Catalyst layer design, manufacturing and in-line quality control

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Solutions Through Advanced Technology MAINSTREAM ENGINEERING

UCONN

Overview

Timeline

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

Barriers

Hydrogen Generation by Water Electrolysis

F. Capital cost
G. System efficiency and electricity cost
M. Manufacturing

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

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 ^oC 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.

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

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 ^{o}C, and 400 psi differential pressure.

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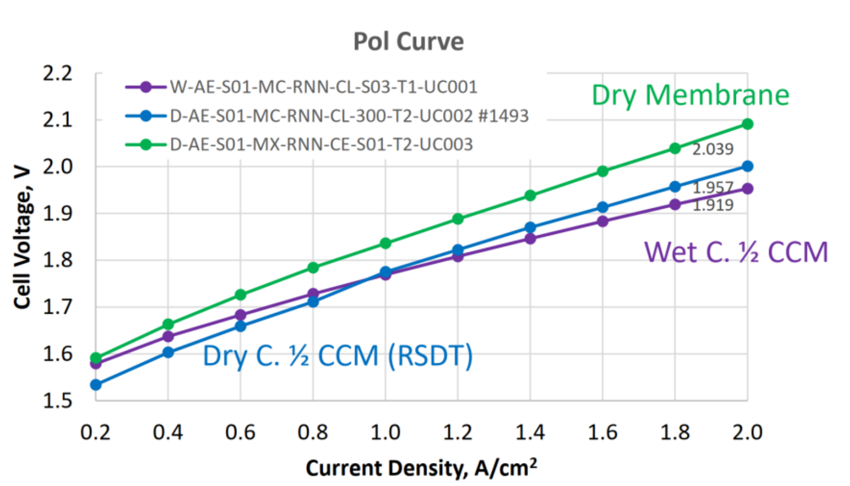
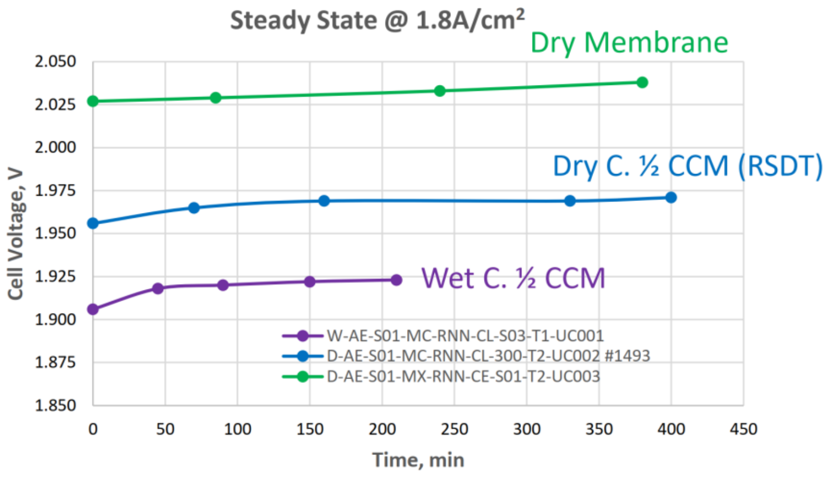
Accomplishments and Progress

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 ^oC, 400 psi differential pressure.





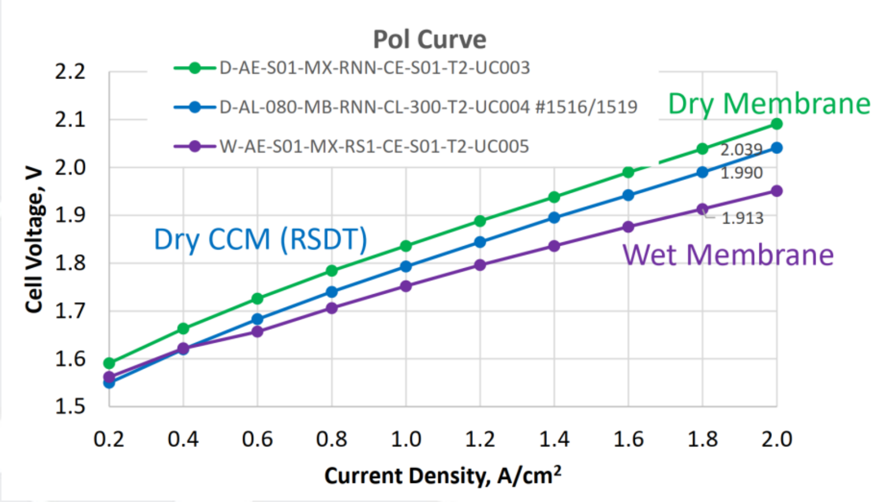
The performance of the half CCM produced by RSDT is 96 mV better than the baseline with the dry MEA build condition at 1.8 A/cm^2,143 mV better than the target 2.1 V.

