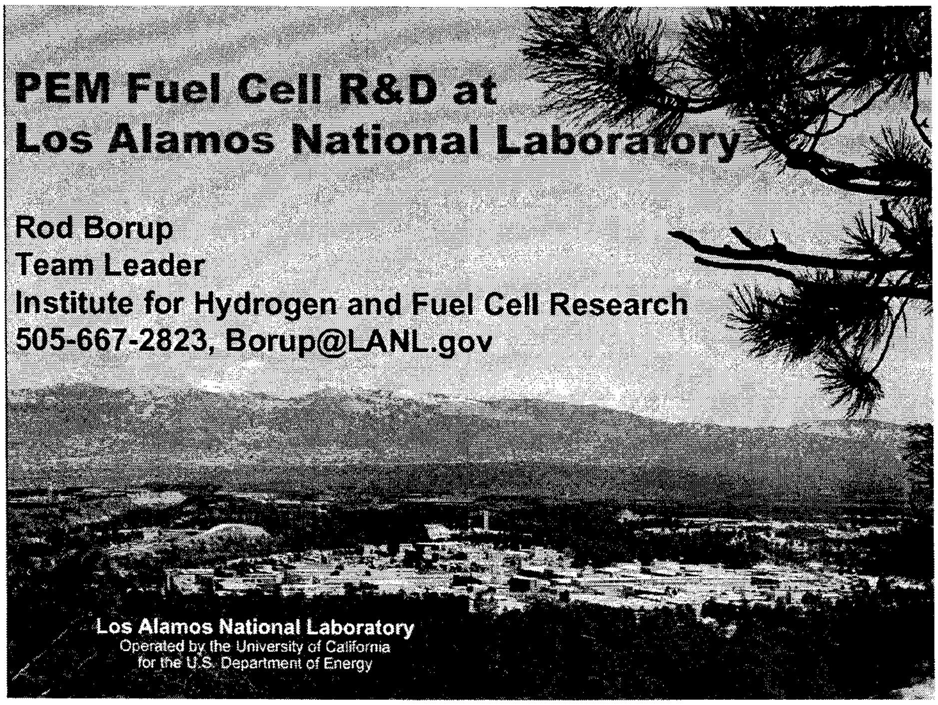

Los Alamos National Laboratory

- ~ $2 Billion annual budget
- ~ 8000 University of California employees
  - > 3800 technical staff members
- ~13,000 people on site each day
- 43 square miles, 2000 buildings with ~ 8 million sq. ft.

Strategic Research Directorate: Works with Academia and Industry

- 2,000 staff, ~$400M
  - Host to ~1,500 students and ~400 Post Docs per year
    - 260+ participating universities
- Intellectual property and economic development (2004)
  - 104 industrial partnerships; 68 CRADAs

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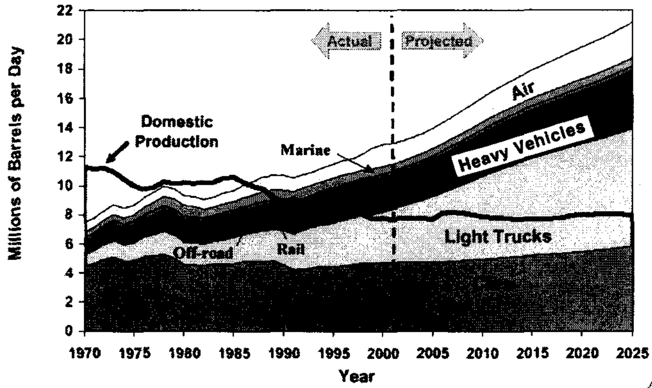
Why Fuel Cells?

