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A Comprehensive Review of Recent Trends in Nano-Technology

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Abstract

Nanotechnology is related to material processing on atomic or molecular scale. The microscopic level generally referred is 1-100 nm in size. Nano technology plays a key role in many applications as this field has reached to almost every sector. It is need of the time to apply nano-technology to solve many raised problems, and to encourage the replacement of existing products with new Nano-products that are more environmentally friendly throughout their life cycles. We opt to review the recent trends in nano-technology like Scanning Tunneling Microscope, Carbon Nanotubes, Fullerenes (Bucky balls), Solar Cells, Nano-fibres, Ultra-light materials, Corrosion and Corrosion prevention etc. This will help the researchers to acquire recent developments in this domain and will encourage them to be familiar with the same.

Key words: Nano-technology; Scanning Tunneling Microscope; Carbon Nanotubes; Solar Cells; NanoFibres

Introductuin

Nano-technology is a branch which deals with the production, characterization, fabrication, management and utilization of nano structured materials for various applications. Nano-structure materials have an intermediate size of 1-100 nm and can be transformed further. It deals with the creation of useful materials, devices and systems using the particles of nanometer length scale and exploitation of novel properties (physical, chemical, biological) at that length scale. Nano-technology means any technology on a nano scale that has applications in the real world. This emerging field is becoming important in enabling breakthrough of new and effective tools in the medical sciences (e.g. nano-medicine), as it offers the possibility of examining biological processes in ways that were not previously available. It is not limited to a specific sector; rather, it is an enabling collection of technologies, which cross all sectors of activity and scientific disciplines. Nano-technology uses the philosophy and techniques of the nanoscale to understand and transform biosystems, which use biological concepts and materials to build new nanoscale devices and systems. Nano-structures have different types of chemical, physical and biological characteristics. Such characteristics make it possible to use the nanostructures for an exceptional number of applications in various sectors including electronics, agriculture, and health care. One of the key benefits of nano-technology is to close the gap between the worlds of macroscopy and microscopy; where nanoparticles are the perfect medium to communicate with biological systems. Nanoparticles have different properties that differentiate them from bulk materials that include large active surfaces, easily controllable surface chemistry that allows binding to small molecular drugs, imaging labels, and ligands such as antibodies, peptides, nucleic acids. Also, their small size allows for exclusive intracellular and extracellular interactions, such as extravasation via endothelial cells and increased permeability and retention in tumor tissues.

Nanomaterials are synthesized in different shapes and sizes, these include 1D, 2D, and 3D structures (inorganic, organic, and dendrimers). The particles can be molded in the form of particles, sheets, rods, and wires based on their dimensionally confined electronic properties. The surface sites and band structures of such designed nanostructures have been prepared via different techniques and processed for multiple uses in various fields of medicine. Two-dimensional carbon materials, such as graphene, or CNTs, quantum dots (TiO2, ZnO, CuO, etc.) and semiconductors are also used to enhance the quality and safety of medicinal therapies. There are several

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technologies already available for improving paramedical or allied health services. This article particularly highlights the fundamental significance of Nano ranged substances for health and medicine-based challenges. This includes diagnosis, drug delivery, gene therapy, and Nano medicine. Nanomaterials have found their way in almost every area of science and daily life. Nano-technology tends to take advantage of recent phenomena when the sizes of the materials are in the range of nanoscale (1-100 nm). To obtain different features from the bulk, electron fluctuations are controlled, or electronic characteristics are manipulated. The macro to nano-sized particles have been explored in various physicochemical processes due to their surface and band gap alterations. Some techniques, such as the luminescence optical emission of specific nanomaterials, are being studied using photoluminescence, which is commonly used in biomedical active Nano composites. Although drug binding and releasing actions are studied by a UV-vis spectrophotometer for several nanomaterials, the inorganic material contained a metallic, a metal-oxide nanostructures absorb and emit a definite frequency of light.

Emerging Trends in Nano-technology

The demand for nanomaterials has increased significantly in recent years with fast growing market of nanotechnology. It is an excellent example of an emerging technology, offering engineered nanomaterials with the great potential for producing products with substantially improved performances. Some of the widely used nanotechnologies are addressed below.

