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Nanotechnology and nanomaterials

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بسم الله الرحمن الرحيم

Dedication and thankful

In the name of God, the Most Gracious, the Most Merciful

God Almighty said:

God will raise those who have believed among you and those who have been given knowledge, by degrees.

I dedicate this success to the one whose name I carry with pride, to the one who harvested the thorns from my path to pave the way for me to knowledge, to the one who crowned

God with awe and dignity... to the one who taught me to give without expectation, to my dear father

to the one whose prayers were the secret to my success, to the one who wove my happiness with threads woven from her heart... to the smile of life and the secret of existence... to the dearest of my beloved mother

to my family and brothers.

I also thank everyone who contributed to the completion of this work, especially Mr. AMMAR BOUKHARI

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Abstract

Nanotechnology is a branch of science and engineering that deals with the design, production, and application of materials, devices, and systems by controlling the structure at the nanoscale (from 1 to 100 nanometers). This technology relies on exploiting the unique properties of materials at this scale, where the physical and chemical properties of a material change significantly compared to its larger size. And Nanomaterials are materials designed or manufactured so that their dimensions are in the nanometer range, resulting in new properties that differ from those of bulk materials. Types of nanomaterials include:
1. Nanocarbon: Such as carbon nanotubes and nanodiamonds, which are extremely strong and have unique electrical properties.2. Nanometals: Such as gold and silver nanoparticles, which exhibit unique properties when interacting with light.3. Nanocomposites: Such as zinc oxide or titanium dioxide nanoparticles, used in medical and environmental applications. Nanotechnology has many applications in various fields, such as: Medicine: By improving diagnostic and therapeutic techniques, such as drug delivery systems targeting specific cells using nanoparticles. Environment: In water treatment or pollution removal using nanomaterials. Electronics: Enhancing the performance of electronic devices, such as flexible displays or high-capacity memory. nanotechnology is a promising technology that will likely transform many aspects of daily life in the future

ملخص

تكنولوجيا النانو هي فرع من فروع العلوم والهندسة التي تتعامل مع تصميم، إنتاج، وتطبيق المواد، الأجهزة، والأنظمة عن طريق التحكم في البنية على مقياس النانو (من 1 إلى 100 نانومتر). هذه التقنية تعتمد على استغلال الخواص الفريدة للمواد على هذا المقياس، حيث تتغير الخصائص الفيزيائية والكيميائية للمادة بشكل كبير مقارنةً بحجمها الكبير.والمواد النانوية هي مواد يتم تصميمها أو تصنيعها بحيث تكون أبعادها في نطاق النانو، مما يؤدي إلى ظهور خواص جديدة تختلف عن الخواص التقليدية للمواد عند أحجام أكبر. ومن انواع المواد النانوية. 1. النانوكربون: مثل الأنابيب النانوية والكربون النانوي، وهي مواد قوية جدًا ولها خصائص كهربائية فريدة. 2. النانوالمعادن: مثل الذهب والفضة النانوية التي تظهر خصائص فريدة في التفاعل مع الضوء. 3. النانوالمركبات: مثل أكسيد الزنك أو أكسيد التيتانيوم النانوي، والتي تستخدم في التطبيقات الطبية والبيئية. تكنولوجيا النانو لها العديد من التطبيقات في مجالات متعددة مثل: الطب: من خلال تحسين تقنيات التشخيص والعلاج، مثل الأدوية التي يتم توجيهها إلى خلايا معينة باستخدام الجسيمات النانوية. البيئة: في معالجة المياه أو إزالة الملوثات باستخدام مواد نانوية. الإلكترونيات: تحسين أداء الأجهزة الإلكترونية مثل الشاشات المرنة أو الذاكرات ذات السعة الكبيرة. تكنولوجيا النانو تعد من التقنيات الواعدة التي ستغير العديد من جوانب الحياة اليومية في المستقبل

INTRODUCTION

Introduction:

Nanoscience primarily deals with synthesis, characterization, exploration, and exploitation of nanostructured materials. These materials are characterized by at least one dimension in the nanometer range. A nanometer (nm) is one billionth of a meter, or 10–9 m. One nanometer is approximately the length equivalent to 10 hydrogen or 5 silicon atoms aligned in a line. The processing, structure and properties of materials with grain size in the tens to several hundreds of nanometer range are research areas of considerable interest over the past years. A revolution in materials science and engineering is taking place as researchers find ways to pattern and characterize materials at the nanometer length scale. New materials with outstanding electrical, optical, magnetic and mechanical properties are rapidly being developed for use in information technology, bioengineering, and energy and environmental applications. On nanoscale, some physical and chemical material properties can differ significantly from those of the bulk structured materials of the same composition; for example, the theoretical strength of nanomaterials can be reached or quantum effects may appear; crystals in the nanometer scale have a low melting point (the difference can be as large as 1000°C) and reduced lattice constants, since the number of surface atoms or ions becomes a significant fraction of the total number of atoms or ions and the surface energy plays a significant role in the thermal stability. Therefore, many material properties must now be revisited in light of the fact that a considerable increase in surface-to-volume ratio is associated with the reduction in material size to the nanoscale, often having a prominent effect on material performance. Historically, fundamental material properties such as elastic modulus have been characterized in bulk specimens using macroscopic, and more recently microscopic, techniques. However, as nanofabrication advances continue, these bulk properties are no longer sufficient to predict performance when devices are fabricated with small critical dimensions. Although nanotechnology is a new area of research, nanomaterials are known to be used for centeries. For example, the Chinese used gold nanoparticles as an inorganic dye to introduce red color into their ceramic porcelains more than thousand years ago. Roman glass artifacts contained metal nanoparticles, which provided beautiful colours. In medivial times, nanoparticles were used for decoration of cathedral windows. What really new about nanoscience is the combination of our ability to see and manipulate matter on the nanoscale and our understanding of atomic scale interactions. Advances in the materials processing along with the precipitous rise in the sophistication of routine, commonly available tools capable for characterization of materials with force, displacement and spatial resolutions as small as picoNewtons (pN = 10–12 N), nanometer (nm = 10–9 m) and Angstrom (A = 10–10 m), respectively, have provided unprecedented opportunities to probe the structure and mechanical response of materials on nanoscale. In addition, major improvements in computer support have allowed the simulations of material structures and behavior with a degree of accuracy unimaginable as recently as a decade ago. Although study on materials in the nanometer scale can be traced back for centuries, the current fever of nanotechnology is at least partly driven by the ever shrinking of devices in the semiconductor industry. The continued decrease in device dimensions has followed the well-known Moore's law predicted in 1965 [1].

CHAPTER 1: NANOTECHNOLOGY

1 Nanotechnology :

1.1. What is nanotechnology :

Nanotechnology, also known as ultrafine technology, is a new technology that has the potential to revolutionize many aspects of science in the near future. The term "nanotechnology" comes from the Greek word "nanos," which means dwarf, and a nano is equivalent to one billionth of a meter. Nanotechnology encompasses the creation and development of novel materials and gadgets on a scale between nanometers and 100 nanometers. Networking and cooperation across information technology, biology, physics, electronics, and materials science are essential to nanotechnology. To create tools, equipment, materials, and goods with unique qualities, it is necessary to investigate the atomic or molecular structural structures of living things [2].

