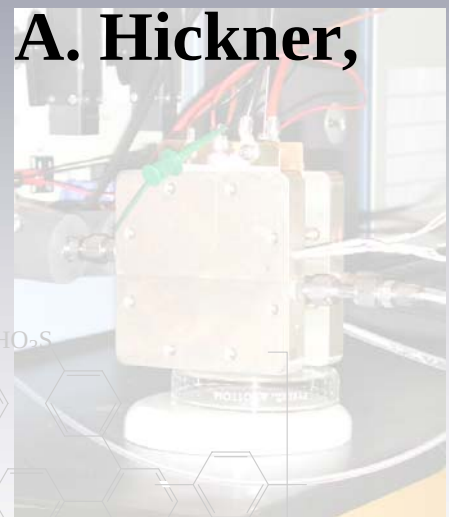
HTMWG Meeting 2004

High Temperature Fuel Cell Performance of Sulfonated Poly(phenylene) Proton Conducting Polymers

Chris J. Cornelius, Cy H. Fujimoto, Michael A. Hickner, and Darin Leonhardt

Chem and Bio Technologies
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185
cjcorne@sandia.gov



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PEM Challenge

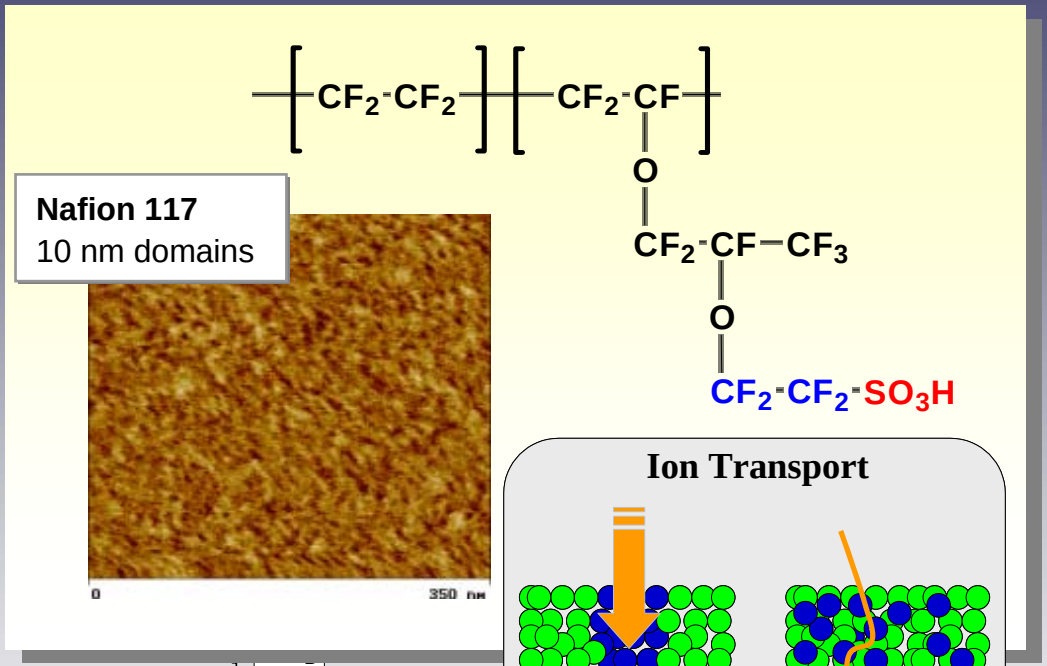
Fundamentals

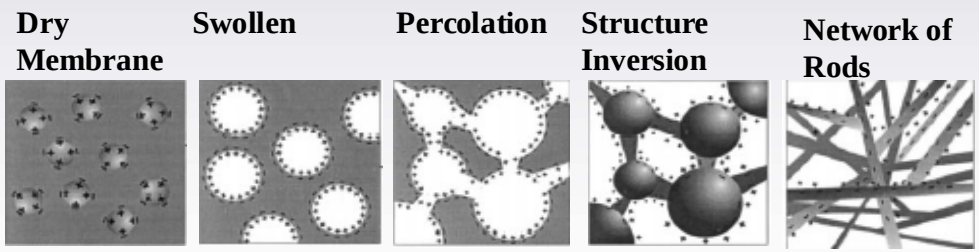
Advantages

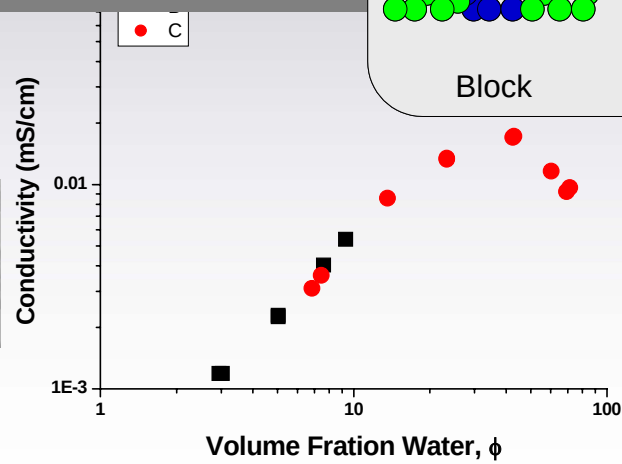
- High Proton Conductivity
- Material Processibility
- Durability (Lifetime)

Disadvantages

- Temperature Limitation
- Mechanical Properties
- Fuel Crossover (DMFC)
- ***Cost***







Gebel, G. *Polymer* **2000**, *41*, 5829

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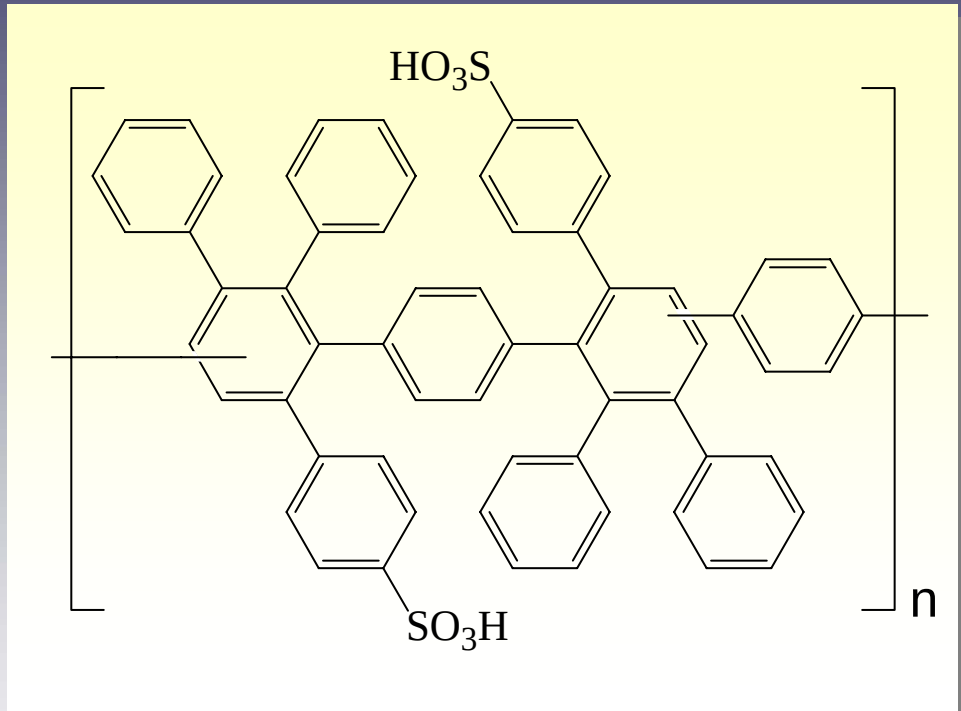
Polyphenylenes

