Towards competitive European batteries

Basics of rechargeable batteries

Alexander Warnecke
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Batteries2020 – “Towards Realistic European Competitive Automotive Batteries”

Potential customers complain about range and price of electric cars

Objectives:
- Batteries with higher energy density
- Cheaper batteries
- Second life usage for cost optimization
120 Scientists
About 100 students

Research fields:
- Power Electronics and Electrical Drives
- Battery research

Symbiosis of electronics and batteries

Source: [www.isea.rwth-aachen.de](http://www.isea.rwth-aachen.de)
1. Battery Technology

2. Working Principle Lithium Ion Batteries

3. Components and Structure

4. Typical Materials

5. Safe use of lithium-ion batteries
No lifetime information in this graph!
Classification and types of Li-Battery systems

Li-Systems

Systems with metallic lithium:
- **Li-Metall**
  - Liquid electrolyte: Li-Metall-Liquid
  - Polymer electrolyte: Li-Metall-Polymer

Systems without metallic lithium:
- **Lithium-Ion**
  - Liquid electrolyte: Li-Ion-Liquid
  - Polymer electrolyte: Li-Ion-Polymer

Anode material (neg. electrode)

Different type of electrolytes

EV: Electric Vehicle,
HEV: Hybrid Electric Vehicle

**Application**
- EV & HEV
  - Higher temperatures and reduced power application
  - USA: AVESTOR
  - Fr: Bollore
  - Not many activities
  - Only for coin cells

**EV & HEV**
Working principle

LiMO₂ → e⁻ → Graphit

Oxygen
Li⁺ LiC₆
Metall-Ion
Graphit
Separator

POSITIVE
Electrolyte & Separator
NEGATIVE

Source: Saft
Solid-Electrolyte interface (SEI)

Charging

Solid Electrolyte Interface (SEI)

Source: LITHIUM-ION BATTERIES, Perla B Balbuena & Yixuan Wang
On the negative active material surface a passivating layer is created, the so called SEI (solid electrolyte interface).

- Its creation can’t be stopped.
- SEI Formation is influenced by the electrolyte.
- Creation during first charging process.
- The cell characteristic is influenced by SEI -> ions have to pass it (higher inner resistance).
- SEI growing is the main ageing process of Li-Ion batteries.

Solid Electrolyte Interface (SEI)

Source: LITHIUM-ION BATTERIES, Perla B Balbuena & Yixuan Wang
Components and structure

Anode: graphite on Cu-foil

Cathode: Li-Me-mixed oxide on Al-foil

<table>
<thead>
<tr>
<th>Material content in mass-% (consumer cells)</th>
<th>Metal prices (LME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>housing</td>
<td>~ 25</td>
</tr>
<tr>
<td>LiCoO₂</td>
<td>~ 20</td>
</tr>
<tr>
<td>graphite</td>
<td>~ 20</td>
</tr>
<tr>
<td>electrolyte</td>
<td>~ 15</td>
</tr>
<tr>
<td>Cu-foil</td>
<td>~ 9</td>
</tr>
<tr>
<td>Al-foil</td>
<td>~ 5</td>
</tr>
<tr>
<td>separator</td>
<td>~ 5</td>
</tr>
</tbody>
</table>

Source: IME / RWTH Aachen

**Metal prices (LME)**

- Co (59 u) ~ 95 US$/kg
- Ni (59 u) ~ 20 US$/kg
- Mn (55 u) ~ 3 US$/kg
- Fe (56 u) ~ 0.7 US$/kg
- Li (as Li₂CO₃) (7u) ~ 43 US$/kg
Anode, cathode and separator are porous materials that are filled with electrolyte.
Anode, cathode and separator are porous materials that are filled with electrolyte. Active materials and passive materials are components in lithium-ion cells.

**High-Power cell design**

**High-Energy cell design**
Designs of lithium-ion cells

**Round cells**
- A lot of experience in cell design
- High life-time
- Complex Cooling
- Supplier e.g. Saft, GAIA, A123, Sanyo

**“Pouch“ cells**
- Good cooling character
- High energy density
- Main question: Tightness of the film
- Supplier e.g. Leclanché, Kokam

**Prismatic cells**
- Easy stacking in battery packs
- Combines characteristics of the other cell designs
- Supplier e.g. Sanyo, SBLimotive
Active materials in lithium-ion batteries

Li-Ion liquid

**cathode material**
- LiCoO₂
- LiNiO₂
- LiMn₂O₄
- LiCo₁/₃Ni₁/₃Mn₁/₃O₂
- LiCoₓNiₙMn₂O₂
- LiFePO₄

**anode material**
- Hard Carbon LiC₆
- Graphite LiC₆
- Titanate Li₄Ti₅O₁₂
- Silicium Li₂₂Si₆

- **Good lifetime high safety risk**
- **Highest safety risk, good performance**
- **Cheaper, safety better than for Co & Ni**
- **Popular material, wide range of variability for optimizing prop.**
- **Wide variability in materials**
- **3.3 V material”, cheap & safe**
- **“3.7 V material”, small number of full cycles**
- **“3.7 V material”, expensive, high number of full cycles**
- **“2.2 V material”, safe, low energy density**
- **“3.7 V material”, high energy density, currently F&E**
Electric properties

Specific Capacity [mAh/g] vs. Potential in mV vs. Li/Li+

- LiFePO₄
- LiMn₂O₄
- Li(Ni,Co,Mn)O₂
- Li(Ni,Co)O₂
- LiCoO₂

Source: ZSW Ulm

Only cathode materials
Operation limits

- Collector-corrosion
- Normal operation
- Discharging of „Metalloxid-sponge“

Cell Voltage (V)

Charged amount in % of rated capacity

Allowed operation range
Operation limits

Negative

<table>
<thead>
<tr>
<th>Lithium plating</th>
<th>C_6 / LiMeO_2 (Me = Co, Ni, Mn, Al)</th>
<th>C_6 / LiFePO_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>4.2 V (fully charged)</td>
<td>3.6 V (fully charged)</td>
</tr>
<tr>
<td>Safe</td>
<td>Safe</td>
<td>Safe</td>
</tr>
</tbody>
</table>

Positive

<table>
<thead>
<tr>
<th>LTO / LiMeO_2</th>
<th>2.7 V (fully charged)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe</td>
<td>Safe</td>
</tr>
<tr>
<td>LTO / LiFePO_4</td>
<td>2.1 V (fully charged)</td>
</tr>
<tr>
<td>Safe</td>
<td>Safe</td>
</tr>
</tbody>
</table>
Lithium-ion systems have excellent electrical performance

- New materials still offer a high research potential

- Safety and costs are the main „real“ issue

- Requests on lifetime for HEV and EV are fulfilled

- NiMH (HEV) and NaNiCl₂ high temperature batteries as technology alternatives show worse performance
Thank you

Eskerrik asko

Danke

Merci

Gracias

Grazie

Tak