Annals of the Academy of Romanian Scientists
Series on Science and Technology of Information
ISSN 2066 - 8562 Volume **3**, Number **2/2010** 91

NANOSCIENCE AND NANOTEHNOLOGY

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Abstract. *In this paper, after introduction, it's presented the main strategic and current research areas in the nano world. The author presents the main direction of development of the nanotechnology, and the necessity of the regulations and standardization in the field of the nanotechnology. The main conclusion of this paper is that nanotechnology has advanced beyond the stage of an infant scientific field to provide now a tool kit that is poised to help us to solve a number of pressing problems.*

Keywords: nanoscience, nanotechnology, nanodevices, nanoelectronics, nanophotonics, nanosensors, molecular junction, nanofabrication, metamaterials

1. Introduction

Nanoscience and nanotechnology, without any doubt, will lead in the XXI century to many technological revolutions. Even, in our times, nanotechnology starts an industrial revolution that may have a bigger impact than the industrial and technological revolutions in the past 250 years brought on by great inventions such as the steam and internal combustion, electrical power generation, the automobile, the airplane, the integrated circuit e.g., which brought major changes in manufacturing, transportation and communications, that have had a profound effect on the socioeconomic and cultural conditions of mankind.

We can be sure that nanoscience and nanotechnology are revolutionary quests that will transform almost everything we do, the way we live and work, and the organizations around us.

If, the steam power revolution has been started in Great Britain, the internal combustion engine has been started in Germany, or the integrated circuit industrial revolution has been started in the United States, and they have been spread throughout all over the word, nanoscience and nanotechnology have been developed in many regions around the world, with unprecedented levels of global financial and intellectual investments.

The nanoscience and nanotechnology revolution can be compared with other major social history turning points like invention of farming or the rise of the first city-states.

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The first use of the concepts found in „nano-technology” was in „There's Plenty of Room at the Bottom," a talk given by physicist Richard Feynman[1] at an American Physical Society meeting at Caltech 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 proportionally smaller set, and so on down to the needed scale. This basic idea appeared plausible, and exponential assembly enhances it with parallelism to produce a useful quantity of end products. The term „nanotechnology" was defined by Tokyo Science University Professor Norio Taniguchi in a 1974 paper [1] as follows: „Nano-technology mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule". In the 1980s the basic idea of this definition was explored in much more depth by Dr. K. Eric Drexler, who promoted the technological significance of nano-scale phenomena and devices through speeches and the books „Engines of Creation: The Coming Era of Nanotechnology”[2] (1986) and „Nanosystems: Molecular Machinery, Manufacturing, and Computation”,[2] and so the term acquired its current sense.

Nanotechnology and nanoscience got started in the early 1980’s with two major developments; the birth of cluster[3] science and the invention of the scanning tunneling microscope (STM)[4].

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[1] Richard Phillips Feynman (May 11, 1918 – February 15, 1988) was an American physicist known for his work in the path integral formulation of quantum mechanics, the theory of quantum electrodynamics and the physics of the super fluidity of super cooled liquid helium, as well as in particle physics. For his contributions to the development of quantum electrodynamics, Feynman, jointly with Julian Schwinger and Sin-Itiro Tomonaga, received the Nobel Prize in Physics in 1965.

[2] „Engines of Creation: The Coming Era of Nanotechnology” is considered and now the first book on the topic of nanotechnology.

[3] Clusters are finite aggregates of atoms or molecules that are bound by forces which may be metallic, covalent, ionic, hydrogen-bonded or Van der Waals in character and can contain from a few to tens of thousands of atoms. The oldest route for the preparation of clusters is by colloidal chemistry: back in 1856 Faraday famously investigated the optical properties of gold colloids. Typically, clusters produced by this method are stabilized by the addition of a passivating layer, as compared to the naked clusters produced in molecular beams. One of the main advantages of this method is that large quantities of clusters can be produced. Furthermore, significant advances have now been made in controlling the size, shape and structure of these particles In the last thirty-five years, cluster science has become a rapidly expanding field of interdisciplinary study as experimental and theoretical techniques have advanced and computational power has increased.

[4] In the field of the nanotechnology, there were several important modern developments. The atomic force microscope (AFM) and the Scanning Tunneling Microscope (STM) are two early versions of scanning probes that launched nanotechnology. There are other types of scanning probe microscopy, all flowing from the ideas of the scanning confocal microscope developed by Marvin Minsky in 1961 and the scanning acoustic microscope (SAM) developed by Calvin Quate and coworkers in the 1970s, that made it possible to see structures at the nanoscale. The tip of a scanning probe can also be

This development led to the discovery of fullerenes[1] in 1985 and carbon nanotubes[2] a few years later. In another development, the synthesis and properties of semiconductor nanocrystals was studied; this led to a fast increasing number of metal and metal oxide nanoparticles and quantum dots.

