MEA and Interfacial Issues in Low Temperature Fuel Cells

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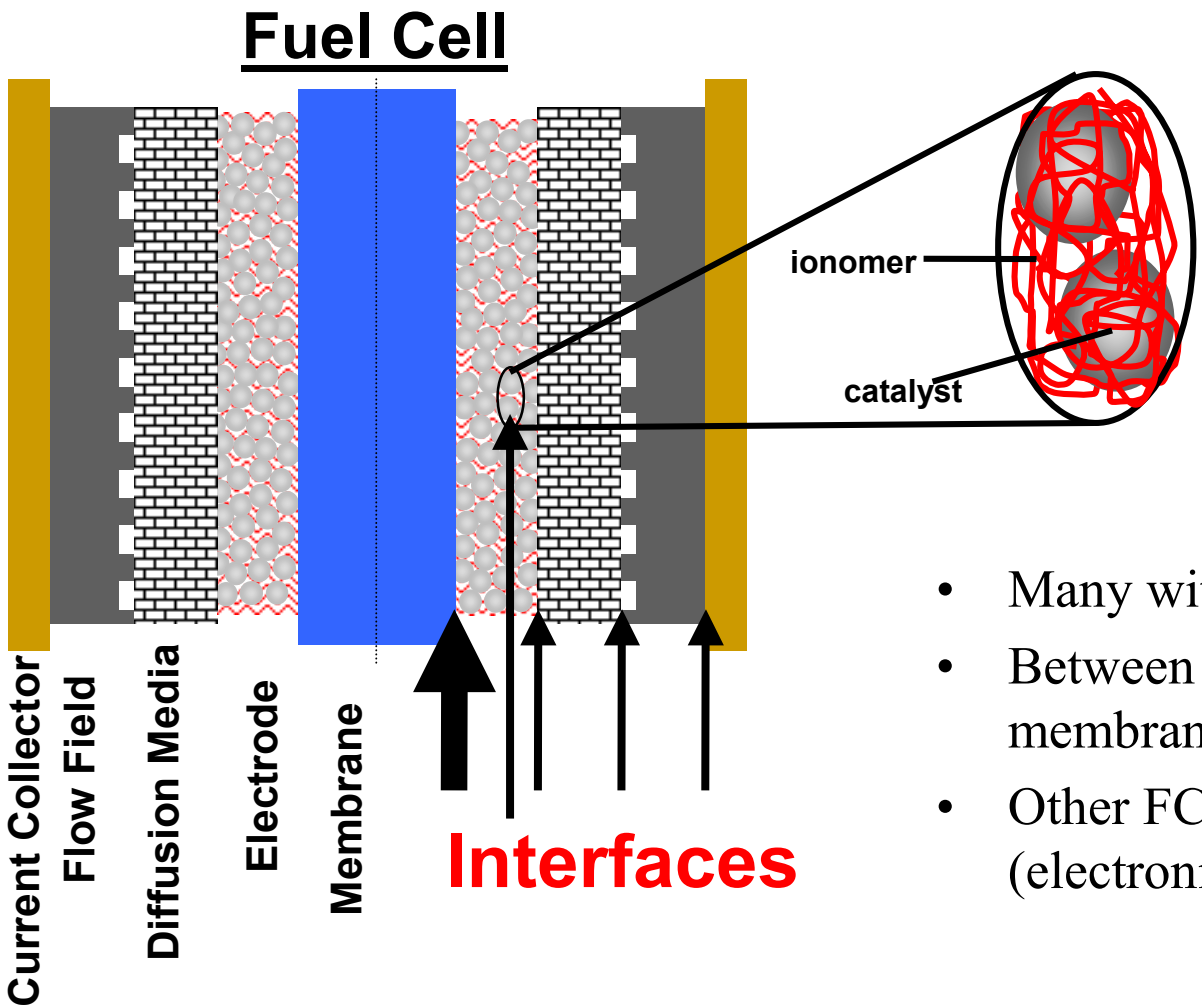
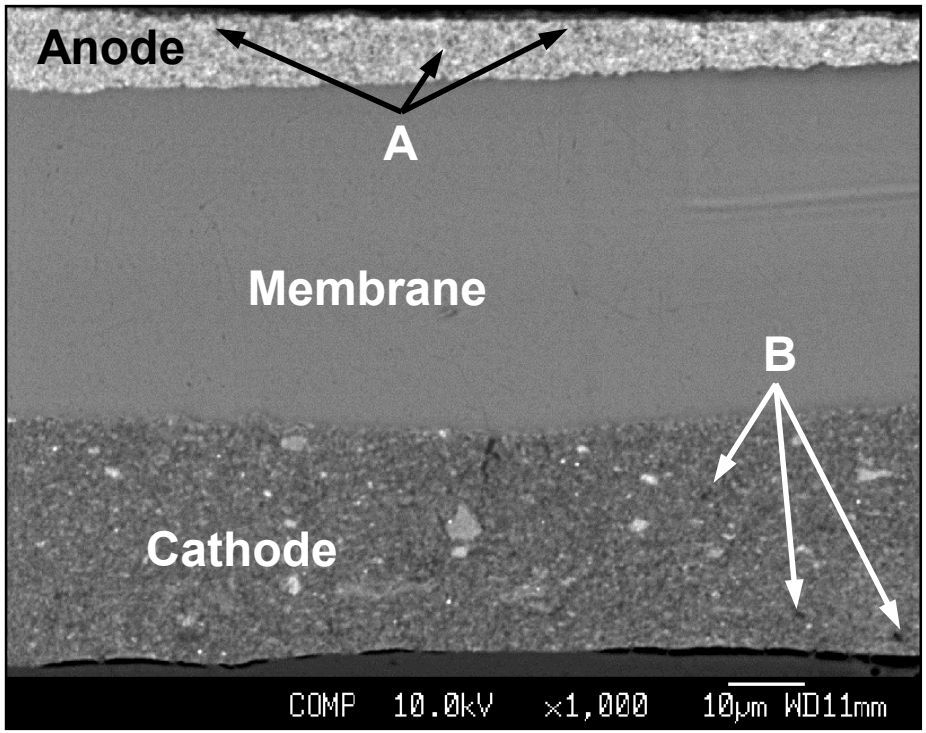
Interfaces in a Fuel Cell

