Alternative sustainable binders and solvents for cathode application in Li-ion battery

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From the ecological and environmental point of view, the use of renewable energies is becoming more and more important in our days and in the future. To this effect, Li-ion batteries have proven to be promising systems on the way to more ecological energy supply, especially for electromobility. In commercial evaluable Li-ion batteries, cathode binders are based on fluorinated polymers and copolymers, especially polyvinylidene fluoride (PVDF). The use of these polymers is problematic, as their processing requires toxic organic solvents such as N-methylpyrollidin-2-one (NMP), a harmful solvent that entails expensive efforts for safety reasons and equipment. Our developments focus on sustainable battery assembly processes by substitution of the toxic NMP and expensive and halogenated binders.

One of the research objectives is to functionalize bio-based alternative binders and adapt them to alternative solvents for cathode application. Additionally, cobalt lithium manganese nickel oxide (NMC622) is used as active material and carbon black (Super P) as conductive agents in cathode slurry manufacturing. For the use of renewable raw materials as binders, bio-based reactive resins have established themselves as potential and promising components. In this work, pre-polymerized epoxy resins and curing agents made by linseed oil and its fatty acids are served as flexible binders. Within the scope of this project, there are used epoxy modified fatty acids with a viscosity in the range of 4500 - 90000 mPa·s. These differ in the degree of crosslinking and thus in viscosity. Two non-toxic bio-based solvents - ethyl 4-oxovalerate and γ-valerolactone - substitute NMP as slurry ingredient. Both solvents are promising alternative candidates because of their closeness to NMP properties like polarity due to their chemical structures, high flash points (≥ 55 °C) and boiling points (≥ 200 °C).

First results highlight slurry application with alternative epoxy binders in combination with the alternative solvents, NMP622 and carbon black. After slurry preparation, the new systems of binder/solvent combinations show homogenous and stable slurries. The curing conditions and time efforts high temperature about 140 °C and 120 minutes until the epoxy binder is completely cured. Initial investigations have already ruled out some systems due to poor film forming properties (cracking and low flexibility or too rigid systems). Systems that showed promising film forming properties could be narrowed down as potential candidates for slurry production, used for further analysis and compared to conventional systems with regard to mechanical tests (T-Peel experiments), optical measurements of surface phenomena and conductive properties. As references, a PVDF/NMP/NMC622/carbon black slurry and a PVDF/ γ-valerolactone/NMC622/carbon black slurry are used. PVDF/ γ-valerolactone show poor solubility behavior at ambient conditions but it is soluble at a process temperature of 60 °C [Schmitt-Hansberg at al., ACS Appl. Energy Mater. 2021, 4, 696−703].

Based on the initial results, comprehensive investigation of electrochemical performance - especially cell capacity and cycle stability - will be carried out in the further course of this exploratory research. The influence of binder evaluation and functionalization, structure-interaction relationships, formulation variations and application studies on the electrochemical performance will be taken into account and finally, the sustainable materials for cathode application will be subjected to an ecological and economic evaluation compared to PVDF/NMP and PVDF/ γ-valerolactone.

ÖkoMatBatt “Ecologically and economically sustainable materials for cathode and anode coating in the lithium-ion battery” is funded by BMBF (03XP0401B).