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Nanotechnology in Industry

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Abstract Nanotechnology refers to the manipulation of matter at the atomic and molecular scale to create materials with new properties. It is multi-disciplinary in nature, involving a vast range of disciplines such as chemistry, biology, physics, pharmaceuticals, computer science, and material science. Nanotechnology has had thriving applications in many industries. In this paper, market opportunities for nanotechnology will be presented from an industrial perspective covering food, automotive, construction, medicine, and oil and gas.

Keywords nanotechnology, nanometerials, nanotechnology industry

Introduction

The term "nano" means something small, tiny and atomic in nature. The application of the term in science led to a field called nanotechnology. Nanotechnology refers to the characterization, fabrication and manipulation of structures, devices or materials that have one or more dimensions that are smaller than 100 nanometers. It may be regarded as an area of science and engineering where phenomena that take place at the nano-scale (10-9m) are utilized in the design, production, and application of materials and systems.

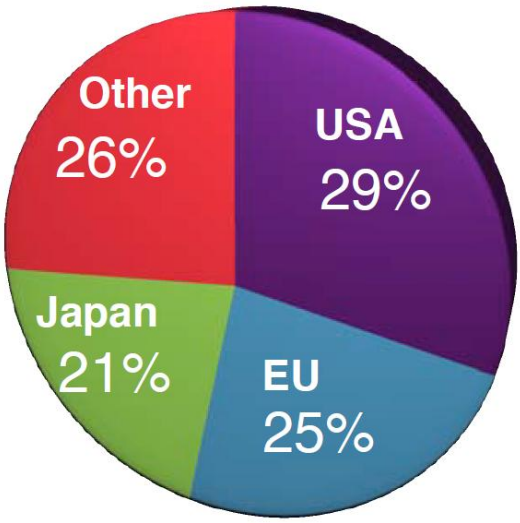

Figure 1: Distribution of US$4.681 billion worldwide government R & D expenditure on Nanotechnology in 2006 [1]

Nanotechnology has been reported as the new industrial revolution. The past decade has proven the applicability of nanotechnology in almost all fields. Nanotechnology has been predicted to be a main driver of technology

and business in this century. It has become the new frontier of science and technology around the world. Both developed and developing nations are investing in nanotechnology to secure a market share. The global demand for nanotechnology in all industries is evidenced by the ever-growing volume of investment made by the private investors. Nanotechnology promises significant improvements of advanced materials and manufacturing techniques, which play critical role for the future industries. The United States remains the global leader in the volume of nanotechnology government investment. Figure 1 shows the worldwide distribution of government R & D expenditure on nanotechnology in 2006 [1].

Overview of Nanotechnology

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. The term "nanotechnology" was coined in 1974 by Norio Tanigutchi, a professor at Tokyo Science University. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. It is the science of small things—at the atomic level or nanoscale level [2]. Nanotechnology also includes domains like nanoscience, nanomaterials, nanomedicine, nanomeasurement, nanomanipulation, nanoelectronics, and nanorobotics.

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as *nanotechnology*, the materials or objects themselves are called *nanomaterials*, and the study and discovery of these materials is known as *nanoscience*.

Nanotechnology may be regarded as the controlled manipulation of nanomaterials with at least one dimension less than 100nm. Thus nanomaterials are basically chemical substances or materials that are manufactured and used at a very small scale. Nanoscale materials can be engineered from minerals and nearly any chemical substance. Engineered nanomaterials have been deliberately manufactured by humans to have certain required properties. Nanomaterials may also be produced incidentally as a byproduct of mechanical or industrial processes [3]. They can be classified in 0D, 1D, 2D and 3D nanomaterials. Nanomaterials such as Carbon nanotubes are 100 times stronger than steel but six times lighter. Nanomaterials are widely used in consumer and industrial applications.

Nanotechnology has the idea that the technology of the future will be built on atoms. It has impact on every area of science and technology. Nanotechnology involves imaging, measuring, modeling, and manipulating matter at the nano scale. At this level, the physical, chemical, and biological properties of materials fundamentally differ from the properties of individual atoms and molecules or bulk matter [4].

Nanotechnology covers a wide variety of disciplines like physics, chemistry, biology, biotechnology, information technology, engineering, and their potential applications.

Nanotechnology features two primary approaches, which are "bottom up" where materials or devices are self-assembled from molecular components, and "top down" where nanoscale objects are constructed by micro-scale and macro-scale devices.