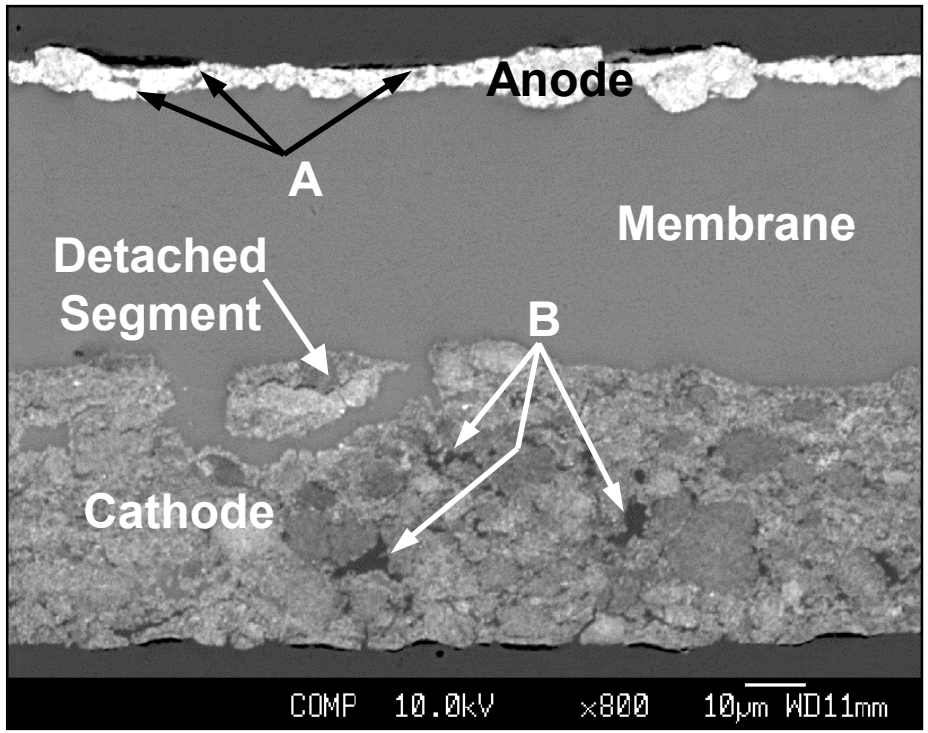


- Many within electrodes
- Between electrodes and membrane (skin layer?)
- Other FC components (electronic effects)

