Multi-scale Correlative Tomography of Lithium Ion Battery Electrodes

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Capacity and performance of lithium ion battery electrodes are strongly affected by chemical composition and microstructure. Advanced tomography methods like focused ion beam (FIB) / scanning electron microscopy (SEM) tomography [1] and X-ray tomography [2] can be used to analyze the complex morphology of multi-phase electrodes. These methods deliver 3D image data containing the information of all electrode phases (i.e., active material, carbon black, and pore phase) with their respective size distributions, surface areas and tortuosities. However, the structural analysis of state-of-the-art LIB cathodes is not a trivial task, as all phases show important structural details in the micro- and in the nanometer range. Consequently one single tomography method could provide meaningful information up to a certain extent, but is not enough to gain information about the electrode as a whole.

Moreover, irrespective of the applied tomography method and the type of electrode under investigation, various challenges arise during reconstruction and analysis: (1) the detection and separation of the different phases is highly non-trivial, as especially the carbon black typically shows very low contrast, (2) small feature size or a fissured texture or porosity inside the active material or the solid electrolyte demand for a resolution in the 10 nm range while (3) large feature sizes (typically particles of the active materials or inhomogeneities) demand for a representative volume element of several 100 m and more.

In this contribution, a detailed microstructural analysis using X-ray and FIB/SEM tomography [3] on commercial LIB cathodes is applied. Arising challenges, possibilities and limits of the methods will be discussed, alongside with possible sources of error and their impact on the results. A composite electrode will be analyzed in detail to give more insight into the potential of tomography methods for the analysis of battery electrodes.

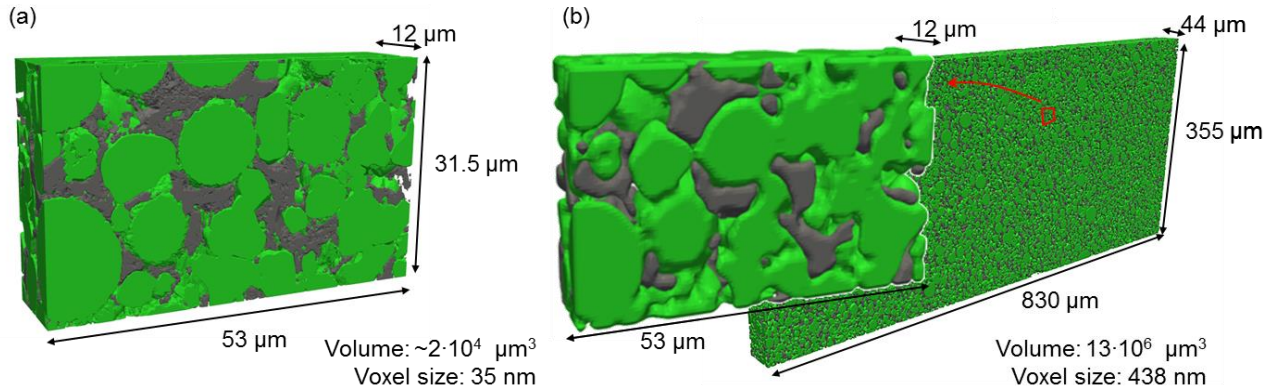

Figure 1: Comparison of a $LiCoO_2$-$Ni_{0.8}Co_{0.15}Al_{0.05}$ (LCO-NCA) cathode reconstructed by (a) FIB-SEM tomography and (b) X-ray tomography. Green corresponds to LCO-NCA, black to carbon black.

[1] M. Ender, J. Joos, T. Carraro and E. Ivers-Tiffee, *J. of the Electrochem. Soc.*, **159**, A972-A980 (2012)

[2] P.R. Shearing, L.E. Howard, P.S. Jorgensen, N.P. Brandon and S.J. Harris, *Electrochemistry Communications*, **12**, 374-377 (2010)

[3] R. Moroni, M. Börner, L. Zielke, M. Schroeder, S. Nowak, M. Winter, I. Manke, R. Zengerle and S. Thiele, *J. of the Electrochem. Soc.*, **159**, A972-A980 (2012)

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