Most recent advances at HIU towards environmentally-friendly and safer lithium batteries

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The continuously increasing importance of lithium-ion batteries for small-, medium-, and large-scale applications, ranging from mobile phones and laptops to electric vehicles and stationary energy storage, has triggered an increasing awareness concerning their environmental impact and safety [1,2].
With regards to the environmental issue, the utilization of water-soluble binding agents as, for instance, sodium carboxymethyl cellulose (CMC) for graphite anodes has led to a substantial improvement in terms of cycling stability and first cycle coulombic efficiency [3]. For the cathode side, however, the pronounced sensitivity of any kind of lithium transition metal oxide (e.g., $LiNi_{0.5}Mn_{1.5}O_4$ (LNMO), $Li[Ni_{1/3}Mn_{1/3}Co_{1/3}]O_2$ (NMC), or Li_2MnO_3*NMC) towards water in combination with the resulting severe pitting corrosion of the aluminum current collector has so far prevented the implementation of aqueous binders and processing techniques [4,5]. Herein, we will show that these issues can be overcome when introducing new complementary strategies, resulting in lithium-ion cathodes offering enhanced cycling stability, improved rate performance, and overall higher specific capacities [6-8].
With respect to safety, all-solid-state batteries (ASSBs) promise increased energy densities by enabling the safe use of lithium metal anode. Owing to their good ionic conductivity at room temperature, high ductility and low density, sulfidic electrolytes are among the most attractive candidates for high-energy ASSBs. Herewith, we report two different, but potentially complementary, approaches for the development of bulk-type ASSBs based on sulfidic solid electrolytes.
Firstly, we discuss the importance of materials selection to achieve high active material utilization with practical electrode loadings. As an example, the Li-S system is chosen for its particularly challenging, sluggish, cathode kinetics. We demonstrate how composite cathodes incorporating transition metal sulphides (such as, e.g., FeS_2) can improve sulphur utilization providing stable areal capacities [9].
Further, an easily scalable production procedure taking advantage of the ductility of sulfidic electrolytes is discussed. The tape casting procedure herein developed allows to easily process a slurry-based composite cathode ($LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$) by means of binder and solvent compatibles with the β-Li_3PS_4 electrolyte [10].

References

[1] D. Bresser et al., Energy Environ. Sci. 11 (2018) 3096-3127.
[2] J. Kalhoff et al., ChemSusChem 8 (2015) 2154-2175.
[3] H. Buqa et al., J. Power Sources. 161 (2006) 617-622.
[4] M.M. Thackeray, J. Am. Ceram. Soc. 82 (1999) 3347-3354.
[5] X. Zhang et al., J. Power Sources. 196 (2011) 5102-5108.
[6] N. Loeffler et al., ChemSusChem. 9 (2016) 1112–1117.
[7] N. Loeffler, et al., J. Power Sources. 248 (2014) 915–922.
[8] M. Kuenzel et al., ChemSusChem 11 (2018) 562 – 573.
[9] U. Ulissi et al., Adv. Energy Mater. (2018) 1801462.
[10] T. Ates et al., Energy Storage Materials, (2018) 10.1016/j.ensm.2018.11.011.