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COMPREHENSIVE STUDY& OVERVIEW OF NANOTECHNOLOGY

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ABSTRACT
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. The main unifying theme is the control of matter on a scale smaller than one micrometer, normally approximately 1 to 100 nanometers, as well as the fabrication of devices of these sizes. It is a highly multidisciplinary field, drawing from fields such as applied physics, superamolecular chemistry and even electrical and mechanical engineering. Nanotechnology can be seen as extension of existing sciences using newer and more modern term.

Keywords: Nanotechnology

INTRODUCTION

Nanotechnology is a field of science and technology covering a broad range of topics. The term nanotechnology can be defined as "a field which mainly consists of the processing of separation, consolidation and deformation of materials by one atom or by one molecule."

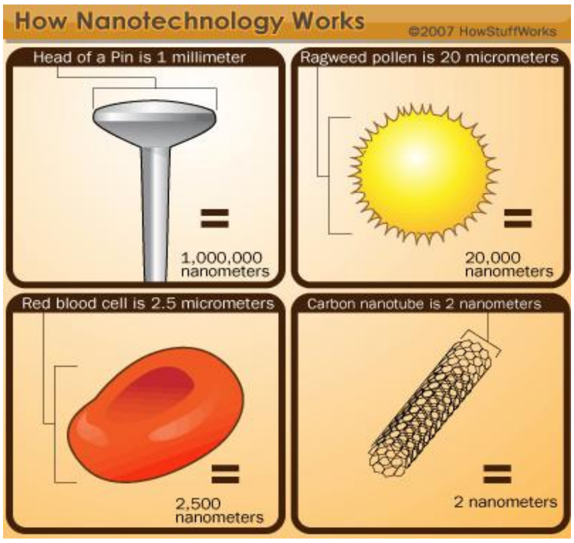

Fig 1: Basics of Nanotechnology

Nanotechnology uses two main approaches, that is bottom-up approaches and top-down approaches. In bottom-up approaches materials and devices are built from molecular components which assembles themselves chemically by principles of molecular recognition. In the top-down approach, nano-objects are constructed from large entities without atomic level control.

The impetus for nanotechnology comes from a renewed interest in colloidal science, couples with a new generation of analytical tools such as the Atomic Force Microscope (AFM) and Scanning Tunneling Microscope (STM). Combined with refined processes such as Electron Beam Lithography and Molecular Beam Epitaxy, these instruments allow the deliberate manipulation of nanostructures and led to the observation of novel phenomena.

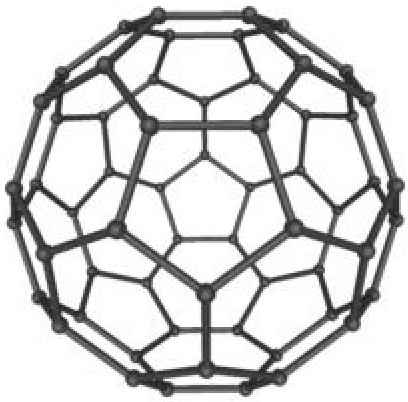

Fig 2: Buckminsterfullerene $C_{60,\ also}$ known as the buckyball, is the simplest of the carbon structures known as fullerenes. Members of the fullerene family are a major subject of research falling under the nanotechnology umbrella.

ORIGIN

The term ‘nanotechnology’ was first used by noble prize winner physicist, Richard Feynman on December 29, 1959. Feynman described a process by which the ability to manipulate individual atoms and molecules might be developed, using one set of precise tools to build and operate another proportionality smaller set, so on down to the needed scale. In the course of this, he noted, scaling issues would arise from the changing magnitude of various physical phenomena gravity would become less important, surface tension and Van der Waals attraction would become more important. This basic idea appears feasible and exponential assembly enhances it with parallelism to produce a useful quantity of end products.

Nanotechnology and nanoscience got started in the early 1980's with two major developments, the birth of cluster science and invention of the Scanning Tunneling Microscope (STM).

This development led to the discovery of fullerenes in 1986 and carbon nanotubes a few years later. In other development, the synthesis and properties of semiconductor nanocrystals was studied.

FUNDAMENTAL CONCEPTS

One nanometer (nm) is the one billionth, or 10^{-9} of a meter. For comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 12-15nm, and a DNA double helix has a diameter around 2nm.

Fig 3: With 15,342 atoms, this parallel-shaft speed reducer gear is one of the largest nanomechanical devices ever modeled in atomic detail.

1. Larger to smaller: A material perspective

A unique aspect of nanotechnology is the vastly increased ratio of surface area to volume present in many nanoscale materials which opens new possibilities in surfacebased science, such as catalysis. A number of physical phenomena become noticeably 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 particles size from macro to micro dimensions. However, it becomes dominant when the nanometer size range is reached. Additionally, a number of physical properties change when compared to macroscopic systems. One example is the increase in surface area to volume to materials. This catalytic activity also opens potential risks in their interaction with biomaterials.

