New study on properties of carbon nanotubes, water could have wide-ranging implications

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A fresh discovery about the way water behaves inside carbon nanotubes could have implications in fields ranging from the function of ultra-tiny high-tech devices to scientists' understanding of biological processes, according to researchers from the University of North Carolina at Chapel Hill.

The findings, published in the Oct. 3, 2008, issue of the journal *Science*, relate to a property of so-called "nano-confined" water – specifically, whether hollow carbon nanotubes take in the liquid easily or reluctantly, depending on their temperature.

As well as shedding light on the characteristics of human-made nanomaterials, researchers note that such properties are relevant to the workings of biological structures and phenomena which also function at nano-scales.

The team of scientists, led by Yue Wu, Ph.D., professor of physics in the UNC College of Arts and Sciences, examined carbon nanotubes measuring just 1.4 nanometers in diameter (one nanometer is a billionth of a meter). The seamless cylinders were made from rolled up graphene sheets, the exfoliated layer of graphite.

"Normally, graphene is hydrophobic, or 'water hating' – it repels water in the same way that drops of dew will roll off a lotus leaf," said Wu. "But we found that in the extremely limited space inside these tubes, the structure of water changes, and that it's possible to change the relationship between the graphene and the liquid to hydrophilic or 'water-liking'."

The UNC team did this by making the tubes colder. Using nuclear magnetic resonance – similar to the technology used in advanced medical MRI scanners – they found that at about room temperature (22 degrees centigrade), the interiors of carbon nanotubes take in water only reluctantly.

However, when the tubes were cooled to 8 degrees, water easily went inside. Wu said this shows that it is possible for water in nano-confined regions – either human-made or natural – to take on different structures and properties depending on the size of the confined region and the temperature.

In terms of potential practical applications, Wu suggested further research along these lines could impact the design of high-tech devices (for example, nano-fluidic chips that act as microscopic laboratories), microporous sorbent materials such as activated carbon used in water filters, gas masks, and permeable membranes.

"It may be that by exploiting this hydrophobic-hydrophilic transition, it might be possible to use changes in temperature as a kind of 'on-off' switch, changing the stickiness of water through nano-channels, and controlling fluid flow."

Wu also noted that this research relates to scientists' understanding of the workings of many building blocks of life (such as proteins, whose structures also have nano-confined hydrophobic regions) and how their interaction with water plays a role in how they function. For example, such interactions play an important role in the process known as "protein folding," which determines a protein's eventual shape and characteristics. Misfolded proteins are believed to be a cause of several neurodegenerative and other diseases.

"We don't fully understand the mechanisms behind protein unfolding upon cooling," Wu said. "Could this kind of cooling-induced hydrophobic-hydrophilic transition play a role? We don't know but it's worth investigating."

Source: University of North Carolina at Chapel Hill