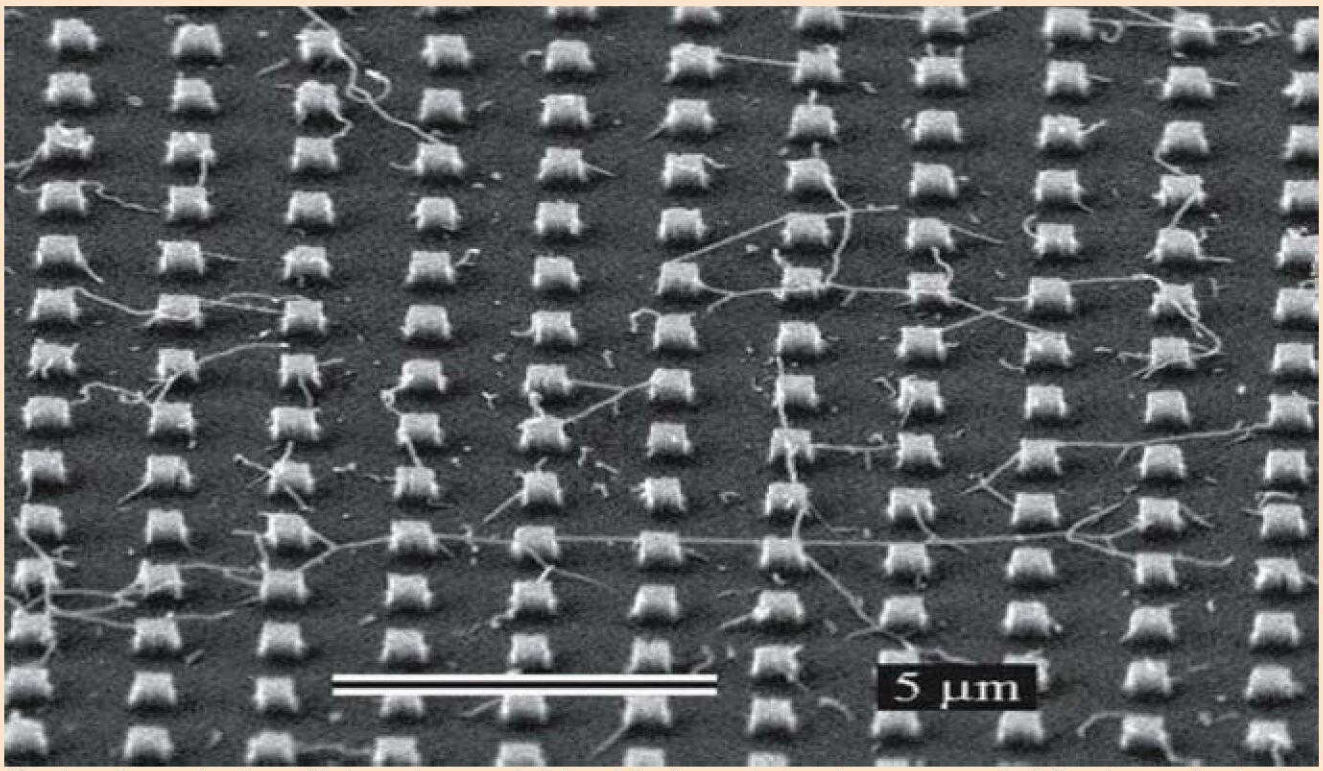
BY UFMG INSTITUTE OF NANOSCIENCE



Nanotecnology makes it possible to create new materials and develop products and processes manipulating atoms and molecules

The world on a nanometric scale

Relatively recent and not very well known by society in general, nanotechnology promises to revolutionize the manipulation of atoms and molecules. Research in this area is headed towards the development of new materials with distinct applications, which even encompass agribusiness

by Rodrigo Moraes

"Size doesn't matter", as they say in Brazil, can be used to describe many situations. And this popular quotation also explains very well the meaning of some news of the technological world, in which the smaller the component or equipment, the more it is worth! In the nanoscientific universe, the dimensions are even smaller, and can not be reached by the human eye. But what is nanotechnology, after all? You could be asking the same question, upon seeing the word used in this article. To simplify everything, and explain the term, we can say that nanotechnology is the ability to create new materials and develop products and processes using the possibility of manipulating atoms and molecules. But to better understand what it means to work with nanoparticles, it is first necessary to understand the dimension of a nanometer.

