**REVIEW ARTICLE**

# Nanotechnology and its Applications: A Scientific Boon for Future

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***Received: 01st January, 2022; Revised: 14th February, 2022; Accepted: 10th March, 2022; Available Online: 25th March, 2022***

## ABSTRACT

Nanotechnology is a technique that issued at very small-scale sand has a wide range of real-world applications. Nanostructures are among the smallest organisms that can be formed, but they each have their own set of characteristics. Due to its minute particle size, they are extensively used in different fields of chemistry, physics, biology, and medicines for several useful applications including early disease diagnosis, rapid diagnosis and the advancement of treatment that are difficult to attain with the traditional technologies. Nanomaterials are widely being used in medical diagnosis and selective drug delivery systems. Nanotechnology has the potential to speed up the advancement of proper medicine, in which patient's treatment is customized to their unique genetic and disease profile. In this review we have tried to highlight all the types of nano technologies that are widely used in various fields and combined the concept of nanosensors which are serving the human in disease identification, monitoring their health, weaving the illness, and decreasing the hospital stay of patient's. Nano technologies are also playing a key role in medical, construction, engineering, electrical and IT sectors, energy, and environmental sectors. This technology has advanced, and a lot of applications are discussed here and more advancement in future is waiting for using this technology.

**Keywords:** Applications of nanotechnology, Disease diagnosis, Nanotechnology, Nanosensors.

International Journal of Drug Delivery Technology (2022); DOI: 10.25258/ijddt.12.1.80

**How to cite this article:** Yadav R, Dubey A, Tiwari SP, Shrivastava P, Mandal S. Nanotechnology and its Applications: A Scientific Boon for Future. International Journal of Drug Delivery Technology. 2022;12(1):454-461.

**Source of support:** Nil.

**Conflict of interest:** None

## INTRODUCTION

Man has attempted to perceive matter at its most basic level ever since he assumed charge of the universe and transformed it in such a way that it would fulfill human needs in the future. At the beginning of the twenty-first century, it has been possible to study, plan, and synthesize structures with a billionth of a metre of precision. Nano science is the study of fundamental principles of matter on a scale of 1 to 100 nm, whereas nanotechnology is the application of those knowledge.[1] Material properties at the nanoscale differ greatly from those at the bulk size. Gold nanoparticle, for example, has completely different chemical, physical, electrical, magnetic, and collective properties than bulk gold.[2]

Nanotechnology is a multidisciplinary field of study which combines chemistry, physics, biology and medicines for several useful applications including early disease diagnosis, rapid diagnosis and the advancement of treatment that are difficult to attain with the traditional technologies. Nanomaterials are widely being used in medical diagnosis and selective drug delivery systems. Nanotechnology has the potential to speed up the advancement of proper medicine, in which patient's treatment is customized to his/her unique genetic and disease profile.[4] In the current scenario where people are facing a lot of problems. They are not getting proper treatment. Nanotechnology can provide proper treatment with early disease diagnosis within expensive diagnostics. This sector is quickly evolving and developing around the world. By keeping the view of current scenario, we had chosen this topic as our area of interest.

## HISTORY

The development and usage of the tiniest particles that are transparent to the naked eye are not new; they have been used for many years. In the fourth century AD, humans were the first to use nanoparticles and fabrics. Richard Zsigmondy, the Nobel Prize in Chemistry laureate in 1925, was the first to suggest the concept of a "nanometer." He invented the term nanometer to define particle size, and he was among