When the term „nanotechnology" was independently coined and popularized by Eric Drexler[3], it referred to a future manufacturing technology based on molecular machine systems. 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[4] means,

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used to manipulate nanostructures (a process called positional assembly). Feature-oriented scanning-positioning methodology suggested by Rostislav Lapshin appears to be a promising way to implement these nanomanipulations in automatic mode. However, this is still a slow process because of low scanning velocity of the microscope. Various techniques of nanolithography such as optical lithography, X-ray lithography dip pen nanolithography, electron beam lithography or nanoimprint lithography were also developed. Lithography is a top-down fabrication technique where a bulk material is reduced in size to nanoscale pattern.

[1] A fullerene is any molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid, or tube. Spherical fullerenes are also called Bucky balls, and cylindrical ones are called carbon nanotubes or Bucky tubes. Fullerenes are similar in structure to graphite, which is composed of stacked graphene sheets of linked hexagonal rings; but they may also contain pentagonal (or sometimes heptagonal) rings. The first fullerene to be discovered, and the family's namesake, was buckminsterfullerene C_{60}, made in 1985 by Robert Curl, Harold Kroto and Richard Smalley. The name was an homage to Richard Buckminster Fuller, whose geodesic domes it resembles. Fullerenes have since been found to occur (if rarely) in nature. The discovery of fullerenes greatly expanded the number of known carbon allotropes, which until recently were limited to graphite, diamond, and amorphous carbon such as soot and charcoal. Buckyballs and buckytubes have been the subject of intense research, both for their unique chemistry and for their technological applications, especially in materials science, electronics, and nanotechnology.

[2] CNTs can be viewed as log graphene sheets rolled into seamless cylinders, and a single walled carbon nanotube (SWNT) can be as long as several centimeters, while the diameter is only ½ nm. Graphene is a flat monolayer of carbon atoms tightly packed into a two-dimensional (2D) honeycomb lattice, and is a basic building block for graphitic materials of all other dimensionalities. It can be wrapped up into 0D fullerenes, rolled into 1D nanotubes or stacked into 3D graphite. Previously, graphene was also defined in the chemical literature as follows: A single carbon layer of the graphitic structure can be considered as the final member of the series naphthalene, anthracene, coronene, etc. and the term graphene should therefore be used to designate the individual carbon layers in graphite intercalation compounds. Use of the term "graphene layer" is also considered for the general terminology of carbons. Graphene is considered to be a very promising material for high frequency nanoelectric devices such as oscillators and switches and it can play an important role in new innovative high frequencies nanoelectronic devices.

[3] In the literature it’s said that Drexler didn’t know about earlier Norio Taniguchi’definition of nanotechnology.

[4] Biomimetic is developing biologically inspired technologies, and ranges from materials that work as an artificial eyelid to neural inspired computing models.

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[1] [3].

The International Conference on Nanoscience and Technology, China 2009 has been hold between September 1-3, 2009 in Beijing. This was the third conference following the successful ChinaNANO 2005 and ChinaNANO 2007 held also in Beijing. The conference China NANO 2009 has been focused on nano-information materials, nano-energy and environmental materials, nanodevices and sensors, Nan medicine, Nan pharmacy and biomedical engineering, nanofabrication and Nan metrology, characterization of nanostructures, nano-optics and plasmonics, as well as modeling and simulation of nanostructures [4].

Nanoscience and nanotechnology is a major thrust for research laboratories, which should offer solutions to many current problems by means of smaller, lighter, faster and better performing materials, components and systems. It's possible to plan to bring expertise in materials synthesis and characterization to bear on the opportunities in nanoscience and technology. By precisely manipulating atoms and molecules our research could yield safe, just-in-time sources of hydrogen for a wide range of energy applications, new instruments to observe chemical processes in living cells, and miniaturized sensors to detect pathogens in foods and the environment.

The usage of nanoscience and nanotechnology in engineering directly links academic research to industries and daily life. As a result, numerous nanomaterials, nanodevices and nanosystems for various engineering purposes have been developed and used for human betterment.

2. Nanoscience

In the XXIth century, the sciencetists have committed to move the science to the market place. So it's a necessity to be strengthened the engineering and technology capabilities. With nanoscience will be discovered new properties, will be created improved functionalities and pressed these gains forward to new devices and systems.

It has been realized that collaboration and teamwork are absolutely essential and the complexity of the technical challenges that the nanoscientists have faced required this. Furthermore it's necessary that nanoscientists, from all over the world, to seek to work together as partners on this exciting new researches domain.

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[1] The physics and engineering performance of exemplar designs were analyzed in Drexler's book „*Nanosystems*".

In the nanoscience [5] the main strategic research areas are:

- To achieve dramatic, innovative enhancements in the properties and performance of structures, materials, and devices those have controllable features on the nanometer scale (i.e., tens of angstroms).

