DOE Hydrogen Program

Development of Alternative and Durable High Performance Cathode Supports for PEM Fuel Cells

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Project ID #
FCP29

Overview

Timeline

- Project start date Jan 2007
- Project end date Dec 2010
- Percent complete 8%

Budget

- Total project funding
  - DOE share $4,234K
  - Contractor share $255K
- Funding received in FY07
  - $1,241 (federal, requested)
  - $820K (federal, approved)
  - $72K (cost share)
- Funding reduced in FY07 due to late start. Hence project duration extended by 4 months to Dec 2010

Barriers

- Barriers addressed
  - A. Durability of cathode catalyst supports
  - C. Performance of cathode supported catalyst

Partners

- Ballard Power Systems – guidance on fuel cell testing
- Oak Ridge National Laboratory – mesoporous carbon supports
- University of Delaware – Tungsten carbide support
- Pacific Northwest National Laboratory
  - cathode synthesis and cathode/fuel cell testing
  - project management

Objectives

Overall	• Develop and evaluate new classes of alternative and durable high-performance cathode supports
2007	• Fundamental understanding of model systems • Synthesis of high surface area cathode supports • Downselect carbon support with potential for better stability than commercial carbon black support
2008	• Identify lead cathode compositions with potential for better durability than carbon black supported Pt cathode
2009	• Identify compositions with mass activity of > 0.44 A/mg Pt and 5X better stability than carbon black supported catalyst for cell demonstration.
2010	• Demonstrate durability under accelerated test protocols that meet lifetime criteria under development at DOE

