Facilitated Direct Liquid Fuel Cells with High Temperature Membrane Electrode Assemblies

Emory S. De Castro
Advent Technologies, Inc.

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Los Alamos NATIONAL LABORATORY EST. 1943

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Project ID FC128

Overview - Program

Timeline

Project Start Date: June 1, 2015

Project End Date: May 31, 2017

Budget

Total Funding: $1,251,000

Advent Cost Share: $252,000 (20%)

Barriers (FCTO-MYRDDP, 2014)

A. Durability: new membrane approach
B. Cost: elimination of reformer. Lower PM
C. Performance: highly active anode catalyst

Partners

LANL (P. Zelenay): catalyst and testing

Relevance

- **Objective:** Demonstrate direct dimethyl ether (DME) oxidation at high temperature MEA significantly better than direct methanol fuel cells (DMFC)
- **Program Targets**

Key Performance Indicator	Current DMFC	Target Hi T Direct DME
Maximum power (>)	0.180 W/cm^2	0.270 W/cm2
Total precious metal loading	5 mg_{PGM}/cm^2	3 mg_{PGM}/cm^2
Degradation rate	19 μV/h at a 0.2 A/cm^2	10 μV/h at a 0.2 A/cm^2
Loss in start/stop cycling	1.5 mV/cycle; cycle	0.75 mV/cycle; cycle
Anode mass-specific activity	50 A/g measured at 0.5 V	75 A/g measured 0.5V

- **Benefit:** carbon neutral auxiliary power for trucks and transport; extended run back up power

Approach - Overview

1. Benchmark

6 mo.

- Run high temperature MEAs at LANL
- Compare Pt anode w MeOH, EtOH, and DME at 160 °C – 180 °C
- Use both PBI and TPS Hi T MEAs

2. GDE at 5 cm^2

6-12 mo.

Go/No Go

- Make gas diffusion electrode (GDE) with LANL ternary anode catalyst, test DME
- Compare to Pt:Ru with DME
- Evaluate PBI and TPS DME cross-over and performance

3. Scale to 50 cm^2

12-24 mo.

- Optimize anode GDE for mass transport
- Refine cathode, if needed
- Adjust reaction conditions

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Approach - Milestones

Task No.	Title	Type	No.	Description	Date
1	Benchmark	Milestone	1.1.1	LANL=Advent Hi-T test results	By 3rd month
1	Benchmark	Milestone	1.3.1	Baseline power and degradation w DME and Pt anode	6th month
2	Catalyst / GDE @ 5 cm^2	Milestone	2.1.1	DME anode mass specific current 1.5X over DMFC (75 A/g at 0.5V), unrestrained cathode	9th month
2	Catalyst / GDE @ 5 cm^2	Milestone	2.3.1	Select best of TPS or PBI systems	12th month
2	Catalyst / GDE @ 5 cm^2	Go/ No-Go	Sole Go/ No-Go	Anode specific mass activity ≥ 75A/g at 0.5V using unrestrained cathode and ≤ 4.5 mgPGM/cm^2, and optionally improved baseline KPIs (power, durability)	12th month

