Overview of ORNL Hydrogen, Fuel Cell, and Infrastructure Program

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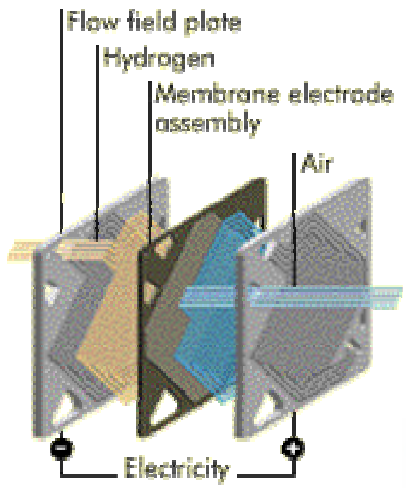
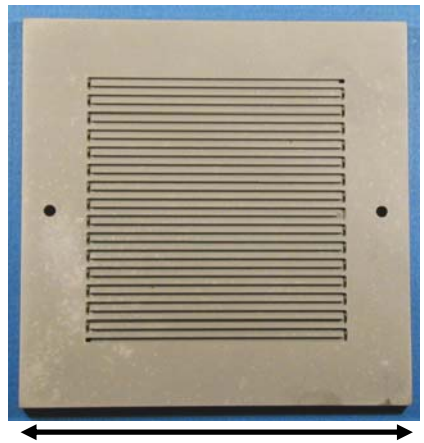
ORNL's Hydrogen Fuel Cell Program Focuses on Component Development

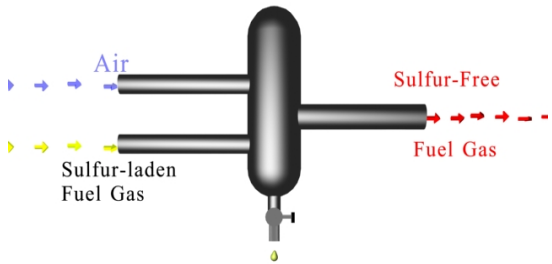
- Metallic and carbon bipolar plate development
- Carbon based heat exchangers
- Fiber optic temperature sensors
- Sulfur mitigation/catalysts
- MEA Characterization



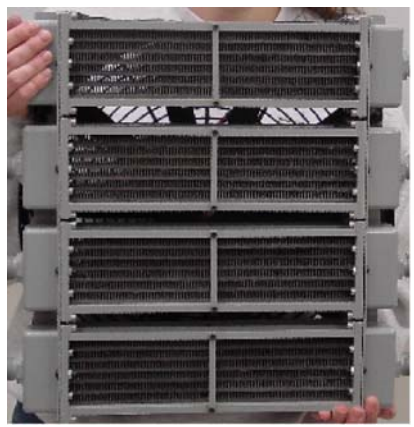


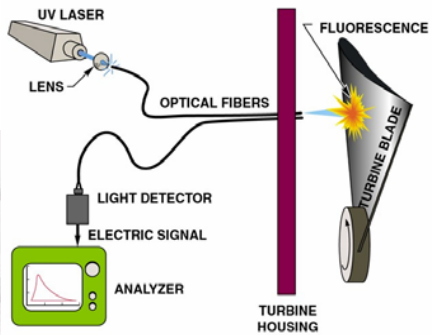
New Project

- Development of high-temperature (150°C) polymer membranes



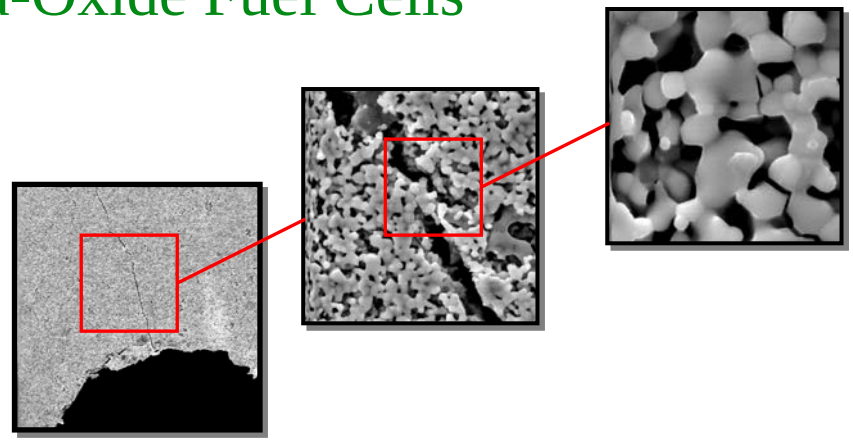
$H_2S + 1/2\ (O_2 + 3.76\ N_2) = 1/n\ S_n + H_2O + 1.88\ N_2$

