

FUTURISTIC TRENDS IN NANOTECHNOLOGY

Abstract

Nanotechnology is a developing science that discussed the use of materials on a nanometric scale. It is an auspicious resource of employing distinct atomic and molecular level of a body at the nanoscale. It is an emerging science which has probable future developments. Even though it is hard to forecast what will happen towards nanotechnology in the upcoming hundred years, we can positively say that nanotechnology will become an influential tool of technology in near future. This chapter presents current advancement of nanotechnology and its futuristic possibility.

Keywords: Technology; Nano technology; Future of Nanotechnology; Nanomaterials.

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I. INTRODUCTION

The term “Nano technology” simply defines the technology based on Nano scale. The technology depends on the scale covering 1-100 nm with atomic level accuracy. The technology is being connected with the materials and components which have novel and highly advanced physical, chemical as well as biological properties and processes. Thus the term Nano technology can also be defined as a branch of knowledge incorporated with sub classification of technology in physics, chemistry, biology and other scientific fields surrounding the study of any phenomena in Nano scale. Nanotechnology is a developing science which has a very rapid strong future expectation. The advancement of nanotechnology has been predicted to be of four distinct generations. Currently, we are experiencing the first and second generation nanomaterial only. The first generation nanomaterial includes the materials combine with passive nanostructures. These could be achieved in the form of coatings or in the form of carbon nanotubes. The second generation utilizes the active nanostructured materials. This could be achieved by coating the Nano particles with some specific proteins. The major application of second generation Nano materials include in the field of medicines. The third and fourth generation nanomaterial includes the advancement of Nano systems like Nano robotics moving on to a molecular Nano system to control growth of artificial organs [1].

Nanotechnology influences everyday human life. The key assistances of nanotechnology are man and miscellaneous, they are overwhelming and very attractive. Now, nanotechnology is being utilized in makeups, sunscreens, clothing, and numerous consumer products also. Today, Nanotechnology is empowering scientists to tame atoms. The potential involvement of nanotechnology in many manufacturing industries creating many jobs alongside. Despite of these, there are some known barriers in futuristic progress of nanotechnology and its applications. There is no doubt that Nanotechnology has implausible potential, still there are some issues related to social and public recognition, ethics and human safety. These issues necessarily are solved before the technology could be seen as the opportunity of providing extraordinary healthcare. Detractors directed the major alarms of nanoparticles with bad influences on human health. Hence we can say that the any prediction about the future of any major technology is tough [2].

This chapter presents an overview of the recent advancement of nanotechnology in different fields including some recent examples. A brief summary of application of nanotechnology in fields like agriculture, food processing, medicine and utilization of nanomaterial in different arenas and their futuristic aspects have been discussed.

II. RECENT ADVANCES OF NANOTECHNOLOGY

1. Agriculture: The principal idea behind introducing nanotechnology is to attain substances with enhanced properties such as surface area, mechanical strength and solubility. As the world’s population is increasing day by day there is an increasing demand of agricultural output. Due to the limited availability of sources such as potassium and phosphorus more efficient techniques are needed to utilize it more effectively in agricultural field [3]. The main aim behind execution of nanotechnology in food and agricultural field is to boost the properties mentioned above (solubility, surface area etc.). These properties play an important role in application of nanomaterial in

