Low Cost Metal Bipolar Plate Carbon Coating Technology for Heavy Duty Fuel Cells

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DOE Hydrogen Program

2024 Annual Merit Review and Peer Evaluation Meeting

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Project Goal

- Reduce the manufacturing cost of PEM fuel cell metal bipolar plate in order to meet DOE's cost target of < $5kW.
  - Develop carbon based coating technology (DuraC) for heavy duty fuel cell metal plate application.
  - Develop the coating process that is suitable for roll to roll (R2R) manufacturing process.
- Meet the performance and durability requirements for HDV application.
  - By *ex-situ* and *in-situ* testing of the coating metal plates.
- Focused both Titanium and stainless steel substrates.
  - Stainless steel is the major focus of metal BP materials for automobile fuel cells.
  - Titanium based plate is still a material of interest for some automobile companies Investigate the coating electrical conductance and degradation mechanism.

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Project Overview

Timeline

- Project Start Date: July 10, 2023
- Project End Date: July 9, 2024, 2014
- Percent Complete: 40%

Budget

- Total Project Funding: $199,716
- Spending (to Feb. 2024) $87,689

Barriers

- Barriers Addressed : Bipolar Plate Durability and cost
  - Cost: < $5/kW (2025)
  - resistivity < 10 $m\Omega.cm^2$
  - corrosion < 1 $x10^{-6}A/cm^2$

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Relevance/Potential Impact

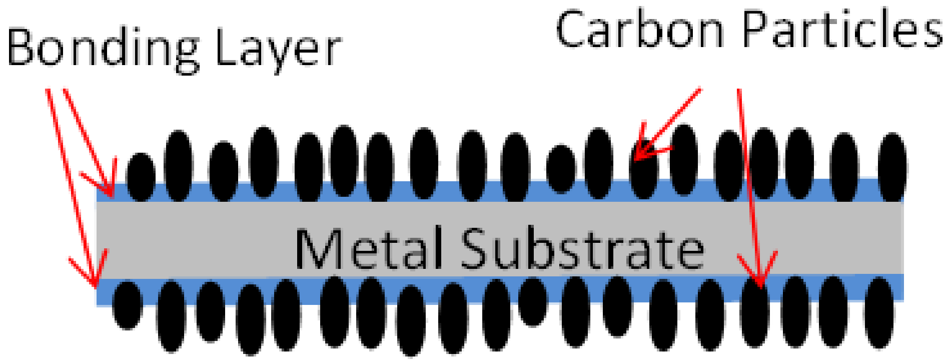
- Bipolar plates are the second most expensive component in PEMFC stacks.
- Low-cost metal bipolar plates and fabrication techniques are critical to meet HFTO 2030 cost and performance targets for heavy-duty applications.

Barriers	DOE Targets	Project Impacts
Cost	<\$5/kW	Develop carbon based coating technology for metal plate to meet the cost target.
Durability	>25,000 hrs	Using AST protocol for rapid evaluation.
Performance	Corrosion Current: $< 1\ \mu A/cm^2$ Contact Resistance: $<10\ m\Omega.cm^2$	Investigate the coating degradation mechanism to achieve the superior performance.

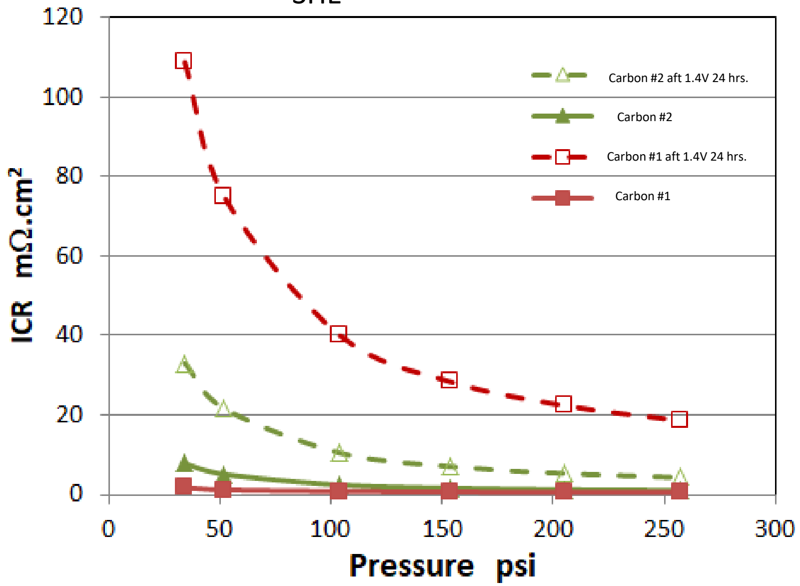
Project objectives and impacts directly contribute to meet HFTO 2030 Targets