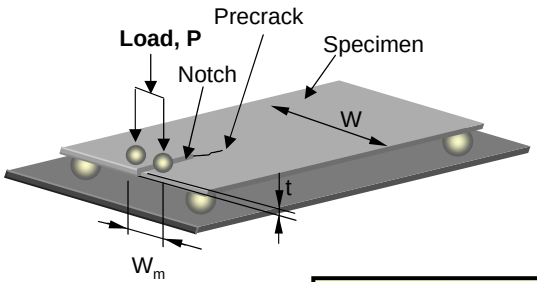




Durability and Reliability of Materials and Components for Solid-Oxide Fuel Cells

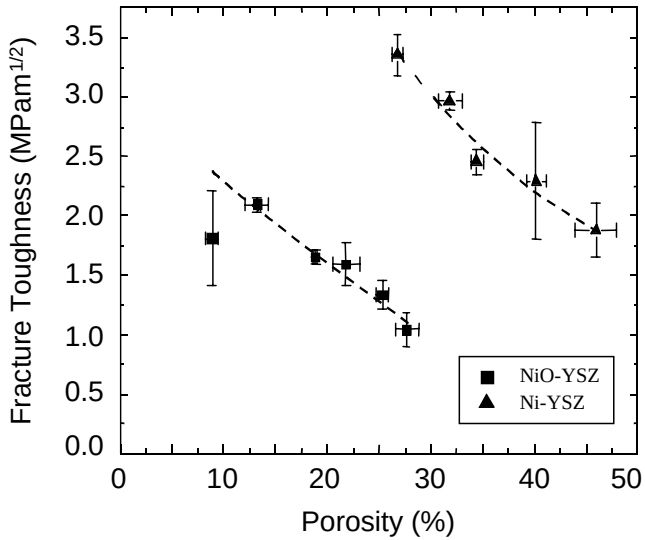
ORNL is participating in the SECA Core Technology Program to support the SECA Industrial Teams, in the identification of the mechanisms responsible for the failure of SOFC materials and components. ORNL is also formulating models to predict the reliability and durability of SOFC materials and components. The implementation of such models, which account for the stochastic nature of the mechanical properties of these materials, will lead to the development of more reliable and durable SOFCs.





double-torsion test

- The porosity of NiO-YSZ samples increases after reduction.
- The fracture toughness of NiO-YSZ and Ni-YSZ materials <u>decreases</u> with increasing porosity.
- Ni-YSZ materials are <u>tougher</u> than their NiO-YSZ precursors



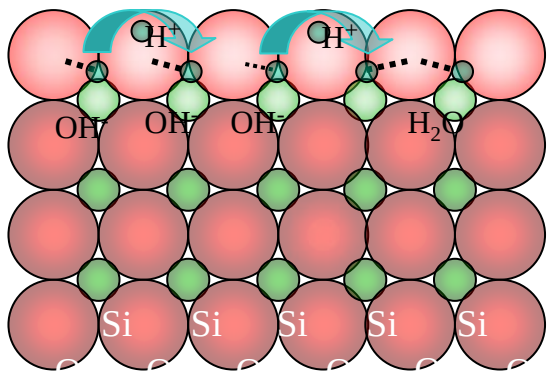
Fracture Toughness of Ni-based electrodes

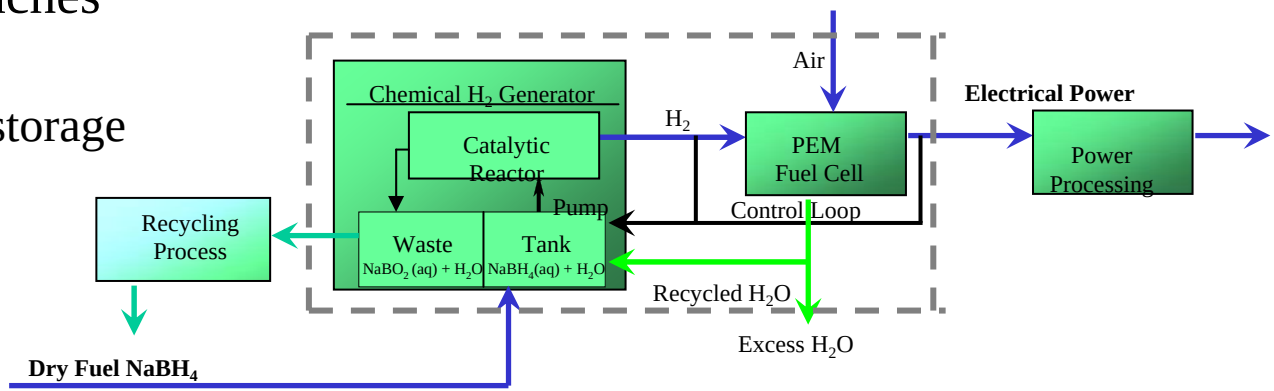
ORNL Will be Initiating a New Hydrogen Program in FY 2004

