PAJARITO POWDER
FUEL CELL CATALYSTS

Development of Durable Active Supports for Low Platinum Group Metal Catalysts

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Overview

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Timeline

- Project Start Date: 02/21/17
- Project End Date: 11/20/17
- Total Project Budget: $149,973

Barriers

- Durability, Cost, and Performance low-PGM content PEMFC catalyst supports is insufficient (FCTO MYRDD)

Budget

- Total Project Budget: $149,973
- Total recipient share: $0
- Total Federal share: $149,973
- Total DOE funds spent: $3,615

Partners

- Pajarito Powder
  - –Durable Active Carbon Supports & catalysts
- Advent Technologies
  - –Electrodes and MEAs

Advent

Relevance: Objectives

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- Develop Pajarito's Durable Active Carbon Supports (DACSs)
  - Optimize materials characteristics
  - Optimize Pt/support interactions
  - Increase support carbon corrosion resistance
  - Increase active support/Pt activity and durability synergism
- Deploy Pt/DACS in MEAs for validation
  - Integrate Pt/DACS into the MEA structure
  - Test and provide MEAs for validations
- Impact
  - Increase the durability of fuel cell electrocatalysts
  - Improve economics of PEMFC

Approach

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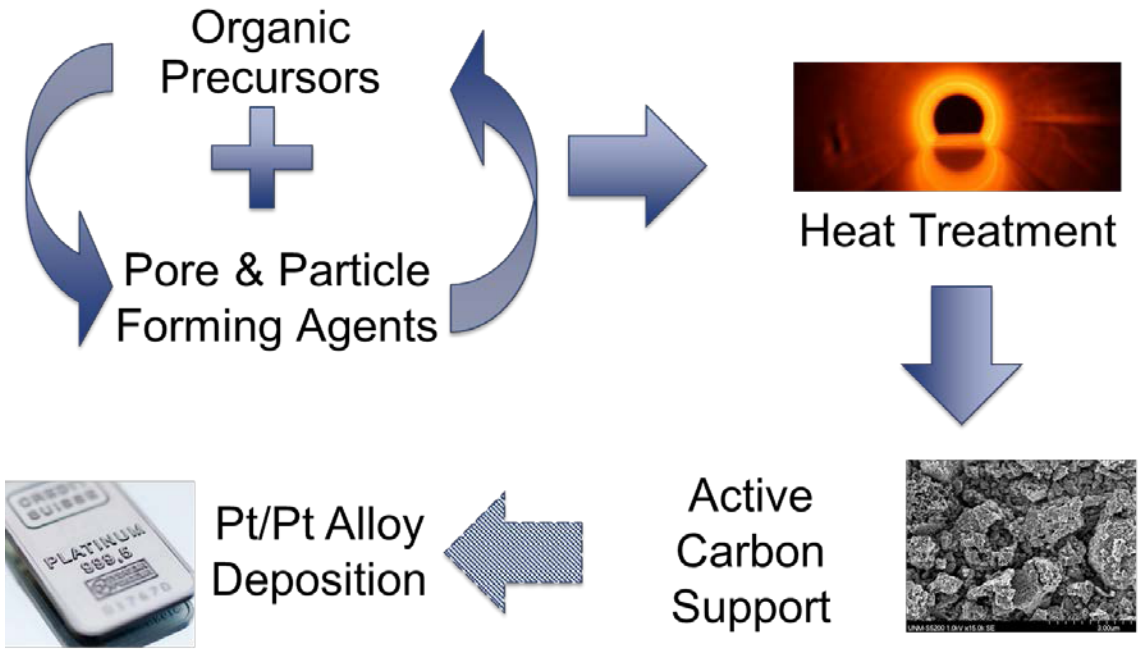
- Improve stability of M-N-C type PGM-free ORR catalysts developed with assistance of FCTO projects (DACS). Design Pt/DACS catalysts with increased durability
  - Fe, Co, and Mn based



Approach

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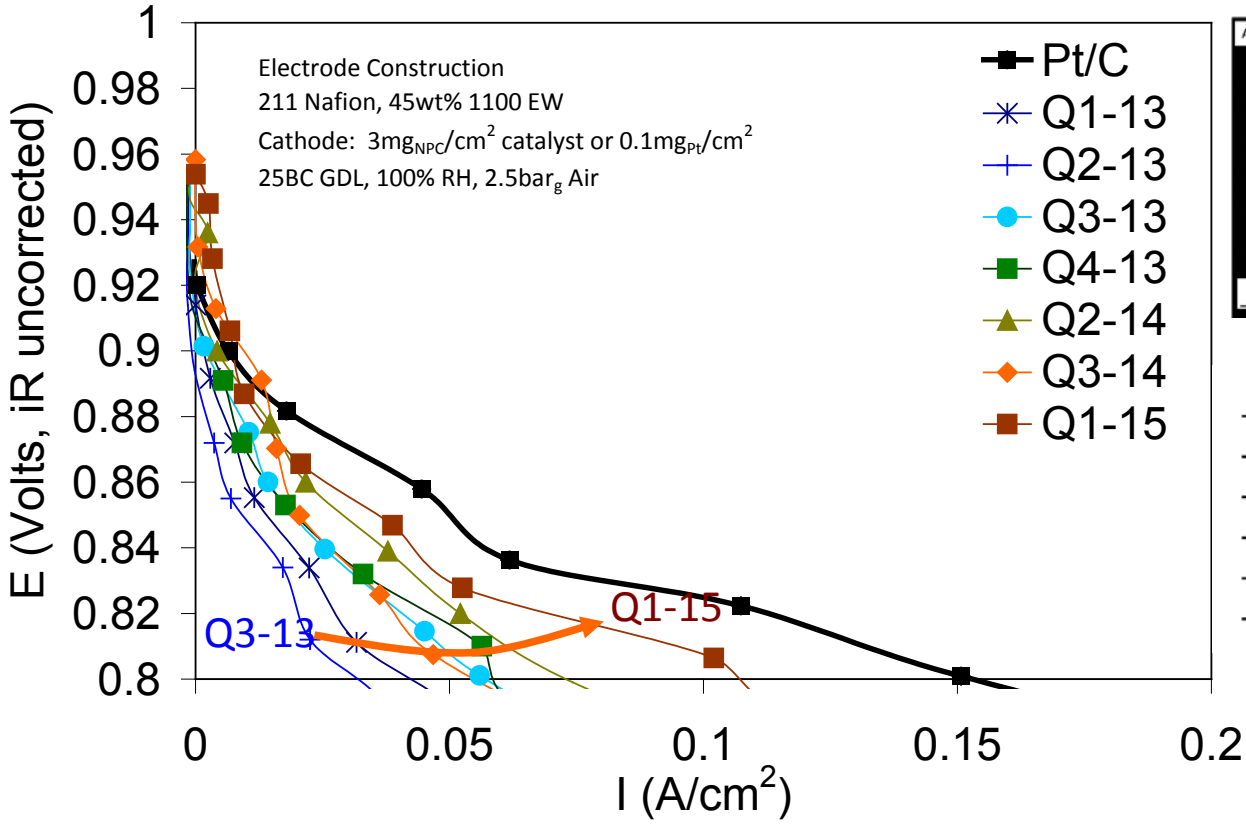