SEM Pictures Comparing MEA Cross-Section Before/After ~2200 Durability Test

Cryogenic Sectioning with $N_{2(l)}$ Used to Obtain MEA Cross-Sections



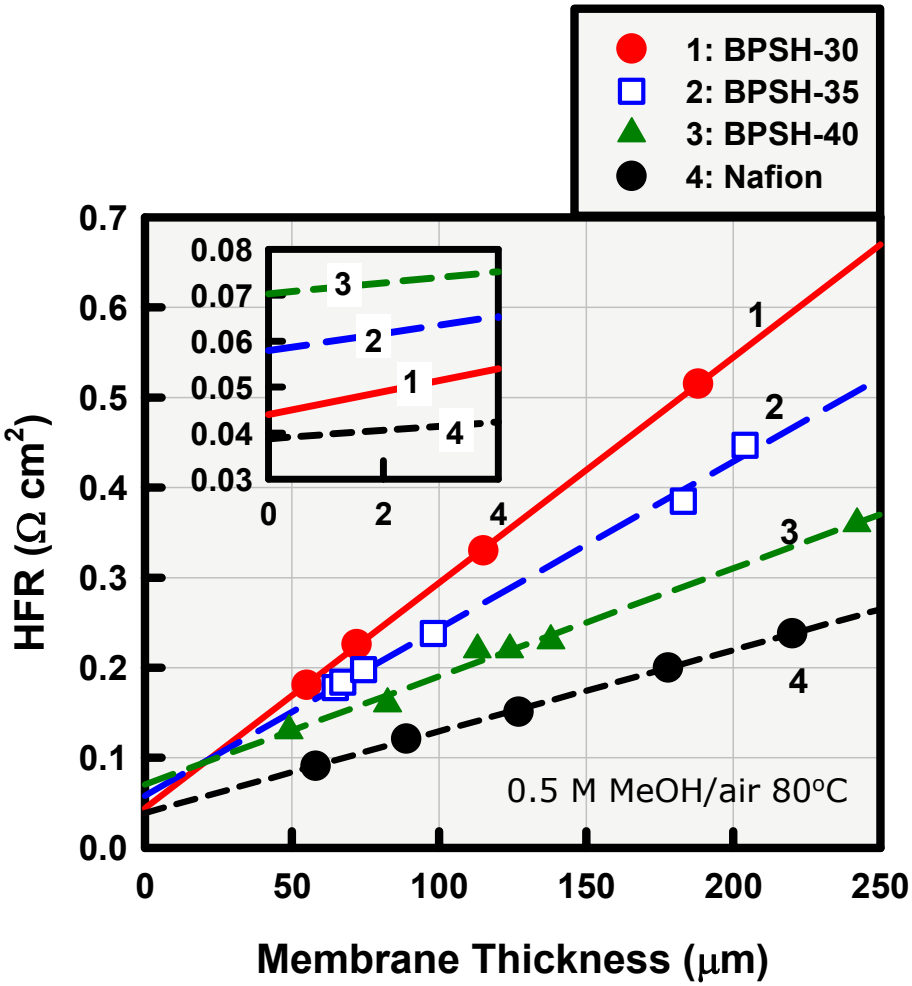


- Relatively uniform catalyst layer compositions & thicknesses.

- Significant deterioration of catalyst layer compositions & structures.
- Decrease in thickness uniformity of catalyst layers.

*Wood et. al., 206th Meeting of The Electrochemical Society, Honolulu, Hawaii, October 5th, 2004

Membrane – Electrode Interface



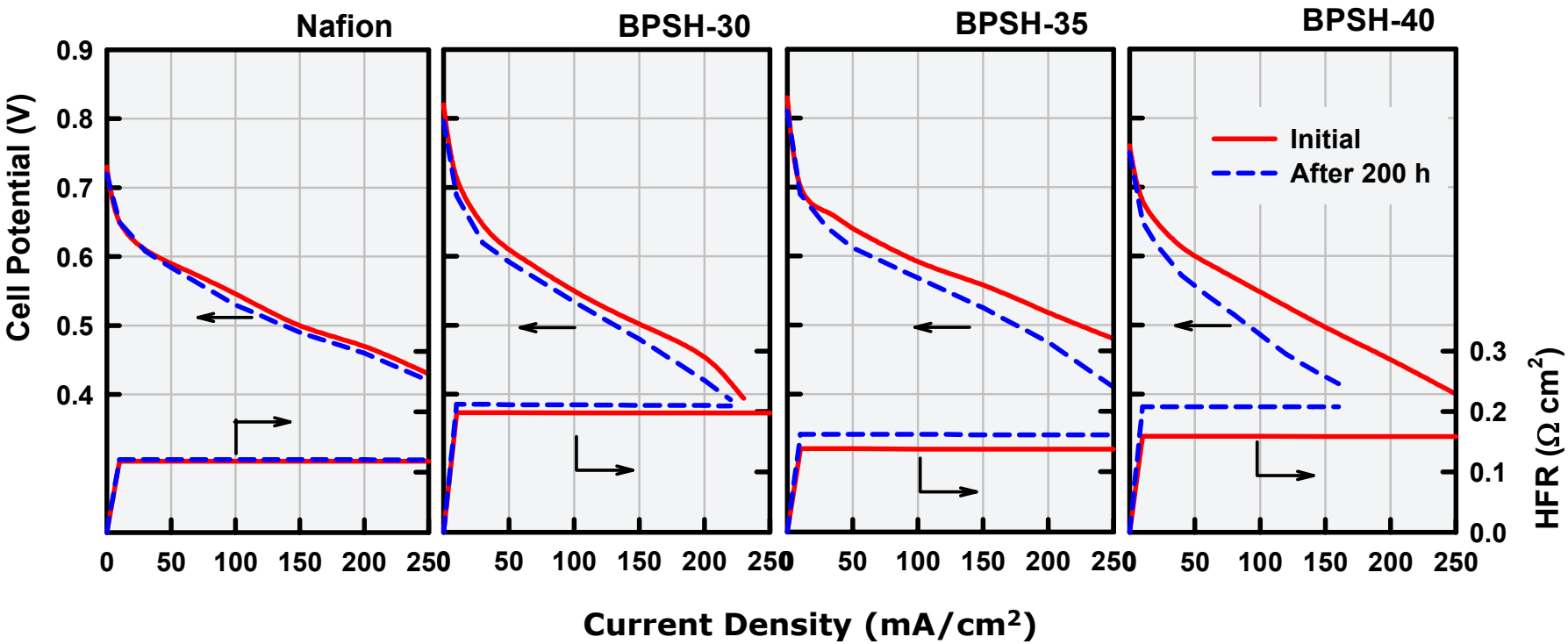
Conductivity, σ, Interfacial Resistance, $R_{interface}$

