NANOTECHANOLOGY :WORLD OF SMALL THINGS

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ABSTRACT

In 1980 Eric Drexler was first who uses the term Nanotechnology, refers to the engineering of tiny devices and machines. This is a technology involving the potential ability to fabricate structures and devices with atomic precision by controlling the size of the matter at the scale of 1-10nm. Materials this size display unusual physical and chemical properties caused by many factors including the increase in surface area compared to volume which occurs as particles get smaller. Possibilities for the future are numerous. By Nanotechnology it may possible to manufacture lighter, stronger, and programmable materials that require less energy to produce than conventional materials, that produce less waste than with conventional manufacturing, and that promise greater fuel efficiency in land transportation, ships, aircraft, and space vehicles. In this paper a brief history of nanotechanology, types of nanomaterials, its synthesis techniques characterization and applications are discussed.

Keywords– Fullerenes,nanomaterials, nanoscale, thin film, quantum mechanical effect.

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1.Introduction

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometersbeing one-billionth of a meter.Nanotechnology is generally defined as the design, production, and application of structures, devices, and systems through control of the size and shape of the material at the 10^{-9} of a meter scale.It is a highly multidisciplinary field, bringing together many fields, including electrical and mechanical engineering, physics, chemistry, and biosciences. Nanotechnology will radically affect all these disciplines and their application areas.

Physicist Richard Feynman was the first who gave the ideas and concepts of nanoscience and nanotechnology by his talk entitled "There's Plenty of Room at the Bottom" at an American Physical Society meeting at the California Institute of Technology on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a process in which scientists would be able to manipulate and control individual atoms and molecules. A major advancement was the invention of molecular-beam epitaxy by Alfred Cho and John Arthur at Bell Laboratories in 1968 and its development in the 1970s, which enabled the controlled deposition of single atomic layers.

In contrast to recent engineering efforts, nature developed "nanotechnologies" over billions of years, employing enzymes and catalysts to organize with exquisite precision different kinds of atoms and molecules into complex microscopic structures that make life possible. These natural products are built with great efficiency and have impressive capabilities, such as the power to harvest solar energy, to convert minerals and water into living cells, to store and process massive amounts of data using large arrays of nerve cells, and to replicate perfectly billions of bits of information stored in molecules of deoxyribonucleic acid (DNA).

At nanoscale dimensions material properties depend on and change with size, as well as composition and structure.The physical, chemical, and biological properties of structures and systems at nanoscale are substantially different than the macro-scale counterparts due to the interactions of individual atoms and molecules thereby offering unique and novel functional applications. As the size of the particles gets reduced to nanoscale range, there is an immense increase in the surface to volume ratio which increases reactivity and changes the mechanical, electrical, and optical properties of the particles.For example, the reactivity of a metal catalyst particle generally increases appreciably as its size is reduced macroscopic gold is chemically inert, whereas at nanoscales gold becomes extremely reactive and catalytic and even melts at a lower temperature. Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts [Bhattacharyya2009,Roco 2011, Hasanny et. al. 2012, Zhang and Webster 2009, Pal et. al. 2011]. Fig. 1 shows comparison between macro, micro and nanoscale.

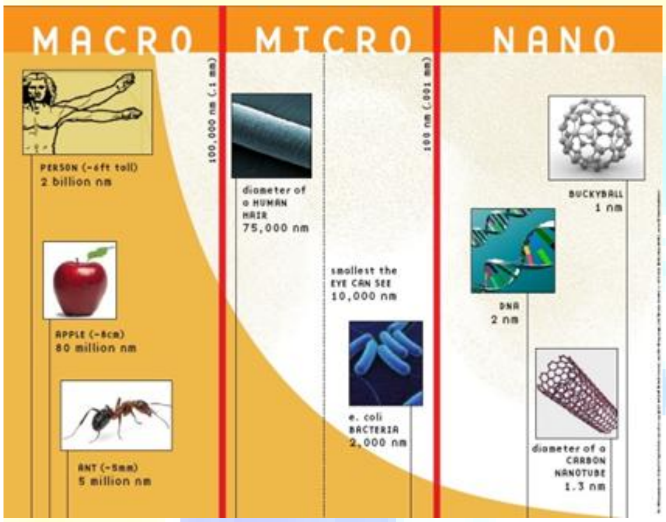

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Fig.1. comparison between macro, micro and nanoscale.

