Application Note

Poseidon™

Lithiation and Delithiation in Batteries

Problem Statement

One of the fundamental electrochemical processes in lithium ion batteries, the process of lithiation and delithiation of the battery materials, had never been observed at the nanoscale. Scientists had understood that during discharge lithium ions carry the current from the negative to the positive electrode and then charging forces the reverse of this reaction by applying an over voltage to the battery. They have, however, never been able to make analytical and quantifiable observations while observing the reactions.

Background

High energy density, no memory effect, and low standby energy drain are attributes that make lithium ion batteries a popular selection for consumer electronics. Lithium ion batteries have seen constant improvement in recent years to charge density, portability, weight, size, and charging times. The market, however, demands constant innovation and improvement as consumer electronics evolve into higher power consumption applications and smaller sizes. In addition, recent safety concerns with Li-ion have brought new attention to understanding the changes happen at the molecular level. Observing the function of batteries on the nanoscale has proven difficult to researchers, as the electron microscope is not compatible with most forms of the electrochemistry. The process of lithiation and delithiation (discharging and charging) of battery materials is now observable in real time, within an electron microscope.

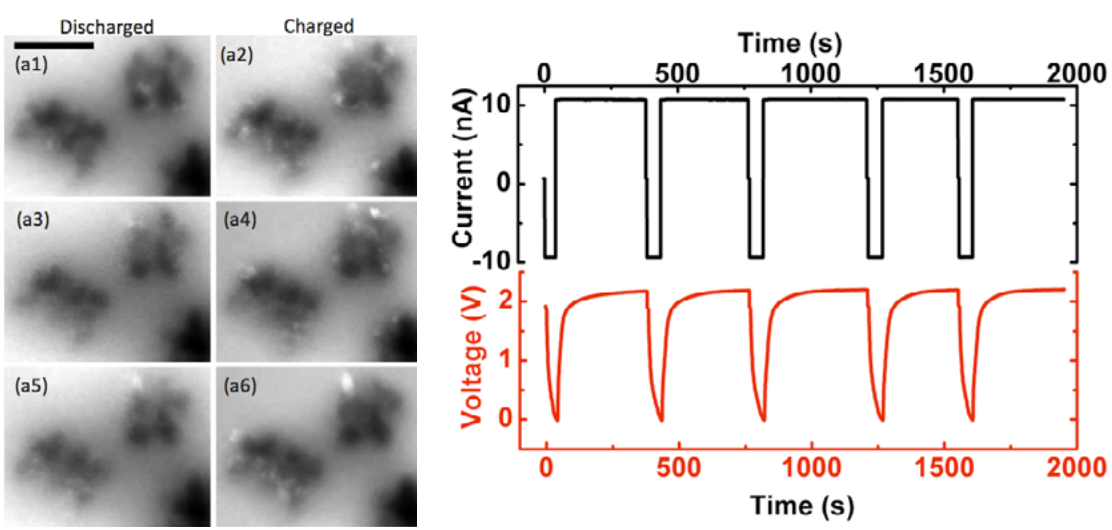

Figure 1: Charging and discharging of the cathode material $LiFePO_4$ *in situ*. The 5eV spectroscopic EFTEM images of charging and discharging are shown with a 400 nm scale bar. Bright regions are delithiated $FePO_4$ and dark regions are $LiFePO_4$. There are more bright regions of $FePO_4$ at the end of charge cycles and less during the discharges.

Methods

The electron microscope is a researcher's most powerful imaging tool and is capable of imaging structures down to the atom. Dr. David Muller's research team at Cornell University used the Poseidon 500 system in his FEI Titan electron microscope to observe the charging and discharging process of a Li-ion battery. The key to preventing a loss of efficiency in batteries is to prevent lithium from getting trapped within the battery. Dr. David Muller spectroscopically tracked the lithiation and delithiation within battery to understand how lithium moved during the experiment.

Conclusions

Poseidon 500 combines the resolving power of the microscope and the ability to perform electrochemical experiments. Designed for liquids, the research can select the exact electrolyte demanded by the experiment. Battery functionality can then be observed in real time at the nano or atomic level. The quantitative data produced through the system, combined with the *in situ* observations led to the development of a model that explains possible mechanisms which trigger trapped lithium within a battery. Further understanding of this process will lead to new battery designs and the creation of high efficiency batteries that are resistant to performance loss over time. The future of stored automotive energy is the fuel cell and continued research in degradation mechanisms is essential for commercial success. Contact us to discuss the full range of capabilities of Poseidon. We can be reached at (919) 377-0800 or at contact@protochips.com.