Membrane	σ *(mS/cm)*	$R_{interface}$ *(mΩ·cm²)*
BPSH-30	39	16
BPSH-35	54	30
BPSH-40	78	42
Nafion	111	7

$$HFR = R_{non\text{-}mem} + R_{mem}(x)$$

$$R_{non\text{-}mem} = R_{elec} + R_{int}$$

Influence of Interfacial Compatibility on Longer-Term Performance

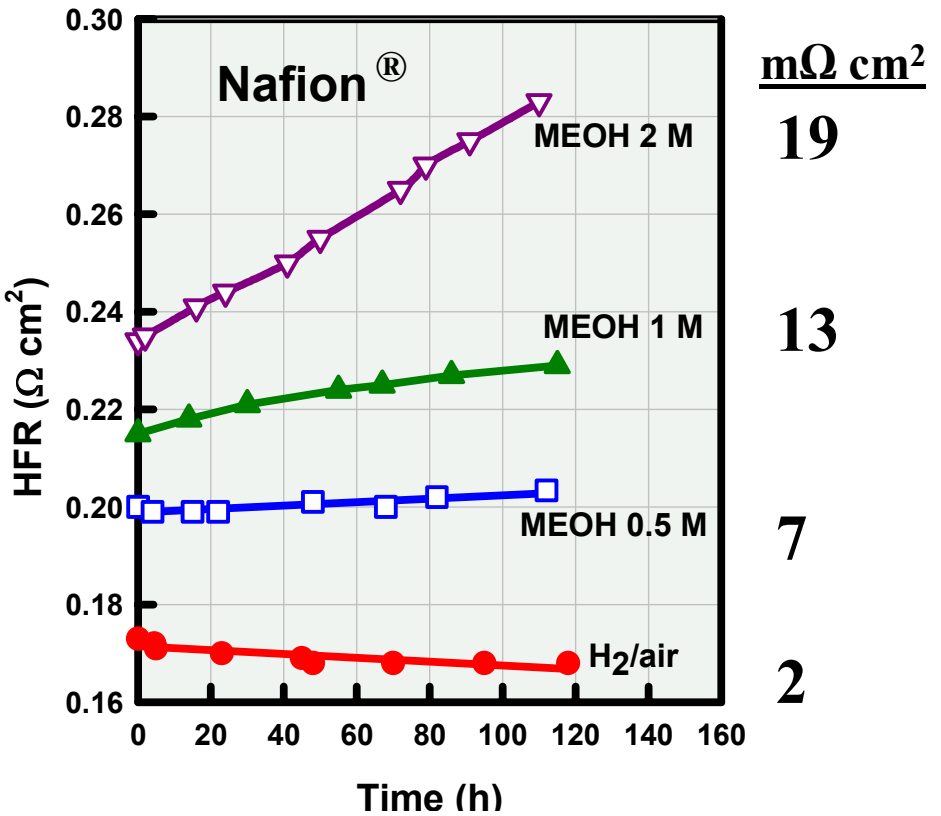


7 **16** **30** **42**

Interfacial resistances (mΩ cm²)

0.5 M MeOH/air 80°C

Effect of Methanol Feed Concentration on Cell Resistance during Extended-Term Test



