FuelCell Energy

Liquid Fuels and Electricity from IT-Fuel Cells

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Partners

- University of Connecticut – Cell manufacturing technology development
- Pacific Northwest National Laboratory – GTL catalyst and cell development
- Energy and Environmental Research Center at the University of North Dakota – GTL catalyst evaluation and pressurized testing
- Massachusetts Institute of Technology – Electrode interface characterization

Massachusetts Institute of Technology

EERC
Energy & Environmental Research Center®
Putting Research into Practice

Pacific Northwest NATIONAL LABORATORY

UCONN
UNIVERSITY OF CONNECTICUT

Objective

Project Objective:

To develop a cell technology capable of direct conversion of methane to liquid product, methanol or formaldehyde, by electrochemical partial oxidation at intermediate temperatures (<500˚C), to provide means for an economic utilization of stranded gas.

Targets:

High Methane Conversion Yield

High Selectivity for Methanol Production

Composite Low Temperature Electrolyte

Redox Tolerant Anode

Scalable Manufacturing Methods

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Value Proposition

Western ND

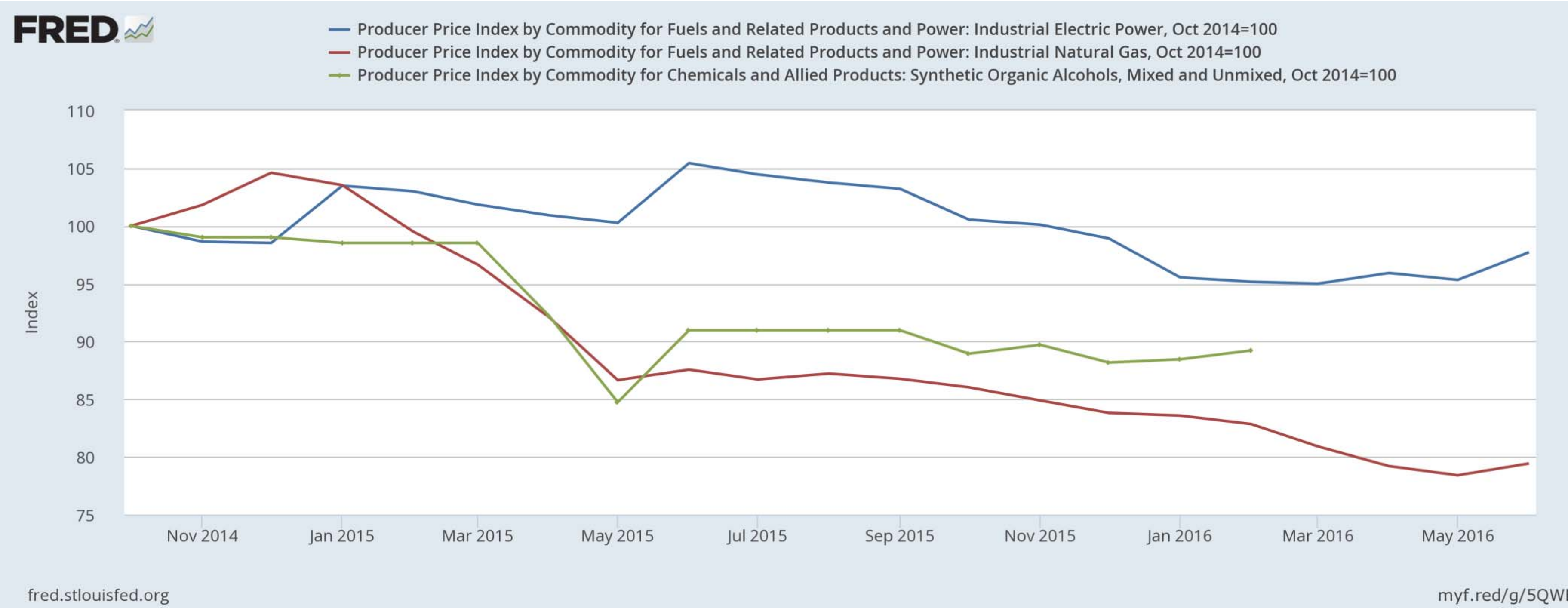
Population
~100,000

Eastern NY, CT, MA & RI
Population
~25,000,000

Satellite image of visible light sources in US, demonstrating level of natural gas flaring
Image – NASA Earth Observatory

