

Nanotechnology and Nanoscience: A Blueprint for Chemistry Revolution

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ABSTRACT

Nanotechnology is emerging as one of the principal areas of investigation that is integrating the chemical industry and material science and in some cases those with biology to create new and yet undiscovered properties that can be exploited to gain new market opportunities. It is one of the most important tools in modern chemistry, and is anticipated to become a driving economic force in the near future. The role of chemistry in nanotechnology has been reviewed as well as the benefits to mankind, the tremendous opportunities that it has presented to the chemical industry, that is capable of introducing new products that could energize the world economy, solve major societal problems, revitalize existing industries and create new business. The programme combine core chemistry with Nano chemistry, nanophysics and nanotechnology (and will expand into new applications) in areas as diverse as chemical engineering, chemistry, biochemistry, medicine, microelectronics, communications and aerospace. Nanotechnology is changing the world and the way we live, creating scientific advances and new products that are smaller, faster, stronger, safer and more reliable. It is actually revolutionizing our lives.

Keywords: Chemistry, Nana science, Nanotechnology, Devices, Materials and Opportunities

INTRODUCTION

Chemistry is the branch of science concerned with the substance of which matter is composed, the investigation of their properties and reactions and the use of such reactions to form new substances. It is also one of the physical science that helps us describe and explain the world. It plays a vital role in man's understanding of material phenomena in his capability to act upon, modify, control and invent new expressions of them.

Nanoscience is the emerging science of objects that are intermediate in size between the largest molecules and the smallest structures that can be fabricated by current photolithography; that is, the science of objects with smallest dimensions ranging from a few nanometers to less than 100 nanometers [1-3]. It is the science of objects with typical sizes of 1-100 nm, is one of the most important developments in the last decades. Miniaturization of electronic devices to sizes of the elementary units below 1 μm has revolutionized our daily live. New technologies were required to enter the nanoscale because many of the traditional techniques do not work

at the nanoscale. The relation between nanoscience and technology is like a symbiosis. Scientific discoveries lead to new technologies. The technology enables new fundamental insights. Two new technologies which enabled the progress of nanoscience are scanning tunneling and scanning force microscopy. They allow to image and manipulate objects on surfaces with sufficient precision even in ambient conditions or in liquids. In chemistry, this range of sizes has historically been associated with colloids, micelles, polymer molecules, phase-separated regions in block copolymers, and similar structures typically, very large molecules, or aggregates of many molecules. A similar motivation drives scientist to integrate and miniaturize chemistry and to try to understand and manipulate smaller and smaller amounts of liquids. This is essential when only small amounts of reactants are available. It also helps to better control potentially toxic or explosive reactions. The idea is to integrate a complete laboratory into a silicon waver or a plastic chip. Although this concept has not penetrated our everyday live to the same extent as microelectronics has, the first

commercial applications are meanwhile available, e.g., enzymatic analysis and DNA-sequencing.

The combination of the promise of new phenomena, new science with an extension of an extremely important technology is the force that drives Nano science. There is also a less rational form of propulsion: Nano science and nanotechnology has become a playground for futurist's people who imagine how the future might be and of science fictionists; sometimes the two overlap [4-8].

Nanotechnology is a discipline that is truly on the cutting edge of science. It is a new science where chemistry merges into modern aspects of communications, electronics, photonics, aerospace, transport, pharmaceutical materials, bioengineering and IT. The beauty of chemistry lies in the fact that through chemistry career one could become creative in life. Through chemical reactions, one can create new drugs, new materials, new technologies, new theories, new policies, and new businesses or even become an inventor of a nanotechnology.

Nanotechnology, as an emerging technology, presents an important opportunity for the scientific and business community. Nanotech is unlike some other sectors of the chemical industry, where significant capital is already invested in the form of large plants and established supply chains in which production techniques are technologically and culturally embedded. In fact, the need to develop both new Nano products and their equally novel production techniques presents an important opportunity for innovators. In this case, there is an unusual opportunity to use science, engineering and policy knowledge to design novel products that are benign as possible to human and environment health.

