Interplay of Degradation Phenomena during Fast Charging : Li plating and SEI Growth

Nireas Rigos[a,b], Lars v. Kolzenberg[a,b], Simon Hein[a,b], Birger Horstmann[a,b,c], Timo Danner[a,b], Arnulf Latz[a,b,c]
German Aerospace Center (DLR), Institute of Engineering Thermodynamics, 70569 Stuttgart, Germany
Helmholtz Institute Ulm for Electrochemical Energy Storage (HIU), 89081 Ulm, Germany
Ulm University, Institute of Electrochemistry, 89081 Ulm, Germany
nireas.rigos@dlr.de

Lithium-ion batteries are still the leading technology for electrochemical energy storage in the fields of mobile applications, such as electric vehicles and portable electronics. Despite the significant improvements in rate capability and energy density over the recent years, battery performance and durability is affected by various degradation mechanisms. These lead to gradual deterioration or even sudden failure and safety relevant events.

Two dominant ageing mechanisms in Li-ion batteries are metallic lithium deposition (Plating) and continuous Solid Electrolyte Interface (SEI) growth. Especially during fast-charging, the identification and prediction of those complex electrochemical processes is crucial for the development of efficient and long-lasting batteries. Despite insightful studies on electrode optimization by tailoring the design [1], the interplay between SEI growth and Li-Plating over the lifetime of the battery under fast-charging conditions is not yet properly understood.

The present work employs a model-based approach to study the aging phenomena on the surface of graphitic anode materials for medium and high charging currents. For this purpose, a combined surface model is formulated, which couples the aforementioned anode aging mechanisms and enables a correlation to the local conditions at the graphite surface. The coupled description is based on models for lithium plating and SEI growth recently developed in our group [2,3], as well as ongoing work.

The developed model is integrated within a thermodynamically consistent transport theory [4] and implemented in the electrochemical simulation framework BEST [5] for 3D micro-structure resolved simulations. The results of current methodology will allow us to relate the electrode microstructure with degradation processes, especially for fast charging applications. Additionally, efficient numerical schemes which allow correlation to experimental data will be presented.

[1] De Lauri et al., “Beneficial Effects of Three-Dimensional Structured Electrodes for the Fast Charging of Lithium-Ion Batteries”, ACS Applied Energy Materials, doi: 10.1021/acsaem.1c02621
[2] S. Hein, T. Danner, and A. Latz, “An Electrochemical Model of Lithium Plating and Stripping in Lithium Ion Batteries”, ACS Appl. Energy Mater., vol. 3, no. 9, pp. 8519–8531, 2020, doi: 10.1021/acsaem.0c01155.
[3] L. von Kolzenberg, A. Latz, and B. Horstmann, “Solid–Electrolyte Interphase During Battery Cycling: Theory of Growth Regimes”, ChemSusChem, vol. 13, no. 15, pp. 3901–3910, 2020, doi: 10.1002/cssc.202000867.
[4] A. Latz and J. Zausch, “Thermodynamic consistent transport theory of Li-ion batteries”, J. Power Sources, vol. 196, no. 6, pp. 3296–3302, 2011, doi: 10.1016/j.jpowsour.2010.11.088.
[5] “BEST Battery and Electrochemistry Simulation Tool - Fraunhofer ITWM.” https://www.itwm.fraunhofer.de/best (accessed Jan. 3, 2022).