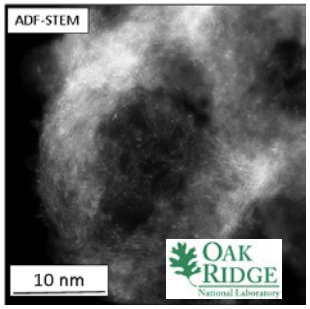

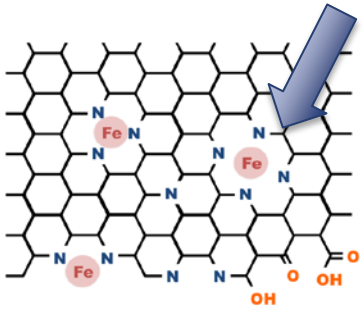

Precious Metal Free Supports performance now exceed 50mA/cm² @0.8V

Approach

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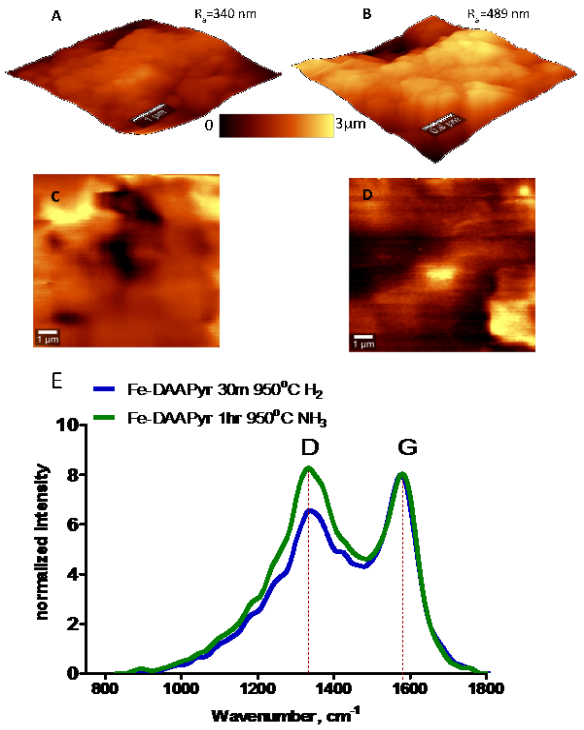
- Iteratively modify catalysts
  - Modify the precursors used in making PGM-free catalysts to
    - Control DACS morphology (surface area, porosity etc) through the design of synthetic approach
    - Increase Pt dispersion via increased Pt-support interaction
    - Increase graphitic content through selection of graphene-forming organic molecules (N-C precursors)
    - Resist membrane and ionomer degradation trough decrease of H_2O_2 generation



Approach:
Timeline and Milestones

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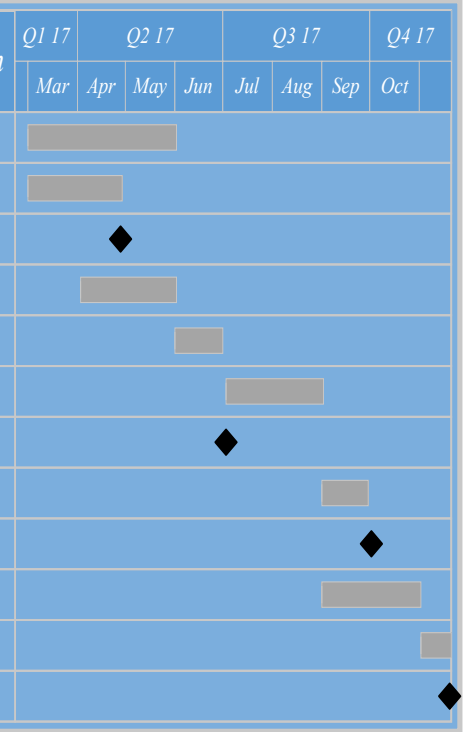
ID	Task Name	Start	Finish	Duration
1	Synthesis of active supports for initial testing.	3/1/2017	6/1/2017	67d
2	Testing of AS in RRDE and RDE MEA	3/1/2017	4/28/2017	43d
3	Downselect to 3 supports	4/28/2017	4/28/2017	0d
4	Decoration of AS with Pt	4/3/2017	6/1/2017	44d
5	Testing of Pt/AS in MEA	6/1/2017	6/30/2017	22d
6	Re-optimization of new catalysts for MEA	7/3/2017	9/1/2017	45d
7	Achieve 3nm Pt particles on 2-3 DACS	7/3/2017	7/3/2017	0d
8	Testing re-optimized catalysts in MEA	9/1/2017	9/29/2017	21d
9	Downselect to 2 supports	10/2/2017	10/2/2017	0d
10	Scale up of re-optimized catalysts to 25gr level	9/1/2017	11/1/2017	44d
11	Collection of results and writing report, Phase 2 plan	11/2/2017	9/20/2018	231d
12	Deliver MEAs for validation	11/20/2017	11/20/2017	0d



"Any proposed future work is subject to change based on funding levels."

Pajarito participated at SBIR Kick-off meeting.
Project started according to the schedule.

Accomplishments:
Commercial Baseline

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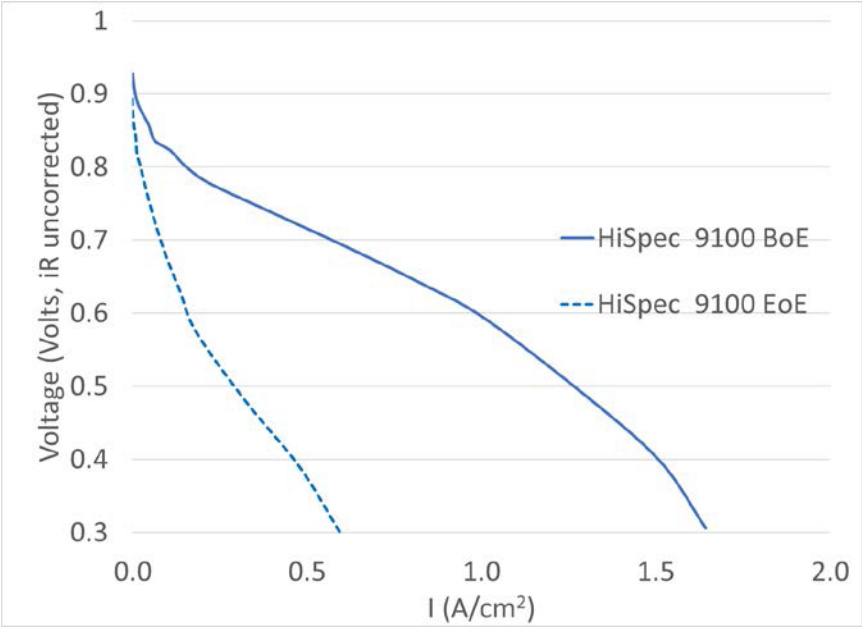
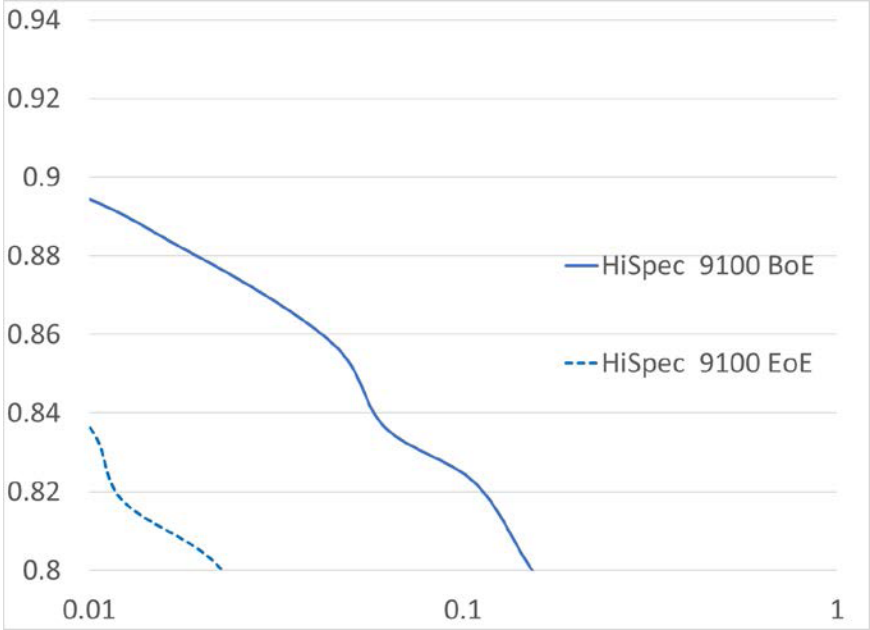
Polarization Curve



