intervals after excitation, the researchers resolve an initially reduced tunneling current, which exponentially decays back to the ground state level with a relaxation time of between 50 ns and 250 ns. Control experiments in which either the tip or the surface adatom is spin inactive indicate that spin relaxation is indeed responsible for the change in current. The relaxation time is also strongly dependant on the magnetic field, which can further split the spin states and increase their lifetimes.

Significantly, it is possible to observe small differences in spin relaxation times for adatoms in slightly different surface environments. This versatile "pump-probe" technique could also be extended to monitoring the evolution of a range of surface states of suitable lifetime, such as conformational changes in molecular motors or even spin precession.

Tobias Lockwood

Energy Focus

Graphene nanosheet supercapacitor achieved high-frequency ac circuit-filtering capacity

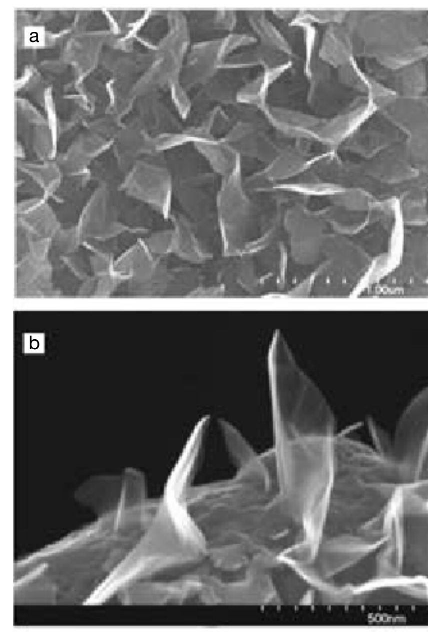
Supercapacitors, also called electric double-layer capacitors (DLC) are effective charge storage devices, and have applications ranging from electric vehicles to computer memory power backup. A major limitation of current DLCs is their inability to filter voltage ripple in rectified 120 Hz alternating current (ac) line power. The resistor-capacitor (RC) time constant, which is a measure of how fast the capacitor can be charged, is typically ~1 s for present capacitors, a value far too long for effective filtering when the period is ~8.3 ms. This limitation is caused by the highly porous nature of present electrodes, which behaves like a resistor rather than a capacitor at 120 Hz. Recently J. R. Miller of JME, Inc. and Case Western Reserve University; R.A. Outlaw of College of William and Mary, and B.C. Halloway from the Defense Advanced Research Project Agency have developed a graphene nanosheet DLC that achieved an RC time constant of 200 µs, along with other performance improvements.

As reported in September 24th issue of *Science* (DOI: 10.1126/science.1194372; p. 1637), the researchers synthesized vertically oriented graphene nanosheets on heated nickel (Ni) substrates using radio frequency, plasma-enhanced chemical vapor deposition. These graphene nanosheets were ~600 nm high and <1 nm thick. They have exposed edge planes and random open surfaces, but essentially no porosity.

This design is more effective for numerous reasons: edge planes provide higher capacitance compared to basal plane; exposed planes are directly accessible for charge storage; less porosity reduces ionic resistance; graphene is highly conductive; and ion intercalation on the edge sheet creates pesudocapacitance, another potential benefit.

The researchers prepared capacitors using these graphene nanosheet electrodes and KOH solution as electrolyte. The prototype capacitor was 2.5 cm diameter, ~175 µm thick, and weighs only ~0.8 g and at 120 Hz, showed a capacitance of 175 µF compared to 25 µF for bare nickel electrode. At a frequency less than 1 Hz, the capacitance was even greater. Use of organic electrolyte further increased the capacitance value.

The graphene DLC not only demonstrated fast response, but it also has less weight and smaller volume than competing technology, and thus very suitable for portable devices. It can be manufactured through standard semiconducting process techniques. The performance can



(a) Plan scanning electron micrograph (SEM) of coated Ni electrode; (b) SEM of a coated fiber, showing plan and shallow-angle views. Reproduced with permission from *Science* **329** (2010) DOI: 10.1126/science.1194372; p. 1637. ©2010 AAAS.

be improved further by optimizing various parameters. The researchers are optimistic that graphene DLC will exceed the performance of current low-voltage capacitor technology.

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