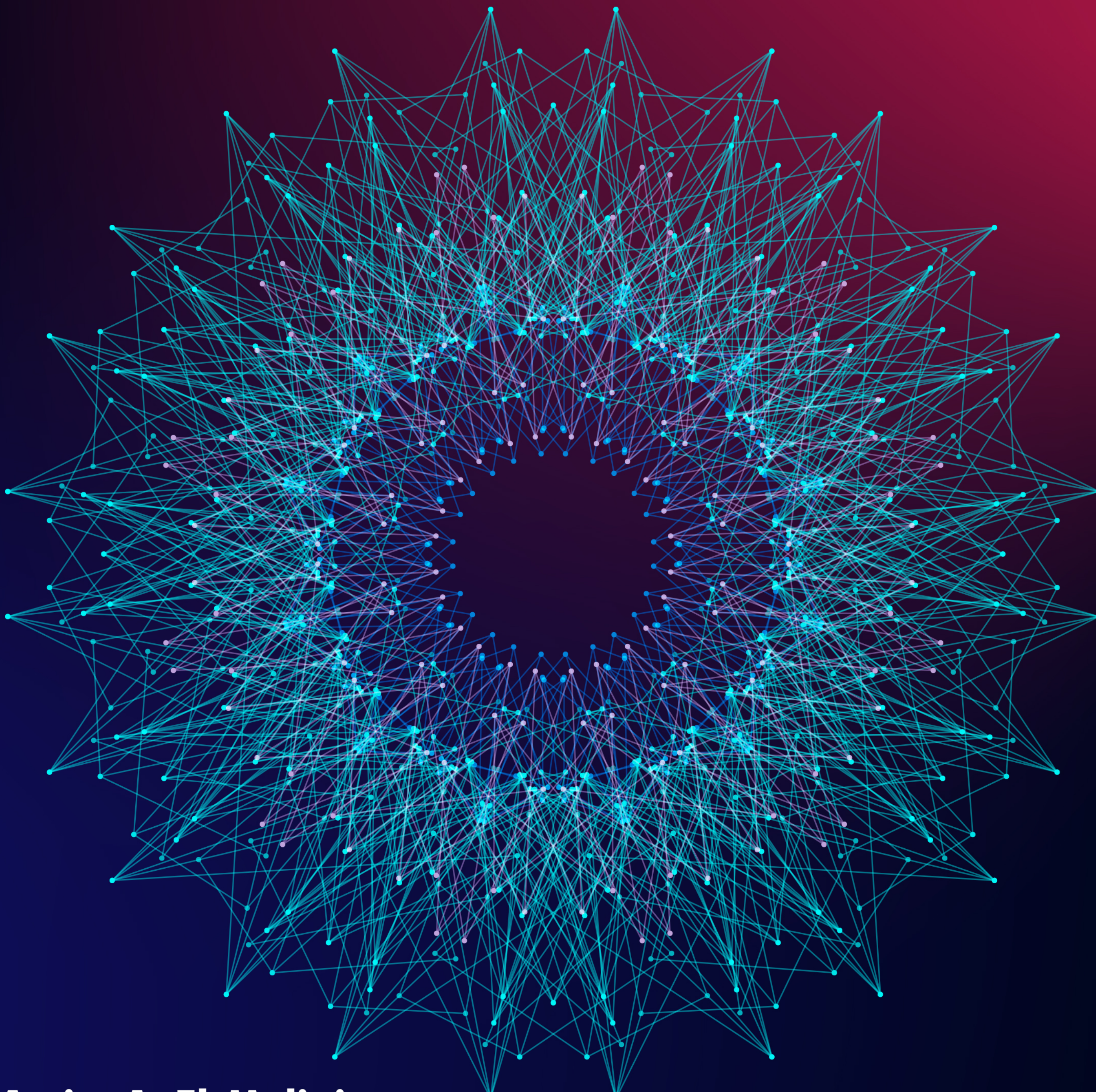
THE ART OF NANOMATERIALS



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The Art of Nanomaterials

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The Art of Nanomaterials

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FOREWORD

"The evolution and widespread use of nanotechnology in many facets of everyday life is a fascinating story. The unique physical and chemical properties of materials at the nanoscale allow them to be utilized in ever-growing new applications. We most likely encounter nanomaterials in our daily life unknowingly. The book by Dr. Amin El-Meligi takes the reader through the history of nanomaterials from their appearance in the arts of the ancients, methods of fabrication, and their current utility in medicine and the environment. The author dedicates a chapter to the use of nanomaterials in medicine and the side effects of their use. Dr. El-Meligi also writes on water treatment by nanomaterials as well as the contamination of the environment by nanomaterials such as nanoplastics. The book concludes with a future look into nanotechnology and how it will transform human life. The book is a good read and a reference for researchers and students alike."

