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CO_2 adsorption and separation behavior of azole-based ionic liquid impregnated adsorbents supported on porous silica

Takashi Makino[a]*, Yuki Kohno[a], Tatsuya Fujii[a], Kazuhiro Sakamoto[b], Manabu Shindo[b]

[a]*National Institute of Advanced Industrial Science and Technology, 4-2-1 Nigatake, Miyagino-ku, Sendai, Miyagi, 983-8551, Japan*
[b]*Research and Development Center, Tohoku Electric Porwer Co., Ing., 7-2-1 Nakayama, Aoba-ku, Sendai, Miyagi, 981-0952, Japan*

Abstract

CO_2 capture from natural gas combustion flue gas is gaining increasing attention. Compared with coal-fired flue gas, it features lower CO_2 concentrations and higher oxygen content, posing challenges for energy-efficient separation. Ionic liquids (ILs) have emerged as promising materials for CO_2 capture due to their low volatility, structural tunability, and low heat capacity. Among them, azole-based ILs exhibit small viscosity change upon CO_2 absorption, enabling stable adsorption/desorption kinetics, especially when immobilized on solid supports. In this study, we prepared solid adsorbents by impregnating tetraalkylphosphonium azolates onto mesoporous silica and investigated their CO_2 capture behavior. The effects of IL structure, loading amount, and support particle size were examined. Photographs of the IL-impregnated adsorbents, experimental setups, and chemical structures of the ILs used are shown in Fig. 1. CO_2 adsorption/desorption experiments were conducted using a fixed-bed column under simulated flue gas conditions (humidified mixture of 5 vol% CO_2 + 95 vol% N_2 for adsorption, and humidified N_2 for desorption). Compared with a tetraethylenepentamine (TEPA)-impregnated reference, the IL-based adsorbents showed lower saturation capacities but higher effective CO_2 capacity. In multi-cycle experiments (5 min adsorption/desorption cycles), [P_{4444}][2CNPyr], [P_{66614}][2CNPyr], and [P_{66614}][BzIm]-impregnated adsorbents exhibited 83%, 76%, and 13% higher effective CO_2 capacity than TEPA, respectively. Further evaluation under cyclic operation was conducted using a two-column vacuum swing adsorption (VSA) setup. In the presentation, we will discuss how IL loading and particle size influence adsorption performance, and present CO_2 recovery and purity data under various process conditions. These findings provide a basis for discussing the potential applicability of azole-based IL-impregnated adsorbents in energy-efficient CO_2 capture from natural gas flue gas.

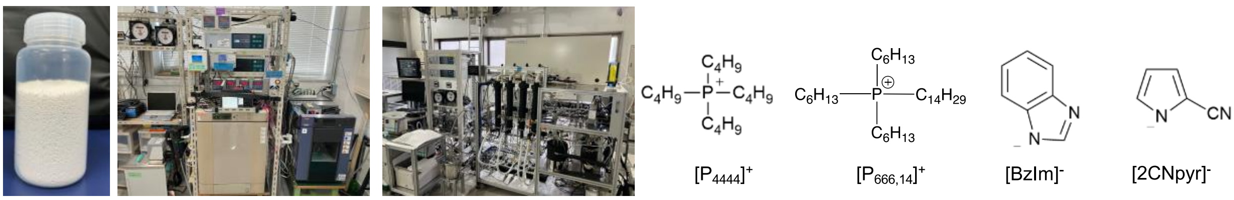

Fig. 1 Photographs of IL-impregnated adsorbent and experimental setups, and chemical structures of ILs used in this study.

Keywords: Ionic liquid; Adsorption; Natural gas combustion fule gas; Vacuum swing adsorption

* Corresponding author. Tel.: +81-50-3522-8155
E-mail address: makino.t@aist.go.jp