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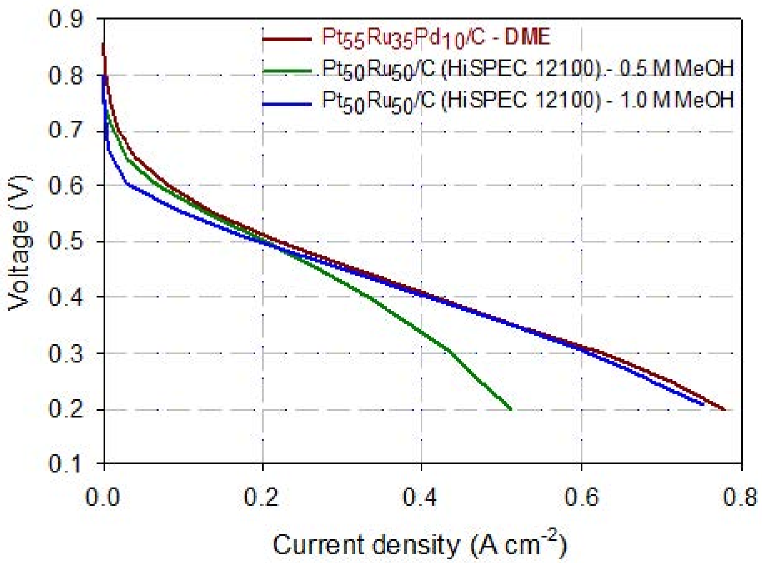
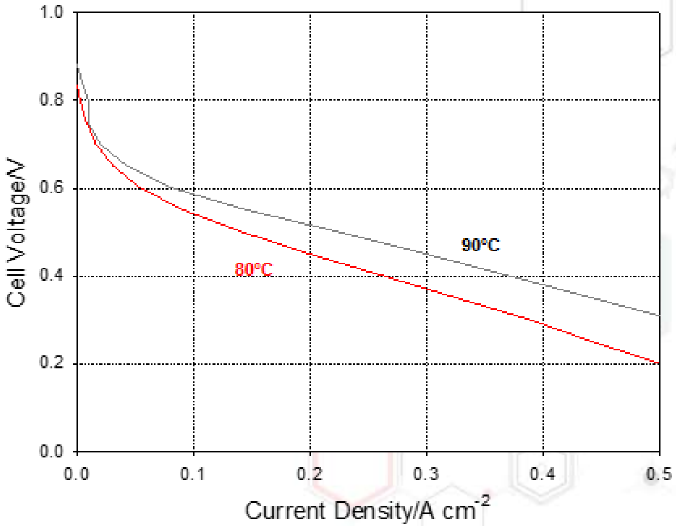
Approach – Milestones (continued)

Task No.	Title	Type	No.	Description	Date
3	Scale to 50 cm2	Milestone	3.1.1	Mass-transport loss less than in DMFC anode (intermediate milestone)	By 15th month
3	Scale to 50 cm^2	Milestone	3.1.2	Mass-transport loss 50% less than in DMFC anode (final milestone)	18^{th} month
3	Scale to 50 cm^2	Milestone	3.3.1	Cathode catalyst selected	21^{st} month
3	Scale to 50 cm^2	Milestone	3.3.2	DME Hi-T MEA > DMFC (Max. power, PM, Degradation rate, loss with off/on, and anode mass specific activity)	24^{th} month

Prior Accomplishments Leading to Concept



DME and methanol fuel cell performance comparison. Anode: 4.0 mg_{metal} cm^{-2} PtRuPd/C, HiSPEC® 12100, 40 sccm DME gas, 26 psig, 1.8 mL/min 0.5 M or 1.0 M MeOH, 0 psig; cathode: 2.0 mg cm^{-2} Pt/C HiSPEC® 9100, 100 sccm air, 20 psig; Membrane: Nafion® 212 (DME), Nafion® 115 (MeOH); cell: 80 °C.



Temperature dependence of DME fuel cell performance. Anode: 4.0 mg_{metal} cm^{-2}, PtRu/C (HiSPEC® 12100), 40 sccm DME (gas), 26 psig; cathode: 4.0 mg cm^{-2} Pt black, 500 sccm air, 20 psig; membrane: Nafion® 212; cell: 80 °C.

