POWERING A CLEANER FUTURE

R&D on an Ultra-Thin Composite Membrane for High-Temperature Operation in PEMFCs

Chao-Yi Yuh

(DE-FC02-99EE27567)

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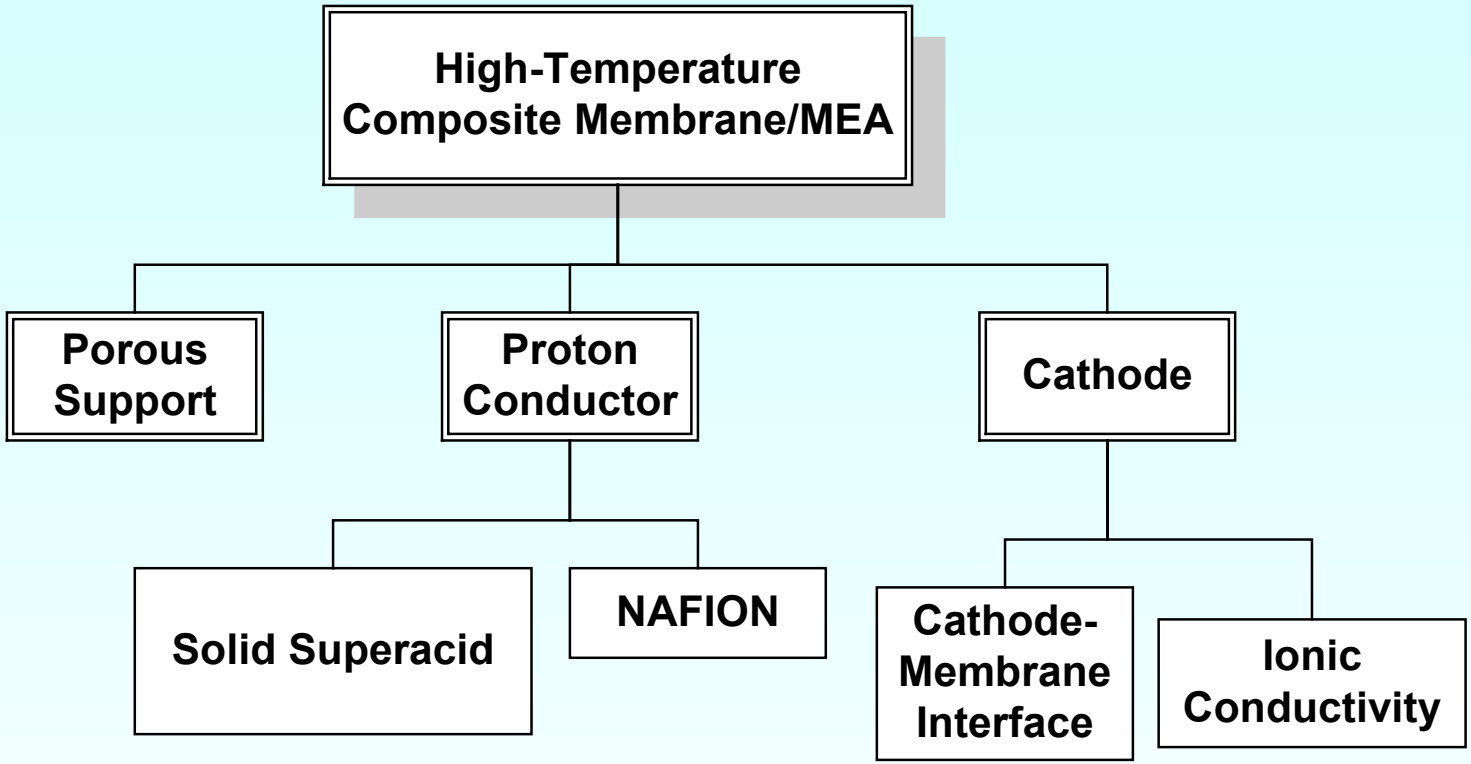
HIGH-TEMPERATURE MEA (STATIONARY SYSTEM)

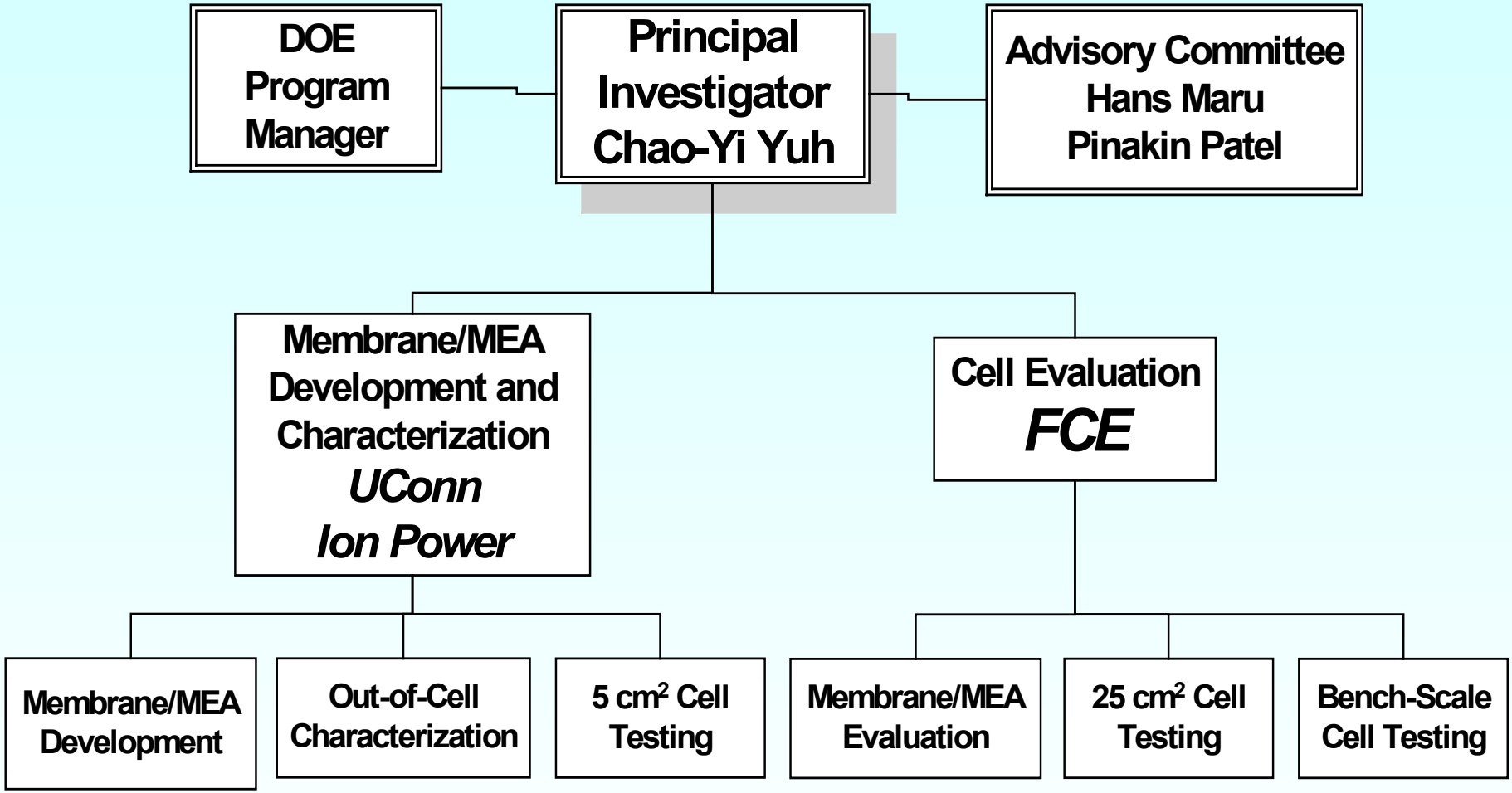
- **Advantages:**
  - Easier CO Management
  - Accelerated Electrochemical Reaction Kinetics
  - Easier Water & Thermal Managements
- **Issues:**
  - Dehydration
    - Ohmic Resistance Increase (Membrane and Electrode)
    - Electrode Polarization Increase (Slower ORR)
    - Reduced durability
- **DOE Ultimate Goal:**
  - >100°C (120-150°C) Membrane
  - 0.32 W/cm^2 at 0.8V (at 400mA/cm^2)
  - Membrane ASR <100 mΩ•cm^2; < 1% Cross-Over
  - Atmospheric Pressure Operation
  - >40,000h Life and <$1500/kW System Cost

