Chapter 1

Overview of Applications of Nanotechnology

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Abstract

Nanotechnology has changed science and technology. Every discipline is now making use of nanomaterials (NMs) and nanotechnology. NMs have size below 100 nm. Variety of nanoparticles (NPs) with different size and functions are available in the nature. Nowadays, NPs are being synthesized under controlled conditions in laboratories and are called engineered nanoparticles. Nanotechnology is an interdisciplinary discipline and used in different industries such as agriculture, food, biotechnology, medicine, textile, electronics, drugs, etc. In Layman's language, nanotechnology is the science of organizing, manipulating, manufacturing, and engineering products and materials at the nanoscale. This article gives an overview of nanotechnology applications in different areas.

Keywords

Nanomaterials, Nanotechnology, Agriculture, Food, Textile, Construction

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1. Introductions
The term “nano” has been taken from a Greek word “nanos” meaning “dwarf”. Particles with size less than 100 nm are known as nanomaterials. Properties of materials at this scale are entirely different as compared to that of bulk materials. The study of science of such materials is termed as nanoscience. Nanotechnology is a branch of science and engineering, which concerns with designing and producing devices using nanomaterials. Nanotechnology is an “atomically precise technology” or “engineering with atomic precision” [1]. It relates to systems and materials, in which the components and structures possess novel physical, chemical, and biological properties, because of their nanoscale size. Nanotechnology is also defined as “the design, characterization, manufacture and shape and size-controlled application of matters in the nanoscale” [1]. Nanotechnology also plays an important role in producing innovative methods and products, which perform better in different sectors [2]. Nanotechnology also gives solution to many existing problems in different sectors [3]. Classification of nanotechnology can be made as given in Fig.1 [3].
Seeing the importance of nanomaterials and nanotechnology, this chapter gives an overview of applications of nanotechnology in different sectors.

2. **Applications of nanotechnology**

Nanotechnology is used for various applications in different sectors (Fig.2). Some of the applications of nanotechnology are discussed.

![Figure 2 Applications of Nanotechnology](image)
2.1 Agriculture

Many agrochemicals are used for protecting the plants from diseases and increasing production of crops, and improving the quality and yield. Agrochemicals also protect plants from damage and infections. However, only a limited portion of agrochemicals are taken up by plants and other portion becomes just a waste. Many a time, agrochemicals are dangerous. If nano-enabled agrochemicals are used, they offer controlled effectiveness and reduce the toxicity of agrochemicals. Nano-enabled agrochemicals increase uptake of agro-nutrients, improve stability and solubility and control disease of crops. Nanomaterials improve the growth of plants, quality of seeds and flowers, quality of soil, etc. The use of nanomaterials and their role for different functions in agriculture are shown in Fig.3[4,5].

Fig. 3. (a) Soil health and nanotechnology (b) Plant growth in two types of soil.

Nanotechnology has increased agricultural productivity and proficiency with less waste and lower cost. Nanotechnology protects plant from different diseases as shown in Fig.4 [4].
2.2 Food sector

It is believed that nanotechnology may have greater advantage in the food sector in the 21st century [6,7]. Nanotechnology is being used in different industries including agriculture to food processing, packaging, safety, and nutrient delivery (Fig.5) [8,9]. Use of nanotechnology in food systems has generated novel products with better food quality such as taste, texture, sensory properties, stability, etc.

Food processing and packaging are the most important aspects of nanotechnology. Food processing combines different steps such as procuring suitable raw materials, palatability enhancement, removal of toxin, enzymes deactivation, spoilage organisms, minimization of pathogens, fortification and enrichment with micronutrients packaging, storage, and transportation. Since number of steps are involved, there is huge possibility of intervention of nanotechnology-based applications [9]. Nanomaterials are generally used as fillers in food and additives in improving durability and mechanical strength of packaging materials. Use of different type of nanomaterials in food packaging serves the purpose [9]. Applications of nanotechnology in food sector is still in early stages of development and depends on cost-effectiveness [7].

Fig. 4. Nanotechnology in plant disease management [4]
2.3 Cosmetics

Technically, the word ‘cosmetics’ refers to the products that amplify the “appearance of the skin, intensify the cleansing, and promote skin beauty”. Although, the use of ‘cosmetics’ word backs to the time of Egyptians around 4000 BCE, but this term was first coined in 1961 by the “founding members of US Society of Cosmetic Chemist, Raymond Reed”. The technology of using nanoparticles started early 1960s when the use of liposome technology was applied to moisturizers and skin creams. On using liposomes, the optical properties of the products, solubility and absorption increased. Number of cosmetics such as lotion, sunscreens, haircare products, anti-aging creams, etc. have been using NPs since long and even today nanotechnology has a brighter future in cosmetic industry [10, 11].

