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HISTORY, FUNDAMENTAL CONCEPT AND IMAGINATIVE PIONEERS OF NANOTECHNOLOGY

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ABSTRACT

Nanoscience breakthroughs in almost every field of science and nanotechnologies make life easier in this era. Nanoscience and nanotechnology represent an expanding research area, which involves structures, devices, and systems with novel properties and functions due to the arrangement of their atoms on the 1–100 nm scale. This definition reflects the fact that quantum mechanical effects are important at this quantum-realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter which occur below the given size threshold. It is therefore common to see the plural form "nanotechnologies" as well as "nanoscale technologies" to refer to the broad range of research and applications whose common trait is size. Because of the variety of potential applications, governments have invested billions of dollars in nanotechnology research..

Keywords: Nanoscience and nanotechnology, category.

INTRODUCTION

The Imaginative Pioneers of Nanotechnology

The American physicist and Nobel Prize laureate Richard Feynman introduce the concept of nanotechnology in 1959. During the annual meeting of the American Physical Society, Feynman presented a lecture entitled “There’s Plenty of Room at the Bottom” at the California Institute of Technology (Caltech). In this lecture, Feynman made the hypothesis “Why can’t we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?”, and described a vision of using machines to construct smaller machines and down to the molecular level. This new idea demonstrated that Feynman’s hypotheses have been proven correct, and for these reasons, he is considered the father of modern nanotechnology. After fifteen years, Norio Taniguchi, a Japanese scientist was the first to use and define the term “nanotechnology” in 1974 as: “nanotechnology mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule”.

After Feynman had discovered this new field of research catching the interest of many scientists, two approaches have been developed describing the different possibilities for the synthesis of nanostructures. These manufacturing approaches fall under two categories: top-down and bottom-up, which differ in degrees of quality, speed and cost.

The top-down approach is essentially the breaking down of bulk material to get nano-sized particles. This can be achieved by using advanced techniques such as precision engineering and lithography which have been developed and optimized by industry during recent decades. Precision engineering supports the majority of the micro-electronics industry during the entire production process, and the high performance can be achieved through the use of a combination of improvements. These include the use of advanced nanostructure based on diamond or cubic boron nitride and sensors for size control, combined with numerical control and advanced servo-drive technologies. Lithography involves the patterning of a surface through exposure to light, ions or electrons, and the deposition of material on to that surface to produce the desired material.

The bottom-up approach refers to the build-up of nanostructures from the bottom: atom-by-atom or molecule-by-molecule by physical and chemical methods which are in a nanoscale range (1 nm to 100 nm) using controlled manipulation of self-assembly of atoms and molecules. Chemical synthesis is a method of producing rough materials which can be used either directly in product in their bulk disordered form, or as the building blocks of more advanced ordered materials. Self-assembly is a bottom-up approach in which atoms or molecules organize themselves into ordered nanostructures by chemical-physical interactions between them. Positional assembly is the only technique in which single atoms, molecules or cluster can be positioned freely one-by-one.

The general concept of top down and bottom up and different methods adapted to synthesized nanoparticles by using these techniques are summarized in Figure 1. In 1986, K. Eric Drexler published the first book on nanotechnology "Engines of Creation: The Coming Era of Nanotechnology", which led to the theory of "molecular engineering" becoming more popular. Drexler described the build-up of complex machines from individual atoms, which can independently manipulate molecules and atoms and thereby produces self-assembly nanotructures. Later on, in 1991, Drexler, Peterson and Pergamit published another book entitled "Unbounding the Future: the Nanotechnology Revolution" in which they use the terms "nanobots" or "assemblers" for nano processes in medicine applications and then the famous term "nanomedicine" was used.

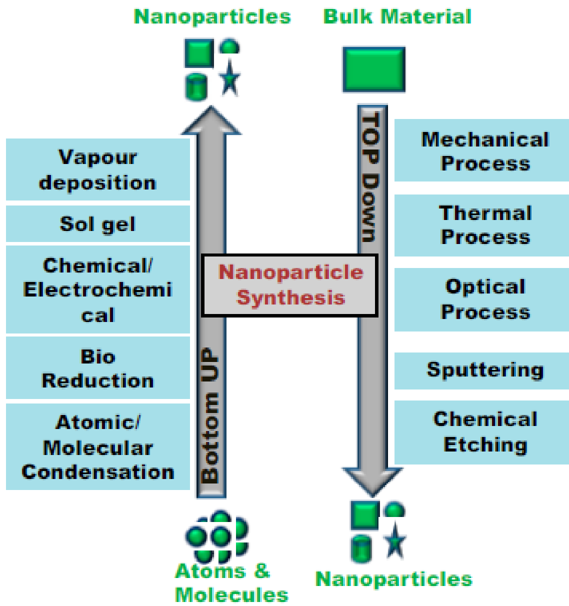

Fig-1 : The concept of top down and bottom up technology : different methods for nanoparticle synthesis

HISTORY OF NANOTECHNOLOGY

The Lycurgus cup, from the British Museum collection, represents one of the most outstanding achievements in ancient glass industry. It is the oldest famous example of dichroic glass. Dichroic glass describes two different types of glass, which change color in certain lighting conditions. This means that the Cup have two different colors: the glass appears green in direct light, and red-purple when light shines through the glass.