Scanning Tunnelling Microscope

A scanning tunneling microscope (STM) is used to see individual atoms on the surface of a sample in 3-D. This technique is used to study things such as conductive materials and even DNA molecules. It is an instrument for imaging surfaces at atomic level. Gerd Binning & Heinrich Rohrer invented the STM in1981and won the Nobel Prize in physics in1986.

STM is based on the principle of quantum mechanical electron tunneling i.e., if two flat surfaces of metals are separated by an insulator or vacuum, the electrons in the material cannot transfer from one surface to another through the insulator due to energy barrier. But if a voltage is applied between the two surfaces, then a driving force acts for electrons to move across the barrier by tunneling and a small current flows when the distance between two surfaces is very small.

STM utilizes a tip made from tungsten metal or platinum-iridium alloy where at the end of tip there is only one atom of material. The scanner tip is attached to a piezoelectric tube scanner. By adjusting the voltage on the piezoelectric element, the distance between the tip and the surface can be regulated. Piezoelectric crystals expand and contract depending on the voltage applied to them. Scanning tip is the most important aspect of the STM as tunneling current is carried by that particular atom. STM deals with extremely fine position measurements so the isolation of any vibrations is very important and is achieved by means of vibration isolation system.

STM are versatile. They can be used in ultra-high vaccum, air, water and other liquid and gases. STM gives three dimensional profiles on surface, which allows researchers to examine a multitude of characteristics, including roughness, surface defects and molecule size. STM needs very clean surface, excellent vibration control while operation. Also it requires single atom tip.

Carbonnanotubes

Carbon is the chemical element with atomic number 6 and has six electrons which occupy $1s^2$, $2s^2$ and $2p^2$ atomic orbital. It can hybridize in sp, sp^2 or sp^3 forms. Discoveries of very constant nanometer sizes p^2 carbon bonded materials such as graphene, fullerenes, and carbon nanotubes have encouraged to make inquiries in this field. Most of the physical properties of carbon nanotubes derive from graphene. In graphene, carbon atoms are densely organized in a regular sp2-bonded atomic-scale honeycomb (hexagonal) pattern, and this pattern is a basic structure for other sp^2 carbon bonded materials (allotropes) such as fullerenes and carbon nanotubes. Carbon nanotube is theoretically distinct as a cylinder fabricated of rolled up grapheme sheet. It can divide into a single well or multiple wells. Nanotubes with single well are described as single-wall carbon nanotubes (SWCNTs) and were first reported in 1993, while the ones with more than one well are multiwall carbon nanotubes (MWCNTs) and were first discovered in by (Iijima1991) (Figure1).

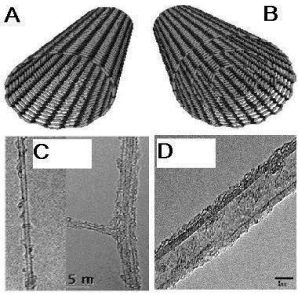

Figure1: Schematic structure and TEM images of SWCNT and MWCNT. (A)Schematic structure of SWCNT and (B) MWCNT. The transmission electron microscope (TEM) images of a (C) SWCNT and (D) MWCNT

CNT is one of the most important nanomaterial at present time. Before 1991, only two allotropes of carbon were known namely diamond and graphite. But in 1991, Japanese physicst Sumio Lizima discovered another allotrope of carbon called "Carbon Nanotube (CNT)". When you roll up 2-D graphite sheet (Graphene) into a cylindrical tube, we get CNT. The diameter of CNT is about 1-3 nm and can have length upto few micrometer. CNT exhibit extraordinary mechanical properties. It can also describe as a sheet of grapheme rolled into a cylinder. CNTs are closely related to spherical fullerenes and are type of curved carbon structure.

Single-walled carbon nanotubes consist of a seamless one atom-thick graphitic layer, in which carbon atoms are connected through strong covalent bonds. Double-walled carbon nanotubes consist of two single-walled carbon nanotubes. One carbon nanotube is nested in another nanotube to construct a double walled carbon nanotube. In multi-walled carbon nanotubes, multiple sheets of single-layer carbon atom are rolled up. In other words, many single-walled carbon nanotubes are nested within each other. From different types of nanotubes, it can be concluded that the nanotubes may consist of one, tens, or hundreds of concentric carbon shells and these shells are separated from each other with a distance of 0.34 nm. Carbon nanotubes can be synthesized via chemical vapor deposition, laser ablation, arc-discharge and gas-phase catalytic growth.

