New Nanotechnology Effect: Moving Water Molecules by Light

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A team of researchers at Arizona State University has demonstrated the ability to move water molecules by light -- a phenomenon they believe could have widespread use in analytical chemistry and possibly pharmaceutical research. The discovery could have an important effect on the fledgling field of microfluidics, said Tony Garcia, an associate professor in the Harrington Department of Bioengineering.

The use of an ordinary beam of light to move water around without the need for potentially damaging electric fields, air bubbles (which can denature proteins), or moving microscopic mechanical pump parts (which are expensive to make and difficult to repair) could significantly aid development of microfluidic devices, which are themselves tiny, sophisticated devices that can analyze samples.

"This discovery can speed the development of microfluidic devices," Garcia said. "These devices could require only one drop of blood for a battery of 20 to 30 tests, with results provided in the time spent waiting to consult with the physician," Garcia explained. "They also could help pharmaceutical companies screen for a new drug by allowing for tests to be run on an extremely small scale and in simultaneous fashion."

The ASU researchers discovered an amplification effect of the surface change in water contact angles through nanotechnology. Details of their work will appear in a paper titled "Lotus Effect Amplifies Light-Induced Contact Angle Switching," in the Journal of Physical Chemistry. It is now available from the Journal's online ASAP service (go to pubs.acs.org/journals/jpcbfk/ and click on articles ASAP).

In addition to Garcia, the team includes Devens Gust, professor of chemistry and biochemistry; Tom Picraux, professor of chemical and materials engineering; Mark Hayes, associate professor of chemistry and biochemistry; Rohit Rosario, a postdoctoral researcher in the Harrington Department of Bioengineering; Jennifer Taraci, a postdoctoral researcher in chemical and materials engineering; and graduate students Teresa Clement and Jeff Dailey working in Picraux's group.

In nanotechnology, devices are designed from the molecular level up. As the overall size of these devices shrink, the nature of the surface plays an increasingly important role because a greater percentage of the molecules in a nanotech device reside on the surface. The ability to manipulate surface molecules using everyday means, such as shining a light or connecting to a battery, becomes very important because ordinary tools like pumps and valves are hard to make on a nano scale.

The ASU team theorized and then proved that a change in water wettability – the ability of the water molecules to easily move across a surface – when induced by light can be significantly amplified through a combination of very high nanoscale roughness and chemically coating the surface with molecules.

"What we found was the 'sweet spot' in surface roughness where the amplification effect was the greatest," Garcia said. "Our theory showed where the sweet spot would be, meaning the optimal roughness of the surface, and then we proved it."

"We have been working on the problem of using light to move microscopic amounts of water around for drug delivery and microanalysis applications," said Tom Picraux. "However, we were stymied by the vexing problem of the combined small effect created and the high degree of attraction that water retains on even a very waxy, or hydrophobic, flat surface.

"Our advance came when we realized that if the surface was roughened at the nanoscale, not only would we obtain the 'lotus leaf effect,' but we could also magnify the small change in water repelling controlled by light to a level that can overcome the hysteresis, or the attraction, that causes water to stick even when a drop is pushed along, " Picraux said. "Rohit Rosario mathematically derived the theory for surface change amplification and proved it in the laboratory."

The lotus leaf effect is a fairly well known phenomenon that combines the microscopically rough surface of the plant's leaves with a waxy chemical coating and leads to high water repellency and self-cleaning of the surface. It is already employed commercially in stain repelling pants.

What appears to aid this effect is tiny 'nanowires' on the surface of a material, the ASU researchers said. Nanowires are small, high-aspect-ratio wire-like structures composed of semiconducting and other materials. Typical wire dimensions are tens to hundreds of nanometers in diameter and micrometers in length.

"We have used our expertise in nanowire growth to influence a new physical property for nanowire surfaces, namely the behavior and motion of fluids," Picraux said. "While nanowires give exquisite control over the surface for creating extremely rough surfaces, we point out there are many practical ways to nanostructure the surface once the basic principles of surface amplification of switching are understood."

The ASU team now is working to design a device that can move drugs dissolved in water, or droplets of water and samples that need to be tested for environmental or biochemical analyses.

Another potential application is reducing the amount of proteins or enzymes needed for testing during drug development. Usually, making and purifying these candidate drugs is time-consuming and small amounts are made at a time.

In a microfluidic device, the cells, DNA, or proteins that are used to test the candidate drug efficacy also are reduced so that a small amount of candidate drug can be mixed with its target and the result recorded. This reduces the time needed to screen all of the drug candidates and allows as many tests as possible to be run simultaneously.

"The payoff of this scientific collaboration is the first demonstrated ability to use a beam of light to move microdroplets of water around on surfaces, in extremely small channels or place them in predetermined positions for analysis," Garcia said. "Other nanotechnology researchers can follow our lead and look at ways of magnifying the triggering of surface changes through electric fields or through solution conditions such as temperature or acidity."

Source: Arizona State University

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