Increasing the gap in Rechargeable Battery Materials

Kurt Vandeputte
Senior Vice-President
Rechargeable Battery Materials
Agenda

Business profile

Accelerated growth in Electrification

Success factors

Key takeaways
20+ years of innovation in li-ion battery materials

- 1995: Initiate research into LCO for Portables
- 1998: First LCO plant in Korea
- 1999: Research into high nickel cathode material
- 2003: First NMC materials synthesized and tested for Portables
- 2006: First NMC cathode materials plant in Korea
- 2007: First large scale NMC sale to automotive market (EV)
- 2009: Market introduction dedicated NMC for high power applications
- 2011: High Energy LCO-IP acquisition from FMC
- 2012: Mass market introduction NMC622
- 2014: Start LFP commercialization under beLife JV
- 2015: Install high throughput production technology
- 2016: Acquiring NMC-IP from 3M
- 2017: Expand IP-coverage for NMC (ANL, CSEM)
Business model

Product innovation based on strong application know-how

Established industrial footprint close to the customer

Strong industrialization capabilities building on historical Umicore key competences

Process innovation fuels productivity improvements while maintaining highest quality standards (stringent automotive standards)

Integrated process flows with guaranteed access to critical raw materials allows an agile market approach
Battery market projections

RECHARGEABLE BATTERY MARKET (GWH)

Source: Avicenne, Navigant, Roland Berger, AABC, IHS, Gartner, SNR, CRU, Roskill
Battery market projections

- **Portables**
  - Societal driver

- **Energy Storage System**
  - Regulatory driver

**Graph: Rechargeable Battery Market (GWh)**

Source: Avicenne, Navigant, Roland Berger, AABC, IHS, Gartner, SNR, CRU, Roskill
Battery market projections

Electrification
Regulatory driver

Portables
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**Electrification**
Regulatory driver

**Portables**
Societal driver

**Energy Storage System**
Regulatory driver

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**RECHARGEABLE BATTERY MARKET (GWH)**

- Heavy Duty Vehicles
- Electrification Current Scenario
- Portables
- ESS

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Source: Avicenne, Navigant, Roland Berger, AABC, IHS, Gartner, SNR, CRU, Roskill
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Accelerated growth in Electrification

Success factors

Key takeaways
Intensified regulatory push
Electrification triggered by legislation

Europe: voting CO₂ standards cars as of 2015 (130 gr/km)

China: central NEV subsidy program ‘13-'15

Europe: central NEV subsidy program as of 2021 (95 gr/km)

Europe: voting CO₂ standards post 2020 (65 gr/km by 2030)

China: central NEV subsidy program ‘16 –’20

China: NEV subsidy program ‘17-’20 for cars + buses

China: NEV mandate policy for cars

Europe (national level): Several countries setting EV adoption targets / announcements of EV subsidies, tax breaks or special driving privileges

Initiatives not yet known at previous CMD in Sept. 2015
Intensified regulatory push in China
New Energy Vehicle mandate policy for cars

A milestone policy in China, the world’s largest passenger car market - since April 1, 2018

**NEV CREDIT TARGETS**

<table>
<thead>
<tr>
<th>NEV credit targets:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 9% in 2019</td>
</tr>
<tr>
<td>• 10% in 2020</td>
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</table>

<table>
<thead>
<tr>
<th>Credits per NEV depending on metrics incl. electric range and energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher performance vehicles get more credits</td>
</tr>
</tbody>
</table>

Government target of 5 million NEV sales by 2020

China expected to account for over 40% of future xEV demand
Intensified regulatory push in China
Updated NEV Subsidy Program

- Updated subsidy program for NEV cars and buses, valid through 2020
- Decrease in the per vehicle subsidy; subsidies attributed in function of battery size and capabilities

**NEV CARS**
- Higher focus on advanced technologies
- Two new requirements: battery energy density and energy consumption

