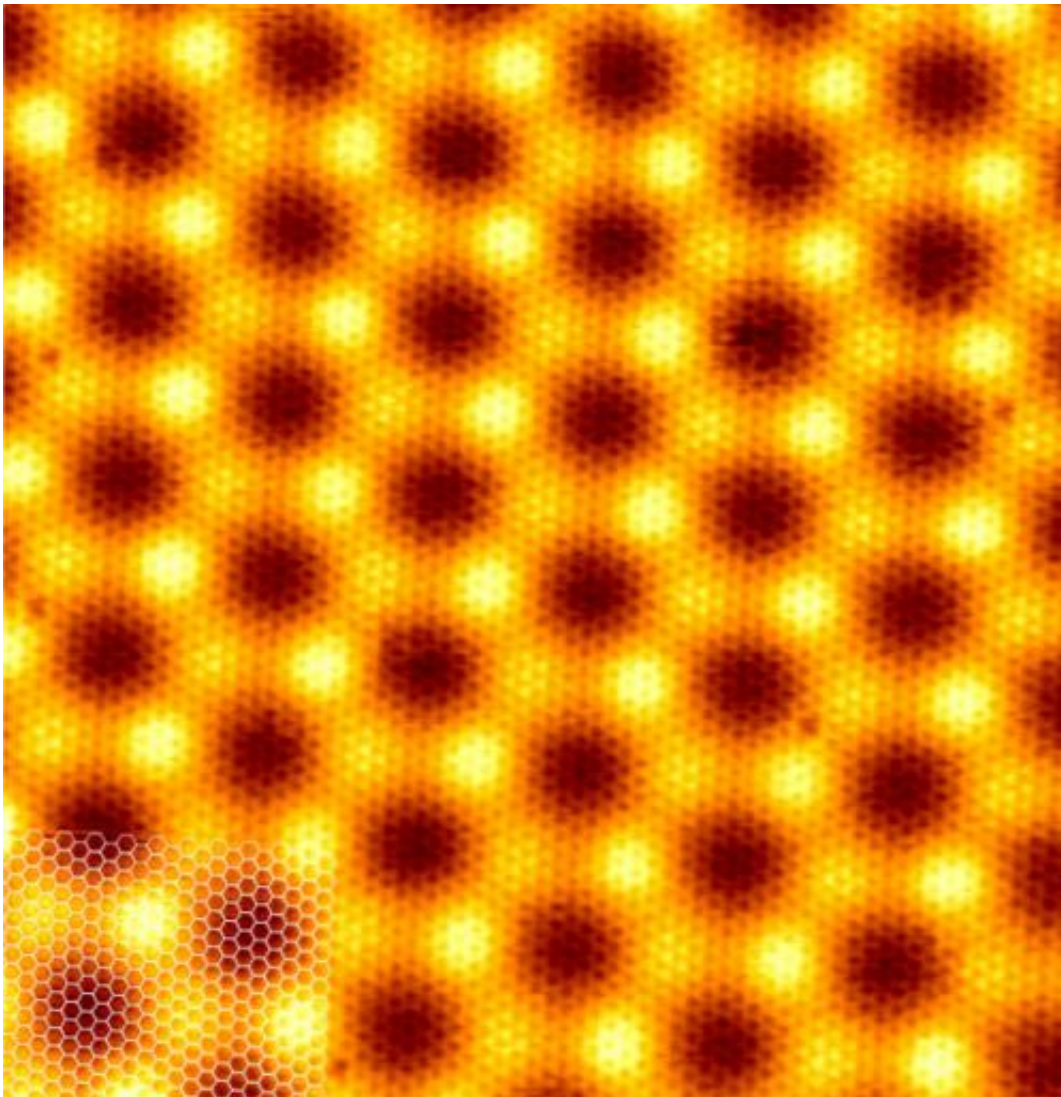


Could hemp nanosheets topple graphene for making the ideal supercapacitor?

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Scanning tunnelling microscopy (STM) image of graphene on Ir(111). The image size is 15 nm × 15 nm. Credit: ESRF

As hemp makes a comeback in the U.S. after a decades-long ban on its cultivation, scientists are reporting that fibers from the plant can pack as much energy and power as graphene, long-touted as the model material for supercapacitors. They're presenting their research, which a Canadian start-up company is working on scaling up, at the 248th National Meeting & Exposition of the American Chemical Society (ACS).

