Two-Dimensional Simulation of All-Solid-State Lithium-ion Batteries

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Abstract

There is great interest in developing all-solid-state rechargeable lithium-ion batteries. They are ideal micro-power sources for many applications in portable electronic devices, electric vehicles and biomedical engineering, which require high energy and power densities, good capacity retention for thousands of discharge/charge cycles, and an extremely low self-discharge rate [1-3]. It is known that all-solid-state lithium-ion batteries are often fabricated by thin film methods, with thicknesses in the range of a few micrometers. Since porous electrodes are not used, all electrochemical reactions take place on the interface between the electrolyte and solid electrode domains.

Now all-solid-state lithium-ion batteries have become the state-of-the-art in modern battery technology [4]. Since the conductivity of the solid electrolyte is typically several orders of magnitude lower than that of a traditional liquid electrolyte lithium-ion battery, many previous investigations were focused on material properties of the solid electrolyte. In order to make further improvement in solid-state battery technology, an in-depth understanding of the electrochemical processes involved in the solid-state battery is necessary. There is no doubt that the numerical simulation method is a powerful tool to realize the purpose.

In this work, we present a simulation research based on a two-dimensional model of all-solid-state lithium-ion batteries [5] using the COMSOL Multiphysics® software. The Tertiary Current Distribution interface and the Transport of Diluted Species interface are coupled. The results show the concentrations of lithium ions in the electrolyte and the lithium concentrations in the positive electrode. The discharge curves (cell voltage vs. time) for various discharge rates are obtained and analyzed.

Reference

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[4] D. Danilov, et al., "Modeling all-solid-state Li-ion batteries", Journal of The Electrochemical Society 158 (3), A215-A222 (2011).
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Figures used in the abstract

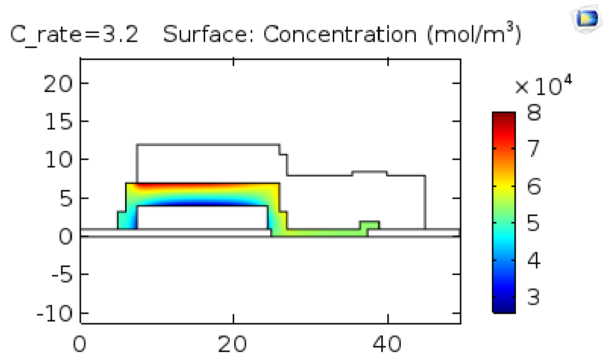

Figure 1: Concentration of lithium ion in the electrolyte at the end of 3.2 C-rate discharge

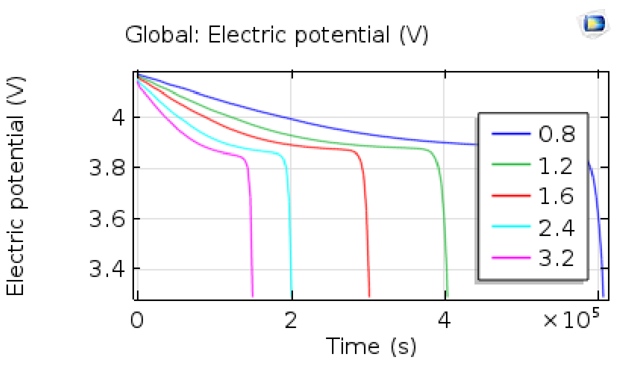

Figure 2: Discharge curves for various discharge rates