

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

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May 17, 2007

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	<ul style="list-style-type: none"><li>• Develop and evaluate new classes of alternative and durable high-performance cathode supports</li></ul>
2007	<ul style="list-style-type: none"><li>• Fundamental understanding of model systems</li><li>• Synthesis of high surface area cathode supports</li><li>• Downselect carbon support with potential for better stability than commercial carbon black support</li></ul>
2008	<ul style="list-style-type: none"><li>• Identify lead cathode compositions with potential for better durability than carbon black supported Pt cathode</li></ul>
2009	<ul style="list-style-type: none"><li>• Identify compositions with mass activity of <math>&gt; 0.44</math> A/mg Pt and 5X better stability than carbon black supported catalyst for cell demonstration.</li></ul>
2010	<ul style="list-style-type: none"><li>• Demonstrate durability under accelerated test protocols that meet lifetime criteria under development at DOE</li></ul>

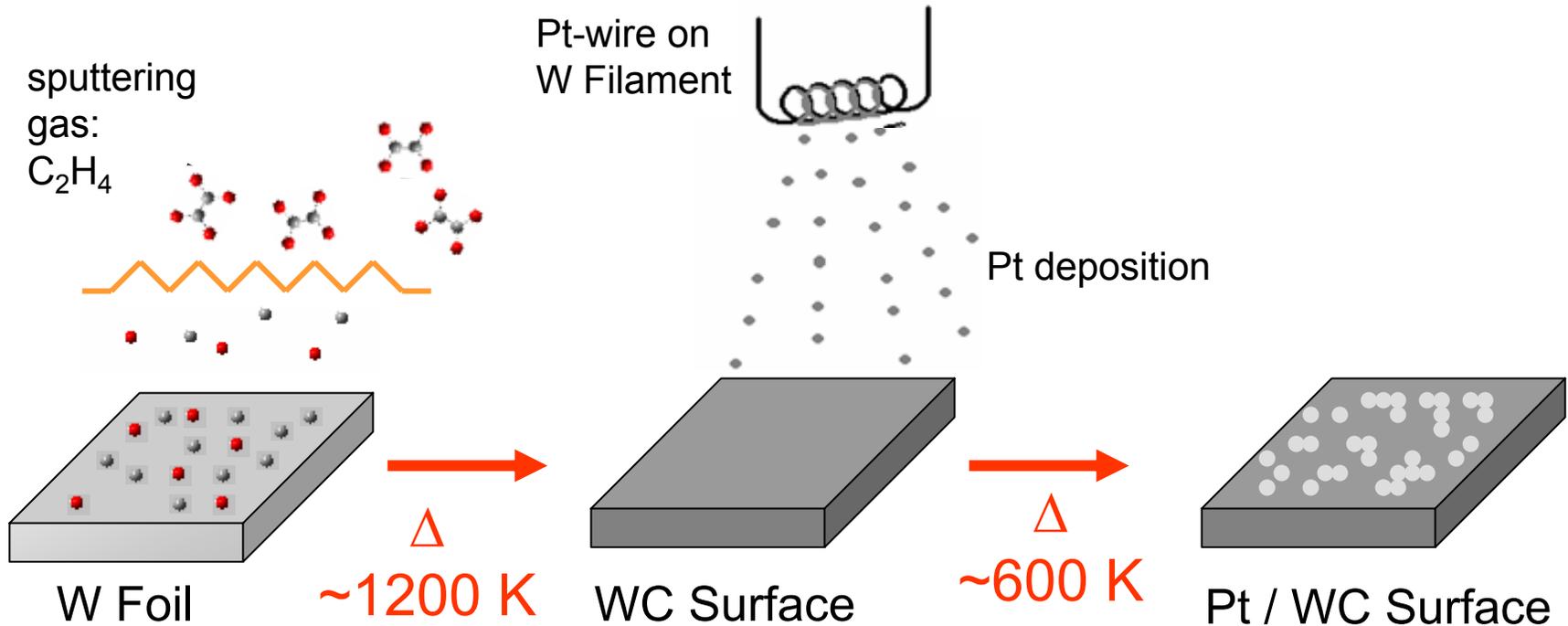
# Approach

- **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**

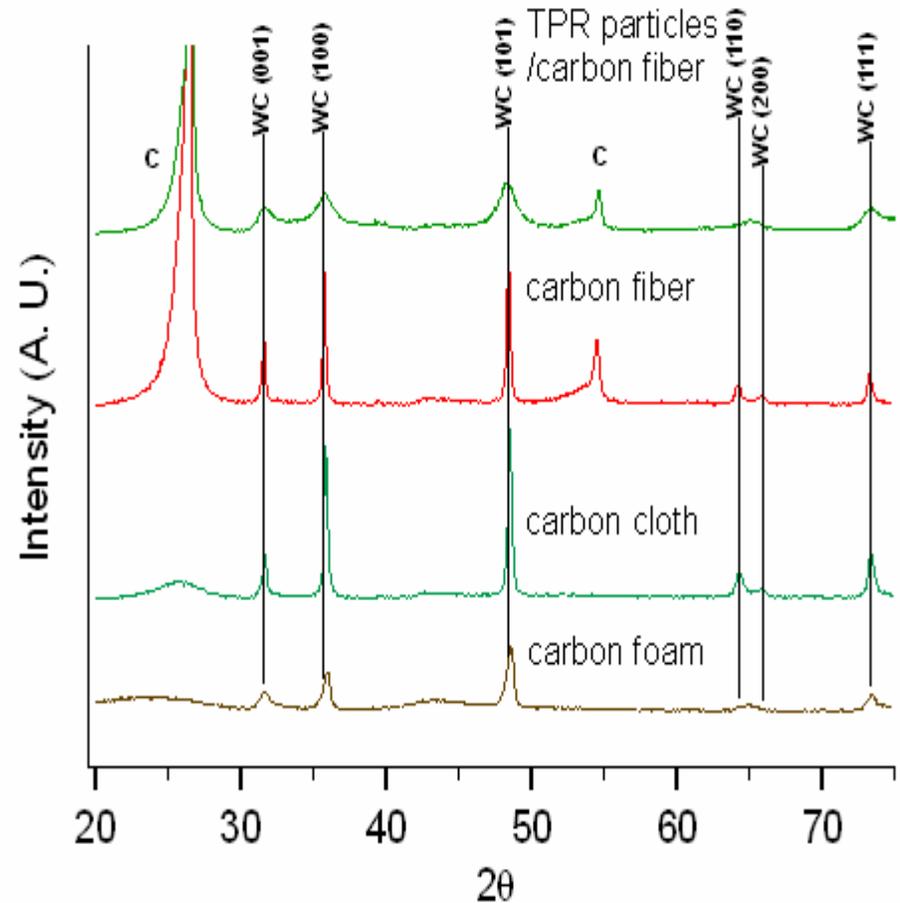
# Synthesis of Pt/WC



- Decomposition of ethylene over hot filament
- Annealing by resistive heating to  $\sim 1200\text{ K}$  to form WC
- Analysis of surface composition using XPS

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

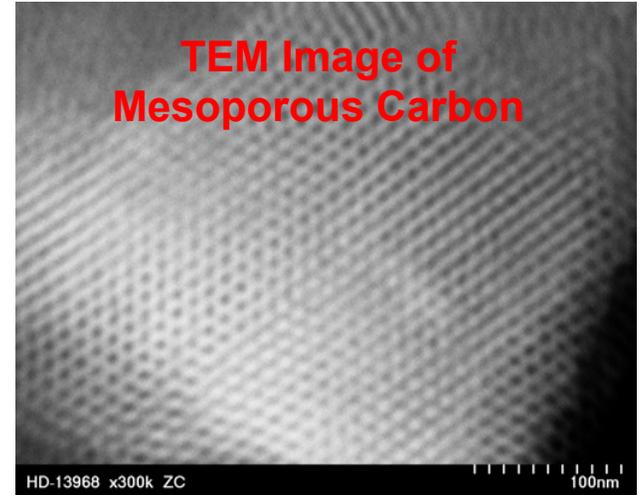
- PVD reactive deposition with post annealing produced pure WC on various carbon substrates for fuel cell testing
- Similar WC films produced from CVD synthesis
- Supported WC particles produced by temperature programmed reaction (TPR)