1.2. History of nanotechnology :

In nature and ever since the beginning of the earth, nanotechnology has been in occurrence through mutation, adaptation and evolution. By this process and via the helpof very small conformations namely “chloroplast” that exist in nanometer, plants passedthrough a photosynthetic route. Moreover, one more usual occurrence is in the field of bioscience using enzymes otherwise chemical catalysis using catalysts involving in catalyzing a particular chemical or biochemical reaction. James Clerk Maxwell 1867 was the first man to carry out an investigation on a molecule utilizing nano range. The foremost to categorize constituents in dimensions on nanolevel base was Zsigmondy in 1914, from which advances were being made in character izationinparticulate sizes by Blodgett and Langmuir in 1920s through introduction of monolayer.Measurement of surface force was also first reported by Derjaguin (1954).Nanotechnology was first learned from Richard Feynman in 1959 (Fig.1) fromhispopular speech, titled “There is plenty of room at the bottom” hosted by the American Institute of Technology. He proposed a technique using some specific tools for the manipulation of atoms and molecules. With various improvements, nanotechnology was proposed to be defined by Taniguchi (1974) (Fig.3) as amethodthat involves manipulating matter at the nanoscale which involves processing, separating, consolidating and deforming of molecules of interest. Among the toolsusedin the 1980s were atomic force microscopy, scanning tunneling microscope, molecular beam epitaxy and scanning probe microscopes. Asaresult of latest development in skills and knowhow, new methodical apparatusesarenow in use to determine, morphological and surface structure, quantifythe phasecomposition, basic conformation in addition to crystal dimension of a nanosample.Among these equipments include Atomic force microscopy , X-ray diffraction,X-Ray photoelectron spectroscopy , high resolution scanningele ctronmicroscopy-electron diffraction spectroscopy and the list goeson [3].

Figure 1.1: Pr. Richard feynman.

Figure 1.2: Pr. norio Taniguchi

1.3. The importance of nanotechnology :

Nanotechnology has become at the forefront of the most important and exciting areas in physics, chemistry, biology, engineering, and many other fields.and many other fields, it has given great hope for the emergence of scientific revolutions in the near future.The widespread interest in nanotechnology dates back to the period from 1996 to 1998, when the American World Technology Evaluation Center (WTEC) studiedThe American World Technology Evaluation Center (WTEC) studied the topic, and conducted an evaluation study in nanotechnology research, and its importance in the creation of this technologyThe study summarized the most important points:In all areas of medical, military, informatics, electronic, computing, and medical fields.Nanotechnology has a great future.Petrochemical, agricultural, biomedical,

- Nanotechnology is multidisciplinary and relies on the principles of physics, chemistry, electrical and chemical engineering.in addition to biology and pharmacy.
- Researchers in any field should reach out to other researchers in other journals to get aof nanotechnology and actively participate in this exciting field.
- The abundance of environmentally benign materials used to provide clean water resources.
- Genetically modified crops and foods contribute to abundant and increased agricultural yields with minimal labor requirements
- Promote and support the self-interactive aspects of nutrition.
- Increase clean, efficient manufacturing capacity.

- Manufacturing smart interactive devices to maximize human performance through convergent technologies.
- The concept of nanotechnology is based on particles less than 100 nanometers in size that impart new properties to the material in which they are embedded new properties.
- This is because nanoparticles have physical and chemical properties, which leads them to a new behavior in which they depend on microparticles, and it has been observed to change the electronic structure such as conductivity, reactivity, melting point, and mechanical properties of the material at the nanoscale, that is, as the nanoscale size of the material approaches the atomic dimensions, the material is subject to the laws of quantum mechanics instead of the laws of conventional physics.
- The dependence of the behavior of a material on its size enables us to control the engineering of its properties, based on this, the researchers concluded that this concept has great technical implications, including wide and varied technical fields, including: Producing light and strong materials, reducing the delivery time of nanomedicine to the human circulatory system, increasing the capacity of magnetic tapes, making fast computer keys ..... etc.
- The benefits of nanotechnology also include improved manufacturing methods, water purification systems, energy grids and health promotion
- environmental and nanomedicine, as well as improved production methods for the large-scale food industry, automotive infrastructure and other industries, and nanotechnology products that are high-yield, low-cost and have modest requirements in terms of energy materials.
- In spite of all this, there are many difficulties that need further research, the most important of which are: The possibility of accessing cheap and practical methods; preparing different nanomaterials commercially; and using them in different applications.
- Another difficulty is how to connect the concept of the modern nano-world with the macro-world that is currently used in the manufacture of electronic devices[4].

1.4. Applications of Nanotechnology :

The significance of the applicability of nanotechnology towards conservational, engineering function and decrease in energy utilization that provides lesser priceandinturn improving the making effectiveness can never be overstressed. Although, it maynot be a complete way out to today’s world’s problem but perhaps, this technical know how can confidently minimize world’s financial trials especially those existingin the developing countries like Africa to be more specific.

Examples of suchdra wbacksmay include; treatment of epidemic diseases, the need for clean water, various manufacturing purposes and numerous methodical innovations. Presently, governments of European countries, USA, China and South Africa are contin uingtogive precedence to technical know how via huge investments in nanotechnology with single goal of streng the ning financial improvement. Africa on the other hand, is also indesperate need of such innovative technology.

1.4.1 Nanotechnology application for water treatment:

The high surface area to volume ratio possessed by nanoparticles which can becontrolled chemically present’s great potential of nanotechnology; as sorbents, materials which latch on to pollutants and extract them out of solution. Example is multi-walledcarbon nanotubes which show a leading position, activated carbon less effectiv ethancopper and cadmium, a sorbent that is generally utilized. Other nano dimensione dparticles that also act potentially as catalysts may include nanometer ironof zerovalency and titania nano dimensioned particulates which can be useful in cutt ingdownin tractable organic contaminants into nontoxic substances. An example is nanometerzero valent iron can make organic substances of halogens harmless. Silver andmagnesium are example of other bioactive nanoparticles which can destroymicrobes and utilized instead to sanitize water in the presence of chlorine.

Due to the difficulty of the current technology to trap, pin point and eliminateviruses and other toxins, devices that are used in filtration and nano-manufactured membranescan be applicable. Such membranes and filtration devicesmayhelp in monitoring these pollutants at the manufacturing areas and water sanitizin gfactories. Nanospores membranes are constructed to simult aneously iden tifyan dget ridof those contaminants. Industrial waste water and also the ocean having great potentialto eradicate undesirable materials might come to be obtainable to maximize thesourceof sanitized water. A promising example among others is nanometer ironof zerovalency which is being examined and utilized in getting rid of solvents fromdrive nground water. Nano titanium (IV) oxide can remain activated by sunlight when scattered into a polluted water and in turn potentially degrading reasonably ahugeamount of organic contaminants like dioxins including PCBs with the help of hydroxylradicals produced.

This technology was assumed responsibly to possess influence on water managemen tstarting using sorbents of nanoscale and nano bioactive particles which maybein corporated in a functional refining scheme. Novel types of tools that utilized nanotechnology to enhance the effectiveness of purification, getting rid of additional types of contaminants and roles, like water-purity sensors could event uallyreplace entirely these first hybrid technologies. Researchers are presently examining considerably certain number of materials that exist at nano level. Novel lesser scalewater treatment schemes may include sorbents, catalysts, sensors all of nanoscaleandsmart membranes, nanosensors and other types of nanotechnology ical appliances.

Unfortunately, despite our challenges towards dealing with longstanding drawbacks, novel typed contaminants are being increasingly revealed in water supplies. Assuch improved nano water separation schemes systems may be established to deal with the sepollutants. Nano enhanced technology as applicable to water refining systems isviaa material usually known to be nanomaterial. There exist materials of this nano range which function in as membrane for purification of water, thus these include carbon nanotubes, metal nanoparticles and many more

Thes enanomaterials present new ability detoxify contaminated ground water, outward waterand inner water which may be contaminated by inorganic materials and pathogens. Nano size materials are incredibly efficient for water detoxification as they have quiteamount of properties involved, nanomaterials possess large surface area to volum eratiothat happens due to decrease in dimension of adsorbent material fromlarge tothesizeof a nanometer.

