Electrolytes for Fuel Cells

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“Air-Breather” Fuel Cell Stack Systems

DCH/Enable Prototype

Laptop Demo

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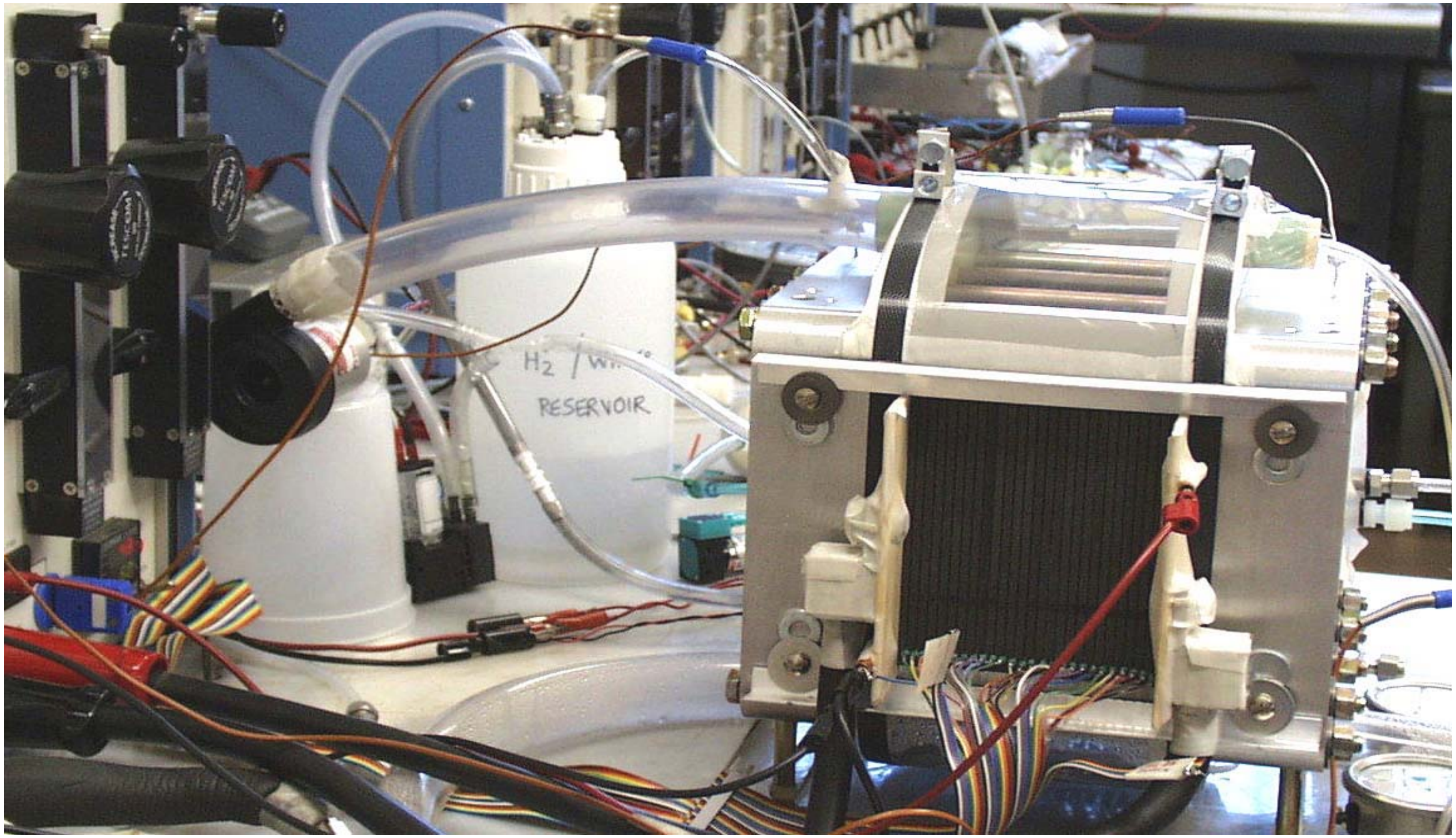
Small Battery - Fuel Cell:

