+ PRESSURISED HIGH TEMPERATURE CO-ELECTROLYSIS
General Information about sunfire
Company Facts

- **90 employees**
- **Stacks**
- **Systems**
- **Fuel**
- **Ceramics**
- **Production**
- **Business**

**Partners & Investors**
- Audi
- Lufthansa
- ThyssenKrupp
- Vaillant
- CEZ GROUP
- idinvest PARTNERS
- Total
- EDF
- KfW
- ELECTRANOVA CAPITAL

**Financials**
- **Value**: ~ 60 M € pre-investment, incl. build up ceramic and stack tech. | Grants > 15 M €

**Patents**
- 40 patent families (i.e. „process patent sunfire“ WO/2008/014854)

**Recognition**
- 2016 Global Cleantech 100
- ECOSUMMIT AWARD
- FAST COMPANY
- NATIONAL GEOGRAPHIC

Company: Sunfire
One core – Four products – Multiple markets

Individually

Solid Oxide Power Core

- Reliable power generation in remote sites
- 1 – 20 kW

Or integrated into three key products.

SO Off-Grid Generator

- Efficient co-generation for commercial use
- 20 – several 100 kW

SO Commercial Generator

- Efficient electrical storage and hydrogen production
- Grid balance and resilience

SO Reversible Generator

sunfire’s established solid oxide cell (SOC) stack design

Multiple markets

SO Commercial Generator

Efficient co-generation for commercial use
20 – several 100 kW

SO Reversible Generator

Efficient electrical storage and hydrogen production
Grid balance and resilience

Jörg Brabandt / PRESSURISED HIGH TEMPERATURE CO-ELECTROLYSIS
Pressurised High Temperature Co-Electrolysis
• Hydrogen is source in many industrial applications
  - Refineries, chemical industry, steel works, H₂ refueling…
  - Power-to-Gas (e.g. Methane) and Power-to-Liquid (e.g. Naphta, Diesel)
• Most of these processes run under pressure (10 … 100 bar) or require a pressurized supply line or storage
• Compression of gas is a major impact of overall system efficiency
• About 5% overall system efficiency can be saved if hydrogen compression (0 → 10 bar) could be skipped
  → producing pressurized H₂ would be advantageous

• Using steam (e.g. produced by excess heat) instead of water for electrolysis increases efficiency further 5…10%
  - Excess heat may come from further process like the exothermal Methanation
For energy storage, \( \text{H}_2 \) seems to play a minor role
\( \rightarrow \) conversion to Syngas (and further to methane, diesel etc.) required
- Existing distribution infrastructure can be used

In contrast to a PEMFC, HT fuel cells (SOFC) can handle CO that is oxidized to \( \text{CO}_2 \)
- Therefore it is nearly to test the vice-versa process as well
\( \rightarrow \) use \( \text{CO}_2 \) as source for electrolysis and produce CO

Feed of \( \text{H}_2\text{O} \) and \( \text{CO}_2 \) to electrolyser to produce \( \text{H}_2 \) and CO (syngas) in one step is called co-electrolysis
- Other expensive process parts for CO production like RWGS reactor can be skipped
01. Introduction

- High temperature ELectrolysis and METHanation project: [www.helmeth.eu](http://www.helmeth.eu)
- co-electrolysis targeted outlet gas composition as inlet feed for methanation:

\[
FEED: \frac{[H_2] - [CO_2]}{[CO] + [CO_2]} = 3
\]

- Reaction that takes place at HTE cell:

\[
x \cdot H_2O + y \cdot CO_2 \xrightarrow{co\text{-electrolysis}} x \cdot H_2 + y \cdot CO + \left(\frac{x+y}{2}\right) \cdot O_2
\]

- Water gas shift (WGS) reaction takes place even at OCV condition

\[
H_2 + CO_2 \leftrightarrow H_2O + CO
\]

→ main reaction at cell is likely to be steam electrolysis
02. Experimental: Stack and HotBoP components

- **sunfire SOC-stack:**
  - Electrolyte Supported Cells
  - 128 cm² active area / cell
  - 30 cells / stack
  - Hydrogen electrode: Ni-GDC
  - Oxygen electrode: LSCF
  - Electrolyte: 3YSZ (or 5YbSZ or 6Sc1CeSZ)

- **Hot BoP components developed by sunfire**
  - plate-type heat exchangers
  - electrical gas heaters
  - electrical evaporator (for independent operation)
02. Experimental: pressure vessel

- Pneumatic pressure control valves
- Pressure vessel in container
- Fluid supply panel
- H₂ / H₂O condenser
- Container ventilation inlet

- Operation pressure fixed to max. 16 bar (approved by TÜV due to pressure equipment directive)
03. Results: co-electrolysis outlet composition

- Operation point: \( j = -500 \text{ mA/cm}^2; \ T = 860^\circ \text{ C}; \) ambient pressure

- Output composition (gas analysis) close to desired values for methanation feed
- Composition can be tuned by varying the inlet gas composition
03. Results: I-V curves for different compositions

- Variation of inlet gas compositions
- Wide range of compositions possible without any sign of significant influence on stack performance

### Molar fractions in %

<table>
<thead>
<tr>
<th>Composition</th>
<th>H₂</th>
<th>H₂O</th>
<th>CO</th>
<th>CO₂</th>
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<tbody>
<tr>
<td>1</td>
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<td>95</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>5</td>
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<td>0</td>
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<td>15</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>55</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>
03. Results: co-electrolysis variation of conversion

- Variation of steam conversion
- Moderate increase of stack voltage
- High conversion rates also possible for co-electrolysis

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</table>
03. Results: pressurized electrolysis

- Pressure increase 1…8 bar (g) shows no significant influence on stack performance
- Gas inlet temperatures are decreasing due to worse measurement conditions and worse performance of microporous thermal insulation material
• sunfire SOC stacks offer the possibility of CO\(_2\) and co-electrolysis
• Outlet composition can be well tuned, but prediction of co-electrolysis outlet composition hardly possible, must be tested and measured
• Operation of a full scale stack under pressure up to 8 bar works; higher pressure operation under preparation

• Coupling and thermal integration of Methanation unit and pressurized high temperature Electrolyser leads to a considerably higher overall system efficiency for PtG
The projects under which the pressurized HT-electrolysis and co-electrolysis have been developed were funded by:

- FCH (Fuel Cells and Hydrogen Joint Undertaking)
- HELMETH (Hydrogen Enhanced Light Methane)
- European Union
- DLR (Deutsches Zentrum für Luft- und Raumfahrt) Project Management Agency
- Federal Ministry of Education and Research
Thank you for your interest!