This decrease in size of adsorbent particle makes adsorption egarded economically more viable and effective method for purification of water. Nanomaterial's characteristics makes higher number of particles attached the mselvestotoxins which in turn enhances the adsorption ability of sorbent constituents. The higher surface zone, dimension and other properties like electronic and catalyticof nanomaterials render compromising chances to make more effective water detoxi fying catalysts as well as redox vibrant media that has been gaining consideration recently, forexample in UV light detoxification of water photocatalyst like TiO_2. TiO_2 nanoparticles ynthesis using sol-gel, precipitation and so on are familiar investigatory techniques. As struggles persists in solving global water pollution problem, TiO_2 whichis part of the hetero geneous photocatalysts was recognized in findings and innovations, apartfrom that, the method presents less-expensiveness, environmentally welcome ingandmain tainable in the industry devoid generating harmful sludge. With various chemicalgroups, these cutting-edge nano particulate materials can also be restrained oelevatetheir attraction towards particular compound.

1.4.2 Nanotechnology application for energy development:

Although not accessible, there will be a need to convert the energy existing aroundusinto a usable form. Considering the availability and convenient forms of energy inenergy-rich materials, they are also quite less difficult to change into somes pecific yields, such as articulated energies, and electricity which can be extensively circulated. This technology can function in minimizing losses as renovation of energy precedes there by paving way for an alternative when fossil fuels are being depleted. For example, generation of several products of petroleum as a result of conversion of crudeoil could be improved by nano-engineered catalysts, together with coal renovation intospotless fuels for producing electricity.

Nanotechnology can be used tomax imize opportunities in oil and gas applications, in more precisely to produce geother malreserves by improving thermal conductivity, down-hole split-up improvement, and production of non-destructive substances which can function in geothermal-energy development could be achieved. Metallic nanomaterials may be utilized in geochemicalexploration by delineating ore deposits. This technology could also beused inimproving the drilling processes. In justification to that, enhanced fluid that is coupledwith nano particulate matter and fine powder which importantly improves penetrating speed has been developed by some specialized petroleum laboratories. This blendmakes it possible to extract more oil by extinguishing or eliminating destruction tothereservoir well.

Additionally, enhancement of the unconventional and stranded gas resources is an application of nanotechnology. The efficiency and in frastructure of liquefied-natural-gas (LNG), LNG quality, and developing gas-to-liquids (GTL) technology are near term challenges of great focus. In solving the challenges linked with gaining access to stocked natural-gas sources, nanoscale catalysts and nanoscale membranes for GTLproduce and nano constituents for compacted-natural-gas conveyance can be developedand created respectively.

Novel electrical generating method as another nanotechnology application includeselectro-kinetic power generation; this involves fluids with charged ions that createcurrent when enforced via a nano dimensioned pathway. This method mimics the electro-chemical technique in animal neurons (nerve cells) during action potentialge neration. Despite its non-usage for huge capacities of power generation, thistechnical knowhow is admirably important in initiating other nano appliances. Inenergy storage, solar energy assembling and proficiency is enhanced with theincreasein surface area to volume ratio of nanoparticles, this improvement is achieved with revealing additional surfaces of conducting feature to the sunlight. The most probably promising alternative energy production is solar cells research and development using nanotechnology.

Solar cells can be more efficient, cheaper and lighter using quantumdots, fulle renesand carbon nanotubes (CNT). For example, amount of light collection can greatly increaseby creating photovoltaics with CNTs. Quantum dots that have the potential to captivate several rays of light which give active solar cells are been used by Notre Dame Researchers in the near future. Increase in photovoltaic effectiveness thru the utilizationof substances such as lead-selinide is another area that nanotechnology will impactgreatly. When a light photon hit these materials, the materials cause more electrons (and therefore more electricity) to be released. Additionally, nanotechnology canbeused to modify structural properties of photovoltaics.

Photovoltaics that gives rise to highly improved solar cells suppleness which has notbeen featured with several silicon made cells where been able to be constructed from nanowires by the ASTAR Institute of Microelectronics. Energy must be storedandtobe used when needed. The application of nanotechnology in the near termcouldhe lpincreating devices and other products that efficiently store much amount of energy, thisimplies taking up charge by those appliances or devices and holding it over atimeperiod. Engineered nanomaterials are utilized by many research groups to create better batteries.

Power density to battery size will increase in batteries when they are constructed with nanomaterials, Battery streng the fficiencysome what rely on dispersion distance and electrolyte polymers of hydrophili cnature and battery efficiency is set to dramatically increase. A prototype battery develope dbyAltair Technologies which can be charged in six minutes has three times thecapacity existing batteries. The two final issues in lithium-ion batteries are concerns that scientist are presently trying to address. In that regard, they have invented batter iesthatdo not allow electrode contact before battery activation. As opposed to twoyears, itrenders the resultant produces active of 25 years and an approximately limitless shelflife. In addition, normally toxic outputs from typical batteries are neutralized by chemical sreleased by reserve cells within the batteries during disposal.

Application of nanotechnology could revolutionize hybrid car industryin battery production. Powered by Altair-Nano lithium-ion Nano-safe battery, Micro-Vett FiatDoblo had journeyed 186 miles amid charging (<10min). Five hundred nano-enhanceds porting value automobiles in an estimation will be selling in future by phoenixmotors and to be featured by Altair technology. The use of viruses to self-gather battery constituents and “printable” sheets of batteries produced from CNTs are concerningfields being investigated to improve battery technical know how.

Similarly, this technology will provide impressing improvements in hydrogen energy production, distribution as well as storage. Related techniques to photovol taicsare applied in hydrogen production systems. Hydrogen production that involves separating molecule of water by light can eliminate reliance on remnant fuels. Thus, the techniqueneeds accuracy, and presently, examination into this development process existsatinfancy. Among the greatest interesting fields where nanoscale know ledge willinfluence greatly to hydrogen power is its effective storing. Currently, there exist nonreliable knowhow to preserve huge amount of hydrogen due to the fact that it isei ther expensive or too large to be stored, as such this justifies the role of nanotechnology asanother way of generating energy in this regard.

Exceptionally slim, even and with elevated surface area “nano blades” possessbe ingdeveloped by researchers at Rensselaer. Furthermore, researchers have discovere dfullerenes was able to retain huge quantity of hydrogen which is equal to its (hydrogen)density in Jupiter. Presently, pipelines are used, however, the use of carbon nanotubes wiring could greatly further improve the efficiency of hydrogen transport insteadof thepipelines. There will be an increase in power, steadiness and conductivity of theselines when there is rise in temperature. Scientists are studying carbon nanotube connections olely to serve that need. İn addition, New Mexico Tech created nanoparticles monitors to detect potential impurities when placed in hydrogen transport pathways.

Moreover, it could also serve in developing novel types of materials of good conductin gproperty for efficient energy transmission; these materials lose a very little amount ofpower when electricity travels below. Findings and investigation have been ongoing bymany research groups to discover whether nano coatings and nanowires couldred ucelosses in electrical-transmission lines. The application of nano-science mayresult toinventions that will deviously safeguard huge quantities of remnant energies forefficient energy utilization. Nano manufacturing may also pave way in creatingentire materials types while utilizing little amount of energy. Considering nano sizedsensorsas an example, may be utilized to reduce waste and to detect the kind of energyused.

1.4.3 Nanomedicine applications :

Nanomedicine Assist in fore sighting main illnesses which could be suspecte dtomanifest in an individual’s body system. The aim is to thorough fully examine with accuracy numerous of several constituents in an individual’s body to determin ediseaserisks. Hence, will there by help in understanding the overall individual’s state of health. Many researchers are working on creating a “labon-a-chip” device usingnanoscale know ledge to perform detailed analysis of a drop of blood. This discovery would notifythe doctor to early precursors of disease that reveal both genetic tendenciesand environmental factors, such as exposure to air pollution, diet, exercise andstress. Preventive treatment concentrates on timely involvement. With its help, patients areprevented from the total manifestation of diseases and manage it efficientlyover time. Nano based knowledge assist in improving growth of profound investigativ etests, together with disease management and fitness controlling devices.

