Elements of introduction: nanoscience and nanotechnology

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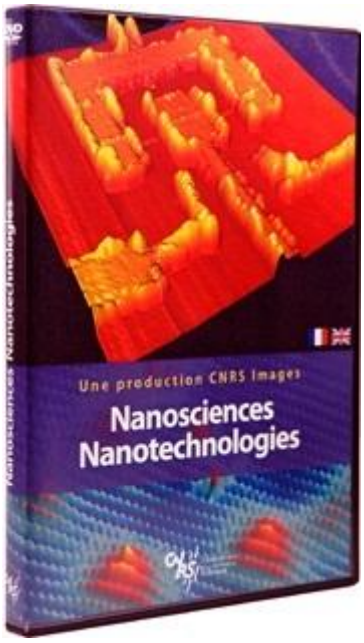
Aims

- Understand the various definitions of nanoscience and nanotechnologies
- Identify the scientific, technological, industrial, social, ethical and political stakes of nanoscience and nanotechnologies

Introduction

The module explores the emergence and development of the field of **nanoscience and nanotechnology** and provides several ways to define it according to different issues, interests and stakeholders. The module also explores the controversies raised in society by nanoscience and nanotechnology.

What is nanoscience and nanotechnology ?



According to the French National Center for Scientific Research (CNRS),

"A new world is being formed. Populated by objects with strange behaviors, this world is the one of nanometers, the size of atoms and molecules."

(http://www.cnrs.fr/cnrs-images/nano/index.html)

The term nanotechnology was used for the first time in 1974 by the Japanese physicist, professor at the University of Sciences in Tokyo, **Norio Taniguchi** to describe the processes of design, manufacture and use of structures at the nanometer scale.

Thus nanoscience and nanotechnology are both:

_ A field defined by its **scale** (an order of magnitude from approximately 1 to 100 nanometers).

_ A multidisciplinary field of research directed towards a **technological purpose**.

_ A new horizon of **research policies**: label and NBIC convergence.

_ A technology that early became a **societal issue**.

But it is important to understand that:
"The definition, meaning and scope of the term "nanotechnology" are still debated. Definitions compete in the public sphere. Definitions of nanotechnology vary within different groups and interests in terms of what they hope to get." (Fourniau, 2011).

A. Definition by size

- This definition is the simplest and also the most widespread. It can cover a wide range of activities or products under the label "nano". Nanotechnology can be presented as a set of research at the nanometer scale (10^{-9}m, or one billionth of a meter).

- In other words, it is the knowledge and techniques, through which we create, manipulate, visualize and use objects (materials or equipment) that are in the nanometer range.

Definition of the European Union

It should be noted that the definition of the term "nanomaterial" in the legislation of the European Union is **based solely on the size of the constituent particles of the material**, to the exclusion of any consideration of the risks or dangers that they may present. This definition, based solely on the size of the material covers natural materials formed accidentally or manufactured.

(Recommandation n° 2011/696/UE du 18/10/11 related to the definition of nanomaterials, **JOUE n° L 275 of 2011 October 20**

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:275:0038:0040:FR:PDF)

In addition

The baseline report of the Joint Research Centre of the European Commission, established in June 2010 and entitled «**Considerations on a Definition of Nanomaterials for Regulatory purposes**» [EUR 24403 EN], suggests that the definition of nanomaterials to cover particulate nanomaterials be generally applicable under the laws of the Union and join the line of other approaches adopted in the field worldwide. The size should be the sole constitutive feature of the definition. This requires to clearly establish the boundaries of the nanoscale.

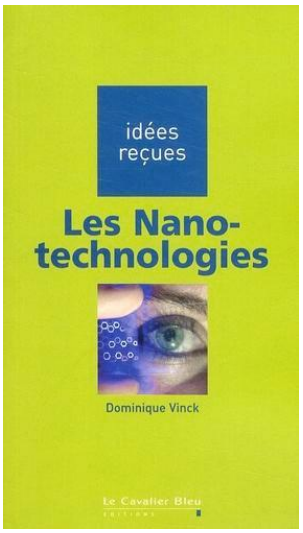
http://ec.europa.eu/dgs/jrc/downloads/jrc_reference_report_201007_nanomaterials.pdf

Définition de la NNI

Referring to official documents of the United States **National Nanotechnology Initiative** (NNI), the field of nanoscience and nanotechnology would work on developing technologies at the atomic, molecular and macromolecular level in a range between 1 and 100 nm.

(NSF, 2000 and 21st Century Nanotechnology R&D Act *http://www.nano.gov*)

But if nanosciences and nanotechnologies involve the design, characterization, production and application of materials and systems at the nanoscale, a question arises: can we delineate domain boundaries, size limits of the objects? (Corriu, Nozières & Weisbuch, 2004; Vinck, 2009)



Idées recues - Les nanotechnologies

For instance, while definitions present a size between 1 and 100 nm, can we consider an object to be called "nano" if:

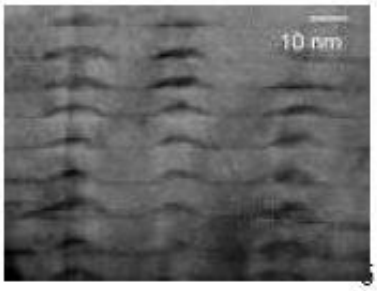
- At least one of its dimensions is of the order of nanometer?

The "nanos" thus concern any object that can measure several microns, millimeters, centimeters or meters:

- Long: nanotubes or nanowires for instance;

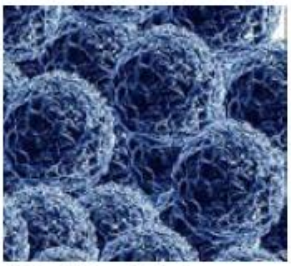
© CNRS/sagascience. Illustration Eric Vanneste

- Wide: nanoscale layers.



Source : inac.cea.fr

On the contrary, an object can only be considered « nano » if …



Source: NanoPrism Technologies, Inc.

- **All dimensions are at the nanoscale?**

Nanotechnology would then be limited to nanoobjets, nanorobots nanoparticles with dimensions not exceeding 100 nm;

Other issues raised :

More generally, are the following devices considered "nanos" :

- **All "nanostructured" surfaces ?**
That is to say in a controlled ordered.

- **Objects whose one element size is nano?**
For example in the case of microsystems composed by several parts.

- **Objects larger than the nanometer scale, but "nano-frabriqued"?**

If the precision is such, it concerns, in particular, the miniaturization of electronics but some consider that it has nothing to do with nanotechnology.
Thus the designation would be reserved to the case where the function performed by the object is positioned on a few nanometers, with an accuracy of manufacturing approximately of 0.05 nanometer.

- **Nanostructured materials or nanomaterials?**

For example, inclusion of nano-objects or nanowires to strenghten the nano-objects like in tennis rackets or tires?
This definition is also ambiguous as also almost all the materials (cement, metal, wood) are naturally nanostructured. Also, some restrict the designation of nanomaterials to that was knowingly nanostructured by humans.

In addition

In 2004, the Royal Society and Royal Academy of Engineering (UK) expressed the following definition of the field of nanoscience research: "Nanoscience is the study of phenomena and manipulation of materials at atomic scales, molecular and macromolecular where properties differ significantly from those at a larger scale, "and another definition of the research field of nanotechnology : " Nanotechnology covers the design, characterization, production and application of structures, devices and systems by controlling the shape and size applied at the nanoscale. "

You can see a distinction made between nanoscience and nanotechnology, the first term including the "study of phenomena and manipulation" of the particles at the nanoscale and the second covering the "design, characterization and production" of structures devices, and systems at the nanoscale.

Comment

But these distinctions between « design » and « manufacture » are also questionned for the "nanos" (see module 2).

B. Definition by physical properties

Warning

Defining the nanos by their size is very hardly discussed and questioned, since working on elements at the nanoscale is not new to most chemists, biologists and physicists also.

For the European Union

Measuring the size and size distribution in the case of nanomaterials pose difficulties frequently and there is no guarantee that the measurements made by different methods produce comparable results. It is necessary to develop harmonized measurement methods to ensure that the purposes of the definition produces consistent results at all times and for all materials. Waiting to have harmonized measurement methods, the best methods available should be used. (Recommandation n° 2011/696/UE du 18/10/11 related to the definition of nanomaterials).

JOUE n° L 275 of 2011 october 20

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:275:0038:0040:FR:PDF)

Warning

Most of what we know of the behavior of atoms, molecules and the physical world is based on research carried out on a larger scale that the nano one.
At the nanoscale, observed properties can be quite different from those at larger scales.
Thus the idea of unique properties of objects at the nanoscale is mentioned in several definitions of "nano".

For the **National Nanotechnology Initiative (NNI)**, the field of nanoscience and

nanotechnology would work to the development of technologies at the atomic, molecular and macromolecular level in a range between 1 and 100 nm, for a fundamental understanding of phenomena and materials at the nanoscale

(NSF, 2000 et 21st Century Nanotechnology R&D Act, *http://www.nano.gov/*)

For the British Royal Society and Royal Academy of Engineering, "the study of phenomena and manipulation of materials at atomic and macromolecular scales, where properties differ Significantly from those at the larger scale".

(Royal Society & Royal Academy of Engineering, 2004)

The "nano" then represents a kind of knowledge that consists not in science laws but in unknown or unexpected behaviors:

- For example, the adhesion phenomena

At the nano-scale these phenomena are different from those at macro scales.
This is illustrated by the iconic photos below where insects and other animals such as gecko has hairs providedby nanostructures to move on the surface of liquids, walls and ceilings.

