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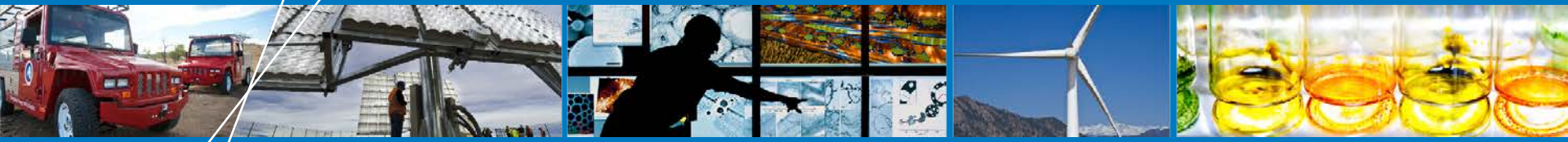
# High Aspect Ratio Nano-Structured Pt-based PEM Fuel Cell Catalysts



DOE Hydrogen and Fuel Cells Program Review 2012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# Overview

## Timeline

- Start – December 2011
- Finish – December 2013
- 20% complete

## Barriers

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

## Budget

- Total project funding: $113,200
- DOE FY11 Funding: $113,200

# Relevance

## Objective

- **Produce novel high aspect ratio nano-structured Pt-based catalyst materials with increased activity and increased Pt utilization, moving towards meeting all 2015 DOE catalyst targets**

**Table 3.4.12 Technical Targets: Electrocatalysts for Transportation Applications**

| Characteristic | Units | 2005 Status [a] | | Stack Targets | |
|---|---|---|---|---|---|
| | | Cell | Stack | 2010 | 2015 |
| Platinum group metal total content (both electrodes) | g / kW (rated) | 0.6 | 1.1 | 0.3 | 0.2 |
| Platinum group metal (pgm) total loading [b] | mg PGM / $cm^2$ electrode area | 0.45 | 0.8 | 0.3 | 0.2 |
| Cost | $ / kW | 9 | 55 [c] | 5 [d] | 3 [d] |
| Durability with cycling | | | | | |
| Operating temp $\leq$80°C | hours | >2,000 | ~2,000 [e] | 5,000 [f] | 5,000 [f] |
| Operating temp >80°C | hours | N/A [g] | N/A [g] | 2,000 | 5,000 [f] |
| Electrochemical area loss [h] | % | 90 | 90 | <40 | <40 |
| Electrocatalyst support loss [h] | mV after 100 hours @ 1.2V | >30 [i] | N/A | <30 | <30 |
| Mass activity [j] | A / mg Pt @ 900 $mV_{iR\text{-}free}$ | 0.28 | 0.11 | 0.44 | 0.44 |
| Specific activity [j] | μA / $cm^2$ @ 900 $mV_{iR\text{-}free}$ | 550 | 180 | 720 | 720 |
| Non-Pt catalyst activity per volume of supported catalyst | A / $cm^3$ @ 800 $mV_{IR\text{-}free}$ | 8 | N/A | >130 | 300 |

