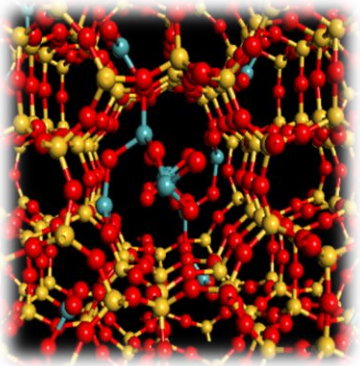
NETL-RUA
Regional University Alliance

U.S. DEPARTMENT OF ENERGY



Carbon Capture

David Luebke

Carbon Capture Technical Coordinator

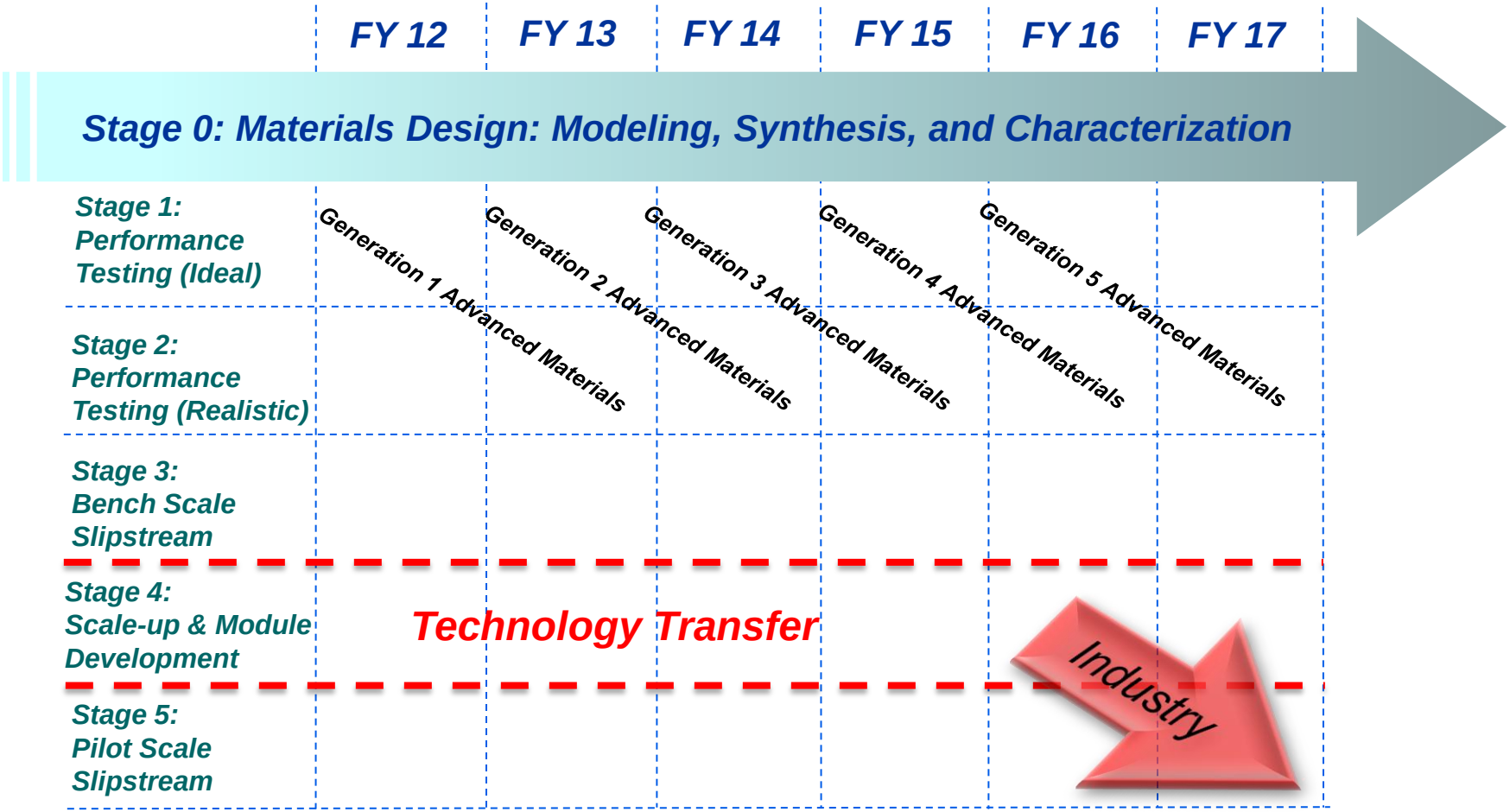
David.Luebke@netl.doe.gov

NETL Carnegie Mellon PENNSTATE University of Pittsburgh VirginiaTech WestVirginiaUniversity URS

