Magnetic Mixed Matrix Membranes for Oxygen Separation

Wing Chung Liu, Roman Selyanchyn, Shigenori Fujikawa

International Institute for Carbon-Neutral Energy Research, Kyushu University

Membrane-based direct air capture (m-DAC) has recently been introduced as an alternative method to remove CO_2 from the atmosphere. By treating ambient air using membranes with high CO_2 permeances and selectivity over other gases, CO_2 can be efficiently captured in the permeate gas and subsequently electrochemically reduced to useful chemicals such as methane and ethanol.[1] However, the reduction reaction is easily disrupted by any O_2 in the permeate gas.[2] Therefore, membranes with high CO_2/O_2 selectivity are essential for the process. Since oxygen is paramagnetic, we propose using magnetic membranes to control the oxygen permeation through the membranes. In this work, we design mixed matrix membranes (MMM) with magnetic nanoparticle (MNP) fillers and study the effects of the MNPs on membrane performance, particularly CO_2/O_2 selectivity.

Freestanding MMMs containing MNPs dispersed within PDMS or PolyActive™ polymer matrices were prepared. The CO_2 and O_2 permeances of membranes with up to 50 wt% MNPs were measured while a magnetic field was applied across the membranes using neodymium magnets. We found that the CO_2/O_2 selectivity increased with the MNP content, signifying the magnetic interaction of O_2 with MNP. This effect was much greater under an applied magnetic field. The increase in selectivity was caused by the presence of MNPs, which decreased oxygen permeability. The external magnetic field magnetizes the MNPs, which plausibly attracted the oxygen around them. Higher MNP contents provides more sites for such interactions. The experimental results were supported by mathematical model calculations. Overall, the magnetic PolyActive™ MMMs containing 40 wt% MNPs achieved the highest selectivity of 35 under a magnetic field of 800 mT, corresponding to a selectivity enhancement of 60% over pure PolyActive™ membranes. Our findings demonstrate the potential of using magnetic fields to control gas transport for applications which require the separation of O_2 from other gases.

[References]

1) Fujikawa S, Selyanchyn R, Kunitake T: *Polym J* **53**, 111–119 (2021)
2) Harmon N, Wang H: *Angew. Chem.Int. Ed.* **61**, e202213782 (2022)