Nanocosmetics are categorized depending upon the characteristics of the system, method of preparation, and involved components [10]. Figure 7 gives general classification about nanomaterial’s applications in cosmetics [12].

Nanotechnology based cosmetics have been developed but some regulations should also be developed for toxicity.
Fig. 6 Applications of Nanocosmetics

Fig. 7 Types of nanocosmetic formulations based on type of nanocarrier system or nanomaterial employed [10]
2.4 Construction

In construction industry ordinary Portland cement (OPC) concrete and geopolymer cement and concrete are the most important binding materials. NMs, when added in cement and concrete, modify different properties as shown in Fig.8 [13].

Effect of nano silica (NS), nano alumina, nano CaCO₃, nano TiO₂, nano Fe₂O₃, nano ZnO, nano clay, carbon nanotube, graphene, etc. on the properties of cement and concrete have been studied extensively and all of them improve the properties. For example NS accelerates the heat evolution and improves the mechanical properties (Fig.9,10) [14,15]. Improvements of properties are due to additional nucleation sites provided by NMs. For example the presence of NS in cement, due to pozzolanic activity, consumes Ca(OH)₂, converting it to calcium silicate hydrate (C-S-H), an additional binding material. As a result, the hydration is accelerated. The overall mechanism of hydration of cement in presence of NS is given in Fig.11 [16].
Fig. 10 Effect of NS on the mechanical properties of cement

Fig. 11 Mechanism of action of NS on early-age hydration [16]

When CNTs are mixed in concrete, it acts as a bridge during crack formation and protects the structure (Fig. 12) [15].
2.5 Geopolymer cement and concrete

Geopolymers are new type of binders and can replace OPC composites. The production of geopolymer composites has lower carbon footprint and utilises less energy as compared to OPC manufacture. In recent years, attempts have been made to add various kinds of nanoparticles (NPs) to geopolymer composites in order to improve the properties and performance [17]. Switching off one material from the macro scale to the nanoscale, resulted in significant changes in their chemical reactivity, mechanical properties, surface energy, shape, conductivity, and optical properties. Numerous studies have been done using geopolymer concrete and NMs to examine the new composite's performance in terms of chemical durability, mechanical and structural performance, fresh and microstructural properties, physico-mechanical properties, fire resistance and permeability. The filler effect, which occurs when nanoparticles are added to cement composites, is the result of free water becoming immobile because the NMs fill the pores and spaces among cement particles. Additionally, the NMs contribute to the pozzolanic reaction's formation of fresh calcium silicate hydrate (C–S–H) gel, which improves the interfacial transition zone between the aggregates and binder pastes and, as a result, improves the bond strength properties of the mixture. Geopolymer composites have low compressive strength when cured in an ambient condition. In order to overcome this problem, NMs are mixed within geopolymer concrete composites. This is achieved by atomically modifying the geopolymer concrete's microstructure, which significantly improves the material's fresh and hardened state features as well as its structural properties. Numerous NMs such as nano-silica slurry (NS), nano-zinc oxide (NZ), waste glass nano powder (WGNP), colloidal nano-silica (CNS), nano-calcium carbonate (NC), nano-clay platelets (NCP), multi-wall carbon nanotubes (MWCNTs), nano-titanium oxide (NT), carbon nanotubes (CNTs), etc. have been used to enhance different properties of geopolymer composites. However, NS is most used NM in geopolymer composites (Fig. 13) [17]. In the presence of different NMs,
polymerization, mechanical properties and resistance against aggressive atmosphere are increased and microstructures become dens.