High DME activity with PtRuPd/c combined with temperature sensitivity

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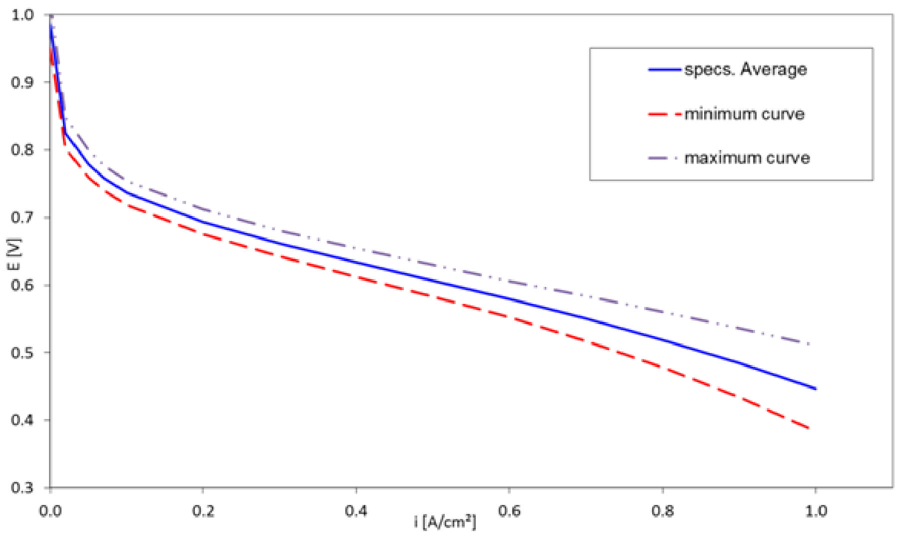
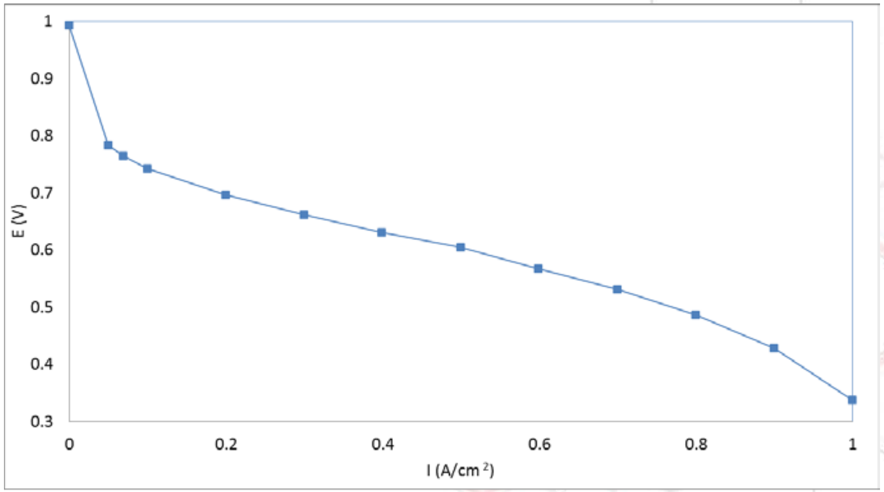
Standard High Temperature MEA Performance





PBI-based high-temperature MEA, cathode alloy, cathode average+/-3σ, T=160 °C pressure=1 bara, stoich: 1.2/2 H_2/air. Average and sigma derived from 360 single cell tests over several large scale production batches of gas diffusion electrode (Total PM = 1.78 mg/cm^2)

TPS-based high-temperature MEA, same electrode system as on the left T=180 °C pressure=1 bara, stoich: 1.2/2 H_2/air.

Both PBI and TPS operate w/o additional water and tolerate 1-3% CO, a DME oxidation intermediate