MEMBRANE/MEA TECHNICAL APPROACHES



GOAL: ULTRA-THIN, DURABLE, >100°C HIGH-TEMPERATURE COMPOSITE MEMBRANE/MEA

PROJECT ORGANIZATION



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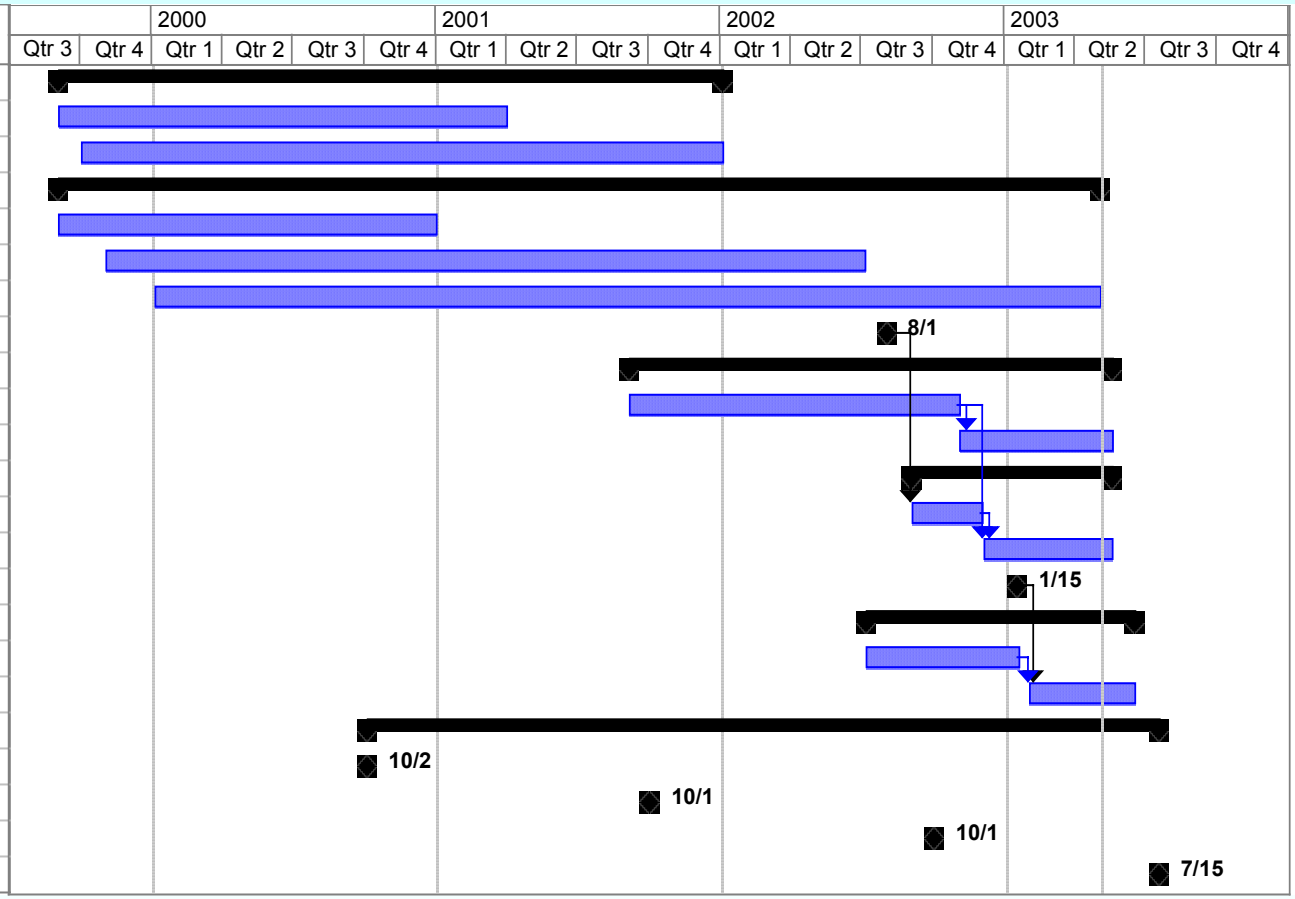
Project Schedule

ID	Task Name
1	**1. Membrane Development**
2	Composite Membrane Development
3	Membrane Characterization
4	**2. MEA Development**
5	Commercial MEA performance/endurance
6	MEA development
7	Lab-scale cell testing
8	Achieve 600mV 120C performance
9	**3. Fabrication of Bench-scale Membrane**
10	Membrane scale-up to 300cm2
11	Membrane Fabrication
12	**4. Fabrication of Bench-scale MEA**
13	MEA scale-up to 300cm2
14	300cm2 MEA fabrication
15	300cm2 MEA for cell testing
16	**5. Bench-scale Cell Testing**
17	Bench-scale cell design and fabrication
18	Bench-scale cell testing
19	**6. Analysis and Reporting**
20	2000 Annual Report
21	2001 Annual Report
22	2002 Auunal Report
23	Final Report



The Program to Be Completed in June, 2003

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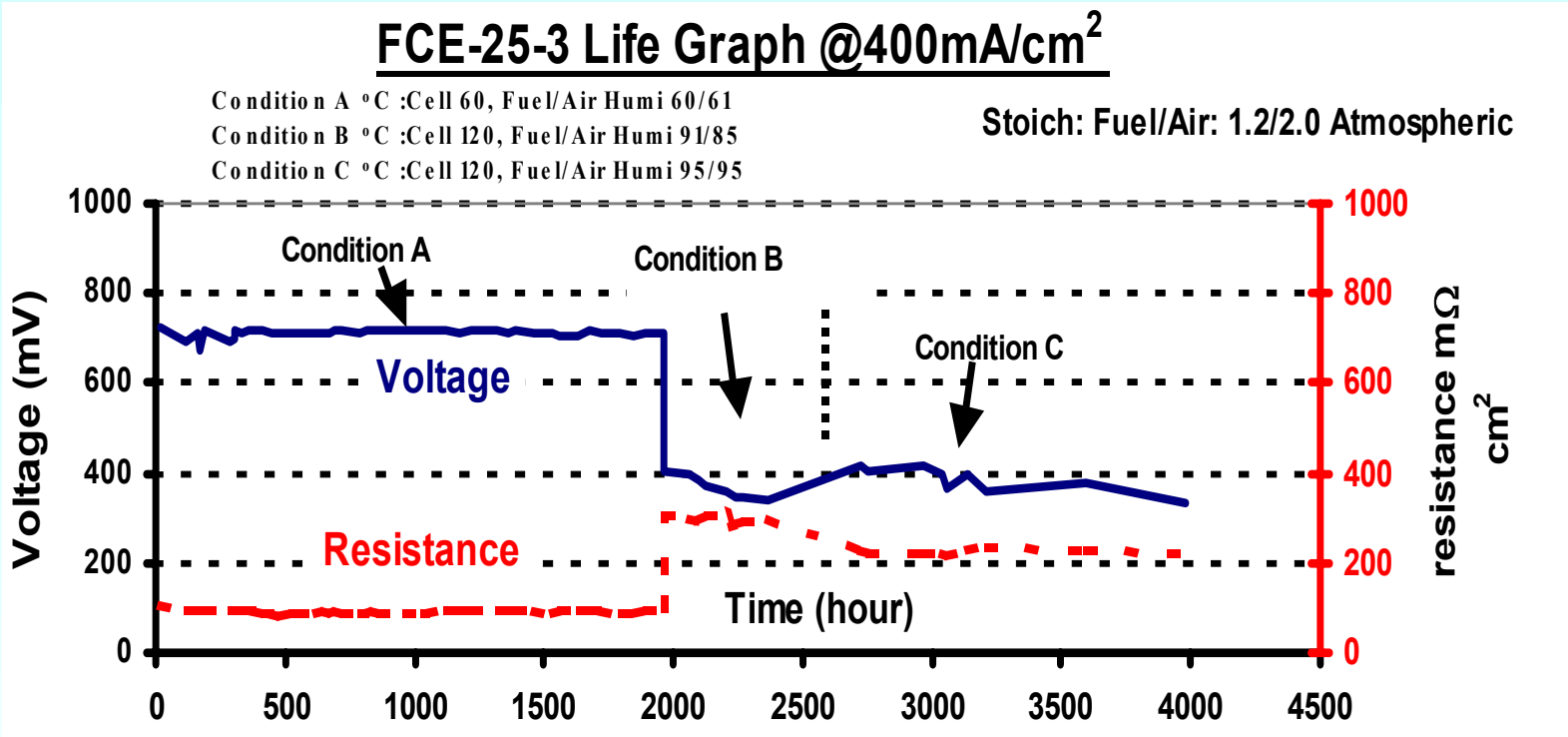
BASELINE NAFION MEA WITH 25μm MEMBRANE