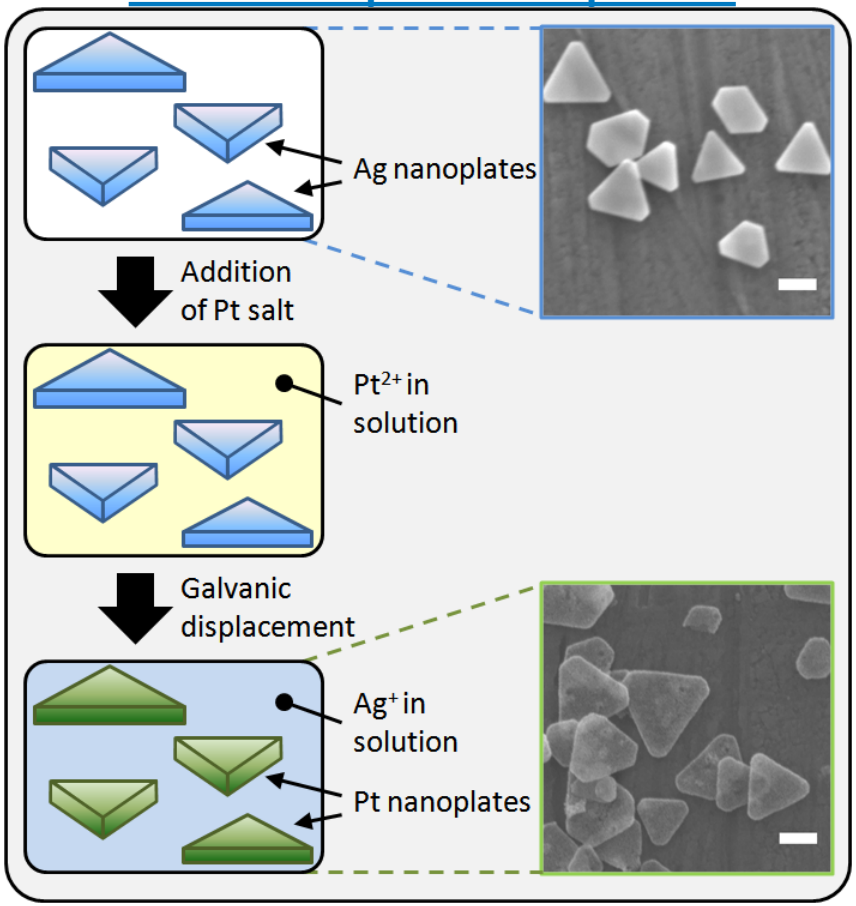
# Approach

**Synthesis of Extended Thin-Film Electrocatalyst Structures: ETFECS**

- **Galvanic displacement of controlled shape nanomaterials**
- **Control of galvanic displacement reactions can allow tuning of catalyst morphology**