Diabetes management among major areas will be at an advantage, early stages of insulinr esistance could be detected by Nano based diagnostic tests. Equally, preventive medicine may of significance in dealing with heart dysfunction and hyper tension efficiently that affects large portion of a population. Such method can be enhancedtobe applied in controlling several illnesses, e.g. arthritis as well as lupus. Equally, personal medication’s dream was that a person’s information could be utilizedin 10 observing and controlling the medication. The physician’s effective medical strategycould be much greater if perhaps has an idea on a particular individual’s illnesstype, metabolic information about drugs, hepatic condition and other illnesses risks. Nanoengineering can make available novel apparatuses required in assembling compr ehensive figures on statuses of disease changes and on distinctive factorsofm anagement. Significantly, this technology could outgrow the personal medicationup rising through facilitating actual, thoughtful control of drug treatment. Byproviding recurrent response, the physician can without difficulties modify medicin esandpres criptions for a person’s treatment.

On the other hand, in contributory (reformative) medication, the anticipation concerning possibility for reformative medication largely concentrated upon stemcells. Inaddition, nano based technology can additionally result to profoundly novel therapy that will dealwith spinal injuries, Type 1 diabetes, macular deterioration and other medical problems. The aim, regarding all these instances, was to normalize a section of a person’sbodyfrom injuries owing to disease, normal aging or genetic malfunctions. Perhaps, researchers may focus on stem cells ability to regenerate tissues and reconstruct function, nevertheless a similarly hopeful method is to engage artificial tissues of nano scale based. Nonetheless, it is stagnant premature several test center sarein vestigating coupled with extensive materials scaffoldings which could make cells to produce synthetic tissues, example; liver or bone. Inoculating nanomaterials with todamage nerves seems to be a promising method of making channeling structures. Somenano manu factured structures demonstrate potentially bases aimed at developing3-Dcomplexes of blood vessels. Moreover, redeveloping dead cells is another tactic and missing role that might also be reest ablished by means of Nano-enhanced replac emen tparts for the body devices that hook into the nervous system.

1.4.4 Other applications of nanotechnology :

Apart from the three most vital applications of nanotechnology talked over above, it hasbeen proven to be beneficial and useful in various other areas. Nano-technological advances are on the loose in diverse means to affirmative effects on the protection of resources and environment. For example, newly available nano sized catalysts arethebases for alternative reaction paths in the chemical industry, it preservedat lower temperatures additional energy as well as the low amounts of by-products justifying its selectivity, allow optimal material usage. As naturally pleasant materials, entire lynovelstarting constituent resources, example is novel bioplastics, possessed the poten tialityins ubstituting conservative polymers and equally metals, for instance car construction.They are categorized via virtually neutral CO_2 stability and made of renewables, andalso lead to an increase in liberation starting with petroleum centered initial constituents.It was known that CNT acts progressively significant function towards enhancing novelcons tituents

Literature also makes known that the idea of nanotechnology can be useful in the advan cement of conservational defensive constituents, nano scaled substance forbrilliant highway, stab or bullet-proof nanoscale material, lowfriction material anddetection of fabricating materials. Additionally, application fields of nano based technical know how can be; agriculture as well as nutrition, electronics, communication[3]

CHAPTER 2: NANOMATERIALS

2 *Nanomaterials :*

2.1. What is nanomaterials :

Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers. A nanometer is one millionth of a millimeter - approximately 100,000 times smaller than the diameter of a human hair. Nanomaterials [5] .

2.2. Types and Classifications of the Nanomaterials:

As the field of nanotechnology is growing rapidly, tremendous amount of NMs have been produced and all these NMs must be identified based on the structure, shapes, size, and chemical synthesis in order to differentiate from each other. Interestingly, NMs can be broadly typed into seven categories which are described below [6].

2.2.1 Carbon Nanomaterials :

The NMs which contain carbon are called carbon nanomaterials, and these carbon nanomaterials can be synthetized in different shapes such as (1) hollow tubes or (2) spheres. In addition, carbon nanofibers, graphene, fullerenes, carbon black, carbon nanotubes, and carbon onions are also classified as carbon nanomaterials (Figure 1.3) [6].

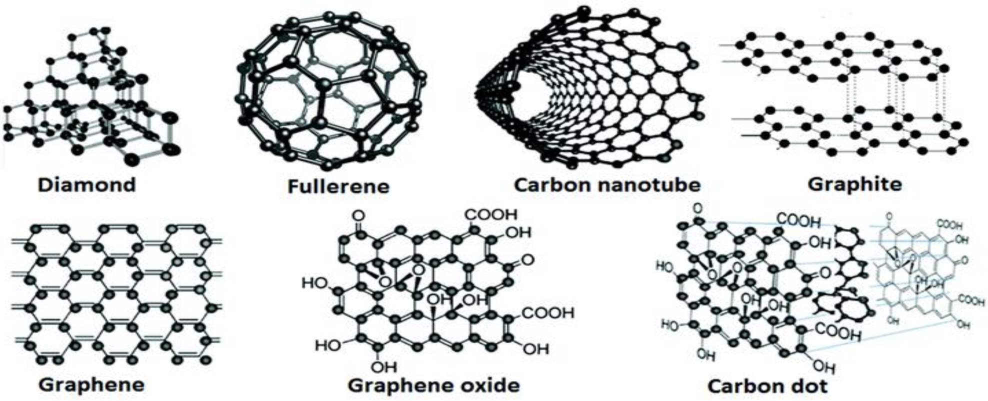

Figure 2.1: Different Carbon-base nanomaterials.

2.2.2 Metal and Metal Oxide Nanomaterials:

The metal and metal oxide can also be used to produce NMs which are called as metal and metal oxide nanomaterials or inorganic nanomaterials. Some of these NMs are gold (Au), silver (Ag) nanomaterials and metal oxides-based nanomaterials are titanium dioxide (TiO_2) and zinc oxide (ZnO) nanomaterials [6].

2.2.3 Organic Nanomaterials :

This type of NMs mostly contains organic matter, without carbon or inorganic based nanomaterials. One of the characteristics of these organic nanomaterials is that they possess noncovalent bonds (weak in nature, which can be easily broken). These organic materials can be easily modified to produce different shapes of nanomaterials like liposomes, dendrimers, micelles, and polymers (Figure 1.4) [6].

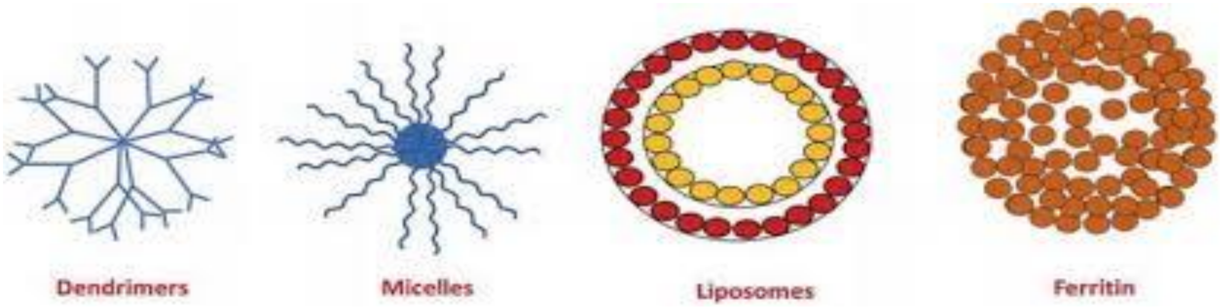

Figure 2.2: Different types of organic nanomaterials.

