Metal Oxide Composite Membranes for PEMFCs

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First International Conference on
Fuel Cell Development and Deployment
University of Connecticut
March 7-10, 2004

Frick Laboratory, Princeton University,Princeton NJ 08544

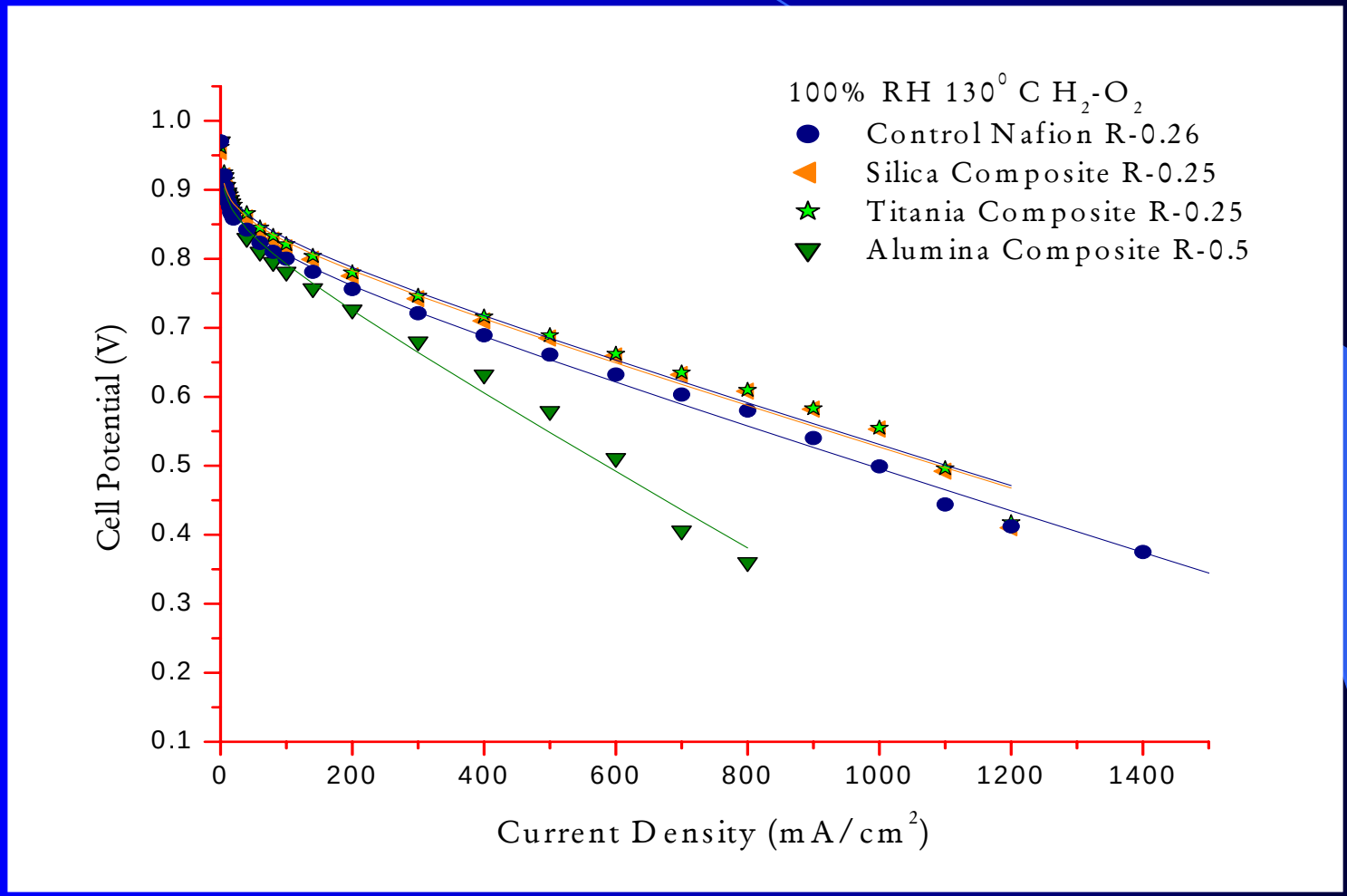
High Temperature Operation of a PEMFC

- Faster Electrochemical Kinetics
- Better water management
- High-quality waste heat
- Enhanced CO tolerance

Preparation of Composite Membranes

- Recast Membranes from Nafion solution
- Impregnation of metal oxides
- Post-treatment of membranes using H_2O_2 and acid
- Metal Oxides: SiO_2, TiO_2 and Al_2O_3
- Electrodes: Commercial ETEK Electrodes