Kinetic Region (Log Scale)



Commercial catalyst degrades drastically under DoE Start-Stop AST: 89% activity loss

Approach and progress:
Pore Size Control

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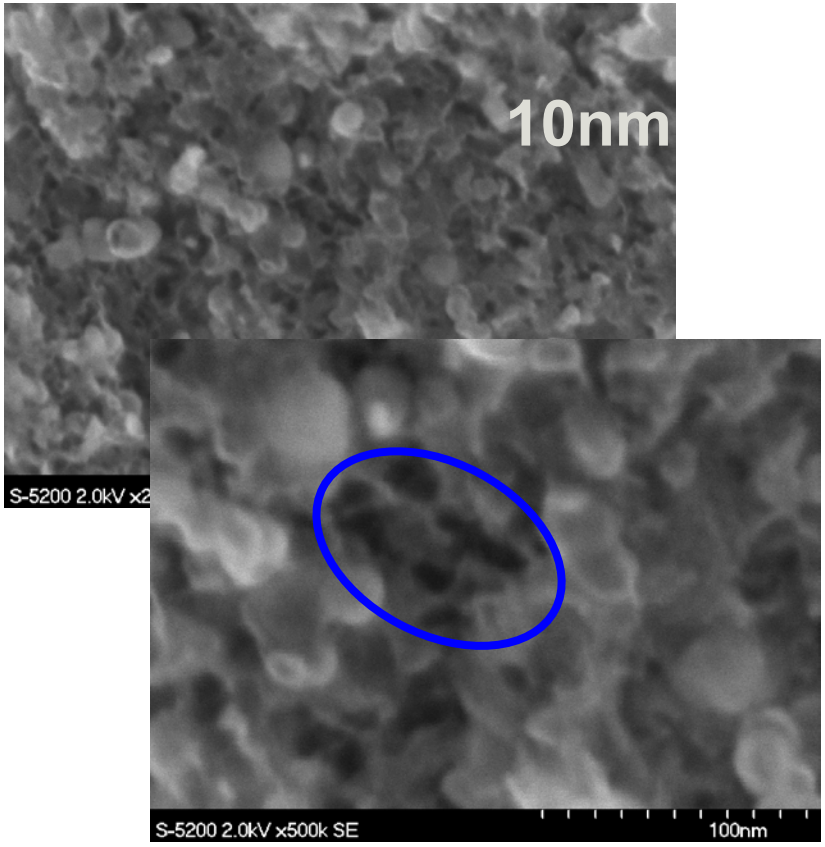

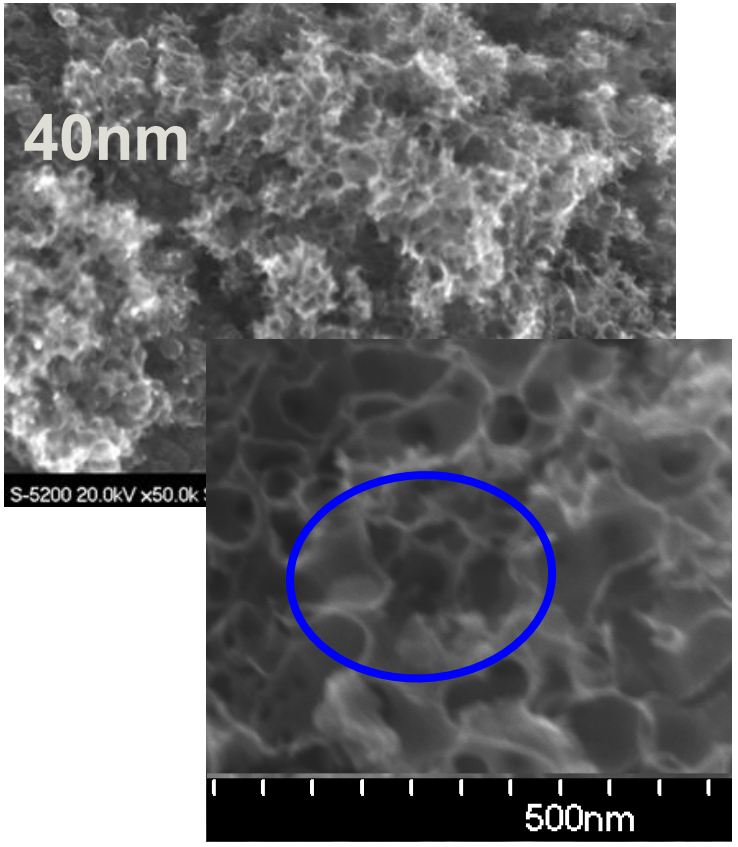

Design of DACS by VariPore® approach allows control support morphology

Approach and progress:
Graphitization

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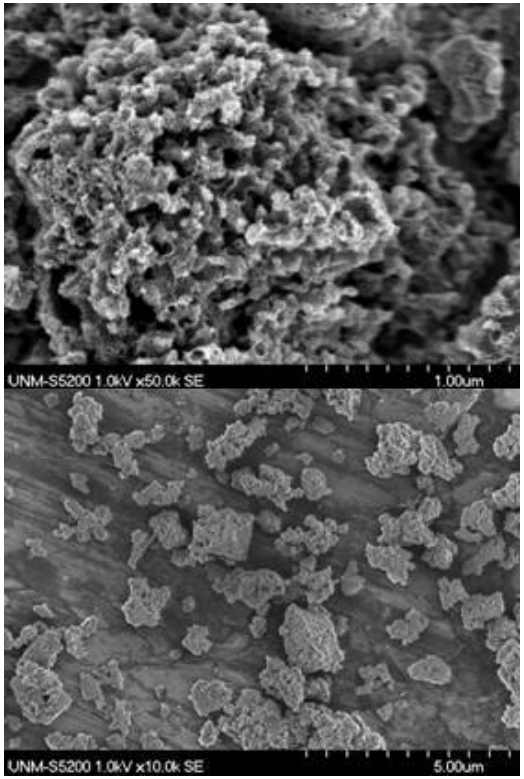