Meniscus-climbing insects
David L. Hu & John W. M. Bush
Department of Mathematics, MIT

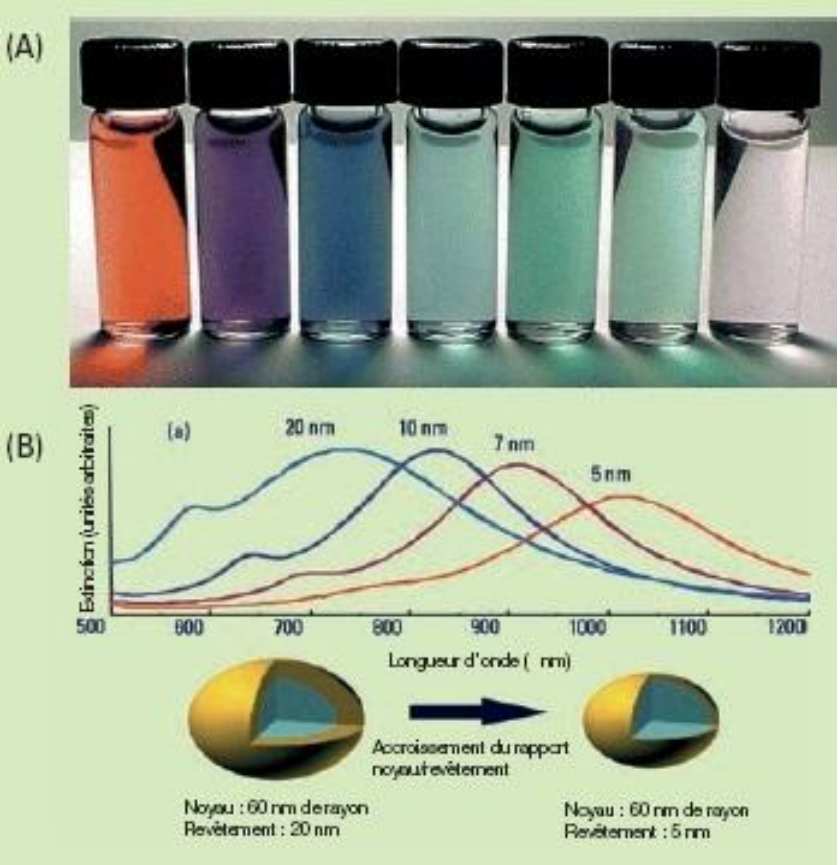
Microscopic hairs, lined with thousands of spatulas approximately 200 nm in width, line the bottom of the legs of geckos (image below). These spatulas may be close to a surface to nanometric distances. At these distances, there are strengths and bonds between the molecules very small but very numerous. They add up and allow the gecko to move on smooth vertical surfaces and even ceilings.

- Another example is the absorption of light

The "gold nanoshells" are nanoparticles consisting of a dielectric core surrounded by a thin metallic coating. By varying the relative dimensions of the core and cladding, we can design particles that either absorb or scatter light in the visible and much of the infrared part of the electromagnetic spectrum.

(A) The bottles of the image below contain either a colloidal suspension of gold (red characteristics on the far left) or a suspension of nanoparticles coated with gold whoserelative dimensions of the core and the coating vary.
Then the color of the solution changes.

(B) The optical properties of nanoshells are predicted by the theory of light scattering of Mie. For a given core size, the finer the coating thickness, the greater the wavelength at which there is an optical resonance.



West, J. L. et Halas, N. J. 2003. Engineered nanomaterials for biophotonics applications: Improving sensing, imaging, and therapeutics. Annual Review of Biomedical Engineering, vol. 5, p. 285 292.

C. Definition by instruments and technologies

Research in micro and nano technologies are practiced at scales only recent instruments can explore. And in this field, the different physical properties of materials determine the applications. For microscopes, the equation is similar: the different physical properties provide different images! Hence the need for a variety of instruments to study all the characteristics of different nano-objects.

(http://www.cea.fr/technologies/les_microscopes/les_microscopes_explorateurs_de_l_infime)

1. Instruments

For Alain Costes, in charge of the project "Nano Innov" in France: " Nanotechnology is not an invention of Human, the great innovation lies in our ability to look at the atom and the molecule through the development of the equipement, including microscopes " (*http://www.objectifnews.com/node/872*)

Observe and understand the new properties of nanoscale objects is useful (from the viewpoint of engineering) if these elements can be manipulated and exploited to create new combinations of molecules, new appliances and devices.

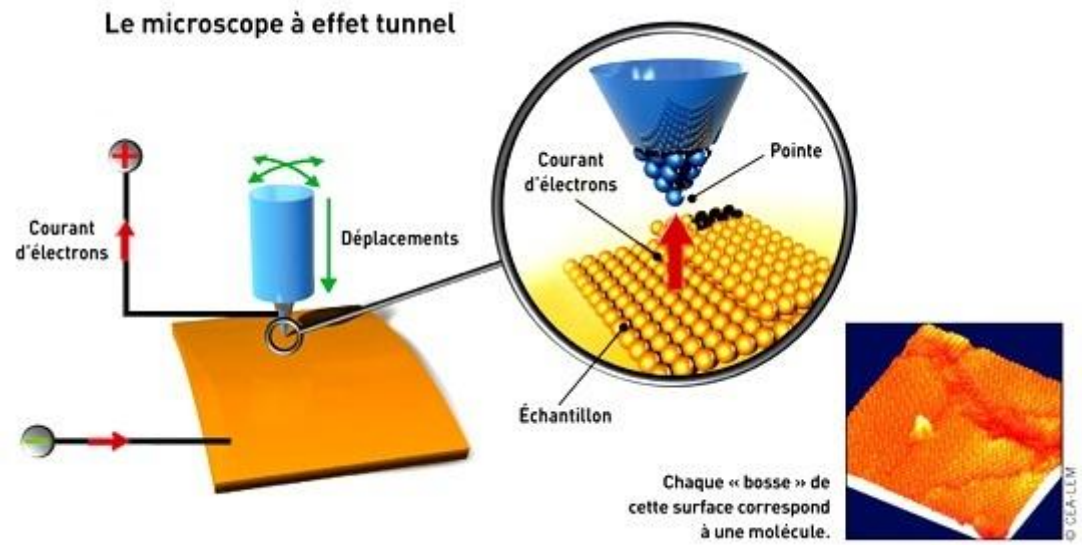
It is important to note here a nanoscience and nanotechnology specificity : The role of instrumentation that allows both observation and direct engineering of molecules or atoms.

We can then talk of molecular or atomic manipulations.

Thus in the case of "nano", the researcher is also an engineer, the perspective is to know and to make "nanos" within the same dynamic.

Scanning Tunneling Microscope (STM)

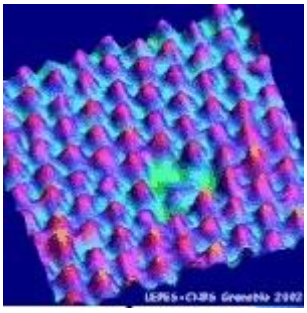
In the early 80s, two physicists Gerd Binniget Heinrich Rohrer (at IBM Research Laboratory in San Jose, California) conducted experiments that lead to the production of the scanning tunneling microscope, which allowed them to obtain Nobel Prize in Physics in 1986. This realization allows us to observe the atoms and move them one by one.



The scanning tunneling microscopy is a technique that can achieve the resolution of millionths of a millimeter (or nanometer) and thus allows to distinguish the atoms at the surface of an object

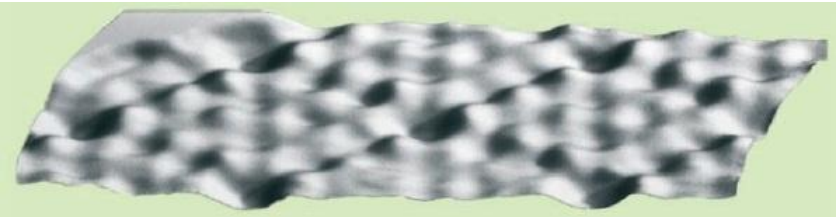
Unlike conventional microscopes operating with light, a STM (Scanning Tunneling Microscope) uses a very sharp mobile tip which terminates in a single atom which is

used to scan the surface to be observed. During scanning, the last atom of the tip follows the contour of the surface. In practice, a squared area is scanned line by line to reconstruct an image. The topography of the body "observed" is obtained with maps in relief.

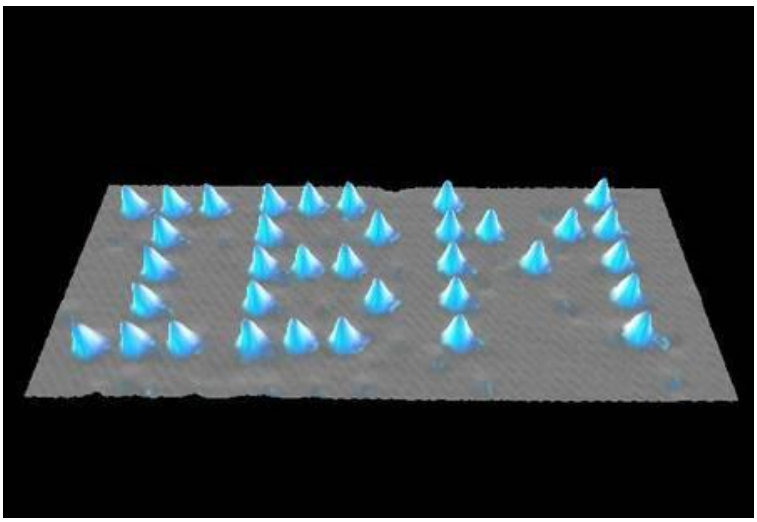


Nickel atoms observed by the scanning tunneling microscope.
Image size: 2.3 nm x 2.3 nm

Visualization of atoms with a scanning tunneling microscope. Binnig, G. and Rohrer, H. 1987. Scanning tunneling microscopy: From birth to adolescence. Review of Modern Physics, Vol. 59, No. 3, p. 622. Copyright 1987: American Physical Society.



- In 1989, Donald Eigler, a researcher at IBM, succeeds using an STM to move one by one, like Lego blocks, 35 xenon atoms and draw the initials IBM using the fine tip of the scanning tunneling microscope in the manner of a clamp.



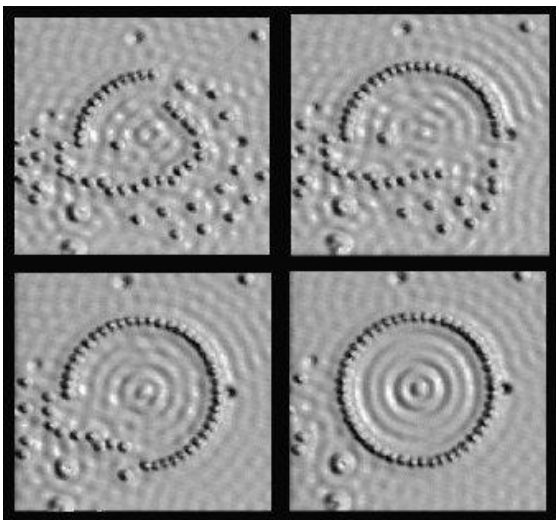
This photo is very famous and widely used in the dissemination documents on "nanos".

In 1993, Donald Eigler made the first "nanoexpérience" which consisted in the assembling of 48 iron atoms into an electronic drum.

