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DOE Hydrogen Program

Novel PEMFC Stack Using Patterned Aligned Carbon Nanotubes as Electrodes in MEA

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Overview

DOE Hydrogen Program

Timeline

- Start – January 2007
- End – December 2008
- Completion-to-Date – 15%

Budget

- Total Project Funding
  - DOE $ 1,000K
- Funding Received in FY07
  - $ 420K

Barriers

- Barriers

A. Durability – Carbon black as support is chemically unstable

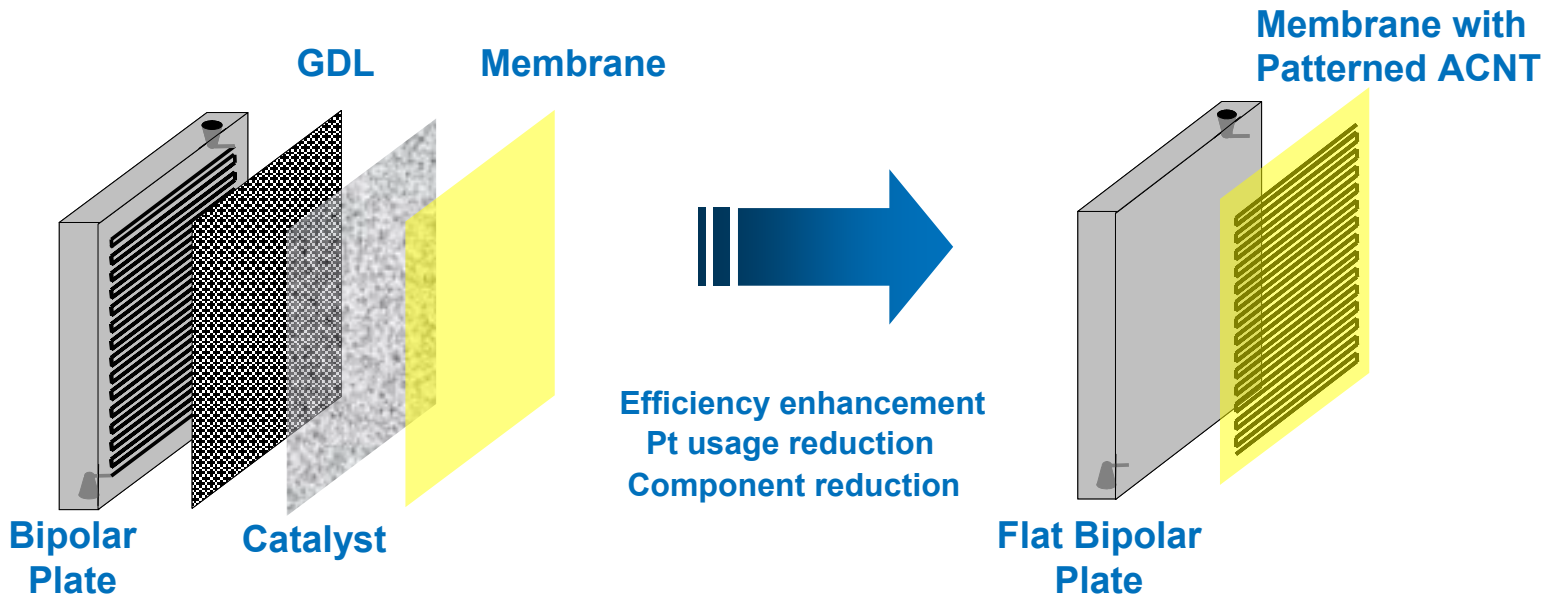
B. Cost – Pt Usage and GDL as component add significant cost to PEFC

C. Performance – Fuel utilization and electro-conductivity are limited by the existing MEA architecture

- Target
  - MEA Cost: $10/kW
  - Durability: 5000 h @ 80ºC

Objective

- To develop a novel aligned carbon nanotube (ACNT)-based membrane electrode assembly and fuel cell with:
  - improved efficiency
  - reduced Pt usage
  - simplified stack design



Approach

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The ACNT PEMFC Stack Development Consists of Three Main Tasks