(Major funding come from U.S. DOE)

- **U.S. Highway Transportation Uses More Oil Than Is Produced Domestically**
- (U.S. Reserves/Production is estimated as low as 7 years)
- To Reduce Oil Consumption – **Target is the transportation sector**



Source: Transportation Energy Data Book: Edition 22, September 2002 and EIA Annual Energy Outlook 2003, January 2003

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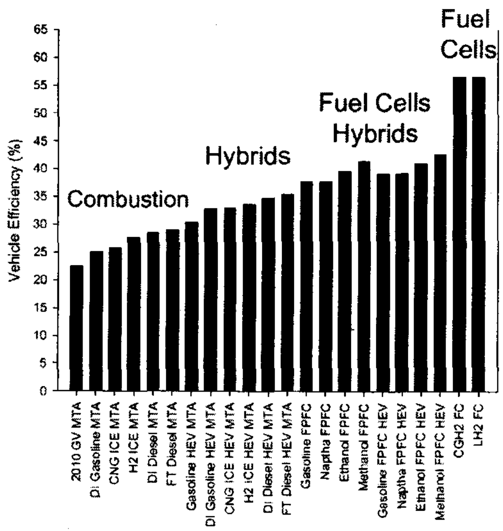
Vehicle Efficiencies



Hydrogen Fuel Cells show the greatest vehicle efficiency

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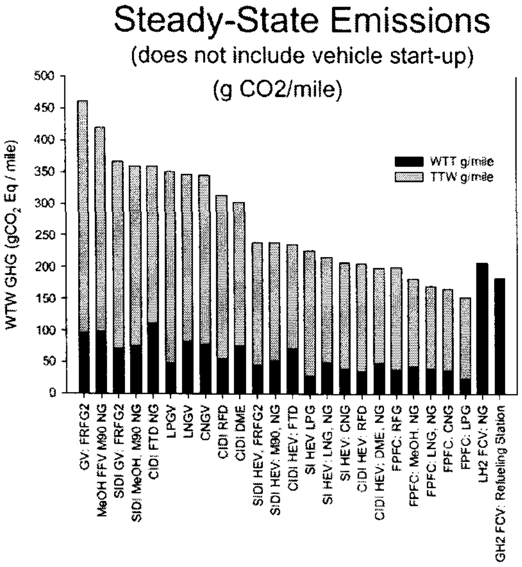
Well-to-Wheel Green-House-Gas Emissions



Fuel cell vehicles show the lowest green-house gas emissions

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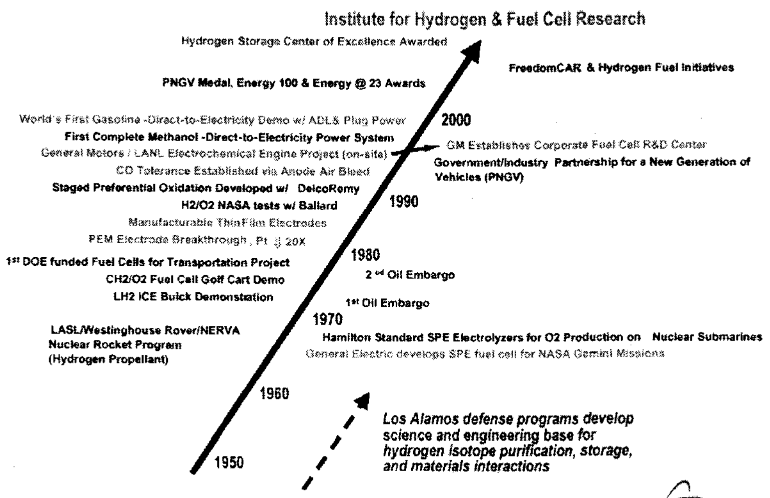
Fuel Cell & Hydrogen Timeline at Los Alamos

Los Alamos activities & accomplishments vs. external events



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Fuel Cells
Some currently funded research areas

Sponsors include DOE/EERE, DOE/FE, DARPA and industry

- **Electrode Optimization**
- **Non-Precious-Metal Catalyst Development**
- **Development of New Higher-Temperature Membranes**
- **Non-Nafion Electrodes**
- **Stack Durability**
- **Solid-State Sensors for Fuel Cell Applications**
- **Freeze and Cold Operation**
- **Fundamental Science for Cost and Durability**
- **Direct Methanol Fuel Cell R&D**
- **Small Hydrogen Fuel Cells for Battery Replacement**
- **Hydrogen Production**
  - Hydrogen purification
  - Diesel reforming for SOFC APU applications
  - Methanol steam reforming for portable power applications
  - High-temperature electrolysis
- **International Hydrogen Codes and Standards Development**