Recognition of this opportunity has led to the development of the "green nanoscience" Concept [9] [10]. Green nanotechnology has drawn on the field of green chemistry, and the framework of the 12 Principles of Green Chemistry [11] features significantly in work to design new nanotechnologies for joint economic, social, and health/environmental benefit [12]. These efforts have been aided by awareness throughout the nanotech community that they need to address the potential negative impacts of nanotechnology from the outset [13]. Awareness is still limited in many sectors, and nanoscience more broadly, still faces significant challenges in transitioning from concept to reality.

Nanotechnology presents an opportunity to develop a revitalized, sustainable chemical and materials manufacturing base. This new emerging science and associated technologies do not have to follow the typical path of many past innovations in the chemical industry that, despite providing significant benefits, also turned out to have unanticipated costs to human and environment health. The development and commercialization of viable green nanotechnologies is difficult, and the challenges mentioned below will require effort from the scientific, research and government communities.

Chemistry is critical to solving today's problem. Each new day contain issues where chemistry matters such as faster and cheaper drug development, cleaner and more economical fuel sources, safer air and drinking water, biotechnology to improve health and food sources around the world, nanotechnology to reduce the size and environmental impact of many consumer goods and green industrial processes to prevent pollution. The beauty of chemistry lies in the fact that though chemical experiments are conducted in the laboratories equipped with apparatus (like beakers, flasks, burettes, pipettes, analytical balances, etc.) all of which operates on the microscopic scale perceptible to ordinary human senses, the actual chemical transformation occur in the microscopic word of Atoms and Molecules (tiny objects too small to be detected directly by human beings). The equipment in the laboratories are thus the bridge between these worlds of macroscopic and the microscopic, giving the chemist not only the means to influence the actions of the atoms and molecules but also the means to measure their responses to changes in their environment. Before the advent of nanotechnology, we think of construction of machines and devices as being associated with the usage of component, for the product assembly, that are cut out from a larger block of material by a range of often sophisticated engineering methods rather than with a process that can be carried out atom by atom. However, with nanotechnology, for example, those on a computer chip are nowadays so small that we could indeed envisage building them up from individual atom or molecules. This is also evident in the increased durability of material against mechanical stress or weathering, helping to increase the useful life of a product; nanotechnology based dirt-and water resistance coatings to reduce cleaning efforts; novel

insulation materials to improve the energy efficiency of buildings; adding nano particles to reduce weight and save energy during transport. In the chemical industry sector, nano material's are applied based on their special catalytic properties in order to boost energy and resource efficiency and nano material's can replace environmentally problematic chemicals in the fields of application. Hence, nanotechnology brings a transition from classical engineering concepts to chemical assembly. Nano technology is therefore a linking field between chemistry and engineering.

CHEMISTRY AND TECHNOLOGY

It can be recalled that chemistry is the branch of science that deals with the study of composition, structure and properties of matter (comprises of all things that have weight and occupy space) together with the associated changes (chemical and /or physical) and such changes impact on the welfare of man and society. Chemistry can thus be considered as the study of everything, as there is nothing on earth that is not matter and hence chemistry. The fact that chemistry is the central science and science is the foundation on which technology is built, buttresses the central position of chemistry in technology (i.e. all forms of technology) including nanotechnology. Chemistry is also an art, by its very essence, its ability to create. Chemistry actually fashions out, new worlds that do not exist.

Technology is the study, development and application of devices, machines and techniques for the development and application of devices, machines and techniques for manufacturing and productive processes [14]. Technology develops and applies devices/ techniques for the manufacture of materials /substances which chemistry has shown to be feasible. Chemistry provides route for tailoring the properties of existing substances to meet some particular need or application and for creating entirely new materials designed from the beginning to have desired particular properties. By such accomplishment, chemistry has made dramatic contribution to a whole a lot of human living in various areas like; Agricultural production, controlling the spread of diseases, increasing the efficiency of energy production, reducing environmental pollution. The innovative properties of chemistry have led to cutting edge advancements in applied technologies, in Medical devices, aerospace, Computing, Cars, Fuels and more. The business of chemistry excels at continuously bringing new imaginative and innovative ideas to market.