Technical Approaches

Schematic drawing of DuraC coating structure

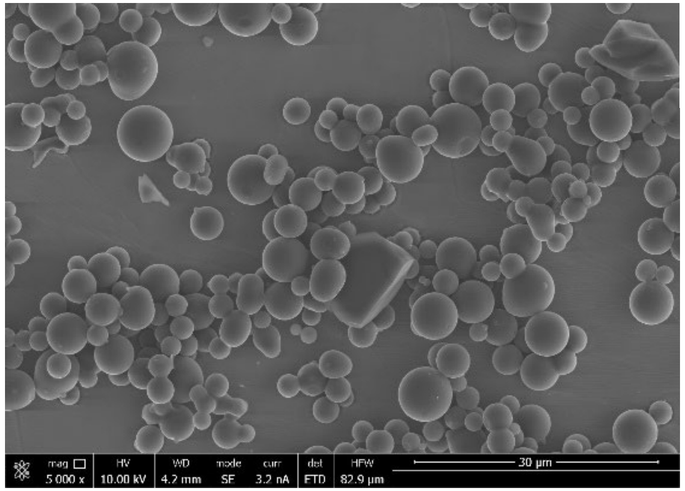


ICR of titanium Plate coated with carbon particles before and after 1.4V_{SHE} 24 hrs. corrosion tests



<u>Manufacturing Technology:</u>

- Directly bond carbon particles (DPB process) on metal substrate surface to obtain the desired structure and properties.



The long-term stability of the DraC coating is highly rely on the carbon particle material properties. Some carbon particle could meet the application requirements.

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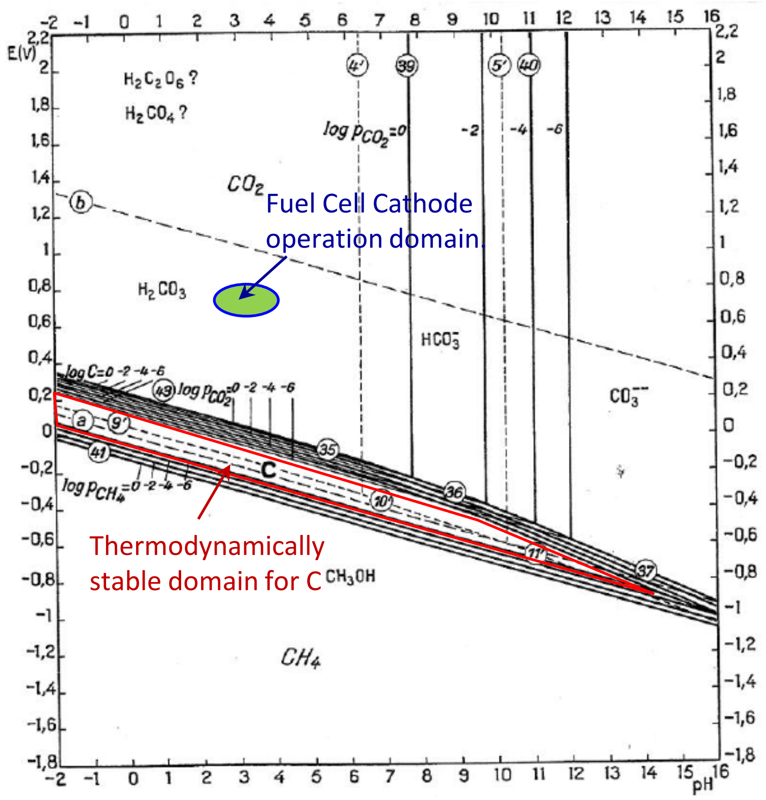
Accomplishments and Progress

Carbon Particle Material Selection

Thermodynamically carbon is not stable in fuel cell cathode operation condition

Pourbaix diagram of carbon



Kinetically some carbon materials can meet the cathode operation requirement. A lot of carbon materials have been used in fuel cells.

- Generally, graphitized carbon is more stable than amorphous carbon materials.
- Even highly graphitized carbon still contains residue amount of amorphous phase that is not stable in fuel cell conditions.
- The selection of carbon raw material critical for the final coating performance.

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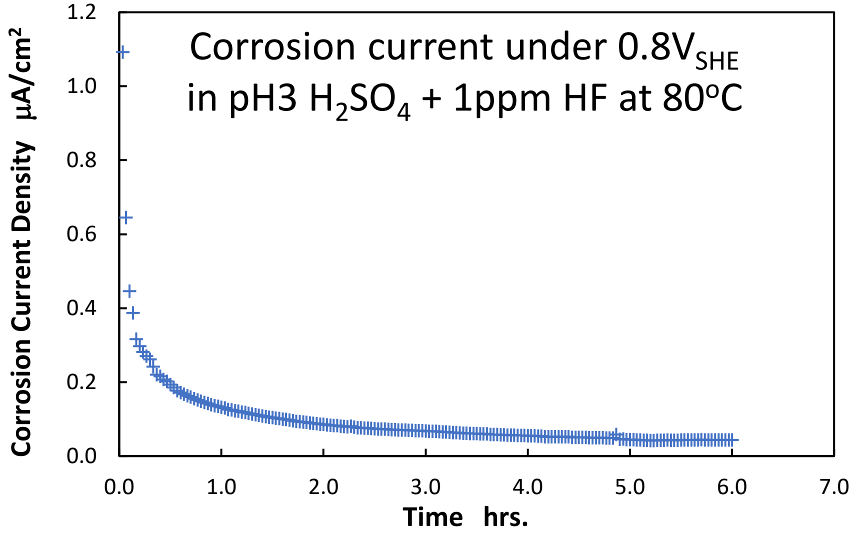
Accomplishments and Progress