Sulfonated Diels-Alder Polymer (SDAPP)

- Thermal Stability
- Good Chemical Stability
- Low Fuel Cross-Over
- Gas Transport (*Tunable*)
- Low Interfacial Resistance (*MEA – Electrodes*)
- Chemical Diversity
- ***Morphology***



C.H. Fujimoto, M.A Hickner, C.J. Cornelius, D.A. Loy *Macromolecules* in press.

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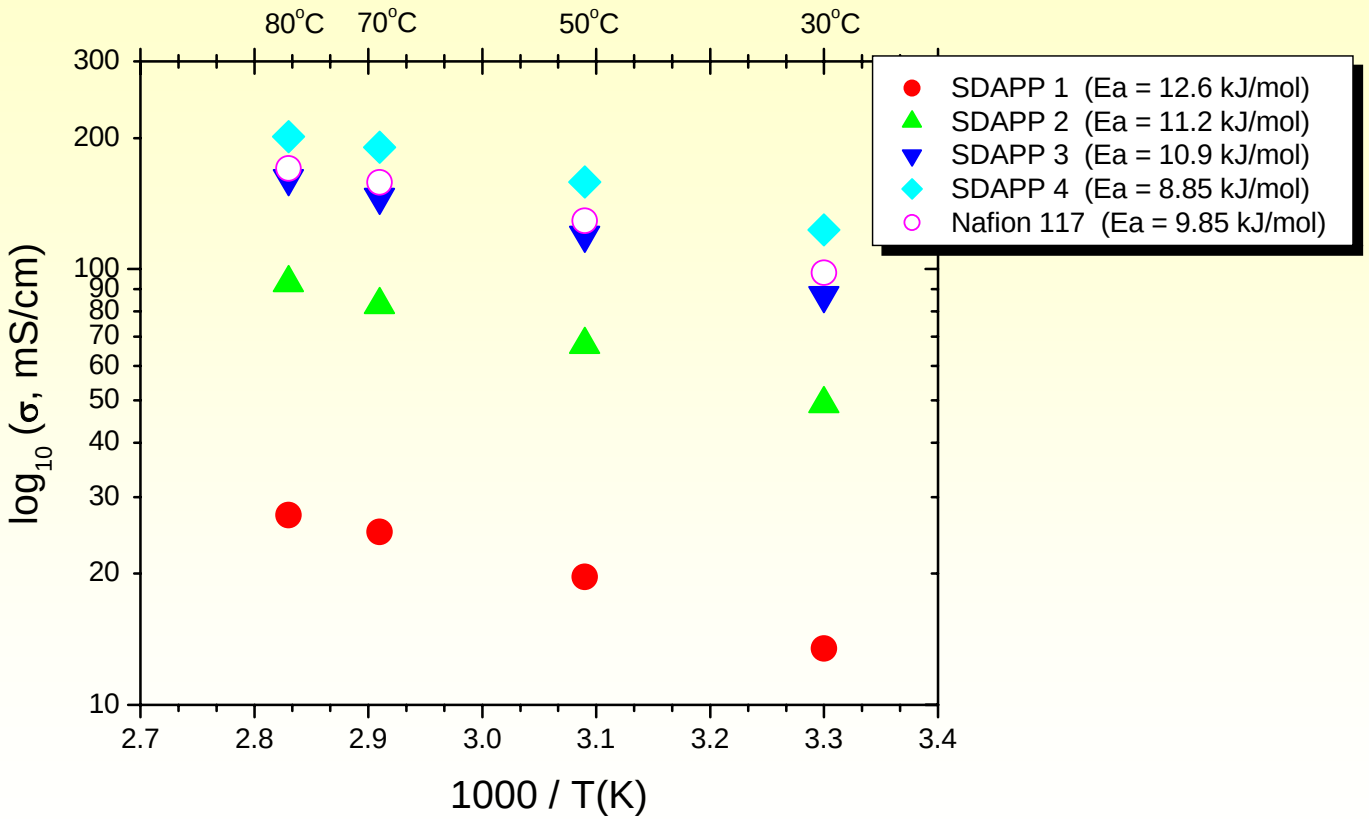
Physical Properties

