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High aspect ratio nano-structured Pt-based PEM fuel cell catalysts

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Background and Introduction

This project will develop novel Pt-based fuel cell catalyst materials that **exceed 2015 DOE cost and performance targets**: High aspect ratio, Extended Surface Pt-based (HES-Pt) catalyst materials

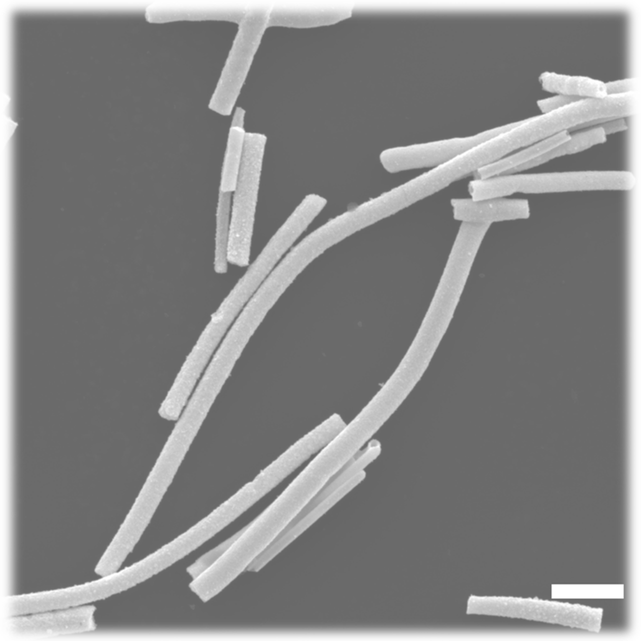


Figure 1 – Nanotube HES-Pt catalysts synthesized at NREL. Scale bar is 1 μm.

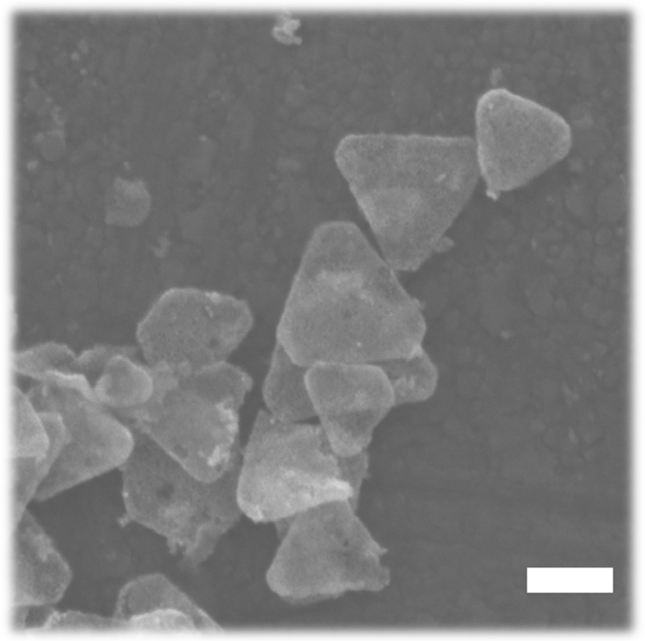


Figure 2 – Nanoplate HES-Pt catalysts synthesized at NREL. Scale bar is 200 nm.

