Sulfide-Composite Solid Electrolyte for High voltage cathode in Li metal batteries

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Abstract

Over the past 30 years, lithium-ion batteries (LIBs) gained tremendous success in powering portable electronics and electric vehicles (EVs). However, when it comes to medium or large applications such as EVs, ensuring safety becomes of paramount importance. Nevertheless, the liquid electrolyte in LIBS has intrinsic flammability, causing serious safety concerns. In contrast, solid-state Li batteries (SSLBs) have garnered considerable attention in the past few years due to their numerous advantages, including low-cost, high-energy density, wide electrochemical potential window, and, most importantly, enhanced safety as they are non-flammable. The solid electrolyte is the indispensable component in solid-state Li batteries. Therefore, extensive research should take place in developing and processing novel SE materials. Solid composite electrolyte (SCE) combines the advantages of inorganic (fast ion transport) and polymer electrolytes (superior flexibility), which enables them as one of the most promising SE candidates for SSLBs. In this work, we report the synthesis of two sulfide composite electrolyte membranes (thickness of 50-80 μm) and demonstrate their cycling ability in solid-state Li metal batteries. The designed SCEs consist of a fixed amount (10 wt%) of inorganic sulfide (Li_7PS_6 or Li_3PS_4) embedded in a polyvinylidene fluoride-co-hexafluoropropylene (PVDF-HFP) polymer matrix and LiTFSi salt. The ionic conductivity of the Li_7PS_6-composite is measured to be 3.5×10^{-4} S cm^{-1}, while the Li_3PS_4 composite exhibits an ionic conductivity of 2.75×10^{-4} S cm^{-1}, both higher than that of the polymer electrolyte (PVDF-HFP). We have successfully demonstrated the cycling ability of SCEs paired with high voltage cathode material, namely $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$ (NMC 111), across a wide range of electrochemical windows (2.5- 4.0 V and up to 4.4 V). The NMC| SCE| Li cells demonstrate an impressive initial specific capacity of 150 $mAhg^{-1}$ and stable cycling over 100 cycles at a charge-discharge rate of 0.1 C within the voltage window of 2.5-4.0 V.

Biography of Sharmin Akter

Sharmin Akter is currently a Ph.D. student in the Mechanical Engineering department at the University of Louisville (UofL). She has completed her MS in Physics and Astronomy from the UofL. She has been working in the Conn Center for energy storage systems under Dr. Hui Wang since 2021. Her current research focuses on developing solid-state Li-ion batteries, solid composite electrolytes, materials synthesis, and Solar cells. Her prior experience deals with Molecular Spectroscopy and Non-linear optics. She was nominated for a 2019-20 Faculty Favorite award by the Delphi Center for Teaching and Learning as a Teaching Assistant.