Integrated Technology Development

Integrated Technology Development

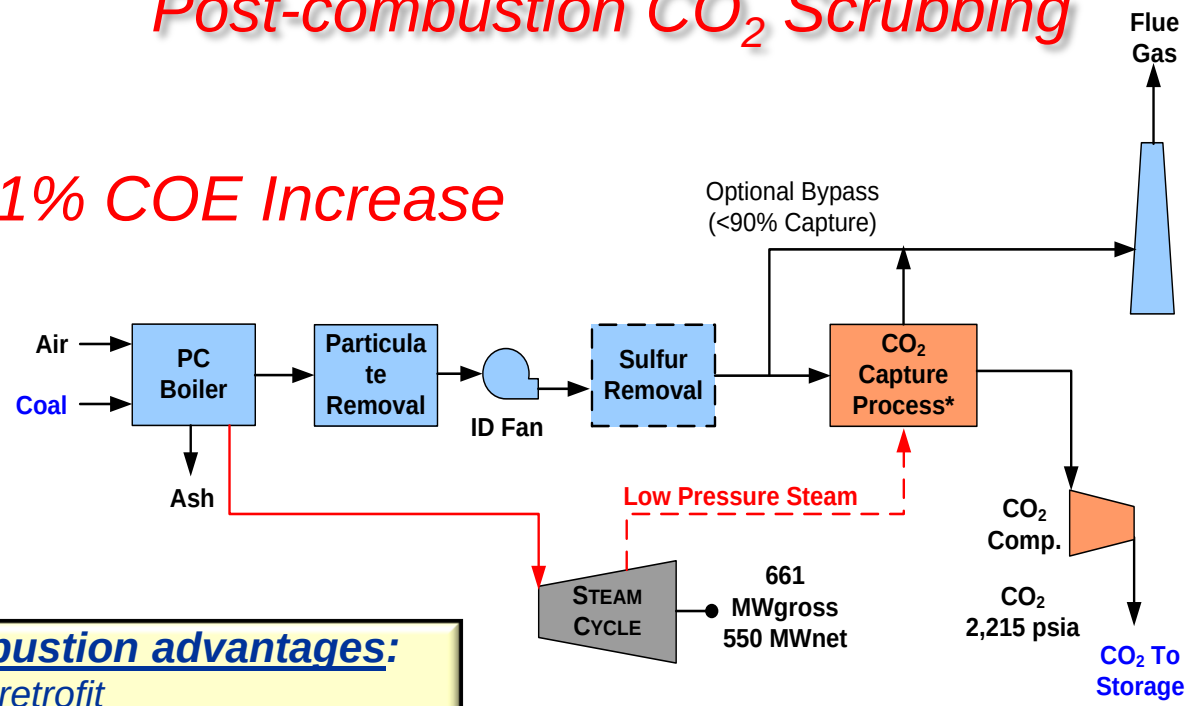
Technology Pathway



Pulverized Coal Power Plant System

Post-combustion CO_2 Scrubbing

~81% COE Increase



Post-combustion advantages:

- *Back-end retrofit*
- *Slip-stream (0 to 90% capture)*

Amine scrubbing Advantages:

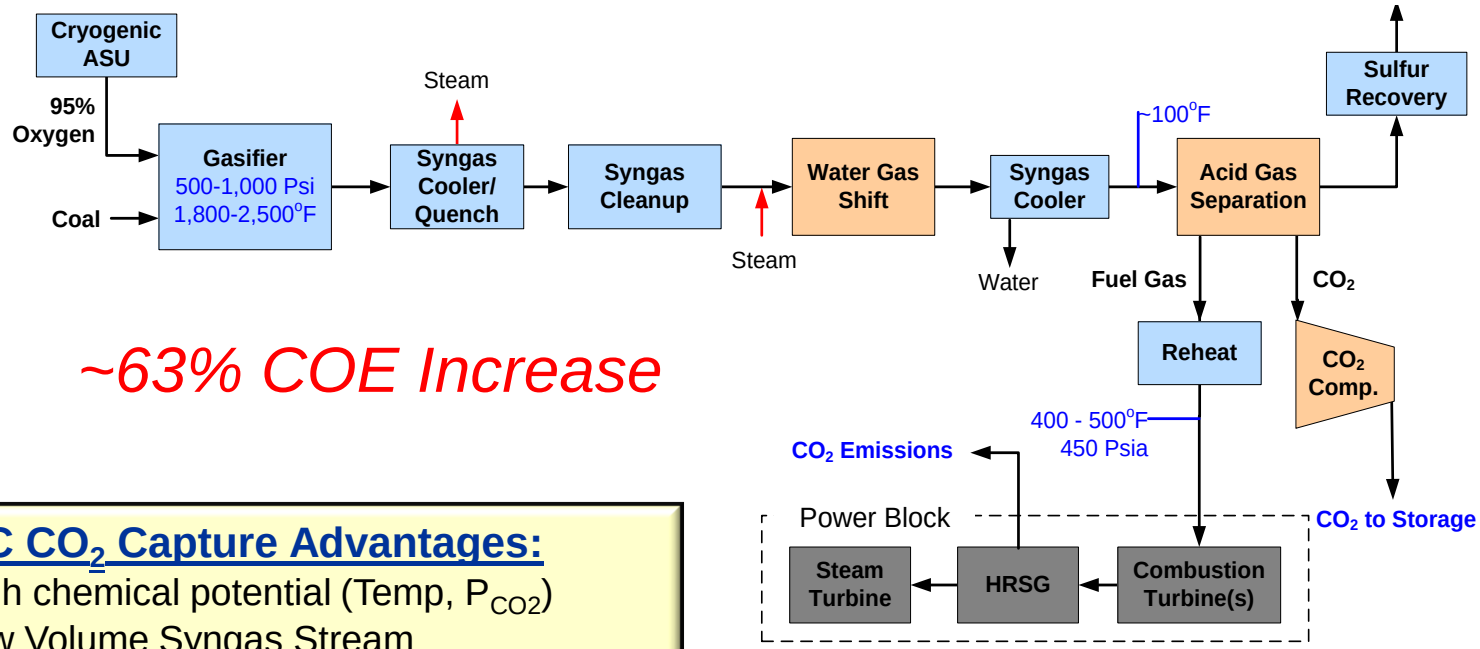
- Proven Technology (Petroleum refining, NG purification)
- Chemical solvent → *High* loadings at *low* CO_2 partial pressure
- Relatively cheap chemical ($2-3/lb)

Key Challenges:

- *Dilute flue gas (12-15 volume %)*
- 2-3 MM acfm for a 500-600 MWe plant
- *~50% currently scrubbed for SOx/NOx*
- *Increased cooling requirements*

IGCC Power Plant System

Pre-combustion CO_2 Scrubbing



~63% COE Increase

IGCC CO_2 Capture Advantages:

- High chemical potential (Temp, P_{CO2})
- Low Volume Syngas Stream

Selexol™ CO_2 Capture Advantages:

