CODEN [USA]: IAJPBB ISSN: 2349-7750

INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES

http://doi.org/10.5281/zenodo.3473977

Available online at: http://www.iajps.com *Review Article*

NANOCHEMISTRY: A REVIEW

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Article Received: August 2019 **Accepted:** September 2019 **Published:** October 2019

Abstract:
Nanotechnology, shortened to "Nanotech", is the study of manipulating matter on an atomic and molecular scale. Generally nanotechnology deals with structures sized between 1 to 100 nm and involve developing materials or tools within that size. For comparision "10 nanometers is 1000 times" smaller than the diameter of a human hair. Nanotechnology has the capacity to improve the capability to prevent, detect, and remove environmentally containants in air, water, and soil in a cost effective and environmentally friendly manner. Nanoscience and nanotechnologies are revolutionizing the understanding of concern and are likely to have profound implications for all sectors of the economy, including agriculture and food, energy production and efficiency, the automotive industry, cosmetics, medical appliances and drugs, household appliances, computers and arm.

Keywords: *Nanotechnology , Nanomaterials.*

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Please cite this article in press Sheeja Rekha A G et al., **NANOCHEMISTRY: A REVIEW.,** *Indo Am. J. P. Sci, 2019; 06[10].*

INTRODUCTION:

Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, energy storage, microfabrication, molecular engineering, etc. The associated research and applications are equally diverse, ranging from extensions of conventional device physics 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 nanomedicine , nanoelectronics , biomaterials energy production , and consumer products . On the other hand, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials ,[8] and their potential effects on global economics, as well as speculation about various doomsday scenarios. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted[1,2,4].

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.

The concept of a metal nanolayer-base transistor was proposed in the early 1960s, by American physicist Albert Rose in 1960, and then independently in 1962 by Egyptian engineer Mohamed Atalla and Korean engineer Dawon Kahng at Bell Labs, and by American engineer Donovan Verloe Geppert. They proposed a device that has a metallic layer with nanometric thickness sandwiched between two semiconducting layers, with the metal forming the base and the semiconductors forming the emitter and collector. Nanolayer-base transistors were first demonstrated by Atalla, Kahng and Geppert in 1962. Their pioneering work involved depositing metal layers [the base] on top of single crystal semiconductor substrates [the collector], with the emitter being a crystalline semiconductor piece with a top or a blunt corner pressed against the metallic layer [the point contact]. With the low resistance and short transit times in the thin metallic nanolayer base, the devices were capable of high operation frequency compared to bipolar transistors[3,5].

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 nanotechnology concepts and implications.

The emergence of nanotechnology as a field in the 1980s occurred through convergence of Drexler'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 prospects of atomic control of matter. Since the popularity spike in the 1980s, most of nanotechnology has involved investigation of several approaches to making mechanical devices out of a small number of atoms[4,6,7].

In the 1980s, two major breakthroughs sparked the growth of nanotechnology 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 Binnig and Heinrich Rohrer at IBM Zurich Research Laboratory received a Nobel Prize in Physics in 1986. Binnig, Quate and Gerber also invented the analogous atomic force microscope that year[8,9].

Larger to smaller: a materials perspective:

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 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 kinetic 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[10,11,12].

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 nanoelectronics, nanomechanics, nanophotonics and nanoionics have evolved during the last few decades to provide a basic scientific foundation of nanotechnology[13,14].

Larger to smaller: a materials 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 supramolecular assemblies consisting of many molecules arranged in a well defined manner.

These approaches utilize the concepts of molecular self-assembly and/or supramolecular 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 basepairing 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[15,16,17].

Molecular nanotechnology: a long-term view:

Molecular nanotechnology, sometimes called molecular manufacturing, describes engineered nanosystems [nanoscale machines] operating on the molecular scale. Molecular nanotechnology is especially associated with the molecular assembler, a machine that can produce a desired structure or device atom-by-atom using the principles of mechanosynthesis. Manufacturing in the context of productive nanosystems is not related to, and should be clearly distinguished from, the conventional technologies used to manufacture nanomaterials such as carbon nanotubes and nanoparticles.

