LC-BAT-14: HINDERING DENDRITE GROWTH IN LITHIUM METAL BATTERIES

Grant Agreement n° 957202

D[1.1]: Specifications for the HIDDEN solutions, with details for every WP from all project partners

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Deliverable nature	Report
Dissemination level	CO (Confidential)
Contractual delivery date	M6 – 28/02/2021
Actual delivery	09/03/2021
version	V1.0

Public Summary

HIDDEN project aims at:

1. preventing dendrite growth in Lithium Metal Batteries (LMB) with the help of three self-healing methods: TILC (i.e. thermotropic ionic liquid crystals), piezoelectric separators, and protecting additives.
2. Demonstrating on-demand repeatable self-healing functionalities, which are controlled by the BMS and supported by analysis and modelling tools.
3. Creating an industrial process for the self-healing batteries

In this light, the specification document has covered all the functionalities (hardware or software), their capabilities, and the set of tests they must undergo.

As regards of *materials developments*, partners agreed that two generations of TILCs and self-healing TILC electrolytes (SHEs), i.e. TILCs supplemented with additives aiming at avoiding the nucleation and growth of lithium dendrites, will be produced. The 1st generation will consist of monocomponent TILCs featuring quasi-1D and 2D lithium-ion transport while the 2nd generation (monocomponent TILC or mixtures of TILCs enabled by the MAP and BIG-MAP approaches) will pave the way toward 3D Li^+ transport. As a starting point, a model TLC (thermotropic liquid crystal) structure has been selected to guide the access to orientate the first TILCs. Additionally, screenings of additives will be performed to allow for the generation of SHE-Gen1. In order to maximize the results and performances as well as to facilitate the access to the 2nd generation of TILCs and SHEs, TILCs-Gen2' TILCs' design must be guided by the MAP and BIG-MAP approaches, this provides HIDDEN the capabilities to perform physics-based modelling of the critical mechanisms as well as data-driven high-throughput screening and optimization of new candidates. A mini library of TILCs will be developed, additives will be scrutinized, and the best performing TILCs and SHE upscaled to pre-pilot scale.

As regards of *battery cell layers developments*, some of the battery components in HIDDEN project have been agreed in advance between partners such as electrodes-they have been specified in-depth throughout the document. As the project target is to utilize innovative self-healing techniques of lithium batteries, lithium anode is the obvious choice together with a commercial NMC cathode. Thermotropic liquid crystalline electrolytes are developed in the project as well as its upscaling processing concept. At least two processing methods will be evaluated and the most promising one upscaled into pilot.

One self-healing strategy is based on a fluoropolymer separator that, in addition to respecting all the requirements of common separators, has piezoelectric properties. Another technique is based on heating the TILC electrolyte up to a phase transition temperature, during which lithium dendrites are destroyed. To do so, a heating system is attached to the battery and it will be controlled by the battery management system. The heating system developed in the HIDDEN project needs to have a three-dimensional heating profile on the battery surface with an adequate operating voltage level. Assuming that the above-mentioned self-healing strategies are compatible, the partners could combine them.

As regards of *cell production/processing characteristics*, The HIDDEN partners agreed that the self-healing mechanisms developed in the project will be tested with multi-layered pouch cells with estimated capacity of 670 mAh. The cells will be built in different variants allowing to test the different

self-healing mechanisms independently and jointly. A flexible laboratory scale process will be established to enable the HIDDEN project to produce test samples in all desired configurations.

The liquid crystalline electrolyte deposition process will be upscaled to deliver equal or higher than 2 m/min output while delivering the product quality required for the final cells. Further, for lithium metal anode production the laser cutting method will be investigated with emphasis to cut edge quality.

The work package and the project will be supported by building a data repository, which allows tracking material lots and cells produced during the project along with test and characterization data produced for each component.

As regards of *analysis and modelling features*, The HIDDEN project will investigate non-invasive technique for the detection of dendrite growth process. The technique should rely upon measurements commonly available on battery management system hardware: voltage, current and temperature sensed at cell level.

The methodology will be based on three consecutive steps: (i) a first literature screening about the possible cell characterisation techniques, which shall create a reference ranking table; (ii) the analysis of the most promising characterisation techniques based on a testing campaign on LMB cells, which should create an a-priori knowledge of dendrite growth in LMB (e.g. dendrite evolution map); (iii) the development of a dedicated algorithm to detect and trigger the self-healing mechanism, which should be based on a meaningful modelling of LMB cells. All the steps will be supported using *ex-situ*, *in-situ,* and *operando* techniques to validate the whole methodology.

As regards of *Proof-of-concept functionalities*, Cells will be first tested individually with ad-hoc testing protocols. Different testing possibilities have been specified: performance tests, aging tests, and modelling tests. At a preliminary stage, focus will be given in understanding the state-of-art of LMB cells with respect to dendrite's evolution. Later, a similar set of tests will be applied onto HIDDEN samples to benchmark them and to quantify the self-healing benefits trough testing.

Finally, the full functionalities will be tested and validated in a small battery pack designed to provide 48V with a 14S2P configuration. BMS solutions for the purpose will have to be developed throughout following either an offline approach (i.e. standard BMS with additional triggering capability for self-healing activation, but sensing externally) or online approach (i.e. ad-hoc BMS with sensing and activation capabilities integrated).