Progress on Reversible Solid Oxide Cell, Stack, and System Technologies

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Nexceris Mission

Our vision is to create a better world through energy innovations.

We collaborate with leading global customers and partners to transform powerful ideas into solutions that make energy production safer, more efficient, and environmentally responsible.
The Value of Nexceris

Nexceris is Vertically Integrated for SOC Development

Products
- fuelcellmaterials.com provides standard and custom SOC materials and components
  - Powders
  - Inks
  - Substrates
  - Cells
- We work with customers to provide materials and components from lab-scale to industrial-scale
- Quickly and accurately tailor powders and components to fit the needs and processes of our customers

Services
- Joint development and contract R&D services
- Leveraging our expertise and 25+ years of know-how in the SOC industry
- Accelerate customer development timelines on material, cell, and stack levels
- Our facilities accommodate a variety of synthesis and testing methods
- Fast-paced, versatile development structure
Nexceris Innovation

- **Materials**
  - SOCs and energy storage

- **SOCs**
  - Stationary and military

- **Sensors**
  - Transportation and energy markets

- **Catalysts**
  - H₂ and chemicals production

- **Protective Coatings**
  - SOC and high temperature
Versatile Reversible Solid Oxide Cell System for Hydrogen and Electricity Production (DEFE0031986)

**Project Objectives**

- ≥ 1kW\textsubscript{e} power generation in fuel cell mode with roundtrip stack efficiency (RTE) of ≥ 60%.
- Achieve long-term electrolysis and define a path to produce H\textsubscript{2} at ≤ $2/kg (at scale).
- Achieve dynamic switching between modes in response to grid demands (6-hr cycles).
- Demonstrate versatile fuel composition in electrolysis mode (H\textsubscript{2}O + CO\textsubscript{2}).
System Design
Pressurized System to Increase RSOC Stack Efficiency

• Theoretical round-trip-efficiency (RTE) of the stack is a function of temperature and pressure

  Chemical Energy (H₂/CO) >60%

  Electrical Energy (e⁻)

• RTE increases with pressure
  o Stack performance (kinetics, mass transport) also expected to increase with pressure

• Majority of RTE increase is gained up to ~8 bar

NEXCERIS
where energy meets environment
System Design
Major Challenges and Goals for Proposed System

**Electrode Performance & Stability**
- Cell performance → $>1 \text{Acm}^2$
- Cell durability → 0.5%/1000hrs
- Dynamic switching

**Stack Validation & Co-Electrolysis**
- Dynamic (6hr) stack cycling
- Stack RTE $>60$
- Co-electrolysis exhaust analysis with GC

**System Demonstration**
- Pressurized BOP construction at CSM
- Ambient BOP construction at Nexceris
- 1$kW_e$ with 60% stack RTE at 0.7 Acm$^2$
Electrode Evaluation for SOEC/SOFC

Developing & Understanding
Pressurization

Screening & Scaling High Performance

- 16 cm² cells
- 800°C

Perovskite
- Perovskite composite
- Other
- Other Composite

- SOFC
- SOEC
- Average

- Electrode Mode
  - Electrolysis Mode
  - Fuel Cell Mode

- 3:1 H₂O:H₂
- H₂

- 0.824 A/cm²
- 0.524 A/cm²

- 0.2 – 1.7 V

- 0 – 1500 h

- 0.2 – 1.7 V

- 0 – 1500 h

- 0.2 – 1.7 V

- 0 – 1500 h

- 800°C

- Gen 3
- Gen 2
- Gen 1
- DOE Target
- Baseline
Stack Level Performance & Stability
RSOC Durability Test on a 5-cell “Rainbow” Stack

RSOC Rainbow Stack Durability
3-cells (42-cm² Active Area) Stack

SOEC: CD = 0.60 A/cm² (25% H₂/H₂O)

SOFC: CD = 0.45 A/cm² (25% H₂O/H₂)

～1%/kh

800°C

Average Cell Potential (V)

Time (h)

Current (amps)

RSOC Stack Demonstrating 60 percent RTE
3:1 Fuel:Product Ratio
(5-cell, 42-cm² active area)
• Protective coating locks Cr evaporation in source.
• No evidence of Cr deposition in cathode.
• No evidence of air electrode or barrier layer delamination.
• Collaboration with PNNL planned for further post-mortem analysis.
Stack Level Performance & Stability
Co-Electrolysis on a 5-cell Stack

Steam Electrolysis
Steam Utilization = 27%
T = 800 °C, J = 0.6 A/cm²

Co-Electrolysis
CO₂/H₂O Utilization = 60%
T = 840 °C, J = 0.6 A/cm²

Control of Product Syngas Composition

5-Cell Stack (42 cm² area)

H₂O/CO₂ Utilization = 70%

H₂/CO Product Ratio

H₂O/CO₂ Feed Ratio

5-Cell Stack (42 cm² area)
T = 825 °C, J = 0.6 A/cm²
Path to Commercialization

• Process flow diagram (PFD) developed for initial techno-economic analysis (TEA).

• PFD will be combined with an electrochemical model for TEA of a pressurized system.

• Pressurized stack testing capabilities (< 10 bar) under construction at Colorado School of Mines.
  • Long-term, stack-level durability testing under RSOC conditions

• A 1kW_e demonstration system is planned at Nexceris for the end of 2022.
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Look for Nexceris team members walking around!