V.D.14 High Aspect Ratio Nano-Structured Pt-Based PEM Fuel Cell Catalysts

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Project Start Date: December 5, 2011
Project End Date: December 4, 2013

Fiscal Year (FY) 2012 Objectives

- Demonstrate the synthesis of shape-controlled Pt-alloy fuel cell catalysts
- Quantify the enhanced activity of these fuel cell catalysts

Technical Barriers

This project addresses the following technical barriers from the Fuel Cell section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Cost
(C) Performance

Technical Targets

This project will provide a pathway towards successfully achieve the electrocatalyst DOE technical targets for Pt mass activity. The Pt-based materials developed in this project will support the cost and performance targets in Table 1 by significantly improving the Pt utilization in Pt-based electrocatalyst, thus lowering the primary cost of polymer electron membrane fuel cell systems.

Approach

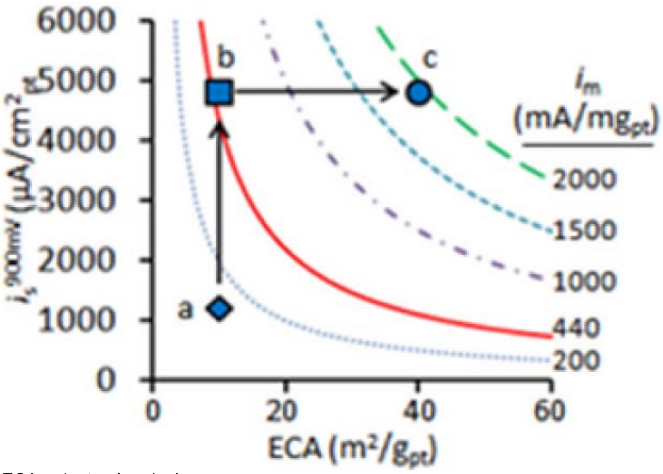
Fabrication of Pt-based fuel cell electrocatalysts that will exceed U.S. DOE mass activity targets by synthesizing nanostructured Pt and Pt-alloy materials with high aspect ratios. This approach has been developed to leverage two proven strategies for improving electrocatalyst activity: 1) alloying Pt with other metals, such as Fe, Co, and Ni, and 2) creating high-aspect ratio materials that exhibit "extended surface" enhancement of their electrocatalytic activity. Both of these strategies, forming Pt alloys and extended surfaces, will increase the specific activity of the high aspect ratio, extended surface Pt-based (HES-Pt) catalyst materials that will be developed in this project. In addition, methods will be developed to create high surface areas for the HES-Pt catalysts, and the combination of the enhanced specific activity and high surface areas will result in mass activities that will surpass the DOE mass activity targets. This approach is depicted in Figure 1.

FY 2012 consists of the following main tasks:

- Fabricate base metal (Ni, Co, Fe) nanowires or nanoplates – Ni, Co, and Fe have been selected as

TABLE 1. Technical Targets for Electrocatalysts for Transportation Applications

Table 3.4.13 Technical Targets: Electrocatalysts for Transportation Applications				
Characteristic	Units	2011 Status	Targets	
			2017	2020
Platinum group metal total content (both electodes)	g/kw (rated)	0.19	0.125	0.125
Platinum group metal (PGM) total loading	Mg PGM/cm^2 electrode area	0.15	0.125	0.125
Loss in initial catalytic activity	% mass activity loss	48	<40	<40
Electro catalyst support stability	% mass activity loss	<10	<10	<10
Mass activity	A/mg Pt @ 900 mV$_{iR\text{-}free}$	0.24	0.44	0.44
Non-Pt catalyst activity per volume of supported catalyst	A/cm^3 @ 800 mV$_{iR\text{-}free}$	60 (measured at 0.8 V) 165 (extrapolated from >0.85 V)	300	300



ECA - electrochemical area

FIGURE 1. Electrocatalyst mass activity may be increased by separate strategies to increase specific activity (A → B) and ECA (B → C). The colored lines are constant mass activities corresponding to the i_m labels on the right of the plot.