**E-BUSES**
- Minimum range increased to 200 km
- Additional requirements: battery mass ratio, charging speed and battery energy density

Significant impact on cathode material chemistry: shift from LFP to NMC
Intensified regulatory push in Europe

CO₂ Directive and low emission credits

Europe expected to account for up to 30% of future xEV demand
Legislation triggered electrification
And car OEMs embrace electrification

“BMW Group announces next step in electrification strategy
25/07/2017

“Volkswagen Group to expand production of electric vehicles worldwide on a massive scale
13/03/2018

“Hyundai Motor Group Reveals Next-Generation Powertrain Strategy
28/10/2017

“VOLVO CARS TO GO ALL ELECTRIC
05/07/2017

“GM Outlines All-Electric Path to Zero Emissions
02/10/2017
Car OEMs roll-out their e-mobility strategies
...with an emphasis on flexibility

“There’s going to be a co-existence between combustion engines and electrified drive systems over the next 10 to 20 years, so against this background we should all be patient and relaxed and leave the decision to our customers, they should decide which concept they prefer.

Herbert Diess,
VOLKSWAGEN, CEO

“We all know electrification is coming, but no one was aware how quickly it will arrive. Another challenge is that we don’t know when, where, or what customers will buy in the future. To meet this challenge, we have decided to launch future products on a flexible architecture.”

Hanno Kirner,
JAGUAR LAND ROVER, EXECUTIVE DIRECTOR CORPORATE AND STRATEGY

Major OEMs are massively increasing their offerings and this for a wide range of electrified vehicles
Agenda

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Accelerated growth in Electrification

Success factors

Key takeaways
It takes a lot to play in the automotive league

Car OEMs need:

High quality cathode materials
- ... custom made for different types of xEVs
- ... in massive volumes
- ... at the highest speed and flexibility
- ... at a competitive price
- ... without any sustainability image risk.

- excellent product quality on 20+ specs
- wide spectrum of cathode material technologies
- industrial capabilities
- ability to scale up fast
- cost-efficient processes
- ethically sourced materials

It takes product technology, process technology and supply
Product, process and supply

Key success factors

1. Product Technology
   - Wide spectrum of cathode material technologies
   - Ability to scale up fast
   - Cost-efficient processes
   - Industrial capabilities
   - Best in class product quality on 20+ specs:
     continuous fine-tuning at lab, pilot and industrial scale

2. Process Technology

3. Supply
   - Raw materials
   - Feed flexibility
   - Battery recycling
   - Lab scale
   - Pilot scale
   - Industrial scale
### Long wish list of users’ requirements

<table>
<thead>
<tr>
<th>Cell maker</th>
<th>Cell type:</th>
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<tbody>
<tr>
<td></td>
<td>• hard case prismatic</td>
</tr>
<tr>
<td></td>
<td>• cylindrical</td>
</tr>
<tr>
<td></td>
<td>• pouch</td>
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<table>
<thead>
<tr>
<th>Cell maker</th>
<th>Electrode</th>
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<tr>
<td></td>
<td>• Wound</td>
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<tr>
<td></td>
<td>• Zigzagged</td>
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<tr>
<td></td>
<td>• Stacked</td>
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<table>
<thead>
<tr>
<th>Car OEM</th>
<th>Solvent:</th>
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<tbody>
<tr>
<td></td>
<td>• NMP</td>
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<tr>
<td></td>
<td>• water</td>
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<td></td>
<td>• none</td>
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<tr>
<th>Regulator</th>
<th>Size:</th>
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<tr>
<td></td>
<td>• 4-10-40-150Ah</td>
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Long wish list of users’ requirements

