New book highlights status of research into carbon nanotubes

June 24 2005

'Applied Physics of Carbon Nanotubes' is aimed at scientists, engineers and investors

Since their discovery 14 years ago, carbon nanotubes have captured the imagination of scientists and lay people alike. The science of nanotubes almost seems more science fiction than science. These structures, so minuscule they cannot be seen, are stronger than diamonds. They are formed from organic material but act as metals or semi-conductors. As such, nanotubes offer great potential in electronics, lasers and medicine.

To highlight the status of research on nanotubes, Slava V. Rotkin and Shekhar Subramoney have edited a new book, "Applied Physics of Carbon Nanotubes: Fundamentals of Theory, Optics and Transport Devices," which was just released by Springer. The book's 12 chapters are written by top researchers in the field.

Rotkin is an assistant professor of physics and a faculty member with Lehigh's Center for Advanced Materials and Nanotechnology. Subramoney, a researcher with Dupont Central Research and Development Laboratories, is co-chair of the nanotube section of the Fullerenes, Nanotubes and Carbon Nanostructures Division of the Electrochemical Society Inc.

The book offers basic information about the properties and characterization of nanotubes as well as information about new research tools, like nanotube optical spectroscopy, some of which are only 18 months old. With its emphasis on applications, the book is intended for scientists, engineers and investors.

Nanotubes are sheets of carbon atoms connected in a honeycomb-like pattern that are rolled into tiny cylinders one nanometer in diameter. One nanometer is one one-billionth of a meter, or one 10,000th the thickness of a human hair. The properties of the tube depend on how the cylinder is rolled, just as the properties of chemical elements depend on their weight.

Rotkin and Subramoney's book covers four main areas of nanotube research: theories and modeling, synthesis and characterization, optical spectroscopy, and transport and electromechanical applications.

The first section, on the theories and modeling of nanotubes, includes a chapter by Rotkin titled "From Quantum Models to Novel Effects to New Applications: Theory of Nanotube Devices." Rotkin's research has focused on designing a novel type of electronic switch called a metallic field-effect transistor. He reported a breakthrough in this area in an article in Applied Physics Letters last year.

In the second section, readers learn about nanotube properties, which vary widely, and about how nanotubes are made, identified and classified. Given the right chemical conditions, nanotubes grow on their own. So far, the longest nanotubes created have been measured in centimeters.

The third section describes new work on the use of optical spectroscopy to study nanotechnology. This revolutionary new method, Rotkin says, uses light to identify the properties of a nanotube. The progress in nanotube synthesis, their separation and research in optical spectroscopy will result in developing "robust tools to bring nanotubes to the tables of engineers," he says.

Optical spectroscopy allows researchers to study how nanotubes "breathe," or vibrate, by regularly expanding and contracting. Like fingerprints, each nanotube has a unique pulse. The pulsing nanotubes reflect light waves like a car reflects the sound waves from a police radar gun. As the radar gun measures a car's speed by the frequency of the sound waves it reflects, scientists determine the pulse of nanotubes by measuring the frequency of the light waves they give off. From the pulse they can then identify a nanotube's properties even if it is invisible.

The final section of the book discusses electronic applications of nanotubes. Although uses of nanotubes are only just beginning to explored, the field holds great promise. Already, Samsung electronics and Motorola are using nanotubes in flat panel display screens. Nanotube field emitters are "better, cheaper and longer lasting" than the metal tip emitters used before, Rotkin says.

"Electronic applications of nanotubes in their childhood," Rotkin says, "are much, much better than silicon devices were in their childhood."

Nanotubes, which emit light, may also be used for lasers and other optoelectronic devices. Scientists believe the nanotubes could increase the range of laser power, making them useful for detecting chemical and biological weapons.

Another chapter discusses the mechanical properties and future uses of nanotubes. Some scientists believe that nanotubes could be used for a space elevator. Nanotubes are the only material strong enough to support an elevator extending miles into space from the earth's surface. If scientists can make a nanotube long enough, then the elevator would be possible.

Nanotubes could also be used to treat sickle-cell anemia and other diseases resulting from malfunctioning ion channels. Since all living organisms are constructed from carbon, the nanotubes would not be rejected by the body.

The book contains a chapter on DNA and nanotube interactions that was written by Anand Jagota, professor of chemical engineering and director of Lehigh's bioengineering and life sciences program. When nanotubes are created, they form a dense clump, like a box of uncooked spaghetti noodles, Rotkin says. To separate nanotubes, researchers originally added soap, which peeled nanotubes apart. Then strong acceleration caused the heavier nanotubes to fall and the smaller ones to float.

The process worked but not without drawbacks. The soap chemically changes nanotubes. Jagota and other researchers are looking for other ways to separate nanotubes. By wrapping DNA and proteins around the nanotubes, Jagota achieved the same result as soap without the chemical difficulties.

Jagota's work in this area complements Rotkin's current investigations into the theoretical aspects of DNA-nanotube interactions.

Source: Lehigh University