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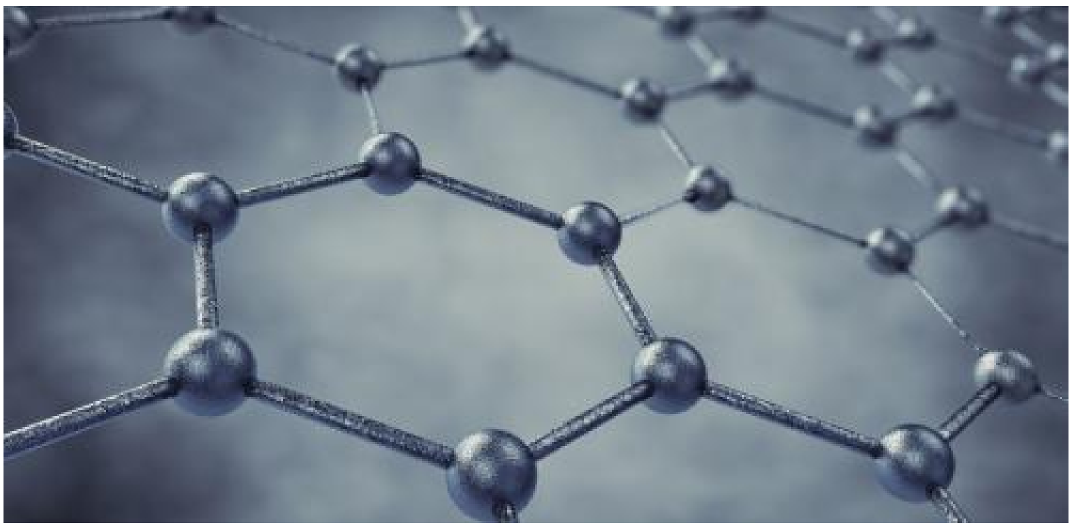
Chunky mobile devices? Soft graphene could help you downsize

August 27 2013, by Chi Cheng



The world's thinnest, strongest and most conductive material – graphene – can boost energy storage capacity by almost threefold. Credit: Argonne National Laboratory

Assuming you are geeky enough to open up any mobile device on the market – a phone, tablet or laptop – the most glaringly obvious component of the device is the battery: it generally consumes up to (if not more than) 60% of space.

It's disappointing to think the gadgets you carry are basically packs of energy-storage devices. Just think how much more portable those devices could be if their batteries were smaller and more powerful.

Such possibilities may not be far off.

Electrochemical capacitors, as an emerging type of advanced energy storage device, have attributes better than their conventional battery counterparts such as fast charging capability and almost unlimited lifespan.

Today, in *Science*, my colleagues and I show how energy storage capacity of an electrochemical capacitor can be doubled by manipulating a single layer of carbon atoms known as graphene.

Electrochemical capacitor evolution

While we should be stunned by how far we've increased computing power in downsized space (the first computers filled entire rooms) the efficiency of an energy-storage device – the amount of energy stored per unit volume – needs to catch up.

The idea of increasing this efficiency is to pack more active, energy-storing materials in the same amount of space. As simple as that sounds, it's very difficult to do.

One common material used in energy storage devices is porous carbon. Porous carbon is produced by riddling a base material, such as coconut shell, with small pores, increasing the base material's surface area.

The pores are important for capacitive energy storage as in general terms, more pores means larger surface area for physical adsorption, which in turn leads to higher storage capacity.

Traditional porous carbon, once made, has a set volume with fixed pores randomly scattered inside and out.