Quantum corral

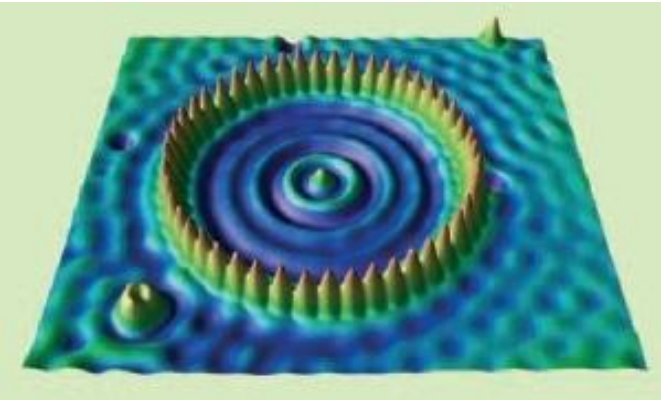
The first "quantum corral" made of iron atoms on a copper surface, was obtained in 1993 by Christopher Lutz, Donald Eigler and Michael Crommie (IBM). The quantum corral is an enclosure formed of atoms positioned on a substrate by a scanning tunneling microscope. This speaker creates a standing wave in the sea of electrons from the surface.

This oven may be viewed by a scanning tunneling microscope. The following figure shows the different stages of the construction of "Quantum Corral" assembled with 48 Fe atoms known Cu (111). The electron waves are confined to the surface of the inside and form corral "quantum wave" whose amplitude increases as and when the assembly of the "nanoresonator" of electronic wave.



(From D. EIGLER et al., IBM Research Division, Almaden Research Center, California,USA)

Here is a coloured image that shows its definitive shape :

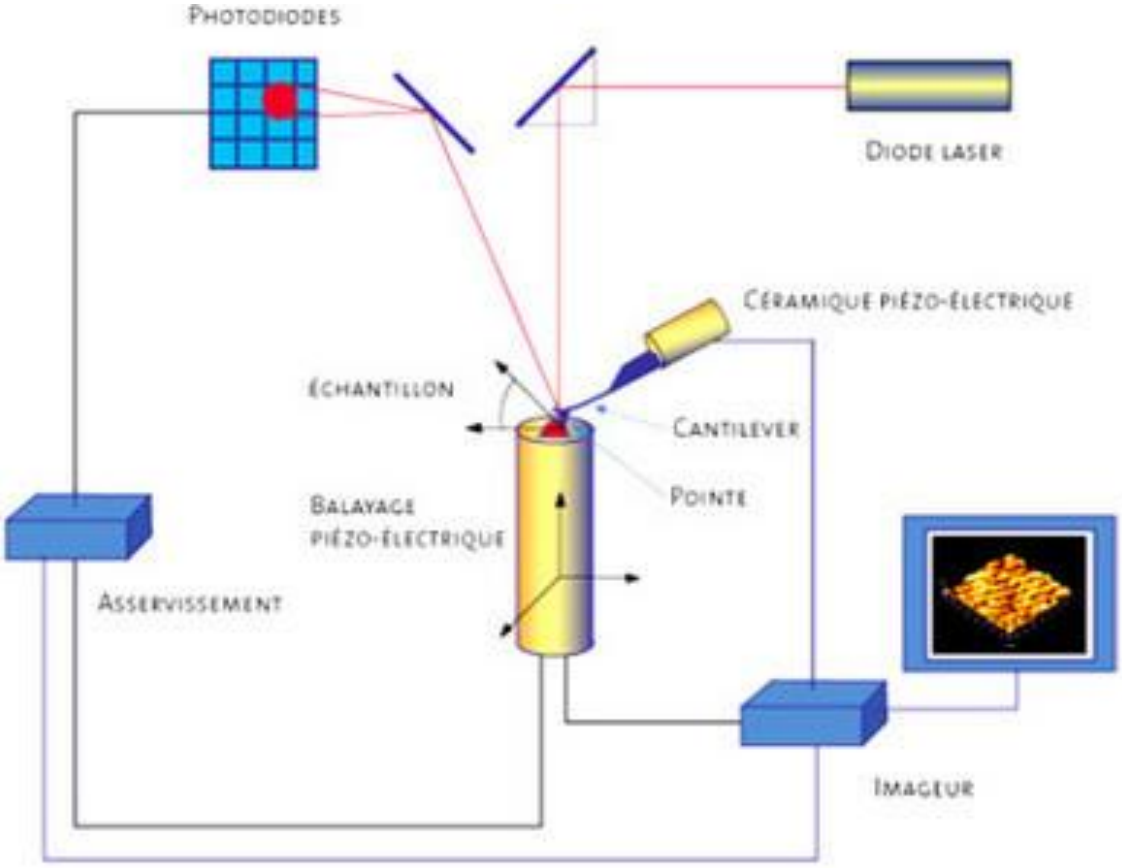


Quantum corral (Eigler, D. M et Schweizer, E. K. 1990. Positioning single atoms with a scanning tunneling)

Atomic Force Microscope (AFM)

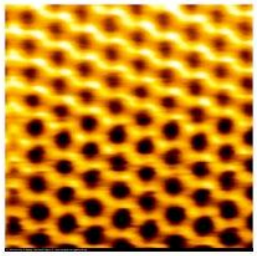
Developed in 1986 by G. Binning (Research Laboratory of IBM in San Jose, California and in Zurich) F. Quate (Research Center of XEROX Palo Alto, CA) and C. Gerber (Research Laboratory of IBM Zurich), the atomic microscope (AFM Atomic Force Microscope) allows the study of surfaces of insulating materials at the atomic scale. This type of microscopy is essentially based on the analysis of an object point by point by scanning via a local probe, similar to a sharp point. The atomic force microscope is a derivative of the scanning tunneling microscope, which can be used to visualize the topology of the surface of a sample that does not conduct electricity.
The principle is based on the interaction between a sample and a tip mounted on a cantilever. The tip scans the surface to be represented, and one can acts on its height as a feedback parameter. A computer records the height and thus can reconstitute an image of the surface.

The difference between the AFM and STM is the measurement taken into account in the feedback used: the STM uses a tunnel current, the AFM uses the deflection of the lever, that is to say indirect interaction forces between the tip and the surface.

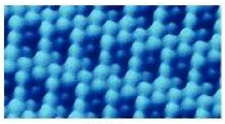


Atomic Force Microscope (AFM) © C. Reyraud

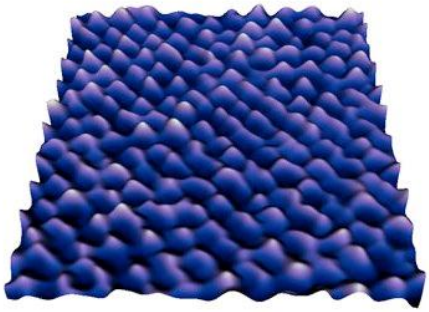
(http://www.cea.fr/technologies/les_microscopes/le_microscope_a_force_atomique_afm_simple_et)



Graphite

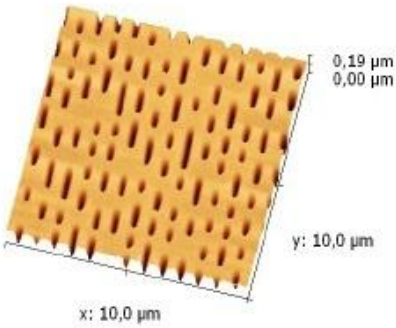


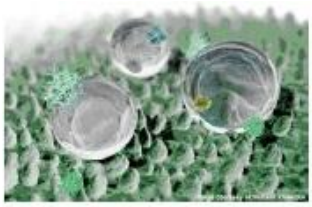
Silicium



Mica

Images by an atomic force microscope

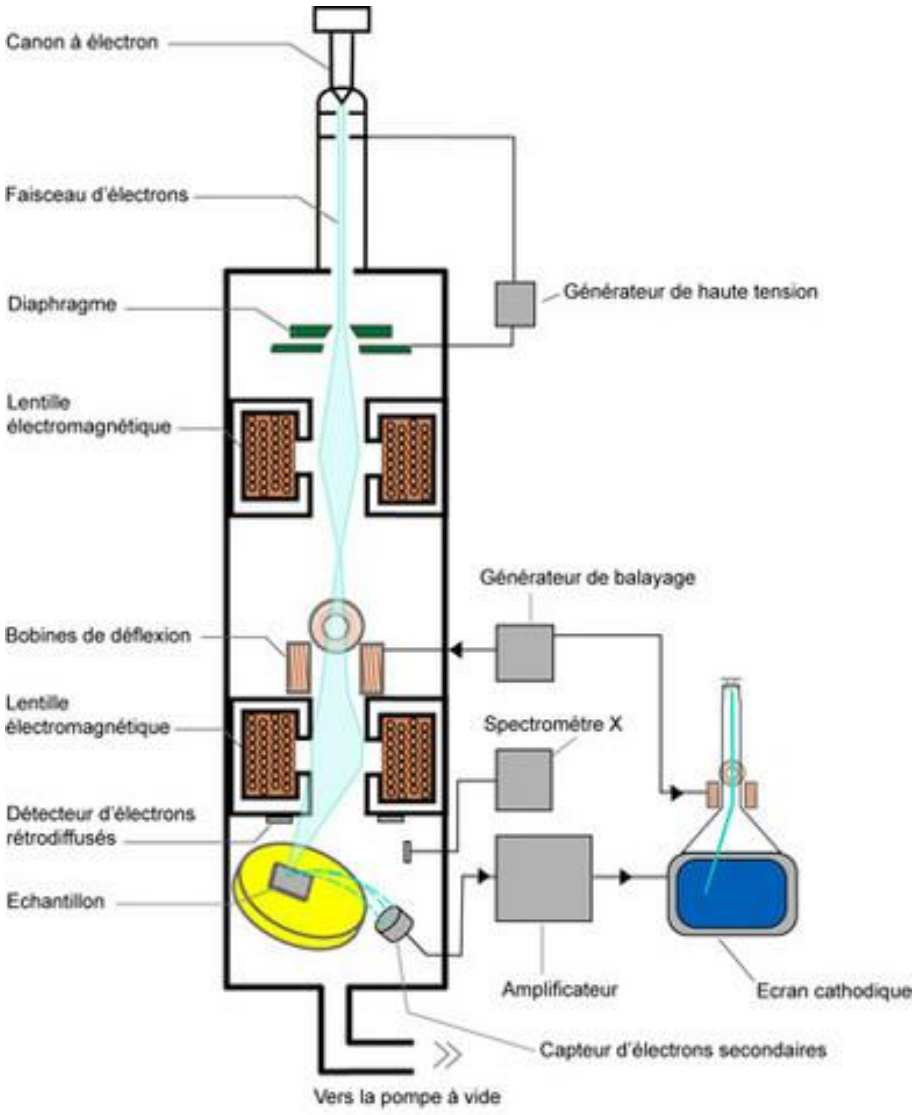




Topographie d'un disque DVD optique
par microscopie AFM (image du CIME-Nanotech)

The scanning electron microscope

Electron microscopes replace the light beam of optical microscopes by an electron beam. There are two types of electron microscopes. The scanning microscope explores the surface of the sample with a very sharp beam of electrons and the electrons retransmitted by the sample are detected. The resolution is about 1 nm.
In a transmission microscope, the electron beam passes through the sample which must be relatively thin (20 to 200 nm). This technique allows to visualize volume. Transmission microscopes have a higher resolution than the scanning microscopes (0.17 nm).