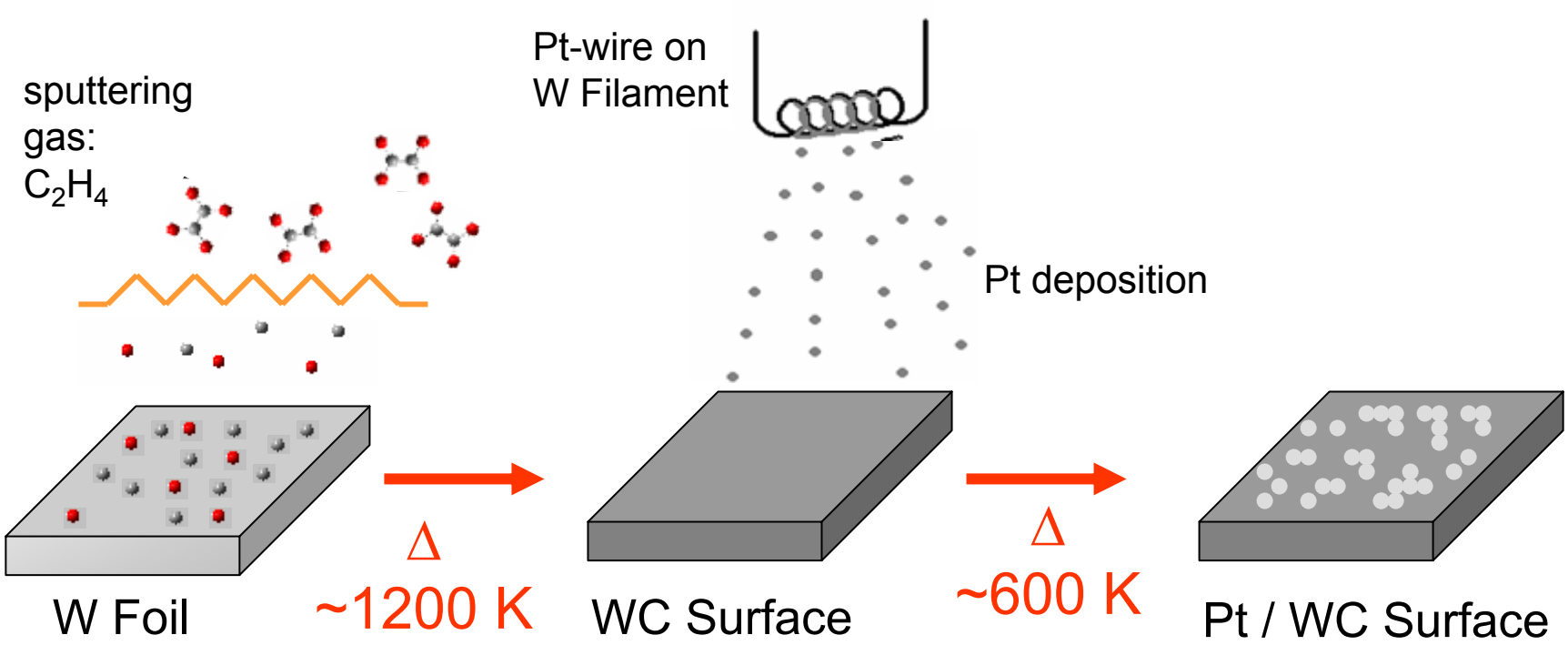
Approach

- Develop and evaluate new classes of alternative and durable cathode supports using graphitized carbons as scaffolds and protect the carbon surface with
  - Tungsten carbide (WC)
  - Oxycarbides
  - Conductive metal oxides (ITO)
- Enhance Pt dispersion and stability on these new classes of cathode supports.
- Conduct electrochemical tests on above supported catalysts

Technical Accomplishments

- **Synthesized Pt/WC**
  - **Surface preparation of polycrystalline W**
  - **Decomposition of ethylene over hot filament and annealing by resistive heating at 1200K to form WC**
  - **Analysis of surface composition using XPS**
- **Synthesized WC on different carbon substrates using PVD, CVD and TPR**
- **Established protocol for synthesis of highly stable mesoporous carbons retaining porosities under graphitization conditions**
- **Conducted preliminary TGA corrosion tests of graphitized ordered mesoporous carbon loaded with Pt**
- **Loaded Pt on various supports by incipient wetness**
- **Controlled Pt particle size by varying the incipient wetness process parameters such as solvent, Pt loading, carbon surface properties and post-incipient wetness process conditions.**
- **Conducted preliminary electrochemical experiments to determine ECSA, performance and stability of supported catalyst**