- The ability to affordably fabricate structures at the nanometer scale will enable new approaches and processes for manufacturing novel, more reliable, lower cost, higher performance and more flexible electronic, magnetic, optical, and mechanical devices.

Other current fields of nanoscience research are the following [5]:

a. - Artificial antibodies made from plastic shown to work in living animals

A research team has developed methods for synthesizing protein-sized polymer particles with a binding affinity and selectivity comparable to those of natural antibodies by combining molecular imprinting nanoparticles synthesis with a functional monomer optimization strategy. In effect, they have created a plastic antibody, an artificial version of the real thing. They have also demonstrated that it works in the bloodstream of a living animal. As a result, we can now consider synthetic polymer nanoparticles, prepared by an abiotic process in the chemical laboratory, as alternatives to biological macromolecules.

b. - Fabrication of gold nanoparticles with chiral[1] surfaces

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[1] W.H. Thompson (Lord Kelvin) has given, in Baltimore Lectures (1884), for the chiral notion the next definition: „I call any geometrical figure, or any group of points chiral (χειρ, greek for hand), and say it has chirality, if its image in a plane mirror, ideally realized, cannot be brought to coincidence with itself". When used in the context of chemistry, chirality usually refers to molecules. Two mirror images of a molecule that cannot be superimposed onto each other are referred to as enantiomers or optical isomers. Because the difference between right and left hands is universally known and easy to observe, many pairs of enantiomers are designated as „right" and „left handed". A mixture of equal amounts of the two enantiomers is said to be a racemic mixture. Chiral molecules are mostly carbon containing compounds. If a carbon atom in tetrahedrical environment is bounded to four different atoms or groups, then the species will be chiral.

A method for generating stable nanostructured thin films and surfaces has been proposed. The chiral surfaces will be fabricated in a two-step process in which an achiral substrate is first modified by the adsorption of one enantiomer of a helical molecule. This will provide a chiral matrix for subsequent physical vapor deposition (PVD) of metals. It is expected that the helical molecules will serve as nucleation sites for the formation of screw dislocations. All steps of the fabrication are performed in ultrahigh vacuum (UHV) and monitored in-situ with scanning tunneling microscopy (STM). As the organic chiral matrix, a closed packed monolayer of heptahelicene, a aromatic hydrocarbon, on a nickel surface was generated. The investigation on the structure of this matrix as well as first results of its influence on the structures of subsequently deposited palladium and copper layers are reported.

Chiral surfaces are predicted to have outstanding nonlinear optical activity. Raman and Rayleigh scattering were calculated to be three orders of magnitudes larger than from bulk material [Hecht94].

Nanoparticle chirality has attracted much attention among nanoscientists, and the application of chiral nanoparticles in chemistry, biology and medicine is of great importance for the development of new molecular nanosystems. In chemistry, chirality usually refers to molecules. Discovering efficient methods to produce, control and identify enantiomerically[1] pure chiral compounds is critical for the further development of pharmaceuticals, agrochemicals, and food additives. An important example in the area of nanomaterials is the synthesis of metallic nanoparticles with controlled size, shape, composition, and morphology.

c. - Bucky paper improves fire retardancy of plastic materials

Flame retardant materials have become a major business for the chemical industry and can be found practically everywhere in modern society. Unfortunately, conventional methods for making plastic flame retardant involve a range of often very toxic chemicals. It has already been demonstrated that the flame retardancy of polymeric materials without the use of toxic chemicals could become possible thanks to the synergistic effect of nano clay and carbon nanotubes. In a step further, researchers have now shown that the use of Bucky paper is more efficient as a fire retardant in polymer composites in comparison to directly mixing carbon nanotubes.

d. - Titanium dioxide powers light-driven micro-and nanomotors

For nanotechnology researchers, movement at the nanoscale is a challenging problem and there is much to be learned from nature's motor systems. There are various approaches to creating self-propelled micro-and nanosized motors and one promising approach rests on catalytic conversion of chemical to mechanical energy - a process that is ubiquitous in biology, powering such important and diverse processes as cell division, skeletal muscle movement, protein synthesis, and transport of cargo within cells.

e. - Biorefinery concept shows a way out of a world dominated by petrochemicals

Developing chemicals, molecular precursors, and industrial products from petroleum resources is a conventional practice. Plastics, detergents, even pharmaceuticals are derived from petrochemicals. With an increasing focus on the economic and environmental issues associated with the processing of petroleum-

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Also a large circular difference response of second harmonic generation (or second harmonic optical activity, SHOA) was measured on chiral surfaces.