When the term "nanotechnology" was independently coined and popularized by Eric Drexler [who at the time was unaware of an earlier usage by Norio Taniguchi] it referred to a future manufacturing technology based on molecular machine systems. The premise was that molecular scale biological analogies of traditional machine components demonstrated molecular machines were possible: by the countless examples found in biology, it is known that sophisticated, stochastically optimised biological machines can be produced.

It is hoped that developments in nanotechnology will make possible their construction by some other means, perhaps using biomimetic principles.

However, Drexler and other researchers have proposed that advanced nanotechnology, although perhaps initially implemented by biomimetic means, ultimately could be based on mechanical engineering principles, namely, a manufacturing technology based on the mechanical functionality of these components [such as gears, bearings, motors, and structural members] that would enable programmable, positional assembly to atomic specification. The physics and engineering performance of exemplar designs were analyzed in Drexler's book *Nanosystems*[18,19,20].

In general it is very difficult to assemble devices on the atomic scale, as one has to position atoms on other atoms of comparable size and stickiness. Another view, put forth by Carlo Montemagno,[35] is that future nanosystems will be hybrids of silicon technology and biological molecular machines. Richard Smalley argued that mechanosynthesis are impossible due to the difficulties in mechanically manipulating individual molecules.

This led to an exchange of letters in the ACS publication Chemical & Engineering News in 2003. Though biology clearly demonstrates that molecular machine systems are possible, non-biological molecular machines are today only in their infancy. Leaders in research on non-biological molecular machines are Dr. Alex Zettl and his colleagues at Lawrence Berkeley Laboratories and UC Berkeley. They have constructed at least three distinct molecular devices whose motion is controlled from the desktop with changing voltage: a nanotube nanomotor, a molecular actuator, and a nanoelectromechanical relaxation oscillator. See nanotube nanomotor for more examples[21,22].

An experiment indicating that positional molecular assembly is possible was performed by Ho and Lee at Cornell University in 1999. They used a scanning tunneling microscope to move an individual carbon monoxide molecule [CO] to an individual iron atom [Fe] sitting on a flat silver crystal, and chemically bound the CO to the Fe by applying a voltage[23,24,25].

CURRE Nanomaterials:

The nanomaterials field includes subfields which develop or study materials having unique properties arising from their nanoscale dimensions.[41]

- 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 flavor.
- Progress has been made in using these materials for medical applications; see Nanomedicine.
- Nanoscale materials such as nanopillars 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.
- Recent application of nanomaterials include a range of biomedical applications, such as tissue engineering, drug delivery, and biosensors[26,27,28].
- **Bottom-up approaches**
- 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.
- 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.
- Molecular Beam Epitaxy allows for bottom up assemblies of materials, most notably semiconductor materials commonly used in chip and computing applications, stacks, gating, and nanowire lasers[29,30,31].
- **Top-down approaches**
- These seek to create smaller devices by using larger ones to direct their assembly.
- 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,[47] as do atomic layer deposition [ALD] techniques. Peter Grünberg and 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 precursor 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.

Functional approaches

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

- Magnetic assembly for the synthesis of anisotropic superparamagnetic materials such as recently presented magnetic nano chains.
- Molecular scale electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nanoelectronic device. For an example see rotaxane.
- Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar[32,33,34].
- **Biomimetic approaches**
- Bionics or biomimicry seeks to apply biological methods and systems found in nature, to the study and design of engineering systems and modern technology. Biomineralization is one example of the systems studied.
- Bionanotechnology is the use of biomolecules for applications in nanotechnology, including use of viruses and lipid assemblies. Nanocellulose is a potential bulk-scale application.

Speculative

These subfields seek to anticipate what inventions nanotechnology might yield, or attempt to propose an agenda along which inquiry might progress. These often take a big-picture view of nanotechnology, with more emphasis on its societal implications than the details of how such inventions could actually be created.