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PREFACE

The evolution of nanotechnology started in the middle of 20^{th} century. As stated, the ideas and concepts behind nanoscience and nanotechnology started with a talk titled “There's Plenty of Room at the Bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used”. Nanotechnology appeared in the art of ancient Egyptian. The beautiful pictures of ancient Egyptians have been discovered with fine, gorgeous blue and other colors. It is important to say that there is an art behind the formation of nanomaterials and their applications in nanotechnology revolution. Nanotechnology applications include many aspects, such as materials protection and environmental protection. Nanomaterials are the backbone of nanotechnological applications. Nanomaterials are characterized by their small grain sizes (1-100 nm) and high volume fraction of grain boundaries, which often give rise to unique physical, chemical and mechanical properties compared with those of their cast counterparts. It can be said that corrosion protection relies on the improvement in the properties of the materials due to nanostructure. Nanomaterials are the basis for nanotechnology. The theme of nanotechnology is the control of matter on an atomic and molecular scale. The application of nanotechnology is confirmed in many fields, such as medicine, cosmetics, lubricants, coats, water purification, environmental protection, and corrosion prevention of metals and alloys. The nanostructures enhance selective oxidation, forming a protective oxide scale with superior substrate adhesion. Nanomedicines have been produced for more efficient healing, nanocosmetics have been developed for highly efficient look, nanolubricants have been developed to increase the efficiency of car parts friction, *etc*. A polymer nanocomposite coating can effectively combine the benefits of organic polymers, such as elasticity and water resistance to that of advanced inorganic materials, such as hardness and permeability. The art of nanomaterials and nanotechnology continues to produce more products for better life, and who knows what will be in the near future. New materials may appear with smaller sizes of atoms than nanosizes such as picomaterials followed by picotechnology. Reaching femto second (10-15 sec) time may support this idea.

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CHAPTER 1

History of Nanomaterials and Nanotechnology

Abstract: The secret of nanomaterials is not the size of the particles, but it is in the applications of nanomaterials and the art of making. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is an amazing field dealing with very small size particles; imagine that a meter of cloth has been cut into a billion pieces (1 meter $=10^9$ nm). Thousands of years ago, the monuments were fabricated and reflected the art and coloures of paints. The Egyptian monuments reflect the beauty and art of paints in the papyrus papers, for example, the ancient pigment known as Egyptian blue may have important new applications in nanotechnology. Lotus flowers were once considered sacred in Egypt and parts of Asia. Significant advances in nanotechnology are helping researchers analyze the type of pigments used to paint mummy portraits in ancient Egypt. Scientists at Boise State University led by a Materials Science and Engineering Professor Darryl Butt, have taken a sliver of wood smaller than a human hair and extracted five extraordinarily tiny fragments—about 20 nanometers wide—and two thin foils of purple paint from a Romano-Egyptian mummy portrait dating to between A.D. 170 and 180. There is a new challenge facing the world, especially in the field of nanotechnology. It was stated by James Canton (2001) that if Nanotechnology, the manipulation of matter at the atomic level, at maturity achieves even a fraction of its promise, it will force the reassessment of global markets and Economies and industries on a scale never experienced before in human history. Nanotechnology will be discussed from all aspects of economics such as wages, employment, purchasing, pricing, capital, exchange rates, currencies, markets, supply and demand. Nanotechnology may well drive economic prosperity or at the least be an enabling factor in shaping productivity and global competitiveness.

Keywords: Ancient Egyptian, History of Nanomaterials, Nanotechnology, Nanotechnology and Economy, Romano-Egyptian Mummy.

INTRODUCTION

The story of nanotechnology started in the middle of the twentieth century, as stated: the ideas and concepts behind nanoscience and nanotechnology started with a talk titled “There's Plenty of Room at the Bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechno-

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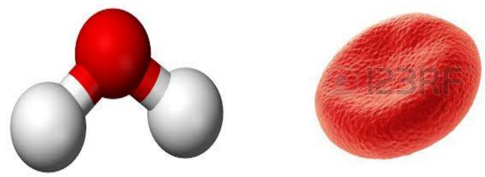
logy was used [1]. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is an amazing and very small size; imagine that a meter of cloth has been cut into a billion pieces (1 meter $=10^9$ nm). We can imagine a number of common materials when they are in a nanosize, for example, a water molecule (H_2O) is 0.3 nm across, 10 hydrogen atoms lined up is measured at about 1 nm, a grain of sand is 1 million nm, a red blood cell is nearly 7,000 nm wide, and DNA molecules are 2.5 nm wide, as shown in Fig. (**1**) [2].



(a) Water molecule (b) Red blood cell

Fig. (1). (a) Source: http://en.wikipedia.org, **(b)** Source: http://www.123rf.com [2].

Feynman said People tell me about miniaturization, and how far it is progressed today. They tell me about the electric motors that are the size of the nail in your small finger. And there is a device in the market, they tell me by which, you can write Lord's Prayer on the head of a pin. But that is nothing; that's the most primitive, halting step in the direction I intend to discuss. It is a staggeringly small world that is below. In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that began seriously to move in this direction. Why cannot we write the entire 24 volume of Encyclopedia Britannica on the head of a pin [1].

Nanoscience and nanotechnology involve the ability to follow and control individual atoms and molecules. Food, clothes, buildings, homes, and our bodies are made of atoms. About 30 years ago, the nanotechnology era emerged . As stated by Ashby *et al*., Imagine dissociating a human body into its most fundamental building blocks. We would collect a considerable portion of gases, namely hydrogen, oxygen, and nitrogen; sizable amounts of carbon and calcium; small fractions of several metals such as iron, magnesium, and zinc; and tiny levels of many other chemical elements. The total cost of these materials would be less than the cost of a good pair of shoes. Are we humans worth so little? Obviously not, mainly because it is the arrangement of these elements and the way they are assembled that allow human beings to eat, talk, think, and reproduce. In this context, we could ask ourselves: What if we could follow nature and build whatever we want, atom by atom and/or molecule by molecule? [3].

