NEXCERIS
where energy meets environment

Northwestern University

COLORADO SCHOOL OF MINES

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

Samuel A. Horlick, Ph.D.

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

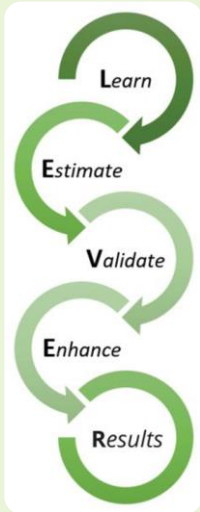
Products

- **fuelcell**materials.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	Sensors	Catalysts	Protective Coatings
SOCs and energy storage	Stationary and military	Transportation and energy markets	H_2 and chemicals production	SOC and high temperature

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Versatile Reversible Solid Oxide Cell System for Hydrogen and Electricity Production (DEFE0031986)

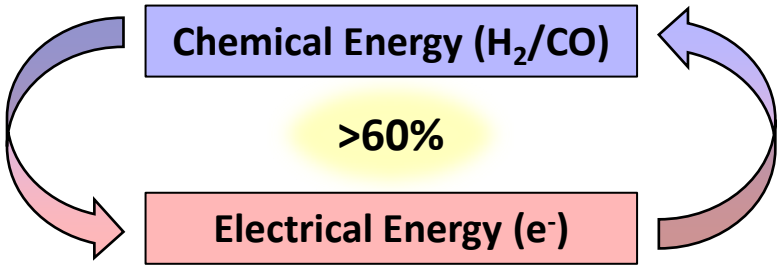
Project Objectives

- ≥ 1kW$_e$ power generation in fuel cell mode with roundtrip stack efficiency (RTE) of ≥ 60%.
- Achieve dynamic switching between modes in response to grid demands (6-hr cycles).
- Achieve long-term electrolysis and define a path to produce H_2 at ≤ $2/kg (at scale).
- Demonstrate versatile fuel composition in electrolysis mode (H_2O + CO_2).

System Design

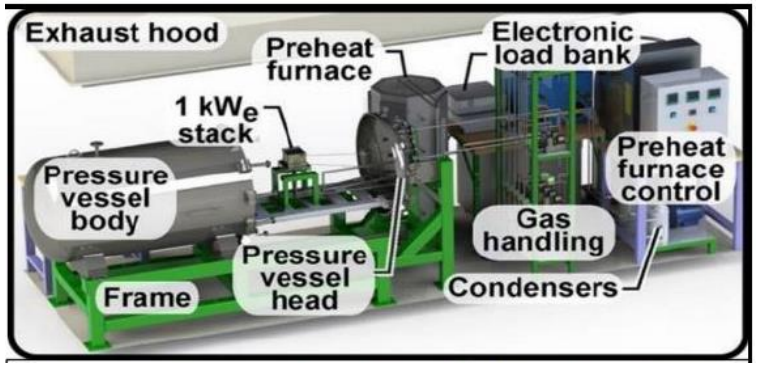
Pressurized System to Increase RSOC Stack Efficiency

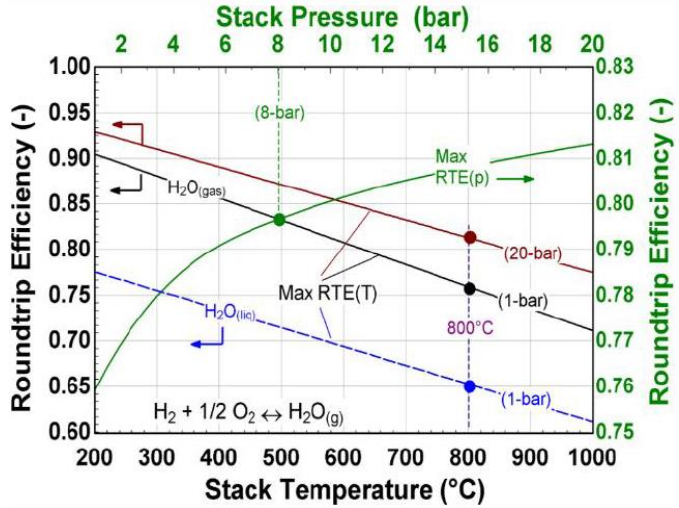
- Theoretical round-trip-efficiency (RTE) of the stack is a function of **temperature** and **pressure**