- Molecular nanotechnology is a proposed approach which involves manipulating single molecules in finely controlled, deterministic ways. This is more theoretical than the other subfields, and many of its proposed techniques are beyond current capabilities.
- Nanorobotics centers on self-sufficient machines of some functionality operating at the nanoscale. There are hopes for applying nanorobots in medicine. Nevertheless, progress on innovative materials and methodologies has been demonstrated with some patents granted about new nanomanufacturing devices for future commercial applications, which also progressively helps in the development towards nanorobots with the use of embedded nanobioelectronics concepts.
- Productive nanosystems are "systems of nanosystems" which will be complex nanosystems that produce atomically precise parts for other nanosystems, not necessarily using novel nanoscale-emergent properties, but well-understood fundamentals of manufacturing. Because of the discrete [i.e. atomic] nature of matter and the possibility of exponential growth, this stage is seen as the basis of another industrial revolution. Mihail Roco, one of the architects of the USA's National Nanotechnology Initiative, has proposed four states of nanotechnology that seem to parallel the technical progress of the Industrial Revolution, progressing from passive nanostructures to active nanodevices to complex nanomachines and ultimately to productive nanosystems.
- Programmable matter seeks to design materials whose properties can be easily, reversibly and externally controlled though a fusion of information science and materials science.
- Due to the popularity and media exposure of the term nanotechnology, the words picotechnology and femtotechnology have been coined in analogy to it, although these are only used rarely and informally.

Dimensionality in nanomaterials

Nanomaterials can be classified in 0D, 1D, 2D and 3D nanomaterials. The dimensionality play a major role in determining the characteristic of nanomaterials including physical, chemical and biological characteristics. With the decrease in dimensionality, an increase in surface-to-volume ratio is observed.This indicate that smaller dimensional nanomaterials have higher surface area compared to 3D nanomaterials. Recently ,two dimensional [2D] nanomaterials are extensively investigated for electronic , biomedical , drug delivery and biosensor applications[35,36].

PROPERTIES AND APPLICATIONS OF NANO-MATERIALS:

PROPERTIES OF NANOMATERIALS

Mechanical properties:

The mechanical properties of carbon nanotubes in the radial [transverse] direction. Carbon nanotubes are one of the strongest materials in nature. Carbon nanotubes [CNTs] are long hollow cylinders of graphene. Although graphene sheets have 2D symmetry, carbon nanotubes by geometry have different properties in axial and radial directions. It has been shown that CNTs are very strong in the axial direction. Young's modulus on the order of 270 - 950 GPa and tensile strength of 11 - 63 GPa were obtained. On the other hand, there was evidence that in the radial direction they are rather soft. The first transmission electron microscope observation of radial elasticity suggested that even the van der Waals forces can deform two adjacent nanotubes. Later, nanoindentations with atomic force microscope were performed by several groups to quantitatively measure radial elasticity of multiwalled carbon nanotubes and tapping/contact mode atomic force microscopy was also performed on single-walled carbon nanotubes.

Catalytic Properties:

Functionalized metal nanoparticles are more stable in solution compared to non-functionalized metal nanoparticles. In liquid solutions, the metal nanoparticles are close enough together to be affected by van der Waals force. If there isn't anything to oppose these forces, then the nanoparticles will aggregate, which will lead to a decrease in catalytic activity by lowering the surface area. For organometallic functionalized nanoparticles, ligands are coordinated to the metal center to prevent aggregation. Using different ligands alters the properties and sizes of the nanoparticle catalysts. Nanoparticles can also be functionalized with polymers or oligomers to sterically stabilize the nanoparticles by providing a protective layer that prevents the nanoparticles from interacting with each other. Alloys of two metals, called bimetallic nanoparticles, are used to create synergistic effects on catalysis between the two metals.

Magnetic Properties:

In magnetic nanoparticles, the energy of magnetic anisotropy may be The measured parameters include electrical resistivity, chemical activity, magnetic permeability, thermal conductivity, and capacitance.

Automobiles with Greater Fuel Efficiency: Currently, automobile engines waste considerable amounts of gasoline, thereby contributing to environmental pollution by not completely combusting the fuel. A conventional spark plug is not designed to burn the gasoline completely and efficiently. that small that the vector of magnetization fluctuates thermally; this is called superparamagnetism. Such a material is free of remanence, and coercitivity. Touching superparamagnetic particles are losing this special property by interaction, except the particles are kept at distance. Combining particles with high energy of anisotropy with superparamagnetic ones leads to a new class of permanent magnetic materials.