Fuel Cell Performance-Degussa Huls MO_x



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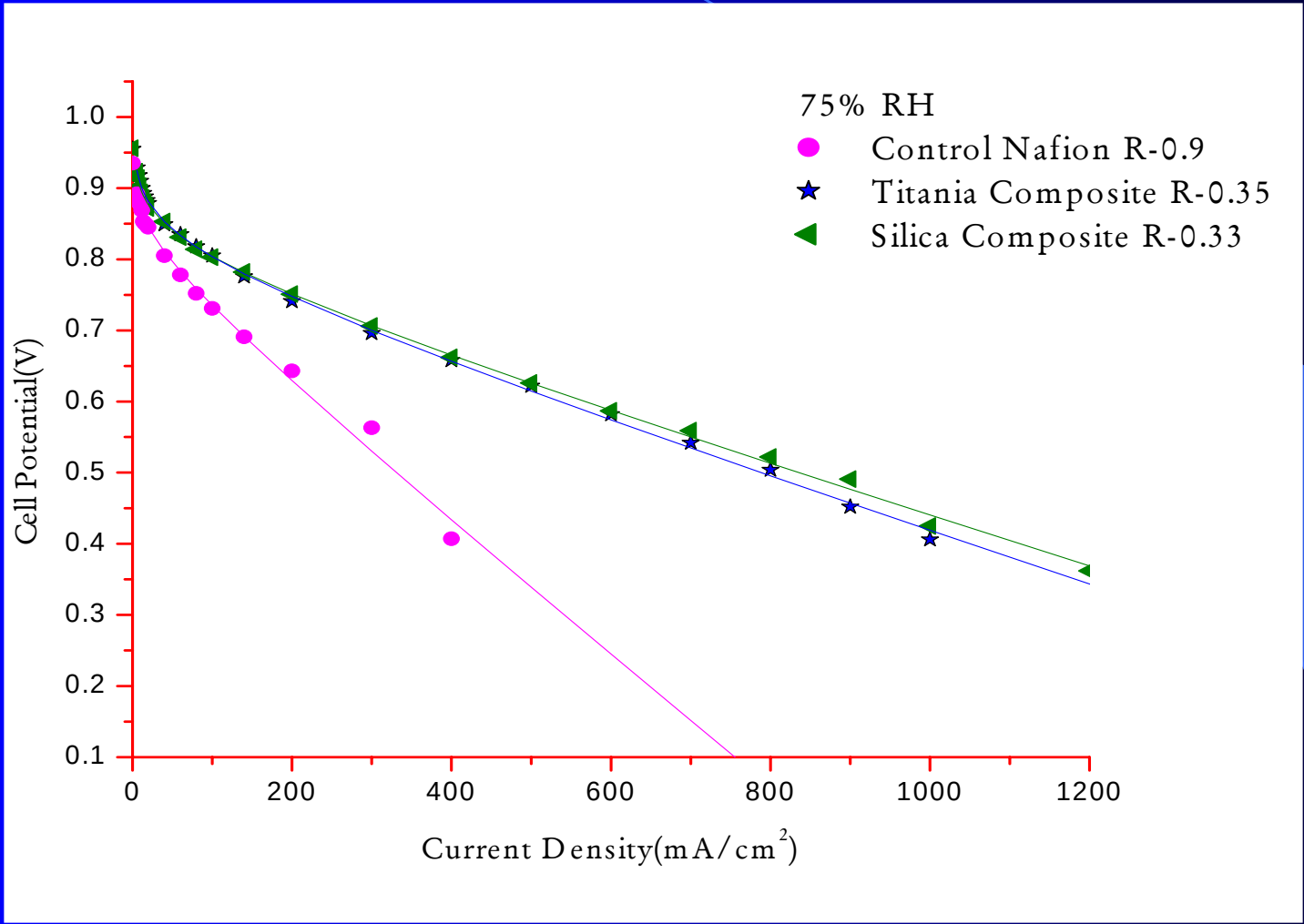
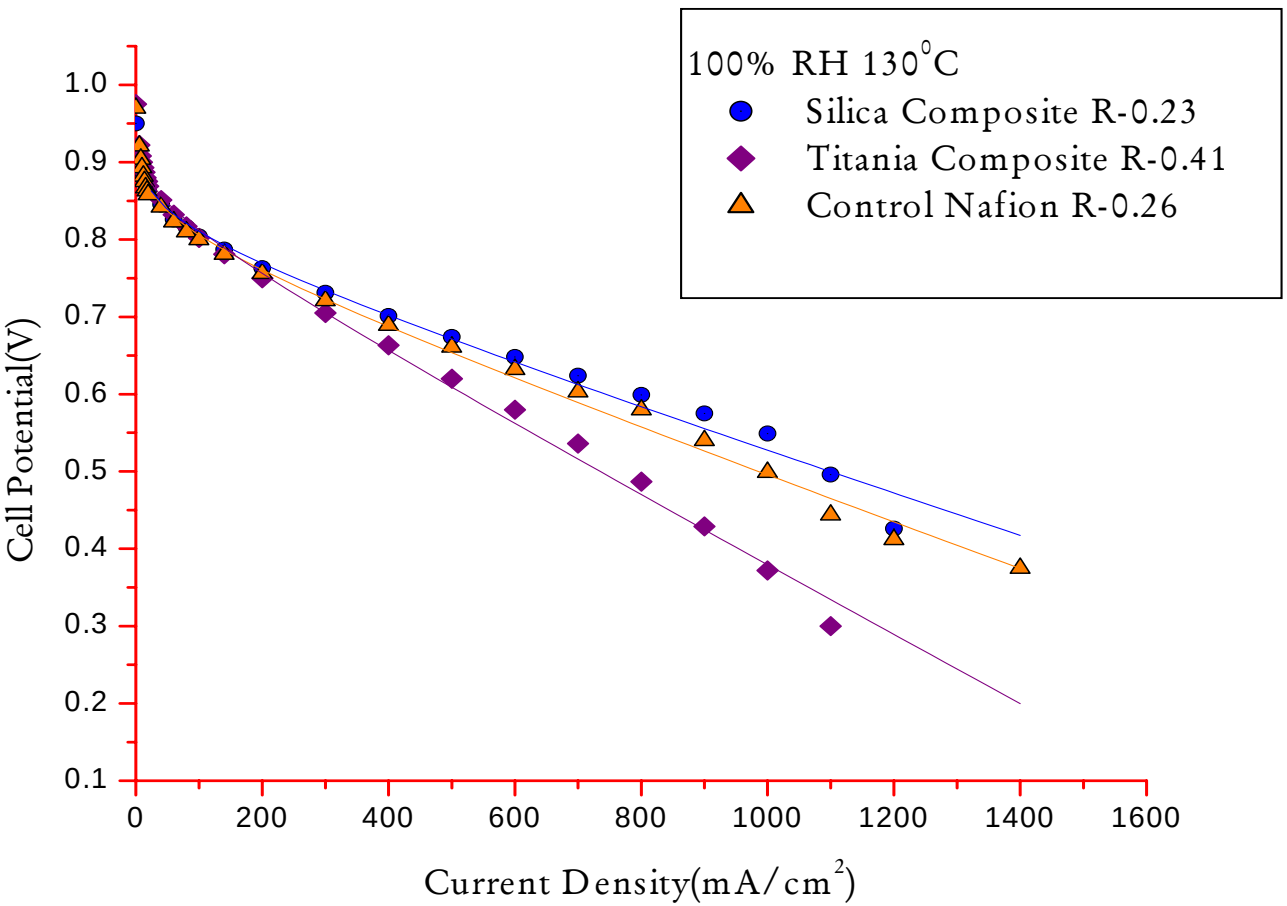
Performance at 75% RH