- Stable > 700mV Performance at 60°C for 2,000 Hours
- Significant Performance Loss and decay at 120°C
  - >300 mV Additional Loss (40-80mV Ohmic, >250mV Electrode Polarization); Steady Membrane Ohmic Loss

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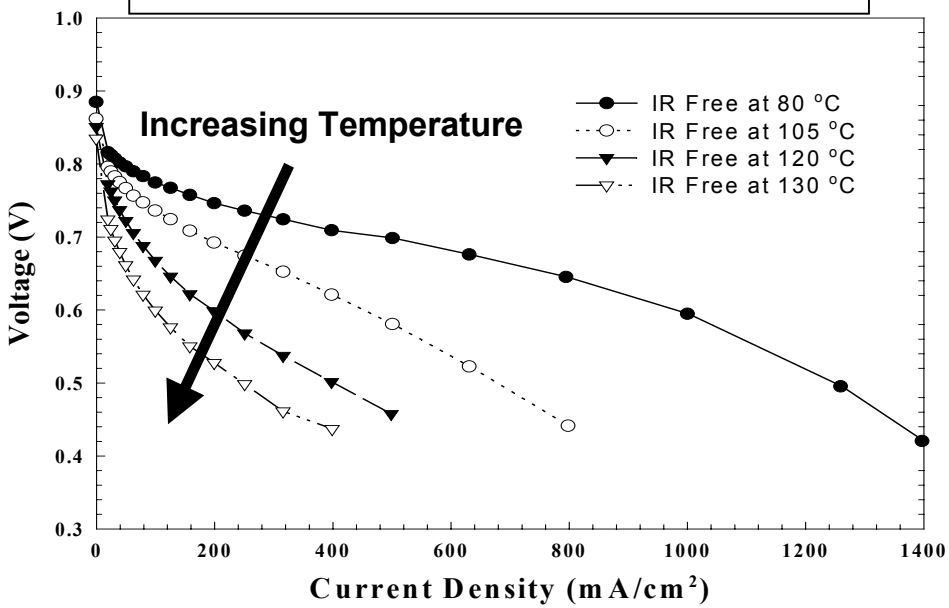
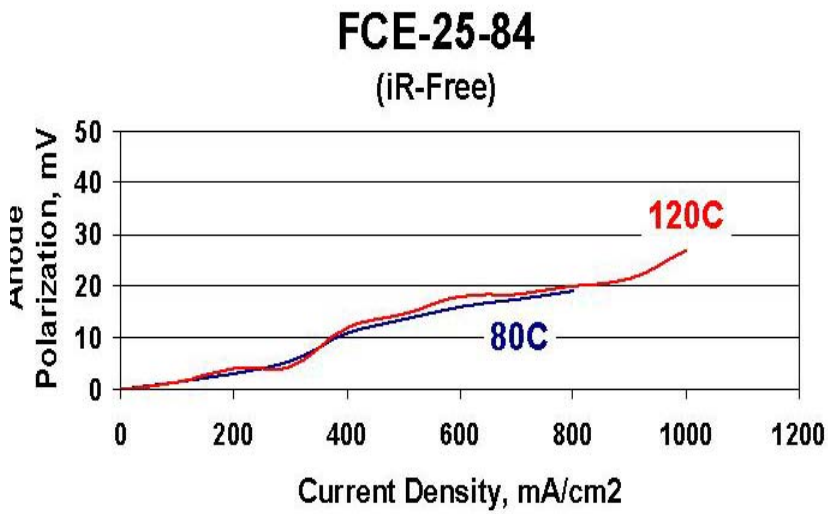
ELECTRODE POLARIZATION

Total Electrode Polarization



Anode Polarization



- **Total Electrode Polarization Increases Significantly with Temperature, but Negligible Anode Polarization Increase**
- **Majority (>60%) of Cell Performance Loss Attributed to Cathode ⇒ *High-Temperature Cathode Needed***

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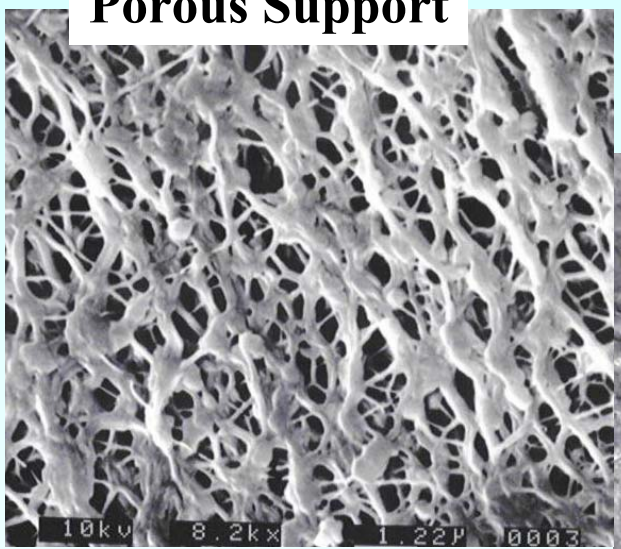
COMPOSITE MEA AND TEST CONDITIONS

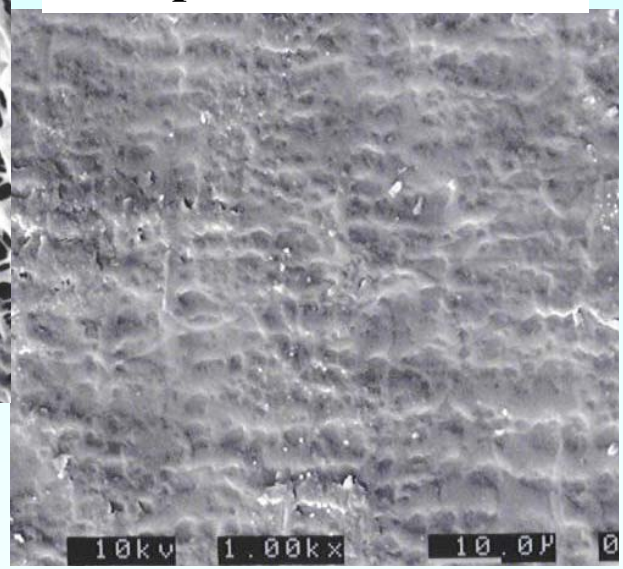
- 25cm^2 Cell Area
- Pt Loading (0.4 mg/cm^2 Each Electrode)
- Ultra-Thin Membrane (<25μm)
- High-Temperature Proton Conducting Additives: in Membrane and/or Cathode
  - Phosphotungstic Acid (PTA), Zeolite, Nano sulfated Oxide, Zirconium Hydrogen Phosphate (ZHP)
  - Low EW Ionomer
- Atmospheric Pressure, 60-120°C
- Neat H_2 Fuel, 1.2 Stoich; Air Oxidant, 2.0 Stoich
- Humidification:
  - Cell 60, 80°C: 100% R.H.
  - Cell 120°C: R.H.<40% (90-95°C Humidification)