Le microscope électronique à balayage

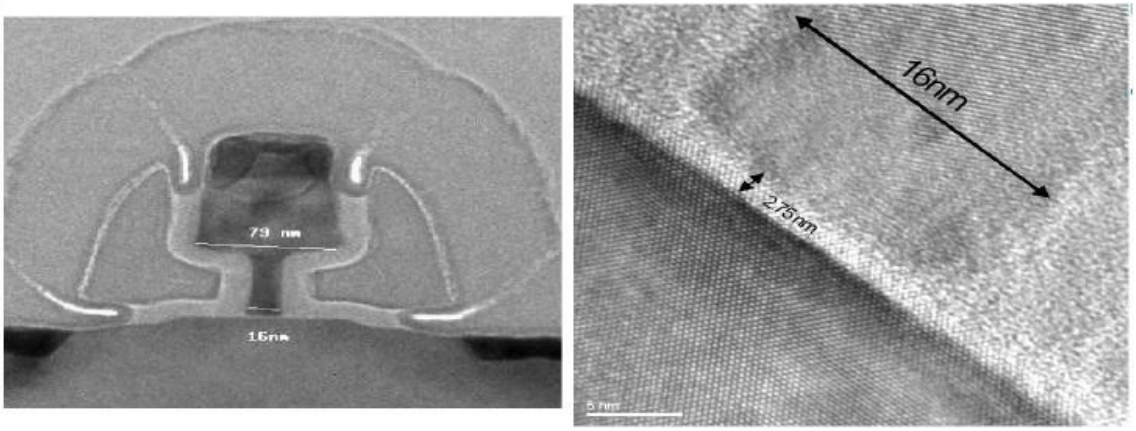
The scanning electron microscope © C. Reyraud

(http://www.cea.fr/technologies/les_microscopes/le_microscope_electronique_a_balayage_meb)

The photo below is an image of zinc oxide nanowires on sapphire obtained by a scanning electron microscope.

http://www.maxisciences.com/microscope/le-fonctionnement-du-microscope-electronique-a-balayage-meb-explique-en-video_art546.html

The following pictures were taken with a scanning electron microscope: it is a transistor Research 16 nm gate width (note the very small thickness of the gate insulator, 2.75 nm , about 9 atoms) (document ST Microelectronics).



From « Nanosciences – Nanotechnologies » by the Académie des Sciences et de l'Académie des Technologies - rst n° 18 - avril 2004

2. Technologies

«Top down» approach

Some microcomponents and microsystems are gradually reducing their size and approach the nanometer scale following the downlink "top-down", thus becoming nanodevices and nanosystems.

For 30 years, the manufacture of micro-electronic components is increasingly miniaturized. Thus, every 18 months the number of transistors on the chip surface double and the size of the grid decreases by a factor of 1.3. This trend is known as Moore's law, named after its author, Gordon Moore, an engineer at Fairchild and co-founder of Intel. The average area of a transistor, the basic element in making processors faster and faster, is 1 squared micrometer and the patterns made by

lithography is up to 100 nm. But it seems that the technical problems of miniaturization becomes more difficult to solve.

Reports from senators on micro/nanoelectronics

According to the report for the Senate by senators Jean-Louis Lorrain and Daniel Raoul established May 6, 2004 and entitled "Nanoscience and medical progress," the miniaturization of semiconductor components reaches a limit insurmountable. The extrapolations show that in 2010 these dimensions are of the order of tens of nanometers. One thinks that one has reached the ultimate limit of this approach. We should then replace it with a bottom-up approach in designing devices where the transistor is composed of an organized set of a very small number of molecules (or even a single molecule). The ultimate goal of molecular electronics would be to make electronic circuits using functionalized molecules as components.
(*http://www.assemblee-nationale.fr/12/rap-off/i1588.asp*)

Similarly, the report by Senator Claude Saunier established on 25 June 2008 on "the evolution of the area of micro / nanoelectronics, "discusses the problems related to the increased miniaturization of electronic components. It appears that since 2003 "microelectronics is passed to the nanoscale down below 100 nm gate width of the transistor (node 90 nm)" and that since September 2006 " resolution of integrated circuits is 65 nm and at the beginning of 2008, it decreased to 45 nm for fast microprocessors. Meanwhile, resolutions of 32 nm and 22 nm are already being prepared, while in laboratory widths as small as 6 nm were obtained.
(*http://www.senat.fr/rap/r07-417/r07-4178.html#toc73*)

The transistor, fundamental component of integrated circuits

In December 1947, John Bardeen, Walter Houser Brattain and Shockley William Bradford (physicists and engineers from Bell Labs, co-winners of the Physics Nobel Prize in 1956) realized the first transistor with germanium. They developed the following year the junction transistor and the associated theory. In the mid 1950s, transistors are made of silicon (Si), which is until now a widely used semiconductor, due to the exceptional quality of the interface created by silicon and silicon oxide (SiO_2), which serves for insulation.

In 1958, Jack Kilby (physicist and electrical engineer at Texas Instruments, co-laureate of the Physics Nobel Prize in 2000) invented the integrated circuit by manufacturing five components on the same substrate. The 1970s saw the first Intel microprocessor (2250 transistors) and the first memories. The complexity of integrated circuits has grown exponentially (doubling every two or three years, according to "Moore's Law") with the miniaturization of transistors.

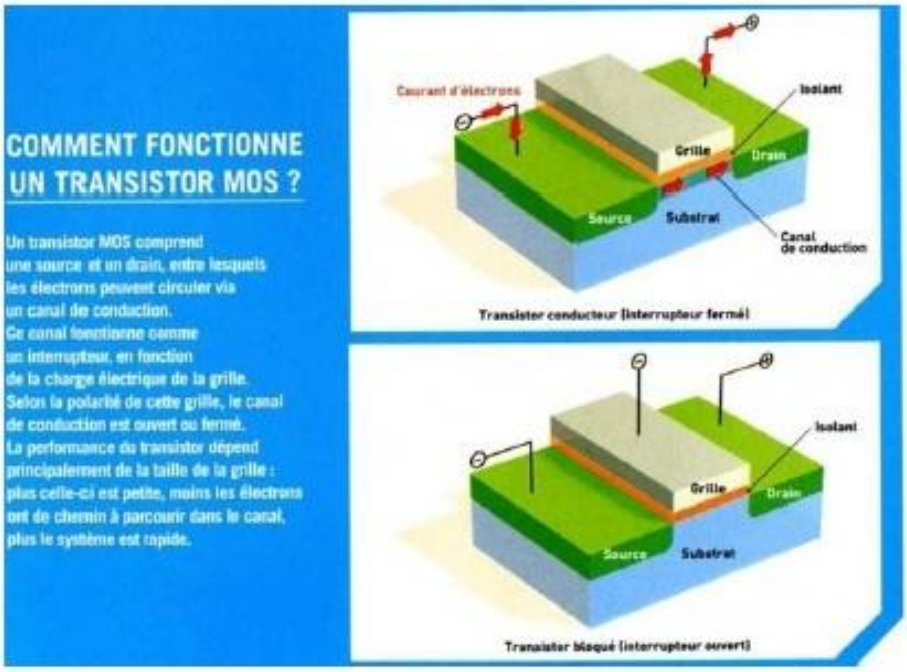
Transistor (from the English transfer resistor), basic component of microelectronic integrated circuits, will remain a basic component at the nanoscale: also adapted to amplification, among other functions, it assumes indeed an essential basic function : pass a current or interrupt it on request, in the manner of a switch. Its basic principle therefore applies directly to binary language processing (0, the current does not pass, 1 it goes through) in logic circuits (inverters, gates, adders, memory cells).

Transistor based on electron transport in a solid and no more in a vacuum as in electron tubes of the old triodes, comprises three electrodes (anode, cathode and gate). Two serve as reservoirs of electrons: the source, equivalent emitter of the filament of an electron tube, the drain, equivalent of the collector plate and the grid, the "controller". These elements do not work in the same way in the two main types of

transistors used today, bipolar junction transistors, which were the first to be used, and the field effect transistors (FET). Bipolar transistors implement two types of charge carriers, electrons (negative charges) and holes (positive charges) and consist of two parts of the semiconductor substrate doped identically (p or n), separated by a thin layer of inversely doped semiconductor.

The assembly of two semiconductors of opposite types (p-n junction) can only pass current in one direction.Whether they are of type n-p-n or p-n-p, bipolar transistors are fundamentally current amplifiers, controlled by a gate current (1): in a n-p-n transistor, the voltage applied to the p part controls the flow of current between the two n regions. Logic circuits using bipolar transistors, called TTL (Transistor Transistor Logic), are more current consumers that the field effect transistors, which present a zero gate current under static regime and are controlled by applying a voltage.

It is the latter, as MOS (metal oxide semiconductor), which now compose most logic circuits like CMOS (Cfor « complementary ») (2). A crystal of p-type silicon, two n-type regions are created by doping the surface. Also called source and drain, these two regions are separated by a small gap p-type. Under the effect of a positive voltage to a control electrode disposed above the semiconductor and which naturally carries the name gate, the holes are repelled from the surface, where the few electrons of the semiconductor accumulate. A small conduction channel can be formed between the source and the drain. When a negative voltage is applied to the gate, electrically insulated by an oxide layer, the electrons are repelled out of the channel. The higher the positive voltage, the more the resistance decreases and current passes.



The nanoworld, science applications, Clefs CEA n ° 52 - Summer 2005

In an integrated circuit, transistors and other components (diodes, capacitors, resistors) are original embedded within a "chip" with more or less complex. The circuit consists of a stack of layers of conductive materials and insulators formed by lithography.

The most emblematic example is the microprocessor located in the heart of the computer and contains several hundred million transistors (whose size has been reduced by 10,000 since 1960) and soon one billion, which led to industrial split core

processors into several units working in parallel!

