Nanoporous Separator Development for Various Redox Flow Batteries at Pacific Northwest National Laboratory

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Redox flow battery (RFB) considered as one of the most promising large-scale stationary energy storage technologies has attracted much attention both academically and industrially (1). RFB demonstrates many attractive advantages, such as separation of energy storage and power output, exceptional design flexibility, excellent scalability and modularity, long service life, high efficiency, *etc.*, making it a well-suitable option to stabilize the power grid and tackle the intermittency of the renewables. However, broad market penetration of RFB is still hindered by critical technical and economic barriers such as long-term operation stability and high cost. The membrane component is one of the major limiting factors. Traditionally used perfluorinated membranes such as Nafion feature high conductivity and excellent chemical stability, but suffer from low ionic selectivity and high cost. Hydrocarbon membranes show attractive performance but their long-term stability remains a concern.

This report summarizes our efforts at PNNL to develop a number of low-cost nanoporous separators for application in various aqueous RFB systems including mixed-acid all-vanadium system and iron-vanadium system (2-5). The separators are estimated to be at least an order of magnitude more inexpensive than Nafion membranes. They have no ion exchange capacity and are composed of silica particles enmeshed in a polymer fibril matrix. The silica particles afford the separators with high hydrophilicity and unique porous structures as transport channels in RFB operation. The polymer component such as polytetrafluoroethylene (PTFE), polyvinylchloride (PVC) and polyethylene (PE) in different separators provide excellent chemical stability to the RFB environments, and sufficient mechanical strength and flexibility for reliable RFB assembly and operation.

Flow cells using the separators deliver energy efficiency comparable to Nafion and exhibit excellent rate capability and great temperature tolerance. In addition, the separators demonstrate great capability of convenient mitigation of capacity decay, enabling long-term stability of RFB operation. Therefore, the separators well combines the necessary membrane requirements of high conductivity, stable energy delivery, good chemical stability and low cost. Especially, use of the separators in RFB systems is expected to significantly reduce the capital and cycle costs. Such a great potential makes these separators promising membrane substitutes to leverage the overall system efficiency at lower capital investments, which will promote the commercial update of these RFB systems.

References

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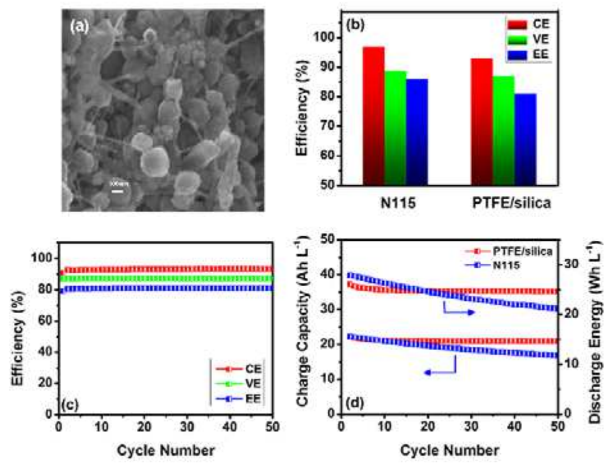

Figure 1. A PTFE/silica nanoporous separator: (a) cross-sectional FESEM of the separator showing microstructure of silica particles enmeshed in a PTFE matrix; (b) flow cell efficiencies; (c) stable flow cell cycling efficiency; (d) cycling charge capacity and discharge energy showing capacity retention. N115 was used as a reference. All tests are done in 2.5M mixed-acid all-vanadium RFB at 50mA·cm^{-2}.