Catalyst layer design, manufacturing and in-line quality control

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Project ID: TA027

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Overview

Timeline
Project Start Date: 10/1/18
Project End Date: 10/1/20

Budget
DOE funding released: 12/14/18
Total project budget: $2.5M
DOE funding: $2M
UConn cost share: $500K
FY18 budget received: $1,084,318
FY19 budget planned: $915,682

Barriers
Hydrogen Generation by Water Electrolysis
F. Capital cost
G. System efficiency and electricity cost
M. Manufacturing

Partners
• Proton OnSite:
  – Dr. Katherine Ayers
• Mainstream Engineering
  – Dr. Paul Yelvington
Relevance

**Overall objectives of the program:**
- Scale-up CCMs of 680 cm\(^2\) with 10\% the catalyst loading of commercial MEAs.
- Electrolyzer stability of >1000 hours at 1.8 A/cm\(^2\), 80 °C and 400 psi differential pressure.
- Material cost reduction: Catalyst materials: 85\% (reduce catalyst loading by 90\%)
  - Membrane: 50\% (reduce thickness and improve sealing configuration)
- Energy cost reduction: From $13.22 per MEA (Proton OnSite current) to $2.42 per MEA (projected RSDT projected) for 680 cm\(^2\) MEA.

**For the current period (Jan. – Mar. 2019), the objectives are:**
- Development of a membrane coating to decrease hydrogen permeation.
- Demonstration of half MEA performance within 50 mV of baseline commercial electrodes at 1.8 A/cm\(^2\), 2.1V.
- Integration of RSDT electrodes into a single MEA.

<table>
<thead>
<tr>
<th>Barriers</th>
<th>Impacts</th>
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<tbody>
<tr>
<td>F. Capital cost</td>
<td>Cost reduction with RSDT process: 10X catalyst loading reduction.</td>
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<tr>
<td>G. System efficiency and</td>
<td>Development of high-performance electrolyzer MEA. Reduce electric power</td>
</tr>
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<td>electricity cost</td>
<td>consumption and improve the cell efficiency.</td>
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<td>M. Manufacturing</td>
<td>Scale-up manufacturing at 680 cm(^2) cell stack level coupled with in-line quality control. Achieve stability of &gt;1000 hours at 1.8 A/cm(^2), 80 °C and 400 psi differential pressure.</td>
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Approach

Technical approach:

• Finalize MEA fabrication procedure to re-establish the MEA performance in the 2016 project (DE-SC0009213).
• Reduce hydrogen crossover with the design of recombination layer.
• Examine MEA homogeneity with fixed-angle reflectance.
• Evaluate catalyst activity with RDE methods.
• Evaluate MEA performance and stability at 1.8 A cm$^{-2}$, 80 °C, and 400 psi differential pressure.
Accomplishments and Progress

Re-establish the MEA baseline performance
Performance of RSDT cathode (half CCM): cathode

Cathode (RSDT): Pt/Vulcan XC-72R, 0.3 mg_{Pt}/cm^2, I/C ratio 0.15;
Anode (commercial), Ir loading, 3 mg/cm^2; Membrane: N117, 50 °C, 400 psi differential pressure.

The performance of the half CCM produced by RSDT is 96 mV better than the baseline with the dry MEA build condition at 1.8 A/cm^2, 143 mV better than the target 2.1 V.
Accomplishments and Progress

Re-establish the MEA baseline performance

Performance of RSDT full CCM

Cathode: Pt/Vulcan XC-72R, 0.3 mg/cm², I/C ratio 0.15: Anode IrOx/Nafion, Ir loading, 0.08 mg/cm²; Membrane: N117, 50 °C, 400 psi differential pressure.

The performance of the full CCM produced by RSDT is 49 mV better than the baseline with the same cell build condition at 1.8 A/cm², 110 mV better than the target 2.1 V.
Accomplishments and Progress

Recombination layer development

Nafion coating by RSDT, 1-5 μm

Pt nanoparticles by RSDT, ~2 nm

The average Pt particle size is 1.5-2 nm. Estimated Pt coverage on the membrane is 2%.
Accomplishments and Progress

Recombination layer development

Cathode: Proton GDE, 3±0.3 mg Pt/cm²; Anode Proton GDE, 3±0.3 mg Ir/cm²; Membrane: N117, 50 °C, 400 psi differential pressure.

