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Nanotechnology, Big things from a Tiny World: a Review

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Abstract

The purpose of this paper is to look into the present aspects of "Nanotechnology". This paper gives a brief description of what Nanotechnology is?? And its application in various fields viz. computing, medicine, food technology, Robotics, Solar cells etc. It also deals with the future perspectives of Nanotechnology, risks in advanced nanotechnology.

Keywords: *Nanotubes, NanoFilms, Grey Goo, Nanoelectronics, Nanomedicine.*

1. Introduction

Nanotechnology operates at the first level of organisation of atoms and molecules for both living and anthropogenic systems. This is where the properties and functions of all systems are defined. Nanotechnology promises the ability to build precise machine and components of molecular size. In its original sense, 'nanotechnology' refers to the projected ability to construct items from the bottom up, using techniques and tools which are being developed to make high performance products. This theoretical capability was envisioned as early as 1959 by physicist Richard Feynman. According to National science Foundation and NNI, Nanotechnology is the ability to understand, control and manipulate matter at the level of individual atoms and molecules [1].

Nanotechnology is sometimes referred to as a general purpose technology because in its advanced version it will have significant impact on almost all industries and all areas of society [2].

Science and engineering are the primary drivers of global technological competition. Unifying science based on the unifying features of nature at the nanoscale provides a new foundation for knowledge, innovation, and integration of technology [1].

There is a longitudinal process of convergence and divergence in major areas of science and engineering. For example the convergence of sciences at macroscale was proposed during the Renaissance, and it was followed by narrow disciplinary specialization in science and engineering in the 18th-20th centuries. The convergence at the nanoscale reached its strength in about year 2000, and one may estimate a divergence of the nanosystem architectures in the next decades. The figure1shows how the nanoworld was reached and how technologies converged to nanoparticles [1].

2. Putting Nanotechnology to use

Over the past two decades, scientists and engineers have been mastering the intricacies of working with nanoscale materials. Now researchers have a clearer picture of how to create nanoscale materials with properties never envisioned before. Products using nanoscale materials and process are now available. Anti bacterial wound dressings use nanoscale silver. A nanoscale dry powder can neutralize gas. Batteries for tools are being manufactured with nanoscale materials in order to deliver more power, more quickly with less heat. Sunscreens containing nanoscale titanium dioxide or Zinc Oxide are transparent and reflect ultraviolet light to prevent sunburns [3]. Various techniques and products based on nanoscale particles are described in brief.

2.1 Drug-Delivery Technique

Dendrimers are a type of nanostructure that can be precisely designed and manufactured for a wide variety of applications, including the treatment of cancer and other diseases. Dendrimers carrying different materials an their branches can do several things at one time, such as recognising diseased cells, diagnosing diseased states (including cell death), drug delivery, reporting location, and reporting outcomes of therapy [3].

2.2 Nano films

Different nanoscale materials can be used in thin films to make them water repellent, anti reflective, self-cleaning, Ultraviolet or infrared-resistant, anti-fog, anti-microbial, Scratch-resistant, or electrically conductive. Nano films are used now on eyeglasses, computer display and cameras to protect or treat the surfaces [3]. Nano film is shown in figure 2.

2.3 Water Filtration technique

Researchers are experimenting with carbon nanotubes based membranes for water desalination and nanoscale sensors to identify contaminants in water system. Other nanoscale materials that have great potential to filter and purify water include nanoscale titanium dioxide, which is used in sunscreen and which has been shown to neutralize bacteria [3].

2.4 Nano Tubes

Carbon nanotubes (CNTs) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 28,000,000:1, which is significantly larger than any other material. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science, as well as potential uses in architectural fields. They exhibit extraordinary strength and unique electrical properties, and are efficient conductors of heat. Their final usage, however, may be limited by their potential toxicity [3]. Nano tubes is shown in figure 3.

2.5 Nanoscale Transistors

Transistors are electronic switching devices where a small amount of electricity is used like a gate to control the flow of larger amount of electricity. In computers, the more transistors, the greater the power. Transistors sizes have been decreasing, so computer have become more powerful. Until recently, the industry’s best commercial technology produced computer chips with transistors having 45-nanometer features. Recent announcements indicate that 32 nanometer feature technology soon will be here [3].

