

Mesoporous Non-Carbon Catalyst Supports for PEMFC

**PI: Jacob Coppage-Gross
CertainTech Inc.**

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Project ID: FC165

Timeline and Budget

- **Project Start Date: Feb 21, 2017**
- **Project End Date: Nov 21, 2017**
- **Total Project Budget: \$ 138K**

DoE Goals for Catalysts/Electrodes:

- **Develop electrocatalysts and electrodes with reduced PGM loading, increased activity, improved durability / stability, and increased tolerance to air, fuel, and system-derived impurities**
- **Optimize electrode design and assembly**

Barriers

- **Degradation of carbon catalyst support**
- **Activity of platinum catalyst on support materials**

Partners

- **Dr. Sirivatch Shimpalee (Hydrogen and Fuel-Cell Center, University of South Carolina)**
- **Dr. Kris Rangan (Materials Modification Inc.)**

DOE Performance Goals:

Characteristic	Unit	2015 Status	2020 Target
Platinum group metal total content	g / kW @ 150kPA	0.16	0.125
Platinum group metal loading	mg PGM / cm²	0.13	0.125
Mass activity	A / mg PGM @ 900 mV	>0.5	0.44
Loss in initial catalytic activity	% mass activity loss	66	<40
Loss in performance at 0.8 A / cm²	mV	13	<30
Electrocatalyst support stability	% mass activity loss	41	<40
Loss in performance at 1.5 A / cm²	mV	65	<30
PGM-free catalyst activity	A / cm² @ 900mV	0.024	<0.044