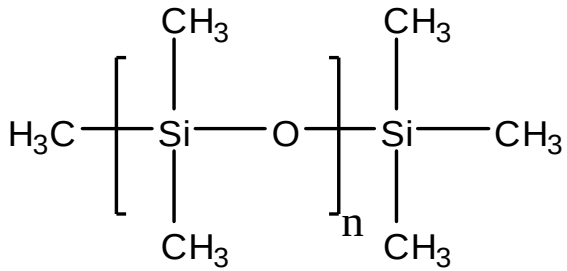
- *30+ years of commercial operation (55 worldwide plants)*
- Physical Liquid Sorbent
- Highly selective for H_2S and CO_2
- CO_2 is produced at "some" pressure

Key Challenges:

- *Complex, integrated power process*
- *Additional process (WGS) to get high capture rates*
- *Current technology (Selexol) requires cooling and reheating*

Technologies

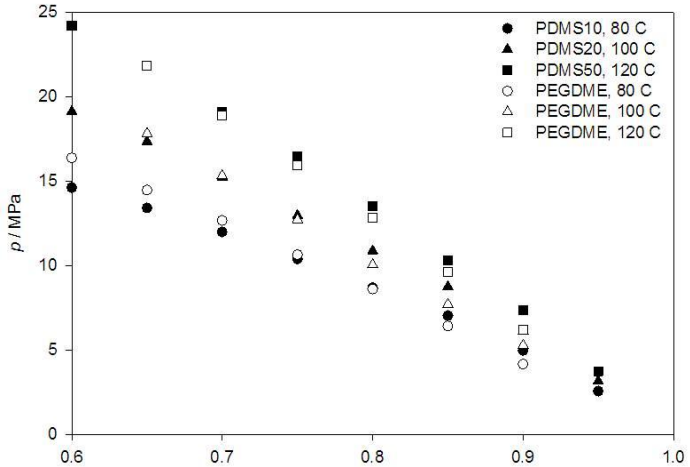
PDMS



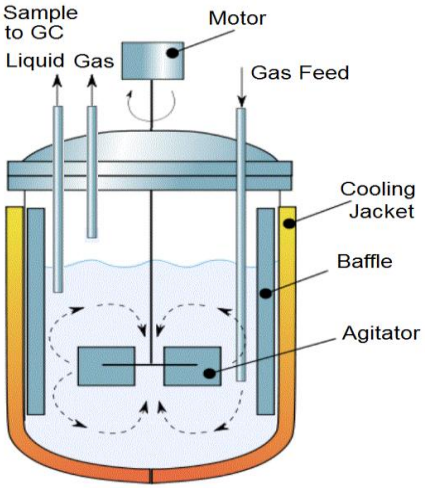
Chemical Modification

Hunaid Nulwala, CMU
Robert Thompson, URS

Phase Behavior



Bob Enick, Pitt



CSTR
Scale-up

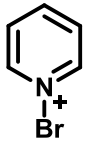
Fan Shi, URS
Dave Luebke, DOE

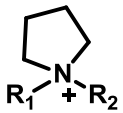
Why the names?

…to show that the RUA really works.

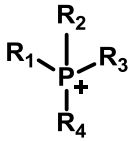
…so you know who you should be talking to.

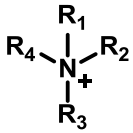
Ionic Liquids

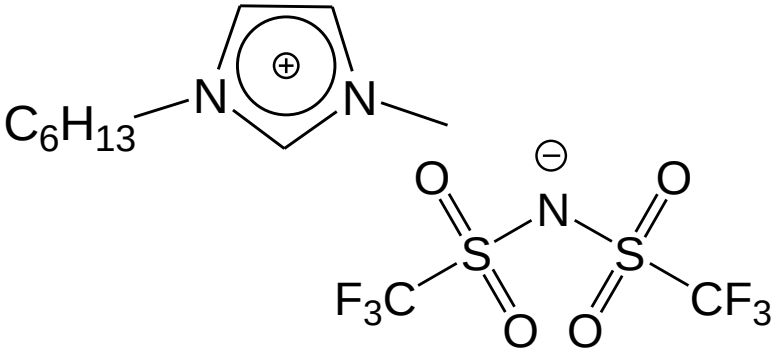

Pyridinium

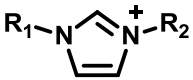

Pyrrolidinium

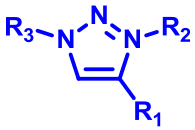
Estimated 10^{14} possible ionic liquids