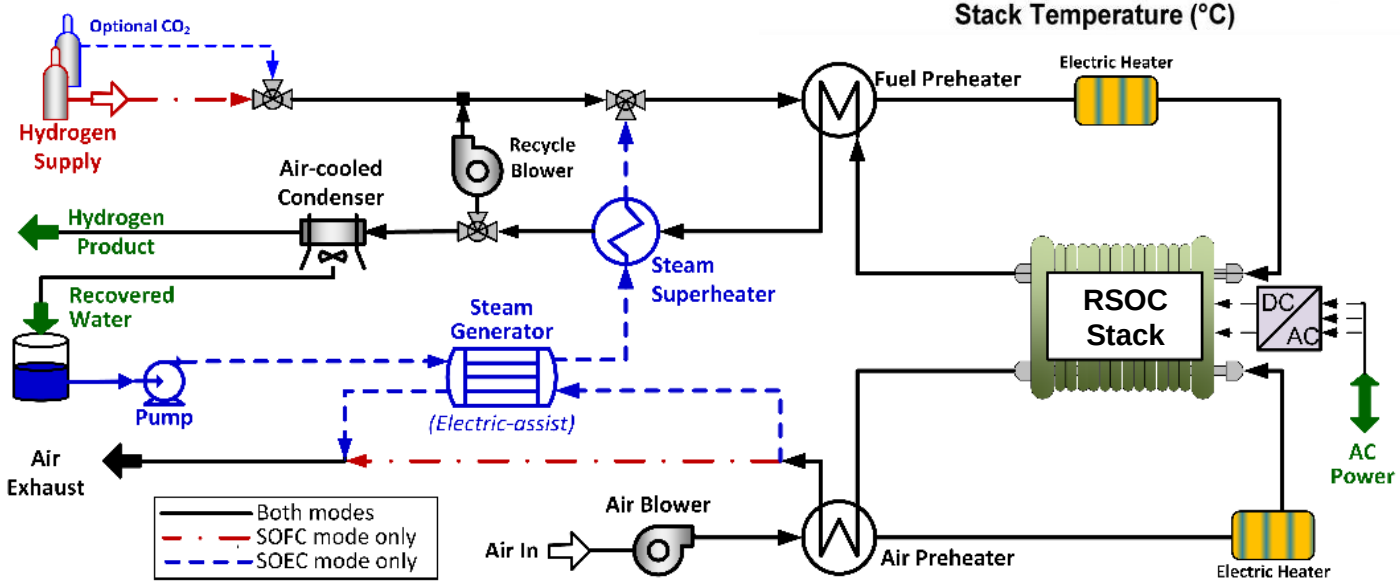


- RTE *increases* with **pressure**
  - Stack performance (kinetics, mass transport) also expected to increase with pressure

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







System Design

Major Challenges and Goals for Proposed System

Electrode Performance & Stability

- *Cell performance → >1Acm^{-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*

