Use of Membranes in Non-Traditional Applications and Emerging Markets

DOE Membrane Technology Workshop
July 24, 2012

Zissis Dardas
Group Leader, Environmental Science
Physical Sciences Department
United Technologies Research Center

UTC Membrane Applications for Energy & Environment

Polymer membranes significantly enhance the efficiency & safety of multiple products

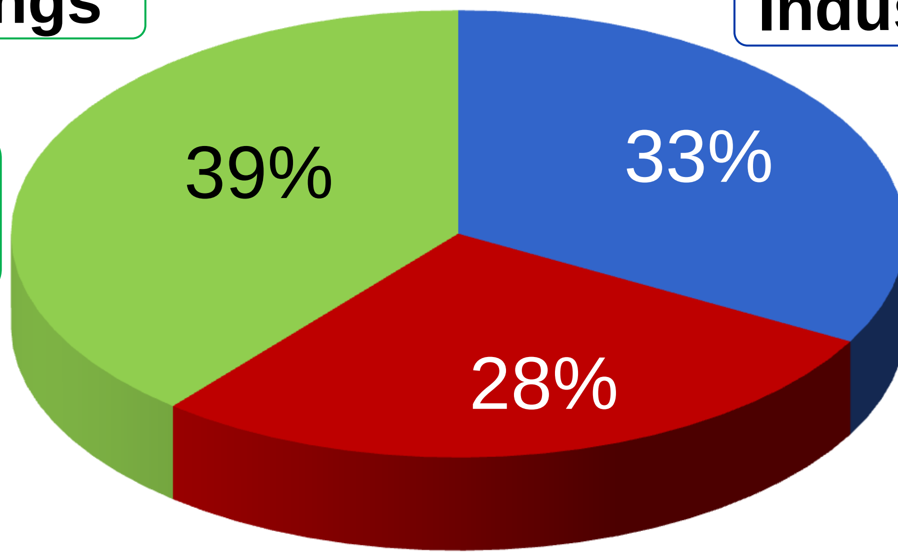
US Energy Consumption*

Buildings

Air dehumidification
Flow Batteries
Fuel Cells

Industrial

N_2 Removal from Natural Gas



Transportation

Aircraft
Fuel tank inerting
Fuel deoxygenation

Automotive
PEM Fuel Cells
Perishable Transport (O_2/N_2 separation)

Ships
LNG

United Technologies Research Center

* U.S. DOE Office of Energy Efficiency and Renewable Energy, 2005

Polymeric Membrane Challenges

Materials:

- Reliability/Durability
- Cost
- Performance
- Effective dialogue between membrane developers and system integrators/end users
- Incorporation of emerging smart materials & scale up
- Applications enabled by stimuli responsive nanomaterials

Module / System:

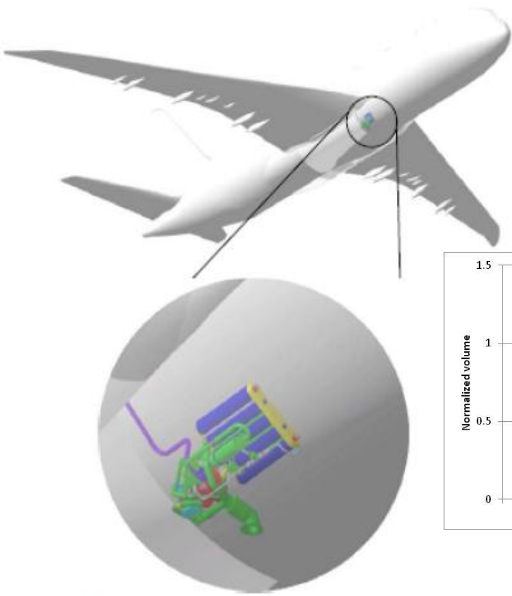
- Reliability
- Design & system integration for performance, footprint and cost

