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A Review on —Nanomaterials"

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Abstract: "*Nanomaterials" are gaining much more importance rapidly as a most powerful material in the universe. Because, it has a large background support of the technology which is called "Nanotechnology". Today, the products made using nanomaterials have general as well as special applications like in Tissue engineering, Cancer treatments, Sports instruments, Lithium batteries, Solar cells, materials required for Aerospace, Cosmetics etc. Also, special nanomaterials like Aerogel, Fullerene, Carbon nanotube are introduced here properly. The effect of Nanomaterials in humans' life is increasing tremendously day by day. So, the people should know the importance of nanotechnology and nanomaterials. The present paper represents the overall information from "origin of nanotechnology" to "Green nanotechnology". It also reviews the recent advancements in the field of nanotechnology. All the general information regarding nantechnology and nanomaterials are equipped in proper manner, so the people can easily understand the subject.*

Keywords: Nanomaterials, Universe, Nanotechnology, Tissue engineering.

1. Introduction

Nanotechnology and research on this area are becoming more and more popular everyday. The emerging field of nanoscience and nanotechnology is leading to a technological revolution in the new millennium. The application of nanotechnology has enormous potential to greatly influence the world in which we live. From consumer goods, electronics, computers, information and biotechnology, to aerospace defense, energy, environment, and medicine, all sectors of the economy are to be profoundly impacted by nanotechnology. In the United States, Europe, Australia, and Japan, several research initiatives has been undertaken both by government and members of the private sector to intensify the research and development in nanotechnology.

The prefix ‗nano' means a billionth. The ‗billionth' of ‗a meter' (10^{-9} meter) is called as ‗a nano'. The size of a nanomaterial is almost 100 nm. If it exceeds above 100 nm, then it is a bulk material. The radius of a nanomaterial ranges from 1 nm to 50 nm. The radii of atoms most of the molecules are less than a nanometer. A cluster of 1 nm radius has approximately 25 atoms.

Some of the facts that are unbelievable like
i) The diameter of a human hair is 75000 nm.
ii) The diameter of a Hydrogen atom is 0.1 nm and its nucleus is of 0.00001 nm [1].

2. History

Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. Nanotechnology is a relatively recent development in scientific research. On 29 December 1959, at an American Physical Society meeting in Caltech, the American physicist —Richard Feynman" lectured, "There's Plenty of Room at the Bottom," which is often held to have provided inspiration for the field of nanotechnology [2].

In 1974 ,the Japanese scientist —Norio Taniguchi" of the Tokyo University of Science used "Nano-technology" term [3]. He used it in the conference to describe semiconductor processes like ion beam milling exhibiting characteristic control on the order of a nanometer and thin film deposition. He defined the term Nano-technology as it consists of the material's deformation, processing of separation and consolidation by a single atom or molecule". But up to 1981, the term was not focussed again when —Eric Drexler" does not know Taniguchi's prior, and he published his first paper on nanotechnology in the same year [4][5][6].

Due to publishing of the paper, K. Eric Drexler popularized and invented the concept of nanotechnology as well as produced the field of —Molecular Nanotechnology". He promoted the technological significance of nano-scale phenomena. Therefore, this Drexler's vision of nanotechnology is often called "Molecular Nanotechnology" (M.N.T.) or "Molecular Manufacturing" [7].

Nanotechnology and Nanoscience got a boost in the early 1980's with two major developments: the birth of cluster science and the invention of the Scanning Tunneling Microscope. These developments led to the discovery of —Fullerene" in 1985 and —Carbon Nanotubes" after some few years.

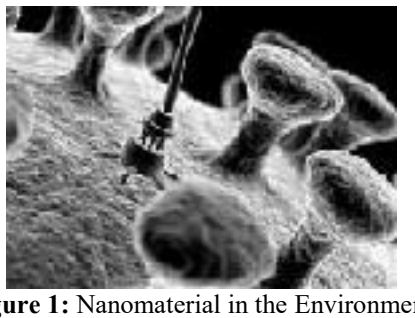

Figure 1: Nanomaterial in the Environment

3. Nanomaterials

Nanomaterial is the term related to nanotechnology. Because, it obeys the all principles of nanotechnology. The materials

which are created from blocks of nanoparticles or they are defined as a set of substances where at least one dimension is less than approximately 100 nm. A single nanomaterial is a very small thing in the universe that cannot be seen by naked eyes. We always require a high power electron microscope to observe them. The term ―nanomaterial" is defined by various organizations in different manner as follows:-

International Organization for Standardization: It says that ―material with any external dimension in the nanoscale or having internal structure in the nanoscale" and nanoscale can be defined as ―the dimension ranges from 1 nm to 100 nm approximately" [8].