David Mitlin, Ph.D., explains that [supercapacitors](#) are energy storage devices that have huge potential to transform the way future electronics are powered. Unlike today's rechargeable batteries, which sip up energy over several hours, supercapacitors can charge and discharge within seconds. But they normally can't store nearly as much energy as batteries, an important property known as energy density. One approach researchers are taking to boost supercapacitors' energy density is to design better electrodes. Mitlin's team has figured out how to make them from certain [hemp](#) fibers—and they can hold as much energy as the current top contender: graphene.

"Our device's electrochemical performance is on par with or better than graphene-based devices," Mitlin says. "The key advantage is that our electrodes are made from biowaste using a simple process, and therefore, are much cheaper than graphene."

The race toward the ideal supercapacitor has largely focused on graphene—a strong, light material made of atom-thick layers of carbon, which when stacked, can be made into electrodes. Scientists are investigating how they can take advantage of graphene's unique properties to build better solar cells, water filtration systems, touch-screen technology, as well as batteries and supercapacitors. The problem is it's expensive.

Mitlin's group decided to see if they could make [graphene](#)-like carbons from hemp bast fibers. The fibers come from the inner bark of the plant

and often are discarded from Canada's fast-growing industries that use hemp for clothing, construction materials and other products. The U.S. could soon become another supplier of bast. It now allows limited [cultivation](#) of hemp, which unlike its close cousin, does not induce highs.

Scientists had long suspected there was more value to the hemp bast—it was just a matter of finding the right way to process the material.

"We've pretty much figured out the secret sauce of it," says Mitlin, who's now with Clarkson University in New York. "The trick is to really understand the structure of a starter material and to tune how it's processed to give you what would rightfully be called amazing properties."

His team found that if they heated the [fibers](#) for 24 hours at a little over 350 degrees Fahrenheit, and then blasted the resulting material with more intense heat, it would exfoliate into carbon nanosheets.

Mitlin's team built their supercapacitors using the hemp-derived carbons as electrodes and an ionic liquid as the electrolyte. Fully assembled, the devices performed far better than commercial supercapacitors in both [energy density](#) and the range of temperatures over which they can work. The hemp-based devices yielded [energy](#) densities as high as 12 Watt-hours per kilogram, two to three times higher than commercial counterparts. They also operate over an impressive temperature range, from freezing to more than 200 degrees Fahrenheit.

"We're past the proof-of-principle stage for the fully functional supercapacitor," he says. "Now we're gearing up for small-scale manufacturing."

More information: Title: Interconnected carbon nanosheets derived from hemp for ultrafast supercapacitors with high energy

Abstract

We created unique interconnected partially graphitic carbon nanosheets (10-30 nm in thickness) with high specific surface area (up to 2287 m² g⁻¹), significant volume fraction of mesoporosity (up to 58%), and good electrical conductivity (211-226 S/m) from hemp bast fiber. The nanosheets are ideally suited for low (down to 0°C) through high (100°C) temperature ionic liquid-based supercapacitor applications: At 0°C and a current density of 10 A g⁻¹, the electrode maintains a remarkable capacitance of 106 F g⁻¹. At 20, 60, and 100 °C and an extreme current density of 100 A g⁻¹, there is excellent capacitance retention (72-92%) with the specific capacitances being 113, 144 and 142 F g⁻¹, respectively. These characteristics favorably place the materials on a Ragone Chart providing among the best power - energy characteristics (on an active mass normalized basis) ever reported for an electrochemical capacitor: At a very high power density of 20 kW kg⁻¹ and 20, 60 and 100 °C, the energy densities are 19, 34 and 40 Wh kg⁻¹, respectively. Moreover the assembled supercapacitor device yields a maximum energy density of 12 Wh kg⁻¹, which is higher than commercially available supercapacitors. By taking advantage of the complex multi-layered structure of a hemp bast fiber precursor, such exquisite carbons were able to be achieved by simple hydrothermal carbonization combined with activation. This novel precursor-synthesis route presents a great potential for facile large-scale production of high-performance carbons for a variety of diverse applications including energy storage.

Provided by American Chemical Society

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