Impact of Chemistry in Nanotechnology

Chemistry is dealing with atoms and molecules, with great attention laid on their arrangement. Therefore it seems to be the paradigm of the vision of Nanotechnology: To build up new structures, atom by atom.

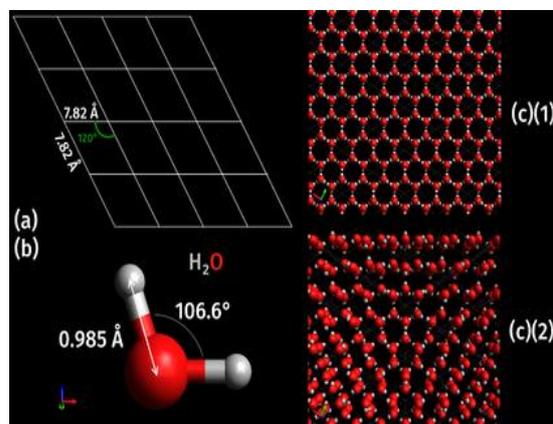


Figure1. Arrangement of atoms to form water

For example, Due to new developments of analytic tools and process technology, it is now possible to construct planar surfaces with the accuracy of atomic layers. Other examples are coatings with a thickness of a few atoms, which are composed of different elements, or ceramics and other compound materials with crystallites in the nm range and the re-arrangement of atoms in dirt, water and air can give potatoes [15].

The term Nanotechnology encompasses a wide range of tools, techniques and potential applications. Most of them are concepts and ideas rather than real technologies. It is the technology that allows man to:

Get essentially all the right atoms and molecules in the right place, Make almost any structure consistent with the laws of chemistry and physics that can be specified in molecular detail, Manufacturing cost not exceeding the cost of required materials and energy.

The history of technology suggests, however, that where there is smoke, there will eventually be fire; that is, where there is enough new science, important new technologies will eventually emerge. In nanotechnology, two approaches are widely employed "bottom up where devices and materials are built from molecular components which assemble themselves chemically by principle of chemical recognition and "bottom down approach where Nano objects are constructed from larger entities without atomic level control. Nanotechnology employs the fact that a number of physical

phenomenon's of systems become pronounced as the size of the system decreases.

Traditional chemistry is based on covalent atomic bonds.

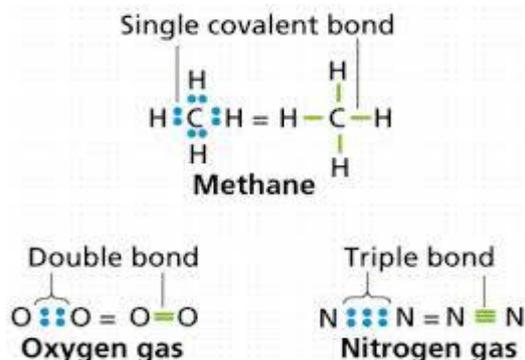


Figure 2. Example of covalent bond

At the same time, the synthesis of complex Nano systems and molecular devices that are used in nanotechnology require more than just the covalent chemistry feature because such system may contain several thousands of atoms. This is where intermolecular interactions play vital role. The can help to combine individual molecules into complex assemblies called supra molecular structures.

The emergence of supra molecular chemistry has had a profound effect on how efficiently chemists prepare structures of different sizes and shapes with dimension in the range of 1 to 100 nm using spontaneous secondary interactions such as hydrogen bonding, dipole-dipole, charge transfer, Vander Waals, and π - π stacking interactions [8-13]. The said methods would utilize the concept of molecular self-assembly and/or supra molecular chemistry to automatically arrange atoms and molecules into useful conformation through a bottom up approach which seek to arrange smaller components into more complex assemblies. Also, in synthetic chemistry, self-assembly has made recent advances in the area of supra molecular chemistry which are divided in three main fields (organic chemistry, inorganic chemistry, and polymer chemistry).

This “bottom up” approach that has been used to construct nanostructures is advantageous over the “bottom down” approach such as microlithography which requires substantial effort to fabricate microstructures and devices as the target structures are extended to the range below 100 nm.