[1] Either of a pair of crystals, molecules, or compounds those are mirror images of each other but are not identical, or that rotate the plane of polarized light equally, but in opposite directions. Also called enantiomers, optical isomer. In chemistry, an **enantiomer** is one of two stereoisomer that are mirror images of each other that are "non-superposable" (not identical), much as one's left and right hands are "the same" but opposite. The term, pronounced /ɨˈnæntɪ.əmər/, is derived from the Greek 'ἐνάντιος', opposite, and 'μέρος', part or portion.

based chemicals, scientists are seeking for alternative routes to develop molecules from naturally available plant or crop-based raw materials. Particularly interesting for the fields of nanotechnology is the design and development of soft nanomaterials from renewable sources.

f. - Bottom-up fabrication of carbon nanosystems by trapping single metal atoms

Among the various production methods for carbon nanotubes and graphene, currently only chemical vapor deposition techniques demonstrate a significant opportunity for mass production of carbon nanotubes (CNTs) material. Using a process based on the catalytic action of metals, manufacturers can combine a metal catalyst such as iron with reaction gases such as hydrogen to form carbon nanotubes inside a high-temperature furnace. In order to optimize the synthesis process, a detailed understanding of the interaction between nanotubes or graphene and metal atoms is required - something that has been missing so far.

g. - Current research focus in nanodevices

Nanotechnology research focuses on the incorporation of low-dimensional nanostructured materials and devices, employing processes compatible with mass-manufacturing. Unlike the research-based approach of sequentially connecting electrodes to individual nano-structures for device physics studies, massively parallel and manufacturability interfacing techniques are crucial for reproducible fabrication and incorporation of dense, low-cost nanodevices arrays in highly integrated material systems. One research team has developed two novel nano-device integration and mass-production techniques termed „*nano-bridges*" and „*nano-colonnades*" that are entirely compatible with existing microelectronics fabrication processes. Major focus research group has been nanoepitaxy for homo and heterogeneous nanomaterials synthesis, characterization, device integration of nanomaterials and substrateless device fabrication for energy conversion.

h. - Metamaterials

In order to manipulate the propagation of light, a study is underway on a new class of materials, called „negative index metamaterials (NIM)" that demonstrate unusual electric and magnetic properties not found in nature and offer opportunities for unprecedented functionalities in virtually every area of classical optics and photonics. His group is involved in developing new methods and tools for constructing 3D NIM using manufacturability nanofabrication techniques and studying nano-structure integrated NIM based theoretical and experimental schemes. Besides device integration, the group is also actively involved in minimizing the losses that are inherent in NIM by exploring various thin film nucleation methods. The overall research activities in NIM are based on exploiting the synergy of nanoepitaxy for eventual monolithic realization of NIM enabled electronics and photonics.

i. - Solar energy devices

The work on photovoltaic devices addresses the solar-grade semiconductor scarcity (silicon and other materials) and the cost of manufacturing devices and panels. To this end, it has been fabricated devices in the shape of vertically oriented micro/nano-pillars to transfer them to low cost, flexible and amorphous surfaces using a mass-manufacturability polymer assisted shear-fracturing process at room temperature. This allows the improving the efficiency and lower the costs since the original epitaxial wafers can be repeatedly used for generating more devices. We believe that it is wasteful and environmentally detrimental to employ an expensive wafer solely for mechanically supporting a thin layer of devices. The initial work has already demonstrated the potential of the array transfer process based on the innovative shear fracture method. This was the first demonstration of such an approach that is not dependent on any specific substrate material. The light gathering function of our micro/nano-pillar shaped devices that resemble 'antennas' is also offers opportunities for higher efficiency.

j. - Fundamental forces in nanoscale devices

Quantum electro dynamical (QED) phenomena lead to Casimir force which can be observed when metallic, semiconductor or dielectric surfaces are placed in close proximity (<100 nm).

This opens doors to exciting opportunities, particularly in the field of nanodevices and nano mechanics, such as nanoscale levitation, stiction[1] prevention, and highly responsive sensors.

Nanotechnology is capable of fabricating devices with diminishingly small dimension and this force cannot be disregarded any more.

The mentioned research group has studied this and other fundamental physical forces in nanoscale devices for improving old and creating new technologies.

In our times, it's considered that the nanoscience has the following recognized applications [5]**:**

- Ultra small, highly parallel, computers with multi-teraflop speed;
- Image information processors, e.g., extraction and recognition;

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[1] **Stiction** is an informal portmanteau of the term "static friction" (μ_s), perhaps also influenced by the verb "stick". Two solid objects pressing against each other (but not sliding) will require some threshold of force parallel to the surface of contact in order to overcome static cohesion. Stiction is a *threshold,* not a continuous force. In situations where two surfaces with areas below the micrometer range come into close proximity (as in an accelerometer), they may adhere together. At this scale, electrostatic and/or Van der Waals and hydrogen bonding forces become significant. The phenomenon of two such surfaces being adhered together in this manner is called stiction. Stiction may be related to hydrogen bonding or residual contamination.

