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Nanotechnology in Green Chemistry- A study

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Abstract

Nanotechnologies as well as Nano scale technologies refer to the broad range of research and applications whose common trait is size. 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. One nanometre (nm) is one billionth, or 10−9, of a meter which means nanometre to a meter is the same as that of a marble to the size of the earth. Green chemistry, also called sustainable chemistry encourages the design of products and processes which minimize the use and generation of hazardous substances. In this article the applications of Nanotechnology in different fields are summarized that reduce or eliminate the use or generation of toxic materials and also the synthesis of Nano material and their uses are discussed. However the people's opinion about Nanotechnology throughout the world differs regarding its safe sustainability in future.

Keywords: Nanotechnology, Green Chemistry, Nanometre, Nano scale, Mosfet.

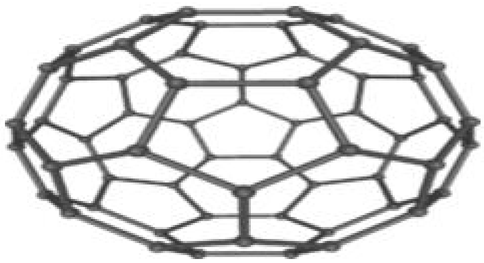
Introduction

Nanotechnology (sometimes shortened to "nanotech") is the manipulation of matter on an atomic and molecular scale. A more generalized description of nanotechnology was subsequently established by the National Nanotechnology Initiative, which defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometres. 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.

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 manometer (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 an 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 micro technology.

History of Nanotechnology:

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.
Fullerenes were discovered in 1985 by Harry Kroto, Richard Smalley, and Robert Curl, who together won the 1996 Nobel Prize in Chemistry. C_{60} 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.

Figure1: Fullerene

In 1986 the idea of nano scale assembler was introduced which would be able to build a copy of itself and of other items of arbitrary complexity with atomic control.In the early 2000s, the field garnered increased scientific, political, and commercial attention that led to both controversy and progress. Advancements in nanoscale technologies began emerging which lead to bulk applications of nanomaterials and do not involve atomic control of matter like

- Silver Nano platform for using silver nanoparticles as an antibacterial agent.
- Nano particle-based transparent sunscreens.
- Carbon nanotubes for stain-resistant textiles.

Further, projects emerged to produce nanotechnology road maps which centre on atomically precise manipulation of matter and discuss existing and projected capabilities, goals, and applications.

Material & Tools:

The nanomaterials 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 nanoparticles and nanorods.
- Nanomaterials with fast ion transport are related also to nanoionics and nanoelectronics.
- Nanoscale materials can also be used for bulk applications; most present commercial applications of nanotechnology are of this flavour.
- Progress has been made in using these materials for medical applications like nano medicine.
- Nanoscale materials 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 example quantum dots.

Creation of complex assemblies from smaller assemblies :

- DNA nanotechnology utilizes the specificity of Watson–Crick base pairing to construct well-defined structures out of DNA and other nucleic acids.
- Approaches from the field of "classical" chemical synthesis (inorganic and organic synthesis) also aim at designing molecules with well-defined shape (e.g.bis-peptides).
- More generally, molecular self-assembly seeks to use concepts of supramolecular chemistry, and molecular recognition in particular, to cause single-molecule components to automatically arrange themselves into some useful conformation.

Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical upon a surface in a desired pattern in a process called dip pen nanolithography. This technique fits into the larger subfield of nanolithography.

Creation of smaller devices from larger devices:

- Many technologies that descended from conventional solid-state silicon methods for fabricating microprocessors are now capable of creating features smaller than 100 nm, falling under the definition of nanotechnology.
- Giant magnetoresistance-based hard drives already on the market fit this description, as do atomic layer deposition (ALD) techniques.
- Peter Grünbergand Albert Fert received the Nobel Prize in Physics in 2007 for their discovery of Giant magnetoresistance and contributions to the field of spintronics.
- Solid-state techniques can also be used to create devices known as nanoelectromechanical systems or NEMS, which are related to microelectromechanical systems or MEMS.
- Focused ion beams can directly remove material, or even deposit material when suitable pre-cursor gasses are applied at the same time. For example, this technique is used routinely to create sub-100 nm sections of material for analysis in Transmission electron microscopy.
- Atomic force microscope tips can be used as a nanoscale "write head" to deposit a resist, which is then followed by an etching process to remove material in a top-down method.