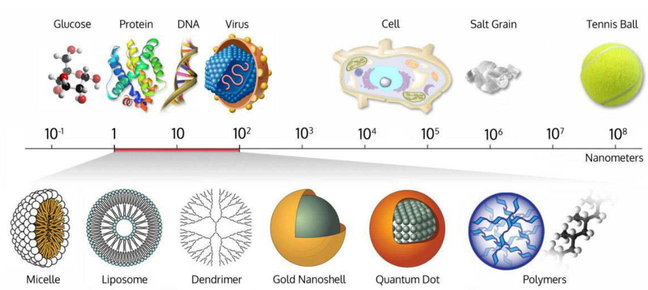


**Figure 1:** Comparison of sizes of nanomaterial[3]

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the first to use a microscope to measure the size of particles such as gold colloid.[4] Current nanotechnology was conceived by Richard Feynman, the 1965 Nobel Laureate in Physics. During the American Physical Society meeting at Caltech in 1959, he delivered a lecture titled "There is plenty of room at the bottom," in which he pioneered the concept of forming matter at the atomic level. This ground-breaking idea showed new modes of thought, and Feynman's ideas were later shown to be right. As a result of these reasons, he is generally recognized as the Founder of Modern Nanotechnology.[5] Roughly following 15 years of Feynman's talk, a Japanese researcher named as Norio Taniguchi first utilize the expression "nanotechnology" to portray semi-conductor measures that happened on the request for a nanometer. He recommended that the nanotechnology was the arranging, separation, combination, and twisting of materials by a niotaora particle. In 1980's the brilliant time of nanotechnology started when Kroto, Smalley and Twist found fullerenes and Eric Drexler of the Massachusetts Establishment of Innovation (MIT) applied ideas from Feynman's "There is a lot of Room at the base "and Taniguchi's statement" nanotechnology" in his book named "Motors of creation: The Coming Period of Nanotechnology". Drexler proposed the idea of a nanoscale constructing agent, which is equipped for repeating itself and different objects of self-assertive complexity. Drexler's idea of nanotechnology is regularly alluded to as sub-atomic nanotechnology. Another Japanese physicist, Lijima, progressed the investigation of nanotechnology by creating carbon nanotubes[6]. During a discourse at Caltech in January 2000, President Bill Clint on upheld for help by financing for research in this new innovation. Following 3 years, President George W. Bramble marked the 21st Century Nanotechnology Innovative works Act into Law. The law set up the Public Innovation Drive (NNI) and announced nanotechnology research a public need. Today, the NNI is taken care of inside a construction that incorporates the President's Bureau level Public Science and Innovation Committee (NSTC) and its sub committees. The Sub-committee on nanoscale Science, Designing, and Innovation (NSET) of the Panel is responsible for the NNI's planning, execution and assessment, and is comprised of individuals from 20 US organizations just as autonomous commissions and departments.[4,7]

## NANOSTRUCTURE USED AS DIAGNOSTICS AGENTS

Materials with a scale of 100 nm in at least one dimension are considered as nanostructures. Nanostructures exist in three dimensions: zero dimensional (0D), one dimensional (1D), and two dimensional (2D). Nanostructure measurements are useful in diagnostics since they are comparable to the sizes of different biomolecules such as nucleic acids, small proteins, and viruses. An in vitro diagnostic method is often made up of an ingredient that is capable of to recognize a biochemical modification, behavior, or concentration of a single molecule of biological significance in the solution of interest. A transducer is used in a nano biosensor to transform the biochemical signal into a quantifiable signal.[8] The use of nanomaterials in the design of in vitro diagnostic systems has resulted in sensors with high precision, flexibility, and robustness. Metallic nanoparticle, quantum dots (QDs), silica nanospheres, magnetic nanoparticle, which belong to the zero-dimensional (0D) systems, carbon nanotubes (CNTs), silicon nanowires, nanopores, which belong to the one-dimensional (1D) systems, and graphene, nano structured surfaces, and metal films, which belong to two-dimensional (2D) systems they all found attractive applications in in-vitro diagnostic tests.[9]

### Metallic Nanoparticles

Metals, especially gold and silver, have the invaluable capacity to speak with outside fields like light, radiofrequency, and X-beams. Metals exhibit Surface Plasmon Reverberation (SPR), the wavering of free electrons on a molecule's surface, at a given frequency; subsequently, they can be productively matched with conventional strategies like colorimetry or ingestion spectroscopy. The fluid example segment and an immobilized ligand (like immune response) on a SPR-dynamic gold-covered glass slide are the basic instances of SPR biosensing. This strategy will assemble a slim stream cell where in the example can stream in the fluid arrangement. A slight (apparentor close to infrared) is projected through the glass slide and onto the gold surface at points and frequencies near the SPR condition, the optical reflectivity of the gold changes with a specific goal in mind when a genuine association happens between the example and the ligand of the gold. The most widely recognized clinical use for these nanoparticles is in quick testing, for example, pregnancy test units, in which gold nanoparticles are utilized as a shading marker.[10] Super magnetic iron oxide nanoparticles (SPIOs) are used for magnetic separation in a number of immuno magnetic applications such as cell sorting, nucleic acid detection, purification, and recognition of bacteria, cancer cells, and other rare populations in asolution.[11]