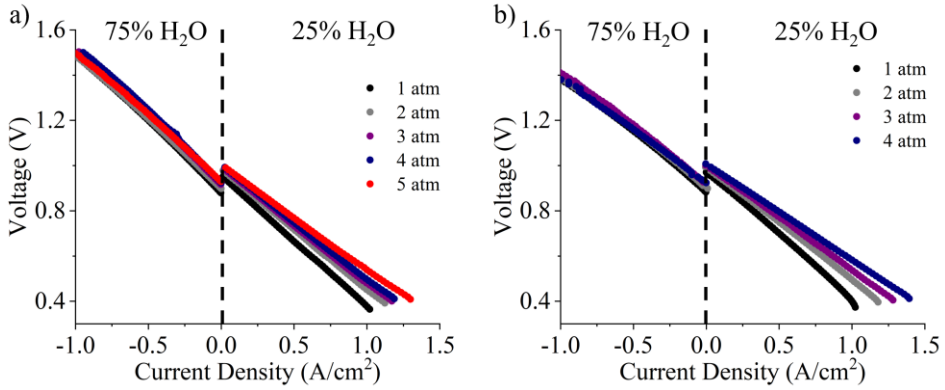
System Demonstration

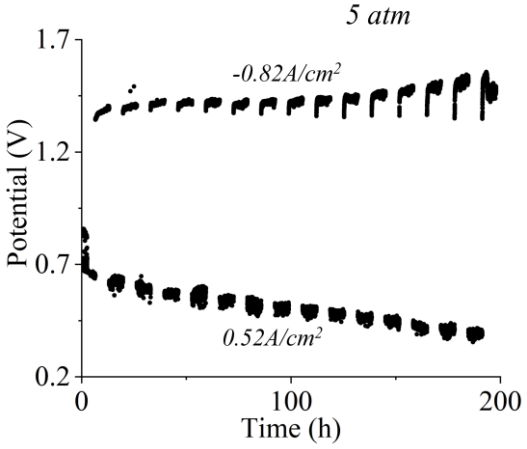
- *Pressurized BOP construction at CSM*
- *Ambient BOP construction at Nexceris*
- *1kW$_e$ with 60% stack RTE at 0.7 Acm^{-2}*

Electrode Performance & Stability

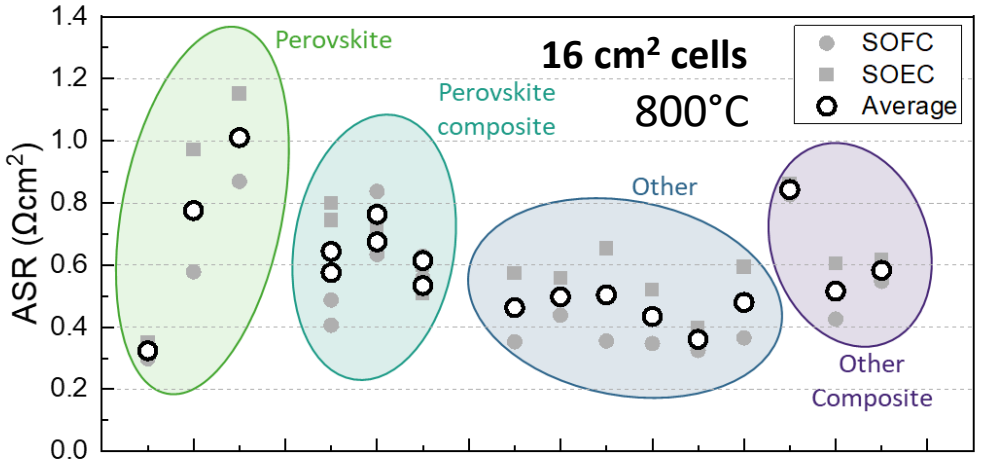
Electrode Evaluation for SOEC/SOFC

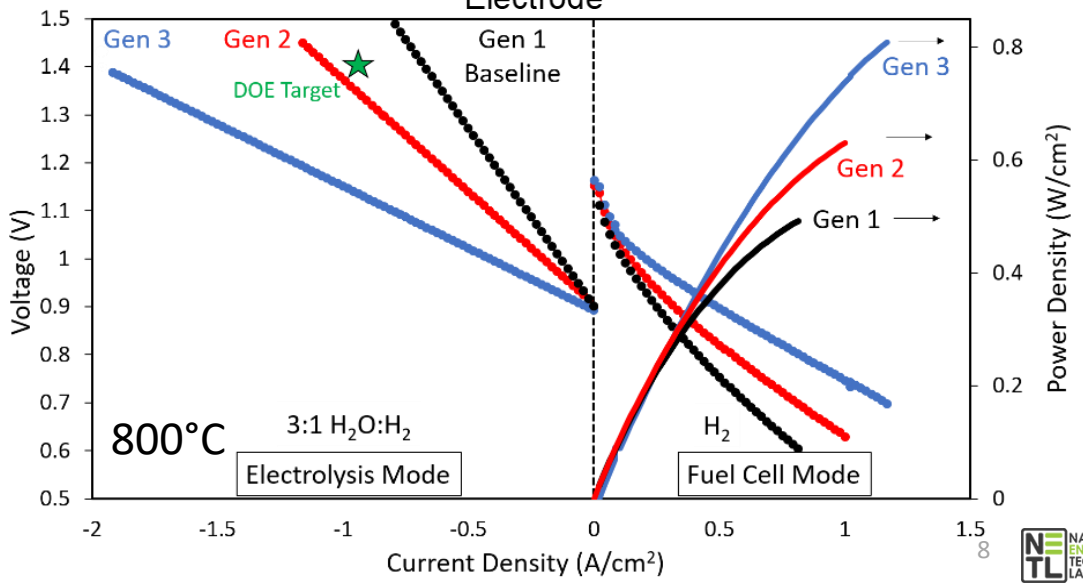
Developing & Understanding Pressurization