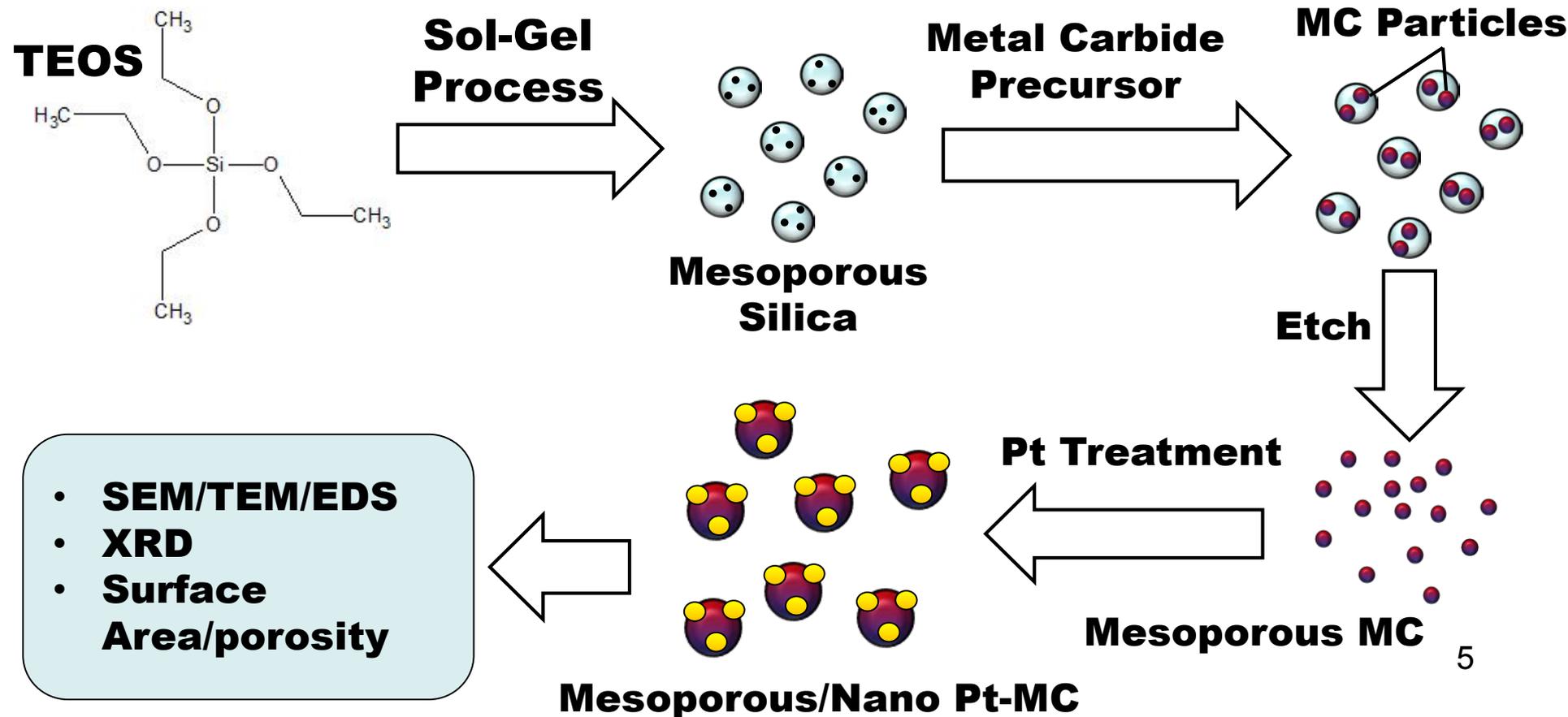
Relevance

- **Improve durability and cost efficiency of fuel cell performance through mesoporous platinum-metal carbide (Pt-MC) catalyst-support material**
- **Benefits of Pt-MC over traditional carbon based catalyst supports:**
 - **Improved resistance to corrosion (from impurities, fuel mixture changes, water, etc.)**
 - **Lower platinum loading with unique mesoporous nanostructured support**
- **Approach:**
 - 1. Pt-MC nanocomposite synthesis and characterization**
 - 2. Demonstration of electrochemical performance of MEA incorporating Pt-MC**

Approach

1. Pt-MC nanocomposite synthesis and characterization

- Produce high surface area Pt-MC mesoporous powders through nanocasting method
- Determine morphology of Pt-MC material



Approach

2. Demonstration of electrochemical performance of MEA incorporating Pt-MC

- Electrochemical evaluation of catalyst-support material
- Performance assessment of prototype MEA incorporating the catalyst-support

Rotating Disk Electrode Test

- Electrochemically active surface area (ECA), 100-200 cycles
- Oxygen reduction activity (ORR)

Optimization of Catalyst-Support

- MC particle size/shape
- Pt loading level
- Process Parameters

MEA Testing

- Polarization Curves
- Cyclic Voltametry
- Comparison with SOA Pt/C catalysts

MEA Construction (up to 25cm² cell size)

