HTMWG
May 18, 2009

Welcome!

Agenda

9:00 am	Welcome	Nancy Garland,DOE
9:05 am	Update on Membrane Approaches	J. Kopasz, ANL
9:25 am	Integration of non-traditional membranes into MEAs	Yu Seung Kim, LANL
10:10 am	MEA Testing Issues and Fabrication from team members	Jim Fenton FSEC
10:55 am	OEM perspective	Craig Gittelman GM
11:40	Open discussion	

Membrane Project Presentations at the DOE H_2 Program Annual Merit Review

- Poster Session–Crystal Gateway

Grand Ballroom 6-9 PM,
FCP 10 K. Mauritz

Tuesday AM Fuel Cell Session
Crystal Gateway Salon IV
8:30 FC 01 J. Fenton UCF/FSEC
9:00 FC02 C.Mittelsteadt Giner
9:30 FC03 S. Lvov Penn State
10:00 FC04 J. Mays U. of Tennessee
10:30 Break
11:00 FC05 J. McGRath Virginia Tech
11:30 FC06 D. Gervasio Arizona State
12:00 FC07 S. Creager, Clemson

Tuesday PM Fuel Cell Session
1:45 FC08 M. Litt Case Western
2:15 FC09 P. Pintauro, Vanderbilt
2:45 FC10 L. Lipp, FCE
3:15 FC11 A. Herring Colorado School of Mines
3:45- Break
4:15 FC12 J. Goldbach Arkema
4:45 FC13 S. Hamrock, 3M
5:15 FC14 J. Kerr, LBNL

Wednesday AM Fuel Cell Session
Crystal Gateway Salon IV

8:30AM FC 15 S. Das, Kettering

Membrane Classification Scheme – Update with some results

High Temperature Membrane Working Group

May 14, 2007

Huge variety of possible polymer membranes to investigate

- Hydrocarbon, Fluorocarbon, Inorganic
- Branched, Comb, hyperbranched, dendritic,,
- With additives
- With structural supports,

What avenues should be pursued?

Which are dead ends?

How do we decide?

Need a way to organize/manage information gathered

A wide variety of approaches for High temperature PEMFC membranes are being pursued

	Morphology	Molecular Approach			Additive Approach				Micro/nano engineering approach	
Conduction Mechanism		Other Polymer	Block Copolymer	Rigid Rods	ZrPhosphate	HPA	Zeolite	Other	Structured Support	Structured Ionomer
Aqueous										
	FC-SO3H	■			■	■		■	■	■
	HC-SO3H	■	■	■	■	■				■
	Hydrous Metal Oxides									
	sulfonyl imides	■						■		
Potential Non Aqueous										
	polyPOMs	■								
	Phosphates	■								
	Phosphonic acid	■								
	Phosphoric acids									
	Heterocyclic bases	■	■					■		
	Ionic liquids	■								

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	Hydrous Metal Oxides									
	sulfonyl imides									
Potential Non Aqueous										
	polyPOMs									
	Phosphates									
	Phosphonic acids									
	Phosphoric acid									
	Heterocyclic bases									
	Ionic liquids									
	DOE/EERE									
	Other									

DOE Membrane Targets

Characteristic	Units	2006 status	2005 target	2010 target	2015 target
Maximum operating temperature	°C	80	120	120	120
Area specific proton transfer resistance at:					
Maximum operating temp and water partial pressures from 40 – 80 kPa	Ohm cm^2	0.03	0.02	0.02	0.02
80°C and water partial pressures from 25 - 45 kPa	Ohm cm^2	0.03	0.02	0.02	0.02
30°C and water partial pressures up to 4 kPa	Ohm cm^2	0.04	0.03	0.03	0.03
-20°C and water partial pressures up to 0.1 kPa	Ohm cm^2	0.3	0.2	0.2	0.2
Oxygen cross-over[a]	mA/cm^2		5	2	2
Hydrogen cross-over[a]	mA/cm^2		5	2	2
Cost [b]	\$/m^2	[c]		20	20
Durability					
mechanical[e]	5 cycles w<10 sccm 5 crossover	200		20,000[e]	20,000[e]
chemical[f]	H2 crossover 15 < 2mA/cm^2			500 h	500 h
Minimum Electrical resistance	Ohm cm^2			1000	1000

Targets in numbers we're familiar with

- 0.02 ohm-cm^2 corresponds to a conductivity of 0.1 S/cm for a 20 micron thick membrane

