Ultra-thin membranes and applied desalination for CO2 capture and separation from industrial gas streams

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Capture and separation of CO2 from industrial flue streams presents substantial economic and technical challenges. Current technologies in post-combustion, pre-combustion, and oxyfiring have well circumscribed costs largely constrained by energy demands. To reduce cost, scientists at the Lawrence Livermore National Laboratory (LLNL) are using technology developed for national security applications to this major environmental mission. Two approaches show strong promise: advanced membrane technologies with superior selectivity and application of current and novel desalination technologies.

The first approach involves nano-engineered fabrication of membranes by depositing polymers (i.e. polyimides) through a vapor to fabricate uniform, extremely thin membranes. The SLIP approach (Solvent-Less vapor deposition and In-situ Polymerization) makes with much greater CO_2 separation selectivity than conventional membranes. SLIP membranes could conceivably achieve 90% capture of CO_2 from coal-fired power plants. By significantly lowering the power requirements for the plant's separation process, SLIP membranes could reduce costs to $1/3^{rd}$-$1/6^{th}$ of conventional MEA (monoethanolamine) process for post combustion capture.

A DOE funded, Phase I study investigated SLIP membranes for post-combustion capture.

- The CO_2 permeabilities (throughput) of the coatings were 6 to 15 times greater than those of the original materials.
- We observed CO_2 permeabilities and CO_2/N_2 selectivities that were improved over commercial materials.
- Samples with polyimide coating thicknesses ranging from 100 to 400 nanometers per side exhibited the best combination of CO_2 permeability and CO_2/N_2 selectivity.

Based on these results, a consortium of industry, national laboratories, and end users have been constructed in order to facilitate commercialization of the SLIP technology for carbon capture. Proposed Phase II efforts would fabricate large-scale composite membranes based on novel materials. Such materials need not focus exclusively on post-combustion capture, and we are confident that other selective polymers could be used to separate O2 from air and to separate CO and CO2 from H2.

The second approach involves application of desalinization technologies, including reverse osmosis, electro-dialysis, and the Cussler ion pump. In all cases, flue-gas dissolves through water to be treated (fresh, brackish, or saline). When this gas mixture reacts with a slightly alkaline aqueous fluid, carbon dioxide, SO_x and NO_x selectively partition into the aqueous phase, leaving the other gases behind for atmospheric discharge. The CO_2 can then be selectively removed from solution through desalination, which increases the bicarbonate concentration and "salts out" the CO_2 as a pure gas stream. Initial testing demonstrates that CO2 can enter into aqueous streams and be separated from brines. Co-separation of SOx and NOx with CO2 might provide a means to reduce the capital and operating expense for new-build power plants. Our current work is aimed at mass-balance, understanding of the process kinetics, and engineering. Based on the current energy demands of the system, we believe that the desalination technology is already competitive with MEA and other temperature swing adsorption methods, and that performance could be substantially greater (e.g., an integrated price of $20-25/ton). To achieve this goal, additional work must focus on reactor and pump engineering to minimize inertial losses and increase through-put.