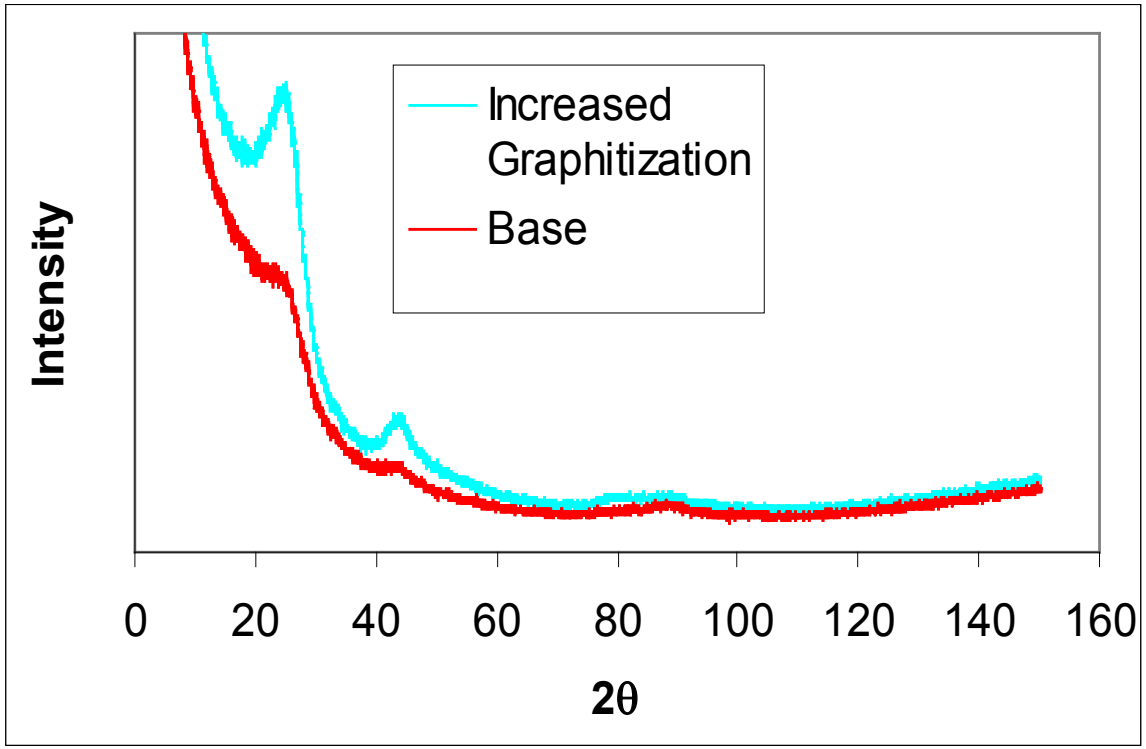

Higher graphitization leads to more corrosion resistance under Start-Stop AST protocol

Approach and progress:
Graphitization

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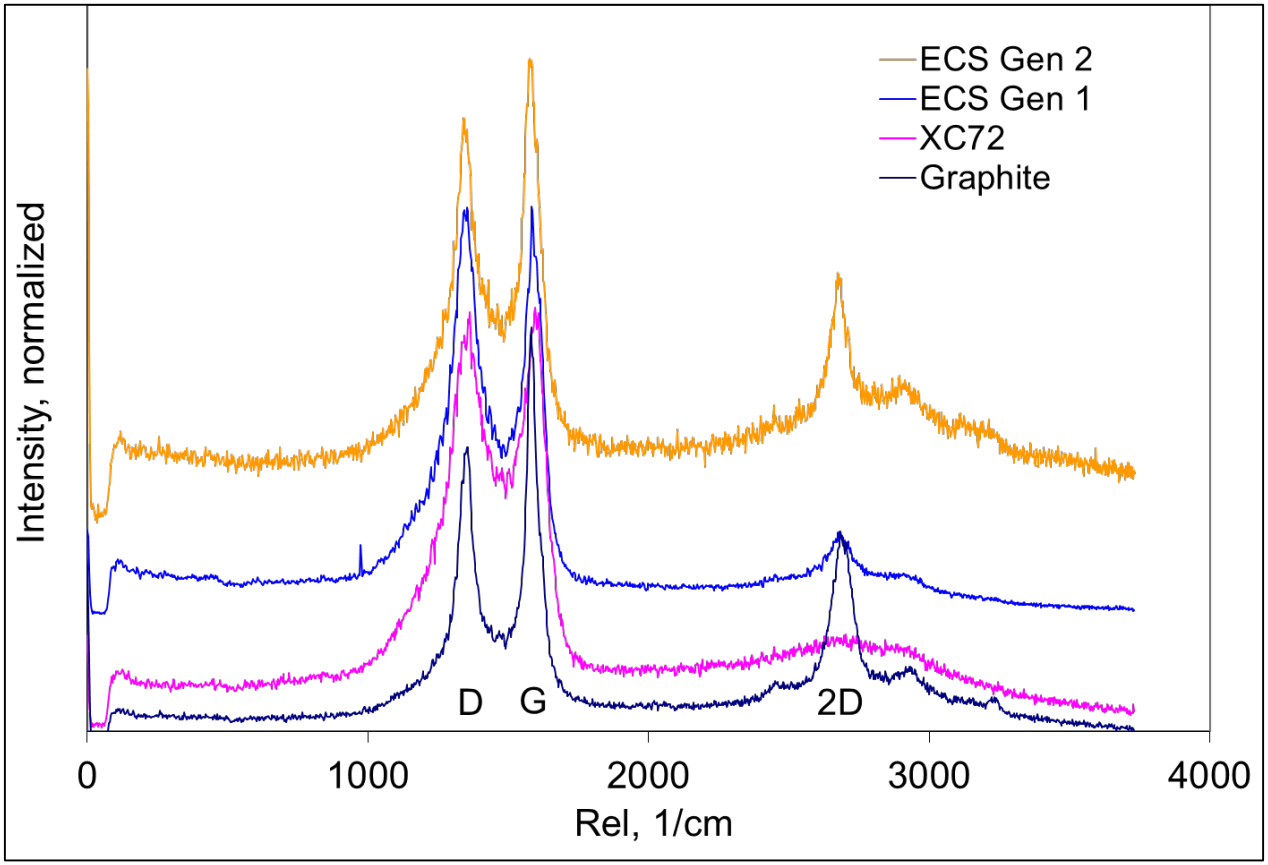

Graphitic content is controlled by heat treatment conditions and nature of organic precursor