# Synthesis of Highly Stable Mesoporous Carbons

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

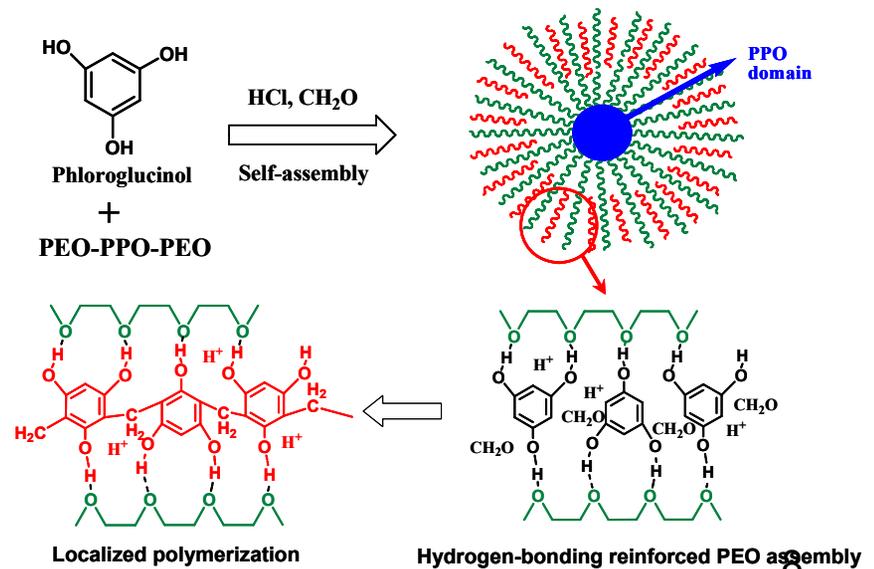
- synthesis of ordered mesoporous carbon catalyst supports
- synthesis of carbon-supported WC .