2.Clasification of Nanoparticles

There are various approaches for classification of nanomaterials. Nanoparticles are classified based on one, two and three dimensions **[**Pal et. al. 2011].

2.1.Nanomaterial in One dimension

One dimensional system, such as thin film or manufactured surfaces, has been used for decades in electronics, chemistry and engineering. Production of thin films (sizes1-100 nm) or monolayer is now common place in the field of solar cells or catalysis. This thin films are using in different technological applications, including information storage systems, chemical and biological sensors, fibre-optic systems, magneto-optic and optical device.Nano film is shown in Fig. 2, [Bhattacharyya2009].

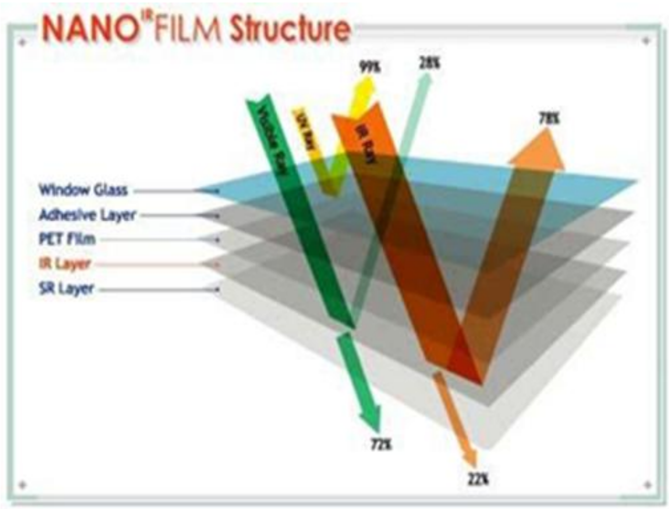

Fig. 2.Nano Films.

2.2.Nanomaterial two dimension

Carbon nanotubes are hexagonal network of carbon atoms, 1 nm in diameter and 100 nm in length, as a layer of graphite rolled up into cylinder. CNTs are of two types, single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) .The small dimensions of carbon nanotubes, combined with their remarkable physical, mechanical and electrical properties, make them unique materials. They display metallic or semi conductive properties, depending on how the carbon leaf is wound on itself. The current density that nanotubes can carry is extremely high and can reach one billion amperes per square meter making it a superconductor. The mechanical strength of carbon nanotubes is sixty times greater than the best steels. Carbon nanotubes have a great capacity for molecular absorption and offering a three dimensional configuration. Moreover they are chemically and chemically very stable.Nano tubes is shown in Fig. 3.

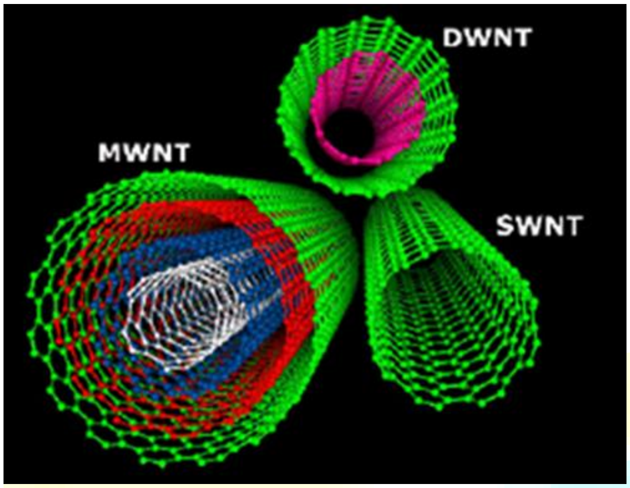

Fig. 3 Single-walled and multi-walled carbon nanotubes

2.3. Nanomaterial three dimension

Fullerenes are spherical cages containing from 28 to more than 100 carbon atoms, contain C_{60}. This is a hollow ball composed of interconnected carbon pentagons and hexagons, resembling a soccer ball. Fullerenes are class of materials displaying unique physical properties. They can be subjected to extreme pressure and regain their original shape when the pressure is released. These molecules do not combine with each other, thus giving them major potential for application as lubricants. They have interesting electrical properties and it has been suggested to use them in the electronic field, ranging from data storage to production of solar cells. Fullerenes are offering potential application in the rich area of nanoelectronics. Since fullerenes are empty structures with dimensions similar to several biological active molecules, they canbe filled with different substances and find potential medical application.

