ISSN : 0974 - 7494 Volume 8 Issue 2

Nano Science and Nano Technology
An Indian Journal

Full Paper

NSNTAIJ, 8(2), 2013 [39-45]

Nanotechnology - The invisible revolution?

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ABSTRACT

The scientific revolution happened in the last two decades has given birth to a new branch called as nanoscience and nanotechnology. This new technology can now offer materials which can act like as store house of human knowledge and to unveil many fundamental secrets of nature and solve several technical difficulties. It is a world of technology witnessing a revolution in the exploration of matter at the small invisible scale. This technology is expected to be the unique bridge for linking the technical gap between the solved and unsolved problems. With the help of this technology, one can detect brain treating diseases like Cancer, AIDS, Alzheimer and many other harmful viruses etc. and this has also brought a revolution in the area of electronics by creating RFID robots and sensors. In this write up, we briefly discuss the potential benefits of nanotechnology and their ground-breaking applications which can make our future better and stronger.

WHY NANOTECHNOLOGY

Although there are so many technologies but the buzz word all over the world is "Nanotechnology" because the present day technologies have not satisfied our demands and expectations. For instance, our best photovoltaic devices convert light with only 16 per cent efficiency in energy conversion. While cooking we use only 38 per cent of the thermal energy produced by gas. However, the efficiency of the naturally occurring photosynthetic process by the plants is incomparable compared to the above instances. This is all man has learnt from nature but he has to learn a lot more to get closer to nature because no one has reached the efficiency of photosynthesis and no factory does water purification and storage as efficiently as coconut trees or watermelon. To achieve the above, the evolving technology in front of us is "Nanotechnology". The use of this type of technology is not new to us. With the help of this technology only, the alchemists in Alexandria developed a powerful colloidal elixir known as "liquid gold" a preparation that was meant to restore youth and the Lycurgus cup made by romans in 4 Th century AD. This cup appears red in transmitted light (if a light source is kept within the cup) and appears green in reflected light (if the light source is outside). The composition of this cup is just like our normal glasses but this speciality lies in adding of very small amounts of gold and silver in the form of nanoparticles[1].

Historically nanotechnology was for the first time formally recognized as a viable field of research by Richard P. Feynman, a Noble laureate in his mythical speech "There is a plenty of room at the bottom" in 1959. Although he has not used a single word about this technology in his talk, the word "nanotechnology" was coined later by Eric Drexler. Nanotechnology is a new category of technology that involves the precise manipulation of materials at the molecular level or nano scale of roughly 1 to 100 nanometres. The word "nano" itself says it is dwarf, i.e., small. This is not just a new field of science and engineering but a new way of looking at and studying. Using this, researchers and manu-

facturers can now fabricate materials literally molecule by molecule.

WHY NANO BEHAVES DIFFERENTLY FROM BULK

While macro scale objects are widely used, they have not caused the same excitement as nanomaterials. The reason is macro scale objects have essentially the same properties as bulk materials. However, at the nano scale the fundamental properties of materials depend on their size, shape, and composition in a way that they do not exhibit at any other larger scales and sizes. Some of the possible reasons that nanoscale objects have such amazing properties are as follows:

a) Quantum size effect

When a metal particle having bulk properties is reduced in size to a few hundred atoms, The continuous density of states in the band is replaced by a set of discrete energy levels which may have high energy level spacing's and the gap opens up. The small cluster is analogous to a molecule having discrete energy levels with bonding and anti-bonding orbitals. Eventually a size is reached where the dimensions of the particles are in the order of wavelengths of the electrons. In this situation, the energy levels can be modelled by the quantum-mechanical treatment of a particle in a box. This is referred to as the quantum-size effect.

For example, if we consider a semiconductor like CdS, which is normally reddish in colour. If it brings down to Nano scale it shows different colours. i.e., at 4 nm size it shows orange and at 3 nm size it shows yellow and at 2 nm size it shows white colour. Similarly, gold nanoparticles also show different optical properties with respect to their size and shape. Not only the visual properties but also the other properties can change dramatically.

b) Geometric structure

Generally crystal structure of large nanoparticles is the same as the bulk structure. Recent x-ray diffraction studies of 80 nm aluminium particles shows that they have (Fcc) unit which is the structure of unit cell of bulk aluminium but small particles having diameters of 3-5 nanometres have icosahedral structure. For these well-structured nanoparticles, the surface-area to volume is very high and hence, the chemical and physical properties can also be altered remarkably.