In an article published by ComCiência magazine, physicist and emeritus professor from Unicamp, Cylon Gonçalves da Silva, makes the following comparison: "imagine a beach that begins in the city of Salvador (BA) and goes all the way up to Natal (RN). Grab one grain of sand from this "beach". Very well. The dimensions of this grain of sand to the length of the beach, is the same as a nanometer is to a meter" (read more in the box about "nano-curiosities").

Although relatively recent, nanoscience and nanotechnology studies involve interdisciplinary aspects (chemistry, physics and computer sciences, among others) and promise to revolutionize the understanding and methods of using the resources of materials. "Today, the methods and techniques for analyzing and producing materials, and even the scientific understanding of these materials, have increased substantially. It is possible to produce a material in a controlled manner, seeking to resolve and adapt specific problems. It is clearly a revolutionary breakthrough that is going to change our habits", says Marcos A. Pimenta, professor of the Physics Department at the Federal University of Minas Gerais (UFMG) and coordinator of the National Research Group in Carbon Nanotubes with a PhD from the Massachusetts Institute of Technology (MIT).

Forecasts as to when this revolution will take place are a bit difficult to pinpoint. But little by little products and processes based on nanotechnology are surfacing in the

market, in a very rapid manner, as informed by Paulo Roberto Martins, researcher at the Technological Research Institute (IPT), sociologist, doctor of social sciences and coordinator of the Nanotechnology, Society and Environment Research Network (Renanosoma). "At present, there are more than 450 products on the market with nanotechnology-based particles, processes and products. For such, it is necessary to know more about the impacts of nanotechnology on society and the environment, support investments, develop the necessary regulations and, at last, approximate society to the ongoing discussions about this revolutionary matter", said Martins.

Among the products that incorporate nanotechnology and already available on the market are stain-resistant fabrics that do not crumple up; glass coating, sunscreen lotion quickly absorbed by the skin; material for protection against ultraviolet rays; and even medical equipment, products for the cleansing of toxic waste, cosmetics, air and water filtering systems, microprocessors and electronic equipment in general.

Nanoparticles do not work on their own in these items that incorporate nanotechnology in their composition. It is possible to use nanometric material with other materials well-known to everyone, such as plastic, paper, resin, among others, to the point of giving rise to new properties for conventional materials. It is the miracle of transformation, based on the universe of science and technology!

For example, "let's say that you wish to create a paper that is good as heat conductor, or the opposite", says Pimenta. "By mixing, for example, nanoparticles in this paper, it is possible to make it more or less conducive, according to the changes to its properties." Going beyond in this attempt to popularize scientific knowledge about nanotechnology, the UFMG researcher provides another example of materials: plastic and metal. "Plastic possesses characteristics of flexibility and low electricity conduction, while metal is rigid and possesses excellent electricity conduction attributes. The ideal would be to have a plastic capable of conducing electricity, without losing its flexibility. If we mix metallic nanoparts to a plastic material, the result would be a plastic with its mechanical properties coupled with the electric properties from these metallic nanoparticles".

FROM NANOTECHNOLOGY TO AGRIBUSINESS

With so many innovation possibilities, nanotechnology could add significant value to the already consolidated potential of Brazil's agribusiness industry, in terms of elevating its competitiveness to a world-class level. "There exist a series of opportunities that nanotechnology could generate for agribusiness, precisely because many of nature's phenomena occur on a nanometric scale",

The future presented in 1959

"Known as the father of nanotechnology, physicist Richard Feynman presented a lecture in 1959 at the California Institute of Technology called 'There's plenty of room at the bottom'. In his speech, Feynman said that in the not so distant future engineers would be able to get atoms and place them wherever they wanted, as long as the laws of nature were not violated. With this, materials with entirely new properties would be able to be created. A dream? Perhaps, forty years ago. But, just as Feynman said himself in his conference, nothing in this dream violates the laws of nature. Therefore, making it real is only a matter of knowledge and technology."

Excerpt from the article "What nanotechnology is", by Cylon Gonçalves da Silva

"The possibility of taking an atoms and moving it from its place has already been demonstrated using state of the art equipment. Feynman was right in his statement, for this means that yes, it is possible to manipulate atoms. However, this was a demonstration done in a laboratory, using sophisticated equipment, and is still at a fundamental laboratory research level. The idea of making it possible to join atom by atom is still somewhat distant from happening in an industrial scale."