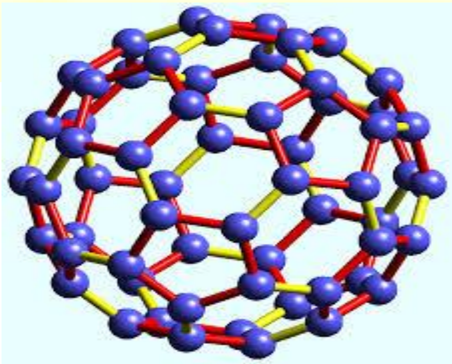

Fig. 4 Fullerenes

3.Sythesis of Nanomaterials

It is classified as bottom up manufacturing which involves building up of the atom or molecular constituents as against the top up method which involves making smaller and smaller structures through etching from the bulk material as exemplified by the semiconductor industry. It is observed that field of nanomaterial synthesis is very dynamic. Many process such as gas condensation, chemical vapor synthesis, mechanical attrition, chemical precipitation, Sol-Gel technique, electrodeposition, some other methods widely used are molecular beam epitaxy, ionized cluster beam, liquid metal ion source, consolidation, sputtering and gas aggregation of monomers, chemical precipitation in presence of capping agents, reaction in microemulsions and autocombustion are commonly used techniques for synthesis of nanophosphors [Rajput, 2015].

4.Charaterization

Nanoparticle characterization is necessary to establish understanding and control of nanoparticle synthesis and applications. Characterization is done by using a variety of different techniques, mainly drawn from materials science. Common techniques are electron microscopy (TEM, SEM), atomic force microscopy (AFM), dynamic light scattering (DLS), x-ray photoelectron spectroscopy (XPS), powder X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), matrix-assisted laser desorption/ionizationtime-of-flight mass spectrometry (MALDI-TOF), ultraviolet-visible spectroscopy, dual polarisation interferometry and nuclear magnetic resonance (NMR) [Pal et. al. 2011, Rajput 2015].

5.Application of Nanotechanology

Currently, Nanotechnology is described as revolutionary discipline in terms of its possible impact on industrial applications. Nanotechnology offers potential solutions to many problems using emerging nanotechniques. A number of Nanotechnology products are available and a tremendous amount of researches are still going on in universities, government and research laboratories. Nanotechnology applications are being developed that could impact the global market for agricultural, mineral, and other non-fuel commodities. Depending on the strong inter disciplinary character of nanotechnology there are many research fields and several potential applications that involves nanotechnology. Here are some fields where nanotechnology has been implemented [Bhattacharyya2009].

5.1. Agricultural Productiviy Enrichment

Agricultural productivity can be increased through nanotechanology as nanoporous zeolites for slow release and efficient dosage of water and fertilizers for plants and of nutrients and drugs for livestock, nanocapsules for herbicide delivery, nanosensors for soil quality and for plant health monitoring, nanomagnets for removal of soil contaminants.

5.2.Food

The food and bioprocessing industry is facing enormous challenges for developing and implementing systems that can produce high quality, safe foods as well as feeds while also being efficient, environmentally acceptable, and sustainable. These complex set of engineering and scientific challenges in the food and bioprocessing industry for manufacturing high quality and safe food through efficient and sustainable means can be solved through nanotechnology. Bacteria identification and food quality monitoring using biosensors; intelligent, active, and smart food packaging systems; nanoencapsulation of bioactive food compounds are few examples of emerging applications of nanotechnology for the food industry [Neethirajan 2011,Thembela and Hlophe 2007].

5.3.Drug-Delivery Technique

Dendrimers are a type of nanostructure that can be precisely designed and manufactured for a wide variety of applications, including the treatment of cancer and other diseases. Dendrimers carrying different materials an their branches can do several things at one time, such as recognizing diseased cells, diagnosing diseased states (including cell death), drug delivery, reporting location, and reporting outcomes of therapy [Bhattacharyya2009].