«Bottom up» approach

- The so-called "bottom" or "bottom up" is to build nano-objects atom by atom or build molecules that can then be added to a larger system. The assembly is used to accurately control the structure. For this specific instruments are needed as the scanning tunneling microscope which is able not only to distinguish the atoms of a surface, but also move them one by one.
- It is for engineers and scientists to devise ways to create all kinds of products or materials "in bottom", that is to say, atom by atom using nanoscale factories. This approach would have the advantage of an almost infinite flexibility, to develop all kinds of substances, objects, devices, appliances or materials by performing atom by atom.

Lithography techniques

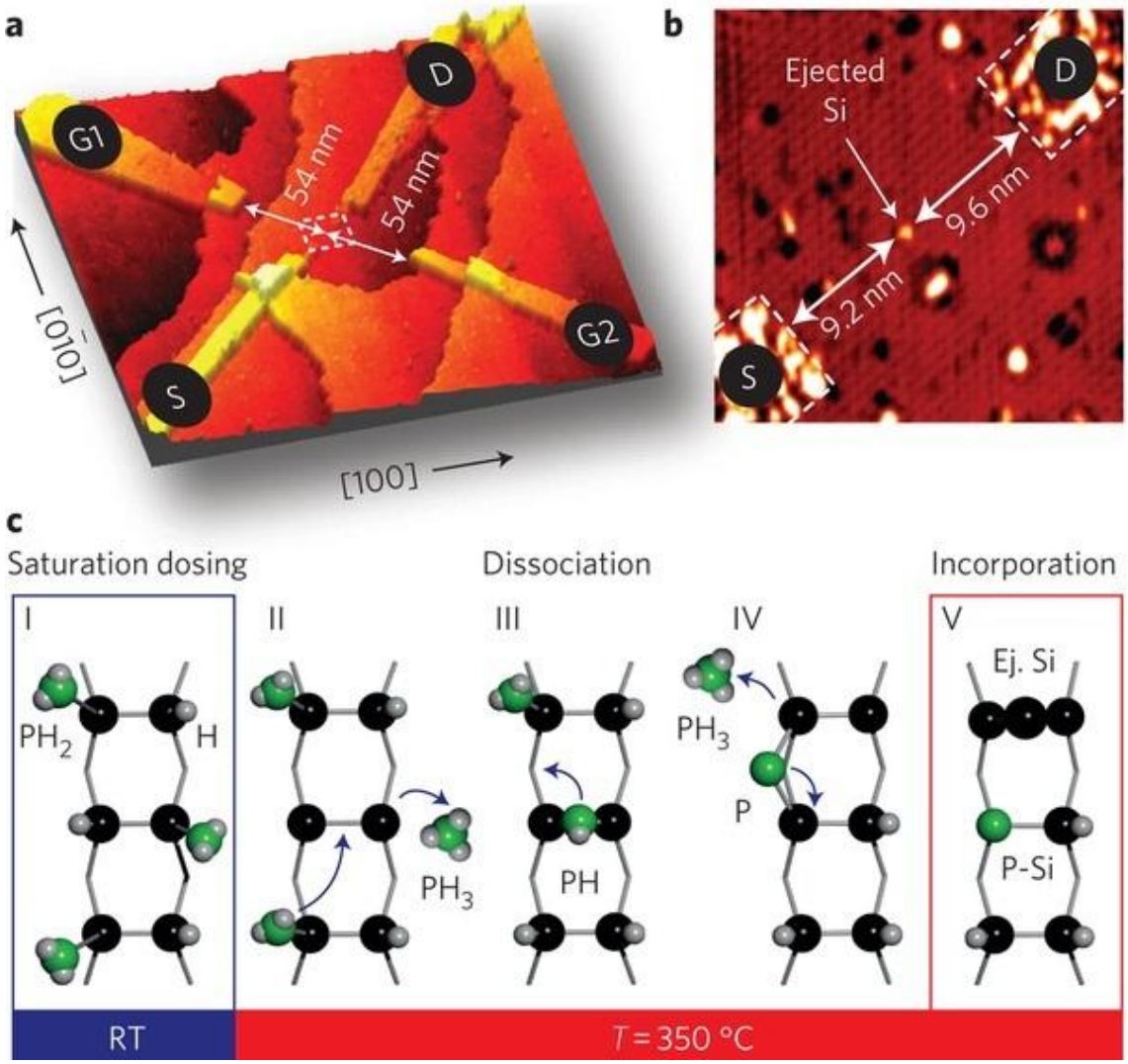
You can also make "nanos" using new variants of lithography techniques (extreme ultraviolet lithography, electron beam lithography, nano-imprint). These new techniques are constantly pushing the precision manufacturing of nanostructures. This is done under special conditions relative pressure, temperature, humidity and dust called cleanrooms to signify the absence of impurities from the outside.

Salle blanche de l'institut FEMTO-ST (http://www.femto-st.fr/fr/Agenda/agenda-2009/Inauguration-de-la-salle-blanche-2-octobre-2009/)

Salle Blanche TEMIS, Zone Lithographie (http://www.femto-st.fr/fr/Centrale-de-technologie-MIMENTO/Ressources-disponibles/Nanotechnologies/Lithographie-electronique)

Single-atom transistor

http://www.nature.com/nnano/journal/v7/n4/full/nnano.2012.21.html



Single-atom transistor based on deterministic positioning of a phosphorus atom in epitaxial silicon (Revue "Nature nanotechnology", http://www.nature.com/nnano/journal/v7/n4/full/nnano.2012.21.html)

a, Perspective STM image of the device, in which the hydrogen-desorbed regions defining source (S) and drain (D) leads and two gates (G1, G2) appear raised due to the increased tunnelling current through the silicon dangling bond states that were created. Upon subsequent dosing with phosphine, these regions form highly phosphorus-doped co-planar transport electrodes of monatomic height, which are registered to a single phosphorus atom in the centre of the device. Several atomic steps running across the Si(100) surface are also visible.

b, Close-up of the inner device area (dashed box in a), where the central bright protrusion is the silicon atom, which is ejected when a single phosphorus atom incorporates into the surface.

c, Schematic of the chemical reaction to deterministically incorporate a single phosphorus atom into the surface. Saturation dosing of a three-dimer patch (I) at room temperature (RT) followed by annealing to 350 °C allows successive dissociation of PH3 (II–IV) and subsequent incorporation of a single phosphorus atom in the surface layer, ejecting a silicon adatom in the process (V).

(From the journal "Nature nanotechnology" http://www.nature.com/nnano/journal/v7/n4/full/nnano.2012.21.html)

3. New technoscientific areas

Spintronics

Albert Fert (scientific director of the Joint Physics Unit CNRS / Thales associated with the Université Paris-Sud and co-winner of the Nobel Prize in Physics 2007) paved the way for a new electronics, spintronics, which no longer uses the charge of electrons to convey information but their spin.

"The spin magnetic moment of the electron can take only two values. It can be used to store binary information. The principle of spintronics is simple: thin layers of magnetic materials, placed in the path of the electrons allow some spin orientation and not the other. "
(*http://www.cnrs.fr/*)

Thales is a group specializing in the markets of defense, security, aerospace, information technology and ground transportation.
(http://www.thalesgroup.com/Group/A_propos_de_Thales(2)/)

Originally Thales Group's development "Thomson-CSF" (CSF for "General Company of wireless telegraphy"), through internal growth and through acquisitions, including the acquisition in June 2000 of the British company "Racal Electronics " fundamentally changes the field activities of this group, including civil markets information technology and mobile telecommunications. In July 2000, a new organization into three divisions is placed around the defense, aerospace, and information technology and services. In December 2000, Thomson-CSF became Thales.

(*http://fr.wikipedia.org/wiki/Thales*)

Magnetic Random Access Memory MRAM

One of the first major applications of spintronics is the design of MRAM (Magnetic Random Access Memory) that will operate the tunneling in magnetic junctions. These MRAM are also faster than standard RAM with a huge advantage: the information is permanent because it is due to magnetism.

Photonics

Photonics using different semiconductors to fabricate devices that emit or detect light handling. Its objective is to obtain comparable circuits electronic circuits but in which the photons have the role of electrons, then performing calculations at the speed of light.

MEMS

MEMS (Micro Electro Mechanical Systems or microelectromechanical systems) devices are sized between 1 and 300 microns can detect or generate mechanical forces, electromechanical, thermal and acoustic. Appeared in the 1980s, they are the source of important industrial and commercial successes, for example, the impact sensors airbags or injection heads of inkjet printers.

MEMS microsystems are transposing the mechanical performance of miniaturization technologies for the electronics.

The Quantronium

The electronic component is a quantronium quantum, that is to say, a component that will be used to achieve quantum effects more efficient electronic circuits.

D. Definition of research policies

" Other definitions focus on the questions of :

- Allocation of resources (grants for research or for industrial development)

- Accession of the public and social acceptance of products,

- And constraints (product standardization, legislation, organization of research and development programs).

The definition is strategic for the actors "(Vinck, 2009)

In France

- In 1999, launched "Research Network in Micro and Nanotechnologies" (RMNT) led by the Ministry of Research to promote cooperation between industry and government laboratories in the field of nanotechnology.

In the United States

- In the autumn of 2000, launch of "National Nanotechnology Initiative" (NNI) with a budget of $ 450 million for 2001.

- This is an interdepartmental program established to coordinate research in the field of nanotechnology and nanosiences between various government agencies funding research and development.

- Since the inception of the NNI in 2001, the government's total investment amounted to U.S. $ 12 billion (over ten years, 2001-2010).

- The NNI budget for the year 2012 amounted to $ 1.64 billion, which represents one third of the defense budget.

- In March 2002, the U.S. Army and the Massachusetts Institute of Technology (MIT) founded the Institute for Soldier Nanotechnologies (ISN).

- The National Science Foundation has played an important role in funding research in nanotechnology, in particular by creating regional centers focused on specific aspects of this discipline.

- For 2012, the site of the NSF reported a budget request of more than $ 2.1 billion for 2012.

In Europe

- The European Union spends 0.5% of its total budget "nanos". Thus, as part of research funded by the EU 6th Framework Programme for Research and Development Framework Programme (which was the general framework of EU activities in the field of science, research and Innovation from 2002 to 2006). Included a budget of 1.3 billion euros in nanos.

  (*http://europa.eu/legislation_summaries/research_innovation/general_framework/i23012_fr.htm*)

- Forecast for FP7 (2007 to 2013): 3.5 billion will be devoted to "nanos".

- Officially opened June 2, 2006 in Grenoble, the European scientific complex MIcro Nano Technologies "MINATEC" is dedicated to nanotechnology. It brings the total 4200 persons (2400 researchers, 1200 students and 600 companies). He is currently the leading European center dedicated to nanotechnology, and the third worldwide.
- Minatec represents an investment of € 150 million between 2002 and 2005.

