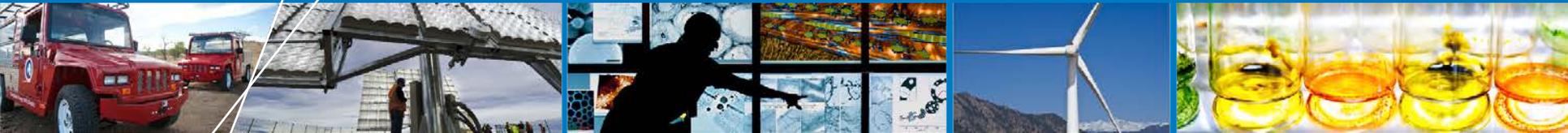


# High aspect ratio fuel cell catalysts



**2013 DOE Hydrogen and Fuel  
Cells Program Review**

**Brian A. Larsen, Ph.D.**

**5/16/2013**

# Overview

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## Timeline

- Project start date: 12/5/2011
- Project end date: 4/12/2013
- Percent complete: 100%

## Barriers addressed

- Cost (Catalyst/MEA)
- Performance (Catalyst/MEA)

## Budget

- \$150,000 over FY12-13
- In-kind laboratory support from NREL

# Relevance

## Objective

- Produce novel high aspect ratio nano-structured Pt-based catalyst materials with increased activity and increased Pt utilization, moving towards meeting all 2017 DOE catalyst targets

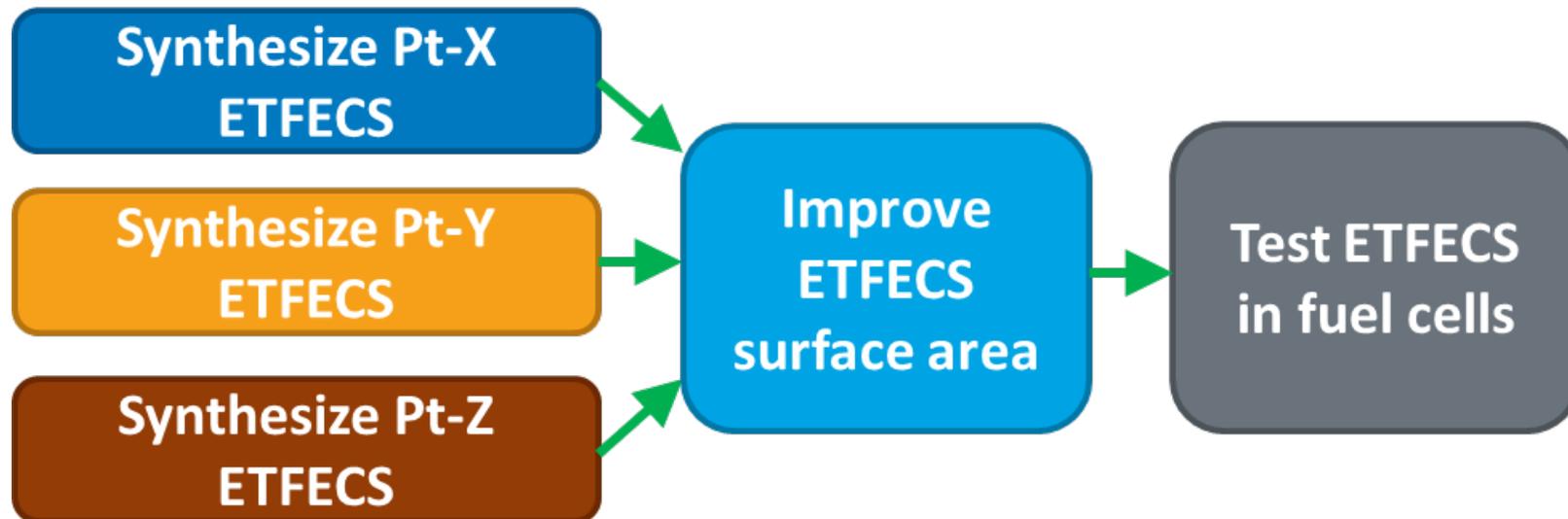
Table 3.4.13 Technical Targets: Electrocatalysts for Transportation Applications