Figure 13. Uses of NPs in geopolymer composites [17]

2.6 Textiles

In recent years, smart fabrics are being designed using nanotechnology. NMs when used in textile industry, generate fabrics with ultraviolet resistant, antimicrobial, optical, electrically conductive, hydrophobic, and flame-retardant properties. Various functions such as sensing, drug release, energy harvesting and storage, and optics are exhibited when NMs based smart devices are integrated with the textiles. This type of technology has now applications in the fashion industry and are being used in healthcare and on-body energy harnessing applications and defence. The incorporation of nanotechnology in textiles show innovative applications in different areas (Fig. 14)[18].
2.7 Sports

Different NMs with different benefits are being used in sports industry (Table 1)[19]

Table 1 NMs in different sports with their benefits [19]

<table>
<thead>
<tr>
<th>Sports</th>
<th>Nanomaterials</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennis/Badminton</td>
<td>Carbon nanotubes</td>
<td>Increase consistency, stiffness, impact, durability, resiliency, repulsion power and vibration control of rackets</td>
</tr>
<tr>
<td>Golf</td>
<td></td>
<td>Lower torque/spin of clubs and reduce weight</td>
</tr>
<tr>
<td>Kayaking</td>
<td></td>
<td>Easy padding in kayaks and enhance abrasion/crack resistance</td>
</tr>
<tr>
<td>Archery</td>
<td></td>
<td>Better vibration control in arrows</td>
</tr>
<tr>
<td>Tennis/Badminton</td>
<td>Silica nanoparticle</td>
<td>Increase power, durability and stability of rackets</td>
</tr>
<tr>
<td>Skiing</td>
<td></td>
<td>Facilitate transition in skis and decrease torsion index</td>
</tr>
<tr>
<td>Fly fishing</td>
<td></td>
<td>Enhance hoop and flex strength of rods</td>
</tr>
<tr>
<td>Tennis/Badminton</td>
<td>Fullerenes</td>
<td>Reduce weight and twisting of racket frames</td>
</tr>
<tr>
<td>Golf</td>
<td></td>
<td>Facilitate flexible club whipping</td>
</tr>
<tr>
<td>Bowling</td>
<td></td>
<td>Reduce chipping and cracking of balls</td>
</tr>
<tr>
<td>Carbon nanofibers</td>
<td>Cycling</td>
<td>Increase stiffness of bicycles and reduce weight</td>
</tr>
<tr>
<td>Watercraft</td>
<td>Nano clay</td>
<td>Enhance speed of water-boats and reduce weight</td>
</tr>
<tr>
<td>Tennis/Golf</td>
<td></td>
<td>Increase bounce of balls and residency</td>
</tr>
<tr>
<td>Tennis/Badminton</td>
<td>Nano-titanium</td>
<td>Transmit more power to ball /shuttlecock, increase strength and durability of rackets, resist deformation of rackets</td>
</tr>
<tr>
<td>Golf</td>
<td>Nano nickel</td>
<td>Increase stability of clubs and moment of inertia</td>
</tr>
</tbody>
</table>
2.8 Energy storage

Metal organic framework based templates are receiving more attention for the porous metal oxides and nanocomposites preparation because metal oxides have some limitations, such as decreased capacitive performance because of continuous faradic reactions from electrolyte to electrode. They can increase their capacity for electrochemical storage by preparing Metal organic framework based oxides in conjunction with carbon-based materials including graphene, carbon nanotubes and reduced graphene oxide. Due to their high specific surface area, high surface to volume ratio, and high ion mobility during intercalation, nanomaterial-based devices are advantageous in the conversion and storage of energy.

As nitride-based nanomaterials bear good specific capacitance value, they are gaining greater attention in energy devices together with other graphene based nanomaterials, metals or metal oxides, and graphene quantum dots-based nanomaterials. NiO electrodes with particle sizes of 70 nm can show enhanced capacitance value to 132 F/g at 10mV/s of scan rate. Cobalt (Co), with its high theoretical capacitance value of 3560 F/g, has received a lot of attention for its usage as an electrode in super capacitors and for its strong electrochemical performance. Polymers like polyaniline vary their behaviour during the charging and discharging process as a result of ion doping and dedoping. To solve this problem, a coating of carbon or metal oxide can be deposited on a polyaniline film, improving its stability and capacitance behaviour.

Nanomaterials based on carbon are more appropriate as electrode materials as they offer high electrical conductivity, excellent chemical stability, high specific surface area and bear strong electrochemical property. While having less specific surface area than activated carbon, multiwall carbon nanotubes’ mesopores nevertheless allow ions of electrolyte to easily pass across the electrode electrolyte interface. It has been shown that multiwall carbon nanotubes can be carbonised to increase their specific surface area, which in turn improves capacitance with a decent rate of charge and discharge as well as good retention after several cycles. An increase in capacitance value was seen when polymer, metal oxide, or metal nanoparticles were combined with graphene or graphene oxide.

