High Performance and Durable Low PGM Cathode Catalysts

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Project Overview

Timeline

- **Project Start Date**
  September 2014
- **Project Duration**
  1 year
- **Project End Date**
  September 2015

Barriers

- **Durability (cathode)**
- **Cost (catalyst)**
- **Performances (loss and activity)**

Budget

- **Total project funding**
  $300K for FY2015
  - PNNL: $180k
  - LANL: $120k

Partners

- **2 National Laboratories**
  - PNNL (lead)
  - LANL

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Relevance and Objectives

Relevance:

2020 DOE Targets for Electrocatalysts

- Platinum group metal total content: 0.125 mg PGM/cm^2
- Mass Activity (A/mg Pt@ 900 mV (IR free)): 0.44
- Loss in initial activity (mass activity loss): < 40%
- Electro catalyst support stability (mass activity loss): <10%

Objective:

Improve stability of catalysts by enhancing metal/support interactions and improved carbon support durability.

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Approaches

- "2-D to 3-D" engineering of graphene to enhance the diffusion properties
- ITO coating to improve the durability
- Pt loading using chemical reduction method developed at PNNL and vapor deposition method developed at LANL
- Electrochemical evaluation using an RDE test station to demonstrate both the ORR activity and stability using the standard DOE protocol.
- MEA Fuel cell testing at LANL (1.2V/400h hold, measuring ORR every 24h) will be used to demonstrate the durability of Pt-ITO-3D graphene catalyst. CO_2 generation rates will be determined to measure carbon support loss.
- Build off of our strong base in fundamental catalysis science:
  - Institute for Integrated Catalysis (IIC),
  - Environmental Molecular Sciences Laboratory (EMSL)

EMSL

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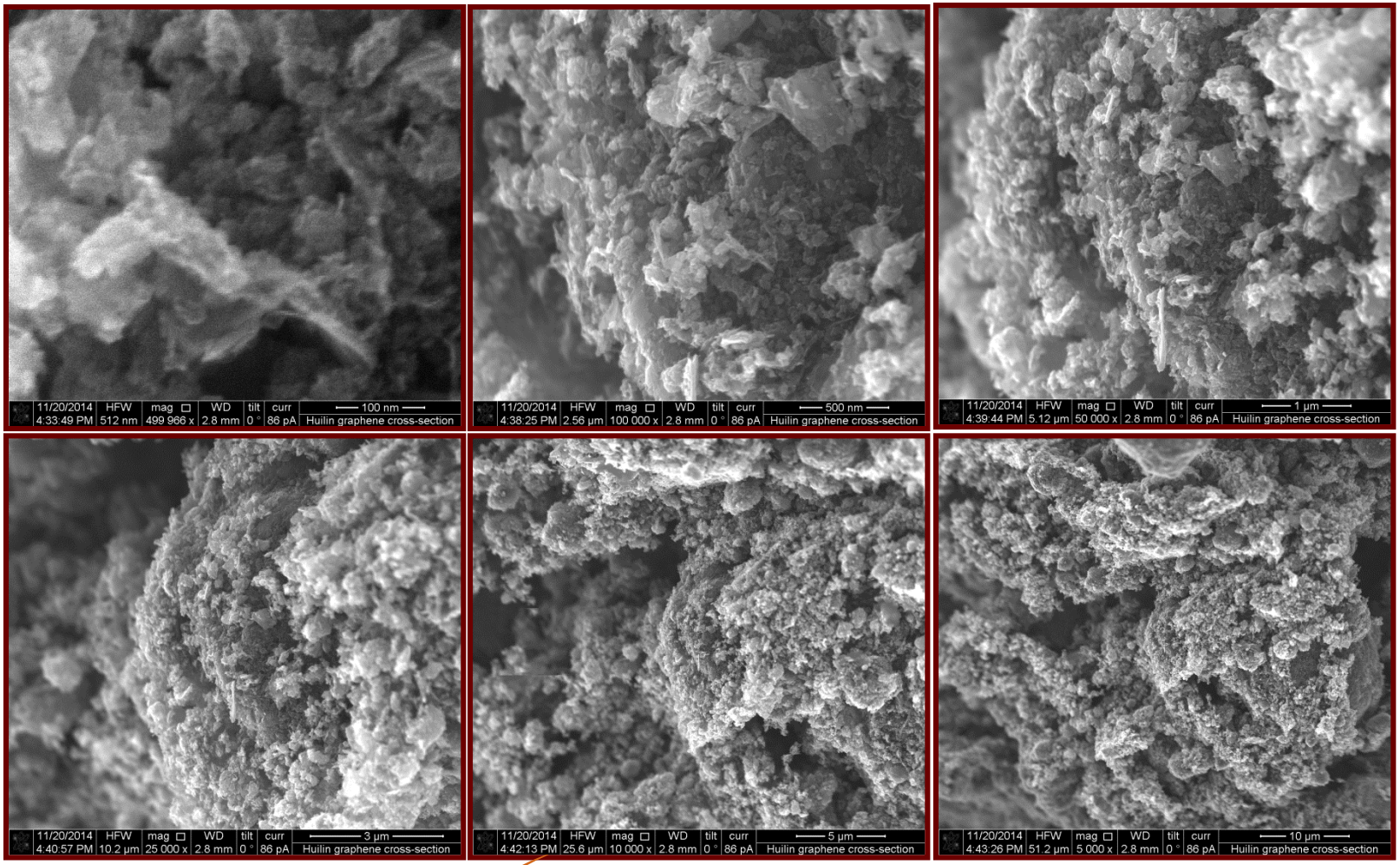
Milestones