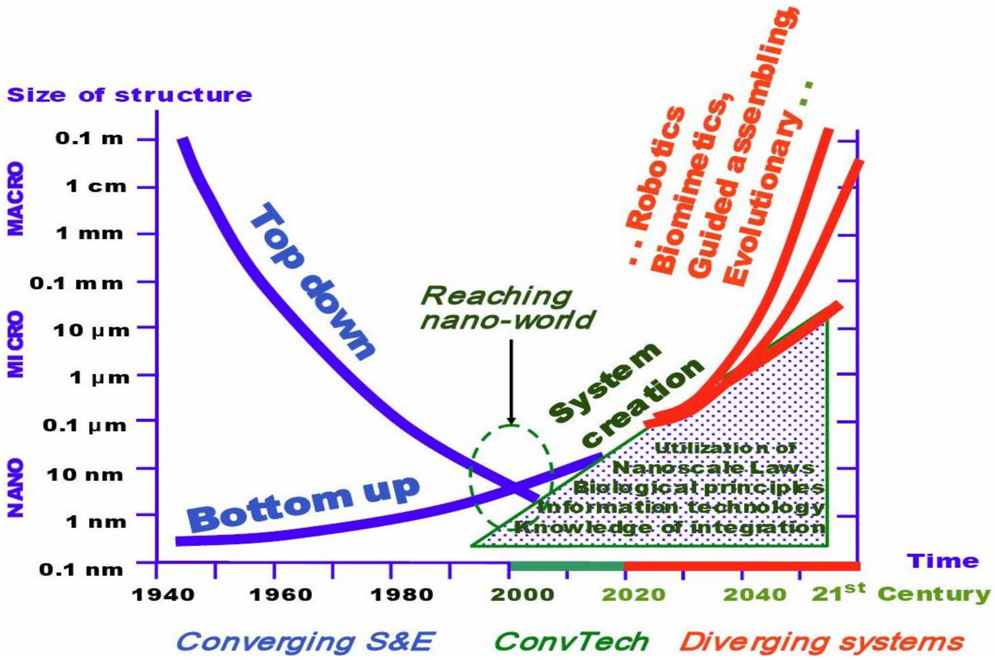

Figure 1. Reaching at the nanoworld (about 2000) and "converging technologies" approach for system creation from the nanoscale (2000-2020) towards new paradigms for nanosystem architectures in applications (after 2020).

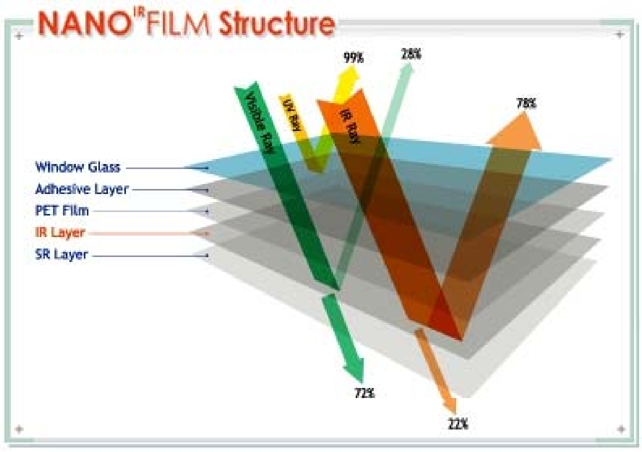

Figure 2. Nano Films.

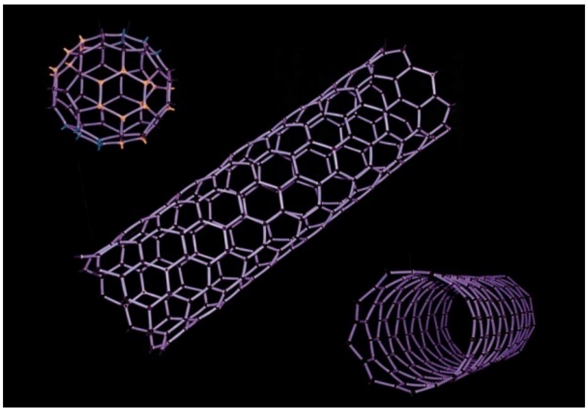

Figure 3. Nano Tubes.