Phosphonium

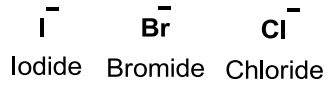

Ammonium




Imidazolium

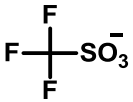

Triazolium

~1000 ionic liquids commercially available

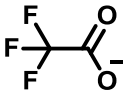


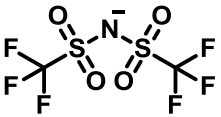
Tetrafluoroborate

Hexafluorophosphate


Trifluoromethylsulfonate

Acetate


Triflouroacetate


TF_2N

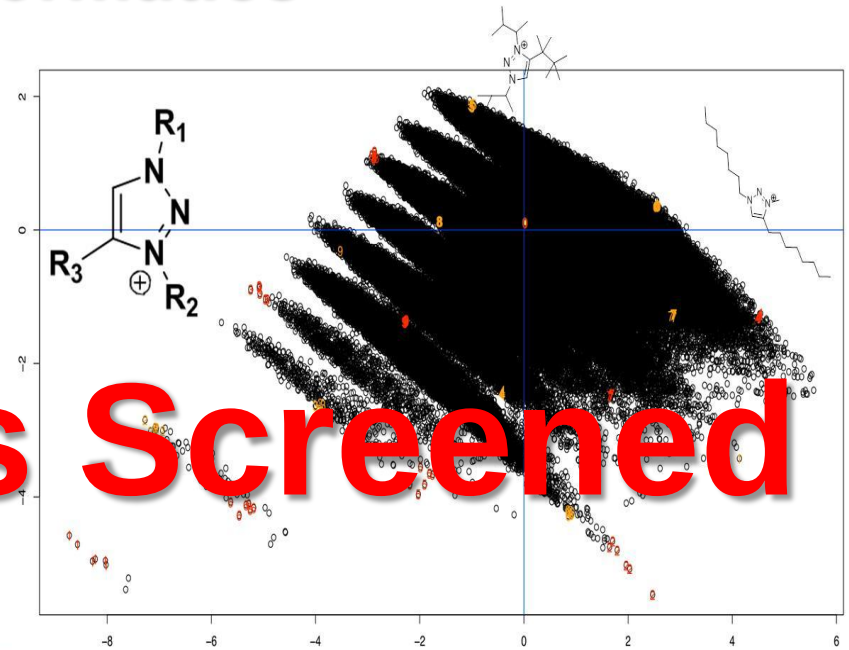
- Highly Tailorable Liquid Salts
  - Negligible Vapor Pressure
  - Good Thermal Stability
  - High CO_2 solubility relative to CH_4, N_2, and H_2

