Key developments in Rechargeable Battery Materials

Capital Markets Event
Seoul, 24 May 2012
What is a Li-ion battery?

Anode (= negative)
- Graphite/carbon

Separator
- Ion permeable inert membrane

Cathode (= positive)
- Lithium cobaltite, NMC or LFP as cathode material

Electrolyte
- Liquid or gel

Charge: Li-ions from cathode to anode
Discharge: Li-ions from anode to cathode
Li-Ion Batteries for electronics
Cathode content

10-15 g

50-80 g

15 g

100 g
Li-Ion Batteries for automotive Cathode content

HEV

~5 kg

~50 g

PHEV & BEV

~40 kg
Li-Ion Batteries for stationary
Cathode content

a couple of tonnes
End user market developments trigger fast material evolution
Cathode material - Technology development

Precursor

Micron-size mixed metal oxides, hydroxides, carbonates,... (precursors)

Product

Nano to micron-size Lithium mixed metal oxides, phosphate,... (cathode materials)

Application

Li-ion polymer cell for validation of electric & safety performance for energy and power applications

materials for a better life
Where is Umicore in the value chain?

supply → metal → product → application → market

- **Co residues**
- **Ni residues**
- **Recycling & intermediates**

**Metal**
- Co
- Ni

**Product**
- LCO
- NMC

**Application**
- Portable electronics
- Power tools
- (P)HEV / EV
- E-bikes
- Stationary power

**Market**
Umicore’s global business presence in rechargeable batteries

- Olen, Belgium
  - Co intermediates production
  - Group R&D

- Hoboken, Belgium
  - Battery recycling

- Engis, Belgium
  - beLife (49% JV)
  - Industrial Pilot line LFP

- Hanau, Germany
  - Automotive test centre
  - HEV testing
  - Battery dismantling centre

- Maxton, USA
  - Battery dismantling centre

- Cheonan, Korea
  - Li-ion cathode production
  - Research & technology centre
  - Application lab

- Kobe, Japan
  - Li-ion cathode production
  - Application lab

- Jiangmen, China
  - JUC (70% JV)
  - Li-ion cathode production
  - JCU (40% JV)
  - NiMH cathode production

Total workforce > 800 people

Research & development in Europe and Asia

materials for a better life
# Overview of Li-ion cathode material technologies

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Power</th>
<th>Safety*</th>
<th>Life</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LCO</strong></td>
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<td>+</td>
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<td>lithium cobaltite LiCoO₂</td>
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<tr>
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<tr>
<td>nickel manganese cobalt Li(NiₓMnₙCo₁₋ₓ₋ₙ)O₂</td>
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<td><strong>LFP</strong></td>
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* Impacts battery package design

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*materials for a better life*
Overview of Li-ion cathode material technologies
Best fit for portable electronics

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Overview of Li-ion cathode material technologies
Best fit for HEVs

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<tr>
<td><strong>LFP</strong>&lt;br&gt;lithium iron phosphate&lt;br&gt;LiFePO$_4$</td>
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Overview of Li-ion cathode material technologies
Best fit for PHEVs and BEVs

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Overview of Li-ion cathode material technologies
Best choice for energy storage systems

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Application requirements determine cathode materials used.
Umicore well positioned over different materials and applications, which offers technology and production synergies.
Umicore’s product positioning

Wide multi-chemistry portfolio of advanced cathode materials

- LCO compounds
- NMC and NCA compounds
- LFP compounds

> 50% of Umicore products on the market for less than 3 years

Umicore offers all main cathode materials with peace of mind for the customer, whatever Li-ion battery application is targeted, thanks to a strong IP portfolio

- Umicore owns the concept IP for latest generation LCO suitable for high-end portable electronics used in high capacity, thin batteries
- Umicore owns patents on NMC as well as licenses from 3M, offering full freedom to operate for the different compositions, both for current and future families of products
- Umicore can now offer LFP with global freedom to operate, in collaboration with Prayon
Umicore’s production positioning

Installed production capacity already on industrial scale today

- Track record > 15 years in Li-ion technology
- Production synergies from strong position in automotive, portable electronics, stationary power and power tools
- 4 production plants, 3 research sites
- TS16949, ISO9001, ISO14001 certified

Battery recycling and metals management in closed loop

Leading global supplier of cathode materials

- Strong market leadership in high end applications
- Serves all key players in the battery industry
- > 12 XEV platforms will be on the market with Umicore material in next 1½ years
Electrification of the powertrain requires batteries of different size and complexity.