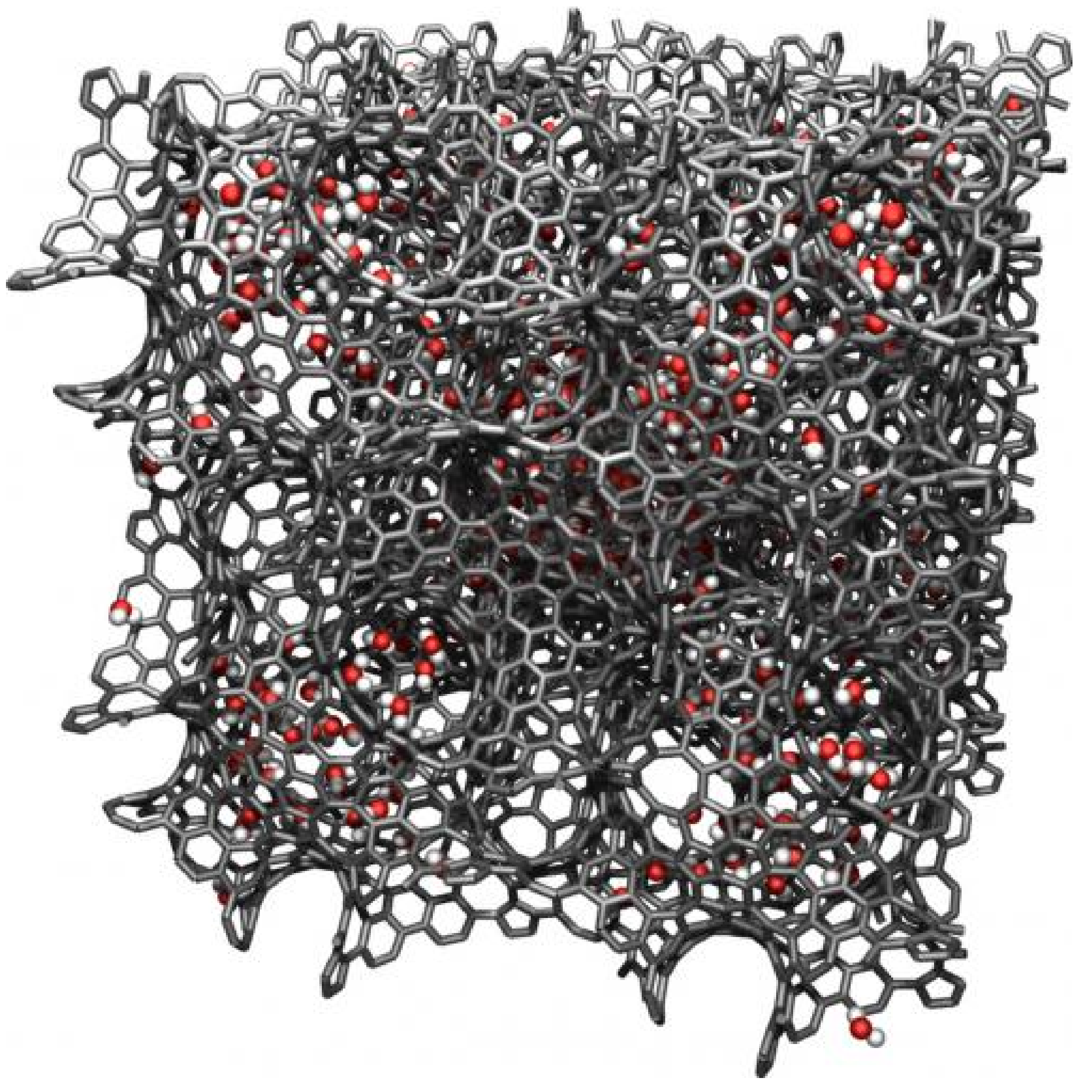
It isn't really possible to readjust the structure and jam more porous carbon in the same amount of space without crumpling a fraction of the pores that are especially crucial for capacitive energy storage.

Introducing graphene

Graphene – a single-layer sheet of carbon atoms – was first isolated in 2004 and since then, major efforts have been devoted to exploring its physics.

It is the thinnest material known to man, yet tougher than diamond. It channels electrons pretty much with no resistance, making it the single most conductive material.

Graphene also happens to be the fundamental building block for porous carbon, so starting with graphene gives us ultimate control over porous carbon structure.