Example : CIME Nanotech

For example, the annual budget of the platform CIME Nanotech (Interuniversity Microelectronics Centre and Nanotechnology), on the site of "MINATEC" amounted to 3 million euros per year (excluding salaries), nearly 0 , 6 million in investment.

http://www.minatec.org/recherche/plate-forme-technologique-formation-recherche-en-nanotechnologies

Japan

- The Japanese Ministry of Education, Culture, Sports, Science and Technology has allocated some $ 250 million for research in various areas of nanotechnology.

United Kingdom

- The British Royal Society reports that in the European Union, the total amount of funding is around one billion euros, the United Kingdom, for its part devoting currently some 45 million pounds each year.

In other countries

- China, Iran, Brazil and Israel have all made it clear that nanotechnology were among the priorities of the national research in science and technology.

Comment

In view of the huge investments and are already enshrined in research on "nanos" in the last decade and in different countries, we can understand that research policies in these countries are oriented in the same dynamic development " nanos. "
This is a proof of the great interest aroused by the "nanos" for different actors (EU, NSF, Military, Industrial, ...) and in many industrial fields. Many products using "nano" are already on the market.

Examples of different sectors involved in research

1. Production of sensors for imaging "nanodiamond: applications in bio-imaging and nano - François Treussart (ENS Cachan), Laboratory of Quantum and Molecular Photonics (ENS Cachan / CNRS)."

2. Achievement of "nanoelectromechanical systems" for nanoélectromécanique system such as car airbags, some video projectors and the Wii controller: "How do we measure the mass of an atom with a NEMS

3. Realization of batteries for energy storage: "The interest of nanostructured materials for lithium batteries - Frédéric Le Cras (CEA-Liten, Laboratory of Innovation for New Energy Technologies and Nanomaterials)."

E. Definition by productions

For the National Nanotechnology Initiative (NNI), the field of nanoscience and nanotechnology would work to the development of technologies at the atomic level, molecular and macromolecular in a range between 1 and 100 nm, for knowledge fundamental phenomena and materials at the nanoscale and to create and leverage structures, devices and systems with new properties and functions because of their small size or medium size. (NSF, 2000 et 21st Century Nanotechnology R&D Act)

Warning

New properties are likely to be used for new applications. Hence the importance of nanotechnology in industrial and manufacturing for the production of objects, the implementation of applications in various industrial sectors.

1. Already 1317 products on the market in March 2011

Tennis rackets, pregnancy tests, flash memory mp3 players or sunscreens, most consumer products "nano" are essentially based on the effects of surface modification on the material strength or increased penetration capacity of the active ingredients.

Research on surface effects, for example, leads to the production of rough-textured objects, waterproof, "easy to clean", "Lotus-Effect" antimark finger, self-cleaning, anti-graffiti, anti-microbial, anti fog, etc..

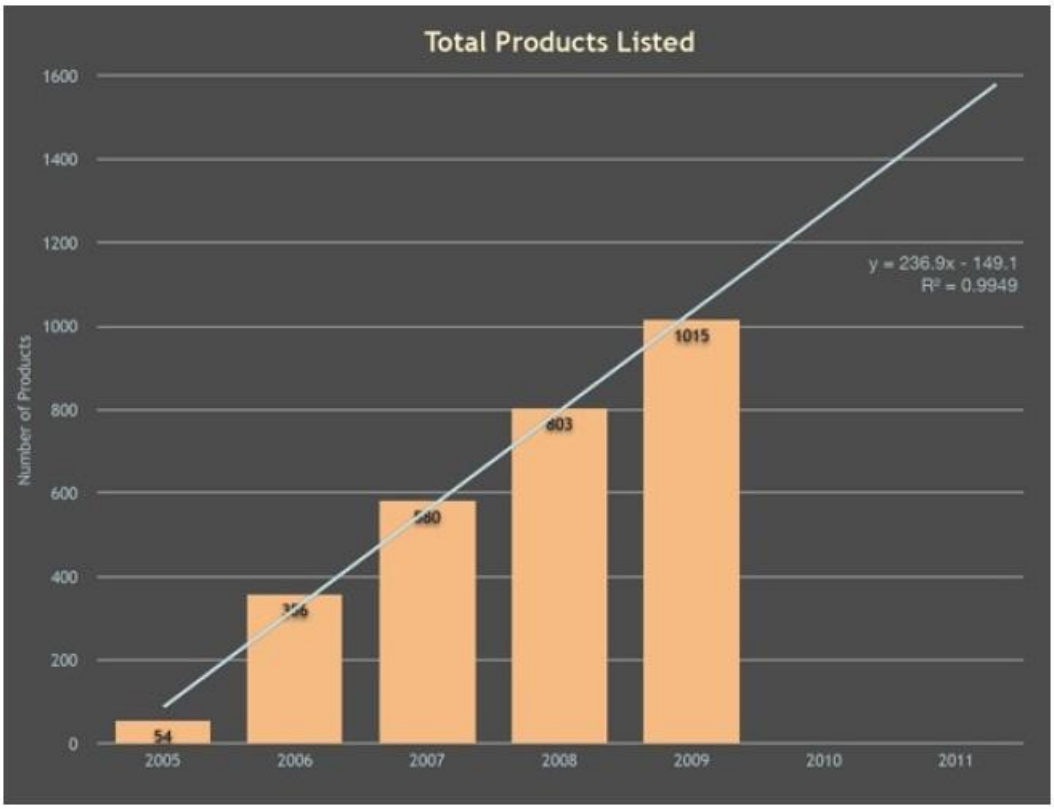
Example

Regarding the surfaces easy to clean, for example, the goal is to modify the properties of glass, textiles or cement, so that they absorb less easily other materials, while maintaining their ownership transparency, softness and strength.

a) An inventory of the Project on Emerging Nanotechnologies

It seems that the inventory is the best known and most included: inventory "Consumer Products" think tank American Project on Emerging Nanotechnologies (PEN) at the Woodrow Wilson Institute. In its last update in March 2011, the inventory in 1317 lived products on the world market, which 367 at European level: a clear majority related fields of cosmetics / personal care, clothing and cosmetics manufactured by Number of years.

Number of manufactured products per year



http://www.nanoceo.net

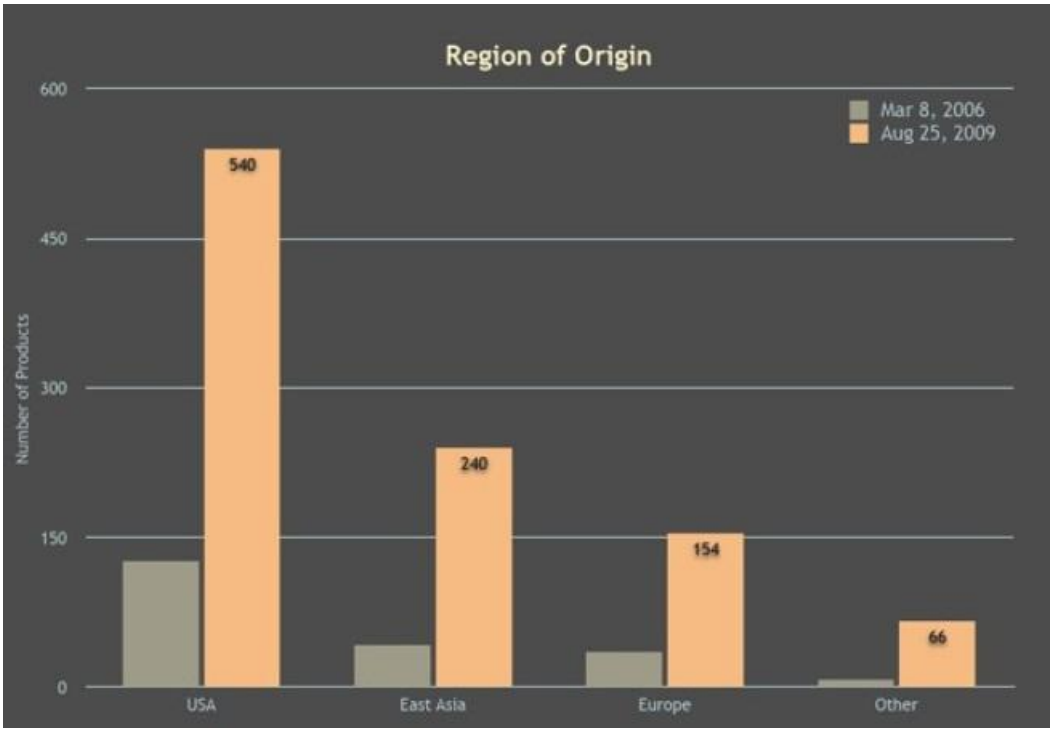
In 2012, the market for finished products manufactured with nanotechnology represents a market of $ 1,000 billion.

Example of nanotech products marketed

- Fart ski Nanowax Cerax
- Waterproof ski jacket Franz Ziener (Nano-Tex)
- Clothing and intachables wrinkle treatment by Nano-Care
- Cream skin care to high penetration L'Oréal
- Camera Kodak OLED (organic light emitting diode)
- Antiréflective coating Nanofi lm sunglasses high protection Sunscreen _ Z-COTE
- Tennis Racket Babolat nanotube
- Tennis Balls of nanotech InMat
- Soles thermal generation Aerogel Shockjock
- Washable mattress Simmons (Nano-Tex)
- Golf clubs Maruman & Co. using "buckyballs titanium"
- Golf Balls NanoDynamics
- Custom Skin Care Bionova
- Nucryst against burns dressings, covered with a layer of nanosilver
- Disinfectant (nanoemulsion) of military grade EcoTrue in Envirosystems

- Aerosol superhydrophobique Mincor from BASF for waterproofing building materials
- Aerosol window ClarityDefender from home Nanofilm
- Cream against joint pain and muscle Power Flex (using "liposomes of 90 nm")
- Dental Adhesive (nanohydroxyapatite) 3M