In comparison to individual carbon nanotubes, hybrid structures made of carbon nanotubes and gold nanowire has been shown to have a greater power density. Hybrid nanomaterial-based electrodes were used in lithium ion batteries in addition to supercapacitors [20]. The potential hydrogen storage materials include a variety of nanomaterials like carbon-based materials, metal organic framework-based nanomaterials, boron nitride nanotubes, nano-Mg-based hydrides, TiS2/MoS2 nanocomposite, and polymer-based monohybrid.

Hydrogen is an energy carrier which can store a huge amount of energy. Fuel cells using hydrogen may produce power, energy, and heat. The nanomaterial modifies the diffusion length and rate, which has an impact on the thermodynamics and kinetics of hydrogen sorption and absorption. It has been found that alloys based on magnesium make excellent hydrogen storage precursors because of their superior mechanical properties. Mg2NiH4
has been used to encapsulate MgO nanoparticles, giving them exceptional hydrogen sorption capabilities. They are also resistant to further oxidation by lingering oxygen.

2.9 Defense

Modern armed forces are utilising new technologies in an effort to outperform rivals on a qualitative level. By incorporating many cutting-edge technologies, it is possible to shift from "mass and mobility" to unconventional methods of boosting comparative combat capabilities. We are forced to adopt revolutionary combat strategies by technologies like stealth technology, remote sensing, night vision, sensors, precision-guided missiles, image processing, and, most essential, computer networks and digital communications. Aeronautics, nautical, shielding, electronics, automotive, electromagnetic interference (EMI), energy storage and constructions are among the industries involved in the defence industry. Nanotechnology has the potential to have a significant impact on the defence industry in a number of areas, specifically increasing weapon viability, surveillance, securing communication and protecting targets like strategic assets, soldiers and equipment, and creating lightweight aerial naval, and ground platforms.

The development of defensive technologies from the Stone Age to the present can be used to illustrate the significance of material science and technology. In addition to functionality, the choice of material for military applications must be durable in adverse conditions, such as temperature changes, sandstorms, rain, corrosion due to humid and salty environments, and structural stability. The material should also be light in weight and affordable. Submarines, aircraft, naval ships, combat vehicles, military personnel, sailors, mariners, and pilots also need modern material components that enable significant changes in manoeuvrability, safety from chemical, nuclear, and biological weapons, protective cover from explosives through signature step-down and heavy military force, and involvement with highly focused firepower and robust logistics. The military and defence industries have witnessed the spectacular expansion of nanotechnology over the years as it greatly raises the calibre of military equipment and improves worker comfort and safety. The most practical way to develop advanced defence technologies is to use carbon-based composites that incorporate different carbonaceous materials like black carbon, coke, activated carbon, char, carbon fibre along with other carbon based nanomaterials like graphite, carbon nanofibres, carbon nanotubes and graphene. PNCs are used to create military infrastructure and equipment that is lightweight, relatively tiny, less expensive, more accurate, creative, and robust.
2.9.1 Smart military uniforms

For the protection of soldiers, PNCs are used to create footwear, helmets, gloves, intelligent materials, and bulletproof vests. When supplemented with nanomaterials like carbon nanotube (CNT), Kevlar, graphene etc., polymer matrix permits the fabrication of exceptionally robust, smart, and lightest high-tech fighting suits. When silica nanopowder-containing shear thickening fluids are added, body armour becomes more compact, durable, and extremely flexible. The wearer of these body armour vests can move more freely, protect themselves from poisonous substances, endure the impact of high-speed gunshots, and avoid getting hurt by blunt objects like bars, stones, and sticks.

Lightweight military platforms and armors

Steel-made heavyweight military platforms in concern to their speed, high fuel consumption, thick armours to defend against explosive and ballistic attacks and mobility in the fighting effectiveness represent a big issue. Composites made of hybrid nanoparticles and fibres exhibit good mechanical and fatigue properties as well as superior scratch and
impact energy attenuation. Composites can transmit electricity when conductive nanoparticles like graphite, carbon black (CB), carbon nanotubes, graphene, or metals are added.

