Effects of membrane thickness on the performance of vanadium redox flow batteries

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Proton exchange membranes (PEM) have been successfully employed in vanadium redox flow batteries (VRFB) as the separators which transport charge carrier ions while blocking the crossover of the active species [1]. The proton conductivity and vanadium permeability are considered as two of the most important properties of PEMs for VRFBs [2]. While the proton conductivity determines voltage efficiency of the batteries, the vanadium permeability dictates the coulombic efficiency of the system. However, there is a tradeoff between these two properties, through which the cell performance could be largely optimized. Generally the control of ion exchange capacity (IEC) of PEMs is the first step towards balanced proton conductivity and vanadium permeability after the backbone structure of the PEM is selected [3]. Further modifications such as hybridizing or blending with other desirable components can also lead to better-balanced properties [4].

Among the properties, the membrane thickness is also a key properties in terms of VRFB performance perspective as it dictates the membrane ohmic resistance and mechanical properties such as compressibility and osmotic stability. Moreover, it governs the amount of permeated electrolyte during charge/discharge cycle of the cell. While the mechanical strength of the membranes is guaranteed with the thicker membranes, the voltage efficiency of the system diminishes due to the increased ohmic resistance. However, at the same time, having thicker membranes helps to avoid capacity fade because of unwanted vanadium transport (crossover), which results in improved coulombic efficiency. Therefore, a similar trade-off between coulombic and voltage efficiency as in the proton conductivity and vanadium permeability occurs in the membrane regarding to the thickness of this important component. In order to better understand the role of membrane thickness in the performance of a VRFB, herein the thickness effects of an IEC-optimized PEM are investigated.

Experiments are performed for a PEM membrane that has different thickness. It can be seen from Figure 1 that the coulombic efficiency (CE) of the VRFBs assembled with 28 μm, 45 μm and 80 μm membranes increased with increasing thickness, from 97.9% to 99.1% then to 99.5%. As expected, this is because the electrolyte permeation was suppressed by increasing the membrane thickness. Furthermore, the voltage efficiencies (VEs) of the VRFBs assembled with 28 μm, 45 μm and 80 μm membranes are observed to be 83.0%, 83.7% and 81.0% respectively. This result can be attributed to the fact that while the thicker membrane had the higher ohmic resistance, the thinner membrane had larger short circuit voltage loss. Both limits hinder the VE of the system. Therefore, among the tested membranes, the 45 μm thick membrane appears to have the best balance of these two factors, yielding the highest VE. These observations indicate the importance of membrane thickness for optimizing VRFB performance.

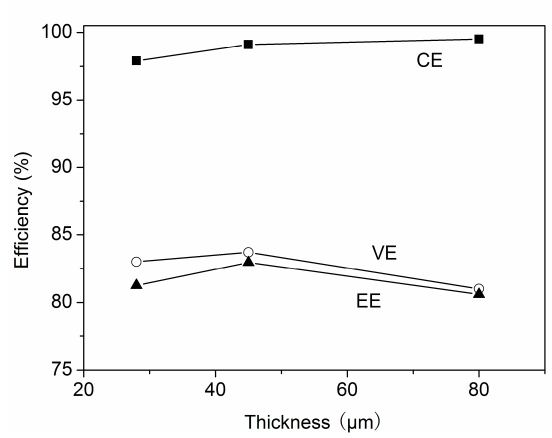

Figure 1. Influence of membrane thickness on coulombic efficiency (CE), voltage efficiency (VE) and energy efficiency (EE) of the selected VRFBs at 80 mA cm^{-2}.

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