Screening & Scaling High Performance





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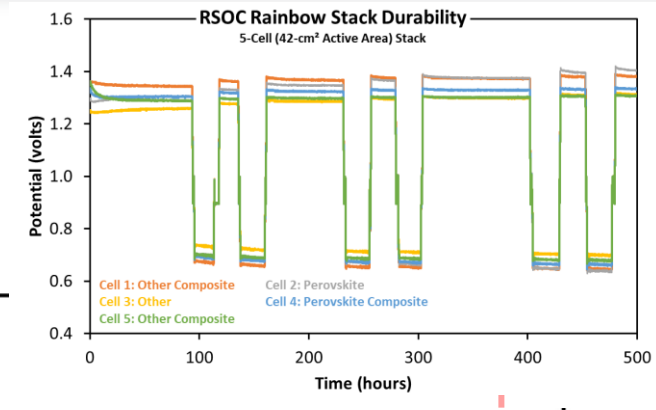
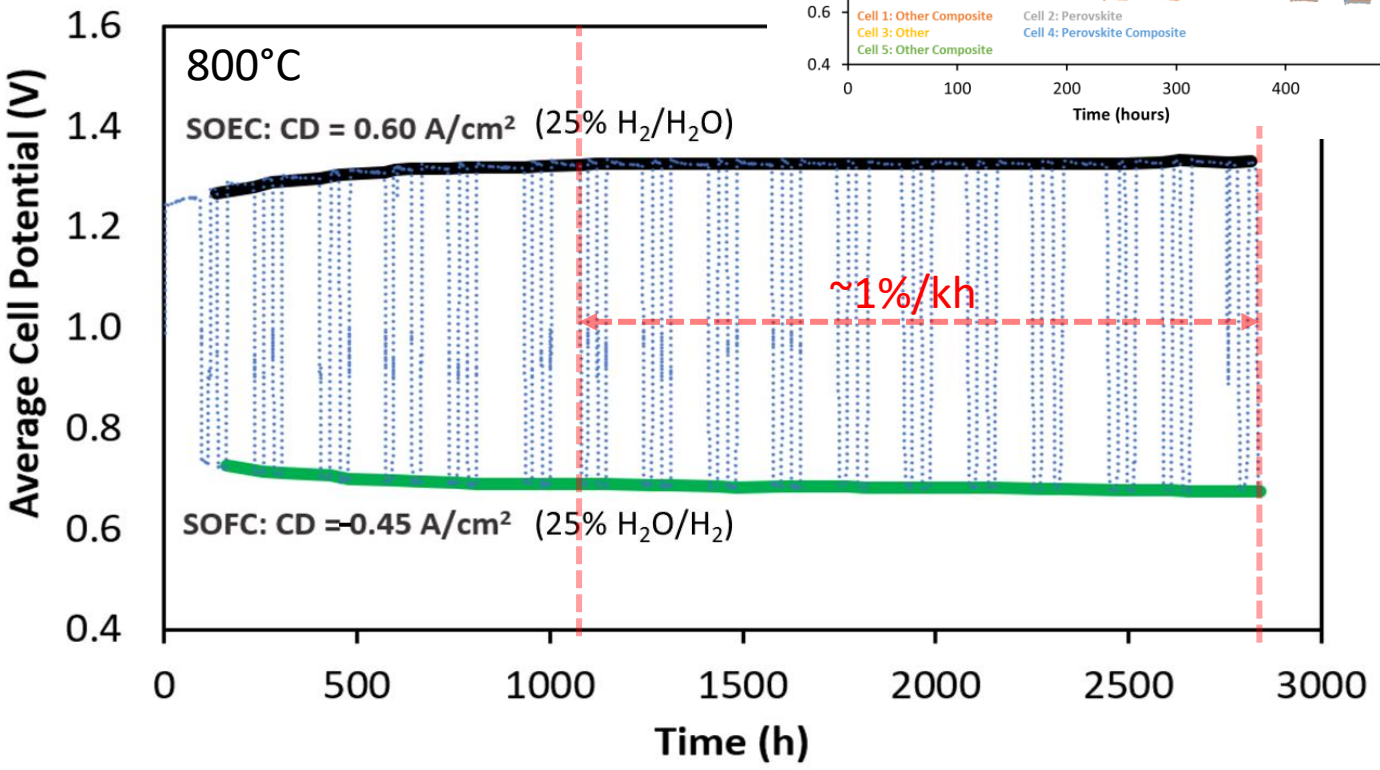
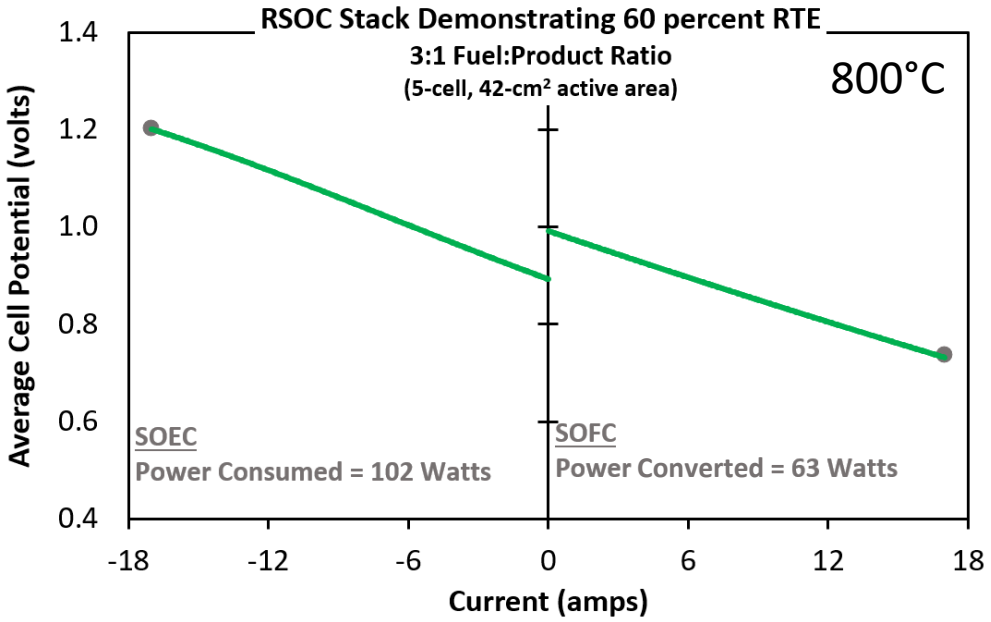
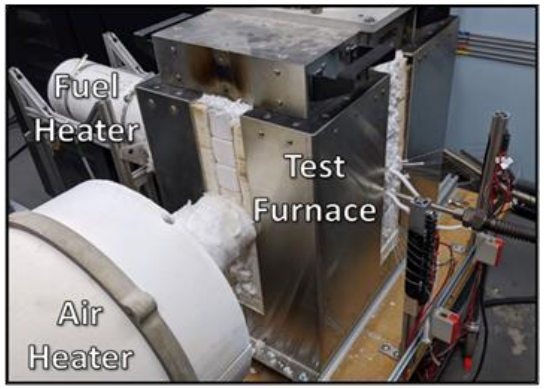
Stack Level Performance & Stability