<table>
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<tr>
<th>ELECTRIFICATION</th>
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<th>HEV</th>
<th>PHEV</th>
<th>EV</th>
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<td></td>
<td>Normal</td>
<td>Start-stop</td>
<td>Mild</td>
<td>Full</td>
</tr>
</tbody>
</table>

| Relative size         | +      | +      | ++     | ++     | +++    | ++     |
| Relative complexity   | +      | ++     | +++    | ++     | ++     | ++     |
Impact of electrification on CO₂ reduction

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<td>Parallel system</td>
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- ICE
- HEV
- PHEV
- EV

- Normal
- Start-stop
- Mild
- Full
- Parallel system
- Range extender
- BEV
- FCEV

CO₂ Emissions
3 scenarios for the electrification of the car xEV production

**Scenario 1**
The CO₂ limits will be reached through ICE improvement and xEV introduction
*(OEM push only)*

**Scenario 2**
The CO₂ limits will be reached through xEV introduction
*(OEM push only)*

**Scenario 3**
On top of meeting CO₂ limits, there is also a positive TCO for consumers
*(OEM push + customer pull)*

Source: Umicore estimate based on external data sources
3 scenarios for the electrification of the car
Total Li-ion cathode market per application

**Scenario 1**
The CO₂ limits will be reached through ICE improvement and xEV introduction (OEM push only)

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On top of meeting CO₂ limits, there is also a positive TCO for consumers (OEM push + customer pull)

Source: Umicore estimate based on external data sources
3 scenarios for the electrification of the car
Total Li-ion cathode market per material

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The CO₂ limits will be reached through ICE improvement and xEV introduction (OEM push only)

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Scenario 3
On top of meeting CO₂ limits, there is also a positive TCO for consumers (OEM push + customer pull)

Source: Umicore estimate based on external data sources
3 scenarios for the electrification of the car
Total cathode materials ratios

2011
[tonnes]

2020 Scenario 1
[tonnes]

2020 Scenario 2
[tonnes]

2020 Scenario 3
[tonnes]
How is Umicore responding to market dynamics?

Increasing capacity

Developing products within NMC family for cost and performance

Include LFP in the product offer
Continuous expansion of production capacity and capabilities since start of production

**Umicore Li-ion cathode sales**

<table>
<thead>
<tr>
<th>Year</th>
<th>Tonnages</th>
</tr>
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<tbody>
<tr>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>2012</td>
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Umicore figures (estimate for 2012)

**Recent investments**

- Expansion of Cheonan plant
- Greenfield plant in Kobe
Developing products within NMC family for cost and performance

Different NMC material generations are being developed

- Reducing cost/kg
- Increasing kWh/kg

⇒ Reducing cost/kWh

To be introduced in the market in the coming years
Cost/kWh is strongly influenced by the impact from the metals market.
NMC generation 1
NMC (1:1:1) is the recognized standard

NMC (1:1:1) fulfils current automotive requirements in terms of performance and safety

Cellcore® MX
NMC (1:1:1)

LiNiO2
LiCoO2
LiMnO2
NMC generation 2
OEMs striving for better cost and/or performance

Two main development paths are co-existing depending on cell design and global region

**Higher Ni content**
Pushes energy density
- Increase kWh/kg
- Maintaining cost/kg
⇒ Decreases cost/kWh

**Lower Co content**
Reduces metal cost
- Decrease cost/kg
- Maintaining kWh/kg
⇒ Decreases cost/kWh

<table>
<thead>
<tr>
<th></th>
<th>Cost/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMC (1:1:1)</td>
<td>100%</td>
</tr>
<tr>
<td>Low Co</td>
<td>75% - 80%</td>
</tr>
<tr>
<td>High Ni</td>
<td>75% - 80%</td>
</tr>
</tbody>
</table>
NMC generation 3
HLM/HNS could improve cost/kWh by ~40%

The main cost/kWh driver with HLM/HNS is a performance technology breakthrough to a higher voltage design.

