NTU JOURNAL OF PURE SCIENCES
EISSN: 2789-1097

RESEARCH ARTICLE
Open Access

Nanotechnology; the science of present and future (principle and applications)

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Received: 20-06-2022, **Accepted:** 17-07-2022, **Published online:** 20-09-2022

Abstract. Nanotechnology acts as a means to combine different branches of sciences: medicine, pharmacy, engineering, biology, chemistry, agriculture, water desalination, energy storage, production, and conversion. They are optimal and most important use of nanotechnology as the production of solar cells and hydrogen fuel cells to reduce environmental pollution and diversity sources of energy consumption. The interest in studying nanomaterials and metallic particles is increasing, for instance gold and silver nanoparticles due to their mechanical, optical, electronic, magnetic, and high electrical conductivity properties .As well as, the chemical properties and the large surface area regarding to the large size of the same material, leads to an increase in its toxic properties, when collected in huge numbers on the surfaces of cells, consequently to inhibit and kill pathogenic organisms such as viruses, bacteria, and fungi. Manufacture of nanomaterials that use some plants (biosynthesis) to reduce their hazards to the humans and environment and reduce the costs of extracting process which is called a green synthesis.

Keywords: Natotechnology, Nanomaterials, Solar cells.

Introduction

The word 'Nano' came from the Greek word Nanos, which means dwarf, from which came the nanometer, which is a very small unit of measurement equivalent to one billionth of a meter (measures 3 carbon atoms lined up together. Nanotechnology it is the science concerned with study the processing of matter on atomic and molecular scale, and is concerned with properties of electromagnetic and optical materials that change depending on atomic and molecular assembly as well as a decrease in the melting point of the substance when it becomes nanoscale. Nanotechnology is a technology of tiny particles, it is a modern technology that deals with materials, whether they are atoms or molecules, with dimensions not exceeding 100 nanometers (1-100nanometers) [1]. Nowadays, Nano materials with high performance properties are used in large quantities due to their inexpensiveness and clarity, plus their products takes short time to be produced [2].

Nanotechnology was first to be used by the Greeks in the manufacture of glass (the glass vessel of king Lycurgus) in the fourth century BC, It can be seen in the British Museum . The vessel contains nanoparticles of gold and silver, which change from green to red when its exposed to light. The Romans used to dye their hair white to keep it for a long time, its secret was known by researchers from France and Germany, which was a paste of (4-15 nanometers) Nano – lead oxides. In the middle ages they used to introduce gold in glass melting furnaces to obtain glass containing spherical gold nanoparticles, many damascene swords in the Islamic era was known for their hardness and flexibility at the same time as they were made of special steel that has been strengthened with carbon nanotubes [3] .

In the 20th century, the physicist Richard Feynman was the first to discuss and clarify the concepts of possibility of dealing with single small particles in 1959, then in 1974 Norio Taniguchi of Tokyo University of science used the term nanotechnology for the first time when he explained the processes of separating, combining, and reshaping materials into a single particle. [4]. Eric Drexler shed the light on the importance of nanotechnology and the development of nanoscience with the emergence of molecules assembling science,

and discovery of the Scanning Tunneling Microscope (STM), the atomic microscope, and discovery of fullerenes in 1985. In 1990 Schweizer and Eigler were able to confirm that processing particles by STM is possible using Xenon atoms, thus nanotechnology grew in advanced industry with a budget of billions of dollars [2][1].

Nanophysics

Nanophysics occupy an intermediate position in the study of the scales of quantum mechanics and modern (microscopic) physics that are governed by Newton and Einstein's laws. Nanoscience is such a broad science that scientists divided it into:

1-Nanoscience
2-Nanofluidics
3- Nanoscience of Optics
4- Science of magnetic Nano
5-Science of electron nanotubes
6-Science of quantum transport
7-Nanoelectronics
8-Science of Nano magnetism and electrons rotational nanophysics

The last has contributed to the invention of self-cleaning glass, antibacterial socks, the delivery of drugs to the targeted areas within the body with high accuracy, and a solution for excessive eating by making the stomach fill with small amounts of food [5][6].

Shapes of nanomaterials

They are divided according to several types depending on size, shape, physical, chemical, and mechanical properties into:

1-Nanospheres
2-Nanotubes
3-Nanofibers
4-Nanowires
5-Nanocomposites
6- Nanoparticles [7][6].