- P_{H2O} 25-45 kPa at 80°C ~ 50-95%RH
- P_{H2O} 40-80 kPa at 120C ~ 20-40% RH

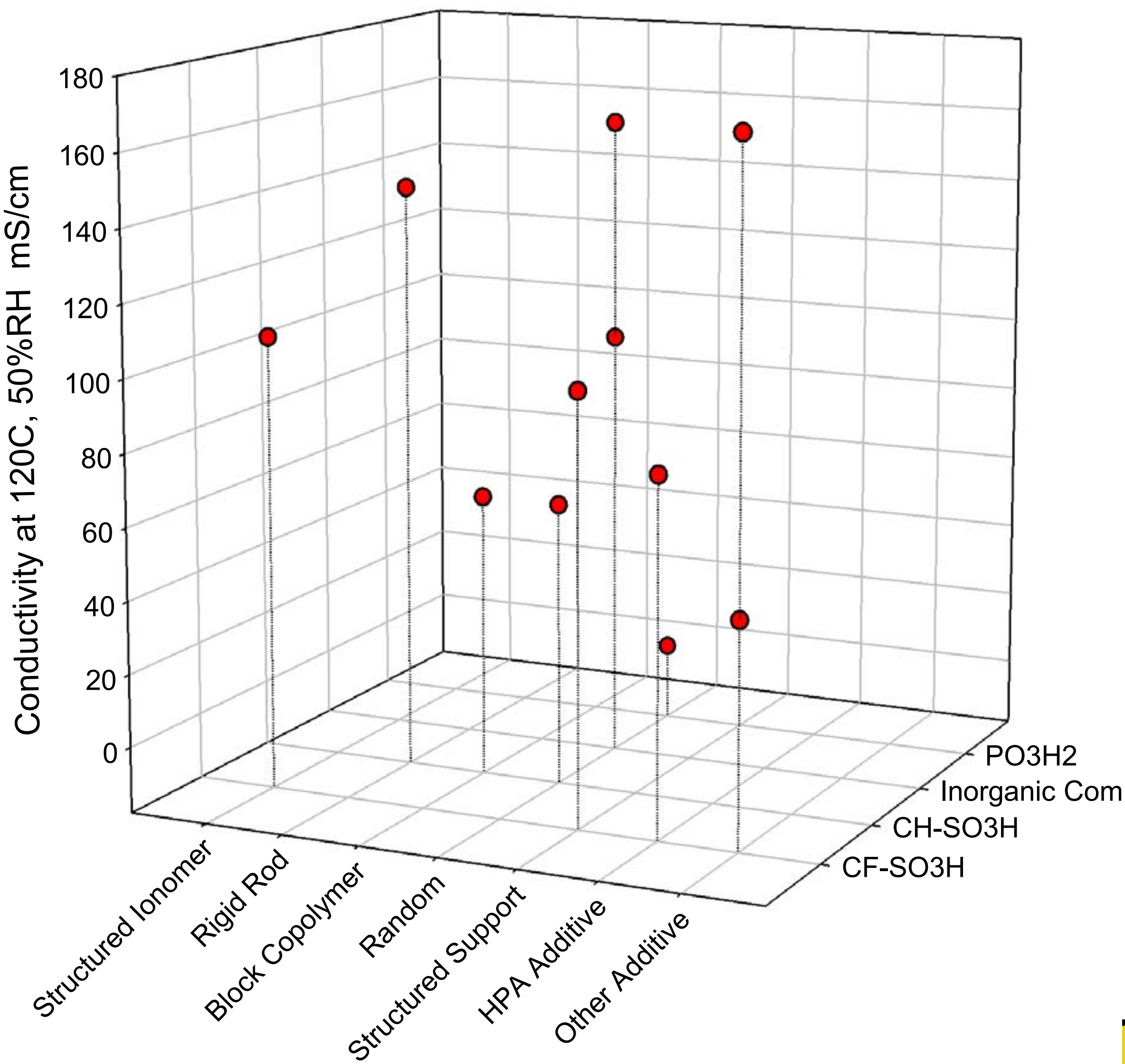
Conductivity Results at 80°C and 80% RH

Aqueous										
	FC-SO3H									
	HC-SO3H									
	Hydrous Metal Oxides									
	sulfonyl imides									
Potential Non Aqueous										
	polyPOMs	*								
	Phosphates									
	Phosphonic acids									
	Phosphoric acid									
	Heterocyclic bases									
	Ionic liquids									
		>200 mS/cm								
		100-200 mS/cm								
		Less than 100 mS/cm								
	*	measured in house and by a second party (not FSEC/BekkTech)								

DOE Projects have achieved high conductivity at 120°C 50% RH with a variety of approaches

