Towards Ultrahigh Osmotic Energy Harvesting by Metal-organic Framework and Covalent-organic Framework Membranes

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The chemical energy stored between seawater and river water, the so-called osmotic energy (or blue energy), can be harvested by an ion-selective membrane. However, previously reported membranes suffer from insufficient ion selectivity and inferior transmembrane ionic flux (low conductance), thus impeding practical application. For example, the output osmotic power density reported by most of existing ion selective membranes is typically below the commercial benchmark of 5 W/m^2. Taking the inspiration from electrocytes in electric eel, which consist of a large number of sub-nanoscale rectified ion channels that allow unidirectional ion transport with amplified flux, we engineered two types of sub-2 nm-scale metal-organic framework (MOF) and covalent-organic framework (COF)-based ionic diode membranes for osmotic energy harvesting. We show that the two MOF and COF-based heterogeneous membranes can rectify ionic current even in high salt concentration. We then probe application of these membranes in harvesting energy from salinity gradients. Notably, in addition to ultrahigh ion selectivity, these sub-2 nm-scale ionic diode membranes can achieve an unprecedented power density, higher than the commercial benchmark bandgap and outperforms all the state-of-the-art ion selective membranes. Our works would open up new avenues of using pinhole-free MOF and COF membranes towards next-generation highly selective and ultrahigh-performance sustainable energy harvesting.