5.4.Nano films

Different nanoscale materials can be used in thin films to make them water repellent, anti reflective, self-cleaning, Ultraviolet or infrared-resistant, anti- fog, anti-microbial, Scratch-resistant, or electrically conductive. Nano films are used now on eyeglasses, computer display and cameras to protect or treat the surfaces [1]. Nano film is shown in figure 2.

5.6.Water Filtration technique

Researchers are experimenting with carbon nanotubes based membranes for water desalination and nanoscale sensors to identify contaminants in water system. Other nanoscale materials that have great potential to filter and purify water include nanoscale titanium dioxide, which is used in sunscreen and which has been shown to neutralize bacteria [Bhattacharyya2009, Thembela and Hlophe2007].

5.7.Textiles

The use of engineered nanofibers already makes clothes water- and stain-repellent or wrinkle-free. Textiles with a nanotechnologicalfinish can be washed less frequently and at lower temperatures. Nanotechnology has been used to integrate tiny carbon particles membrane and guarantee full-surface protection from electrostatic charges for the wearer.

5.8.Cosmetics

One field of application is in sunscreens. Sunscreens which use nanosized zinc oxide particles to absorb and reflect UV rays. This makes lotions transparent and smooth as opposed to sticky and white which will therefore make it more appealing to the consumer.

5.9.Sports

Nanotechnology may also play a role in sports such as soccer, football, and baseball. Materials for new athletic shoes may be made in order to make the shoe lighter (and the athlete faster). Baseball bats already on the market are made with carbon nanotubes that reinforce the resin, which is said to improve its performance by making it lighter. Other items such as sport towels, yoga mats, exercise mats are on the market and used by players in the which use antimicrobial nanotechnology to prevent parasuram from illnesses caused by bacteria.

5.10. Aerospace and vehicle manufacturers

Lighter and stronger materials will be of immense use to aircraft manufacturers, leading to increased performance. Spacecraft will also benefit, where weight is a major factor. Nanotechnology might thus help to reduce the size of equipment and thereby decrease fuel-consumption required to get it airborne.

5.11.Biological Sensors

Nanotechnology can improve the military's ability to detect biological agents. By using nanotechnology, the military would be able to create sensor systems that could detect biological agents. The sensor systems are already well developed and will be one of the first forms of nanotechnology that the military will start to use.

5.12.Uniform Material

Nanoparticles can be injected into the material on soldiers' uniforms to not only make the material more durable, but also to protect soldiers from many different dangers such as high temperatures, impacts and chemicals. The nanoparticles in the material protect soldiers from these dangers by grouping together when something strikes the armor and stiffening the area of impact. This stiffness helps lessen the impact of whatever hit the armor, whether it was extreme heat or a blunt force. By reducing the force of the impact, the nanoparticles protect the soldier wearing the uniform from any injury the impact could have caused.

5.13.Construction

Nanotechnology has the potential to make construction faster, cheaper, safer, and more varied. Automation of nanotechnology construction can allow for the creation of structures from advanced homes to massive skyscrapers much more quickly and at much lower cost. In the near future, Nanotechnology can be used to sense cracks in foundations of architecture and can send nanobots to repair them [Das 2014].

6.Risk of Nanotechanology

Health and environmental issues combine in nanoparticles and nanotechnology research is one main cause of concern. It is known that nanoscale particles are likely to be more reactive than the same material in bulk, and that nanoparticles may be able to penetrate human cells. To properly assess the health hazards of engineered nano-particles the whole life cycle of these particles needs to be evaluated, including their fabrication, storage and distribution, application and potential abuse, and disposal. The impact on humans or the environment may vary at different stages of the life cycle.

Another concerns which is often mentioned about nanotechnology is that a small nanomachine capable of replication could in theory copy itself too many times. If it were capable of surviving outdoors, and using biomass as raw material, it could severely damage the environment

.Sufficiently powerful products would either hostile governments or angry individual, to wreak havoc. Destructive nanomachines could do immense damage to unprotected people and objects. If the wrong people gained the ability to manufacture any desired product, they could rule the world, or cause massive destruction in the attempt. Clearly, the unrestricted availability of nanotechnology poses grave risks, which may well outweigh the benefits of clean, cheap, convenient, self contained manufacturing. Development of nanotechnology must be undertaken with care to avoid accidents.

