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DOE Hydrogen Program

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

***Di-Jia Liu, Magali Ferrandon,
Nancy Kariuki, Jennifer Mawdsley,
Suhas Niyogi, Junbing Yang***

*Chemical Engineering Division
Argonne National Laboratory*

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**Project ID
FCP 30**

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Timeline

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

Budget

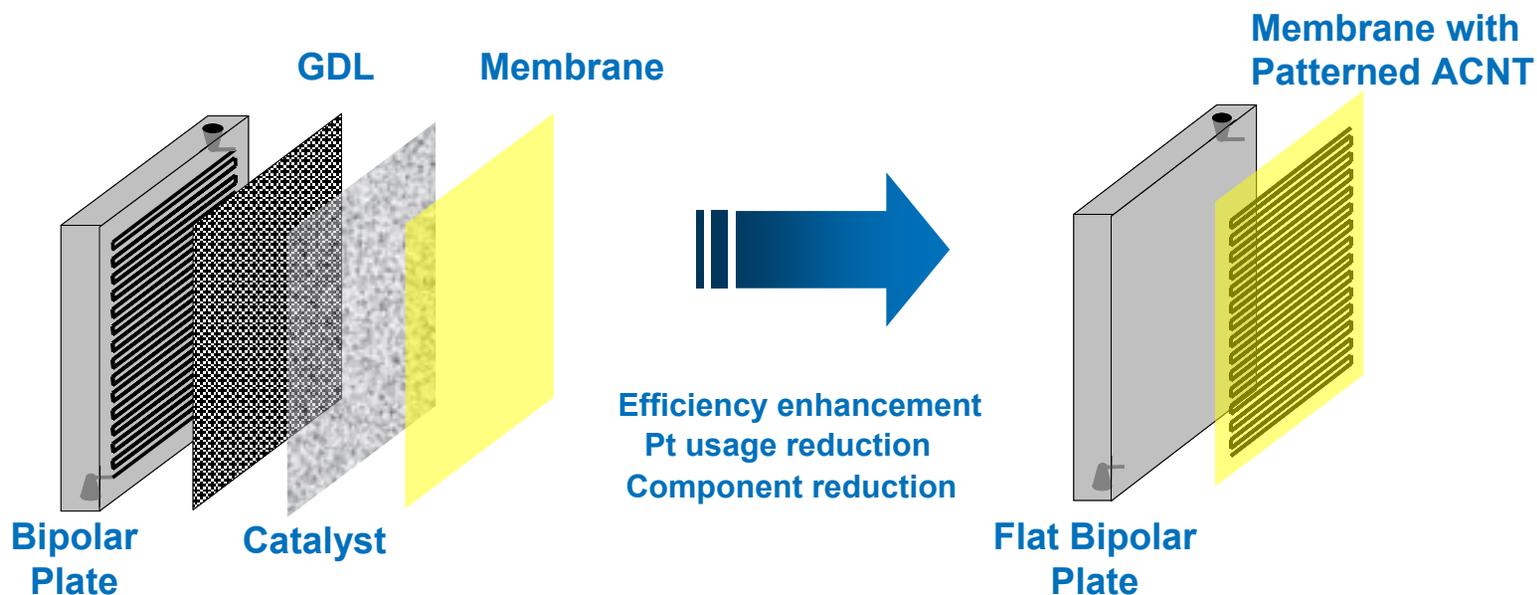
- Total Project Funding
 - DOE \$ 1,000K
- Funding Received in FY07
 - \$ 420K

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 @ 80°C

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



The ACNT PEMFC Stack Development Consists of Three Main Tasks

Catalyzed ACNT

- ACNT synthesis
- Catalyzing through CVD
- Catalyzing through wet chemistry
- Structure & activity characterization

3-D MEA Development

- Modeling & simulation
- Preparation of patterned ACNT
- Preparation of MEA with patterned ACNT

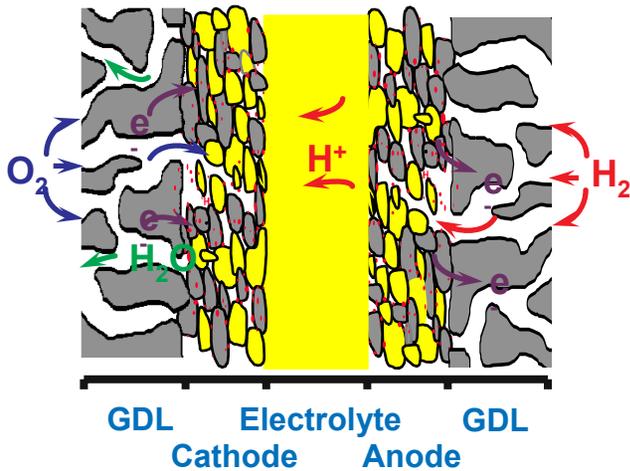
Packaging & Testing

- Packaging method optimization
- Cell performance evaluation

Approach (continued)