Fuel Cell Performance- AA oxides



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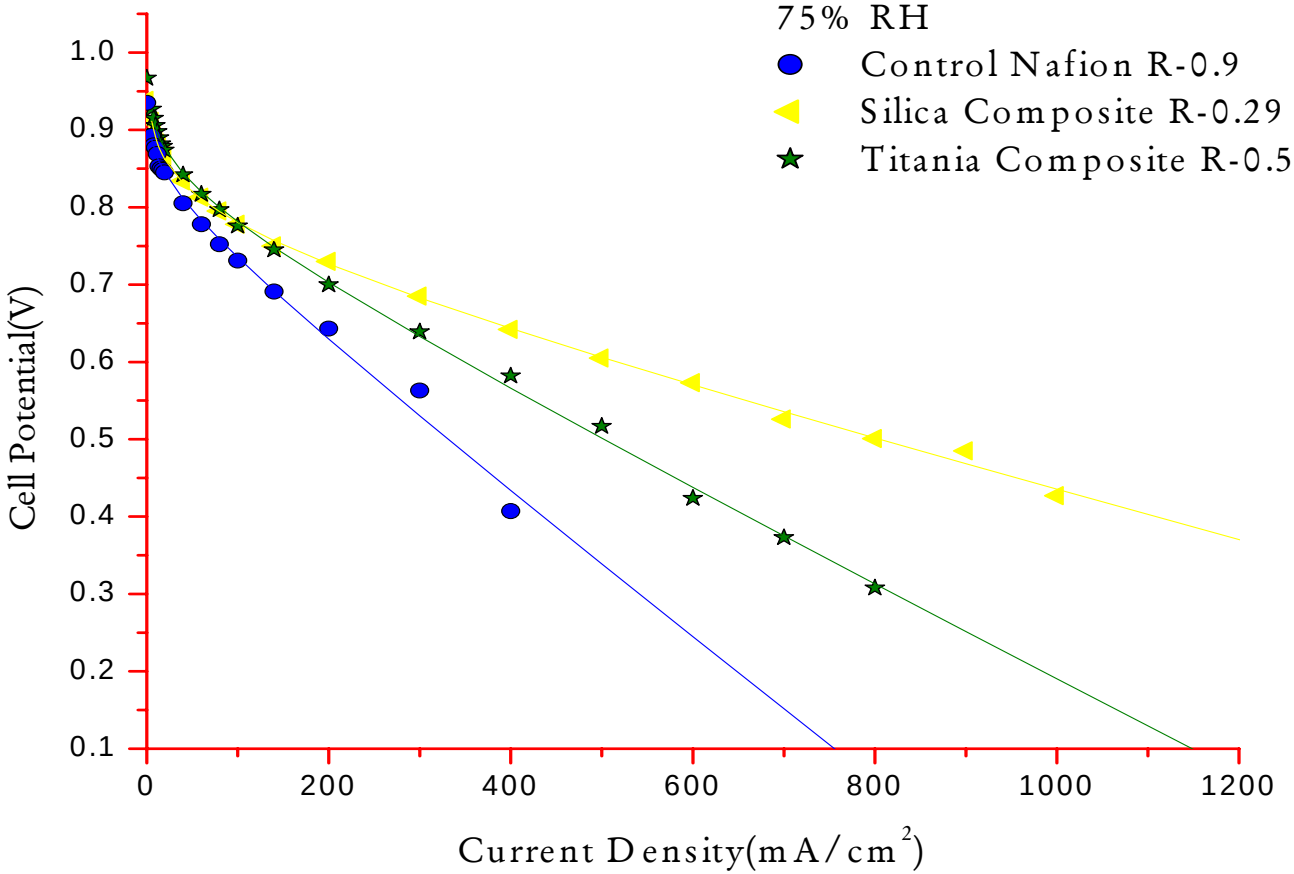
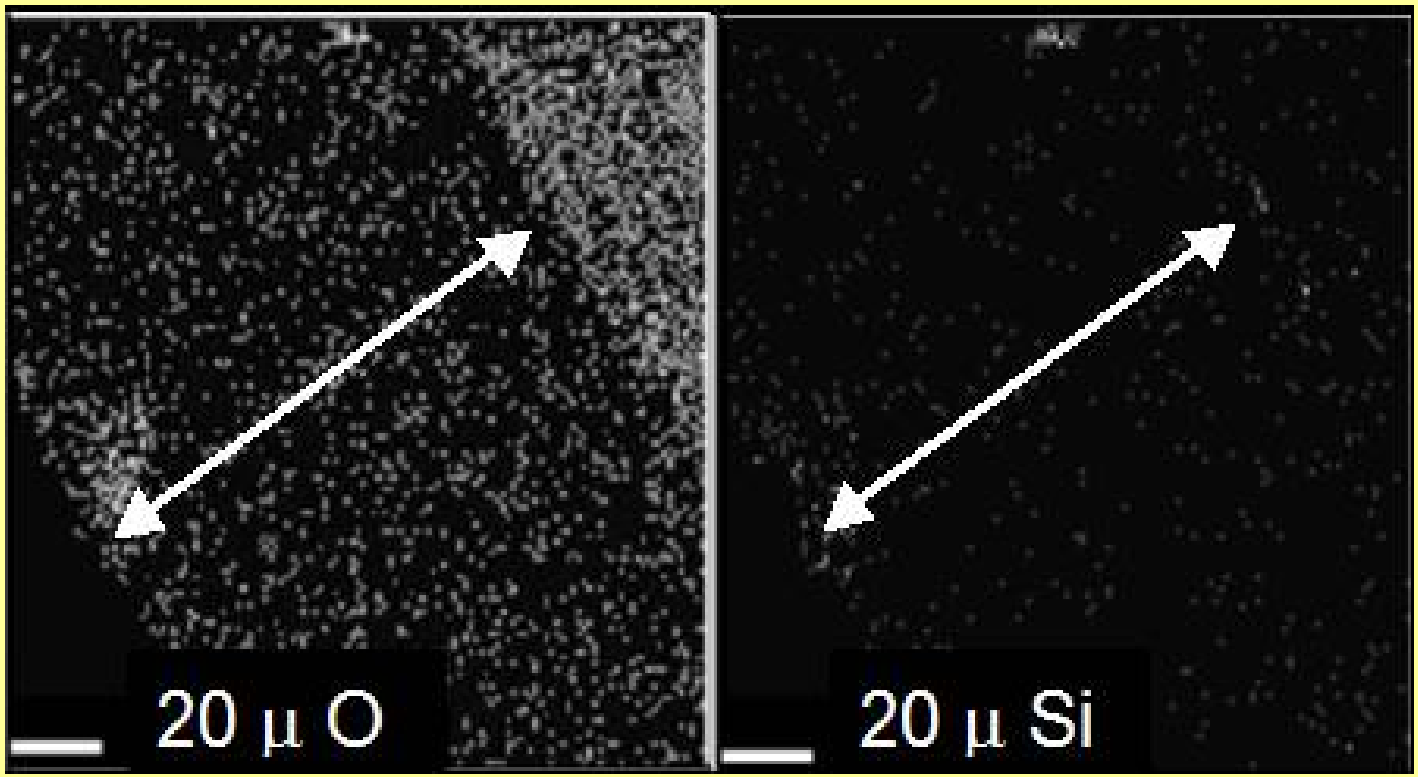