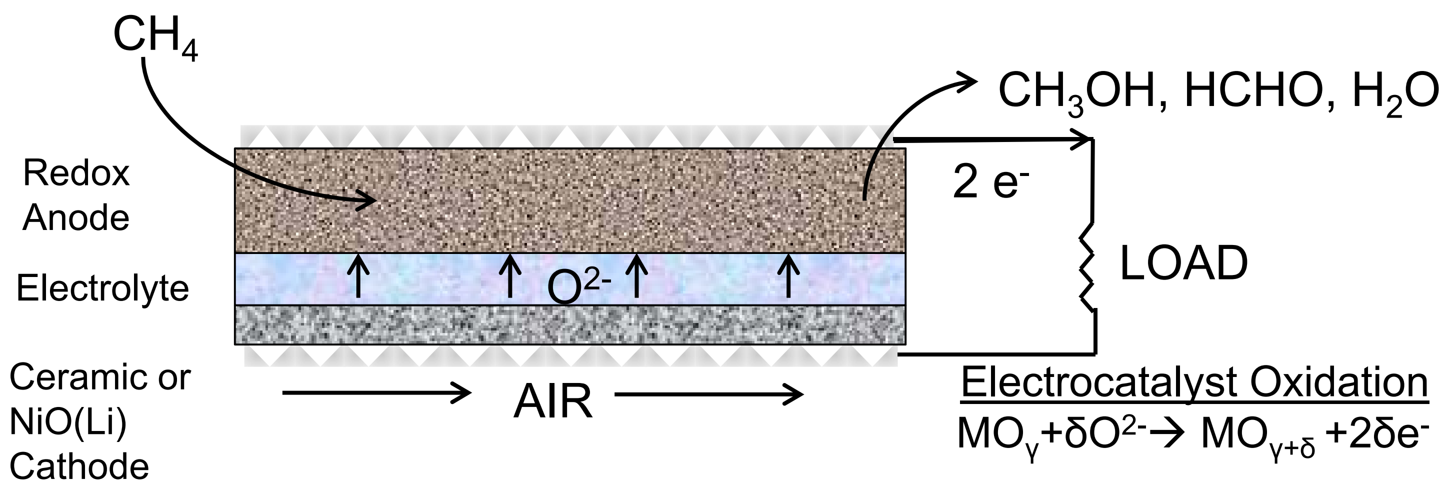
- Electrochemical Gas-to-Liquid (EC-GTL) offers a cost effective method for reducing emissions impact of stranded gas sources
- Scalability, modular nature, and transportability of electrochemical system also provide the means to economically utilize associated gas at low production wellheads
- The EC-GTL technology will meet ARPA-E's Mission Areas:
  - Enhance the economic and energy security of the United States
  - Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies

Value Proposition



US. Bureau of Labor Statistics, Producer Price Index by Commodity for Fuels and Related Products and Power: Industrial Electric Power [WPS054321], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WPS054321
US. Bureau of Labor Statistics, Producer Price Index by Commodity for Fuels and Related Products and Power: Industrial Natural Gas [WPU0553], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WPU0553
US. Bureau of Labor Statistics, Producer Price Index by Commodity for Chemicals and Allied Products: Synthetic Organic Alcohols, Mixed and Unmixed [WPU061403996], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/WPU061403996

Concept



<u>Electrocatalyst Oxidation</u>

$MO_{\gamma} + \delta O^{2-} \rightarrow MO_{\gamma+\delta} + 2\delta e^{-}$

<u>Fuel Formation</u>

$MO_{\gamma+\delta} + \delta CH_4 \rightarrow \delta CH_3OH + MO_{\gamma}$

$MO_{\gamma+\delta} + \delta CH_4 \rightarrow \delta/2\ HCHO + Mo_{\gamma} + \delta/2\ H_2O$

Electrochemical Gas-to-liquid cell utilizes a metal/metal oxide redox couple, which serves as the anode electrocatalyst, to partially oxidize CH_4 to CH_3OH and HCHO.