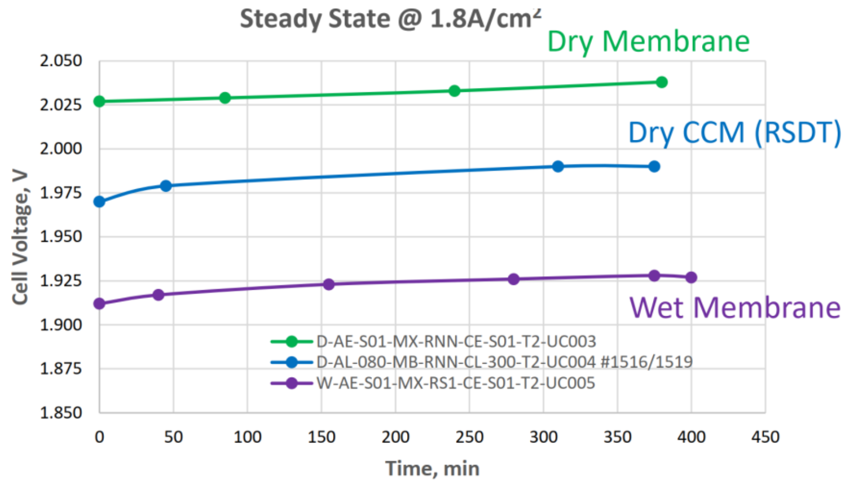
Accomplishments and Progress

Re-establish the MEA baseline performance

Performance of RSDT full CCM

Cathode: Pt/Vulcan XC-72R, 0.3 mg/cm^2, I/C ratio 0.15: Anode IrOx/Nafion, Ir loading, 0.08 mg/cm^2; Membrane: N117, 50 ºC, 400 psi differential pressure.

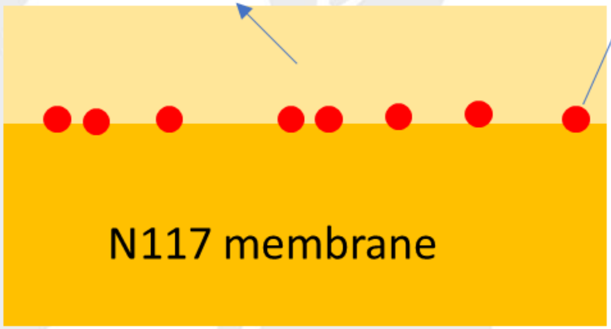




The performance of the full CCM produced by RSDT is 49 mV better than the baseline with the same cell build condition at 1.8 A/cm^2,110 mV better than the target 2.1 V.

Accomplishments and Progress

Recombination layer development



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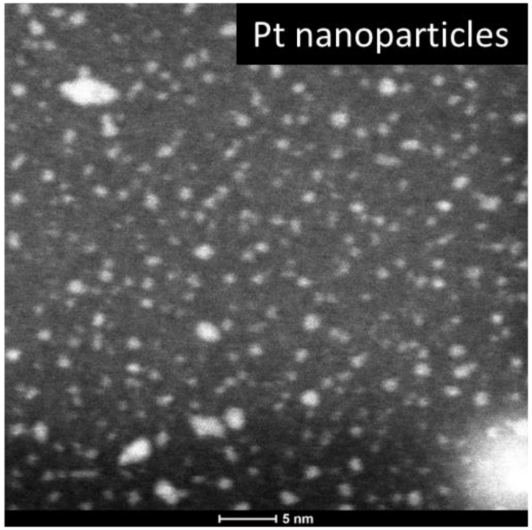
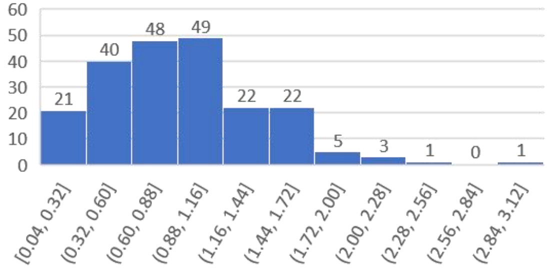