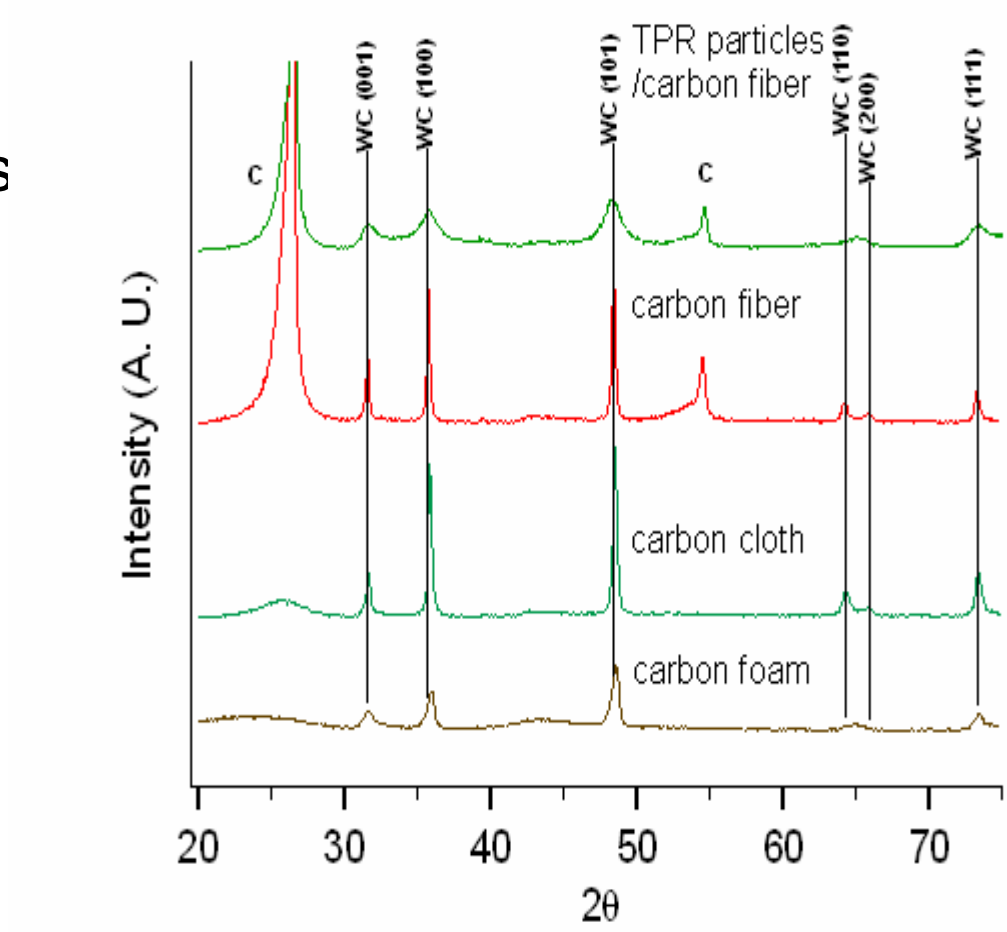
Synthesis of Pt/WC



- Decomposition of ethylene over hot filament
- Annealing by resistive heating to ~ 1200 K to form WC
- Analysis of surface composition using XPS

Synthesis of WC on Different Carbon Substrates: PVD, CVD and TPR

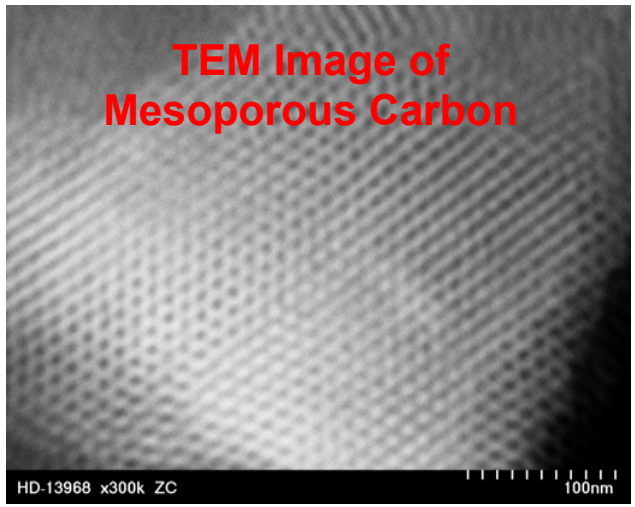
- PVD reactive deposition with post annealing produced pure WC on various carbon substrates for fuel cell testing
- Similar WC films produced from CVD synthesis
- Supported WC particles produced by temperature programmed reaction (TPR)



Synthesis of Highly Stable Mesoporous Carbons

Goal: Develop and evaluate new classes of alternative and durable high-performance cathode supports