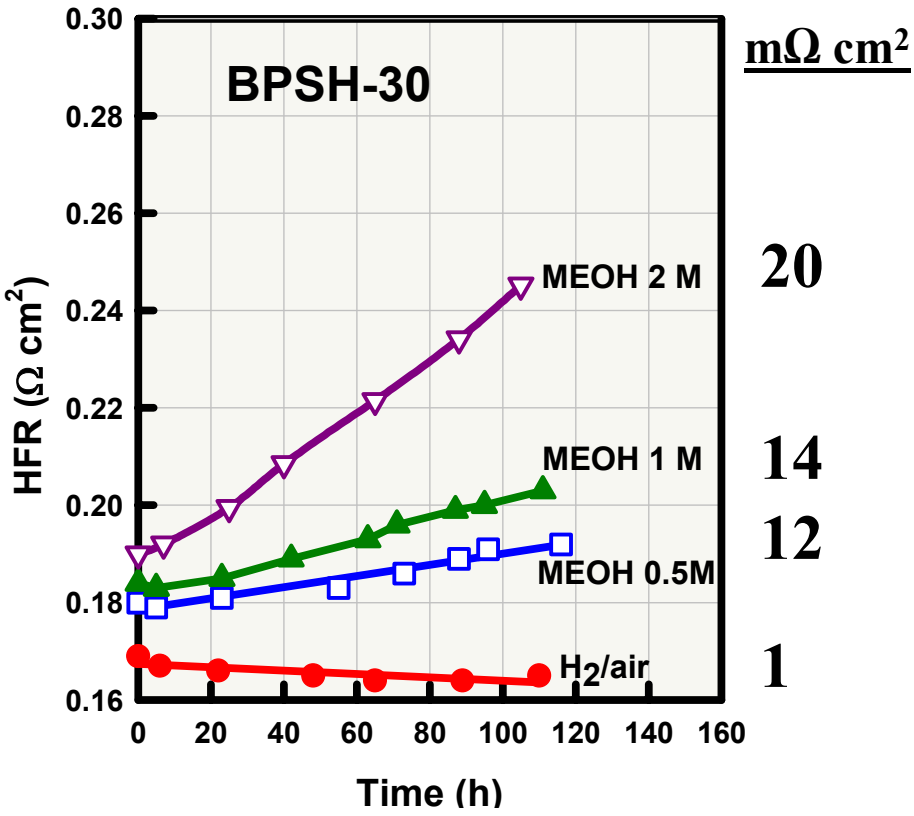
mΩ cm²

19

13

7

2



mΩ cm²

20

14

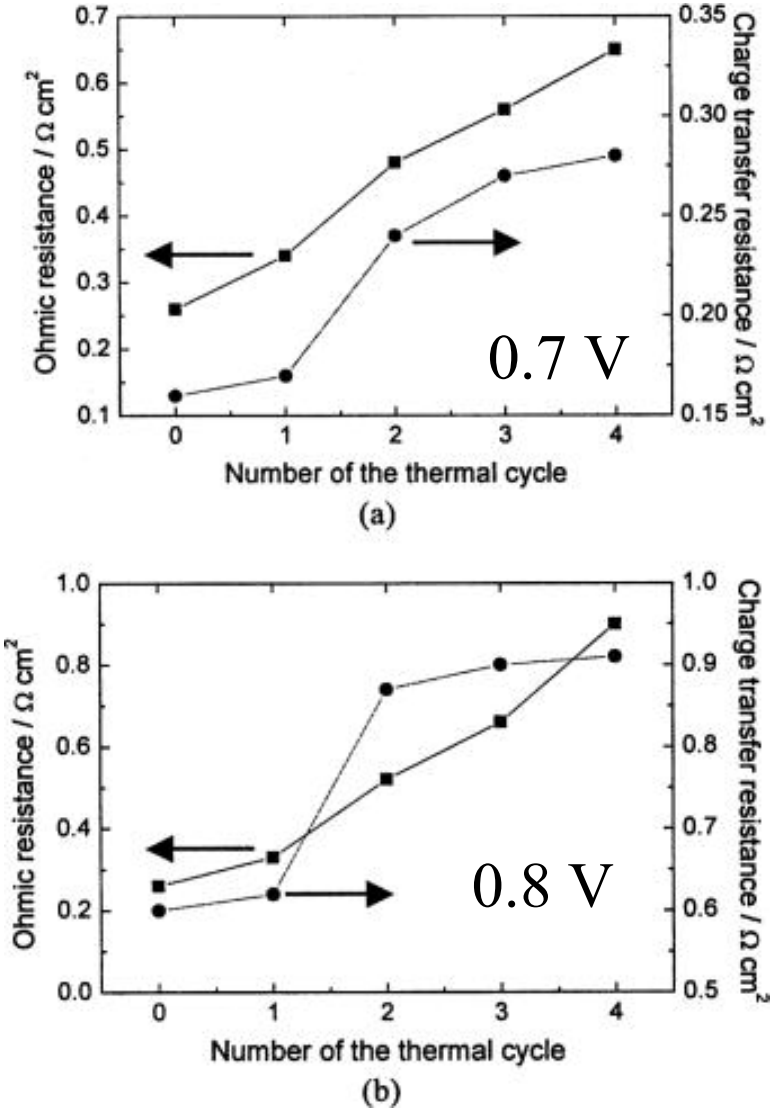
12

1

Correlated Factors:

Initial Interfacial Resistance, HFR gain, performance loss

Literature Degradation: Interfacial Failure?

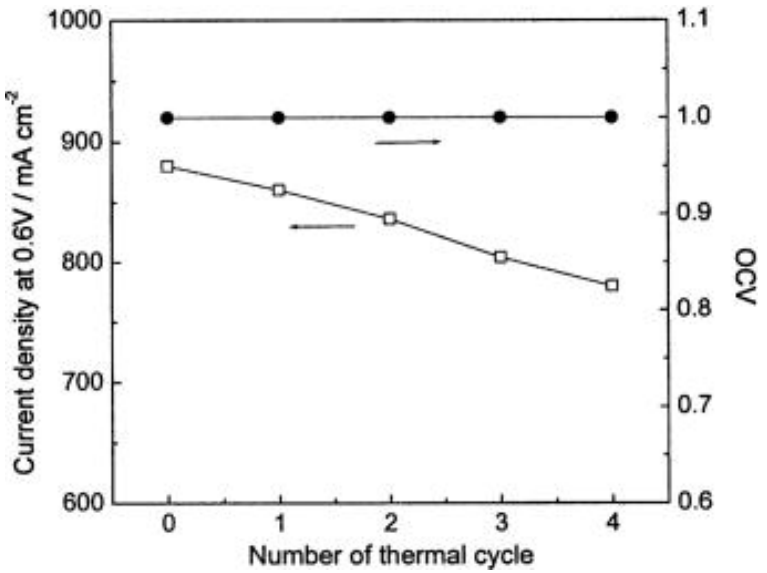


- Membrane resistance was not changed after thermal cycling
- Increased resistance most likely due to interfacial losses

Ref. Cho et. al. *J. Electrochem. Soc*. **150**, A1667 (2003)

Performance degradation after freezing/thawing cycle

- ✓ **OCV was maintained while current density at 0.6 V decreased.**



Effects of thermal cycles from 80 to –10°C on the OCV and current density measured at a cell voltage of 0.6 V and at a cell temperature of 80°C.