Safety approach:
- cell
- system

Strategy:
- compliance
- embrace

Range:
- long
- compliance focused

Price
- premium
- mainstream

Warranty
- cooling
- voltage adjustment
Long wish list of users’ requirements

**CO₂ emission:**
- Technology influence
- Public transport promoting
Long wish list of users’ requirements

Purchase motivators:
- TCO
- environmental
- driving performance
- range needs

Car size:
- LDV
- HD
- e-bus
Long wish list of users’ requirements

- **Cell maker**
  - Cell type
  - Electrode
  - Solvent
  - Size

- **OEM**
  - Safety approach
  - Strategy
  - Range
  - Price
  - Warranty

- **Regulator**
  - CO₂ emission
  - Technology influence

- **Customers**
  - Public transport
  - TCO
  - Driving pleasure
Long wish list of users’ requirements
Defines key cell performance specs

- Safety
- Capacity
- Warranty

- Power
- Cost
- Cycleability
Cathode material specs to fulfil cell performance specs

Cathode material product specs

- Particle size
- Morphology
- Composition
- Purity
- Packing density
- Porosity
- Consistency
- and more

Cathode material performance specs

- Capacity
- Power (charge/discharge)
- Cycle life
- Safety
- Charge efficiency
- and more

Tailoring cathode material characteristics to the cell specs requires:

- Fundamental chemistry know-how to design the right product composition during lab phase
- Ability to further enhance the product designs during 12-24 month qualification cycles in pilot phase
There is no such thing as one xEV

<table>
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<tr>
<th>Feature</th>
<th>Low nickel NMC</th>
<th>High Ni chemistries</th>
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**BEV mid range**
There is no such thing as one xEV

- **Safety**
- **Driving Range**
- **Durability/warranty**
- **Cost**
- **Power**

Low nickel NMC to High Ni chemistries
There is no such thing as one xEV

Low nickel NMC | High Ni chemistries

Safety
Driving Range
Durability/warranty
Cost
Power
And not one solution will fit all

Wide spectrum of cathode materials is and will be needed

With excellent product quality on 20+ specs
Process technology as enabler for fast growth and cost efficiency

**FAST GROWTH**
- Efficient from pilot to industrial scale
- Excellent product quality at large industrial volumes
- Capability to respond to market swings
- Production lines forward and backward compatible

**COST EFFICIENT**
- Controlled capital intensity
- High throughput rate
- Maximize first pass yield
- Operational expenditures

**Umicore**
- Industrial capabilities
- Ability to scale up fast
- Cost-efficient and lean processes
- Excellent product quality on 20+ specs
Recent expansions deploying Umicore’s innovative proprietary process technology

Expansions on track:

• Sales projected to reach **100,000 t in 2019**
• Total capacity of at least **175,000 t in 2021** (full spectrum NMC grades)

Progress:

• **Korea**: first and most advanced project
• **China**: project on existing site is on track with a planned commissioning wave starting in Q4
• **Europe**:
  • Process Competence Center in Belgium as of end 2019
  • New site in Nysa (Poland) expected to be operational as of end 2020
Access to raw materials
Unique integration in the value chain

Flexibility in supply feed, high speed to market and responsiveness to customer needs
Access to raw materials
Battery recycling as critical additional source of supply

- Urban mining indispensable for global electrification of transportation
- Proven industrial capabilities for all types and formats of Li-ion batteries
- Patented recycling technology
- High recovery rates for lithium, cobalt, nickel and copper
- Highest environmental standards

Flexibility in supply feed, high speed to market and responsiveness to customer needs
Increasing the gap

Further extend technology and market leadership in xEV through strong focus on innovation and accelerated capacity additions.

Cost leadership through economies of scale, process development, competitive sourcing and operational excellence.

Strong ties along the value chain with suppliers, cell makers, OEM’s allowing a real, sustainable closed-loop model.
Agenda

- Business profile
- Accelerated growth in Electrification
- Success factors
- Key takeaways
Key takeaways

Increasing electrification drives massive market demand

Clear trend of product customization

Umicore uniquely positioned to capture significant growth in this segment:

• Full spectrum of highest quality cathode materials

• Process technology and ability to scale up fast

• Innovation pipeline spanning the next 20 years

• Integrated supply chain and battery recycling
materials for a better life