2.9.2 Acoustics absorption

Designing military and aerospace vehicles takes into account acoustics damping in order to achieve comfort and structural stability. Nowadays, nanofillers like silica are added to PU foams, which are already widely utilised as sound-absorbing materials, to create polymer matrix composites for ballistic protection. The tensile, flexural, and shear strengths of glass fibre with 6, 7, and 8 wt% SiO₂ were improved, along with the component adhesion and surface damage area. The tensile impact and flexural strength of aramid fibre are improved by adding 0.15, 0.3, and 0.5 weight percent of multiwall carbon nanotube. Barium sulfate, calcium carbonate, or fibreglass are added to advanced polymer nanocomposites to increase the level of acoustic absorbency. Sung et al. looked into the PU/nanosilica foams' ability to absorb sound and discovered a considerable reduction in acoustic wave. Baferani et al. created PU/CNT foam nanocomposites that can effectively absorb sound waves with a wide frequency range (400–3600 Hz). [21].

2.9.3 Camouflage printed fabric

With advancements in long-range munitions and picture identification technology and equipment, soldiers and military infrastructure can now be completely invisible, giving commanders incredible control over the combat. The electromagnetic spectrum's many wavelength ranges must be covered by the current military materials, particularly the thermal or far-infrared region (35 and 814 m), the near-infrared region (NIR) (750-1200 nm), and the visible region (400-800 nm) [23]. Karpagam et al. used thermochromic colorants, which showed reversible colour changes in response to electrical power and temperature change, to create a camouflage printed fabric with a jungle theme. According to Alehi et al., adding activated carbon nanoparticles and carbon black to viscose/polyester fabrics significantly reduced the textiles' IR reflectivity for both the green and black textures.

In order to tailor the fabrics' NIR concealment and visibility for a desert environment, Mehrizi et al. created nylon/cotton textiles with varying concentrations of CB nanoparticles and colors. Additionally, Mehrizi et al. looked at how adding multiwalled CNT particles (MWCNTs) to a fabric made of 50% nylon and 50% cotton might lower the NIR reflectance criteria for printed textiles in light brown, olive green, and dark brown [22]. Similar to this, Siadat and Mokhtari demonstrated the impact of coated cotton/nylon textiles with cerium dioxide (CeO₂) and zirconium dioxide (ZrO₂) nanoparticles and cerium dioxide (CeO₂) nanoparticles in desert and forest patterns, as well as coated nylon/cotton textiles with ZrO₂ and magnesium oxide (MgO) in desert and jungle patterns [23].
2.9.4 Corrosion protection

Metal corrosion has now become a significant problem that has cost the military sector a lot of money and poses a big risk to the public. Since impairment or decline in quality cannot be entirely stopped, it is restricted and hampered in order to minimise financial losses. Because of the huge surface area to volume ratio of the nanoparticle, water molecules cannot diffuse to the twisted channel, providing better surface protection than bulk counterparts. It seems like an intriguing idea to create a PNC coating to protect metal surfaces against corrosion. There have been many nanoparticle-based coatings found, including TiO₂, Al₂O₃, SiO₂, ZnO, and Fe₂O₃.

2.9.5 Wound care for soldiers

The contamination of war wounds is frequently severe, and in the event of bomb assaults, contamination with foreign human material can make things even more difficult. Combat wounds are challenging to dress because to their size and exudate. There are antimicrobial components in many dressings. While some dressings collect wound exudate and employ the antibiotic there to limit microbial development, other dressings discharge the antimicrobial straight into the wound. Dressings with nanomaterial coatings provide regulated protein and medication release over a predetermined period of time. Additionally, the distinct feature of nanoparticle aggregate wound dressing makes it feasible for the exciting prospects of controlling the quantities of growth factors and other active components to hasten wound healing [24].

2.9.6 Sensory applications

Innovative nanomaterial-based sensor technologies are in demand to intensify military intelligence aggregation by military personnel on the battlefield. Nanosensors, for instance, can recognise hazardous substances. Chemical sensors built on graphene (G) and CNT-infused polymer composites are being researched for a number of applications, such as gas sensing, biosensing, and chemical sensing based on optical and electrochemical recognition methods. Chemical sensors based on individual single-walled nanotubes were developed by Kong et al. They discovered that the electrical resistance of semiconducting single walled nanotubes significantly changed when it was exposed to gas molecules like NH₃ and NO₂ [25].