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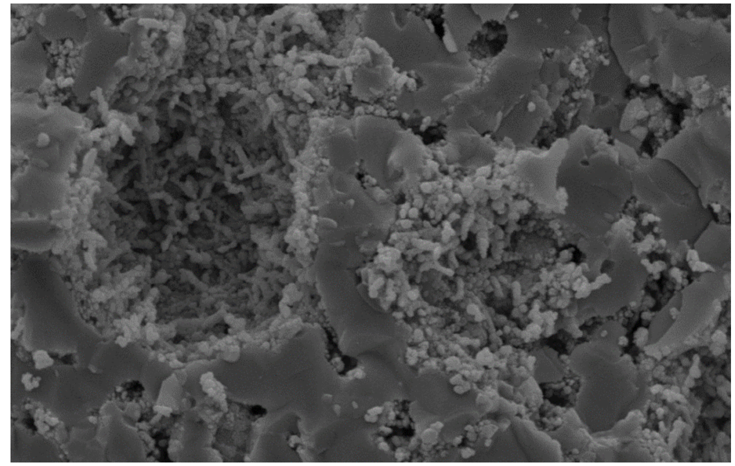
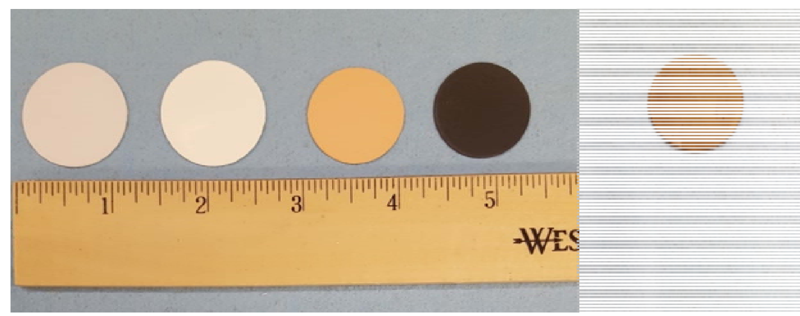
Development Approach

- Development of a novel EC-GTL cell presents an opportunity for top-down approach
- Incorporation of the catalyst within the EC-GTL anode requires ability to withstand constant redox cycling
- Chosen cathode and electrolyte must provide sufficient electrode activity and O^{2-} ionic conductivity to support the Redox reaction with the EC-GTL anode
- Institutional experience with MCFC commercialization can be leveraged to facilitate pathway to commercialization





a) Green Support Tape
b) Pre Sintered Support
c) AFL Coated Anode Support
d) Anode Infiltrated with Catalyst
e) Electrolyte Deposited on Anode