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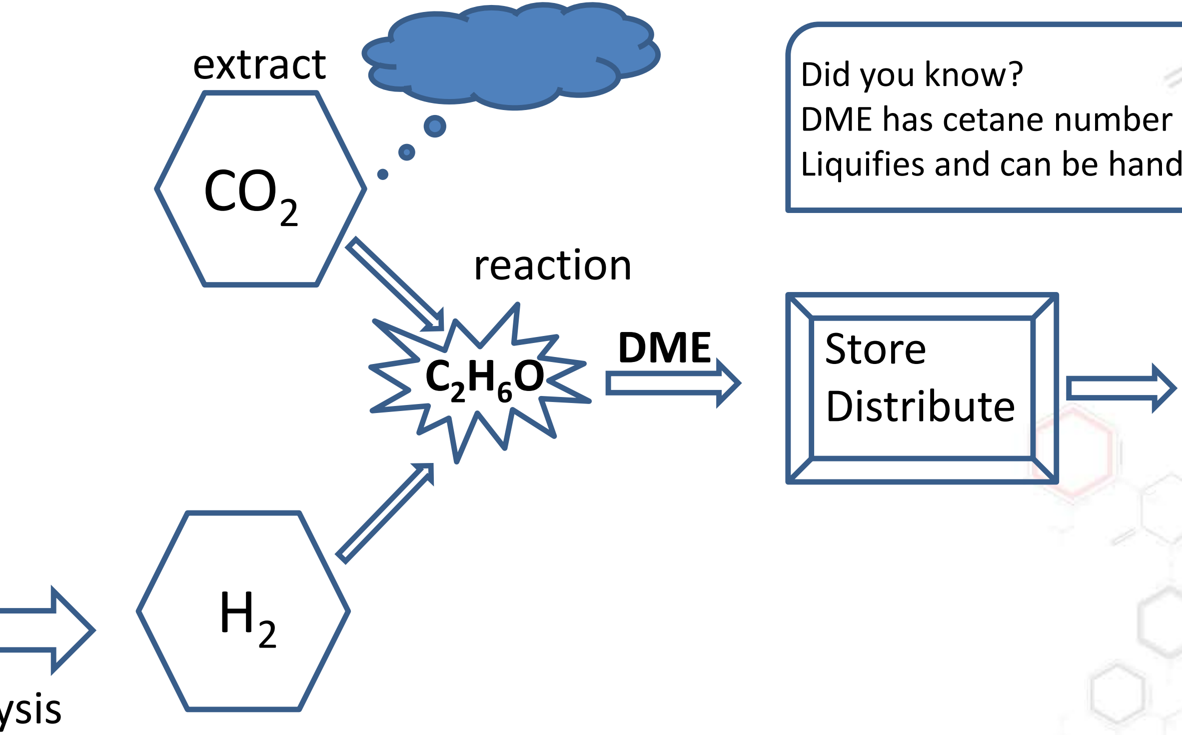
Collaborations: Anticipated

- Suppliers of non-precious metal cathode catalyst
  - Separate effort at LANL
  - Northeastern University (S. Mukergee)
  - Pajarito Powder
- Next generation PBI membranes
  - University of South Carolina (B. Benicewicz)
- Makers of reformed methanol systems using high T MEAs
  - UltraCell LLC

Technology-to-Market

- Advent will approach Hi T MEA customers that currently build systems based on reformed methanol
- Advantage will be reduction in system cost (no reformer) and simplicity
- UltraCell LLC can use 45 cm^2 scale in current systems
- SerEnergy (Denmark) has interest in auxiliary power for marine systems that use low emission, carbon neutral fuels
  - Advent will need to scale to at least 165 cm^2
  - SerEnergy has previously demonstrated battery range extenders for electric vehicles using reformed MeOH

Overview – Wind to Wheels



Did you know?
DME has cetane number similar to diesel
Liquifies and can be handled like propane

DME for modified diesel and/or high temperature Fuel Cell (this program)

DME is hydrogen carrier and stores renewable energy

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Summary

- **Objective**: Demonstrate direct DME oxidation with high temperature MEA and LANL catalyst significantly outperforming state-of-art DMFC
- **Relevance**: DME is a carbon neutral hydrogen carrier that can be used both for internal combustion and cost effective auxiliary fuel cell power on transport vehicles
- **Approach**: Incorporate new ternary anode catalyst in gas diffusion electrodes designed for high temperature MEAs. Evaluate with two different high temperature membranes (PBI and TPS). Optimize reaction conditions

THANK YOU

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Contacts: EmoryDeCastro@Advent-Energy.com
Zelenay@LANL.gov