Therefore, there is an increasing realization that the “bottom up” approach would open a route to

nanostructures that are currently inaccessible by the “bottom down” approach. Thus far the development of the “bottom up” methods to create nanostructures has been inspired primarily by Nature, which displays a wide variety of complex nanostructures with astonishing precision [16-17]. These Nano scale structures in biological systems are specifically put together from two or more small molecular components by means of secondary interactions. The precision and specificity are indicative of control and directionality displayed by secondary interactions between complementary components in biological systems. In addition, the “bottom up” approach benefits from having thermodynamic minima in its resulting nanostructures due to the reversible nature of secondary interactions. Obviously, the challenge is to synthetically create nanostructures with such precision and specificity as seen in biological systems by cleverly incorporating complementary recognition sites in the molecular components for secondary interactions. This challenge is only met by first understanding how molecular self-assembly in biological systems operates to generate well-defined aggregates and then transferring the knowledge learned from biological systems to chemical synthesis chemistry.

Molecular chemistry establishes its power over the covalent bond while beyond molecular chemistry lies the field of supra molecular control over the intermolecular bond. Supra molecular chemistry is an interdisciplinary field that deals with interaction between molecules, how they can recognize each other, assemble and function on a molecular scale. It provides a bottom up approach Nano scale system with applications covering chemical, physical, material and biological features. Supra molecular chemistry methods are widely used in chemical analysis, medicine, catalysis, and photochemistry. Supra molecular structures form the basis for a great number of biologically active substances, the creation of photo and chemo sensors, molecular electronic devices, the development of Nano catalyst, the system of materials for nonlinear optics and the simulation complex biological complexes (Biomimetic).

OPPORTUNITIES AND CHALLENGES OF NANOTECHNOLOGY

Nanotechnology presents an opportunity to develop a new technology, and a new industry in a sustainable way from the outset. We are at a unique point where we have more

understanding of how to go about this than at any time in the past. This new emerging science and associated technologies do not have to follow the path that has been typical of many past innovations in the chemical industry that, despite providing significant benefits, also turned out to have significant, unanticipated costs to human health and the environment.

Scientific Opportunities for Chemist

The opportunities for chemistry to make important contributions to Nanoscience abound. Such opportunities include:

- **Synthesis of Nanostructures:** Chemistry is unique in the sophistication of its ability to synthesize new forms of matter. The invention of new kinds of nanostructures will be crucial to the discovery of new phenomena. In Nano science, chemistry can be on the streets at the beginning of the revolution.
- **Materials:** Materials science and chemistry are, over much of their shared border, indistinguishable. Chemistry has contributed (and will continue to contribute) to the invention and development of materials whose properties depend on Nano scale structure. Chemistry and chemical engineering will, ultimately, be important in producing these materials reproducibly, economically, and in quantity;
- **Molecular Mechanisms in Nano biology:** A comprehensive understanding Of the molecular mechanisms of functional nanostructures in biology, the light harvesting apparatus of plants, ATPase's, the ribosome, the structures that package DNA ultimately, and the cell is an area where chemistry, with its singular understanding of molecular mechanism, can make unique contributions.
- **Tools and Analytical Methods:** The scanning probe microscope invented by Binnig and Rohrer at the IBM laboratory in Zurich is the instrument that ignited the explosion of Nano science [18-19]. Developing new nanostructures requires knowing what they are. Physical and analytical chemistry will help to build the tools that define these structures
- **Risk Assessment and Evaluation of Safety:** Understanding the risks of nanostructures and nanomaterial's will require cooperation across disciplines that range from chemistry

to physiology and from molecular medicine to epidemiology [19-20].