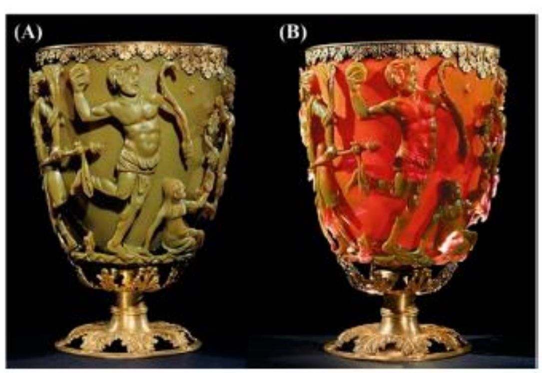

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Fig.-2 : The Lycurgus cup. The glass appears green in reflected light (A) and red-purple in transmitted light (B) Reproduced with permission

In 1990, the scientists analyzed the cup using a transmission electron microscopy (TEM) to explain the phenomenon of dichroism. The observed dichroism (two colors) is due to the presence of nanoparticles with 50–100 nm in diameter. X-ray analysis showed that these nanoparticles are silver-gold (Ag-Au) alloy, with a ratio of Ag:Au of about 7:3, containing in addition about 10% copper (Cu) dispersed in a glass matrix. The Au nanoparticles produce a red color as result of light absorption (~520 nm). The red-purple color is due to the absorption by the bigger particles while the green color is attributed to the light scattering by colloidal dispersions of Ag nanoparticles with a size > 40 nm. The Lycurgus cup is recognized as one of the oldest synthetic nanomaterials. A similar effect is seen in late medieval church windows, shining a luminous red and yellow colors due to the fusion of Au and Ag nanoparticles into the glass. Figure 3 shows an example of the effect of these nanoparticles with different sizes to the stained glass windows.

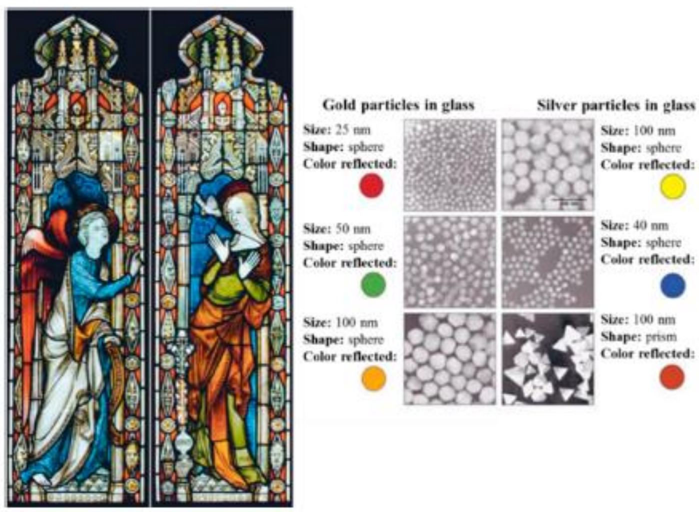

Fig.-3 : Effect of nanoparticles on the colors of the stained glass windows. Reproduced with permission

During the 9th–17th centuries, glowing, glittering "luster" ceramic glazes used in the Islamic world, and later in Europe contained Ag or copper (Cu) or other nanoparticles. The Italians also employed nanoparticles in creating Renaissance pottery during 16th century. They were influenced by Ottoman techniques: during the 13th–18th centuries, to produce "Damascus" saber blades, cementite nanowires and carbon nanotubes were used to provide strength, resilience, and the ability to hold a keen edge. These colors and material properties were produced intentionally for hundreds of years. Medieval artists and forgers, however, did not know the cause of these surprising effects.

In 1857, Michael Faraday studied the preparation and properties of colloidal suspensions of "Ruby" gold. Their unique optical and electronic properties make them some of the most interesting nanoparticles. Faraday demonstrated how gold nanoparticles produce different-colored solutions under certain lighting conditions]. The progression in nanotechnology due to the blessings of nanoscience are summarized in the Figure-4.

