the ENERGY lab

R&D FACTS

Carbon Capture

Post-combustion Membranes for Carbon Capture

Background

Carbon capture and storage from fossil-based power generation is a critical component of realistic strategies for arresting the rise in atmospheric CO_2 concentrations, but capturing substantial amounts of CO_2 using current technology would result in a prohibitive rise in the cost of producing energy. The National Energy Technologies Laboratory-Regional University Alliance (NETL-RUA) is pursuing a multifaceted approach, which leverages cutting-edge research facilities, world-class scientists and engineers, and strategic collaborations to foster the discovery, development, and demonstration of efficient and economical approaches to carbon capture.

Compared to other separation technologies like solvents and sorbents, membranes offer a comparatively simple separation process. Unlike conventional solvent or sorbent-based separators, few moving parts are required and no regeneration phase is required resulting in potential cost savings. Additionally, the capital and maintenance costs, both initial and long-term, are reduced due to the process simplicity.

Approach

A typical flue gas stream contains less than 15% CO_2 and is only slightly above ambient pressure. This results in a very low driving force for separation. To overcome this lack of driving force, highly permeable and highly selective membranes are required. Polymeric membranes are cheap and easy to process but are limited by an inherent tradeoff between permeability and selectivity – polymeric membranes can have high permeability or high selectivity but it is very difficult to achieve both. Conversely, metal organic frameworks (MOFs) are inorganic crystallite materials that show excellent potential for CO_2 capture. However, fabricating defect-free membranes from MOFs is very difficult and at least an order of magnitude more costly than polymeric materials.

Membrane material development at NETL-RUA focuses on mixed matrix membranes (MMM) which are a class of materials consisting of inorganic crystalline particles (MOFs in this case) dispersed in a polymer matrix. These materials are particularly attractive because they have the capability to combine the excellent processibility of polymers with the superior separation capability of the inorganic filler particles. Integrating filler particles into a polymer membrane increases the selectivity and permeance of the membrane while providing the fillers an efficient mechanism for contacting the feed gas stream. Because of its increased selectivity and permeance, the system is better able to deal with a low partial pressure driving force than conventional polymers. However, MMMs often suffer from poor contact between the polymer matrix and filler. This phenomenon, known as the sieve-in-a-cage effect, can cause gas streams to by-pass the filler without separation. Overcoming this problem is key to developing MMMs which are defect free and possess the separation characteristics necessary to meet DOE goals.

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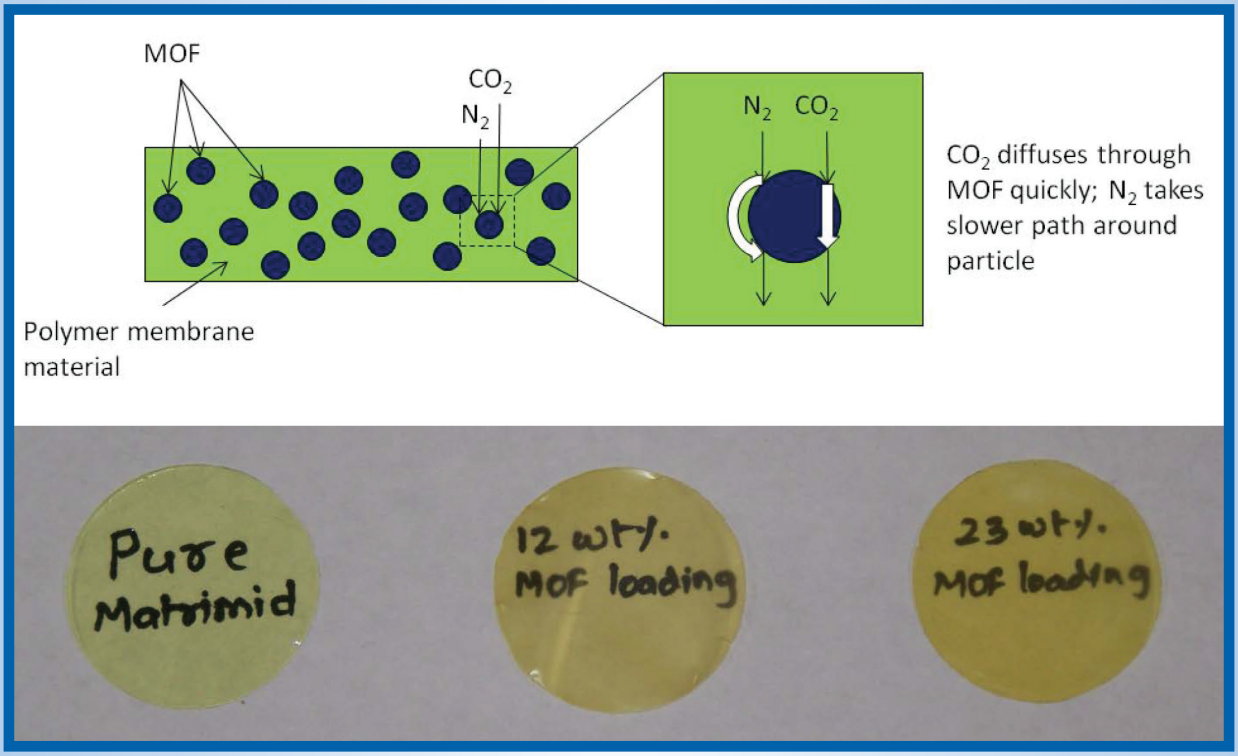

Accomplishments

Generation 1 MMM development focused on enhancing the interaction between the polymer and MOF phase by modifying the MOF particles. Membranes have been successfully fabricated using four different modifications of the MOF UiO-66 dispersed in the polymer Matrimid. Gas separation tests performed on these membranes revealed that by modifying the MOF, the interaction between the polymer and the MOF at the interface can be controlled thereby reducing or eliminating the sieve-in-a-cage effect. The best performing of these membranes showed a permeability increase of greater than 3-fold compared to membranes fabricated from neat Matrimid. Moreover, these membranes show a selectivity which exceeds the targets established by systems modeling. Building on this success, the next step is to increase the permeability. Generation 2 membranes are currently in development and focus on greatly increasing the permeability of the polymer phase to improve the overall performance of the membrane.

Expected Outcomes

Membrane technologies will be developed and evaluated under realistic testing conditions at successively larger scales with eventual bench scale testing in the presence of real fuel gas at the National Carbon Capture Center. The technologies will then be transferred to industrial partners for further scale up and commercialization.

Benefits

The research will accelerate the development (ranging from the discovery of innovative materials through evaluation in real systems) of efficient, cost-effective fossil fuel conversion systems that meet the programmatic goal of capturing 90 percent of the CO_2 produced by a pulverized coal power plant at a cost of less than \$40/tonne CO_2.