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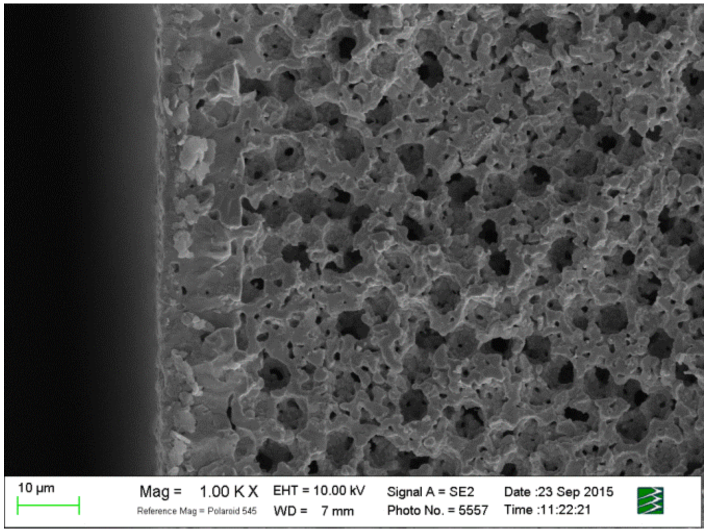
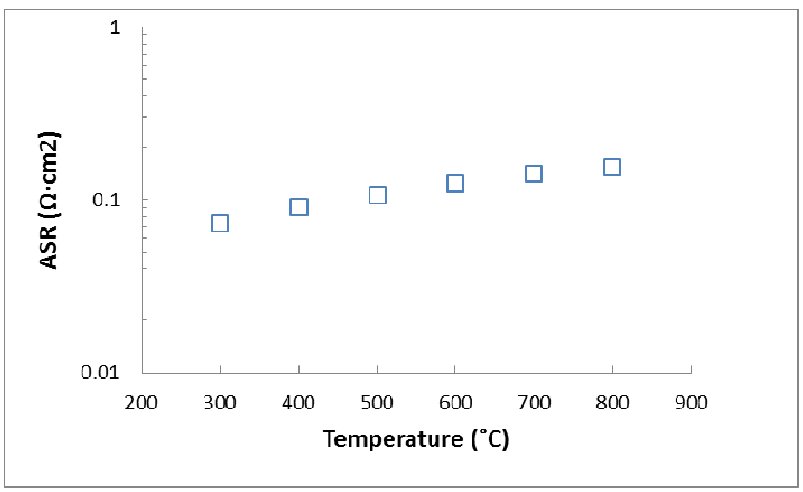
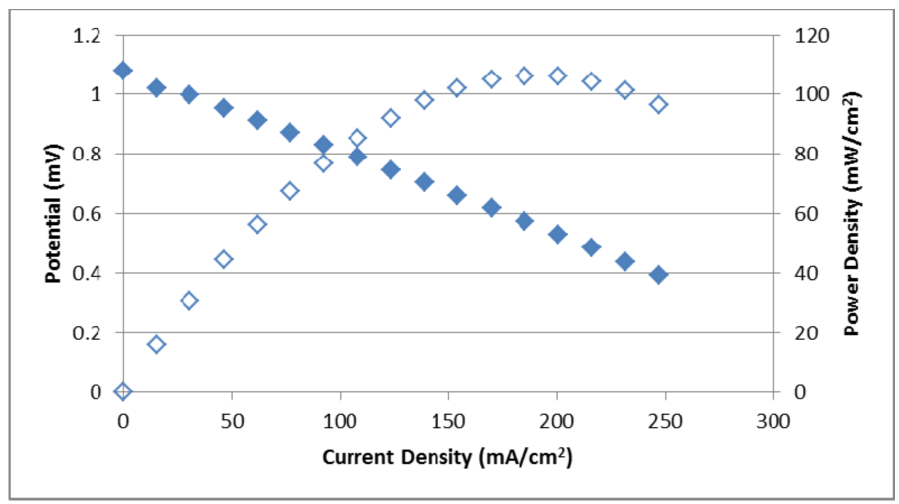
Cell Support



- Developed anode side support with adequate mechanical and electrical properties, capable of withstanding redox cycling.
- Demonstrated operation with carbonate electrolyte.





