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CPI (High Value
Manufacturing
Catapult)

CASE STUDY

The Challenge

The battery industry has become a highly competitive sector as an ever-growing demand for energy storage is required to reach Net Zero commitments throughout the globe. Whether they are used for small portable electronic devices, large electric vehicles or to store renewable energy sources, lithium-ion batteries age due to inherently unstable chemical interfaces. This project tackles the problem of extending lithium-ion battery life by applying a protective coating to commercially available cathode active materials. This must be done in a way that is sustainable, cost effective and scalable to be suited for highly demanding applications. The University of Liverpool has worked on the coating of battery powders for the last five years, optimising several reaction parameters and achieving significant improvements in charge retention. Up to the Researchers-in Residence project, this platform has been developed at laboratory scale on both the synthesis and the battery testing. The partnership with the Centre for Process Innovation (CPI) worked to scale-up this process, without any detrimental performance loss, characterising the inorganic material and the battery performance and translating a lab-scale method towards commercial scale.

Innovation

Scaling up a chemical process 25 times is a big challenge. With larger amounts of volume and a different cell geometry, key parameters such as fluid dynamics and heat transfer do not necessarily translate, and reactions parameters need to be readjusted to ensure a homogeneous coating. At this scale, safety is also a bigger concern, and protocols had to be redefined. The project started with several visits from the catapult's engineers to Liverpool, to allow a knowledge transfer of the coating reaction. At first, a small 5 times scale-up was developed at CPI using the same lab scale apparatus, following that, a 25 times scale-up using a chemical engineering industry Radleys reactor. The effect of using different suppliers for the cathode materials, varying particle size distribution, was also analysed. The physicochemical characterisation, battery assembly and testing took place at Liverpool under standard conditions, and the effect of cell assembly parameters was studied by the catapult partner. Throughout the project, a rapid direct analytical tool to determine quality of coating was developed and implemented using a pH meter and a standard operating procedure was devised.

Result

Battery active materials coated at industry scale during the project performed without capacity fade compared to uncoated samples. This was a concern for the success of the project, as the coating layer is an insulating inorganic alumina phase, which can restrain the flow of lithium ions above a critical thickness. The charge retention when cathodes were coated was close to 90% compared to 25% for uncoated samples after 300 charge/discharge cycles. The cycling tests were performed at harsh conditions to drive degradation, high currents and cut-off voltages, to stress test the effectiveness of the protective layer. When analysing different material suppliers, an important observation was made about the role of particle size distribution, which below 5 μm results in weaker coatings and faster degradation kinetics. Batteries tested at high current (fast degradation processes) showed similar performance compared to low current tests. Battery assembly protocols such as electrode calendaring had no effect on battery performance when using coated

particles, which would ultimately reduce cost and time. Before the Researchers in Residence project, the protocol at Liverpool to test the quality of the coating obtained involved assembling and testing a coin cell, which takes a couple of days. The analytical tool based on pH sensing of coated and uncoated samples developed during the project reduced that time to one hour.

Impact

The family of cathode chemicals used in the project with high nickel content can provide superior energy density, however their application is limited by faster degradation processes. The main impact of the project was to protect this high nickel material producing the sol-gel coating reaction at 25 g scale, from a 1 g laboratory start point, and that the alumina coating significantly deters degradation reactions that reduce charge over time which is of vast interest for the battery industry. Upscaling commercially available and relevant battery raw material allows this technology to be tested at small prototype cells, mAh-Ah, which was not possible before the project. A deeper understanding of the chemical process and the prerequisites of the starting material for a successful coating reaction helps to translate this method to other battery chemistries. Battery manufacturing protocols were evaluated aiming to reduce cost and time. Ultimately, the project addresses an important issue in the battery sector, increasing battery lifetime and allowing for fast charging by protecting some of the known degradation mechanism with the potential to provide fast charging of electric vehicles and assist with range anxiety.



Filipe Braga

Working in the RiR programme was a big career development opportunity for me. It helped me gain skills in material synthesis and characterisation outside of the laboratory space and closer to what is needed in the industry sector. I was able to get trained in battery manufacturing towards pilot line assembly to become a more capable battery chemist. It gave me a deeper understanding of the commercialisation steps in my field, as well as in impact generation and intellectual property. For me it was a special project as it was my first individual funding acquired and my first experience with project management as the principal investigator. Finally, I believe the RiR programme played an instrumental role in achieving my first academic appointment after years working as a research associate.

CPI (HVM Catapult)

Collaborating with the Researcher in Residence exposed us to innovative technology in the batteries space. This speaks to CPI's key goals, with sustainable energy materials being one of our key strategies. Working on this project has allowed us to develop our internal understanding and capabilities of battery material coating and has led to internal discussions on where the learnings can be applied to future projects. It has also given exposure of junior engineers and chemists to the type of research being carried out in academia and lit a passion in them to pursue PhDs to develop their own research skills.