Composition of nanomaterials:

1- Materials with an inorganic base including: fullerenes, quantum dots, and gold nanoparticles
2-Materials with an organic base including: dendrimers, liposomes, and polymeric
3-Materials with a carbon base
4-Composite materials
[8][9]

Properties of nanomaterials:

Compounds of Nano-sized particles are much stronger than their constituents in larger size, with the same material produced in the largest area (by nanotechnology), which leads to these materials becoming chemically effective and increases their strength and electrical properties in a positive way. Sometimes the inert materials in a large space may get activated when they are placed in a small space that is when the particles that makes up the materials are small, a very large proportion of the atoms are present on the surface compared to those on the inside. 5% of the particles that have a size of 30 nm are present on the surface, 20% of the particles with 10 nm of size are present on the surface, and 50% of the 3nm particles are

present on the surface, and since chemical reactions occurs at the surface, nanomaterials are more active than their constituent materials in the larger space because they are more likely present at the surface [6][10].

Mechanical properties

The benefits are from reducing the size of the particles of the materials and the presence of their atoms in huge numbers on the surfaces increases the degree of hardness of metallic materials and their alloys. Thus increase their weight lifting and resistance stress. Ceramic materials have been given a great deal of strength and ability to bear stresses that were not capable of withstanding before, and this means the creation of new items of these materials [11][5] .

Chemical activity

The greater the number of atoms on outer surfaces of materials, the greater their chemical reactivity as they act as stimulants that react vigorously with toxic gasses, which then filters the toxic gases and play the most important role in reducing environmental pollution. Fuel cells are one of the low-cost applications of Nano catalysis, and it is one of the most important sources of new and clean energy [12]

Physical properties

The values of melting point of the material are affected by the reduction in dimensions of its grains. Melting point of gold in its natural size reaches 1064 degrees, decreases to 500 degrees after reducing its grains to about 1.35 nanometers [13].

Magnetic properties:

The smaller the grains of materials and the greater the presence of atoms on their outer surfaces the greater the strength and effectiveness of its magnetic power, this enables us to use it in large electric generators, ship engines, magnetic resonance imaging, and the manufacture of ultra-high-resolution analyzers. Those of a size less than 100 nanometers has an increased electric current conducting ability, [11][14].

Biological properties:

Doubling the possibility of penetrating biological membranes and improving biocompatibility to facilitate the delivery of therapeutic drugs to the affected part with high concentrations [15][16].

Methods of preparing nanomaterials

Physical methods

Starting from vapor state of material by heating the material or by bombarding it with a beam of electrons or by thermally dissolving it using laser beams, then the vapor is cooled by striking it with a neutral gas to become more saturated, and then it’s placed on a cold surface quickly to avoid crystals building up. Nanomaterials are then prepared using waves, lasers, and PVD [6][5].

Chemical methods

The vapor of materials to be prepared enters the CVD reactor, and the particles are mix on a substrate surface at a certain temperature, then they react with other gases to form a solid tape on the surface of the substrate. This method is used to prepare Nano materials like sweaters [17][18].

Mechanical composition:

1. The mechanical compaction stage and the metal powder dissolving stage so that we can form it the way we desire after cooling.
2. Grinding method: this methods is used to obtain powder from nanomaterials in which the basic material is exposed to very high energy, and then grinded.
3. Electrochemical method: by placing a silicon chip at the positive electrode and a polycarbonate sheet at the negative electrode in a chemical solution, and exposing the slides to an electric current.
4. Laser extraction method: by exposing the material to a pulse of very high energetic laser beam, so that the laser beam interacts with the target leading to the volatilization of particles of the material and the formation of plasma base that forms thin films of the particles.
5. The method of deflection: by exposing the materials to a very low pressure [10][3].

Biological methods:

The physical and chemical methods which is used in the manufacture of nanoparticles requires long time, solvents, and dangerous materials to humans and environment. These materials are difficult to dispose of later and require a high source of energy. Compared to biological methods which are more productive, cheaper, simpler, faster, safer, environmentally friendly, do not require high energy and depend on the metabolism of living microscopic organisms such as (bacteria, molds, fungi, yeasts, and algae), as well as plant extracts [19][16].

