NANOMATERIALS AND NANOTECHNOLOGY: FUTURE EMERGING TECHNOLOGY

Prof. Abhinav V. Deshpande
Assistant Professor,
Department of Electronics & Telecommunication Engineering,

Prof. Ram Meghe
Institute of Technology & Research, Badnera, Amravati, Maharashtra, India,

ABSTRACT

This paper focuses on the problem of minimizing complex electronic circuits to scale of 10-9 m (1 nano meter) thus helping in the process of fast operation, better performance, low cost, reliability, simple in size and easy to fabricate. The materials which are used in the manufacturing of nano electronic devices are commonly called as nano materials. The use of nano materials led to design and development of nano devices which ease the process of design of logic circuits. The applications of nano technology include medical, engineering and pure as well as applied sciences. In this paper, a detailed study of how the different nano materials are manufactured and how the manufacturing of nano electronic devices is done is clearly described. This paper illustrates the need for nano technology in modern era and facilitates the use of nano technology as a prerequisite for the development of modern engineering technology.

Keywords: Nano Technology, Nano Materials, Nano Particles, Nano Photonics, Nano Mechanics, Nano Electronics, Micro Technology

1. INTRODUCTION

Nano technology ("nano tech") is the manipulation of matter on an atomic, molecular, and supramolecular scale. The earliest, widespread description of nanotechnology [1] [2] referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macro scale products, also now referred to as molecularnanotechnology. A more generalized description of nanotechnology was subsequently established by the NationalNanotechnology Initiative, which
defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometers. 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 that occur below the given size threshold. It is therefore common to see the plural form "nano technologies" as well as "nano scale technologies" to refer to the broad range of research and applications whose common trait is size. Because of the variety of potential applications (including industrial and military), governments have invested billions of dollars in nano technology research. Through its National Nano technology Initiative, the USA has invested 3.7 billion dollars. The European Union has invested 1.2 billion and Japan 750 million dollars.[3] Nano technology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, micro fabrication, etc. [4]. The associated research and applications are equally diverse, ranging from extensions of conventional devicephysics to completely new approaches based upon molecular self assembly, from developing new materials with dimensions on the nanoscale to direct control of matter on the atomic scale.

Scientists currently debate the future implications of nanotechnology. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production. On the other hand, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nano materials [5] and their potential effects on global economics, as well as speculation about various doomsdayscenarios. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted.

2. ORIGINS

The concepts that seeded nanotechnology were first discussed in 1959 by renowned physicist Richard Feynman in his talk There's Plenty of Room at the Bottom, in which he described the possibility of synthesis via direct manipulation of atoms. The term "nano-technology" was first used by Norio Taniguchi in 1974, though it was not widely known. Inspired by Feynman's concepts, K. Eric Drexler used the term "nanotechnology" in his 1986 book Engines of Creation: The Coming Era of Nanotechnology, which proposed the idea of a nanoscale "assembler" which would be able to build a copy of itself and of other items of arbitrary complexity with atomic control. Also in 1986, Drexler co-founded The Foresight Institute (with which he is no longer affiliated) to help increase public awareness and understanding of nano technology concepts and implications.

Thus, emergence of nano technology as a field in the 1980s occurred through convergence of Drexler's theoretical and public work, which developed and popularized a conceptual framework for nano technology, and high-visibility experimental advances that drew additional wide-scale attention to the prospects of atomic control of matter. In 1980s two major breakthroughs incepted the growth of nano technology in modern era.

First, the invention of the scanning tunneling microscope in 1981 which provided unprecedented visualization of individual atoms and bonds, and was successfully used to manipulate individual atoms in 1989. The microscope's developers Gerd Binning and Heinrich Rohrer at IBM Zurich Research Laboratory received a Nobel Prize in Physics in 1986. [6] [7] Binning, Quate and Gerber also invented the analogous atomic force microscope that year.
Second, Fullerenes were discovered in 1985 by Harry Kroto, Richard Smalley, and Robert Curl, who together won the 1996 Nobel Prize in Chemistry. C60 was not initially described as nanotechnology; the term was used regarding subsequent work with related graphene tubes (called carbon nanotubes and sometimes called Bucky tubes) which suggested potential applications for nanoscale electronics and devices.

In the early 2000s, the field garnered increased scientific, political, and commercial attention that led to both controversy and progress. Controversies emerged regarding the definitions and potential implications of nanotechnologies, exemplified by the Royal Society's report on nanotechnology. Challenges were raised regarding the feasibility of applications envisioned by advocates of molecular nanotechnology, which culminated in a public debate between Drexler and Smalley in 2001 and 2003.

Meanwhile, commercialization of products based on advancements in nanoscale technologies began emerging. These products are limited to bulk applications of nano materials and do not involve atomic control of matter. Some examples include the SilverNano platform for using silver nanoparticles as an antibacterial agent, nanoparticle-based transparent sunscreens, and carbon nanotubes for stain-resistant textiles.

Governments moved to promote and fund research into nanotechnology, beginning in the U.S. with the National Nanotechnology Initiative, which formalized a size-based definition of nanotechnology and established funding for research on the nanoscale. By the mid-2000s new and serious scientific attention began to flourish. Projects emerged to produce nanotechnology road maps which center on atomically precise manipulation of matter and discuss existing and projected capabilities, goals, and applications.
3. FUNDAMENTAL CONCEPTS

Nano technology 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 these atoms 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 smallest cellular 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 that 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.

Areas of physics such as nano electronics, nano mechanics, nano photonics and nanoionics have evolved during the last few decades to provide a basic scientific foundation of nanotechnology.