European Commission: It defined as ―natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm to 100 nm. In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50% may be replaced by a threshold between 1 to 50%" [9].

The various nanomaterials are aerogel, carbon nanotube, fullerene, nanopolymers, nanovectors, nanocomposites, nanocrystals, nanofibers, nanoclays, nanofilters, nanohorn, nanowires, nanosprings, nanorods and so on.

3.1 Aerogel

'Samuel Stephens Kistler' created an Aerogel first in 1931 [10]. It has composition of particles with sizes in the nanometer range and they are covalently bonded together. They have very high porosity and often manufactured as composite paper non-woven paper made of carbon fibers, impregnated with resorcinol–formaldehyde aerogel and pyrolyzed. Carbon aerogels are electrically conductive and useful for electrodes in capacitors or de-ionization electrodes depending on the density. Also, they are used to create supercapacitors because of their high surface area [11].

Figure 2: Aerogel

3.2 Fullerene

In 1985, the scientists R. F. Curl, H. Kroto and R. E. Smalley discovered a molecule by vaporizing graphite using a laser beam that contains 60 carbon atoms (C_{60})called as ―Fullerene" or ―Buckyball". Its chemical structure has a closed cage having 12 pentagons of 5 and 20 hexagons of 6 carbon atoms which looks like a soccer ball.

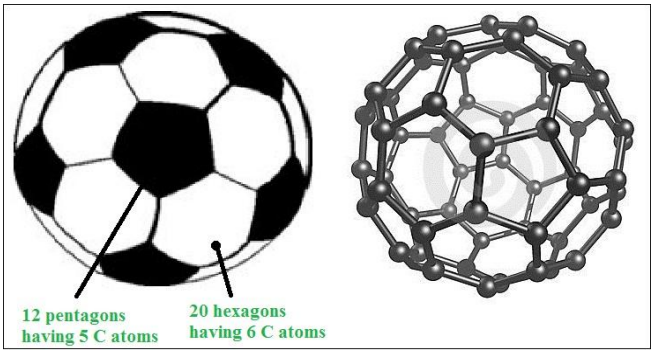

Figure 3: Fullerene

Fullerene has its types as buckyball clusters, nanotubes, megatubes, polymers, nano-onions etc. Fullerene has applications in the medical field for delivery of drugs in small amount for slow release in the area of cancer treatment [12].

3.3 Carbon nanotube (C.N.T.):

CNTs were discovered in 1991 by the Japanese electron microscopist Sumio Iijima who was studying the material deposited on the cathode during the arc-evaporation synthesis of fullerene [13].
CNT is a sheet of rolled graphite like a tube. They are molecular tubes having cylindrical nanostructure with diameters of a few nanometers made up of lattices of carbon atoms. There are three kinds of nanotubes:

a) **Armchair nanotube:** It contains a line of hexagons parallel to the axis of the nanotube.
b) **Zigzag nanotube:** It's a nanotube in which there is a line of carbon bonds down the centre.
c) **Chiral nanotube:** It exhibits a twist or spiral around the nanotube.

Also, carbon nanotubes exist as nanotubes within nanotubes, leading to the categorization of Single-Walled Carbon Nanotubes (S.W.N.T.) and Multi-Walled Nanotube (M.W.N.T.) SWNT contains only a single cylinder while as MWNT contains more than one nanotube cylinders. All cylinders have diameter as 1 nm hardly [14][15]. Chemical vapour deposition, laser ablation and arc discharge are the standard procedures for manufacturing of CNTs.