Microbes can resist, survive, and grow in presence of high concentrations of metal ions, depending on the incubation conditions, including temperature, acidity and nature of medium in which bacteria live and grow, as well as negative charge of cell wall of microbes, which reacts electrically to positive charge of metal ions. [20][21]**.**

As for cell wall enzymes, they work to reduce metal ions to be converted into circular, oval, helical, rod lamellar, triangular, or quaternary particle and nanoparticles, as for plants and their extracts they are considered as reducing agents when preparing nanoparticles such as gold and silver nanoparticles in the so called (green chemical pathway) for making nanomaterials fast and easy. This reaction does not require high temperature and pressure it's done at a lower cost in a relatively short time, with out using and production of toxic and harmful substances. It provides a better treatment, in which the shape, size, growth, and stability for nanocrystals are controlled, as well as the it ensures the purity of the product [22][14].

Diagnosis: Nano materials

Various techniques and equipment were used such as:

1. UV and visible spectroscopy
2. Infrared spectroscopy
3. X- ray diffraction spectroscopy
4. Aerosol technique
5. Ultrasonic wave
6. Electron microscopes including atomic force microscopy (AFM)
7. Transmission electron microscope (TEM)
8. Scanning electron microscope (SEM)
9. Electron microscopy provides information on dimensions of nanoparticle, alignment, gives the precise minute dimensions, and provides a clear image of the matter in a three-dimensional figure, it depends on the electrons that bounce off the surface of the samples and appear on the display screen. [1][2]

Mechanism of nanoparticles effect on antimicrobial resistance:

There are several mechanisms including:

1- Adherence to the cell wall and damaging it to change the transport activity across the cell well.
2- When it penetrates the microbial cell, it interacts with cellular organelles and biomolecules to affect their functions, by releasing ions that binds with thiol (-SH) groups (which are involved in the synthesis of the amino acids) to form a stable bond that inhibits enzymes synthesis.
3- Damages microbial DNA by binding with purine and pyrimidine bases and breaking the hydrogen bond between these opposite nitrogenous bases in DNA strands.
4- Undoing the double helix twisting and causing denaturation in the DNA.
5- Participates in the formation of reactive oxygen inside the cell causing cell damage.
6- Causes interaction between positive ions of nanoparticles with sulfur-containing proteins present in microbial cell wall in a non- reversible way leading to the inhibition of their function
7- Activating process: of oxidative stress by releasing free radicals that attack cell membranes and disrupt their permeability causing cell death.
8- Addition of nanoparticles: as the addition of silver particles to antibiotics that leads to a synergistic effect against microbes to resist and inhibit them.
[12][7][15][16][23]

Advantages of metallic nanoparticles

1- large surface energy, compared to traditional material due to its large surface area compared to size.
2- Quantitative confinement
3- Plasmon excitation
4- Increases numbers of defects
5- Improves bioavailability by enhancing aqueous solubility
6- Increases resistance time (increases half- life), increases specificity for its cognate receptors
7- Targeting of drugs to specific locations in the body (location of action)
8- Protection from toxicity
9- Enhancement of pharmacological activity
10- Enhancement of stability of materials
11- Sustainable delivery
12- Decrease side effect of conventional drugs
13- Improves tissues macrophage distribution
14- Enhancement of permeability (through blood brain barrier)
15- Improves therapeutic effects of drugs
16- Increases tolerability
17- Protection from chemical, physical, biological degradation
18- Increases dermal penetration and oral bioavailability [11][14]

Disadvantages of metallic nanoparticles

1- They are thermodynamically unstable and subjected to transformation, causing low quality, poor resistance to corrosion, and difficulty in maintaining its shape.
2- It must be wrapped to overcome the impurities, because when it is exposed to pollutions during its production in an impure environment it reacts with the pollutants as it is highly reactive.
3- The exothermic reaction leads to explosions, so it becomes strong explosives.
4- It may cause irritation.
5- Difficulty of installation, difficult to be kept in a solution form.
[14][24]

