RECENT DEVELOPMENT OF SOFC AND SOEC

Jan Froitzheim

Energy and materials
Chemistry and chemical engineering
Chalmers University of Technology
- 400 oral presentations
- 800 attendees
- Broad scope

- Alternating SOFC/PEMFC focus
- 2020 on SOFC again

- Focus on SOFC
- Every 2nd year
- ~400 participants
SOFC applications

- Trend to larger units
- μ CHP is one market but others become more important.
Solid Oxide Fuel Cell (SOFC)

Advantages

• High electrical efficiency

• \( \text{O}_2^- \)-conductive electrolyte
  ➢ Fuel flexibility (H\(_2\), natural gas, biogas, diesel)

• High operating temperature
  ➢ No need for expensive catalysts such as Pt
SOEC as a complement to renewables

The New York Times
Power Prices Go Negative in Germany, a Positive for Energy Users

Power from wind and solar waxes and wanes with the breeze and sunshine, not in response to when it is most needed. - Gordon Walker for The New York Times

www.bloomberg.com

Negative Power Prices
Number of occurrences in day-ahead markets

- Germany
- California, U.S.
- Czech Republic
- Slovakia
- Denmark
- Switzerland
- France
- Ireland

Sources: Epxe Spot, Nord Pool, CAISO, SEMO and OTE
Cell materials

- Cathode
  La based ceramic e.g. La$_{0.6}$Sr$_{0.4}$CoO$_3$

- Electrolyte
  Yttria doped zirconia (YSZ)

- Anode
  Nickel/YSZ mixture
Solid Oxide Fuel Cell (SOFC)

Electrolyte supported: >800 °C
Anode supported: 800-650 °C
Metal supported: 700-500 °C

There is a general trend towards lower operating temperatures.

⇒ Possibility to use less expensive materials
⇒ Higher efficiency possible
⇒ Longer lifetimes
⇒ Faster heating/cooling
Solid Oxide Fuel Cell (SOFC)

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Ceres - Partners

...for a range of potential power equipment applications

...SOFC stack, deployed within a Nissan designed fuel cell module suitable for operation with a variety of high efficiency fuel types (including biofuels). [EV-range extender]

...technology transfer and licensing [...] on 5kW SteelCell® stacks...The collaboration will further develop the technology, establish low-volume production at Bosch [...] for use in multiple applications including small power stations to be used in cities, factories, data centres and charge points for electric vehicles

...demonstration of EV range extender concept with Weichai for its fuel cell electric vehicle (“FCEV”) bus programme expected mid-2019

Completed design and build stage of 10kW module power system under the US Department of Energy programme with Cummins and progression into testing phase [Data centre]
Ceres builds new plant

- Investment of £7 million over 2 years
- Manufacturing capacity of ~2MW per year by end of 2019, expandable to 10 MW
- New site to act as "lead plant" to provide near-term volume and further develop processes to enable high volume manufacture with international partners under license
- More plants with partners
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Bloomenergy, sunfire, HEXIS, elcogen, CeresPower
Solid Power

- >1000 units installed
- > 18M operating hours
- Announced plans for production plant

“… it simplifies the process of powering servers and how this could almost double the energy efficiency of datacenters…” Chris Belady, General Manager Cloud Infrastructure Strategy and Architecture at Microsoft.
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Bloomenergy®

sunfire

HEXIS

Fuel cell technology
elcogen

CeresPower limited
GrInHy

- 150/30kW SOEC/SOFC mode
- 80/50%\textsubscript{LHV} system efficiency
- 40Nm\textsuperscript{3}/h hydrogen production
GrInHy2.0

2nd stage:

- 720 kW input
- By end of 2022 >13 000h operation and production of 100 tonnes H₂
• rSOC module in Mellach (AT)
• Operated in SOFC or SOEC mode
• 40Nm³ in SOEC mode
Solid Oxide Fuel Cell (SOFC)

Electrolyte supported

Anode supported

Metal supported

>800 °C

800-650 °C

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Elcogen stacks have achieved a WORLD RECORD in primary energy conversion efficiency to electricity of 74 %

12m€ EUR loan by EIB
Elcogen is a Finnish/Estonian SOFC developer selling cells and stacks
The FFI project

Kostnadseffektiva IT-SOFC Bränsleceller för mobila applikation
Interconnects stand for up to 35% of stack cost\(^1\).
We investigate low cost steels in combination with protective coatings.

\(^1\) Manufacturing cost analysis of 1 kW and 5 kW solid oxide fuel cell (SOFC) for auxiliary power applications. 2014, Battelle.