agricultural field or any other area of science. One such application of nanotechnology can be in agrochemicals which are generally sprayed on the crops to protect the plant and improve the growth of the plant. But they are generally used in minimum amounts because of which the amount of concentration that is needed for the protection of crops does not reach the targeted site. This leads to the reapplication of agrochemicals again and again which can cause harmful effects on the environment as well as the crops. The invention of nano-encapsulated agrochemical can make the process less toxic by including all the necessary properties in it such that using correct proportion of chemicals which only attacks the targeted site with controlled release of the agrochemicals. Let's say surface altered hydrophobic Nano silica is used successfully as pesticides in agricultural field. It damages the wax layer by getting absorbed into the circular lipids of pests or insects by process known as physisorption which results in the death of the insects. This types of Nanobio pesticides proves to be more helpful to the plants as well as to environment as related to the common chemical pesticides. With the help of nanotechnology genetic constituents of plants can be improved and can further prove to be a protective shield against pathogens (for example bacteria, microbes etc.) The genetically modified plants can enhance their properties such as resistance to different types of weather condition, climatic changes which can be drought, cold, disease salinity etc. For example, Zn nanoparticles improve productiveness of Pennisetum americanum seed. Nanotechnology also helped in improvement of seed quality, seed storage, monitoring the plant growth stages etc. For example Carbon nanotubes as one of the success of nanotechnology can be used to strengthen the germination of tomato seeds by conveying moisture, using of Nano sensors to pinpoint insects or fungus present inside the storage house of grains, using of Nano sensors to monitor the each stages of plant growth to get maximum yield etc. are key success of nanotechnology [4]. With the development of technology since the last two decades, nanotechnology has evidenced to be an auspicious tool in transforming the food and agricultural system. With the utilization of Nano encapsulated agrochemicals, can not only improve the seed quality but also provide protection of crops. From the above discussion we can summaries that in the future, the execution of nanotechnology with more advanced or improved features can diminish most of the agricultural problems.

2. **Food sector:** The broad extent of food sector in which nanotechnology is generally applied includes food packaging, food processing and food preservation. The detail of the applications are summarized below
 - **Food processing:** The foods which are developed by utilizing nanotechnology are known as Nano-food. Nanotechnology can be found to be of great use in food processing with the improved properties like texture, uniformity, taste or even cover up the foul smell of the food. Nanotechnology can too be custom-made to change the structure of food. For example, in place of fat rich products, Nano-structured lipids have been introduced which works by matching the oily or creamy texture of foods. Using of Nano-coatings in food industry is one of the major successes of nanotechnology. Nano-coatings can be consumed in meat, cheese, fruits vegetables etc. It can also act as a blockade for gas and moisture. These coatings add flavor to the food as well. Other examples include the application of Nano-filters to remove lactose from milk by substituting with some other sugar for those people who are lactose intolerant [5].

- **Food packaging and preservation:** The application of nanotechnology in the area of food packaging is likely to prove it to be an efficient way in the process of food preservation. Wastage of food is one of the main reason of loses in food industry. This wastage of food further leads to shortage of food. The main motive behind this food wastage is microbial action on the food particles. In order to protect food from pathogens or microbes, some nanoparticles has been introduced. For example, nanomaterial containing antioxidants and antimicrobial properties are utilized in packaging which aids food preservation. Nanomaterial with suitable properties like heat resistance, antimicrobial, changing the penetration activities of foils etc, are used for wrapping the food. Some of the metal oxides or metal oxide nanoparticles mostly iron, silver, zinc oxides, titanium oxides etc. which are inorganic nanoparticles, in some cases are used as antimicrobials [5]. Although, Nanotechnology has vast applications in food industry still the concern associated with the use of nanotechnology in the food sector is that they can be harmful for the plants and animals. So some standard policies should be introduced for more safe use of the nanomaterial. Thus we can say that nanotechnology has been introduced in food sector but its application has not been properly utilized yet. There is still a need to work on those sectors if we study the future perspective. So if we work on those sectors and try to reduce the harmful effects, then nanotechnology will be considered as a potential applicant in the food industry with more efficiency.
3. **Electronics:** People are now expanding their capabilities in every area of science. The rapid pace of technological change is clearly visible but much of that one may not see the exceeding small physical components of exchange called nanotechnologies that are catalyzing the revolution. Nano technologies have led to advancement in device engineering that feature more compact and capable computers. Now our smartphone has more computing capabilities that massive computers used to send astronauts to the moon during the Apollo space program only because of nanotechnology. Nano technology has vast application in electronic device such as laptops, computer cell phones, TV's, airplanes, trains and autonomous vehicles etc. Nano technology can provide new surfaces and nano coating for strength and high performance as well [6]. Now a day, robotic has been transformed by nanotech because of the increasing performance and intelligence capability and also reducing size of the device to a convenient size but this area of technology is not fully utilized and need to pay more attention in nearby future.
- **Memory and memory related device:** In earlier time Nano crystal memories including single electron memory, ferromagnetic memory and ferroelectric memory were discovered. Memories that utilized single electron effects are an attempt at combining the discreteness observable in transport of electrons to very small capacitances (10^{-18} F) and into three dimensionally quantum confined states presented the utilization of gold (Au) colloid nanoparticle assembled single walled tube and electronic prospects for the single electron transfer one of the most important type of single electron used device to float gate memory [7].
4. **Microscopy:** Microscopy plays an irreplaceable role in nanotechnology owing to its recycled materials and simple procedures, on a Nano scale range where samples could be damaged by high-energy electrons fire. In normal microscopic techniques, it is not a problem, but problems may arise due to stringent sample preparation methods. The scanning electron microscope (SEM) TEM (transmission electron microscopy) and STM (Scanning

