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Nanorevolution

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Abstract

Nanotechnology is now a science and technology priority area for many countries with governments making efforts to put the results of nanotechnology development to commercialization. Nanotechnology aims to change the existing technology systems and bring about an industrial revolution: "*the nanorevolution*". This article of scientific divulgation gives some general aspects of the nanotechnology and in the final part; it illustrates the exponential scientific production of reports in several journals in the world in the last years as a result of "*fashion of Nano*".

Keywords: Nanorevolution, nanoscience, nano, nanotechnology and Nano-fashion.

Resumen

La nanotecnología es hoy una ciencia y tecnología prioritaria para muchos países con gobiernos haciendo esfuerzos para usar los resultados del desarrollo de la nanotecnología para la comercialización. Nanotecnología tiene como objetivo cambiar la tecnología actual de los sistemas y lograr una revolución industrial: "la nanorevolución". Esta artículo de divulgación científica da algunos aspectos generales de la nanotecnología y en la parte final, ilustra la producción científica exponencial de los artículos de varias revistas en el mundo en los últimos años como un resultado de la "Nano-moda".

Palabras clave: Nanorevolución, nanociencia, nano, nanotecnología y nano-moda.

Nanotechnology

For several years the sciences have developed new scientific research lines. This is the case of Nanotechnology; this word is used extensively to define sciences and techniques that are applied at the nanoscale. These scales allowing work and manipulate molecular structures and their atoms. Therefore, nanotechnology will allow for making the materials and machines from the reordering of atoms and molecules.
The development of this discipline takes place from the proposals made by Richard Feynman[†]. Visionary physicist, in his prescient 1959 Caltech speech "There's Plenty of Room at the Bottom", issued a public challenge: "I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously. . . The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big". Therefore, when matter on the so very small scale is manipulated, a totally new sample is obtained with new exceptional properties [1-3].

Based on Feynman's vision, some researchers in the world has realized the application of this idea until K. Eric Drexler popularized the word "*nanotechnology*" in the 1980's. He was talking about building machines on the scale of molecules, a few nanometers wide—motors, robot arms, and even whole computers, far smaller than a cell [4, 5]. Drexler spent the next ten years describing and analyzing these incredible devices, and responding to accusations of science fiction. Meanwhile, ordinary technology was developing the ability to build simple structures on a molecular scale. As nanotechnology became an accepted concept, the meaning of the word shifted to encompass the simpler kinds of nanometer-scale technology [5].

Nanotechnology is often referred to as a general-purpose technology. That is because in its advanced form it will have significant impact on almost all industries and all areas of society. It offers better built, longer lasting, cleaner, safer, and smarter products for the home, for communications, for medicine, for transportation, for agriculture, and for industry in general. For this reason, as reported by Joachim [6]: "*The "fashion of the Nano" is taking much interest and attention from the scientific world; due to a fear of missing-the nano-revolution".* Thus, this fashion has been absorbed by a great part of the scientific and technology community to participate with their contributions.

Scientists use nanotechnology to create novel and inexpensive materials, apparatus and systems with unique properties. Numerous advances for many industries and new materials with extraordinary properties have been developed in several fields. Based on progress in the nanosciences, these advances will change the world in the next years.

[†] Richard Phillips Feynman (May 11, 1918 – February 15, 1988) was an American physicist known for expanding the theory of quantum electrodynamics, the physics of the superfluidity of supercooled liquid helium, and particle theory. For his work on quantum electrodynamics, Feynman was a joint recipient of the Nobel Prize in Physics in 1965, together with Julian Schwinger and Shin-Ichiro Tomonaga; he developed a way to understand the behaviour of subatomic particles using pictorial tools that later became known as Feynman diagrams.

Fundamental concepts

One nanometer (nm) is one billionth, or 10^{-9} of a meter. For comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 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 [7].

Larger to smaller: a materials perspective

A unique aspect of nanotechnology is the vastly increased ratio of surface area to volume present in many nanoscale materials which opens new possibilities in surface-based science, such as catalysis. A number of physical phenomena become noticeably pronounced as the size of the system decreases. These include statistical mechanical effects, as well as quantum mechanical effects, for example the "quantum size effect" where the electronic properties of solids are altered with great reductions in particle size. This effect does not come into play by going from macro to micro dimensions. However, it becomes dominant when the nanometer size range is reached. Additionally, a number of physical properties change when compared to macroscopic systems. One example is the increase in surface area to volume of materials. This catalytic activity also opens potential risks in their interaction with biomaterials.

Materials reduced to the nanoscale can suddenly show very different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances become transparent (copper); inert materials become catalysts (platinum); stable materials turn combustible (aluminum); solids turn into liquids at room temperature (gold); insulators become conductors (silicon). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales. Much of the fascination with nanotechnology stems from these unique quantum and surface phenomena that matter exhibits at the nanoscale [7].