As presented in Wikipedia "The emergence of nanotechnology in the 1980s was caused by the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985, with the elucidation and popularization of a conceptual framework for the goals of nanotechnology beginning with the 1986 publication of the book Engines of Creation" [4].

Art of Nanosize

The formation of nanosizes is an art. (Fig. **2**) represents that "medieval stained-glass windows are an example of how nanotechnology was used in the pre-modern era" [4]. Nanomaterials have outstanding mechanical and physical properties due to their fine grain size and high grain boundary [5]. It is stated that Nanotechnology is extremely diverse, ranging from novel extensions of conventional device physics, to completely new approaches based upon molecular self-assembly, to developing new materials with dimensions on the nanoscale, even to speculation on whether we can directly control matter on the atomic scale) [6 - 8].

Fig. (2). Medieval stained-glass windows show the application of nanotechnology in the pre-modern era. (Courtesy: NanoBioNet) [4].

In 2009, Japan's National Institute of Industrial Science and Advanced Technology reported the manufacture of a nanometer-sized "diamond ruler" [9]. The art of nanosize has reached the minimum-scale 0.2 nm by utilization of the crystal structure of diamond.

CHAPTER 2

Nanotechnology and Health

Abstract: Nanomedicine is a reality nowadays. The first generation nanomedical capabilities, in the form of functionalized nanoparticles, comprising a wide range of organic and inorganic materials at various nanoscale dimensions, initially emerged in the early 1990s, and have since undergone dramatically rapid expansion. Nanomedicine is one of the important applications of nanotechnology. The development of smaller, less invasive, smarter, more precise, and more efficient medical devices is a fast-expanding global trend. The creation of specialized nanoparticles for use in medicine, such as magnetic nanoparticles and gold nanoshells, is advancing daily. This development is happening while nanomedicine is still in its early stages. As reported, superparamagnetic iron oxide nanoparticles are being used to specifically target and thermally destroy cancer cells without causing collateral damage to surrounding healthy cells and tissues.

Keywords: COVID19, Drug delivery, Medical Nanobot, Nanomedicine, Nanotechnology and Health.

INTRODUCTION

Nanomedicine has been considered one of the possibilities since, Richard Feynman first introduced the concept of nanotechnology in 1959, in his famous talk at Caltech, “There’s Plenty of Room at the Bottom” [1, 2].

Feynman mentions that one of his friends: “(Albert R. Hibbs) suggests a very interesting possibility for relatively small machines”. Surgery would be exciting if the surgeon could be placed inside the patient's body to perform the surgery, despite the fact that it is a novel and surprising concept. When the mechanical surgeon is positioned inside the blood vessel, enter into the heart, and takes a “look” inside of the organ. (The information must, of course, be fed into it). It detects any valve that has a problem and treats it. Other small machines may be permanently integrated into the body to help some organs that are not working well enough [1, 3]. It is mentioned that despite the emergence of nanoparticles in relation to biomedicine in the late seventies, thousands of research papers have been published in the field of nanomedicine, and the term “nanomedicine” appeared only at the beginning of the twenty-first century. Thirty scientific papers were published in the field of nanomedicine. As reported, the published research

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on nanomedicine has increased significantly until the number of publications reached more than ten thousand in 2015 [4].

In another development in nanomedicine, the idea of repairing cells using certain machines was put forward, and this development can contribute to repairing damaged DNA, organelles and other cellular structures, and this was done with great accuracy in 1986 [1, 5].

Many books have been published, which show a number of applications of nanomedicine, such as diamond-shaped applications and robotics. As mentioned, a large number of research papers have been published that demonstrate different uses for nanomedicine [1, 6].

The field of nanomedicine first emerged in the early 1990s and consists of numerous organic and inorganic materials with various nanoscale dimensions. These nanoparticles are the first of their age to have applications in medicine. These nanomaterials with medicinal capabilities represent the first generation in this important field [1].

Nanomedicine Applications

Nanotechnology affects many areas and has many applications. The transition from macroscale to nanoscale particle size has had an impact on the material characteristics. This is because “nanomaterials” have substantially larger surface areas, making a far larger amount of their chemical composition available for particular interactivity with their environments. For example, nanocatalysts can be doubly more active than their bulk counterparts because they have a very large number of accessible active sites for catalytic reactions. There are many nanoproducts on the market, and the number of these products has reached more than 1,600 nanoproducts. Many essential items we use every day are made of nanomaterials, including glass, highly hydrophobic bathroom tiles, cosmetics, food goods, auto paints, auto lubricants, and carbon nanotube-reinforced car tyres [6].

The following is passage shows how the European Science Foundation defines nanomedicine: “Nanomedicine uses nano-sized tools for the diagnosis, prevention and treatment of disease and to gain increased understanding of the complex underlying patho-physiology of diseases. The ultimate goal is to improve quality of life” [3, 6].

There are many applications of nanotechnology, one of the most important of these applications is nanomedicine. It is important to note that there is a global trend to develop medical nanotechnology to be more effective.

