Reversible Fuel Cell Stacks with Integrated Water Management

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Project ID: FC324

Project Overview

- **Timeline**
  - Start Date: 03/18/2020
  - End Date: 03/31/2022

- **Budget**
  - Overall: $1,246,353
    - DOE: $ 795,764
    - FFRDC: $200,000
    - Cost Share: $250,582
  - $40,000 spent (DOE)*

*As of 5/30/20

- **Barriers**
  - High capital cost for separate traditional hydrogen production and fuel cell systems
  - Complicated reversible fuel cell system BOP leading to poor system durability and performance
  - DOE RFC Technical Target: 55% RTEv @ 0.5 A/cm2 FC and 1 A/cm2 EL (2025 target)

- **Collaborators**
  - Giner, Inc. (Prime)
  - University of Connecticut (UCONN)
  - Los Alamos National Lab (LANL)

Relevance

- **Objectives**
  - Demonstrate the feasibility and system level advantages of an unitized reversible non-flow through fuel cell (UR-NFTFC) with optimized stack level water management
- **Project Impacts**

Barriers	Project Impacts
High capital cost for separate FC and EL stacks	Adding reversibility to commercial ready electrolyzer with minimum cost
BOP complexity leading to poor system level performance and durability	Remove gas compressor and saturators from the BOP with Giner's non-flow through FC design
DOE RFC Technical Target: 55% RTE_v @ 0.5 A/cm^2 FC and 1 A/cm^2 EL (2025 target)	50% RTE_v @ 0.5 A/cm^2 FC and 1.5 A/cm^2 EL with a 5-cell 160 cm^2 active area stack using optimized water management

Approach

GINER LABS + **UCONN** + **Los Alamos**

- Single cell discrete and unitized reversible fuel cell testing with received components
- Water management plate(bubble point membrane) integration
- Test stand construction and modification
- Components scale-up and stack construction
- Full size UR-NFTFC stack testing

- Bifunctional MEA fabrication using Reactive Spray Deposition Technology (RSDT)
- Electrochemical Surface Area (ECSA) measurements before and after testing at Giner
- Electrode reactivity and water management optimization through fabrication parameter improvements

- Amphiphilic microporous layer (AMPLs) as oxygen diffusion media development
- In situ and ex situ property testing
- AMPL performance optimization through design and fabrication improvements

Approach: Tasks & Milestones

<u>Task 1. Bifunctional MEA fabrication and optimization</u> (M1 – M12)

1.1.1 Establish MEA performance baseline and deliver 12 MEAs

1.1.2 Optimize MEA performance and deliver 12 MEAs with one obtaining **>40% RTE at 1500 mA/cm^2 EL and 500 mA/cm^2 FC**

<u>Task 2. Amphiphilic microporous layer fabrication and optimization</u> (M1 – M12)

2.1.1 Establish AMPLs performance baseline and deliver 6 AMPLs

2.1.2 Optimize AMPLs performance and deliver 6 AMPLs with one obtaining **>750 mA/cm^2 fuel cell** operating without flooding

<u>Task 3. Single-cell UR-NFTFC testing on 50 cm^2 platform</u> (M1 – M12)

3.1 Discrete single-cell testing to confirm MEA performance

3.2 Discrete single-cell testing to confirm AMPL performance

Go/No-Go 3.3 Unitized single-cell testing to demonstrate stable reversible fuel cell performance at no less than **500 mA/cm^2** in fuel cell mode and **1500 mA/cm^2** in electrolyzer mode with a **40% voltage round trip efficiency (RTE$_V$)** and successful manual mode switching

<u>Task 4. 5-cell UR-NFTFC testing on 160 cm^2 platform</u> (M13 – M24)

4.1 Test stand modification for 160 cm^2 platform

4.2 Optimize MEA performance and deliver 20 160 cm^2 MEA that can obtain **50% RTE$_V$ at 1500 mA/cm^2 EL and 500 mA/cm^2 FC**

4.3 Optimize AMPL performance and deliver 15 160 cm^2 AMPLs that can obtain **>1000 mA/cm^2 fuel cell** operating

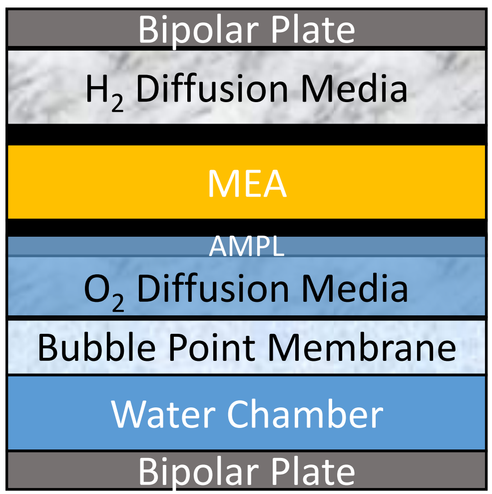
4.4 Unitized single cell 50 cm^2 testing to confirm MEA and AMPL performance