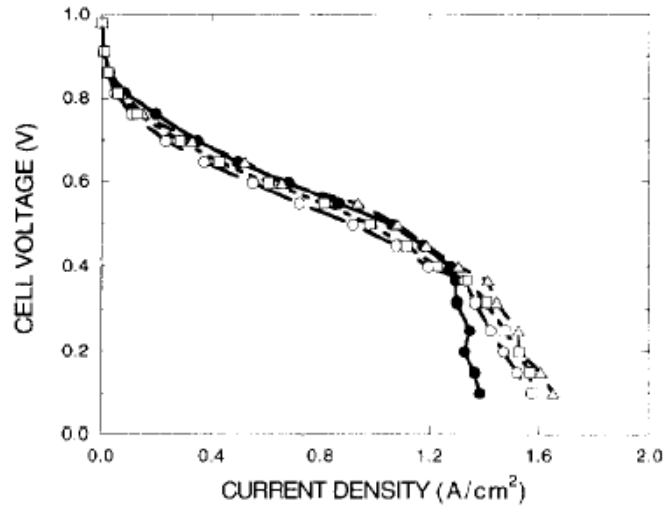


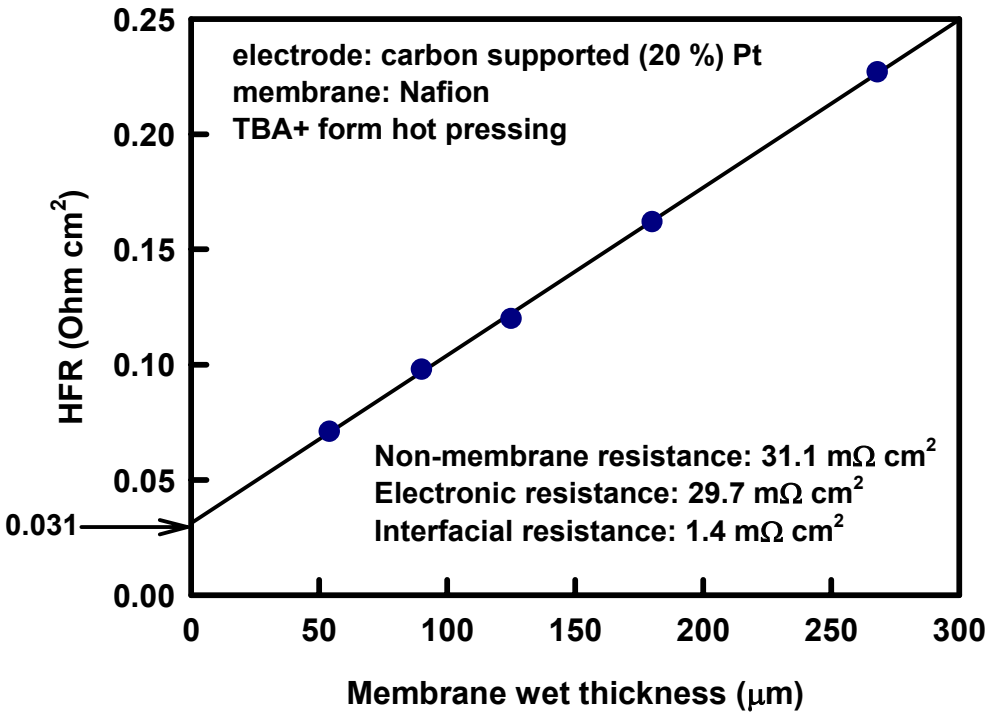
Fig. 12. Effect of several freeze-thaw cycles on the performance of a single cell with TBA^+ thin film catalyst layers. Frozen at −10°C. Operation conditions are the same as in Fig. 2. (● before freezing, (△) after the 1st freeze, (○) after the 2nd freeze, and (□) after the 3rd freeze.

Electrochem. Acta, Wilson et al., **40**, 355, (1995)

Performance discrepancies

Ref. Cho et. al. *J. Electrochem. Soc*. **150**, A1667 (2003)