Approach and progress:
Platinization

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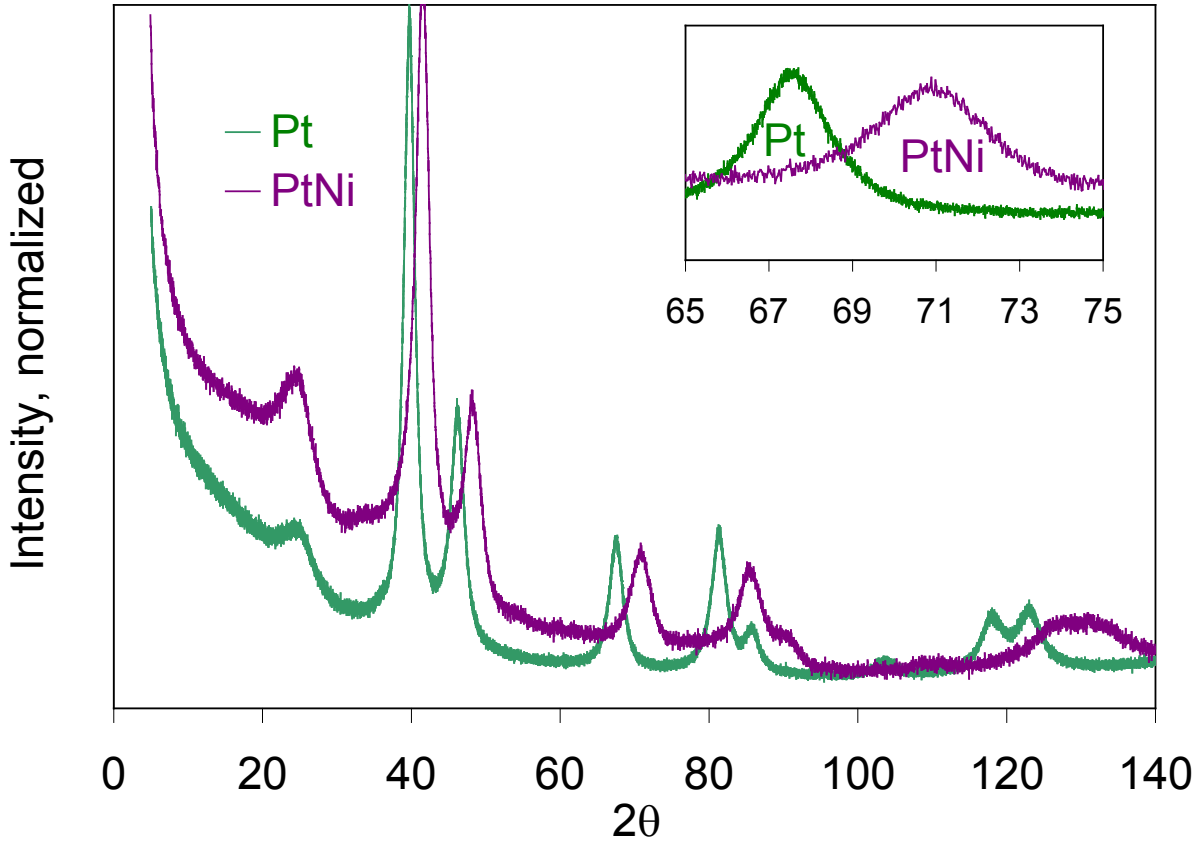

Proprietary Pt deposition method with control of: particle size and chemical composition (alloys)

Approach and progress:
MEA Manufacturing at Pajarito

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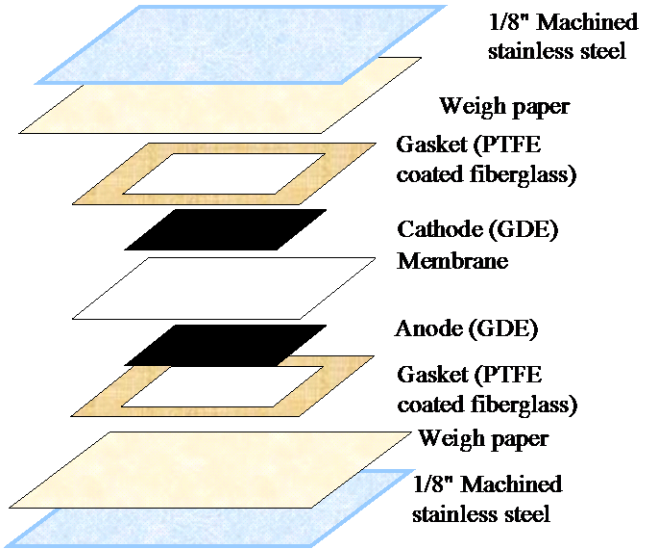
Silverson high shear mixer
2-5wt% solids
Ink

→ Sonotek ExactCoat
25kHz sonic nozzle
2-200μgr/cm²/pass



→ Carver 3860
heated press
~6+ minutes
131°C+
75psi for 25cm²
60psi for 50cm²

Approach and progress:
Accelerated Start-Stop Durability test

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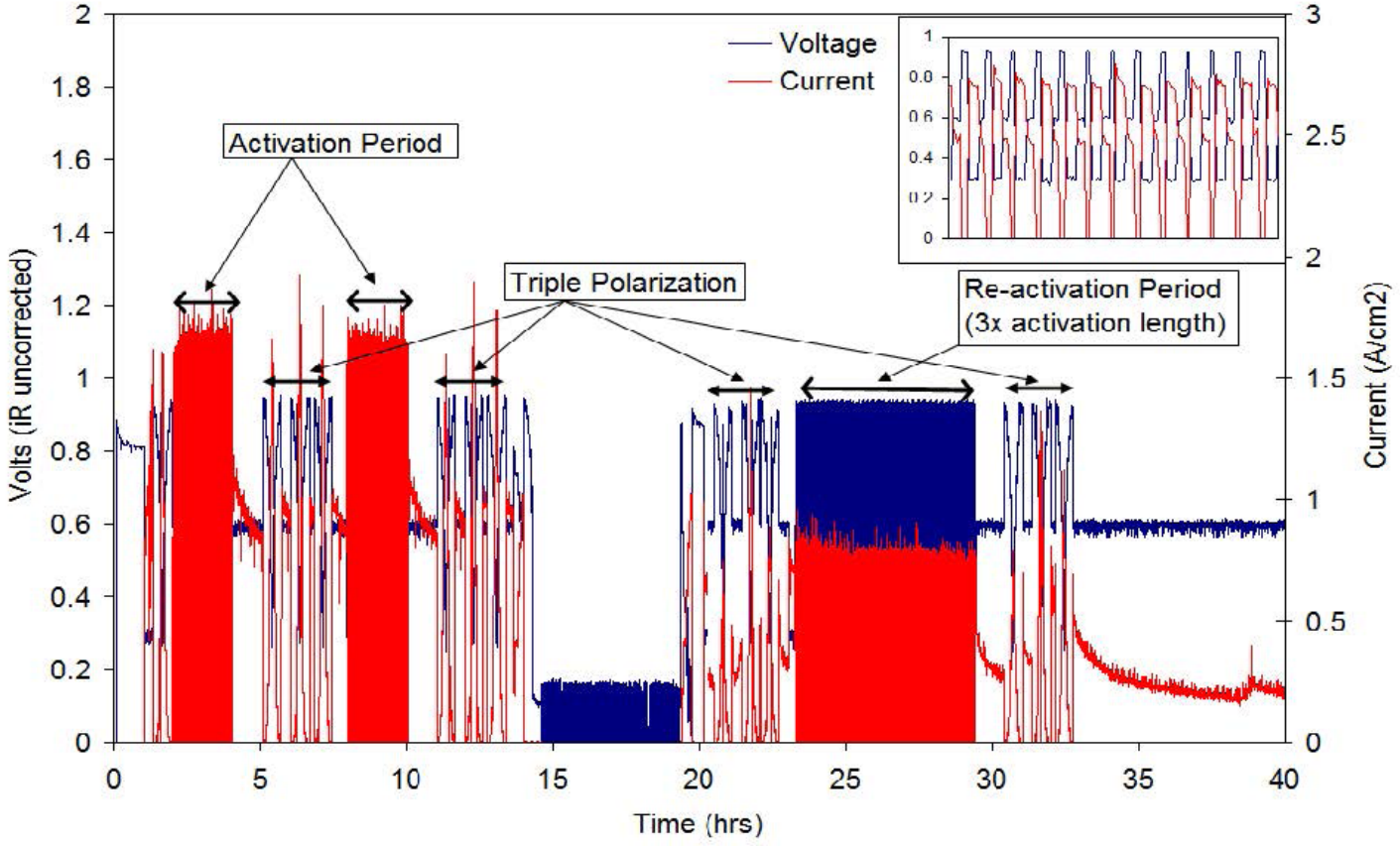