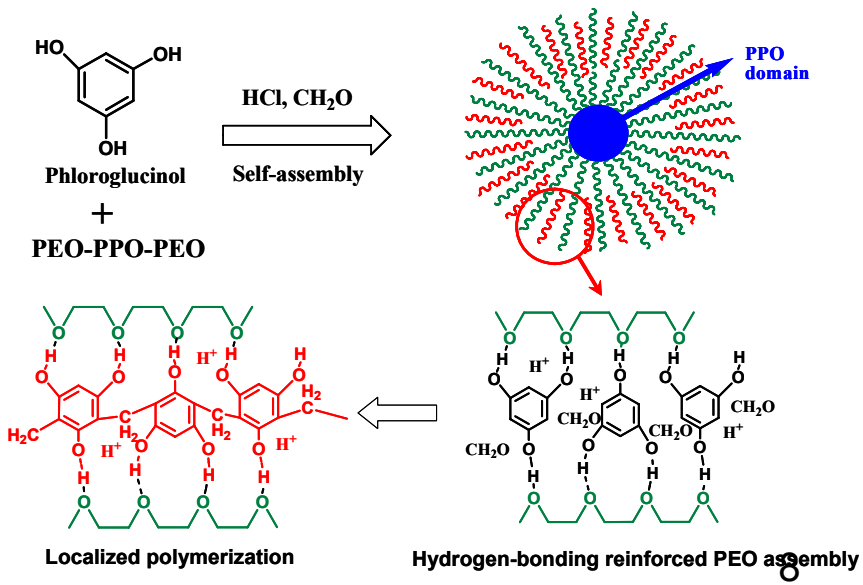
- **synthesis of ordered mesoporous carbon catalyst supports**
- **synthesis of carbon-supported WC .**



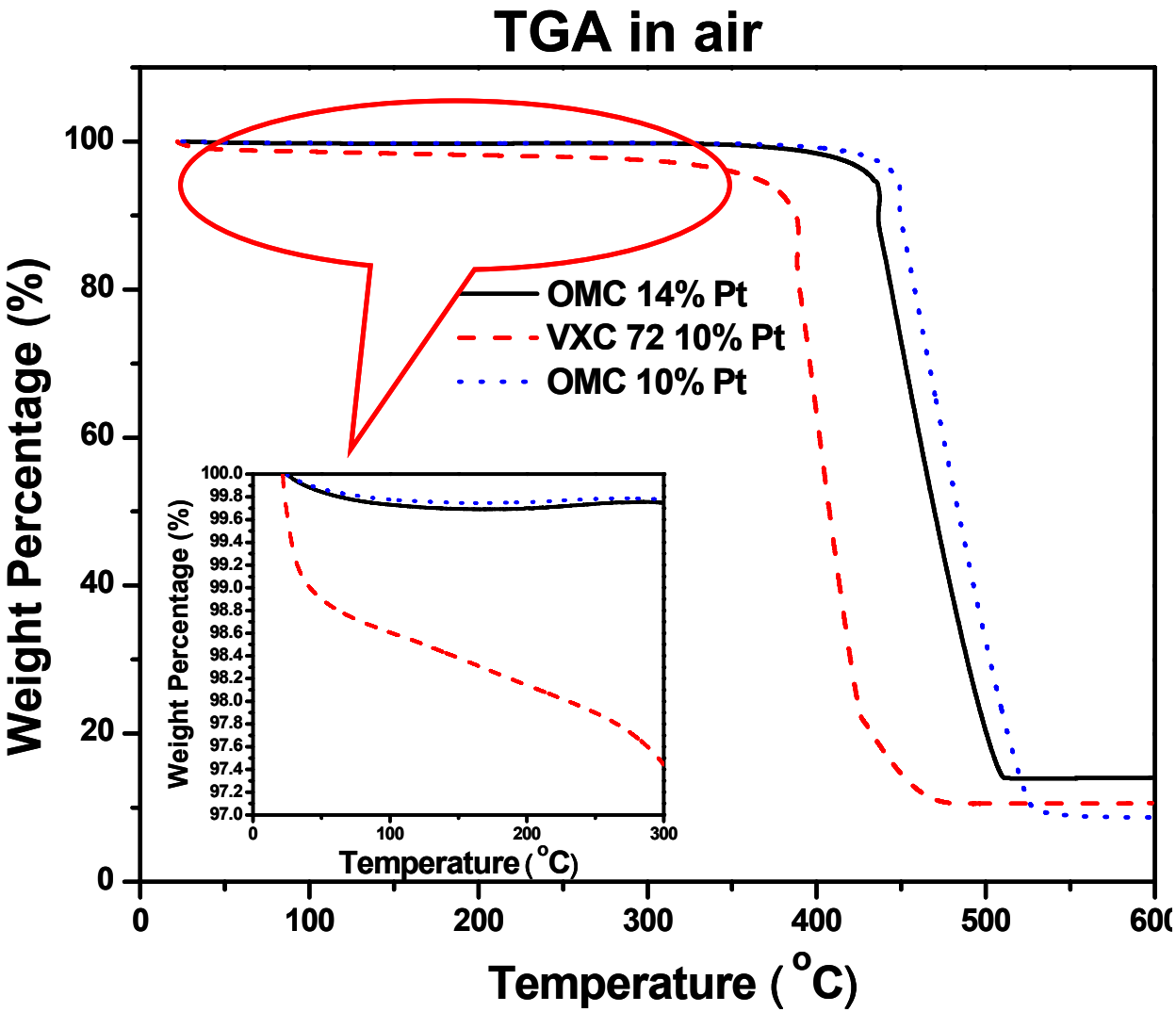
Accomplishments:

