New micro-supercapacitor structure inspired by the intricate design of leaves

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There was a time during the early development of portable electronics when the biggest hurdle to overcome was making the device small enough to be considered portable. After the invention of the microprocessor in the early 1970s, miniature, portable electronics have become commonplace and ever since the next challenge has been finding an equally small and reliable power source. Chemical batteries store a lot of energy but require a long period of time for that energy to charge and discharge plus have a limited lifespan. Capacitors charge quickly but cannot store enough charge to work for long enough to be practical. One possible solution is something called a solid-state micro-supercapacitor (MSC). Supercapacitors are armed with the power of a battery and can also sustain that power for a prolonged period time. Researchers have attempted to create MSCs in the past using various hybrids of metals and polymers but none were suitable for practical use. In more recent trials using graphene and carbon nanotubes to make MSCs, the results were similarly lackluster.

An international team of researchers led by Young Hee Lee, including scientists from the Center for Integrated Nanostructure Physics at the Institute for Basic Science (IBS) and Department of Energy Science at Sungkyunkwan University in South Korea, has devised a new technique for creating an MSC that doesn't have the shortcomings of previous attempts but instead delivers high electrochemical performance.

When designing something new and complex, sometimes the best inspiration is one already found in nature. The team modeled their MSC film structure on natural vein-textured leaves in order to take advantage of the natural transport pathways which enable efficient ion diffusion parallel to the graphene planes found within them.

To create this final, efficient shape, the team layered a graphene-hybrid film with copper hydroxide nanowires. After many alternating layers they achieved the desired thickness, and added an acid solution to dissolve the nanowires so that a thin film with nano-impressions was all that remained.

To fabricate the MSCs the film was applied to a plastic layer with thin, ~5µm long parallel gold strips placed on top. Everything not covered by the gold strips was chemically etched away so that only the gold strips on top of a layer of film were left. Gold contact pads perpendicular to the gold strips were added and a conductive gel filled in the remaining spaces and was allowed to solidify. Once peeled from the plastic layer, the finished MSCs resemble clear tape with gold electrical leads on opposite sides.

The team produced stunning test results. In addition to its superior energy density, the film is highly flexible and actually increases capacitance after initial use. The volumetric energy density was 10 times higher than currently available commercial supercapacitors and also far superior to any other recent research. The MSCs are displaying electrical properties about five orders of magnitude higher than similar lithium batteries and are comparable to existing, larger supercapacitors. According to Lee, "To our knowledge, the volumetric energy density and the maximum volumetric power density in our work are the highest values among all carbon-based solid-state MSCs reported to date."

In the future, consumers will likely power their devices with MSCs instead of batteries. Applications for light, reliable energy storage combined with a long lifespan and fast charge/discharge time. The team's MSCs could be embedded into an electronic circuit chip as power sources for practical applications such as implantable medical devices, active radio frequency identification tags, and micro robots. If engineers utilize the material's incredible flexibility, these MSCs could be utilized in portable, stretchable, and even wearable electronic devices.

Provided by Institute for Basic Science

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