**Pt nanotubes synthesized by galvanic displacement**

**Galvanic displacement process**

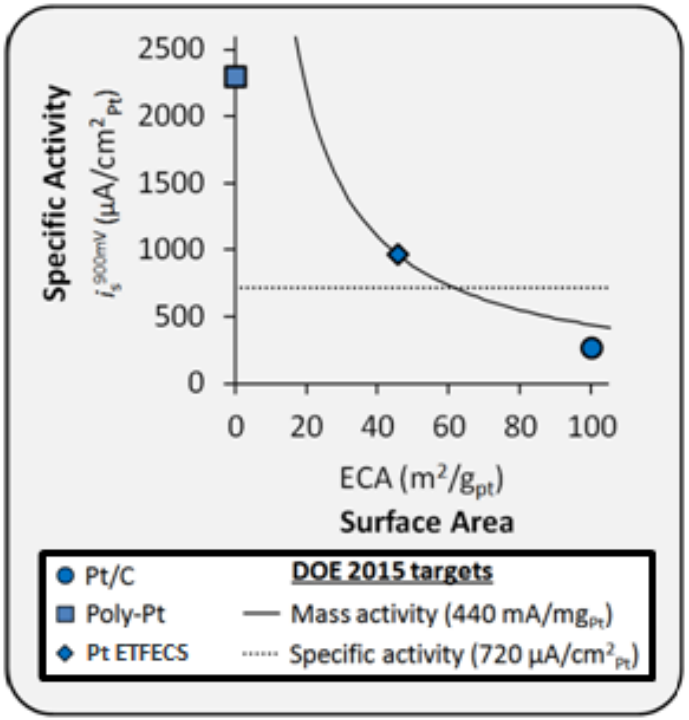


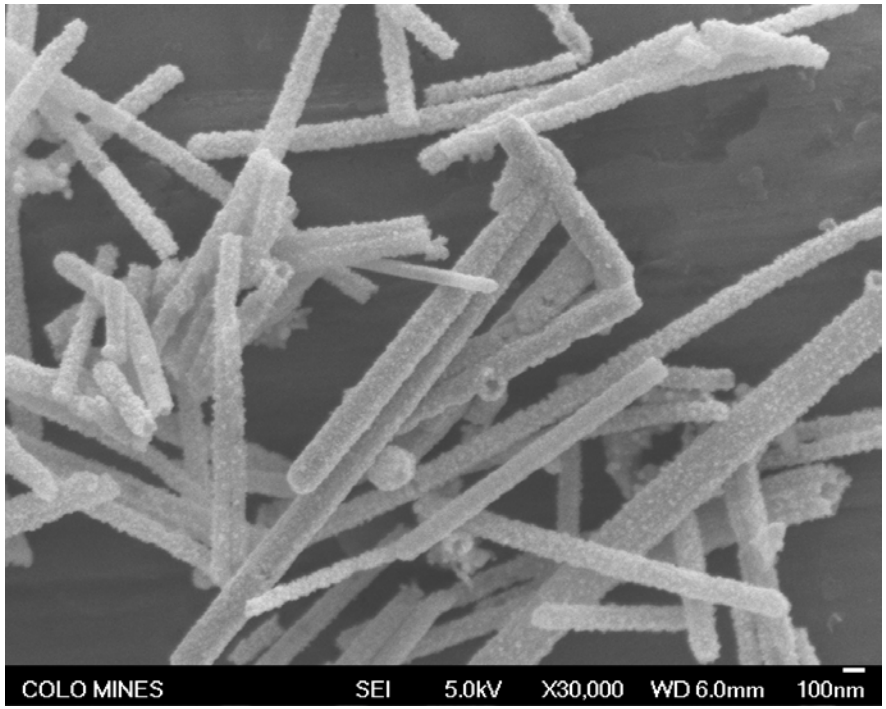

*Scale bars are 1 micron

# Accomplishments and Progress

## Synthesis of Pt nanotube

- Ag used as template materials
- High specific activity for both materials (>1000 $\mu A/cm^2_{Pt}$)
- Pt nanotubes achieved 450 mA/mg Pt in RDE half-cell testing
- Synthesized in gram scale quantities