***Synthesis* – Established the protocol for synthesis of highly stable mesoporous carbons retaining porosities under graphitization conditions.**

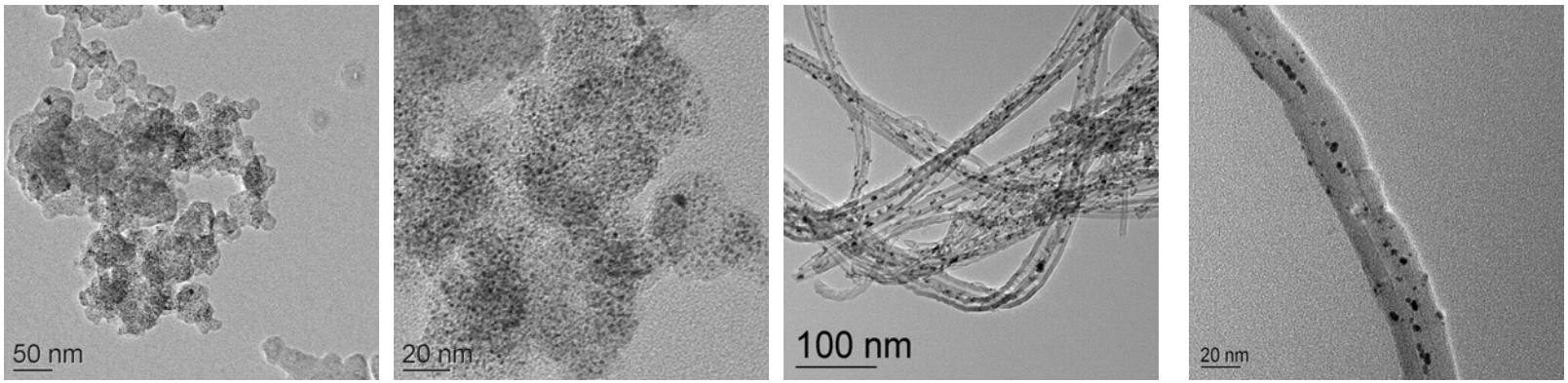
***Processing* –Mesoporous carbons were used to disperse conducting oxide materials.**



Preliminary TGA Corrosion Tests of Graphitized Ordered Mesoporous Carbon (OMC) Loaded with Pt