COMPOSITE MEMBRANE/MEA FABRICATED

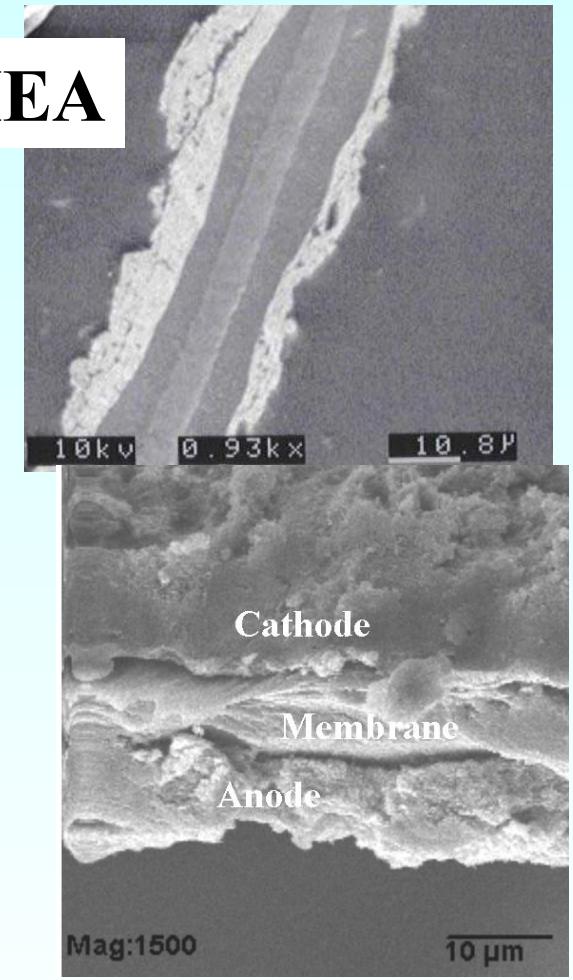
Porous Support



Composite Membrane



MEA



- **Pore-free membrane/MEA successfully fabricated**

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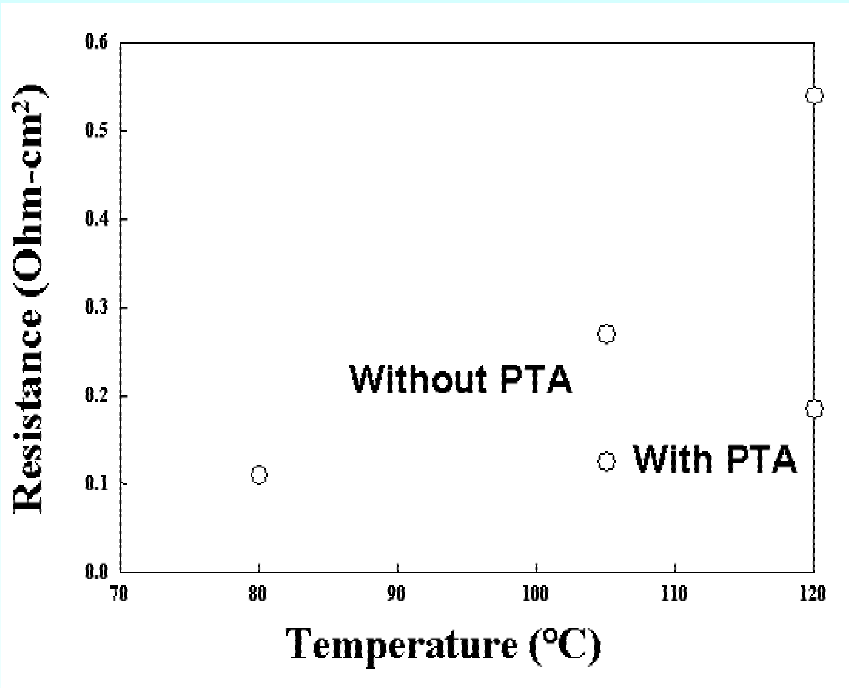
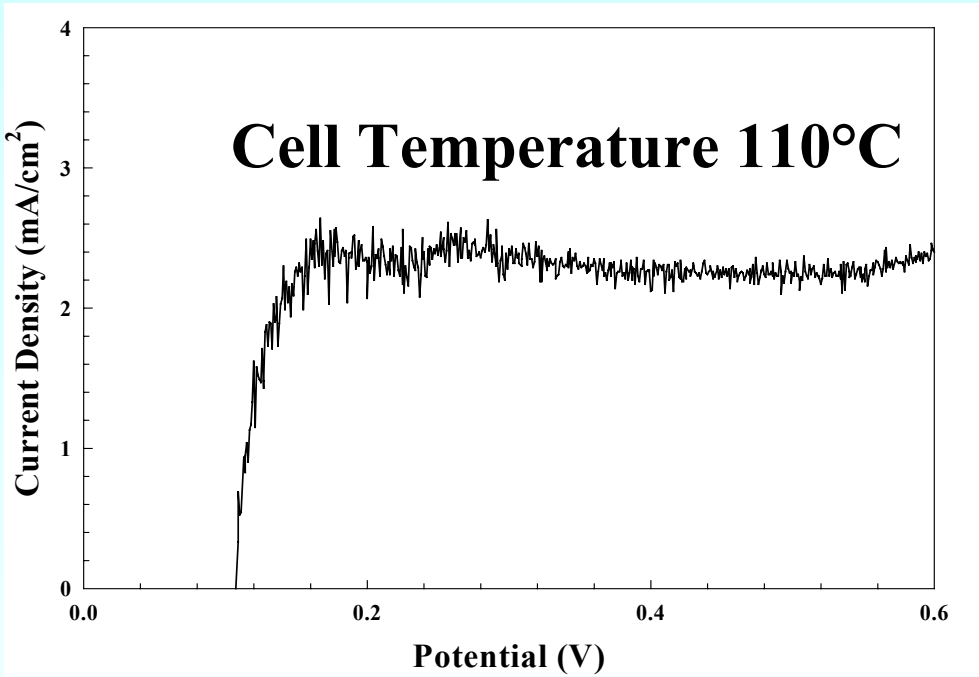
PTA IMPREGNATION IN SUPPORTED NAFION MEMBRANE





PTA Impregnation Reduces Ohmic Resistance Significantly at 120°C; However, Resistance Still Higher Than Well-Humidified Nafion® at 80°C

Low Membrane Cross-Over Achieved

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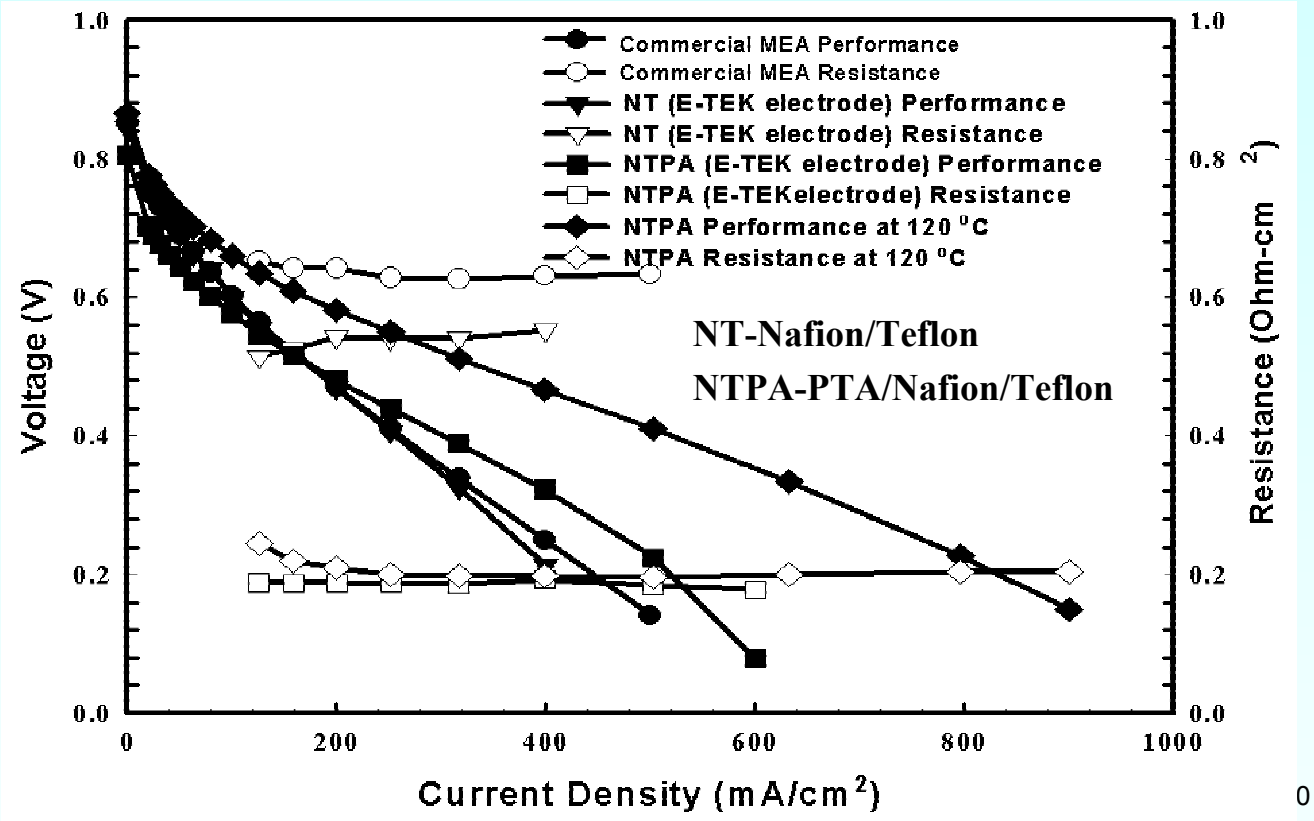
Improvements Achieved to 2001