By Marcos A. Pimenta, researcher at the Federal University of Minas Gerais' Physics Department (UFMG) and nanotechnology researcher

points out Luiz Henrique Capparelli Mattoso, researcher at the National Nanotechnology Laboratory for Agribusiness, which is run by Embrapa (Brazilian Agribusiness Research Company). The laboratory, established in 2006 by Embrapa Instrumentação Agropecuária, is temporarily operating out of the head office in São Carlos (SP), until construction of the new building is concluded.

The lines of research developed by the laboratory include everything from the development of sensors and biosensors applied to quality control; the certification and traceability of food; characterization and synthesis of new materials, such as nanostructured polymers and materials, with specific properties; to thin films and surfaces for producing intelligent packaging, nanoparticles, fiber compounds for developing reinforced materials, using natural products like hemp, coconut and pulp fibers.

It's precisely from this plethora of nanotechnology possibilities for agribusiness that the pulp and paper industry is still starting to discover the importance of nanotechnology techniques for its production lines. "As we begin studying the nanostructure of paper, that is, studying paper at a molecular level, we can slowly begin to improve its characteristics, with new paper formulations that utilize pulp nanofibers with better mechanical resistance in relation to commercial paper that exists today", said Capparelli.

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Virtual image of a carbon nanotube formed by sheets of carbon atoms in a hexagonal shape

Well beyond the eyes...

One of the most important instruments for nanoscience and nanotechnology is the Scanning Tunneling Microscope (STM). Its conception is simple and can even be compared to the 'stick' used by the visually impaired. It is an extremely thin needle that taps the surface without actually touching it.

During this scanning process by the needle, electrons perform a movement called tunneling (of quantum origin and that occurs on an atomic scale). Based on this tunneling current, a computer builds an extremely magnified image of the surface, at which time it is possible to see the layout of atoms. It is this way that makes it possible to see and investigate the atomic relief of a body surface.

Among the compounds and molecules with special characteristics for using in nanotechnology experiments, carbon nanotubes are formed by sheets of carbon atoms in a hexagonal shape, which roll up to form a "spaghetti" with a two-nanometer diameter. "Like very fine carbon fibers, these nanotubes are extremely rigid and, if mixed with other materials, can form lighter and even more resistant agglomerations than even steel. Additionally, they are capable of operating at much higher temperatures", explains Marcos A. Pimenta, professor of the Physics Department at the Federal University of Minas Gerais (UFMG) and coordinator of the National Research Group in Carbon Nanotubes.

Pimenta also shows that there are two ways to obtain materials and devices at a nanometric scale. In the first, it is necessary to build from a bigger material, just like a sculptor sculpts a given material until its minute details. This procedure is known as "top-down" and makes use of lithography techniques (selective and extremely precise chemical corrosion of a material). The second procedure is the so-called "bottom-up" and consists in organizing the basic components (atoms and molecules), as pieces to a jigsaw puzzle until forming the nanometric structure.

Nanotechnology research and products have assisted the pulp and paper industry in its pursuit of optimizing the use of raw materials in the production process. "In the case of the paper industry, nanotechnology can particularly contribute with regards to chemical materials, coating materials and products for the wet end chemistry. All these are materials used in paper production", adds Osvaldo Vieira, chemical engineer, PhD in chemical engineering sciences, and research and development coordinator at Klabin Papéis Monte Alegre.

IN ALL SENSES

One of Embrapa's main achievements was the development of an "electronic tongue". That's right! An electronic tongue that possesses a device that combines chemical sensors of nanometric thickness with a sophisticated computer program for detecting flavors. "Additionally, sensitivity of the electronic tongue is much greater than that of humans", says Capparelli, who headed the research group responsible for the project.

Before getting lost in your imagination due to the possibility of nanotechnology interfering in our day-to-day routine, it is necessary to keep our feet on the ground and talk about one of the factors that limit advancement of the nanotechnology universe in real life. When it comes to capital volume invested in nanotechnology research and development, Brazil doesn't even come close to the United States, Japan and European countries.

"While the U.S. government invested US$ 1.4 billion in nanotechnology in 2006, Brazil invested only US$ 70 million over the 2001-2006 period", highlights Paulo Roberto Martins, from IPT. According to the researcher, this difference in investment will certainly increase the existing disparity. "However, it is important to point out that Brazil's level of investment in science and technology has been growing gradually these past years", added Pimenta, from UFMG.