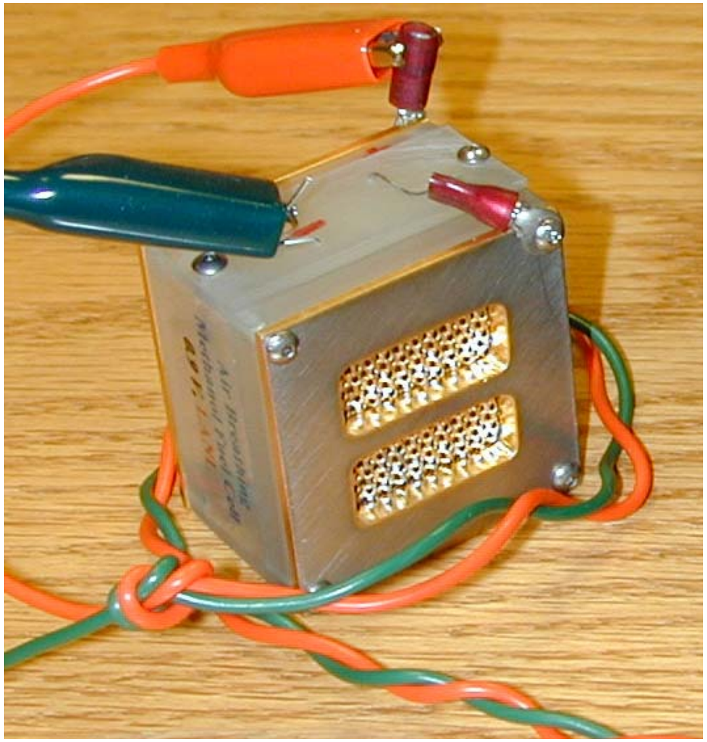
1 W Air-Breather

- Fuel Cells for Personal Electronics ("Micro" FCs)
  - Substantial interest in < 2 W systems.
  - Higher current densities, but higher A/V ratios.
  - Maximizing active area is key.
    - Different designs than the larger stacks.

