Cycling Effects on Lithium Vanadium Oxide Phosphate Rechargeable Battery Cathodes

ABSTRACT

While the prevalence of reversible energy storage has grown in the past few decades, the need for longer-lasting batteries remains. Current batteries exhibit modest energy density capacities and degrade significantly over many cycles. This research focuses on a LiVOPO₄ compound as a battery cathode. Previous experiments have found this compound to exhibit an energy capacity between 250-270 mAh/g. This experiment involved the synthesis of LiVOPO₄, through ball milling and annealing (to achieve the desired P₂ structure) and the creation of 12 half-cells. After assembling these cathodes into complete batteries in an argon-filled environment, an automatic cycle was used to charge and discharge these cells through a specified number of cycles. Then, removing these cells in their charged and discharged states after various numbers of cycles, these cathodes were extracted and structural changes were investigated using X-ray diffraction in the laboratory and X-ray absorption studies at the Advanced Photon Source (APS).

MOTIVATION

While traditional rechargeable lithium-ion batteries have advanced to modest efficiencies, the exploration of cells with a LiVOPO₄ cathode could lead to further developments in rechargeable battery technology. Electric vehicles will surely benefit from the next generation of batteries that could withstand thousands of charging cycles and that can store a greater amount of energy when compared to that of current batteries. In addition, this experiment offers a wide range of learning opportunities for the students involved. Students actively participated in the research, design, manufacture, and testing battery half-cells. The X-ray structural studies exposed students to large-scale equipment available at the Illinois Institute of Technology and the Argonne Advanced Photon Source as students understood how both the laboratory and X-ray structure can be studied using X-ray diffraction and X-ray absorption. Additionally, in conducting such an experiment, students work closely with professional scientists. Finally, the need to interact with primary resources in professional journals provided students with the opportunity to understand how scientific research is conducted today.

DATA COLLECTION & EXPERIMENTAL PROCESS

To synthesize Lithium Vanadium Oxide Phosphate, starting materials Li₂CO₃, NH₄VO₃, and NH₄HPO₄ were mixed in a stoichiometric ratio of 1:1:1. The materials were then ball milled in an argon atmosphere at 800°C. From X-ray diffraction, the desired LiVOPO₄ crystal structure was observed. The LiVOPO₄ was then annealed in an argon atmosphere at 300°C for 20 hours. This experiment involved the synthesis of LiVOPO₄ through ball milling and annealing (to achieve the desired P₂ structure) and the creation of 12 half-cells. After assembling these cathodes into complete batteries in an argon-filled environment, an automatic cycle was used to charge and discharge these cells through a specified number of cycles. Then, removing these cells in their charged and discharged states after various numbers of cycles, these cathodes were extracted and structural changes were investigated using X-ray diffraction in the laboratory and X-ray absorption studies at the Advanced Photon Source (APS).

RESULTS

Cycling Data for LiVOPO₄ Cathode

Extended X-ray Absorption Fine Structure (EXAFS) Data for LiVOPO₄ Cathode

CONCLUSION

The material LiVOPO₄, combined with the four conductive materials–carbon black, nanosheets, graphite, and Super P–were first cycled and then analyzed at IIT to measure their voltages through the first charging and discharging cycle. For the first cycle, the LiVOPO₄ was charged to 4.3 V, and then discharged to 2.0 V. From the EXAFS data, it can be seen that the radial distance between the atoms in the LiVOPO₄ structure decreased, while the distance increased for Super P.

ACKNOWLEDGEMENTS

This research was supported by Argonne National Lab’s Educational Programs (HRI), the APS User Office, mentor scientist Carlo Segre, science teacher Jeffrey Rylander, the Illinois Institute of Technology, Glenbrook South High School, and beanie-10 BM: MCAT operations are supported by the DOE and the MRCC/RMCU members institutions. The Argonne National Laboratory (ANL), a U.S. DOE Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.