### Quantum Dots

In the field of in vitro applications, nanoparticles are generally utilized as a biomolecules producer since they enjoy numerous optical benefits which make them appropriate for assortment of diagnostics test like PCR, the production of biochips, or multiplex in g rather than the regular colors which is utilized each day in clinical practice. With that in mind,

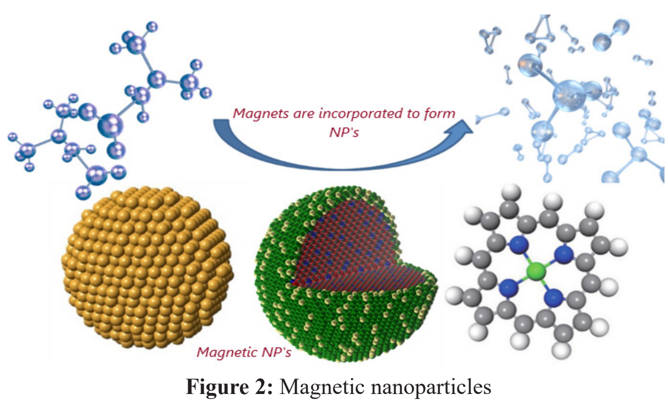



**Figure 2:** Magnetic nanoparticles

inorganic fluorescent nanoparticles, for example, semi-conductor nanoparticles (quantum spots) or nanoparticles like nanophosphors are being examined, bringing about expanded affectability and accuracy, just as the chance of investigating different analytes, which offers large scale manufacturing openings. Quantum specks, semiconductor nanocrystals covered with inorganic mixtures, are likewise as of now utilized in basic cell science research and clinical symptomatic testing. All the more explicitly, when contrasted with regular natural colors, QDs are proficient energy contributors, especially as color acceptors in FRET (fluorescence reverberation energy move) based tests.[12,13]

### Silica Nanospheres

Inorganic dye-loaded silica particles, like QDs, have excellent photostability, sharp mission peaks, and long fluorescence lifetimes. They are suitable for dispersing aqueous liquids due to their hydrophilic surface. They are usually used to conjugate optical labels such as organic or inorganic dye molecules (lanthanide and ruthenium based) to increase the identification signal.[14]

### Carbon nanotubes

There are little electrically safeguarded cylinders or pores that can recognize a solitary particle as it goes through the cylinder or pore. The distinguishing proof of atoms is reliant upon changes in the ionic flow of the electrolyte arrangement including the particle so interest, which causes a distinction in the electrical flow (movement occasion signal). Since every DNA base has a particular sub-atomic construction and hence an exceptional movement occasion signal, the combination of biochips and nanofluidic with nanopores or nanotubes would have the option to supplant the setup DNA sequencing strategies in clinical practice. Nanofluidic gadgets are being assembled that utilization numerous estimations on single particles to improve the capacity to measure DNA atoms. Strategies for joining films with nanopores into microfluidic frameworks, which diminish clamor and permit the plan of nanopore-containingnetworks.[16]

### Silicon Nanowires

Nanowires are as of now suspected to be exceptional and useful for the advancement of a nano biosensing framework. Nanowires are nanoscale current-conveying channels made of carbon nanotubes, metal oxides, or silicon. They should be incorporated at high temperatures and are normally set up on silicon wafers.[17] Antibodies are typically utilized as identifiers on the outside of nanowires. Antibodies meddle with the natural object of interest, and the conformational distinction causes an adjustment of the current that moves through the nanowire, considering delicate and exact identification. The utilization of nanowires in a cluster mode, with various antibodies formed to each nanowire, empowers mass ID of various types of illness or the arrangement of a rigid atomic profile of one kind of sickness.[18]