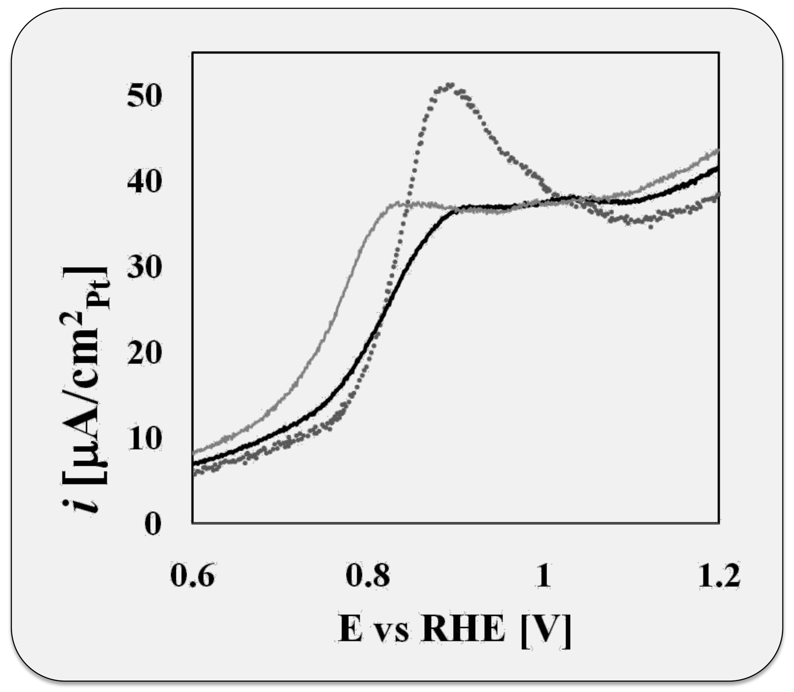
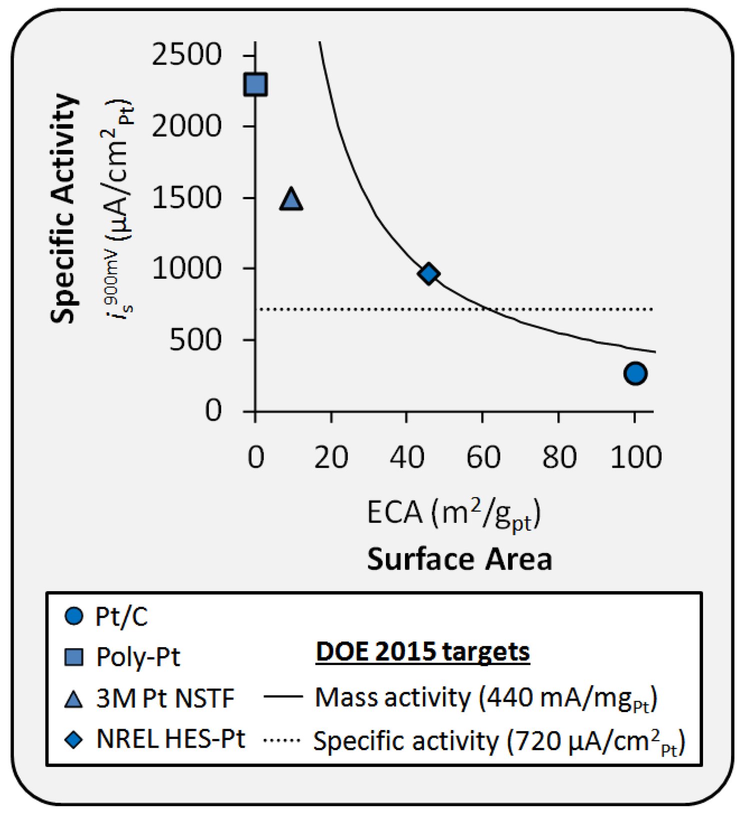


Figure 3 – Bulk-like ORR behavior is observed in HES-Pt electrocatalyst materials. For HES-Pt electrocatalysts (solid black line), the onset of Pt oxide formation is shifted towards bulk polycrystalline Pt (dotted gray line) relative to Pt nanoparticles (solid gray line)



Current state of the art:

- Commercial materials: Carbon-supported Pt nanoparticles (Pt/C)
  - Moderate mass activity (high surface area, but low specific activity)
  - Poor durability due to small particle size
- In-development: 3M Pt Nanostructured Thin Films (Pt NSTF)
  - Improved mass activity (moderate surface area & high specific activity)
  - Poor water management due to continuous film nature

Figure 4 –Specific activities (ORR) and electrochemically available surface areas are shown for several materials: carbon–supported Pt nanoparticles (Pt/C), bulk polycrystalline Pt (Poly-Pt), 3M Pt Nanostructured Thin Films (3M Pt NSTF), and NREL synthesized HES-Pt electrocatalysts

Approach

Synthesis of HES-Pt alloy catalysts by galvanic displacement

- Controlled shape Pt-based nanomaterials may be effectively synthesized by galvanic displacement reactions
- Galvanic displacement reaction is an electroless deposition process in which a sacrificial substrate material serves as a reducing agent and template for a more noble metal which deposits on the substrate surface and displaces the oxidized substrate metal cations.
- The high reduction potential of Pt and the template based nature of galvanic displacement reactions are both ideal characteristics to synthesize the proposed HES-Pt alloy electrocatalysts

