Selective Ion Transport through Three-Dimensionally Interconnected Nanopores of Quaternized Block Copolymer Membranes for Energy Harvesting Application

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Figure S1. Plan-view (a, c) and cross-sectional (b, d) FE-SEM images of PS-P2VP membranes prepared by NIPS method with different evaporation time at room temperature. (a, b) 10 s; (c, d) 50 s.
Figure S2. Plan-view and cross-sectional FE-SEM images of PS-P2VP membranes prepared by NIPS method with different evaporation temperature for 20 s. (a - c) 90 °C; (d - f) 100 °C; (g - i) 110 °C.
To confirm the interconnectivity of nanopores in the PS-P2VP membrane, permeation tests with deionized (DI) water were performed at different working pressure in a stirred cell module (Amicon 8010, Millipore). As shown in Figure S3, the PS-P2VP membrane exhibited a water flux of 17 L m$^{-2}$ h$^{-1}$ at a pressure of 0.1 bar and a linear increase in water flux with working pressure, indicating good dimensional stability of the PS-P2VP membrane.

**Figure S3.** Flux data of deionized water using the PS-P2VP membrane from the evaporation condition of 100 °C and 20 s. (a) Flux change with increasing working pressure in permeability test and (b) plot of water flux as a function of working pressure.
Figure S4. Molecular structure of methyl blue (CAS number: 28983-56-4).
Calculation of ion transport number

To calculate ion transport number, the diffusion potential \( E_{\text{diff}} \), which is generated by ionic diffusion across the membrane, needs to be determined by \( E_{\text{diff}} = V_{\text{OC}} - E_{\text{redox}} \).\(^{1,2}\) In this equation, the redox potential \( E_{\text{redox}} \) is arose from the different potential drops at the electrode-solution interfaces in the two KCl reservoirs. We measured \( E_{\text{redox}} \) (18.5 mV) by inserting Ag/AgCl electrodes in the two KCl solutions (0.01M and 1M) that were connected by a salt bridge. From the diffusion potential, ion transport number \( t \) can be further determined by\(^{1,2}\)

\[
t = \frac{1}{2} \left[ 1 + \frac{F}{RT \ln(a_H/a_L)} \right]
\]

where \( F \) is the Faraday constant, \( R \) is the ideal gas constant, \( T \) is the temperature, and \( a_H \) (or \( a_L \)) is the activity of KCl in the solution at high (or low) concentration. From the equation (1), ion transport numbers were evaluated as 0.43, 0.57, 0.87, 0.87, and 0.68 for PS-QP2VP membranes with 0, 6, 12, 18, 24 h of quaternization, respectively.
Figure S5. (a) Open-circuit voltage, (b) short-circuit current and (c) output power of concentration-gradient cells with commercial anionic-exchange membrane (Fujifilm) under the same experimental conditions with Figure 3 (main text).
Figure S6. Photograph of polycarbonate containers utilized for the connection of concentration-gradient cells.

References

2 D.-K. Kim, C. Duan, Y.-F. Chen, A. Majumdar, Microfluid Nanofluid., 2010, 9, 1215.