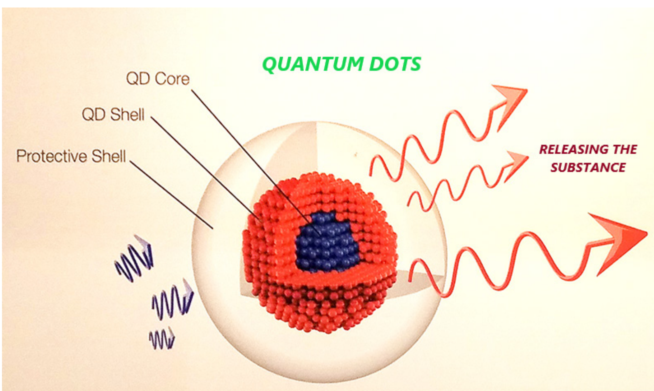



**Figure 3:** Quantum dots

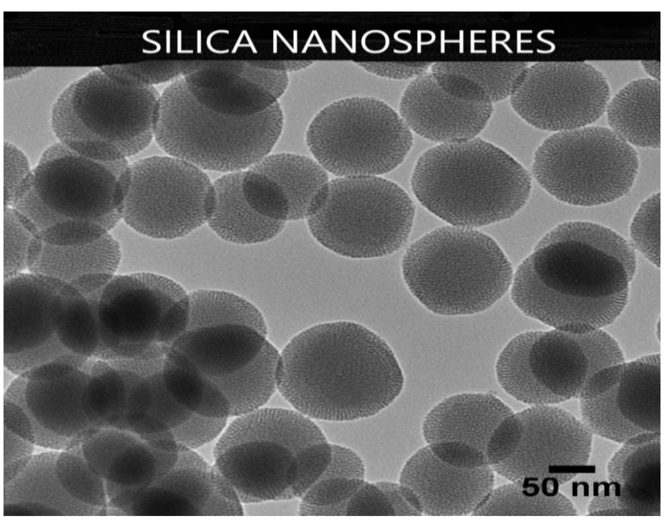



**Figure 4:** Silica nanospheres

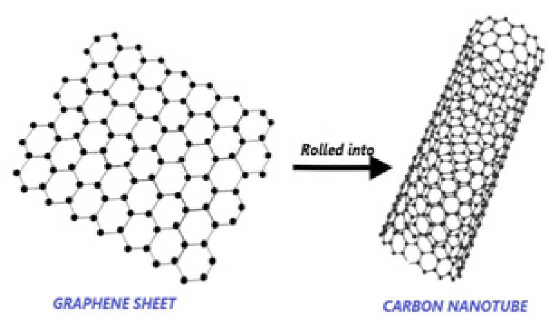



**Figure 5:** Carbon nanotubes

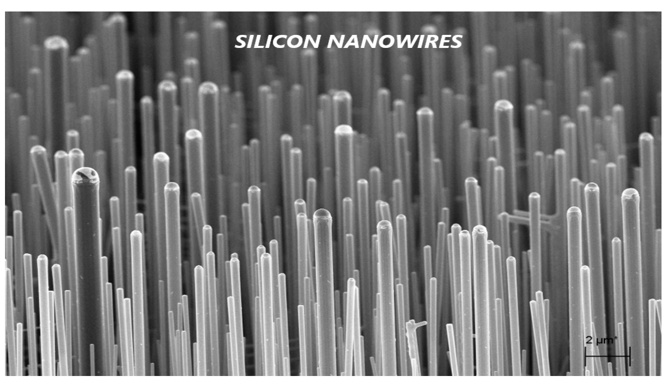



**Figure 6:** Silicon nanowires

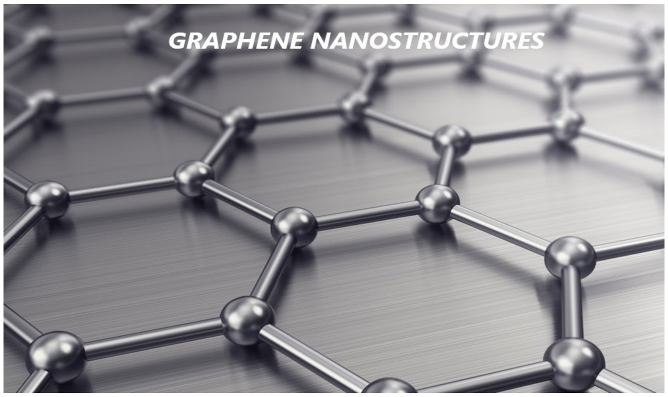


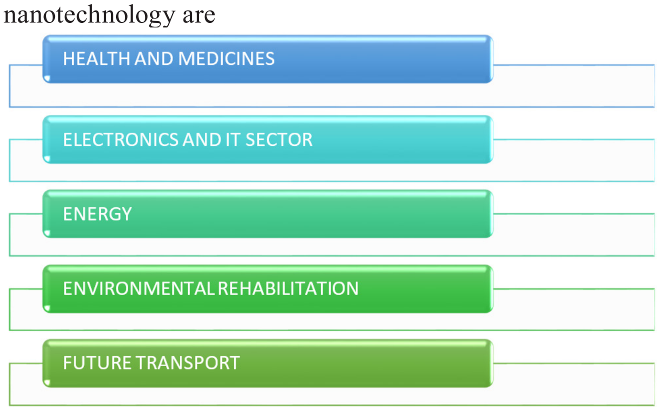

**Figure 7:** Graphene nanostructures

### Graphene, Metal Film, and Nanostructured Surfaces

They are both representations of two-dimensional nanostructures. They are the form with a single dimension of 100 nm. When the sample comes into contact with them, they are used as racks to conjugate and immobilize ligands for selective binding. They are usually sheets of a particular nanomaterial with properties that differ from the corresponding bulk content. Since graphene is an exceptionally stable one-layer 2Dsurface of carbon atoms with unusual optical and conductive properties, it can be used in rapid diagnostic testing with high sensitivity.[19,20]

## APPLICATION OF NANOTECHNOLOGY IN VARIOUS FIELDS

The various fields that realize possible application of nanotechnology are




### Nanotechnology in Health and Medicines Sector

In the 21st century where individuals are confronting a ton of challenges in the space of medical care. Sadness, hypertension, diabetes, malignancy and an assortment of irresistible sicknesses area couple of the average results of a high speed, upsetting way of life. From the previous few years, we can see that the Nanotechnology is extended the clinical hardware, information and the treatments which are accessible for the subject matter expert.[21] The execution of nanotechnology in meds is known as nanomedicines which draw on regular size of natural science to give the precise answer for the anticipation of infection, conclusion, and treatment. A few models where nanotechnology has expanded over whelming are-In industrial uses, gold nanoparticles have been modified as probes for the detection of specific nucleic acid sequences, and gold nanoparticles are also being used commercially as substitute medicines for certain diseases such as cancer. Nanotechnology is improving imaging and monitoring capabilities, laying the ground work for earlier diagnosis, more tailored care options, and better clinical success rates.[22] Nanotechnology is being used to study atherosclerosis or the buildup of plaque in arteries, for both diagnosis and treatment. The researchers created a nanoparticle that resembled the body's healthy cholesterol, known as HDL (high-density lipoprotein), which aids in plaque removal.

