# Energy Storage in Batteries: Materials, Systems, and Manufacturing

## SCCER Summer School 11-15 July 2016 Möschberg, Switzerland

### Energy storage in Batteries

Energy storage devices are key components in current energy systems but will be even more important in the near future, in particular for electric mobility and renewable energy storage. Both stand for a climate-friendly energy future and rely to a great extent on the availability of durable, inexpensive, and safe electricity storage systems. Current challenges for battery research, development, and manufacturing include higher energy density, safety issues, as well as cost reduction and durability of state of the art battery systems resulting in an improved driving range for mobility and more cost-effective storage systems for energy application.
If you are a chemist, material scientist, mechanical engineer, electrical engineer or the like, grab the chance to educate yourself in this promising area where experts are needed and wanted.

### Course Contents

The summer school provides a compact overview of major aspects of lithium-ion battery research and manufacturing. The program is tailored for advanced students (Master, PhD) and trained professionals, and covers the following topics:

- Battery related electrochemistry and material science
- Characterization of materials and components up to complete systems
- Modelling of components, cells, and systems
- Aging, failure, safety, and life cycle aspects
- Design and manufacturing

### Organizing Committee

**Prof. Dr. Petr Novák** | Electrochemistry Laboratory | Paul Scherrer Institute PSI | Work Package Leader SCCER HaE

**Prof. Dr. Andrea Vezzini**| BFH-CSEM Energy Storage Research Center | Bern University of Applied Sciences BFH | Deputy Head SCCER Mobility

### Swiss Competence Centers for Energy Research

The Summer School Energy Storage in Batteries is organized by the Swiss Competence Centers for Energy Research SCCER HaE and SCCER Mobility, two out of eight national competence centers funded by the Commission for Technology and Innovation CTI.

HE Storage
Swiss Competence Centers for Energy Research

**SCCER HaE** | For future non-nuclear and $CO_2$ free energy supply, energy storage is a key element. Since energy, sourced from renewable sources like wind, sun or tidal energy is only available on a stochastic basis, storing the surplus energy during times of low demand and release during times of high demand is the only way to ensure the uninterrupted supply of energy. SCCER HaE explores the field of heat- and electricity storage systems, focusing on material research for batteries, latent- and sensible heat storage, hydrogen production and storage, power to value research, and interaction of storage systems.

sccer mobility
*Swiss Competence Center for Energy Research*
*Efficient Technologies and Systems for Mobility*

**SCCER Mobility** | SCCER Efficient Technologies and Systems for Mobility develops knowledge and technologies essential for the transition of the current fossil fuel based transportation system to a more sustainable one, featuring minimal $CO_2$ output and primary energy demand as well as virtually zero-pollutant emissions. The Competence Center aims at understanding the complex dynamics of mobility and transportation, including their interdependencies with the overall energy system. It serves as a platform for the integration of a broad range of research areas that result in sustainable and efficient interventions.

# Program

## Monday 11 July 2016

**11.00 - 12.00** | **Welcome and Introduction**

**13.30 - 15.15** | **Prof. Dr. Petr Novák**
Electrochemistry Laboratory | Paul Scherrer Institute PSI

### Basics of Battery Electrochemistry

The very first module of the course will introduce the definitions and expressions relevant to the technical electrochemistry. Then, the basics of battery electro-chemistry will be discussed including both the thermo-dynamics (electrode potential, cell voltage) and the kinetics (ohmic, charge transfer, and concentration overpotentials). Finally, the application of this basic knowledge to porous electrodes will be shown.

**15.45 - 17.30** | **Prof. Dr. Maksym Kovalenko**
Laboratory of Inorganic Chemistry | ETH Zürich

### Basics of Materials Science

This lecture will cover the structure, synthesis and characterization of materials used in rechargeable Li-ion batteries and in closely related battery technologies. First, the major intercalation-type cathode and anode materials will be addressed. Then the advantages and shortcomings of going to “nano” (down-sizing) and "smart engineering" of the electrode materials will be discussed. Finally, materials aspects of post-Li chemistries will be briefly reviewed.

