FC132

INNOVATIVE NON-PGM CATALYSTS FOR HIGH-TEMPERATURE PEMFCs

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Project Overview

This project aims to revolutionizing the CHP relevant proton exchange membrane fuel cell technology encompassing the membrane imbibed phosphoric acid (150-220°C) fuel cells. The primary barrier is the cost of the MEA, where noble metal loading is a critical factor. In addition there is the perennial issue of carbon corrosion. This effort primarily addresses both of these issues and thereby aims at transforming the combined heat and power (CHP) technology at this temperature range. The targeted application of this project is micro combined heat and power (micro-CHP). Micro-CHP is defined as appliances of less than 10 kW electricity and heat typically for residential or possibly small commercial buildings. Aim of this effort is to bring the current installed cost of such units from $30,000 - $50,000 to less than $ 10,000 (5 KW). Ramification of such an adoption will bring significant changes in energy efficiency, hence our carbon footprint and United States energy security.

Objectives

1. **Develop Unique Non-PGM Catalysts with Immunity to Phosphate Anion Poisoning, a Typical Occurrence on Supported Noble Metal Catalysts.**
2. **Improve Mass Transport for Solute (O_2), Protons in the Reaction and Gas Diffusion Layers.**
3. **Scale up of the Catalyst and MEA Fabrication.**
4. **Extensive Single Cell Tests under Stationary Fuel Cell Conditions.**
5. **Fuel Cell Durability Tests under Stationary Fuel Cell Operating Conditions**
6. **Techno-Economic Analysis for Commercial Viability.**

Acknowledgement

This work emerged from prior efforts on DOE EERE grant 0000459 and ARO Single Investigator Grant 53048 CH. Use of the National Synchrotron Light Source (beamline X3B), Brookhaven National Laboratory was supported by the US DOE, Office of Basic Energy Sciences, (DE-AC02-98CH10886).