3. Nanotechnology applications

A number of Nanotechnology products are available and a tremendous amount of researches are still going on in universities, government and research laboratories. Nanotechnology applications are being developed that could impact the global market for agricultural, mineral, and other non-fuel commodities. Currently, Nanotechnology is described as revolutionary discipline in terms of its possible impact on industrial applications. Nanotechnology offers potential solutions to many problems using emerging nanotechniques.

Depending on the strong inter disciplinary character of nanotechnology there are many research fields and several potential applications that involves nanotechnology.

In this section we provide a brief overview about some nanotechnology and nanoscience current developments. Obviously it can't provide an exhaustive report of the developments in nanoscience and nanotechnology an all scientific and engineering fields. Here are some fields where nanotechnology has been implemented [4].

3.1 Nanorobot Development for Defense

The defense industry should remarkably benefit from achievements and trends on current nanobiotechnology systems integration. Such trends on technology have also resulted in a recent growing interest from the international scientific community, including medical and pharmaceutical sectors, towards the research and development of molecular machines.

3.2 Medical Nanorobots

The research and development of nanorobots with embedded nanobiosensors and actuators is considered a new possibility to provide new medical devices for doctors . As integrated control mechanisms at microscopic environments differ from conventional control techniques, approaches using event-based feed forward control are sought to effectively advance new medical technologies. In the same way the development of microelectronics in the 1980s has led to new tools for biomedical instrumentation, the manufacturing of nanoelectronics , will similarly permit further miniaturization towards integrated medical systems, providing efficient methodologies for pathological prognosis.

The use of microdevices in surgery and medical treatments is a reality which has brought many improvements in clinical procedures in recent years . For example, among other biomedical instrumentation, catheterization has been successfully used as an important methodology for heart and intracranial surgery. Now the advent of biomolecular science and new manufacturing techniques is helping to advance the miniaturization of devices from micro to nanoelectronics. Sensors for biomedical applications are advancing through tele operated surgery and pervasive medicine, and this same technology provides the basis for manufacturing biomolecular actuators. A first series of nanotechnology prototypes for molecular machines are being investigated in different ways, and some interesting devices for propulsion and sensing have been presented. More complex molecular machines, or nanorobots, having embedded nanoscopic features represent new tools for medical procedures.

4. Applications under Development

Researchers are looking into the following applications of nanotechnology in space:

a. Using carbon nanotubes to make the cable needed for the space elevator, a system which could significantly reduce the cost of sending material into orbit.
b. Employing materials made from carbon nanotubes to reduce the weight of spaceships while retaining or even increasing the structural strength.
c. Producing thrusters for spacecraft that use MEMS devices to accelerate nanoparticles. This should reduce the weight and complexity of thruster systems used for interplanetary missions.
d. Using carbon nanotubes to build lightweight solar sails that use pressure of light from the sun reflecting on the mirror-like solar cell to propel a spacecraft. This solves the problem of having to lift enough fuel into orbit to power spacecraft during interplanetary missions.
e. Deploying a network of nanosensors to search large areas of planets such as Mars for traces of water or other chemicals [5].

4.1 Nanotechnology and Space

Nanotechnology may hold the key to making space-flight more practical. Advancements in nanomaterials make lightweight solar sails and a cable for the space elevator possible. By significantly reducing the amount of rocket fuel required, these advances could lower the cost of reaching orbit and travelling in space. In addition, new materials combined with nanosensors and nanorobots could improve the performance of spaceships, spacesuits, and the equipment used to explore planets and moons, making nanotechnology an important part of the 'final frontier' [5].

4.2 Nanotechnology in Electronics: Nanoelectronics

How can nanoelectronics improve the capabilities of electronic components?

