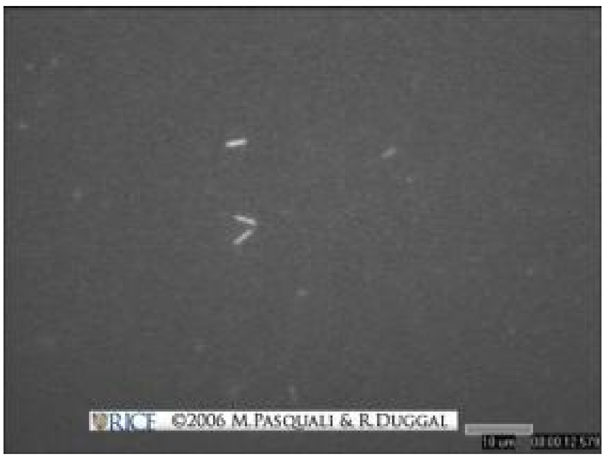
Movies show nanotubes bend like sluggish guitar strings

June 27 2006



In an exciting advance in nanotechnology imaging, Rice University scientists have discovered a way to use standard optical microscopes and video cameras to film individual carbon nanotubes – tiny cylinders of carbon no wider than a strand of DNA. The movies show that nanotubes can be "plucked" by individual molecules of water and made to bend like guitar strings.

"Nanotubes are fairly stiff, and when they are long enough, the bombardment by the surrounding water molecules makes them bend in harmonic shapes, just like the string of a guitar or a piano," said lead researcher Matteo Pasquali, associate professor of chemical and biomolecular engineering and chemistry, and co-director of Rice's Carbon Nanotechnology Laboratory.

The results, which are due to appear in an upcoming issue of *Physical Review Letters*, were published online June 23.

Pasquali said the analogy with stringed instruments doesn't completely fit with the nanoscale world. Unlike the guitar string, for example, the carbon nanotube is plucked randomly in many places at the same time. Also, it cannot resonate like the guitar string because the nanotube has too little mass, and its vibrations die quickly because it's surrounded by viscous liquid.

Carbon nanotubes are hollow, hair-like strands of pure carbon that are 100 times stronger than steel but weigh only one sixth as much. Nanotubes are one nanometer, or one billionth of a meter, wide. Human hair, by comparison, is about 80,000 nanometers wide.

Nanotubes tend to clump together. To isolate individual tubes, Pasquali and doctoral student Rajat Duggal, now a research engineer at General Electric Co., put clumps of tubes into a mixture of water and a soap-like surfactant called sodium dodecyl sulphate, or SDS. When the nanotube clumps were broken apart with ultrasonic sound waves, the SDS surrounded the individual nanotubes and held them apart, in the same way laundry detergent surrounds and separates dirt particles in the wash.

In order to see individual nanotubes with a standard optical microscope, like those found in most biological laboratories, Pasquali and Duggal added a common red fluorescent dye that's often used to stain cells. The dye, which attached itself to the SDS surrounding each nanotube, glows brightly enough to be seen with the naked eye under a microscope.

"I had been working on fluorescence visualization of DNA, and other students in the lab were working on nanotubes," Duggal recalled. "A colleague was disposing of nanotube suspensions after an experiment, and I asked them to spare me a vial so I could try them with an optical microscope. I thought of decorating the nanotubes with a fluorescent dye that would prefer to be with the SDS rather than the water, and when I looked under the microscope – to my delight – I found bright dancing nanotubes."

Duggal said scientists have used electron microscopes to observe the underdamped vibrations of nanotubes in vacuum, but his and Pasquali's technique gives scientists the ability to see how nanotubes behave in liquids in real time.

Pasquali and Duggal videotaped dozens of nanotubes at 30 frames per second. A frame-by-frame analysis of the tapes revealed harmonic bending in several nanotubes that were 3-5 microns long and showed that the measured amplitude of the bending motion is consistent with earlier predictions of Rice materials scientist Boris Yakobson, professor of mechanical engineering and materials science and of chemistry.

Pasquali said the method works with other surfactants and it may be useful for life scientists who want to find out how nanotubes interact with cells, biomolecules and other biological entities.

"Our method doesn't provide the sensitivity or precision you get with the infrared, single-nanotube imaging methods developed last year by Rice chemist Bruce Weisman and doctoral student Dmitri Tsyboulski, but the equipment we need is less expensive," Pasquali said. "It's akin to the difference between playing a Stadivarius and playing a common violin."

Source: Rice University