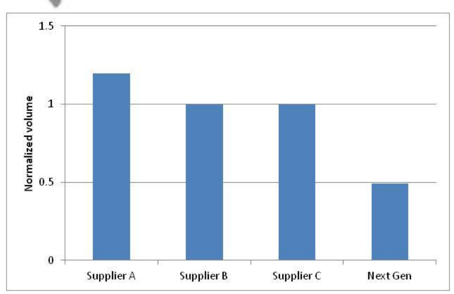
O_2/N_2 Separation Membranes

Applications safety-focused but membrane challenges application-specific

Aircraft Fuel Tank Inerting

Hamilton Sundstrand
A United Technologies Company



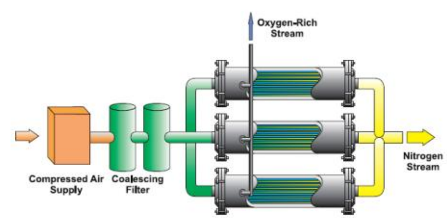


Challenges

- Volume & Weight
- Pressure Drop
- Durability / Reliability

LNG Tank Inerting

United Technologies
Climate | Controls | Security

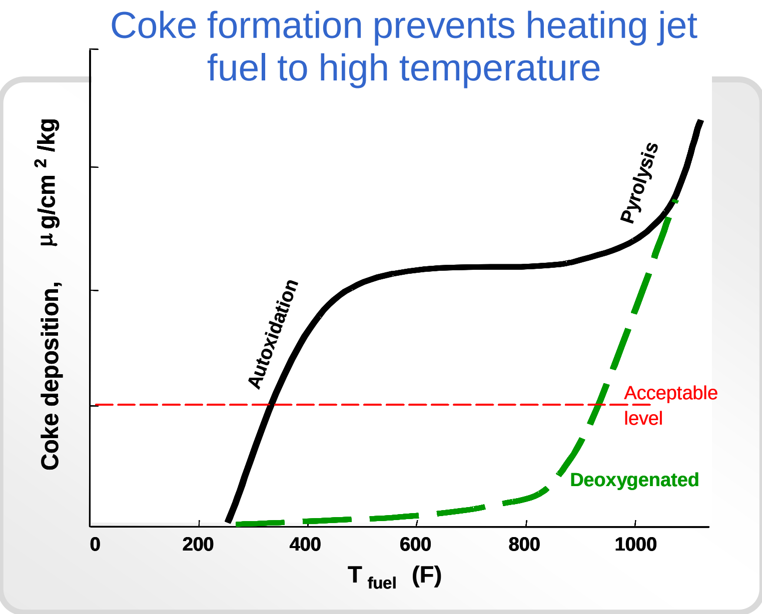


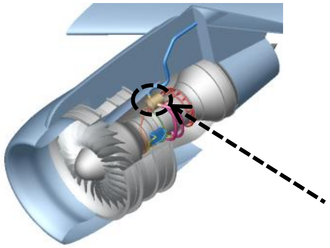
Challenges

- Durability / Reliability
- Selectivity

O_2/Fuel Separation for Aircraft Application

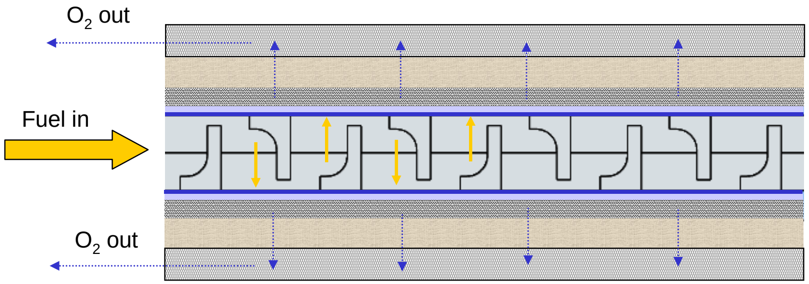
Challenges: No fuel leakage, volume & weight, durability, system integration