Applications

Nanotechnology is poised to have dramatic impact on all sectors of industry. Nanotechnology and nanomaterials have thriving applications in many industries. They exhibit the potential use of nanomaterials in various fields such as food, manufacturing, construction, medicine, energy, automobile, and so on. Figure 2 illustrated various industrial applications of nanotechnology in industry [5]. Some of these applications are discussed as follows [6-11]:

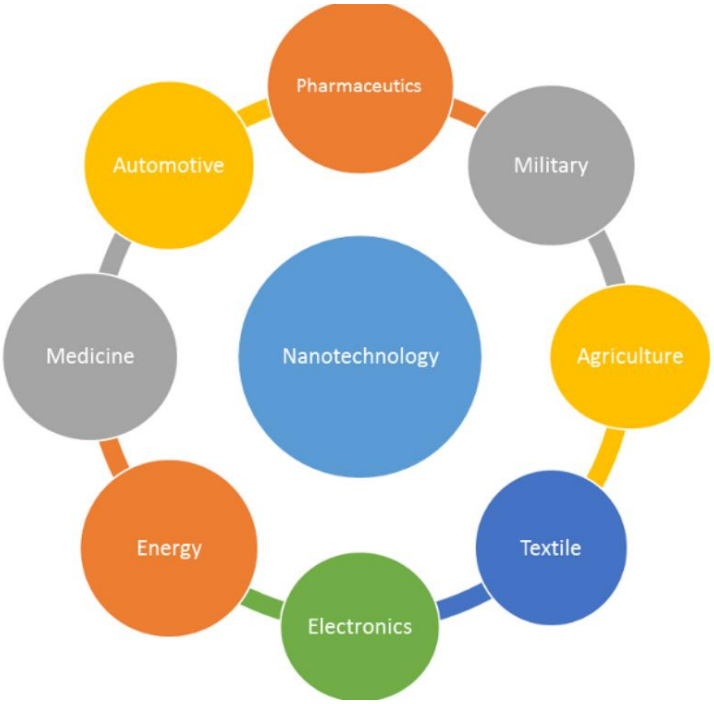

Figure 2: Various industrial applications of nanotechnology [5]

Food Industry: This is an area where nanotechnology play an important role. Nanotechnology can be applied in various aspects of food manufacturing, food protection, food processing, food package, food safety, food preservation, and food delivery systems. Food quality monitoring using biosensors; smart food packaging systems; nanoencapsulation of bioactive food compounds; and detection of chemical and biological substances for sensanges in foods; better management of spoilage extent of food products; food processing aided by nanocapsules are examples of emerging applications of nanotechnology for the food industry. For food applications, nanotechnology can be applied by two different approaches, either "bottom up" or "top down." (These will be explained a little later.) The application of nanotechnology in the food industry has made it easy to transport foods to different parts of the world by extending the shelf-life of food products. It also helps in curbing food wastage due to food spoilage by the microbial infestation. To maintain leadership in food industry, a company must work with nanotechnology in the future. Figure 3 depicts the role of nanotechnology in different aspects of food industry [12].

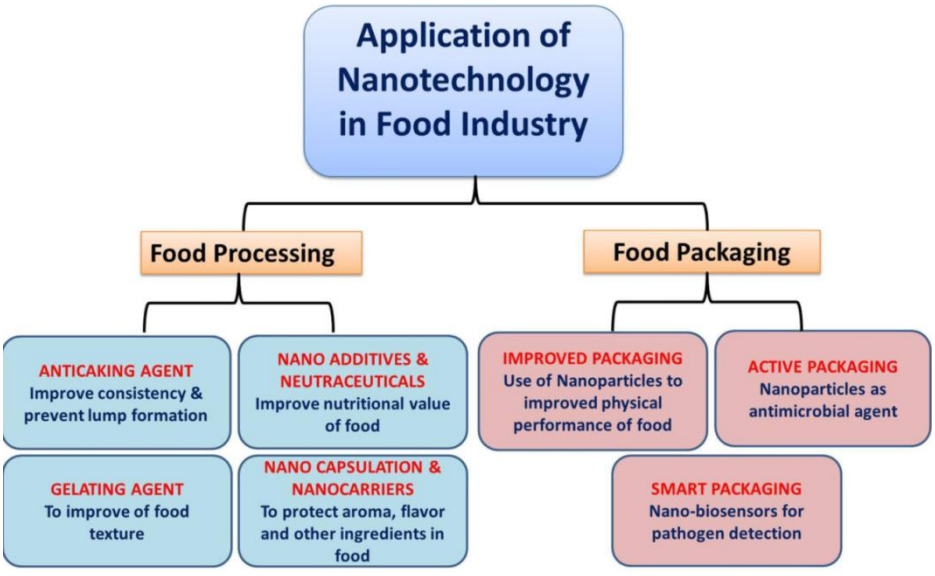

Figure 3: The role of nanotechnology in different aspects of food industry [12]

Manufacturing: Nanotechnology and nanomanufacturing are revolutionizing many manufacturing sectors, including information technology, defense, medicine, transportation, energy, environmental science, telecommunications, and electronics. Nanomanufacturing is the scaled-up, repeatable and cost-effective manufacturing of nanoscale materials and systems. Being able to manufacture flexible, lightweight, and highly efficient electronics opens the door to developing countless smart products. There are basically two approaches to nanomanufacturing: top-down **or** bottom-up. Top-down nanofabrication involves working with bulk materials and reducing them to nanometer size. This is the most common currently used technique. With the bottom-up approach, a product is created by building it up from atomic-scale components. Nanotechnology will completely change the way we produce and consume. It will allow for manufacturing processes to be scaled up and down at will, dictated by what customers want.