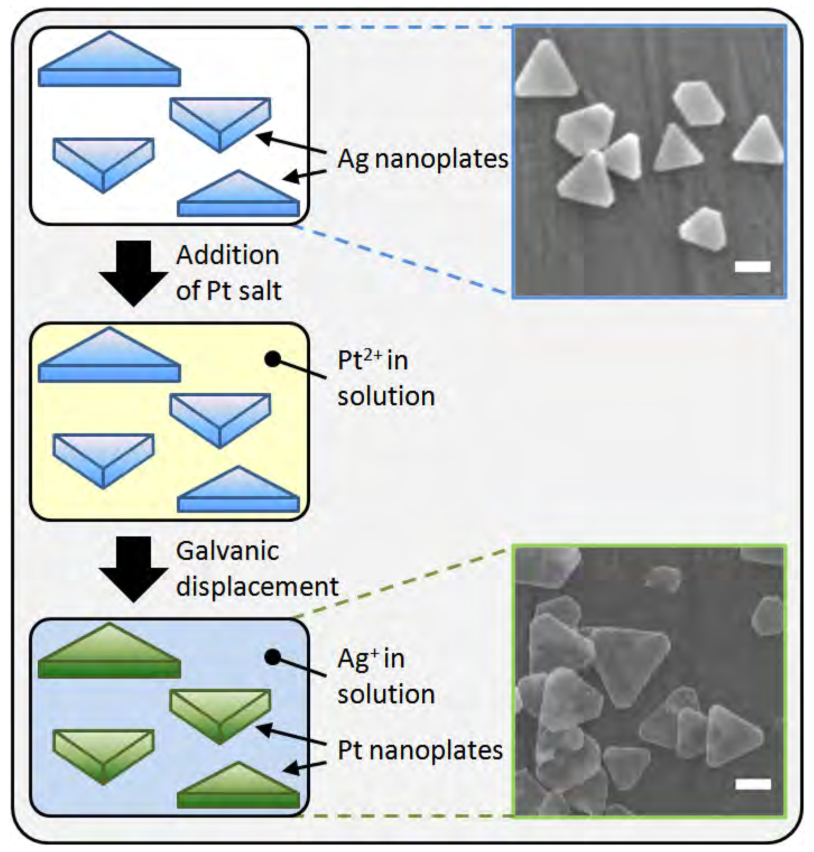


Figure 5 – Diagram of the galvanic displacement process

HES-Pt alloy catalysts will exceed 2015 DOE targets by increasing the activity and/or surface area of current NREL HES-Pt electrocatalysts

Pt-alloys: Increase intrinsic activity

- Synthesizing HES-Pt alloys with transition metals, such as Cu, will increase the electrocatalyst specific activity

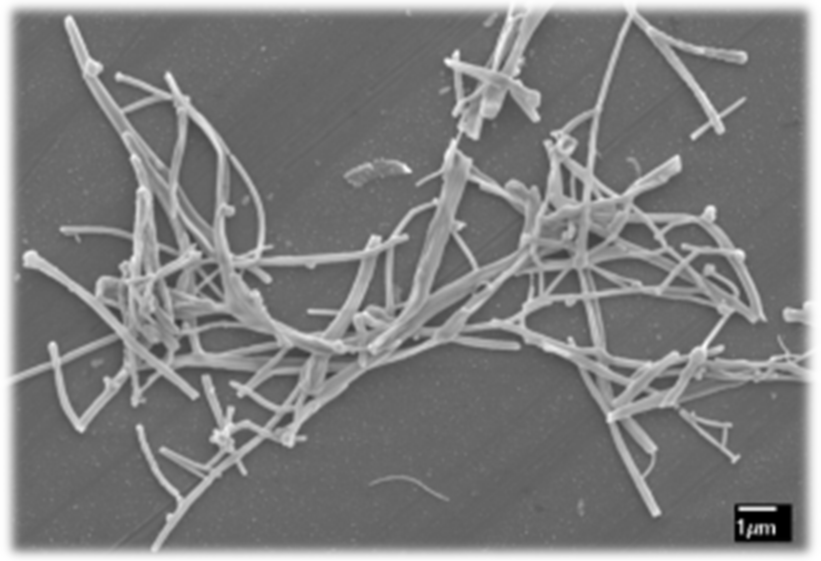


Figure 5 – Example of Pt_4Cu_6 nanowires synthesized by galvanic displacement

Controlling surface morphology: Increase electrochemical surface area

- Manipulation of reaction parameters will allow for maximization of the surface area for HES-Pt alloy electrocatalyst synthesized by galvanic displacement. These methods will be utilized to control HES-Pt alloy surface morphology.