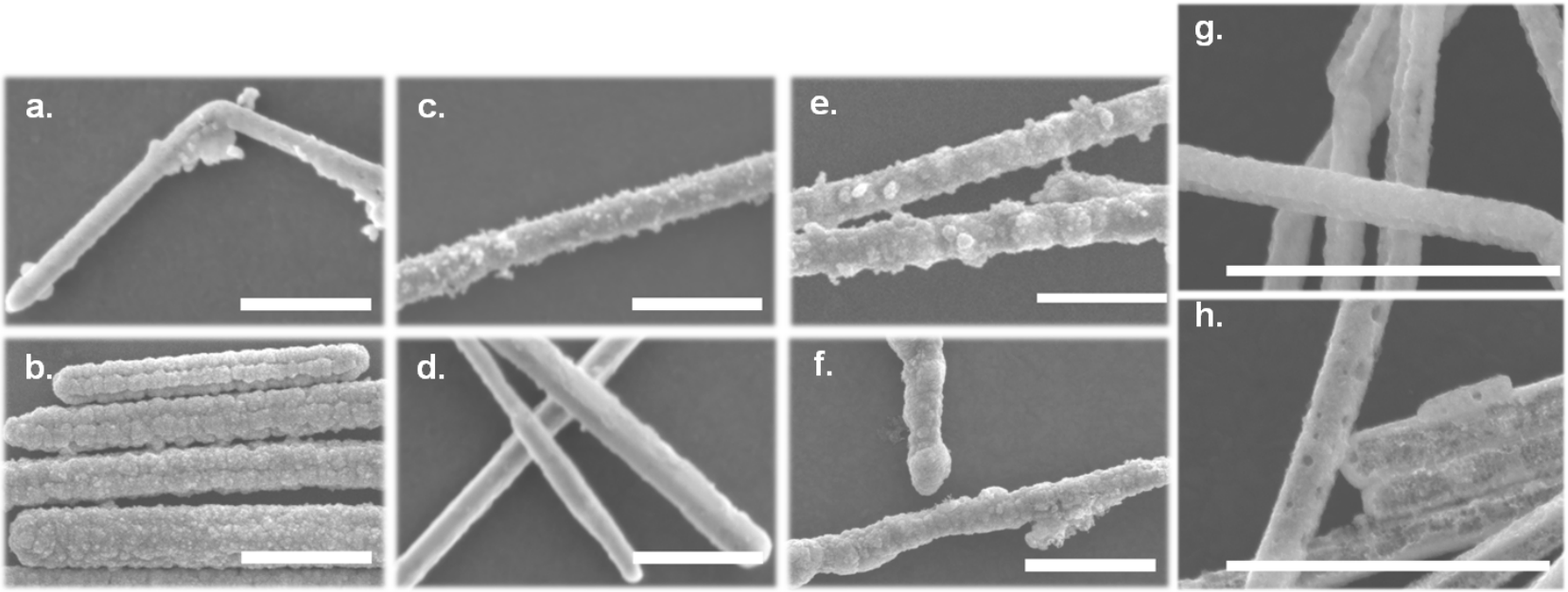


# Accomplishments and Progress

**Development of methods to tune ETFECS surface area**

- **Surface ligand effects**
- **Control of surface deposition**
- **>45 m2 per gram achieved**

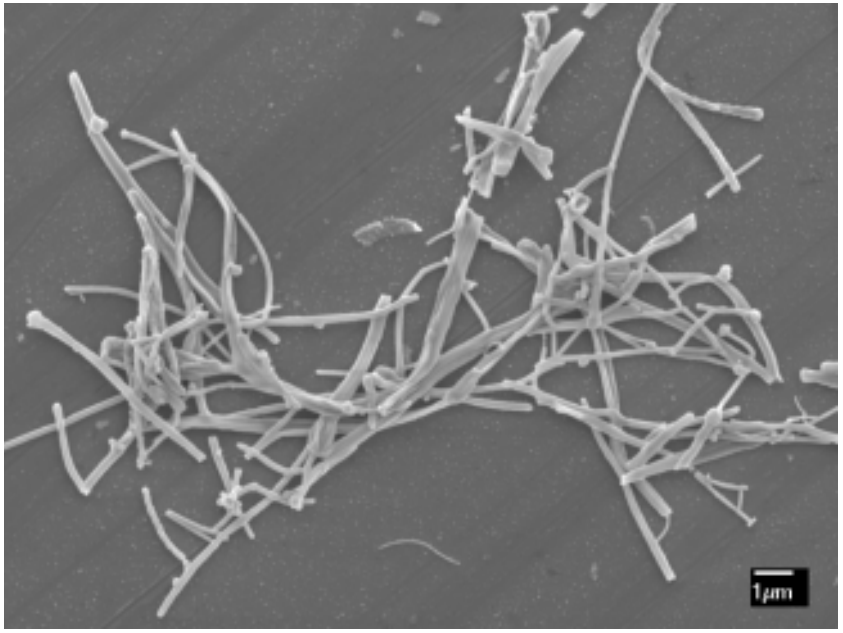



*The surface morphology of materials synthesized by galvanic displacement may be controlled by several parameters, such as utilizing surface ligands with different binding affinities (alkanoic acids [a, b], alkylamines [c, d], and alkanethiols [e, f]) or disrupting conformal deposition on the template surface (g and h).*

# Proposed future work

## Exploration of new Pt-alloy ETFECS materials, including Cu, Ni, and Co

**Initial synthesis results of PtCu ETFECS materials**




$Pt_4Cu_6$

# Project Summary

**Relevance:**

**Meeting all platinum-based electrocatalysts 2015 DOE technical targets for transportation applications.**

**Approach:**

**Synthesize ETFECS (Extended Thin Film ElectroCatalyst Structures) using galvanic displacement reactions.**

**Technical Accomplishments and Progress:**

**Synthesized gram-scale quantities of Pt ETFECS that have exceeded DOE 2015 mass activity target in RDE half-cell testing (450 mA/$mg_{Pt}$).**

**Proposed Future Research:**

**Explore new Pt-alloy ETFECS materials.**

# Acknowledgements

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