Characterization of composite membranes

- EPMA
- SAXS
- Fluorescence
- IEC measurements

Microprobe Analysis



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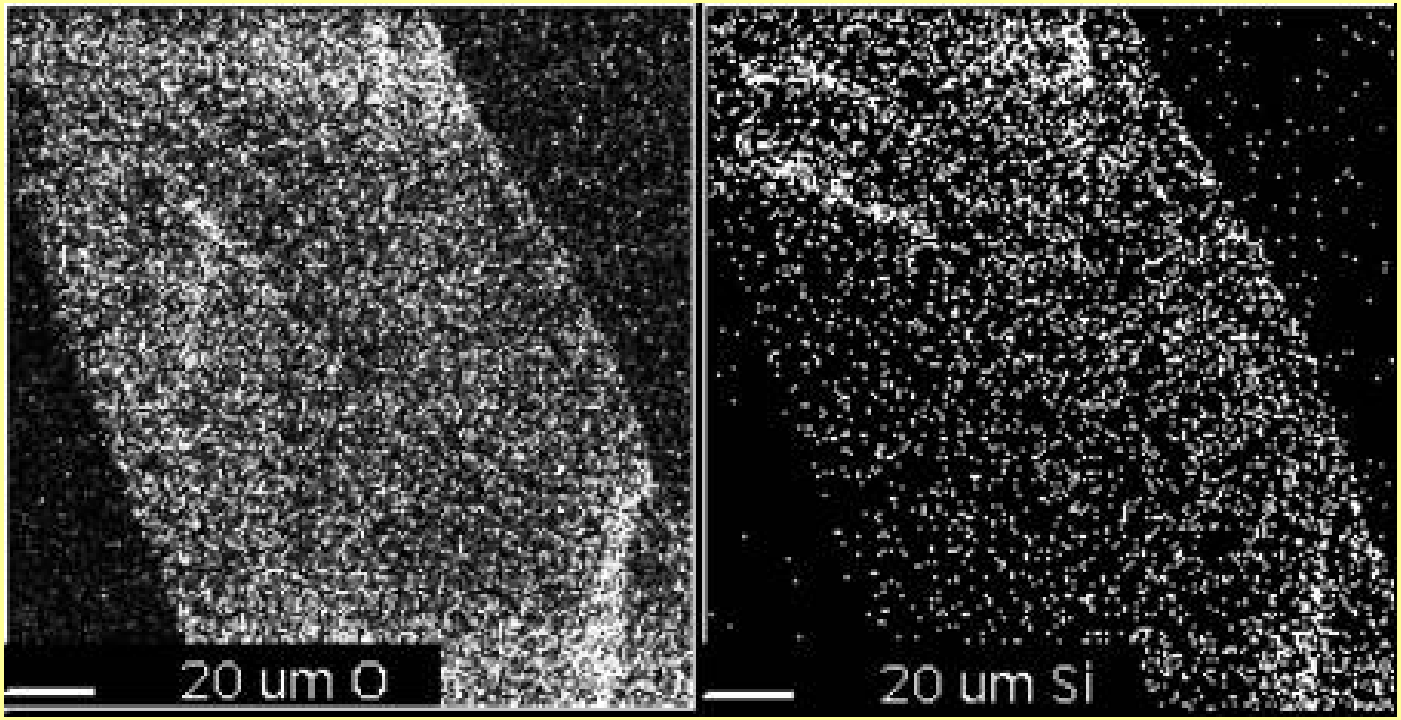
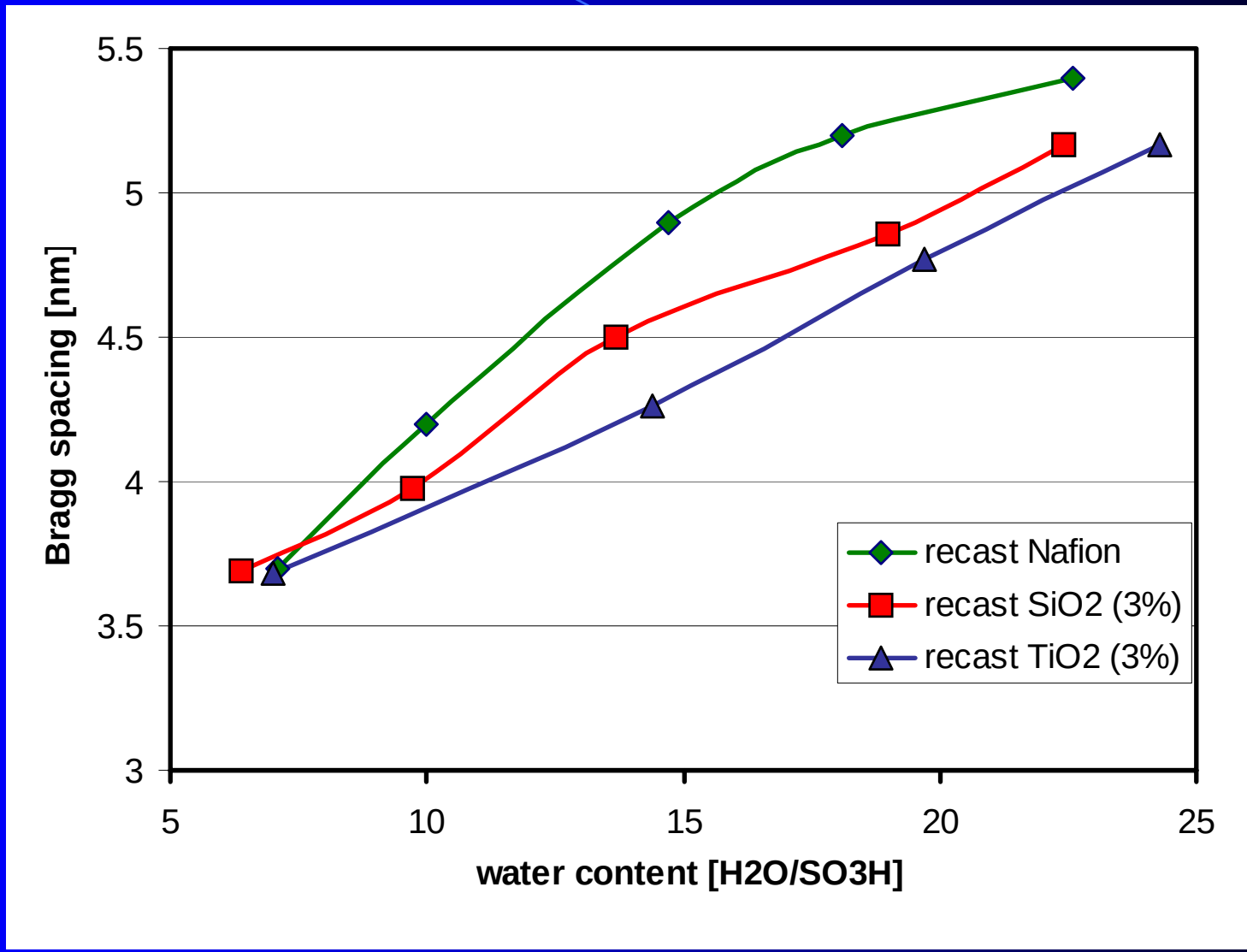
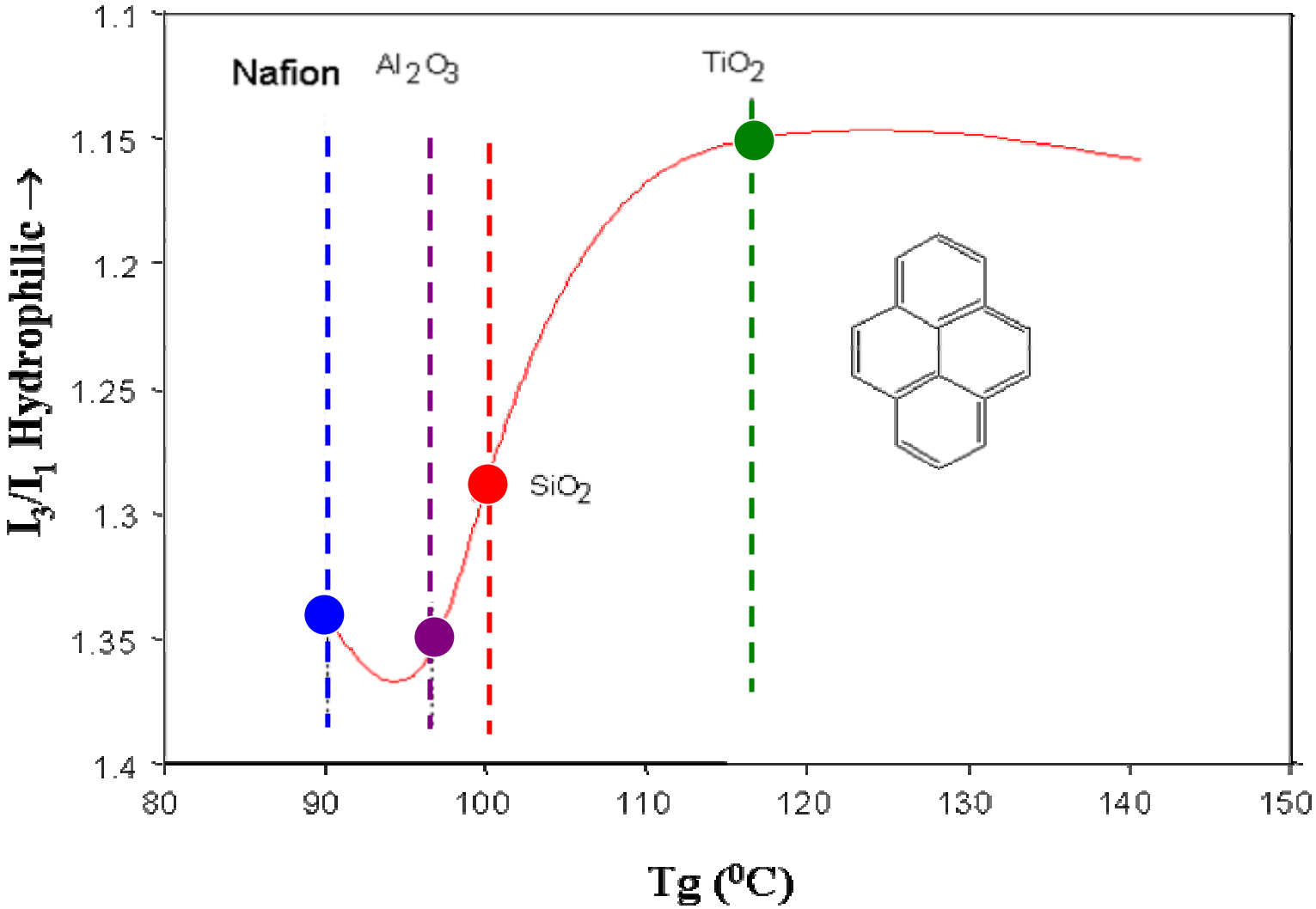