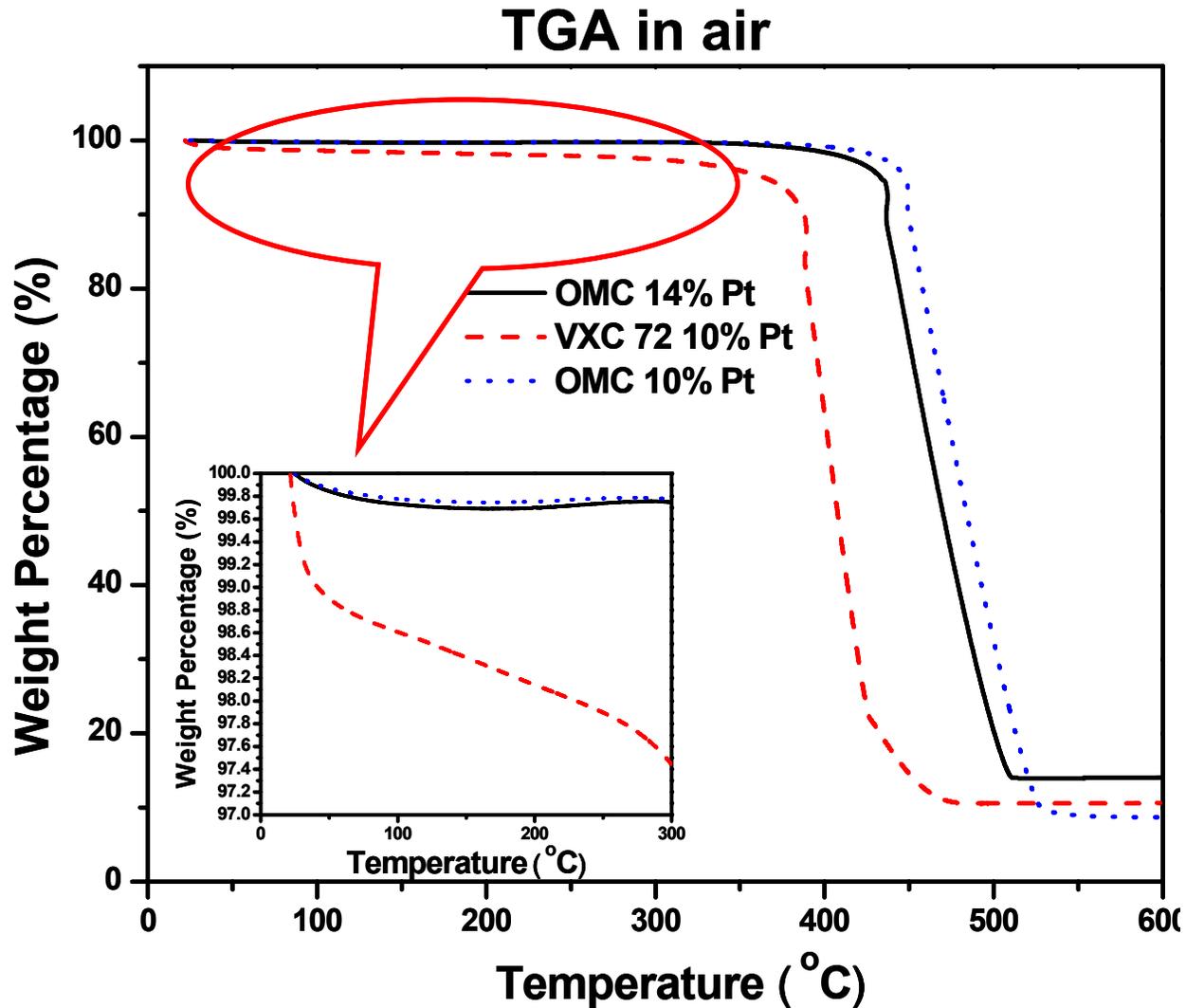
## Accomplishments:

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

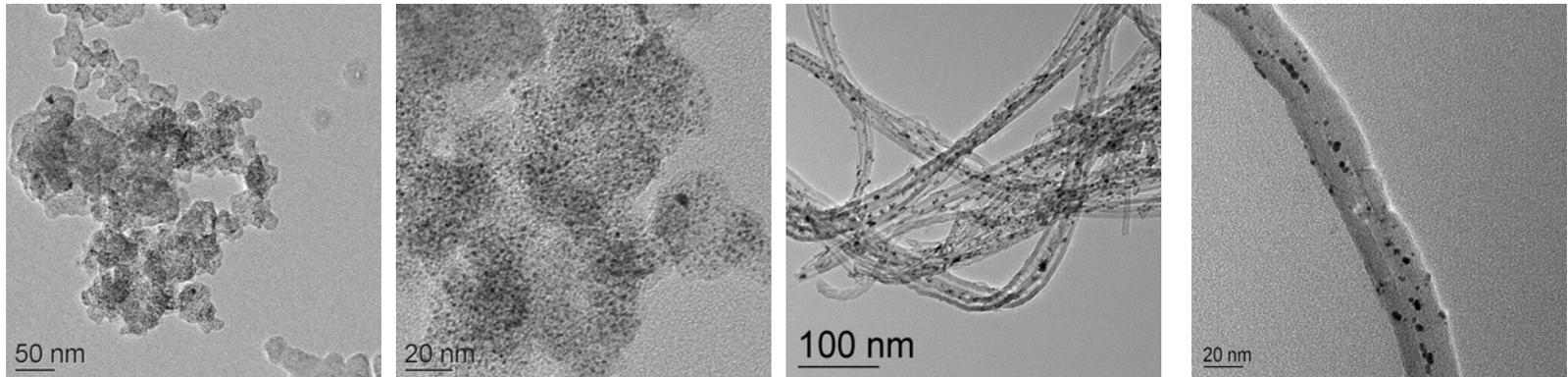
**Processing** – Mesoporous carbons were used to disperse conducting oxide materials.



