Bilayer metal-organic framework membrane for lithium extraction

Milton Chai[a], Mojtaba Abdollahzadeh[b], Ehsan Hosseini[c], Mohammad Zakertabrizi[c], Munirah Mohammad[d], Hadi Ahmadi[b], Jingwei Hou[a], Sean Lim[e], Asghar Habibnejad Korayem[c], Vicki Chen[a], Mohsen Asadnia[b], Amir Razmjou[d]*

[a] School of Chemical Engineering, University of Queensland, Brisbane, Queensland 4072, Australia

[b] School of Engineering, Macquarie University, Sydney, New South Wales 2109, Australia

[c] Nanomaterials Research Centre, School of Civil Engineering, Iran University of Science and Technology, Tehran 1684613114, Iran

[d] School of Engineering, Edith Cowan University, Joondalup WA 6027

[e] Electron Microscope Unit, Mark Wainwright Analytical Centre, The University of New South Wales, Sydney, NSW, 2052 Australia

* amir.razmjou@ecu.edu.au / milton.chai@uq.edu.au

Abstract:

The demand for lithium is forecasted to increase significantly over the coming years due to the increased penetration of electric vehicles and popularisation of renewable energy. Australia is currently the leading producer and exporter of lithium, and thus with the increasing demand, it is highly desirable to explore additional resources of lithium. Among various processes that can be employed to extract lithium from brine resources, direct lithium extraction using ion-selective membranes has attracted great interest due to the small footprint and modularity of membrane processes. Nevertheless, the development of an ion-selective membrane that can effectively separate chemically similar monovalent ions remains a major challenge. Biological ion channels that transport ions across cell membranes feature angstrom-scale asymmetrical cavity structures, which are the key to achieving highly efficient separation of alkali metal ions from aqueous resources. Inspired by this, this study explored a hierarchically structured bilayer metal-organic framework (MOF-on-MOF) membrane in which energy barriers are implanted in the sub-nanometer pores. The MOF-on-MOF membrane exhibited exceptionally high monovalent ion selectivity ratios of 84 and 80 for K^+/Li^+ and Na^+/ Li^+, respectively (1.14 Li^+ mol m^{-2} h^{-1}). Furthermore, ionic current rectification behaviour was observed, with a rectification ratio as high as 105. The high selectivity is believed to be due to the combined effects of spatial hindrance and nucleophilic entrapment as the ions move across the bilayer MOF-on-MOF film. This work demonstrates a striking advance in developing monovalent ion-selective membranes and has implications in separation, sensing and energy storage technologies.

Keywords: Metal-organic framework, ion separation, ion rectification, lithium recovery