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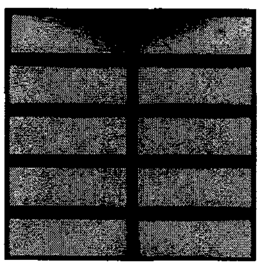
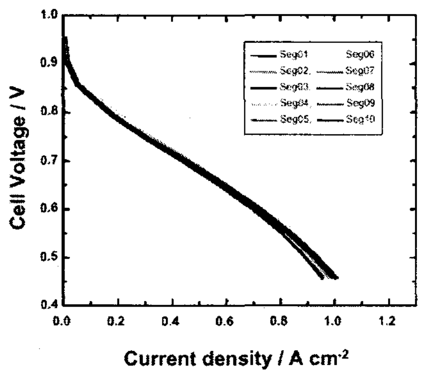
XRF Imaging and Segment Performance in the Segmented Cell





Anode: 810 sccm H_2, T_A=105°C, p=30psig

Cathode: 4000 sccm Air, T_C=80°C, p=30psig

Cell temp. = 80°C, 0.2 mg Pt/cm^2 at each electrode

- **Image shows even Pt distribution in all segments**
- **Even Pt distribution generates equivalent currents in all segments**

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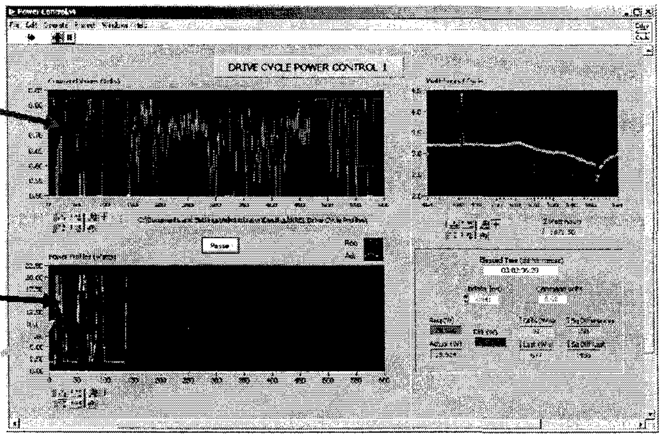
Durability: Fuel Cell Drive Cycle Testing

Voltage control profile:
Volt vs. Time (sec)

Power control profile
and
Power response profile
Watts vs. Time (sec)



1 cycle occurs every 20 minutes

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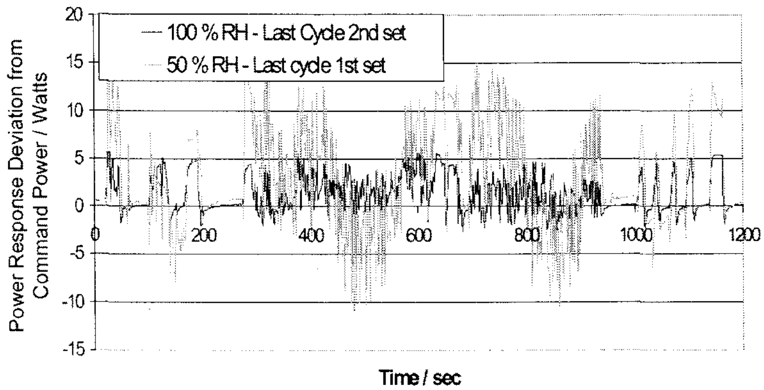
Power Response Deviation from Command Power



- 50% RH drive cycle cell shows lower power response than 100% RH cell
  - Commanded power is identical
- 50% RH power response shows greater deviation from commanded power