MEA Details
Nafion 211 or XL Membrane, 45wt% 1100 EW Nafion, 29BC GDL
Cathode: $3mg_{NPC}/cm^2$ or $0.1mg_{Pt}/cm^2$
Anode: $0.05mg_{Pt}/cm^2$ HS2100
Testing Conditions
100% RH, $1.5H_2$: 2.5Air, $26psi_g$

1-1.5V, 5000 cycle Start-Up/Shut-Down test procedure

Approach and progress:
Start-Stop Results for Gen 1

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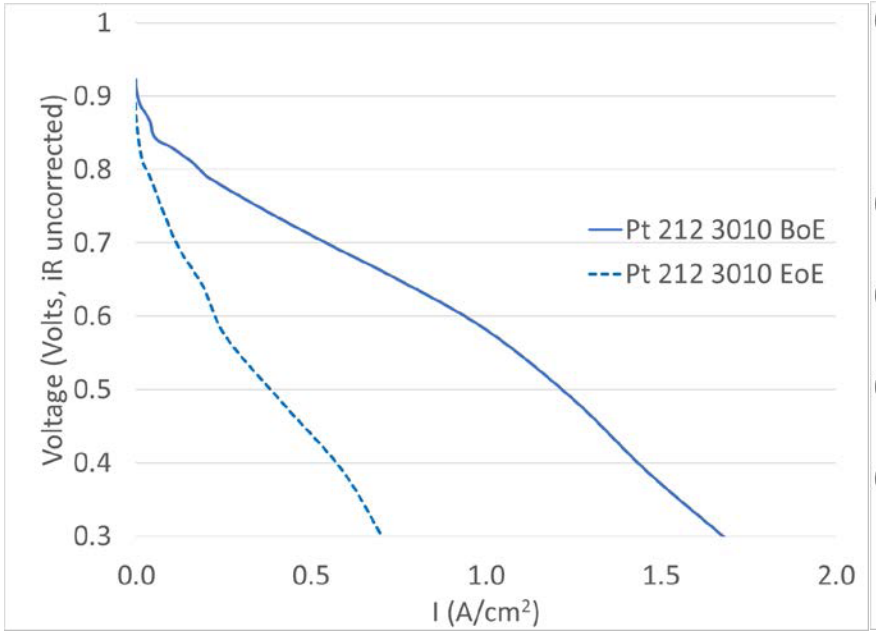
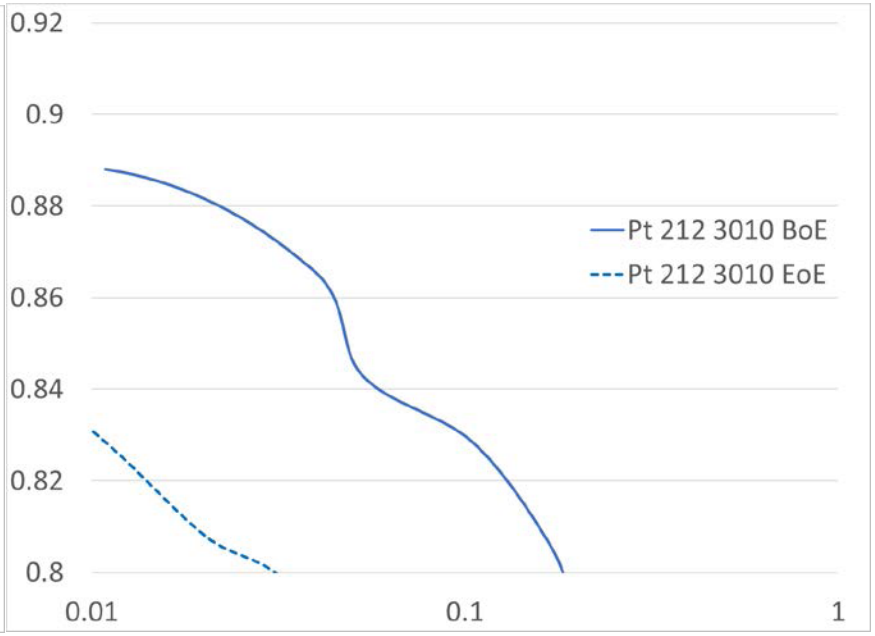
Polarization Curve



Kinetic Region, Log Scale



Gen 1 of Pajarito Pt/DACS 3010 degrades on the same level as a commercial Pt/C (89% activity loss)

Approach and progress:
Start-Stop Results for Gen 2

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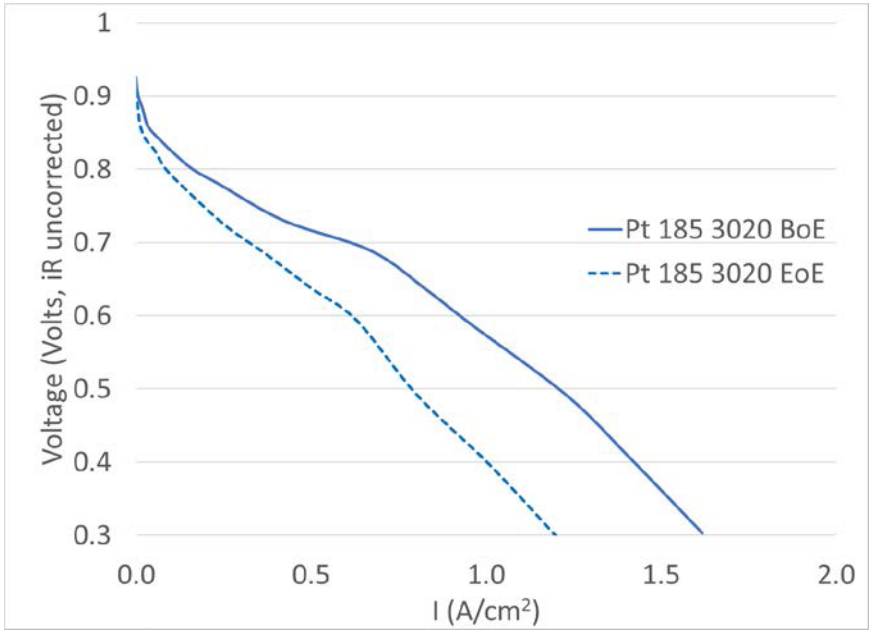
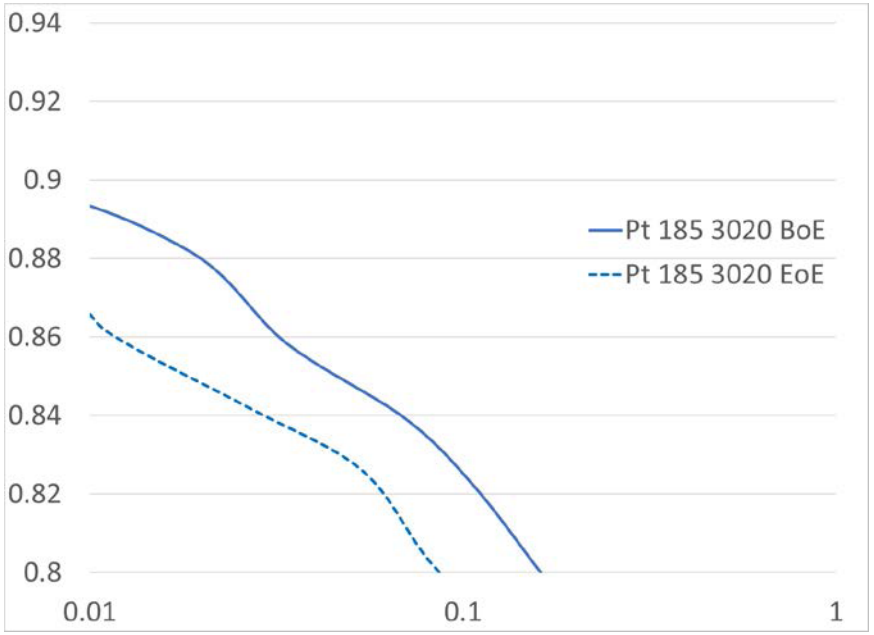
Polarization Curve