- ACHIEVED SIGNIFICANT RESISTANCE REDUCTION AND PERFORMANCE INCREASE

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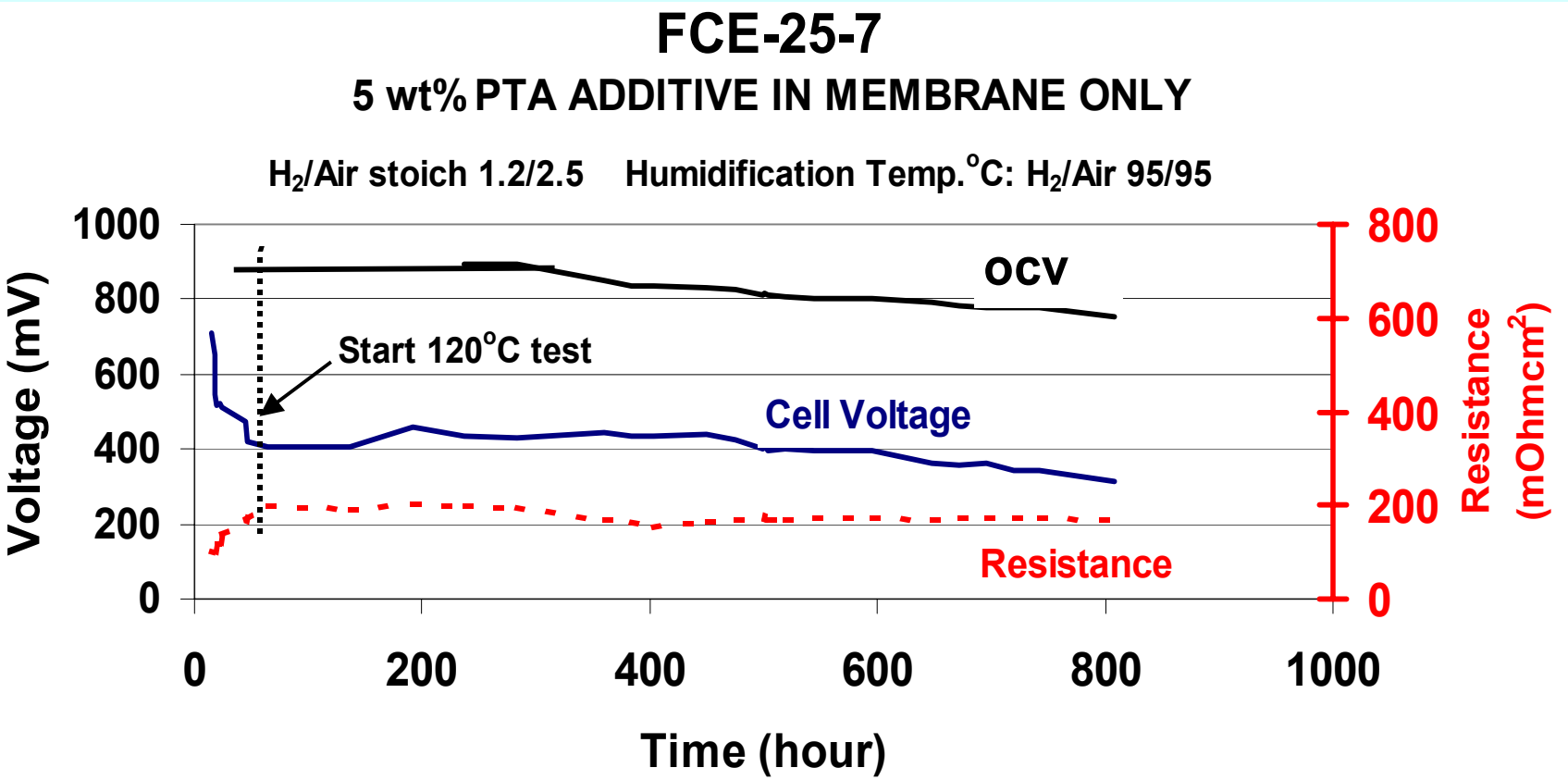
120°C ENDURANCE OF PTA MEA



- ~400mV 120°C Performance (at 400mA/cm^2)
- Cell Voltage Decay due to Membrane Cross-Over increase

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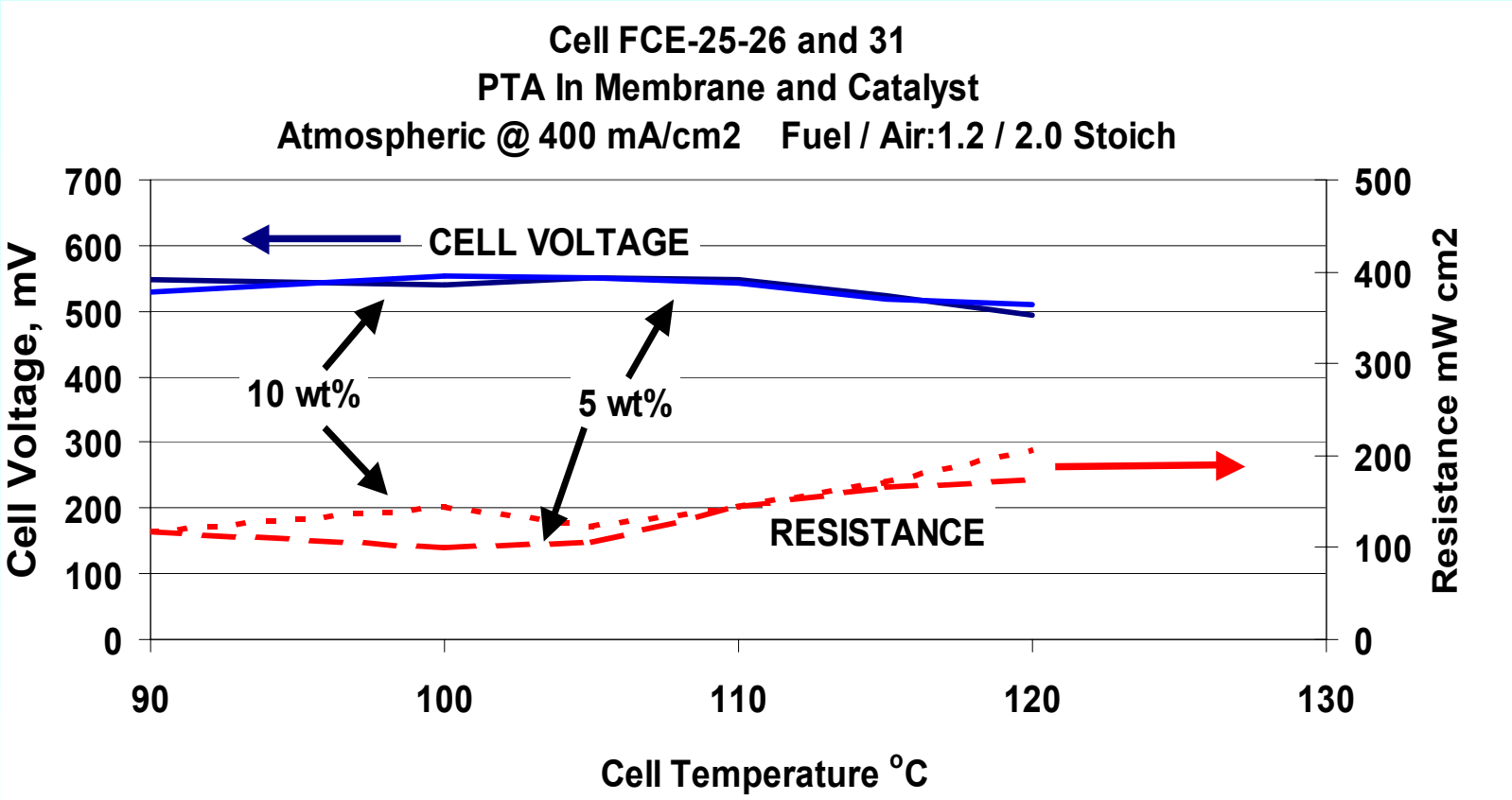
EFFECT OF TEMPERATURE (PTA ADDITIVE in Membrane and Catalyst)