Status	Due Date	Type	Milestones, Deliverables, or Go/No-Go Decision	Decision Criteria
Met	11/13/2014	Regular	2-D to 3-D engineering of graphene support	Successfully fabricate a 3-D porous structure. Target is to produce 10grams
Met	12/31/2014	Regular	Pt deposition on ITO-modified 3-D support	Deposit PT achieving a <4 nm Pt particle size
Met	3/31/2015	Stretch	RDE test of 3-D porous electrocatalysts	Report on the ability to achieve an ORR 80 mA/mg with 20% higher durabilty than baseline.
Progress	6/30/2015	Stretch	MEA test of optimized catalysts Deliverable: provide pathway to •reduce Pt loading by factor of 3 to achieve 240 mA/mg Pt •Mass activity loss <10%	Report on the ability to achieve an ORR 80 mA/mg, 2X reduction in carbon corrosion over baseline and< 20% loss in activity after 1.2V hold test.

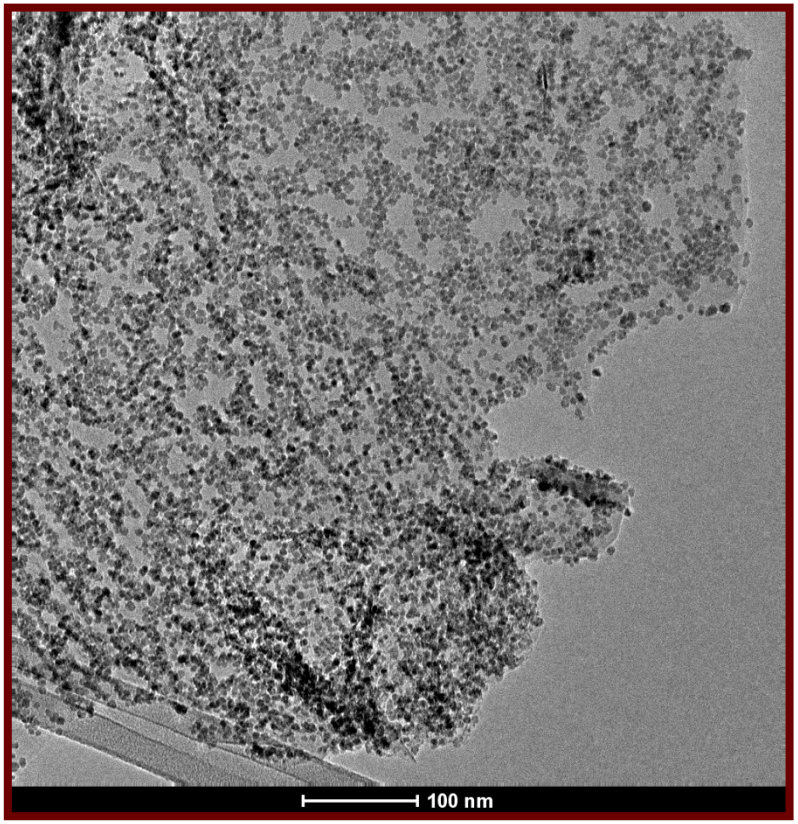
Technical Accomplishments

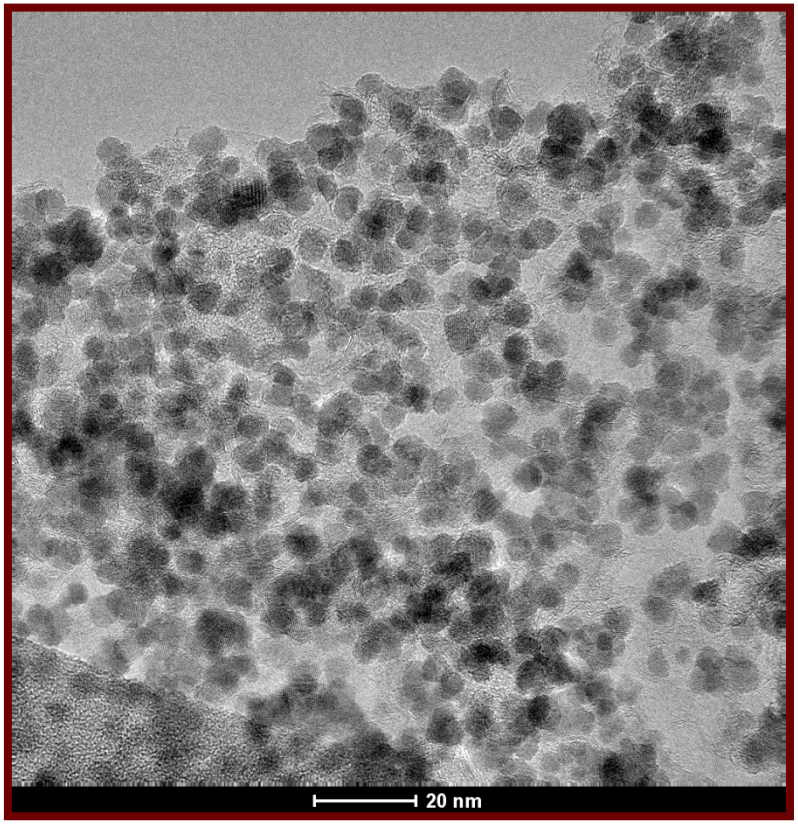
Success in Synthesizing 3D Graphene



Technical Accomplishments

Highly Dispersed ITO on 3D Graphene





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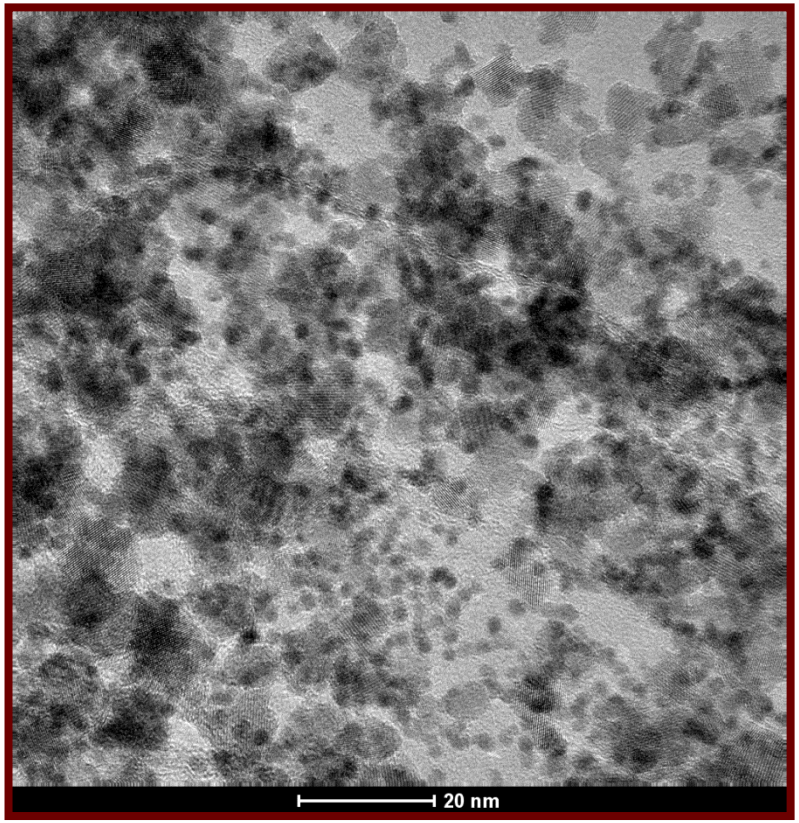
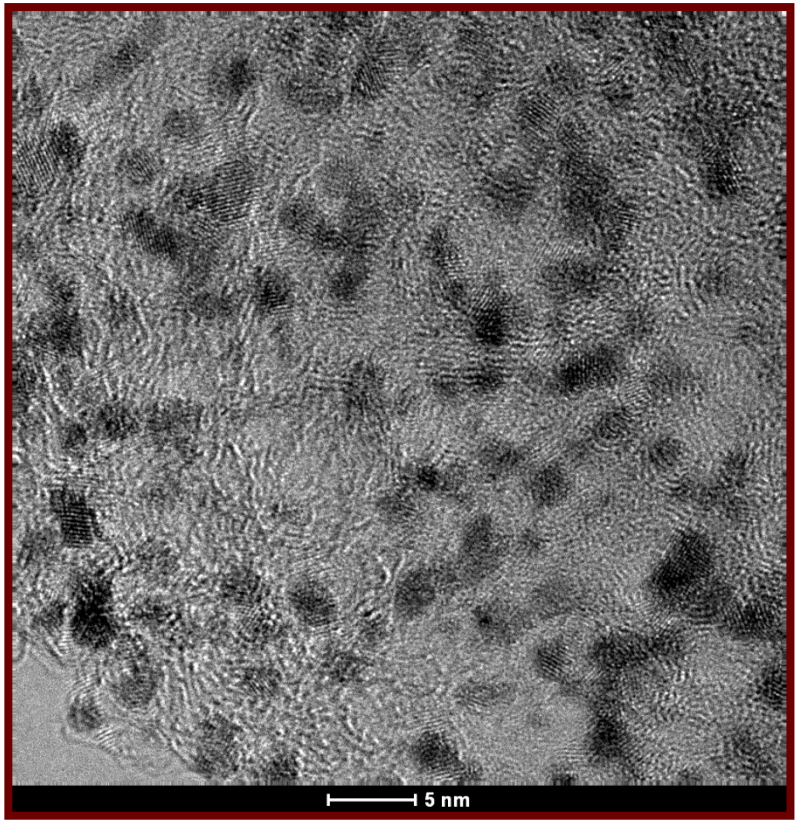
Technical Accomplishments

Pt loaded onto 3D Graphene Using Solution Chemistry Method

With ITO



Without ITO



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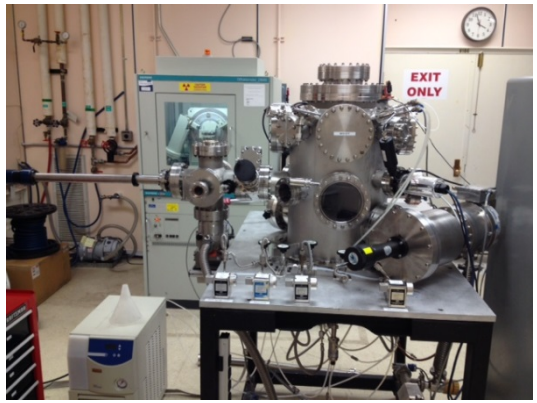
Pt Coating Using PVD at LANL

- Dedicated sputter deposition system.
  - 4 sputter guns (1 DC, 3 RF), Load lock chamber and two turbo pumps came with system
  - Inficon QCM rate monitor for programmed depositions
  - 4 controlled-leak valves for reactive sputtering
- Large chamber / interior volume to accommodate experiment and project growth
- Special BN vacuum built to accommodate acoustic motor and post affixing Chladni plate designed for the project