SAXS Studies



Fluoroscence Experiments



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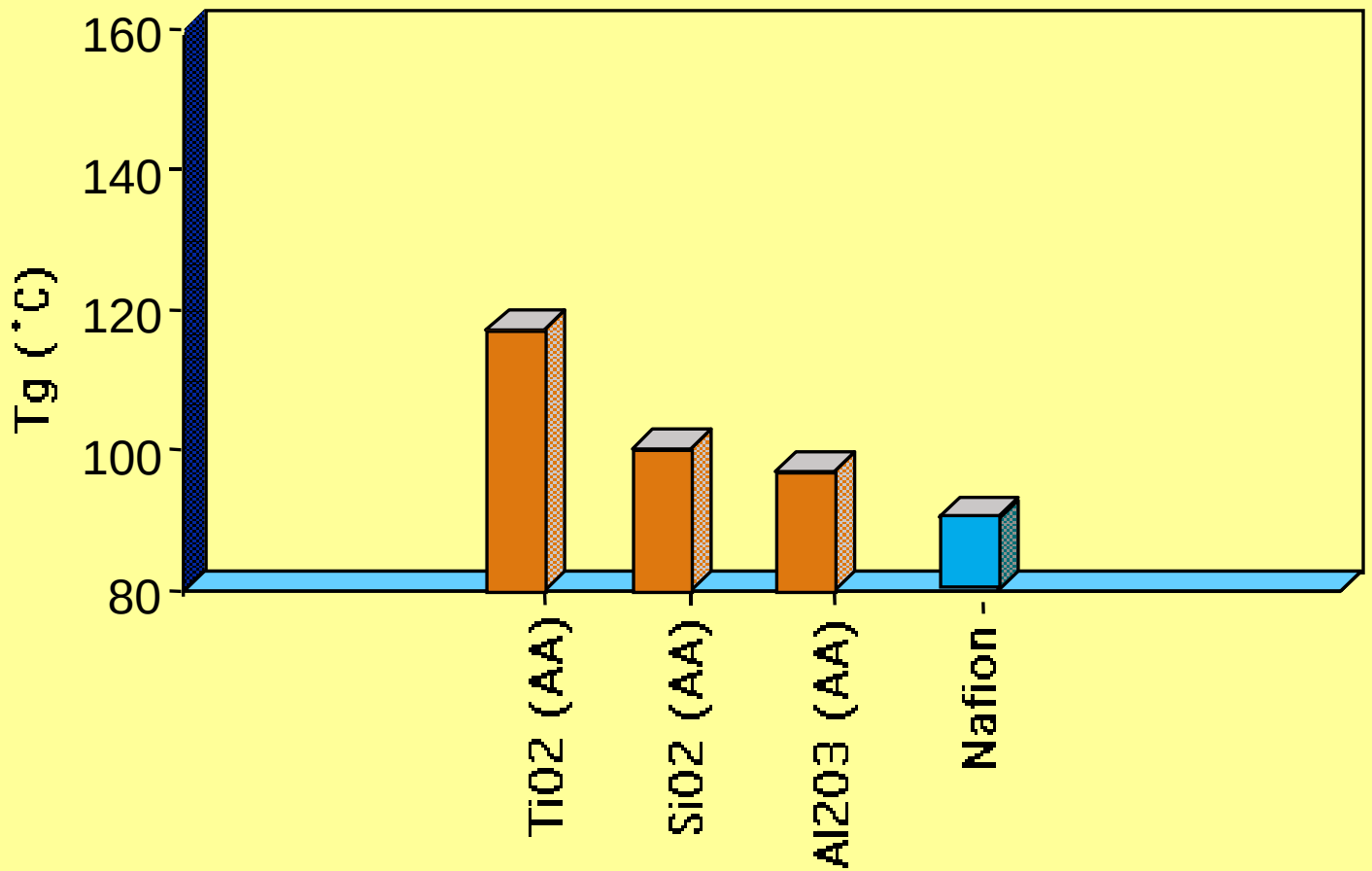
DMA Measurements