Efficient Fuel Cell Systems: 1.5 kW Adiabatic Stack

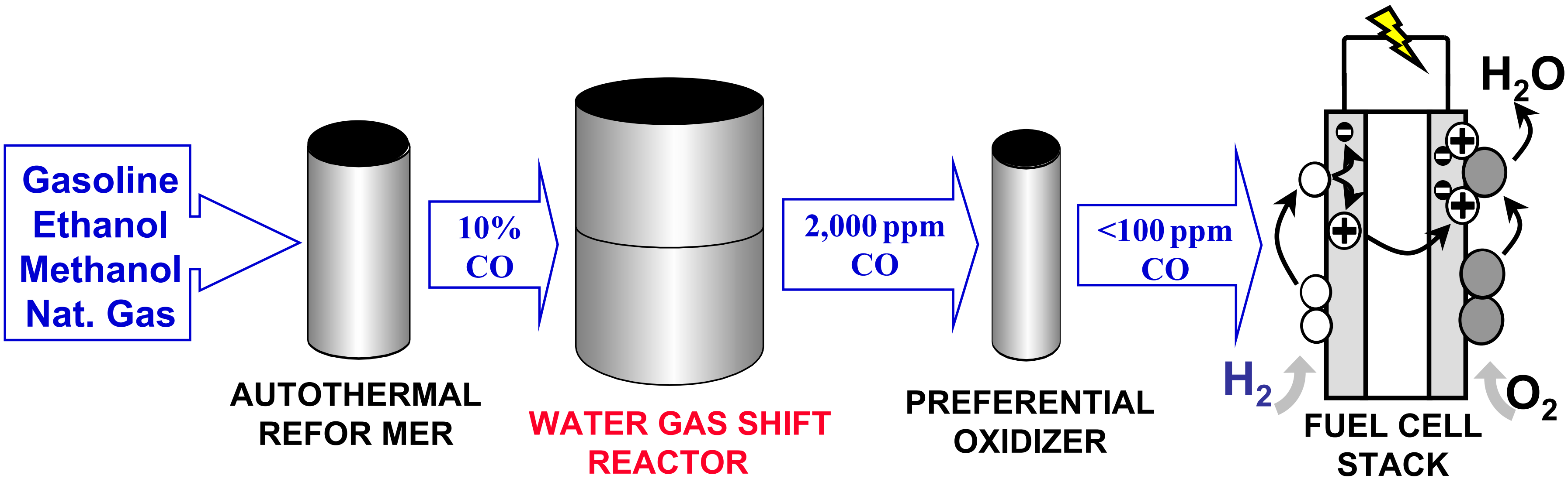


DMFC CRADA
Between LANL and MOTOROLA



Two Passive Air DMFCs
connected in Series,
> 150 mW power output

Gasoline to Electricity for Autos
The DOE/OAAT-PNGV Program



New Membranes are Required

- ‘High’ Temperature (150-200^{o}C) Membranes
  - Improved CO Tolerance
  - Improved Heat Rejection
- Lower Cost Membranes
- Membranes with High Longevity in Fuel Cell Environment
- Improved Water Management
  - Lower Electroosmotic Drag
  - Higher Conductivity with low water for air breathers
- Improved Membranes for Direct Methanol Fuel Cells
  - Lower Electroosmotic Drag
  - Lower Methanol Cross-over with Conductivity Maintained

Some Proposed Approaches to Improved Membranes

- 'Synthesize and be damned'--infinite funding for synthetic organic and polymer chemists
- More thermally stable or less costly membranes
  - BUT need to keep water in or replace its function (high T)
  - Typically sulfonated aromatics
- Water 'replacements'
  - Imidazole (Kreuer)
  - Inorganic phases
  - Phosphoric Acid and other acids
- Water 'traps'
  - Sol-gel phase
- No light at end of tunnel for methanol blocking or decreased drag either