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

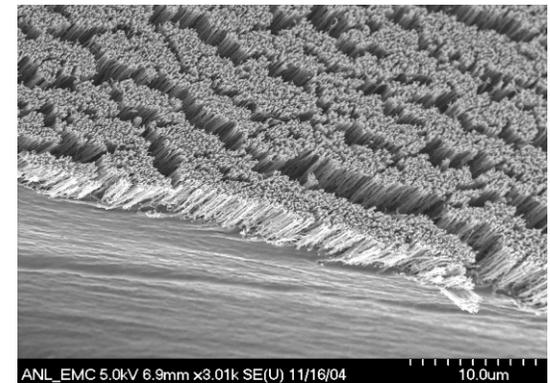
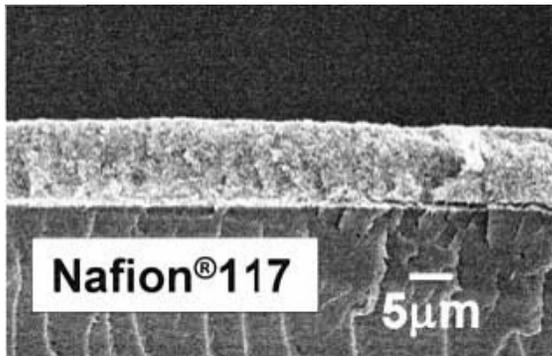
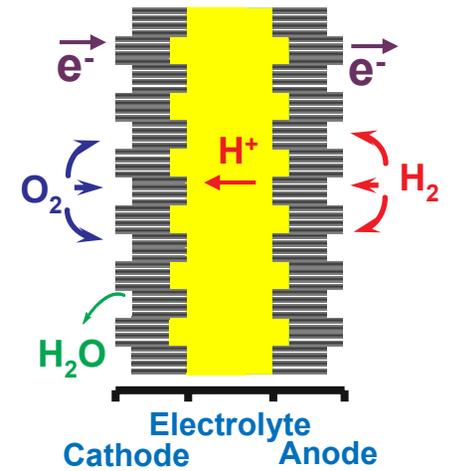
Conventional MEA