Catalyzed ACNT → **3-D MEA Development** → **Packaging & Testing**

Catalyzed ACNT	3-D MEA Development	Packaging & Testing
■ ACNT synthesis ■ Catalyzing through CVD ■ Catalyzing through wet chemistry ■ Structure & activity characterization	■ Modeling & simulation ■ Preparation of patterned ACNT ■ Preparation of MEA with patterned ACNT	■ Packaging method optimization ■ Cell performance evaluation

Approach (continued)

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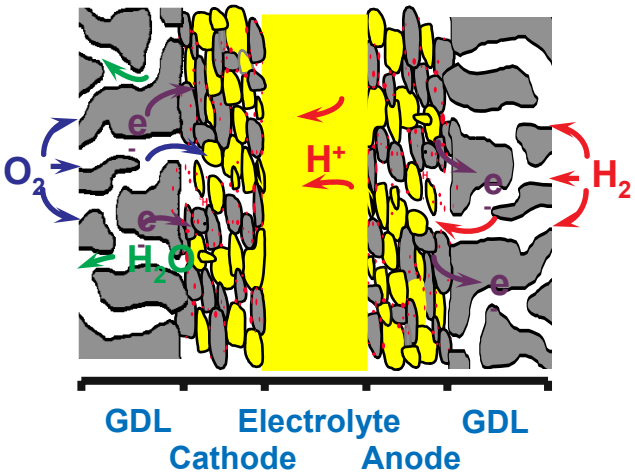
Concept of Aligned Carbon Nanotubes (ACNT) as MEA for PEFC

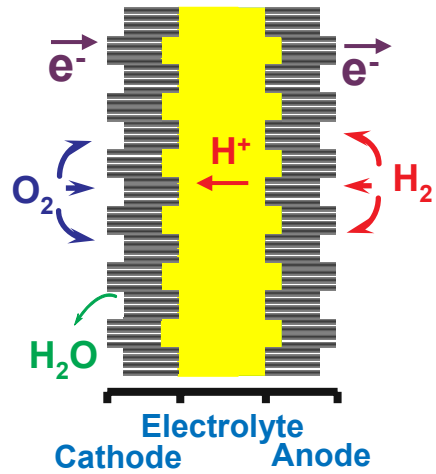
Conventional MEA

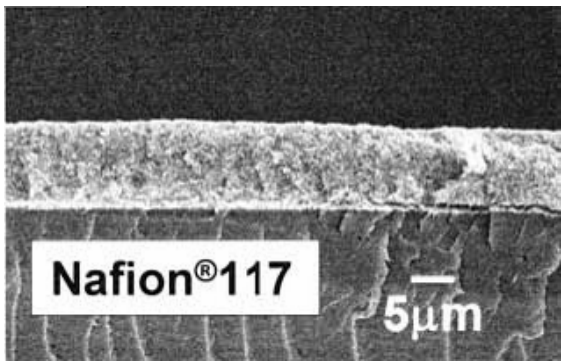


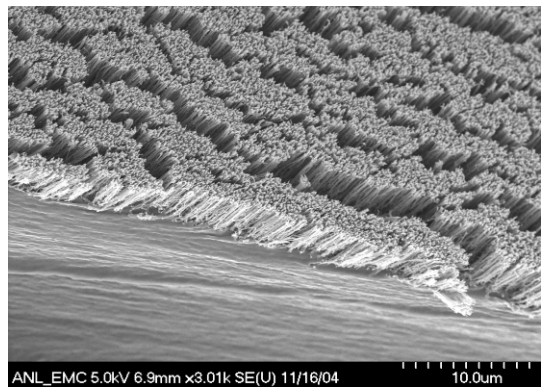
Advantage of ACNT MEA

- Better catalyst utilization
- Better support stability
- Better electrical & thermal conductivity
- Better water management
- Better mass transport
- Built-in catalytic activity through functionalized ACNT with potential to replace costly Pt/C

ACNT MEA







Approach (continued)