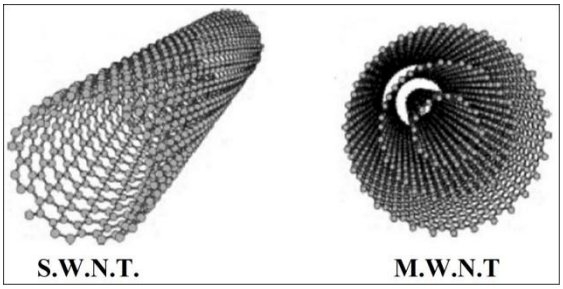

Figure 4: S.W.N.T. and M.W.N.T.

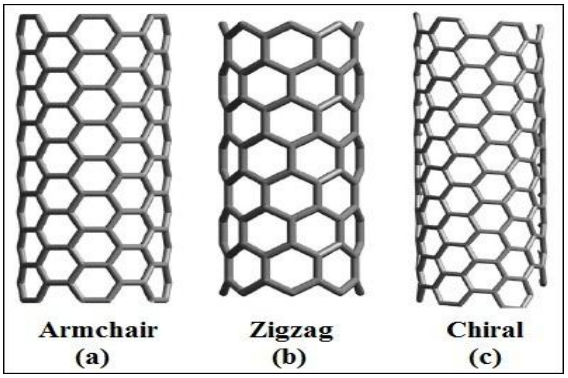

Figure 5: Armchair, Zigzag and Chiral nanotubes

CNTs are at least 100 times stronger than steel. In addition, they conduct heat and electricity better than copper. CNTs have been filled with potassium atoms, making them even better electrical conductors.

4. Properties

The nanoparticles show unique properties that changes with their size. Classical Mechanics is able to explain properties of bulk materials but is unable to explain properties of nanoparticles. So, the Quantum mechanical principles have to be used to explain properties of the nanoparticles. Some of the properties of nanoparticles are listed below.:-

4.1. Optical:

The bulk materials and nanoparticle both have different colours. For Example, Gold appears yellow in bulk while as it appears bright red in colour.

4.2. Electrical

Consider a flat conducting plate having large length and width with small thickness. Suppose, the thickness of a plate is in nanometers. In this case, an electron will be confined along one dimension but will move freely along the remaining two dimensions. This phenomena is known as ―Quantum well".

Consider a conducting wire having long length but the diameter of a wire is very small. In this case, an electron will freely along the length but confined in two remaining mutually perpendicular directions. This configuration is known as a ―Quantum wire".

If all three dimensions of a conductor are in nanometer range, an electron will be confined in all three dimensions. This configuration is known as ―Quantum dot". The Coulomb staircase is as shown in fig.

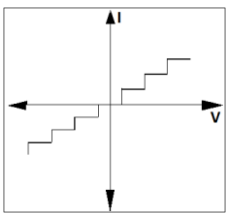

Figure 6: Coulomb staircase

4.3 Magnetic:

When bulk ferromagnetic materials are subjected to alternating magnetic fields, they show hysteresis while as nano-sized ferromagnetic particles does not. The B-H curve for bulk ferromagnetic material and nano-sized ferromagnetic particle are as shown in fig. 7 and 8 respectively.

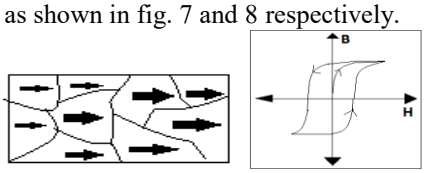

Figure 7: B-H curve for bulk ferromagnetic material

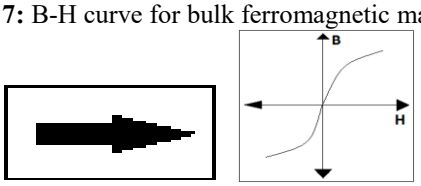

Figure 8: B-H curve for nanosized ferromagnetic particle

4.4 Structural:

The crystal structure of small nanoparticles observed to be same as the bulk material but with different lattice parameters.

4.5 Mechanical:

The mechanical properties like hardness, elasticity and ductility depends upon the bonds between atoms. Imperfections in the crystal structure and impurities result in changes in these properties.
The carbon nanotubes are 20 times stronger than steel [16].