For many researchers in this field, another dependence in Brazil for becoming competitive in technological development for the industrial sector is related to the need for joining and creating mutual support between the industrial sector and the state-owned nanotechnology research and development network. That is, something that has been said for a long, long time, but has not been carried out at the level desired, which is to establish partnerships between research centers of public universities and private initiative.

Today, the private sector's dependence on government investments in advanced technology research and development is significant, which situation is the opposite in other countries like the United States, where the percentage of investments by the private initiative exceed the budget earmarked for nanotechnology by the government. Only a cultural change in Brazil would be capable of transforming private initiative discourse into concrete actions of developing projects in partnership with the government, in a joint responsibility manner for the wins and losses in scientific research.

Even without favorable conditions, Brazil is sort of close to other countries in the race towards recent developments in applying nanotechnology to agribusiness. Therefore, it is necessary that the country invest to ensure a favorable position in this ranking of agribusiness market competitors. "The levels of investment today for the next few years is what will define whether Brazil will be able to keep up with this development pace", says Capparelli.

POPULAR NANOTECHNOLOGY

If the future has not yet arrived, it is necessary to live the present of nanotechnology. And this moment calls for efficient communication actions for approximating society to the yet unknown nanotechnology. Or else, the unknown becomes so feared that certain beliefs begin to surface among popular debate circles, which will be difficult to change as time goes by and research advances. Conclusion? Resistance and movements contrary to scientific and technological progress, supported by unfounded arguments.

Such as the already stated legend that nanoparticles can fly through space, without being seen and infecting people. This does not occur, because even during the preparation process of these nanoparticles, they tend to agglomerate. "Therefore, nanotechnology needs to be studied,

"Nano-curiosities"

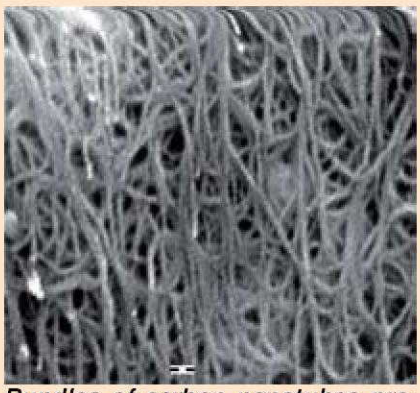
- A nanometer symbol is nm and equals 1×10^{-9} meters, or one billionth of a meter;
- The nano prefix comes from Greek and means "dwarf";
- An atom measures roughly two tenths of a nanometer;
- The diameter of a string of hair measures roughly 60 thousand nanometers;
- Chinese ink has existed for at least 2,000 years. Today, we know that this ink is nothing more than nanoparticles of graphite in a colloidal suspension of water and gum arabic;
- 100 nanometers is the typical scale of a virus;
- The stained glass works in ancient churches from the Middle Age already contained nanotechnology in their glass. To make the glass red, at the time, a recipe containing gold mixed with glass was used. Today, we know that it was nanoparticles of gold that were mixed with glass.

observed and reflected by society, not only by engineers and scientists who promote it. This will be important to implement, since the socio-environmental impact will be one of the limiting factors in the advancement of certain scientific research, as we already see around the world", alerts Paulo Roberto Martins, researcher at the Technological Research Institute (IPT) and coordinator of the Nanotechnology, Society and Environment Research Network (Renanosoma).

Direct or indirectly, every object of study and knowledge produced by the natural and exact sciences end up causing a direct impact on society and the environment. "And until now, the scope and speed by which they are being placed on the market, a large part of the products have been basically determined by business interests of large companies", points out Martins. Hence, the importance for nanotechnology knowledge to be popularized in a clear manner, regarding the use and risks of this technology for society and the environment.

According to a sample survey conducted in England about people's level of nanotechnology knowledge, only 29% said informed they had heard about the subject. However, only 14% were capable of formulating a phrase (without determining whether the phrase was right or wrong) about the concept of nanotechnology. "Of course there may be damages and risks, both for health and the environment. The issue is to know what these risks are, so that they can be overcome and provide safer benefits", says Pimenta.

Normally, the more technologically advanced companies, when initiatives such as nanotechnology are proposed, possess a security sheet in which are analyzed product related issues such as worker and end user safety, as well as environment protection. "We, at Klabin, utilize some chemical products in packaging that come into contact with foods. For such, we obtain all kinds of permits, from both the European and American markets, in order to safeguard this issue. This is what all companies should do in all segments", says Osvaldo Vieira, at Klabin.



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Bundles of carbon nanotubes produced by the electric arc method