Simple to complex: a molecular perspective

Modern synthetic chemistry has reached the point where it is possible to prepare small molecules to almost any structure. These methods are used today to produce a wide variety of useful chemicals such as pharmaceuticals or commercial polymers. 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 conformation or arrangement is favoured due to non-covalent intermolecular forces. 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, broadly speaking, be able to produce devices in parallel and much cheaper than top-down methods, but could potentially be overwhelmed as the size and complexity of the desired assembly increases. The challenge for nanotechnology is whether these principles can be used to engineer novel constructs in addition to natural ones [7].

Current research

The applications of the nanotechnology can be very different and with diverse degrees of complexity that the specialists prefer to speak of nanotechnologies, in plural form, more accurately to appreciate such diversity. For example, the nanomaterials are used in drugs and novel therapeutic treatments; in some cosmetics and products of cleaning; in the improvement of the efficiency of photovoltaic cells; in the textile production with properties antispots or antiwrinkles (nanofibras); in the design of materials *ad hoc* to be used in the aeronautics industry and, practically in all the one of the transport, as well as in the development of armament of last generation.
For this reason, the *nanotechnology* is a very broad term, with many fields and subfields which create the *nano-world* [7].

Nanomaterials

This includes subfields which develop or study materials having unique properties arising from their nanoscale dimensions. Colloid science has given rise to many materials which may be useful in nanotechnology, such as carbon nanotubes and other fullerenes, and various nanoparticles and nanorods. Nanoscale materials can also be used for bulk applications; most present commercial applications of nanotechnology are of this flavour. Headway has been made in using these materials for medical applications [7].

Bottom-up approaches

DNA Nanotechnology utilizes the specificity of Watson-Crick basepairing to construct well-defined structures out of DNA and other nucleic acids.
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 [7].

Top-down approaches

Many technologies descended from conventional solid-state silicon methods for fabricating microprocessors are now capable of creating features smaller than 100 nm, falling under the definition of nanotechnology. Giant magneto-resistance-based hard drives already on the market fit this description,[8] as do atomic layer deposition (ALD) techniques.

Solid-state techniques can also be used to create devices known as nanoelectromechanical systems or NEMS, which are related to microelectromechanical systems or MEMS.
Atomic force microscope tips can be used as a nanoscale "write head" to deposit a chemical on a surface in a desired pattern in a process called dip pen nanolithography. This fits into the larger subfield of nanolithography [7].

Functional approaches

Molecular electronics seeks to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nanoelectronic device. Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nanocar [7].

Speculative

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 is beyond current capabilities. Nanorobotics centers on self-sufficient machines of some functionality operating at the nanoscale. There are hopes for applying nanorobots in medicine, while it might not be easy to do such a thing because of several drawbacks of such devices [8-12].
Programmable matter based on artificial atoms seeks to design materials whose properties can be easily and reversibly externally controlled. 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 [13].

Exponential production of Nanotechnology

The development of new investigation areas or technological applications where is included the *nano* concept, have been rapidly expanded. Thus, we can find research fields in: Nanomaterials, nanostructures, nanofibers, nanophysics, nanopolymers, nanolaws, nanoneurosciences, nanooptic, nanorobots, nanoimprint, nanochips, nanoconnections, nanocommunications, nanobiotechnology, nanochemistry, nanoelectronics, nanofuel cells, nanosystems, nanocars, nanosynthesis, nanostructures, nanocomputers, nanotransports, nanosoldiers, nanomedicine, nanoeconomy, nanosensors, nanoconstructions, nanokinetics, etc. With these new branches, nanotechnology will allow for making many high-quality products at very low cost. It represents a rapid, cheap and clean science, but the means of production will be able to reproduce exponentially. It is a revolutionary, transformative, powerful, and potentially very dangerous/beneficial technology. For this reason, we have displayed three graphics where we have illustrated a general panorama of the growth of these concepts in the last 13 years. These figures clearly show the scientific articles published from 1994 to 2008. Data were collected using the Data Base elaborated and registered by the American Chemical Society, known by SciFinder 2006®. As it can be seen in Figure 1, the most used concept is *Nanotechnology*, contrary to *Nanoscience*. Whereas the word "*Nano*" has been extensively used during these years.

Based on these results, the exponential expansion of these three concepts indicates the quick growth of these applications in daily and scientific life. Nanotechnology advances continuously change society and knowledge; with a great repercussion in business, employment and social instrumentation.