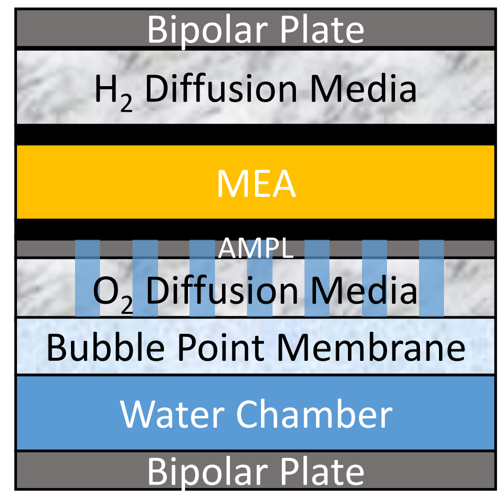
4.5 Unitized single cell 160 cm^2 testing to confirm scaled-up components' performance

4.6 Unitized 5 cell 160 cm^2 testing to demonstrate stable reversible fuel cell performance at no less than **500 mA/cm^2 in fuel cell mode and 1500 mA/cm^2 in electrolyzer mode with a 50% voltage round trip efficiency (RTE$_V$)**, with 100 successful cycling tests and 500 hours of successful simulated solar operation

Approach: UR-NFTFC Concept

UR-NFTFC operation concept in electrolyzer and fuel cell modes



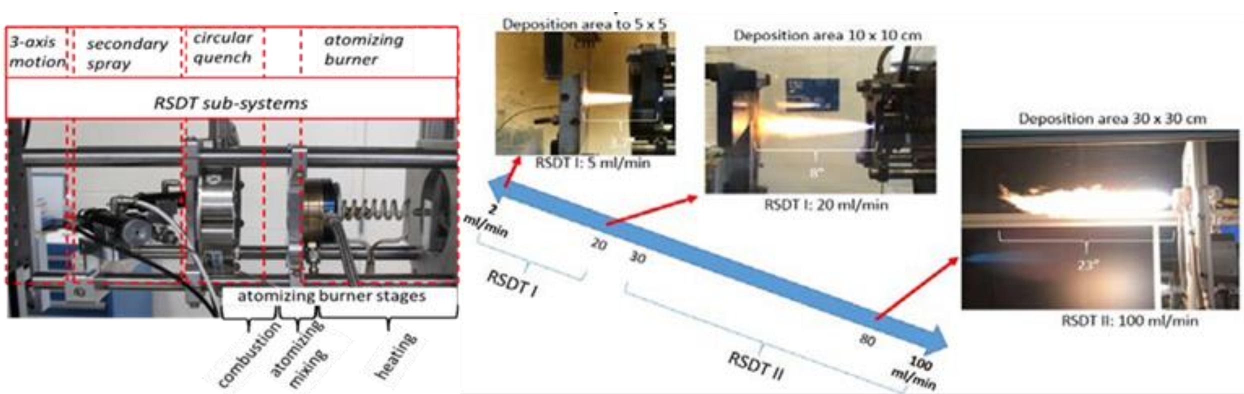


Oxygen chamber completely filled with high pressure circulating water in electrolyzer mode

Water is removed from oxygen chamber via amphiphilic diffusion media and bubble point membrane in fuel cell mode under pressure gradient

Approach: Bifunctional MEA Optimization

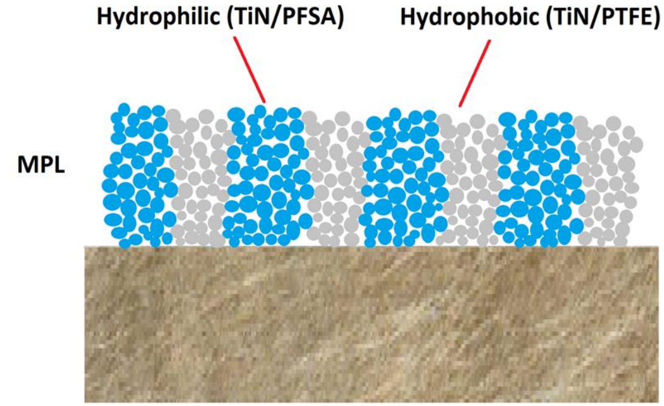
- Standard MEA fabrication methods cannot achieve uniform hydrophobicity, which hinders the water removal from the catalyst layer in fuel cell mode
- Reactive Spray Deposition Technology (RSDT) developed at UConn is capable of precise layer-by layer catalyst deposition with customizable composition which allows fine tuning of hydrophobicity and reactivity in the catalyst layer

