EUROLIS -
European lithium sulphur cells for automotive applications

Patrik Johansson$^{1,2}$ and Robert Dominko$^{2,3}$

$^{1}$Department of Applied Physics, Chalmers University of Technology, SE-41296, Göteborg, Sweden,
E-mail: patrik.johansson@chalmers.se

$^{2}$Alistore-European Research Institute

$^{3}$National Institute of Chemistry, Hajdrihova 19, SI-1000 Ljubljana, Slovenia
Why Li-S batteries?

- Sulphur:
  - 32.06 g/mol
  - 2.07g/cm³
  - Non-toxic, “green” material
  - Abundant, cheap (28 US$/ton)
  - Theor. Cap.: 1,675 mAh/g

<table>
<thead>
<tr>
<th>Material</th>
<th>Theoretical Capacity (mAhg⁻¹)</th>
<th>Specific Capacity (mAhg⁻¹)</th>
<th>Relative Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiCoO₂</td>
<td>275</td>
<td>130-140</td>
<td>1</td>
</tr>
<tr>
<td>Li-NMC</td>
<td>~270</td>
<td>150-160</td>
<td>0.59</td>
</tr>
<tr>
<td>Li-NCA</td>
<td>~270</td>
<td>170-180</td>
<td>0.89</td>
</tr>
<tr>
<td>LiMn₂O₄</td>
<td>148</td>
<td>100-120</td>
<td>0.26</td>
</tr>
<tr>
<td>LiFePO₄</td>
<td>170</td>
<td>140-150</td>
<td>0.37</td>
</tr>
<tr>
<td>S</td>
<td>1675</td>
<td>200-1200</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Basics of Li-S batteries

- @ Anode: $2\text{Li} \rightarrow 2\text{Li}^+ + 2\text{e}^-$
- @ Cathode: $\text{S} + 2\text{e}^- \rightarrow \text{S}^{2-}$
- Overall: $2\text{Li} + \text{S} \rightarrow \text{Li}_2\text{S}$
- Cell max: 2.15 V

- $\text{Li}_{(s)}$: 3,860 mAh/g
- $\text{S}_{8(s)}$: 1,675 mAh/g

- $\Rightarrow$ 2567 Wh/kg & 2800 Wh/l
- Today: > 350 Wh/kg (cell)
Problems of Li-S batteries vs. Li-ion batteries

- $S$ an insulator – $S/C$ composites
- Many many reactions...
- How to control the solubilities?
- Low C rates – often C/10

\[
S_8 + 16Li^+ + 16e^- \rightarrow 8Li_2S
\]

\[
4S_8^{2-} \rightarrow 4S_6^{2-} + S_8
\]

\[
2S_6^{2-} \rightarrow 2S_4^{2-} + S_8
\]

\[
S_8^{2-} + S_6^{2-} \rightarrow 2S_3^{2-} + S_8
\]

\[
S_6^{2-} \rightarrow 2S_3^{2-}
\]

\[
S_6^{2-} + 2e^- \rightarrow 2S_3^{2-}
\]

\[
S_3^{2-} + e^- \rightarrow S_3^{2-}
\]

\[
2S_3^{2-} + e^- \rightarrow S_3^{2-}
\]
The Eurolis project

- “Advanced European lithium sulphur cells for automotive applications”
- FP7 Program: Theme 4 – NMP – Nanosciences, Nanotechnologies, Materials and New Production technologies
- GC.NMP.2012-1 Innovative automotive electrochemical storage applications based on nanotechnology, FP7-2012-GC-MATERIALS
- 1/10 2012 + 48 months, 3.8 M€

**Timeline:**
- **M1.** Kick off meeting
  - October 2012
- **M2.** Release of 1st generation of 18650 cell with 300 Wh/kg
  - March 2014
- **M3.** Release of 2nd generation of 18650 cell with 400 Wh/kg
  - March 2015
- **M3.** Release of 3rd generation of 18650 cell with 500 Wh/kg
  - March 2016
Eurolis Aims & Layout

- 500 Wh/kg & 1000 W/kg for normal operation.
- Charge eff. > 95 % (cycle life) & temp. range -25 - +80 deg. C
- Durability for automotive industry; 5 years and 1000 cycles
- Safety standards and low costs: i.e. a maximum 150€/kWh
Eurolis Partners

- Coordination – NIC Slovenia
- Battery – SAFT
- Vehicles – Renault, Volvo
- Basic research & development – materials focus
Eurolis Approach to Li-S

- Composite cathodes to disperse S, high surface area of mesoporous C
- Functionalization of outer surface of C particles
- Alter the PS solubility via polymeric solvents and ionic liquids
- Look at life-cycle analysis, re-cycling and eco-design issues

- Create new analytical techniques for reliable monitoring of Li-S batteries
- Develop simulation approaches to Li-S electrolytes
- Aim at understanding the mechanisms needed for stable battery operation
- Compare alternative configurations of Li-S batteries
Some 1\textsuperscript{st} results...

- $\Delta V = 1.5$ V, C/10 rate, ion selective separator:
Some 1st results...

- Modelling development – pretty far from EV application...
Questions & More information

- [www.eurolis.eu](http://www.eurolis.eu)
- [patrik.johanssone@chalmers.se](mailto:patrik.johanssone@chalmers.se)
- [robert.dominko@ki.si](mailto:robert.dominko@ki.si)