- ORNL selected as national lab lead for EERE Delivery Tech. Team
- EERE Projects
  - Production (Separation)
    - Porous Support Tube Fabrication for Hydrogen Separation
    - Pyrochlore/Perovskite Ion Transport Membranes
  - Delivery
    - Hydrogen Permeability and Integrity of Hydrogen Transfer Pipelines
- FE Projects
  - Development and Characterization of Novel Materials for H_2 Separation Seed Money
  - Development Of a New High-Temperature Proton–Electron Mixed Conductor For Hydrogen Separation
  - Alanates for High-Capacity Hydrogen Storage Hydrogen Storage in Advanced Nanoscale Materials
- EERE Proposals Pending
  - Storage
    - Solid-State Electrochemical Hydrogen Storage at Oxide/Semiconductor Interfaces
    - Alkali-Silicate and Related Glasses as Novel Hydrogen-Storage Materials
    - Chemical Hydride Center of Excellence
    - Novel Synthetic Approaches for Metal Hydrides
    - Synthesis and Processing of Single Walled Nanohorns
  - Separations
    - Sulfur Tolerant Pd-Cu Alloy Membranes for H_2 Separation

Hydrogen Storage is Critical Enabling Technology for Transportation

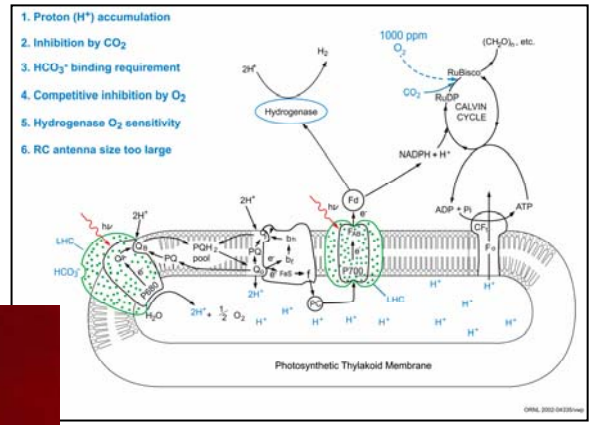
- R&D activities ongoing:
  - Carbon
    - Nanohorns
  - Interstitial hydrides
    - Alanates
    - Thin film materials
  - Chemical hydrides
    - B based materials
  - Novel Approaches
    - Glass
    - Solid state storage





The Hydrogen Program Builds on Core Strengths

- Algal production of H_2
- Enzymatic production of H_2 from glucose
- H_2 Separation
  - Microporous membranes
  - Ion transport membranes
- Sulfur removal and mitigation
  - Carbon fiber composite sieves



Pipeline delivery is being considered as one of the methods for transporting hydrogen from central refo

PERGAMON

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Developing an infrastructure for hydrogen vehicles: a Southern California case study

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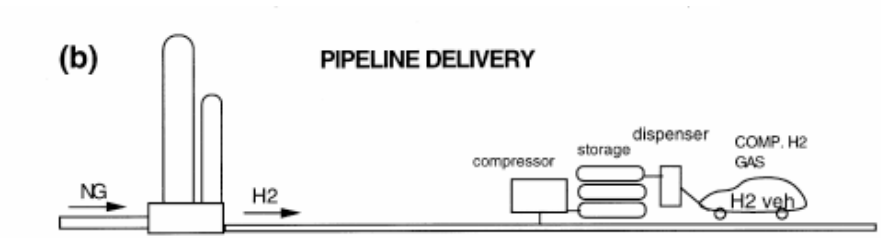