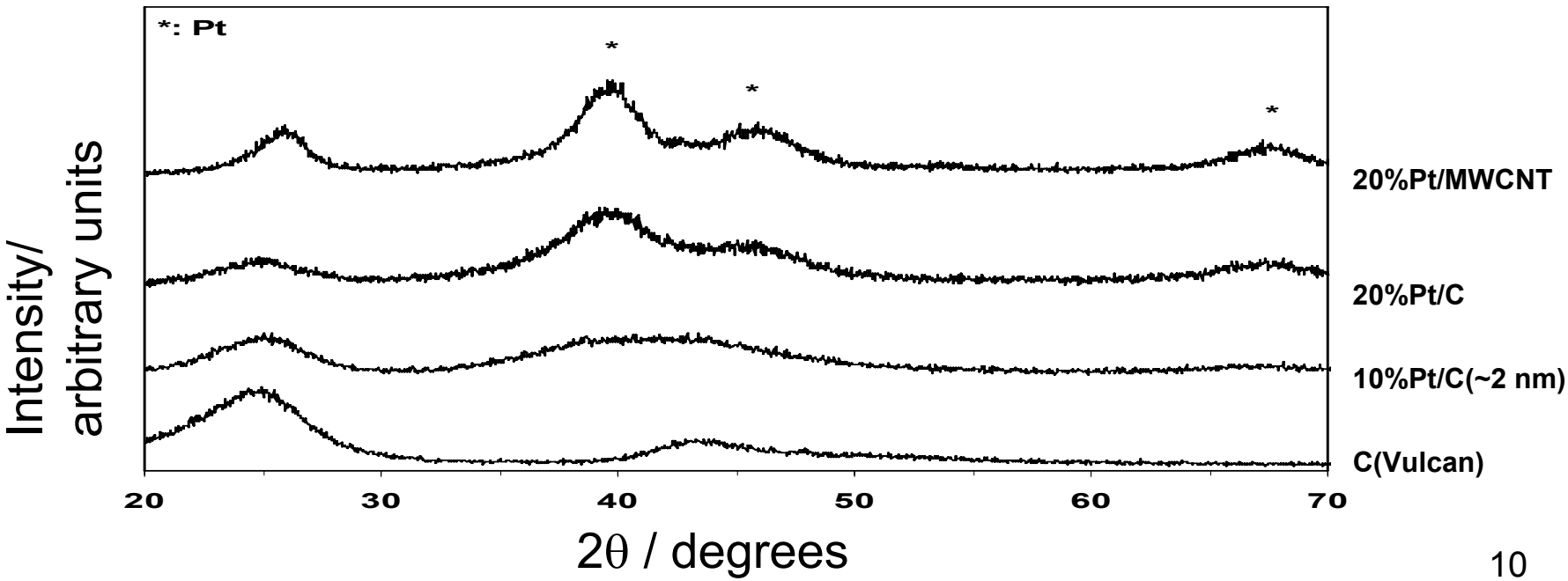


Pt Loading by Incipient Wetness



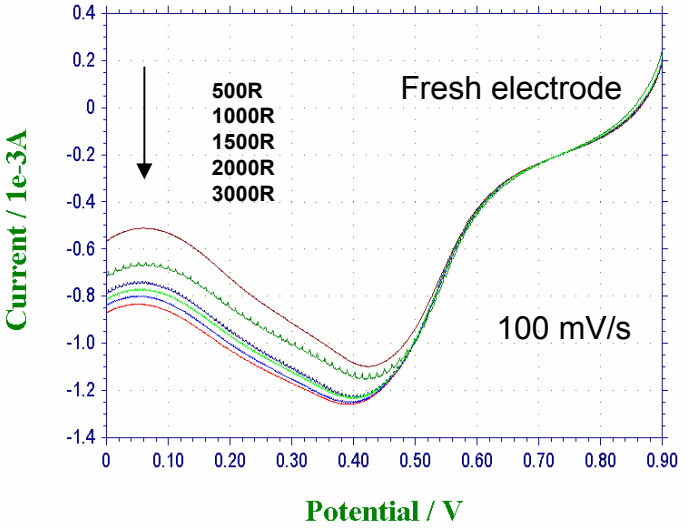
10%Pt/Carbon(Vulcan X72C)

