Electrochemical Strain Microscopy

New Microscopy Technique Could Advance Battery Performance

Researchers at the Oak Ridge National Laboratories, USA have developed electrochemical strain microscopy, a new method to detect the motion of lithium-ions on a nano-scale, which could enhance lithium-ion battery performance. The advances of electrochemical strain microscopy are most important for electric car batteries, whose longevity would make electric cars a much more competitive technology.

"Ultimately we'd like to have Li-ion batteries that have longer lifetimes, a higher charge-storage capacity, and higher reliability and safety," said Mark Hersam, material scientist and professor at Northwestern University.

Electrochemical strain microscopy was created to allow for battery systems to be studied on the nano-scale. "A nanometer scale understanding of lithium ion batteries has been difficult to achieve. There are a number of groups trying to develop a variety of techniques that will allow us to observe the inner workings of lithium ion batteries," said Hersam.

Typical electrochemical methods measure electric currents, but their measurement threshold is beyond the nano-scale. Instead, electrochemical strain microscopy measures strain - the amount of stretching that occurs in materials - because it can be detected levels that are a million times smaller.

The new method is based on a previous microscopy method called scanning probe microscopy. "We combined the technology that was created before with these principles," said Dr. Sergei Kalinin, nanoscientist at Oak Ridge.

Electrochemical strain microscopy uses a cantilever - a beam supported only on one side - with a sharp, nano-sized tip that was applied to the material they tested. As the tip touched the material, a Li-ion battery structure with a silicon layer, bias, or an electric current, was applied. The electric current causes the lithium ions to move.

According to Hersam, silicon has a much higher charge storage capacity than graphite, the material most commonly used in lithium ion batteries. However, silicon is unable to withstand the large expansions and contractions it undergoes as lithium ions move in and out. "Silicon is a brittle material, and when you subject a
brittle material to large forces it cracks," said Hersam.

The expansions and contractions, resulting from the movement of the lithium ions, then cause the tip to move up and down, and the displacement is measured.

The displacement tells researchers what the electrochemical process is inside the battery. "The junction between the tip and the material works like a very small electrochemical cell," said Kalinin.

Using electrochemical strain microscopy at different points along the material, Kalinin and his team compare good and bad electrochemical behavior in order to begin to establish good and bad electrochemical materials. "Being able to look is not equivalent to being able to see," he said, referring to the need to tie the material structures with the properties they exhibit.

Understanding the links between the material structures and their properties, Kalinin said, will allow them to tailor material synthesis to make batteries live longer.

Though they do not understand the full depth of these links, Kalinin is optimistic. "We have demonstration of proof of principle," he said. "If someone had told me two years ago that this approach for studying electrochemistry works I wouldn't have believed [them]."

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Authors

Frank Jackson