Medical nanomaterials have become more specialized, for example, gold nanoparticles can target cancer cells directly only without affecting healthy cells in the body. This indicates the important and continuous development in the use of medical nanotechnology to treat diseases in its specific place [4, 5]. In addition to the gold nanoparticles discussed earlier, other nanomedicines, such as liposomes and polymeric nanoparticles, can carry pharmaceuticals to infected cells, particularly cancer cells. The resolution of medical images can be improved by using nanoparticles for some materials such as carbon nanotubes and magnetic nanoparticles [4, 5].

Effect of Nanomaterials on Health

Nanomaterials have a significant impact on health. Many nanoparticles exist, including precious metals like gold and silver. Cancer cells are affected by gold atoms, especially after surgery. It was found that gold atoms were able to detect and kill cancer cells [4, 5, 7].

As mentioned, "clusters of gold atoms can detect and kill cancer cells commonly left behind after tumor-removal surgery, according to a study of a new nanotechnology technique". This application has been tested in a few mice. The researchers are designing a clinical trial that could begin testing the treatment in humans. [7]. To stop the patient's body from developing new tumour cells, surgeons must carefully remove all infected cells. To remove any cancer cells that may have persisted after surgery, it must be followed up with chemotherapy or radiotherapy.

Gold nanoparticles are effectively used in the treatment and diagnostic process. The active use of gold is due to its biocompatibility. In reality, the basis for using any substance in medical treatment is biocompatibility. Additionally, due to their high delivery efficiency, gold nanoparticles can be used in drug delivery applications [8].

The researchers administered the extract of Euphrasia Officinalis to test the anti-inflammatory effects of gold nanoparticles (EO-AuNPs) and an extract of the conventional folk remedy Euphrasia Officinalis on lipopolysaccharide (LPS)-stimulated RAW 264.7 macrophages. The results confirmed the successful synthesis of AuNPs by E. officinalis.

Transmission electron microscopy images showed obvious uptake of EO-AuNPs and internalization into intracellular membrane-bound compartments, resembling endosomes and lysosomes by RAW 264.7 cells [9]. Cell viability assays showed that EO-AuNPs exhibited little cytotoxicity in RAW 264.7 cells at 100 µg/mL concentration after 24 hours. EO-AuNPs significantly suppressed the LPS-

CHAPTER 3

Future of Nanomedicine

Abstract: There is no doubt that nanomedicine has a bright future and that it is being produced with increasing efficiency. It should be mentioned that the immune system is being improved by nanomedicine, and drug resistance can be managed since bacteria and viruses will be destroyed using a variety of techniques, including mechanical and thermal methods. This is done by continuous monitoring of the immune system. It will also benefit the technological development of nanomedicine in astronaut clothing. Spacecraft will contain a nanomedicine spacesuit to provide effective treatment to astronauts. Technological development, especially in the field of artificial intelligence, will be used to maximize nanomedicine use.

Keywords: Artificial Intelligent and Medicine, Future of Nanomedicine, Nanobot and Complex Surgeries, Nanotechnology and Health.

INTRODUCTION

As expected, nanomedicine will work on common diseases and this proves that nanomedicine is the future. The human body will be protected from all forms of infections. Nanomedicine helps to strengthen the immune system. Bacteria and viruses will be managed by nanomedicine, according to one futuristic vision, as a result of which, drug resistance will be overcome. In addition, nanodevices are expected to be smaller than a typical human body cell size. This expectation will give other advantages of nanomedicine to work efficiently in treating various diseases [1]. As stated, space travel will be easy with the help of nanomedicine. Nanomedicine will make it possible to treat any unforeseen diseases in space and to overcome any emergency. And this is always the case with new inventions.

Recent Research in Nanomedicine

One of the most serious diseases is cancer, and its therapy is still not ideal or very effective. This is a result of the side effects of chemotherapy. Accordingly, there is a need to have efficient medicine with very minimal side effects. Gold is one of the precious metals. Human beings have been using it without any problem from ancient times to the present [2]. Gold nanoparticles have been developed as a drug delivery mediator for a specific cancer drug. The polyethyleneimine coating on gold nanoparticles makes it easier for a specific compound to assemble on the sur-

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face. There is an improvement in treatment due to the synergistic effect of drug and gene delivery together on their individual delivery [3].

Nanotechnology actually offers a big advantage because it improves current drug delivery technologies. This occurs due to the high surface area and passive targeting capabilities of the nanomaterials. Many types of nanomaterials have been studied for drug delivery, photothermal therapy, imaging, tissue engineering, and electroporation [4 - 9].

Wound healing is an important issue especially after surgeries. A new type of multifunctional wound dressing is being developed by combining graphene oxide/copper nanocomposites with chitosan/hyaluronic acid. This manufacturing provides great opportunities for wound repair, especially wounds at risk of infection with bacteria [10]. The combination of the aforementioned materials has acceptable biocompatibility and antimicrobial efficacy both *in vitro* and *in vivo*. Also, this combination accelerates the healing process of wounds, especially of bacteria-infected wounds. The wound healing has improved by using magnetic nanoparticles and exosomes extracted from bone mesenchymal stem cells [11]. In reality, a well-structured integration of cell migration and proliferation, collagen synthesis and deposition, angiogenesis, re-epithelialization, and wound remolding is necessary for skin wound healing. [12, 13].