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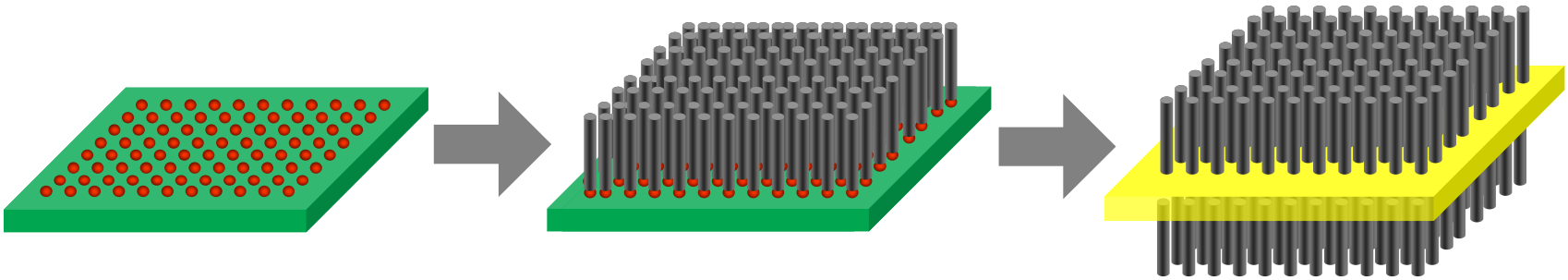
Process of Fabricating ACNT as MEA for PEFC



Seeding Catalyst *Growing and Catalyzing ACNT* *Forming MEA*

Processes for Functionalizing/Catalyzing ACNT

- *Gas phase CVD*
- *Wet chemistry*

Approach (continued)

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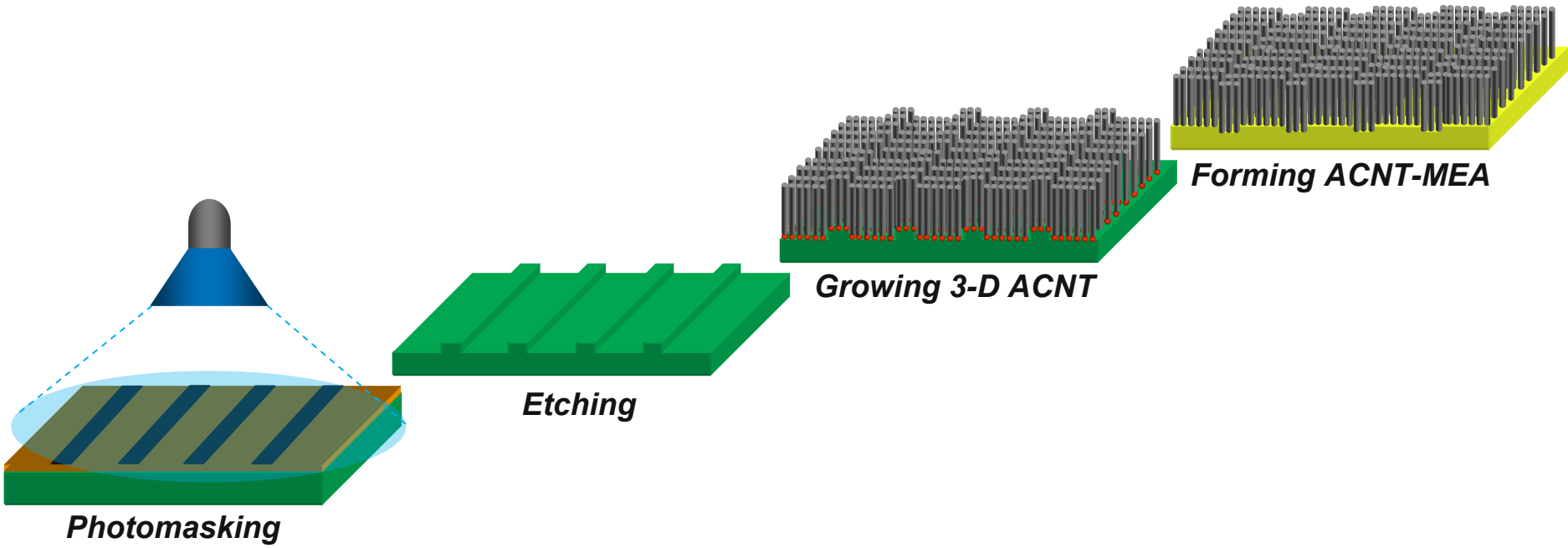
Process of Building 3-Dimensional ACNT/MEA



- Photolithographic method produces 3-D substrate with flow-field pattern
- 3-D ACNT carpet growth over 3-D substrate
- Transfer 3-D ACNT layer onto membrane electrolyte