Kinetic Region, Log Scale



Gen 2 Pt/DACS 3020 catalyst, degrades 63%

Approach and progress:
Start-Stop Results Summary

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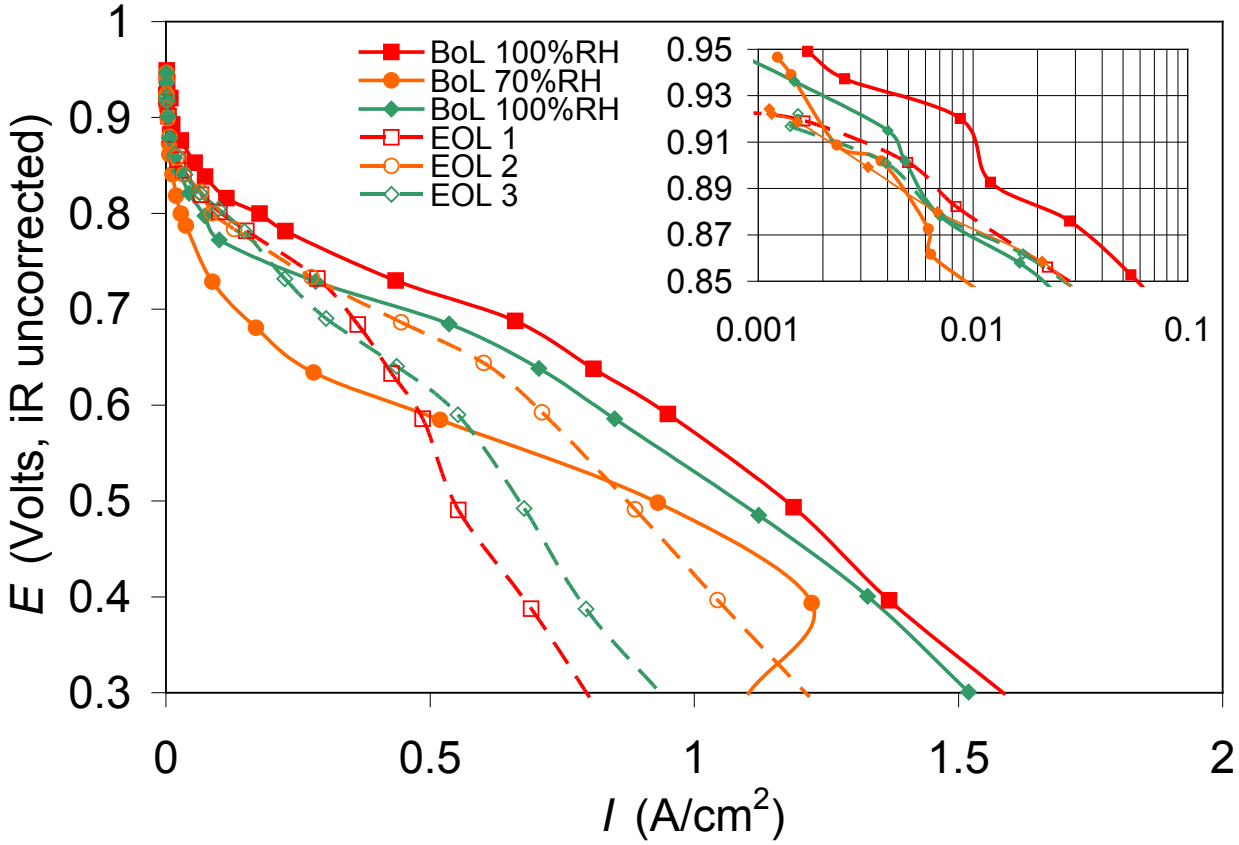

MEA Details
211 or XL Membrane, 45wt% 1100 EW Nafion, 29BC GDL
Cathode: 0.1mg$_{Pt}$/cm^2
Anode: 0.05mg$_{Pt}$/cm^2 HS2100
Testing Conditions
100% RH, 1.5H$_2$: 2.5Air, 26psi$_g$

Integration of Pt/DACS into the catalytic layer needs improvement. Excellent durability confirmed.

Techno-Economic Analysis

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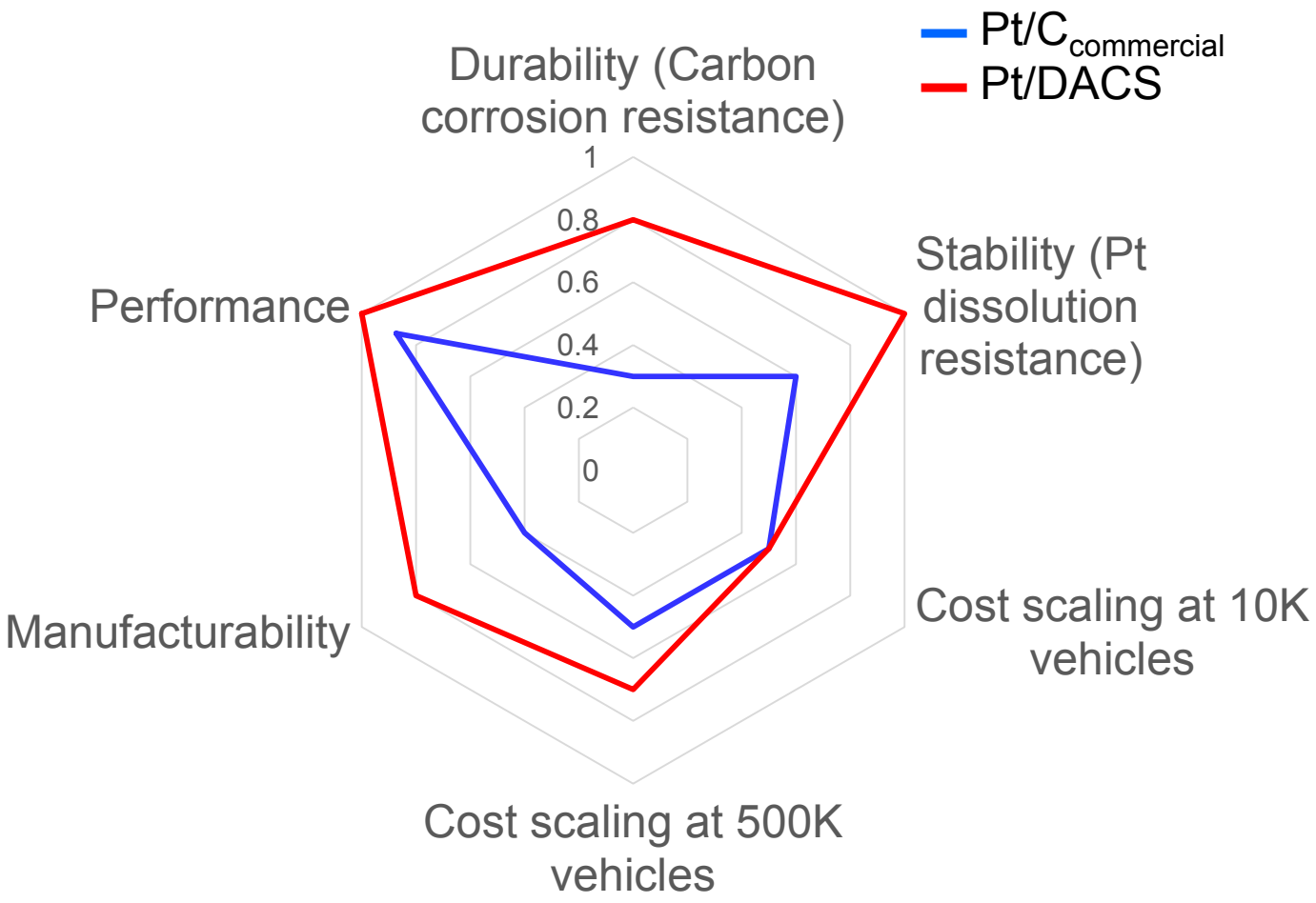