Characteristic	Units	2011 Status	Targets	
			2017	2020
Platinum group metal total content (both electrodes) <sup>a</sup>	g / kW (rated)	0.19 <sup>b</sup>	0.125	0.125
Platinum group metal (pgm) total loading <sup>a</sup>	mg PGM / cm <sup>2</sup> electrode area	0.15 <sup>b</sup>	0.125	0.125
Loss in initial catalytic activity <sup>c</sup>	% mass activity loss	48 <sup>b</sup>	<40	<40
Electro catalyst support stability <sup>d</sup>	% mass activity loss	<10 <sup>b</sup>	<10	<10
Mass activity <sup>e</sup>	A / mg Pt @ 900 mV <sub>iR-free</sub>	0.24 <sup>b</sup>	0.44	0.44

# Approach

## Synthesis of Pt Alloy Extended Thin-Film Electrocatalyst Structures: Pt Alloy ETFECS

- **Synthesis of Pt alloy ETFECS using 3 different alloying metals**
  - The objective of this activity is to maximize the Pt ETFECS specific activity
- **Development of methods to increase ETFECS surface area**
  - Increasing the surface area will increase the mass activity of the Pt ETFECS
- **Integrate and evaluate ETFECS in MEAs**

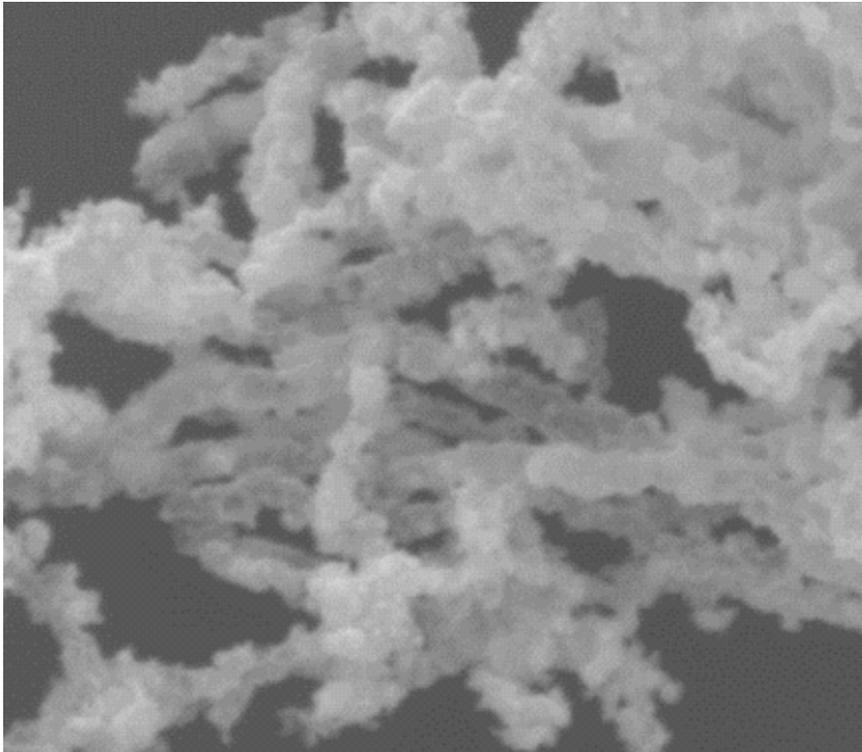


# Approach

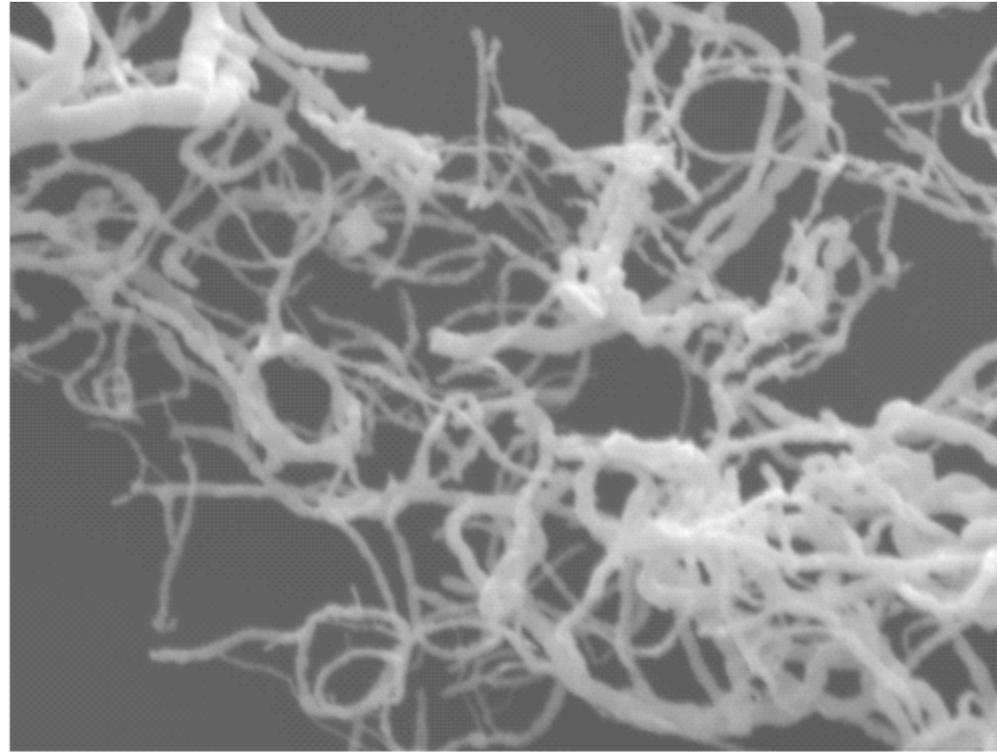
## 2012 Milestones

- Fabricate 2 different Pt alloy ETFECS that demonstrate 2X specific activity relative to pure Pt ETFECS
  - Both milestones were completed: PtNi nanowires and PtCo nanowires