- Low-power personal and autonomous communication and computation devices;
- high-density information storage devices, e.g., terabit/cm2 nonvolatile memory;
- Lasers and detectors for weapons and countermeasures;
- Optical (infrared, visible, ultraviolet) sensors for improved surveillance an targeting;
- Integrated sensor suites for chemical and biological agent detection;
- Catalysts for enhancing and controlling energetic reactions;
- Synthesis of new compounds (e.g., narrow-bandgap materials);
- Designer materials with combinations of properties that do not currently exist.

3. Nanotechnology

Nanotechnology exists for creating nanometer-sized devices and structures; many fabricated by the same capabilities that supply the silicon integrated circuit industry. For example, it is possible to create single atom thick tubes of carbon (carbon nanotubes) that have many fascinating structural and electrical properties. It is also possible to engineer nanometer-sized machines that can interact with individual cells. As of yet, the application of many of these structures has yet to be explored.

All the nano-scientists are eager to make revolutionary strides in putting nanotechnology to work for the benefit of humanity. Nanotechnology has been a hot topic in recent years and is expected to be the engine for the future advancement in the fields of electronics, renewable energy, biomedical science, and materials among others [6].

Nanotechnology is any technology that contains components smaller than 100 nanometers[1], and involves developing materials or devices within that size. For scale, a single virus particle is about 100 nanometers in width. Nanotechnology has an important role in the combination of the top-down and bottom-up

[1] One nanometer is one billionth of a meter, and materials at this length scale exhibit distinctively different properties from their bul counterparts. 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. 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 [7].

approaches. The top-down approach anticipates nanodevices that must be built piece by piece in stages, much as manufactured items are made.

Scanning probe microscopy is an important technique both for characterization and synthesis of nanomaterials. Atomic force microscopes and scanning tunneling 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. By using, for example, feature-oriented scanning-positioning approach, atoms can be moved around on a surface with scanning probe microscopy techniques. At present, it is expensive and time-consuming for mass production but very suitable for laboratory experimentation. In contrast, bottom-up techniques build or grow larger structures atom by atom or molecule by molecule. These techniques include chemical synthesis, self-assembly and positional assembly. Dual polarization interferometry is one tool suitable for characterization of self assembled thin films. Another variation of the bottom-up approach is molecular beam epitaxial (MBE). MBE allows scientists to lay down atomically precise layers of atoms and, in the process, build up complex structures[1]. Important for research on semiconductors, MBE is also widely used to make samples and devices for the newly emerging field of spintronics[2] [8].

One of the most essential techniques for enabling research in the nano world is utilizing a tool to handle nano-objects or modifying objects at nanoscale, and an important subfield of nanotechnology related to energy is nanofabrication. Nanofabrication is the process of designing and creating devices on the nanoscale. Creating devices smaller than 100 nanometers opens many doors for the development of new ways to capture, store, and transfer energy. The inherent level of control that nanofabrication could give scientists and engineers would be critical in providing the capability of solving many of the problems that the world is facing today related to the current generation of energy technologies.

Nanotechnology is broadly defined as the creation and applications of nanometer-scale materials, and it has enabled the production. Also, most scientist and engineers are already aware, nanotechnology is a highly multidisciplinary domain that incorporates knowledge from areas such as applied physics, material science, interface and colloid science, device physics, supramolecular chemistry, biochemistry and specifically from engineering disciplines such as nano-robotics

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[1] Samples made by MBE were key to the discovery of the fractional quantum Hall effect for which the 1998 Nobel Prize in Physics was awarded for Robert B. Laughlin,Horst L. Störmer and Daniel C. Tsui

[2] Spintronics (a neologism meaning "spin transport electronics"), also known as magneto electronics, is an emerging technology that exploits the intrinsic spin of the electron and its associated magnetic moment, in addition to its fundamental electronic charge, in solid-state devices.

and micro electromechanical systems or integrated circuit. As a result, following developments in the nanoscience and nanotechnology space requires not only a substantive global view; the researcher should have broad and deep knowledge of the science domains and of the industrial sectors that will be affected by the rise of nanoscience and nanotechnology. Nanotechnology by its nature is interdisciplinary, and chemists, physicists, biologists, and engineers all have roles to play in the development and implementation of Nanotechnology. The first of these is nanostructured materials, which includes both new composite materials as well as electronic and optical materials.

Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly[1], from developing new materials with dimensions on the nanoscale to investigating whether we can directly control matter on the atomic scale.

Another group of nanotechnological techniques include those used for fabrication of nanowires, those used in semiconductor fabrication such as deep ultraviolet lithography, electron beam lithography, focused ion beam machining, nanoimprint lithography, atomic layer deposition, and molecular vapor deposition, and further including molecular self-assembly techniques such as those employing bi-block copolymers. However, all of these techniques preceded the nanotech era, and are extensions in the development of scientific advancements rather than techniques which were devised with the sole purpose of creating nanotechnology and which were results of nanotechnology research.

However, new therapeutic products, based on responsive nanomaterials, such as the ultra deformable, stress-sensitive transfer some vesicles, are under development and already approved for human use in some countries [9].