RSOC Durability Test on a 5-cell "Rainbow" Stack









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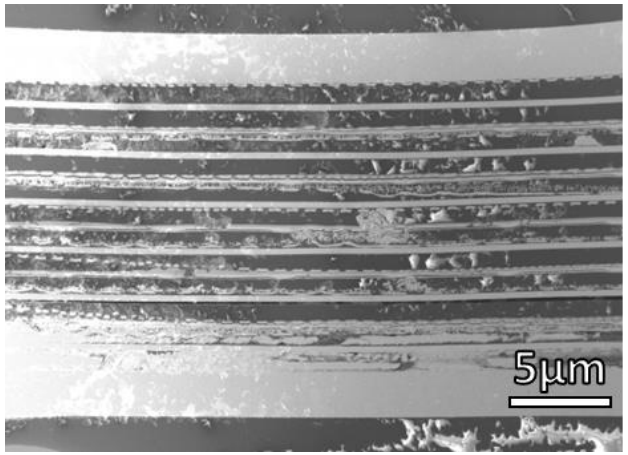
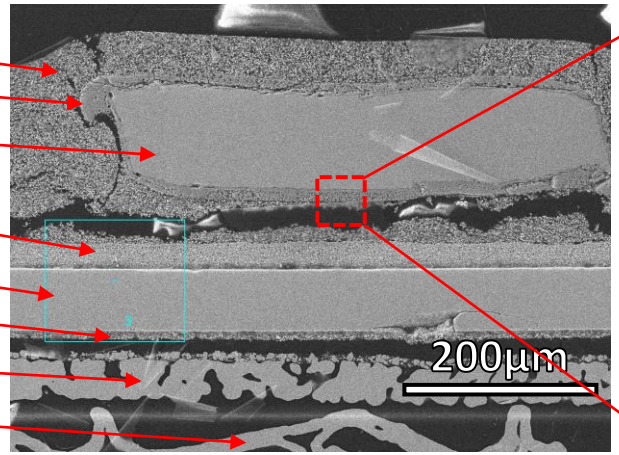
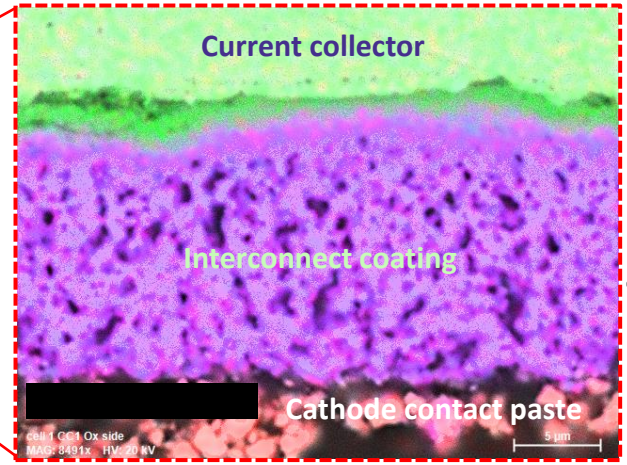
Stack Level

3000hr Post-Mortem SEM-EDS Analysis

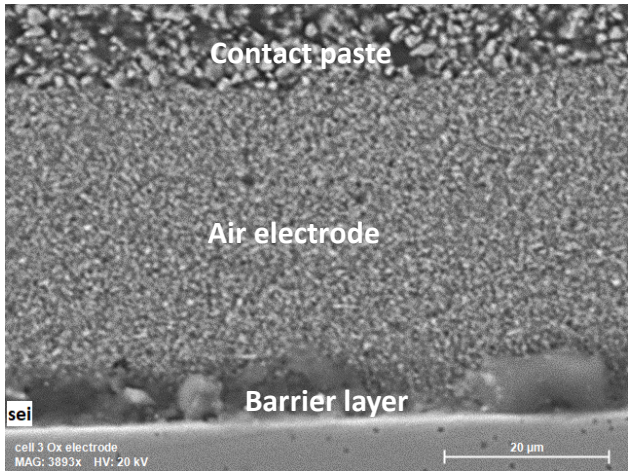


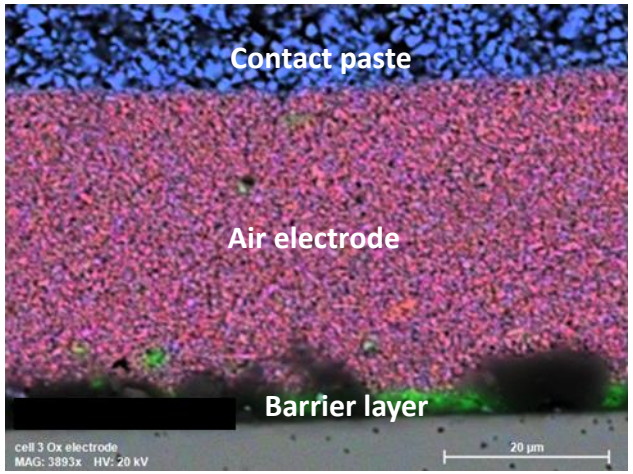
Contact paste
Protective coating
Current collector mesh
Air electrode
Electrolyte
Fuel electrode
Contact paste
Current collector mesh





3000hr stack operation





- 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.