Researchers are concentrating on a variety of therapeutics in which a nanoparticle can encapsulate or even assist in the direct delivery of drugs to cancer cells whilst minimizing the risk of harm to healthy tissue. This has the potential to change how doctors treat cancer and significantly reduce the side effects of chemotherapy.[23] Nanomedicine researchers are studying how nanotechnology can improve vaccines, such as needle-free vaccine delivery. Researchers are currently working on a generic vaccine scaffold for the annual flu vaccine, which will cover more strains and require fewer resources, such as time and money, to produce each year. Nanotechnology innovation for regenerative medicine encompasses a wide range of applications, including bone and neural tissue engineering. For example, novel materials can be engineered to mimic the crystal mineral structure of human bone or used as a dental restorative resin. Researchers are attempting to work out how to cultivate a variety of tissues in the hopes of one day being able to produce human organs for transplant. Researchers are now looking at using graphene nanoribbons to help in the treatment of spinal cord injuries; tentative research suggests that neurons grow well on the conductive graphene surface. Nano sensor refers to a sensor that uses a nanometer-sized transducer to communicate with analyte and generates a detectable electrical or optical signal. The type of analyte determines whether the classification is physical, chemical, or biological.[24] The medical field requires various types of sensors to measure physical characteristics such as strain, temperature, stress level, viscosity, and flow rate; chemical parameters such as pH level, oxygen, toxin, medications, and organic volatiles compounds; and biological characteristics such as glucose, proteins, lipids and microbes. Physical instruments often have a physical measure and a physical transduction system, like measures of variations in density, force, temperature, or surface tension as shift in electrical current, voltage, or frequency. In chemical and biological sensors, the basic contact processes between the measure and the transducer are chemical in nature, such as hydrogen- bonding interaction, polar interaction, and coordination, but a biosensor differs in that either the analyte or the transducer medium, or both, are biomaterials. In a biosensor, the analyte transducer pair relationship is more complex than in a chemical sensor.[25]

### Structure and Mechanism of Action of Nanosensors

A nano sensor is usually made up of a bio sensitive layer that contains bio-recognition components or is made up of bio-recognition compounds that are tightly bonded to the transducer. Association between target analyte with the bio-receptor is expected to result in physio-chemical changes that can be calculated and transform into a quantifiable result, as well as an electrical signal. Bio receptors are salient because they provide selectivity to biosensor technologies. They allow the particular analyte to be bound to the sensor for calibration with marginal interference from other elements in sampling mixtures. Biological sensing components may be either biological molecular pieces or alive biological systems that use a biochemical process for detection. Detection of biosensors can be accomplished using a range of read out methods, like electrical, electrochemical and mass-sensitive read out.[26] The bulk of nanosensors are made up of two types of receptor molecules: affinity-based and catalytic-based. Affinity-based nanosensors are used to bind molecular species of interest in an on-catalytic and irreversible manner. Antibodies, nucleic acids and hormone receptors are a few examples. Catalytic sensors, including enzymes and microbiological cells, detect and bind a target molecule, then catalyze the chemical conversion of that molecule into a compound that can be sensed. It operates by transferring charge amongst molecules and a receptive substrate, which results in an electrical or optical signal that is unique to the shape and number of molecules.[27,28]

**Nanosensors for Disease Diagnostics**

*Nanoparticle Sensors*

Nanoparticle development, application, and control for disease chemotherapeutics is a major area in biomedical research today. Since the positions of electronic configuration in nanoparticles are discredited and differ with particle size, material properties on the nanoscale vary dramatically from those in bulk. Thus, through structuring nanoparticles of suitable lengths, for selective binding of different target bio analyte, it is necessary to confer a variety of desirable interaction affinities.[29] The detection can be done either specifically by detecting changes in the nanoparticles' optical absorption or radiation properties in response to analyte binding (label-free detection) or indirectly by labeling target analyte with nanoparticles (labelled detection).

*Labelled Sensing*

The named implies that the association between analyte and transducer is calculated in directly by few interaction mechanisms with the aid of a probe agent (redox or phosphor molecules).

*Label-free Sensing*

The analyte relationship with the sensor platform has either been directly converted into an identifiable electrical contribution or intrinsically coupled with another transduction device for signal enhancement and detection for label free recognition (without the use of a probe molecule or a mediator).[30]

*Electrochemical Sensors*

The most robust and sensitive systems for label-free sensing are nanosensors based on electrochemical principles. The readout signals are instantly translated to electrical form for analyte capture cases. A catalytic enzyme layer or a nanoparticle-polymer hybrid film is inserted onto the sensing electrode in most electrochemical sensors, specifically binding input molecules and activating the oxidation-reduction reaction. Selective analyte capture and redox reaction properties can be imbued on nanoparticles and polymers using the right materials. The voltametric or amperometry sensor signal outputs the difference in charge distribution at the electrode or the rate of charge transfer to the electrode at a constant applied voltage.[31] By coating the sensing electrode with a suitable biomaterial, these single electrodes may also be equipped as an immune sensor for catching target antigen, antibody, or protein molecules in a sample through complementary binding interactions. For amperometry sensors, the sensor data is typically read as changes in cell thermal conductivity or impedance. A three-electrode cell configuration is often used since the third additional electrode shields the standard electrode from the charged movement kinetics of electrolytic procedure using sensing. For symbol lab-on-chip bio-analytics for point-of-care health care diagnostics, this holds a lot of hope.[32]