Nanoelectronics holds some answers for how we might increase the capabilities of electronics devices while we reduce their weight and power consumption. Some of the nanoelectronics areas under development include:

a. Improving display screens on electronics devices. This involves reducing power consumption while decreasing the weight and thickness of the screens.
b. Increasing the density of memory chips. Researchers are developing a type of memory chip with a projected density of one terabyte of memory per square inch or greater.

c. Reducing the size of transistors used in integrated circuits. One researcher believes it may be possible to "put the power of all of today's present computers in the palm of your hand" [6].

4.3 Nanotechnology in Medicine

Applications of nanotechnology in medicine currently being developed involve employing nano-particles to deliver drugs, heat, light or other substances to specific cells in the human body. Engineering particles to be used in this way allows detection and/or treatment of diseases or injuries within the targeted cells, thereby minimizing the damage to healthy cells in the body [7].

4.4 Current Applications

While most applications of nanotechnology in medicine are still under development. Nanocrystalline silver is already being used as a antimicrobial agent in the treatment of wounds [7]. Following applications also will be released very soon:

a. Qdots that identify the location of cancer cells in the body.
b. Nanoparticles deliver chemotherapy drugs directly to cancer cells to minimize damage to healthy cells.
c. Nanoshells that concentrate the heat from infrared light to destroy cancer cells with minimal damage to surrounding healthy cells.
d. Nanotubes used in broken bones to provide a structure for new bone material to grow.
e. Nanoparticles that can attach to cells infected with various diseases and allow a doctor to identify, in a blood sample, the particular disease [7].

4.5 Researchers are looking into the following nanoelectronics projects

a. Using electrodes made from nanowires that would enable flat panel displays to be flexible as well as thinner than current flat panel displays.
b. Using carbon nanotubes to direct electrons to illuminate pixels, resulting in a lightweight, millimeter thick "nanoemmissive" display panel.
c. Making integrated circuits with features that can be measured in nanometers (nm), such as the process that allows the production of integrated circuits with 45 nm wide transistor gates.
d. Using nanosized magnetic rings to make Magnetoresistive Random Access Memory (MRAM) which research has indicated may allow memory density of 400 GB per square inch.
e. Developing molecular-sized transistors which may allow us to shrink the width of transistor gates to approximately one nm which will significantly increase transistor density in integrated circuits [6].

5. Risks of Nanotechnology

These days it seems you need the prefix “nano” for products or applications if you want to be either very trendy or incredibly scary. Molecular manufacturing operations could be carried out with failure rates less than one in quadrillion. As soon as molecular manufacturing was proposed risks associated with it began to be identified. Engines of Creation described one hazard possible: grey goo. A small nanomachine capable of replication could in theory copy itself too many times. If it were capable of surviving outdoors, and using biomass as raw material, it could severely damage the environment [8].

Sufficiently powerful products would either hostile governments or angry individual, to wreak havoc. Destructive nanomachines could do immense damage to unprotected people and objects. If the wrong people gained the ability to manufacture any desired product, they could rule the world, or cause massive destruction in the attempt. Certain products such as powerful aerospace weapons, and microscopic antipersonnel devices, provide special cause of concern. Grey goo is relevant here as well. Clearly, the unrestricted availability of nanotechnology poses grave risks, which may well outweigh the benefits of clean, cheap, convenient, self contained manufacturing [8].

Development of nanotechnology must be undertaken with care to avoid accidents. Once a nanotechnology-based manufacturing technology is created, it must be administered with even more care. Irresponsible use of molecular manufacturing could lead to black markets, unstable arms races ending in immense destruction, and possibly a release of grey goo [8].

Another important aspect of the nanoscale is that the smaller a nanoparticle gets, the larger its relative surface area becomes. Its electronic structure changes dramatically, too. Both effects lead to greatly improved catalytic activity but can also lead to aggressive chemical reactivity. There are tremendous differences in particle number concentration and particle surface area [9].

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! [10].