Proton Conductivity vs. Temperature



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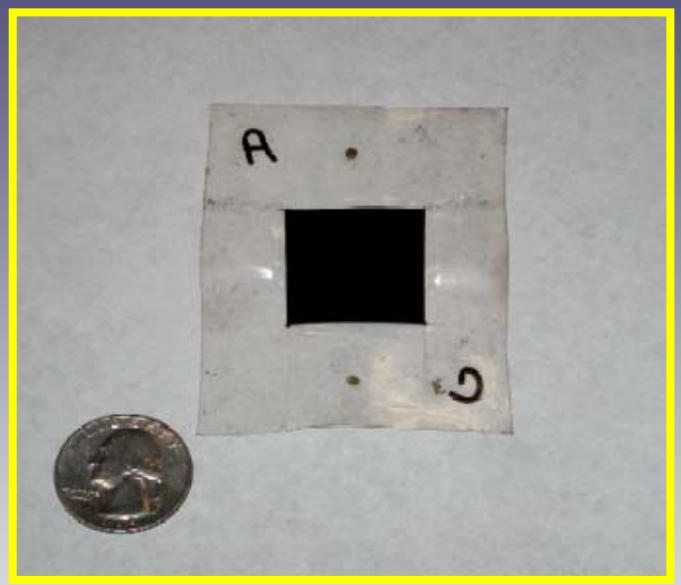
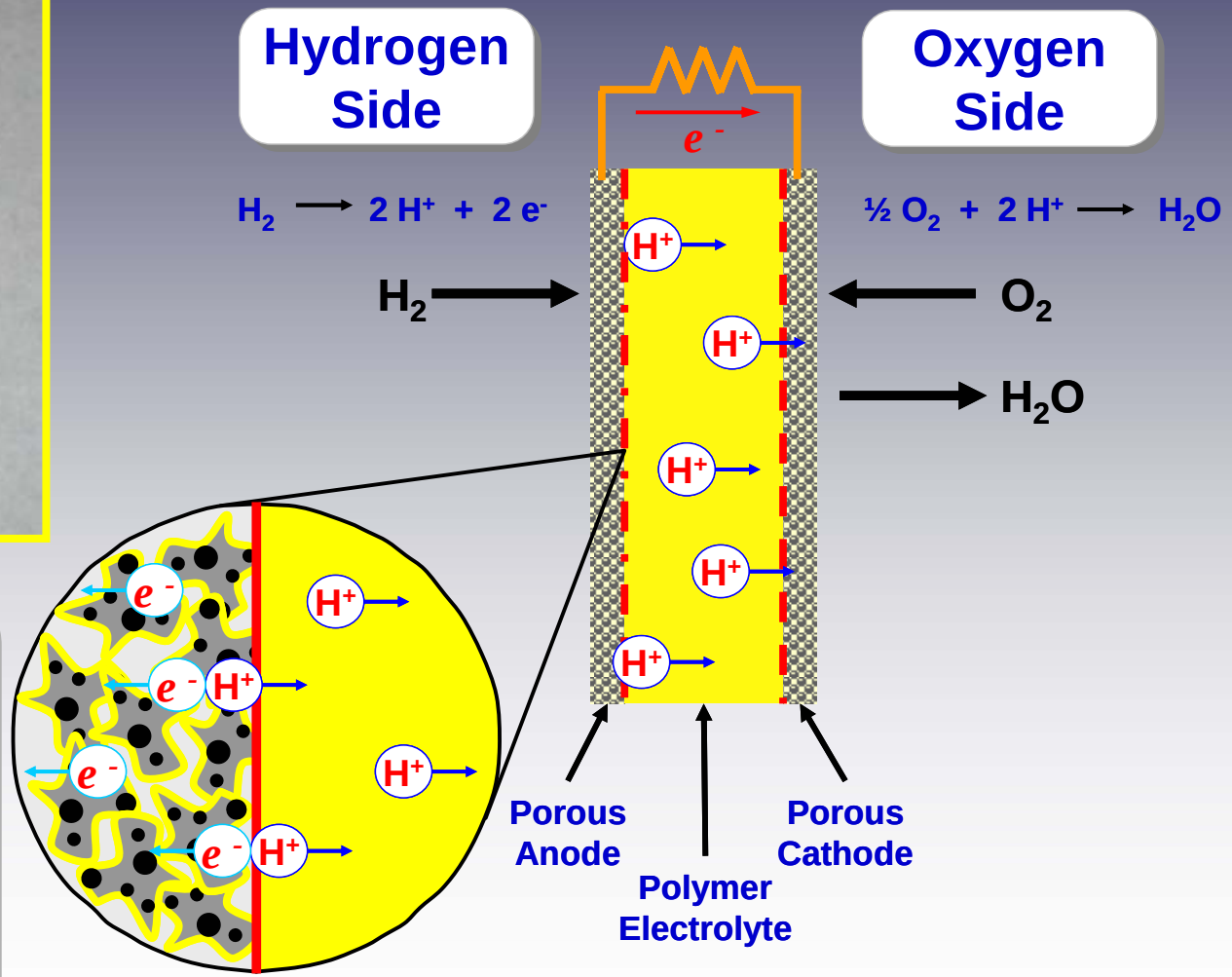
Fuel Cell

PEM & MEA Function



- Stable Interface
- Good Transport
- Low Interfacial Resistance
- Mechanical Integrity



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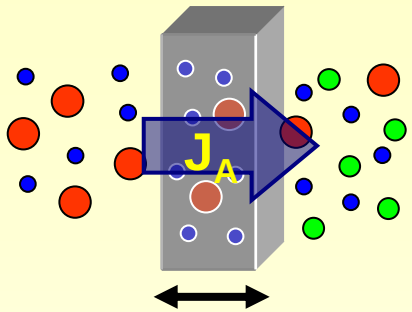
Fuel Cell

PEM & MEA Function



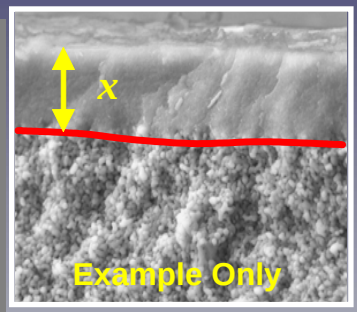
x

Film Thickness

$$Flux\left(J_A\right) = D_A \frac{\partial C_A}{\partial x}$$

$$E_D = n_d \frac{I}{F}$$

$$W_{BD} = D_w \frac{\Delta C}{\delta}$$



Hydrogen Side

Oxygen Side

$H_2 \rightarrow 2\,H^+ + 2\,e^-$

$\frac{1}{2}\,O_2 + 2\,H^+ \rightarrow H_2O$

H_2

O_2

H_2O

e^-

H^+

Porous Anode

Polymer Electrolyte

Porous Cathode

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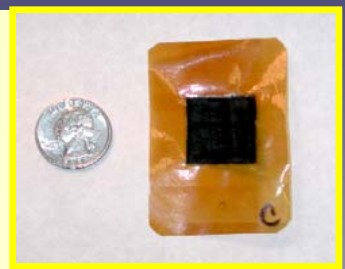
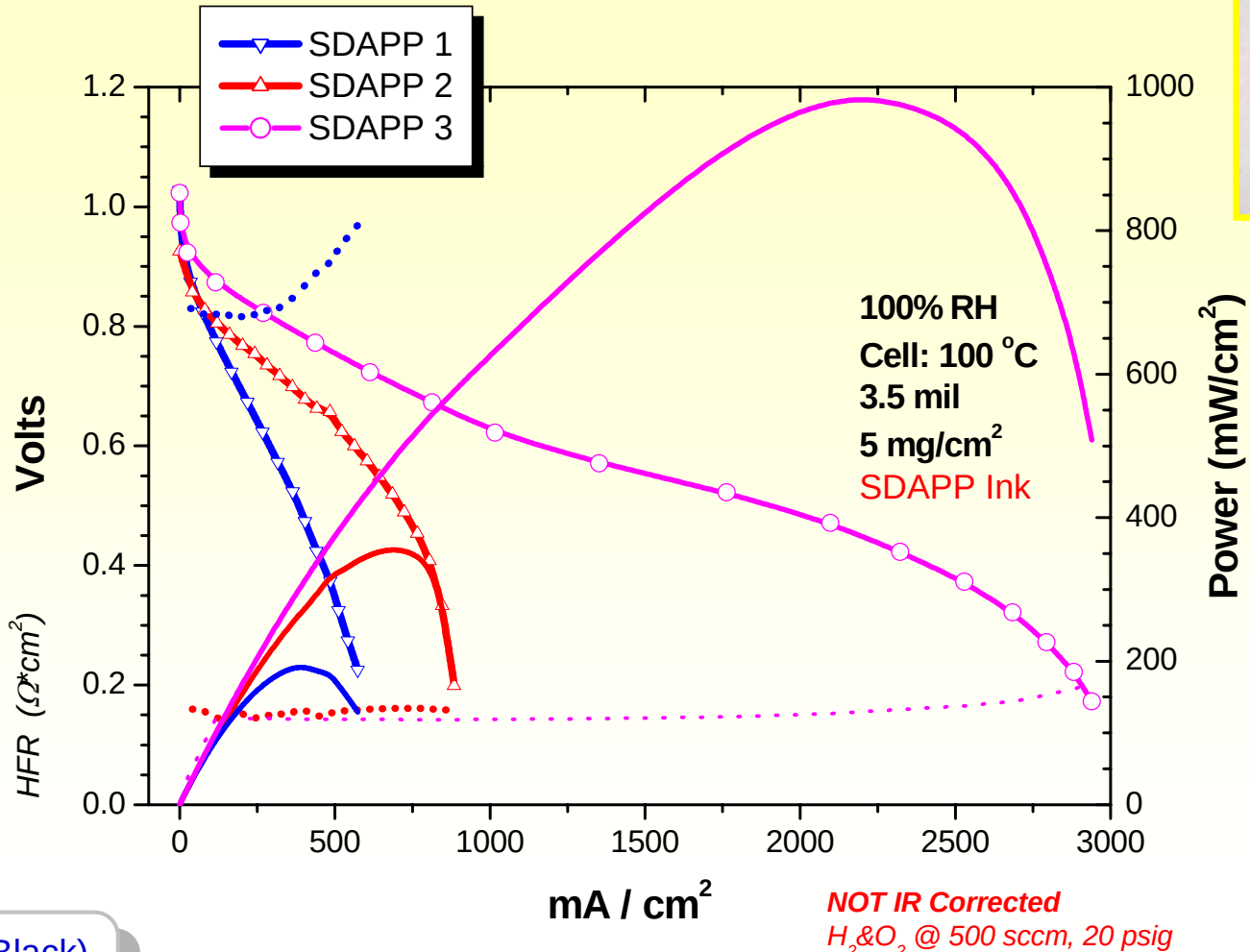
Fuel Cell Testing