Electronic pollution in the environment

Electromagnetic (EM) radiations or waves, electronic noise, radiofrequency interference (RFI) and electromagnetic interference (EMI) are a few examples of particular types of electronic pollution in the environment that have arisen due to the rapid development of technology and the substantial rise in the use of electronic and electrical devices. Polyacrylonitrile (PAN) solution was able to permeate CNT fibres made via floating catalytic chemical vapour deposition, according to Li et al. Such composite fibres demonstrated an almost 300% increment in breaking load, a 350% improvement in strength, and a roughly 700% rise in modulus when compared to pure CNT fibres. The
materials' electrical characteristics have been improved by the addition of CNT as carbon nanoparticles.

2.10 Biotechnology

The expensive old manufacturing process will be replaced by less expensive, environmentally friendly goods that have flexible, precise, and long-lasting architecture. Using this technology, it is possible to create strong yet lightweight materials for things like sensors, microrobots, surgical instruments, electronic devices, and circuits. Another example in nanobiotechnological research is nanospheres coated with luminous polymers. Researchers are trying to develop polymer patterns that can dim fluorescent light when they interact with a certain class of molecules. DNA nanotechnology is a significant instance of bionanotechnology. Utilizing the intrinsic properties of nucleic acids (such as DNA) to create synthetic membranes and self-assembling proteins is the promising field of this modern technology.

The uses of the molecules made from DNA are being investigated due of their complexity. This is achievable if these structures are changed into colloidal superstructures when DNA is utilised to govern delivery, removing inorganic nanoparticles. A full superstructure-designed molecule’s building blocks are nanoparticles that have the surface chemistry, size, and assembly architecture of the superstructure. The entire structure can interact with cell organelles in accordance with their inherent design and is later catabolized into components for exocytosis. This shortens the time that nanoparticles spend inside cells, which improves the accumulation of a tumour in vivo as well as the removal of the entire body. This shortens the time that nanoparticles spend inside cells, which improves the accumulation of a tumour in vivo as well as the removal of the entire body. The superstructures could be used for imaging or as a carrier for therapeutic agents to prevent the deterioration of the enzymes. The superstructures could be used for imaging or as a carrier for therapeutic agents to prevent the deterioration of the enzymes. There should be some methods for creating nanostructures that could result in both multifunctional nanomedicines and compounds that are capable of biodegradation.

2.11 Biomedical

Innovative nanoparticles for medical applications were created using a variety of metal salts, including titanium, zinc, silver and other inorganic salts. Infection in the wound region is a common issue, regardless of the type of wound. The primary cause of wound complications, microorganisms, are progressively developing resistance to the widely used antibacterial medications. To keep the pathogenic bacteria under control, it is necessary to produce nanoparticles with effective antimicrobial potential. In general, there are four steps in which a wound heals: haemostasis, inflammation, proliferation, and maturation. In addition to being utilised topically as an ointment, these nanoparticles can also be incorporated into electrospun nanofibers, hydrogels or sponges.

According to research, inorganic nanoparticles like (CoO, CuO, AgO, TiO2, ZnO, Ag) that are made using environmentally friendly procedures can treat skin sores. Due to their
adaptable activity against a variety of pathogenic bacteria and their low or nonexistent toxicity towards mammalian cells, silver nanoparticles (AgNPs) have become one of them and have significantly increased in popularity in the biomedical field. Additionally, materials based on nanosilver are useful therapeutic and preventive agents for preventing microbial colonisation of wounds. Consequently, nanosilver has been utilised in a variety of applications, including contact lens coatings, antimicrobial gel formulations, orthopaedic applications, instruments, medical catheters, dressings for wound healing, implants, and 3D and 4D printing [26].

Another relevant inorganic substance is zinc oxide (ZnO), which has potential biocidal activity as a result of its photocatalytic properties. Nano ZnO and biomaterials derived from it have surfaces that produce free radicals when they come into contact with light. It has been shown that the active radicals produced in this way can suppress microorganisms. Additionally, they are biocompatible, non-toxic, affordable, transparent, and eco-friendly materials, making them perfect for cutting-edge medical applications. They are efficient adsorbents due to their large surface area to volume ratio and strong adsorption characteristics. Nanomaterials are used to regulate bone homeostasis and modulate cellular activity as therapeutic carriers or multifunctional platforms. In order to detect bone microfractures, malignancies, and metastases at early stage, biological imaging is made possible by rare earth, gold, and metal oxide nanomaterials and quantum dots.