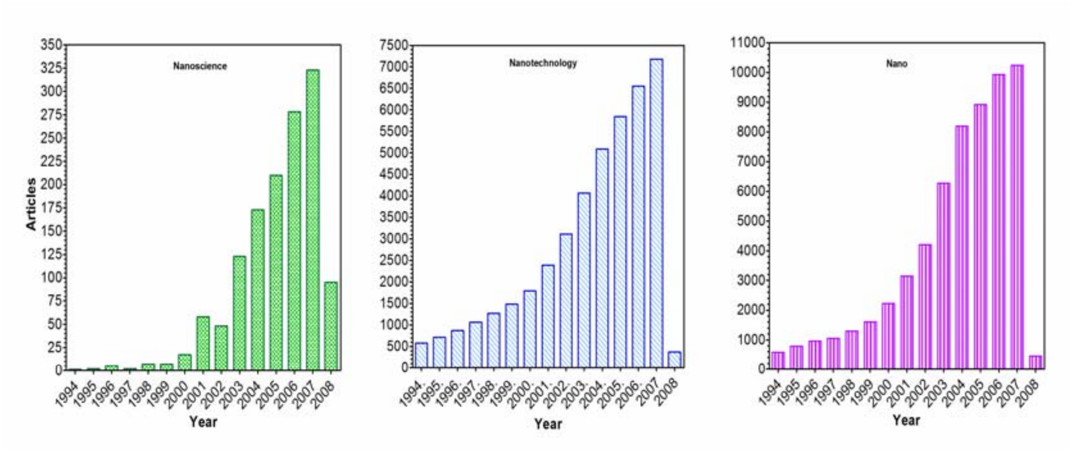

Figure 1. Exponential scientific production about nanoscale. Data Base of the American Chemical Society, known by SciFinder 2006®.

The discovery of atom manipulation opens the access to another observable and exploitable world well below the materials science and molecular biology scale. Exploration of this new world is also likely to generate its own ethical problems in the next years from now, which we have to anticipate. This new frontier confirms the infinite character of scientific exploration.

Most important scientific journals

Based on the results obtained by SciFinder 2006® Data Base, the most important scientific journals or magazines in the world, where the industry, governments or scientific community are currently published the new advances in these areas are reported in Table 1. In these scientific journals/magazines are made public the most important results about the nanotechnology and nanosciences. At the same time, several scientific reports contain with the Nano concept were reported. It is important to remarks that these journals are classified into the Chemistry applications; however, the nanorevolution are ultimately acquired new positions and applications in areas like Biology, Neurosciences, Engineering, Physics and so on.

Pos.	**Nanotechnology**	**Nanosciences**
1	Journal Nanoscience and Nanotechnology	Journal American Chemical Society
2	Nanoletters	Journal Nanoscience and Nanotechnology
3	Nature Materials	Physical Review Letters
4	Small	Advanced Materials
5	Journal American Chemical Society	Chimia
6	Analytical Chemistry	Journal of Physical Chemistry B
7	Biomaterials	Nanotechnology
8	Science	Small
9	Nature	Journal of Materials Chemistry
10	Angewandte Chemie	Physical Chemistry Chemical Physics

Table 1. Most relevant journals in the nanotechnology sciences.

Perspectives

We know that the use and production of nanomaterials will expand significantly over the coming years, with implications for human health, the environment and broader trade relations. However it is hard to know how many of the hypothetical higher-tech applications of nanotechnology will actually come to fruition, and when. Some of the current applications of nanotechnology are described briefly below, according to reported by Friends of the Earth organization [14].

Present day: Applications based primarily on the use of passive and active nanomaterials for their novel properties. This draws on well-established branches of applied science including materials science. Key applications are in coatings, pigments, electronics and photonics and biotechnology.

Medium-term (2015): Half of all newly designed advanced materials and manufacturing processes may be built using control at the nanoscale, with increased used of nanoscale devices. Creation of three-dimensional nanosystems and the development of precise molecular assembly. Healthcare and life sciences applications become significant as nanoenabled pharmaceuticals and medical devices emerge from lengthy human trials. Technology convergence enables vastly superior treatment of disease (including an effective treatment for cancer) and life extension, including via the production of synthetic organs. 'Smart' foods interact with consumers to 'personalize' food, changing color, flavor or nutrients on demand or in response to an individual's allergies or nutrient needs.

Longer term (2015-2050): Development of molecular assembly-based nanofactories capable of decentralized, atomically-precise manufacture of everything from bicycles to supercomputers to weapons. Atomic-level genetic control of crops, plants and animals; use of ubiquitous nano surveillance and monitoring systems on farms increases productivity and reduces labor needs. Fast, broadband interfaces directly between the human brain and machines that transform work in factories, control automobiles, ensure military superiority to its early developers, and enable new sports, art forms and modes of interaction between people. "Instead of harvesting grain and cattle for carbohydrates and protein, nanobots could assemble the desired steak or flour from carbon, hydrogen and oxygen atoms present in the air as water and carbon dioxide".

Conclusions

From an optimistic perspective that the development of the nanotechnology in the international scope stimulates, and before the high degree of complexity and uncertainty that characterizes nano-world, it is more and more necessary the study, the evaluation and the public debate on its social, ethical, environmental and legal implications. On each continent, governmental organizations keep a share of their science and technology budget for nano-applications and do not miss at the *fashion of nano*.

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