sectors. The costs will be lower and the energy industry will be more effective thanks to the application of nanotechnology in these areas. Due to the urgent need for clean, affordable energy on a worldwide scale, we must accelerate research in order to develop cutting-edge nanotechnology applications that will help us use energy more effectively in the future. Any country's military has recognized nanotechnology's enormous potential. Therefore, it should not come as a surprise that the military funds most nanoscience research, which is then primarily geared toward military applications. For example- Certain nanomaterials can be used to coat wound dressings, which will allow for controlled medication and protein release for a predetermined amount of time. This will speed up the healing process. Military apparel is made from lightweight, durable, and multipurpose fabrics that provide better protection and improved communication. Nanorobotics may play a significant role in the development of nanotechnology. These nanorobots have the capacity to perform both human duties and impossible tasks for humans. It may be possible to restore the ozone layer once it has been destroyed. Nanorobots could identify specific water pollutant compounds. Since they could dissect water contamination down to its individual atoms, we could employ these haughty robots to keep the environment cleaner than before.

8. References

1. Sozer N, Kohini, JL (2008) Nanotechnology and its applications in the food sector, *Trends in Biotechnology 27*(2):82–89.
2. Dowling, AP (2004) Development of nanotechnologies, *Materials Today* 7, 30–35.
3. Moraru C, Panchapakesan C, Huang Q, Takhistov P, Liu SX, Kokini J (2003) Nanotechnology: a new frontier in food science, *Food Technol* 57: 24–20.
4. Oberdorster G, Maynard A, Donaldson K, et.al (2005) Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy *Part Fibre Toxicol* 2: 1–35.

5. Egusquiaguirre SP, Igartua M, Hernandez RM, et.al (2012) Nanoparticle delivery systems for cancer therapy: advances in clinical and preclinical research. *Clin Transl Oncol* 14: 83–93.
6. Sanguansri P and Augustin MA (2006) Nanoscale materials development- a food industry perspective *Trends Food Sci. Technol* 17: 547–556.
7. Jain KK (2008) The Handbook of Nanomedicine. Springer.
8. West JL, Halas NJ, 2003, Engineered Nanomaterials for Biophotonics Applications: Improving Sensing, Imaging, and Therapeutics *5*: 285–292.
9. Som C, Nowack B, Krug HF, Wick P (2013) Toward the development of decision support tools that can be used for safe production and use of nanomaterials, *Accounts of Chemical Research 46*(3):863–872.
10. Som C, Wick P, Krug H, Nowack B (2011) Environmental and health effects of nanomaterials in nanotextiles and façade coatings, *Environmental International 37*:1131–1142.
11. Serrano AL, Olivas RM, Landaluze JS, Cámara C (2014) Nanoparticles global vision, Characterization, separation, and quantification holds. Potential environmental and health impacts, *Analytical Methods 6*:38–56.
12. Markovic D, Zivkovic D, Cvetkovicm D, Popov R (2012) Impact of nanotechnology in ICT on sustainability and energy efficiency, *Renewable and Sustainable Energy Reviews* 16: 2966–2972.
13. Englert BC (2007) Nanomaterials and the environment: uses, methods and measurement *J. Environ. Monit. 9*: 1154–1161.
14. Madhumathi K, Kumar STS, Sanjeed MT, Muhammed SA, Nazrudeen S, et al. (2014) Silver and Gadolinium Ions Co-Substituted Hydroxyapatite Nanoparticles as Bimodal Contrast Agent for Medical Imaging. *Bioceram Dev Appl* 4:079.
15. Nagai N, Ito Y (2014) A New Preparation Method for Ophthalmic Drug Nanoparticles. *Pharm Anal Acta* 5:305.
16. Chang PEJ, Purushotham S, Rumpel H, Kee IHC, Ng RTH, et al. (2014) Novel Dual Magnetic Drug Targeting and Hyperthermia Therapy in Hepatocellular Carcinoma with Thermosensitive Polymer-Coated Nanoparticles. *J Gastroint Dig Syst* 4:198.
17. Banach M, Szczyglowska R, Pulit J, Bryk M (2014) Building Materials with Antifungal Efficacy Enriched with Silver Nanoparticles. *Chem Sci J* 5:085.

18. Konstantinovic Z, Vodnik V, Saponjic Z, Nedeljkovic J, Pomar A, et al. (2013) Self-Assembled Nanostructures as Templates for the Integration of Nanoparticles in Oxide Surfaces. *J Nanomedine Biotherapeutic Discov* 3: 112.

19. Borase HP, Patil CD, Salunkhe RB, Salunke BK, Patil SV (2013) Phyto-Synthesized Silver Nanoparticles: A Potent Biolarvicidal Agent. *J Nanomed Biotherapeut Discov* 3:111.

20. Banu A, Rathod V (2013) Biosynthesis of Monodispersed Silver Nanoparticles and their Activity against Mycobacterium tuberculosis. *J Nanomed Biotherapeut Discov* 3:110.

21. Deepak Gupta, Phoung Nguyen and Monica Yu (2014) Nanoparticles for Superior Pharmacokinetics and Enhanced Efficacy *J Dev Drugs* 3:e137.

22. Morris B, Behzad F (2014) The Effects of Gold and Silver Nanoparticles on an Enzymatic Reaction Between Horseradish Peroxidase and 3,3',5,5'-Tetramethylbenzidine *Biochem Pharmacol* 3:146.

23. Bora, T., Dutta, J., 2014, Applications of nanotechnology in wastewater treatment: a review, *Journal of Nanoscience and Nanotechnology 14*:613–626.

24. Mlalila N, Kadam DM, Swai H, Hilonga A (2016) Transformation of food packaging from passive to innovative via nanotechnology: concepts and critiques *J. Food Sci. Technol.* 53 (9): 3395-3407.

25. Cerqueira MA, Vicente AA, Pastrana LM (2018) Nanotechnology in Food Packaging: Opportunities and Challenges," in *Nanomaterials For Food Packaging: Materials, Processing Technologies, and Safety Issues*, 1-11

26. Bumbudsanpharoke N, Choi J, Ko S (2015) Applications of nanomaterials in food packaging American Scientific Publishers *J. Nanosci. Nanotechnol* 15 (9): 6357-6372.

27. Gregor-Svetec D (2018) Intelligent Packaging," in *Nanomaterials For Food Packaging: Materials, Processing Technologies, and Safety Issues* 203-247.

28. Pereira C, Pereira AM, Freire C, Pinto TV, Costa RS, Teixeira JS. (2020) Chapter 21 - Nanoengineered textiles: from advanced functional nanomaterials to ground breaking high-performance clothing. In: Handbook of Functionalized Nanomaterials for Industrial Applications, 611–714.

29. Lim TH, Kim SH, Oh KW. Fabrication of Organic Materials for Electronic Textiles. In: Tao X, editor. Handbook of Smart Textiles. Singapore: Springer Singapore; 2015. p. 739–73.

30. Kubley A, Chauhan D, Kanakaraj SN, Shanov V, Xu C, Chen R, et al. (2019) Smart textiles and wearable technology innovation with carbon nanotube technology. In: Nanotube Superfiber Materials, 263–311.

31. Korkin A, Krstic PS, Wells JC (2010) Nanotechnology for Electronics, Photonics, and Renewable Energy.