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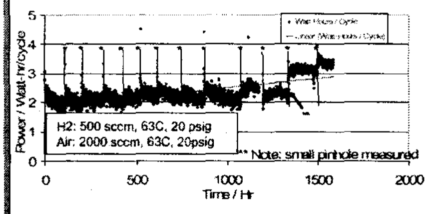
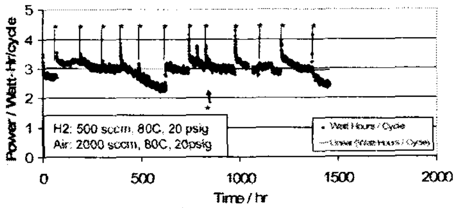
Drive Cycle Power Response

50% RH Humidification



100% RH Humidification



50 % Relative Humidity Operation

- Power output has shown a gradual power increase over time.
- Power output increased after pinhole formed in membrane
- Cycle/cycle power variations higher than 100% RH

- 100 % Relative Humidity Operation
- Power output for 100% RH drive cycle cell has shown ~ little decay

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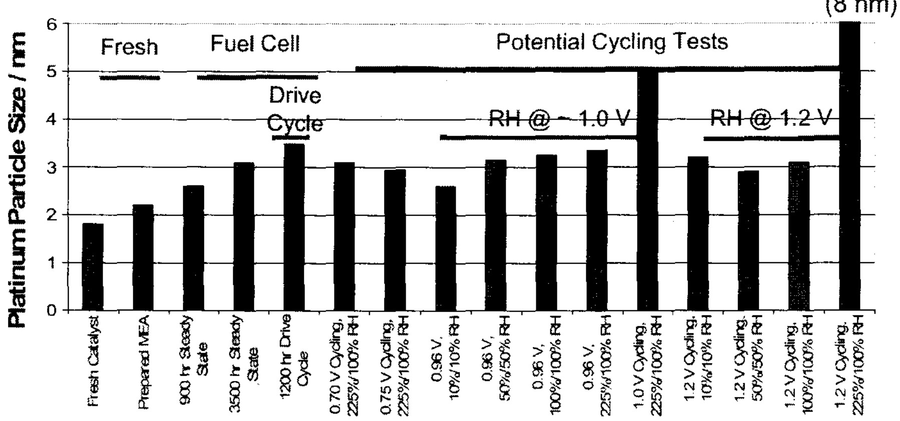
Electrocatalyst Growth



- Cycling is more detrimental than steady state operation
- # cycles has larger effect on catalyst sintering than time
- Pt particle growth on cathode occurs for steady-state, enhanced with cycling
- Greater particle growth at high temperatures
- Lower particle growth at low humidification

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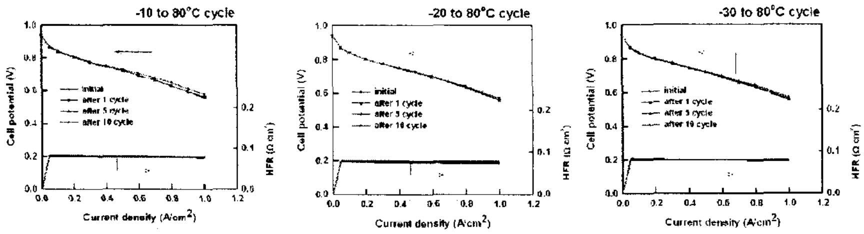
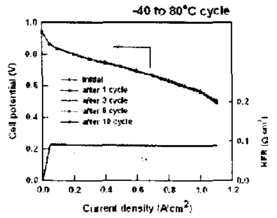
Freeze/Thaw cycling

GDL: carbon cloth (E-tek), Active area: 5 cm^2





- Each soak 4-16 hours
- No systematic degradation observed
- HFR remains constant
- DOE target for survivability is -40°C