PtNi nanowires



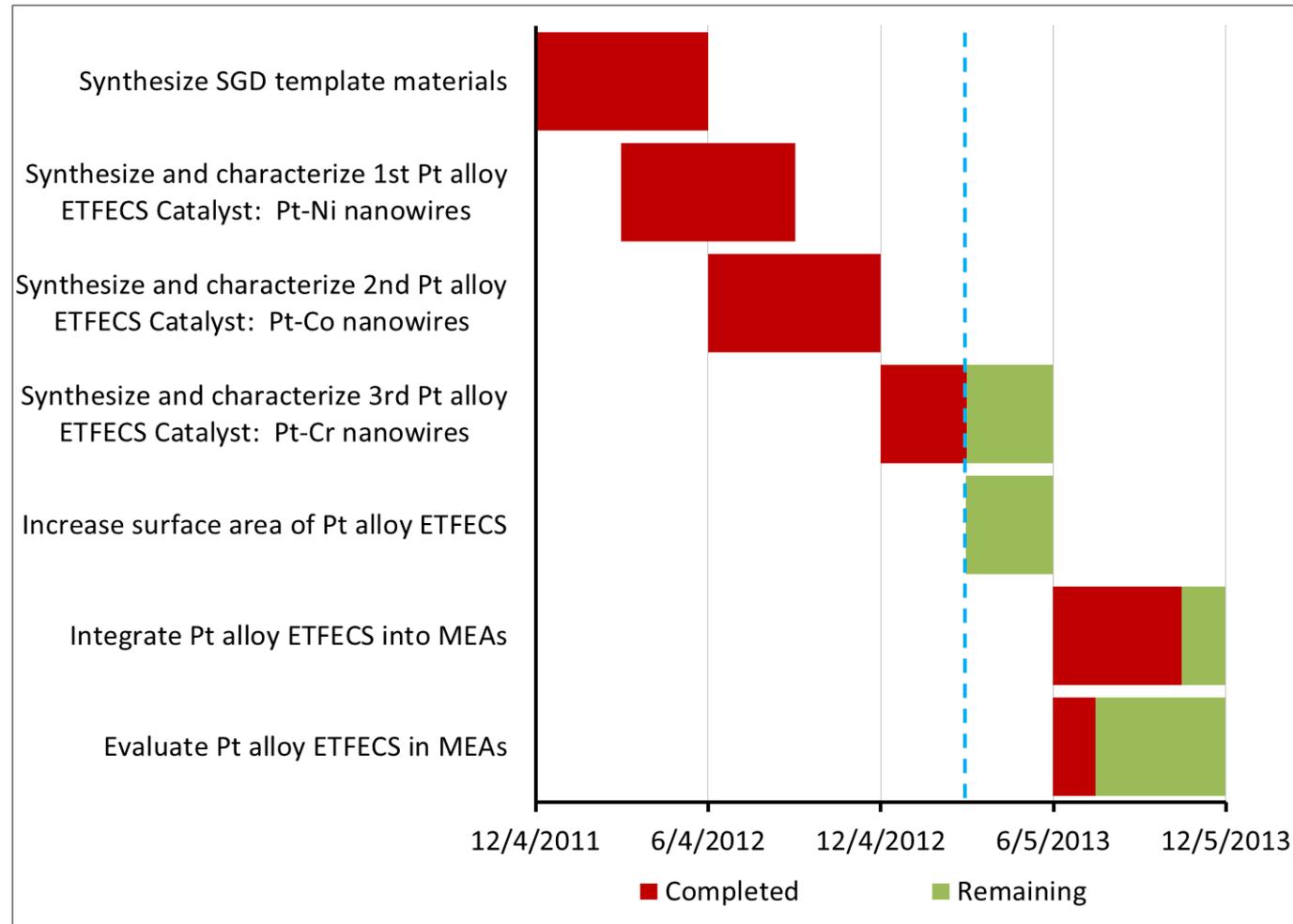
PtCo nanowires



# Approach

## Progress & Milestones

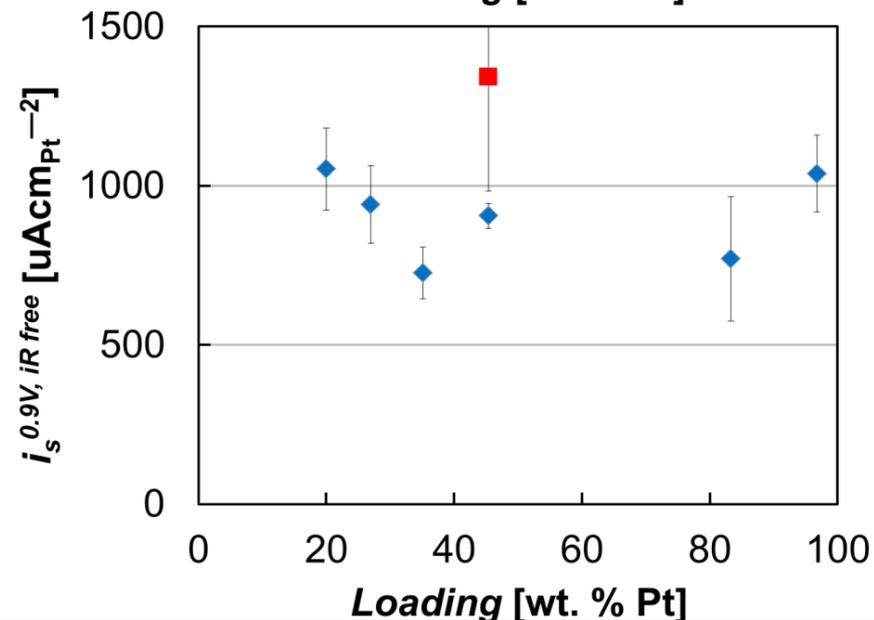
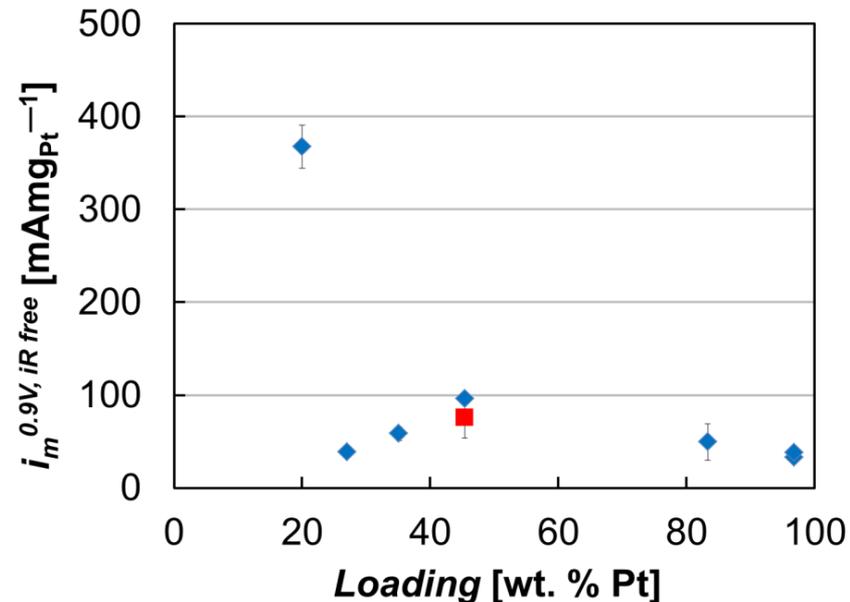