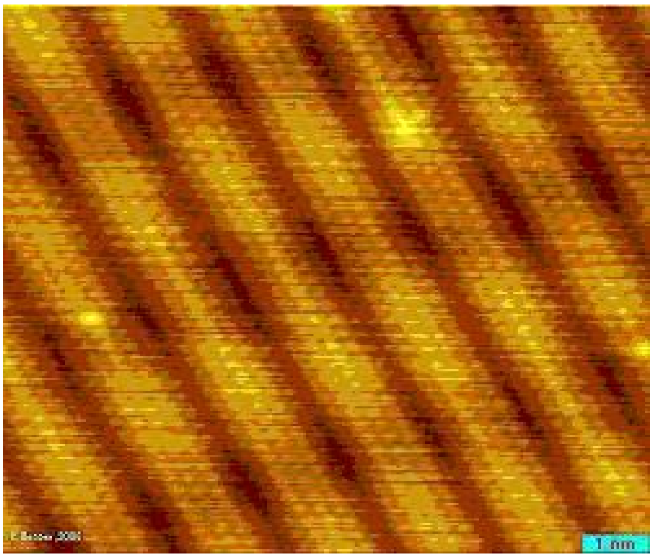

Fig 4: Image of reconstruction on a clean Au (100) surface, as visualized using Scanning Tunneling Microscopy. The individual atoms composing the surface are visible.

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 produce a wide variety of useful chemicals such as pharmaceuticals or commercial polymers.These approaches utilizes the concepts of molecular self-assembly and/or superamolecular chemistry to automatically arrange themselves into some useful conformation/arrangement through a bottom-up approaches. The concept of molecular recognition is especially important; molecules can be designed so that a specific conformation or arrangement is favored due to non- covalent intermolecular forces.Such bottom-up approaches should, broadly speaking, be able to produce devices in parallel and 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.

Nanomaterials

This includes subfields which develop or study materials having unique properties arising from their nanoscale dimensions.

- 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.
- Nanoscale 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 like nanomedicine.

2. Molecular Technology

Molecular nanotechnology, sometimes called molecular manufacturing, is a term given to the concept of engineered nanosystems (nanoscale machines) operating on the molecular assembler, a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis.When the term "nanotechnology" was coined, it referred to a future manufacturing technology based on molecular machine systems. Dr. Alex Zettle and his colleagues at Lawrence Berkeley Laboratories and U C Berkeley have constructed three distinct molecular devices whose motion is controlled from the desktop with changing voltage: a nanotubes nanometer, a molecular actuator and a nanomechanical relaxation oscillator.

APPROACHES

As nanotechnology is a very broad term, there are many disparate but sometimes overlapping subfields that could fall under its umbrella. The following avenues of research could be considered subfields of nanotechnology. Note that these categories are fairly nebulous and a single subfield may overlap many of them, especially as the field of nanotechnology continues to mature.

1. Top-down approaches

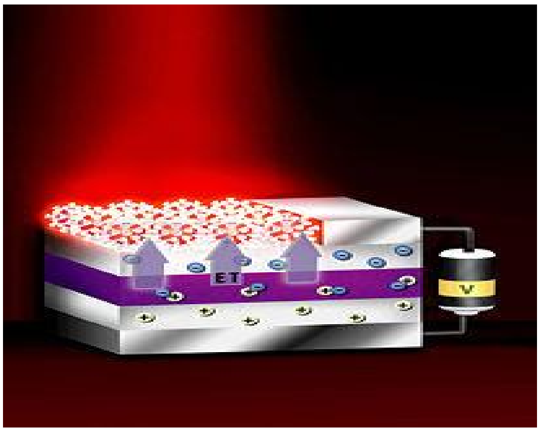

Fig 5: Device transfers energy from nano-thin layers of quantum wells to nanocrystals above them, causing the nanocrystals to emit visible light.

These seek to create smaller devices by using larger ones to direct their assembly.

- Many technologies 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 devices already on the market fit this description as do Atomic Layer Deposition (ALD) techniques.
- Solid-state techniques can also be used to create devices known as nanoelectromechanical systems or NEMS, which are related to microeletromechanical systems or MEMS.
- Atomic Force Microscope tips can be used as a nanoscale “write head” to deposit a chemical on a surface in a desired pattern in a process called dip pen nanolithography. This fits into the layer subfield of nanotechnology.

2. Bottom-up approaches

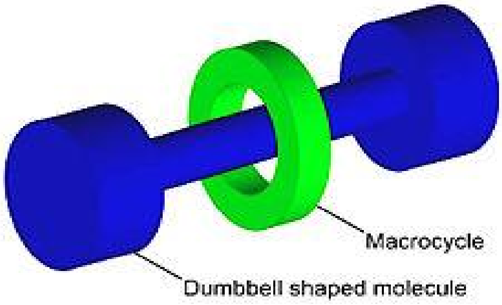

Fig 6: Graphical representation of a Rotaxane, useful as a molecular switch.