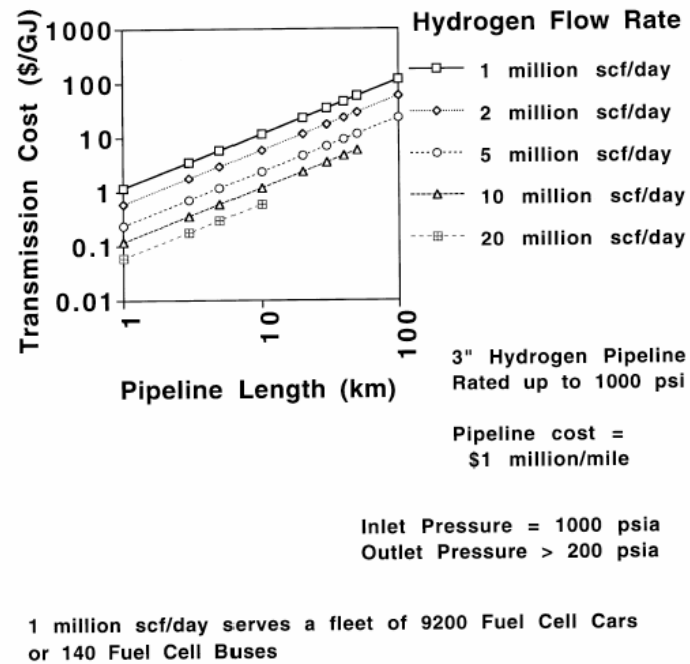


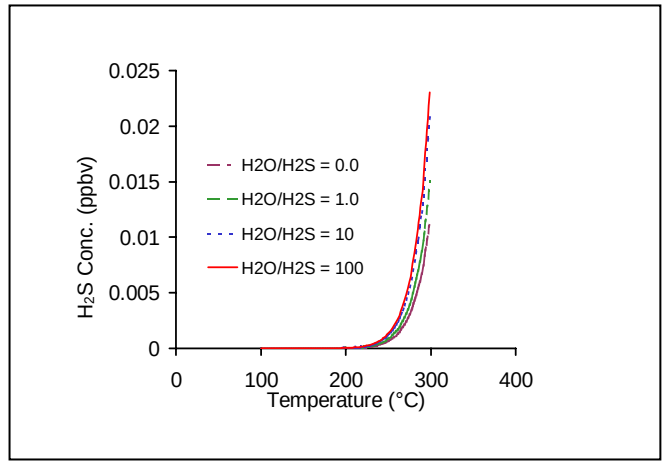
Fig. 9. Levelized cost of small-scale hydrogen pipeline transmission vs Pipeline length and flowrate.

- Currently, the price of pipeline transportation is related to flow rate of hydrogen.
- We can extend the current technology for natural gas pipeline using high strength steels for hydrogen piping.

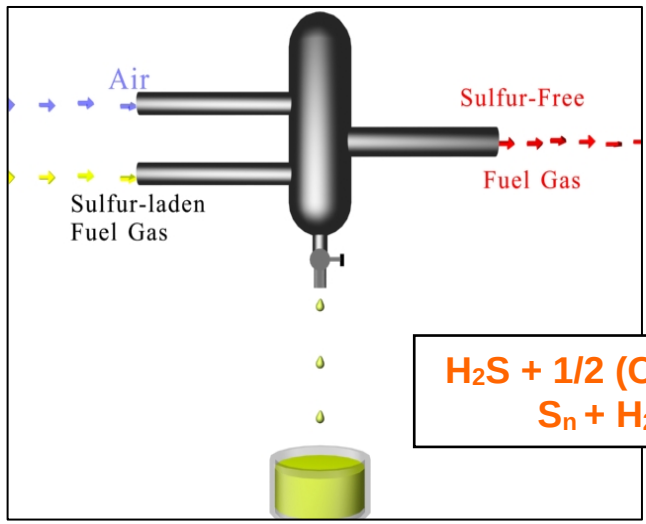
Selective Catalytic Oxidation of Hydrogen Sulfide

Objective: Assess sulfur selective catalytic oxidation technology as a direct sulfur removal technology at low temperatures.

