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State of Health Determination of Lithium-Ion Batteries: Mechanistic Modeling Approach

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Expected duration in hours of the tutorial: ~3 h

Abstract:

State of health (SOH) determination in lithium-ion batteries (LIB) is an essential parameter to proper manage and control the battery packs of electric vehicles (EVs). To accurately track SOH, quantification of the degradation processes in LIBs is essential. In LIBs, degradation originates from complex inner physico-chemical processes, usually interacting simultaneously in various degrees of intensity [1]. Due to its complexity, to date, identifying battery aging mechanisms to accurately track SOH remains challenging.

Still, improvements in battery SOH identification have been developed, including validated, *in-situ* incremental capacity (IC) [2], coupled with mechanistic modeling construction and simulation [3]. Due to their *in-situ* and non-destructive nature, IC and mechanistic modeling is a feasible tool for on-board battery management systems (BMSs). Yet, despite its key advantages, the understanding and applicability of these techniques is not straightforward: it requires both electrochemical and material science insights, as illustrated in Fig. 1.

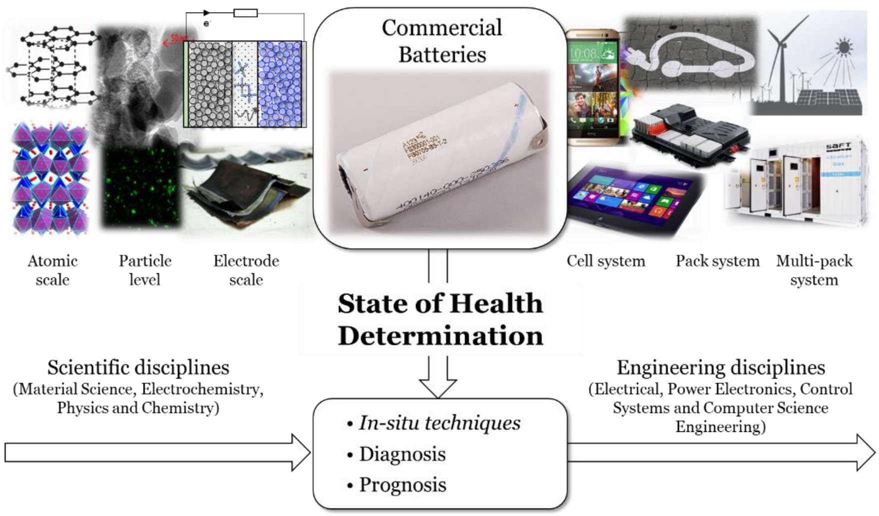

Fig. 1. General perspective of disciplines, background, and system levels that takes place during the process of SOH determination in lithium-ion battery system

In general, BMS design teams are mainly integrated by electrical engineers and may not include battery scientists. This lack of comprehension between teams presents a major hurdle in the BMS conception-to-design process. Aiming to bridge gaps in knowledge between engineering disciplines and battery science on battery degradation identification, this short course will present a systematic and validated approach to track SOH [4].

An overview of the approach to be presented in this course is shown in Fig. 2. We will cover first the fundamentals of LIBs to gain the required knowledge on cell degradation mechanisms. Then, we will provide the necessary tools, concepts and best practices to both carry out the battery laboratory testing for *in-situ* aging mode identification and the battery model construction [5]. We then present how linking battery testing data with reconstructed modeling allows us to decipher both qualitatively and quantitatively the underpinning aging modes ongoing on a given battery [6]–[9]. These findings lead to battery diagnosis and prognosis.