What is the Chemistry???

Fuel Cell Performance depends on

- Chemistry of various of oxides
- End groups
- Reactivity of metal ions
- Interaction of Nafion with metal oxides

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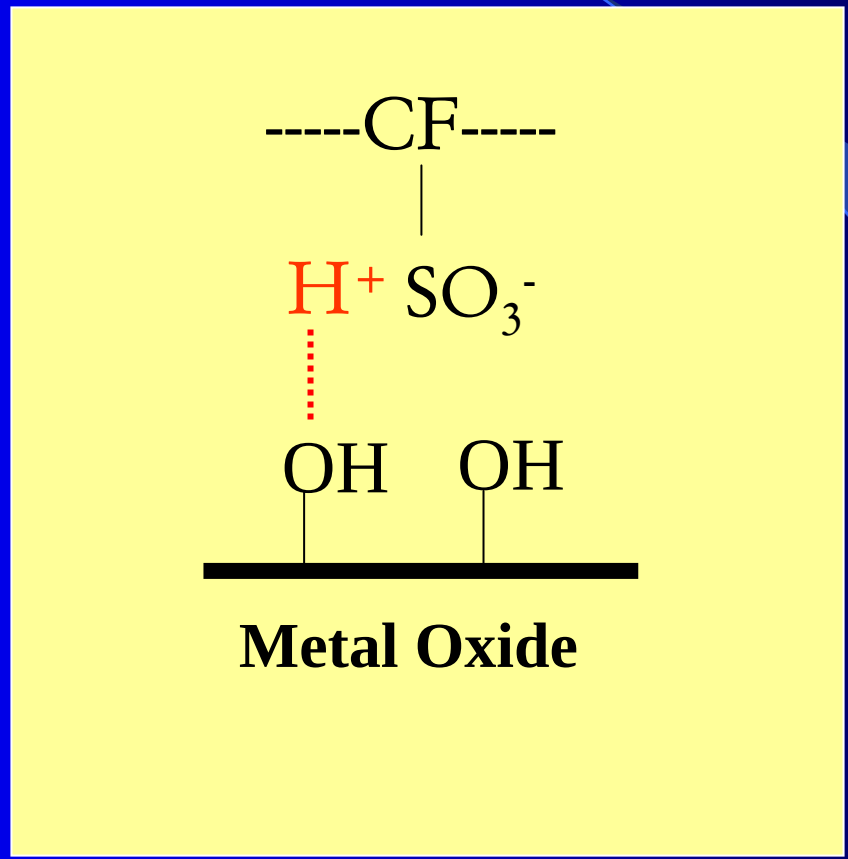
Possible Mechanisms