NANOTECHNOLOGY IN NATURE AND CURIOSITIES IN SCIENCE: SMALL IS BEAUTIFUL

Fundamental understanding of the natural phenomenon around us can also lead to new discoveries and progress in science and technology. For example: In recent times there has been a new understanding about how the hydrophobic surfaces and hydrophilic surfaces work. This effect has been there for millions of years and now is recognized as the "Lotus effect". Lotus is a beautiful flower known to all civilizations. How it appears beautiful and its leaves do not become dirty even by staying in muddy water without letting water stick to it has been a point of wonder. However, it has been investigated and found that this is due to the micro-nano structure of the lotus. When it is observed under electron microscope, it exhibits some bumps of micro-meter size and bumps are decorated with nano-meter sized structures. This can help a water drop stay on the leaf without spreading it. When the water drop rolls on the leaf, it collects the dirt on the surface and makes the surface clean. The phenomenon of wettability in lotus is also common in many other plant leaves, flowers, butterfly wings and many others in plant and animal kingdom. Scientists have tried now to make use of this phenomenon to artificially obtain the hydrophilic/hydrophobic surfaced in various materials of different sizes and shapes.

Somewhat similar interesting phenomenon observed in nature over centuries and wondered about is so-called "Gecko effect" or swarming of a lizard on wall. How does a lizard balance its weight? Does it secrete any fluid to stick or what else? Now the scientists believe that the particular construction of the tip of its feet on which millions of nano hair exist help it in crawling. Interestingly the force that each hair strand exerts between wall and itself is just weak van der Waals force. This effect may be useful to make robots which would climb the walls or do some scientific operations without manual aid. Some simple minded application of gecko effect would be a stick tape which can be used number of times without failing; like a lizard[2].

NANOTECHNOLOGY'S ROLE IN CATALYSIS

Catalysis plays a vital role in providing fuels, fine chemicals, pharmaceuticals and means for strengthening environmental safeguards in comparison with many other fields of chemicals and material sciences. Catalysis was one of the first fields to take advantage of nanotechnology supported noble metal catalysts with particle sizes down to a few hundred nanometres and zeolite catalysts with pore sizes of sub-nanometres, all developed in 1950s-1960s are widely used in today's chemical processes. The field of catalysis continuously reinvites itself and become highly interdisciplinary. Many of the recent advantages are a result of such interdisciplinary developments involving nanotechnology. The nanotechnology guided the design, fabrication and enhancement of their activity or selectivity, as well as the reduction in cost of catalysts which will have enormous impacts to the chemical industry and hence, the society as well. The ability to harness the large surface area-to-volume ratios and the unique binding sites of nanoparticles, especially in heterogeneous catalysis, constitute major diving force in fundamental research and practical applications of nanoparticle catalysts importantly. Tailoring of the nanoparticle size, shape and surface could also lead to improved or catalytic properties. A major challenge for exploring nano-particles in heterogeneous catalysis is the controlled size, shape, surface and interparticle spatial properties. The ultimate goal is to achieve high catalyst by design with and high activity and 100% selectivity. A large number of nanoparticle catalysts have rapidly emerged in recent years, especially the nanoparticles supported oxides, encapsulated organic monolayers are of are selectively applied in the both traditional and new approaches[2].

NANO MEDICINES: AN EVOLVING INTERFACE TO TREAT BRAIN TEASING DISEASES

Today nanoparticles are being developed to have accurate, controllable, and rapid responsive diagnostic and treatment solutions for various kinds of diseases. With the recent advancements in drug discovery process, stress is an effective drug delivery to the affected organ. It is well-known that many therapeutic agents have intracellular compartments as their site of action. For example, the nucleus is the site of action for anti-cancer intercalating agents whereas the cytoplasm is the centre for a number of steroids. Accordingly, the efficiency of drug depends on its sustained availability at the targeted point of delivery and various studies confirm the fact that particle size should be sufficiently small for it to get transported across the membrane and this transport occurs more readily for nanoparticles, they work efficiently in drug delivery process. The particles are coated with antibodies to fight a particular virus, so that they will form clumps that would be visible on conventional body scans. The nanodrugs synthesized in various forms such as nanospheres (drug present on the nanoparticle as a capping agent), nanocapsules (drug confined in a cavity surrounded by a polymeric layer), nanopores (nanoparticle surface perforated with holes, holes containing drug molecules). The purpose of encapsulation or entrapment is to gain a better degree of control over the drug release process. Recently, attempts have also been made towards developing biodegradable polymeric nanoparticles as potential drug delivery devices and also various research groups have also established the use of polymeric nanoparticles for nasal and ophthalmic delivery of drugs. This group of nanoparticles have also shown prominence for use in neuro-disorders Furthermore, nanosize carriers as vitamin molecules such as vitamin A and E, have potential applications in dermatology and cosmetics[1].