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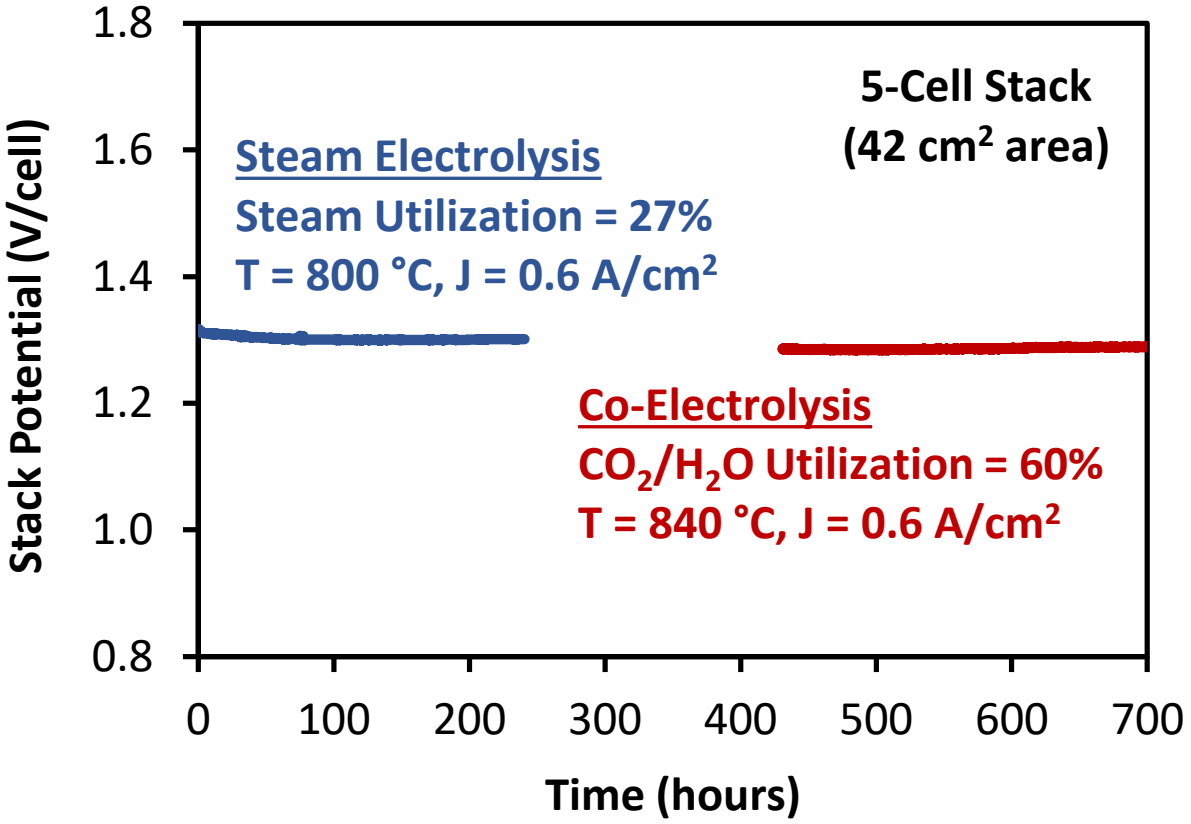
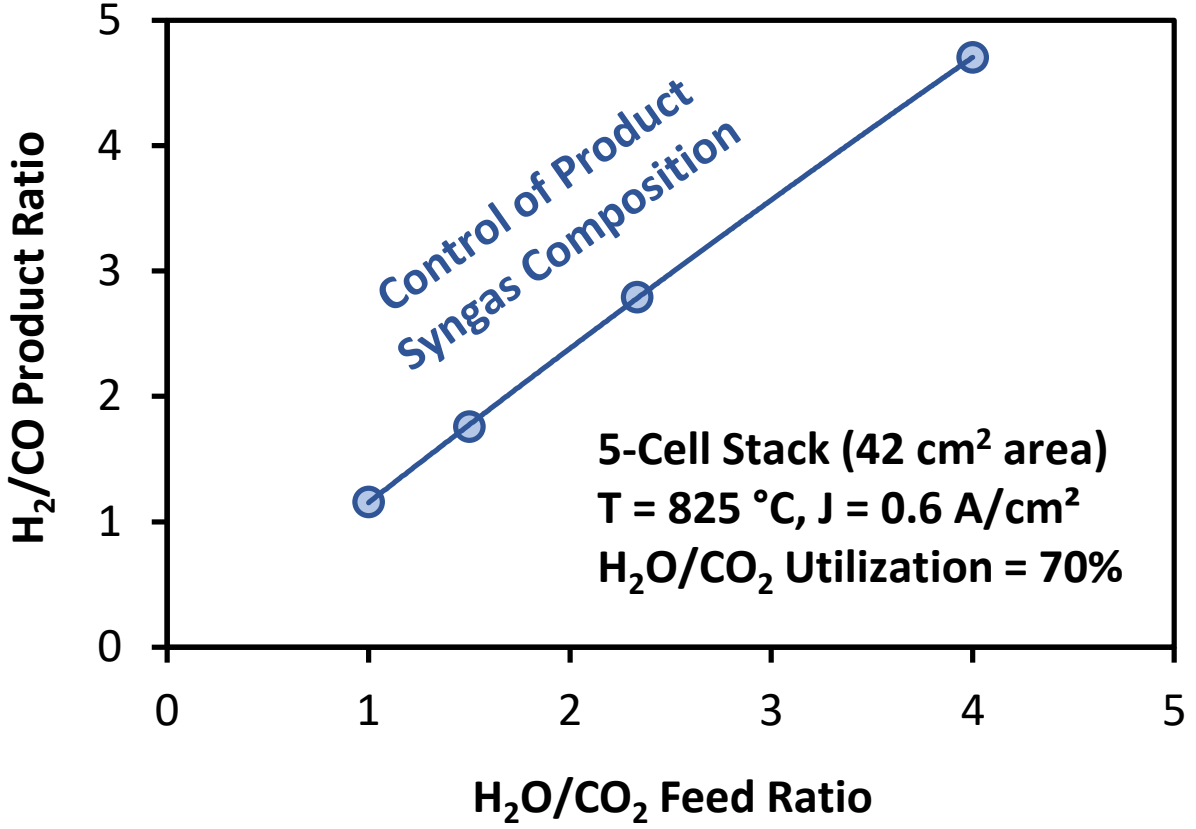
Stack Level Performance & Stability