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Functional Approach

- Molecular scale electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nanoelectronic device Example rotaxane.
- Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar.

Biometric Approach

- Bionics or bio mimicry seeks to apply biological methods and systems found in nature, to the study and design of engineering systems and modern technology example Bio mineralization.
- Bio nanotechnology is the use of bio molecules for applications in nanotechnology, including use of viruses and lipid assemblies.
    - Nan cellulose is a potential bulk-scale application.

Tools:

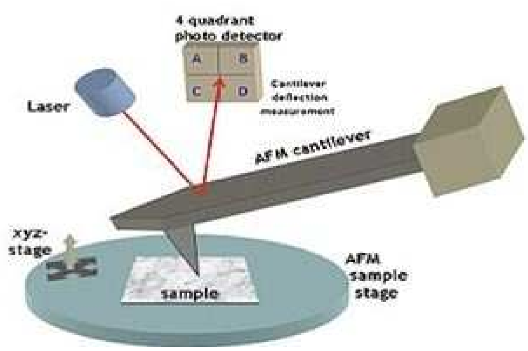

Figure2: Atomic Force Microscope

A micro fabricated cantilever with a sharp tip is deflected by features on a sample surface, much like in a phonograph but on a much smaller scale. A laser beam reflects off the backside of the cantilever into a set of photo detectors, allowing the deflection to be measured and assembled into an image of the surface.The atomic force microscope (AFM) and the Scanning Tunnelling Microscope (STM) were the two early versions of scanning probes that launched nanotechnology. Apart from this 1961 Marvin Minsky developed scanning confocal microscope and similar to this in 1970's Calvin Quate and co-workers introduced a scanning acoustic microscope(SAM) with better resolution. Various techniques of nanolithography such as optical lithography, X-ray lithography dip pen nanolithography, electron beam lithography or nano imprint lithography were also developed. Lithography is a top-down fabrication technique where a bulk material is reduced in size to nanoscale pattern.In top approach Atomic force microscopes and scanning tunnelling microscopes can be used to look at surfaces and to move atoms around. By designing different tips for these microscopes, they can be used for carving out structures on surfaces and to help guide self-assembling structures. In contrast, bottom-up techniques build a larger structures atom by atom or molecule by molecule. These techniques include chemical synthesis, self-assembly and positional assembly, example Dual polarisation interferometer is one tool suitable for characterisation of self assembled thin films. Another variation of bottom up approach is is molecular beam epitaxy or MBE which is a research tool for the discovery of Fractional Quantum Hall Effect and for that John R. Arthur. Alfred Y. Cho and Art C. Gossard were awarded a noble prize in physics in the year 1998. MBE is not only used for research in semiconductors but also widely used to make samples and devices for the newly emerging field of spintronics.

Applications of Nanotechnology

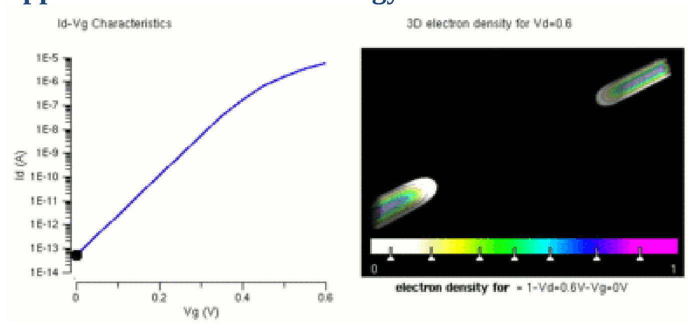

Figure 3: Characteristics of Nano-wires in MOSFET.

One of the major applications of nanotechnology is in the area of nanoelectronics with MOSFET's being made of small nanowires ~10 nm in length. Here is a simulation of such a nanowire.

NanoFibers:

Nanofibers are defined as fibers with diameters less than 100 nanometers, however in textile industries it is extended up to 1000 nm.