Interfacial Resistance between Nafion and Carbon Supported Pt Electrode

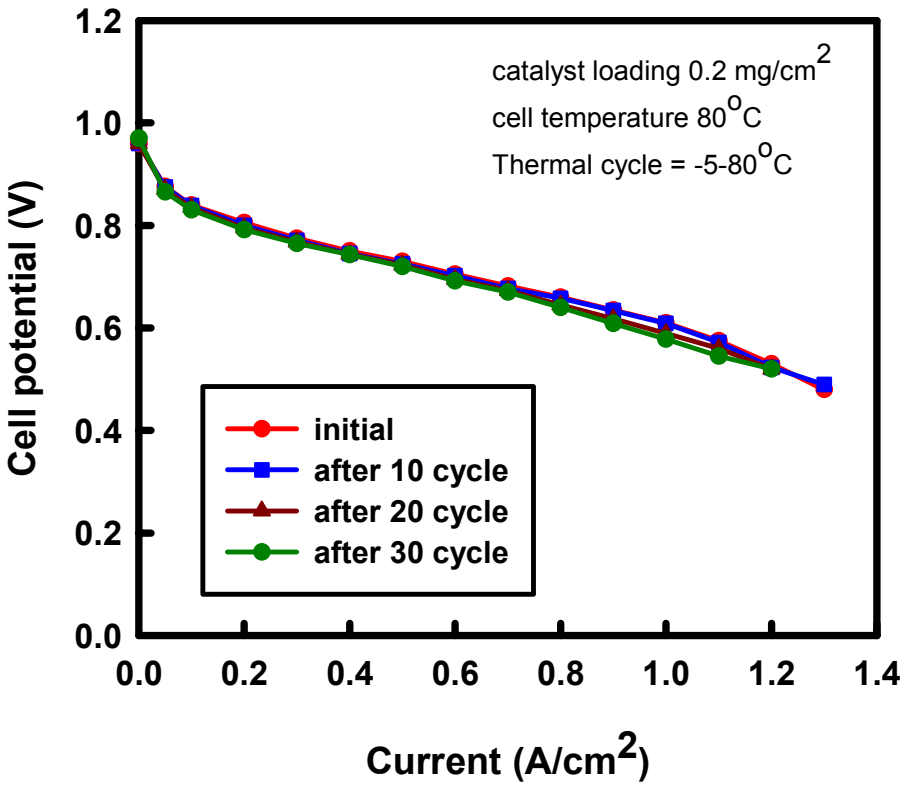


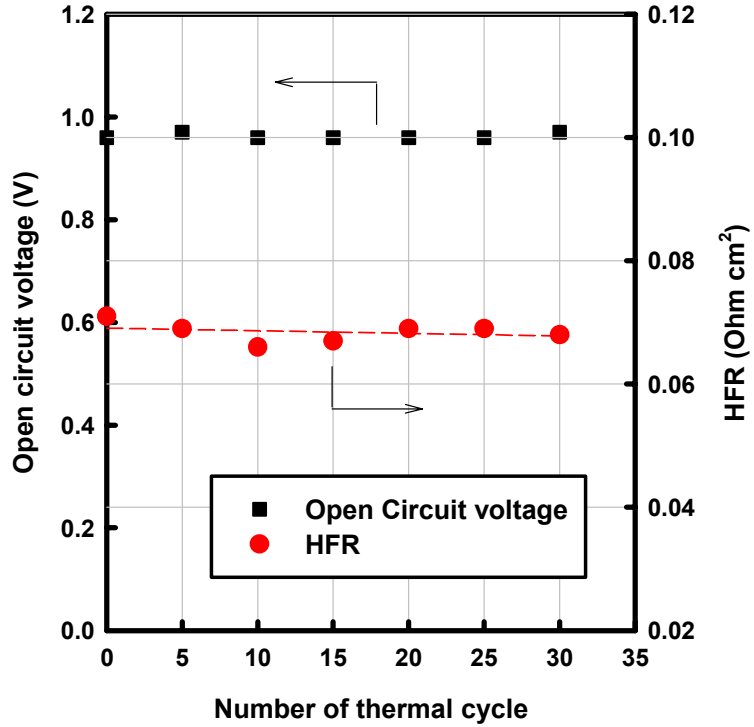
Cell HFR vs. Membrane Thickness

- Interfacial resistance between Pt electrode (20% carbon supported) and Nafion membrane was small (1.4 mΩ cm^2).

- MEA was fabricated from TBA+ form Nafion solution followed by hot pressing (220 ^{o}C).

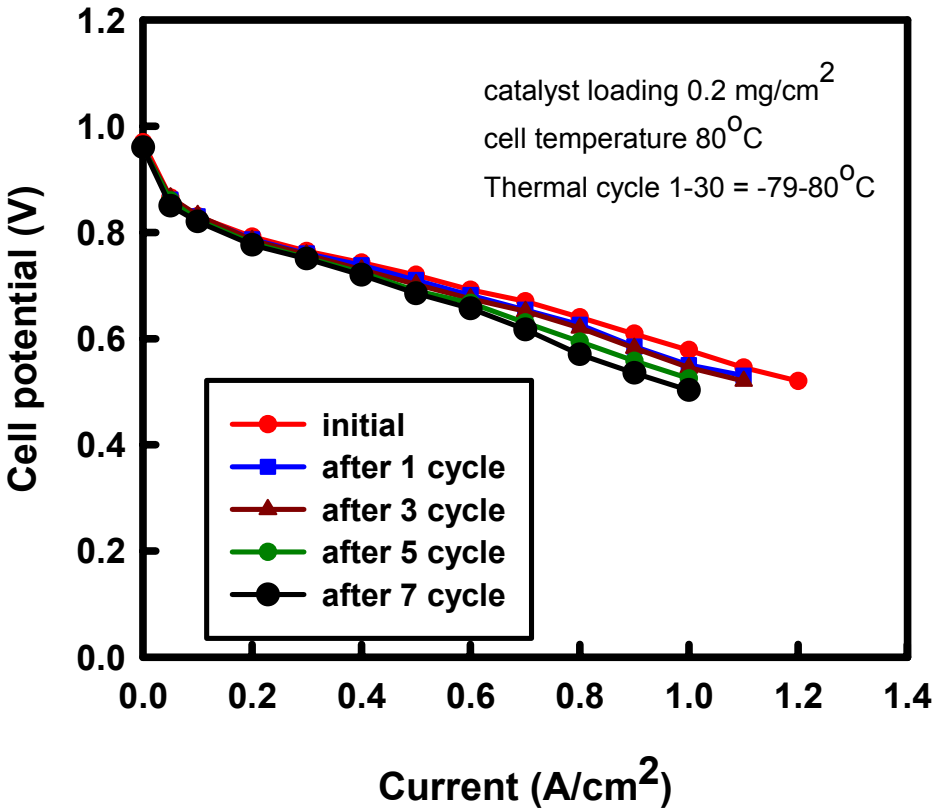
Performance Change after Freeze/thawing Cycle (Temp. cycle = -5-80°C)

