Nanoscale mapping of ion diffusion in a lithium-ion battery cathode

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Achievement

The movement of Li in and out of cathodes is a critical component of the design of new and better batteries, but is dominated by nanoscale processes which have been difficult to identify. We have developed a scanning probe microscopy based method, electrochemical strain microscopy (ESM), to investigate the electrical-bias induced Li-ion transport in thin-film $LiCoO_2$ electrode materials. ESM utilizes the intrinsic link between bias-controlled Li-ion concentration and molar volume of electrode materials, providing the capability for new types of studies with nanometer precision. Using ESM, local electrochemical processes can be studied on relevant length scales to unravel the complex interplay between structure, functionality, and performance in Li-ion batteries.

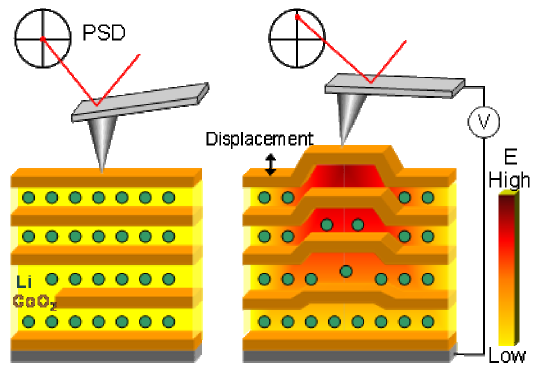

Figure 1 | ESM: Inducing local Li-ion transport in a layered cathode material through a biased atomic force microscopy tip.

This work demonstrates how ESM can be used to investigate the Li-ion transport in layered cathode materials, such as $LiCoO_2$. Through its layered structure, the Li-ion transport and the corresponding volume change is strongly dependent on the crystallographic orientation of the $LiCoO_2$ grains. With ESM it was possible to identify grains and grain boundaries with enhanced Li-ion kinetics.

Significance

The growing need of renewable energy sources is strongly tied to the need for advanced energy storage technologies which currently do not perform as demanded by many applications. The functionality of energy storage systems, such as Li-ion batteries, is based on and ultimately limited by the rate and localization of ion flows through the device on different length scales ranging from atoms over grains to interfaces. The fundamental gap in understanding ionic transport processes on these length scales strongly hinders the improvement of current and development of future battery technologies. The development of ESM has opened the pathway to understand Li-ion batteries on a level never achieved before. The unique information about the local Li-ion flow obtained with ESM will inevitably lead to breakthroughs in material development for battery applications. Knowledge of the interplay between the ionic flow, material properties, microstructure, and defects is the key to battery operation and can be used to optimize the device properties and understand what happens during battery fading.

Credit

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