*Nano-mechanical Sensors*

In these types of sensors any mechanical properties of the analyte binding like surface tension, mass, and/or elastic stiffness, are transformed into mechanical quantities like displacement, mass, velocity, or frequency shift. The above are whether immediately measurable or require additional transformation for calculation through any integrated second stage transduction procedure. The fusion of these sensors with micro fluidics and microelectronics on a chip, as well as the analysis of their outputs using computational intelligence approaches, opens up new avenues for precise real-time diagnostics and therapeutics. Disease biomarkers maybe active bio-agents in body fluid, reactive organic compounds in exhaled air, or a mixture of the two. The feasible sensitivity and detection limit, noisy perturbations, parasitic, operating constraints (whether in liquid or gaseous atmosphere) and cost all influence sensors election for a specific application. Because of the low effect of surroundings and parasitic on this class of sensors, they are best suited for sensing in the gaseous phase.[33]

*Applications of Nanosensors*

Nanosensors can be used in-

- Glucose monitoring
- Gas leak detection
- Asthma detection
- Detection of organo-phosphorus compounds
- pH sensing
- Protein and DNA detection
- Drug discovery
- Microorganism detection
- Detection of bacteria
- Detection of viruses
- Cancer diagnosis
- Cell monitoring[34]

*Nanotechnology in Electronics and in IT Sector*

Nanotechnology has assisted major advances in computers and electronics, culminating in faster, lighter, and more portable machines capable of handling and storing ever-increasing amounts of data. Among these ever-changing implementations are the following: Using magnetic random-access memory, computers will be able to boot almost instantly (MRAM). MRAM is powered by nanometer-scale magnetic tunnel junctions, which can save data quickly and efficiently during system, shut down or allow resume play features. Nanoparticle copper suspensions have been developed as a cleaner, less expensive, and more dependable alternative to lead-based solder and other dangerous materials currently used in the assembly process to fuse electronics. Nanotechnology enhances electronic product capabilities while reducing weight and power consumption. It also increases memory chip density while decreasing the number of transistors used in integratedcircuits.[35]

*Nanotechnology in Energy Applications*

Nanotechnology has a wide range of uses in conventional energy sources, as well as better renewable energy strategies to help satisfy the world's rising energy demands. Many scientists are working on how to develop healthy, dependable and renewable energy supplies, as well as how to reduce energy use and environmental toxicity.

Carbon nanotube scrubbers and film are being examined by analysts to remove carbon dioxide from power plant exhaust, via improved catalysis; nanotechnology is building up the exhibition of fuel creation from crude oil materials. It additionally considers slower fuel utilization in vehicles and power plants because of higher-proficiency ignition and diminished grinding. Nanotechnology is likewise being utilized in oil and gas investigation, for example, the utilization of nanotechnology-empowered gas lift valve sin seaward tasks or the location of minuscule down well oil pipeline cracks utilizing nanoparticles. Now-a-days nanotechnology is being utilized to make different kinds of batteries which have a ton of benefit like they are quicker to charge, all the more impressive, lighter in weight, have higher force limit and they convey an electrical charge for a more drawn out time frame. Nanotechnology will be incorporated into sun-based boards to all the more successfully change day light to power, offering less expensive sunlight-based force later on. Nanostructured sun-based cells can be more affordable to deliver and simpler to mount since they can be made in minimal rolls as opposed to singular boards utilizing print-like creation methods.[36] As indicated by new examinations, potential sun-based converters could likewise be paintable. To amplify the measure of energy that wind mills can deliver, an epoxy containing carbon nanotubes is being utilized to make windmill cutting edges that are bigger, heavier, and lighter-weight than most edges. Researchers are planning dainty film sun based electric boards that can be mounted on to PC cases, just as light weight piezoelectric nanowires woven into garments, to deliver valuable power in a hurry from light, rubbing, and additionally body warmth to control versatile electronic gadgets.[37]