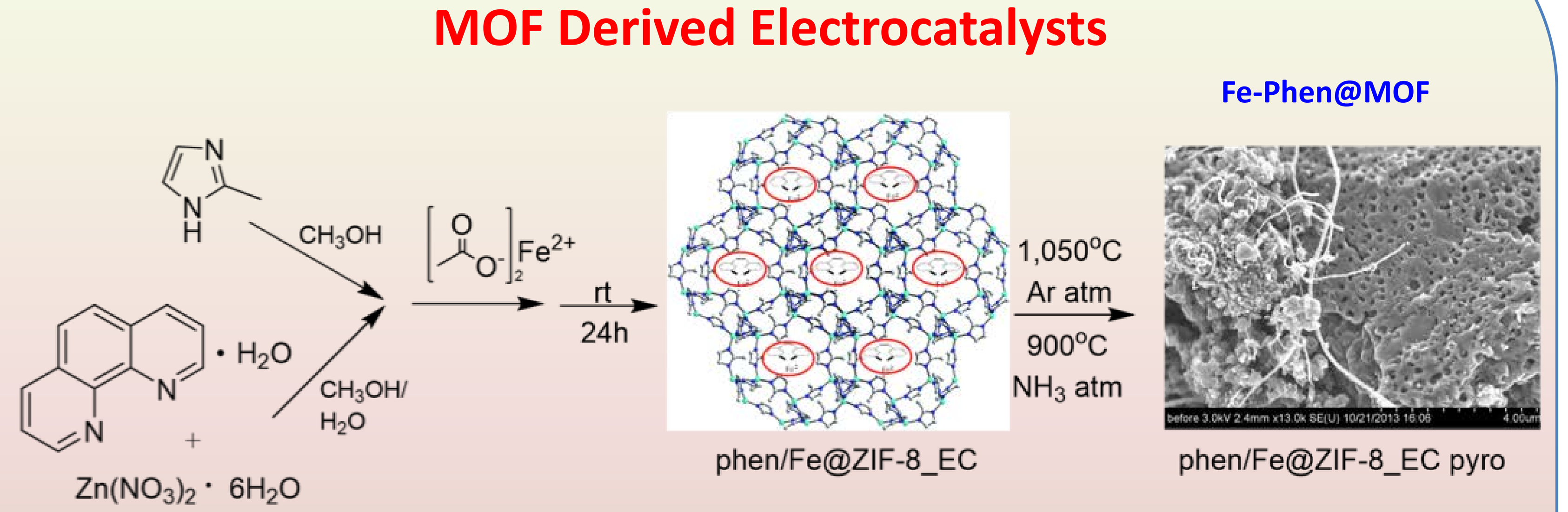
Membrane Based Phosphoric Acid Fuels

- Successfully commercialized for stationary power applications
- Demonstrated10 year stack life and 20 year product life
- Operates at ~ 150-200 °C, ideal for most CHP applications.
- 90% total efficiency, total CHP efficiency 81% (HHV)
- High CO and S tolerance so significantly lower balance of plant when operated with common fuels such as natural gas or methanol reformers.
- 90-100% Phosphoric Acid electrolyte
  - Highly Durable Membranes
- Pt-based catalyst for anode and cathode are the current state of the art.

Key Barriers

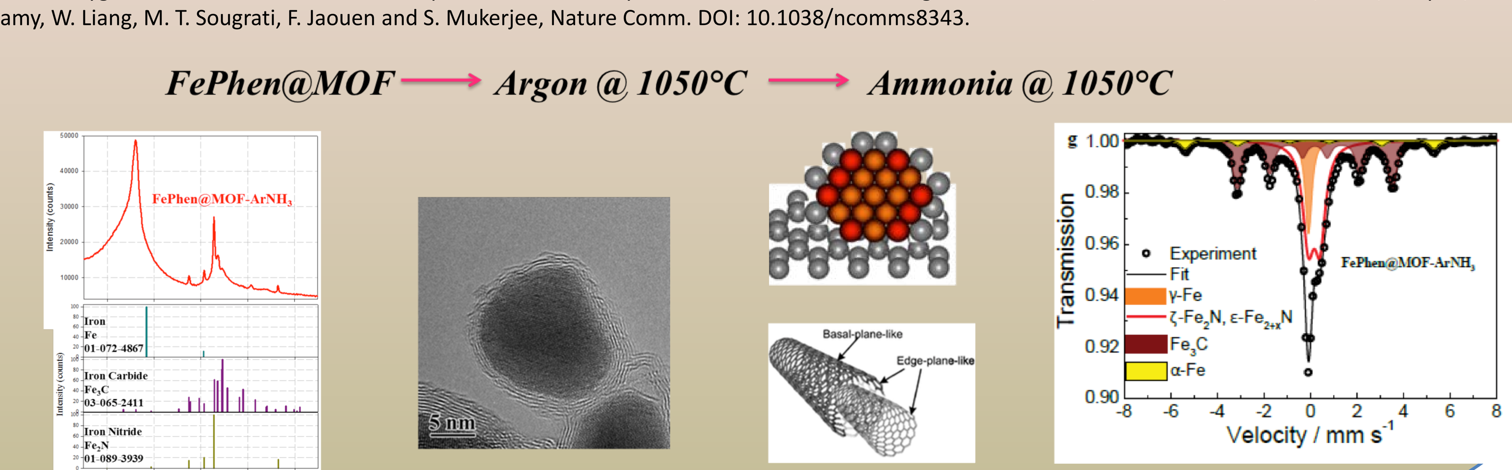
- Very high noble metal loading, typically 2-4 mg/cm^2 amounting to a noble metal cost of $ 750-1000/KW (with 200 mW/cm^2 at 0.7 V, H_2/Air, 2.5 bar total pressure).
- Phosphate anion poisoning on supported noble metals a key source of activity loss.
- High mass transport losses.
  - 5 Fold lower O_2 permeability.
  - 6 fold lower proton conductivity (150-190°C)

Non Noble Metal Novel Catalysts with Phosphate Anion Immunity
MOF Derived Electrocatalysts

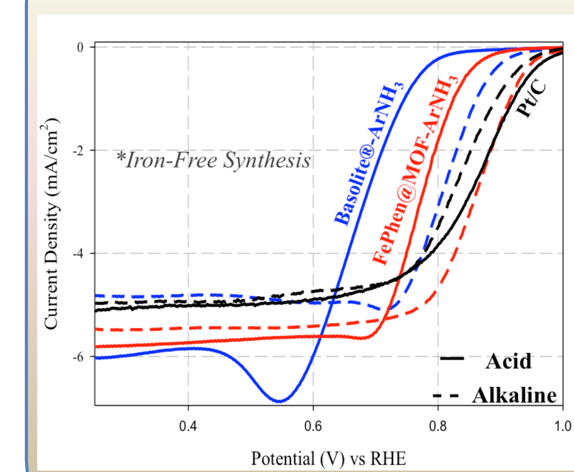


ZIF-8 image source: Demessence, A. *J. Mater. Chem.* **2010**.