Achieved 500mV Performance and 200mΩcm² Resistance at 400mA/cm² and 120°C

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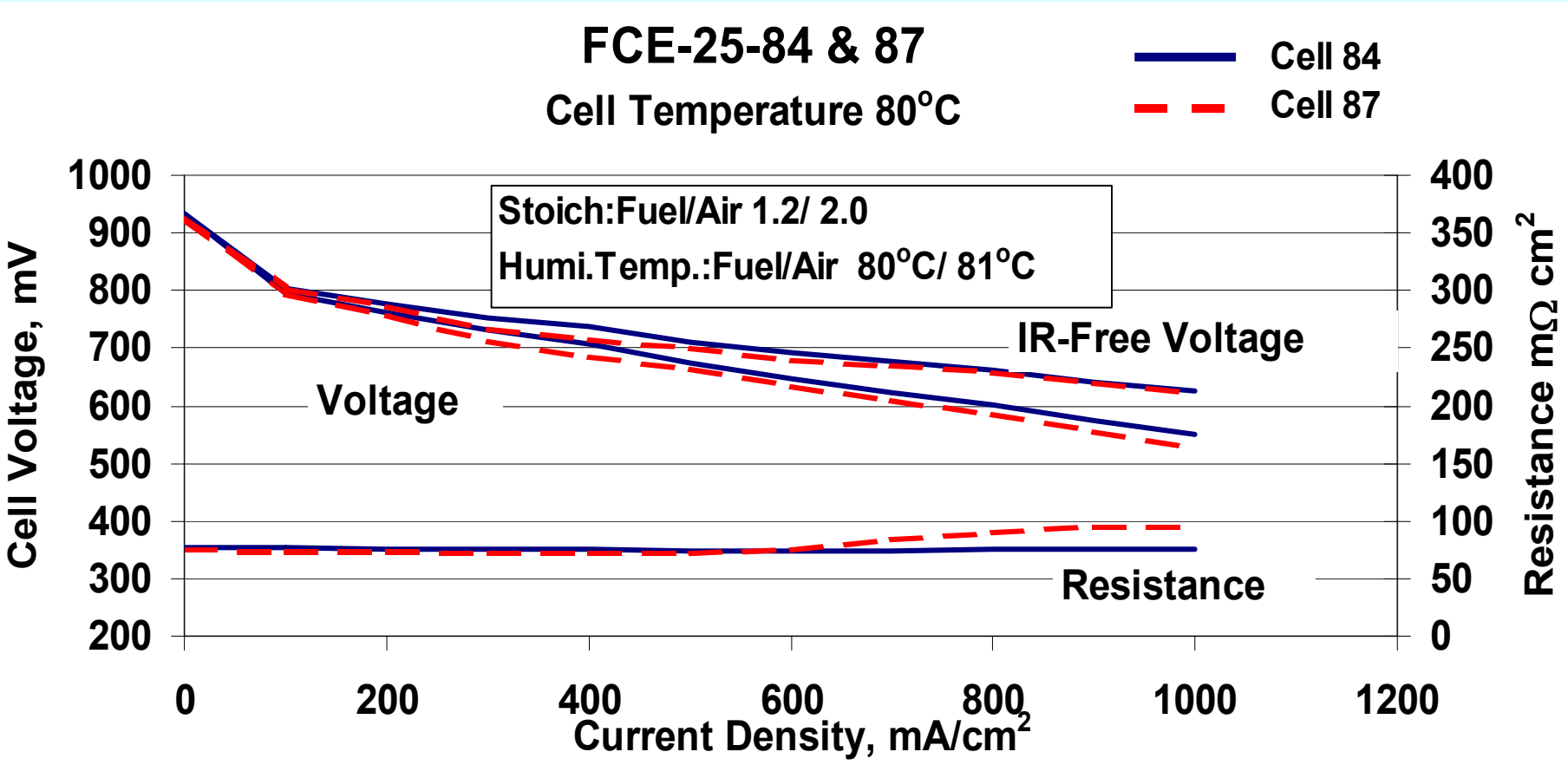
~700mV Performance at 80°C with Alternative Proton Conducting Additive



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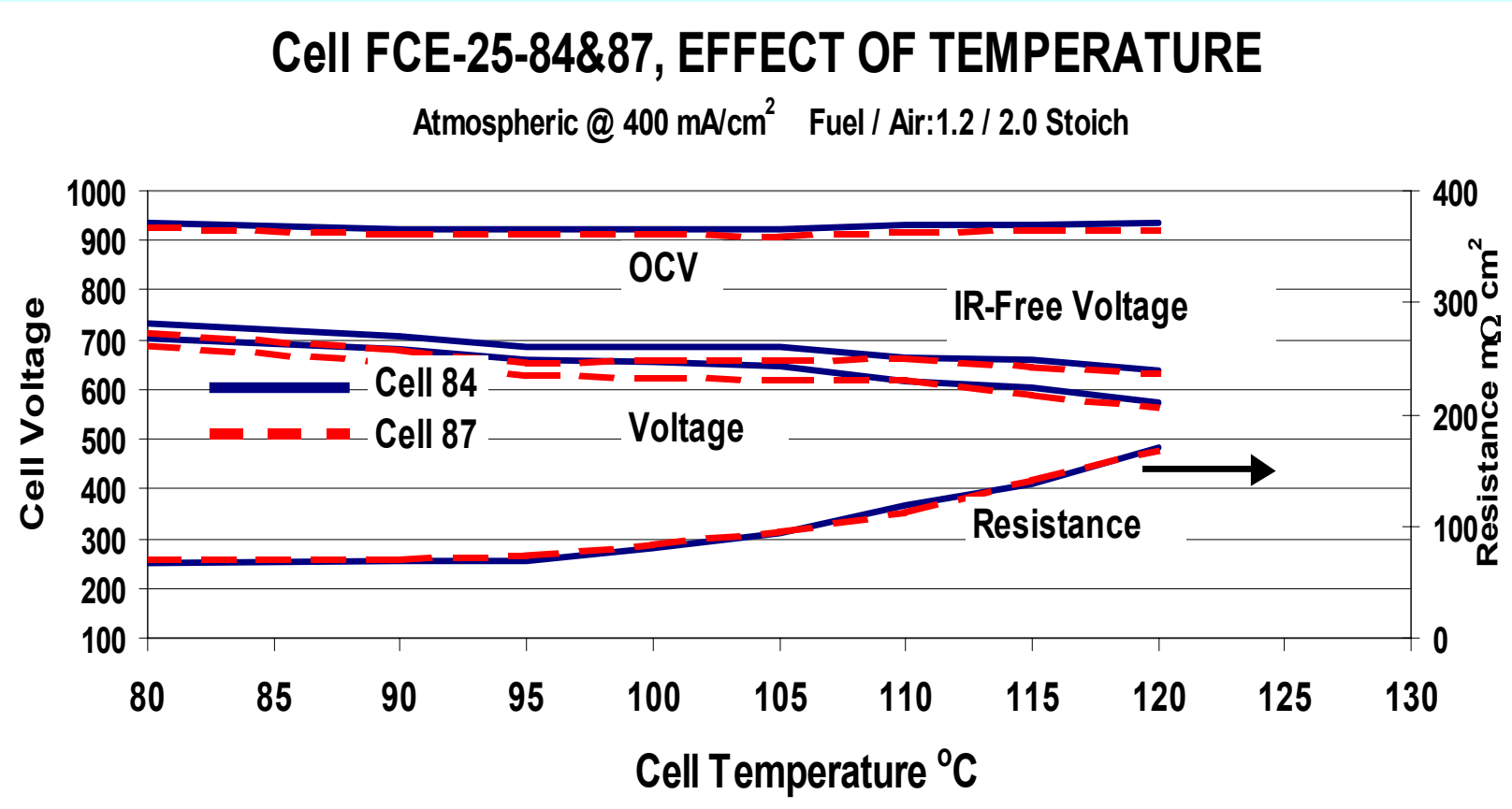
EFFECT OF TEMPERATURE