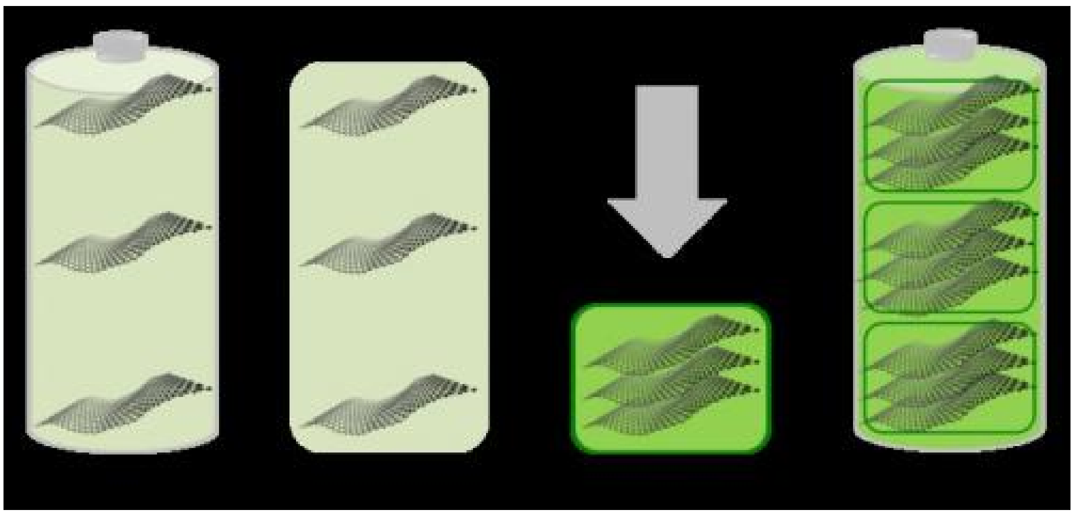


Porous carbon structure. Credit: oakridgelabnews

To pack active materials in a certain amount of space as much as possible, it is not hard to figure out the most efficient way is to pack sheet-like graphene in a face-to-face manner, as shown in the diagram below.

But problems kick in when two pieces of graphene are packed too closely together. Like magnets, when placed closer than a critical distance, graphene sheets will irreversibly adhere onto each other, diminishing their surface area, and as a result, lose their capacity for energy storage.

Therefore, there is a sweet spot where the packing of graphene, neither too loose nor too compact, is just right: maximum loading without hurting its ability to store energy.



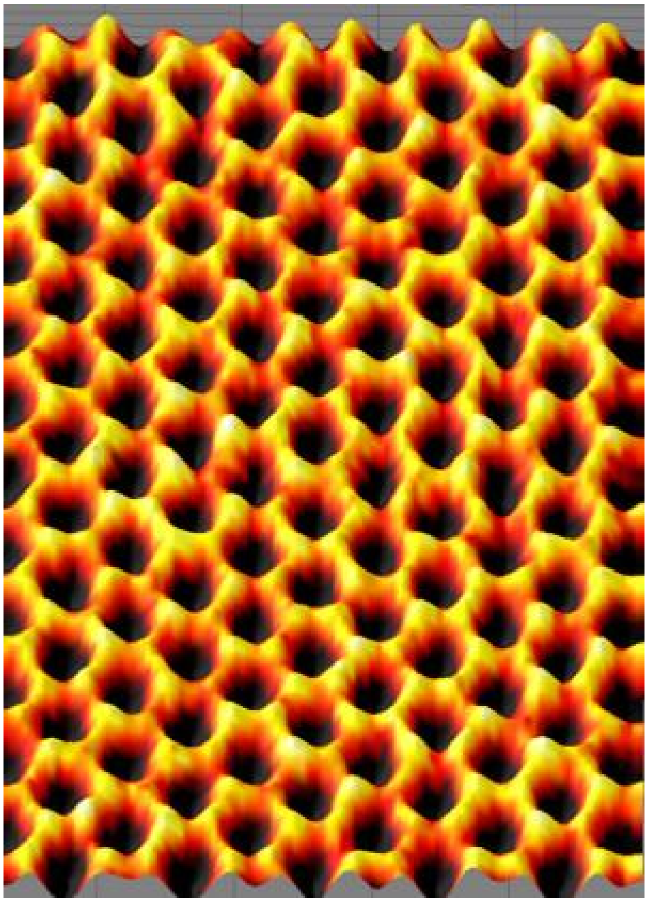
Credit: Chi Cheng

Just add liquid

Finding that sweet spot requires fine structure tuning at nanoscale. If you think of a hard material that won't easily deform, this seems challenging – but it's natural for a liquid to take on any shape in which it's contained.

Inspired by this, we used liquids as a mediator between graphene sheets and managed to adjust the packing of graphene into films in a nearly continuous manner, giving us what we call "soft" graphene.

Electrochemical capacitors based on the resulting films can obtain volumetric energy densities approaching 60 Watt-hours per litre, which is approaching that of lead-acid batteries found in cars.



Graphene viewed with an electron microscope. Credit: U.S. Army Materiel Command

Our work, as one example of the many "soft" features of graphene, will encourage researchers from both graphene and soft matter fields to develop new "soft" concepts to address the key scientific and technical challenges relating to scalable synthesis, processing and assembly of graphene-related materials.

We believe that implementation of this technology will revolutionise many energy sections, such as fast-charging personal electronics as well as affordable, long-distance electric vehicles.

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