J. Chem Inf. Model. **2007** 47, 1111-1122.

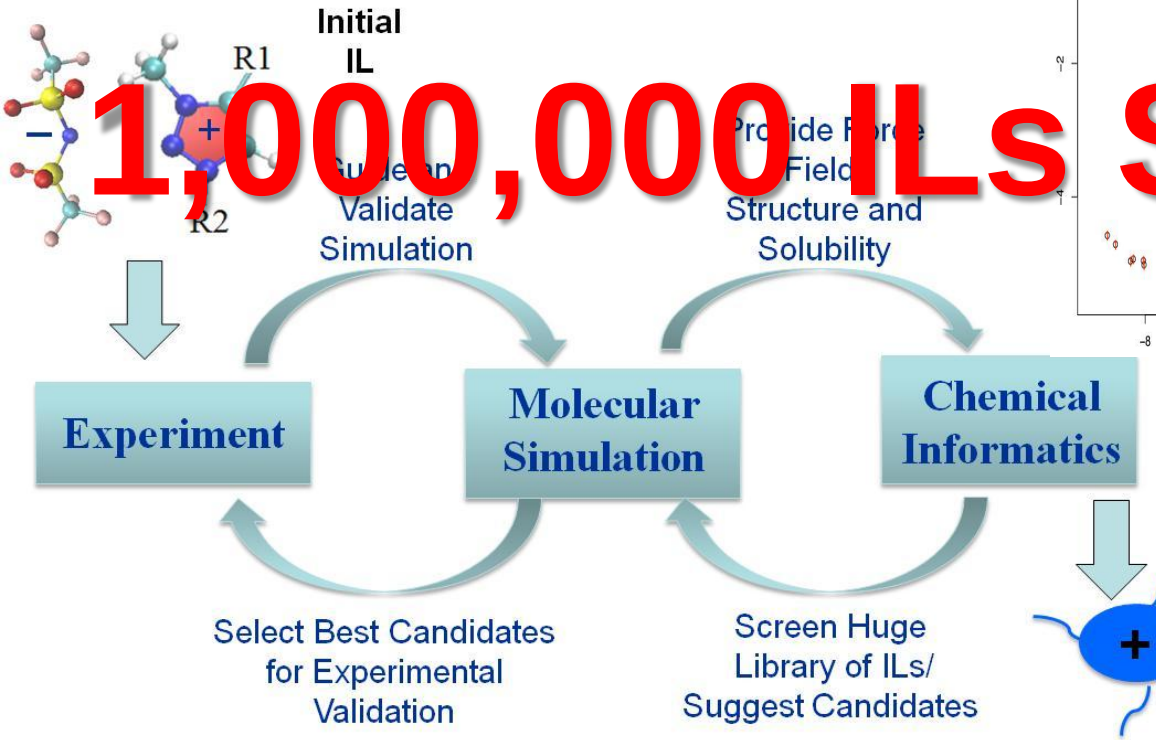
Ionic Liquids

Chemical Informatics

Hunaid Nulwala, CMU
Robert Thompson, URS
Michael Lartey, ORISE

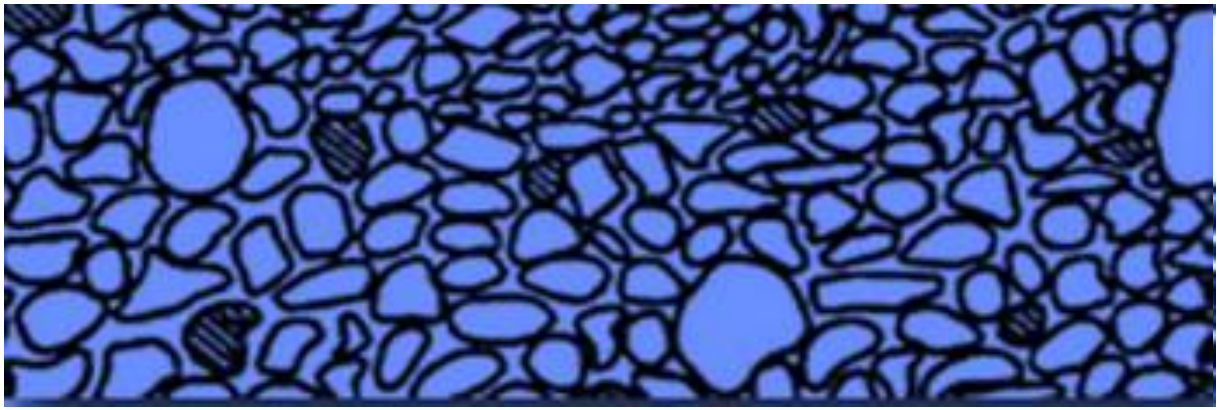


1,000,000 ILs Screened



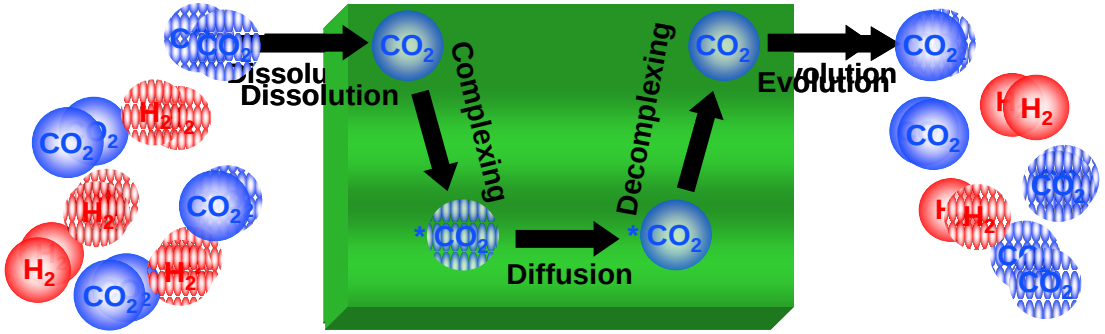
Berend Smit, Berkeley
Maciej Haranczyk, Berkeley
Jeff Kortright, LBNL

