Development of selective electrodialysis membranes in ion resource recovery

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Abstract:

Selective ion transport is fundamental in many areas of science and technology for purifying ions of interest. In particular, tailoring high-precision separation materials would enable fit-for-purpose recovery of pure water, extract minerals and capture energy from a complex solution environment such as wastewater, seawater, salt lakes, and flow batteries.[1] Driven by the European directives of circular economy, the development of efficient separation technologies are urgently demanded for ion resource recovery. Electro-driven membrane processes using ion exchange membranes show promise in promoting the selective transport of target ions under electrical field [3]., but still faces the fundamental challenge to achieve high precision/selectivity via electrostatic interactions, among ions of similar electrochemical properties.

Thus, this work uses several examples of in-house designed ion exchange membranes with superior properties promoting target ion transport. On one hand, homogenous ion exchange membranes were preprepared via a newly-developed dynamic layer-by-layer (dLBL) method utilizing the cation-π interaction between dopamine chemistry and electrolytes. The resulting membrane demonstrated thin selective layer with up to 6.5 bilayers of alternating charged functional moieties, producing much more homogenous morphology and enhanced stability in repeated separation experiments. The selectivity towards monovalent ions such as K^+ from a mixed solution was attributed to the combined mechanism of ion sieving, electrostatic and affinity interactions between the target ion and functional sites on the membrane surface. On the other hand, heterogenous ion exchange membranes were designed by incorporating 2D porous materials (e.g., MOF) into the membrane matrix. By fine tuning the fabrication conditions (e.g., types and dosage of charged monomers), a series of MOF-based membranes were obtained with high selectivity towards target monovalent ions such as Cl^- vs PO_4^{3-}, and Li^+ vs Mg^{2+} [4, 5]. Finally, the main design principals of target ion selective membranes are summarized, coupled with analysis on ion transport mechanisms.

Keywords: Ion resource recovery; Electro-driven membranes; Permselectivity; Ion recovery efficiency

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