Hydrophilic Microporous Polymer Membranes with High Permselectivity for Ionic and Molecular Separations

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Abstract:

Trade-off between permeability and nanometer-level selectivity is an inherent shortcoming of membrane-based ionic and molecular separations. Exploring new polymer materials and new membrane processes are important to overcome the limitation of current membrane materials and processes. Polymers of microporosity (PIMs) are a group of recently developed polymers with stiff and distorted backbone structures, which give rise to high free volumes and high concentration of sub-2 nm intrinsic microcavities. These highly connected micropores could provide fast water transport routes while regulating the permeation of ions. This talk will present the study on a hydrophilic amidoxime modified polymer of intrinsic microporosity (AOPIM-1) as a membrane material for reverse osmosis desalination. AOPIM-1 is casted into a defect-free dense membrane, and the micropores are controlled in the size range of 0.3 to 0.8 nm, closed to the size of hydrated metal ions. The rapid transport through the microporous channels gives the AOPIM-1 membrane a water permeability of 1.92×10^{-7} m·L/m^2·h·bar with NaCl rejection as high as 98.5%. The membrane thickness-normalized water permeability of AOPIM-1 exhibits order-of-magnitude improvement comparing to conventional polyamide-based desalination membranes. This study confirms the possibility of utilizing microporous polymers as reverse osmosis membrane materials for highly efficient ionic separation and water desalination.

Besides pressure-driven size sieving membrane processes, new membrane materials could bring unique separation capability for unconventional membrane separation processes. The large amount of micropores also endows PIMs materials with large specific surface area and abundant active cites for adsorption, indicating possibility for highly efficient adsorptive separation. While most highly porous materials with high adsorption capacity lack solution processability and stability for achieving adsorption-based molecule separation, PIMs possess good solution-processability to be processed into microporous membranes. This talk will also introduce AOPIM-1 as a membrane adsorption material to selectively adsorb and separate small organic molecules from water with ultrahigh processing capacity (Figure 1). The membrane adsorption capacity for Rhodamine B reaches 26.114 g m^{-2}, 10~1000 times higher than previously reported adsorptive membranes. Meanwhile, the membrane achieves >99.9% removal of various nano-sized organic molecules with water flux 2 orders of magnitude higher than typical pressure-driven membranes of similar rejections. This work confirms the feasibility of microporous polymers for membrane adsorption with unprecedented capacity, and provides the possibility of adsorptive membranes for molecular separation.

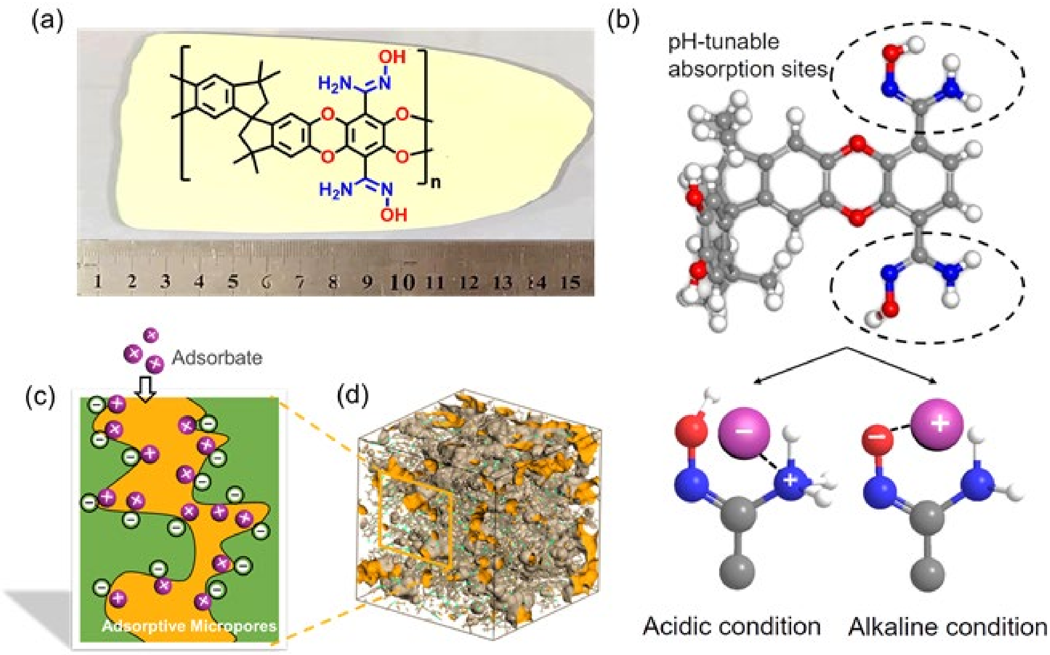

Figure 1. (a) Chemical structure of AOPIM-1 polymer and optical image of AOPIM-1 membrane; (b) The pH-tunable chargeability of AOPIM-1 under acidic or alkaline conditions, where the gray, white and red spheres represent C atoms, H atoms and O atoms, respectively; (c) Schematic diagram of microporous polymer membranes for adsorptive separation of organic molecules; (d) Three-dimensional view of an amorphous cell of the AOPIM-1 polymer.

Keywords: microporous polymer, reverse osmosis, membrane adsorption, molecular separation, permselectivity