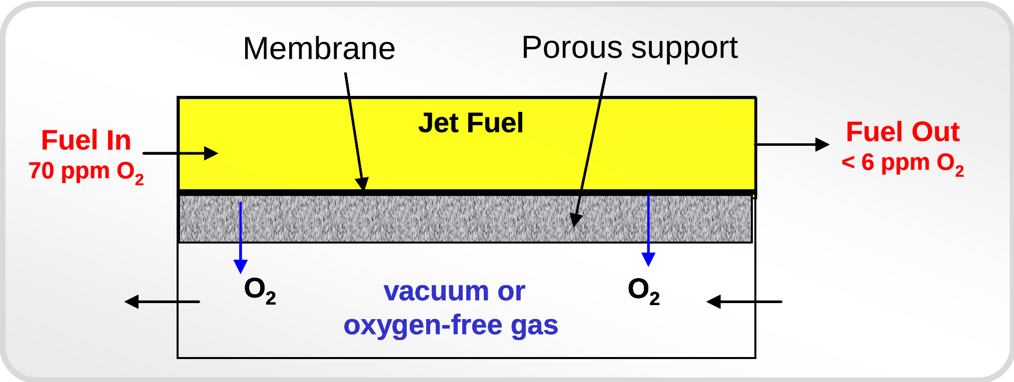


Advanced Membrane Developed

- 10X lower fuel leakage
- 5X higher oxygen permeance
- 2X lower membrane mfg. cost
- 40% less membrane needed



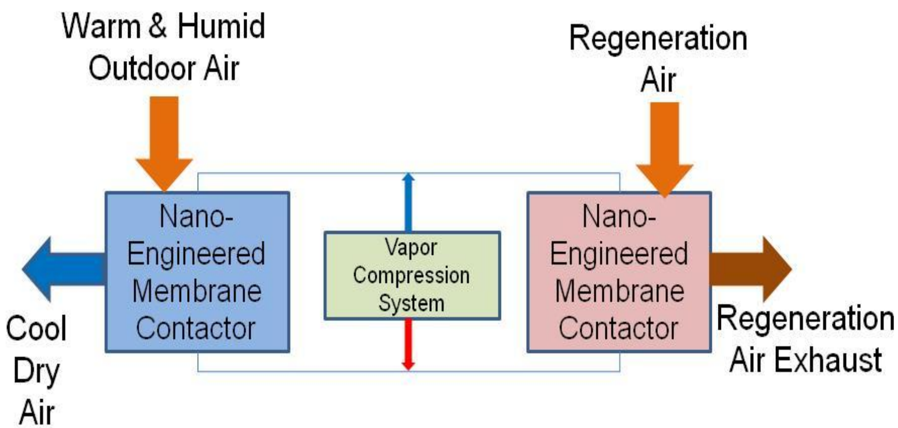
O_2 concentration gradient provides driving force



Dehumidification for Energy Efficient Buildings

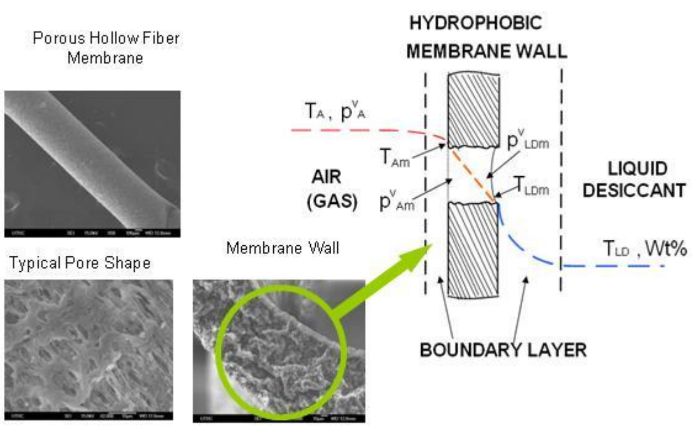
Challenges: Durability, cost, performance, pressure drop

Liquid Desiccant Membrane-Based Air Conditioning



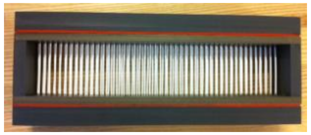
Benefits

- *30% system efficiency vs. traditional system hot and humid climates*
- Independent temperature and humidity control
- No liquid desiccant carry-over

