Interplay between microstructural properties with ionic/electronic conductivity in Na3PS4-based composite cathodes for Na-SSBs

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The potential of having high energy and power density in all-solid-state batteries (ASSBs) makes them attractive candidates for energy storage systems of the future [1]. They also have several advantages over traditional liquid electrolyte-based systems, including safety and a wide operating temperature range [2]. Furthermore, the higher abundance of sodium relative to lithium makes solid state sodium ion batteries a more cost-effective alternative [3]. One challenge is the limited ionic transport capabilities of current solid electrolytes (SE), but also the development of a suitable cathode, which is as crucial as having a promising SE for practical applications [4]. An optimized composite cathode (CC) should provide a percolating network of ions and electrons with short transport pathways and a large active interphase area between SE and cathode active material (CAM) [4,5]. Therefore, the composite cathode must be carefully built by optimizing the phase fractions between CAM, SE, and CA (conductive additive), particle characteristics, and phase distribution to ensure percolation and adequate ionic and electronic transport.

In this work, our motivation is to gain a deeper understanding of the relationship between the microstructure and the ionic/electronic conductivity of the composite cathode. Within this aim, as a CAM, NaCrO2 was mixed with the conductive matrix (CM), which consists of Na3PS4 as a SE and vapor growth carbon fiber (VGCF) as a CA. The effective ionic and electronic conductivity of the composite cathodes were measured using electrochemical impedance spectroscopy (EIS) with two different configurations (ion blocking and electron blocking). The cross-sectional microstructures of CCs were investigated via scanning electron microscopy (SEM) and FIB-tomography. Our findings revealed that reducing the Na3PS4 (SE) and VGCF (CA) content simultaneously results in a balanced ionic and electronic conductivity (70 wt. % CAM contained CC) at 10 MPa stack pressure. Additionally, both ionic and electronic conductivity values increase with increasing stack pressure. 2D microstructural information from SEM images showed slightly reduced density but a better CAM distribution by reducing CAM content. To obtain 3D information from the microstructures XRM & FIB tomography analyses will be performed and presented in this study.

Keywords:

Sodium solid-state batteries, Microstructural design

Reference:

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