Products by region of origin

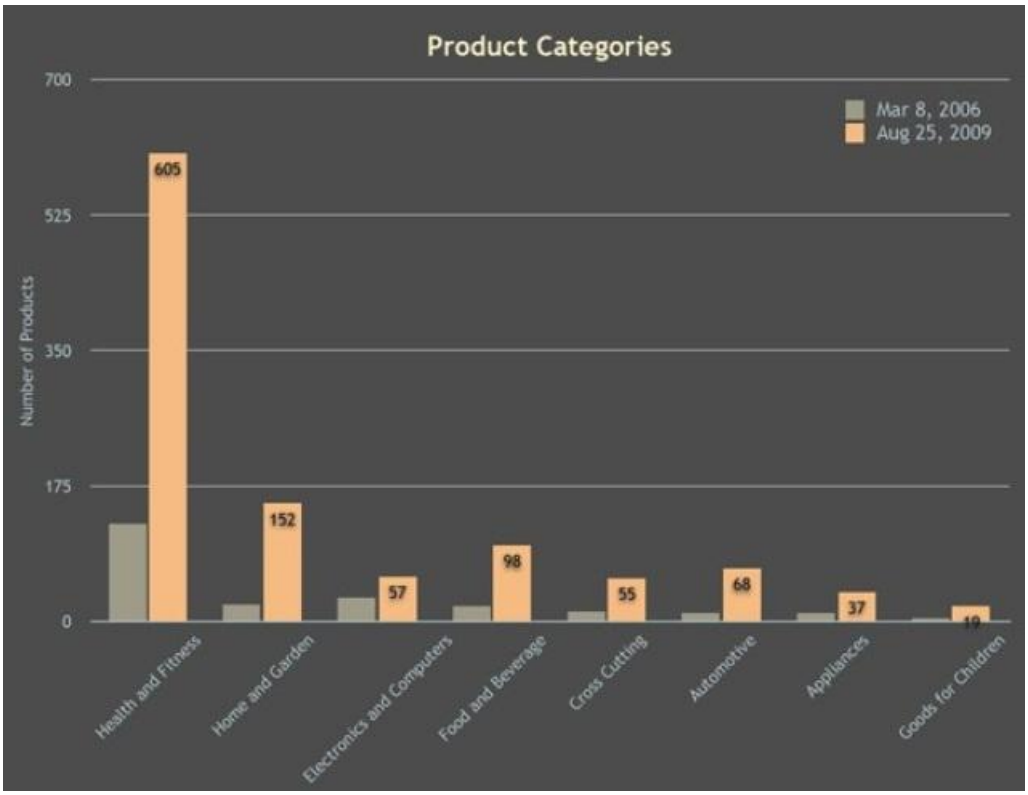


Categories of products sold

After more than twenty years of basic and applied research, nanotechnologies are increasingly used in the commercial field. Currently there are nanomaterials in electronics, cosmetics, in automotive products and in the medical field. It is difficult to know how many products "nano" are available to consumers and the market for goods that could be called "nano". While not being exhaustive, the proposed inventory lists over 1,000 products made available and identified as consumer products based on nanotechnology are currently on the market.
Several categories of nanotechnology products: transportation, electronics, textile, food, cosmetics ...

(*http://www.nanotechproject.org/inventories/consumer/*)

Categories of nanotechnology products : transports, electronics, clothing, food, cosmetics ...



Categories and subcategories of products "nanos" :

- Appliances

Batteries
Heating, Cooling and Air
Large Kitchen Appliances
Laundry & Clothing Care
Automotive
Exterior
Maintenance & Accessories
Watercraft

- Cross Cutting

Coatings

- Electronics and Computers

Audio
Cameras and Film
Computer Hardware
Display
Mobile Devices and Communications
Television
Video

- Food and Beverage

Cooking
Food

Storage
Supplements
- Goods for Children

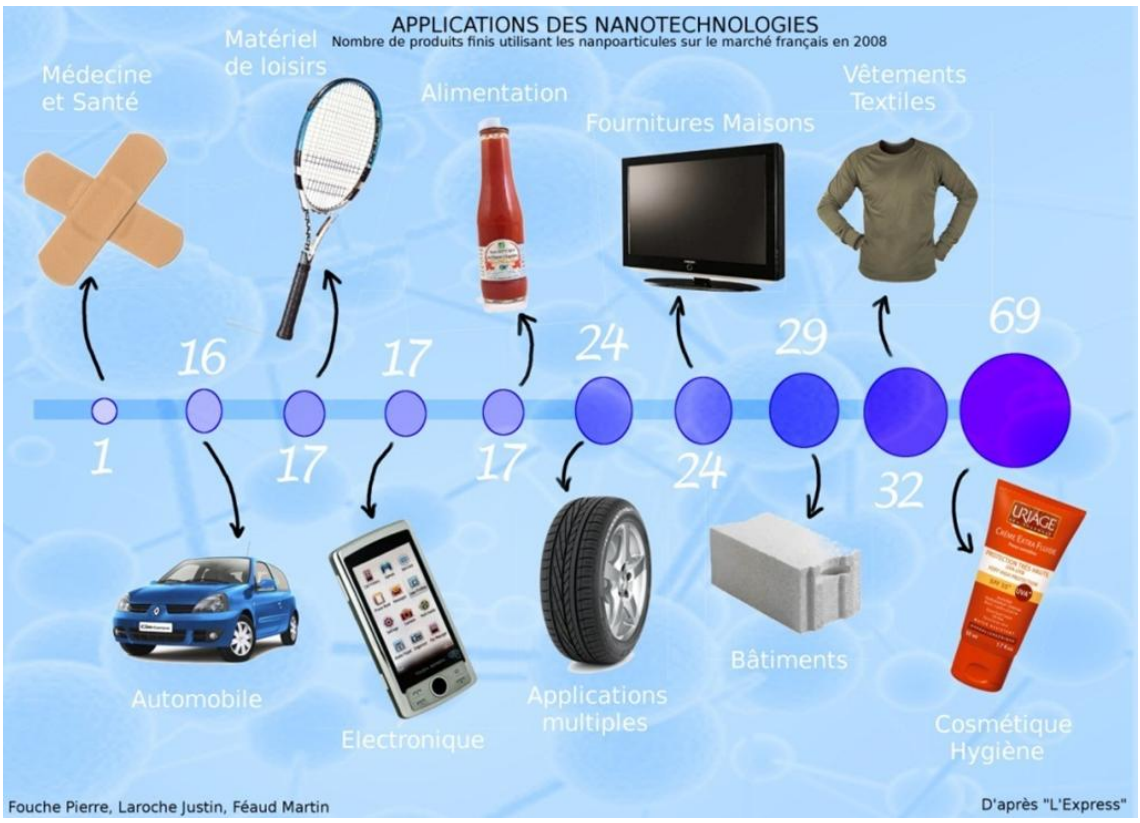
Basics
Toys and Games
- Health and Fitness

Clothing
Cosmetics
Filtration
Personal Care
Sporting Goods
Sunscreen
- Home and Garden

Cleaning
Construction Materials
Home Furnishings
Luggage
Luxury
Paint
Pets

b) Industry sectors

Many sectors are interested in nanotechnology from industrial to medical.



Some areas of nanotechnology

Example : *In the field of clothing*

- There are many applications in the field of textile designing clothing with anti-bacterial compounds of silver nanoparticles.
- In 2008, the French institute of clothing has identified over 1950 references of nanoparticles and nearly 140 manufacturers.

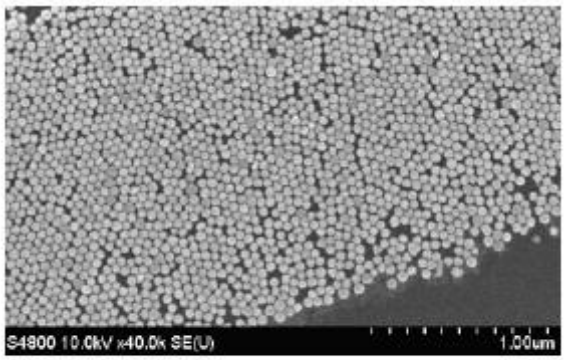
Example : In the automotive field

- The automotive seems also very involved in the implementation, manufacture and use of nanotechnology.
- Since 2003, Mercedes is covered with anti-scratch paint consisting of nanoparticles of titanium oxide, silicon or ceramic.

In addition

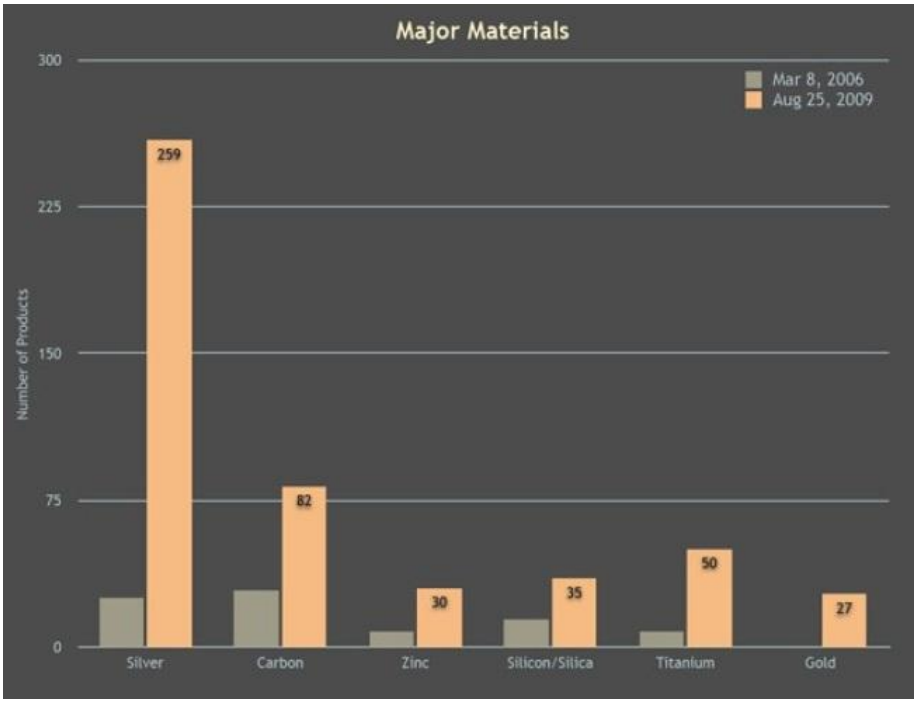
The company "Nanomade Concept" offers diagnostics technology platforms based nano components for professionals in the health, food, defense and communication.

(*http://www.cnrs.fr/dire/creation-entreprises/docs/2009A_NANOMADE.pdf*)



© Assemblée de Nanoparticules d'or pour réalisation de Nano-jauges de contraintes ou capteurs innovants (collaboration Nano-made-LPCNO)

Main materials used



In cosmetics

Sunscreen for "translucent", we use zinc oxide or titanium oxide, which are ultraviolet absorbers have long been known, but whose tendency to leave white marks on the skin after application.