Accomplishment & Progress

DOE Hydrogen Program

- Project initiated in January 2007 with the technology baseline established through an Argonne internally supported project
- Project team formed and resources allocated
- Effort in 1st Quarter focused on catalyzing method development
  - Completed literature review
  - Initiated the exploratory study on functionalizing ACNT via CVD process
  - Initiated several parallel studies on wet chemistry catalyzing methods
  - Initiated structural characterization and the electrochemical performance evaluation for catalyzed ACNT

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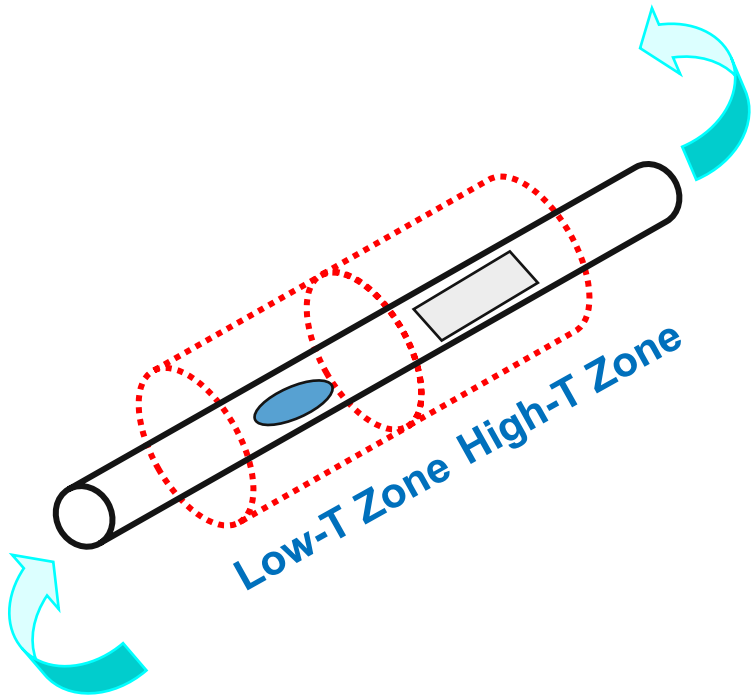
Synthesis of Aligned Carbon Nanotube (ACNT)

- Prepared through a two-stage CVD process
- Generally multi-walled
- Diameter ranges from <10 nm to >100 nm
- Length ranges from <1 μm to >100 μm



Accomplishment & Progress (continued)