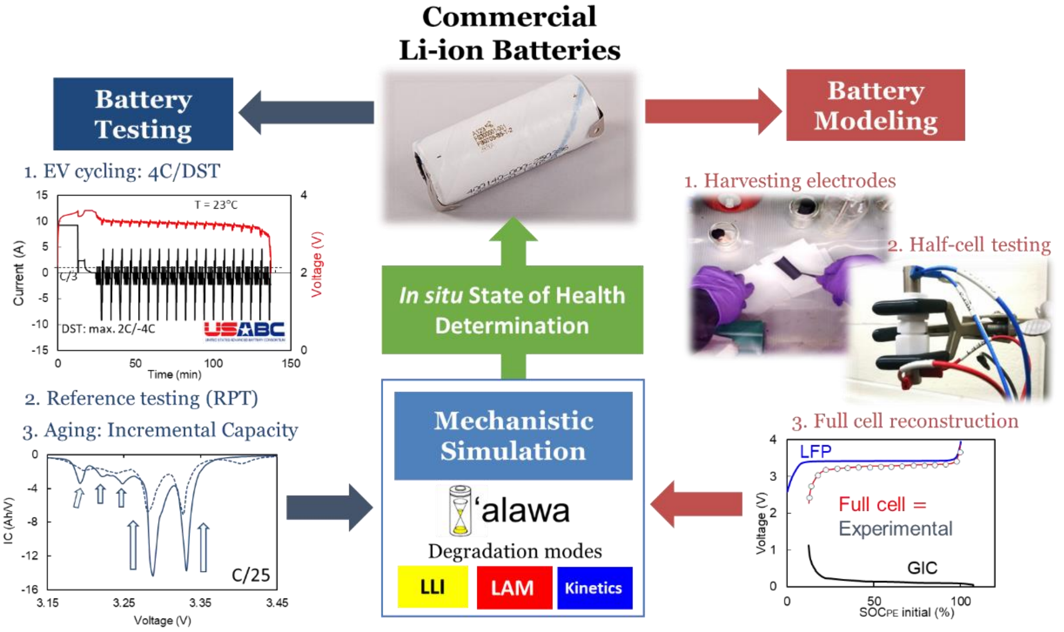

Fig. 2. Mechanistic modeling approach to determine the state of health of lithium-ion batteries

The last part of the class will be interactive and feature live analysis using Matlab®-based toolbox [10], specifically designed to simplify the use of these techniques, help diagnose SOH and identify and quantify the underlying degradation modes. Attendees will be able to adopt a pro-active attitude during a hands-on toolbox demonstration, as part of this short course.

Outline of the Tutorial

- An overview of commercial-based lithium-ion battery (LIB) fundamentals, including novel, Silicon based anode technologies
- A detailed presentation (from an Engineering perspective) of the degradation mechanisms in LIBs and its correspondence to mechanistic modeling
- A detailed analysis, presentation and insights of the incremental capacity (IC) and peak area (PA) electrochemical techniques
- Evaluation and design of testing protocols and reference performance tests to track SOH. Best practices and recommendations
- A detailed presentation of the battery modeling approach: techniques, recommendations, equipment and processes to accurately harvesting electrodes, half-cell testing and full-cell model mechanistic reconstruction
- Overview of the mechanistic simulation process with the Matlab® based, *'alawa* toolbox
- Hands-on toolbox demonstration to diagnose and prognose real-life battery testing data obtained from our laboratory
- Final remarks, applicability and future views of the presented approach

References

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Short bios of the instructor:

David Anseán received the M.Eng. degree from the University of Granada, (Spain), in 2007, and the Ph.D. degree (with honors) from the University of Oviedo, (Spain), in 2015, both in electronics engineering. Before pursuing his PhD, he gained international industry experience (Basingstoke, U.K., and Berkeley, CA, USA) in technological companies. As a doctoral student, he was the recipient of a research fellowship stay at the Electrochemical Power Systems Laboratory, at the University of Hawaii, USA, which he later joint as a Postdoctoral Fellow, to work in Dr. Dubarry's group on advanced diagnosis and prognosis techniques on lithium-ion batteries on.

Since 2016 he is an Assistant Professor at the University of Oviedo, where he is the instructor of undergraduate and graduate courses including power electronics, digital integrated circuits, and embedded systems. His research interests include lithium-ion battery degradation mechanisms analysis via non-invasive methods, battery testing and characterization, and design of battery fast charging.

In 2018 and in 2019 he was the recipient of Visiting Scholar Research Fellowships and joined the Institute for Power Electronics and Electrical Drives (ISEA) at RWTH Aachen University (Germany), and the Electrochemical Power Systems Laboratory, at the University of Hawaii, (USA), respectively.