Supported Ionic Liquid Membranes



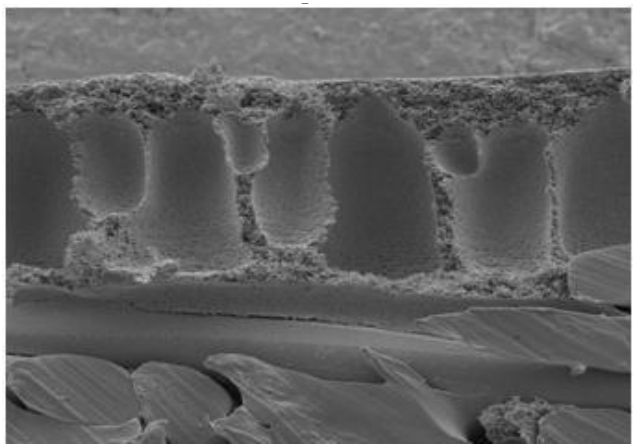
+ IL

IL Development



Michael Lartey, ORISE

Polymer Support

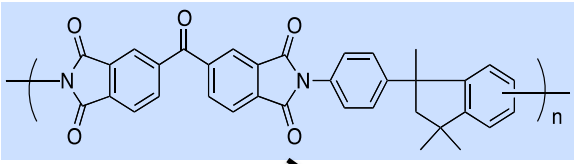


Victor Kusuma, ORISE

NETL-RUA

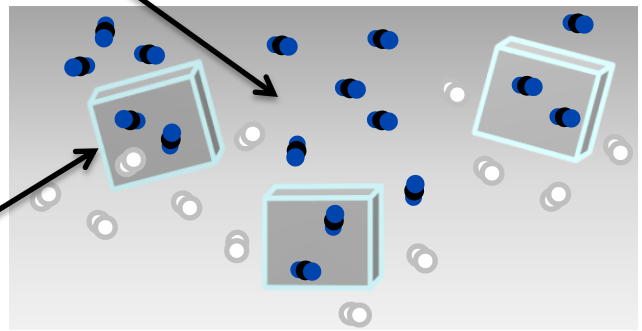
Mixed Matrix Membranes

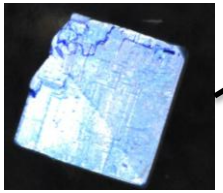
MOF-based Composites



Polymer Membrane

Brian Adzima, ORISE
Hunaid Nulwala, CMU





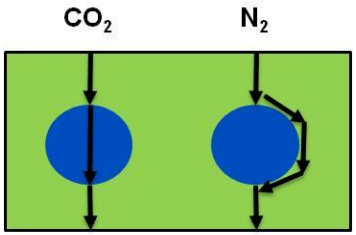
MOF

MMM

David Hopkinson, DOE
Surendar Venna, ORISE

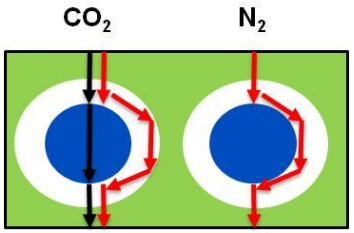
Brian Kail, URS

Nathaniel Rosi, Pitt



"True" MMM Transport

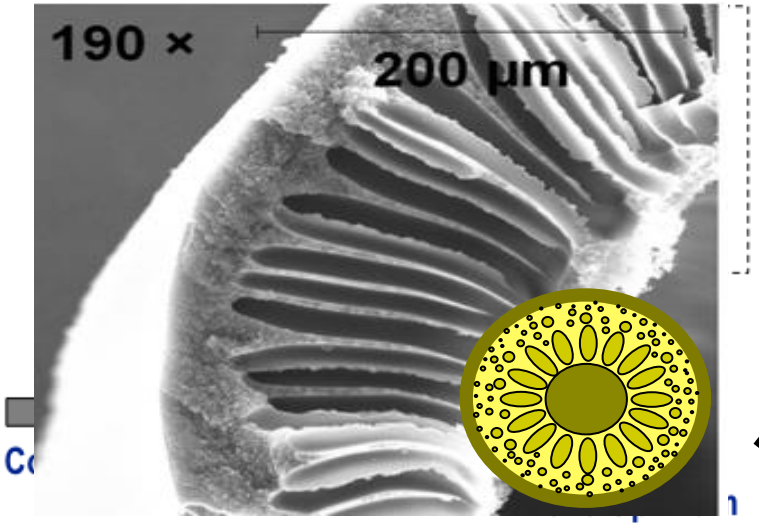
Particle Bypass



Membrane Development

Fiber Modules and High Throughput Testing

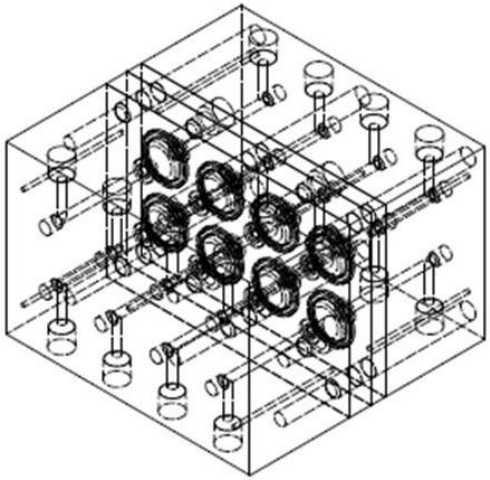
Fiber Fabrication



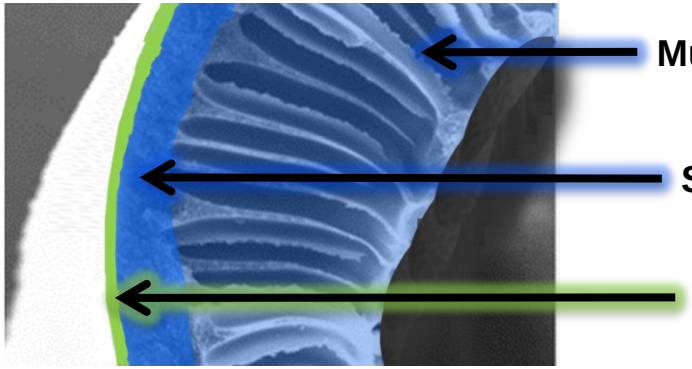
Shan Wickramanayake, URS

Dave Hopkinson, DOE

Erik Albenze, URS



SILM Fiber Development



Much Too Thick (~200 micron)

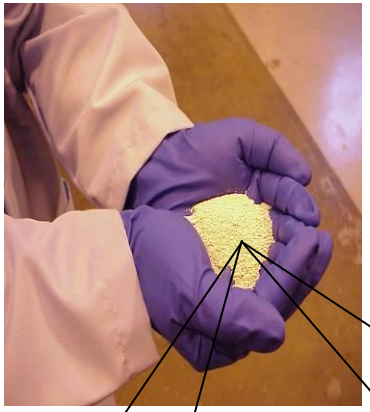
Still Too Thick (~20 micron)

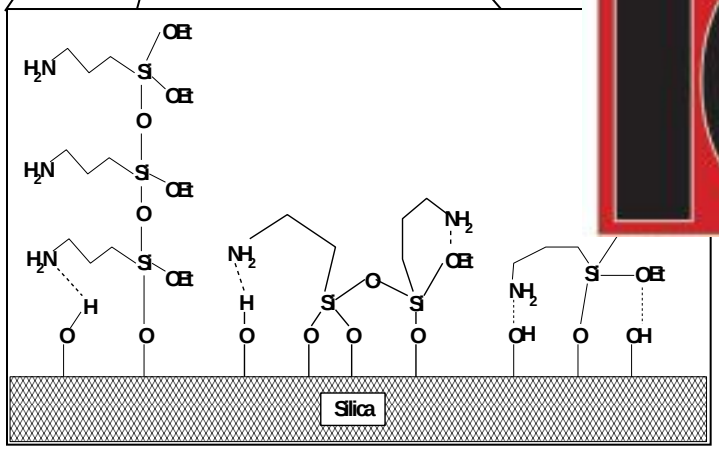
Practical Membrane Thickness (~1 micron)

