Chemical & Engineering News

Latest News

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Electron Microscopy

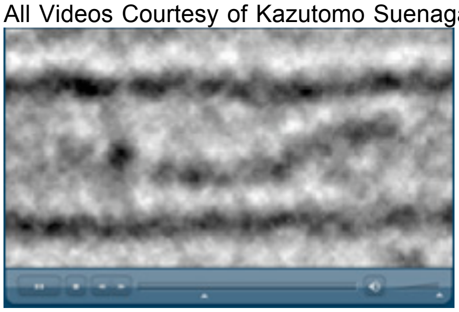
Molecular Close-Up

Images show motions of single, confined molecule

Ron Dagani

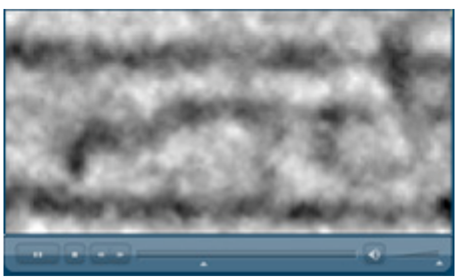
Videos

All Videos Courtesy of Kazutomo Suenaga, Hiroyuki Isobe, and Eiichi Nakamura



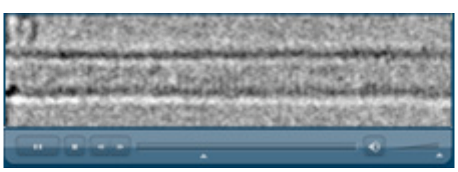
Transmission electron microscope video shows conformational changes in a carborane molecule bearing two alkyl chains that is confined inside a carbon nanotube 1.2 nm in diameter.

Launch Video*



TEM video shows conformational changes in a carborane molecule bearing two alkyl chains that is wobbling inside a carbon nanotube 1.3 nm in diameter. The molecule appears to be attached to a defect in the nanotube wall.

Launch Video*

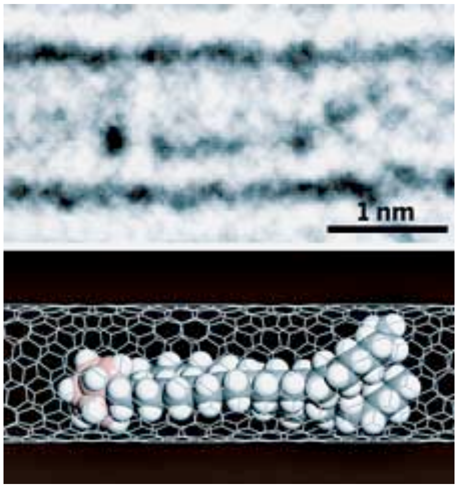


A carborane bearing two alkyl chains moves left, then right, along the length of a carbon nanotube over a period of about 60 seconds.

Launch Video*

* Macromedia Flash Player 8 is required to view videos.

By confining a single, small organic molecule inside a narrow, single-walled carbon nanotube, scientists in Japan have been able to use transmission electron microscopy (TEM) to follow the molecule's motions with near-atomic resolution (*Science,* DOI: 10.1126/science.1138690).



Courtesy of Kazutomo Suenaga, Hiroyuki Isobe, and Eiichi Nakamura
TEM image (top) and molecular model (bottom) show the conformation of a carborane bearing two alkyl chains inside a carbon nanotube. Boron atoms are pink; hydrogen, white; carbon, gray.

"What we did is like trapping a flying bee in a glass tube to see how the wings move," remarks Eiichi Nakamura, the chemistry professor at the University of Tokyo who led the discovery team supported by the Japan Science & Technology Agency. In a vacuum, small molecules tend to move too fast, he explains, but trapping them in a nanotube slows them down enough to allow close observation.

Nakamura and coworkers studied several guest molecules, including *ortho*-carboranes bearing two adjacent alkyl chains up to 22 carbon atoms long. They vaporized the molecules and allowed them to diffuse into the nanotubes in vacuum. By irradiating the nanotubes with electrons at roughly 2-second intervals, the researchers were able to capture the molecules' motions in stop-action videos. These videos reveal the molecule moving along the length of the nanotube as well as undergoing conformational changes. The images show that an alkyl tail sometimes momentarily sticks to the nanotube wall. "You can also study the entanglement of the tails" to get a measure of the competition between tail-tail and tail-wall attractions, comments chemist Roald Hoffmann of Cornell University.

"This is the most direct visualization of the motion of a molecule inside a nanotube" that he's seen, Hoffmann tells C&EN, and it's "damn clever."

Two reviewers of the paper were similarly impressed, calling the work "an exciting achievement" and "a very ambitious study" offering "amazing" data.

TEM has been used previously to image molecules such as proteins and fullerenes. Scientists have attempted to image small organic molecules in thin films, but these tend to decompose under electron impact, partly due to heat formation, Nakamura points out. "What we discovered is that a single molecule in a nanotube in vacuum survives TEM conditions for some time."

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