Reactive Separations with Inorganic Membranes: Transitioning from Fundamental Studies to Practical Applications

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Abstract

Inorganic membranes show good potential for use in high-temperature conventional and reactive separation applications. They are of current scientific interest, with issues of membrane preparation, reproducibility, and robustness to the application environments being a key focus. Research efforts to date have resulted in many advances, but high-temperature industrial applications are lacking. In this talk, we will discuss efforts by our Group focused on promoting such practical applications.

The first effort involves a membrane- and adsorption-enhanced water gas shift (WGS) reaction process employing a carbon molecular sieve membrane (CMSM)-based membrane reactor (MR) followed by an adsorptive reactor (AR) for H2 production and simultaneous CO2 capture. In the project, highly permselective CMSMs were prepared and performance-validated under real gasification conditions. Experiments were then carried-out in the laboratory to determine MR and AR performance under integrated gasification combined cycle (IGCC)-relevant conditions, proving that the CMSM, the adsorbent, and the WGS catalyst utilized are all robust and stable during long-term syngas exposure. A pilot-scale MR-AR system was then constructed and field-tested using real syngas, with results showing that the technology met the goals of >90% carbon capture, >95% CO2 purity, at a cost of electricity of 30% less than baseline approaches. Ongoing efforts focus on further process scale-up, and on pivoting the technology towards distributed biomass gasification applications.

The second study involves a post-combustion CO2 capture and utilization (CCU) technology that converts waste CO2 into methanol. Our Group has developed a novel methanol synthesis (MeS) from syngas process, employing a membrane contactor reactor (MCR) in which an appropriately modified mesoporous inorganic membrane with the desired characteristics serves as an interface between the MeS environment and a sweep liquid flow in the permeate-side. For this CCU process, the MeS-MCR unit is integrated with a separate reactor (RWGSR) which converts the CO2 into a syngas via the reverse water gas shift reaction. Efforts to date have focused on the lab-scale study of the performance of the integrated (RWGSR/MeS-MCR) system, and on preliminary process TEA. Ongoing efforts involve the construction/testing of a pilot scale system for further process scale-up.