Partial conductivities of single NCM-111 secondary particles and sintered pellets

Julian Zahnow [a,b], Simon Burkhardt[b,c], Janis K. Eckhardt[b,c], Amalia C. Wagner[d], Joachim R. Binder[d], Peter J. Klar[b,c], Matthias T. Elm[a,b,c], Jürgen Janek[a,b],

[a] *Institute of Physical Chemistry, Justus-Liebig-University, Heinrich-Buff-Ring 17, 35392 Giessen*

[b] *Center for Materials Research, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen*

[c] *Institute of Experimental Physics I, Justus-Liebig-University, Heinrich-Buff-Ring 16, 35392 Giessen*

[d] *Institute for Applied Materials, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen*

E-mail: julian.zahnow@phys.chemie.uni-giessen.de

Lithium-ion batteries are widely used as power sources in various applications. However, a further improvement of the battery performance such as cycle life time or efficiency is desirable, which is mainly determined by the microstructure of the electrode material and side reactions with the electrolyte. With regard to further optimization a fundamental understanding of the influence of the microstructure on the ionic and electronic transport pathways in the active cathode material is necessary. In the presented work the partial conductivities of the cathode material NCM-111 were determined for single secondary particles with a diameter between 20 and 40 µm and for sintered pellets without the addition of conductive additives. NCM-111 was chosen as reference cathode active material (CAM), as its conductivities are high enough to perform impedance measurements even on single particles without encountering too high impedances.

The pellets were contacted with different metal electrodes (gold, silver, copper) and characterized via impedance spectroscopy. The measurements were performed in a temperature range between -60 and 100 °C using an amplitude of 50 mV. To extract the partial conductivities the impedance spectra obtained were fitted with an equivalent circuit for mixed conductors proposed by Maier et al.[1] including an additional RC-element representing the contact resistance of the sample-electrode interface. By using different metal electrodes, the resulting contact resistance could be determined.

For the electrochemical characterization of single NCM-111 secondary particles using impedance spectroscopy two different approaches were used. First, the secondary particles were fixed on a conducting sample holder and contacted individually with micromanipulators in a scanning electron microscope. Second, the single particles were positioned individually on a predefined position of a patterned substrate in a specially designed electrochemical cell. The results determined imply a correlation of the total resistance with the diameter of the secondary particles. The estimated conductivities are in good agreement with the values calculated from the measurements performed on the macroscopic samples.

References:

[1] J. Maier, Physical Chemistry of Ionic Materials. Chichester, UK: John Wiley & Sons, Ltd, 2004..