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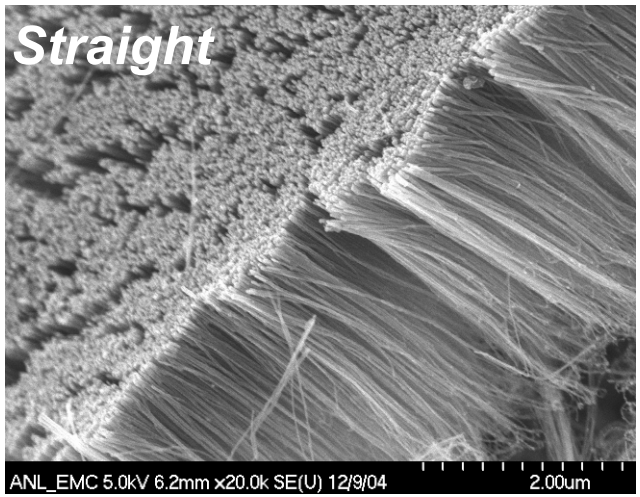
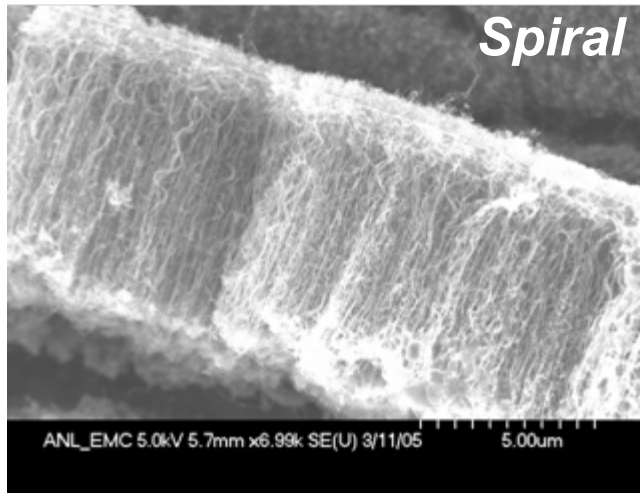
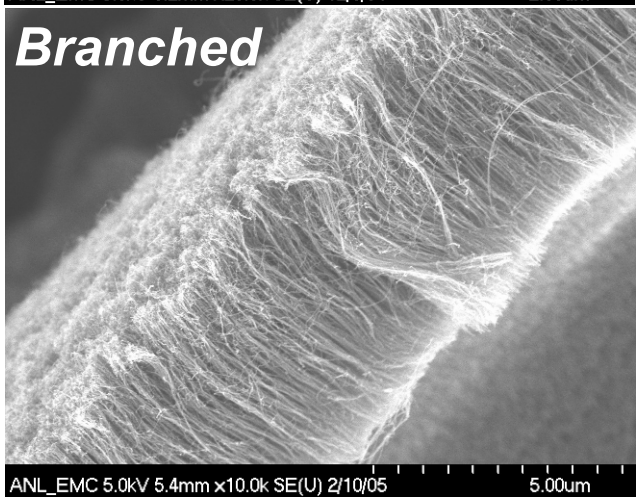
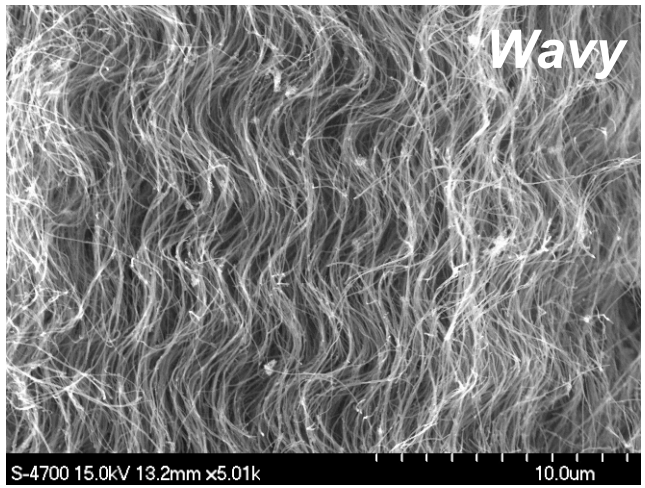
Examples of ACNT prepared under different conditions









Accomplishment & Progress (continued)