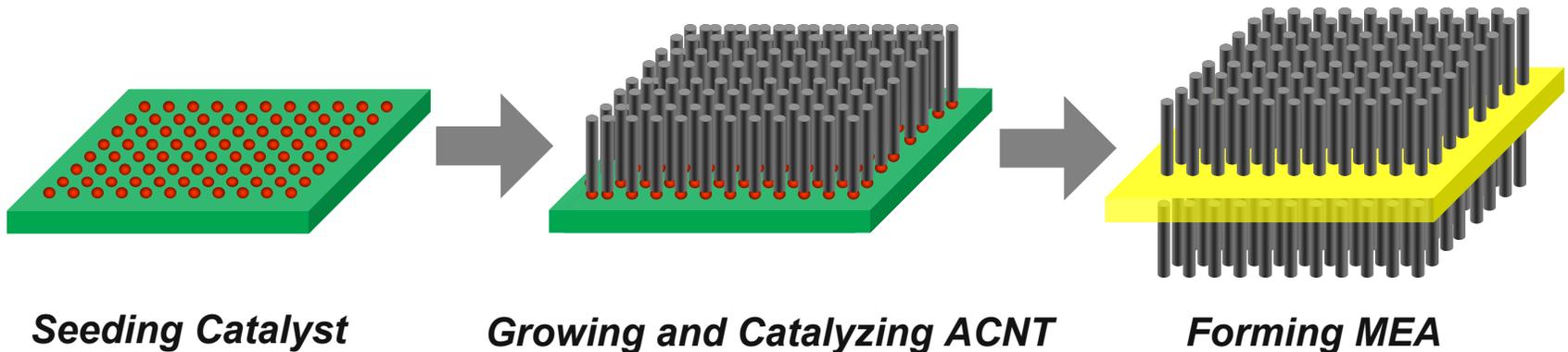
Advantage of ACNT MEA

- 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



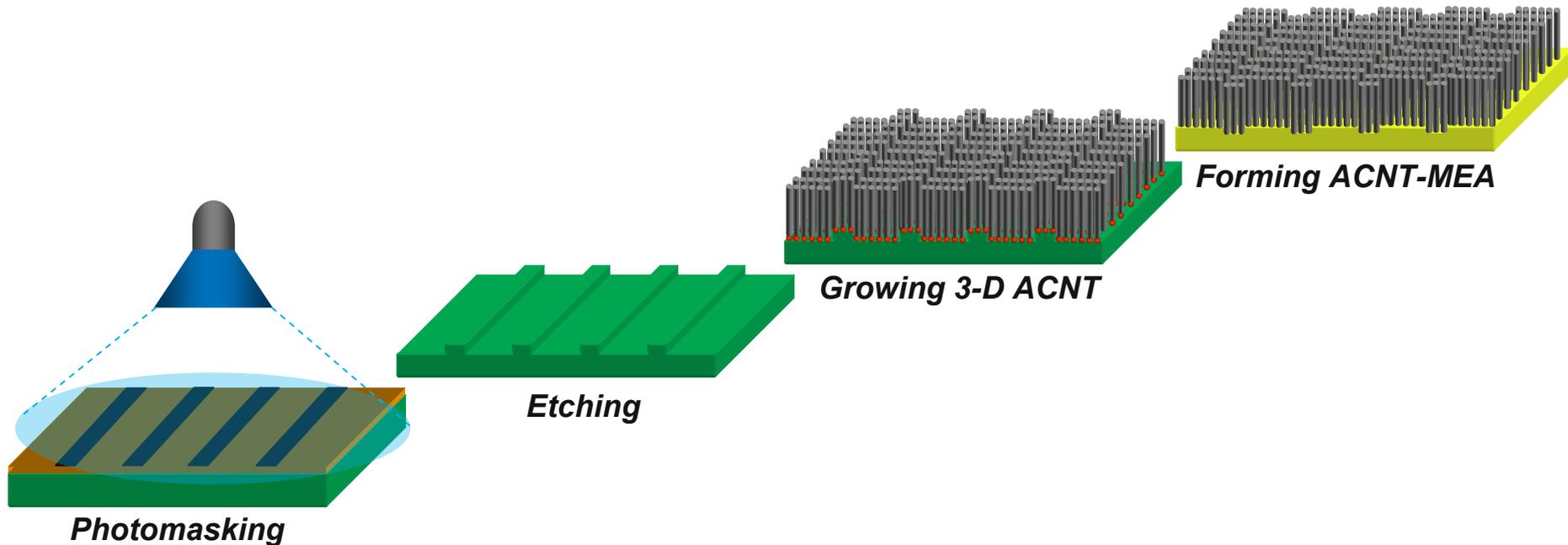
Process of Fabricating ACNT as MEA for PEFC



Processes for Functionalizing/Catalyzing ACNT

- Gas phase CVD
- Wet chemistry

Process of Building 3-Dimensional ACNT/MEA



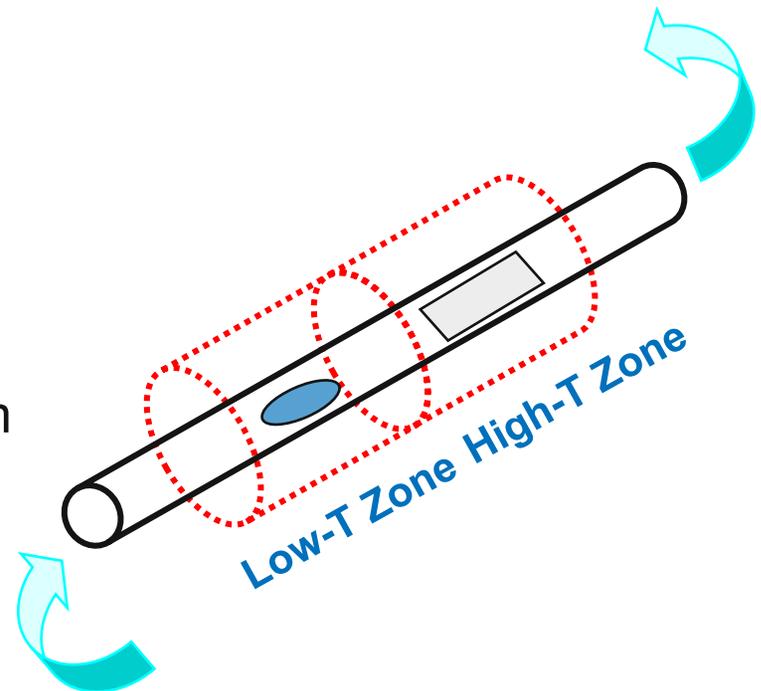
- Photolithographic method produces 3-D substrate with flow-field pattern
- 3-D ACNT carpet growth over 3-D substrate
- Transfer 3-D ACNT layer onto membrane electrolyte