Tunneling Microscopy) need finely prepared sample that must be electrically conductive. There are many ways to avoid this, but the fact that remains is that it could take hours to prepare and mount a sample correctly. Nanotechnology customs two important classes of microscopy. The first class comprises of a stationary sample in line with a high-speed electron gun. Here, Scanning electron microscope (SEM) technique is utilized. The second type of microscopy includes a stationary scanner and a moving sample with the two microscopes techniques namely Atomic Force microscope (AFM) and Scanning Tunneling Microscope (STM)[7].

5. Nanoparticles: Nano material is a material having internal structure or surface structure at the Nano scale, which could exhibit novel characteristics compared to the same material without the nanoscale features. The material with just one dimension with a nanometer scale is considered as one of the most important implementation of nanotechnology. Materials like Nano fiber, nanowire, carbon, nanotubes, inorganic nanotubes or biopolymers and three dimensions on the nanoscale (carbon nanoparticles, fullerenes, dendrimers or quantum dots) are considered as nanoparticles. Nanomaterials cover a heterogeneous range of materials with a classification by types still it is not completely clear of controversy. The European Commission has classified the following categories, based in various Sustainable and Responsible Investment (SRI) consulting reports which are summarized in the following paragraph

- **Inorganic non-metallic nanomaterials:** This type comprises of various types of oxides and hydroxides like titanium dioxide (TiO_2), Zinc oxide (ZnO), Silicon dioxide (SiO_2), aluminium hydroxides, aluminium oxo-hydroxides, nickel monoxide (NiO), diiron trioxide (ferric oxide, hematite, Fe_2O_3), triiron tetraoxide (ferrous-ferric oxide, magnetic, Fe_3O_4), cerium dioxide (CeO_2), zirconium dioxide (ZrO_2), calcium carbonate (CaCO_3), barium titanate (BaTiO_3), barium sulphate (BaSO_4), strontium titanate (SrTiO_3), strontium carbonate (SrCO_3), indium tin oxide (ITO), antimony tin oxide (ATO), disbismuth trioxide (Bi_2O_3), disilver oxide (Ag_2O), aluminium nitride (ANI), silicon nitride (Si_3N_4), titanium nitride (TiN), titanium carbonitride (TiCN), tungsten carbide (WC), tungsten sulphide (WS_2) etc [1].
- **Nanoparticles based on Metals and metal alloys:** This type includes metals and their alloys. Metals like gold, platinum, palladium, copper, iron, nickel cobalt, aluminum, zinc, manganese, molybdenum, tungsten, lithium, rhodium Nano particles and their related alloys are particularly present in this category.
- **Carbon based nanoparticles:** This type of Nano materials comprises of carbon based nanomaterial commonly called Fullerenes (C_{60}), carbon nanotubes (CNT), carbon nanofibers (CNF), carbon black and grapheme flaks etc.
- **Nano polymers and dendrimers:** This type contains the polymer nanoparticles like poly (Glycidyl Methacrylate) (PGMA), fibers like Nano cellulose, nanostructured polymer-films like polyacetylthiophene-films, polystyrene-polyethylene oxide films, acrylic glass Polymethacrylate films, and styrene-ethylene-butylene-styrene films and polyacrylonitrile nanostructures (PAN) films etc. All the mentioned nanoparticles have different applications in different areas which will be discussed in forthcoming paragraphs [1].

