Experimental Results of Pressure Swing Adsorption (PSA) for Pre-combustion CO₂ Capture with Metal Organic Frameworks

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Abstract

Vacuum Pressure Swing Adsorption (VPSA) has already proved that it can be used for capture of CO₂ from the tail gas of the PSA process for hydrogen purification [1]. The demo operated in Port Arthur by Air Products has already captured more than 1 million metric tons of CO₂. Although the scale of pre-combustion is larger than the one in a refinery to produce hydrogen, the technology has already proven that it can perform the task.

The removal of CO₂ from this project is done under vacuum and thus consuming energy. The removal under vacuum conditions is due to the strength of adsorption of CO₂ in the adsorbents used. Improvements in the process to minimize the energy consumption should come from a combination between material science and process engineering. If other materials with high capacity (and selectivity) are used, it would be possible to reduce the energy consumption of the capture. However, materials with other properties might require another sequence of conditioning steps to improve their utilization.

In this study we are showing for the first time experimental results of a metal-organic framework (MOF) termed UTSA-16 that was formulated and used in a laboratory-scale PSA unit. The material has a relatively high adsorption capacity of CO₂ (similar to zeolites) with the advantage of not having such a high steepness (lower heat of adsorption). Moreover, the material presents a relatively high (compared to zeolites) adsorption towards CO which helps reducing the hydrogen contamination of the CO₂-rich stream.

The material was produced in large scale and then formulated with minimal loss of surface area and adsorption capacity towards CO₂ [2]. The isotherms of CO₂, H₂, CO and CH₄ at 298 K in this material are shown in Figure 1. Breakthrough curves using over 100 grams of material were performed at 16 bars with a mixture containing 76% H₂, 17% CO₂, 3% CH₄ and 4% CO simulating the off-gas of a typical steam-methane reformer. Results are shown in Figure 2. It is observed that the material is highly selective to CO₂ and that a mathematical model based on adsorption equilibrium of pure components can be used to describe the experimental data. Thus, this mathematical model is used for designing a proper PSA cycle to produce high purity and high recovery of CO₂. Results indicate that this material is a serious candidate to succeed in this application, although cost evaluations are necessary to confirm that.

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Figure 1. Adsorption equilibrium of CO$_2$, CO, CH$_4$, N$_2$ and H$_2$ on extrudates of UTSA-16 at 298K.

Figure 2. Breakthrough curve of a mixture with 17% CO$_2$, 4% CO, 3% CH$_4$ and 76% H$_2$ in a column packed with extrudates of UTSA-16 at 305K.

References