Accomplishment & Progress

- 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

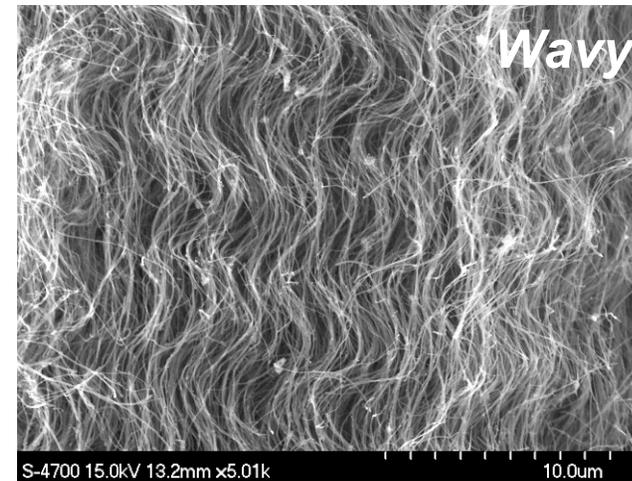
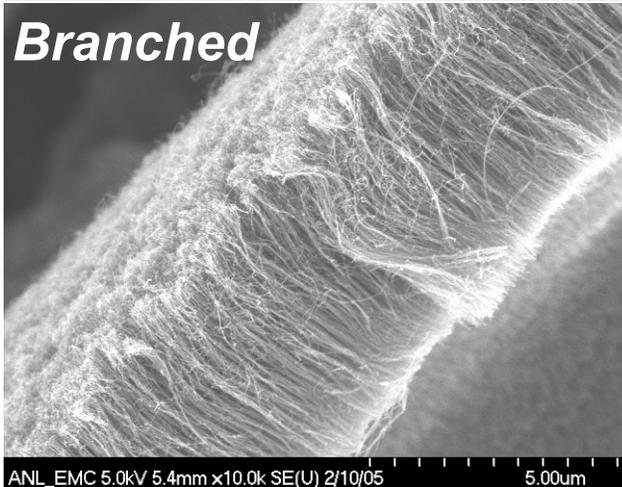
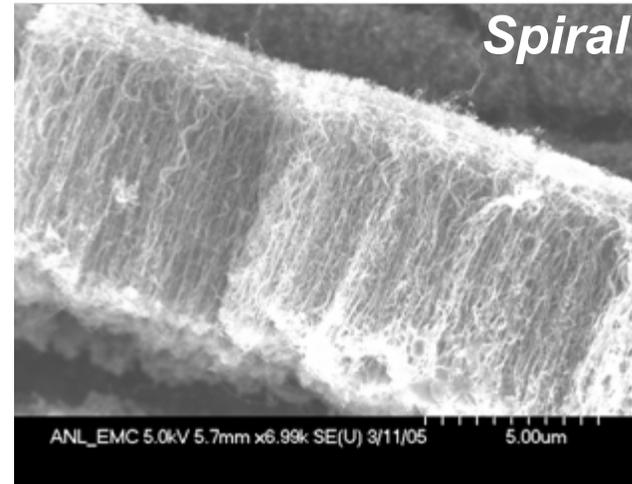
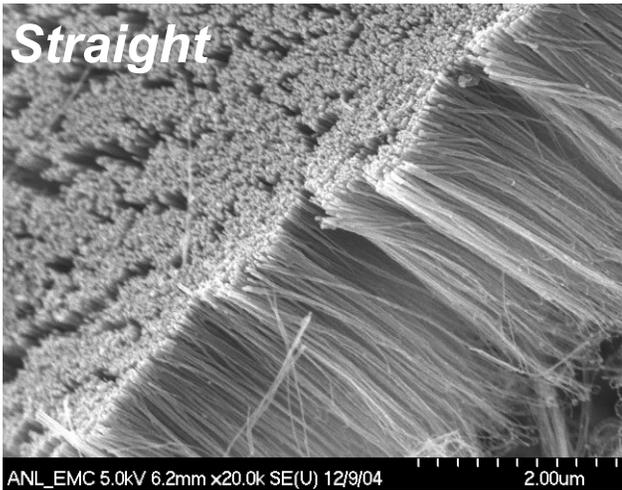
Synthesis of Aligned Carbon Nanotube (ACNT)

