All-Solid-State Li Rechargeable Batteries

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Introduction

The progress of electric vehicles (EVs) and electrical energy storage (EES) is hindered due to the limited energy density of the present Li-ion battery and safety issues related to the use of flammable organic liquid electrolyte. The objective of this research is to produce an all-solid-state Li rechargeable battery that uses an inorganic solid material as an electrolyte.

Completed steps:
1. Synthesis of known anode, electrolyte and cathode materials: we designed and constructed a model battery to use and to test electrochemical properties of electrodes with a fast-Li+ ion conducting solid electrolyte. Li1.5Ti2.5Al1.5 (PO4) or Li3PS4 glass ceramic is used as a solid electrolyte and LiMn2O4 is used as our anode and cathode.
2. Design of a laboratory-sized all-solid-state battery cell is shown in Figure 1.
3. Data analysis and optimization of the cell: The anode electrode, the solid electrolyte, and the cathode electrode were pressed together into a three-layered pellet with 7 mm in diameter.

In-Process steps:
4. Preliminary materials screening: new candidates for anodes (<1.0V vs. Li+/Li0) and cathodes (>4.5V vs. Li+/Li0) are screened.

Next steps:
5. Materials characterization: promising materials from step 4 will go through characterization (macro- and microscopic structures, and their more detailed electrochemical performance under a range of conditions. X-ray diffraction measurements will provide detailed insights into structural changes and stabilities during lithium insertion and re-extraction under repeated cycling.
6. Whole-cell fabrication and evaluation: Fabrication and testing of "whole-cell" type using the most promising electrodes to emerge from step 5 will be made. This will be developed to reproduce the conditions prevailing under commercial Li-ion battery production.

Methods

Results

We found that the cell impedance decreases by increasing the pressure, which generates higher Li-ion conductivity by providing better contact between solid electrolytes and solid electrode. When the cell is charged, it produces 1 voltage. After optimizing the cell components, the new anodes and cathodes will be used to manufacture all-solid-state Li rechargeable batteries with a high energy density.

Discussion and Summary

All-solid-state Li rechargeable battery is assembled by using fast Li-ion conducting solid electrolyte and solid electrodes.

The Li-ion conductivity of the assembled cell increases by applying higher pressure, which provides better contact between solid electrolyte and solid electrode.

The prepared all-solid-state battery is rechargeable. However, the cell has to be more optimized to produce better cycle-life at fast charge/discharge current.

This preliminary data shows that it is possible to build all-solid-state Li rechargeable battery without using any liquid electrolytes.

This type of battery can be valuable to the next-generation electrochemical devices.