SOLIDBAT

Deliverable D3.1

1st generation of battery materials and components

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1.PUBLISHABLE SUMMARY

The SOLIDBAT project, funded under the Horizon Europe program, aims to develop competitive and sustainable lithium solid-state battery technology for large-scale automotive applications. The project focuses on overcoming key challenges in battery performance, efficiency, and scalability. Deliverable D3.1, titled "1st Generation of Battery Materials and Components", summarizes the progress made during the first year of the project in the development of battery materials and components, with a particular focus on tasks T3.1 (High-Energy Cathode Development), T3.2 (Hybrid Gel Polymer Electrolyte (HGPE) Development), and T3.3 (Lithium Metal Anode Development), of WP3.

High-Energy Cathode Development: The development of high-energy cathode materials is crucial to achieving the targeted performance of solid-state batteries. The SOLIDBAT project focuses on water-processed nickel-rich layered oxide cathodes, specifically $Li(Ni,Co,Mn)O_2$ (NMC), with Ni ≥ 80%. These materials provide high specific capacity and nominal voltage, which are essential for meeting the energy density requirements of automotive applications. However, high-nickel cathodes suffer from several degradation mechanisms, including particle cracking, oxygen release, and the formation of a rock-salt phase during cycling. Furthermore, water-based processing poses additional challenges, due to the potential degradation of the cathode active material in aqueous media. The SOLIDBAT team addressed these issues by applying protective coatings to the cathode materials, using both spray-drying and mechanofusion techniques, and by developing water-soluble binders. Preliminary results indicate that these coatings successfully reduce degradation mechanisms and improve cycling stability, particularly at high current rates. After the first year of development, first generation coated active materials were selected for production of larger quantities (≥ 50 g) via spray drying and shipment to the partners.

In parallel, water-processed cathodes have been developed with uncoated cathode active material and with appositely synthesized copolymer binders. Water-processed cathodes with areal loading >3 $mAh \cdot cm^{-2}$ and electronic conductivity above 0.1 $S \cdot cm^{-1}$ have been developed. Further development will focus on optimizing the cathode formulation, to improve performance and cyclability.

Hybrid Gel Polymer Electrolyte (HGPE) Development: One of the project's key innovations is the development of HGPEs, which aim to replace traditional liquid electrolytes and enhance the performance of solid-state batteries. The development has targeted different aspects, from a) monomer synthesis, b) solid ceramic electrolyte development, c) GPE development, d) separator screening. The HGPEs being developed exhibit high ionic conductivity (≈0.5 $mS \cdot cm^{-1}$ at 25 °C), high electrochemical stability (≈4.5 V *vs.* Li/Li^+), and good compatibility with other battery components, thereby contributing to enhanced performance and longer lifespans of the battery. The project has made significant progress in optimizing the composition and properties of the HGPEs, showing promising results in early tests. A cycle life of nearly 180 cycles with capacity retention of 89% was achieved for NMC-811||Li cells with an area capacity of 3 $mAh \cdot cm^{-2}$, at C/3 rate. In a parallel development, the effect of the microporous separator was investigated. The results showed the possibility of using thinner separators (17 µm), which could contribute to increased cell energy density. The next steps will focus on further refinement to increase cycle life and on testing in combination with developed cathodes.

Lithium Metal Anode Development: In parallel with advancements in cathode and electrolyte materials, the SOLIDBAT project also focuses on 3D structured lithium anode development, which is also crucial for improving the C-rate capability, cyclability and both the electrical and mechanical properties of the battery. Several electrolytes` formulations have been tested to identify the optimal composition for Li plating/stripping performance. Some of these tested compositions demonstrated good performance at challenging cycling conditions of 2 $mAh \cdot cm^{-2}$ and a C/3 rate. First trials have been performed to reduce the thickness and structure of the surface morphology of lithium anodes. Thin Li-Cu electrodes have been delivered to WP3 partners for further development within the frame of WP3.

Future Directions: The first generation of battery materials has undergone extensive electrochemical testing to assess key performance metrics such as discharge capacity, coulombic efficiency, and cycling stability. The results are promising, with the coated cathode materials showing improved stability and cycling performance compared to the uncoated materials. However, further optimization is required to improve long-term cycling performance and scalability. The next phase of the project will focus on refining these materials, optimizing the manufacturing processes, and scaling up production for large-scale battery production suitable for automotive applications.



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