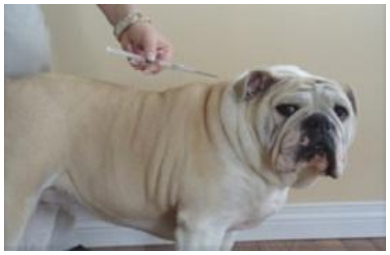
Their "advantage" at the nanoscale is that they no longer absorb visible light, but only the UV. Some brands also offer cosmetic creams containing nanoparticles or whose principles are nano-encapsulated, highlighting the fact that it improves their coverage or penetrating (nano-particles encapsulated in liposomes penetrate the barrier more easily skin).

Nano-electronic devices

Downsizing of electronic devices at the level of "nanos", allows many applications in various fields.

Example : veterinary traceability

Subcutaneous implantation of chips for geolocation animals.



Example : Tracking travels

RFID chips in cards, and passports for custom recording the movements of individuals.

Passport with RFID

Transportation card with chip

Example : Inventory Management

RFID chips in products marketed for inventory management, pricing, payment and security products.

Example : Medical Imaging

Implants

Search for identity

Examples in food

- Plastics and food packaging

- Food Additives:

_ The silicon dioxide (SiO_2) is authorized as a food additive (E 551).

_ Nanosized silicas have long been used in food for their rheological properties under the same number of additive (precipitated silica and fumed silicas, for example).

_ Titanium dioxide (TiO_2) is permitted as a food additive (E171).

- Food :

Silver Hydrosol

Nanoparticles of lycopene

Nanoparticles of titanium nitrite (TiN)

Sources :

« Nanotechnology consumer products Inventory » *http://www.nanotechproject.org/*

« Project on emerging nanotechnologies de Woodrow Wilson International Center for

Scholars » *http://www.nanotechproject.org*

« Nanotechnologies for Food and Beverages (2007) » *http://www.researchandmarkets.com/reports/357299*

Example : Lycopene

Since 2005, the lycopene from nanoparticle synthesis by BASF chemical has been notified as an ingredient in various foods marketed in the USA.

(*http://www.corporate.basf.com/en/innovationen/felder/nanotechnologie*)

It is difficult to obtain information on the use of "nano" in the food industry whether in products or processes.
According ANSES (National Agency for Sanitary Safety of Food, Environment and Labour), only certainty is that no process water treatment using nanoparticles was placed on the French market and any veterinary medicinal product or plant pharmaceutical nanotechnology has been subject to authorization in Europe.

(*http://www.anses.fr/index.htm*)

In summary?

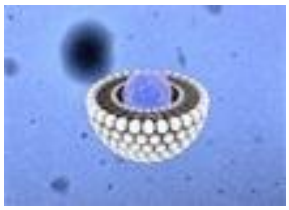
The field of "nano" key several industrial sectors and are therefore all competing in the same market instead of being organized in branches of independent activities (cosmetics, automotive, electronic, mechanical, food, ...)

2. In the medical domain

The three main applications of nanotechnology in the medical field are drug vectorization, DNA chips and the use of quantum dots (QD) in bio-imaging.

Definition

Drug vectorization, is the specific delivery of the required dose of active substance at the organ, tissue or diseased cell.



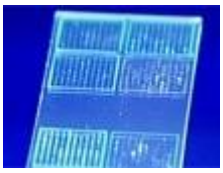
Drug vectorization (http://www.cnrs.fr/)

Drug vectorization is based on the principle of addressing that encapsulates the drug in a nanovector (usually a liposome), so that it does not deliver the active ingredient after penetrating the diseased cell and not during his "journey" through the bloodstream.

The purpose of the address is greater control of the therapeutic index, so as to reduce drug toxicity and side effects or simply to improve their effectiveness.
DNA microarrays are used to diagnose cancer. The quantum dots used as markers in biological imaging.

The biochip

At the interface between electronics and biology, an important application of nanotechnology in biology and medicine is the development of biochips. The first microarray DNA chips were, but now they are diverse: protein microarrays, cell microarrays, real laboratories on a chip ....
These biochips are designed to help detect molecules or perform analyzes on very small quantities.



Biochip (http://www.cnrs.fr/)

Tissue Engineering

Tissue engineering is the science that aims to reconstruct biological tissues: skin, corneas, cartilage ... Nanotechnology to enable nanostructuring of materials used throughout the lifetime. The principle is to build scaffolding to guide the growth of the cells to mimic tissue. These biocompatible scaffolds are then destined to self-destruct when the tissue is regenerated.

Tissue Engineering (http://www.cnrs.fr/)

This is probably in the medical field that the hopes and utopias are the most prolific, though it is still far, very far from self-healing tissue opening lines of immortality, or nanorobots would suffice to ingest an inner adventure therapy.

1. In the military field

We know that nanotechnology interested Army (fourth colossal budget devoted to research in nanotechnology in the United States is devoted to the defense). Camouflants textiles, uniforms communicating or exoskeletons could be used to "improve" consequently infantry equipment already overequipped. Not to mention the strategic advantage that represent ownership of nanodrones the size of a dragonfly, undetectable, or nanocapsules toxic no barrier, no gas mask could not stop ...

Comments

In 2002, the U.S. Army, MIT (Massachusetts Institute of Technology) and a group of businessmen have teamed up to put in place: "The Institute for Soldier Nanotechnology (ISN) to develop applications based on military nanotechnologies.

German physicist at the University of Dortmund Jürgen Altmann class military nanotechnology projects in three categories:

_ Miniaturization, weight reduction, increased resistance equipment.

_ Use of new nanostructured materials.

_ Improved some functions of body systems, determining performance, hybridization, implants, dentures and chips.

Specifically, the transition to the nanoscale is expected to store and analyze more and more information to equip missiles nano-computers embedded, trigger alerts in case of attack or death, implement sensors the soldiers to monitor their state of health or countermeasures against curative (automatic injection of analgesic, anti inflammatory, etc..), or to enhance the shielding by adding carbon nanotubes. While some of these projects are still (bad) dreams, others such as nanodrone "Dragonfly" or exoskeleton "Hercules" funded by the DGA (Directorate General of Armaments) are real ...

Example: As the name suggests, nanodrone "Dragonfly" is a project biomimetic imitating the shape and flight of this insect. It has four wings 3 cm driven by artificial muscles 180 000 and weighs 120 milligrams.

(*http://www.lemonde.fr/cgi-bin/ACHATS/acheter.cgi?offre=ARCHIVES&type_item=ART_ARCH_30J&objet_id=948358&xtmc=libellule_le_futur_ange_gardien_du_fantassin&xtcr=1*)

http://www.defense.gouv.fr/dga/industrie2/espace-pme/soutenir-et-developper-l-innovation/(language)/fre-FR#SearchText=libellule#xtcr=1

Example: The exoskeleton "Hercules", manufactured by the DGA, is designed to carry heavy loads without any back pain. This model allows exoskeleton currently carry 40 kilos over a range of four hours. By 2015, it is expected that it can carry a hundred pounds.

Exosqueleton Hercule Eurosaty 2012 —Jonathan Duron / 20 Minutes (http://www.20minutes.fr/high-tech/952859-video-exosquelette-hercule-brouette-futur)

B. Definition by controversies

Nanotechnology ... wonder why? (Lacour, 2010)

The questions are crucial for many players may be because nanotechnology is already changing our lives, generating uses that can change:

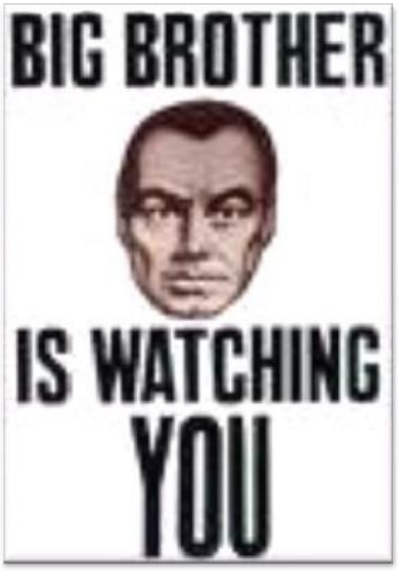
- **Our relationships :**

- example of the Internet everywhere and for all with powerful processors and inexpensive;

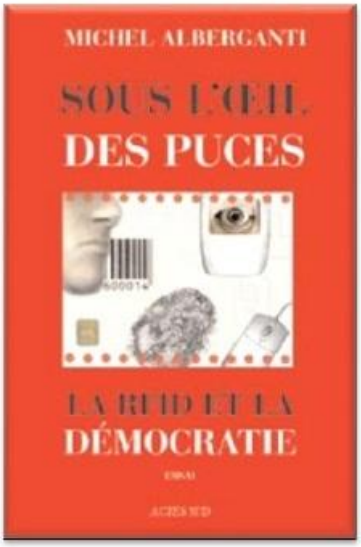
Ubiquitous computing will enable diverse wireless applications, including monitoring of pets and houseplants, operation of appliances, keeping track of books and bicycles, and much more.

- **Our freedoms :**

- examples: monitoring 24h/24, what we eat, what is in our cosmetics, our clothes ...



- **The risks we take for ourselves and our environment?**



- example of hunting bacteria by silver nanoparticles;

1. Societal issues

We have seen in previous sections that the "nanos" unfold in society and are already on the market in many areas and in many countries.
The "nano" also raised criticism and opposition from various social groups (consumer associations, environmentalists, unions, citizens ...).
They are the subject of discussion in society in a context of changing relationships between technoscience and society since the 70s and especially marked by numerous health and environmental crises (Chernobyl, mad cow disease, asbestos, contaminated blood, OGM, mediator, Fukushima, .. .).
These are the discussions that we will discuss in detail in the second module called

"public debate on nanosciences and nanotechnologies: issues of citizenship education for all."

2. In the media ?

The "nano" are subject to huge investments and raise hopes of economic gain considerable media relay (photo below).

3. Hopes and promises?

The same idea of hope and promise and is amplified in the demiurgic process that is embodied in objects of design and manufacturing of nanorobots, man-machine hybrids (cyborgs) devices to overcome the motor impairments visual, auditory or diminished capacity due to old age for a perfect dream of life and immortality.

4. Risks ?

Like any new technoscience was also raises the question of risks to health and the environment.

5. Challenges ?

Debates raised in society about "nanos" does not, however, reduce the risk issue. Citizens to organize and mobilize to question the value of "nanos", the social and political changes that generally, how is organized and financed innovation and that decisions are made in terms of research policy and innovation. This is illustrated in the following photo of a manifestation in Grenoble opponents of the project Minatec.

To conclude

Nanoscience and nanotechnology concern several industrial sectors and raise scientific, technological, environmental, regulatory… stakes. In this module, several definitions have been exposed. These definitions are strategic for the concerned actors, and also raise debates in society.