- Removal Efficiency: selective catalytic oxidation has part per trillion (ppt) thermodynamic sulfur removal efficiencies.
- Water Sensitivity: Unlike most metal oxide based systems, selective catalytic oxidation is relatively insensitive to water content



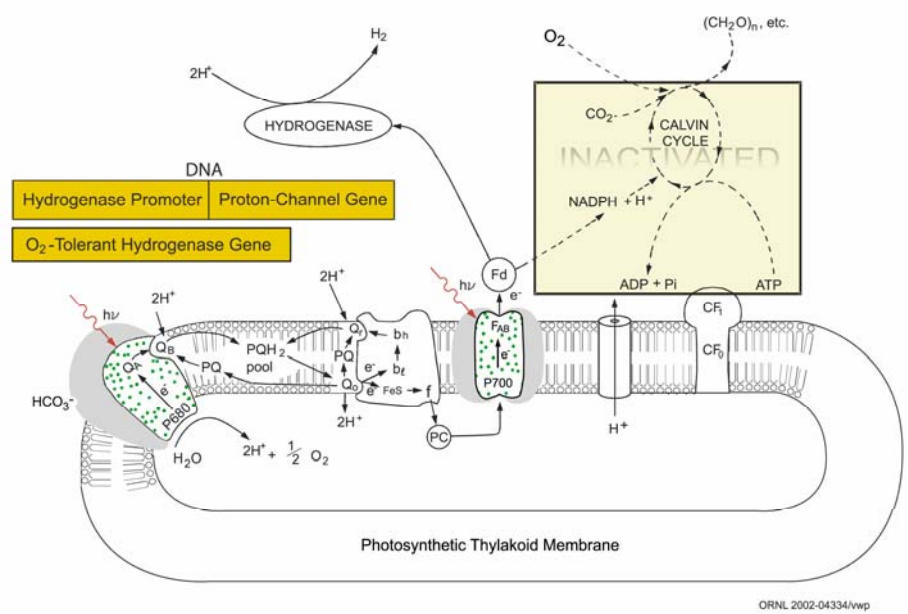
- **Carbon-based catalysts offer very exciting potential to reach low (ppt) sulfur levels**

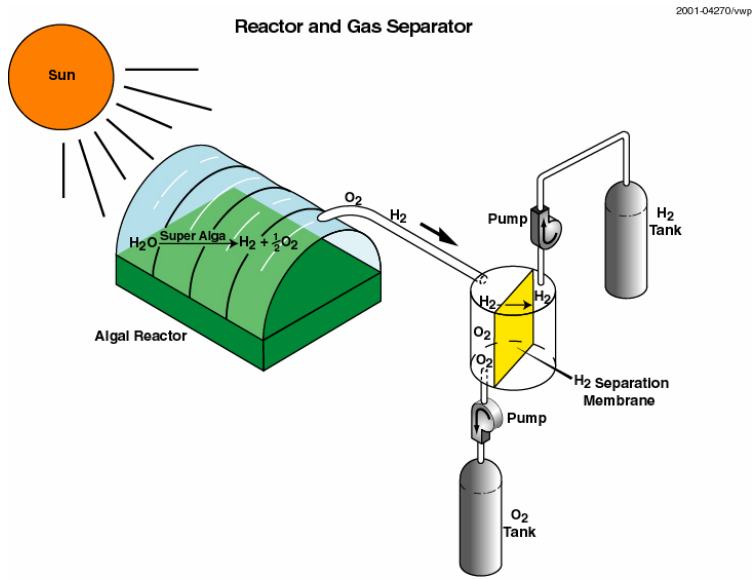


$$H_2S + 1/2\,(O_2 + 3.76\,N_2) = 1/n\,S_n + H_2O + 1.88\,N_2$$

Development of Efficient and Robust Algal H_2-Production Systems

In this project, a "designer alga" will be created for efficient and robust production of H_2 by genetic insertion of a hydrogenase-linked proton channel into the thylakoid membrane at ORNL. This designer alga will be integrated also with the benefits of an O_2-tolerant hydrogenase that will be created by NREL and a smaller chlorophyll antenna size that will be created by UC Berkeley. Therefore, this ORNL project is complementary with those of NREL and UC Berkeley, and will contribute jointly with the sister NREL and UC projects to achieving a common goal of effective photobiological H_2 production