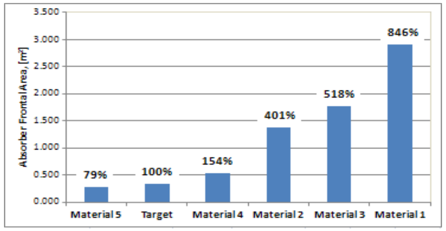


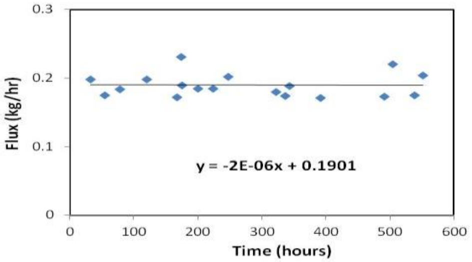
Humidity mass transport mechanisms in hollow fiber membrane heat and moisture exchangers

Membrane module Development



Membrane performance & durability

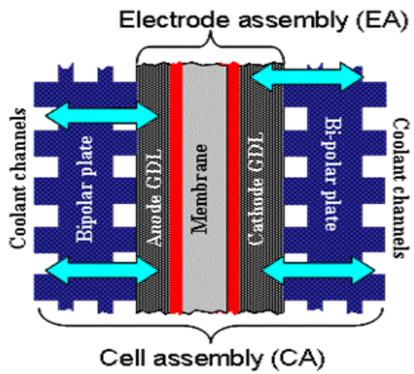




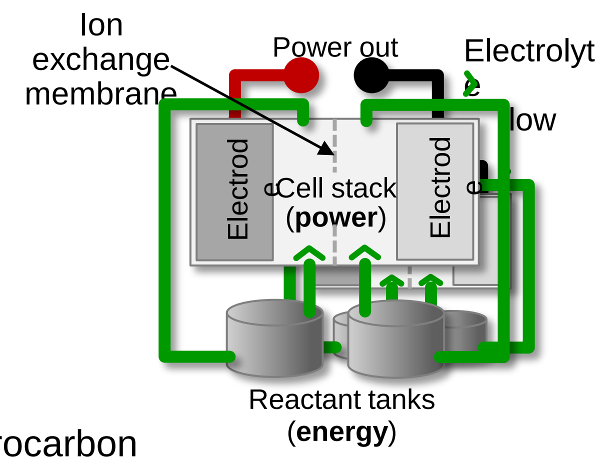
PEM Fuel Cells for Transportation & Flow Batteries

Challenges: Durability, performance, cost

PEM Fuel Cells for Transportation

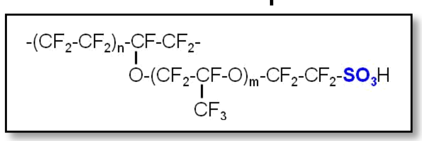


Flow Batteries for Energy Storage

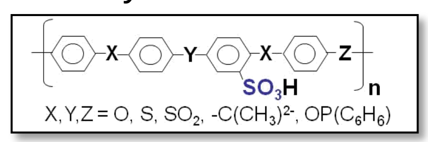


Commercial Materials

PerFluoroSulphonic



Hydrocarbon

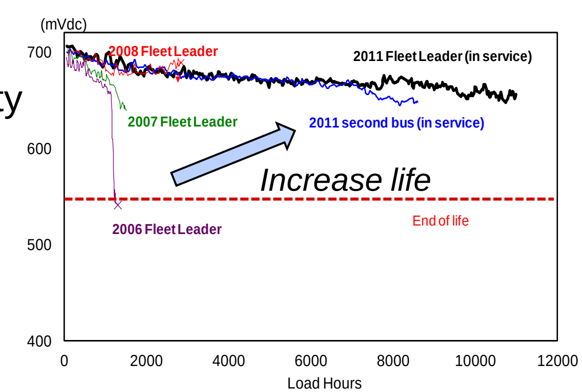


Function

- Transport protons
- Separate the reactants

Desired attributes

- High proton conductivity
- Low gas cross-over
- High durability (chemical / mechanical)



Desired attributes

- Low Ohmic resistance
- No ion cross-over
- Good proton conductivity
- High durability (chemical / mechanical)