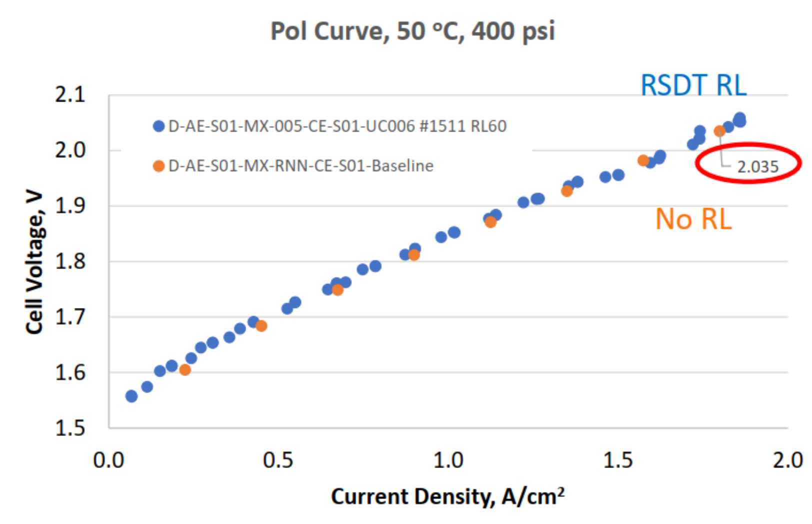


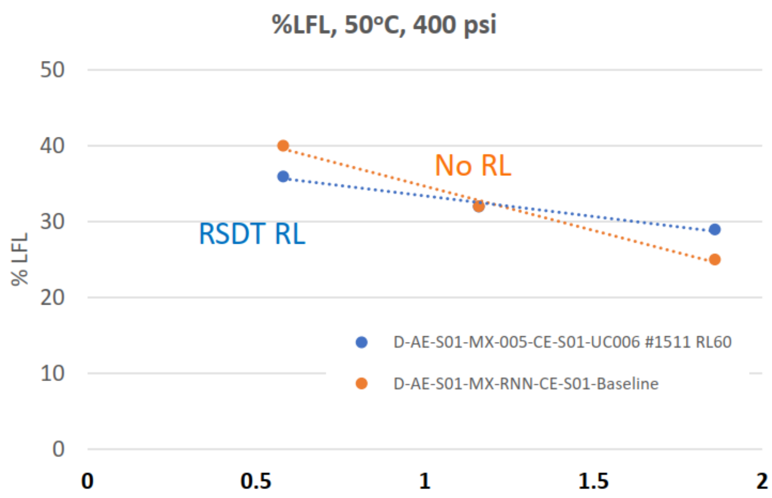
The average Pt particle size is 1.5-2 nm. Estimated Pt coverage on the membrane is 2%.

Accomplishments and Progress

Recombination layer development

Cathode: Proton GDE, 3±0.3 mg_{Pt}/cm^2; Anode Proton GDE, 3±0.3 mg_{Ir}/cm^2; Membrane: N117, 50 ^oC, 400 psi differential pressure.



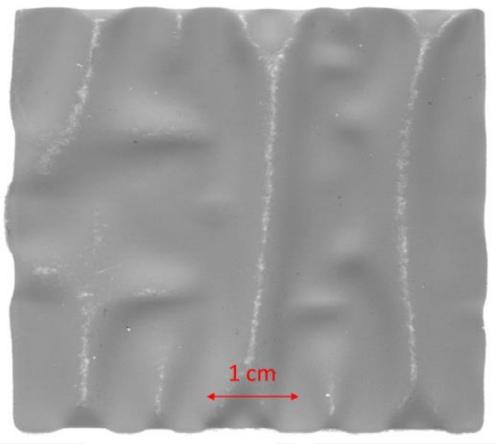


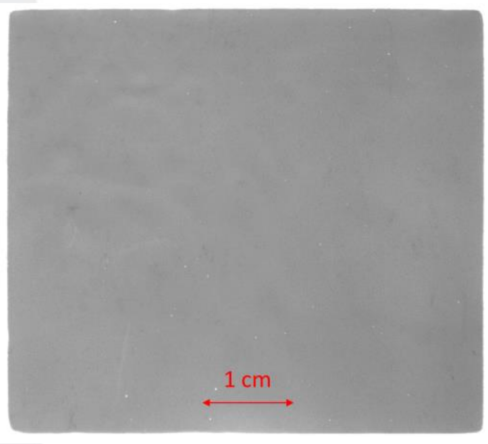
- In the Initial test, no significant difference in H_2 crossover was observed between membrane with and without recombination layer (RL).
- Solution path: (1) Increase the Pt coverage.
  (2) Increase the thickness of Nafion® coating.

Accomplishments and Progress

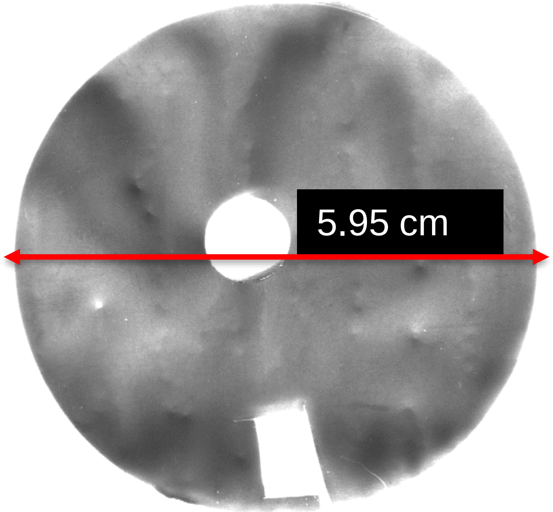
Initial tests for quality control: Reflectance measurements at 45º angle illumination

Pt/C cathode





IrOx/Nafion anode



- 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.

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Collaboration & Coordination

Partner	Project Roles
University of Connecticut	Project lead, MEA fabrication, materials analysis, management and coordination
Proton OnSite	MEA evaluation and MEA device design
Mainstream Engineering	In-line quality control for MEA fabrication, device design for spectroscopic analysis

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

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

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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 ^oC, 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.