~600mV and 160mΩcm² at 120°C

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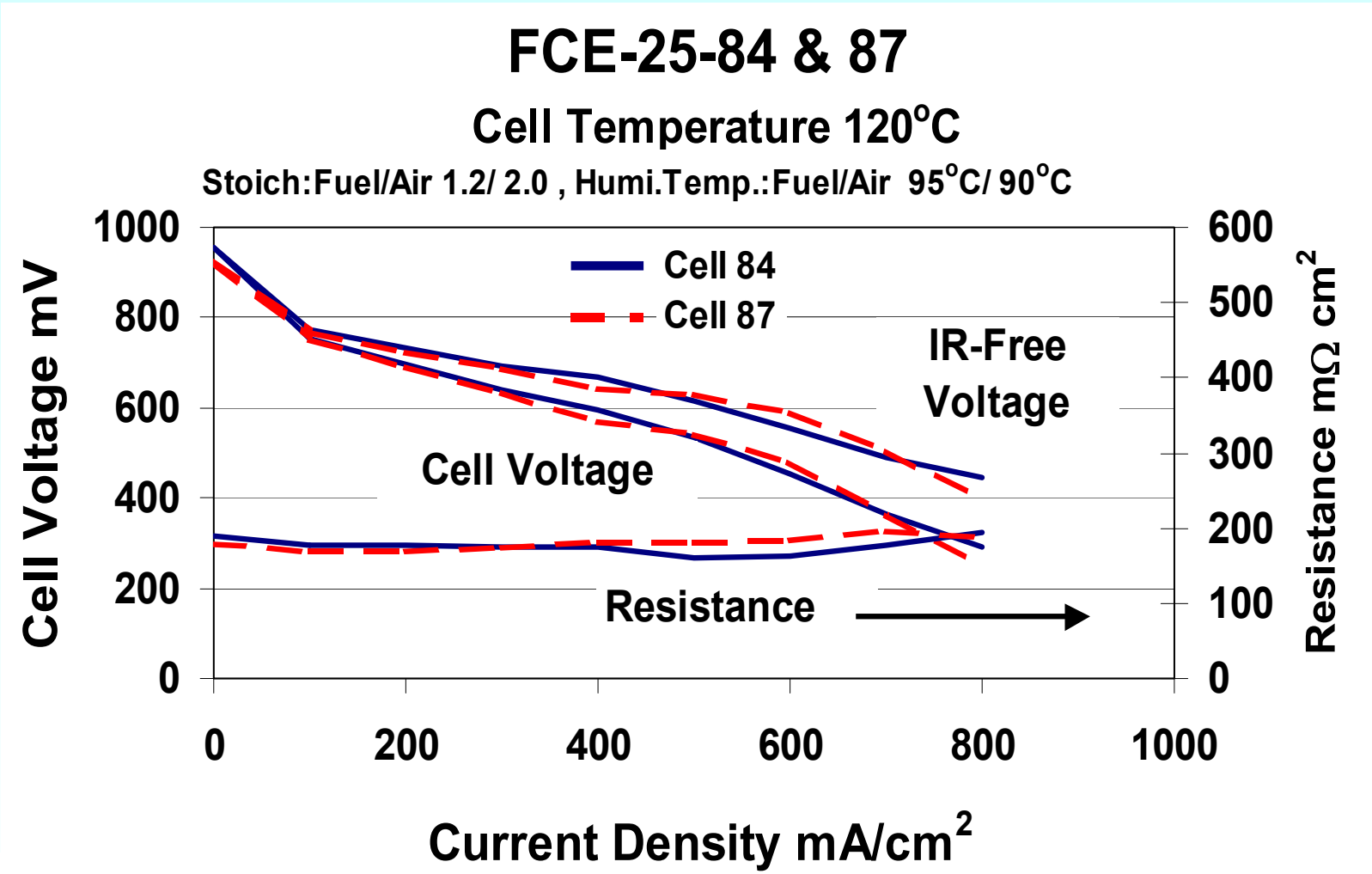
600mV Achieved at 120°C and 400mA/cm²



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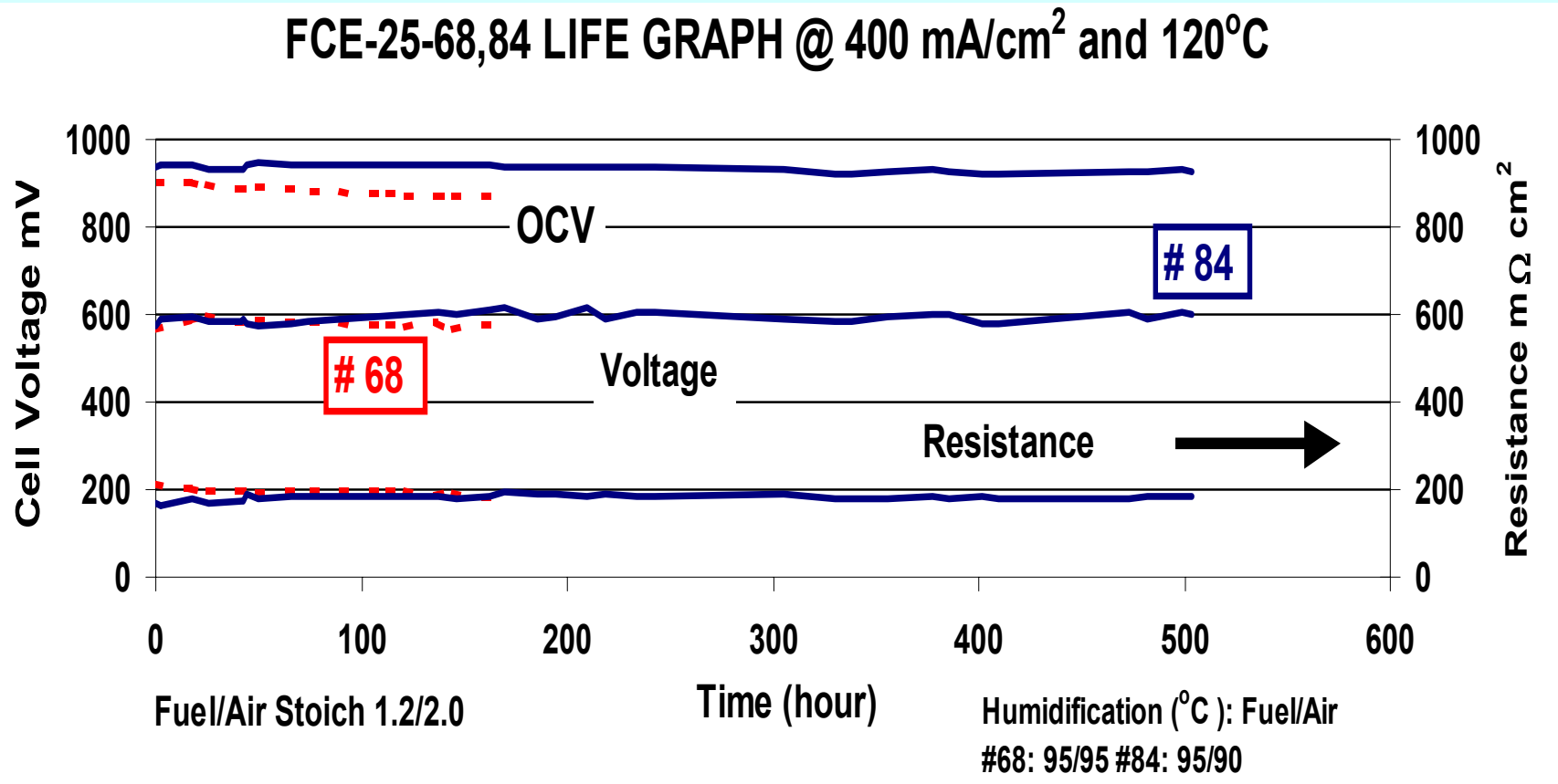
MEA ENDURANCE AT 120°C