- Non-Noble Electrocatalysts for Oxygen Depolarized Cathodes and Their Uses, S. Mukerjee, U. Tylus, E. Miner and K. Strickland, PCT/US14/10502, 2014 (January).
- ' Highly Active Oxygen Reduction Non-Platinum Group Metal Electrocatalyst Without Direct Metal-Nitrogen Coordination', K. Strickland, E. Miner, Q. Jia, U. Tylus, N. Ramaswamy, W. Liang, M. T. Sougrati, F. Jaouen and S. Mukerjee, Nature Comm. DOI: 10.1038/ncomms8343.

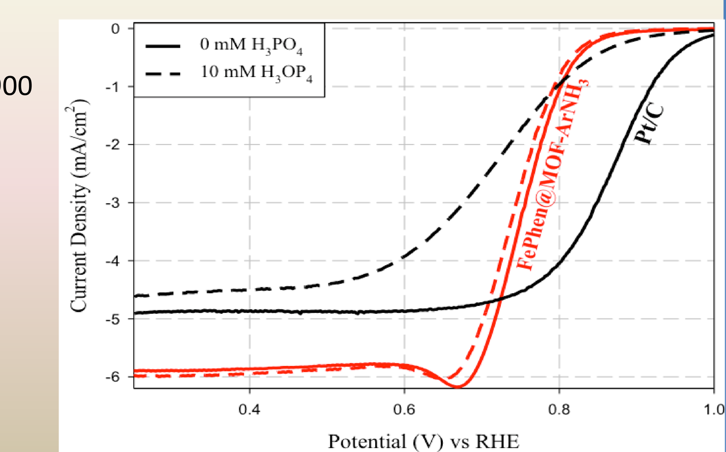


Electrochemical Performance



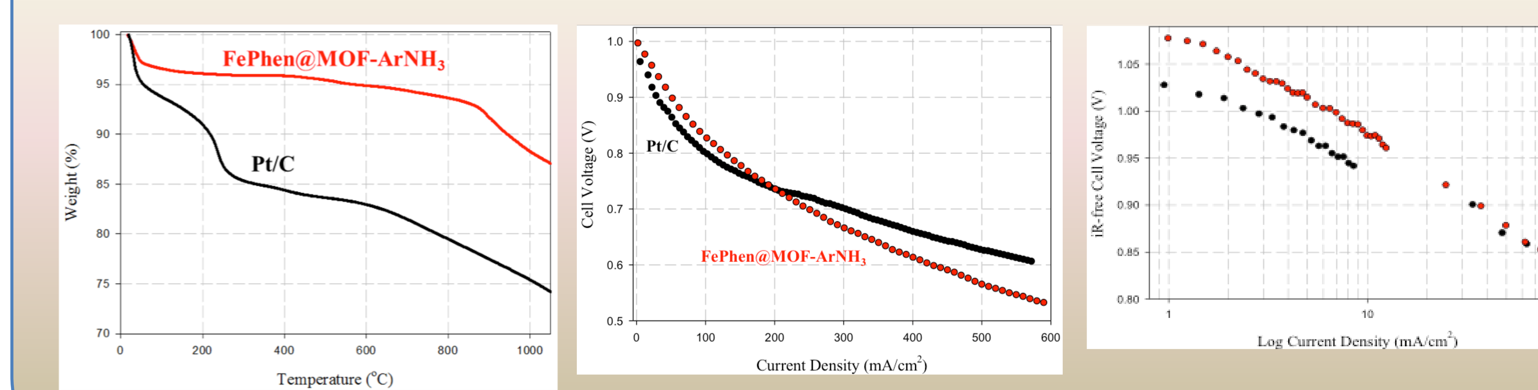
(Left) RRDE studies @ 900 rpm, 0.1 M $HClO_4$ and NaOH.