Cost Projection at Scale

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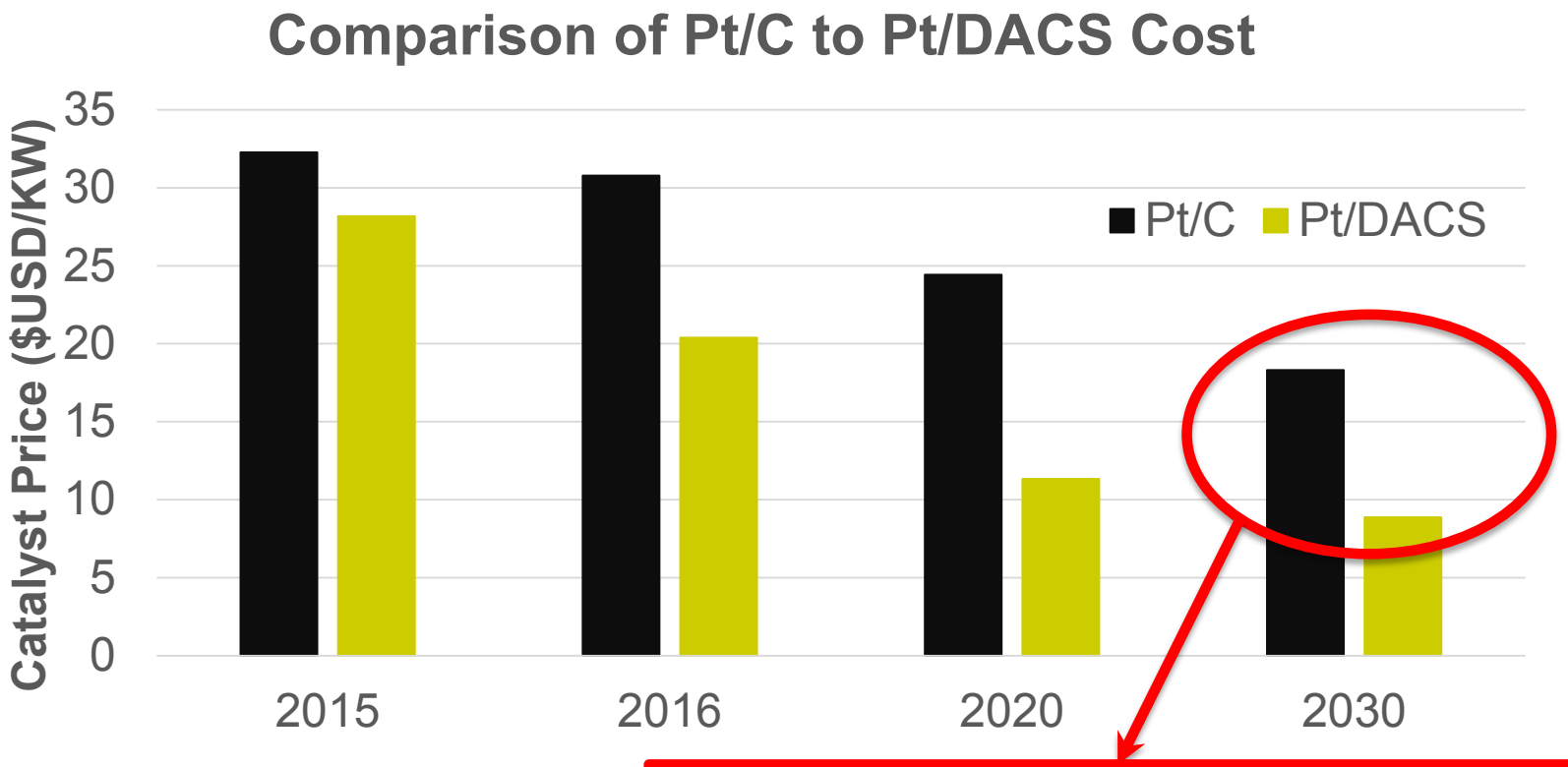

Pt/C Cost from DOE "Fuel Cell System Cost – 2015"; Pt price fixed at 2015 levels

Collaborations

- Pajarito Powder (Prime)
  - Management
  - Synthesis of Durable Active Supports (DACS)
  - Platinization of DACS
  - Manufacturing and testing of MEAs
- Advent Technologies (sub)
  - MEA catalyst layer optimization
  - Feedback on electrode/catalyst interaction
  - Improved MEA construction
- Pajarito and Advent have been collaborating closely under an MOU as well as partnership in a DoE Incubator program (FC132)

Summary

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- Pajarito Powder performed analysis of preliminary data on DACS synthesis and characterization
  - Early results show ~40% increase in durability
- Commercial Pt/C materials were selected for benchmarking activity and durability
- Initial parameters for synthesis of DACS and Pt/DACS were identified and materials are being synthesized by Pajarito
- Advent began making electrodes

Future Activities

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- Phase 1
  - Demonstration of concept
  - Identification of challenges, barriers, and advantages
  - Proposing mitigation scenarios
- Phase 2
  - Continued refinement of approach
    - Include Pt-alloys in the catalysts
    - Increasing of support carbon corrosion resistance
    - Inclusion of additional PGM-free manufacturing platforms
      - LANL-based approach recently licensed by Pajarito
      - Promising technologies arising from EMN/ElectroCat
  - Perform electrode and MEA modification and improvement
  - Testing and diagnostics of MEA performance
  - Feedback of testing results to modify catalyst supports
  - Automotive and lab validation, diagnostics and feedback
- "Any proposed future work is subject to change based on funding levels."