Roadmap Swedish Electromobility Centre Thematic Area - Energy storage

Introduction

The battery is the by far most critical component in a hybrid electric or battery electric vehicle, defining many of the technical limitations of the powertrain, adds weight and volume, and contributes to additional cost of the system.

Hence a successful development of an energy efficient and cost-effective system relies on a good understanding of the possibilities and limitations of the battery. Deeper knowledge about battery behaviour is therefore important in all stages and levels of system development, and not only for development and selection of the very battery. Thus, this thematic area, energy storage, has the primary function of deepening the understanding of battery packs, cells, materials, and performance limiting processes, and help make this knowledge useful for all electrical and hybrid vehicle systems development.

Scope and boundaries of the thematic area

The thematic area focuses largely on energy storage using lithium-ion battery technology. We work in fields ranging from electrochemistry, material science and physics, to control engineering centred on the battery. A shared theme of the research is the direct link to battery usage in the vehicle, though applied to all levels from surface reactions to cell/pack behaviour. A major topic is the degradation and aging behaviour of the battery linked to relevant usage patterns or systems. One objective here, contributing to the system development of the electric vehicle, is improved predictability and optimized usage of the battery on-board. Method development in alignment with the research topics is also pursued.

Besides batteries, there are also other possibilities for intermediate energy storage on board vehicles, like flywheels, super-capacitors or pneumatic systems. However, batteries are judged to have superior overall properties. Among all possible battery technologies the family of lithium-ion battery chemistries is considered to be the only alternative in short and medium term. Nevertheless, major technological breakthroughs in battery development may change this picture, and openness for this must be maintained. The maturity of the lithium-ion technology and incorporation to industry-led research and development may also open for beyond lithium-ion technologies entering the thematic area.

Trends in the area

Research on battery cells, with regards to energy and power density as well as lifetime and safety, is ongoing. Much attention is put into new better battery chemistries, i.e. improved electrolytes and electrode materials. However, in the near future no revolutionary new materials are expected to be introduced in the batteries used for traction applications. Current cell material technology still improves, however, based on incremental optimization of already existing materials and manufacturing methods. Insights with regards to lifetime and aging issues is also gained by a growing

number of publications on battery lifetime data for different battery charge/discharge cycles, for instance fast-charging applications. Experience from these kind of studies will likely improve lifetime for battery system by avoiding detrimental operation regimes.

Activities in the area had initially a focus on hybrid electric vehicles (HEV), i.e. power-optimised storage systems able to deliver relatively high powers but small amounts of energy. However, the further advancement of broader concepts such as plugin hybrid electrical vehicles (PHEV), battery electrical vehicles (BEV) and intermittent charging of vehicles while driving has widened the interest to energy-optimised storage systems.

A consequence of the automotive manufacturers' expected future demand of large volumes of energy optimised cells is that battery manufacturers today focus their development and production on these type of cells, where substantial cost reduction is expected. Thus, it is likely that also power-demanding vehicle applications will have to be based on energy optimised cells, which will require adaption of the whole system.

Mechanical aspects of cell behaviour in relation to performance, such as cell swelling and pressure evolution, are increasingly studied phenomena as battery development pushes to higher voltage and more energy dense systems. Questions of performance prediction, safe-operation-area, and design of cells and packs are lifted in relation to these phenomena.

A trend in the area is that the responsibility for the full battery system including assembling of cells into modules and the Battery Management System (BMS) is shifting from the cell manufacturers to the OEMs. This will require broader battery competence in the automotive industry.

Recent initiation of LIB cell production in Sweden may in the long term also affect the interplay between OEMS and cell manufacturing. Cell production in Sweden could open up for interaction between OEMS and material development at an earlier state of cell production.

In the 2025 time perspective, development of high-voltage cells will be of importance for vehicle application, as well as an introduction of silicon in the negative electrode, or Li-metal. A review of prospects of various next-generation and post- LIB and can be found in the Electromobility Centre report "Batteries – Present and Future Challenges" (Ahlberg Tidblad et al, SEC report 10-2015).

Long-term objective

The field of battery research and development is highly competitive globally. This results in a massive flow of information, impossible for any single actor to fully grasp. Therefore, the selection and interpretation of vital information will likely be much easier for a cohort of active researchers with different background and focus. Thus an important long-term objective of this thematic area is to maintain sufficient competence at the universities to extract information about global trends, and to follow the status of future technologies, but also to actively asses new technology by pursuing own research on emerging battery chemistries such as higher-voltage chemistries and multiple charged ion charge carriers, or improved operandi and in situ analysis methods. This requires a broader view of the

thematic area, where the scope of SEC activities can be connected to research funded by other/external sources.