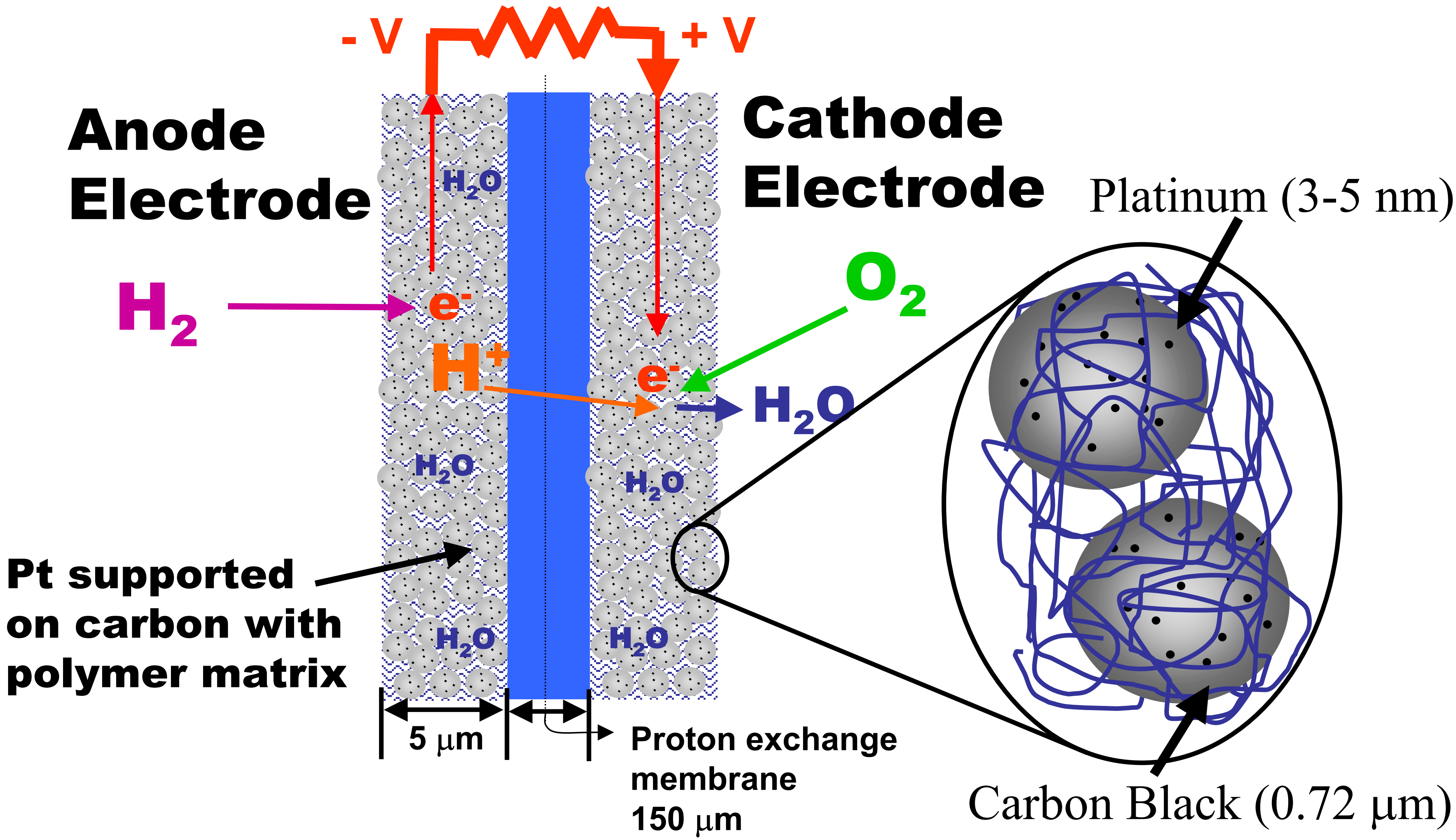
A Path to Progress: Synthesis Based on Understanding Physical Chemistry of Membranes

- **Understand the factors that affect transport of water and ions in proton exchange membranes via experimentation on model systems and carefully controlled polymer types/series**

- **Understand the molecular level details of proton dissociation and transport via modeling and experiments**
- **Develop an ion and water transport model for hydrated polymer electrolyte membranes that includes specific molecular scale information.**
  - **Bridge the macroscopic (hydrodynamic) and molecular scales (structure) through modeling-accomplished via statistical mechanics and classical molecular dynamics**

- **Propose and Synthesize new membranes with specific characteristics for particular processes or applications**

Fuel Cell CCM Structure



Necessary Membrane Properties Depend Strongly on Application

- High-temperature hydrogen fuel cell

  requires : mechanical integrity and conductivity at low relative humidity
  - lowers CO poisoning and increases kinetics
  - waste heat aspects within system

- Direct methanol fuel cell

  requires : low methanol permeation and electro-osmotic drag
  - fuel efficiency
  - water management - strongly dependent on device size

Critical Gaps in Understanding

- High-temperature membranes

  how do we replace water as a proton-transport medium?