Optical Properties:

Distributions of non-agglomerated nanoparticles in a polymer are used to tune the index of refraction. Additionally, such a process may produce materials with non linear optical properties. Gold or CdSe nanoparticles in glass lead to red or orange coloration. Semi-conducting nanoparticles and some oxide-polymer nanocomposites exhibit fluorescence showing blue shift with decreasing particle size.

APPLICATIONS OF NANOMATERIAL

Since nanomaterials possess unique, beneficial chemical, physical, and mechanical properties, they can be used for a wide variety of applications. These applications include, but are not limited to, the following:

- Next-Generation Computer Chips: The microelectronics industry has been emphasizing miniaturisation, whereby the circuits, such as transistors, resistors, and capacitors, are reduced in size.
- Kinetic Energy [KE] Penetrators with Enhanced Lethality: The Department of Defense [DoD] is currently using depleted-uranium [DU] projectiles [penetrators] for its lethality against hardened targets and enemy armoured vehicles.
- Better Insulation Materials: Nanocrystalline materials synthesised by the sol-gel technique result in foam like structures called "aerogels." These aerogels are porous and extremely lightweight; yet, they can loads equivalent to 100 times their weight. Aerogels are composed of three-dimensional, continuous networks of particles with air [or any other fluid, such as a gas] trapped at their interstices. Since they are porous and air is trapped at the interstices, aerogels are currently being used for insulation in offices, homes, etc.

- Phosphors for High-Definition TV: The resolution of a television, or a monitor, depends greatly on the size of the pixel. These pixels are essentially made of materials called "phosphors," which glow when struck by a stream of electrons inside the cathode ray tube [CRT]. The resolution improves with a reduction in the size of the pixel, or the phosphors.
- Low-Cost Flat-Panel Displays: Flat-panel displays represent a huge market in the laptop [portable] computers industry. However, Japan is leading this market, primarily because of its research and development efforts on the materials for such displays.
- Tougher and Harder Cutting Tools: Cutting tools made of nanocrystalline materials, such as tungsten carbide, tantalum carbide, and titanium carbide, are much harder, much more wear resistant, erosion-resistant, and last longer than their conventional [large-grained] counter parts.
- Elimination of Pollutants: Nanocrystalline materials possess extremely large grain boundaries relative to their grain size. Hence, nanomaterials are very active in terms of their of chemical, physical, and mechanical properties. Due to their enhanced chemical activity, nanomaterials can be used as catalysts to react with such noxious and toxic gases as carbon monoxide and nitrogen oxide in automobile catalytic converters and power generation equipment to prevent environmental pollution arising from burning gasoline and coal.
- High Energy Density Batteries: Conventional and rechargeable batteries are used in almost all applications that require electric power. These applications include automobiles, laptop computers, electric vehicles, next-generation electric vehicles [NGEV] to reduce environmental pollution, personal stereos, cellular phones, cordless phones, toys, and watches. The energy density [storage capacity] of these batteries is quite low requiring frequent recharging. The life of conventional and rechargeable batteries is also low. Nanocrystalline materials synthesised by sol-gel techniques are candidates for separator plates in batteries because of their foam-like [aerogel] structure, which can hold considerably more energy than their conventional counterparts.
- High-Sensitivity Sensors: Sensors employ their sensitivity to the changes in various parameters they are designed to measureThis problem is compounded by defective, or worn-out, spark plug electrodes.
- Aerospace Components with Enhanced Performance Characteristics: Due to the risks involved in flying, aircraft manufacturers strive to make the aerospace components stronger, tougher, and last longer. One of the key properties required of the aircraft components is the fatigue strength, which decreases with the component's age.
- Better and Future Weapons Platforms
- Longer-Lasting Satellites
- Longer-Lasting Medical Implants
- Ductile, Machinable Ceramics
- Large Electrochromic
- Display Devices[37,38,39]

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