H_2 & O_2 Fuel Cell Performance





NOT IR Corrected

H_2&O_2 @ 500 sccm, 20 psig

- 5 mg/cm² (Pt Black)
- Cell: 100 °C
- 100 %RH

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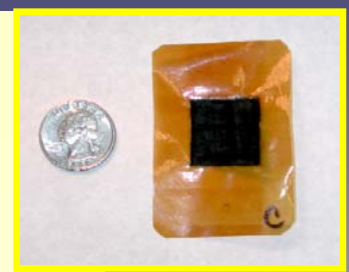
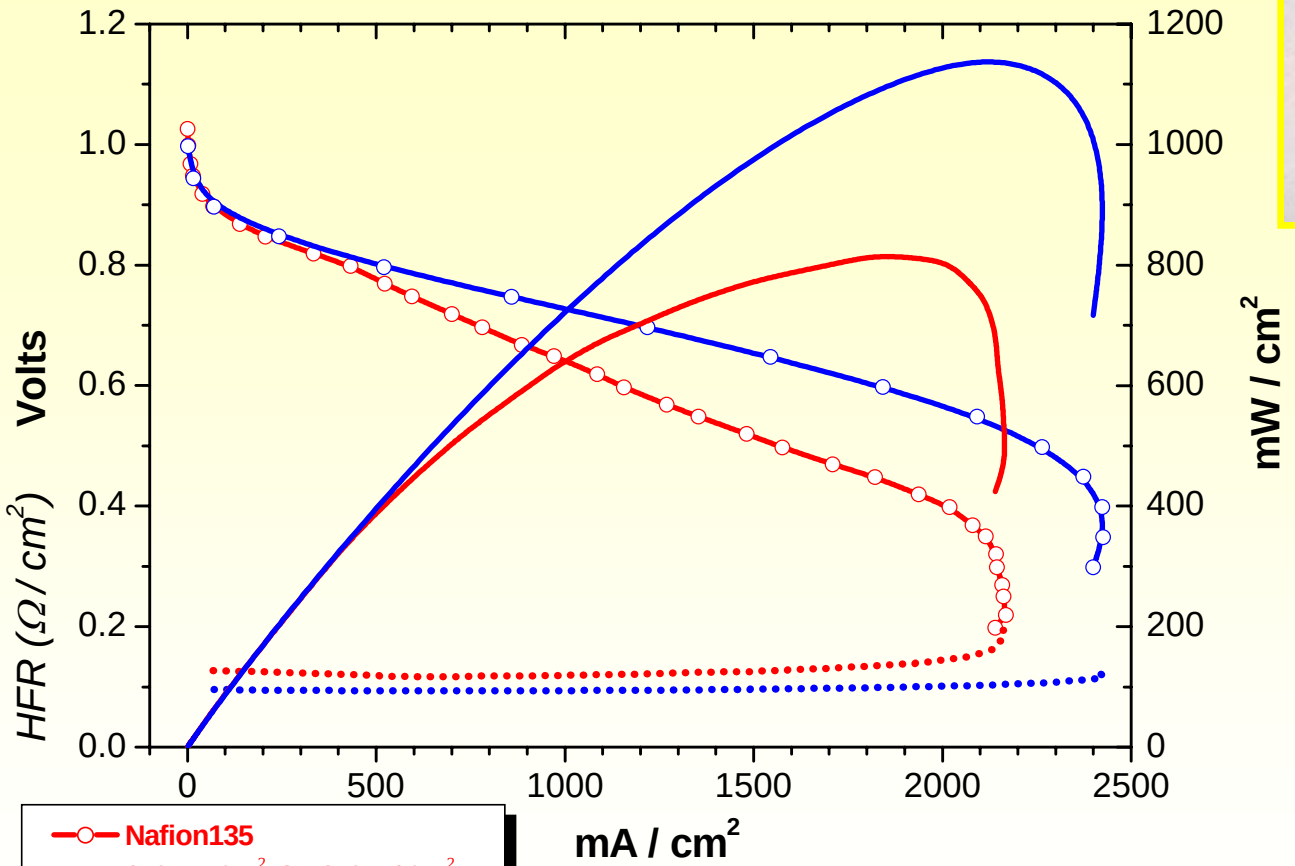
Fuel Cell Testing

