The Influence of Fast Charging on Li-ion Battery Ageing

T3:9a Ageing and Li-ion battery cell testing – in relation to materials properties

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Summary

The main industrial goal for this project was to the study of lithium-ion battery degradation with a focus on how electrode materials will react to fast charging. This project is a part of a larger project involving all partners in SHC Theme 3. It is well known that it is the graphite anode in a Li-ion battery cell which is the critical component for how fast a battery can be charged. It has to do with the graphite not being able to transport the lithium ion fast enough into its atomic structure and therefore a layer of metallic lithium can be deposited on the graphite surface which destroys the ability to store lithium ions. It can also be a problem on the cathode side where particle cracking.

This project contributes with a deepened understanding on what parameters that influences battery life-time and aging when they are exposed to fast charging. This is important for choosing the right cell for a vehicle technology.

The most important result is our study of how the combination fast charging and rest periods to see how much of “self-healing” that takes place, The preliminary results are promising.

Dr. Fernanda Marzano has worked as a post doc in the project.

Background

Li-ion batteries are the rechargeable batteries with the highest gravimetric and volumetric energy densities on the market today. Since the market is still young there is not enough experience of which parameters that influence a fast a battery really can be charged. This project aimed to study the limits for how fast a battery can be charged. The definition by DOE (US Department of Energy) is 10 miles (~16km) of range per minute of charge, e.g. EV with 100 miles range (24 kWh battery pack) should be fully charged in 10 min. The question is how detrimental this is for the battery and if a fast charging once in a while could be handled by the battery.

There are several things that could happen during fast charging. The negative electrode, graphite, could be blocked by a layer of plated lithium metal which would stop the battery from functioning. There could be cracks in the particles of both active materials (anode and cathode) and there could be a consumption of the electrolyte leading to a dryer cell that also influences the long term durability.

This project aims to address these complex issues by studying how the electrode materials (particularly graphite) in model cells of Li-ion batteries can be improved to handle fast charging better. The study is one part of the foundation for an application to the battery fund for a longer study of these phenomena.

General project description

In this project the base-line chemistry chosen by SHC (Theme 3) was graphite vs. lithium iron phosphate ($LiFePO_4$). These are electrode materials that have been extensively studied and where it has been possible for several years to find and test commercial cells. This particular project has been focused on showing how graphite reacts to fast charging by studying graphite electrodes at different temperatures and at different rates. An important aspect of this work has be to combine the graphite with electrolyte formulations that can lead to as fast charging as possible and prevent lithium plating on the graphite surface. Surface treatment to create a better route for the lithium ions to enter the graphite also at high charging rates is also one part of the projecdt.

Achieved results

We report here studies of Li-ion battery cells which we have made ourselves as model systems for studying fast charging The work, which is a collaboration with all partners in SHC Theme 3 (Chalmers, KTH, Scania CV AB, Volvo Cars and AB Volvo,) is built to cover the whole chain from battery cell components to tests of cells in vehicles. The graphite electrodes made at UU have been used to fast charging also by Chalmers in their effort to develop a method to study electrodes exposed.

The studies we have performed are to see the limit of what a graphite electrode can handle. Therefore we have cycled batteries with a rate of 5-10C and studied the electrochemical response as well as the surface chemistries. It is clear that how the graphite is pre-cycled before assembled into a full battery cell is important for how well the battery can function. We have also made a matrix of studies where the graphite is cycled at different temperatures and allowed to rest for different time periods to study if there is any self-healing in the system. This is important for a cell used in real life since it will give information if it would be OK to sometimes use fast charging without influencing battery life time. The preliminary results show that there are signs of recovery but that it is at the expense of drying out the electrolyte. In Fig. 1, the formation of the surface layer on a graphite electrode is show at low rates. This result will be complemented with a similar study performed at high rates. The evaluation of these data is on-going right now.

Fig. 1 The formation of the surface layer on graphite before lithium plating

The second part of our study is to influence the graphite surface by coatings to prevent lithium plating. Here we have used the common method of carbon coating but instead of coating particles we have coated the electrode surface. The risk is here to also block the important pores in the electrode but the results we have are promising and will be followed up in the new battery fond project.

The third part of the project is to build on the prestudy on fast charging to write a review article on this topic. There is a lack of collected information about fast charging. This article builds on seminars held within SHC during 2014 about fast charging [1].

Contribution to hybrid vehicle technology

This project contributes with an in-depth understanding of the limits for fast charging of battery cells. This is important for both HEV and EV. The limits are set to how fast the cell can be charged without significant lithium plating and too sever influence on lifetime and battery ageing.

Uniqueness and news value

The scientific competition in this field is fierce. The most unique with this work is the collected competence within Theme 3 and SHC to address the difficult problem of fast charging from the component level to the battery pack level. The unique competence at UU within this work are the insights about electrode materials, electrolytes and their complex interplay within a battery cell.

Timing and finance

The project has been running as a post doc project supported both from SHC and be in kind activities from Uppsala University (with a research engineer). The timing for the project has been excellent in the sense that new information has been reached.

Executors and collaboration

This work has been taken the advantage of the competence from all partners within SHC Theme 3.

Dissemination of results

1) Invited speaker Kristina Edström "HAXPES and HPPES – some examples of interfacial reactions in Li-based batteries" IBA Big Island Hawaii January 2015.
2) SHC seminar in Hallsberg March 2015
3) Kristina Edström, co-organizer Kraftwerk Batteries, Achen 25-27 April 2015
4) ÅABC battery seminars Fernanda Marzano March 2015.

Papers and publications

[1] Fast charging and its consequence for life time and state of health
Kristina Edström, Katarzyna Ciosek Högström, and Fernanda Lodi Marzano. Manuscript in preparation.

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