Molecular machines drive plasmonic nanoswitches

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Plasmonics -- a possible replacement for current computing approaches -- may pave the way for the next generation of computers that operate faster and store more information than electronically-based systems and are smaller than optically-based systems, according to a Penn State engineer who has developed a plasmonic switch.

"If plasmonics are realized, the future will have circuits as small as the current electronic ones with a capacity a million times better," said Tony Jun Huang, James Henderson assistant professor of Engineering Science and Mechanics. "Plasmonics combines the speed and capacity of photonic -- light based -- circuits with the small size of electronic circuits."

Currently, electronic circuits can be made very small, but they are limited by their capacity and the speed that information can travel in the circuits. Optical circuits send information at the speed of light, but the size is large, limited by the light's wavelength. Plasmonics combines the best of electronic and optical circuits and can transmit electrons and light at the same time using the surface of the device.

Huang's team created a plasmonic switch from switchable bistable rotaxanes. Rotaxanes are complex molecules that consist of a dumbbell shape with a ring or rings encircling the shaft and are sometimes called molecular machines. The ring can either move from one end of the barbell to the other or rotate around the shaft. Changes in molecular shape are the basis of the plasmonic switch.

Computers, in their simplest form, are machines that can say yes or no multiple times to transfer information. The motion of a molecule can serve the same purpose as the on off switch on a light.

The researchers attached their molecular machines to gold-coated nanodiscs fabricated on glass. The machines were attached with disulfide functional groups. The dumbbell shaped molecules have two areas of the shaft primed with two different chemicals. The ring is initially drawn to circle at one primed area. When the chemical there is oxidized, the ring is repelled and moves to the other primed area, flipping the switch. The process is reversible, so the ring returns to its original state to switch on again later. When the molecule moves, it changes the surface plasmon resonance in that tiny area of the metal where it is attached. This change in resonance is what would send the signal on the circuit. The plasmonic switch that Huang and his team developed is not yet part of a circuit.

"Plasmonic circuits have not yet been achieved," said Huang. "In the past, the plasmonic devices made were all passive." These devices were used as light sources, lenses and waveguides

Huang's switches are activated by a chemical process, however, this is not the optimal choice for a working circuit.

"We believe that the chemically-driven redox process can be replaced with direct electrical or optical stimulation, a logical development that would establish a technological basis for the production of a new class of molecular-machine-based active plasmonic components for solid-state nanophotonic integrated circuits with the potential for low-energy and ultra small operations," the researchers state in a recent issue of *Nano Letters*.

In essence, plasmonic devices would allow computers to get faster and have more memory storage in smaller spaces. Storage of as much as 1,000 movies on a typical USB drive would be possible. Huang suggests that applications like YouTube, which are very popular but have terrible resolution, could become places to see high-resolution images.

"We are in the very beginning of this field," said Huang. "Creation of a plasmonic circuit is probably five years away."

Source: Penn State

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