In addition to these, recent advancements in nanotechnology show that the nanoparticles can detect and kill the cancer cells efficiently and they act as bandage (made of nanofibre) to heal wounds. Scientists prepared sensors for the detection of bacterial growth, chemicals, and pathogens. Even the mechanical properties of single DNA molecules were also discovered using advanced manipulation techniques. It is strongly believed that these scientific and technological developments in this area will restore our youth and makes us immortal.

NANOPARTICLES IN COSMETICS

Nanoparticles play an important role in cosmetics. Zinc oxide and titanium oxide nanoparticles of fairly

uniform size are able to absorb ultraviolet light and protect us from sun. Due to their small sizes, nanoparticles-based creams are preferred as they can be used in small amounts and do not leave any gaps between them which also give a smooth appearance. The small particles in some of the creams scatter light in such a way that appearance of the wrinkles is diminished. Some of the creams using nanoparticles are already marketed. It has also been observed that the nano-based dyes and colours are quite harmless to skin and can be used in hair creams or gels. Recently one cosmetic cream was prepared with the assistance of nanotechnology. This cream makes our age looks like less when it is applied on the face. However further research on the effect of nanocosmetics on human bodies is necessary[2].

ENVIRONMENTAL ISSUES ON NANOTECHNOLOGY

Whenever any new technology emerges there is rightfully a concern about its impact on social life, health and environment. Many new technologies were developed in the 21st century which creates numerous benefits to mankind but at the same time we have to face numerous problems by adopting various types of technologies. Some often poses whether nanotechnology would help to solve or increase the problems? Will nanomaterials pollute water, air and food or it harm human bodies, animals and plants by inhaling or by contact? Although ill effects of nanomaterials are possible, they are not well studied yet. Recent researches reveal that particles of size 50 nm can affect cells, 30 nm can affect central nervous system and 70 nm can affect alveoli of lungs. And also carbon nanotubes are able to penetrate into the tomato seeds and affect their germination and growth rates. Analytical methods indicated that the CNTs are able to penetrate the thick seed coat and support water uptake inside the seeds, a process which can inhibit the germination of seedlings[7]. On the other hand, present findings show that the silver nanoparticles promote the growth of Brassica juncea (Indian mustard) seedlings by modifying their antioxidant status, treatment of plants with a mixture of nano SiO_2 and TiO_2 can enhance activities of specific enzymes, increase disease resistivity of plants, increase the yield of crop[4]. It is also believed that nanoparticles themselves can be used to reduce pollution and environment related problems.

SUCCESSFUL APPLICATIONS OF NANOTECHNOLOGY IN THE REAL TIME SCENARIO:

Applications in cancer therapy

a. Ultrafast cancer detection kit using silver nanoparticles

Silver nanoparticle adhered on a glass substrate is shown to be an economical, fast and reliable kit for detection the early stages of cancer. This kit is able to deliver results with 10 times more accuracy within minutes, thus proving to be ideal for cancer detection[3].

b. Nano shells acts as anticancer drugs

Nano shells can act as anticancer drugs. The light used is near - infrared light which gets absorbed by the shells, thereby heating and destroying the cells which are injected with the shells. Detection of the cancer cells is also done by the shells.

c. Carbon nanotubes kill cancer cells

The transporting capabilities of carbon nanotubes, combined with suitable chemical functionalization and their near infra-red optical absorption properties, can be used for destroying cancer cells[5].

Applications in neurology

d. Gold nanoparticles offer a cure for Alzheimer's condition

Beta amyloid fibrils, bound to gold nanoparticles are found to separate on exposure to mild microwave fields. The microwave field was orders of magnitude less than what is used in mobile phones, thereby removing any health hazard. Interestingly, the fibrils were observed to be dissolved and do not reaggregate even after several weeks, thus offering a potential cure for Alzheimer's condition[6].

e. Nano belts to detect nerve agents

For detecting nerve agents, sensors have been made by combining tin oxide "Nano belts" with low power

micro-heaters. These are ultra-stable, highly sensitive and free from the 'poisoning effect' of metal oxides are found in the previous sensors[8].

f. Carbon nanotubes communicate to nerve cells

In a scientific breakthrough, scientists have transmitted electrical signals of nerve cells through carbon nanotubes. The nerve cell grows on carpet of carbon nanotubes which were able to receive and react to the electrical signals from the substrate. This presents the feasibility of using carbon nanotubes and related materials in the treatment of nervous breakdown conditions[9].