H_2 & O_2 Fuel Cell Performance





NOT IR Corrected

Nafion: *Cell: 80 °C*, H_2&O_2 @ 300 sccm & 80°C, 20 psig

SNL-DA: *Cell: 80 °C*, H_2&O_2 @ 500 sccm & 80°C, 20 psig

- 5 mg/cm² (Pt Black)
- Cell: 80 °C
- 100 %RH

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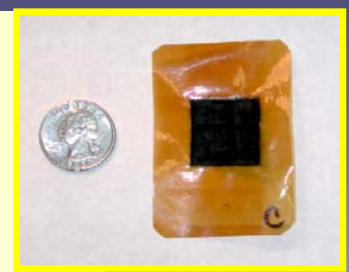
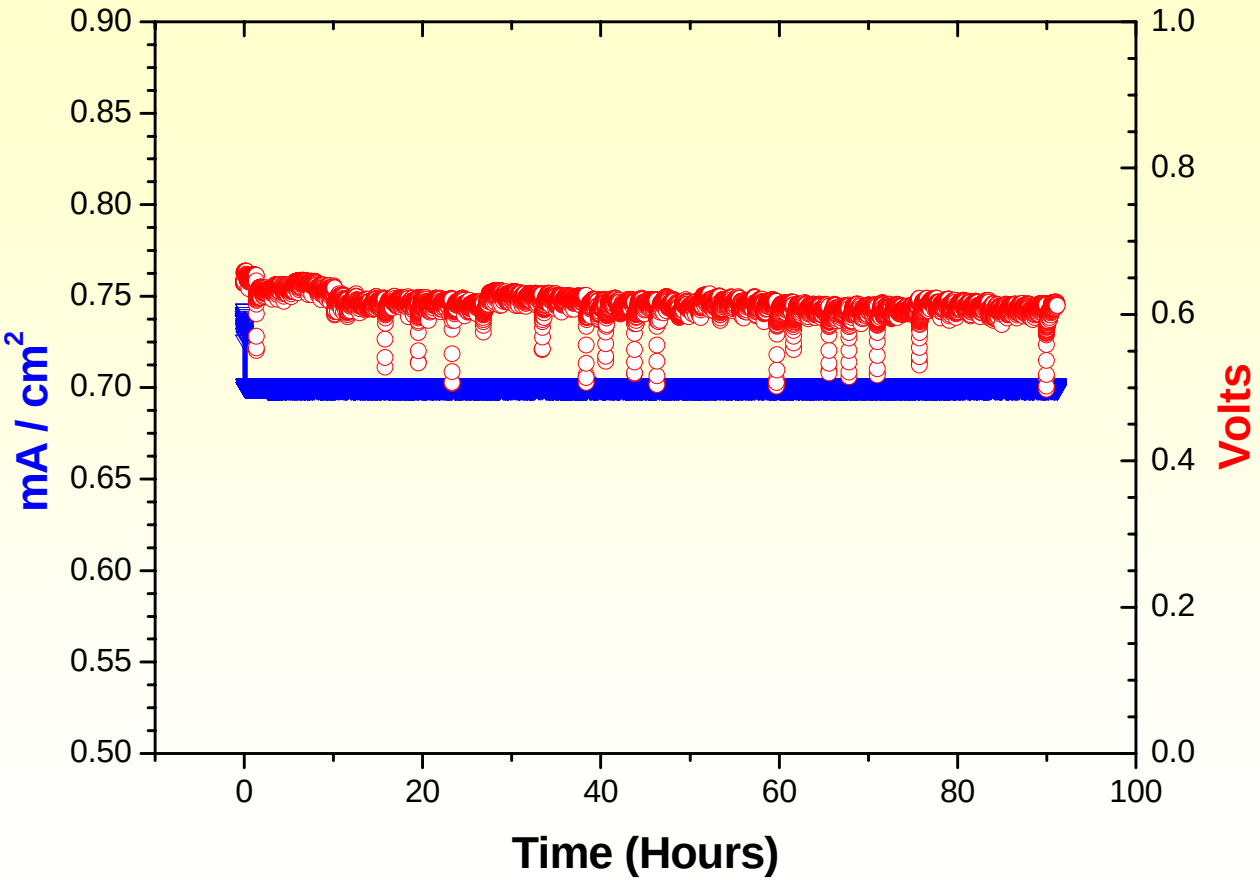
Fuel Cell Testing

H_2 & O_2 Fuel Cell Performance





NOT IR Corrected

Cell: 80 °C, H_2&O_2 @ 400 sccm & 82 °C, 20 psig)

- 5 mg/cm² (Pt Black)
- Cell: 80 °C
- 100 %RH

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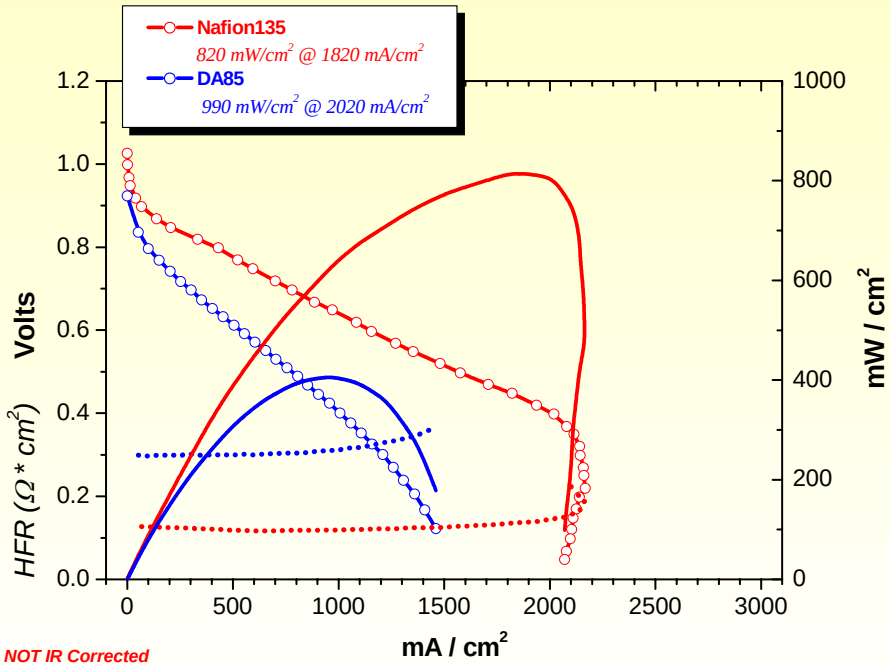
Fuel Cell Testing

Electrode & Performance



NOT IR Corrected

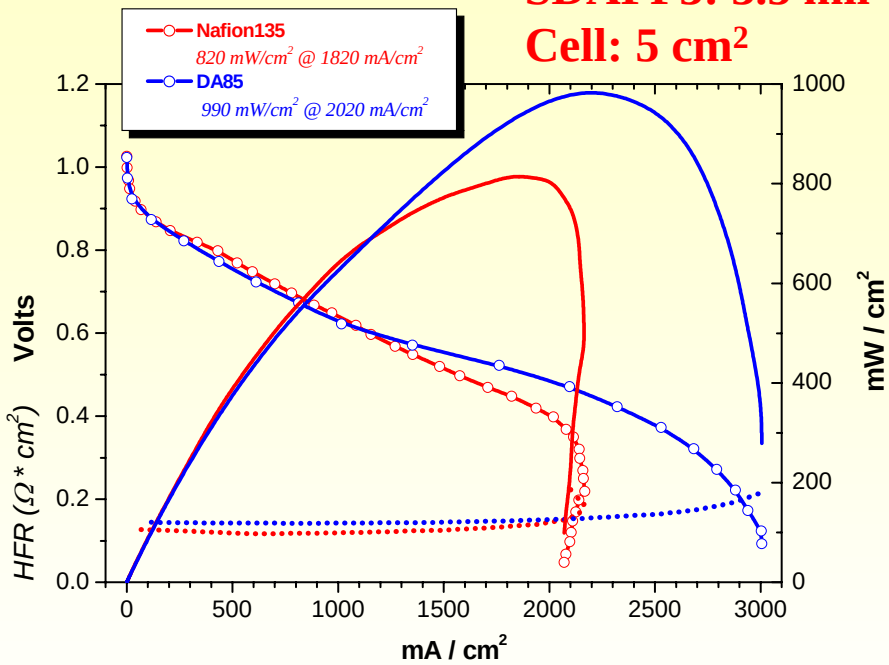
Nafion: *Cell: 80 °C*, H_2&O_2 @ 300 sccm & 80°C, 20 psig