- Nafion 212 membrane
- Carbon Paper GDL
- Pt-MC Catalyst

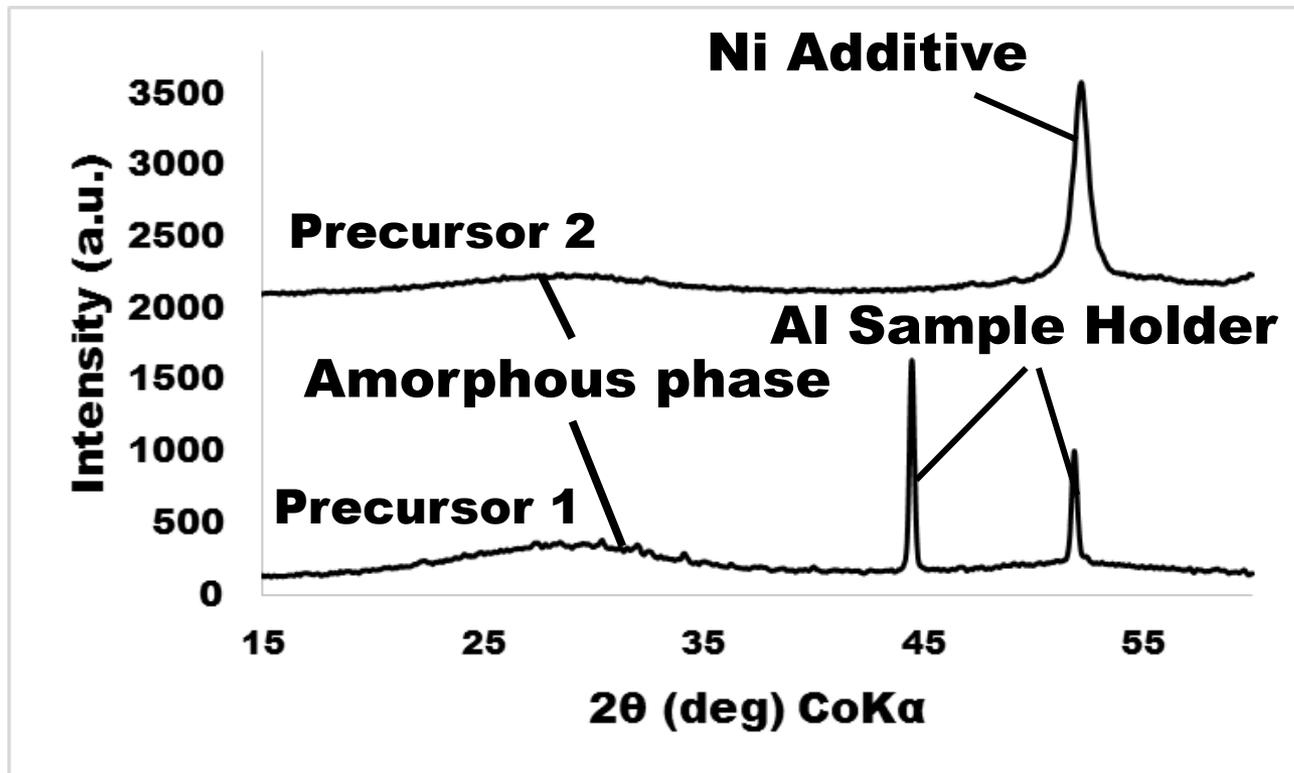
Milestones

Milestone	Metrics Evaluated	Date
1. Preparation of mesoporous Pt-MC <ul style="list-style-type: none">• Synthesis of metal carbide precursor ✓• Synthesis of mesoporous template ✓• Pyrolysis to mesoporous MC• Platinum functionalization• SEM Analysis	Pt Content Porosity Surface Area	5/17
2. RDE Testing <ul style="list-style-type: none">• 100-200 cycle testing• Comparison with traditional carbon support	ORR ECA	7/17
3. MEA Fabrication and Testing <ul style="list-style-type: none">• Assembly of MEA integrating Pt-MC catalyst• Testing of Pt-MC-MEA and comparison with state-of-art MEA	Mass Activity Performance Stability	10/17

Accomplishments and Progress

Synthesis of MC precursor:

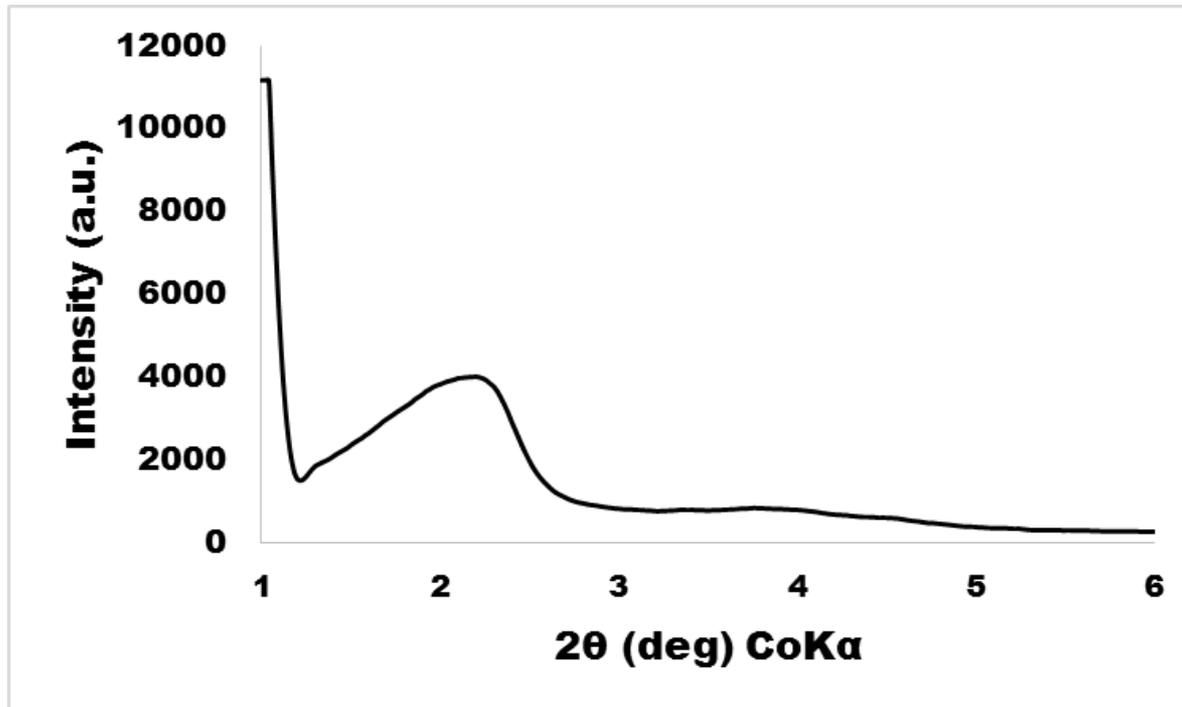
- **Pyrolysis (600°C) of metal-polymer compound prepared by reaction of metallic species with polyvinyl alcohol (PVA)**



