A simple slice of energy storage

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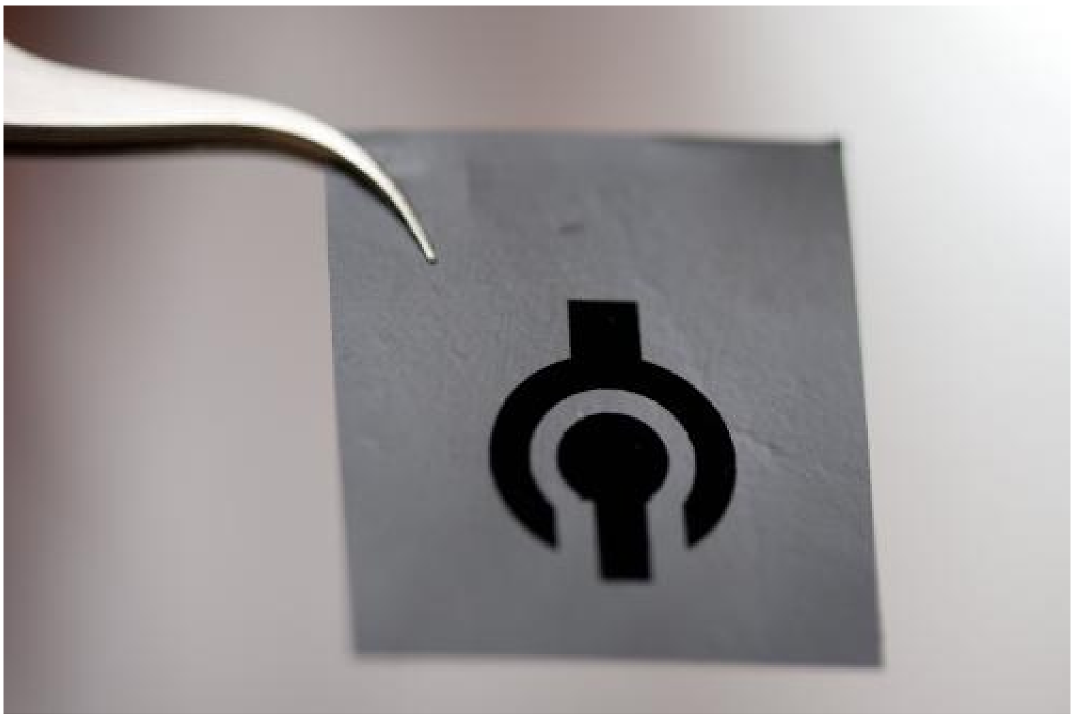

Rice University graduate student Neelam Singh holds a supercapacitor made from a single sheet of graphite oxide. The heat from writing a pattern in the material with a laser turns it into electrically conducting reduced graphite oxide. (Credit: Jeff Fitlow/Rice University)

Turning graphite oxide (GO) into full-fledged supercapacitors turns out to be simple. But until a laboratory at Rice University figured out how, it was anything but obvious.

Rice Professor Pulickel Ajayan and his team discovered they could transform a sheet of GO into a functional supercapacitor by writing patterns into it with a laser. Scientists already knew that the heat of a laser could convert GO -- the oxidized form of graphite, or carbon-based pencil lead -- into electrically conducting reduced graphite oxide (RGO). By writing patterns of RGO into thin sheets of GO, the Rice researchers effectively turned them into free-standing supercapacitors with the ability to store and release energy over thousands of cycles.

The discovery was reported this week in the online edition of *Nature Nanotechnology*.

The surprising find was that GO, when hydrated, can hold ions and serve as a solid electrolyte and an electrically insulating separator. "This is quite easy, as GO soaks up water like a sponge and can hold up to 16 percent of its weight," said Wei Gao, lead author of the paper and a graduate student in the Ajayan Lab.

"The fundamental breakthrough here is that GO, when it contains water, acts as an ionic conductor," said Ajayan, Rice's Benjamin M. and Mary Greenwood Anderson Professor in Mechanical Engineering and Materials Science and of chemistry. "So we're able to convert a sheet of GO into a supercapacitor without adding anything. All you need are a pattern and the electrodes, and you have a device. Of course the devices also perform in the presence of external electrolytes, which is even better.

"I think you're going to see a lot of tiny devices that need smaller power sources. Intermediate-sized devices might also be powered by this material; it's very scalable."

As a control experiment, the team sucked all the water out of an RGO-GO-RGO device in a vacuum to kill its ionic conductivity. Exposing it to air for three hours completely restored its supercapacitor function, another potentially handy characteristic.

To build a fully functional supercapacitor, conducting electrode materials need to be separated by an insulator that contains the electrolyte. When laser-written patterns of conducting RGO are separated by GO, the material becomes an energy storage device, Gao said. The patterns can be layered top and bottom or on the same plane.

In their experiments, heat from a laser at Rice's Oshman Engineering Design Kitchen sucked oxygen out of the surface to create the dark, porous RGO, which provided a level of resistance and restrained the GO-contained ions until their controlled release. Patterns were written in the GO with nearly one-micron accuracy.

Essentially, the devices exhibited good electrochemical performance -- without the chemicals.

Testing of the devices at Rice and by colleagues at the University of Delaware showed their performance compares favorably with existing thin-film micro-supercapacitors. They exhibit proton transport characteristics similar to that of Nafion, a commercial electrolyte membrane discovered in the 1960s, Ajayan said.

While the lab won't make flat supercapacitors in bulk anytime soon, Ajayan said the research opens the way to interesting possibilities, including devices for use in fuel cells and lithium batteries.

He said the discovery is surprising "because a lot of people have been looking at graphite oxide for five or 10 years now, and nobody has seen what we see here. We've discovered a fundamental mechanism of graphite oxide -- an ionic conducting membrane -- that is useful for applications."

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