Optimizing the electrode properties of Lithium solid-state batteries

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Fraunhofer IKTS is developing electrodes and cells for solid-state batteries with oxide, sulfide and polymer electrolytes. Imaging and electrochemical methods are combined to specifically improve the electrode properties. The newly established workflows enable targeted optimization of the electrode morphology. As a result, solid-state batteries can be developed in significantly shorter iteration cycles.

A cathode consisting of an active material (NCM811) and a highly conductive sulfidic electrolyte was optimized so that its function – high capacity at high rate-capability – is improved with the highest possible active material content. The electrodes of solid-state batteries have a more complex structure than those of conventional Li-ion batteries. Different classes of materials from the field of inorganic solid ion conductors – oxide ceramics, sulfides and halides – as well as polymers are used here. The solid electrolyte is an additional component introduced during the manufacturing process. Two interlocked conducting networks (top figure) are formed for electrons via the active material (blue arrows) and for ions via the sulfide solid electrolyte (orange arrows). Passive components, such as binders or residual porosity, interfere with this conduction.

For a detailed understanding and with a view to optimizing this complex morphology, electrochemical measurements were combined with direct imaging techniques (middle figure). Information on the electrochemical bonding of the active material particles and the effective ionic and electronic conductivities can be obtained from capacity, rate capability and impedance measurements. Scanning electron microscopy on electrodes complements this information with morphological data on homogeneity and conduction paths. Secondary ion mass spectroscopy (SIMS) in the helium ion microscope additionally visualizes the binding of individual active material particles by means of lithium analysis.

A major preparative challenge for the sulfide cathodes shown in the top figure was the high demands placed on the working atmosphere. For this reason, a workflow consisting of all analytical steps – preparation, sample transfer, and measurement – was established under an inert gas atmosphere. In this way, fresh electrodes or those recovered from solid-state batteries can be prepared and analyzed completely free of contamination in the absence of air. This combination has enabled electrodes with good electrochemical properties (bottom figure) to be developed in significantly shorter iteration cycles.

Services offered

- Development and post-mortem analysis of solid-state batteries and components
- Electrochemical analysis: ionic and electronic conductivity, full-cell and half-cell tests
- Ion milling and inert transfer into field effect scanning electron microscope and helium ion microscope, lithium detection (SIMS)

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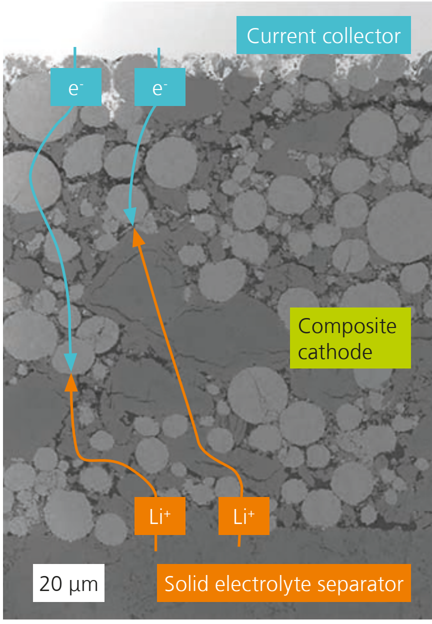
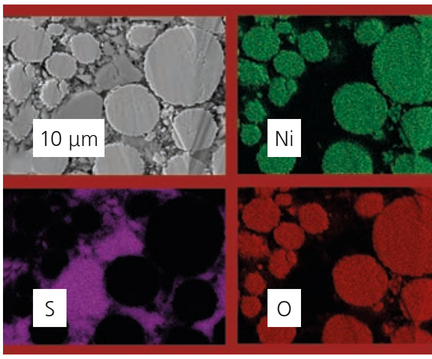
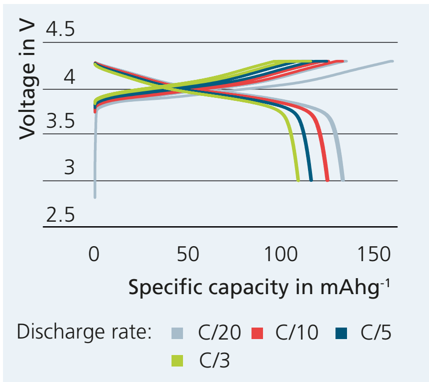


FESEM image of the cut through a sulfide electrolyte-based solid-state cell; conductive path for electrons (blue) and Li-ions (orange).



Cross section of the sulfidic composite cathode in FESEM and EDX element mapping.



Rate capability test of a solid-state battery cell.