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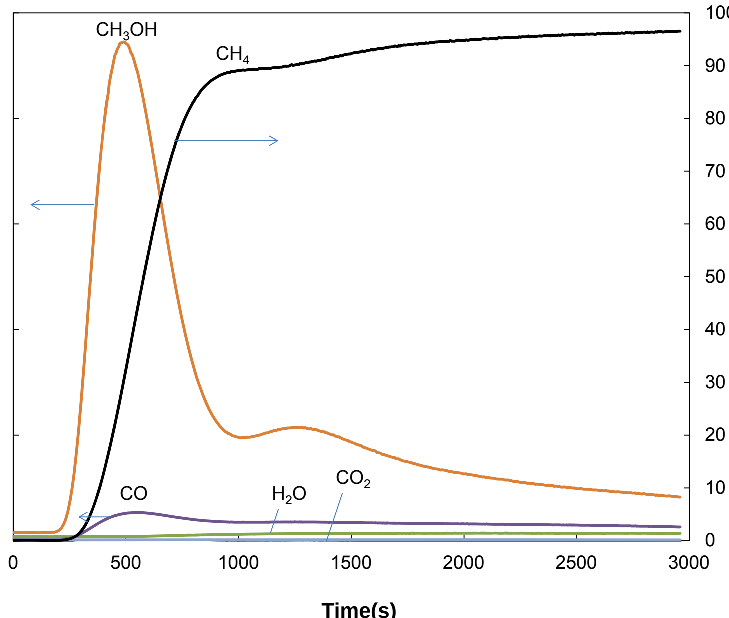
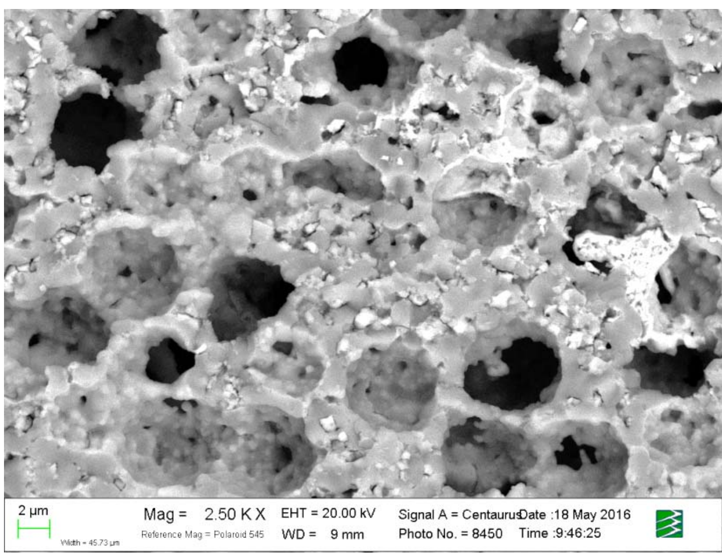
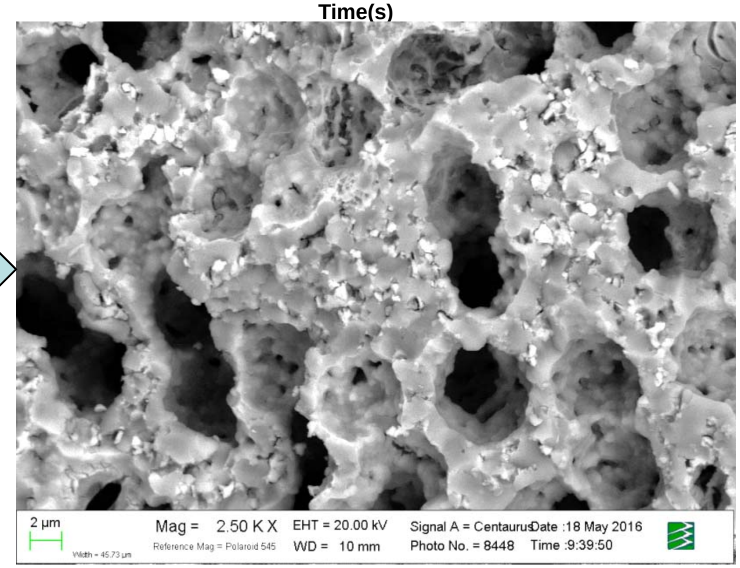
Catalyst Development

- High Selectivity (>90%) catalyst has been successfully infiltrated onto anode support.
- Infiltration process has shown stable particle size after aging tests.
- Increased batch-mode conversion rate (~40%) observed with catalyst on anode support material vs. silica support. Fuel cell operation may increase further.
- Methanol product stability was demonstrated on fully activated catalyst.

