Molecular Transport/ Microporous Hydrogen Separation Systems

Participants

Acquaviva, Jim:	Pall Corporation
Armstrong, Tim:	Oak Ridge National Laboratory
Asaro, Marianne:	SRI International
Berchtold, Kathryn:	Los Alamos National Laboratory
Bischoff, Brian:	Oak Ridge National Laboratory
Cornelius, Chris:	Sandia National Laboratories
Huang, Jason:	ATP/NIST
Katikaneni, Sai:	FuelCell Energy
Krause, Curtis:	ChevronTexaco
Marinangeli, Richard:	UOP
McCarley, Ken:	ConocoPhillips
Perrin, Jerome:	Air Liquide
Ratcliff, Matt:	NREL
Schlasner, Steven:	ConocoPhillips
Shen, John:	US Department of Energy
Staiger, Chad:	Sandia National Laboratories
Taylor, Amy:	US Department of Energy
Welk, Margaret:	Sandia National Laboratories

Performance Goals

- Purity
  - 99% for single-stage microporous membrane system
  - Still achieves 99.99% for overall system
- Durability
  - 100,000 hours is difficult, and there is no way established to demonstrate that you can achieve it
  - May need more realistic or validatable target (performance criteria that will stand in place of the 100,000 hour target)
- Operating Temperature
  - Membrane requirements need to be part of overall system integration (replacing PSA does not have to be high-temperature)

Performance Goals

- Most important performance target is:

  $/scfh

  system design and membrane requirements come from that target

Technology Options

Option	DG or C	Pros	Cons
Zeolites or Zeolite Structures	All	Discrete pore sizes Choice of/cheap raw materials Proven performance of adsorption & catalysis	Hydrothermal stability Low separation factors Brittle High-T stability in steam Difficulty of mfg.
Carbon-Based Membranes	DG	Cheap Large capability in mfg of C Small footprint Module substrate is easily recyclable	Hydrothermal stability Strength Low flux?, selectivity? Easily oxidized Low thermoexpansion coeff.
Ceramics-Based Membranes	All	T stability Structure/pore options Stability (chemical) Potentially high flux Inexpensive starting mtls.	Hard to make thin film Brittle Pore size is not uniform Hydrothermal stability for Si Facilitation factors not there
Hybrid Systems	?	Potentially high facilitation factor Less brittle, more toughness Thermal expansion coefficients	Material incompatibility Lots of unknowns – could be high cost, long term

Top Priority Barriers -- Microporous Separation Systems

- Stability/Durability & Support Issues
  - Durability of thin membrane films
  - Hydrothermal and chemical stability
  - Thermal/chemical incompatability of membrane with substrate
- Fabrication & Defect Management
  - Management of defects in membranes
  - Scale-up to manufacturing
- Characterization & Performance Testing
  - Lack of standardized accelerated durability testing and standard composition to test membrane with

Top Priority Barriers -- Microporous Separation Systems

- System/Module Issues
  - Fouling
  - Module design
- Performance
  - Maximum purity achievable is lower than 99.99%
  - Optimization of selectivity and flux trade-off
- Fundamentals
  - Poor understanding of mass transport diffusion through membrane
  - Lack of transport models

Top Priority R&D Needs – Microporous Separation Systems

- Standardized Tests
  - Develop standardized, universal testing for membranes
  - Develop, standardize, and publicize membrane screening tools
- Module/System Design & Integration
  - Research on integrated membrane reactors (membranes as part of system/module)
  - Design system module development and optimization
- Fabrication Process
  - Develop generic reparation techniques to minimize or plug oversize pores in situ
  - Develop system hybrid-based systems to achieve 99.99% purity
  - Explore comparison of physical and chemical techniques for thin-film deposition
  - Manufacturing technoloyg development (low cost thin film)

Top Priority R&D Needs – Microporous Separation Systems

- Modeling
  - Fundamental research to address top barriers (e.g., diffusion transport modeling)
- Property and Performance Characterization
  - Systematic study of fouling contaminants from gas composition and effects on stability, flux, and purity
  - Understand thermochemical properties along the membrane length
  - Kinetic/thermophysical studies on stability in presence of water
- Materials and Structures Design
  - New materials development
  - Paradigm shift in membrane materials platform
  - Sequential programs: system/module design then materials design

Take-Away Messages

- Microporous membranes have a huge base of materials and manufacturing choices
  - Many material options and manufacturing techniques
- However, goals and objectives are very challenging – may require out-of-the-box thinking, paradigm shifts
- Need innovations in modules, structures, and materials
- Identified a need to develop standardized test methods across the board
- Look at system integration with membrane
- Formation of membrane and fundamental material science are key areas of investigation
- Integrated approach to membrane and support
- Specifications should be $/scfh