Drug delivery systems for nanoparticles allow controlled drug release over time, especially for prolonged therapeutic treatments [14]]. In fact, most of the research suggest not to use a single or a few doses with low nanoparticles' concentrations. This research has screened a number of nanoparticles compounds, either polymeric or lipid-based, in a repeated dose toxicity study, to estimate the safety and tissue distribution of promising nanocarriers to be used in the treatment of chronic diseases. The results show that nanoparticles accumulate in different tissues. There was no sign of toxicity or any disease.

Radiotherapy is actually one of the most significant cancer treatments, but it also includes side effects that are common to practically all medications. Due to an X-ray flaw, radiation has a side effect. The shortcoming of X-rays is the high value of the oxygen enhancement ratio [15]. Additional radiotherapy side effects include tardiness, nausea and vomiting, hair loss, and rough skin. Synergistic radiosensitivity could be increased by functionalized nanoparticles of polyethylene glycol composed of metallic elements such as gold (Au) and platinum (Pt). The nanoparticles of Au and Pt exhibited enzyme-mimicking activities by catalyzing the decomposition of endogenous hydrogen peroxide (H_2O_2) to oxygen (O_2) in the solid tumor [15].

The applications and challenges of mesoporous silica nanomaterials in the field of the diagnosis and therapy of Atherosclerosis (AS) have been summarized. The classification, synthesis, formation mechanism, surface modification and functionalization of mesoporous silica nanomaterials, which were closely related to the theranostic effect of AS, have also been included. Mesoporous silica nanoparticles as a nanocarrier for drug delivery have received extensive attention due to their flexible size, high specific surface area, controlled pore volume, high drug loading capacity and excellent biocompatibility [16].

A natural product is a good source of vitamins, minerals, and nutrients. Okra or Abelmoschus esculentus is an important source of natural products. It was reported that the okra flowers could help as extract-mediated silver nanoparticles [17]. The silver nanoparticles showed significant activities *in vitro* tests, especially *in vitro* cytotoxic and antiproliferative tests against cancer cell lines. The antibacterial effect of silver nanoparticles on different types of bacteria was studied. It was observed that the nanoparticles showed a higher level of antibacterial activity, cytotoxicity and apoptosis at minimal concentrations.

Artificial Intelligence and Nanomedicine

The eventual emergence of artificial intelligence (AI) is expected to provide a clear way to recognize the full potential of combinatorial nanomedicine [18 - 27]. This expectation is because of the fact that AI-determined combination parameters can achieve globally optimal therapeutic outcomes independent of complex disease mechanism information.

In fact, the combination medicine strategy could be realized by the industry as an essential way of treating various diseases, such as pulmonary hypertension, cardiovascular disease, diabetes, arthritis, COPD, HIV, tuberculosis, and oncology [28 - 36]. A challenge in the combination medicine strategy is that the synergy of medicine is time-dependent, dose-dependent, and specificity of patients at any given treatment point. The link between AI and nanomedicine in order to continue to improve or maintain the effectiveness of nanomedicine in treating many diseases has become an established fact. This is because nanomedicine is important to treat many diseases [31 - 36]. AI can practically recognize the full potential of nanomedicine, if drug and dosage standards of combinatorial nanomedicine are optimized [21].

Nanomedicine Transformation Using AI

There are two stages to obtaining the highest benefit from nanomedicine. In the first stage, the drug space and dosage should be investigated in order to characterize the drugs and their identical dosages that ensure efficacy and safety.

CHAPTER 4

Nanotechnology and Water

Abstract: The environment is one of the hot issues nowadays because of pollution, global warming, and other issues. The main sources of energy are still non-renewable resources. Therefore, there is a need to solve environmental problems before it is too late to solve them. All living things on earth suffer because of environmental problems. The United Nation works with all countries to control environmental problems to protect the earth. Researchers pay great attention to help solve environmental problems. In addition to traditional methods of research, researchers use advanced technologies such as nanomaterials and nanotechnology. For example, in the near future, researchers will be able to use nanomaterials to extract energy from the air. Recently, attention has been paid to the relationship between nanoparticles and the environment, especially the impact of nanoparticle emission into the atmosphere on human health. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, size, morphology and interaction of nanomaterials.

Keywords: Heavy Metals in Water, Nanotechnology and Water, Nanomaterials and Water Purification, Water and Contamination.

INTRODUCTION

Nanomaterials have special properties that could enable new technologies for microbial control, decontamination, sensing and monitoring, and resource recovery. The special properties of nanomaterials, which are extremely high surface area, high reactivity, and catalytic properties, are expected to greatly enhance the kinetics and efficiency of various chemical and physicochemical processes used in water and wastewater treatment [1]. Accordingly, the size of the system also reduces chemicals and energy consumption.

Aqueous nanoparticles play an important role in the processes that occur in the atmosphere, but so far, researchers have not reached to explain the shifts in the ice and non-liquid equilibrium and the structures that form upon freezing completely. Here we use molecular dynamics simulation with the model of water to examine unparalleled freezing and dissolve the equilibrium of aqueous nanoparticles with a

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radius of R between 1 and 4.7 nanometers and a crystallization ice structure at temperatures between 150 and 200 K, (Fig. **1**) shows ice nucleation and growth [2].