2.2.4 Nanocomposites :

The combination of one type of nanomaterials with another type of nanomaterials is called as nanocomposites. The nanomaterials either combine with other types of nanowires, nanofibers, or can be combined with larger size materials. These nanocomposites may be any combinations of metal-based, carbon-based, or organic- based nanowires, nanofibers, with any form of ceramic, metal, polymer bulk materials (Figure 1.5)[6].

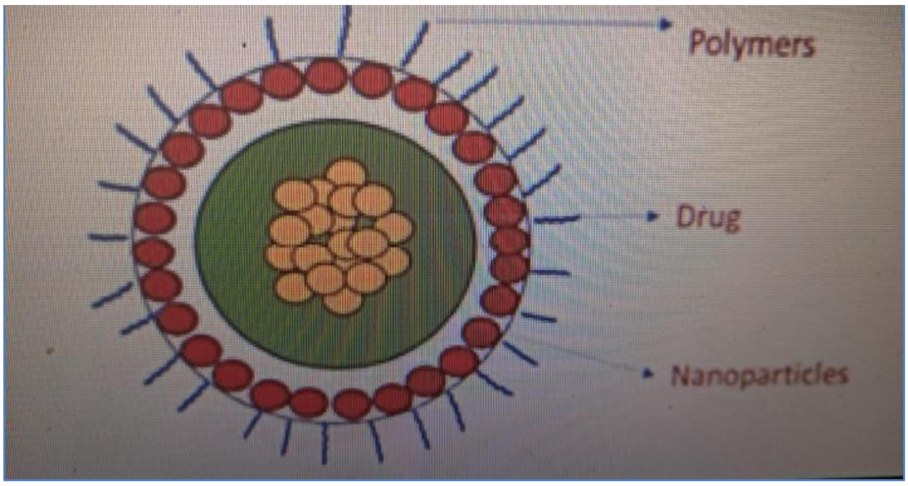

Figure 2.3 : Structure of nanocomposites.

2.2.5 Ceramic Nanomaterials Nanoceramic :

Is a type of NP material composed of ceramics and is further classified as heatresistant, inorganic, and nonmetallic solids made of nonmetal and metal compounds having dimensions smaller than 100 nm. Many chemical and physical methods for the preparation of ceramic NMs have been explored and reported. It was found that these materials exhibited enhanced structural, electro-optical, superconductive, ferromagnetic, and ferroelectric properties. Similarly, the structural and physical properties of Ti-doped BiFeO3 nanoceramics can be changed by changing the doping concentration, which could induce the structural distortion of materials and the elimination of. oxygen vacancies. Sobierajska et al. reported the preparation of porous hydroxyapatite nanoceramics and its applications due to its antimicrobial activity. The calcium hydroxyapatite porous nanoceramics (ncHAP) were prepared by the co-precipitation of high purity hydroxyapatite (HAP) and methylcellulose. The specific surface area and the porosity of ncHAP depend on the sintering temperatures. The interactions between its surface charges and the bacteria influence its ability in antimicrobial activity. The synthesis of nanoceramics under pressure-less and low-temperature conditions produce Al2O3–ZrO2 nanoceramics. The study's results revealed that amorphous materials were successfully formed at low temperatures with the homogeneous mixture and the grain size of NPs[6].

2.2.6 Semiconductor Nanomaterials :

Semiconductor NMs have low bandgap energy of less than 4 eV. Examples of known semiconductors are silicon, germanium, gallium arsenide, and elements near the so-called ‘‘metalloid staircase’’ on the periodic table. These NMs are composed of different compounds from various groups, such as II–VI (ZnO), IV (SiO2), and III–V (GaAs). The modification of the structure of these materials into the nanoscale can alter the chemical and physical properties of the materials due to the quantum size effect or by increasing the surface area. The C/ZnO semiconductor, with its high porosity, showed that the high electrical conductivity of the materials depends on the nanostructure formed. The semiconductor NMs can be divided into two types: (1) intrinsic semiconductors, composed of pure compounds or elements without doping that are present from other metals in the structure. The main characteristic of intrinsic semiconductors is that they have negative temperature coefficients of resistance. This means that by increasing the temperature, the resistivity of the material will decrease and the conductivity will increase; (2) extrinsic semiconductors, which are a type of material added to other metals by doping in its structure, which aims to increase their conductivity, for example, type-n and type-p semiconductors[6].

2.2.7 Polymeric nanomaterials :

Polymeric NMs are solid particles that are nanosized and consist of natural or synthetic polymers. These materials are widely used in pharmaceutical and medical applications as drug release controllers used to sense the body. Polymer-based NMs include the following: (i) polymeric micelles formed by the self-assembly of amphiphilic block copolymers in a specified solvent. Chitosan polymeric micelles can be used for drug delivery due to their unique characteristics, such as their nanosize, stability, biocompatibility, micellar association, and low toxicity; (ii) polymeric NPs, which are generally composed of biocompatible and biodegradable polymers with an average size of 10–1000 nm. These materials are widely used to deliver drugs to specific targets. The preparation methods to produce polymer NPs affect the specific characteristics of the material produced. Generally, the preparation methods are classified as polymerization of monomers, the ionic gelation of hydrophilic polymers, and the dispersion of polymers; (iii) dendrimers, which have a size of less than 15 nm with 3D-shaped macromolecules. These materials are a new type of polymeric NMs that are widely used in pharmaceutical and medical applications due to characteristics such as their structure, size, and multivalence ; and (iv) polymeric nanocomposites, which are a combination of other nanofillers and polymers used to provide superior properties and characteristics[6].

2.3. Classification of Nanomaterials :

2.3.1 Dimensions and Sizes :

As different types of nanomaterials are produced for a variety of applications, it becomes necessary to categorize these nanomaterials for proper applications. The nanomaterials are mostly solid particles, and their size and dimensions can be easily measured by using different methods. The idea for classification of nanomaterials was proposed by a scientist in the year 2000], he classified the nanomaterials based on their crystalline forms and chemical compositions. Still, this method of measuring was not fully complete as it did not measure dimensions of the nanomaterials. In another study, different groups of researchers have made a new classification which was primarily based on 0 Dimension, 1 Dimension, 2 Dimension, and 3 Dimension nanomaterial. The classification of nanomaterial is basically dependent on the movement of electrons in the nanomaterial. The presence of electrons is generally fixed in "0" dimension nanomaterials, whereas for "1" dimension nanomaterials, electrons can move freely along the x-axis, which is commonly less than 100 nm. Similarly, "2" dimension and "3" dimension nanomaterials have better electron movements along the x- to y-axis or x-, y-, z-axis, respectively. It has been found that the ability to predict the properties of nanomaterials determines the classification of the nanomaterials. Moreover, the characteristics of nanomaterials are basically dependent on the grain boundaries as per the Gleiter's classification, whereas the classification by Pokropivny and

Skorokhod suggested that the characteristics of nanomaterials are ascribed to the nanoparticle shapes and dimensionalities[6].

2.3.2 Origin of Nanomaterials :

The nanomaterials can be classified based on their source of origin, which means, the source materials to produce nanomaterials. They can be classified as naturally origin nanomaterials or synthetically produced nanomaterials[6].

2.3.2.1 Natural Nanomaterials :

Natural nanomaterials can be formed in biological species such as microbes, or plants and also through anthropogenic actions. The creation of natural nanomaterials is an accessible process as they are present in the hydrosphere, atmosphere, lithosphere, and biosphere. Interestingly, our planet is comprised of nanomaterials that are naturally formed and are present in the rivers, groundwater oceans, lakes, rocks, soils, magma, or lava as well as in the microbial organisms and also in humans.