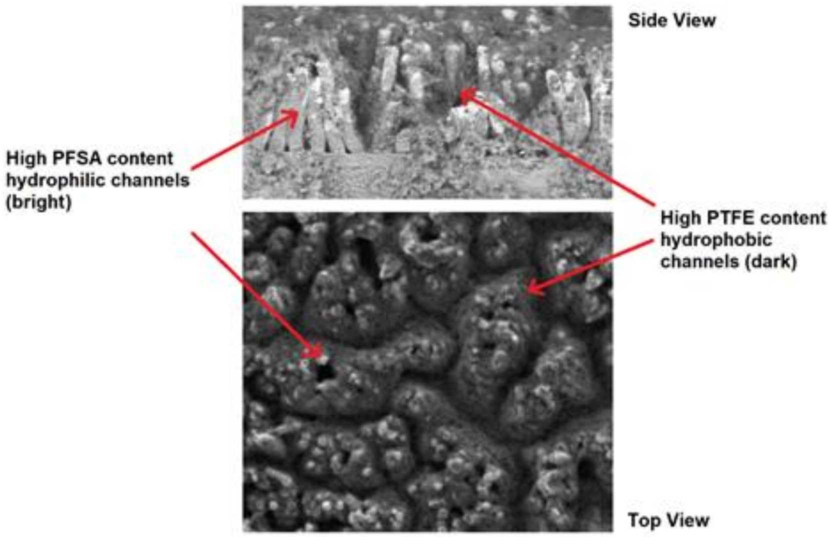


Variable Parameters
- Flame temperature profile
- Sequential precursor injection
- Quench control
- Reacting environment

Approach: Amphiphilic Microporous Layer Optimization

- Water management must extend beyond the electrode to remove water from the surface of the catalyst layer in fuel cell mode
- A novel amphiphilic MPL structure developed at LANL segregates different transport functionality into different structures.
- Hydrophobic regions allow unrestricted feed of reactant gas to the catalyst surface while hydrophilic regions collect and deliver the water to the hydrophilic bubble point membrane





Accomplishment

Laboratory work has not begun as of the submission date

Responses to Previous Year Reviewers' Comments

This project was not reviewed last year.

Collaboration & Coordination

- **Giner (prime)**
  - **PI: Dr. Cortney Mittelsteadt**
  - **POC: Teddy Wang**
  - Project management / reporting
  - MEA and MPL evaluation
  - Test stand construction
  - Stack construction and testing
  - Bubble point membrane
  - Economic analysis
- **Uconn**
  - **PI: Dr. Radenka Maric**
  - Reversible PEM FC MEA optimization and fabrication
  - Electrode characterization
- **LANL**
  - **PI: Dr. Jacob Spendelow**
  - Amphiphilic MPL optimization and fabrication
  - MPL characterization

Remaining Challenges and Barriers

- Bifunctional MEA fabrication and optimization
  - Uncertainties in the fabrication of bifunctional MEA with non-carbon based support using RSDT
  - Scalability of MEAs using RSDT with consistent performance
- Amphiphilic microporous layer fabrication and optimization
  - Uncertainties in durability after being soaked in high pressure liquid water at 60 to 80 ^{o}C
  - Scalability of AMPLs with consistent performance

Proposed Future Work

- **Remainder of FY2020**
  - Baseline performance established for new bifunctional MEAs fabricated with RSDT
  - Confirmation of current AMPL design's compatibility with Giner's high pressure liquid feed electrolyzer
  - Continuous components optimization through material selection and fabrication techniques for both MEAs and AMPLs
  - Optimal operation conditions development
- **FY2021**
  - Continuous optimization of cell components and operating conditions to achieve performance target of 50% RTE_V at 1500 mA/cm^2 EL and 500 mA/cm^2 FC on 50 cm^2 platform
  - Component scale-up for 160 cm^2 platform
  - Test stand modification to accommodate unattended UR-NFTFC operation with automatic mode switching capability

Any proposed future work is subject to change based on funding levels

Tech Transfer Activities

- **Technology-to-Market Strategies**
  - Energy storage and production solution for large scale renewable energy farms
  - Off grid energy conversion and production solution
- **Future Funding Strategies**
  - Private sector - Off grid renewable energy storage and production

Summary

Objectives — Demonstrate the feasibility and system level advantages of a unitized reversible non-flow through fuel cell (UR-NFTFC) with optimized stack level water management

Relevance
- Adding reversibility to commercial ready electrolyzer to lower the capital cost comparing to a RFC system with discrete stacks
- Remove gas compressor and saturators from the BOP with Giner's non-flow through FC design to reduce system parasitic loss and cost
- Achieve 50% RTE_v @ 0.5 A/cm^2 FC and 1.5 A/cm^2 EL with a 5-cell 160 cm^2 active area stack using optimized water management

Approach — Combine optimized bifunctional MEAs with amphiphilic gas diffusion media and gas bubble-point membrane to allow sufficient water removal during fuel cell operation in non-flow through configuration while minimizing performance impact on electrolysis

Accomplishment — Lab work has not begun as of AMR slide submission date

Collaborations — University of Connecticut
Los Alamos National Laboratory