The concept of nanomaterials appeared in the last decades, after the investigation techniques were able to detect the low dimension of these kinds of materials. The ability to control the particle size and the morphology of the nanomaterials is of crucial importance nowadays both from the fundamental and industrial point of view [10]. The domain of nanomaterials includes following subfields which develop or study materials having unique properties arising from their nanoscale dimensions:

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[1] Self-assembly is the fundamental principle which generates structural organization on all scales from molecules to galaxies. It is defined as reversible processes in which pre-existing parts or disordered components of a preexisting system form structures of patterns. Self-assembly can be classified as either static or dynamic. Static self-assembly is when the ordered state occurs when the system is in equilibrium and does not dissipate energy. Dynamic self-assembly is when the ordered state requires dissipation of energy. Examples of self-assembling system include weather patterns, solar systems, histogenesis and self-assembled monolayers. The most well-studied subfield of self-assembly is molecular self-assembly, but in recent years it has been demonstrated that self-assembly is possible with micro and milimeterscale structures lying in the interface between two liquids.

- 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.

- Progress has been made in using these materials for medical applications; see Nanomedicine.

- 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; see quantum dots.

Among the various nanomaterials, carbon nanotubes (CNTs) stand out due to their remarkable electrical, mechanical, optical, and chemical properties. Since their discovery by Sumio Iijima at NEC Corporation in Japan in 1991, CNTs have stimulated enormous interest for both fundamental research and future applications. CNTs are created by vaporizing carbon and allowing it to condense on a surface. When the carbon condenses, it forms a nanosized tube composed of carbon atoms. This tube has a high surface area, which increases the amount of charge that can be stored. The low reliability and high cost of using carbon nanotubes for ultra capacitors is currently an issue of research.

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. In general it is very difficult to assemble devices on the atomic scale, as all one has to position atoms on other atoms of comparable size and stickiness. Another view, put forth by Carlo Montemagno [11] is that future nanosystems will be hybrids of silicon technology and biological molecular machines. Yet another view, put forward by the Richard Smalley[1] [12], is that

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[1] **Richard Errett Smalley** (June 6, 1943 – October 28, 2005) was the Gene and Norman Heckerman Professor of Chemistry and a Professor of Physics and Astronomy at Rice University, in Houston, Texas. He was awarded the Nobel Prize in Chemistry in 1996 for the discovery of a new form of carbon, buckminsterfullerene („Bucky balls") (with Robert Curl, also a professor of chemistry at Rice, and Harold Kroto, a professor at the University of Sussex).
Smalley's research in physical chemistry investigated formation of inorganic and semiconductor clusters using pulsed molecular beams and time of flight mass spectrometry. As a consequence of

mechanosynthesis is impossible due to the difficulties in mechanically manipulating individual molecules[13]. 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 have constructed at least three distinct molecular devices whose motion is controlled from the desktop with changing voltage: a nanotubes nano motor, a molecular actuator and a nano electromechanical relaxation oscillator [14].

An experiment indicating that positional molecular assembly is possible was performed by Ho and Lee at Cornell University in 1999, using 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.

Micro and nanotechnology based systems are increasing in complexity both as stand alone components and highly interconnected/integrated systems. In essence, micro/nano systems technology is advancing towards the realization of, multi-functional, intelligent devices such as the lab-on-a-chip for diagnostics or miniaturized inertial measurement units for aerospace/automotive applications [15]. Nanotechnology, and engineering spearhead the 21st century revolution that is leading to fundamental breakthroughs in the way materials, devices, and systems are understood, designed, made, and used.

With contributions from a host of world-class experts and pioneers in the field, in the international literature there's set forth the fundamentals of micro electromechanical (MEMS) and nano electromechanical systems (NEMS), studies their fabrication, and explores some of their most promising applications. It provides comprehensive information and references for nanoscale structures, devices, and systems, molecular technology and nano electromechanical theory, and promises to become a standard reference for the field.

There are several reasons for developing micro electromechanical systems (MEMS) and nano electromechanical systems (NEMS) as an extension of microelectronics technology that incorporates mechanical, optical, fluidic,

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this expertise, Robert Curl introduced him to Harry Kroto in order to investigate a question about the constituents of astronomical dust. These are carbon rich grains expelled by old stars such as R Corona Borealis. The result of this collaboration was the discovery of C_{60} and the fullerenes as the third allotropic form of carbon. The research that earned Kroto, Smalley and Curl the Nobel Prize mostly comprised three articles. First was the discovery of C_{60} in the Nov. 14, 1985, issue of Nature "C_{60}: Buckminsterfullerene." The second article detailed the discovery of the endohedral fullerenes in "Lanthanum Complexes of Spheroidal Carbon Shells" in the Journal of the American Chemical Society v. 107 p 7779 (1985). The third announced the discovery of the fullerenes in "Reactivity of Large Carbon Clusters: Spheroidal Carbon Shells and Their Possible Relevance to the Formation and Morphology of Soot" in the Journal of Physical Chemistry v. 90 p 525 (1986).

acoustical, and biological systems using semiconductor-processing technology. Systems with very small dimensions have advantages in handling small parts, advantage that include speed, accuracy and gentleness.

