Mixed ionic liquid membranes with 1-ethyl-3-methylimidazolium acetate and diamine-based ionic liquids for direct air capture applications

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To address the growing demand for efficient carbon dioxide (CO_2) separation from ambient air, we utilized supported ionic liquid (IL) membranes for direct air capture applications.[1,2] In the present study, we have developed and evaluated a series of mixed ionic liquid (IL) membranes composed of diamine-based ILs and 1-ethyl-3-methylimidazolium acetate ([emim][AcO]). The separation performance of all tested membranes exceeded the Robeson upper bound, achieving high CO_2 permeability and CO_2/N_2 selectivity. The effects of diamine structure, including hydroxyethyl substitution, alkyl modification, and spacer length between amino groups, were systematically investigated. Hydroxyethyl groups significantly enhanced membrane performance, while ethyl groups or spacer extension beyond an optimal length led to reduced performance. Temperature-dependent measurements revealed that mixed ILs incorporating bis(hydroxyethylene)diamine exhibited the highest CO_2 permeability in the 20–30 °C range. However, these systems showed a decrease in CO_2/N_2 selectivity at 30 °C, whereas ILs based on N-(2-hydroxyethyl)ethylenediamine maintained higher CO_2/N_2 selectivity at this temperature. Activation energies were obtained from the measured temperature profiles, providing insights into the underlying transport mechanisms. Since ambient air contains water vapor, membrane performance was also evaluated under humidified conditions. Under these conditions, nearly all membrane systems exhibited decreased separation performance. These findings offer design principles for mixed IL separation membranes incorporating diamine-based ILs, where high CO_2 separation efficiency can be achieved through functional group selection and operation within an optimal temperature range.

References

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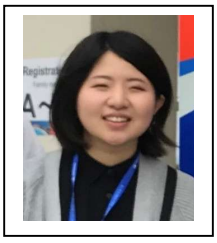

Yu Kanasaki received her Ph.D. degree from Nara Women's University, Japan, in 2016. From 2016 to 2017, she worked as a JSPS Research Fellow at Nara Women's University. In 2017, she joined the Institute for Marine Biology and Engineering at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) as a postdoctoral researcher. In 2019, she became an Assistant Professor at Hiroshima University. She moved to the National Institute of Advanced Industrial Science and Technology (AIST) in 2021 as a postdoctoral researcher and has been working as a Researcher since 2022. Her research focuses on the development and evaluation of CO_2 separation membranes using ionic liquids.