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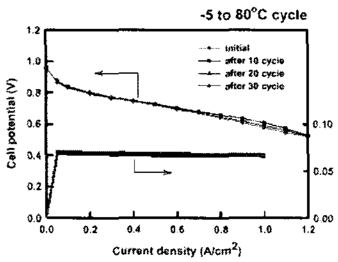
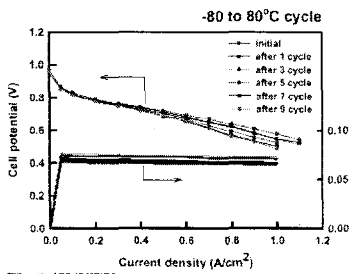
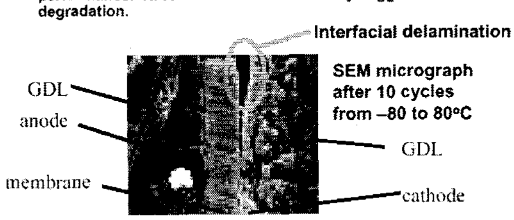
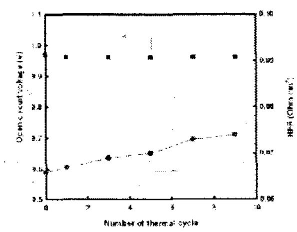
Performance Degradation after Freeze/Thaw Cycling





- Fuel cells stored under wet conditions (no attempt to dry).
- Freezing/Thaw cycling from -5 to 80°C gave no apparent performance degradation after >30 cycles.
- Freezing/Thaw cycling from -80 to 80°C quickly degraded performance. HFR increase and SEM study suggest interfacial degradation.





Interfacial Degradation with every cycle

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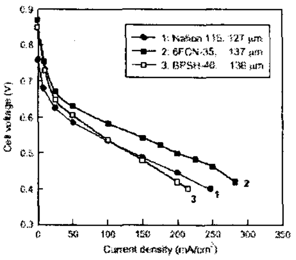
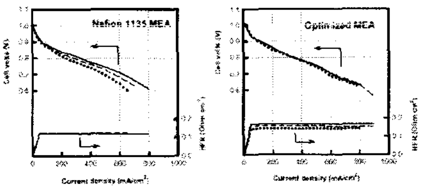
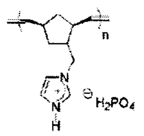
Alternative Membrane Research

DMFCs, Lower Cost, and High T Membranes

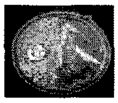




Minimizing interfacial resistance has led to highest reported performance of a DMFC[1] and improved durability in long term H_2 testing.



Alternative polymer significant cost savings and higher T_g's



High T polymers based on ILs have shown reasonable conductivity, work is preliminary.

[1] Kim et. al., *J. Electrochem. Soc.*, in press.

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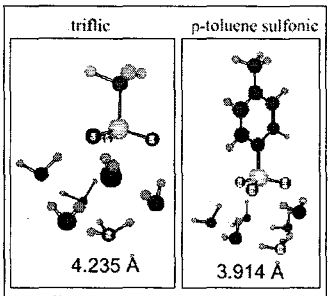
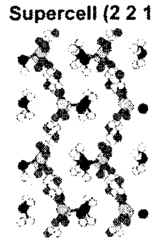
Ab initio Molecular Dynamic (MD) Calculations



Solvation of Protons: Direct DFT Computations on Water-Acid Complexes

Triflic Acid Monohydrate Crystal

Supercell (2 2 1)



Introduced proton defect

(observed mobility through 20000 time steps in MD run)

- **MD models have given insight into proton conduction.**
  - B3LYP lowest energy state calculations of hydrated acid groups (left) correlate to water uptake and acid strength.
  - Dynamic models (right) correlate to proton conductivity

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Non Precious Metal Catalysis

Objective:

Develop low-cost non-precious metal oxygen reduction reaction (ORR) catalyst for the polymer electrolyte fuel cell (PEFC) cathode with similar activity and performance durability to the currently used noble-metal based cathode catalysts.

Focus:

- ***Transition metal macrocycles (e.g. pyrolized TPP & TMPP chelates of Co & Co/Fe)*** – *advanced phase; progress to date summarized in this presentation*
- ***Chalcogenides (e.g. Ru-based and Ru-free catalysts)*** – *early phase, very promising initial results*
- ***Metal oxides (e.g. NiO, Co_2O_3, $NiCoO_2$, perovskitic LaSrCo oxides, CuMn oxides)*** – *part of future research*

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