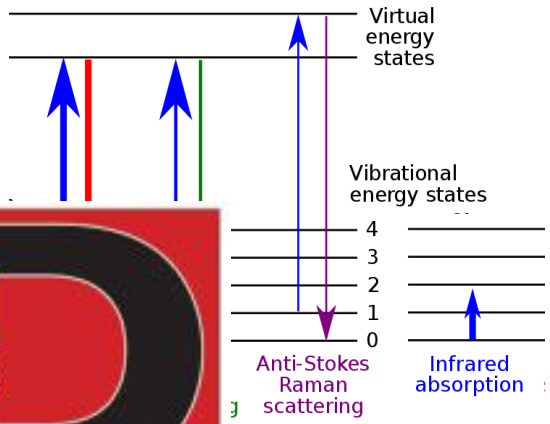
Lie Hong, URS

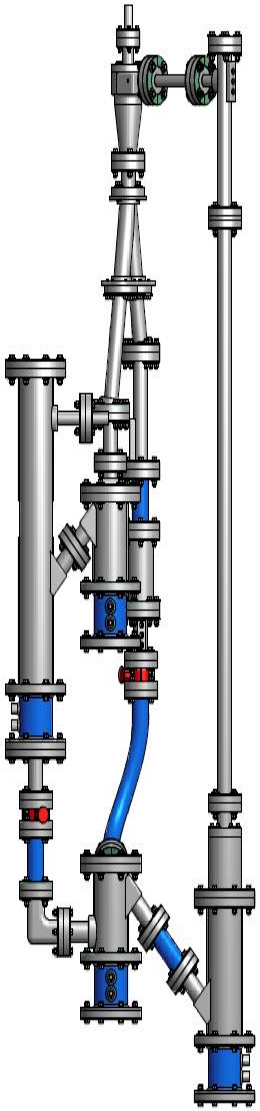
Dave Luebke, DOE

Supported Amine Sorbents









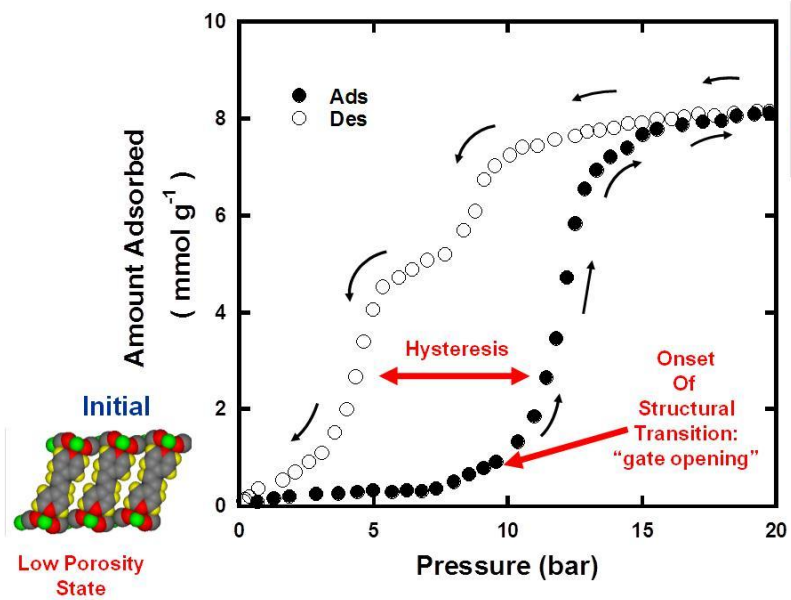
McMahan Gray, DOE
Bingyun Li, WVU

ıin, CMU
lman, DOE
rishnan, Pitt

Scale-up

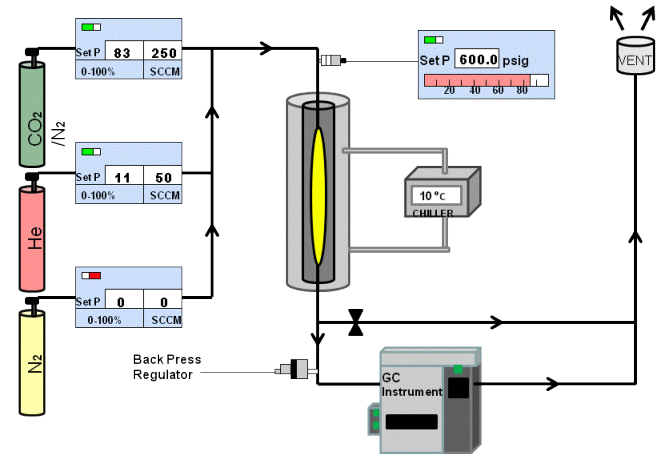
Larry Shadle, DOE
Scott Chen, CCS

Structurally Dynamic MOFs

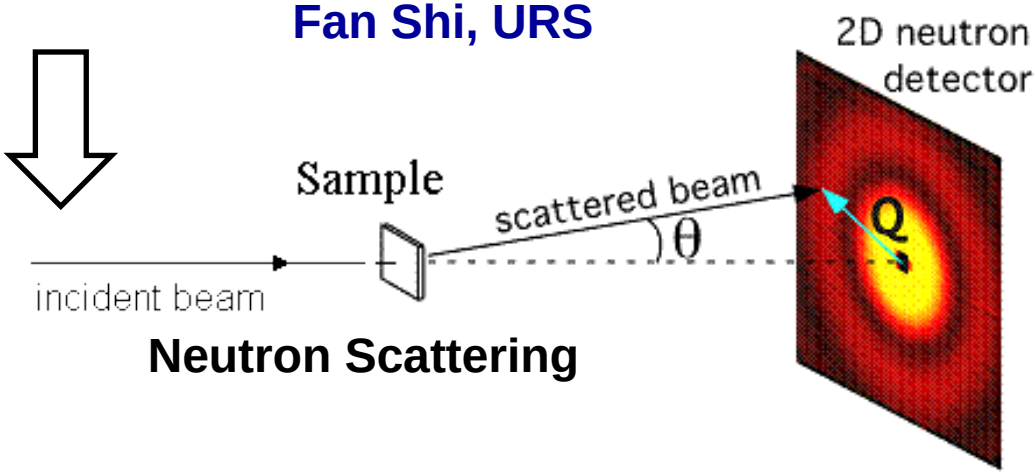


Christopher Matranga, DOE
Jeff Culp, URS

Mixed Gas Testing



Tom Brown, DOE
Fan Shi, URS

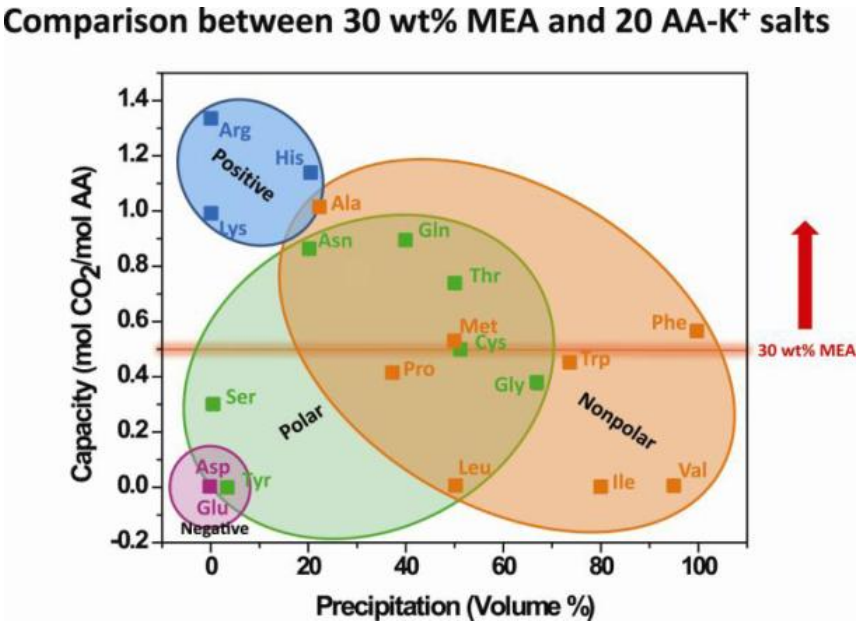


Andrew Allen, NIST

Neutron Scattering

Advanced Research Projects

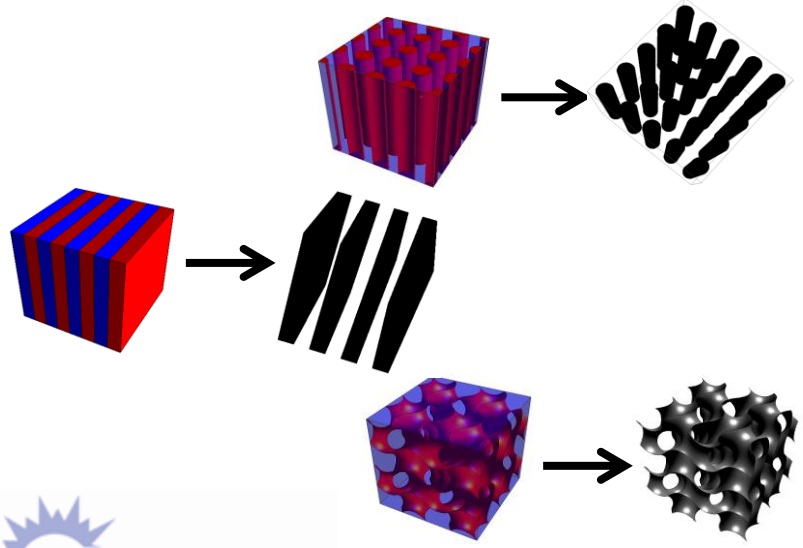
Phase Change Amino Acids



Bingyun Li, WVU

Fan Shi, URS

N-rich Carbon



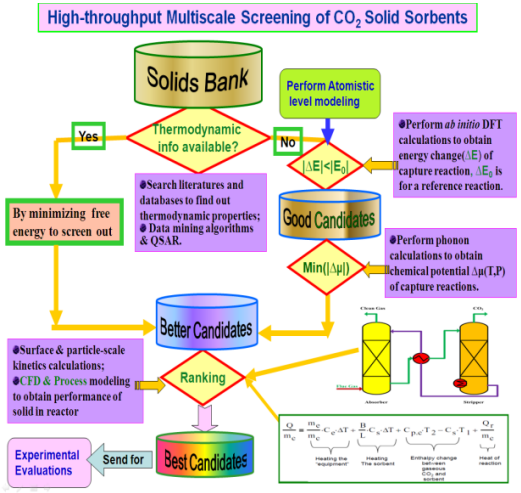
Hunaid Nulwala, CMU

Tomasz Kowalewski, CMU

Sittichai Natesakhawat, Pitt

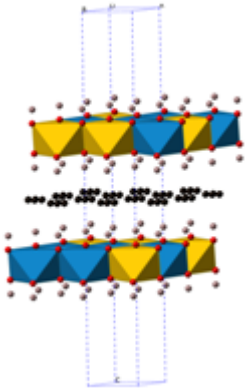