3.1. Larger to Smaller: A Materials Perspective

Several phenomena become pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects, for example the "quantum size effect" where the electronic properties of solids are altered with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions. However, quantum effects can become significant when the nanometer size range is reached, typically at distances of 100 nanometers or less, the so-called quantum realm. Additionally, a number of physical (mechanical, electrical, optical, etc.) properties change when compared to macroscopic systems. One example is the increase in surface area to volume ratio altering mechanical, thermal and catalytic properties of materials. Diffusion and reactions at nanoscale, nanostructures materials and nano devices with fast ion transport are generally referred to nanoionics. Mechanical properties of nano systems are of interest in the nano mechanics research. The catalytic activity of nano materials also opens potential risks in their interaction with biomaterials.

Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macro scale, enabling unique applications. For instance, opaque substances can become transparent (copper); stable materials can turn combustible (aluminum); insoluble materials may become soluble (gold). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale.
3.2 Simple to Complex: A Molecular Perspective

Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to manufacture a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. This ability raises the question of extending this kind of control to the next-larger level, seeking methods to assemble these single molecules into supra molecular assemblies consisting of many molecules arranged in a well defined manner.

These approaches utilize the concepts of molecular self-assembly and/or supra molecular chemistry to automatically arrange themselves into some useful conformation through a bottom-up approach. The concept of molecular recognition is especially important: molecules can be designed so that a specific configuration or arrangement is favored due to non covalent intermolecular forces. The Watson–Crick base pairing rules are a direct result of this, as is the specificity of an enzyme being targeted to a single substrate, or the specific folding of the protein itself. Thus, two or more components can be designed to be complementary and mutually attractive so that they make a more complex and useful whole.

Such bottom-up approaches should be capable of producing devices in parallel and be much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases. Most useful structures require complex and thermodynamically unlikely arrangements of atoms. Nevertheless, there are many examples of self-assembly based on molecular recognition in biology most notably Watson–Crick base pairing and enzyme-substrate interactions. The challenge for nanotechnology is whether these principles can be used to engineer new constructs in addition to natural ones.

4. CURRENT RESEARCH

4.1. Nano materials

The nano materials field includes subfields which develop or study materials having unique properties arising from their nanoscale dimensions. Interface and Colloid Science has given rise to many materials which may be useful in nanotechnology, such as carbon nanotubes and other fullerenes, and various nano particles and nanorods. Nano materials with fast ion transport are related also to nanoionics and nano electronics.

Nano scale materials can also be used for bulk applications; most present commercial applications of nanotechnology are of this flavor. Progress has been made in using these materials for medical applications; see Nano medicine. Nanoscale materials such as nano pillars are sometimes used in solar cells which combats the cost of traditional Silicon solar cells.

Development of applications incorporating semiconductor nanoparticles to be used in the next generation of products, such as display technology, lighting, solar cells and biological imaging; see quantum dots.
5. Tools and Techniques

There are several important modern developments. The atomic force microscope (AFM) and the Scanning Tunneling Microscope (STM) are two early versions of scanning probes that launched nanotechnology. There are other types of scanning probe microscopy. Although conceptually similar to the scanning confocal microscope developed by in 1961 and the scanning acoustic microscope (SAM) developed by Calvin Quate and coworkers in the 1970s, newer scanning probe microscopes have much higher resolution, since they are not limited by the wavelength of sound or light. The tip of a scanning probe can also be used to manipulate nanostructures (a process called positional assembly). Feature-oriented scanning methodology suggested by Rostislav Lapshin appears to be a promising way to implement these nano manipulations in automatic mode. However, this is still a slow process because of low scanning velocity of the microscope.

Various techniques of nanolithography such as optical lithography, dip pen nanolithography, electron beam lithography or nanoimprint lithography were also developed. Lithography is a top-down fabrication technique where a bulk material is reduced in size to nano scale pattern.

6. APPLICATIONS

As of August 21, 2008, the Project on Emerging Nanotechnologies estimates that over 800 manufacturer-identified nanotech products are publicly available, with new ones hitting the market at a pace of 3–4 per week. The project lists all of the products in a publicly accessible online database. Most applications are limited to the use of "first generation" passive nano materials which includes titanium dioxide in sunscreens, cosmetics, surface coatings, and some food products; Carbon allotropes used to produce gecko tape; silver in food packaging, clothing, disinfectants and household appliances; zinc oxide in sunscreens and cosmetics, surface coatings, paints and outdoor furniture varnishes; and cerium oxide as a fuel catalyst.

9. CONCLUSION

In this paper, a detailed study of basic concept of Nanotechnology is made with reference to the materials which are used in the manufacture of Nano devices. The merits and demerits of using Nano technology are given with reference to the current trends in the field of miniature design of any electronic components. The application of Nanotechnology are given which emphasize the importance of Nanotechnology in the modern era. The structure and working of different Nano electronic devices is given and the description of Nano electronics is being given which relates the use of Nano technology in the field of Electronics Engineering. A clear presentation of ideas regarding the particle miniaturizing process is being made with reference to the modern gadgets which are used in today's life. This paper gives the systematic approach towards the switching over of present manufacturing technology to the field of Nano technology with regards to fabrication of electronic devices. It comprises the reduction of cost, size, complexity and time required for manufacturing a particular electronic device by decreasing the efforts of human being in order to build a secure and reliable framework in the field of Nano technology.

10. ACKNOWLEDGEMENTS

This research work was carried out as a part of Departmental Research activity in the Department of Electronics & Telecommunication Engineering in Prof. Ram Meghe Institute of Technology & Research, Badnera, Amravati as a part of improvement in technical education sponsored by TEQIP-2. I would like to thank all of the staff members for their support and kind cooperation in carrying out this research activity. I am looking forward for a warm applause from the managing body.
11. REFERENCES