DA75: *Cell: 80 °C*, H_2&O_2 @ 1000 sccm & 80°C, 20 psig

T_{cell} 80 °C

SDAPP3: 3.5 mil

Cell: 5 cm²



NOT IR Corrected

Nafion: *Cell: 80 °C*, H_2&O_2 @ 300 sccm & 80°C, 20 psig

DA75: *Cell: 100 °C*, H_2&O_2 @ 1000 sccm & 102°C, 20 psig

T_{cell} 100 °C

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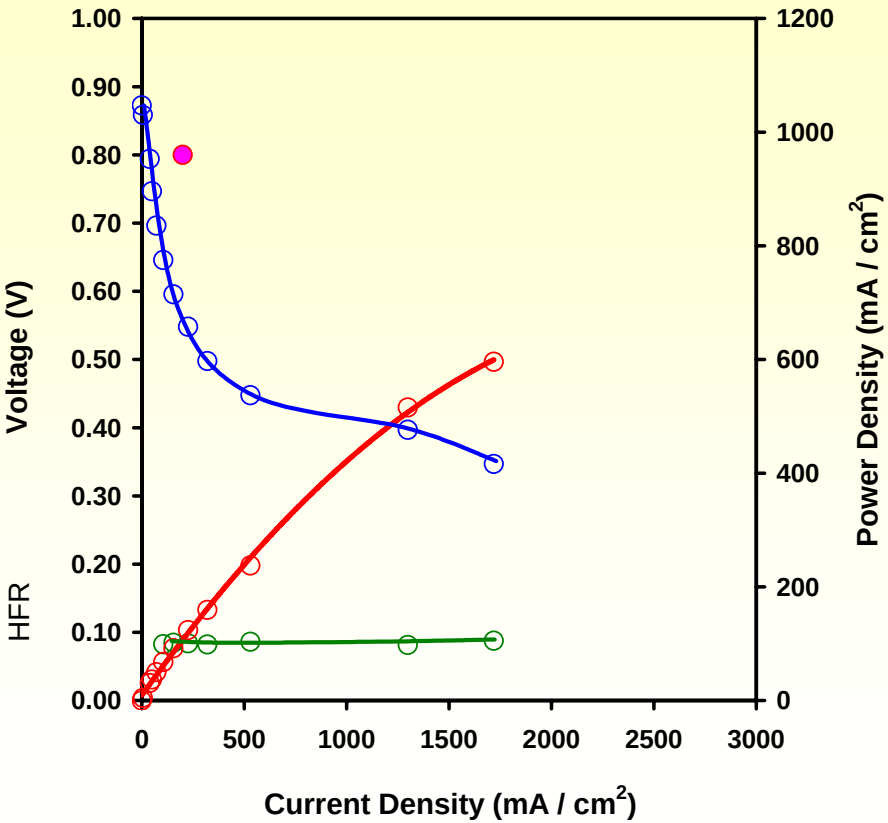
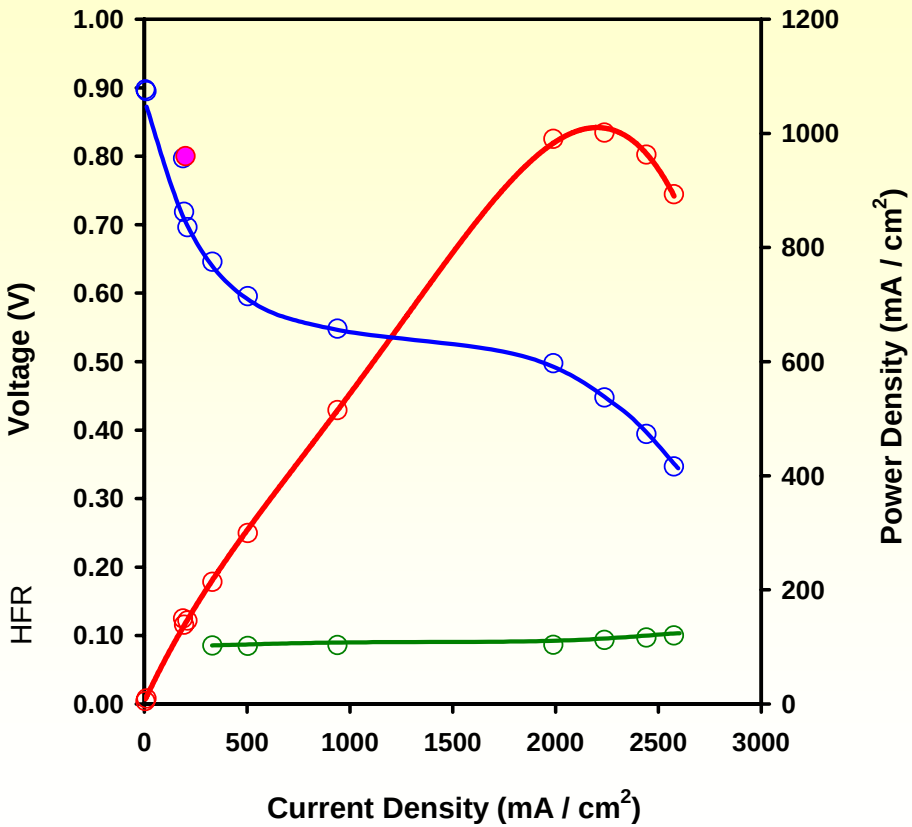
Fuel Cell Testing

