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NANOTECHNOLOGY: CURRENT APPLICATIONS AND FUTURE PROSPECTS

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ABSTRACT

Nanotechnology is the study of structures at nanoscale level ranging from 0.1 to 100 nm. Nanomaterials like nanoceramics, carbon nano tubes, metallic nanoparticles, massive nanoparticles, liposomes, dendrimers, quantum dots, nanowires and fullerenes are used due to their unique properties like electrical conductance, chemical reactivity, magnetic, optical effects and physical strength. The global market of nanoproducts has been increased at a very fast pace and various researchers have focused on developing innovative nanosystems and nanostructured materials. This technology has shown diverse applications in different industrial sectors like paper and pulp, cosmetics, textiles, medicine, electronics, transportation, space exploration, energy and environment etc. However, the research of nanomaterials on tissue culture and cell lines has also shown their hazardous effects and therefore, safety issues are of great concern for their use. Several regulations and guidelines have been issued by the government before the commercialization of nanomaterials at industrial scale.

KEYWORDS: Nanotechnology, Nanomaterials, Nanoparticles, Quantum dots.

INTRODUCTION

Nanotechnology deals with the study of extremely small structures ranging from 0.1 to 100 nm. The word ‘nano’ was derived from Greek word meaning ‘dwarf’ or ‘extremely small’ and this technology is the treatment of small atoms, molecules and compounds for the production of materials and devices with special properties such as electrical conductance, chemical reactivity, magnetic effects, optical effects and physical strength. Some important physico-chemical properties of nanoparticles are given in Box 1. The development in the field of nanotechnology was started by R. Feyman in 1958 and era of molecular nanotechnology was started recently in 2011. Nanomaterials are classified into nano crystalline and nano structured materials. Some of the examples of nanomaterials include nanoceramics, carbon nano tubes, metallic nanoparticles, massive nanoparticles, liposomes, dendrimers, quantum dots, nanowires and fullerenes. It is one of the recent development in the field of science and technology and is evolving at a very fast pace in the current years. The two approaches used for the synthesis of nanoparticles are ‘top down’ and ‘bottom up’ approach. Nanotechnology has shown wide applications in various industrial sectors like paper and pulp, cosmetics, textiles, medicine, electronics, transportation, space exploration, energy and environment etc. The demand of nanotechnology is increasing at a fast rate and is expected to impact atleast $3 trillion across global economy by 2020. Government of different countries have started to focus on research in the field of nanotechnology for the development of innovative nanosystems and nanostructured materials. Nanotechnology is recognized as new emerging field in third Industrial Master Plan (2005-2020). The current article discusses the physico-chemical properties of nanoparticles, approaches for its synthesis, applications and safety issues.

Box 1: Physicochemical Properties of Nanoparticles.

- High surface to volume ratio
- Significant magnetic forces or vander wall forces
- Size less than wavelength of light
- Redox potential and radical formation potential
- Zeta potential (surface charge)
- Characterized by critical length or scattering length or thermal diffusion length
- Photocatalytic activity
- Water solubility and crystalline size.

Synthesis of Nanoparticles

There are two approaches for the synthesis of nanoparticles which are top down (extreme miniaturization) and bottom up (building blocks). Top down approach involves the breaking of larger materials into fine particles, whereas bottom up approach tends to formation of nanostructures from nano- or sub nano-scale objects. In the bottom up approach, size and shape of nanostructure is maintained by adjusting the ratio of concentration of chemical and selected capping material. Commonly used capping materials are polymers, micelles, dendrimers and surfactants.

Top down approach involves different techniques for the manufacture of nano-scale materials are laser ablation, milling, nano-lithography, hydrothermal techniques, physical vapor deposition and electroplating. In this approach, chemical methods are more effective for the mass production of metal nanoparticles compared to physical ones. The devices which are produced by bottom up approach can store enormous amount of information. Bottom up approach is used for the synthesis of nano scale materials through sol- gel processing, liquid phase techniques based on inverse micelles, laser pyrolysis, chemical vapor deposition (CVD) and molecular self assembly.

Applications of Nanotechnology

Nanotechnology has shown significant applications in different sectors like medicine, electronics, transportation, space exploration, energy and environment, textiles, cosmetics, food science, paper and pulp. The applications of nanotechnology in various sectors is shown in Figure 1.