5. Applications

Actually, we are surrounded by nanomaterials. Nanomaterials are almost present everywhere in the environment. Also, by experiencing the use of nanomaterials, we can say that the human life can be difficult without nanomaterials. Is it a fact? Yes, it is. Because, we are utilizing nanotechnology in various fields like engineering, medical, space, sports, etc. Nanomaterials are also used in bumpers on cars, metal-cutting tools, automotive catalytic converters, stain-free clothing, jackets, suits, glasses, different paints and coatings to protect against corrosion, fabrics, cosmetics, dyes and so on. Some of the major applications are listed below:-

5.1 Tissue Engineering

New tools for better monitoring and evaluating of engineered tissues along with new biomaterials to direct tissue growth are needed in tissue engineering. The most important material for tissue engineering is Carbon nanotube. It helps to improve delivery of transfection agents, sensing of micro-environments, tracking of cells and scaffolding for incorporating with the host's body. Using carbon nanotubes for optical, magnetic resonance and radiotracer contrast agents would provide better means of evaluating tissue formation. To design good engineered tissues, monitoring and altering intra and intercellular processes would be useful [17].

5.2 Medical:

A dangerous disease "Cancer" is spreading in all living areas nowadays. So, the nanomaterials can help for cure of Cancer by doing Drug delivery at specified organ in the human body. To realize the full potential of therapeutic molecules, it is essential. These requirements are more important in the case of cancer chemotherapies due to their high toxicity which could lead to serious side-effects. A great number of drug delivery technologies has been optimized including the nano-systems as well as polymer conjugation and micro-systems in the last few years. Hence, drug delivery through nanomaterials can take place safely [18].

5.3 Tennis:

Nanomaterials have been created their impact in Sports also. Tennis world is becoming popular in today's universe. In 2002, the Tennis racquet company "Babolat" introduced the "V.S. Nanotube Power Racquet". They made the racquet with carbon nanotube-infused graphite. Due to use of nanomaterials, the racquet made was light in weight stronger than Steel. Meanwhile, tennis ball manufacturer "Wilson" produced the "Double Core tennis ball". It has a coating of clay nanoparticles on the inner core. This clay acts as a sealant for air which cannot escape outside the ball easily.

Figure 9: Tennis Racquets and Tennis Balls

5.4 Spectacles and Sunglasses

To save delicate eyes from dust particles and sunlight, humans wear Spectacls or Sunglasses. Many glasses contain nanomaterials of "Zinc Oxide" or "Titanium Oxide". The presence of these nanomaterials in glasses protects the human eyes from sunlight. Therefore, the glasses appears red, green or blue [1].

Figure 10: Spectacle

5.5 Electronics

Nanotechnology is increasing in the field of Electronics also. It is used in Field Effect Transistor (F.E.T.), Light Emitting Diode (L.E.D.), Integrated Chip (I.C.) and Hard Disc etc. [16].

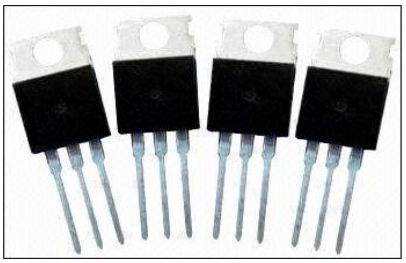

Figure 11: F.E.T.

Figure 12: L.E.D.

Figure 13: I.C.

Figure 14: Hard Disc

5.6 Energy

To store energy, solar cells as well as rechargeable batteries are used and they are made up of nanomaterials. A vital component in new hybrid vehicle is rechargeable Lithium battery. It is required to power portable electronic devices such as computers, laptops, cell phones which stores electricity from renewable sources [19].

Figure 15: Solar cell

Figure 16: Lithium battery

5.7 Automobiles

There are much more applications of nanomaterials in Automobile Engineering. They are in car body frames, bumpers, wheels, dashboards, paintings, coatings etc.
In automobiles, nanotubes are used for Hydrogen fuel storage due to which harmful emissions are reduced.