Commercial Opportunities for Chemist

Nanotechnology also offers the chemical industry at least six interesting opportunities:

- **Tools for Research:** The first of these opportunities and one already well-established is to produce new tools and equipment for research (and increasingly for development and manufacturing). "Instruments for Nano science" is a growing commercial area
- **New Materials:** Materials will be a commercially important class of nanostructures. Examples include structural and electrically/ magnetically/optically functional polymers, particles, and composites for a range of applications, from spray-painted automobile bumpers and Nano scale bar-coded rods [21] to the printed organic electronics of electronic news- papers and smart shipping labels [22] In these applications, chemistry and chemical-process technology will probably be key to commercial realization of the value of the technology
- **New Processes for Fabrication:** Nanomaterial's can only be commercialized if they can be produced. The importance of vapor/liquid/ solid catalytic growth of buck tubes over nanoparticles of iron to the development of "Nanotubes" illustrates this point [23]. The development of new processes to make new materials is an activity in which the chemical industry has always excelled
- **Nano electronics:** The development of new photo resists and processes with which to fabricate structures with the sub-50-nm dimensions required by Nano electronics will present immediate opportunities for materials science and chemistry [24-25]
- **Nano- particle Technology:** Specialized kinds of nano particles will become important in a wide range of applications— from hydrophobic drugs generated and formulated in Nano particulate form to improve bioavailability, to electrodes and lumiphores for new kinds of graphic displays
- **The Revolutionary Unknown:** A final class and the one that is the most exciting comprises the revolutionary ideas, for

example, Nano-CDs (read by an array of parallel atomic force microscope tips known as the “centipede”) [26-27] quantum computers, and biocompatible nanoparticles able to reach, recognize, and report pre symptomatic disease. High-performance functional nano material is an opportunity for the chemical industry. They will, however, pose a dilemma, in that, at least initially, and perhaps perpetually, the volumes required will be low. Nanotechnology will confront the chemical industry in a world that no longer needs new, billion-dollar chemical plants, and in which agility is absolutely required to succeed in seizing technical opportunity—with the choice of trying to manage businesses that make small amounts of boutique materials, or trying to move downstream in principle into competition with traditional customers to capture some of the value of the systems of which the materials become a part [28].

Challenges

The major challenge of nanotechnology is centered on developing useful product for markets, advancing the underlying science and instituting a nanoscience development and development paradigm. Secondly, the challenge of developing Analytical material to obtain a reliable nanomaterial characterization, tools to detect, monitor and track NMS in environment and biological media.

Nanotechnology, Securing a Promised Future:

Nanotechnology is the new science where chemistry merges into modern aspects of communication, electronics, photonics, aerospace, pharmaceutical materials, bioengineering and IT to impact on almost all industries and all areas of the society. In the world of material science, investigators in the world of nanotechnology, the quantum related and other unique opportunities of molecular assemblages built on the nanometer scale to make ever smaller and more powerful electronic devices, new chemical catalyst and other innovative materials. Nanotechnology holds great potential for improving the life of mankind.

While nanotechnology is predicted to be of great importance for the development of new materials and devices for all areas of human activity, the current advances are currently being made in medicine and electronics. It is used in regenerative medicine to create new organs to

grow tissue and organs in the laboratory and allow surgeons to safely implant them when the body is unable to heal itself. Also, it has been employed in the rapid and precise development and manufacturing of medicine and vaccine's. The leading edge technology is now offering the potential to rapidly produce therapeutics, and vaccines against any virtual target.

CONCLUSION

Nanotechnology is the precise biochemical manipulation of matter on an atomic molecular and super molecular scale to shape macro scale properties and characteristics of materials and processes. This manipulation can be achieved using chemical, biological and even mechanical approaches. Today, many commercial products already contain Nano materials and are manufactured using nanotechnology.

Nanotechnology presents a tremendous opportunity for the chemical industry to introduce a host of new products that could energize the world economy, solve major societal problems, revitalize existing industries and create entirely new businesses. It is a well-established multi-disciplinary research area that engages many chemists. It has exciting potential and offers chemist opportunities to really move chemistry career to its peak.

According to Naomi Halas (professor of Chemistry and Electrical and mechanical Engineer at Rice University, America), the key to finding a place in nanotechnology is actually a solid foundation in chemistry, with education and training in material science, Engineering, Physics and Biochemistry. With a strong foundation in chemistry and its exposure to its connections with other fields will equip one to go into nanotechnology. There is a pathway forward, and concrete actions that could construct a solid foundation for an economically profitable and environmentally sustainable future for nanotechnology.

Chemist is and has always been the ultimate nanotechnology. Chemist make new forms of matter and are the only scientist to do so routinely by joining atoms or groups of atoms together with bonds.”

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