Single-walled carbon nanotubes can display metallic or semiconducting behavior. Whether carbon nanotubes show metallic or semiconducting behavior depends on the diameter and helicity of the graphitic rings. The rolling of graphene sheets leads to three different types of CNTs: chiral, armchair, and zigzag.

Carbon nanotubes have become an important industrial material and hundreds of tonnes are produced for applications. Their high tensile strength and high aspect ratio have made carbon nanotubes an ideal reinforcing agent. Carbon nanotubes are ligh tweight in nature and are used to produce light weight and biodegradable Nano composite foams. The structural parameters of carbon nanotubes define whether they will be semiconducting or metallic in nature. This property of carbon nanotubes is considered to be effective for their use as a central element in the design of electronic devices such as rectifying diodes, single-electron transistors, and field-effect transistors. The chemical stability, nano-size, high electrical conductivity, and amazing structural perfection of carbon nanotubes make them suitable for electron field emitter applications. The unique set of mechanical and electrochemical properties make CNTs a valuable smart candidate for use in lithium-ion batteries.

Fullerene

In1985,three scientists of Rice university US Anamely Harold Korto, Richard Smalley, Robert Curl discovered an ewallotrope of carbon in which number of carbon atoms is fixed unlike diamond and graphite. This new allotrope of carbon is called "Fullerene" with elemental formula Cn wheren is the number of carbon atoms.

In 1986, these 3 scientists got Nobel Prize in chemistry for their discovery of new allotrope of carbon. In fullerene, carbon atoms are connected to each other by single or double bonds so as to form a closed mesh. The most commonly occurring fullerene is C-60 which is called Buckminster fullerene after the name of famous american architect buckminister fuller who designed Geodesic Domes in1954. C-60 is also called Buckyballs because of its resemblance with football or soccer balls.

Nanotechnology in Food

Food industry has tremendously improved with the use of nano-technology. They provide nutrients by the range of food articles having unique chemical and physical activities combined with the high quality, taste and repeatability. It is applied to modify taste and color, investigate microorganisms found in food materials and decompose the bacteria. Nanotechnology serves as a significant tool to enable further explanation of nutrient metabolism and food physiology. (Inwati, G.K.,2018) and co-authors explored the antibacterial impact of hybrid nanomaterials and the fundamental mechanism of bacterial cell damage. The metallic and metal-doped semiconducting inorganic nanoparticles are being used for biomedical applications by following their free radical oxygen species in the bacterial cytoplasm. The global manufacturing of high-quality sports tools, materials, and kits is geared towards increasing the durability and functionality of sports equipment. Several industries and businesses are using nano-based building blocks to create high-strength apparatus that will revolutionize sports. The improved quality of nutritional substances and unusual carrier for nutrients transfer into the body parts in the form of vitamins are also employed by using nano-concepts. To make sports equipment and clothing, nanomaterials, such as noble metal-based structures, metal oxides, carbon-based graphene, and their derivatives, are mixed into diverse starting materials. Nanomaterials are lightweight but have stronger stability, resistance, and durability.

Nanotechnology in Medicine

Nano medicine is a branch of nanotechnology used for detection and diagnosis for diseases. The cure and treatment can be done using nanomaterials agents and biomarkers. These kinds of necessities prompted extraordinary research in several nano-sized systems, such as liposome structures, for medicinal uses. Highly effective pharmaceutical carriers are essential for simplifying the various health factors and diseases with minimum toxicity to normal tissues. Bangham studied different categories of many nanoparticles in cancer cure treatment. In the development of liposomal-based drugs, specific lipid units play an important role. It significantly increases the pharmacological impacts. The semiconducting nanomaterials, such as ZnO, TiO_2, are mostly used in drug delivery due to their functionalized stabilities and actions. The functionalized metal-oxide nanoparticles are found more effective towards drug loading and delivery. They have surface modifications and quick actions in biological systems. The decorating surface of such nanoparticles is very studied and commonly employed for biomedical applications, including their confinement effects and surface-to-volume area properties. Apart from the liposomes, CNT, atonic layered structures of carbon (graphene) and its oxides have also been employed. Doped nanomaterials are stabilized micelles systems, noble metal-based nanosystems and other materials that can also be applied for the efficient delivery of drugs. Metal-based nanostructures, including organic and inorganic nanomaterials, have potential in biomedical fields. The use of nano materials for serious disease has many advantages over conventional treatment.