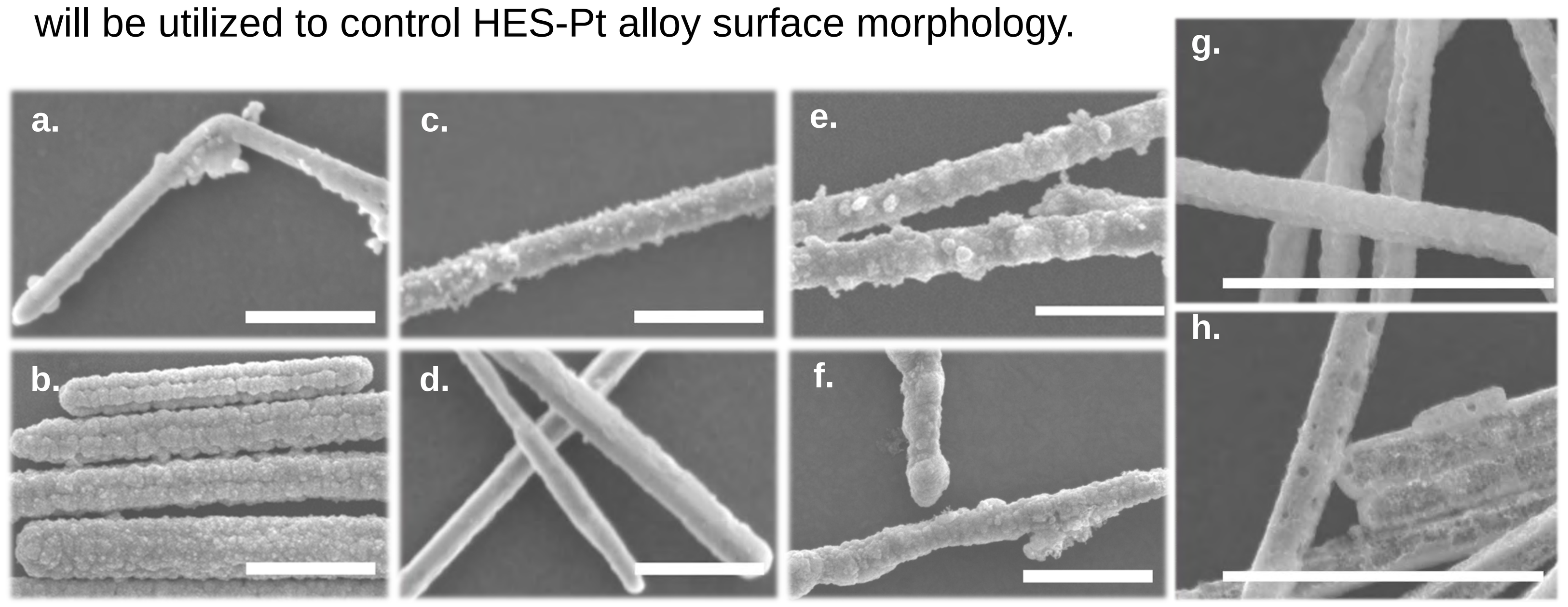


Figure 6 – The surface morphology of materials synthesized by galvanic displacement may be controlled by several parameters, such as utilizing surface ligands with different binding affinities (alkanoic acids [a, b], alkylamines [c, d], and alkanethiols [e, f]) or disrupting conformal deposition on the template surface (g and h).

Impact

The successful development of the high-aspect ratio Pt-based PEM electrocatalysts proposed in **this project will address one of the primary barriers to widespread commercialization of PEM fuel cell vehicles – reducing fuel cell cost by decreasing Pt loading.** Furthermore, the electrocatalysts developed in **this project will overcome several limitations of other promising PEM catalyst materials: improved water management, elimination of carbon supports, and increased catalyst durability**

Acknowledgments

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