

Real Space Mapping of Li-Ion Transport in Amorphous Si Anodes with Nanometer Resolution

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Achievement

We have used the principles of our newly developed scanning probe microscopy based method, electrochemical strain microscopy, to investigate the Li-ion transport through a full thin film battery stack consisting of a LiCoO₂ cathode, a LiPON solid electrolyte, and an amorphous Si anode. A special battery biasing scheme allows probing the Li-ion kinetics without changing the charging state of the battery. An atomic force microscopy tip in contact with the battery surface is used to passively detect local volume changes which are induced by local Li-ion concentration changes. The image of the Li-ion distribution on the surface can be used to interpret the Li-ion transport through the full battery. It was found that the microstructure, which showed grain-like features separated by boundaries, is strongly correlated with the Li-ion transport through the amorphous Si anode. Topography trenches show an enhanced Li-ion content after applying electrical bias to the battery, suggesting the existence of Li-ion conduction channels (see the artistic vision in Figure 1).

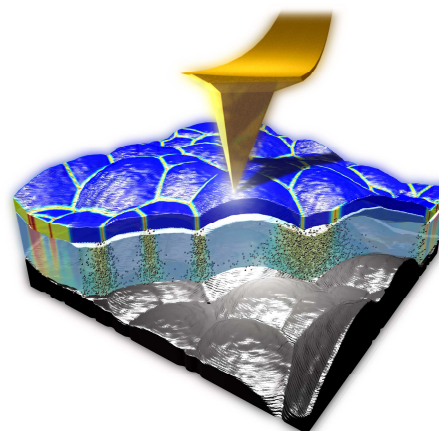


Figure 1 | Detecting the Li-ion transport through all-solid thin film batteries (LiCoO₂/LiPON/a-Si).

Significance

A fundamental understanding of the local mechanisms which define a rechargeable battery, such as ionic transport within the anode and cathode and ionic transport across the electrode/electrolyte interface is necessary to identify and overcome the nanoscale processes which lead to predominant limitations in present battery technology. Our results illustrate that the Li-ion flow through a battery is highly inhomogeneous and can be influenced by local electrical field enhancements as a result of interface roughness, or local changes in material properties such as density or electrical conductivity. Upon battery charging, the Li-ion concentration is strongly increased in the trenches offering a possible origin of the large capacity losses batteries with Si anodes. The specifics of the Li-ion transport in the studied battery structure can identify sources of cracking along the Li-ion conduction channels and can explain the strong battery degradation observed in these heterostructures. Hence, our measurements can lead the pathway to improve the ionic flow by material design and find the origin of battery fading.

Credit

Research was sponsored as part of the Fluid Interface Reactions, Structures and Transport (FIRST) Center, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award Number ERKCC61 (N.B., L.A., N.D., S.V.K.) and by the Scientific User Facilities Division, Office of Basic Energy Sciences, U.S. Department of Energy in projects CNMS2010-098 and CNMS2010-099 (N.B., S.J., I.N.I.). N.B. acknowledges the Alexander von Humboldt foundation.

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N. Balke, S. Jesse, Y. Kim, L. Adamczyk, A. Tselev, I. N. Ivanov, N. J. Dudney, and S. V. Kalinin, *Nano Lett.* 10, 3420-3425 (2010).