Nanotechnology for Hearing Aids

The development of hearing aid equipment is significantly improving by using nanotechnology. New technologies like, aids, nano-coatings to protect from moisture and corrosion, innovative noise reduction algorithms, feedback reduction circuitry trainable hearing, provides greatest gift towards solving the individual's hearing disability. Some semiconducting nanomaterials for medicinal impacts include antipathogenic and antibacterial actions. The study conducted by (Hummel , 2016) shows that to check the effect of moisture on nano-coatings applied hearing aids could stop moisture from entering the hearing aid shell This enhanced the efficiency of the hearing aid against the moist environment by comparing the qualitative and quantitative outcomes. In this regard, the considered results involved different hearing aid creators.

Nanotechnology in Gene Healing

Gene healing therapy is the treatment that involves the introduction of novel genes into cells, the repair or replacement of existing defective genes, or the regulation of gene Crystals 2022, 12, 39 9 of 16 expression. Nanotechnology proved to be one of the most efficient methods for delivering bare therapeutic nucleic acids to target cells without the use of biological or synthetic carrier molecules. Dendrimers have proven to have potential applications in the crucial process of gene and drug deliveries. Gene delivery with the use of dendrimers was first time attempted by (Dufes et al., 2005). Polyamidoamine (PAMAM) dendrimers with few branching points and an ammonium or ethylenediamine core molecule were successfully loaded with the gene. Gold nanoparticlesare also being studied to offer improved drug transfer schemes in the treatment of gene healing. They have impressive features, such as chemical stabilities and simplicity while interacting with this functional groups. Apart from this, fluctuating electrons on top of the conduction bands called Plasmon resonance have given new directions for extensive research to explore their therapeutic potentials.

Nanotechnology In MRI

Nanoparticles in MRI Iron oxide nanoparticles are used to improve MRI imaging of cancer tumors. Iron oxide nanoparticles are functionalized with epithelial growth factor

receptor antibodies, short peptides, such as Arginyl glycyl aspartic acid (RGD), oraptamers. They have been proposed for several cancer diagnoses, including kidney, stomach, liver, breast, colon and brain cancer. Apart from that, synthesized iron oxide nanoparticles can be used for other purposes, such as early thrombosis detection and brain inflammation studies. MRI imaging can also be conducted using nanoparticles made of manganese (Mn), gadolinium (Gd), andiron nanoparticles. Due to the electronic and structural band gap positions, these nano-objects are commonly used in MRI studies in the field of biomedical applications. The d-d, d-f, and f-f intra-band spectral response of certain light energy allow them to be used as the desired alternative. The metal and metal oxides of such nanostructures are easy to employ in the medicinal branches. The elements and their compositions are targeted for the same. Another widely used and medically acceptable substance is super paramagnetic iron oxide nanoparticles (SPION). SPION increases imagining by shortening the T2 relaxation time of nearby water protons. This results in visible signal gaps on T2 weighted images that appear as dark spots. The photoactive spectral intensity in the form of absorption and emission is generally considered a vast factor for MRI and other biomedical applications. The electronic transitions under certain electromagnetic radiations are mentioned for the light active sensing and thus, these metallic and metal-oxides are widely studied.

Nanotechnology in Covid19

The use of nanoparticles has a significant impact on processes, such as protein adsorption, blood clot formation and cell behavior. This occurs during the placement of dental implants. Nanotechnology has the potential to improve spinal fusion efficiency while also minimizing the cost and danger of complications caused by bone morphogenetic protein (rhBMP). Advanced orthopedic implants frequently use nanomaterials. The use of complex highmolecular structure polyethylene (UHMWPE) in arthroplastyareashas been limited due to concerns about probable breakage. However, due to its acceptable biocompatibility and wear-resistant features, nano-ranging techniques or tools have raised awareness in improving the mechanical asset of UHMWPE. CNT incorporation frequently results in unique Nano composites, which represent a significant achievement and could be applied to the acetabular lineror tibial components in the future.