(Right) RRDE studies @ 900 rpm, 0.1 M $HClO_4$ with and 10 mM H_3PO_4



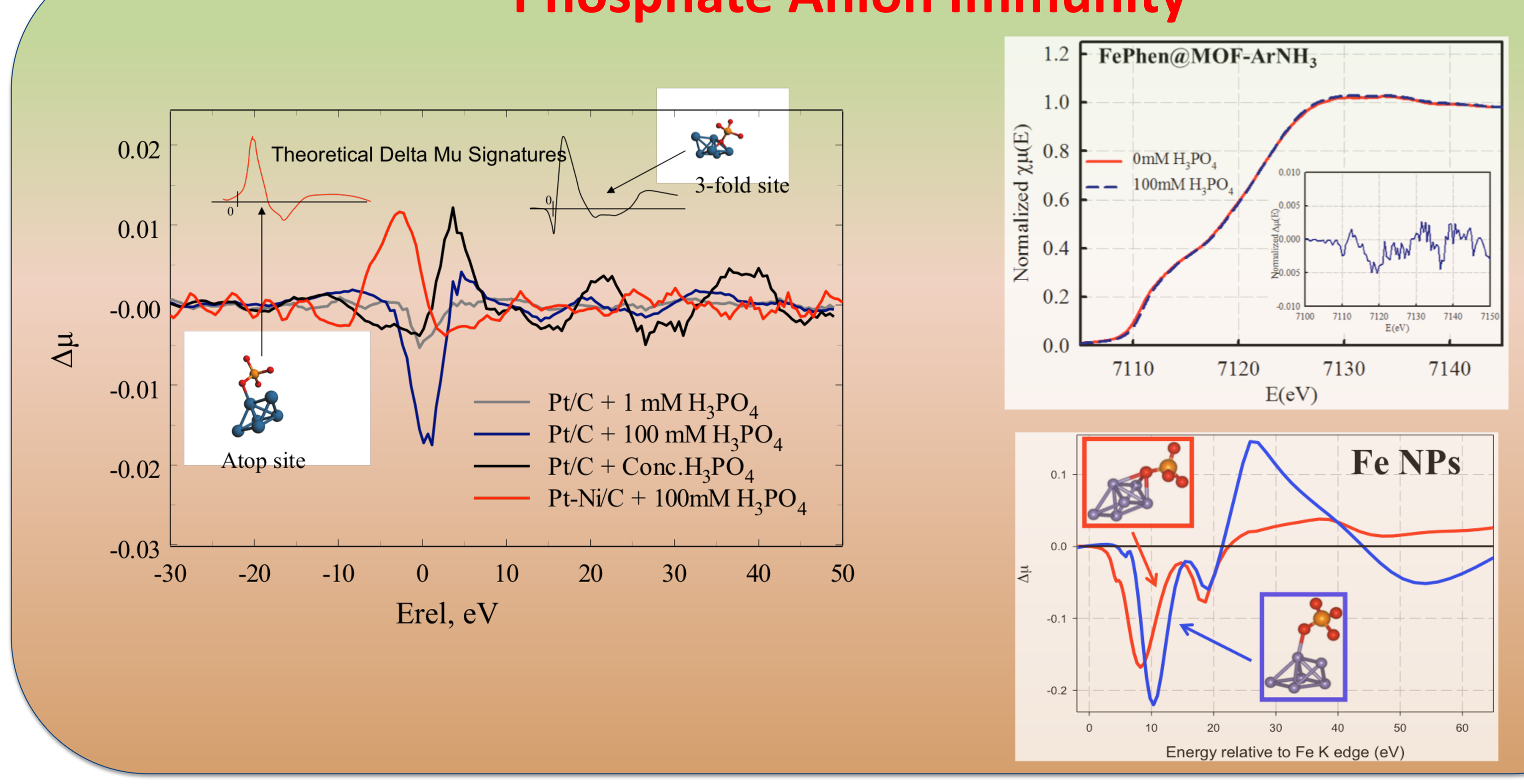
Room temperature RRDE measurements in 0.1 M $HClO_4$ and NaOH with and without H_3PO_4

Thermal Stability and Fuel Cell Polarization



H_2/O_2, 1.5 bar total pressure, 180°C, Advent TPS membrane.

Phosphate Anion Immunity



Summary Project Milestones and Metrics

- **To Achieve 200 mA/cm^2 at 0.6 V, H_2/Air, 2.5 bar total pressure, 180°C, total PGM loading to be less than 1.5 mg/cm^2 (anode).**
- **Catalyst Scale up to 50 gm batch with less than 5% inter and intra batch variation.**
- **Durability under chronoamperometric conditions (0.8 V, H_2/Air, 180°C, 2.5 bar total pressure, with less than 5 % loss in 48 hrs.**