- 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



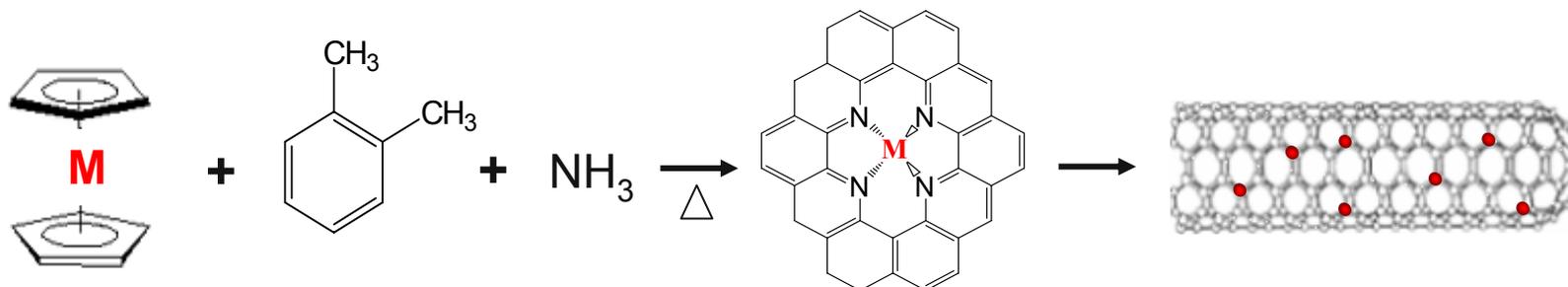
Accomplishment & Progress (continued)

Examples of ACNT prepared under different conditions

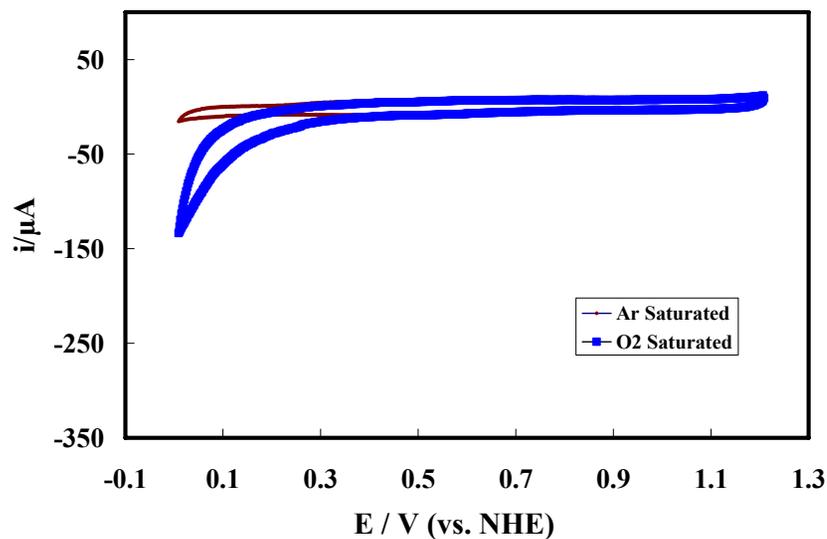


Accomplishment & Progress (continued)

