Carbon Nanotube Industrial Applications

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Carbon nanotubes and other nanocarbons have electrical conductivity, thermal conductivity, and mechanical strength that conventional materials cannot match. With the diversity of their structure, these characteristic values can be achieved over an extremely wide range of conditions. Nanocarbons can be used in a wide range of fields, including chemical, electrical, and mechanical, and offer great promise in the 21st century as a basic material at the core of materials nanotechnology. The Research Center for Advanced Carbon Materials develops the superior characteristics of nanocarbons and links them to the creation of innovative products in a wide range of industrial fields, including IT, the environment, and biotech in an effort to help reinforce the competitiveness of Japanese industry.

1 Nanocarbon Technology Project

The Nanocarbon Technology Project is a five-year plan running until FY2006 and involving eight corporations, one association, and four universities as well as AIST (Figure 1). The project was started in October 2002 with the aim of advancing nanotube mass production technology and a broad range of applied research. From FY2003, it was reconstituted as one of the Focus 21 projects to invigorate economy. Two priority development themes, development of miniature, lightweight, and long-life mobile-type fuel cells using nanotubes as their electrodes, and electron device application technology using nanocarbon materials in semiconductor chip wiring, are receiving accelerated development.

The Research Center for Advanced Carbon Materials is involved in all Nanocarbon Technology Project research themes and is pursuing this research vigorously.

1-1 Development of catalysts for mass production

In the mass production of nanotubes, the catalyst holds the key. The Research Center for Advanced Carbon Materials has developed two types of catalysts. One is a nanometer-size metal particle catalyst (Figure 2). This is a new type of catalyst with many advantages: although nano-size, it can be made from a diverse range of metals, and can combine different metals. In the Nanocarbon Technology Project, this catalyst is being used in the gaseous phase reaction process under development by Nikkiso Co., Ltd. The other catalyst is based on the use of a catalyst carrier for supporting stably the 1-nm nano-particles. In the Nanocarbon Technology Project, this catalyst is being used in the fluidized bed method under development by Mitsubishi Heavy Industries, Ltd.

By the admixture of the so produced nanotubes with plastics, the mechanical strength and electrical and thermal conductivity of the material are improved. The development of applications of nanotubes as new catalyst materials, optical materials, and gas storage materials is in full swing.

1-2 Ultra-high sensitivity electron microscope

The success of the above nanocarbon technologies is underpinned by the development of an ultra-high sensitivity, high-resolution electron microscope, which has sub-nanoscale accuracy and is able to obtain information on the atomic arrangement, element identification, and electronic structure of nanocarbon materials. Our microscope, the sub-nanometer structure analysis system (Figure 3), is being improved, so that we have succeeded in

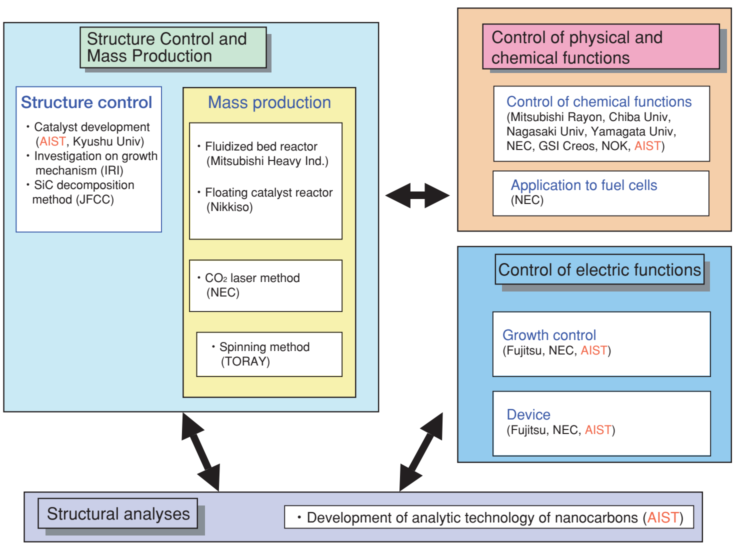

Figure 1. Nanocarbon Technology Project.

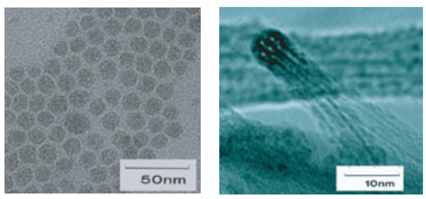

Figure 2. (left) Metal nanoparticle catalyst developed at the Center and (right) single-wall nanotubes synthesized using the catalyst.