Additionally, nanomaterials have amazing promise as biosensors for indicators of arthritis in peripheral blood and synovial fluids. Bone tissue regeneration is significantly impacted by carbon-based nanomaterials with effective cell proliferation and osteogenic differentiation. New therapeutic options for spinal cord injuries have been made possible by nanomaterials. The microenvironment of traumatic cord injury can be improved with the use of performance-based nanoparticles made from a variety of materials, and in some situations, this can encourage neuron regeneration. Functional nanoparticles' nanoscale size enables medications to pass across the blood-spinal cord barrier (BSCB) and collect in the location of the injury. Within 96 hours of an injury, 200 nm nanoparticles may extravasate into the cord parenchyma at the lesion site. Linking targeted groups can also be used to achieve active targeted delivery.

2.12 Optical devices and electronics

Carbon atom sheets that form hexagonal patterns like benzene rings in each layer of the layered substance known as graphite. Graphene is the name for a monolayer of graphite [27]. It is a remarkable drug with a long list of accolades. It is both the thinnest substance in the universe and the toughest material ever researched. Future models could replace silicon with long, thin graphene strips called graphene nanoribbons (GNRs), which can widen the bandgap in the semimetal. In the realm of electronics, particularly in the creation of graphene and related nanomaterials and batteries are widely used. Reduced graphene and nickel sulphide were combined to create a nanocomposite that was employed as anode components in the manufacture of sodium-ion and potassium ion batteries. Additionally, solar cells employ graphene and related nanoparticles as a transparent conductive cathode.
electrode. The reduced graphene oxide can act as both a working electrode and a cathode electrode for the electrochemical deposition of material. Graphene nanoparticles are employed to construct solar cells because the cathode electrodes they use are so important for solar cell applications.

2.13 Water remediation

Nanomaterials (NMs)-based technologies have produced promising results for accessing cleansed water from various resources, and nanotechnology has emerged as a unique possibility for improving current breakthroughs in wastewater treatment. The majority of organic pollutants are chemically stable, making it difficult to clean water using traditional physiochemical approaches without suffering from one or more drawbacks. According to recent reports, nanotechnology may be able to effectively breakdown a variety of organic contaminants, including colours, into harmless byproducts. This process is known as photocatalysis. AgNPs were immobilised onto graphene oxide using green tea extract during an in-situ fast reduction process. The created composite showed 633 mg g⁻¹ of methylene blue degradation.

The photocatalytic activity of green AgNPs against methylene blue, orange red, and 4-nitrophenol was reported. Ruellia tuberosa leaf extract was used as a green reducing and stabilising agent to create iron NPs, which were successful in the photocatalytic degradation of reactive black 5. The removal of dyes and heavy metal ions from water has also been reported to be accomplished by a range of nanomaterials, including Au, SiO₂, FeS, Fe₃O₄ nanoparticles, ZnO, CuO, FeO, TiO₂, SnO₂, Pd nanoparticles, Ag/Pt NPs, Ag-TiO₂ NCs, and ZnO/SnO₂ nanocomposite [28-29].

Bacterial nanotechnology (Bac-Nano), which is helping to advance wastewater treatment technologies, is focused on the intriguing interplay between bacterial cells and nanomaterials. Analyses of the economic viability, environmental risk, performance and possibility for commercial-scale evolution of Bac-Nano for wastewater treatment are conducted. Reactive oxygen species (ROS) production and the impact of metal cations were indicated as the main chemical and physical interactions in the majority of the documented processes. The cell membrane, membrane-linked enzymes, proteins, and nucleic acids are all targets of these mechanisms, making it difficult for bacterial cells to develop defences against all of these biological components. Blocking nutrition intake is another way to induce inhibition. For instance, it has been demonstrated that gallium ions (Ga³⁺) can inhibit bacterial growth via a "trojan horse" mechanism in which the bacterial cells take up the Ga³⁺ along with the Fe³⁺ ions due to their similar chemical properties, and metabolic inhibition results as a result of the inability of the bacterial cells to reduce the Ga³⁺.
Some antibacterial NMs are primarily activated by light and magnetism, which results in a variety of modes of action. Specific light wavelengths activate photocatalytic and photothermal NMs, which restrict bacterial growth by producing ROS and concentrated temperature spikes, respectively. The use of an external magnetic field to increase the antibacterial activity of Fe₃O₄-ZnO nanocomposites against E. coli and S. aureus. After 15-20 minutes of modification with C₆₀, MWCNT, and rGO, TiO₂ completely destroyed the bacterium.