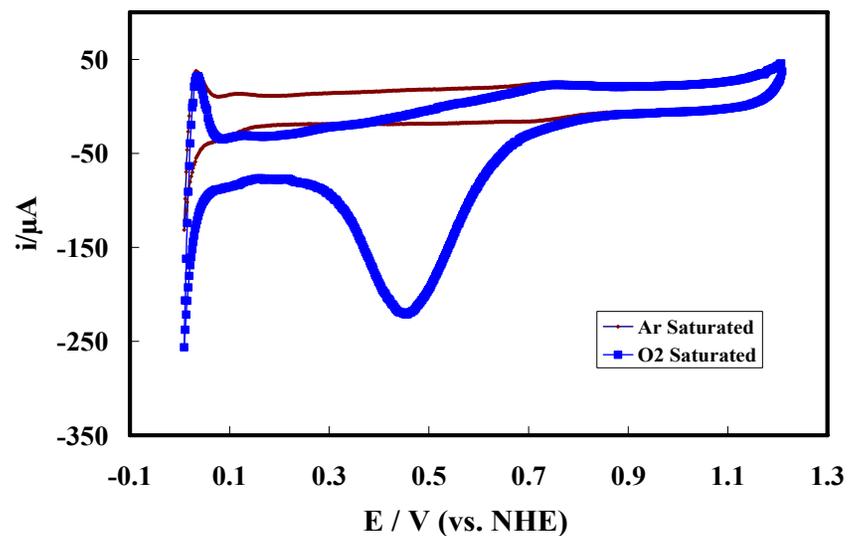
Functionalizing Catalytic Active Site through TM & N-doping



ACNT without N-doping

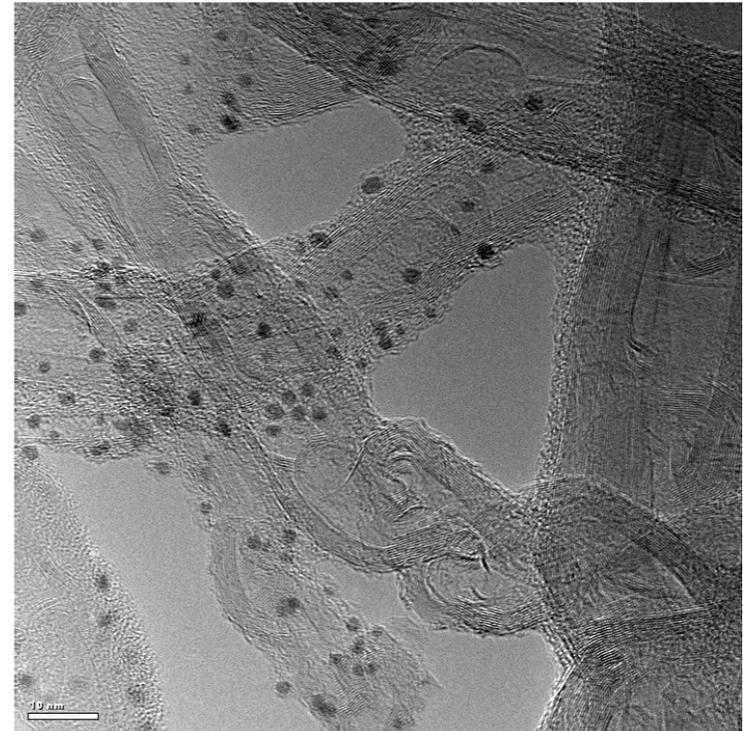


ACNT with N-doping



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

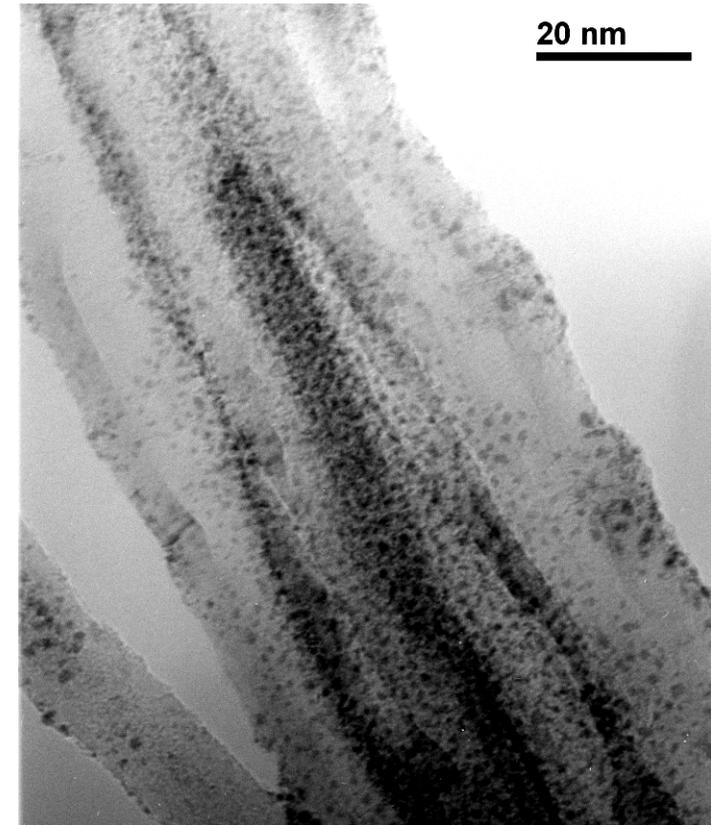


TEM image of Pt-decorated carbon nanotubes by co-CVD

Accomplishment & Progress (continued)