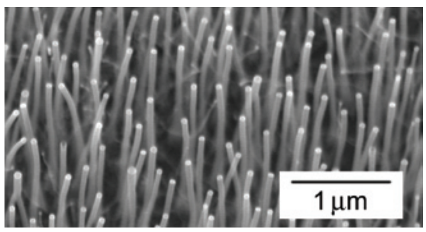

Figure 4. Oriented multi-wall nanotubes grown perpendicularly to the substrate.

revealing individual atoms on a nanocarbon.

2 Further development of carbon nanotube applications
From bulk use to using single nanotube characteristics

As research into nanotubes advances, research is shifting from methods of utilizing bulk nanotubes (in composite resins and FEDs, for example) to utilization of individual nanotube characteristics by combining with nano-processing technologies.

2-1 Application to electronics

The application of nanocarbon technologies to new transistors that surpass conventional silicon-based semiconductors holds great promise. The Center is carrying out research for realizing nanotube devices, utilizing our so far developed technology on catalyst and nanotube syntheses. By the reaction of nanometer-size catalyst with acetylene on a silicon substrate, the Center has succeeded in the fabrication of oriented nanotube film that grow vertically on a substrate, as in Figure 4. One promising application of these oriented films is as electron sources of field emission-type devices.

To extend this technology further to the development of nanotube devices, the Center has been working on developing technologies for more precise growth of nanocarbons. The Center has demonstrated that, by mixing catalysts with resist and forming catalyst patterns by lithography, it is able to selectively grow nanotubes (Figure 5). Through the development of micro-array technology using such catalyst reactions, the Center has opened the way to array nanotubes in lattice patterns on substrates for ultrafine non-volatile memories and field effect transistors.

2-2 Biotech applications

Nanocarbon tubes are 100% carbon and are compatible with cells and other organic matter. In addition, precision growth and position-direction control technologies developed for nanotube electronic device applications have potential for application in a number of areas in the biotech field.

For example, nanotubes have proved excellent characteristics as the probes of scanning probe microscopes (SPM), and application to cell manipulation technology looks very promising. Nanotubes can also be chemically modified and various molecules can be joined to give them DNA separation and protein recognition functions. In addition, expectations are also centering on such areas as the development of drug delivery systems that use nanotubes' interior space.

Toward further development

Still further development can be achieved by merging the carbon nanotube and other nanocarbon fabrication and processing technologies of the Research Center for Advanced Carbon Materials with the nano-material processing and cell processing technologies of other AIST research units. AIST hopes it can create large-scale nanocarbon business centers within AIST to help strengthen the competitiveness of Japanese industry.

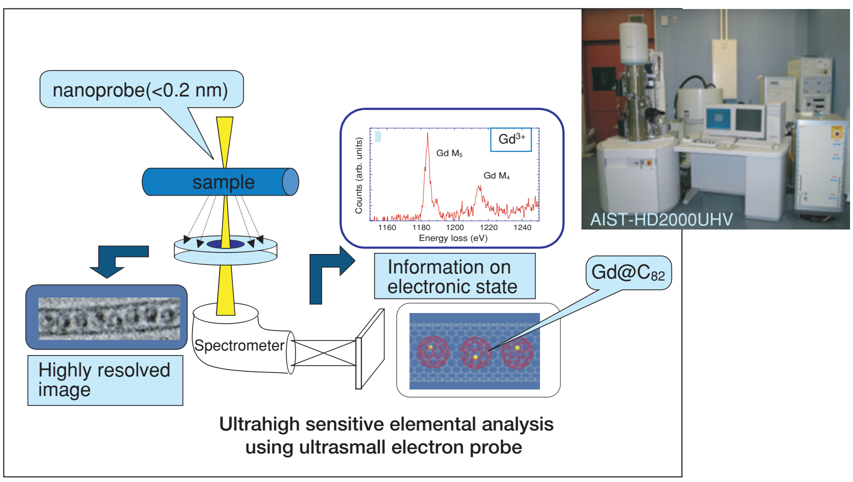

Figure 3. Sub-nanometer structure analysis system developed in the Center.

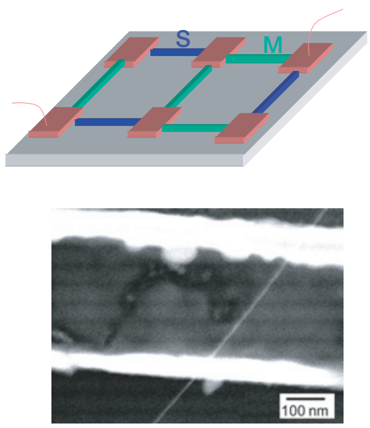

Figure 5. Towards the calculation with a carbon nanotube device.

(upper) Specimen of a carbon nanotube device (S: semiconductor nanotube, M: metallic nanotube). (lower) Nanotube grown on a catalyst pattern fabricated with lithography (a single-wall nanotube crosses over the catalyst patters)