The theme aims to be a forum for discussion between researchers in academia and industry and bridge the communication gap between academic research and vehicle development. In this view, the theme also aims to partake in activities and projects at the LETS facilities. Shared testing facilities with up-scalable testing environments provide an important base for lifting ideas from lab to higher TRLs.

A further expectation of this activity is to educate personnel highly trained in this field. The availability of well-trained students with different backgrounds is a necessary prerequisite for further development of Swedish automotive industry. This requires activities spread among universities and research groups.

The gradual introduction of batteries in vehicles is expected to continue. The pool of joint experiences and methods for evaluating vehicle energy storage within the Theme could possibly be utilized to facilitating for the industry to set up and evaluate databases of vehicle energy storage field data.

Another long-term objective is to build knowledge that makes it possible to make maximum use of the battery system in vehicles without violating safety or the specified lifetime of the system. A specific field that seems to attract more and more attention is the possibility to rapidly charge a battery. This could be a field where cutting edge knowledge could be developed within the SEC network.

Current status

The first generation of doctoral students funded by SEC have graduated. They have been active in projects looking at the interaction of additives on electrode performance and cell safety, and on modelling of battery behaviour and failure modes. Collaboration between partners within the thematic area has been encouraged and many of the results have been presented jointly. Thus, SEC activities have resulted in increased cooperation between the partners.

In its first two stages of SEC, Theme Energy storage has educated PhDs that are now working in the automotive industry, responding to the long-term goal of supporting society with skilled and trained researchers.

During stage 3 of SEC a project on fast-charge of energy optimized commercial cells was initiated and is on-going (2015-2018). This project gathers six SEC partners in a joint effort to characterize and quantify cell aging as a function of operation conditions, cell design, and chemistry; to create models for the dominating aging mechanisms; and to identify suitable cell types and give recommendations for life time optimization for fast-charge applications.

GAP analysis

Resources directly available in SEC are far from sufficient to fully reach our long-term objectives. For example only a very small fraction of relevant battery research and doctoral education at the universities is financially supported by SEC. Thus it is a necessity to either increase the budget of SEC

itself or to connect SEC to on-going battery activities funded by other sources. The latter is the path today, however, to be able to extract and condense available information sufficient competence within the field must be maintained and financially supported inside SEC. We stress the importance of both cash and in-kind contributions from the industry to reach our long-terms goals.

The emerging trends of high-energy materials are expected to gain wider interest within electromobility. This relates to a shift towards BEVs and PHEVs on the market, and also to a maturing of these technologies to a more widespread commercialization. This area needs to be further addressed.

Research needs

The battery is by far the most critical component in a hybrid electrical or battery electric vehicle, as already stated. Still the knowledge and state of maturity are far from sufficient to meet the demands from the automotive industry.

The research needs to meet this gap could be divided into two main areas:

- The batteries available today are far from ultimate from an automotive perspective, and large improvements concerning energy and power density, lifetime, cost and safety must be achieved in order to reach long-term commercial goals. This will require large improvements of material properties and cell designs of the present lithium-ion technology. Solutions involving post lithium-ion technologies must also be explored in this long-term pursuit.
- Our mastery, as users and system integrators, of the currently available lithium-ion batteries is far from sufficient. Better characterisation techniques and engineering tools that can be used to understand and predict battery behaviour, and that can be adopted by the industry, would be immensely valuable. It is not foreseeable that this can be obtained without a profound knowledge about all limiting processed in the battery, from system perspective down to molecular level in the individual cells.

SEC priorities

The research needs stated above represent an enormous challenge, and SEC cannot be expected to cover all areas of the field.

Breakthroughs in battery technology might happen in a long-term perspective. However, near-future hybrid and battery electrical vehicles are most likely to use battery technology available today. Thus, SEC activities should consider a better understanding of present technologies. In addition, upcoming technologies and future needs should also be explored. Here the transition to energy-optimized cells has an important part. Higher voltage material and energy dense systems will also be of relevance. Furthermore, new characterisation techniques, methods, and engineering tools developed to address these needs will be useful for both present and future generations of battery technologies and is therefore and important aspect of SEC activities.

SEC should work to spread results between thematic areas and between partners. Additionally, SEC should also play an essential role in initiating new projects. For this, both academia and industry need to communicate issues arising in their field of research and/or development.

Critical Actions

Characterisation techniques and engineering tools that can be used to understand and predict battery behaviour, and that radically reduce the need for expensive and time-consuming testing by the automotive industry are obtainable in a long-term perspective. The challenges and research needs to achieve this are immense and for SEC to make a difference in this field sufficient resources must be made available inside SEC, as well as by funding sources like FFI, Swedish Energy Agency etc. Direct and explicit support, including both cash and in-kind contributions, from the Swedish automotive industry is critical to achieve this.