A holey graphene electrode framework that enables highly efficient charge delivery

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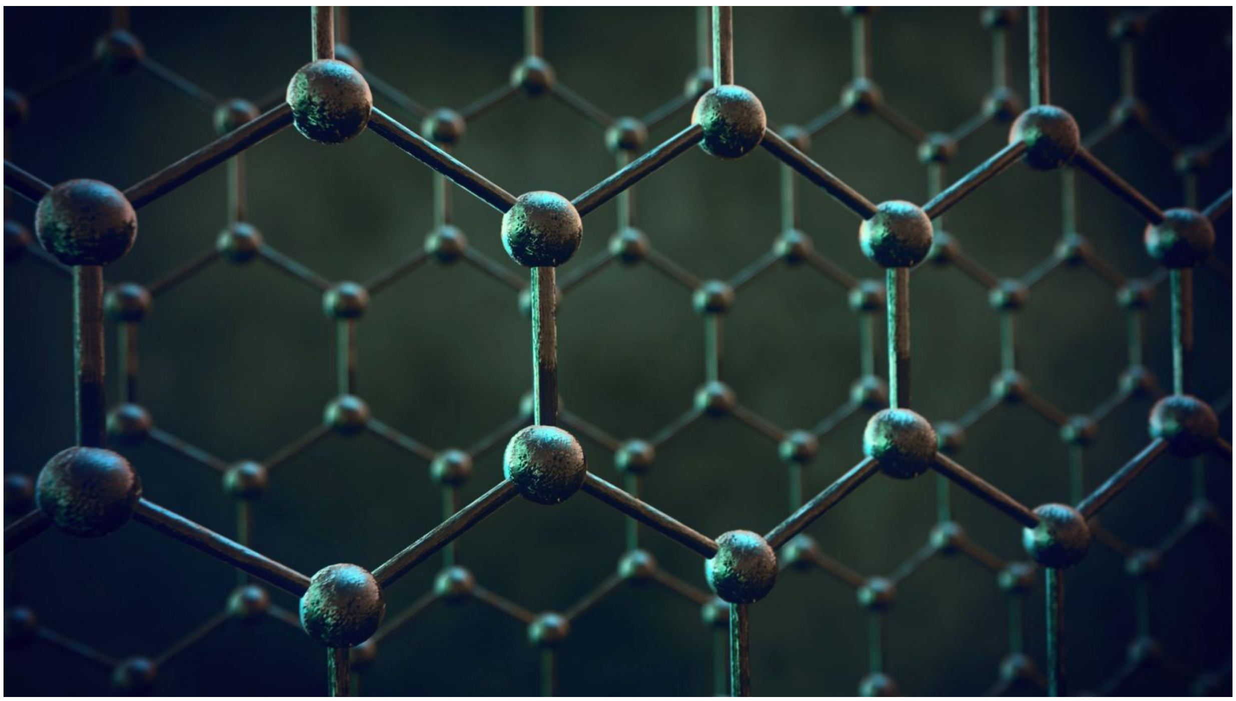

This visualisation shows layers of graphene used for membranes. Credit: University of Manchester

(Phys.org)—A team of researchers affiliated with institutions in the U.S., China and the Kingdom of Saudi Arabia has developed a new type of porous graphene electrode framework that is capable of highly efficient charge delivery. In their paper published in the journal *Science*, the group describes how they overcame traditional conflicts arising between tradeoffs involving density and speed to produce an electrode capable of facilitating rapid ion transport. Hui-Ming Cheng and Feng Li with the Chinese Academy of Sciences offer a Perspective piece on the work done by the team in the same journal issue, and include some opinions of their own regarding where such work is likely heading.

In a perfect world, batteries would have unlimited energy storage delivered at speeds high enough to power devices with unlimited needs. The phaser from *Star Trek*, for example, would require far more power and speed than is possible in today's devices. While it is unlikely that such technology will ever come about, it does appear possible that batteries of the future will perform much better than today, likely due to nanostructured materials—they have already shown promise when used as electrode material due to their unique properties. Unfortunately, their use has been limited thus far due to the ultrathin nature of the resulting electrodes and their extremely low mass loadings compared to those currently in use. In this new effort, the researchers report on a new way to create an electrode using graphene that overcomes such limitations.

The electrode they built is porous, which in this case means that it has holes in it. Those holes, as Cheng and Li note, allow better charge transport while also offering improved capacity retention density. The graphene framework they built, they note, offers a superior means of electron transport and its porous nature allows for a high ion diffusion rate—the holes force the ions to take shortcuts, reducing diffusion.

Cheng and Li suggest the new work is likely to inspire similar designs in the search for better electrode materials, which they further suggest appears likely to lead to new electrodes that are not only practical, but have high mass loadings.

More information: Hongtao Sun et al. Three-dimensional holey-graphene/niobia composite architectures for ultrahigh-rate energy

storage, *Science* (2017). DOI: 10.1126/science.aam5852

Abstract
Nanostructured materials have shown extraordinary promise for electrochemical energy storage but are usually limited to electrodes with rather low mass loading (~1 milligram per square centimeter) because of the increasing ion diffusion limitations in thicker electrodes. We report the design of a three-dimensional (3D) holey-graphene/niobia (Nb2O5) composite for ultrahigh-rate energy storage at practical levels of mass loading (>10 milligrams per square centimeter). The highly interconnected graphene network in the 3D architecture provides excellent electron transport properties, and its hierarchical porous structure facilitates rapid ion transport. By systematically tailoring the porosity in the holey graphene backbone, charge transport in the composite architecture is optimized to deliver high areal capacity and high-rate capability at high mass loading, which represents a critical step forward toward practical applications.