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Nanomaterials and its Potential Applications

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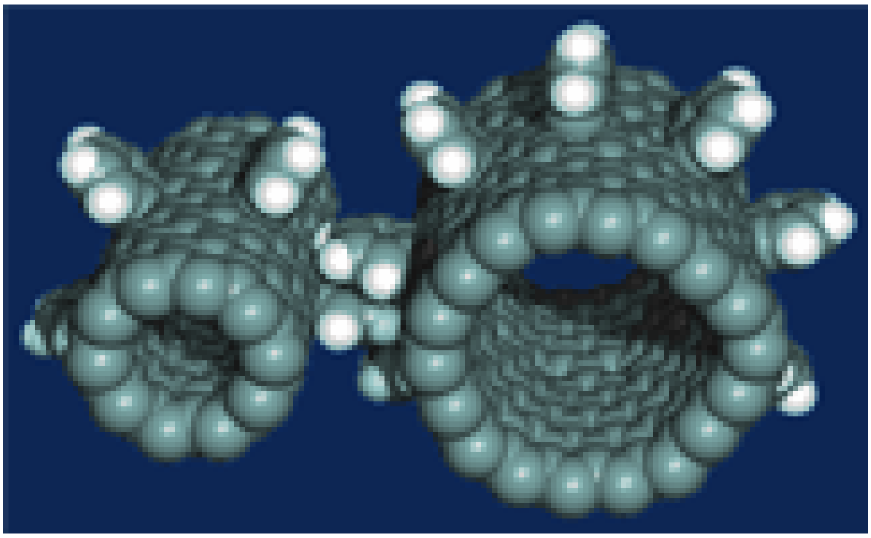
Abstract: Nanomaterials are defined as engineered materials with a least one dimension in the range of 1-100nm. Particles of "**nano**" size have been shown to exhibit enhanced or novel properties including reactivity, greater sensing capability and increased mechanical strength. The nanotechnique offers simple, clean, fast, efficient, and economic for the synthesis of a variety of organic molecules, have provided the momentum for many chemists to switch from traditional method. In the present article an attempt was made to focus on what is nanomaterials, how is it generated and what importance may it have.
Keywords: Nanomaterials-synthesis, properties, applications.

Introduction

The term "**Nanotechnology**" was first defined by **Norio Taniguchi** of the Tokyo Science University in 1974. Nanotechnology[1-3], shortened to "**Nanotech**", is the study of manipulating matter on an atomic and molecular scale. Generally nanotechnology deals with structures sized between 1 to 100 nm and involves developing materials or devices within that size. For comparison, 10 nanometers is 1000 times smaller than the diameter of a human hair. Nanotechnology has the capacity to improve our ability to prevent, detect, and remove environmental contaminants in air, water, and soil in a cost effective and environmentally friendly manner. Nanoscience and nanotechnologies are revolutionizing our understanding of matter and are likely to have profound implications for all sectors[4-6] of the economy, including agriculture and food, energy production and efficiency, the automotive industry, cosmetics, medical appliances and drugs, household appliances, computers, and weapons.

The branch of nanoscience and technology is truly multi-disciplinary and is an emerging technology with full of promises to have an impact on virtually every spectrum of civilization including communications, computing, textiles, cosmetics, sports, therapy, automotives, environmental monitoring, fuel cells and energy devices, water purification, food and beverage industry, etc. The ability to construct tiny objects atom- by-atom or molecule- by- molecule forms one of the exciting prospects of the research field in nano science. It shows great promise for providing us in the near future with many breakthroughs that will change the direction of nanotechnology advances in a wide range of applications[7-11].



The application of nanomaterials can be historically traced back to even before the generation of modern science and technology. In 1857, **Michael Faraday** published a paper which explained how metal nano particles affect the colour of church windows. In 1959, **Richard Feynman** (awarded Nobel prize in Physics in 1965) gave a lecture titled "**There's Plenty of Room at the Bottom**", suggesting the possibility of manipulating things at atomic level. He speculated on the possibility and potential of nanosized materials. This is generally considered to be the foreseeing of nanotechnology. Many of his speculations[12-16] have become reality now. However, the real burst of nanotechnology didn't come until the early 1990s. In the past decades, sophisticated instruments for characterization and manipulation[17-20] such as scanning electron microscopy (**SEM**), transmission electron microscopy (**TEM**) and scanning probe microscopy (**SPM**) became more available for researchers to approach the nanoworld.

In the early 1990s **Huffman** and **Kraetschmer**, discovered how to synthesize and purify large quantities of fullerenes[21-26]. This opened the door to their characterization and functionalization by hundreds of investigators in government and industrial laboratories. Shortly after, at a meeting of the Materials Research Society in 1992, **Dr.T.Ebbesen** described to a spellbound audience his discovery and characterization of carbon nanotubes. This event sent those in attendance and others downwind of his presentation into their laboratories to reproduce and push those discoveries forward. Using the same or similar tools as those used by Huffman and Kratschmer, hundreds of researchers further developed the field of nanotechnology. No one knows how many products on the market today contain nanoparticles or are manufactured with the help of nanotechnologies.