Applications in other fields

g. Nano fibre bandage to heal wounds

A Nano fibre mat which is extracted from fibrinogen, a soluble protein that is present in blood, has been made and it can be used as a wound dressing or tissue - engineering scaffold which is used to heal wounds[10].

h. Injection of magnetic nanoparticles into the blood can reveal where harmful viruses are located

It has been shown that injection of magnetic nanoparticles into the bloodstream can reveal where harmful viruses are located. The particles are coated with antibodies to fight a particular virus, so that they will form clumps that would be visible on conventional body scans.

i. Nano crystals for detecting genetic mutations

A technique that uses Nano crystals for detecting genetic mutations has been developed, which involves the creation of bioelectronics coding[11].

j. Carbon nanotubes based artificial muscles

In a breakthrough research, artificial muscles based on carbon nanotubes have been developed. The nanotubes take on a triple role of fuel cell electrode (to generate electrical energy), super capacitor (to store the energy) and an actuator (to convert electrical energy to mechanical motion). This self-propelling artificial muscle runs on methanol and is thought to bring the scientific community one step closer toward building "humanoids"[12].

k. Silica nanoparticles spring forth life

The normal silica nanoparticles have been shown to provide the structure and function to proteins. The proteins assembled into a particular form with specific structure in the presence of silica nanoparticles, thereby leading an inorganic angle to the origin of life[13].

ROAD MAPS OF NANOTECHNOLOGY AND OUR FUTURE JOURNEYS

Herein, some of our demands and expectations from the emerging area of nanotechnologies are listed below:

Will- Will communication

As we know that the carbon nanotubes have the capacity to communicate with nerve cells[9] and the capable of transmitting information through carbon chain[14], with the help of these we can trap the speech signals of brain and directly send it to the other whose we want to speak, through antenna and receiver system. This means we can stop communicating orally and we will communicate with the nerve impulses only.

b. Scanning the contents of brain

In future, with the help of nanotechnology we could simply scan the contents of brain download them into a computer memory and resuscitated at will, either in another body, or for the real extremists in the form of software in virtual space.

c. Diamond nano fibres in brain

At present our brains are very vulnerable to strong vibration, etc. Once if we transplanted diamond Nano fibres into our brain, the brain would cause only minor discomfort due to the heavy collisions by means of any accidents or strong tremors. If we could weave molecules of diamond into the bones of our skull, it would become partially indestructible.

d. Increasing the day hours by introducing an alternative satellite

A satellite with solar panels, made up of nanotechnology is made with 100% efficiency of receiving the sunlight from sun and storing it, is sent into the space. When the sun sets on west, the satellite which is sensitized to rise slowly in the east and began to start giving light. It receives the sunlight 12 hours from sun in day time and transmits it for another 12 hours in night.

So, there is chance to increase the day time and thus increasing the scientific and technological development in India.

e. Rapid food production by extracting the capacity of cancer cells

The capacity of cancer cells is rapid and unstoppable mitosis. If we extract the gene responsible for it and injected into the cells of food crops, there is chance to enhance the food production. Also the nano pesticides which give the essential nutrients to plants effectively can also enhance the rate of food production.

f. Healing power based on rapid mitosis

Nano cells, which are biocompatible, having the capacity of rapid mitosis (which is extracted from cancer cells), are injected into body. Whenever there is a loss of tissue in the body by wound or other way, these cells react and perform rapid mitosis and thus we can achieve the power of healing.

g. Hydro filled magnetic nano shells for the peptidolysis of pathogen's replication proteins

By breaking the peptide bonds in the proteins present in a pathogen, it is expected to stop the replication of that pathogen which can lead to a potential benefit in cancer therapy. Here we can use water molecules filled magnetic nanoshells to trigger the release of water molecule at the desired area in pathogen.

h. Nano RFID (Radio frequency and identification) robots

The RFID tags (used as robots to monitor the human body activities) are likely to threaten our freedom which is based on microelectronics; but once we made RFID tags made up of Nano electronics, they would be easily inserted into human body. Once they enter, they can monitor blood consumption and also the release of hormones in several glands. If they are injected into brain, they can also record the signals transmitted by neurons which can be useful in analysing our body functions. These machine robots are able to detect the incidence of genetic mutation at molecular scale and hence, there is a chance to correct genetic disproportions to cancer. These robots having their size less than blood cells will repair our organs day and night to create new tissues.

ETHICAL IMPLICATIONS AND CONCLUSION

Nanotechnology products are reaching the market with an annual growth rate of over 25 per cent. Both promises and concerns about the social implications of this new technology are being voiced with increasing frequencies. Ethical aspects are increasing in relative importance and their upstream consideration may be a key for the successful and sustained application of this technology. The potential societal implications of the scientific and technological innovation in the realm of nano are only partially understood and therefore need to be further explored. Although there are so many anti-nanotechnologists around the world but the newly emerging technologies of the 21st century have the potential to revolutionize social and economic development.

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