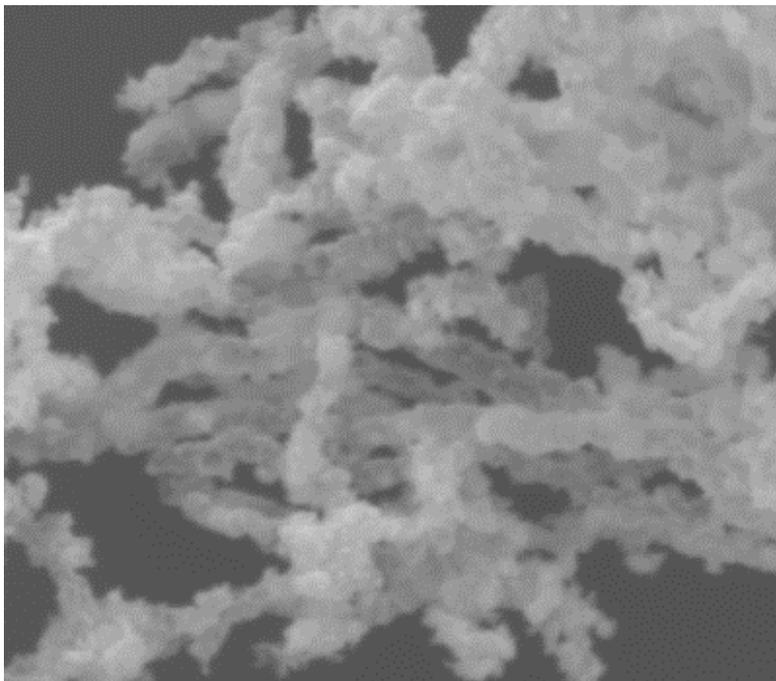
- All past project milestones have been completed on schedule and future milestones are on schedule or ahead of schedule



