Umicore’s position in catalysts to support the green hydrogen economy

26 April 2021
More than 30 years of experience in catalysts for green hydrogen economy

- First developments of Platinum Black as Fuel Cell Catalysts
- CO-tolerant Catalysts for Fuel Cells
- Catalysts for Direct Methanol Fuel Cells
- Catalysts for PEM Electrolyzers
- Catalysts for CHP Systems
- Development of Core/Shell Catalysts for Fuel Cells
- Development of state-of-the-art Anode and Cathode Fuel Cell Catalysts
- Umicore acquires PMG fuel cell catalyst activity
- Creation of SolviCore JV with Solvay on MEA
- Creation of Co-development with HMC on catalyst
- Dedicated focus on PEM fuel cell catalysts: sale of SolviCore joint-venture
- First mass production of catalyst in Korea
- Opening of new facility for the production of fuel cell catalysts in Korea
- Joint R&D program with Anglo American Platinum on LOHC for FCEVS
- Over 30 years more than 250 fuel cell patents filed around the world
Global footprint: 2 production sites and 4 R&D centres in Asia and Europe

- **Copenhagen, Denmark**
  - R&D

- **Hanau, Germany**
  - R&D
  - Applied technology
  - Production
  - Marketing & Sales

- **Incheon, Korea**
  - R&D
  - Applied technology
  - Production
  - Marketing & Sales

- **Tokyo, Japan**
  - Applied technology

- **Suzhou, China**
  - Headquarters
  - Applied technology

- **Olen, Belgium**
  - R&D
Attractive growth opportunities in the hydrogen economy

**MOBILITY OPPORTUNITY**

- TRANSPORTATION FUEL CELLS
  - Attractive near-term growth potential

- LIQUID ORGANIC HYDROGEN CARRIER FOR TRANSPORTABLE FUEL
  - Long-term growth potential

**ENERGY OPPORTUNITY**

- GREEN HYDROGEN (ELECTROLYSIS)
  - Long-term growth potential

---

**Active business**

Profitable with a turnover* of € 40 Mn in 2020

**Business incubation program**

R&D program and joint development agreements to establish future growth and success

---

*Turnover: including metal content
Attractive growth opportunities in the hydrogen economy

**MOBILITY OPPORTUNITY**
- TRANSPORTATION FUEL CELLS
  - Attractive near-term growth potential
- LIQUID ORGANIC HYDROGEN CARRIER FOR TRANSPORTABLE FUEL
  - Long-term growth potential

**ENERGY OPPORTUNITY**
- GREEN HYDROGEN (ELECTROLYSIS)
  - Long-term growth potential

Fuel Cell Recycling
Attractive growth opportunities in the hydrogen economy

Attractive near-term growth potential

Long-term growth potential

LONG-TERM GROWTH POTENTIAL

TRANSPORTATION FUEL CELLS

LIQUID ORGANIC HYDROGEN CARRIER FOR TRANSPORTABLE FUEL

GREEN HYDROGEN (ELECTROLYSIS)
Near-term growth potential in fuel cell catalysts for HDV and long-range LDV

Umicore produces catalysts for the cathode and anode electrode of PEM fuel cells
Near-term growth potential in fuel cell catalysts for HDV and long-range LDV

**MOBILITY OPPORTUNITY**

**TRANSPORTATION FUEL CELLS**

<table>
<thead>
<tr>
<th>Application</th>
<th>Key fuel cell technology</th>
<th>Legislation</th>
<th>Est. market size by 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel cells as perfect solution to cater long range HDV and buses, providing strong propulsive power</td>
<td>Proton-exchange membrane</td>
<td>Supportive in Korea, Japan, China and Europe</td>
<td>HDV &amp; LDV: 150 GW (current: ~4 GW)*</td>
</tr>
<tr>
<td>Most LDV to be battery electric except long range LDVs (&gt; ~750 km)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Est. catalyst demand by 2030**

- 120t (current: < 4t) taking into account increasing thrifting of precious metals

---

**Growth potential for HDV and long range LDV in Korea, Japan, China and Europe**

**Umicore**: ongoing sales and scaling up in view of increasing customer demand

- Qualified *supplier* of more than 10 OEMs across regions: car and truck OEMs as well as stack producers and system manufacturers
- Considered *benchmark catalyst materials* by leading fuel cell companies
- R&D and production capacity in Germany and Korea; mass production plant commissioned in Korea end 2019

---

*Source: “European Union Study on Value Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells Technologies” (Sept. 2019) and assuming 0.8g catalyst per kW
Key customer cooperations with OEMs as well as system integrators, stack and MEA suppliers

Qualified supplier of more than 10 OEMs (car and truck OEMs as well as stack producers and system manufacturers)

