Japan's World-Class Nanotechnology

A nanometer is one-billionth of a meter. The field of nanotechnology seeks to control materials on this microscopic scale. The sheer tininess of a nanometer may be more easily conceptualized through actual examples: A DNA spiral is just 2 nanometers in width, while the diameter of an atom measures roughly 0.1 nanometers. Nanotechnology is currently bringing about advances in a number of fields, from microfabrication and materials development to medical care, and Japan is actively involved in leading-edge research. Hiroaki Ishibashi of the Nikkan Kogyo Shimbun *spoke with Professor* ***Akihiko Tanioka*** *of the Graduate School of the Tokyo Institute of Technology, an expert in ultrafine fibers known as nanofibers, about the present and future of Japanese nanotechnology.*

Akihiko Tanioka

What kinds of nanotechnology research are being undertaken today?

Research is being conducted into many areas. Some of the best known are in electronics, notably LSI circuits and displays; biotechnology, such as research into proteins and DNA; and materials like the famous carbon nanotubes, or CNTs. Recently, attention has been focused on microelectromechanical systems, known as MEMS, which combine mechanical properties with electrical technologies in sensors, and on micro-total-analysis systems, which are miniature medical analysis devices.

Nanoprocessing, such as the grinding and cutting needed to create high-precision optical lenses and laser microfabrication, has become firmly established, as have measuring and evaluation technologies, such as microscopes for observing and analyzing the nanoworld. Nanotechnology is also used in everyday things, like cosmetics and high-performance sporting goods.

Japan is making a major contribution to the development of nanotech research around the world.

Japan has outstanding nanotech capabilities in a broad range of areas, from miniaturization of semiconductors and MEMS to the development of nanomaterials. Japan has traditionally excelled in processing and mass production technologies, and it has great expertise in analytical devices and other evaluation technologies. These skills naturally lead to strengths in the field of miniaturization. Japan has also been responsible for a number of groundbreaking discoveries.

In nanomaterials, for example, Sumio Iijima, director of the Nanotube Research Center, National Institute of Advanced Industrial Science and Technology, was the first to discover carbon nanotubes in 1991. CNTs have many outstanding characteristics, including tensile strength tens of times higher than steel and high electric and thermal conductivity. CNTs have already been commercialized as additives that enable plastics to conduct electricity and resist heat.

Japanese organizations have done a great deal of basic research on CNTs and are actively pushing ahead with development of CNTs with various special properties and research into more effective, lower-cost production methods. In terms of results, Japan is on a par with levels in many Western countries.

So what are the benefits of being able to control materials on the nanoscale?

The properties of a material will sometimes change at that scale. CNTs are built with carbon atoms but have properties not normally associated with carbon, such as high electrical conductivity and other characteristics of semiconductors. Because of their mechanical strength, there are plans for using them in cables for elevators leading to outer space. Miniaturization to the nanolevel has resulted in many new technologies that could not have been achieved before.

In the field of nanofiber research, one benefit is that air resistance becomes extremely low at the nano level. Used in air filters, these ultrafine fibers would barely decrease the speed of airflow, and the filters would be easier to maintain. Also, because of their high ratio of surface area to mass, the fibers can absorb many materials, boosting the efficiency of chemical reactions. This could lead to higher-performance purification devices and fuel cells.

Finally, there is the supermolecular effect. Because molecules in ultrafine fibers are arrayed very evenly, the fibers have high thermostability and conductivity, and there have been reports of antibacterial properties as well.

The same properties are also found in particles and sheets. As additives, even small volumes can have a big effect, possibly leading to a reduction in the use of materials. And because they are very difficult to see with the naked eye, they also offer the possibility of adding certain properties while preserving transparency.

What are some well-known nanotech applications?

CNTs probably claim the greatest number of researchers. Progress is being made in such applications as semiconductors, binders for electrodes for lithium-ion batteries, and additives for boosting the properties of plastics and metals. Research is also being conducted into drug delivery systems, which carry pharmaceuticals to specific, diseased parts of the body.

There are also a wide range of other applications in electronics, autos, medicine, and alternative energies. Multiwalled CNTs, which are inferior to single-walled CNTs in terms of properties but less expensive to make, are already in mass production by several Japanese manufacturers, including Showa Denko and Hodogaya Chemical.

Titanium oxide nanoparticles have applications as photocatalysts and in photovoltaic cells. CNTs in sheet form, called graphenes, are also expected to be useful in a variety of electronics-related applications. In recent years, a growing number of researchers have been looking into nanofibers. A US university has developed a technology for slicing CNTs to produce graphene. Graphene is in sheet form, which makes it easy to handle, and it's likely that Japan will also move forward with research for producing graphene through a similar process.

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How safe are nanomaterials?

Last year a paper was published that claimed that CNTs could cause mesothelioma, just like asbestos. However, counterarguments have also been advanced that test samples failed to completely remove impurities and that it is premature to conclude that there is a causal relationship. Researchers in Europe, the United States, and Japan have largely rejected the theory that CNTs cause mesothelioma. Nevertheless, nothing in this universe is entirely harmless, and so the safety of CNTs over the long term remains to be seen. That is why it's important to properly manage CNTs to prevent them from leaking into the atmosphere even after they have entered the market in various products.

Right now the important thing is to standardize and enhance the reliability of quality assurance and safety testing methods, which are currently approached differently at each company and laboratory. Standardization efforts must also be made at the international level. Without such standards, a new functional material developed in Japan may not be accepted widely in the US and European markets due to safety concerns. Action must be taken quickly so as not to hinder research into materials technology, an area of strength for Japanese researchers.

Will Japan's nanotech capabilities remain competitive in the future?

I think Japan will remain a top player purely in terms of technology, but other countries are better at developing applications. Going forward, Japanese universities will have to develop human resources with strong conceptual powers capable of making schematic designs for applications. HJ