6. Nanocomposites: There are some new types of nanomaterial introduced in the recent development, are regularly referred to as “second generation” (which are generally used in targeted drug delivery system, adaptive structures and actuators), third generation” (utilized in novel robotic devices, 3D-dimensional networks and guided assemblies), and “fourth generation” (with molecule-by-molecule design and self-assembly capabilities) nanomaterial. The third and fourth generation Nano batteries are generally assembled of three parts namely anode, Cathode and Electrolyte. Like lithium ion batteries the anode is always graphite, so most research is being done on the cathode and electrolyte material utilized in a Nano battery. The higher conductivity can be reduced and leading to an increase power in both charge and discharge. Some important technologies used in Nano batteries are Nano phosphatetechnology. Nano pore battery technology and Lithium ion batteries. The net capacity and consistency of an innovative battery system depends mainly on the chemistry used in the construction of cell. Nano phosphate is something different from the standard lithium iron phosphate which has lower rate capability and power. Nano phosphate is lithium ion battery cathode was first introduced by Yet-Ming Chiang and his group. Nano phosphate particles are further divided into two group's viz. Primary and secondary conversely the chemical reaction created in the Nano phosphate technology with increasing cathode surface area with the electrolyte, which allows for faster lithium insertion and thus more power system [1].

In recent development, many researchers have managed to rearrange the materials in Nano battery. The rearranged bundle of Nano batteries are then converted into a larger device. In earlier days, researchers have constructed three dimensional nanostructured batteries by inserting two electrodes within a Nano pore, using ultrathin electrical insulator. There is a drawback in such type of system regarding more power and energy density. Systems with improved power and energy density need complex circuits to shift current. In these concerns, the benefits of the 3D nano structural design cannot be fully utilized owing to the spatial constrains of the material.[1].

Two other battery technology like conventional Lead/acid battery technology, Lithium-ion technology have failed to meet the needs of extended life periods, safety and remote UPS (uninterrupted power supply) applications etc. These technologies cannot suitable for the rude conditions like short circuit, over recharge, over discharge, exposure to extremely high or low temperature etc. In this regards, An American company *ALTAIRNANO* have developed batteries by utilizing lithium titanate nanotechnology which can eliminate the disadvantages of conventional batteries. Unlike, conventional lithium ion technology, *ALTAIRNANO's* Lithium Titanate technology is something different. They have substituted the graphite material, used in conventional batteries with Nanoassembled lithium titanate and thus become a potential applicant in the filled of battery technology. There are so many aspects in utilization of third and fourth generation nanoparticles, still more work and research should be carried in near future so that these types of Nano systems could move on to a molecular Nano system to control growth of artificial organs[1].

7. Medicinal industry: Nano scale technology is going to change the basic of diagnosis of disease, treatment and prevention. These innovations are referred to as Nano medicines by National Institution of Health. Examples include the application of super paramagnetic iron oxide Nano particles applied in the areas of imaging, targeting, drug, and biosensors

owing to their chemical inertness biocompatibility, low toxicity, potent magnetic and catalytic behavior and greater role in multifunctional modalities. Application of magnetic iron oxide nano enzyme is used in cell sorting, DNA extraction and tumor imaging, gene delivery, pathogen exposure, tumor analysis and therapy, biofilm elimination and ROS modulations at multi levels for cell differentiation.. Moreover it is found that iron oxide induce ferroptosis directly to exhibit tumor growth. It inspires more cutting edge expertise in various fields to improve human health. [8]. One of the significant success of Nano technological development is the application of iron oxide Nano particles in the delivery of anti-cancer agents. Scientist has developed a novel water dispersible oleic acid (OA)-pluronic coated iron oxide magnetic nanoparticle design to load easily high doses of water insoluble anticancer agents. These nanoparticles are sustained intracellular drug retention relative to drug in solution and antiproliferatives effect is breast and prostate cancer cell lines [9]. Metal oxide nano particles or Nano crystals are considered as hopeful candidates in the field of medicinal industry because of their less cytotoxic properties and great biocompatibility. In nearby future it will definitely achieve a great balance between the medicine and nanotechnology [10].