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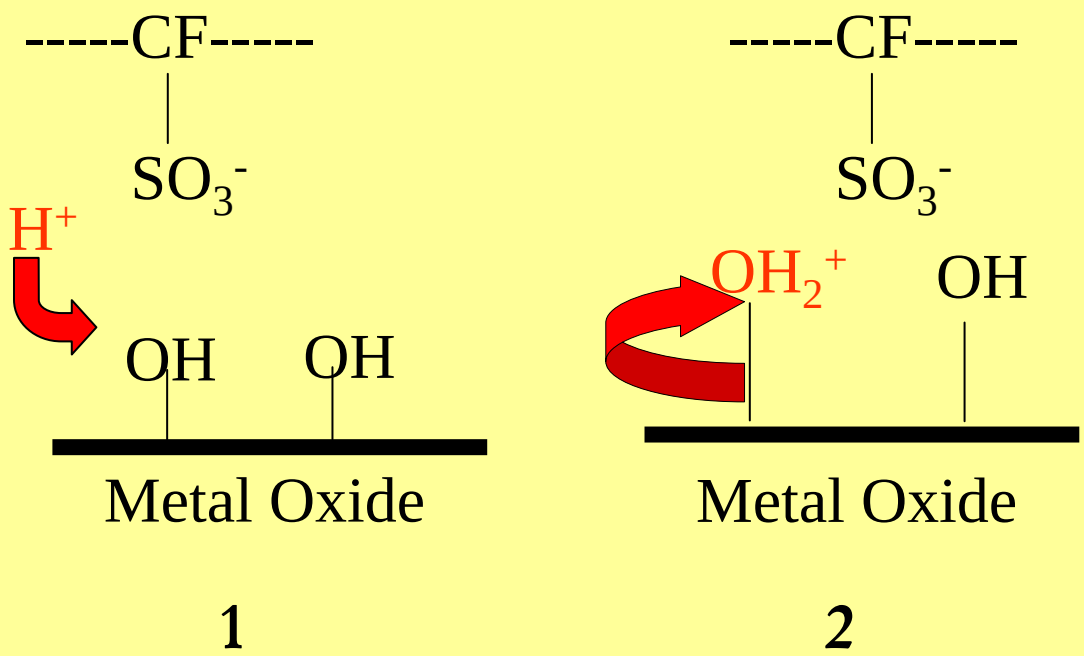

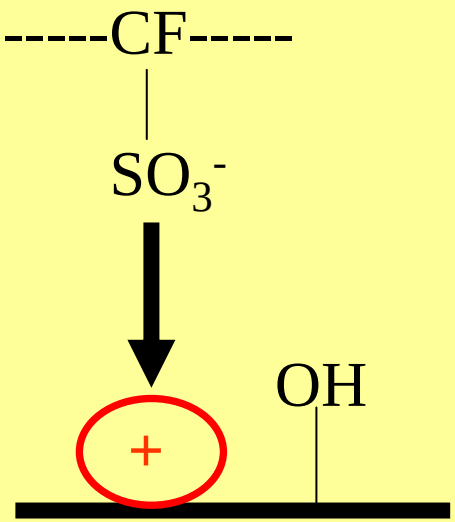

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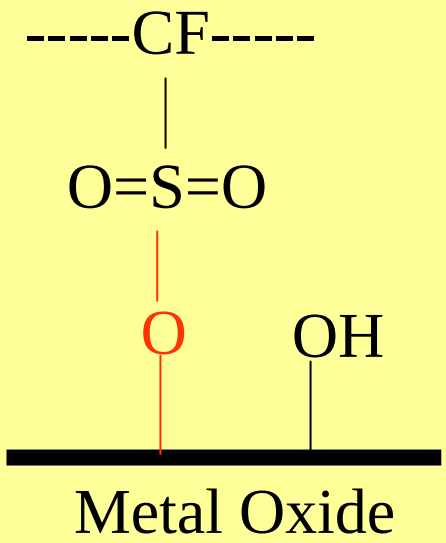

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Electrode Kinetic Parameters- DH oxides

Membrane	RH (%)	E_0 (mV)	b (mV/decade)	R (ohm cm^2)	Cell Potential at 600 mA/cm^2 (mV)
Plain	*100*	*961*	*65*	*0.26*	*632*
	75	*940*	*54*	*0.9*	-
SiO_2	100	954	54	0.25	659
	75	967	65	0.33	587
TiO_2	100	960	54	0.25	662
	75	960	70	0.35	582
Al_2O_3	100	941	48	0.53	511

Electrode Kinetic Parameters-AA oxides

Membrane	RH (%)	E_0 (mV)	b (mV/decade)	R (ohm cm^2)	Cell Potential at 600 mA/cm^2 (mV)
Plain Recast	***100*** ***75***	***961*** ***940***	***65*** ***54***	***0.26*** ***0.9***	***632*** -
SiO_2	100 75	950 975	60 82	0.23 0.29	648 573
TiO_2	100 75	948 976	49 68	0.41 0.58	580 424
ZrO_2-7.5 μ	100 75	958 965	51 72	0.29 0.54	645 458
ZrO_2-1.5 μ	100 75	960 970	55 83	0.32 0.7	620 400
Al_2O_3-1 μ	100 75	946 970	52 84	0.32 0.79	625 406
Al_2O_3-25 μ	100 75	953 970	45 57	0.29 0.7	664 344
TiO_2 (Degreased)	75	908	65	0.33	590
TiO_2 (Silylated)	75	897	77	0.52	400
ZrO_2(Aldrich)	~100 78	944 964	57 64	0.25 0.62	646 442
ZrO_2(GFS)	~100 78	939 986	52 105	0.57 0.85	454 -

IEC Measurements

Metal Oxide	I_3/I_1	% Protons consumed
SiO_2 (AA)	1.29	5
SiO_2 (DH)	1.35	3
Al_2O_3 (AA)	1.35	4
Al_2O_3 (DH)	1.36	3
TiO_2 (AA)	1.36	~4
TiO_2 (AA)-(acid treated /degreased)	1.15	2
TiO_2 (AA)-silylated	1.33	--
TiO_2 (DH)	1.21	<1
ZrO_2 (AA, Aldrich)		<1
Control	**1.34**	--

Colorimetric Analysis for Al using Alizarin S

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Future Work

- Modification of Surface Chemistry of other Metal Oxides- Degreasing, Silylation
- H_2-Air studies
- Lifetime studies
- DoE goal- 120^0 C and 50% RH at 2 atm

Acknowledgements

- Global Photonics Energy Corporation
- UTC Fuel Cells/DoE
- Fuel Cell Research Group at Princeton