With the recent advances in semiconductor technology and micromachining techniques the number of application fields for MEMS has been growing, extending from well-known electromechanical systems such as integrated accelerometers and pressure sensors to the so-called mio-MEMS [16]. Despite the large amount of new technologies at disposal, there are currently only few micro system products on the markets. MEMS and NEMS technology have been used in the creation of micro-scale sensors and actuators. Typical applications are ink-jet printer heads, accelerometers, and micro fluidic pumps. However, among the many possible applications, one should identify the most promising ones in terms of existing or future markets.

To understand the potential of MEMS, one must look to the global context. The two main direction of the present technical society are information technology and micro-miniaturization (Table 1) [17].

Table 1

Information era	**Micro-miniaturization**
▪ Information processing systems ▪ Physical systems monitoring and control ▪ Sensor clusters, data fusion systems, smart sensors	▪ Distributed information processing ▪ High speed, low power, low cost ▪ Arrays of programmable sensors and actuators

The actuators that are used in the macro world often depend upon magnetic forces that scale poorly into the micro and nano domains. Fortunately, scaling theory demonstrated that electrostatics, pneumatics, surface tension and biological forces are all strong enough to be useful in the micro and nano domains.

The nano-bio interface focuses on developing nanotechnologies that are interactive with the biological world for sensing, gene identification, or drug delivery applications. Bionanotechnology is the intersection of biology and nanotechnology, being a broad and somewhat vague term which is sometimes used interchangeably with nanobiotechnology, which usually refers more specifically to the use of nanotechnological devices for applications in biotechnology. The scientists have combined the knowledge in chemistry, physics and biology with the synthesis and manufacturing of nanoinstruments from the chemical engineering and even from microchip industry. They have created tools and materials at a scale of a thousand millionth of a meter, that were not bigger than biomolecules as the DNA, and so, the immune response of the living organism has been abolished.

The integration of nanoparticles and biological molecules, in order to develop new materials for electronics and optics and new applications in biomedical and bioanalytical areas such as controlled drug delivery, medical diagnosis and biosensors is a challenge for scientific and industrial research.

Bionanotechnology may also refer to the use of biomolecules for applications in nanotechnology. A major example of this is DNA nanotechnology, which uses self-assembling nucleic acid structures to control matter at the nanoscale [18].

In a wider sense, bionanotechnology refers to synthetic technology based on the principles and chemical pathways of living organisms. It encompasses the study, creation, and illumination of the connections between structural molecular biology and nanotechnology, since the development of nanomachinery might be guided by studying the structure and function of the natural nano-machines found in living cells.

The science heavily relies on the characterization of biological material on surfaces using e.g. dual polarization interferometry, AFM, QCMD, Surface Plasmon Resonance. Recent advances in nanobiomaterials and information technology are combining to enable the development of the devices and systems with potential effects on individual and public health and safety, as well as on the economic, business and public health and safety, as well as on the economic, business and commerce zone. In the literature, the integration of nanostructures into the micro and macro words is appreciated to be the key to the development and exploitation of the most nanotechnology products [19].

People in the fields of science and engineering have already begun developing ways of utilizing nanotechnology for the development of consumer products. Over the past few decades, the fields of science and engineering have been seeking to develop new and improved types of energy technologies that have the capability of improving life all over the world.

In order to make the next leap forward from the current generation of technology, scientists and engineers have been developing energy applications of nanotechnology. Benefits already observed from the design of these products are an increased efficiency of lighting and heating, increased electrical storage capacity, and a decrease in the amount of pollution from the use of energy.

Benefits such as these make the investment of capital in the research and development of nanotechnology a top priority [16].

4. The necessity of the regulations and standardization of the nanotechnology

The development of the nanoscience and nanotechnology supposes the development of new tools to achieve new breakthroughs. The created new technologies will generate many new jobs and displace many existing workers that will not be trained to work in the new technological domains. There are people who have described nanoscience and nanotechnology as a potential ecological disaster, if would not be elaborated regulations, standards, or controls in place to protect the natural environment.

As in each new domain, nanoscience and nanotechnology needs new standards in order to achieve a high degree of interoperability, create order in the marketplace, simplify production requirements, manage the potential for adverse environmental impacts, and above all, ensure the safety and health of those of us who will be developing and using the next generation of materials and devices.

One area of concern is the effect that industrial-scale manufacturing and use of nanomaterials would have on human health and the environment, as suggested by nanotoxicology[1] research [20]. Groups such as the U.S.A. Center for Responsible Nanotechnology have advocated that nanotechnology should be specially regulated by governments for these reasons. Others counter that overregulation would stifle scientific research and the development of innovations which could greatly benefit mankind.