Synthesis of Nanomaterials

Nanomaterials can be synthesised[27-31] by any one of the following methods.

1.**Pyrolysis**

It involves pyrolysis of hydrocarbons such as acetylene at 700^0C in the presence of Fe-silica or Fe-graphite catalyst under inert conditions.

2.**Carbon arc method**

It is carried out by applying direct current (60-100 A and 20-25 V) arc between graphite electrodes of 10-20µm diameter.

3. **Laser evaporation method**

It involves vapourisation of graphite containing small amount of Co and Ni, by exposing it to laser beam at 1200^0C in a quartz tube reactor. An inert gas like argon is allowed to pass into the reactor to sweep the evaporated carbon atoms from the furnace to the copper collector, on which the nanomaterials condense.

4. **Chemical vapour deposition**

It involves decomposition of vapour of hydrocarbons such as methane, ethylene, acetylene, etc., at 1100^0C in presence of catalysts like Ni, Co, Fe suported on MgO.

Properties of Nanomaterials

Two principal factors cause the properties[32-34] of nanomaterials to differ significantly from other materials: increased relative surface area, and quantum effects. To understand the effect of particle size on surface area, consider a U.S. silver dollar. The silver dollar contains 26.96 grams of coin silver, has a diameter of about 40 mm, and has a total surface area of approximately 27.70 square centimeters. If the same amount of coin silver were divided into tiny particles – say 1 nanometer in diameter – the total surface area of those particles would be 11,400 square meters. When the amount of coin silver contained in a silver dollar is rendered into 1 nm particles, the surface area of those particles is 4.115 million times greater than the surface area of the silver dollar!

a) Electrical properties

The electrical properties of nanomaterials vary between metallic to semiconducting materials. It depends on the diameter of the nanomaterials. The very high electrical conductivity of nanomaterial is due to minimum defects in the structure.

b) Thermal conductivity

The thermal conductivity of nanomaterials are very high, is due to the vibration of covalent bonds. Its thermal conductivity is 10 times greater than the metal. The very high thermal conductivity of nanomaterial is also due to minimum defects in the structure.

c) Mechanical properties

Nanomaterials are very strong and withstand extreme strain. Most of the materials fracture on bending because of the presence of more defects, but nanomaterials possesss only few defects in the structure.

Applications of Nanomaterials

Below we list some key applications of nanomaterials. Most current applications represent evolutionary developments of existing technologies: for example, the reduction in size of electronics devices.

a) Sunscreens and Cosmetics

The traditional chemical UV protection approach suffers from its poor long-term stability. A sunscreen based on mineral nanoparticles such as titanium dioxide offer several advantages. Titanium oxide nanoparticles have a comparable UV protection property. Nanosized titanium dioxide and zinc oxide are currently used in some sunscreens, as they absorb and reflect ultraviolet (**UV**) rays and yet are transparent to visible light and so are more appealing to the consumer. Nanosized iron oxide is present in some lipsticks as a pigment. The use of nanoparticles in cosmetics has raised a number of concerns about consumer safety.

b) Paints

Incorporating nanoparticles in paints could improve their performance, for example by making them lighter and giving them different properties. Thinner paint coatings ('**lightweighting**'), used for example on aircraft, would reduce their weight, which could be beneficial to the environment.

c) Displays

The huge market for large area, high brightness, flat-panel displays, as used in television screens and computer monitors, is driving the development of some nanomaterials. Nanocrystalline zinc selenide, zinc sulphide, cadmium sulphide and lead telluride synthesized by sol gel techniques are candidates for the next generation of light-emitting phosphors.

d) Batteries

With the growth in portable electronic equipment (mobile phones, laptop computers, remote sensors), there is great demand for lightweight, high-energy density batteries. Nanocrystalline materials synthesized by sol–gel techniques are candidates for separator plates in batteries because of their foam-like (aerogel) structure, which can hold considerably more energy than conventional ones. Nickel–metal hydride batteries made of nanocrystalline nickel and metal hydrides are envisioned to require less frequent recharging and to last longer because of their large surface area.

e) Catalysis

In general, nanoparticles have a high surface area, and hence provide higher catalytic activity. Catalysis is important for the production of chemicals. Nanoparticles serve as an efficient catalyst for some chemical reaction, due to the extremely large surface to volume ratio. Platinum nanoparticles are now being considered in the next generation of automotive catalytic converters because the very high surface area of nanoparticles could reduce the amount of platinum required. Some chemical reactions are also carried out using nanomaterials. For example, reduction of nickel oxide to the base metal Ni.

f) Medicine

Nanotechnology has been a boon in medical field by delivering drugs to specific cells using nanoparticles. The overall drug consumption and side effects can be lowered significantly by depositing the active agent in the morbid region only and in no higher dose than needed. This highly selective approach reduces costs and human suffering. Nanotechnology can also help to reproduce or to repair damaged tissue. "**Tissue engineering**" might replace today's conventional treatments like organ transplants or artificial implants. For example, bones can be regrown on carbon nanotube scaffolds.