- **Application of quantum dots in medicinal field:** Quantum dots utilize the very unique photo physical properties which are satisfactory for addressing the needs of personalized medicine. They are different fluorescent labels used in the drug delivery system to monitor the metabolism of drug in the body. They have great resistance capacity to photo bleaching, multiplexing capacity and high surface to volume ratio which makes them great candidates for intercellular tracking, therapeutic delivery, in vivo imaging, diagnostics etc. Examples include the application of quantum dots assembled to immunoglobulin G and streptavidin to label the breast cancer marker on the surface of malignant cells, were successfully employed [11], Application of Doxorubicin, an antibiotic broadly used in chemotherapy immobilized onto quantum dots to improve and control the kinetics of drug release, also applicable as a tool for silencing gene expression. Although these quantum dots are not to assist in every applications, but, definitely, they will become dominant fluorescent reporters in medicine over the next decade [12].
- **Dendrimers in medicinal field:** These are developing as promising drug delivery molecule due to their surprising properties including membrane interaction, mono dispersity, well defined size, and shape and molecule weight. They have multiple benefits that can be further modified in order to ensure drug transport and targeted drug delivery [13].
- **Nanosphere and nano capsules:** Nanosphere are solid polymers with drug embedded in the polymer matrix. They are considered as small vehicles used to transport drugs. Nano capsules are some shell with an inner space loaded with the drug of interest. Both are very useful for control of the release of drugs and protecting them from the surrounding environment. So it is a promising field for drug delivery [14].
- **Aquasomes in medicinal field:** They are novel trilayered non lipoidal vesicular nanocarriers which demonstrate the similarities in structure to ceramic nanoparticles with the thermostatic activity for some disease like antigen delivery and ovarian cancer. They are considered as very important nanocarriers for the treatment of

various diseases like hemophilia A, hepatitis and cancer. They are also potential alternatives over other nanocarriers for insulin, antigen and oxygen delivery. Consequently in the near future, the aquasome based drug delivery system will be fascinating the field of research in nanotechnology [12].

- **Polyplexes / lipopolyplexes used in medicine:** Polyplexes are complexes which are inter polyelectrolyte and spontaneously formed through the electrostatic condensation between a cationic polymer and nucleic acid. They are capable of high density payload condensation which leads to cell internalization and subsequent protection from degradation of enzyme [15].
- **Carbon nanotube derivatives used in medicine:** Carbon nanotubes derivatives, such as trismalonic acid derivatives of the fullerene C60, express superoxide dismutase mimetic properties and they are very protective in cell culture and animals models of injury, degeneration of dopaminergic neurons in Parkinson's disease and nervous system ischemia. Carbon nanotubes has high surface area that is capable of adsorbing or conjugating with a wide variety of therapeutic and diagnostic agents such as drugs, genes, vaccines, antibiotics, biosensors etc. Carbon nanotubes can be made into artificial blood capillaries for the injured part of human body because they are promising drug delivery platform that can be functionalized with a different types of biomolecules, for example: antibiotics, proteins or DNA. In near future, carbon nanotubes are likely to compete with carbon fiber for high endless uses [16]

From the above mentioned examples we can see that nanotechnology has vast impact on every area of science and technology. Nanotechnology articulates two primary approaches via "bottom up" where materials and devices stand self-assembled from molecular constituents and "top down" where Nano scale matters are made by utilizing the micro-scale and macro-scale devices [2].

III. CONCLUSIONS

Nanotechnology has completed massive development over the past few decades and presently considered as one of the important technology of the 21st century. It is hoped that atomic scale nanotechnology will have a revolutionary impact on the future generation. Despite of maturing rapidly, nanotechnology is still in a developmentary phase. Nanotechnology's contributions to society may appear small at the moment but with continued manpower and funding it is hoped it will provide results and innovations. In the next few years, this technology will definitely cover most of the areas of Research and Development. It is supposed to give motivation for all the fields of application by covering all zones of technology and industry. It will provide new hope to make the material of life including electronics, medicines, products, cars as well as homes, in more better and cheaper way, by utilizing only few raw materials. Melodramatic innovations would definitely occur in miscellaneous areas such as food, medicine, computing, energy, and robotics. No one knows how soon these innovative ideas will widespread the Research and Development phase and arrive the market. Nevertheless, we can surely predict that Nanotechnology is there to stay and its uses and applications can be made decently to the value of society to mankind.

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