- Direct methanol fuel cells

  through understanding of effect of morphology on EO, methanol cross-over

High temperature Polymeric Membranes: Rationale and Approach

- GRAND CHALLENGE: WATER-FREE PROTON CONDUCTORS OPERATING ABOVE 100^{o}C
- We cannot trade any performance!
- Different approaches for, 150^{o}C
- 120^{o}C: maybe we can use hydrated polymers
  - Focus on new sulfonic acids or other superacids with greater durability
  - Methods of maintaining hydration or providing conduction at lower water content
  - Nafion works with aggressive hydration (but limited lifetime)
- >150^{o}C: replace water with 'proton mobility facilitator'
  - Focus on different conduction modes, non-volatile molecules to effect proton transfer
  - Durability of any polymeric components also a must

Distance Scales for Mass Transport

- Local solvation phenomena
  - Dissociation and solvation
  - Tightness of packing affects transport
- Mesoscale
  - Transport along segments of pores
- Macroscale
  - Need to connect rigorously to smaller scale behavior

Qualitative Picture of Transport in Nafion

- hydronium ions move via vehicle mechanism

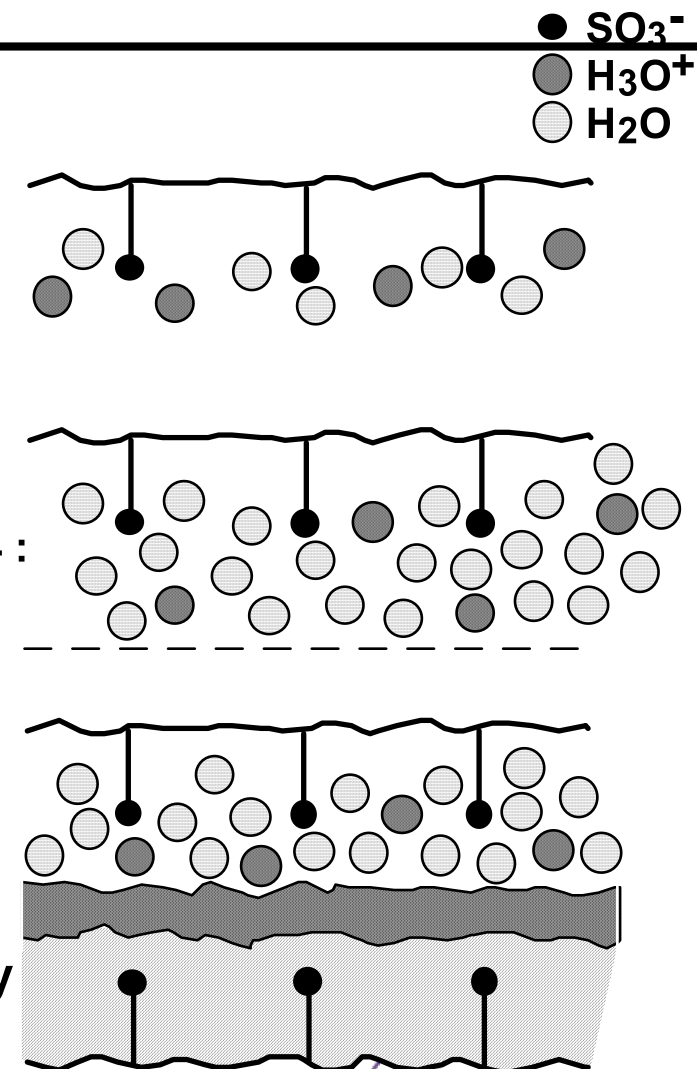
λ ~ 2-3 :

λ ~ 4-14 :

