Novel Stack Concepts: Patterned Aligned Carbon Nanotubes as Electrodes in MEAs

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This presentation does not contain any proprietary or confidential information
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

- Topic 5A – Innovative Stack Concepts

- $ 500 K per year for 2 years
Relevance to FreedomCAR & Fuel Technical Barriers & Targets

This project addresses the following technical barriers:

A. Durability
   - Replace amorphous carbon with more chemically inert graphitic ACNT

B. Cost
   - Reduce or replace Pt with built-in transition metal catalytic site
   - Eliminate GDL and simplify bipolar plate design with 3-D ACNT “carpet”

C. Performance
   - Improve fuel utilization and conductivity through novel nano-architecture

D. Water Transport & Thermal Management
   - Improve water/mass transport and thermal conductivity through patterned nanotubes with micrometer-dimension flowfield

This project addresses the following technical targets for MEA:

- MEA Cost: $10/kW
- Durability: 5000h @ 80°C
Technical Approach

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

**Conventional MEA**

- Oxygen ($O_2$) diffuses through the GDL to the cathode where it reacts with protons ($H^+$) to produce water ($H_2O$).
- Hydrogen ($H_2$) diffuses through the GDL to the anode where it reacts with electrons ($e^-$) and protons ($H^+$) to produce water ($H_2O$).

**Advantage of ACNT MEA**

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

**ACNT MEA**

- Electrons ($e^-$) flow from the cathode to the anode through the ACNTs.
- Protons ($H^+$) and oxygen ($O_2$) diffuse through the MEA.
- Water ($H_2O$) is produced at the cathode and anode.

*Nafion® 117* 5 µm

[Image of Nafion® 117 membrane]

[Image of Aligned Carbon Nanotubes (ACNT) as MEA for PEFC]
Technical Approach

Process of Fabricating ACNT as MEA for PEFC

Growing and Catalyzing ACNT  Forming MEA

Straight  Spiral  Branched
## Project Timeline

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<td>2. Building 3-D MEA</td>
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<td>2.3 Method development for ACNT MEA</td>
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<td>Project Completion</td>
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Gantt chart based on calendar quarters
Functionalize ACNT with Electrocatalytic Activity

Building ORR Active Site through TM & N-doping During CVD Process

ACNT without N-doping

ACNT with N-doping
Probing ORR Active Site Through X-ray Absorption Spectroscopy

ORR likely involves a redox process around active site –FeN₄-
Building Three-Dimensional ACNT/MEA

**Photomasking**

**Etching**

**Growing 3-D ACNT**

**Forming ACNT-MEA**

Photolithography enables construction of any desired patterns for gas distribution channels with micrometer resolution.

![Photomask images](ANL EMC 3.0kV 13.0mm x200 SE(U) 200µm)

![Etched sample image](ANL EMC 3.0kV 12.6mm x110 SE(U) 500µm)
Key Milestones & Go/No-go Decision

- Demonstrate catalytically functionalized ACNT by completing development of two CVD catalyzing methods and two wet chemistry methods, followed by electrocatalytic activity and structural characterization – (Q1 FY08)
- Demonstrate the feasibility of ACNT based MEA by completing patterned layer preparation and membrane transfer technique development – (Q1 FY08)
- Demonstrate ACNT based PEFC by completing packaging method development and cell testing – (Q4 FY08)
- Complete feasibility analysis for material and engineering scale-up and documentation to DOE – (Q1 FY09)

A midterm go/no-go decision will be made at Q1 FY08 based on electrocatalytic performance against the benchmark and success of ACNT-MEA fabrication
**Inputs/Needs**

- We will seek industrial teams’ input and guidance on the research direction through each phase of the project.

- We will consult with the experts from fuel cell manufacturers and other labs during stack packaging and integration development.

- If successful, we will search for industrial partnership to develop roadmap for potential technology transfer and commercialization.
Argonne Team Members & Collaborators

- Junbing Yang
- Magali Ferrandon
- Suhas Niyogi
- Nancy Kariuki
- Jennifer Mawdsley
- Dennis Papadias