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A BRIEF INTRODUCTION TO NANOTECHNOLOGY

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I. INTRODUCTION

The field of nanotechnology has been undergoing tremendous development in the recent decade. Nanotechnology is the ability to work at the atomic, molecular or super molecular levels (on a scale of 1-100 nm, the usual definition of nanoscale; one nanometre=10^{-9} metre) in order to understand, create and use material structures, devices and systems with fundamentally new properties and functions resulting from their small structure.[1] In addition to the developments in scientific disciplines such as electronics, material sciences, space research, robotics and medicinal sciences, nanotechnology is expected to make significant advancement in mainstream biomedical applications including the area of gene therapy, imaging and novel drug discovery and drug delivery in the treatment of diseases like cancer, diabetes, etc.

II. HISTORY OF NANOTECHNOLOGY

The concepts of nanotechnology were first discussed in 1959
by renowned physicist Richard Feynman in his talk (There isPlenty 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. K Eric Drexter inspired by Feynman's concept first used the term "nanotechnology" in 1986 in his book (Engines of creation: The Coming Era of Nanotechnology) in which he proposed the idea of nanoscale.
Thus, emergence of nanotechnology as a field in the 1980s occurred through Drexter's theoretical and public work which developed and popularized a conceptual framework for nanotechnology and high visibility experimental advances that drew additional wide-scale attention to the prospect s of atomic control of matter. In the 1980s, two major breakthroughs sparked the growth of nanotechnology to modern era:

1. The invention of the Scanning tunneling microscope in 1981 which provided unprecedented visualisation of the individual atoms and bonds and was successfully used to manipulate individual atoms in 1989. Gerd Binnig and Heinrich Rohrer at IBM Zurich Research Laboratory received a Nobel Prize in Physics in 1986 for developing scanning tunneling microscope.[2,3] Quate and Gerber also invented the analogous atomic force microscope in the same year.
2. Fullerenes (among them chiefly C_{60}, also known as buckyball) were also discovered in 1985 by Harry Kroto, Richard Smalley and Robert Curl who together won the Nobel Prize for Chemistry in 1996.[4,5]

In the early 2000s, the field garnered increased scientific, political and commercial attention that led to both controversy and progress. Controversies emerged regarding the definition and potential implications of nanotechnologies, exemplified by the Royal Society's report on nanotechnology.[6] Challenges were raised regarding the feasibility of applications envisioned by advocates of molecular nanotechnology which culminated in a public debate between Drexter and Smalley in 2001 and 2003.[7]
Commercialization of products based on advancement in nanoscale technology began emerging. These products are limited to bulk applications of nanomaterials and do not involve atomic control of matter. Some examples of nanomaterial products include the silver Nano platform for using silver nanoparticles based transparent sunscreens, carbon fibre strengthening using silica nanoparticles and carbon nanotubes.
Two main approaches are used in nanotechnology:

a. Bottom-up approaches: In "bottom-up" approaches material and devices are built from molecular components which assemble themselves chemically by principles of molecular recognition. The "bottom-up" approach involves the assembly of atoms or molecules into nanostructured arrays. In this approach, the raw material sources can be in the form of gases, liquids or solids. The bottom-up approaches generally fall into two categories:

Chaotic processes

Chaotic processes involve elevating the constituent atoms or molecules to a chaotic stare and then suddenly changing the conditions so as to make that state unstable. Through the clever manipulation of any number of parameters, products form largely as a result of ensuing kinetics. The collapse from the chaotic state can be difficult or impossible to control and so ensemble statistics often govern the resulting size distribution and average size. Accordingly, Nanoparticle formation is controlled through manipulation of the end state of the products.

Examples of chaotic processes are: Laser ablation, Arc, Flame pyrolysis, Combustion, Precipitation synthesis techniques.

Controlled processes

Controlled processes involve the controlled delivery of the constituent atoms or molecules to the site(s) of nanoparticle formation such that the nanoparticle can grow to a prescribed size in a controlled manner. Generally the states of the constituent atoms or molecules are never far from that needed for nanoparticle formation. Accordingly, Nanoparticle formation is controlled through the control of the state of the reactants.

Examples of controlled processes are self-limiting growth solution, self-limited chemical vapour deposition, shaped pulse femtosecond laser techniques, and molecular beam epitaxy.

b. Top down approach: Knowledge of processes for bottom-up assembly of structures remain in their infancy in comparison to traditional manufacturing techniques. As a result, the most mature products of nanotechnology (such as modern CPUs) rely heavily on top-down processes to define structures. The traditional example of a top-down technique for fabrication is lithography in which instruments (such as a modern stepper) are used to scale a microscopic plan to the nanoscale.

III. CURRENT RESEARCH

Nanomaterials

Scientists have not unanimously settled on a precise definition of nanomaterials but agree that they are partially characterised by their tiny size measured in nanometres (one nanometre=10^{-9} metre). One nanometre is one millionth of a millimetre or one billionth of a metre, and approximately 10^5 times smaller than the diameter of a human hair.

By comparison carbon-carbon bond lengths or the spacing between these atoms in a molecule are in the range of 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 in 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 nanometre diameter) since 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 nanodevice. 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.

Nano-sized particles exist in nature and can be created from a variety of products such carbon or metal like silver, but nanomaterials by definition must have at least one dimension that is less than approximately 100 nanometres. Most nanoscale materials are too small which cannot be seen with the naked eye and even with conventional lab microscopes.

Materials engineered to such a small scale are often referred to as engineered nanomaterials (ENMs) which can take on unique optical, magnetic, electrical, physical, mechanical and other properties. These emergent properties have the potential for great impacts in optical, electronics, electrical, medicine and other fields. For example,

1. Nanotechnology is expected to make significant advances in mainstream biomedical applications, including the areas of gene therapy, imaging and novel drug discovery and drug delivery in the treatment of diseases like cancer, diabetes, etc. Nanotechnology can be used to design pharmaceuticals that can target specific organs or cells in the body such as cancer cells and enhance the effectiveness of therapy.
2. Nanotechnology can also be added to steel, cement, cloth, and other materials to make them stronger and lighter.
3. Their size makes them extremely useful in electrical and electronics industries and they can also be used in environmental remediation or clean up and the neutralisation of toxins.
4. 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 nanoparticles and nanorods. Nanomaterials with fast ion transport are related to nanoionics and nanoelectronics.
5. Nanoscale materials such as nanopillars are sometimes used in solar cells, which combats the cost of traditional silicon solar cells.
6. Development of applications incorporating semiconductor nanomaterials to be used in next generation of products such as display technology, lighting, solar cells and biological imaging.

IV. APPLICATIONS

Most applications are limited to the use of “first generation” passive nanomaterials which include titanium dioxide in sunscreen, cosmetics, surface coatings, and some food products. Further applications allow tennis balls to last longer, golf balls to fly straighter and even bowling balls to become more durable and have a harder surface. Trousers and socks have been with nanomaterials so that they will last longer and keep people cool in the summer. Bandages are being infused with silver nanoparticles to heal cuts faster. Personal computers may become cheaper, faster, and contain more memory thanks to nanotechnology. Nanotechnology may have the ability to make existing medical applications cheaper

and easier to use in places like the general practitioner's office and at home. Cars are being manufactured with nanomaterials so they may need fewer metals and less fuel to operate in the future.
The science and knowledge that the scientific community has today about nanotechnology and its potential versatile applications is enough to benefit mankind in the future.

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