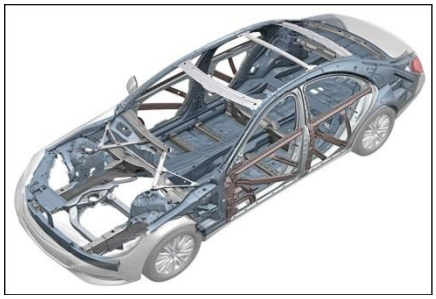

Figure 17: Car body frame

5.8 Space

Aerogel is used in spacecraft for its outer body production, light weight suits and jackets which utilize in the space.

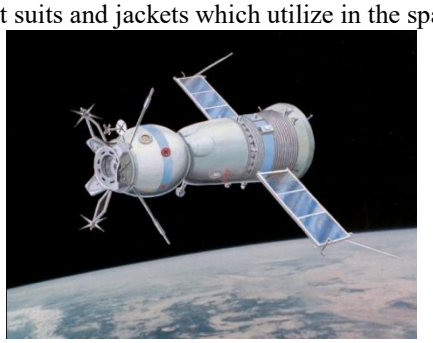

Figure 18: Spacecraft

5.9 Environmental:

Nanoparticle based sensors used for detection of water and air pollution. Nanomaterial catalysts can be used as catalysts to convert harmful emissions from industries and automobiles to less harmful gases.

5.10 Cosmetics:

The nanomaterials of titanium oxide and zinc oxide are used in sunscreen lotions. Nanoparticle based dyes and colours are used in hair creams and dyes [16].

Figure 19: Sunscreen lotion

6. Advances in Nanotechnology

In the future, it is anticipated that nanomaterials will allow major advances in high strength structural materials for aerospace applications, high energy density rechargeable batteries, more energy efficient catalysts, improved low cost solar cells, commercially viable fuel cells, improved methods for treating diseases by targeting diseased tissue, faster and more efficient semiconductor electronics etc.

6.1 Nanodevices in Neurological Surgery Procedures:

The Micro-fabricated devices with nanoscale features have been proposed as new micro-instrumentation for cellular and subcellular surgical procedures. Carbon nanostructures have excellent mechanical, electrical, and conduction properties, and have nanostructure similar to neuritis. So, they are use to improve neural activities and guide severed ends in a nerve through each other. Chemical functionalization can produce various surface charges on MWNTs which in turn control neural growth. It has been reported that activation of the phospholipase C signals pathway in nerve growth factor-treated neurons by CNTs.

The recent surge in nanotechnological advancement resulted in the development of non-invasive minimal access surgery. Nanorobotics technology which leads to the fabrication of nanorobots that were said to be injected into the patient to perform diagnosis or treatment on a cellular nanoscale level. Magnetic nanorobots are used to deliver drugs across Blood Brain Barrier (B.B.B.) safely via local hyperthermic disruption of the BBB [20].

6.2 Chip Fabrication

Extreme ultraviolet lithography will use mirrors to direct light with a wavelength of 13 nm to print features at 32 nm scale. The smaller scale will yield chips that run much faster.

6.3 Aerospace Materials

There would be significant advantages of materials that are 100 times stronger than present materials. Objects made from these materials can be up to 100 times lighter, using 100 times less of quantity of substance. By substituting diamond composite material, this factor could be increased to about 250. As a result, ultra light cars, trucks, trains, aircraft and spacecraft would use far less energy, especially with automically smooth surfaces to reduce internal friction and air resistance losses. Space transportation costs can reduced considerably with use of the products of nanotechnology.

6.4 Nanomesh and Nanofibers

These terms covers CNTs and the other polymeric nanoscale fibers. They are currently used in air and liquid filtration applications. Using a process called "electro-spinning", a polymer "mesh" is formed into a nanofiber membrane, hence "nanomesh" with 150 to 200 nm diameters. Some of them have been made since 1970, but were not called "nano" until recently. One potential use is to prevent body tissues from sticking together as they heal. They also break down in the body over time like biodegradable sutures. The diameters of vapour grown carbon fibers can vary from 100 to 500 nm.