Nanotechnology applications

1- Improving manufacturing methods and improving food production methods.
2- Making Nano-fabrics that remove odor and moisture, and increases flexibility, strength, resistance to bacteria and water resistance (Hardness), fabrics and leathers also, as in the textile laboratory for nanotechnology clothing at Cornell University.
3- Using silver nanowires to warm clothes and shoes for 8-16 hours in countries with very cold weather.
4- Using polymer nanofibers to perform prosthetic surgeries for blood vessels, treating burns and wounds, manufacturing cosmetics, and manufacturing prosthetic devices of protein nanofibers that are implanted in CNS.
5- Using Nano-fertilizers in plants to:
   a. doubling activity of photosynthesis processes by increasing the content of chlorophyll in leaves
   b. doubling the crops for salinity and thirst
   c. increasing the resistance of crops to diseases
   d. preserving the genetic characteristics required for different agricultural crops.
   e. increases the active substances in plants
   f. packaging traditional fertilizers to accelerate their absorption and increase their efficiency.
   g. soaking seeds in Nano fertilizers improves their germination and increases seeding strength to different conditions
   h. using silica nanoparticles in the preservation of plants to reduce mold infection during storage, transportation and export

   [25][13][9][26][5]

Conclusions:

1. Nanotechnology represents an important way to link the sciences such as physics, chemistry, medicine, biology, and engineering.
2. The storage, production and conversion of energy are the optimal and most important purpose of nanotechnology, as in the production of solar cells and hydrogen fuel cells.
3. Interest is increasing in the study of metallic nanomaterials such as gold and silver nanoparticles because they have electronic, optical, mechanical and magnetic features, as well as chemical properties, high electrical conductivity, and a large surface area compared to the large volume of the same substances.
4. The most efficient physical methods for fabricating nanostructures are laser extraction in liquids, which is an example of manufacturing nanoparticles from top to bottom as It is a quick and simple method.
5. The size and shape of nanoparticles can be controlled by adjusting the laser type, wavelength, number of pulses, and the type of solvent substance. Therefore, replacing an atom of an element with an atom of another element produces various other nanomaterials.
6. The preparation of nanomaterials depends on many factors such as temperature, viscosity, and medium concentration.
7. There are many ways to prepare nanomaterials, such as vacuum deposition, vapor deposition by chemical method, chemical (electrolytic) precipitation and sol-technique gel, electrodeposition and laser extraction.
8. Nanotechnology can control the earth's temperature, make atomic computers in size of a cube of sugar, miniaturize surgical machines, making memory cards using Nano deposition technology, and polymer lithography.
9. The properties of nanomaterials such as conductivity, stability and bacterial resistance have been exploited with a variety of technologies including ceramics, optical filters, ultraviolet rays, optoelectronics and biomedical imaging, and modifying the forms of pesticides to make them more effective, less harmful, and more widespread.
10. The properties of chemical and optical gold particles and their geometry (large surface area exposed to interactions relative to volume) made them used in extensive applications such as in: biology ,medicine, pharmacy, agriculture, engineering, industry, dentistry, sterilization of tools, early detection of diseases and control desertification and pollution, treatment and sterilization water, imaging and treatment cancer and tumors , delivery of medicines to the targeted organ, light therapy and increasing efficiency of energy use, improving food production methods.

11. Gold in volumetric dimensions is an inert element that does not interact, while gold in the Nano from becomes a catalyst to increase the rate of chemical reactions.

The surface to size of Nano- gold is large, allowing the carriage of a large number of drug molecules. the mechanical properties of materials changes when transforming to the Nano-shape as the melting temperature for the transformation of pure gold as a metal form (solid) to liquid (the melting point) is 1064C, but when the diameters of its atoms are reduced and the outer surface area is increased, its melting point decreases to $5ooc^{0}$.

12. Copper nanoparticles, with a size of less than 50 nanometers have high hardness whether they were not ductile or ductile unlike their normal form. as for titanium dioxide, which is bright white, but at nanoscale it is transparent, so transparent sunscreens and light –enhancing coatings for glass are made of Nano titanium because they absorb rays above Violet.
13. The shift is made towards the green nanotechnology path depending on plants and their extracts to reduce production and extraction costs and reduce the risk to humans and the environment.
14. Using AFM, TEM, SEM and fluorescent microscopies had a great success in characterizing gold and silver nanoparticles and documenting crystal forms and polymers.

RECOMMENDATIONS

1- Investigate types of bacteria that produce nanoparticles from different environments
2- Study mechanisms of molecular synthesis of metal nanoparticles
3- Study the environment of hot spring waters and the role of physical and chemical factors in biosynthesis of metal nanoparticles
4- Study the role of different metals for their efficiency in the biosynthesis of gold and silver nanoparticles
5- Increase the exploitation of microorganisms in general and bacteria in particular in the manufacture of metal nanoparticles in researches and applications
6- Use molecular biology techniques for accurate diagnosis of bacterial species that produce nanoparticles

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