- In the Initial test, no significant difference in H₂ crossover was observed between membrane with and without recombination layer (RL).
- Solution path: (1) Increase the Pt coverage.
  (2) Increase the thickness of Nafion® coating.
Accomplishments and Progress

Initial tests for quality control: Reflectance measurements at 45º angle illumination

- Samples are from the 2016 DOE program (DE-SC0009213) for initial evaluation.
- One of the Pt/C samples had warping in the membrane and pooling or bulging in the catalyst. The other Pt/C sample is homogeneous.
- IrOx sample was warping significantly. Dimples could be seen that could be due to catalyst loading or membrane.
- Sample would need to be flattened for better analysis.
Collaboration & Coordination

<table>
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<tr>
<th>Partner</th>
<th>Project Roles</th>
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<tr>
<td>University of Connecticut</td>
<td>Project lead, MEA fabrication, materials analysis, management and coordination</td>
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<tr>
<td>Proton OnSite</td>
<td>MEA evaluation and MEA device design</td>
</tr>
<tr>
<td>Mainstream Engineering</td>
<td>In-line quality control for MEA fabrication, device design for spectroscopic analysis</td>
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Remaining Challenges and Barriers

Challenges:

• Demonstrate stability performance >300 hours for full RSDT CCM at 86 cm$^2$ active area.
• Reduce hydrogen crossover with recombination layer.
• Reduce membrane warping for reflectance measurement and in the fabrication process.

Planned resolution:

• Improve the homogeneity of catalyst layers morphology.
• Revise cell planform to improve margin during assembly.
• Increase platinum coverage for the recombination layer.
**Proposed Future Work**

**Remainder of FY2019**

**Milestones and go/no-go decision**

<table>
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<tr>
<th>Milestone Description</th>
<th>Due Date</th>
<th>Complete</th>
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<tbody>
<tr>
<td>Verify hydrogen crossover reduction with RSDT-derived recombination layer</td>
<td>4/19 (M7)</td>
<td>25%</td>
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<tr>
<td>Verify full RSDT CCM at 86 cm² and verify catalyst activity with RDE</td>
<td>6/19 (M9)</td>
<td>50%</td>
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<td>Machine vision components assembled, and fixed-angle reflectance images collected for UCONN cathode and anode calibration samples.</td>
<td>6/19 (M9)</td>
<td>10%</td>
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<td>Laser system installed and verified with Si standard</td>
<td>9/19 (M12)</td>
<td>5%</td>
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<tr>
<td><strong>Full RSDT Cell with 86 cm² is stable at 1.8 A cm⁻², 80 °C, 400 psi hydrogen pressure for 1000 hours. (GO/NO-GO DECISION)</strong></td>
<td>12/19 (M15)</td>
<td>0%</td>
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<tr>
<td>Catalyst loading measurement sensitivity of 0.03 mgPt/cm² and local defect resolution of 250 µm at ±50% of nominal catalyst loading.</td>
<td>12/19 (M15)</td>
<td>0%</td>
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Technology Transfer Activities

Scale-up fabrication of MEA with in-line quality control

- If the proposed technology can meet all the cost and performance targets of this program, Proton OnSite would establish a commercialization for electrolyzers using the RSDT process.
Summary

Objective: Demonstrate a fully fabricated membrane electrode assembly using the reactive spray deposition technology (RSDT) method to meet the cost reduction targets of materials.

For the current period (Jan. – Mar. 2019):
• Development of a membrane coating to decrease hydrogen permeation.
• Demonstration of half MEA performance within 50 mV of baseline commercial electrodes at 1.8 A cm$^{-2}$, 2.1V.
• Integration of RSDT electrodes into a single MEA.

Approach:
• Finalize MEA fabrication procedure for RSDT.
• Reduce hydrogen crossover with the design of the recombination layer.
• Examine MEA homogeneity with fixed-angle reflectance.
• Evaluate catalyst activity and MEA performance at 1.8 A cm$^{-2}$, 50 °C, and 400 psi differential pressure.

Accomplishments: Successfully re-established MEA fabrication procedure and MEA performance. Demonstrated half CCM and full CCM produced by RSDT where MEA performance is >50 mV better than the commercial baseline at 1.8 A cm$^{-2}$ with 10X catalyst loading reduction.