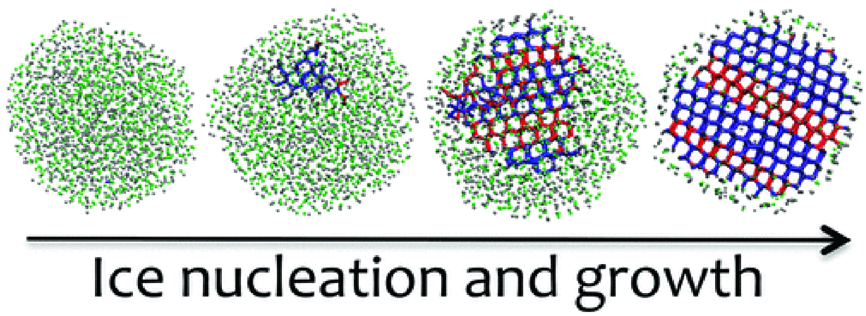

Fig. (1). Water ice nucleation and growth.

Water Purification

Water is essential for life, and all living things on the earth can't survive without water. If there is no pure and clean water, life will be in danger. The purification of water is well known using normal technology, such as chlorination, flocculation boiling and filtration. As mentioned, these water purification steps can reduce 30-40% of diarrheal diseases [3].

Accordingly, nanomaterials can help increase the degree of water purification as many nanomaterials can help through different mechanisms [4]. The mechanisms include removing heavy metals and other pollutants, inactivation of pathogens and removal and transformation of toxic materials into less toxic compounds. The treatment of water is improved by incorporation of nanomaterials in nanostructured catalytic membranes.

Also, some materials such as carbon nantubes, tiania, zero-valent iron, dendrimers (highly ordered, and branched polymeric molecules) and silver nanomaterials, could be used for water purification. In fact, traditional water purification methods are not safe, especially the formation of byproducts of chlorination, which cause various diseases due to carcinogenic disinfection byproducts [5]. Therefore, nanomaterials show many advantages over traditional microstructured materials for water purification [6]. Nanoporous membrane has shown an art in its formation; this can be seen in the nanoporous alumina membrane, which is coated by a large pore size of zinc oxide, as shown in Fig. (**2**) [6]. Also, nanoporous membranes could remove harmful matters in water such as arsenic, nitrates, organic materials, and viruses from groundwater and surface water [7].

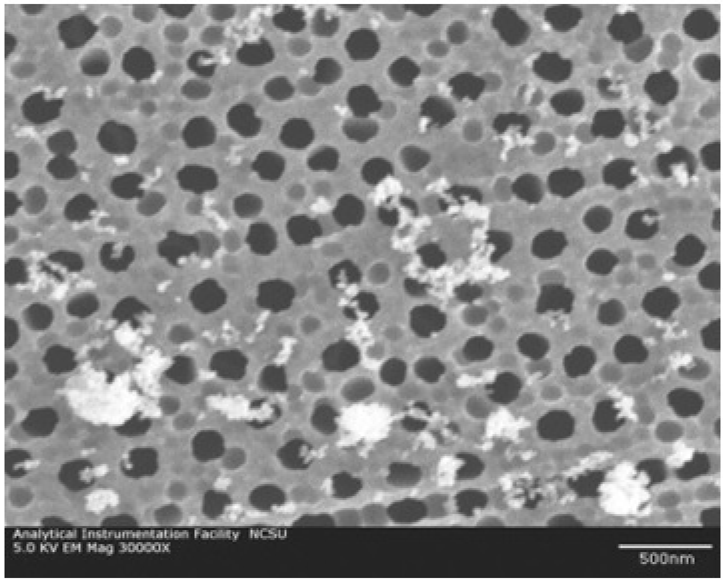

Fig. (2). Plan-view scanning electron micrograph obtained from the large pore side of a zinc oxide-coated 20 nm pore size nanoporous alumina membrane [6].

It was demonstrated that viruses and bacteria could be removed by using a membrane containing carbon nanotubes walls [8]. In fact, there are some defects of the membrane, such as the formation of biofilms on the membrane due to microorganisms in the water. Biofilms affect the permeability of the membrane and increase the cost of water purification [9 - 11]. In addition, water quality may deteriorate due to some microorganisms that may release biological toxins and metabolic products [12, 13]. Therefore, there has been research to address this issue through the use of nano water technologies and of wastewater treatment processes. This includes nanomaterials, such as nanoadsorbents, nanometals, nanomembranes and photocalaysts [14]. (Fig. **2**) shows a scanning electron micrograph of a large pore size of 20 nm ZnO-coated ZnO nanofilm. The usefulness and marketing of these materials have been reported. The arid regions of North Africa and nearly half of the European countries (about 70% of the population) face water shortages. Even industrialized countries such as the United States of America, which provide very innovative technologies for saving and purifying water, show the difficulty of depleting water tanks due to the fact that more water is extracted rather than refilled. In the People's Republic of China, 550 of the 600 largest cities suffer from water shortages, as the largest rivers are highly polluted and their use for irrigation, not to mention drinking water treatment, must be eliminated.

CHAPTER 5

Nanotechnology and the Environment

Abstract: There is no doubt that the environment is one of the hot issues nowadays because of pollution, global warming, and other issues. The main sources of energy are still non-renewable resources. Therefore, there is a need to solve environmental problems before it is too late to solve them. All living things on earth suffer because of environmental problems. The United Nation works with all countries to control environmental problems to protect the earth. Researchers pay great attention to help solve environmental problems. In addition to traditional methods of research, researchers use advanced technologies such as nanomaterials and nanotechnology. For example, in the near future, researchers will be able to use nanomaterials to extract energy from the air. Recently, attention has been paid to the relationship between nanoparticles and the environment, especially the impact of nanoparticle emission into the atmosphere on human health. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, size, morphology and interaction of nanomaterials.