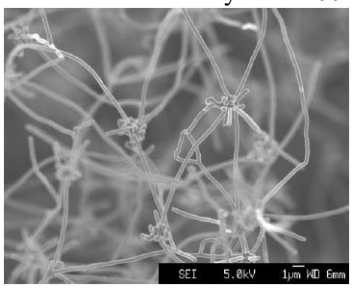

Figure 20: SEM of Vapor grown fibers

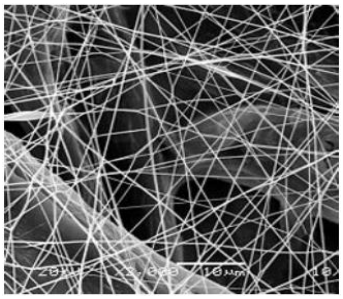

Figure 21: Ultra-Web(R) nanofiber produced on a SEM

6.5 Nanoguitar

It is made for entertainment through the technology. The world's smallest guitar is 10 micrometers long, about the size of a single cell, with six strings each about 50 nanometers or 100 atoms wide [1].

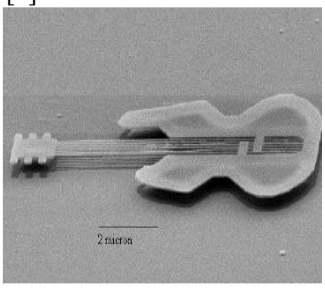

Figure 22: Nanoguitar

7. Advantages

i) The space required for nanomaterials is so much less due to their small size.
ii) Human life is getting more suitability due to utilization of nanomaterials in their daily life.
iii) Humans got a remedy on Cancer in the roll of nanotechnology.

8. Limitations

i) To observe the nanomaterials, a high power electron microscope is required which is very costly.
ii) Due to large surface area per volume of nanomaterial, it is harmful for the human skin and lungs.

9. Green Nanotechnology

Green nanotechnology relates to the use of nanotechnology to enhance the environmental sustainability of processes producing negative externalities. It also refers to use of the products of nanotechnology to enhance sustainability. It includes making green nano-products and using nano-products in support of sustainability. Green nanotechnology is defined as ~~"~~the development of clean technologies to minimize potential environmental and human health risks associated with the manufacture, use of nanotechnology products and to encourage replacement of existing products with new nano-products that are more environment friendly throughout their lifecycle" [21].

Actually, green nanotechnology uses existing principles of green chemistry and green engineering to make nanomaterials and nano-products without toxic ingredients at low temperatures and using less energy as well as renewable inputs wherever possible, and using lifecycle thinking in all design and engineering stages. It has two goals:-
i) To produce nanomaterials and products without harming the environment or human health [22].
ii) To producing nano-products that provide solutions to environmental problems.

The first goal shows that to create nanomaterials and their products by providing less impact to the environment, green nanotechnology uses current manufacturing processes for non-nanomaterials and products which are more environment friendly. This manufacturing process is called as ~~"~~Green Manufacturing Process".

The second goal of green nanotechnology includes developing of products that benefit the environment either directly or indirectly. Nanomaterials or products directly can clean desalinate water, hazardous waste, treat pollutants or sense and monitor environmental pollutants. Indirectly, light weight nano-composites for automobiles and other means of transportation can save the fuel. Also, self cleaning nanoscale surface coatings eliminate many cleaning chemicals which are used in regular maintenance routines [23].

10. Safety

Nanomaterials have a relatively larger surface area when compared to the same volume or mass of the material produced in a larger form. When the given volume is divided into smaller pieces, the surface area increases. So, the particle size decreases and a greater proportion of atoms are found at the surface compared to those inside. Hence, nanoparticles have a much greater surface area per given volume compared with larger particles. But, above phenomena may leads to increase the rate of absorption through the human skin, lungs

or digestive system and cause harmful effects to the lungs as well as other organs. [24].

11. Conclusion

Nanotechnology is often referred to as a general purpose technology. The use of nanotechnology is continuously transforming daily use products, making consumer goods plentiful, inexpensive and highly durable. Space travel and colonization will become safe an affordable with the advances that nanotechnology is bringing in aerospace materials. The nanomaterials will have a drastic impact on the human behavior and society.

i) Consequently, nanomaterials are determining the direction and future of our life as well as the planet.
ii) As the next industrial revolution, nanomaterials will significantly impact the engineering discipline and manufacturing industry, making it possible to develop and produce high-quality products with novel properties at a very low cost and through vastly improved means of production.

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