Stable 600mV 500h Endurance

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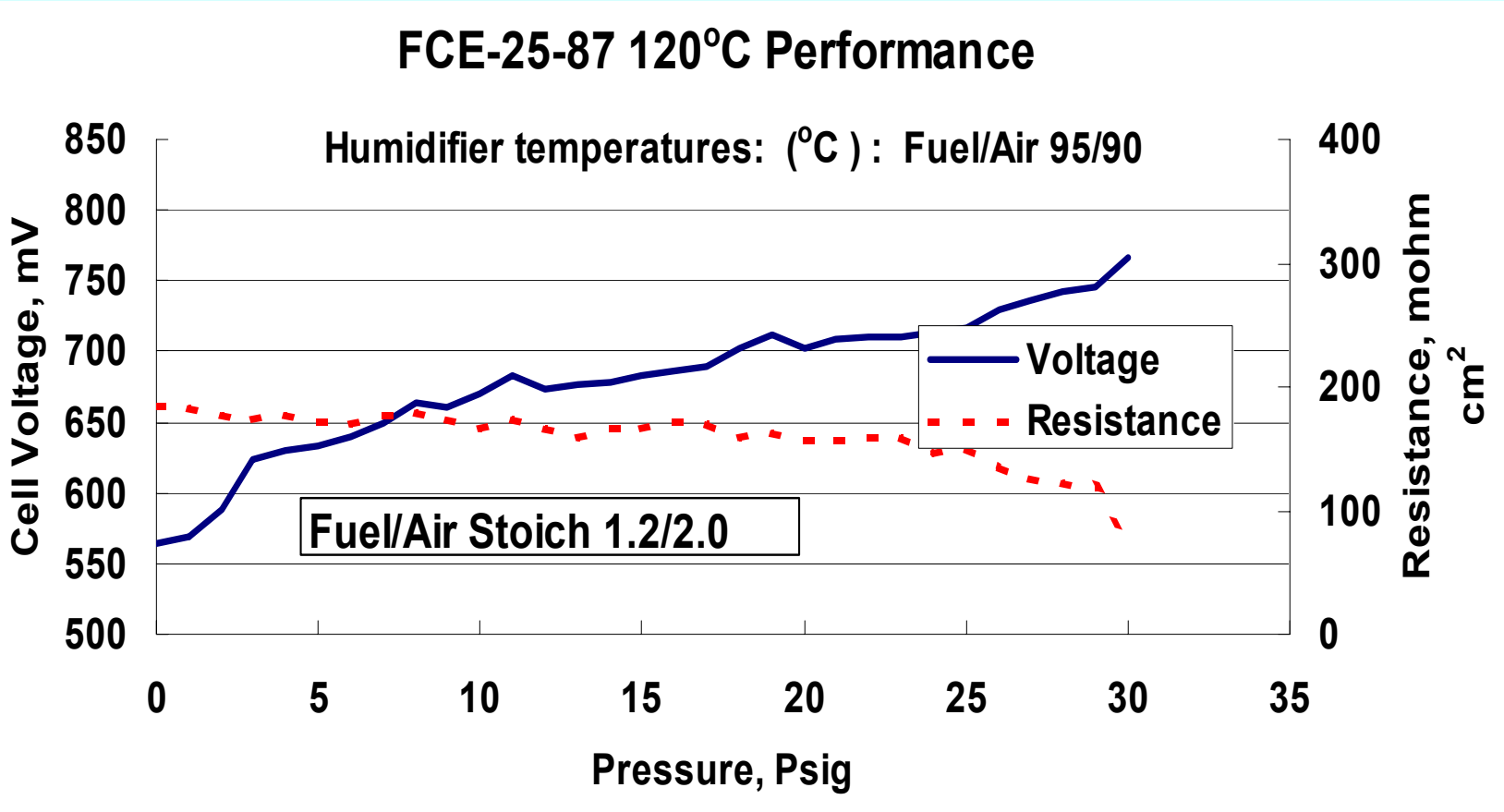
EFFECT OF PRESSURE



>750V at 400 mA/cm^2 at 30 Psig

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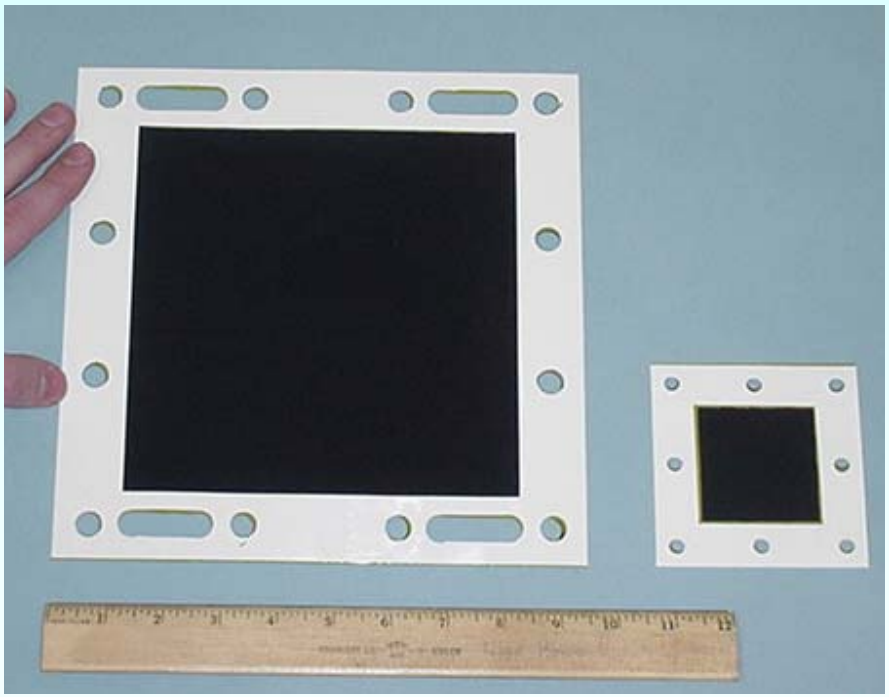
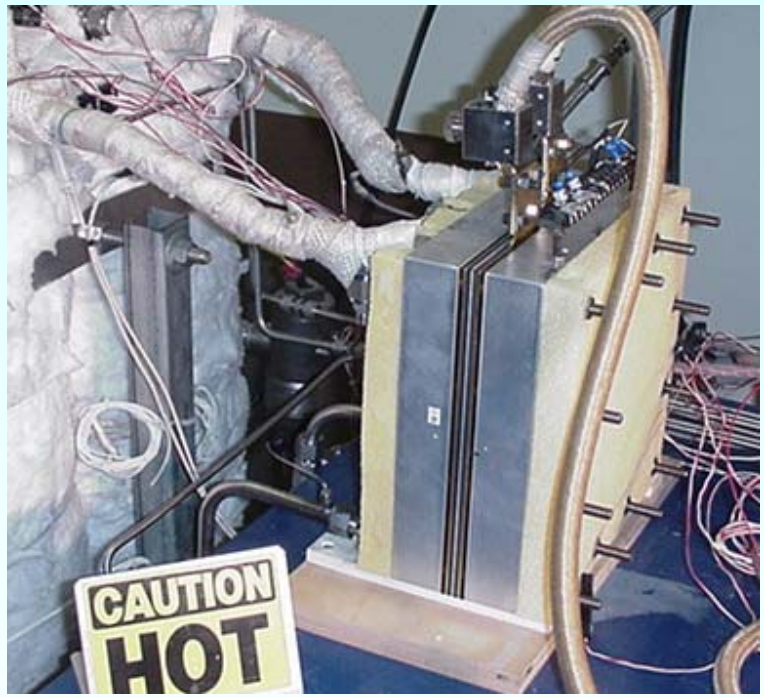
300cm² MEA Fabricated

MEA



300cm² Cell



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CONCLUSIONS

FABRICATED ULTRA-THIN COMPOSITE MEA:

- WITH CONSISTENT LOW OHMIC RESISTANCE (≤200 mΩ-cm^2) AND LOW CROSS-OVER AT 120°C
- STABLE 600mV ATMOSPHERIC-PRESSURE PERFORMANCE FOR 500 HOURS (>200mV IMPROVEMENT OVER BASELINE)

REQUIRE FURTHER EFFORT TO ACHIEVE ADDITIONAL PERFORMANCE AND ENDURANCE IMPROVEMENTS

- ENHANCE PROTON CONDUCTIVITY IN CATHODE
- INCREASE CATALYST UTILIZATION
- UNDERSTAND DECAY MECHANISMS