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

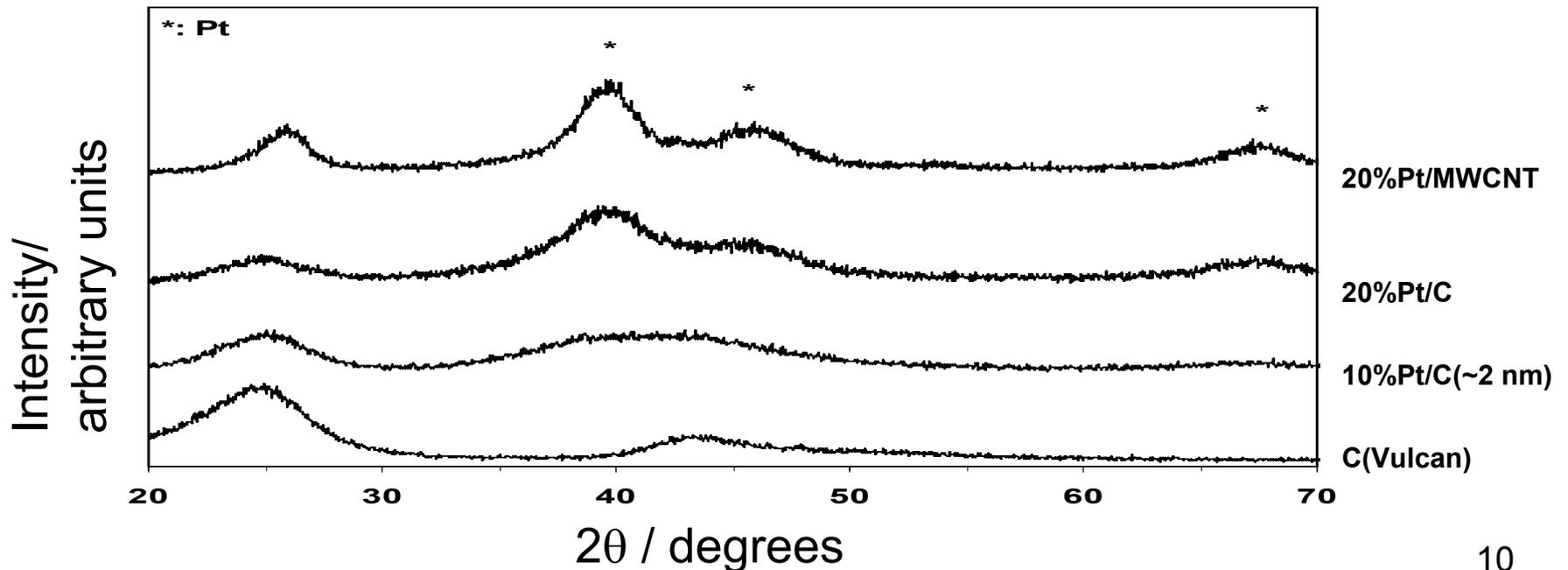


# Pt Loading by Incipient Wetness



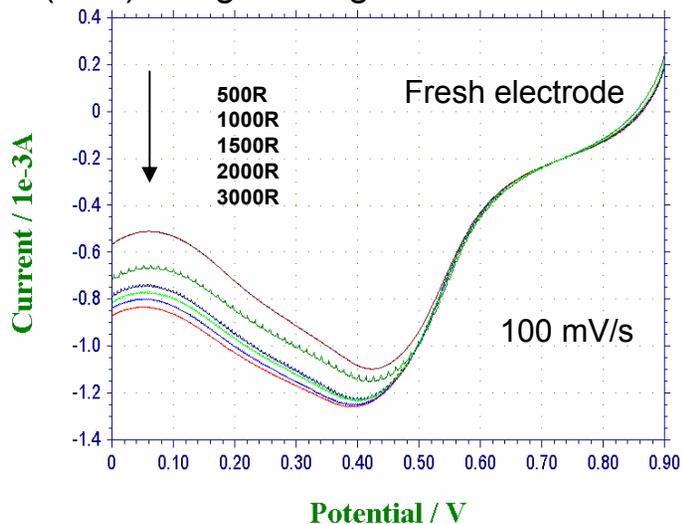
10%Pt/Carbon(Vulcan X72C)

20%Pt/MWCNT

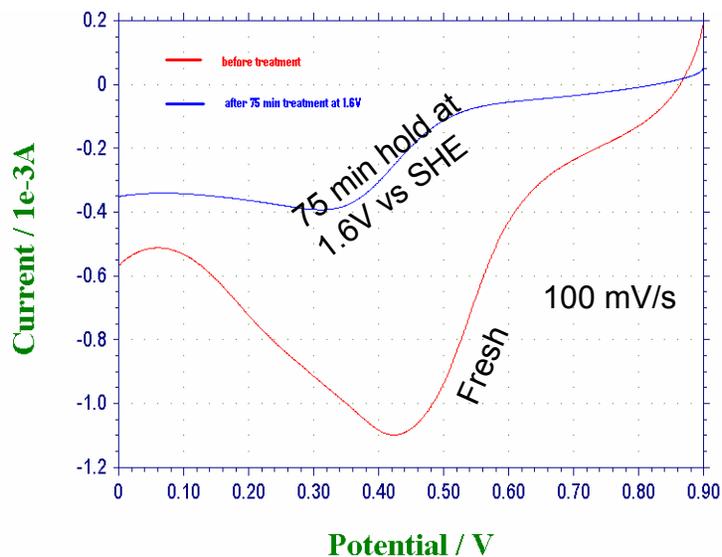
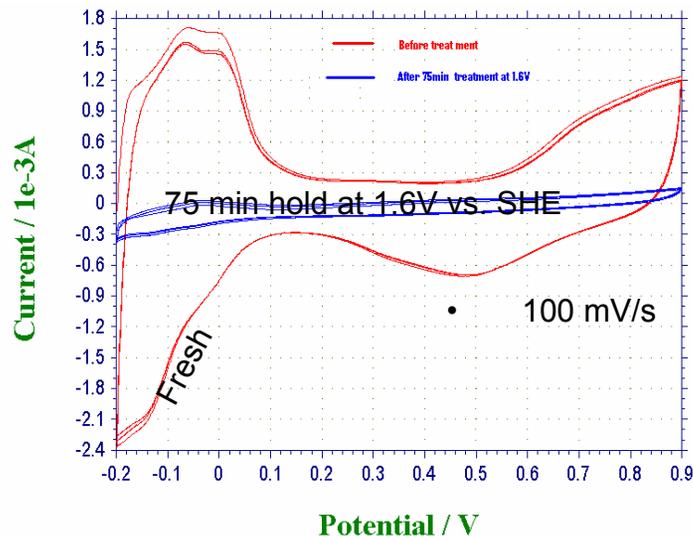


# Durability Testing of Cathode Catalyst

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



ECSA by H<sub>2</sub> desorption



- All potentials shown are vs. Ag/AgCl
- Gold RDE, Pt wire counter, 0.5M H<sub>2</sub>SO<sub>4</sub>
- 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