Advanced Research Projects

Layered Double Hydroxides



Jonathan Lekse, URS

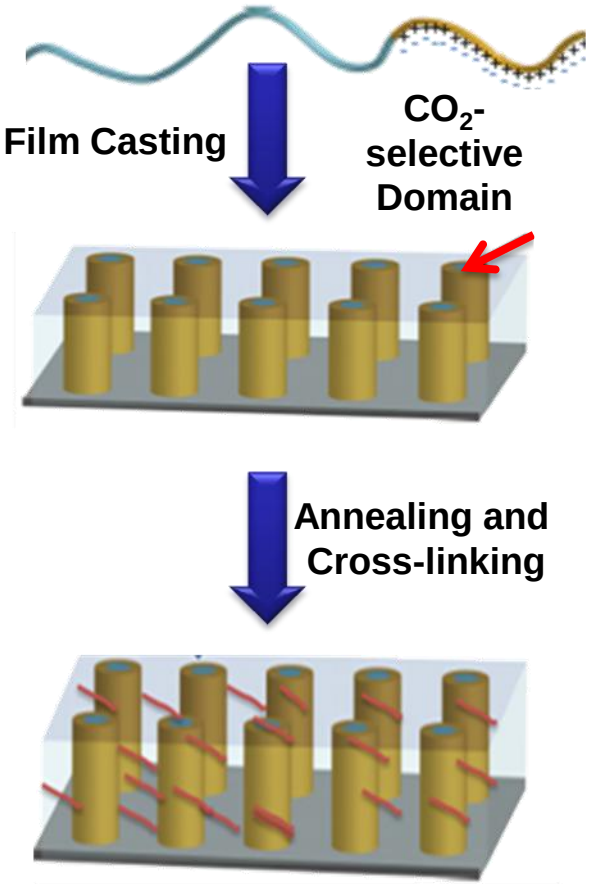
Yuhua Duan, DOE



Brian Adzima, ORISE

Krzysztof Matyjaszewski, CMU

Structured Polymer Membranes



What's Next?

- New Materials
- New Systems Integration Schemes
- New Technological Solutions for Carbon Capture

Ideas for Future Work?

- **Dave Luebke, Carbon Capture Technical Coordinator**
  - David.Luebke@netl.doe.gov
- **Yuhua Duan, Computational TTC**
  - Yuhua.Duan@netl.doe.gov
- **Hunaid Nulwala, Synthesis TTC**
  - Hunaid.Nulwala@contr.netl.doe.gov
- **Dave Hopkinson, Fabrication/Performance Testing TTC**
  - David.Hopkinson@netl.doe.gov
- **Evan Granite, Sorbent Development TTC**
  - Evan.Granite@netl.doe.gov
- **Jim Hoffman, Sorbent Process TTC**
  - James.Hoffman@netl.doe.gov
- **Nick Siefert, Systems Development TTC**
  - Nicholas.Siefert@netl.doe.gov