Electrode & Performance

Air



Oxygen



- 0.4 mg/cm^2 (Pt Black, 7 wt%)
- Cell: 80 ^{o}C
- 100 %RH

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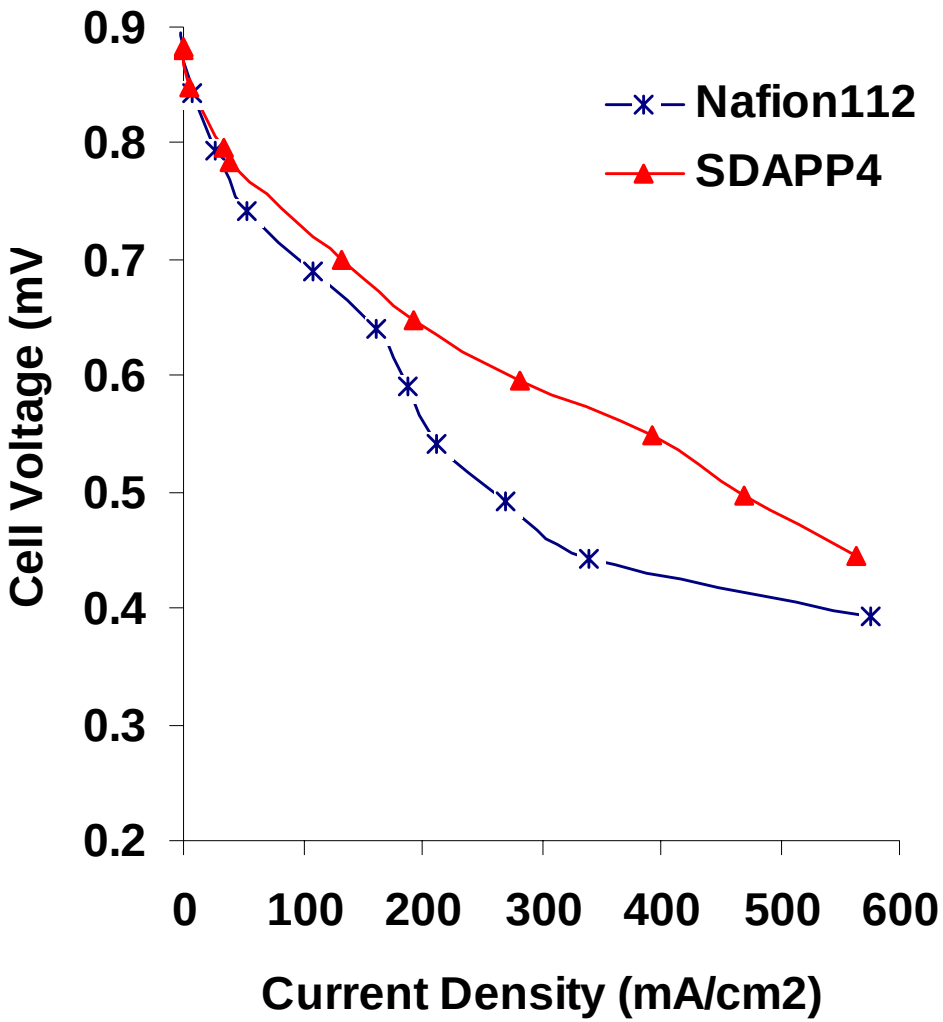
Fuel Cell Testing

Elevated Temperature: 50% RH & 120 °C



Conditions

Cell Temp: 120 °C

Anode/Cathode 100 °C humidified H_2 (200sccm) and air (500sccm)

Anode/Cathode: 0.4 mg/cm2 Pt supported

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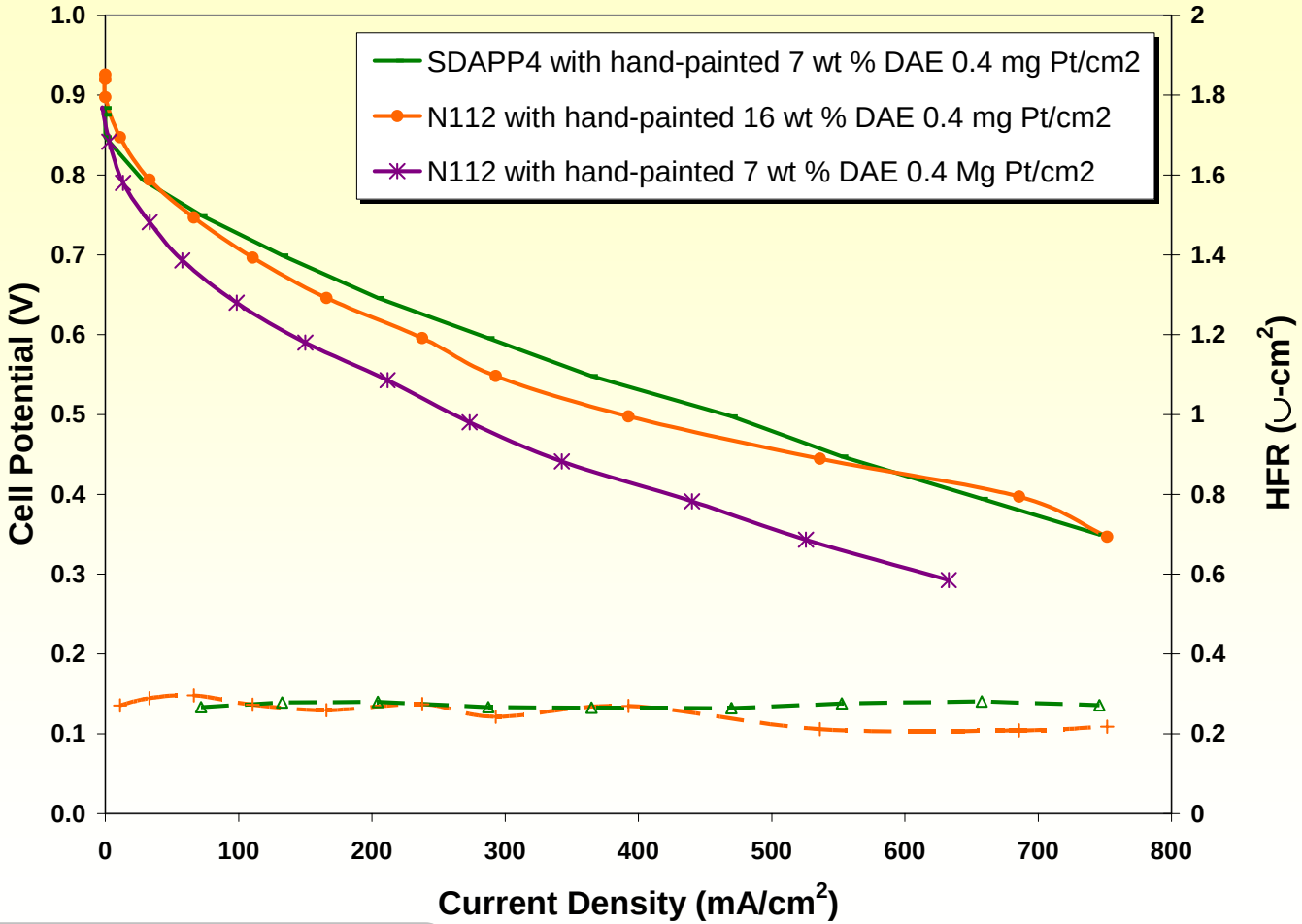
Fuel Cell Testing

Elevated Temperature: 50% RH & 120 °C



- 0.4 mg/cm^2 (Pt Black)
- A/C: H_2 (200sccm) and Air (500sccm)