HLM (High Li, high Mn), HNS (High Ni Spinel)
- Higher kWh performance
- Improved metal base
  ⇒ HLM attractive to automotive applications
Automotive cost/kWh perspective
Long-term reduction of ~40% is possible with NMC

NMC cost roadmap

*assumption: all products in mass production volumes
Li-ion battery cost reduction potential
Cathode material has impact on various levers

Source: Roland Berger, March 2011
Umicore and Prayon join forces to develop and produce phosphate-based cathode materials for lithium-ion batteries

Materials technology leader Umicore is joining forces with phosphate producer Prayon to develop and produce phosphate-based cathode materials for use in lithium-ion (Li-ion) rechargeable batteries. The collaboration will be in the form of a joint venture, named belLife, which is set up on a 51 (Prayon): 49 (Umicore) ownership basis.

belLife will initially focus on developing advanced, cost-competitive products and production processes for lithium iron phosphate cathode materials used in lithium-ion rechargeable batteries. The joint venture is establishing an industrial pilot plant in Engis, Belgium, that will be operational in the coming months with all materials produced being exclusively marketed by Umicore. The materials are dedicated to batteries for energy storage applications as well as batteries for hybrid and electric vehicles.

Umicore and Prayon have been developing Lithium Iron Phosphate (LFP) technology independently for a number of years and both companies will contribute strong intellectual property to the joint venture. This intellectual property will be split equally between Prayon and Umicore. The venture will be treated as a separate legal entity and will be led by a management team.
Combining strengths

Prayon has historical position in phosphate chemicals

- Brings IP
- Brings good access to phosphate raw materials

Umicore has long track record in rechargeable battery materials

- Brings IP
- Brings process upscaling knowhow
- Brings customer intimacy and marketing capabilities

Industrial pilot plant in Engis, Belgium

- 100 tonnes/year capacity
- Focus on process optimisation and product development
- Start commissioning in July 2012
- Products will be marketed by Umicore
Full service model with battery recycling services

- Partner remains owner
- Metal balance account
- One processing fee

Materials for a better life
Conclusions

Li-ion battery application is growing rapidly thanks to fast product turnover in portable electronics and penetration in new sizeable applications (automotive and energy storage systems)

End-user requirements drive cathode material development

Umicore has a leading position as cathode material maker today and has the broadest product portfolio covering the materials of choice for all current and future applications of Li-ion batteries

Umicore can offer significant synergies, both from a technology development point of view, with its broad material coverage, as from a production setup, covering all main applications
Forward-looking statements

This presentation contains forward-looking information that involves risks and uncertainties, including statements about Umicore’s plans, objectives, expectations and intentions.

Readers are cautioned that forward-looking statements include known and unknown risks and are subject to significant business, economic and competitive uncertainties and contingencies, many of which are beyond the control of Umicore.

Should one or more of these risks, uncertainties or contingencies materialize, or should any underlying assumptions prove incorrect, actual results could vary materially from those anticipated, expected, estimated or projected.

As a result, neither Umicore nor any other person assumes any responsibility for the accuracy of these forward-looking statements.
Kurt Vandeputte
VP Rechargeable Battery Materials

Kurt holds a PhD in Chemistry and started his professional career in 1997 with Umicore. After a five year operational assignment at the Umicore Olen plant he joined the Cobalt & Specialty Materials Business Unit in a technology development function. From 2006 to 2008 he was responsible for Sales & Marketing in the Rechargeable Battery Materials business line and took overall responsibility for this business line in March 2008. In January 2012, when Rechargeable Battery Materials became a separate business unit, Kurt was appointed VP.
materials for a better life