Freestanding, Self-Healing CO_2 Separation Nanomembranes Based on PEG-linked α-Lipoate Networks

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The development of efficient and durable CO_2 separation membranes is crucial for advancing carbon capture technologies, particularly for direct air capture (DAC).[1,2] Such membranes require both high gas permeance and selectivity. Gas permeance is known to increase with decreasing membrane thickness. We have previously prepared cross-linked poly(dimethylsiloxane)-based ultrathin membranes with a thickness of about 34 nm that exhibit extremely high CO_2 permeance with a moderate CO_2/N_2 selectivity.[3] In this system, the CO_2 permeance was dramatically increased by reducing the membrane thickness while maintaining the selectivity. However, the fabrication of such a thin membrane is prone to defects, such as pinholes and cracks, which significantly affect the gas separation performance. One of the most effective ways to avoid such defects is to use self-healing polymers to fabricate CO_2 separation membranes. However, there are only a few examples of such self-healing membranes.[4,5] Although these membranes exhibit unique self-healing capabilities, they typically displayed low gas permeance (less than 5 GPU) due to their relatively thick nature. It is well known that α-lipoic acid and its derivatives undergo ring-opening polymerization to form disulfide-containing polymers with a self-healing ability.[6–8] In this study, we present novel CO_2 separation nanomembranes derived from bifunctional monomers composed of two α-lipoic acids linked by polyethylene glycol (PEG). These membranes possess dynamic covalent disulfide bonds, which are expected to enable intrinsic self-healing properties that enhance long-term stability and performance. By optimizing the polymer structure and membrane fabrication conditions, we have successfully prepared ultrathin disulfide-based nanomembranes (minimum thickness of ca. 36 nm) with high CO_2 permeance (up to approximately 1000 GPU) while maintaining excellent CO_2/N_2 selectivity (up to 80).[9]

References

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