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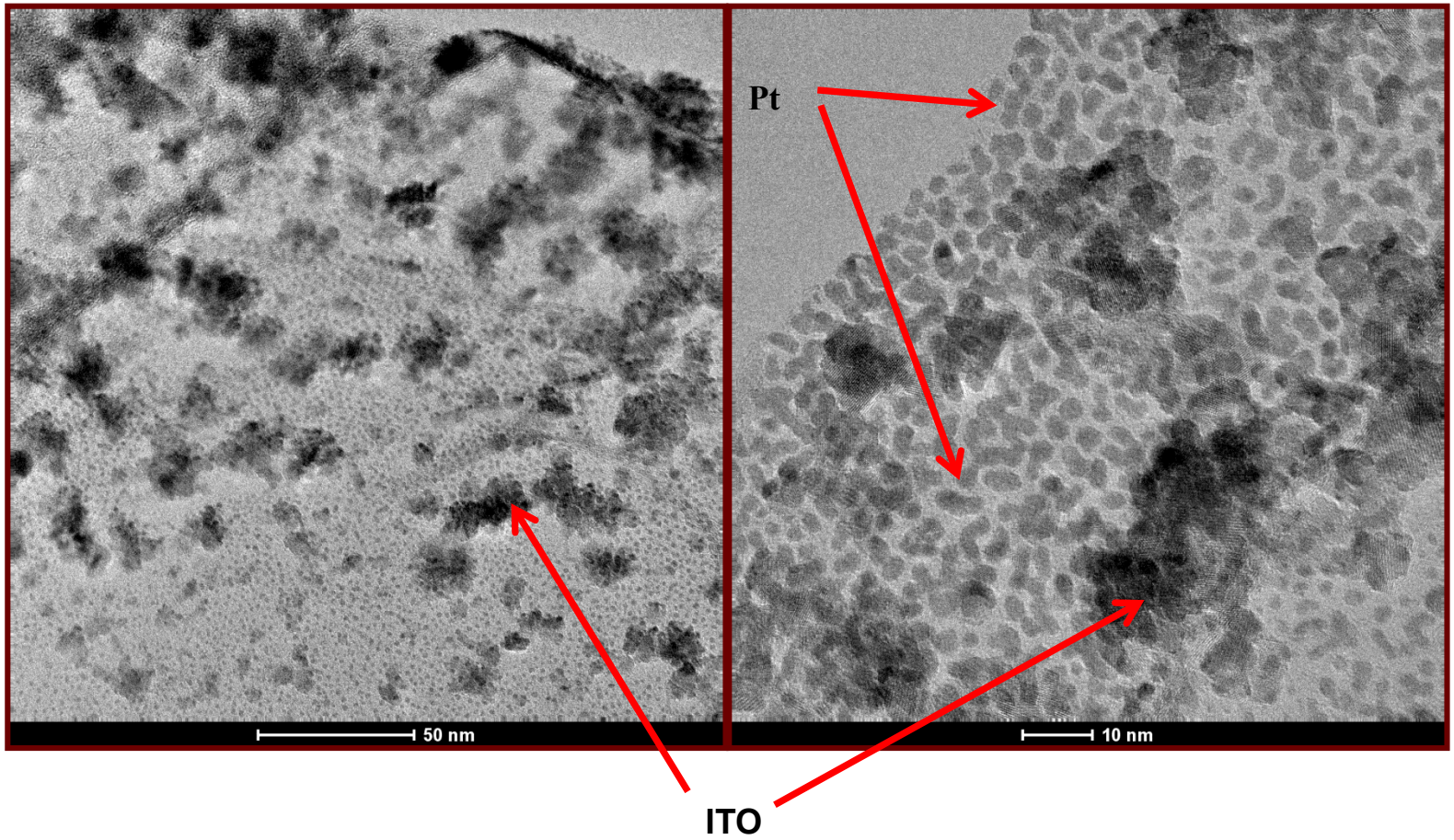
Technical Accomplishments