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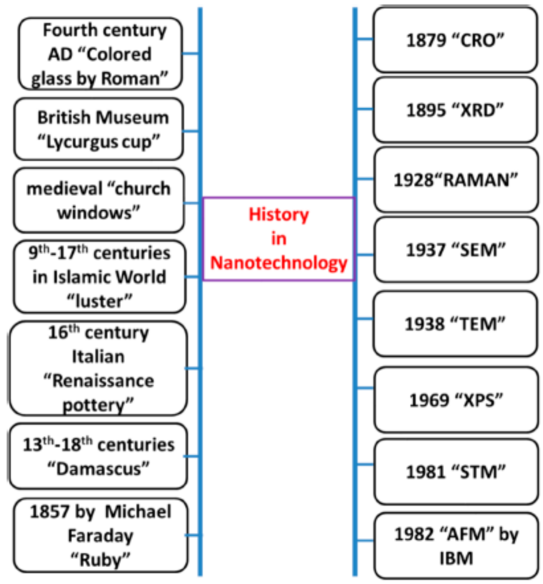

Fig.-4 : Progresses in Nanotechnology

FUNDAMENTAL CONCEPTS

Nanotechnology is the engineering of functional systems at the molecular scale. This covers both current work and concepts that are more advanced. In its original sense, nanotechnology refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products. One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between theseatoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallestcellular life-forms, the bacteria of the genus *Mycoplasma*, are around 200 nm in length. By convention, nanotechnology is taken as the scale range 1 to 100 nm following the definition used by the National Nanotechnology Initiative in the US. The lower limit is set by the size of atoms (hydrogen has the smallest atoms, which are approximately a quarter of a nm diameter) since nanotechnology must build its devices from atoms and molecules. The upper limit is more or less arbitrary but is around the size below which phenomena not observed in larger structures start to become apparent and can be made use of in the nano device. These new phenomena make nanotechnology distinct from devices which are merely miniaturised versions of an equivalent macroscopic device; such devices are on a larger scale and come under the description of microtechnology.

To put that scale in another context, the comparative size of a nanometer to a meter is the same as that of a marble to the size of the earth. Or another way of putting it: a nanometer is the amount an average man's beard grows in the time it takes him to raise the razor to his face. Two main approaches are used in nanotechnology. In the "bottom-up" approach, materials and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. In the "top-down" approach, nano-objects are constructed from larger entities without atomic-level control.

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

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sunburns. Various techniques and products based on nanoscale particles are described in brief.

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.

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. Nano film is shown in figure 5.

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.

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.

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.

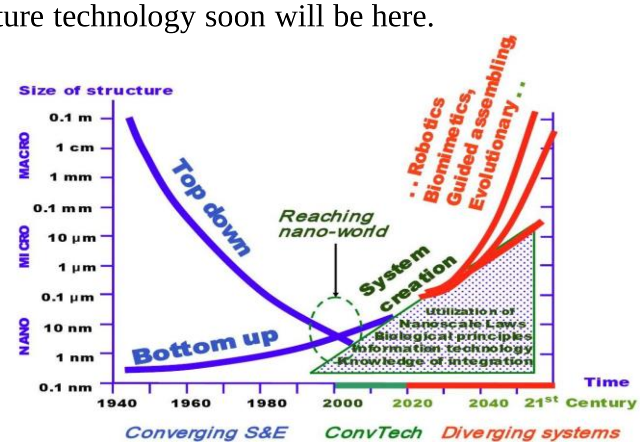

Fig.-5 : Reaching at the nano world (about 2000) and "converging technologies" approach for system creation

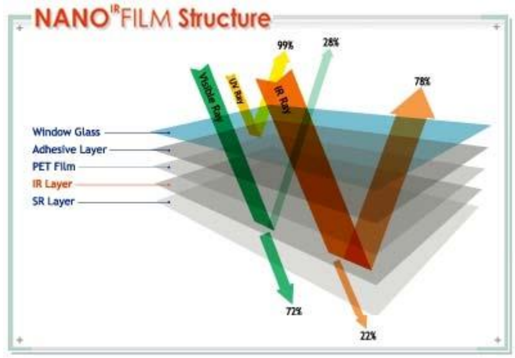

Fig-6 : Nano Films.

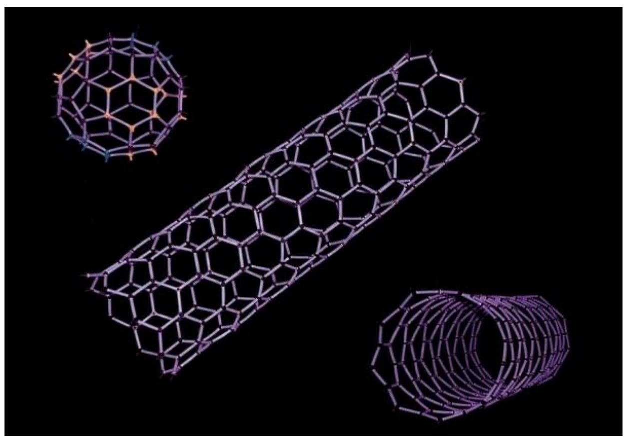

Fig-7 : Nano Tubes

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.

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.

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.

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.

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.

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.

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.

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!.

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.

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