# Accomplishments

PtNi nanowires with mass activity of 380  $\text{mA}/\text{mg}_{\text{Pt}}$

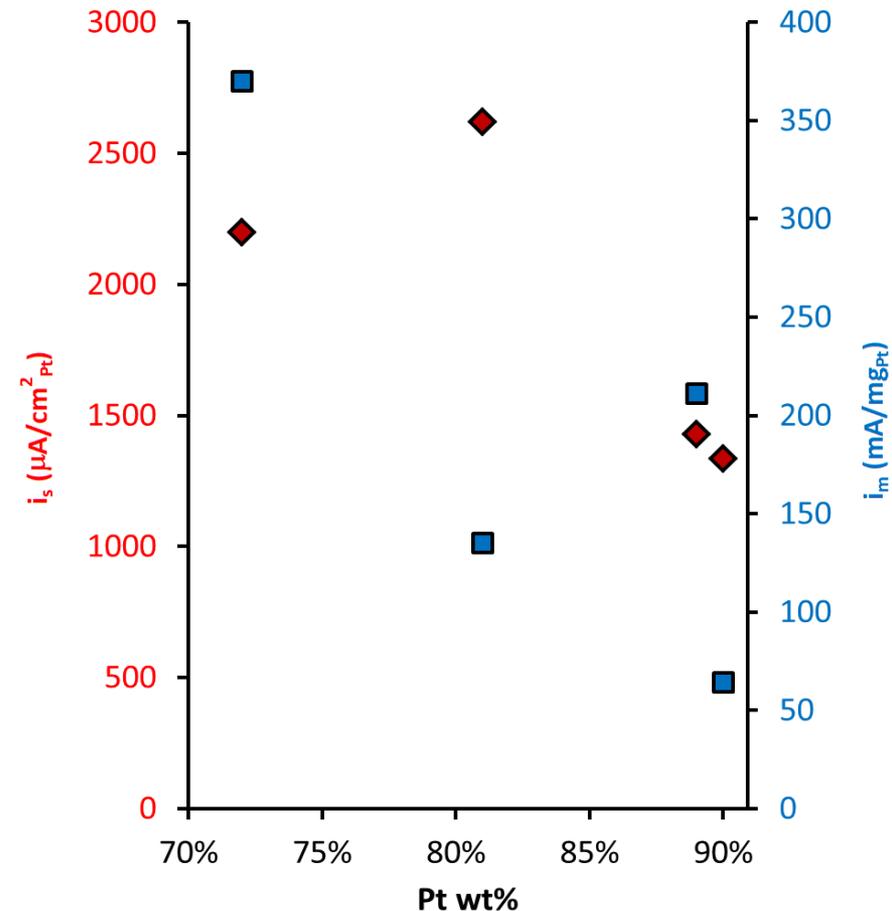
- Synthesized by galvanic displacement of commercially available Ni nanowires
- Highest mass activity at low Pt loading
- Specific activity increased as high as 1400  $\mu\text{A}/\text{cm}^2$  after thermal annealing, but greatly decreased surface area