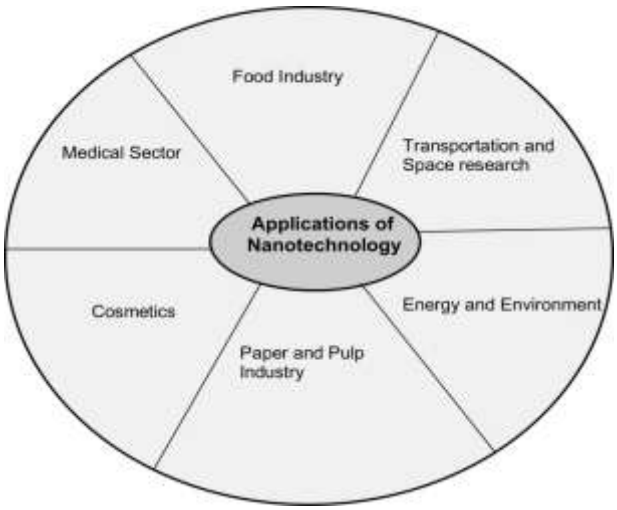

Figure 1: Applications of Nanotechnology in different Industrial sectors.

Nanoparticles are used in medical field to deliver drugs, heat, light and other substances to specific cells in human body with accurate required dose and prevent any side effects. Nanoporous materials, dendrimers, iron nanoparticles and nano robots find application for drug delivery by using this technology. Quantum dots and magnetic nanoparticles have been used for stem cell research and tissue engineering. Nanotechnology is used for the treatment of various diseases like cancer, neurodegenerative disorders, Parkinson disease, Alzheimer disease and tuberculosis. Catalysis is another application of metal nanopaticles in medical sector to treat various diseases which are caused due to metabolic imbalance. This technology shows marked promising potential in forensic analysed studies. Nanofibres (produced from cellulose and lignocellulose) are used in papermaking industry due to their abundance, nanofibrillar structure, renewable source, adhesion properties and self assembly into well defined architecture. Nanomodification (nanoscience and nano-engineering) involves the modification of structure at nanometer scale for the development of new generation composites with improved novel properties like superior mechanical performance, self-cleaning, self-healing, self-sensing capability, low electrical sensitivity and self control of cracks. Nanotechnology is also employed for improving the efficiency of energy generation, wind and geothermal power generation and energy storage. Solar cells synthesized using classic nanostructures like quantum dots, fullerenes and carbon nanotubes are cheaper, lighter and more efficient. This advanced technology is not efficient only for renewable energy generation but it is equally useful in the field of non-renewable energy generation for the economic production of fuel from low grade raw material. Nanotechnology plays an important role in food industry with nanofood applications in the form of food additives (nano inside) to improve nutrient composition, texture, flavor and shelf life. Nanomaterials are also used in food packaging ingredients to enhance product shelf life, quality and also to indicate spoil ingredients. Nanocomposites are used for improved packaging with improved barrier properties for the manufacture of edible oils, beer, carbonated drinks and films. Nano silver, nano magnesium oxide, nanocopper oxide, nano titanium dioxide and carbon tubes are used for active antimicrobial packaging of food products. Engineered nanosensors are being developed to estimate the spoilage of food products using electronic nose, taste, smell, tongue and flavours. Currently, chemical sensors are used by Nestle, MonoPrix Supermarkets and British Airways for the detection of colour change. Development of modified medicated textiles with antimicrobial activity with special functions such as UV-protection, anti-odor, easy clean, stain and water repellent is another application of nanotechnology. Titanium dioxide, zinc oxide, liposome, nano crystals, nano emulsions, solid lipid nanoparticles, hyperbranched polymers and dendrimers are employed in cosmetic products including hair care products, sunscreen, moisturizers and make up.

Future Prospects

Nanotechnology is an emerging field in current global market, which has shown enormous applications in every industrial sector due to its unique properties. The global

market of this advanced technology is increasing at a very fast pace. The use of nanomaterials and nanoproducts is expected to be increased worldwide in the coming years. Many government and private organizations has focused on developing new techniques and products by involving this technology. There is a need of attention and plans of action for research and development activities in nanotechnology. However, previous studies by researchers have shown hazardous effects of some of the nanomaterials on human health and environment. Therefore, there is an urgent need to develop new approaches and standardized test procedures to study the potential hazardous effect of nanoparticles on human health and environment. The research on developing new engineered nanomaterials by adapting advanced and more sensitive techniques should also be focused in future.

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