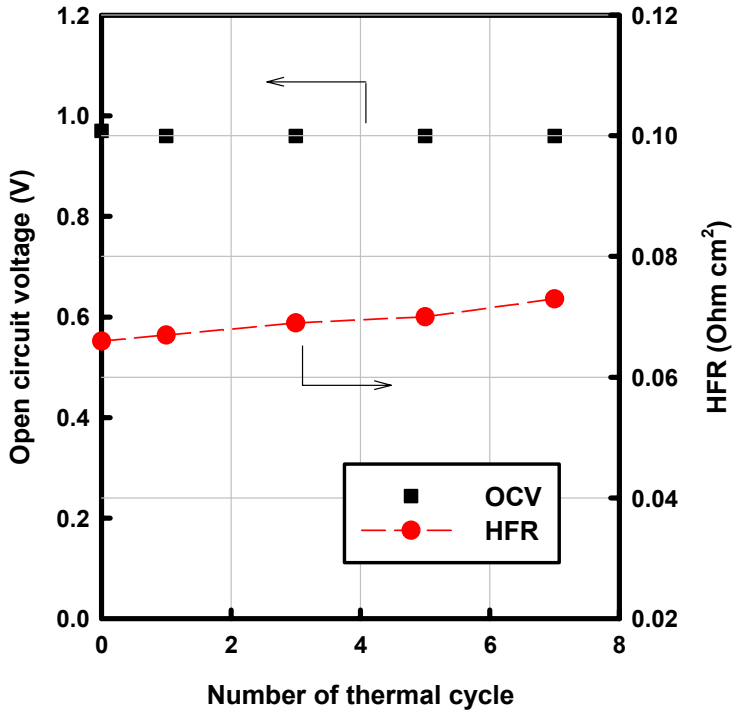




- We observed no performance degradation after 30 freeze/thawing cycle (-5-80°C) with stable OCV and HFR.

Performance Change after Freeze/thawing Cycle (Temp. cycle = -79-80°C)





- We observed the noticeable performance decreased after 7 freeze/thawing cycle (-79-80°C) with increasing HFR.

Summary of Results

	Cho et al.	*Wilson et al.*	*This work*	
Membrane	Nafion 115	Nafion 112	Nafion 112	
Electrode	20 wt% Pt/C (0.4 mg/cm^2)	20 wt% Pt/C (0.16 mg/cm^2)	20 wt% Pt/C (0.2 mg/cm^2)	
GDL	wet proofed carbon paper	hydrophobic carbon cloth	hydrophobic carbon cloth	
MEA processing	Catalyst ink sprayed on GDL / 140^{o}C hot pressing	Decal painting (TBA^+ form catalyst) / 200^{o}C hot pressing	Decal painting (TBA^+ form catalyst) / 200^{o}C hot pressing	
F/T cycle	-10 – 80^{o}C (4 cycle)	-10 – 80^{o}C (3 cycle)	-5 – 80^{o}C (30 cycle)	-79 – 80^{o}C (7 cycle)
Results	Performance drop, HFR increase, catalyst loss	No performance loss	No performance loss	Performance drop HFR increase

Influence of MEA processing Conditions

Membrane	Nafion 112		
Electrode	20 wt% Pt/C (0.2 mg/cm^2)		
GDL	hydrophobic carbon cloth	hydrophobic carbon cloth	wet proofed carbon paper
MEA processing	Catalyst ink painted on GDL / 140^{o}C hot pressing	Catalyst ink painted on membrane / 140^{o}C hot pressing	Catalyst ink painted on GDL / 140^{o}C hot pressing
F/T cycle	-5 – 80^{o}C (~10 cycles)		
Results	Preliminary work suggests little effect from GDL choice and MEA processing		

Effect of Conditions

- Material Concerns
  - MEA (prep, composition)
  - GDL
  - Bipolar/End plates
- Operational
  - Water content
  - Temperature (time)