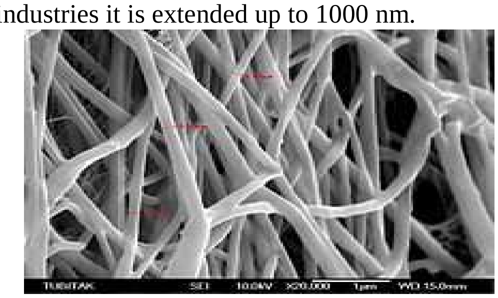

Figure 4: Nano Fibers

Synthesis:

Inorganic nanofibres also called as "ceramic nano fibres" can be prepared from various kinds of inorganic substances by electro spinning technique. Example the ceramic materials with nano

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fiber morphology are titanium dioxide (TiO_2), silicon dioxide (SiO_2), Zirconium dioxide(ZrO_2), aluminumoxide (Al_2O_3), lithiumtitana te ($Li_4Ti_5O_{12}$), titaniumnitride (TiN)or platinum(Pt).T he synthesis usually involves two steps: In the first step, the polymer (organic) nano fibres are made by electro spinning technique and then nano fibres made of inorganic salts or organometallic compounds are heated to get ceramic nano fibres. Apart from this they can be drawn from the solution directly or from the melts.

Nano fibres have wide applications:

i) **In Medicine:**

- For artificial organ components, tissue engineering, implant material, drug delivery, wound dressing, and medical textile materials.
- Recently, researchers have found that nano fiber meshes could be used to fight against the HIV-1 virus, and can be used as contraception.
- In wound healing nano fibers assemble at the injury site and stay put, drawing the body's own growth factors to the injury site

Protective material: For sound absorption materials, protective clothings against chemical and biological warfare agents.

- **As sensor:** For detecting chemical agents.
- In pigments For cosmetic

ii) **In the Textile Industry:**

- For sport apparel, sport shoes, climbing, rainwear, outerwear garments, baby diapers.
- Napkins with nanofibers contain antibodies against numerous biohazards .
- In chemicals that signal by changing colour (especially useful in identifying bacteria in kitchens).

iii) **In Filtration system:**

- Applications include HVAC system filters, HEPA, ULPA filters, air, oil, fuel filters for automotive, filters for beverage, pharmacy, medical applications, filter media for new air and liquid filtration applications, such as vacuum cleaners.

iv) **In Energy:**

- Applications include Li-ion batteries, photovoltaic cells, membrane fuel cells, and dye-sensitized solar cells. Other applications are micro power to operate personal electronic devices via piezoelectric nanofibers woven into clothing, carrier materials for various catalysts, and photo catalytic air/water purification.
- Self-branding of nanofibers:

It is related to a balance between flexibility, adhesion, and evaporation of solvent. Its applications include substances that can change optical properties on demand, molecule capture and release for e.g. timed drug delivery, energy storage, and adhesives.

Nanotechnology in Water Treatment

Nanotechnology offers the potential of novel nanomaterials for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. Due to their unique activity toward recalcitrant contaminants many nanomaterials are under active research and development for use in the treatment of water.

i) **Groundwater remediation applications of nanotechnology:**

Nanotechnology offers the ability to effectively enable contaminant treatment in situ. The process begins with the injection of nanoparticles into a contaminated aquifer via an injection well. The nanoparticles are then transported to the source of contamination by the groundwater flow where they then degrade the contaminant. Nanoparticles can sequester (via adsorption or complexation), immobilizing them, or they can degrade the contaminants to less harmful compounds. Contaminant transformations are typically radix reactions. When the nanoparticle is the oxidant or reluctant, it is considered reactive. Example, TiO2 has been widely used for water treatment as it has wide band gap energy; it is inexpensive, non-toxic, highly photoactive and insoluble in water. A study of the degradation of Reactive Brilliant X-3B (a reactive dye) and catechol (a refractory organic compound) has been performed. The degradation occurred via oxidation with ozone under UV light under these conditions: a) without a catalyst, b) with TiO2 as a catalyst, and c) with carbon black-coated TiO2 catalyst on Al thin films. The reaction rate almost doubled with the use of TiO2 nanoparticles and attacking carbon black TiO2 made the separation from the pollutant easy and affordable.

Conclusion

The Royal Society report identified a risk of nanoparticles or nanotubes being released during disposal, destruction and recycling, and recommended that “manufacturers of products that fall under extended producer responsibility regimes such as end-of-life regulations publish procedures outlining how these materials will be managed to minimize possible human and environmental exposure” .Reflecting the challenges for ensuring responsible life cycle regulation, the Institute for

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Food and Agricultural Standards has proposed that standards for nanotechnology research and development should be integrated across consumer, worker and environmental standards. They also propose that NGOs and other citizen groups play a meaningful role in the development of these standards.The Centre for Nanotechnology in Society has found that people respond differently to nanotechnologies based upon application – with participants in public deliberations more positive about nanotechnologies for energy than health applications – suggesting that any public calls for nano regulations may differ by technology sector.

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