True properties of carbon nanotubes measured

August 15 2008

For more than 15 years, carbon nanotubes (CNTs) have been the flagship material of nanotechnology. Researchers have conceived applications for nanotubes ranging from microelectronic devices to cancer therapy. Their atomic structure should, in theory, give them mechanical and electrical properties far superior to most common materials.

Unfortunately, theory and experiments have failed to converge on the true mechanical properties of CNTs. Researchers at Northwestern University recently made the first experimental measurements of the mechanical properties of carbon nanotubes that directly correspond to the theoretical predictions.

Carbon nanotubes are cylindrical structures usually less than 30 nanometers in diameter and several microns long. Their small size makes them very strong but at the same time quite difficult to test individually; as a result, experiments typically deviate widely from predictions based on quantum mechanics.

"Imaging and measurement resolutions as well as atomic structural ambiguities (defects) obscured the results of most experiments and provided unreliable mechanical predictions," said Horacio Espinosa, a professor of mechanical engineering at Northwestern's McCormick School of Engineering and Applied Science.

Espinosa and his group at Northwestern have resolved these issues using a nanoscale material testing system based on microelectromechanical system (MEMS) technology. This system allows electronic measurements of load and displacement during a test, which is performed inside a transmission electron microscope to provide real-time atomic imaging.

"This method removes all ambiguity from testing results," Espinosa said. "We can be certain of all the quantities we have measured, and the results match quantum mechanics predictions very well."

Espinosa collaborated with George Schatz, Morrison Professor of Chemistry in Northwestern's Weinberg College of Arts and Sciences, as well as with Peter Zapol, a physicist at Argonne National Laboratory. This work is published online in *Nature Nanotechnology* and will appear in print in the journal's October issue.

Further research also was reported in the same article regarding the effect of electron irradiation on these materials. One would think that irradiation would degrade the atomic structure of the material, but the researchers found the opposite.

"Irradiating a multiwalled carbon nanotube with an intense electron beam actually forms bonds among the shells of the tube. This is like combining multiple nanotubes into one to form a stronger structure," said lead author Bei Peng, who recently received his doctoral degree from Northwestern under Espinosa's supervision.

This phenomenon also has been theorized in the past, and the research confirms that the properties of multiwalled nanotubes can easily and controllably be altered by electron irradiation.

The irradiation work was supplemented by detailed atomistic modeling. Using computer simulations of the atomic structure of the nanotubes, the team of researchers was able to isolate the mechanism of strengthening due to irradiation.

"The same procedure used to strengthen individual multiwalled nanotubes by irradiation may also be used to link together individual nanotubes into a bundle," said Mark Locascio, a doctoral student co-author of the paper.

This mechanism of crosslinking is a promising method for creating much larger nanotube-based structures. When nanotubes are packed together, they typically have very weak interactions along their surfaces; a spun nanotube rope would not be nearly as strong as its nanoscale constituents. However, irradiation may be the key to improving these interactions by inducing covalent bonds between tubes. If the properties of nanotubes can be scaled up to macroscale ropes and fibers, they may become a viable option for any high-strength application. This could include large cables for applications in industry or infrastructure, as well as smaller threads for lightweight woven fabrics, ballistic armors or composite reinforcement.

The *Nature Nanotechnology* paper was authored by Espinosa, Peng, Locascio, Zapol and Schatz as well as Steven Mielke, a postdoctoral researcher, and Shuyou Li, an electron microscopist, both at Northwestern.

Source: Northwestern University

Citation: True properties of carbon nanotubes measured (2008, August 15) retrieved 26 April 2024 from https://phys.org/news/2008-08-true-properties-carbon-nanotubes.html