In free form nanoparticles can be released in the air or water during production (or production accidents) or as waste byproduct of production, and ultimately accumulate in the soil, water or plant life. In fixed form, where they are part of a manufactured substance or product, they will ultimately have to be recycled or disposed of as waste. we don't know yet how such pollutants could be removed from air or water because most traditional filters are not suitable for such tasks. The figure 5 shows how nanotechnology effects the environment [Bhattacharyya2009, Hoet et. al. 2004, Phoenix and Treder2003, Nel et. al. 2006].

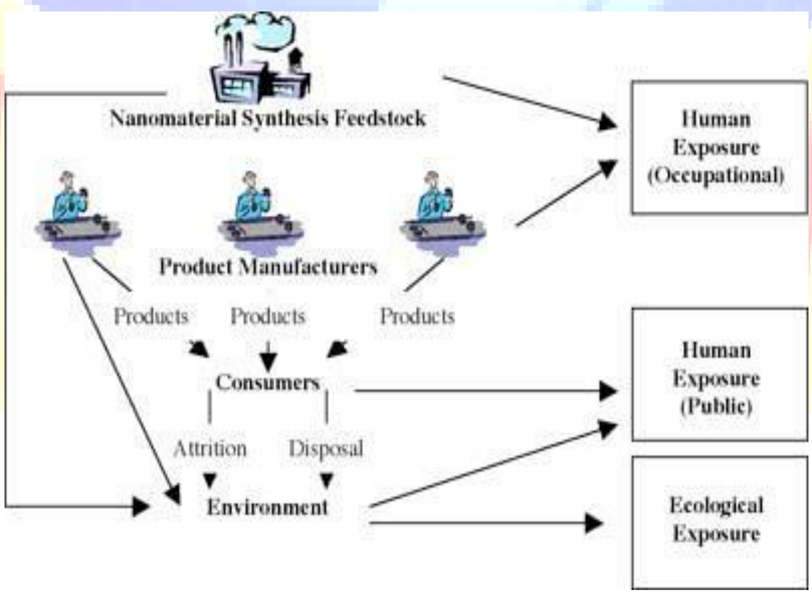

Fig. 5 Potential for release and exposure to nanoscalesubstances .

7.The Future…

The future possibilities for nanotechnology seem endless. In the area of nanoelectronics and computer technology, nanotechnology will allow the construction of smaller circuits and computers. Smaller circuits will run faster enabling far greater computer speeds. New nanomaterials will mean that computers will have a much longer life. For the environment and energy, nanotechnology will have a significant impact. For instance, nanometer sized solar cells could be developed to provide much of the energy needed around the world and nanomaterials will increase the efficiency of fuel cells and batteries. In the future nanotechnology will be used to tackle environmental problems. New 'green' processing technologies will minimise the generation of undesirable by-product effluents by curbing emissions.In health care and medicine biological nanosensors are being developed in the next 5 years and will be used for fast and accurate diagnostics. Further ahead, nanotechnology may be used to build artificial muscle and 'lab on a chip' technology will develop more efficient drug discovery processes [1Hoet et. al. 2004].

8.Conclusion

Today, many of our nation's most creative scientists and engineers are finding new ways to use nanotechnology to improve the world in which we live. These researchers envision a world in which new materials, designed at the atomic and molecular level, provide realistic, cost-effective methods for harnessing renewable energy sources and keeping our environment clean. There are urgent needs for reference materials and methods for measuring manufactured nanomaterials against natural background occurrence. For environmental assessment, the most important need is to establish methods to measure free nanomaterials after dispersal. Tests using living organisms are also needed to improve knowledge of possible risks to people and the environment. Improvements are sought in refining exposure doses in biological testing, and there is an urgent need for long-term exposure studies. The potential for improvements in health, safety, quality of life, and conservation of the environment are vast. At the same time, significant challenges must be overcome for the benefits of nanotechnology to be realized.

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