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Current challenges in fabrication and operation of oxide-based all-solid-state Li-batteries

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All-solid-state Li-batteries (Li-ASBs) promise to alleviate many issues related to the use of organic liquid electrolytes in conventional Li-Ion Batteries since they have the potential to simultaneously increase the energy and power density while offering intrinsic safety and low degradation. They are thus intensely researched worldwide and are of high interest to automotive and portable electronics applications. However, of the many materials and cell chemistries that are explored in fundamental research, successful demonstrations on larger scales are still missing. Of all concepts, oxide based solid electrolytes like the garnet structured $Li_7La_3Zr_2O_{12}$ (LLZ) in combination with Li-metal anodes and thick mixed cathodes promise the highest theoretical energy densities. To demonstrate functionality in larger cells, two main challenges are currently faced during fabrication and one during operation of such large cells using a Li metal anode. For fabrication, scalable synthesis methods for of LLZ itself and processing technologies for large area cell components need to be investigated. While LLZ can be produced with a variety of methods on lab scale, the authors developed a process that allows for large quantities of high quality powder to be synthesized using an industrial established process. Subsequent fabrication of high capacity mixed cathodes requires not just electrochemical stability of the materials used, but also chemical stability at the elevated processing temperatures of ASBs. Secondary phase formation at the electrolyte/cathode interface thus poses further challenges in cell manufacturing. During operation of full all-solid-state cells using Li metal anodes, the difficulty of suppressing the growth of Li dendrites is the main challenge. It is thus essential to understand dendrite formation in LLZ on a fundamental level in order to find mitigation strategies, like the application of interlayers a concept successfully invented by the authors.

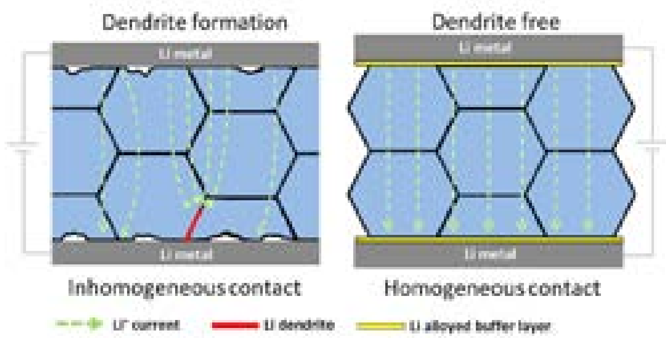

Figure 1: Li dendrite formation in LLZ and suppression via buffer layer.

Recent Publications

1. Uhlenbruck S, Dornseiffer J, Lobe S, Dellen C, Tsai C L, Gotzen B, Sebold D, Finsterbusch M and Guillon O (2017) Cathode-electrolyte material interactions during manufacturing of inorganic solid-state lithium batteries. Journal of Electroceramics DOI 10.1007/s10832-016-0062-x.
2. Dellen C, Gehrke H G, Möller S, Tsai C L, Breuer U, Uhlenbruck S, Guillon O, Finsterbusch M and Bram M (2016) Time of flight - secondary ion mass spectrometry study of lithium intercalation process in $LiCoO_2$ thin film. Journal of Power Sources 321:241-247.
3. Troy S, Schreiber A, Reppert T, Gehrke H G, Finsterbusch M, Uhlenbruck S and Stenzel P (2016) Life cycle assessment and resource analysis of all-solid-state batteries. Applied Energy 169:757–767.

4. Lobe S, Dellen C, Finsterbusch M, Gehrke H G, Sebold D, Tsai C L, Uhlenbruck S and Guillon O (2016) Radio frequency magnetron sputtering of $Li_7La_3Zr_2O_{12}$ thin films for solid-state batteries. Journal of Power Sources 307:684–689,
5. Tsai C L, Dashjav E, Hammer E M, Finsterbusch M, Tietz F, Uhlenbruck S and Buchkremer H P (2015) High conductivity of mixed phase Al-substituted $Li_7La_3Zr_2O_{12}$. Journal of Electroceramics 352:25-32.

Biography

Martin Finsterbusch has his expertise in developing ceramic based cells and components for future electrochemical energy conversion and storage. Majoring in Physics and Material Sciences, he pursued his PhD in the field of solid oxide fuel cells, investigating the degradation behavior via synchrotron based analysis methods. Translating the knowledge of ceramic based synthesis and manufacturing into the all solid state batteries field, concepts are investigated to increase the energy and power density as well as develop scalable synthesis and manufacturing routes in order to enable this technology for commercial application. Starting at new materials and components development and going all the way to full battery cell manufacturing, conventional an in-house developed ceramic synthesis and processing methods are used.

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