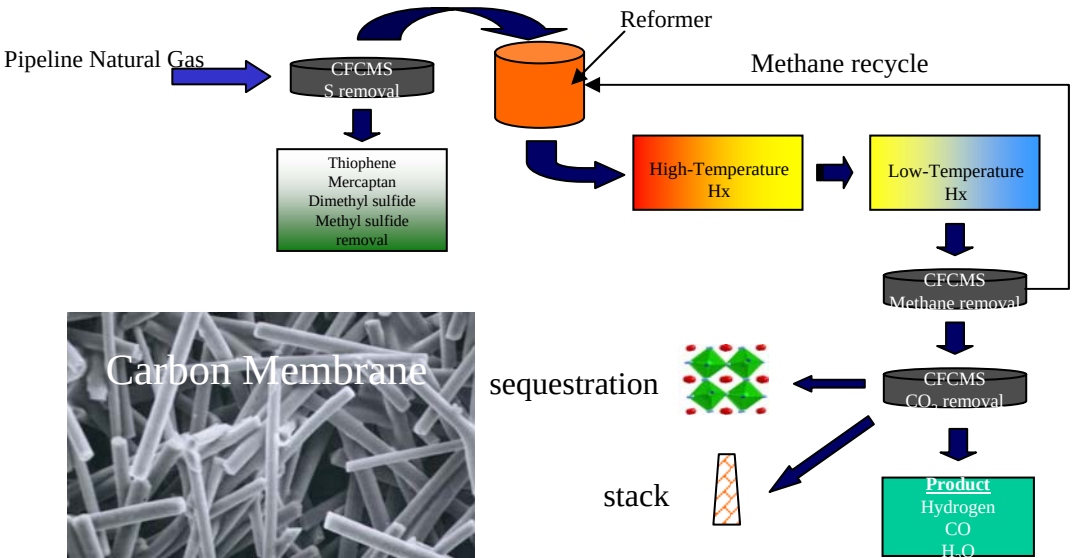




Hydrogen Purification Using a Carbon Fiber Composite Molecular Sieve

Challenge: Simplify reforming process in order to reduce mass, volume, and cost, while improving efficiency.

Objective: Assess carbon fiber adsorption membranes as a method to 1) remove oderants from natural gas and 2) remediate CO_2, H_2S, CO, and CH_4 in gas stream in order to eliminate the shift and partial oxidation stages.

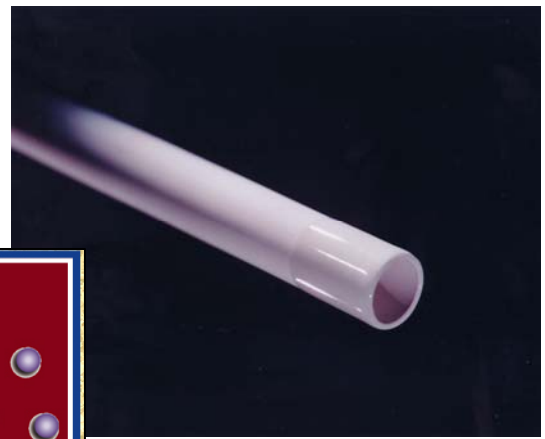
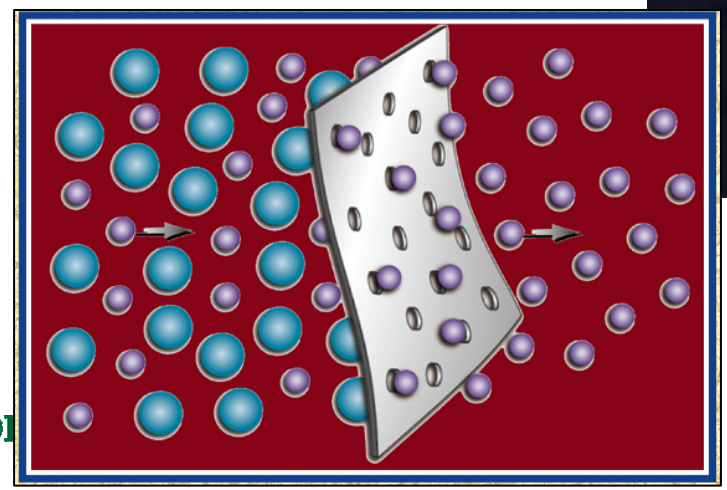


- **Milled Pitch-Derived Carbon Fibers**
- **Phenolic-Resin-Derived Carbon Bond**
- **Macroporosity created by forming process**
- **Microporosity created by activation using steam, oxygen, or carbon dioxide**
- **Selectivity achieved by controlling pore width, pore volume, and surface area**
- **CFCMS is electronically conductive and desorption is accomplished by passage of a low voltage electric current**

Development of a Porous Inorganic Membrane Hydrogen Separation Device

Objective/Challenge

- Develop a Compact and Efficient Hydrogen Separation Device for the Purification of Hydrogen
- Develop, Through Experimental and Theoretical Approaches, Gas Separation Membranes that Meet Rigorous Performance Criteria for Flux, Separation, and Hydrogen Purity



- Transport is via molecular diffusion
- Separation may occur by:
  - Molecular sieving
  - Knudsen diffusion
  - Surface flow