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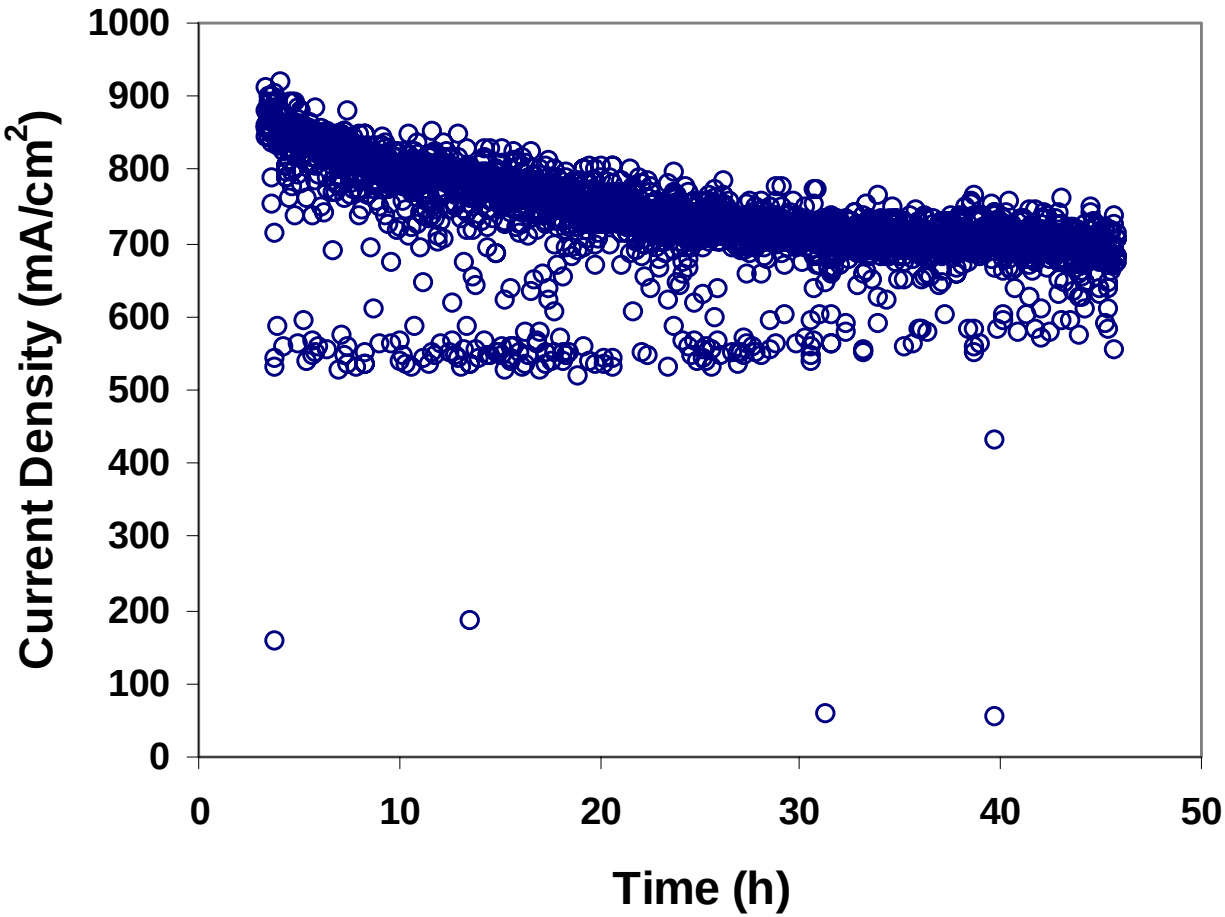
Fuel Cell Testing

Elevated Temperature: 100% RH & 120 °C



- 0.4 mg/cm^2 (Pt Black)
- A/C: H_2 (200sccm) and air (500sccm)

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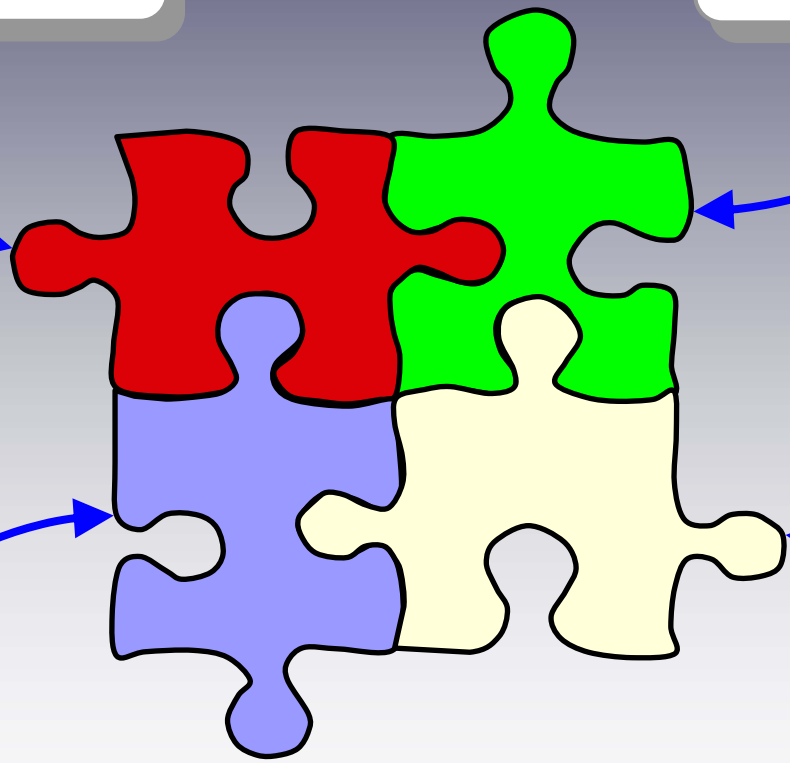
Vision

SNL Fuel Cell Research

Material Science

Morphology



Modeling

Performance

Conclusions

Diels-Alder Polyphenylenes

- SDAPP MEAs show comparable performance to Nafion benchmark at 120°C and 50% RH.
- Optimization of membrane and electrode can provide a route to improved performance over that of standard Nafion MEAs at high temperature and low relative humidity.
- *Optimization of SDAPP polymers in membrane and electrode for enhanced high temperature and low RH performance. Demonstrate gains at 120°C and 50% RH, target 25% RH or lower at 100-150°C.*
- *Study long-term (at least 1000 hours) performance of both membranes and electrodes at high T and low RH. Previously demonstrated 1000 hours of stable membrane performance (crossover and HFR) in DMFC at 80°C.*
- *Demonstrate new membrane concepts for high conductivity at low RH.)*
- ***Electrode Optimization***

Acknowledgements

- ***David Wheeler**, ***Greg Jamison**, *Frank Delnick, David Ingersoll, Ganesan Nagasubramanian*

  Sandia National Laboratories

- ***Douglas A. Loy**[1] & Bryan S. Pivovar[2]*

  [1]MST-7 & [2]MST-11

  Los Alamos National Laboratory

  Los Alamos, NM 87545

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