# Accomplishments

PtCo nanowires with mass activity of 370 mA/mg<sub>Pt</sub>

- Synthesized by solvothermal reduction of Pt(AcAc)<sub>2</sub> and decomposition of Co<sub>2</sub>(CO)<sub>8</sub>
- Highest mass activity at low Pt loading
- Very high specific activity: 2600 μA/cm<sup>2</sup>



# Accomplishments

## Integration of PtCo nanowires in MEAs

- **Best ETFECS MEA performance to date**
  - Greatly improved results relative to Pt ETFECS in MEAs
  - Favorable performance relative to 50 wt% Pt/HSC baseline

### 50 wt% Pt/HSC baseline

	ECA $\text{m}^2_{\text{Pt}}/\text{g}_{\text{Pt}}$	$i_s$ corr $\text{uA}/\text{cm}^2_{\text{Pt}}$	$i_m$ corr $\text{mA}/\text{mg}_{\text{Pt}}$
RDE	100	275	275
MEA	82	160	130

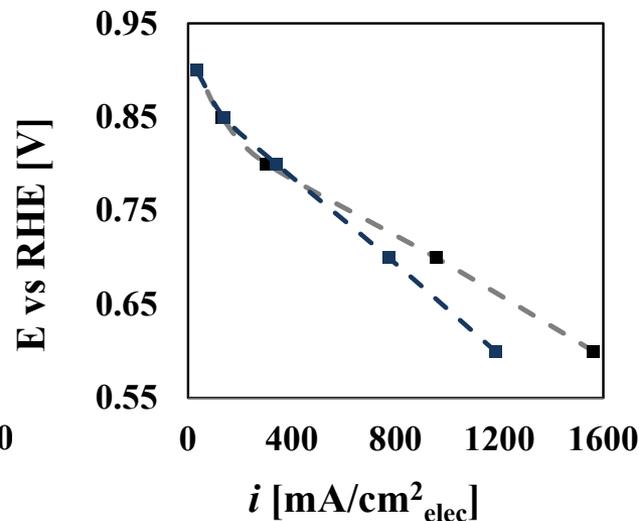
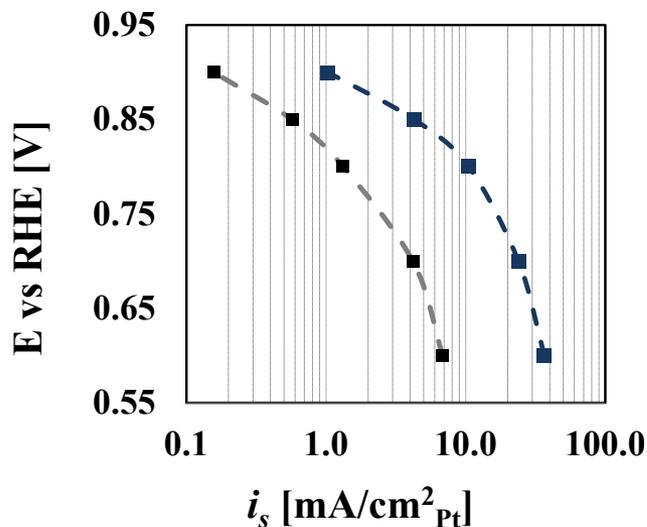
### 50 wt% PtCo ETFECS

	ECA $\text{m}^2_{\text{Pt}}/\text{g}_{\text{Pt}}$	$i_s$ corr $\text{uA}/\text{cm}^2_{\text{Pt}}$	$i_m$ corr $\text{mA}/\text{mg}_{\text{Pt}}$
RDE	17	2200	370
MEA	14	1050	150

