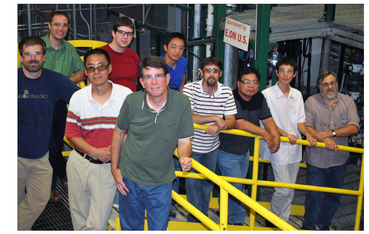
# A Solvent/Membrane Hybrid Post-combustion $CO_2$ Capture Process for Existing Coal-Fired Power Plants

Qiying Jiang, Yongbao Feng, Joseph E. Remias, and Kunlei Liu
*Center for Applied Energy Research*, University of Kentucky



## Motivation

- Primary disadvantage to concentrated aqueous ammonium solvents is ammonia volatility
  - Combat scrubber ammonia loss with more dilute capture solution adding higher needed heat of solvent regeneration
  - A solvent based membrane solution makes dilute solvent feasible since higher heat of regeneration is negated
- To reduce the energy penalty associated with solvent-based post-combustion $CO_2$ capture system by incorporation of dual-function membrane prior to regenerator
  - To Increase carbon loading
    - Water reduced in the solvent by physical separation
    - Catalytic reaction increases the concentration of bicarbonate over carbonate
  - To regenerate solvent catalytically
    - Regenerated by ammonium protons on the surface of membrane

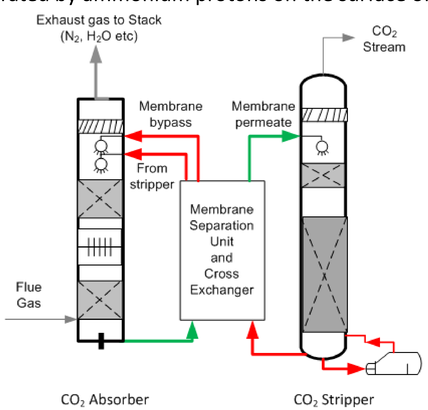



**Figure 1.** System integration

## Project Goals and Milestones (Y1)

- Completed evaluation of commercial supports in terms of blank fluxes
- Ceramic extruder and ancillary equipment commissioning and installation
- Started study of ceramic paste and prepared alumina ceramic tubes
- Constructed bench scale hollow fiber synthesis apparatus
- Developed method and prepared hollow fibers meeting the base flux target
- Started optimization of zeolite membrane on porous ceramic support

## Project Progress

### o Commercial support evaluation

**Table 1**. Commercial supports specification

| Company name | Pricing (current) ($/m²) | Pricing (commercial) ($/m²) | Flux[a] (kg/m²·h) | Porosity (%) | Pore Size (nm)[b] | Notes |
|---|---|---|---|---|---|---|
| Masuda Corporation | 2006 | 430 | 450 | 43 | 1500 | Current material |
| Pall Membralox® | 85,500 | >2800 | 740-3500[c] | ~36 | 20-100 | |
| Pall Sintered Metal | 15,000 | NA | 600 | 42 | 2000 | Development product |
| Pall - Zirconia coated sintered metal | 251,000 | NA | 140 | 30 | 70 | Development product |
| Mott - 0.1 Media grade sintered metal | 18,000 | 800 | | Not determined | 1000 | |

[a] Determined at 30 wt % total carbon, 23 C, and 0.21 MPa (30 psi).
[b] All pore sizes are nominal values.
[c] Increased linearly as a function of $ZrO_2$ coating pore size with 3 sizes evaluated 20, 50, and 100 nm.

### o Ceramic support

**Figure 2.** Dry pressing method

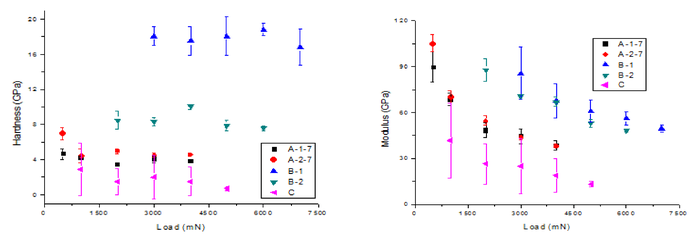



**Figure 3.** Dependence of Young's modulus and hardness on the peak load using micro-indenter; (***left***) hardness; (***right***) Young's modulus; (**A-1-7**) MZS-3 + 40% Kaolin clay (type No. 10) ; (**A-2-7**) MZS-3 + 40% Kaolin clay (type polyclay); (**B-1**)Alumina (MZS-3) + 4% MgO; (**B-2**) DN206 + 4% MgO; (**C**) Masuda mullite support.

**Figure 4**. Ceramic extruder, mixer and furnace.

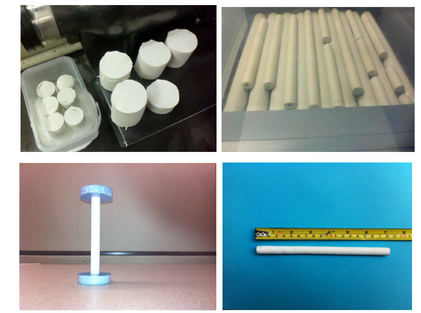


**Figure 5**. Ceramic paste and tube ($Al_2O_3$).

### o Hollow fibers

**Figure 6**. Polymeric hollow fibers synthesis apparatus.

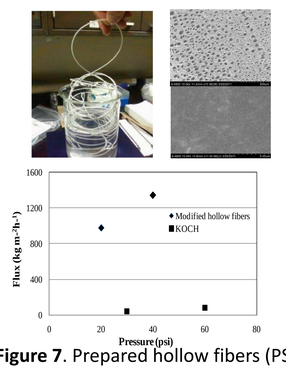



**Figure 7**. Prepared hollow fibers (PSU) and flux.

### o Zeolite membrane on ceramic support

**Figure 8**. Membrane evaluation apparatus.

**Table 2.** Separation performance results for Membrane on Masuda Nikkato mullite tube for 5 wt % $(NH_4)_2CO_3$ solutions.

| Membr. I.D. | Testing time (min)* | Temp. (°C) | ΔP (psi) | Δ(pH) | Flux (kg/m²·h) | Total C Rejection (%) |
|---|---|---|---|---|---|---|
| T-6-2 (Y1Q3) | S1(0-120) | 100 | 50 | -0.04 | 4.89 | -97.3 |
| | S2(120-210) | 100 | 50 | 0.10 | 7.30 | -60.0 |
| | S3(210-300) | 100 | 50 | 0.17 | 9.53 | -32.4 |

* Performance data describes the average for that time
** Tested with solution composition of ca. 10 wt % ammonium carbonate solution
$\Delta(pH) = pH_{permeation} - pH_{reject}$.
Total flux = $m_{permeation}/(A * t)$, $A$: membrane area; $t$: permeation time; $m$: mass of permeate.
Rejection rate $R_i = 1 - C_{ip}/C_{if}$, $C_{ip}$: $i$ permeate concentration; $C_{if}$: $i$ feed concentration