These seek to arrange smaller components into more complex assemblies.

- DNA nanotechnology utilizes the specificity of Watson- Crick basepairing to construct well-defined structures out of DNA and other nucleic acids.

3. Functional approaches

These seek to develop components of a desired functionality without regard to how they might be assembled.

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

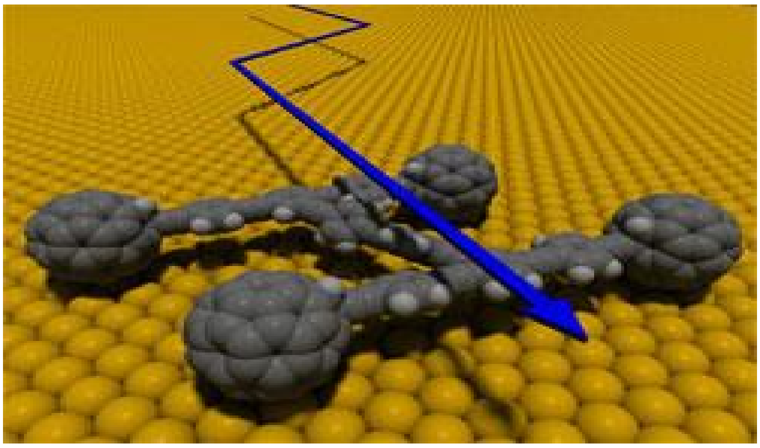

Fig 7: Space-filling model of the nanocar on a surface, using fullerenes as wheels.

TOOLS AND TECHNIQUES

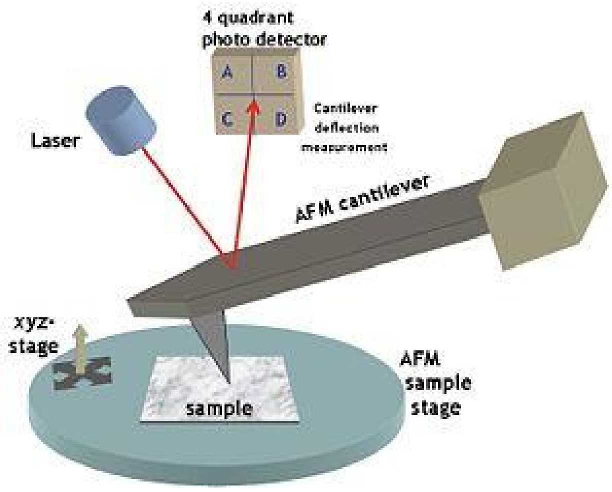

Fig 8:Typical AFM setup, a microfabricated cantilever with a sharp tip is deflected by features on a sample surface, much like in a photograph but on much smaller scale. A laser beam reflects off the backside of the cantilever into a set of photodetectors, allowing the deflection to be measured and assembled into an image of the surface.

Nanotechnology and nanoscience only become possible in 1910's with the development of the first tools which is used to measure and make nanostructures. But the actual development started with the discovery of electrons and neutrons which showed scientists that matter can really exist on a much smaller scale than what we normally think of as small. Due to this, curiosity of nanostructure had originated.

The most important technique of nanotechnology is Scanning Probe Microscopy which includes three different types of tools and they are:

a) The Atomic Force Microscope (AFM) and the Scanning Tunneling Microscope (STM).
b) Scanning Confocal Microscope (SCM).
c) Scanning Acoustic Microscope (SAM).

a) The Atomic Force Microscope (AFM) And The Scanning Tunneling Microscope (STM)

The Atomic Force Microscope and the scanning tunneling microscope are used to look at surfaces and to move atoms around. If we design different types of tips for AFM, they can be used for carving out structures on surfaces and help to guide self assembling structures.

b) Scanning Confocal Microscope (SCM)

Scanning Confocal Microscope was developed by Marvin Minsky in 1901. This Microscope made it possible to see structures at nanoscale.

c) Scanning Acoustic Microscope(SAM)

Scanning Acoustic Microscope (SAM) was developed by Calvin Quate and co-workers in the 1970's. it is also used to see structures at nanoscale. The tip of Scanning Acoustic Microscope can also be used to positional assembly for nanostructure.

Nanotechniques include those techniques which are used for the fabrication of nanowires and in semiconductor fabrication such as deep ultraviolet lithography, electron beam lithography, focused ion beam machining, nanoimprint lithography, atomic layer deposition and molecular vapor deposition.
Scanning Probe Microscopy techniques are expensive and time consuming for mass production but very suitable for laboratory experimentation.

APPLICATIONS

It is used in:

- Medicines.
- Space development and systems.
- Consumer products.
- NASA.
- Biotechnology.
- Biomedical.

CONCLUSION

Nanotechnology itself may never become a huge industry in the classical sense but it could very well have an impact on the commercial world. Nanotechnology promises a new, fast world to the future generation. We can hope for the earth to be ecologically reshaped giving rise to the already extinguished species.

REFFERENCES

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