Antiviral nanoparticles have been used as potential immunostimulatory agents for vaccine development. For example, gold nanoparticles conjugated with swine transmissible gastroenteritis virus have been used to activate macrophages, induce interferon production, and increase anti-coronavirus neutralizing antibody levels in vaccinated animals. Similarly, conjugates of ribonucleicacid and ferritin-based nanoparticles have been used as molecular chaperons to develop a vaccine against MERS-CoV.Thevaccinehasbeenshown to induce a strong T cell response and promote interferon production.

Nanoparticles offer numerous advantages over traditional vaccinations and adjuvants. Nanoparticles improve hydrophobic antigen solubility and reduce post-vaccine adverse effects. Uses of nanoparticles offer a controlled sustainable release of the antigens, with smaller volume and fewer doses. Modifications of nanoparticles can result in their more immunogenic properties with adjuvant. They help to facilitate securely carrying antigens for different pathogens all at the same time. Researchers have also published their work on the development of an efficient spore-based vaccine that was proved to be effective against spores of Bacillus subtilis andanti-clostridium tetani. Vaccines are the most effective way to prevent viral strains, such as SARS-CoV-2. Shin et al., 2020, reviewed contemporary approaches to advancing the COVID-19 vaccine, emphasizing the importance of nano-based techniques that enhanced the production approach for vaccines. Peptide-based vaccines are the most basic type of vaccination, and they may be easily created, validated, and prepared at a lower duration. DNA vaccines are synthesized as an effective solution for diseases and are able to produce cellular immunity, including humoral; these are the safe vaccines so far. DNA vaccines, encapsulated with specific nanoparticles, stabilize DNA formulation and avoid its degradation. Porous silicon micro-particle (PSM)-based therapeutic dendritic cell-vaccination (Nano-DC vaccine) serves as an antigen peptide carrier and an adjuvant both. There is a stronger association between the shape of PSM objects and their absorption owing to circulating dendritic cells. The intravenously approached vaccines highly gathered on the spleens and inguinal lymph nodes. Conversely, popliteal lymph nodes respond higher amounts by intradermal inoculated vaccines. Additionally, it is found that mice have large tumors received a high number of vaccines in lymph nodes compared to those with small or medium-sized tumors. Thus, nanotechnology plays efficient role in future therapeutic cancer vaccines.

Future Prospects

The development of nanotechnologies and their impacts in the biomedical field have been explored by implementing the distinct structures of nanomaterials or nanocomposites with their different morphologies and surfaces. The advanced hybrid metamaterials, including inorganic and organic substances, have significant importance in medical science and medicinal studies. Therefore, combining both nanomaterials and nanotechnology is covered with suitable surface-modified structures (spheres, wires, rods, sheets, etc.) for the rapid progress in human health and science. These miconducting metal-oxides, metals and organic constituents are well explained to study the biomedical sensors and their uses. The different aspects of medical issues, such as audiology, dentistry, nutrition, nano medicines, diagnosis, and imaging, are explained in this review. The structural, optical, surface, and spectral properties of the nano-ranged materials are explained with authentic literature. Consequently, the obstacles of implementing nanotechnology, particularly in the pharmaceutical creation of novel drug products and resolving complicated health issues, are also outlined in this review. These are the features granted by the nanoscale that serve as the biggest challenges. Concerns about the implementation of nanostructures include their physical characteristics, which can lead to a change in pharmacokinetic, pharmacodynamic and metabolic activity. Their ability to pass biological membranes, noxious assets, and persistence more easily in the environment and biology is an outstanding achievement. The importance of nanotechnology and nanosciences open a wider scope for further environmental, energy and biomedical-based applications using nanoparticles and their derivatives.

Conclusion

To conclude, nanotechnology is a fascinating and quickly evolving aspect of engineering that enables us to interact at the radioactive and molecular levels to explore, manage and apply nanometer-dimensional. Nanotechnology has potential applications in many sectors including paints and coatings, textiles and clothing, cosmetics, food science, catalysis, etc. Inaddition, nanotechnology presents new opportunities to improve how we measure, monitor, manage. Nanotechnology has emerged as a growing and rapidly changing field. New generations of nanomaterials will evolve, and with them new and possibly unforeseen issues. Nanotechnology is the future of advanced development. It is everything today from clothes to

foods there are every sector in its range we should promote it more for our future and for more developments in our current life.

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