Ramp-up timeline for already qualified business awards

SOP: start of production

And ongoing engagements for new platforms globally…
Supplier of Hyundai Motor Company for fuel cell catalysts

Hyundai MC: one of the first manufacturers to make hydrogen fuel cell vehicles commercially available

Focus on advanced fuel cell technology to boost range, performance, durability

Launch of NEXO, the only fuel cell SUV in the world, in 2018 with 135kW powertrain and range of 665km

Umicore is supplier and co-developer of PEM fuel cell catalysts with Hyundai Motor Company since September 2009, providing the high performance and durability catalyst requirements
Leading technology on fuel cell catalysts

Roadmap to reduce PGM loading and make fuel cell applications more cost competitive

Launch dates of next gen catalysts

- Gen. 1
- Gen. 2
- Gen. 3
- Gen. 4

Reduce PGM content at high durability

Research network on fuel cells with key institutes in Europe, US and Korea

Open innovation with best-in-class academia and research institutes
Attractive growth opportunities in the hydrogen economy

**MOBILITY OPPORTUNITY**

- TRANSPORTATION FUEL CELLS
- LIQUID ORGANIC HYDROGEN CARRIER FOR TRANSPORTABLE FUEL

**ENERGY OPPORTUNITY**

- GREEN HYDROGEN (ELECTROLYSIS)

Attractive near-term growth potential

Long-term growth potential

Long-term growth potential
Long-term growth potential in liquid organic hydrogen carrier technology for transportable hydrogen fuel
LIQUID ORGANIC HYDROGEN CARRIER (LOHC)

Application
- LOHC are organic compounds that can absorb and release hydrogen through chemical reactions and can therefore be used as storage for hydrogen
- Offer options for (i) transporting hydrogen over long distances as it allows safer, more practical and more cost-efficient hydrogen transport and (ii) simplification of the fueling process

Key fuel cell technology
- Requires PGM-catalysts for hydrogen storage/release

Legislation
- CO₂ regulation accelerating hydrogen economy: Asia, Europe, US to lead

Joint research and development program with Anglo American Platinum to develop PGM-based technologies for LOHC applications on fuel cell electric vehicles

- Pilot project with industrial and academic partners on early-stage LOHC product development
- Aiming for a significant simplification of the fueling process by enabling dehydrogenation at lower temperatures and pressures, thereby providing a viable alternative to onboard storage of compressed hydrogen
- Long-term opportunity in the refueling of FCEVs
Attractive growth opportunities in the hydrogen economy

**MOBILITY OPPORTUNITY**
- Transportation fuel cells
- Liquid organic hydrogen carrier for transportable fuel

**ENERGY OPPORTUNITY**
- Green hydrogen (electrolysis)

Attractive near-term growth potential
Long-term growth potential
Long-term growth potential
Long-term market potential in catalysts for green hydrogen (electrolysis)

**ENERGY OPPORTUNITY**

**GREEN HYDROGEN (H2) - ELECTROLYSIS**

Application
- Electrolysis produces hydrogen from water using renewable and non-renewable electricity sources
- Green hydrogen when electricity produced from renewable sources

Key technology
- Proton-exchange membrane or alkaline

Legislation
- Initiatives to promote green hydrogen in Europe (Green Deal), Japan, Korea and Australia

Est. market size by 2030 for PEM catalysts
- 90 GW (current: 0.1 - 0.2 GW)
- Green hydrogen expected to be cost competitive as of 2030 - 2035

Est. PEM catalyst demand by 2030
- 6-7t (current: < 0.3t)

*Source: *International Renewable Energy Agency (Dec. 2020), assuming 0.7g catalyst per KW

**Long-term market potential in electrolysis for green hydrogen, however long term market potential dependent on CO₂ legislation as well as preferred technology**

**Umicore well positioned to capture future growth in catalysts for electrolysis:**

- Strong knowhow and expertise in PEM catalysts
- Continued R&D investment
- Ongoing collaboration with best-in-class research institutes
Ongoing research on green hydrogen

Open innovation with best-in-class research institutes

Consortia memberships on green hydrogen (electrolysis)
Key takeaways

Increasing government initiatives to promote hydrogen-based economy

Attractive near-term growth potential in fuel cell catalysts used in HDV and long range LDV

Longer term opportunities for catalysts in LOHC for transport & storage and green hydrogen production

Umicore uniquely positioned to capture significant near-term growth in fuel cell based HDV and LDV:

• Established portfolio of PEM catalysts with outstanding performance and durability

• Already qualified supplier of more than 10 car & truck OEMs, system integrators, stack and MEA suppliers

• Global presence with R&D and industrial production in Korea and Germany, HQ in China

• Strong R&D and research partnerships

Ongoing collaboration programs and R&D in view of longer-term growth potential in LOHC and green hydrogen