20%Pt/MWCNT

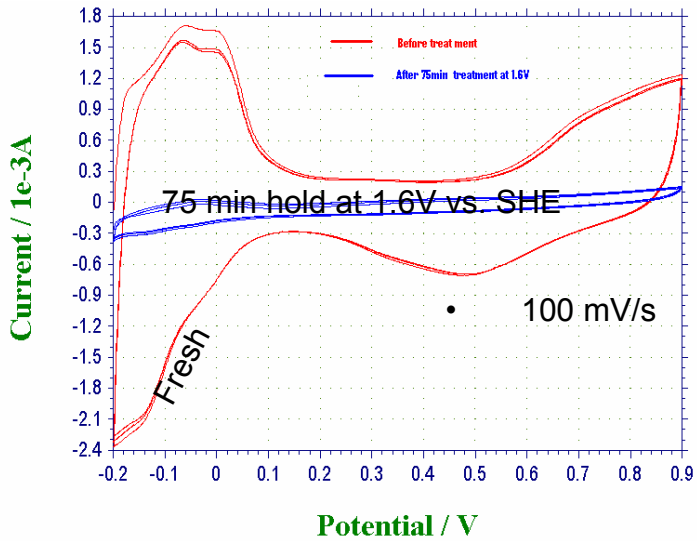


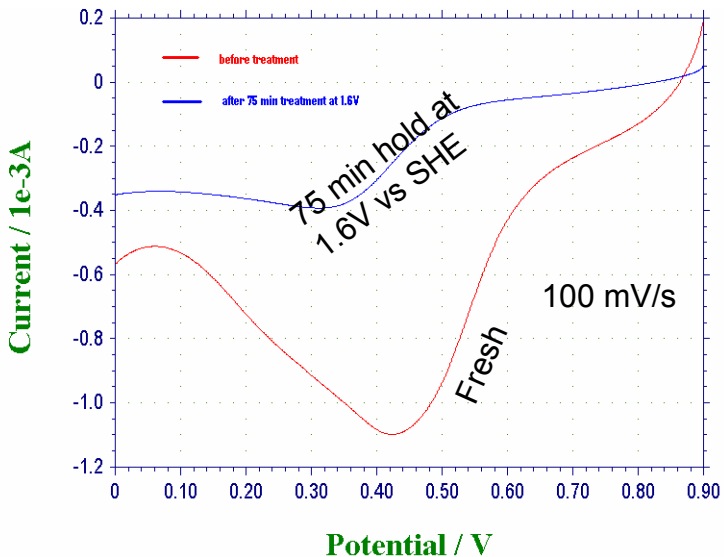
Durability Testing of Cathode Catalyst

Oxygen reduction by Linear Scan Voltammetry (LSV) using rotating disc electrode



ECSA by H2 desorption





- All potentials shown are vs. Ag/AgCl
- Gold RDE, Pt wire counter, 0.5M H2SO4
- Determine ECSA and oxygen reduction current of fresh electrode
- Scan from 0.6-1.1V vs SHE for 300 cycles at 100 mV/sec
- No ECSA loss and no decrease in oxygen reduction current (data not shown)
- Hold at 1.6V vs SHE for 75 minutes
- Significant ECSA loss and decrease in oxygen reduction current

Future Work

FY07

- **Continue development of MWCNTs and mesoporous carbon support coated with WC, oxycarbides and conductive metal oxides**
- **Continue development of Pt supported on above materials**
  - **Develop fundamental understanding of interfacial interaction between Pt/C and Pt/WC by STM**
  - **In-Situ XPS and electrochemical measurements to determine stability**
- **Continue electrochemical evaluation of support and supported catalyst**
  - **Chronoamperometric measurement of oxidation current during hold at various oxidation potentials**
  - **Periodic determination of ECSA loss and decrease in oxygen reduction current**

FY08

- **Identify lead cathode compositions which have high potential for achieving better durability than carbon black supported Pt cathode**

Summary

- Synthesized Pt/WC and ordered mesoporous carbon supports
- Developing fundamental understanding of interfacial interaction between Pt/C and Pt/WC by STM ongoing
- Conducted *in situ* XPS and electrochemical measurements to determine stability
- Loaded Pt on mesoporous carbon and commercial supports by incipient wetness
- Started electrochemical testing of supported catalysts to determine performance and stability