Co-Electrolysis on a 5-cell Stack





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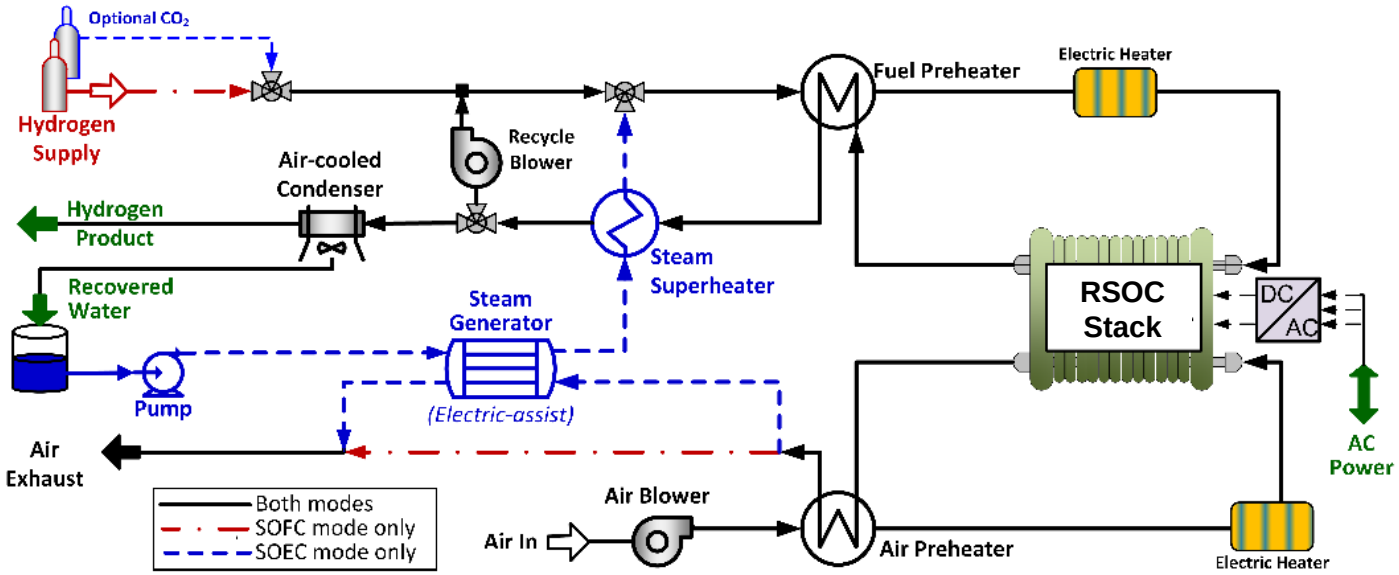
System Level

PFD, TEA, Breadboard Validation

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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Chad Sellers
Dr. Bradley Glenn

Look for Nexceris team members walking around!