Keywords: Environmental Pollution, Nanomaterials and Environment, Nanoparticles emission, Nanowaste.

INTRODUCTION

As known, nanoparticles have special physicochemical characteristics and functionalities that are not similar to their bulk counterparts [1]. Recently, the relationship between nanoparticles and the environment has been a concern, especially the effect of the nanoparticle's emission to the atmosphere on human health. There is an adverse effect of nanoparticles on human health [2]. There is evidence that exposure to nanoparticles has a detrimental effect on human health [3].

There is no doubt that there are risks in handling nanomaterials. Risk assessment is important not only to determine the potential hazards of nanomaterials but also their mode of release, fate and behavior in the environment, and the resulting exposure [4].

Nanomaterials are used to improving the environment, but the improvement depends on the type of application, for example, coating the exterior of a building

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using nanomaterials, producing clean energy using solar cells, *etc*. In fact, the challenge in this era is to find environmental-friendly energy sources to reduce environmental pollution [5 - 7].

Nanostructure and Energy

Researchers have worked to obtain fuel cells that are less expensive and more efficient. A team of researchers from UCLA's Henry Samueli College of Engineering and Applied Sciences has found a way to make fuel cells more durable, efficient, and less expensive. The team created a nanostructure consisting of a compound of three metals. Using this nanostructure, the team believes they can make a much better fuel cell than conventional models [8].

Doing so could unlock a bright new future for fuel cell technology. Researchers have found that the nanostructures they have developed, which are comprised of a platinum-nickel-molybdenum compound, are 81% more efficient than the conventional catalysts that fuel cells use.

Conventional catalysts use a large amount of platinum, which makes them expensive. By reducing the amount of platinum used to make these catalysts, researchers have found a way to cut costs and make fuel cells more affordable, efficient, and durable.

In the near future, researchers will be able to use nanomaterials to extract energy from the air. New nanomaterials and concepts are being developed that show the potential to produce energy from motion, light, changes in temperature, glucose, and other sources with high conversion efficiency.

The electronic transistor and the microphone were invented more than seventy years ago, their size was very small, and with advances in technology, they became even smaller, and today one electronic chip can contain more than five billion transistors. And if technological progress continues to accelerate, we can reach driving a car at three hundred thousand miles per hour [8].

Nanomaterials and the Environment

Nanomaterials have been found on Earth for thousands of years, and humans have used them for various works such as paintings on temple walls. This means that humans have been exposed to and affected by these substances. It can be said that the impact of these substances on the environment extended for thousands of years, but this effect may not have been significant due to the lack of research tools to detect them [9].

Scientists have reached advanced stages in the production and use of nanomaterials, as it was reported that the world was producing about 2,000 tons of nanomaterials, and in 2020 it is expected to produce about 58 thousand tons of these materials [10].

With the steady increase in the production of nanomaterials, the impact of these materials on the environment and on humans will be significant. This was manifested in the technological progress that led to the measurement of the presence of these substances as well as the discovery of their impact on human health.

The emergence of oil, gas and coal had a significant impact on the environment, particularly the combustion process in factories, automobiles, and other human activities. The combustion process produces various substances, especially small volatile particles in the air, which are classified as nanomaterials. These particles appear as thick black smoke [11].

The following equation shows the process of combustion of hydrocarbon materials, such as methane, ethane, propane, *etc*.

$$CH_4 + 2O_2 = CO_2 + 2H_2O \qquad \textbf{(1)}$$

Incomplete combustion of fossil fuels results in so-called soot, and because it is so small, it flies through the air, as well as deposited in water and soil. The nanoparticle uptake rate is controlled by some parameters such as nanoparticle's size, distribution, aggregation and deposition in the cell. Endothelial cells or phagocytes can absorb nanoparticles.

Detecting Nanomaterials in the Environment

Nanomaterials are released into the environment. There is a possibility that the nanomaterials may cause a harmful effect on the environment. In fact, nanoparticles may be released intentionally and unintentionally, for example, iron nanoparticles are used as a treatment agent and are intentionally released into groundwater to remove harmful chemicals. Inadvertent disposal of nanomaterials from wastewater treatment plants occurs. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, their size, morphology and interaction [12].

Nanoparticles can be detected by analytical methods in different environments, such as in the rivers, soil, waste water and fresh water. Some methods can only detect pure nanomaterials at high concentrations. In fact, the detection of nanomaterials faces some challenges. The first challenge is that some methods

CHAPTER 6

Future of Nanotechnology

Abstract: In reality, nanotechnology is transforming many areas of human life. It is a crucial component of many applications, including those that deal with environmental pollution, nanomedicine and health, water purification, and waste treatment. Nanotechnology has a significant role in the economy of many countries. The global nanotechnology market is expected to be more than $ 125 billion in 2024. In fact, this expectation is not fixed, but it can be changed anytime. As known, COVID-19 emerged in 2019 and 2020, and some companies, banks, *etc*. have gone bankrupt. Due to the COVID-19 pandemic, plans and estimates have obviously changed. As reported, there are four generations of nanotechnology. The first generation is concerned with improved nanostructures, and the second generation is concerned with the application of nanostructures, such as drug delivery. The third and fourth generation are concerned with the further integration of nanomaterials applications, such as the use of nanobots in drug delivery.