2.3.2.2 Synthetic Nanomaterials :

The most widely used method to make nanomaterials is the synthetic method, which allows the production of nanomaterials by biological, physical, chemical, or hybrid methods. One of the advantages of the synthetically produced nanomaterials is that it is possible to produce large quantity of nanomaterials with different shapes and sizes. Another important aspect of the synthetic method is that different chemicals or reagents can be linked or conjugated with nanomaterials accurately and precisely. The major concern among synthetically designed nanomaterials is whether present knowledge is sufficient to envisage their performance. In addition, they display a different environment behavior, which is different from natural nanomaterials. Presently, diverse sources of nanomaterials are produced for various biological applications[6].

2.4. Properties of Nanomaterials :

The interest in nanostructured materials arises from the fact that because of the small size of the building blocks and the high density of interfaces (surfaces, grain, and phase boundaries) and other defects such as pores, new physical and chemical effects are expected or known properties can be improved substantially. The physical and chemical properties of nanostructured materials (such as optical absorption and fluorescence, melting point, catalytic activity, magnetism, electric and thermal conductivity, etc.) differ significantly from the corresponding coarser bulk material. Roughly two types of nanostructure-induced effects can be distinguished.

- The size effect, in particular the quantum size effects, where the normal bulk electronic structure is replaced by a series of discrete electronic levels.
- The surface- or interface-induced effect, which is important because of the enormously increased specific surface in particle systems.

Although the size effect is mainly considered to describe physical properties, the surface- or interface-induced effect plays an eminent role for chemical processing, in particular in connection with heterogeneous catalysis. Experimental evidence of the quantum size effect in small particles has been provided by different methods, while the surface-induced effect could be evidenced by the measurement of thermodynamic properties such as vapor pressure, specific heat, thermal conductivity, and melting point of small metallic particles. Both types of size effects have also been clearly separated in the optical properties of metal cluster composites. Very small semiconductor [7].

These special properties of nanomaterials are mainly due to quantum size confinement in nanoclusters and an extremely large surface-to-volume ratio relative to bulk materials, thus leading to the presence of a high percentage of atoms/molecules lying at reactive boundary surfaces. For example, in a particle with 10 nm diameter only around 20% of all atoms are forming the surface, whereas in a particle of 1 nm diameter this figure can reach more than 90%. The increase in the surface-to-volume ratio results in an increase in the surface energy of the particle, which leads to, for example, a decrease in melting point or an increase in sintering activity. Furthermore, large surface area of particles may significantly raise the level of otherwise kinetically and thermodynamically unfavorable reactions. For instance, even gold, which is a very stable material, becomes reactive when the particle size is small enough. Fundamentally, there are seven key characteristics that contribute to the uniqueness of nanomaterials[8] , and these are summarized in Table 1.3. In general, the unique properties of nanomaterials are an outcome of three effects: reduced size, high surface-to-volume ratio, and supramolecular structure arising because of the self-assembly of molecules that are summarized in Table (1.4) [7] .

Table 1.3: Characteristics of Nanomaterial and Their Importance

Characteristic	Importance
Size	Key defining criteria for a nanomaterial
Shape	Carbon nanosheets with a flat geodesic (hexagonal) structure show improved performance in epoxy composites versus carbon fibers
Surface charge	Surface charge is as important as size or shape. Can impact adhesion to surfaces and agglomeration characteristics. Nanoparticles are often coated or “capped” with agents such as polymers (PEG) or surfactants to manage the surface charge issues

Surface area	This is a critical parameter as the surface-to-weight ratio for nanomaterials is huge. For example, 1 g of an 8-nm-diameter nanoparticle has a surface area of 32 m2
	Nanoparticles may have occlusions and cavities on the surface
Surface porosity	Many nanomaterials are characterized with zeolite-type porous surfaces. These engineered surfaces are designed for maximum absorption of a specific coating or to accommodate other molecules with a specific size
Composition	The chemical composition of nanomaterials is critical to ensure the correct stoichiometry being achieved. The purity of nanomaterials, impact of different catalysts used in the synthesis, and presence of possible contaminants need to be assessed along with possible coatings that may have been applied
Structure	Knowledge of the structure at the nanolevel is important. Many nanomaterials are heterogeneous, and information concerning crystal structure and grain boundaries is required

Table 1.4: Size and Shape-Related Attributes and Properties of nanomaterials

Physical Entity	Functionality
A. Size confinement/reduced size (Quantum dots, wires, rods, wells, fibers) Attributes: • Comparable size of nanoparticles with correlation scale of some physical phenomenon • Characteristic length of some transport process • Abnormal phase state	• Electronic: quantum confinement, molecular electronics • Electrical: tunable dielectric, ferroelectric, dc conductivity, electrical rheology • Optical: nonlinear, luminescence, transmission, selective absorption/reflection/ scattering • Magnetic: new magnetic orders such as supermagnetism, paramagnetism, ferromagnetism; GMR, mechanical force transfer (MRF), magnetocaloric effects
B. High surface area (Powders, films, structural elements) Attributes: • Predominance of interfacial phenomenon because of the presence of free bonds, free bonding orbital with affinity for electrons, and occupied bonding orbital with low ionization potential	• Adsorption • Molecular recognition (chemical, biological) • Gas sensing, separation • Mechanical: superplasticity, higher structural strength and toughness, improved elasticity • Electrochemical process • Thermal insulation
C. Supramolecular and self-assembled structure (Nanotubes, fibers, rods, cables, films) Attributes : • Noncovalent and coordination bond • No exchange of electrons between molecules	• Adaptation, evolution, molecular forces holding • Nanostructure electronics • Molecular recognition, directed chemical synthesis • Nonlinear optical phenomenon Thermo-, opto- and electromechanical actuations

	• High-density ultrafast information processing • Ionic and molecular transport

2.5. Methods to Synthesize Nanomaterials :

The "top-down" and "bottom-up" are the two major methods which have been used to successfully synthesize nanomaterials. We have described these methods in further detail (Figure 2.1) [9].

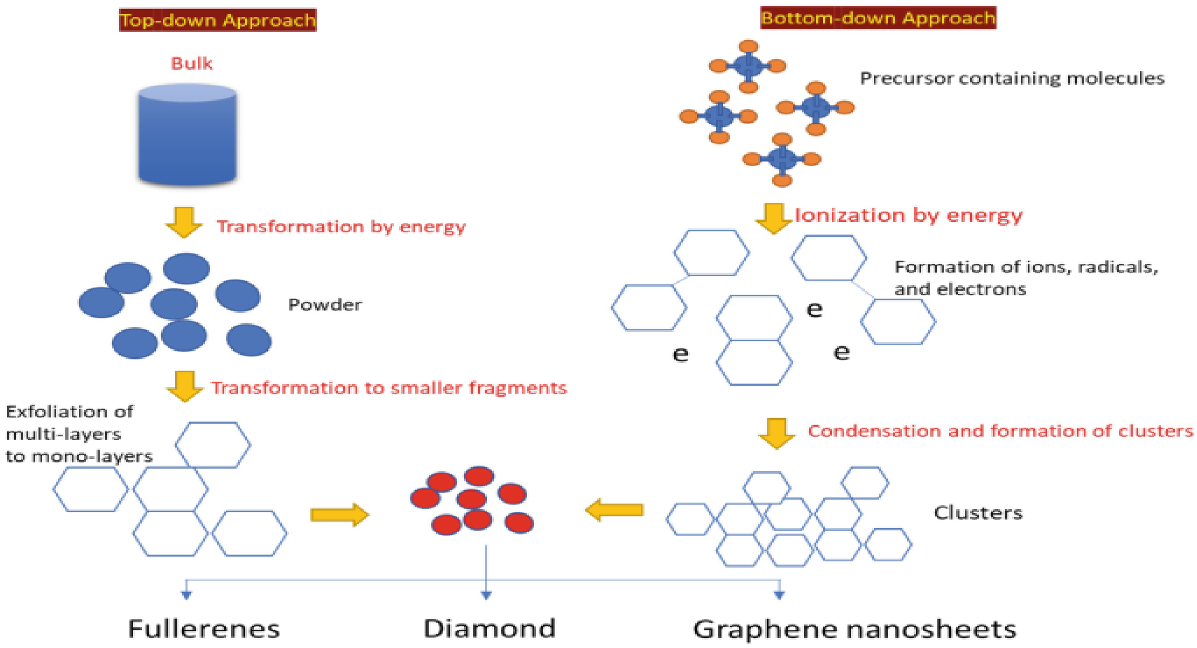

Figure 2.4: Diagrammatic representation of top-down approach and bottom-down approach of making of nanomaterials[9].