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



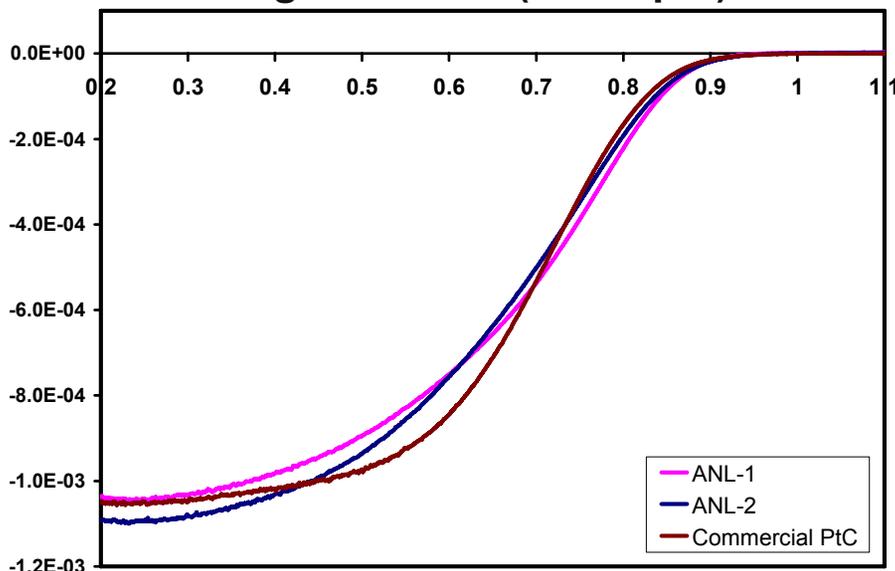
TEM image of Pt/CNT
prepared by wet chemistry

Accomplishment & Progress (continued)

Electrocatalytic Evaluation & Testing

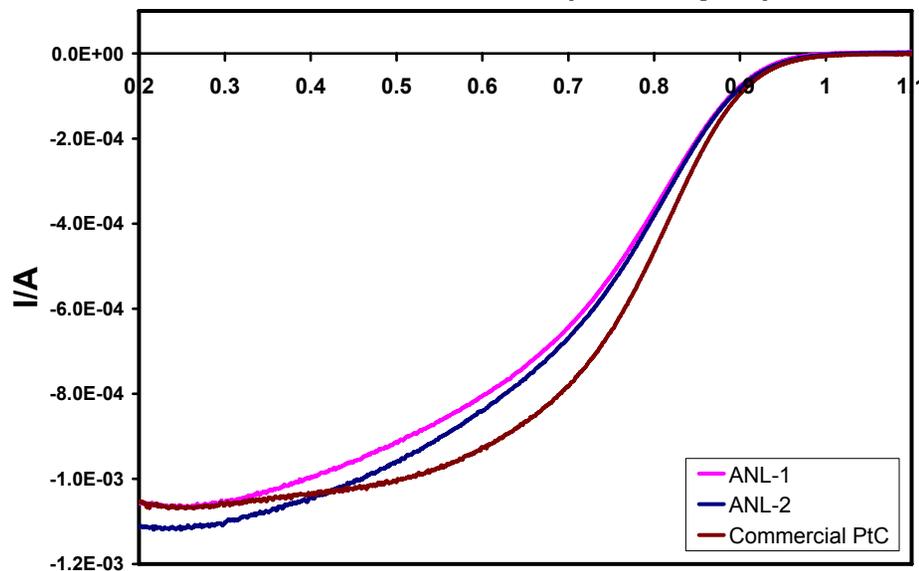
RDE Measurement of ORR Activity

Negative scan (1600 rpm)



E (V vs SHE)

Positive scan (1600 rpm)



E (V vs SHE)

- 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

■ 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

■ 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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