Nanotubes weigh the atom

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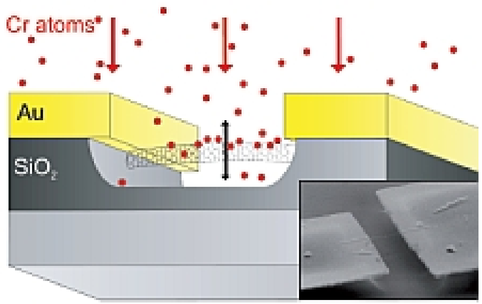

Diagram and insert image of a carbon nanotube. © CARDEQ

(PhysOrg.com) -- How can you weigh a single atom? European researchers have built an exquisite new device that can do just that. It may ultimately allow scientists to study the progress of chemical reactions, molecule by molecule.

Carbon nanotubes are ultra-thin fibres of carbon and a nanotechnologist's dream.

They are made from thin sheets of carbon only one atom thick - known as graphene - rolled into a tube only a few nanometres across. Even the thickest is more than a thousand times thinner than a human hair.

Interest in carbon nanotubes blossomed in the 1990s when they were found to possess impressive characteristics that make them very attractive raw materials for nanotechnology of all kinds.

"They have unique properties," explains Professor Pertti Hakonen of Helsinki University of Technology. "They are about 1000 times stronger than steel and very good thermal conductors and good electrical conductors."

Hakonen is coordinator of the EU-funded CARDEQ project which is exploiting these intriguing materials to build a device sensitive enough to measure the masses of atoms and molecules.

Vibrating strings

A carbon nanotube is essentially an extremely thin, but stiff, piece of string and, like other strings, it can vibrate. As all guitar players know, heavy strings vibrate more slowly than lighter strings, so if a suspended carbon nanotube is allowed to vibrate at its natural frequency, that frequency will fall if atoms or molecules become attached to it.

It sounds simple and the idea is not new. What is new is the delicate sensing system needed to detect the vibration and measure its frequency. Some nanotubes turn out to be semiconductors, depending on how the graphene sheet is wound, and it is these that offer the solution that CARDEQ has developed.

Members of the consortium have taken the approach of building a semiconducting nanotube into a transistor so that the vibration modulates the current passing through it. "The suspended nanotube is, at the same time, the vibrating element and the readout element of the transistor," Hakonen explains.

"The idea was to run three different detector plans in parallel and then select the best one," he says. "Now we are down to two. So we have the single electron transfer concept, which is more sensitive, and the field effect transistor concept, which is faster."

Single atoms

Last November, CARDEQ partners in Barcelona reported that they had sensed the mass of single chromium atoms deposited on a nanotube. But Hakonen says that even smaller atoms, of argon, can now be detected, though the device is not yet stable enough for such sensitivity to be routine. “When the device is operating well, we can see a single argon atom on short time scales. But then if you measure too long the noise becomes large.”

CARDEQ is not alone in employing carbon nanotubes as mass sensors. Similar work is going on at two centres in California - Berkeley and Caltech - though each has adopted a different method to measuring the mass.

All three groups have announced they can perform mass detection on the atomic level using nanotubes, but CARDEQ researchers provided the most convincing data with a clear shift in the resonance frequency.

But a single atom is nowhere near the limit of what is possible. Hakonen is confident they can push the technology to detect the mass of a single nucleon - a proton or neutron.

“It’s a big difference,” he admits, “but typically the improvements in these devices are jump-like. It’s not like developing some well-known device where we have only small improvements from time to time. This is really front-line work and breakthroughs do occur occasionally.”

Biological molecules

If the resolution can be pared down to a single nucleon, then researchers can look forward to accurately weighing different types of molecules and atoms in real time.

It may then become possible to observe the radioactive decay of a single nucleus and to study other types of quantum mechanical phenomena.

But the real excitement would be in tracking chemical and biological reactions involving individual atoms and molecules reacting right there on the vibrating nanotube. That could have applications in molecular biology, allowing scientists to study the basic processes of life in unprecedented detail. Such practical applications are probably ten years away, Hakonen estimates.

“It will depend very much on how the technology for processing carbon nanotubes develops. I cannot predict what will happen, but I think chemical reactions in various systems, such as proteins and so on, will be the main applications in the future.”

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More information: www.cardeq.eu/

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