Engineers Create Super Compressible Carbon Nanotube Foam-like Films

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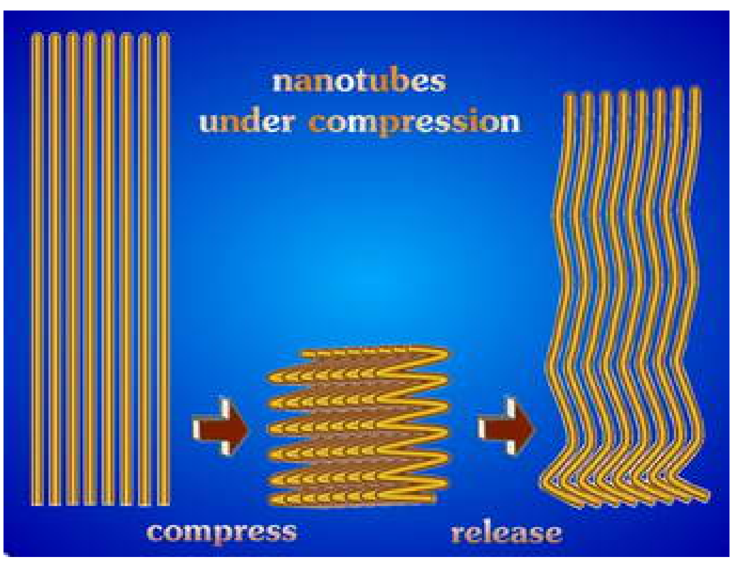
Carbon nanotubes have enticed researchers since their discovery in 1991, offering an impressive combination of high strength and low weight. Now a new study suggests that they also act like super-compressible springs, opening the door to foam-like materials for just about any application where strength and flexibility are needed, from disposable coffee cups to the exterior of the space shuttle.

Image: Buckled carbon nanotubes under compression. Credit: Cao/RPI

The research, which is reported in the Nov. 25 issue of the journal *Science*, shows that films of aligned multiwalled carbon nanotubes can act like a layer of mattress springs, flexing and rebounding in response to a force. But unlike a mattress, which can sag and lose its springiness, these nanotube foams maintain their resilience even after thousands of compression cycles.

First created in 1991, carbon nanotubes are among new forms of carbon called fullerenes because their sides mimic the geodesic domes designed by famed mathematician Buckminster Fuller. Nanotubes are infinitesimal cylinders with single or multiple walls that can be only a few nanometers wide.

Carbon nanotubes are very strong. Mixed with conventional materials, they are already improving the performance of concrete and other products. They also have electrical and magnetic characteristics expected to make them useful in microchips and other electronics.



Right: Illustration of a nanotube array compressed to folded springs and then rebounding.

In foams that exist today, strength and flexibility are opposing properties: as one goes up, the other must go down. With carbon nanotubes, no such tradeoff exists.

"Carbon nanotubes display an exceptional combination of strength, flexibility, and low density, making them attractive and interesting materials for producing strong, ultra-light foam-like structures," says Pulickel Ajayan, the Henry Burlage Professor of Materials Science and Engineering at Rensselaer Polytechnic Institute and coauthor of the paper.

Carbon nanotubes are made from graphite-like carbon, where the atoms are arranged like a rolled-up tube of chicken wire. Ajayan and a team of researchers at the University of Hawaii at Manoa and the University of Florida subjected films of vertically aligned nanotubes to a battery of tests, demonstrating their impressive strength and resilience.

"These nanotubes can be squeezed to less than 15 percent of their normal lengths by buckling and folding themselves like springs," says lead author Anyuan Cao, who did much of the work as a postdoctoral researcher in Ajayan's lab and is now assistant professor of mechanical engineering at the University of Hawaii at Manoa. After every cycle of compression, the nanotubes unfold and recover, producing a strong cushioning effect.

The thickness of the nanotube foams decreased slightly after several hundred cycles, but then quickly stabilized and remained constant, even up to 10,000 cycles. When compared with conventional foams designed to sustain large strains, nanotube foams recovered very quickly and exhibited higher compressive strength, according to the researchers.

Throughout the entire experiments, the foams did not fracture, tear, or collapse.

And their intriguing properties do not end there. Nanotubes also are stable in the face of extreme chemical environments, high temperatures, and humidity all of which adds up to a number of possible applications, from flexible electromechanical systems to coatings for absorbing energy.

The foams are just the latest in a long line of nanotube-based materials that have been produced through collaborations with AjayanTMs lab, all of which have exhibited tantalizing properties. Ajayan and his colleagues from the University of Hawaii at Manoa recently developed tiny brushes with bristles made from carbon nanotubes, which could be used for tasks that range from cleaning microscopic surfaces to serving as electrical contacts. And in collaboration with researchers from the University of Akron, Ajayan and his team created artificial gecko feet with 200 times the sticking power of the real thing.

Source: Rensselaer Polytechnic Institute

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