Assessment of All-Solid-State Batteries with Different Solid Electrolytes

Philipp Braun [a], Michael Weiss [a], Ellen Ivers-Tiffée [a]
[a] *Institute for Applied Materials (IAM-WET), Karlsruhe Institute of Technology (KIT), D-76131 Karlsruhe, Germany*

E-mail: philipp.braun@kit.edu

All-solid-state batteries (ASSBs) operate with solid electrolytes based on oxides, sulfides or phosphates and give new perspective to high specific energy and power density [1]. The promise is to use solid-state electrolytes to eliminate potentially flammable liquids.
Likewise, attention needs to be directed towards improved solid electrolytes, both with respect to ion conductivity and stability over wide chemical activity limits. The study of grain vs. grain boundary contributions [2], as well as interfacial reactions with electrode materials during processing and their impact on electrochemical performance is critical for the understanding and optimization of solid-state batteries, up to novel bi-layer solid electrolytes, electrode/electrolyte composites, and alternative solid-state battery architecture. In this context, the assessment of solid electrolytes, electrode materials, solid electrolyte/electrode interfaces and three-dimensional composite electrodes becomes key.
A newly developed one-dimensional model for ASSBs is presented, based on a design concept with composite electrodes. The expected performance is simulated by linking two phase transmission line models for both composite electrodes with an ohmic resistance for the solid electrolyte. Variations of (i) electrical parameters, i.e. ionic and electronic conductivity, (ii) electrochemical parameters, i.e. charge transfer resistance, and, (iii) microstructure parameters, i.e. phase tortuosity and composite electrode thickness, indicate the most important material and design parameters for high-performance batteries. Performance potential will be presented for various inorganic solid electrolytes, i.e., glassy types (Phosphates, Oxides and Sulfides ($Li_{10}GeP_2S_{12}$)) and crystalline types (LISICON, Garnets ($Li_7La_3Zr_2O_{12}$), Perovskites ($Li_{3x}La_{2/3-x}TiO_3$)). Model calculations will be compared with performance data from literature [3].

References:
[1] J. Janek and W. G. Zeier, Nat. Energy, vol. 1, no. 16141, 2016.
[2] P. Braun, C. Uhlmann, A. Weber, H. Störmer, D. Gerthsen, and E. Ivers-Tiffée, J. Electroceramics, vol. 38, no. 2–4, pp. 157–167, 2017.
[3] Y. Kato, S. Hori, T. Saito, K. Suzuki, M. Hirayama, A. Mitsui, M. Yonemura, H. Iba, and R. Kanno, Nat. Energy, vol. 1, 16030, 2016.

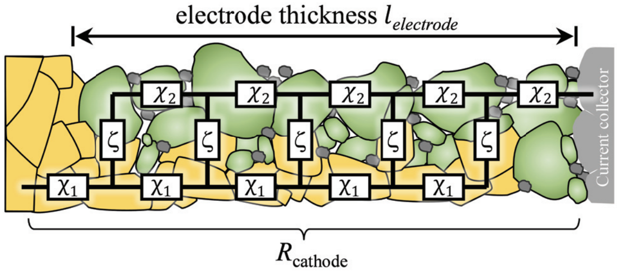

Figure 1 Schematic of a ASSB composite electrode described with a two-phase transmission line model.