	Morphology	Molecular Approach			Additive Approach				Micro/nano engineering approach	
Conduction Mechanism		Other Polymer	Block Copolymer	Rigid Rods	ZrPhosphate	HPA	Zeolite	Other	Structured Support	Structured Ionomer
Aqueous										
	FC-SO3H									
	HC-SO3H									
	Hydrous Metal Oxides									
	sulfonyl imides									
Potential Non Aqueous										
	polyPOMs	*								
	Phosphates	**								
	Phosphonic acids									
	Phosphoric acid									
	Heterocyclic bases									
	Ionic liquids									
		≥ 0.1 S/cm at 120C and 50%RH								
		> 50% of target								
		Less than 50% of target			NRE 212 < 50% of target					
	*	Measured in-house and by a second party								
	**	Measured in-house								

Conductivity Results at 120°C, 50%RH



conductivity at 120°C, 25% RH with a variety of approaches

	Morphology	Molecular Approach			Additive Approach				Micro/nano engineering approach	
Conduction Mechanism		Other Polymer	Block Copolymer	Rigid Rods	ZrPhosphate	HPA	Zeolite	Other	Structured Support	Structured Ionomer
Aqueous										
	FC-SO3H									
	HC-SO3H									
	Hydrous Metal Oxides									
	sulfonyl imides									
Potential Non Aqueous										
	polyPOMs	*								
	Phosphates	**								
	Phosphonic acids									
	Phosphoric acid									
	Heterocyclic bases									
	Ionic liquids									
		met conductiivty target of 0.1 S/cm								
		30-50% of target								
		20-30%			NRE 212 < 50% of target					
		Less than 20% of target								
	*	Measured in-house and by a second party								
	**	Measured in-house								

What is the impact on mechanical properties?

	Morphology	Molecular Approach			Additive Approach				Micro/nano engineering approach	
Conduction Mechanism		Other Polymer	Block Copolymer	Rigid Rods	ZrPhosphate	HPA	Zeolite	Other	Structured Support	Structured Ionomer
Aqueous										
	FC-SO3H									
	HC-SO3H									
	Hydrous Metal Oxides									
	sulfonyl imides									
Potential Non Aqueous										
	polyPOMs									
	Phosphates									
	Phosphonic acids									
	Phosphoric acid									
	Heterocyclic bases									
	Ionic liquids									
		improvement								
		neutral or unknown								
		decrease								

Mechanical Durability Test

Table 4 Membrane Mechanical Cycle and Metrics (Test using a MEA)		
Cycle	**Cycle 0% RH (2 min) to 90°C dewpoint (2 min), single cell 25-50 cm^2**	
Total time	Until crossover >2 mA/cm^2 or 20,000 cycles	
Temperature	80°C	
Relative Humidity	Cycle from 0% RH (2 min) to 90°C dewpoint (2 min)	
Fuel/Oxidant	Air/Air at 2 SLPM on both sides	
Pressure	Ambient or no back-pressure	
Metric	**Frequency**	**Target**
Crossover*	Every 24 h	$\leq$2 mA/cm^2
Shorting resistance	Every 24 h	>1,000 ohm cm^2

* Crossover current per USFCC "Single Cell Test Protocol" Section A3-2, electrochemical hydrogen crossover method

Chemical Durability Test (requires MEA)

Table 3
MEA Chemical Stability and Metrics

Test Condition	**Steady state OCV, single cell 25-50 cm^2**	
Total time	500 h	
Temperature	90°C	
Relative Humidity	Anode/Cathode 30/30%	
Fuel/Oxidant	Hydrogen/Air at stoics of 10/10 at 0.2 A/cm^2 equivalent flow	
Pressure, inlet kPa abs (bara)	Anode 250 (2.5), Cathode 200 (2.0)	
Metric	**Frequency**	**Target**
F^- release or equivalent for non-fluorine membranes	At least every 24 h	No target – for monitoring
Hydrogen Crossover (mA/cm^2)*	Every 24 h	$\leq$2 mA/cm^2
OCV	Continuous	$\leq$20% loss in OCV
High-frequency resistance	Every 24 h at 0.2 A/cm^2	No target – for monitoring
Shorting resistance	Every 24 h	>1,000 ohm cm^2

*Crossover current per USFCC “Single Cell Test Protocol” Section A3-2, electrochemical hydrogen crossover method

Room for improvement

- Using a 2D grid to try to simplify a higher-dimensional system
  - Is there a more useful representation?
  - Is there a better way to deal with projects that use multiple approaches?
- Incomplete data set

Need a way to organize/manage information gathered

- Track different types of approaches
- Determine which strategies are most fruitful
- Determine which strategies are dead ends
- Improve our understanding of proton transport
- Help maximize our return on HTM research

Conductivity Results at 120°C, 25%RH