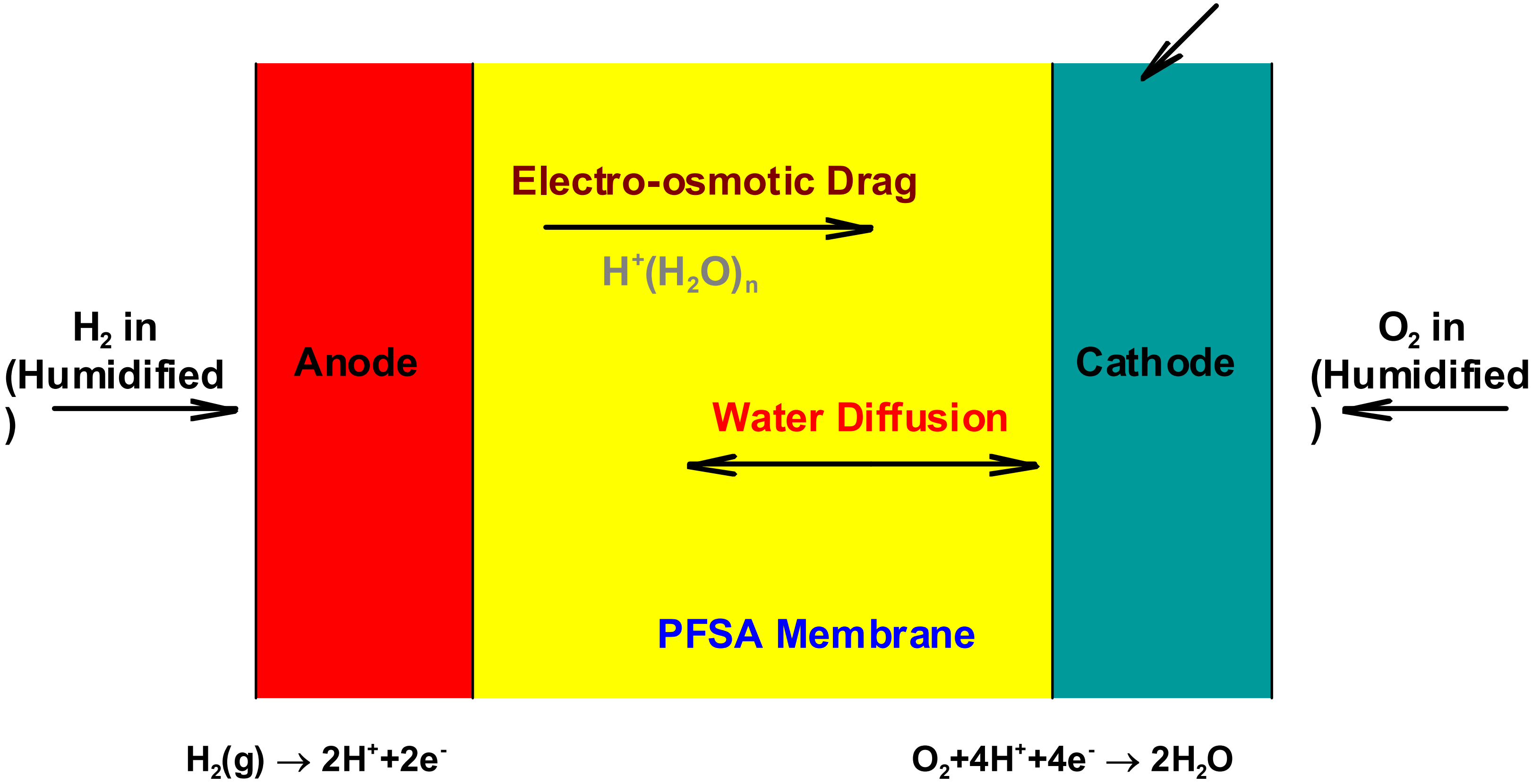
- water in interfacial region screens weakly bound water from ion-dipole interactions

λ >14 :

- water and protons move more freely



Modes of Water Transport in Membrane



Structure-Property Relationships

Develop structure-property relationships for directly polymerized sulfonic acid containing copolymers

Hypothesis: Microphase morphology plays a key role in membrane transport

- water
- protons
- methanol

Conclusions: Key Fundamental Research Needs

- Improved understanding of detailed local processes leading to rational synthesis of acid functionality, acceptor molecules
- Understand ionic domain morphology and structure effects on transport phenomena
- Understand degradation modes for polymers under electrochemical conditions
- New electrolyte chemistries
- Processing of polymers and MEAs

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