Precursor 2 shows no oxide impurities and should yield highly pure metal carbide

Accomplishments and Progress

Mesoporous Silica Template:

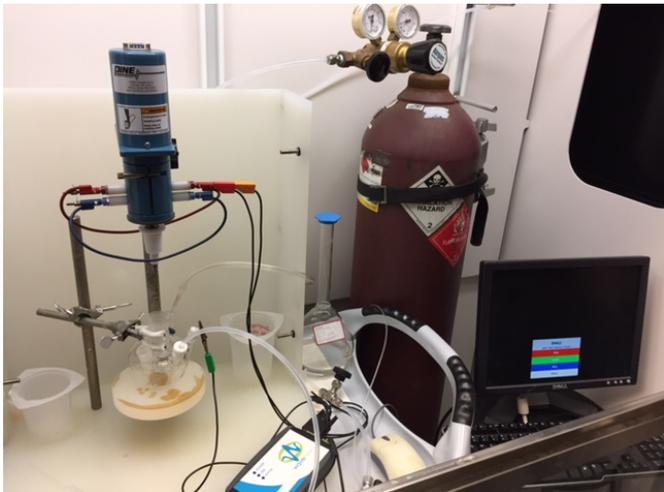


Infiltration of silica with MC precursor will produce mesostructured support material

***Project not reviewed previously**

Collaboration

- **Dr. Sirivatch Shimpalee (University of South Carolina)**
 - **Technical Consultant for MEA construction and testing**

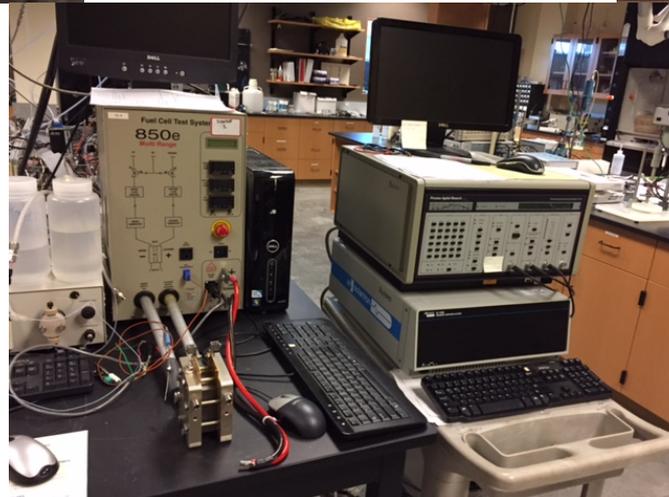


Rotating Disk Electrode (RDE) Testing

MEA Construction



MEA Testing: Performance and Cyclic Voltammetry



Collaboration

- **Dr. Kris Rangan (Materials Modification Inc.)**
 - **Technical Consultant for materials design and fabrication**
 - **Expert in nanomaterials, synthesis, and characterization**
- **University of Maryland Nanocenter (POC Dr. Sz-Chian Liou)**



**COULTER™ SA 3100™
Particle Size Analyzer (MMI)**



Hitachi SU-70 FEG SEM (UMD)

Remaining Challenges and Barriers

- **Confirmation of catalyst performance using a Pt-MC material**
- **Synthesis of Pt-MC using low temperature processes**
- **Identification of low-cost precursors that can be fabricated with the required mesoporous structure to ensure optimal catalyst performance**
- **Long term stability of the metal carbide support**

Proposed Future Work

Phase I Goals (FY2017)

- **Demonstrate minimal loss in Electrocatalytic activity in Pt-MC catalyst and MEA**
- **Reduce required loading level of platinum**
- **Evaluate alternate precursor materials to determine feasibility of producing mesostructured support material**

Phase II Work (FY2018)

- **Optimization of process parameters for fabrication of Pt-MC and scale up method**
- **High Cycle Durability testing of Pt-MC catalyst (up to 30,000 cycles)**
- **Prototype fuel cell fabrication up to 50cm²/short stack**

Summary

- **Metal carbides have attractive properties that make them good candidates for catalyst support materials in fuel cells**
- **This research effort is focused on preparing low-cost mesoporous metal carbide materials that are suitable for catalyst support applications**
- **Performance Targets:**

Characteristic	Unit	2015 Status	2020 Target
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