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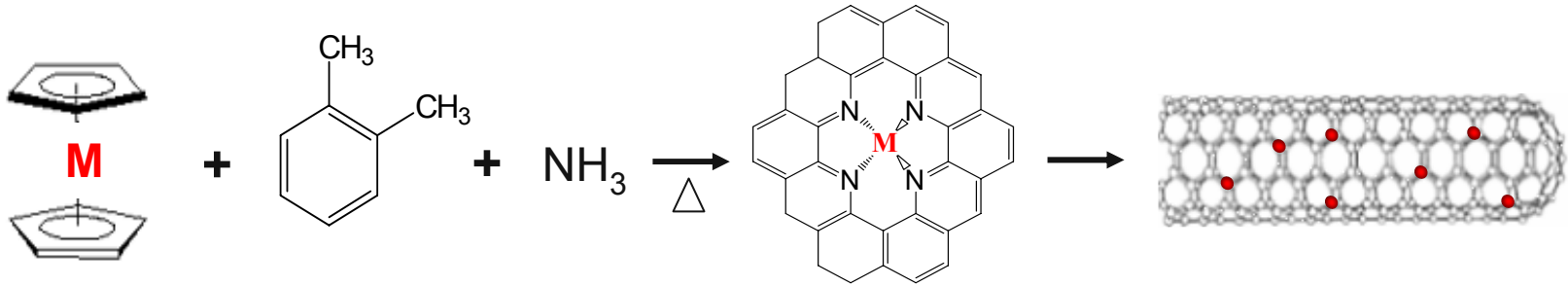
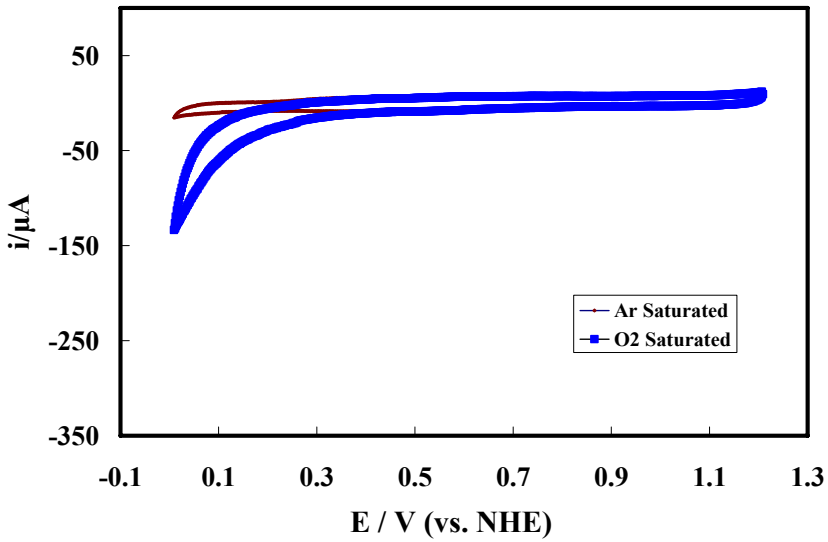
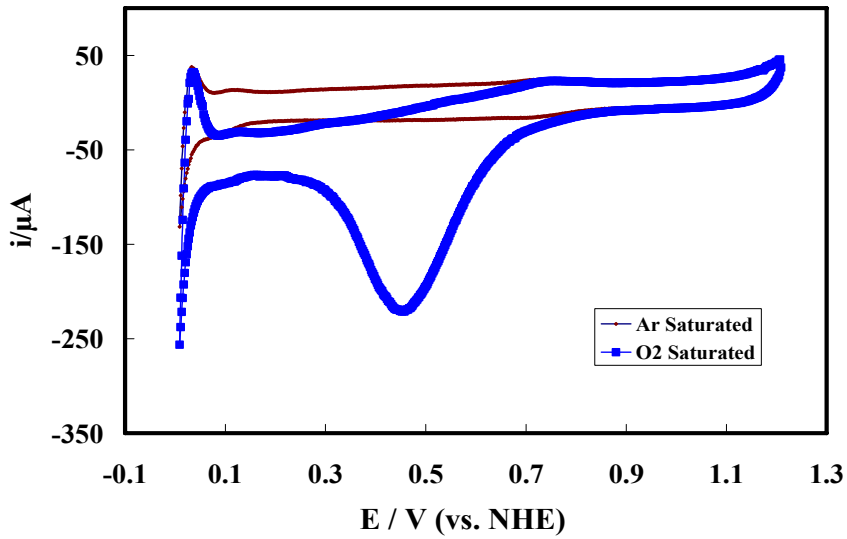
Functionalizing Catalytic Active Site through TM & N-doping



ACNT without N-doping



ACNT with N-doping

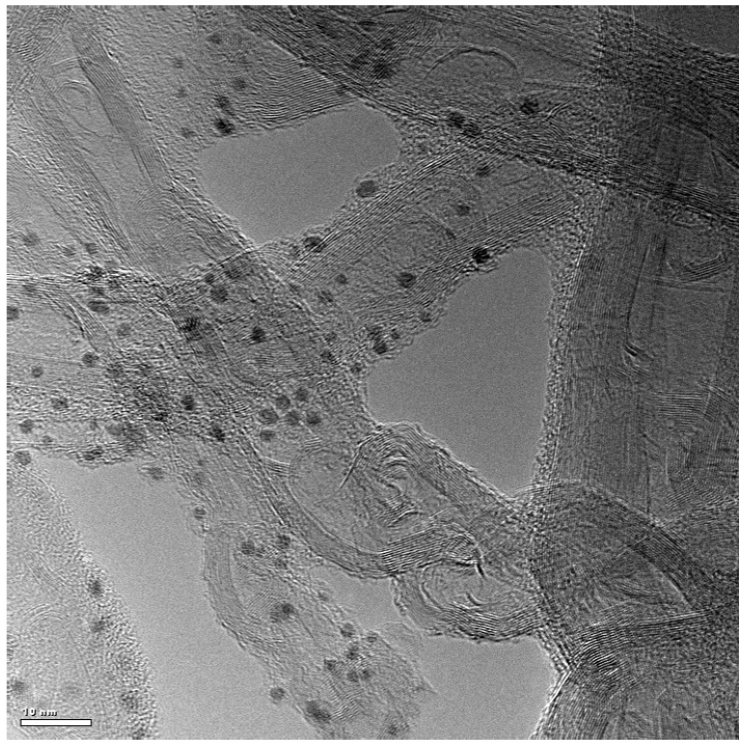


Accomplishment & Progress (continued)