Pt deposition by PVD method



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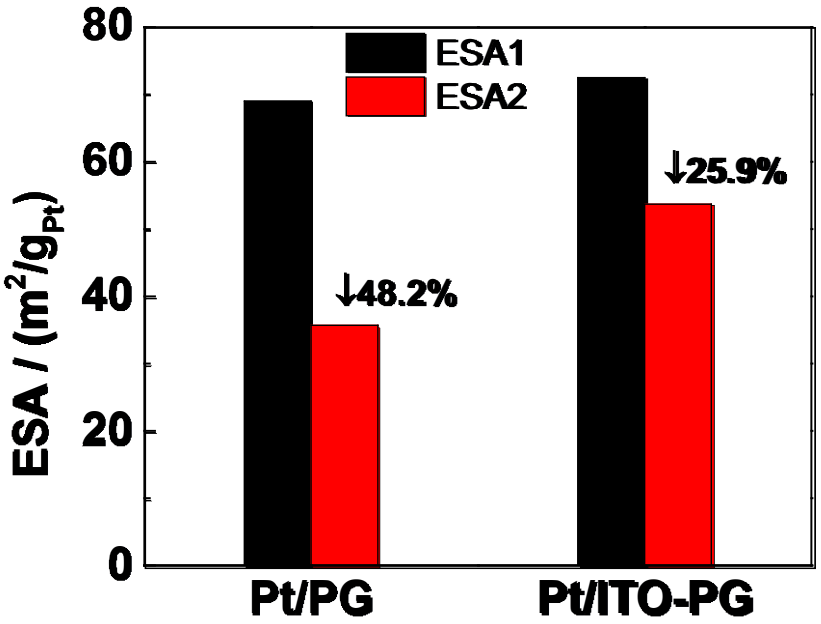
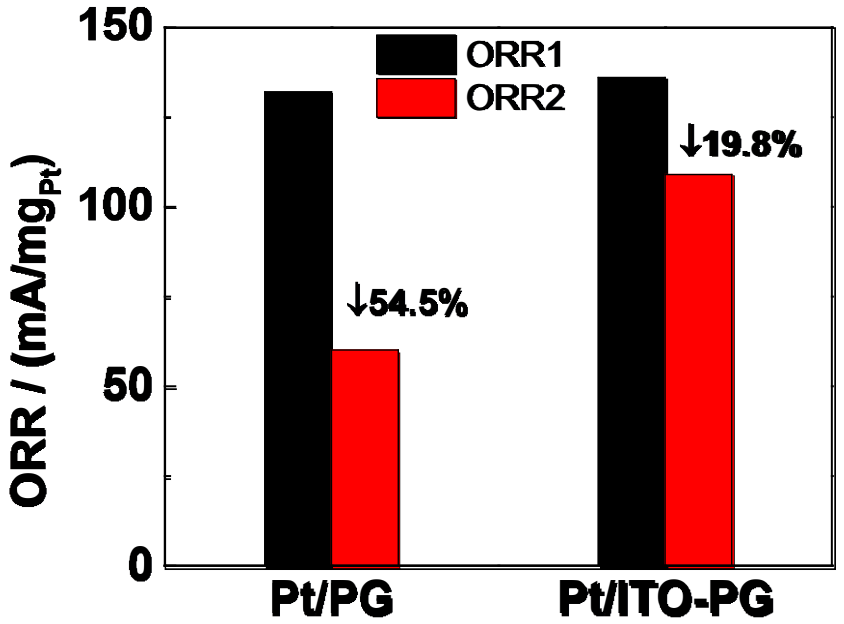
Technical Accomplishments

Improved Electrochemical Activity/Durability





Performances exceeds the targets:

- **ORR: 135mA/mg_{Pt} vs 80mA/mg_{Pt}**
- **Durability: 1.86X (ESA), 2.75X (ORR) vs. 1.2X**

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Technical Conclusions/Summary

- Successfully synthesized 3D structured graphene
- Highly dispersed ITO on 3D structured graphene can be synthesized using solution chemistry method
- Both solution chemistry method and PVD are able to highly disperse Pt nanoparticles on ITO coated 3D graphene
- Activity and durability exceed proposed targets.

Future Work

- **Demonstrate MEA activity/durability using Pt/ITO-3D graphene**
- **Optimize electrocatalyst through post-treatment.**
- **Optimizing PVD system for Pt deposition**

Collaborations

PNNL

- **Synthesis of support materials**
- **Deposition of Pt by solution chemistry**

LANL

- **Deposition of Pt by acoustic agitated PVD**
- **MEA fabrication**
- **MEA Testing**

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Publications/Presentations

- Y Shao, Y Cheng, R Kou, Y Wang, J Liu. “Durable Nanostructured Electrocatalysts for Oxygen Reduction Reaction: Materials Design and Testing Protocol.” 2015 MRS Spring Meeting & Exhibit April 6-10, 2015, San Francisco, California

- Y Shao, Y Wang, J Liu. “Porous nanocomposite from scalable synthesis for electrocatalytic applications”. Invention Report filed on Dec. 9/2014.

- R Borup, E Brosha, J Liu, Y Shao, Y Wang, T Rockward, Fuel Cell Tech Team Review, Detroit, May 13 2015.

Acknowledgements

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