### Testing Conditions:

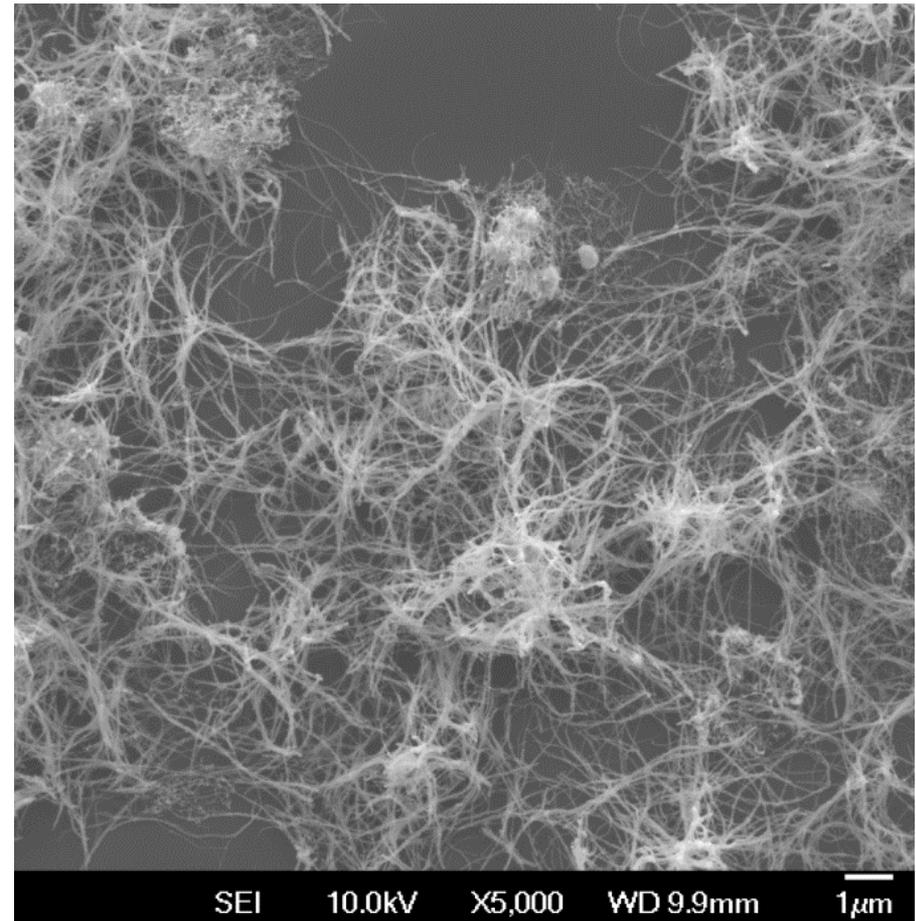
**5cm<sup>2</sup>-single serpentine flow field**  
**80°C 100% RH**  
**H<sub>2</sub>/O<sub>2</sub> 150/300 sccm**  
**150 kPa (~100 kPa H<sub>2</sub>/O<sub>2</sub>)**  
**N212 Membrane**

**15 min per point –Anodic Sweep**  
**JM-GDE (Anode)/SGL25BC**  
**Cathode**  
**0.28 mg<sub>Pt</sub>/cm<sup>2</sup><sub>elec</sub> –Pt/HSC**  
**0.22 mg<sub>Pt</sub>/cm<sup>2</sup><sub>elec</sub> –PtCo w/GCNF2**



# Recommended Future Work

- **Synthesis and characterization of PtCr nanowires**
  - Have already synthesized PtCr materials
  - RDE testing is on-going