DOE Hydrogen Program

Catalyzing ACNT with Pt through Gas Phase CVD Process

- Co-CVD and sequential CVD processes are currently under development to apply Pt over ACNT
- Highly dispersed Pt with particle size from 2 nm ~3 nm is observed
- Electrocatalytic activity of Pt/ACNT is under evaluation



TEM image of Pt-decorated carbon nanotubes by co-CVD

Accomplishment & Progress (continued)

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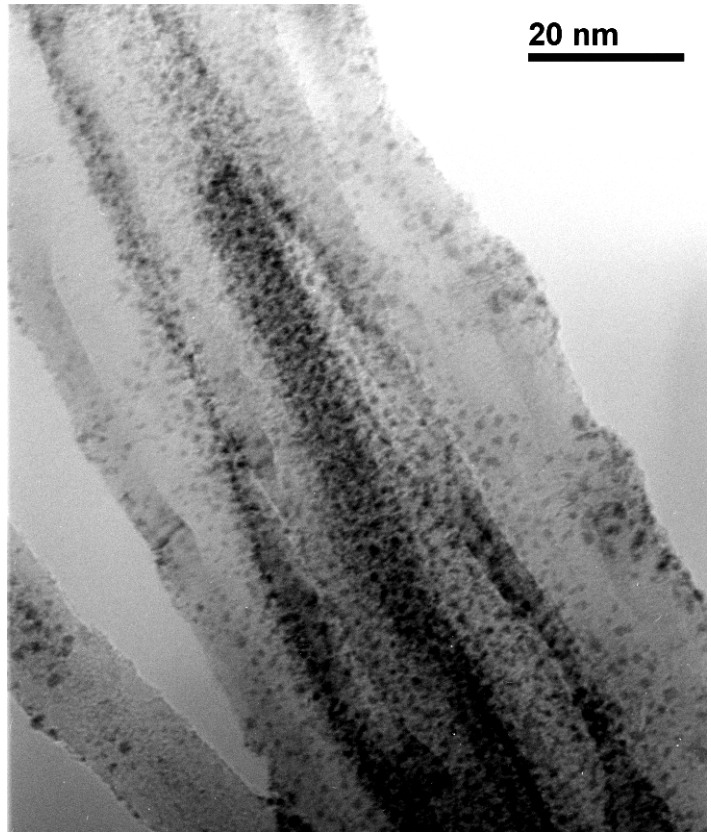
Catalyzing ACNT with Pt through Wet Chemistry Methods

- Three wet chemistry methods are under parallel development
- Highly disperse Pt particles over ACNT were observed
- Electrocatalytic activity evaluation and improvement are under way



TEM image of Pt/CNT prepared by wet chemistry

Accomplishment & Progress (continued)

