New nanoscale electrical phenomenon discovered

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At the scale of the very small, physics can get peculiar. A University of Michigan biomedical engineering professor has discovered a new instance of such a nanoscale phenomenon -- one that could lead to faster, less expensive portable diagnostic devices and push back frontiers in building micro-mechanical and "lab on a chip" devices.

In our macroscale world, materials called conductors effectively transmit electricity and materials called insulators or dielectrics don't, unless they are jolted with an extremely high voltage. Under such "dielectric breakdown" circumstances, as when a bolt of lightening hits a rooftop, the dielectric (the rooftop in this example) suffers irreversible damage.

This isn't the case at the nanoscale, according to a new discovery by Alan Hunt, an associate professor in the Department of Biomedical Engineering. Hunt and his research team were able to get an electric current to pass nondestructively through a sliver of glass, which isn't usually a conductor.

A paper on the research is newly published online in *Nature Nanotechnology*.

"This is a new, truly nanoscale physical phenomenon," Hunt said. "At larger scales, it doesn't work. You get extreme heating and damage.

"What matters is how steep the voltage drop is across the distance of the dielectric. When you get down to the nanoscale and you make your dielectric exceedingly thin, you can achieve the breakdown with modest voltages that batteries can provide. You don't get the damage because you're at such a small scale that heat dissipates extraordinarily quickly."

These conducting nanoscale dielectric slivers are what Hunt calls liquid glass electrodes, fabricated at the U-M Center for Ultrafast Optical Science with a femtosecond laser, which emits light pulses that are only quadrillionths of a second long.

The glass electrodes are ideal for use in lab-on-a-chip devices that integrate multiple laboratory functions onto one chip just millimeters or centimeters in size. The devices could lead to instant home tests for illnesses, food contaminants and toxic gases. But most of them need a power source to operate, and right now they rely on wires to route this power. It's often difficult for engineers to insert these wires into the tiny machines, Hunt said.

"The design of microfluidic devices is constrained because of the power problem," Hunt said. "But we can machine electrodes right into the device."

Instead of using wires to route electricity, Hunt's team etches channels through which ionic fluid can transmit electricity. These channels, 10 thousand times thinner than the dot of this "i," physically dead-end at their intersections with the microfluidic or nanofluidic channels in which analysis is being conducted on the lab-on a-chip (this is important to avoid contamination). But the electricity in the ionic channels can zip through the thin glass dead-end without harming the device in the process.

This discovery is the result of an accident. Two channels in an experimental nanofluidic device didn't line up properly, Hunt said, but the researchers found that electricity did pass through the device.

"We were surprised by this, as it runs counter to accepted thinking about the behavior of nonconductive materials," Hunt said. "Upon further study we were able to understand why this could happen, but only at the nanometer scale."

As for electronics applications, Hunt said that the wiring necessary in integrated circuits fundamentally limits their size.

"If you could utilize reversible dielectric breakdown to work for you instead of against you, that might significantly change things," Hunt said.

Provided by University of Michigan

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