2.5.1 Production of Nanomaterials by Top-Down Method:

In this method, solid and state processing of the materials are mostly used and this method involves breaking of the bulk material into smaller particles using physical processes such as crushing, milling, and grinding methods. Generally, this method is not appropriate for formulating evenly shaped nanomaterials, and it is very difficult to get very small size nanoparticles even with high energy usages. The major difficulty of this method is the shortage of the surface structure as it has significant impact on physical properties and surface chemistry of nanomaterials. In addition, this method also causes substantial crystallographic loss to the processed shapes[9].

2.5.2 Production of Nanomaterials by Bottom-Up Method:

In this method, materials are prepared by atom-by-atom or molecule-by molecule to make large amount of materials. This method is more frequently used for producing most of the nanomaterials.

This method has an ability to produce a uniform size, shape, and well- distributed nanomaterials. It basically controls the chemical synthesis process in a 13 precisely manner to prevent undesirable particle growth. This method plays an important role in the production and processing of nanomaterials with better particle size distribution and better morphology. Another important feature is that its an environment friendly and economical processes for the nanoparticle production[10].There are many approaches for synthesizing nanomaterials like hydrothermal, combustion synthesis, gas-phase methods, microwave synthesis, and sol-gel processing[11] ,which we have described below.

2.5.2.1 Hydrothermal Method :

The hydrothermal method is normally done in a pressurized container which is called as an "Autoclave" where temperature and pressure can be controlled and regulated. During nanomaterial synthesis, the temperature can be increased at the boiling point of water, which allows the vapor to get saturated. This method (Figure 2.2) has been extensively used in the production of different nanoparticles[12],The advantage of this method is that this can be useful to control material size, particle morphology, crystalline phase, and surface chemistry through regulation of the reaction temperature, pressure, solvent properties, solution composition, and additives[13].

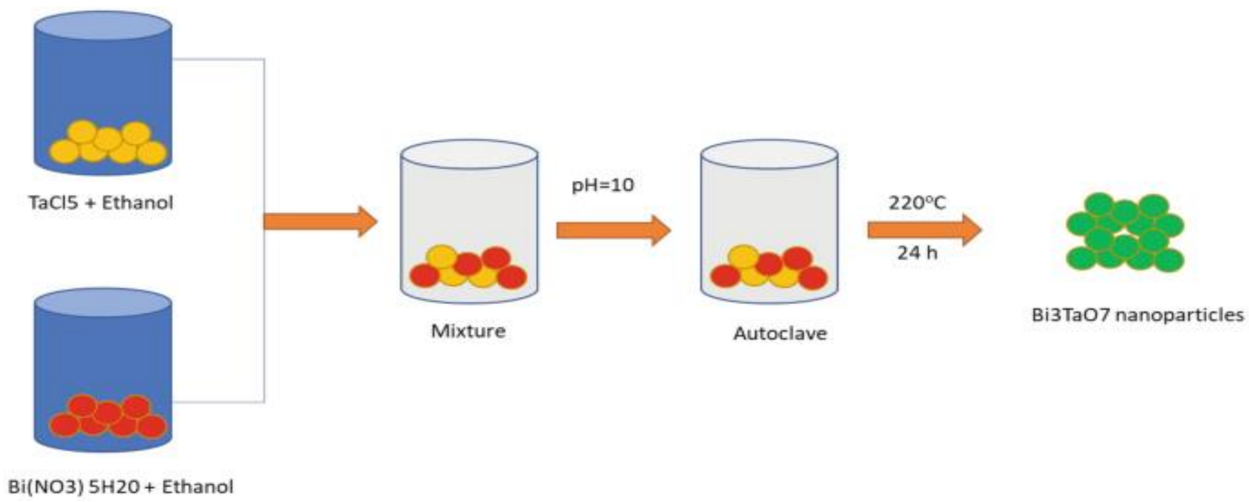

Figure 2.5 : Diagrammatic representation of hydrothermal process nanoparticle production[12]

2.5.2.2 Solvothermal Method :

The solvothermal method (Figur 2.3) is like hydrothermal method, the only difference is that it uses different solvents other than water. Interestingly, this method is more effective in synthesis of nanomaterials with good distribution, especially when organic solvents or chemicals with high boiling points are selected. Moreover, this method provides better controlling method to produce better size and shapes of the materials than the hydrothermal method. This method synthetizes nanomaterials or nanorods with or without the addition of surfactants[14].

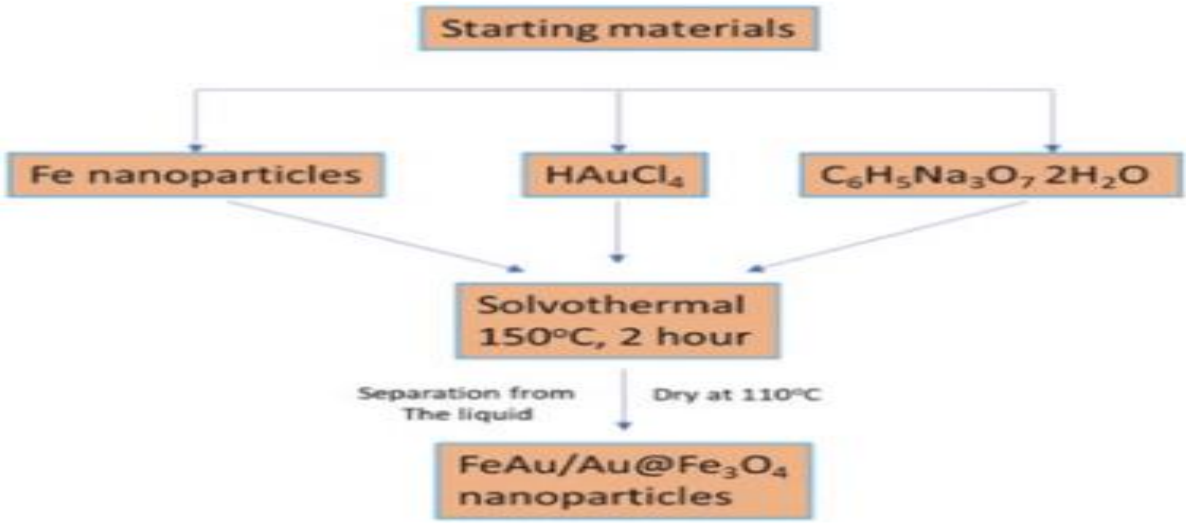

Figure 2.6: Diagrammatic representation of solvothermal process of nanoparticle production[14] .

2.5.2.3 Chemical Vapor Deposition Method :

The chemical vapor deposition (CVD) method is used to manufacture high performance thin nano-films. In this method, substrate is basically treated with volatile precursors which act on the substrate surface to produce the desirable films. Usually, volatile by-products are eliminated by gas flow through the reaction chamber. The quality of the deposited materials on the surface is greatly dependent on several factors like temperature, rate of reaction, and the amount of the precursors[15]. It has been reported that Sn4+doped TiO2 nanoparticle films were produced by CVD method[16]. Another doped TiO2 nanoparticle was synthesized by CVD method where TiO2 is crystallized into the rutile structures depending on the type and number of cations present in the chemical reactions. The advantage of this method is getting consistent glaze of the nano film, but this method has many limitations including higher temperatures required for chemical reactions, and secondly it is difficult to scale up[17] .

