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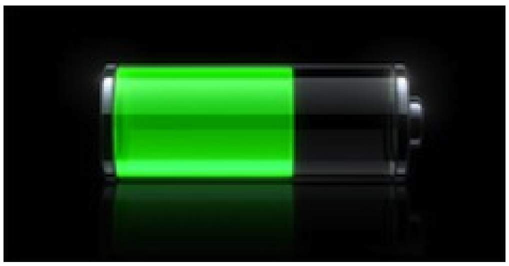
Two takes on lithium-ion batteries

April 16 2013, by Alison Hatt



Lithium-ion batteries have transformed our lives. Without them, we wouldn't have laptop computers or cell phones—at least, not the long-lived, lightweight kindwe're used to—and in the near future they may become more important yet. With sufficiently powerful batteries, renewable energy and electric cars become viable, but we first need to overcome some serious technological challenges. At the recent American Physical Society March Meeting in Baltimore, two Berkeley Lab researchers highlighted different aspects of the problem.

Nitash Balsara: Polymer electrolytes

"There are many amazing things about lithium-ion batteries that just don't exist in other kinds of batteries," said Balsara from Berkeley Lab's Materials Sciences Division and UC Berkeley. "Lithium just glides in and out of the electrode." That reversibility paired with a tremendous energy density gives us portable electronic devices that can be recharged hundreds of times and pack enormous power in svelte form-factors.

But there are drawbacks to the technology. The electrolyte in virtually all lithium-ion batteries is a flammable solvent. Catastrophic failure often starts with degradation of the electrolyte and an internal spark can result in an explosion.

To avoid this problem, Balsara and other researchers are developing non-flammable polymer electrolytes. The electrolyte has to do two things: shuttle ions between electrodes, and be mechanically rigid to protect the battery and prevent electrodes from shorting. This presents a dilemma because soft polymers are best for ion transport but rigid polymers provide better protection.

Balsara's team has hit on a new solution to this challenge. They use block copolymers – long chains of repeating polymer units – that self-assemble into layered domains. One of the layers is soft and good for ion transport, and the other is rigid and provides the necessary structural support. In more recent work, they have developed block copolymers for transport in electrodes. In this case, the rigid domain is a semi-conducting polymer. Perhaps the most exciting feature is that the semi-conducting domain can serve as an automatic switch that turns current off when the battery approaches the fully discharged state. In conventional batteries, external circuits are used to monitor the state of charge of the battery and to turn it off when it approaches the fully discharged state.

Steven Harris: Electrode failure

Steven Harris, also from the Materials Sciences Division, focuses on the electrodes of lithium-ion batteries, and he sees a lot of room for improvement.

"Currently these electrodes are made by pouring crushed graphite into a cauldron and adding eye of newt and stirring," Harris joked at the APS meeting. "So maybe we can do better than that."

Harris comes from a background in fracture mechanics where the only thing that matters in predicting failure is the presence and size of inhomogeneities, such as cracks or variations in local density. So he reasoned that inhomogeneities should also make a big difference in battery failure. For example, local pore structure variation should dictate whether and where electrodes can be overcharged.

To better understand how inhomogeneities affect lithium transport, Harris took time-lapse video of lithium diffusing into graphite, which changes color as it absorbs lithium. The resulting videos show distinct anisotropy in transport around cracks and defects, a far cry from the heterogeneous transport assumed in the models currently used to optimize batteries. Harris suggests that understanding and controlling these inhomogeneities could be the key to building a better battery.

Provided by Lawrence Berkeley National Laboratory

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