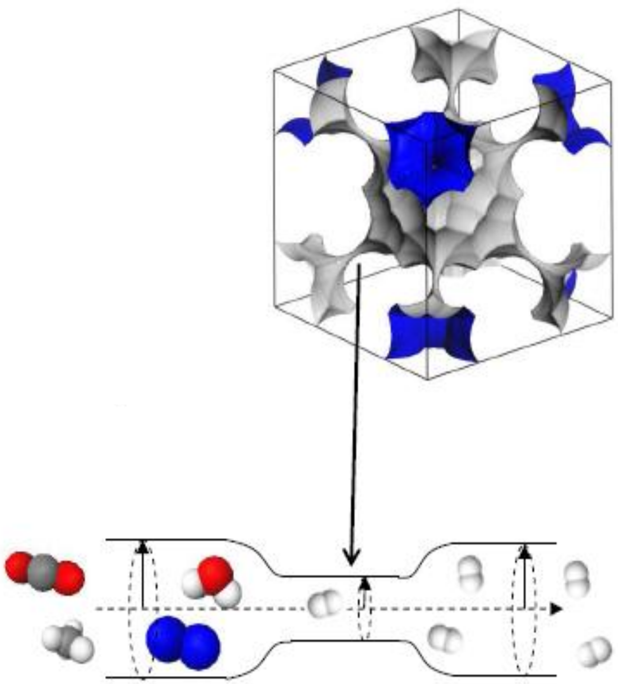
United Technologies Research Center

New Materials for N_2 / CH_4 Separations

Challenges: Durability & performance degradation in real environment; Scale-up and manufacturing cost for emerging materials

Optimize permeance & selectivity
by tailoring pore architecture & chemistry

Zeolitic imidazolate frameworks (ZIFs)



Dr. Anita Hill

United Te
Research Center

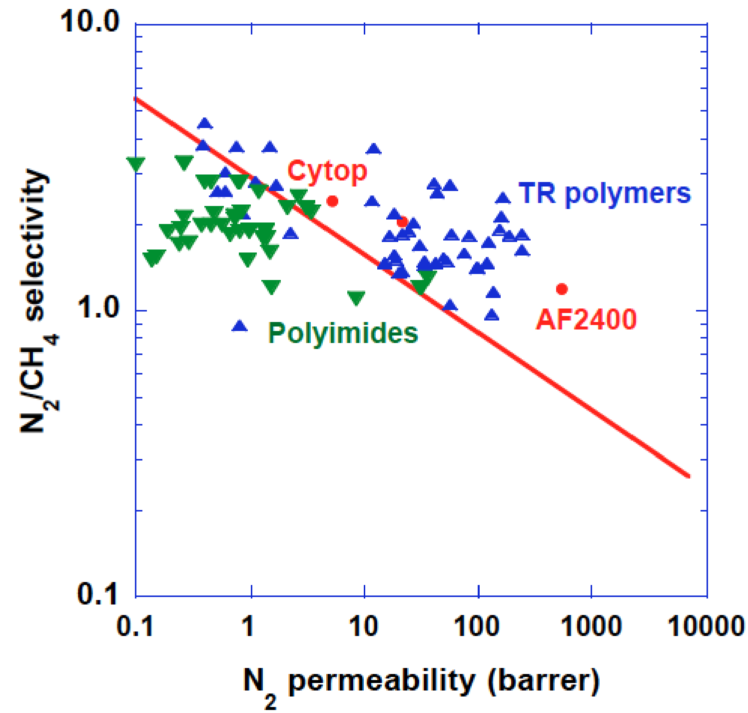


Figure 1: N_2/CH_4 tradeoff plot for TR polymers, fluoropolymers (Cytop, AF 2400) and stiff-chain, aromatic polyimides. The line in this graph is the upper bound.[2] The data in this figure represent pure gas measurements at near ambient temperature and at relatively low pressure (<10 bar). There are no data available yet for gas mixtures. The information we have, which is not extensive, suggests that permeability exhibits sensitivity to fugacity as one would expect from dual mode model considerations,[4,5] which should not be extremely strong for the case of N_2 and CH_4.

Graph provided by Prof. Benny Freeman, U. Texas, Austin