Calls for tighter regulation of nanotechnology have occurred alongside a growing debate related to the human health and safety risks associated with nanotechnology. Furthermore, there is significant debate about who is responsible for the regulation of nanotechnology. While some non-nanotechnology specific regulatory agencies currently cover some products and processes (to varying degrees) – by bolting on nanotechnology to existing regulations – there are clear gaps in these regimes [21].

The extremely small size of nanomaterials also means that they much more readily gain entry into the human body than larger sized particles. How these nanoparticles behave inside the body is still a major question that needs to be resolved. The behavior of nanoparticles is a function of their size, shape and surface reactivity with the surrounding tissue. In principle, a large number of particles could overload the body's phagocytes, cells that ingest and destroy foreign matter, thereby triggering stress reactions that lead to inflammation and weaken the body’s defense against other pathogens. In addition to questions about what happens if non-degradable or slowly degradable nanoparticles accumulate in bodily organs, another concern is their potential interaction or interference with

[1] **Nanotoxicology** is the study of the toxicity of nanomaterials. Because of quantum size effects and large surface area, nanomaterials have unique properties compared with their larger counterparts. Nanotoxicology is a branch of bionanoscience which deals with the study and application of toxicity of nanomaterials. Nanomaterials, even when made of inert elements like gold, become highly active at nanometer dimensions. Nanotoxicological studies are intended to determine whether and to what extent these properties may pose a threat to the environment and to human beings. For instance, Diesel nanoparticles have been found to damage the cardiovascular system in a mouse model.

biological processes inside the body. Because of their large surface area, nanoparticles will, on exposure to tissue and fluids, immediately adsorb onto their surface some of the macromolecules they encounter. This may, for instance, affect the regulatory mechanisms of enzymes and other proteins. The Royal Society identifies the potential for nanoparticles to penetrate the skin, and recommends that the use of nanoparticles in cosmetics be conditional upon a favorable assessment by the relevant European Commission safety advisory committee.

Carbon nanotubes – characterized by their microscopic size and incredible tensile strength – are frequently likened to asbestos, due to their needle-like fiber shape. In a recent study that introduced carbon nanotubes into the abdominal cavity of mice, results demonstrated that long thin carbon nanotubes showed the same effects as long thin asbestos fibers, raising concerns that exposure to carbon nanotubes may lead to mesothelioma[1] [22]. Given these risks, effective and rigorous regulation has been called for to determine if, and under what circumstances, carbon nanotubes are manufactured, as well as ensuring their safe handling and disposal. The Royal Society report [23] 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 Food and Agricultural Standards has proposed standards for nanotechnology research and development should be integrated across consumer, worker and environmental standards.

Because of the far-ranging claims that have been made about potential applications of nanotechnology, a number of serious concerns have been raised about what effects these will have on our society if realized, and what action if any is appropriate to mitigate these risks. There are possible dangers that arise with the development of nanotechnology.

The Center for Responsible Nanotechnology suggests that new developments could result, among other things; in untraceable weapons of mass destruction, networked cameras for use by the government, and weapons developments fast enough to destabilize arms races.

In October 2008, the Department of Toxic Substances Control (DTSC), within the California Environmental Protection Agency, announced its intent to request information regarding analytical test methods, fate and transport in the environment, and other relevant information from manufacturers of carbon nanotubes [24]. The purpose of this information request will be to identify

[1] Cancer of the lining of the lungs caused by exposure to asbestos.

information gaps and to develop information about carbon nanotubes, an important emerging nanomaterial.

One area of concern is the effect that industrial-scale manufacturing and use of nanomaterials would have on human health and the environment, as suggested by nanotoxicology research.

A study at the University of Rochester found that when rats breathed in nanoparticles, the particles settled in the brain and lungs, which led to significant increases in biomarkers for inflammation and stress response [25]. http://en.wikipedia.org/wiki/Nanotechnology - cite_note-34#cite_note-34. A study in China indicated that nanoparticles induce skin aging through oxidative stress in hairless mice [26].

„All sorts of nanomaterials need to be handled very carefully" [27]. In the absence of specific nano-regulation forthcoming from governments, Paul and Lyons (2008) have called for an exclusion of engineered nanoparticles from organic food [28]. A newspaper article reports that workers in a paint factory developed serious lung disease and nanoparticles were found in their lungs [29].

5. Conclusion

Over the past 10–15 years, nanotechnology has advanced beyond the stage of an infant scientific field to now provide a tool kit that is poised to help us to solve a number of pressing problems.

A common hallmark that sets these various nanomaterials apart from more traditional bulk or molecular materials are the experimental handles, or the nanotechnology variables, that give scientists and engineers a whole new design space for optimization of properties.

But, we are obliged to recommend that all sorts of nanomaterials should be used very, very carefully.

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