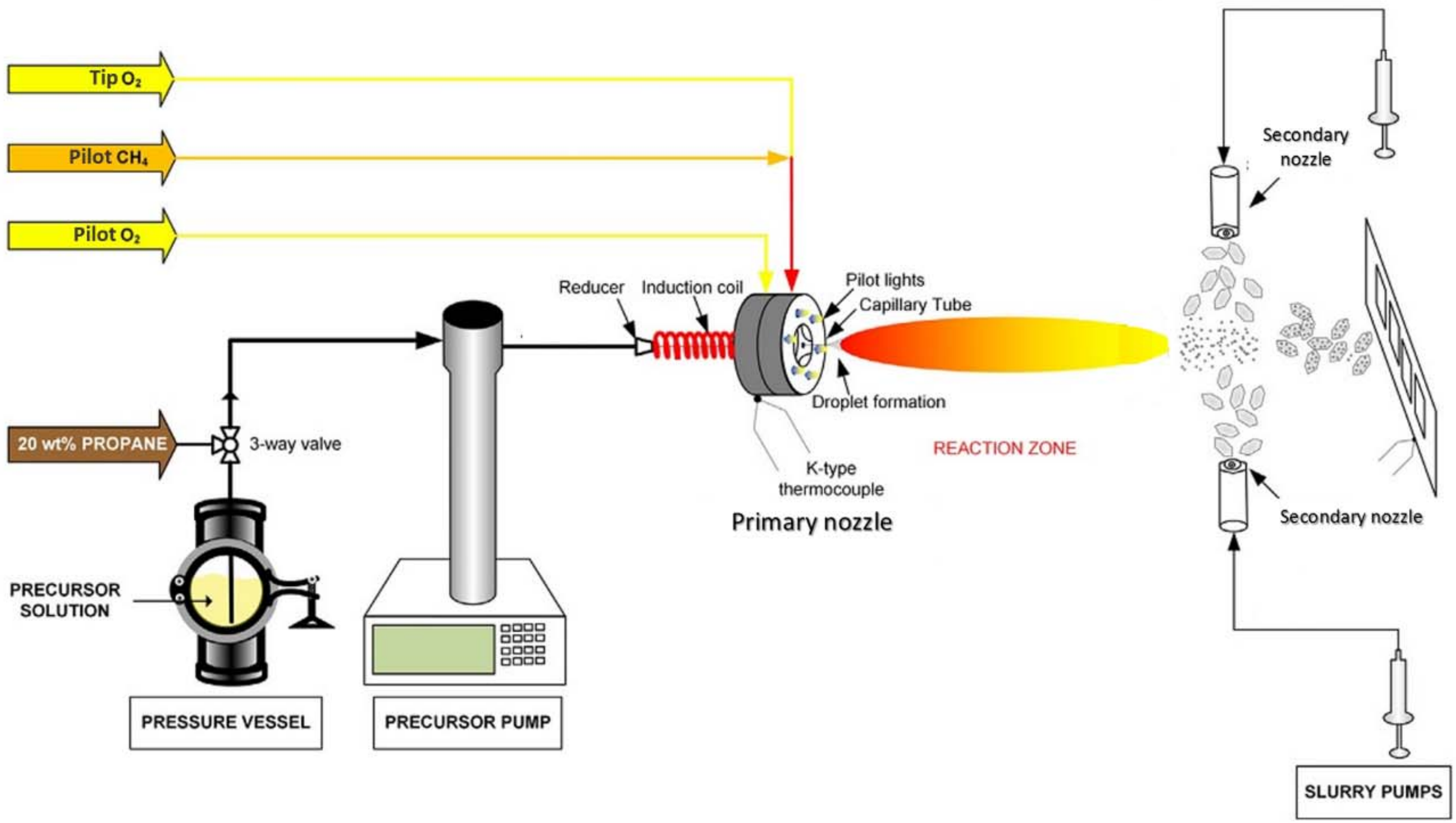




100 hr
@ 600 °C



Manufacturing via RSDT



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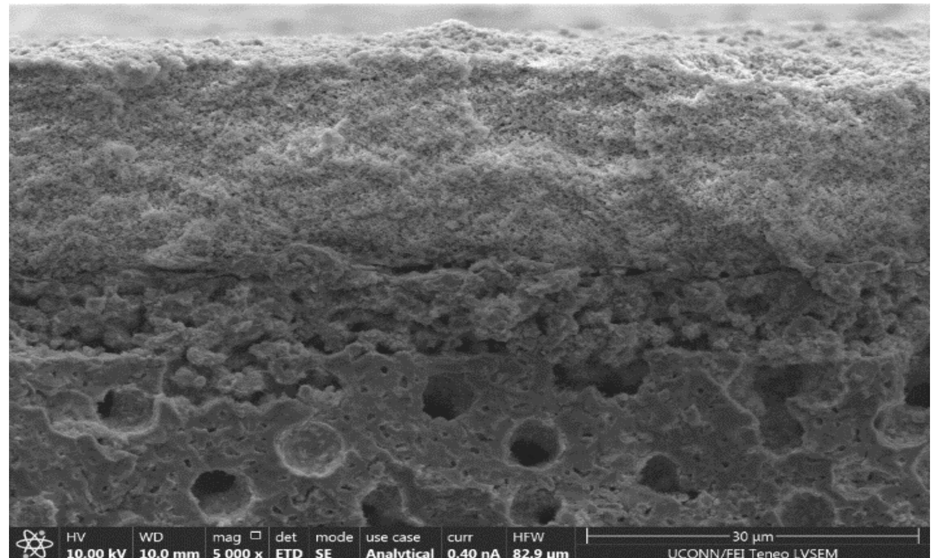
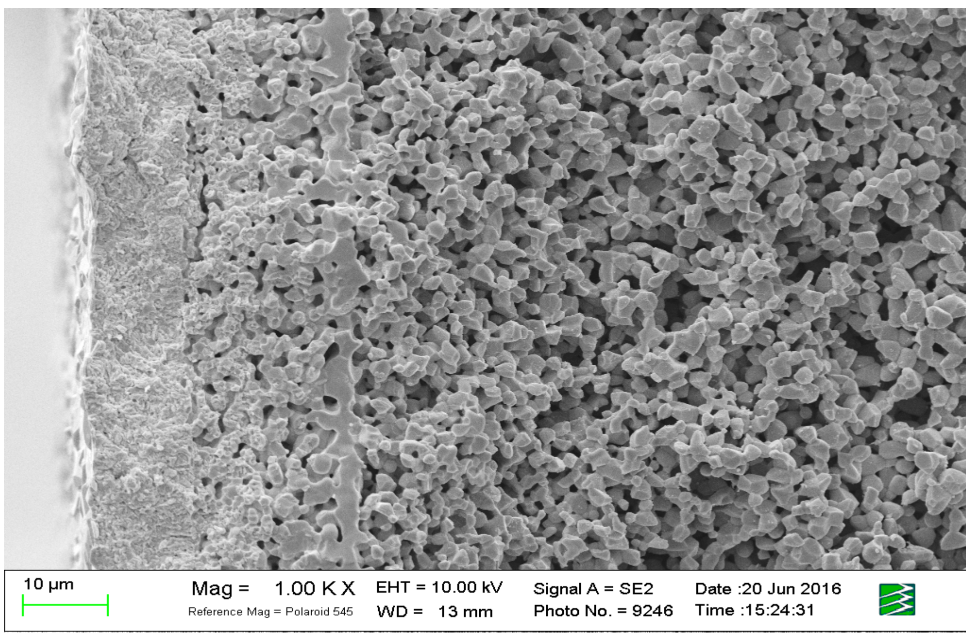
Electrolyte Development

- RSDT has been adapted to co-deposit GDC and carbonate salts.
- Sufficient density achieved at ~ 20 µm.
- Opportunity exists for optimization to achieve full density with thinner layer.