6. Issues

6.1 Environmental issue

In free form nanoparticles can be released in the air or water during production (or production accidents) or as waste byproduct of production, and ultimately accumulate in the soil, water or plant life.

In fixed form, where they are part of a manufactured substance or product, they will ultimately have to be recycled or disposed of as waste. We don’t know yet if certain nanoparticles will constitute a completely new class of non-biodegradable pollutant. In case they do, we also don’t know yet how such pollutants could be removed from air or water because most traditional filters are not suitable for such tasks. The figure shows how nanotechnology effects the environment [10].

6.2 Health issue

Health and environmental issues combine in the workplace of companies engaged in producing or using nanomaterials and in the laboratories engaged in nanoscience and nanotechnology research. It is safe to say that current workplace exposure standards for dusts cannot be applied directly to nanoparticle dusts. To properly assess the health hazards of engineered nano-particles the whole life cycle of these particles needs to be evaluated, including their fabrication, storage and distribution, application and potential abuse, and disposal. The impact on humans or the environment may vary at different stages of the life cycle [10].

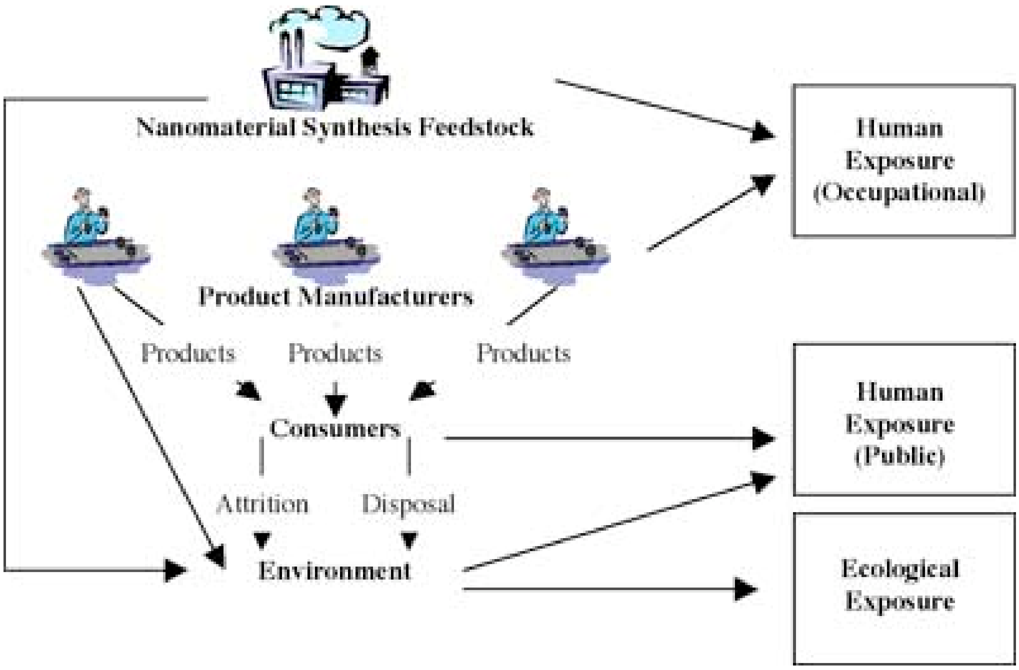

Figure 4. Potential for release and exposure to nanoscale substances (taken from [11]).

7. Conclusion

Today, many of our nation's most creative scientists and engineers are finding new ways to use nanotechnology to improve the world in which we live. These researchers envision a world in which new materials, designed at the atomic and molecular level, provide realistic, cost-effective methods for harnessing renewable energy sources and keeping our environment clean. They see doctors detecting disease at its earliest stages and treating illness such as cancer, heart disease, and diabetes with more effective and safer medicines. They picture new technologies for protecting both our military forces and civilians from conventional, biological, and chemical weapons. Although there are many research challenges ahead, nanotechnology already is producing a wide range of beneficial materials and pointing to breakthrough in many fields. It has opened scientific Inquiry to the level of molecules-and a world of new opportunities.

Acknowledgement

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