Micro-encapsulation of non-aqueous solvents for energy-efficient carbon capture

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Abstract

Many purpose-designed, non-aqueous or water-lean solvents have recently been developed to improve the energy-efficiency of carbon capture. These solvents, including ionic liquids (ILs), phase-changing ionic liquids (PCILs)[1] and CO_2-binding organic liquids, have shown promise for substantially lower energy demand in post-combustion capture than aqueous amines. The low water content reduces the sensible and evaporative heat loads in the stripper, while the tunable heat of reaction can allow either low temperature or high-pressure stripping. However, the solvents pose challenges to conventional process equipment. These include solid precipitation, corrosivity, and high viscosity, leading to slower rates of CO_2 absorption or heat exchange. The larger absorbers and heat exchangers or additional process units can greatly increase capital cost.[2]

Micro-encapsulation is a technique where a solvent is encased in small (~500 μm diameter), spherical shells of a CO_2-permeable polymer, greatly increasing the reactive surface area of the solvent compared to liquid films in a conventional packed tower. This technique was demonstrated previously for potassium and sodium carbonate solutions. It was shown to increase the rate of CO_2 absorption more than 10-fold and to successfully contain solid precipitates.[3] Micro-encapsulation can address the limitations of many advanced solvents. Chemical compatibility of the capsule shell materials with the advanced solvents and practical management of the viscosity and phase-changes of the solvents during production are the first challenges to encapsulation.

Here, we demonstrate micro-encapsulation of several promising designer solvents: an IL, PCIL, and CO_2BOL. We develop custom polymers that cure by UV light in the presence of each solvent while maintaining high CO_2 permeability. We use several new process strategies to accommodate the viscosity and phase changes. We then measure and compare the CO_2 absorption rate and capacity as well as the multi-cycle performance of the encapsulated solvents. These results are compared with previous work on encapsulated sodium carbonate solution. The prospects for designer solvents to reduce the cost of post-combustion capture and the implications for process design with encapsulated solvents are discussed.

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[2] Heldebrant, David J., Vanssiliki-Alexandra Glezakou, Phillip K. Koech, Paul Mathias, David Cantu, Roger Rousseau, Deepika Malhotra, et al. “Evaluating Transformational Solvent Systems for

Post-Combustion CO2 Separations." *Energy Procedia*, 12th International Conference on Greenhouse Gas Control Technologies, GHGT-12, 63 (2014): 8144–52.

[3] Vericella, John J., Eric B. Duoss, Joshuah K. Stolaroff, Sarah E. Baker, James O. Hardin, James Lewicki, Elizabeth Glogowski, et al. "Encapsulated Liquid Sorbents for Carbon Dioxide Capture." *Nature Communications* 6, no. 6124 (February 2015): 1–7.