## Tuesday 12 July 2016

**8.30 - 10.15** | **Dr. Claire Villevieille**
Electrochemistry Laboratory | Paul Scherrer Institute PSI

### Characterization of Cell Components

The goal of this lesson is to get insight into a battery during cycling using advanced characterization techniques and combining information from the bulk, the interface and the surface. We will thus review the characterization techniques existing through various examples looking at the cell components (electrodes, electrolytes, separators etc.).

**10.45 - 12.30** | **Dr. Donat Adams**
Reliability Science and Technology | Empa

### Ageing and Safety of Cell

In this module we will study the different causes of aging of rechargeable batteries (SEI layer formation, electrode dissolution, etc.), and the influence of operational parameters (depth of discharge, temperature, current and current ripples) for the most important cell chemistries. The difference between the capacity fade due to calendar life vs. cycle life is addressed. Finally the contribution of each component to battery safety and the selection criteria for types of rechargeable batteries regarding the costs, safety and capacity fading is discussed in this lecture.

**13.30 - 15.15** | **Prof. Dr. Wolfgang Bessler**
Electrical Energy Storage EES |
Offenburg University of Applied Sciences

### Physicochemical Modeling and Simulation

Physicochemical models are being widely used to understand the properties of lithium-ion batteries, to support electrode and cell design, and to reduce development cost. This class includes a first overview of modeling approaches (Newman-type models, micro-structure-resolved models, multi-scale models). Then governing processes and model equations, simulation software and implementation as well as challenge model parameterization will be discussed. The lecture closes with application examples: Lithium-ion battery lifetime prediction; Metal-air battery chemistry.

**15.45 - 17.30** | **Florian Ringbeck** | Institute for Power Electronics and Electrical Drives | RWTH Aachen

### Battery Management System: Functions and Algorithms

The online estimation of a battery's SOC and SOH are crucial functions of a vehicle’s battery management system (BMS). There are several approaches for improving the algorithms and hardware involved in the battery cell surveillance. These improvements are for example the usage of active impedance measurement techniques to obtain battery data or the implementation of physical-chemical models on BMS. This class concentrates on state of the art BMS functions and the above described trends in their further development.

**19.30 - 20.30** | **Martin Pulfer** | Evening Talk
Swiss Federal Office of Energy SFOE

### SFOE Accumulators and Supercapacitors Research

The SFOE actively promotes research aimed at improving electrochemical and electrostatic energy storage. Martin Pulfer will give an overview of the SFOE Accumulators and Supercapacitors Research Program and present a selection of projects. (in German)

## Wednesday 13 July 2016

**8.30 - 10.15** | **Dr. Gerhard Rizzo**
Institute for the Development of Mechatronic Systems |
University of Applied Sciences and Technology Buchs NTB

### Thermal Modelling and Management

Thermal management is a mayor issue, especially for lithium-ion batteries. Too high as well as too low temperatures causes accelerated degradation. In addition the temperature distribution inside a lithium-ion cell and between different cells of a battery system should be as homogeneous as possible. To achieve this requirements an adequate thermal management is needed, which has to be integrated into the superordinate system.

**10.45 - 12.30** | **Prof. Dr. Axel Fuerst** | **Dr. Pascal Häring**
[a] BFH-CSEM Energy Storage Research Center
[b] Head R&D | Renata AG

### Lithium Battery Design and Production

The implementation of electro-chemical energy storage is demanding as some of the used materials are quite reactive. This lecture gives an insight of principal lithium battery design and production processes. In a second part, a closer look at the development process, from design to production release, will be taken.

**13.30 - 15.15** | **Dr. Olaf Böse**
Center for Solar Energy and Hydrogen Research Baden-Württemberg ZSW

### Modelling Characterization and Tests on Battery Packs

Single cells are integrated to battery packs to increase voltage and/or current level. Extensive testing of battery packs is required to verify if the design values of battery packs are reached to fulfil requirements of customers, standards and legislations. Detailed descriptions of the current state-of-the-art testing routines with respect to electrical, mechanical, thermal and safety characteristics are presented with focus to automotive batteries based on Li-Ion cells.