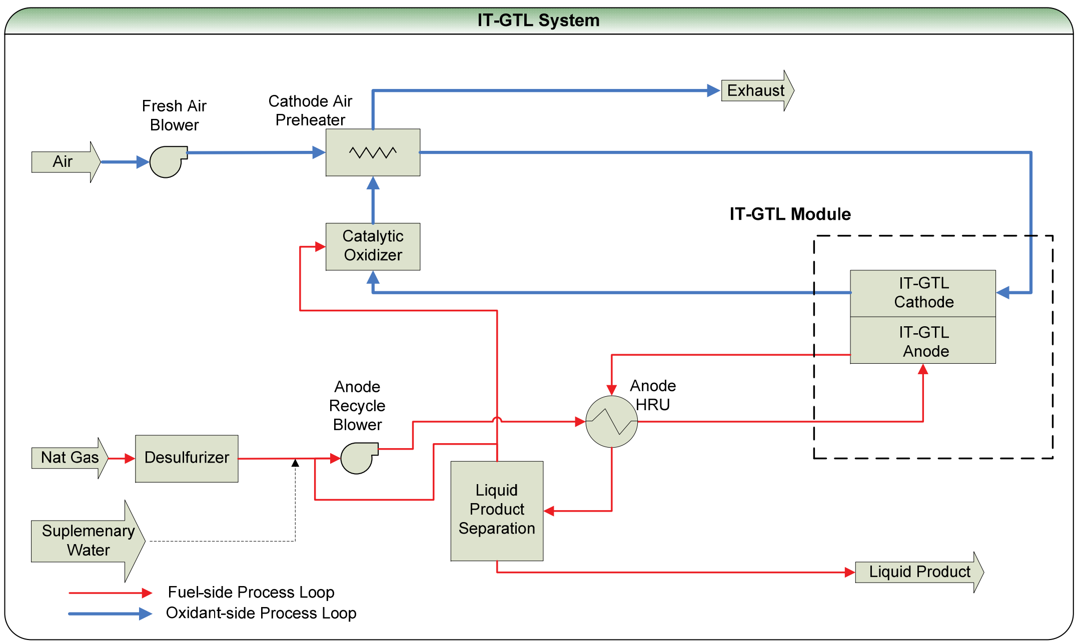




- Parallel path to utilize dense GDC is also under investigation.
- Both approaches have recently shown acceptable microstructure and leak analysis results, awaiting electrochemical testing.

System Design

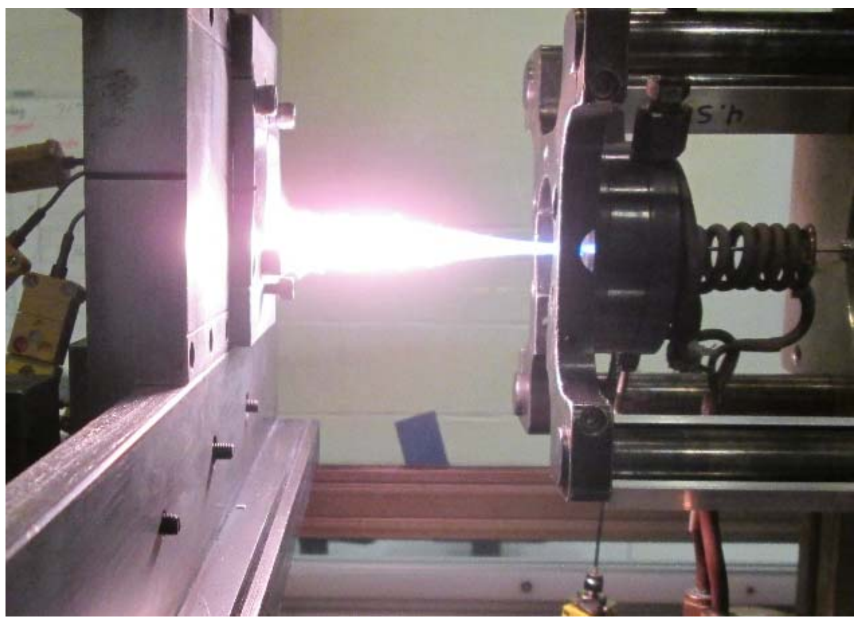
- Developed system process flow sheet identifying balance-of-plant requirements and performed system simulations based on first-principle methods.
- Cell performance based on project milestones, and cost on prior SOFC development, identified small systems as economically attractive.



Results of the System Analysis Basis: One Barrel Per Day (BPD) of Methanol Production		
Raw Gas Input	3.0	MCFD
Cell Area	12.5	M^2
Gross DC Power	12.48	kW
Plant Parasitic Loads	0.90	kW
Net AC Power Output	10.9	kW

Development Roadmap

- Finalize electrolyte fabrication process.
- Revisit cathode deposition with RSDT.
- Optimize anode catalyst deposition for higher activity.
- Map cell operating conditions for optimal performance envelope.
- Increase cell area.



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Acknowledgements

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