# Recommended Future work

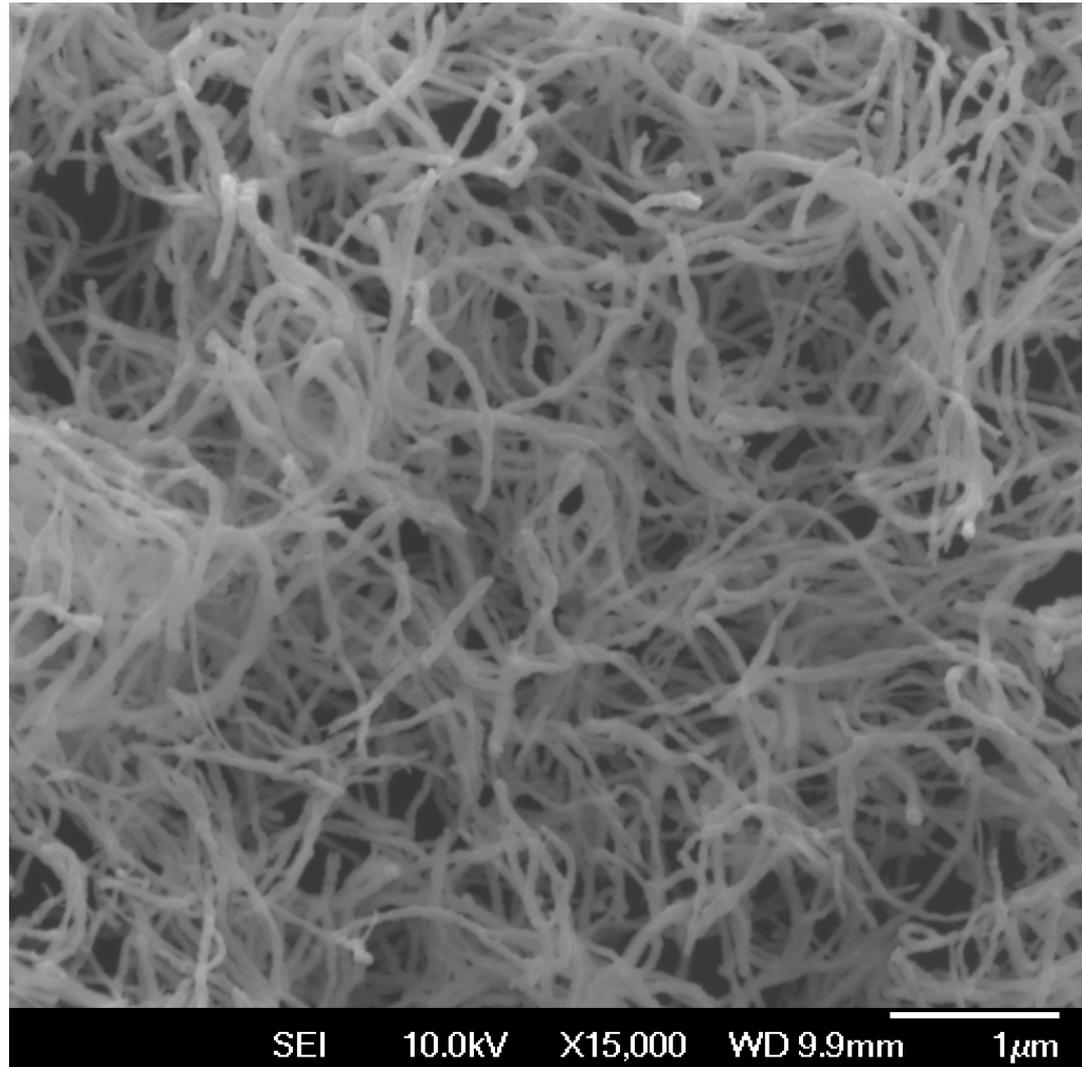
## Increase surface area of ETFECS materials

- Synthesize ternary Pt-alloy ETFECS with sacrificial “leachable” metal (e.g. Fe, Mn)

## Improve MEA integration of Pt-alloy ETFECS

- Increase performance at high current densities

Ternary Pt-alloy ETFECS:  $\text{Pt}_{22}\text{Co}_{75}\text{Cr}_3$



# Summary Slide

- **Relevance**
  - Produce novel high aspect ratio nano-structured Pt-based catalyst materials with increased activity and increased Pt utilization, moving towards meeting all 2017 DOE catalyst targets
- **Approach**
  - Synthesize Pt-alloy ETFECS materials with improved activity relative to pure Pt ETFECS
- **Accomplishments**
  - Synthesized PtNi and PtCo nanowire ETFECS with high mass activities (380 and 370 mA/mg<sub>Pt</sub>)
  - Integrated PtCo in MEAs and outperformed Pt/HSC
- **Recommended Future work**
  - Synthesize PtCr nanowire ETFECS
  - Synthesize Pt ternary nanowire ETFECS to improve surface area
  - Continue Pt alloy ETFECS integration in MEAs