*Nanotechnology in Environmental Rehabilitation*

Nanotechnology also helps in various ways to detect and cleanup the environmental contaminants. Nanotechnology helps to identify and treatment of impurities in water at very low cost. Now a day's nanoparticle is being designed to clean industrial water contaminants out of ground water through chemical reactions that make the pollutants harmless. This system would be less expensive than procedures that involve draining water out of the field fortreatment.[38]

Engineers also developed for energy-efficient desalination, a thin film membrane with nonporous. This molybdenum disulfide (MoS2) membrane purified two to five times the amount of water as standard filters. Researchers have developed a nano fabric paper towel which is made of tiny wires of potassium manganese oxide and it can absorb 20 times its weight in oil for clean up purpose. They have also used magnetic water-repellent nanoparticles in oils pills and magnets to physically filter the oil. Many nanotechnology-based filters are used in airplane cabins that allow mechanical filtration in which the fiber content produces nanoscale pores that capture particles larger than the pores size and the filters can also include charcoal layers that eliminates odors. Now nanotechnology enables sensors and solutions can identify and classify some chemical and biological agents in the air and soil with much greater accuracy than previously possible. Researchers are also looking at the particles like self-assembled mono layers on mesoporous supports (SAMMSTM), dendrimers, and carbon nanotubes to see if their unique chemical and physical properties can be used for hazardous site remediation. NASA has also created a sensor that can be used as a smart phone extension for fire fighters to detect air pollution around fires.[39]

*Nanotechnology in Transportation Advantages in Future*

Nanotechnology holds the promise of enabling the development of multifunctional materials that will aid in the construction and maintenance of lighter, cleaner, smarter and more effective vehicles, airplanes, spacecraft and ships. Furthermore, it has a variety of ways to develop transportation infrastructure:

Nano-engineered materials in automotive development include nanocomposites characteristics parts, rising power rechargeable battery systems, piezoelectric materials for temperature control, lower rolling-resistance tires, greater sensors and electronics, thin-film smart solar panels, and fuel additives and advanced catalytic converters for cleaner exhaust and longer range.[40]

Nano-engineering of aluminium, steel, asphalt, concrete, and other cementitious materials, as well as reused forms, has a lot of potential to improve the efficiency, stability, and durability of highway and transportation infrastructure components while reducing life cycle costs. Established infrastructure goods may be enhanced with innovative features such as self-repairing buildings or the ability to produce or transfer electricity. Nanoscale sensors, communications devices, and other nano electronics-enabled technology would also facilitate an advanced traffic system capable of connecting with vehicle-based networks to assist vehicles in maintaining lane alignment, preventing collisions, changing travel routes to reduce congestion, and up grading drivers' connect or to on board electronics. The advantages of using nanotechnology-enabled lightweight, strong materials for any transportation vehicle would be game changing. According to calculations, reduce the overall weight of a commercial jet aircraft by 20% would result in a 15% drop-in energy usage.[41]

According to a preliminary study conducted for NASA, the development and application of advanced nanomaterials with twice the robustness of normal composites could reduce a launch vehicle's gross weight by up to 63 percent. This would not only minimize the amount of resources required to send satellites in to space, but it will pave the way for single-stage to orbit launch vehicles, reducing launch costs ever further, increasing mission reliability, and allowing for the development of alternative propulsion concepts.[42,43]

## CONCLUSION

The start of the 21$^{st}$ century saw development of interest in the different fields of nano science and nanotechnology. This unique technology has been a promising approach for treating various major illness in the medical field. Now a day's biomimetic nanostructure like nanotubes, nanowires, nanoparticles are also designed for various applications in all sectors. In this review we explained all aspect of nanoparticle like their different types and applications in various sectors. Due to their small size, they are suitable molecule for various targeted drug delivery systems also.

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