2.14 Miscellaneous

2.14.1 Biosensors

With a linear range of 28 mM x mm⁻², Biocompatible-Graphene Oxide demonstrated good sensitivity (8.045 mA x cm⁻² x M⁻¹) as a reliable glucose biosensor. The biocompatibility of as-synthesised GO-nanosheets with human cells was effectively proven in this work for the very first time. The electrode was altered with graphene oxide, and glucose oxidase was immobilised there. This increases the reproducibility and storage capacity of the biosensor. By creating a nanocomposite of Au nanocluster and graphene oxide through electrostatic interaction and sonication, Ge et al. showed an electrochemical biosensor that has the tendency to detect L-Cysteine. An electrochemical biosensor with 0.02 mol/L of LOD can detect L-Cysteine using graphene oxide and an Au nanocluster. Urea with a LOD of 5 g/mL may be detected using a nanocomposite of graphitized nanodiamond and graphene nanoplatelets. Colorimetric biosensors found effective in heavy metal detection due to its high sensitivity, simplicity, specialised detection capabilities without the need for costly equipment and low cost. Looking into the high extinction coefficients and size-dependent optical characteristics of AuNPs, they are frequently used as a colorimetric reporter. Recently developed artificial biomimetic
enzymes known as nanozymes are a prospective candidate for use in the production of colorimetric sensors for heavy metal ions detection [31].

### 2.14.2 Lubricants

Everyday, lubricants are one of the most practical materials since they reduce equipment wear and friction. As lubricant additives, nanocomposites (Mn$_3$O$_4$/G) were utilised. Utilizing the solvothermal method, Sun et al. also created the nanocomposites (graphene oxide/Fe$_3$O$_4$). As lubricant additives, this nanocomposite is employed. Due to their high dispersion stability in water, the nanocomposites in this study had excellent tribological properties. They also have enhanced friction coefficient and reduced wear scar diameter by 33.6% and 32.3% in comparison to base oil alone. Recently, employing electrophoretic deposition on a silicon substrate, Mia et al. created a nanocomposites film (Graphene oxide/Ti$_3$C$_2$) for the first time. This study's tribological test showed that the synthesised nanocomposites film was effectively deposited under 35 V and that wear resistance and the effect of graphene oxide and Ti$_3$C$_2$ synergy on friction rate and wear resistance were also demonstrated.

### 2.14.3 Humidity-sensor

Due to its transparency, flexibility, and extreme water permeability, GO was used in humidity sensors. Its attributes combined with water enable efficient humidity sensing with a response time of up to 30 ms. Numerous applications, such as touchless user interfaces that can be exhibited by whistling-based recognition detection, are made possible by such humidity-based sensors.

### 2.14.4 Gas transport

Metal organic frameworks (MOFs), covalent organic frameworks (COFs), and other 2D nanomaterials are emerging nanomaterials for gas separation and pervaporation that have recently gained a lot of attention. Metal organic frameworks (MOFs), a new class of inorganic materials, are crystalline porous substances produced by the self-assembly of metals and organic ligands. Due to its thinness of just one carbon atom, graphene is a potential material for membranes. Since it creates separation membranes by lowering transparent resistance and raising flow, it is ideal for membrane applications. A study claims that GO sheets are employed and created to achieve the requisite gas separation. The gas transportation is heavily dependent on the degree of interlocking in the stacking structure of graphene oxide and selective gas diffusion is achieved in this by manipulating the channels and pores of gas flow with the aid of various stacking methods. The desired gas was successfully separated since it has unique qualities that make it appropriate for membrane use. According to the proposed study, a membrane made of few-layered graphene oxide and graphene successfully transported a certain gas.
Conclusions

In this chapter, it is highlighted that nanotechnology plays an important role in producing innovative methods and products, which perform better in different sectors. Nanotechnology also gives solution to many existing problems. Classification of nanotechnology has been made. Applications of nanotechnology in different sectors such as Agriculture and food, Energy storage, Defence, Biotechnology, Biomedical, Optical devices and Electronics, Construction, Sports, Textiles, Cosmetics, Paints, Water remediation, etc. have been discussed. In the coming days, nanotechnology may be used in almost all disciplines.

References

[1] Mahmoud Nasrollahzadeh, S. Mohammad Sajadi, Mohaddeseh Sajjadi and Zahra Issaabadi Chapter 1 An Introduction to Nanotechnology (Chapter 1), Interface Science and Technology, Vol. 28. 2019 Elsevier Ltd. https://doi.org/10.1016/B978-0-12-813586-0.00001-8