2.5.2.4 Method of Thermal Decomposition and Pulsed Laser Ablation:

The doped metals can be produced by using decomposing metal alkoxides, salts, heat or electricity. Moreover, the properties of nanomaterials strongly depend on the flow rate of the precursor's concentrations in the reactions and its environment. It has been reported that TiO2 nanoparticles with a diameter < 30 nm can be synthetized by using the thermal decomposition of titanium alkoxide at 1200°Celsius temperature[18]. In another study, TiO2 nanoparticles with a diameter (3–8 nm) were produced by pulsed laser ablation technique[19] . In addition, doped anatase TiO2 nanoparticles were produced by the solution combustion method[20] . Nevertheless, the disadvantages of this method are the high cost, low yield, and difficulty in managing the structure and morphology of the nanomaterials.

2.5.2.5 Templating Method :

The process to construct materials with a similar morphology is known as templating method. The production of nanomaterials which uses the templating method has become exceptionally popular recently. These 16 methods use the morphological characteristics with reactive deposition, so it is possible to prepare numerous new materials with a regular and controlled morphology by simply changing the morphology of the template materials. Over the past few years, a variety of templates have been developed to synthesize different nanomaterials [21]. This method has some shortcomings, like complicated synthetic procedures where templates must be removed, normally by calcination technique, which causes an increase in the manufacturing costs and also chances of contamination.

2.5.2.6 Combustion Method :

The combustion method includes a quick heating of a solution comprising redox groups. This method leads to production of highly crystalline nanoparticles with large surface areas. During production, the temperature reaches to roughly 650°Celisus for 1–2 min to make the crystalline materials[22]

2.5.2.7 Gas Phase Method :

This method is good to produce thin film because it can be performed chemically or physically. Nanomaterials are formed because of chemical reaction or decomposition of a precursor in the gas phase[23] . Moreover, physical vapor deposition (PVD) is another technique which can be used to produce thin film deposition. Interestingly, films are formed from the gas phase method without using chemical transition. To produce TiO2 thin films, a beam of electrons heats the TiO2 material and the electrons are produced and this process is recognized as Electron beam (E-beam) evaporation. There are many benefits of making of TiO2 deposited with E-beam evaporation than CVD method such as smoothness and better conductivity[24].

2.5.2.8 Microwave Radiation Method:

Nanomaterials can also be produced by using microwave radiation and there are several benefits of this method, like this method does not use high temperature calcination for extended period of time and also is a quick method of making crystalline nanomaterials. Moreover, high quality of rutile rods can be created by joining hydrothermal and microwave methods, while TiO2 hollow open- ended nanotubes can be manufactured through reacting anatase and rutile crystals in the NaOH solution[25].

2.5.2.9 Conventional Sol-Gel Method :

This method has numerous advantages, for example, this method allows impregnation or co-precipitation of nanomaterials, which can be used to introduce dopants. To synthesize various oxide materials, sol-gel method has been used, and this method allows better control for the texture formation, the chemical reaction, and the morphological properties of the solid materials. The major benefit of the Sol-Gel technique is the ability to scale up with a high purity of nanomaterials. In Sol-Gel technique process, a colloidal suspension is formed from the hydrolysis and polymerization reactions of the precursors. These precursors are usually inorganic metal salts or metal organic compounds. In addition, any factor that effects either or both reactions are likely to impact the properties of the gel formation and these factors are generally described as Sol-Gel technique factors. These factors include type of solvent, water content, acid or base content, and different type of precursor, precursor concentration, and temperature. These factors affect the structure of the initial gel formation. After this step, the wet gel can be mature in another solvent. The time between the formation of a gel and its drying is known as aging [26] .

Conclusions :

At the end of this research, we conclude that nanotechnology is one of the most important technologies today and in the future and has become at the forefront of the most important fields in all fields of science, because of its importance in improving products, treating diseases and serving humanity in all areas of life, in addition to giving great hope for future scientific revolutions in physics, chemistry, biology, engineering and others.

Therefore, we must work to take advantage of the distinctive properties of nanomaterials to create innovations and inventions that benefit humanity in the fields of peace, accelerate and facilitate life, in addition to getting rid of malignant diseases for which science today has not reached a radical treatment, and many other services.

Since nanotechnology is the focus of science today, we hope that interest in it will increase in Algeria, and that our country will become one of the most sought-after countries in researching this technology and its novelties so that we can catch up with science and unleash the scientific energies and minds in the country to prove their worth and competence.

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Absract

Nanotechnology is a branch of science and engineering that deals with the design, production, and application of materials, devices, and systems by controlling the structure at the nanoscale (from 1 to 100 nanometers). This technology relies on exploiting the unique properties of materials at this scale, where the physical and chemical properties of a material change significantly compared to its larger size. And Nanomaterials are materials designed or manufactured so that their dimensions are in the nanometer range, resulting in new properties that differ from those of bulk materials. Types of nanomaterials include:
1. Nanocarbon: Such as carbon nanotubes and nanodiamonds, which are extremely strong and have unique electrical properties.2. Nanometals: Such as gold and silver nanoparticles, which exhibit unique properties when interacting with light.3. Nanocomposites: Such as zinc oxide or titanium dioxide nanoparticles, used in medical and environmental applications. Nanotechnology has many applications in various fields, such as: Medicine: By improving diagnostic and therapeutic techniques, such as drug delivery systems targeting specific cells using nanoparticles. Environment: In water treatment or pollution removal using nanomaterials. Electronics: Enhancing the performance of electronic devices, such as flexible displays or high-capacity memory. nanotechnology is a promising technology that will likely transform many aspects of daily life in the future

ملخص

تكنولوجيا النانو هي فرع من فروع العلوم والهندسة التي تتعامل مع تصميم، إنتاج، وتطبيق المواد، الأجهزة، والأنظمة عن طريق التحكم في البنية على مقياس النانو (من 1 إلى 100 نانومتر). هذه التقنية تعتمد على استغلال الخواص الفريدة للمواد على هذا المقياس، حيث تتغير الخصائص الفيزيائية والكيميائية للمادة بشكل كبير مقارنةً بحجمها الكبير.والمواد النانوية هي مواد يتم تصميمها أو تصنيعها بحيث تكون أبعادها في نطاق النانو، مما يؤدي إلى ظهور خواص جديدة تختلف عن الخواص التقليدية للمواد عند أحجام أكبر. ومن انواع المواد النانوية. 1. النانوكربون: مثل الأنابيب النانوية والكربون النانوي، وهي مواد قوية جدًا ولها خصائص كهربائية فريدة. 2. النانوالمعادن: مثل الذهب والفضة النانوية التي تظهر خصائص فريدة في التفاعل مع الضوء. 3. النانوالمركبات: مثل أكسيد الزنك أو أكسيد التيتانيوم النانوي، والتي تستخدم في التطبيقات الطبية والبيئية. تكنولوجيا النانو لها العديد من التطبيقات في مجالات متعددة مثل: الطب: من خلال تحسين تقنيات التشخيص والعلاج، مثل الأدوية التي يتم توجيهها إلى خلايا معينة باستخدام الجسيمات النانوية. البيئة: في معالجة المياه أو إزالة الملوثات باستخدام مواد نانوية. الإلكترونيات: تحسين أداء الأجهزة الإلكترونية مثل الشاشات المرنة أو الذاكرات ذات السعة الكبيرة. تكنولوجيا النانو تعد من التقنيات الواعدة التي ستغير العديد من جوانب الحياة اليومية في المستقبل