

Anion exchange membranes for vanadium redox flow batteries

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Vanadium redox flow batteries (VRFBs) employ cationic V^{2+}/V^{3+} and VO_2^+/VO^{2+} redox couples as the energy storage media. The electrolytes are stored in external tanks and pumped through an electrochemical cell to store or release energy during battery operation. The carbon-based electrodes and flow fields are separated by an ion exchange membrane or porous separator to keep the redox couples in the anolyte and catholyte isolated. This configuration allows VRFBs to have independent design of cell output and energy storage capacity which yields promising prospects in large scale energy storage applications, such as load leveling of electricity grids and stabilization of intermittent power from renewable energy technologies [1]. VRFBs are considered to be able to afford high energy efficiency and long cycle life. However, the performance of the ion exchange membrane still needs to be improved in regards to its vanadium permeability and resistivity for high performance VRFBs [2].

Ion containing polymer membranes such as cation exchange membranes and anion exchange membranes have received the most attention as membranes for VRFBs [3]. Cation exchange membranes usually have much lower resistivity than anion exchange membranes with similar ion exchange capacity (IEC), however, anion exchange membranes usually have much lower vanadium permeability than cation exchange membranes due to the Donnan exclusion effect [4]. The vanadium permeation is related to the self-discharge of the cell, resulting in low coulombic efficiency and energy efficiency under circumstances where there is significant vanadium ion crossover. In order to develop low self-discharge VRFBs, herein we prepared and characterized three anion exchange membranes based on quaternary ammonium functionalized Radel (QA-Radel) for VRFBs. These polymers with cationic fixed charges are expected to repel the positively charged vanadium species to promote high coulombic efficiency operation.

It can be seen from Figure 1 that the cell with a QA-Radel separator discharged to nearly 100 % capacity, while N212 only discharged to 92.3% capacity. This data means QA-Radel can afford nearly 100% coulombic efficiency, which is a result of its extremely low vanadium permeability. Therefore, vanadium permeation or self-discharge can be overcome by using this type of anion exchange membrane. It can also be seen from Figure 1 that QA-Radel had higher charge voltage and lower discharge voltage than N212, which gives a lower voltage efficiency for the cell with QA-Radel compared to a cell with the N212 membrane. This difference in voltage efficiency is attributed to the higher resistance of QA-

Radel. In order to achieve better cell performance, the resistance of QA-Radel should be lowered while its vanadium permeability should remain low. Increasing the ion exchange capacity is a facile route to lower the resistance of anion exchange membranes, but a significant increase in vanadium permeability can result. Therefore, this work will focus on the tradeoff of conductivity and vanadium permeation in anion exchange membranes designed for VRFBs.

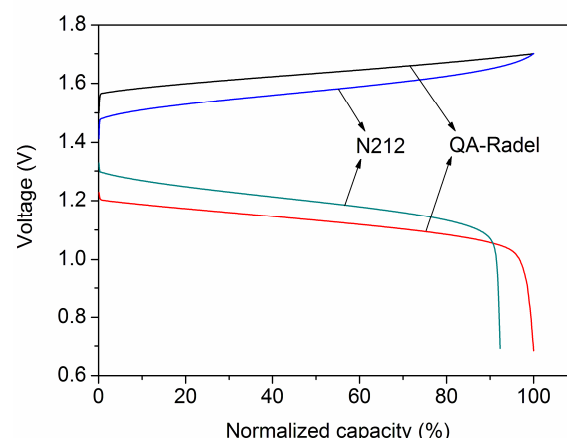


Figure 1. Charge-discharge curves of VRFBs assembled with N212 and QA-Radel at 60 mA cm⁻².

Reference

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