The use of gold in medicinal preparations is not new. In the Indian medical system called **Ayurveda**, gold is used in several preparations. One popular preparation is called ***Saraswatharishtam***, prescribed for the memory enhancement. Gold is also added in certain medical preparations for babies in order to enhance their mental capability. Over 5000 years ago, Egyptians used gold in dentistry. In Alexandria, alchemists developed a powerful colloidal elixir known as **liquid gold**, a preparation that was meant to restore youth. In china, people cook their rice with a gold coin in order to help replenish gold in their bodies.

g) Sensors of gases

The gases like NO_2 and NH_3 can be detected on the basis of increase in electrical conductivity of nanomaterials. This is attributed to increase in hole concentration in nanomaterials due to charge transfer from nanomaterials to NO_2 as the gas molecules bind the nanomaterials.

h) Food

Nanotechnology can be applied in the production, processing, safety and packaging of food. A nanocomposite coating process could improve food packaging by placing anti-microbial agents directly on the surface of the coated film. New foods are among the nanotechnology created consumer products coming onto the market at the rate of 3 to 4 per week. According to company information posted on PEN's Web site, the canola oil, by Shemen Industries of Israel, contains an additive called "**nanodrops**" designed to carry vitamins, minerals and phytochemicals through the digestive system and urea.

i)Construction

Nanotechnology has the potential to make construction faster, cheaper and safer. 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. The Silica (**SiO_2**) is present in conventional concrete as part of the normal mix.When nano silica is added to concrete the particle packing can be improved mechanical properties. The addition of nano silica to cement based materials can also control the degradation of the fundamental C-S-H (**calcium silicate hydrate**) reaction of concrete caused by calcium leaching in water as well as block water penetration and therefore lead to improvements in durability. The strength of concrete can also be increase by adding haematite (**Fe_2O_3**) nanoparticles.

Steel has been widely available material and has a major role in the construction industry. The use of nanotechnology in steel helps to improve the properties of steel. The nano size steel produce stronger steel cables which can be used in bridge construction.

The glass is also an important material in construction. There is a lot of research being carried out on the application of nanotechnology to glass. Titanium dioxide (**TiO_2**) nanoparticles are used to coat glazing since it has sterilizing and anti-fouling properties. The particles catalyze powerful reactions which breakdown organic pollutants, volatile organic compounds and bacterial membranes. Most of glass in construction is on the exterior surface of buildings. So the light and heat entering the building through glass has to be prevented. The nanotechnology can provide a better solution to block light and heat coming through windows.

Coatings is an important area in construction. Coatings are extensively use to paint the walls, doors and windows. Coatings should provides a protective layer which is bound to the base material to produce a surface of the desired protective or functional properties. Nanotechnology is being applied to paints to obtained the coatings having self healing capabilities and corrosion protection under insulation. Since these coatings are hydrophobic and repels water from the metal pipe and can also protect metal from salt water attack.

j) Agriculture

Applications of nanotechnology have the potential to change the entire agriculture sector and food industry from production to conservation, processing, packaging, transportation, and even waste treatment.

k) Energy

The most advanced nanotechnology projects related to energy are: storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving and enhanced renewable energy sources. Today's best solar cells have layers of several different semiconductors stacked together to absorb light at different energies but they still only manage to use 40 percent of the Sun's energy. Commercially available solar cells have much lower efficiencies (15-20%). Nanotechnology could help increase the efficiency of light conversion by using nanostructures.

l) Other Applications

Some commercial products on the market today utilizing nanomaterials include stain resistant textiles and reinforced tennis rackets. Companies like Kraft foods are heavily funding nanomaterials based plastic packaging. Food will stay fresh longer if the packaging is less permeable to atmosphere. Coors Brewing company has developed new plastic beer bottles that stay cold for longer periods of time.

Conclusions

Nanotechnology is already transforming our lives with new technologies and products. Nanotechnology exploits the novel phenomenon and properties of matter at nano scale and may offer new solutions of millions of people in developing countries who lack access basic services, such as safe water, renewable energy, health care and education. There is a steep rise in global funding for nanoscience and technology . There is also growing need to raise the level of awareness and knowledge of the opportunities and challenges in this emerging field not only Science and Industrial professionals but also young students. We are confident that this article would serve its objectives of igniting many more potential minds into this path of nanoscience and technology. We believe that in the future many more nanoproducts will be developed which will simplify time consuming conventional procedures. New "**green**" technologies under development from fuel cells to catalysts for biofuels depend on nanomaterials.

Although nanoscience has recently emerged as a unique discipline of research, the technology is still fairly young and the field remains loosely defined, presenting an opportunity to incorporate new concepts within the existing methodology. The future for the application of nanotechnology looks bright because of its efficiency and its potential to contribute to clean products.

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