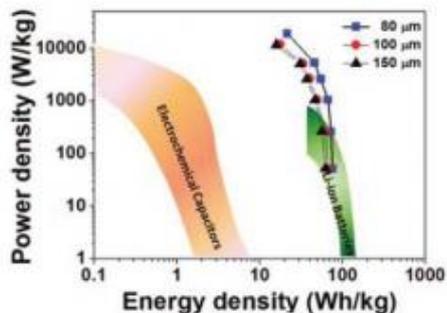
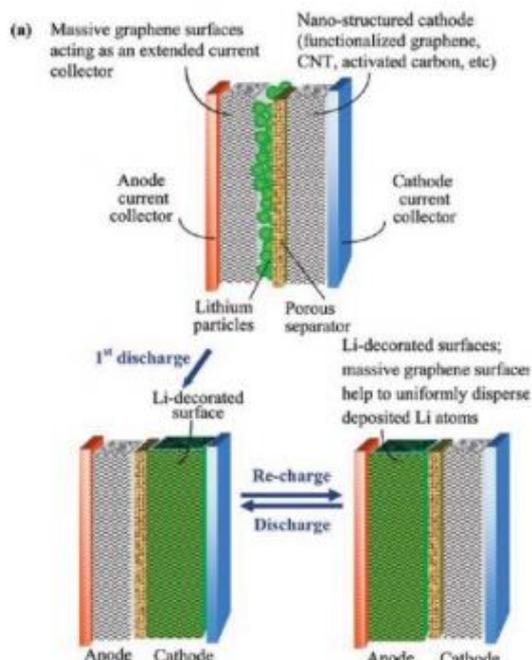


New energy storage device could recharge electric vehicles in minutes



Compared with supercapacitors and batteries, SMCs (with three different electrode thicknesses shown) offer both a high power density and high energy density. Image copyright: Jang, et al. ©2011 American Chemical Society

(PhysOrg.com) -- It has all the appearances of a breakthrough in battery technology, except that it's not a battery. Researchers at Nanotek Instruments, Inc., and its subsidiary Angstrom Materials, Inc., in Dayton, Ohio, have developed a new paradigm for designing energy storage devices that is based on rapidly shuttling large numbers of lithium ions between electrodes with massive graphene surfaces. The energy storage device could prove extremely useful for electric vehicles, where it could reduce the recharge time from hours to less than a minute. Other applications could include renewable energy storage (for example, storing solar and wind energy) and smart grids.



The large surface areas of the SMCs' electrodes enable rapid shuttling of large numbers of ions between electrodes, resulting in a fast recharge time. Image copyright: Jang, et al. ©2011 American Chemical Society

The researchers call the new devices "graphene surface-enabled lithium ion-exchanging cells," or more simply, "surface-mediated cells" (SMCs). Although the devices currently use unoptimized materials and configurations, they can already outperform Li-ion batteries and supercapacitors. The new devices can deliver a power density of 100 kW/kgcell, which is 100 times higher than that of commercial Li-ion

batteries and 10 times higher than that of supercapacitors. The higher the power density, the faster the rate of energy transfer (resulting in a faster recharge time). In addition, the new cells can store an energy density of 160 Wh/kgcell, which is comparable to commercial Li-ion batteries and 30 times higher than that of conventional supercapacitors. The greater the energy density, the more energy the device can store for the same volume (resulting in a longer driving range for electric vehicles).

"Given the same device weight, the current SMC and Li-ion battery can provide an electric vehicle (EV) with a comparable driving range," Bor Z. Jang, co-founder of Nanotek Instruments and Angstrom Materials, told *PhysOrg.com*. "Our SMCs, just like the current Li-ion batteries, can be further improved in terms of energy density [and therefore range]. However, in principle, the SMC can be recharged in minutes (possibly less than one minute), as opposed to hours for Li-ion batteries used in current EVs."

Jang and his coauthors at Nanotek Instruments and Angstrom Materials have published the study on the next-generation energy storage devices in a recent issue of *Nano Letters*. Both companies specialize in nanomaterial commercialization, with Angstrom being the world's largest producer of nano graphene platelets (NGPs).

As the researchers explain in their study, batteries and supercapacitors each have their respective strengths and weaknesses when it comes to energy storage. While Li-ion batteries provide a much higher energy density (120-150 Wh/kgcell) than supercapacitors (5 Wh/kgcell), the batteries deliver a much lower power density (1 kW/kgcell compared to 10 kW/kgcell). Many research groups have made efforts to increase the power density of Li-ion batteries and increase the energy density of supercapacitors, but both areas still have significant challenges. By providing a fundamentally new framework for energy storage devices, the SMCs could enable researchers to bypass these challenges.

"The development of this new class of energy storage devices bridges the performance gap between a Li-ion battery and a supercapacitor," Jang said. "More significantly, this fundamentally new framework for constructing energy storage devices could enable researchers to achieve both the high energy density and high power density without having to sacrifice one to achieve the other."

The key to the SMCs' performance is a cathode and anode that contain very large graphene surfaces. When fabricating the cell, the researchers put lithium metal (in the form of particles or foil) at the anode. During the first discharge cycle, the lithium is ionized, resulting in a much larger number of lithium ions than in Li-ion batteries. As the battery is used, the ions migrate through a liquid electrolyte to the cathode, where the ions enter the pores and reach the large graphene surface inside the cathode. During recharging, a massive flux of lithium ions quickly migrates from the cathode to the anode. The electrodes' large surface areas enable the rapid shuttling of large numbers of ions between electrodes, resulting in their high power and energy densities.

As the researchers explain, the exchange of lithium ions between the porous electrodes' surfaces (and not in the bulk of the electrode, as in batteries) completely removes the need for the time-consuming process of intercalation. In this process, the lithium ions must be inserted inside the electrodes, which dominates the charging time of batteries.

Although in this study the researchers prepared different types of graphene (oxidized, and reduced single-layer and multilayer) from a variety of different types of graphite, further analysis of the materials and configuration is needed for optimizing the device. For one thing, the researchers plan to further investigate the cells' cycling lifetime. So far, they found that the devices could retain 95% capacity after 1,000 cycles, and even after 2,000 cycles showed no evidence of dendrite formation. The researchers also plan to investigate the relative roles of different lithium storage mechanisms on the device's performance.

"We do not anticipate any major hurdle to commercialization of the SMC technology," Jang said.

"Although graphene is currently sold at a premium price, Angstrom Materials, Inc., is actively engaged in scaling up the production capacity of graphene. The production costs of graphene are expected to be dramatically reduced within the next 1-3 years."

More information: Bor Z. Jang, et al. "Graphene Surface-Enabled Lithium-Ion Exchanging Cells: Next-Generation High-Power Energy Storage Devices." *Nano Letters*. [DOI:10.1021/nl2018492](https://doi.org/10.1021/nl2018492)

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