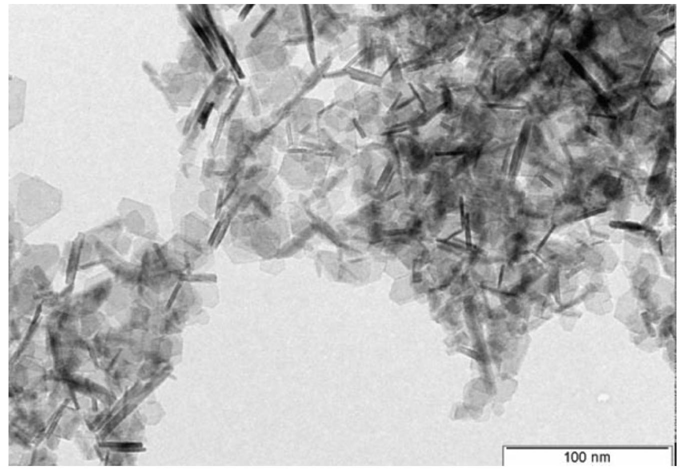


FIGURE 2. Transmission electron microscopy of Ni nanoplates

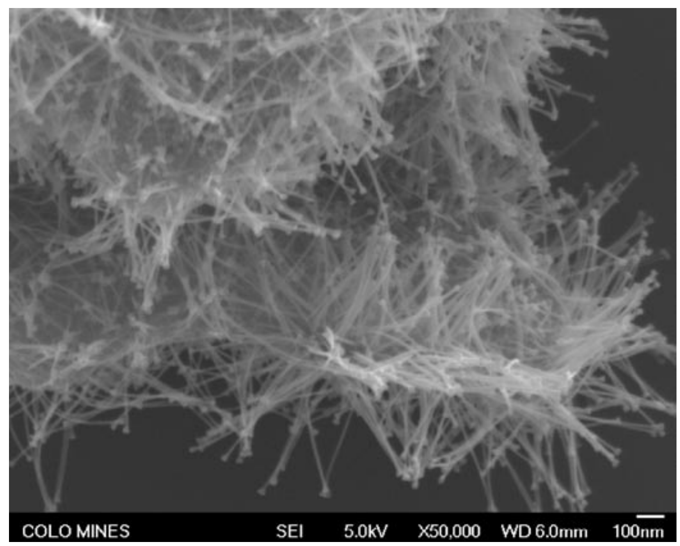


FIGURE 3. Scanning electron microscopy of Co nanowires

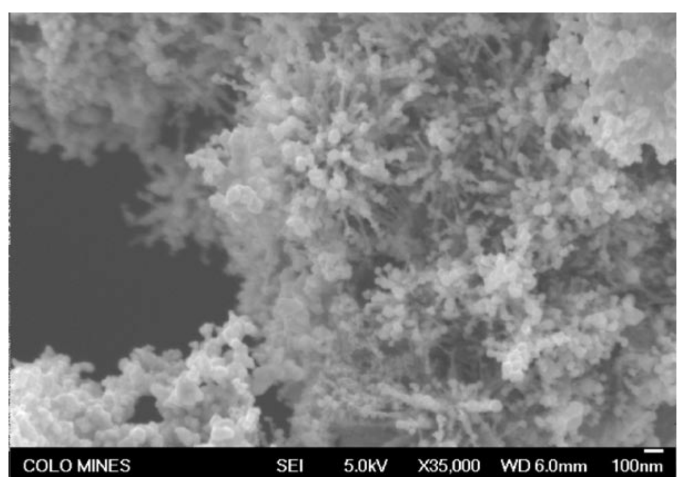


FIGURE 4. Scanning electron microscopy of nanowire-based HES Pt-Co catalyst materials

the best candidates to create high activity HES-Pt alloy catalyst materials based on previous studies of activity enhancement in nanoparticle-based Pt alloys with these metals. The nanowire and nanoplate shapes were selected to yield the extended surface activity enhancement that has been previously observed in Pt nanowires at NREL.

- Create a Pt-alloy using a base metal nanoplate/nanowire – The base metals may be used to create Pt-alloys by the galvanic displacement method, which displaces the base metal atoms with Pt. This has been proven to be an effective method to create alloys with base metals while preserving the base metal shape.
- Characterize the electrochemical performance of the Pt-alloy nanoplate/nanowire by rotating disc electrode (RDE) – Electrochemical characterization of the materials by RDE provides a preliminary means to evaluate the activity of the HES Pt-alloy material to determine the materials best suited for implementation in fuel cells.

FY 2012 Accomplishments

- Task 1 - Synthesized both nanowires and nanoplates of Ni and Co (Figures 2 and 3)
  - Successfully developed methods to fabricate four different base metal materials for HES Pt-alloy catalysts
- Task 2 – Synthesized nanowire HES Pt-Co catalyst (Figure 4)
  - Successfully fabricated the HES Pt-Co nanowire by galvanic displacement of Co nanowires synthesized from Task 1

- Task 3 – Attempted electrochemical characterization of HES Pt-Co catalyst material
  - Results were inconclusive, further development of the HES Pt-Co preparation is needed before electrochemical characterization.

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Future Directions

In FY 2013, the following tasks will be performed:

- Synthesize HES Pt-alloys from another base metal or shape: To fully explore the activity enhancement of HES-Pt alloys, fabricate a Ni nanowire or nanoplate-based HES-Pt alloy material or a Co nanoplate-based HES-Pt alloy material.
- Continue development of existing HES Pt-Co catalyst preparation methods to enable electrochemical characterization.
- Develop methods to create high surface areas for HES-Pt alloy catalysts.

FY 2013 Planned Milestones

- Characterize the compositional dependence of Pt in HES-Pt alloy materials.
- Complete the synthesis and characterization of three separate HES-Pt alloy materials.
- Fabricate and evaluate the highest performing HES-Pt alloy in fuel cells.

FY 2012 Publications/Presentations

1. "Enhanced activity fuel cell electrocatalysts achieved by shape control of platinum nanostructures," Presented at the 2012 World Tech Connect, Larsen BA, Neyerlin KC, Bult JB, Bochert C, Blackburn JL, Kocha SS, Pivovar BS.