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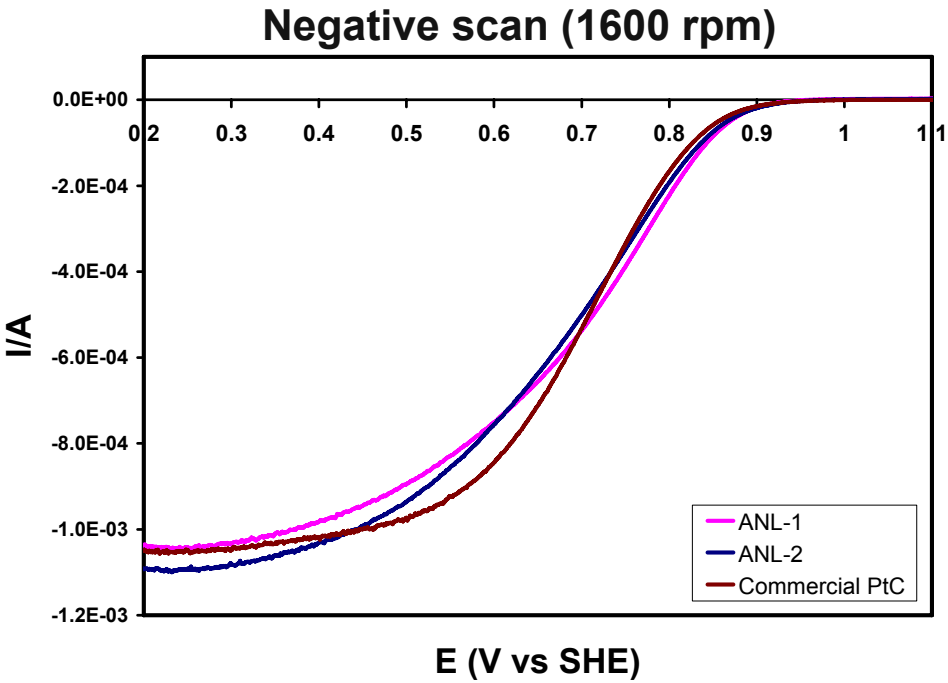
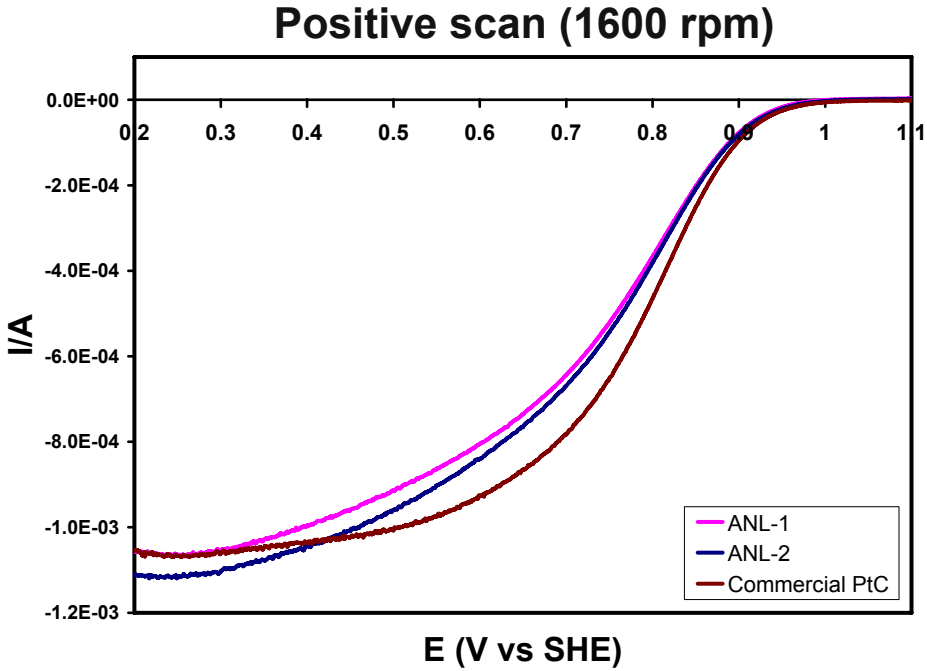
Electrocatalytic Evaluation & Testing

RDE Measurement of ORR Activity





- Pt/ACNT samples prepared in a preliminary study demonstrated encouraging catalytic activity in comparison with commercial carbon black-supported catalyst
- Efforts continue to optimize the preparation and characterization methods

Future Work

DOE Hydrogen Program

- **Complete catalyzing method development – FY07**
  - Complete investigation of CVD catalyzing approach
  - Complete investigation of wet chemistry catalyzing approach
  - Demonstrate catalyzing method improvement through electrocatalytic and structural characterization studies
- **Complete ACNT MEA development – FY07- FY08**
  - Prepare 3-D ACNT
  - Prepare 3-D MEA
- **Mid-term Go/No-go decision**
  - Decide project direction based on outcome of catalyzing & MEA development
- **Complete packaging & testing**
  - Complete cell packaging development
  - Complete cell performance testing

Summary

DOE Hydrogen Program

- **Relevance**
  - This project addresses the technical barriers in fuel cell durability, cost, performance and water transport/thermal management
- **Approach**
  - To develop a novel aligned carbon nanotube (ACNT)-based MEA and fuel cell with improved efficiency, reduced Pt usage and simplified stack design
- **Technical Accomplishment & Progress**
  - Successfully prepared ACNT with different morphology with built-in electrocatalytic activity
  - Obtained preliminary result on gas phase CVD catalyzing approach
  - Obtained preliminary result on wet chemistry catalyzing method

Acknowledgement

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