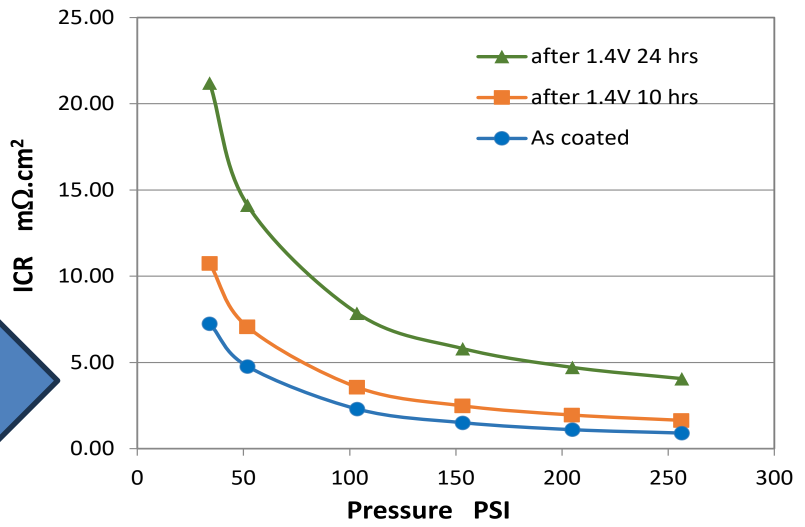
Carbon Particle Material Selection

More than 30 type of carbon materials have been evaluated.

- Bonding tests. Some carbon particles can't be reliably bonded on metal surface .
- ICR measurement. All carbon bonded metal plates have low (< 5 mΩ.cm^2 at 200 psi) .
- *Ex-situ* corrosion tests
  - The residue amorphous carbon oxidization at $0.8V_{SHE}$ could last long time. Its corrosion current could be high after 100 hours test. Longer time corrosion test, or more aggressive testing condition is need to quickly evaluate the coating stability.

Carbon coated Ti plate under *ex-situ* corrosion test





The low ICR (<5 mΩ.cm^2) after the aggressive corrosion tests indicates the exceptional durability of the carbon coating.

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Approach – Safety Planning

Hydrogen Safety Plan (HSP) was submitted on Feburary, 2022 and feedbacks were addressed

Prioritizes safety and analyzes safety hazards

- **Risk Mitigation Plan according to** TreadStone's Flammable Gas Standard:
    1. Hydrogen sensors are coupled with automatic control units to closed solenoid valves to cut off hydrogen line, when the hydrogen sensor is triggered.
    2. Adequate ventilation, with flow sensor, in storage, testing rig and near the lab ceiling. The ventilation flow sensor are couple the hydrogen control unit to automatically shut off hydrogen when the flow sensor is triggered.
    3. All hydrogen cylinders will be inspected with hydrogen detectors when it is received, and installed.
    4. All sensors will be calibrated twice per year.

Incidents/near-misses and learning

- **Track Record on Safety**
    - Fuel cell research has been conducted at TreadStone for 18 years without any serious safety incidents.
- **Well established incident reporting and Investigation**
    - All emergency situations must be reported by dialing extension 609-734-2128 to our host, SRI International, Princeton. SRI security will dispatch appropriate responders to the event.
    - The post-event incendent report will submitted to SRI security as record.

Future Work

- Further demonstrate the DuraC coating on stainless steel, including low grade stainless steel substrate.
- Demonstrate the performance in single cell performance test.
- Conduct the manufacturing cost analysis.

Summary

- ***Objective:***
  - Demonstrate a low cost coating technology that uses low cost carbon particle material as the coating material to meet fuel cell application requirement.
- ***Relevance:***
  - Reducing the metal bipolar plate cost to DOE's performance and cost target.
- ***Approach:***
  - Bonding carbon particle material on metal substrate surface ad the electrical contact point to achieve low electrical contact resistance and low corrosion current.
- ***Accomplishment:***
  - Selected proper carbon particle materials that can meet the application requirements.
  - Demonstrated the coating process on titanium and stainless steel substrates.
- ***Future Work:***
  - Finish the corrosion test of carbon coated stainless steel plates.
  - Demonstrate the coating in single cell tests
  - Conduct the coating manufacturing cost analysis.