## Thursday 14 July 2016

**8.30 - 10.15** | **Prof. Dr. Andrea Vezzini**
BFH-CSEM Energy Storage Research Center

### Battery System Components

For a complete battery system additional hardware is required. The battery management system (BMS) monitors the operating values (voltages, currents and temperatures) and protects the battery cells from being used outside their safe region. The hardware and software structure of such a BMS must meet certain requirements regarding low power consumption, safety critical behavior and accuracy.
The current interrupting devices (CID) as well as fuses and current sensors should be carefully designed and their sizing depends on the application of the battery system.

**10.45 - 12.30** | **Dr. Timothy Patey**
ABB Schweiz AG | RD.E4 "Applied Physics"

### BESS technology for public transportation & green power grid

This lesson begins with business cases for "new" applications. The technology of dimensioning and cooling Li-ion batteries in electric buses, home energy storage, and substations is discussed. A semi-empirical battery model will be introduced, followed by a discussion on the implications and limitations of this approach. Finally, a brief discussion on future electrochemical technologies will be done (time permitting).

**13.30 - 15.15** | **Marcel Held**
Reliability Science and Technology | Empa

### Reliability and Safety

Reliability and safety are basic requirements for cells and battery systems, in addition to performance, life cycle costs and ecological considerations. The cost-effective design and operation of a battery is intimately related to the reliability and safety of its components. In this module the basic failure mechanism of cells and their effects are explained and illustrated. Safety features from cell to battery level, the influence of environmental and operational conditions, safety testing and analysis methods are presented in order to support the design of reliable and safe batteries.

**15.45 - 17.30** | **Marcel Gauch**
Technology and Society Lab | Empa

### Life Cycle Assessment and Environmental Aspects

It's commonly known that the environmental friendliness of electric mobility depends on the source of the electricity driving the vehicles. But how detrimental is the construction and use of the batteries used for mobility? Huge differences exist between public perception and the scientific facts in this instance. In this contribution research results using life cycle assessment methodologies will be presented.

## Friday 15 July 2016

**8.30 - 10.15** | **Christian Köbel** | Director Product Management Primove | Bombardier Transportation

### Application Key Issues I

Battery life time is the major cost driver of e-mobility solutions today. By choosing the right battery size together with the right charging strategy, the optimum for the application can be found. But variations in the application parameters often define a different optimum in battery size in the eyes of the customers.

**10.45-12.30 | Dr. Daniel Brand**
Head of BKW Technology Center

### Application Key Issues II

Control over flexibilities, such as dispatchable power plants, demand side management, storage and (related) grid reinforcement, has always been an perquisite for utilities in order to provide a stable and reliable energy supply. In the framework of the energy transition, the characteristics of energy production and consumption change dramatically, which calls for both, new concepts of control and integration of new types of storage. The BKW Technology Center assesses the potential of emerging technologies for future business and identifies the need for innovation.

### Lunch (optional)

## Registration and Costs

Please revert to fiorella.meyer@sccer.ethz.ch for available places and access link. You'll be asked to pay the course immediately via credit card.

500 CHF for lodging (4 overnight stays in double room, shared bathroom) and board (full pension starting with lunch on Monday, ending with lunch on Friday; mineral water, coffee and tea included., softdrinks and alcoholic beverages self payable, vegetarian meals available).

## Cancellation

Upon receiving your payment (credit card) registration will be definite.
Written cancellation until 15 May 2016 with 100% refund.
After 15 May no refund, except if a replacement is found.

## Venue and Geographic Coordinates

Seminar Hotel Möschberg | 3506 Grosshöchstetten | Switzerland

phone +41 31 710 22 22 | info@moeschberg.ch

coordinates 46.908248, 7.647461

## Side Trip Suggestions

outdoor pool, indoor pool in Grosshöchstetten

Kambly Experience (biscuits) | Chüechlihus (museum)

hiking in the Emmental valley

## Contact

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## Train Connections

dep Basel 8.31 to Bern
dep Zürich 8.32 to Bern
dep Bern 9.36 to Konolfingen
dep Konolfingen 10.00 to Grosshöchstetten
arr Grosshöchstetten 10.04

20 minutes walk to hotel which is located on the hill, luggage will be picked-up at the station by the hotel bus.

dep Grosshöchstetten to Bern every 30 minutes (0.17/0.54), www.sbb.ch

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
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