Keywords: Environment and nanotechnology, Future of Nanotechnology, Nanoarts, Nanomedicine, Nanotechnology and Economy, Water purification.

INTRODUCTION

Human aspiration for technical progress knows no bounds: in practice, there is immense evidence of how technology affects everyday life. As humans reached space and settled on Earth, they created machines to perform tasks previously performed by humans, such as robots that drive cars, serve food and drinks, and perform other tasks. Nanomaterials are of particular interest, and technology companies are constantly looking for new and exciting things. Researchers have been able to employ these materials in a variety of products that we use, including medicines and cosmetics. Some nuts now contain nanometer-sized compounds made of gold. Scientific research will never stop until matter becomes smaller than a nanometer. Therefore, the future of nanotechnology is becoming clear to researchers and investors.

Nanotechnology and Economy

The impact of nanotechnology on the global economy has become evident, and the manufacture of nanomaterials has become easy in all research laboratories

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prepared for that. The growth of nanotechnology has an impact on almost every area of the global economy, including energy, water, the environment, medicine, electronics, the military, transportation, and agriculture. According to a report by Lux Research, Inc., released in October 2004, the nanotechnology value chain cuts from nanomaterials to nanointermediates to nano-enabled products [1, 2]. Lux report predicted that by 2014, emerging nanotechnologies would be incorporated into all computers and consumer electronics devices, 23 percent of drugs, and 21 percent of automobiles and that nanotechnologies would result in $2.6 trillion in product revenue corresponding to 15% of the global gross manufacturing output. It is reported that the global nanotechnology market is expected to exceed US$ 125 billion by 2024 [3]. In fact, the estimated numbers may change due to different circumstances, such as environmental pollution, social and economic problems, and health problems. For example, the COVID-19 pandemic that emerged in 2019 and 2020 caused a number of difficulties and unforeseen changes in the world economy. Worldwide, numerous businesses and banks have declared bankruptcy. Plans and estimations have unquestionably changed as a result of the COVID-19 pandemic.

What is next?

It is obvious that technology will continue to advance. There is a new invention every day. After focusing on macroscale for many years, research has now moved on to nanoscale materials. As of today, the smallest unit of time is the femtosecond, which is equal to 10^{-15} seconds, though it could get even smaller.

Nanotechnology is an emerging science that is expected to have rapid and powerful future developments. It is expected to contribute significantly to economic growth and job creation in the European Union in the coming decades. Scientists predict that nanotechnology has four distinct generations of advancement. As mentioned, the world is currently in the first generation or may be in the second generation of nanotechnology [4]. The four generations are divided as follows: The first generation includes materials science with improved properties that are achieved by incorporating "passive nanostructures". For example, nano-coating and carbon nanotubes are used to strengthen plastic, *etc*. The usage of active nanostructures has advanced further in the second generation; for instance, nanostructure has made it easier to deliver a medicine to a particular target cell or organ in the human body. The nanoparticles of medicine could be coated with specific proteins as a means of reaching this goal. The complexity of the nanosystem has increased in the third and fourth generations.

Nanotechnology for Securing the Future

The humans have progressed from one evolution to another, according to history. The electronic transistor and microchips are two minor inventions that have helped nations work and live for the past 70 years [5]. Both of them were created in 1940. All current electronic devices were inspired by these two discoveries. The size has changed due to technological improvements, becoming smaller and smaller. Today, a single chip can have up to 5 billion transistors [5].

Not only transistors and microchips, but also many inventions have been developed, such as nanorobots, nanomedicines, nanoparticle science, nanofibers, nanolubricants, and carbon nanotubes.

All these inventions of nanomaterials secure the future of humanity, for example, the invention of nanobots is like a doctor in the human body, who can deliver medicine to the affected site in the human body, and can help in carrying out complex operations. To improve eye vision, tiny sensors can be implanted in specific places on the human body, such as retina implants. These tiny sensors can also record crucial data without endangering the patient, assisting medical professionals in developing precise illness treatments. Nanomaterials could be used to create incredibly fine and tiny sensors. The applications of sensors nearly cover most areas that concern people.

Materials' nanostructures alter their physical characteristics and produce some astonishing features.Nanoparticles can quickly migrate to fill up material cracks, acting as a self-healing mechanism that can repair the gaps without the need to shut down the plant. Self healing will be very helpful in the big design such as areoplane to small design such as microelectronics. The advantage of the self-healing is to stop small factures from getting bigger and from becoming a big problem [5]. In addition to the aforementioned advantages of sensors, very tiny sensors can make big data possible by producing more information than we have ever had to deal with before. Huge amounts of data are stored in traffic sensors, which can be utilised to manage traffic. Statistical data can be used to avoid accidents and crimes.

In reality, nanotechnology aids in the development of high-capacity memories that enable the storage of this enormous data, which is a vast resource of knowledge. This also provides inspiration for highly efficient algorithms for data processing, encryption and transmission without changing the authentication of this data. There are many natural examples of big data operations that are efficiently performed in real time by minute structures, such as the parts of the eye and ear that convert external signals and scenes into information for the brain. There is

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