Automotive Industry: Nanotechnology has proved to serve in the field of automotive diligently. Different benefits include reduction in vehicle weight, increased fuel efficiency, and increased product life. Nanotechnology and nanomaterials have a promising future in the automotive industry. They are particularly useful in nanocoatings, improved fabrics and structural materials, nanofluids and lubricants, and tires. Nanomaterials offer lightweight and strong materials for applications in the automotive industry. A number of nanomaterials have been developed and utilized for the improvement of parts and devices used in the automotive industry. Nanomaterials will continue to push the boundaries in the automobile industry.

Chemical Industry: It is a well-known in the chemical industry that the microstructure of a material is key to determining its properties. Controlling structures at the micro- and nano-levels is crucial to new discoveries. Nanotechnology is integrating chemistry and materials science. The chemical industry can reap huge benefits from nanotechnology in the future if new nanomaterials are developed.

Medical/Healthcare Industry: The application of nanotechnology in the field of medicine offers some exciting possibilities. In medicine, nanomaterials offer solutions in diagnostics and treatment of diseases, while nanotechnology promises to revolutionize drug delivery, gene therapy, diagnostics, development and clinical application. Nanotechnology has great potential for applications in the field of cancer research and diagnostics. Clinicians can monitor individual cells in the body. Biomarker detection using nanotechnology offers the possibility of early detection, prevention, and control of diseases. Currently, nanoparticles are being employed to deliver drugs, heat, light or other substances to specific cancer cells. The use of nanotechnology in medicine could revolutionize the way we detect and treat disease in the human body in the future.

Construction Industry: Nanotechnology in construction involves using nanoparticles such as alumina and silica. Manufacturers are also investigating the possibility of producing nano-cement, glass, and coatings. Nanotechnology has the potential to make construction faster, safer, and more affordable. 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. Nanotechnology can offer great prospects to improve the energy efficiency of buildings. Nanotechnology encompasses a number of disciplines such as electronics, bio-mechanics, and coatings, which assist in civil engineering and construction materials. Some construction materials such as cement, concrete, steel, and glass will greatly benefit from nanotechnology. If nanotechnology is implemented in the construction of homes and infrastructure, such structures will be stronger.

Oil & Gas Industry: In oil and gas industry, nanotechnology could be used to increase opportunities to develop geothermal resources by enhancing thermal conductivity and improving downhole separation. Nanotechnology could be used to enhance the possibilities of developing unconventional gas resources. It can address the problems associated with accessing stranded natural gas resources by developing nanocatalysts and nanoscale membranes for gas-to-liquids production. Nanotechnology could help improve oil and gas production by making it easier to separate oil and gas in the reservoir through improved understanding of processes at the molecular level.

Nanotechnology is also being used in pharmaceutical industry, sports industry, textile industry, cosmetics, aerospace industry, wood industry, energy, electronics, and agriculture, and the military/defense. Many other applications have been developed by research institutions around the world. Some of these are currently in production, while others are in an advanced state of development.

Benefits and Challenges

Nanotechnology is the art and science of building materials that act at the nanometer scale and it does it with molecular perfection. Nanotechnology is an enabling technology for controlling matter at the atomic level. It has the potential to enhance food production, food quality, and food safety.

In spite of the development in nanotechnology, there are still some obstacles to a greater impact of industrial applications of nanotechnology. There are some regulations that must be followed to control the health related risks of nanotechnology in food industries. Stakeholders in nanotechnology are divided on whether specific nanotechnology regulation is needed. Manufacturing challenges include operations ranging from particle formation, coating, dispersion, to characterization, and modeling. These challenges would require effective collaboration between the researchers in the academia, research centers, and industry.

Conclusion

Nanotechnology has impacted the world of science and engineering to the extent that it has changed the way researchers think about future technologies. It is providing the capability to produce a wide range of new products that will become commonplace in the near future. Today, nanotechnology can be used to produce tennis racquets that are stronger, sunscreen creams that are more transparent, paints that are brighter and longer-lasting, and socks that do not smell [13].

Nanotechnology is not just the future, it's already here. With much focus, investment, and the continuous effort of researchers around the world, nanotechnology is poised to continue to grow and provide solutions in cosmetics, technology, medicines, and tools that benefit our daily life [14]. Nanotechnology will continue to have a broad impact on nearly all sectors of the global economy. More information about nanotechnology industry can be found in the books in [15-20] and the related journals:

- *Nanotechnology*
- *Nanoscale.*
- *Journal of Nanoscience and Nanotechnology,*
- *Journal of Micro and Nano-Manufacturing*
- *Journal of Nanoengineering and Nanomanufacturing*

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