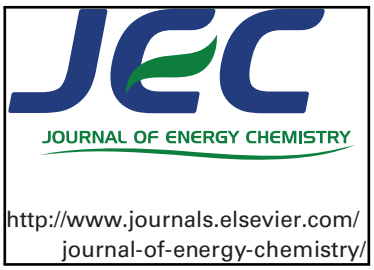

Facile fabrication of amphoteric semi-interpenetrating network membranes for vanadium flow battery applications

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Facile fabrication of amphoteric semi-interpenetrating network membranes for vanadium flow battery applications

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Abstract

For improvement of vanadium redox flow battery (VRB) performance, novel amphoteric semi-interpenetrating membranes (ASIPN) were prepared using poly(ether ether ketone) (PEEK) and polysulfone (PSf), the former bearing sulfonic groups and the latter imidazolium. These two groups form ionic crosslinks between PEEK and PSf; meanwhile, covalent cross links were built between PSf chains with addition of N-(3-aminopropyl)-imidazole. The amphoteric nature of the membrane allows facile proton and anion transport; the IPN structure and the presence of imidazolium cation effectively suppress vanadium ion crossover through the membrane. Therefore, the ASIPN based VRBs show higher coulombic efficiency and energy efficiency than that assembled with pristine SPEEK and Nafion 212 membranes. Our work demonstrates that the ASIPN membranes are promising for VRB applications.

Keywords: Vanadium redox flow battery; ASIPN; Cross-linking; Amphoteric membrane

1. Introduction

The vanadium redox flow battery (VRB) is one of the most promising electrochemical energy storage systems suitable for a wide range of renewable energy applications [1,2]. They have attracted tremendous attention due to high energy efficiency, long cycle life, fast response and flexible design. As one of the key components of VRBs, the separator membrane is to prevent crossmixing of the positive and negative electrolytes and short circuiting of the two half-cell electrodes while allowing the transfer of ions to complete the circuit during cell operation [3].

Currently, the state of the art membranes in VRB is perfluorinated ones such as Nafion.[4,5] They are advantageous over other membranes in terms of ionic conductivity, chemical stability and mechanical strength. However, high vanadium ion permeability due to wide ion channels formed by microphase separation, and high cost limit their widespread commercial application. In view of the above issues, non-fluorinated membranes have received broad attention due to their low cost and high ion selectivity [6–8]. Among them, sulfonated polyether ether ketone (SPEEK) is one of the most extensively studied [9–11]. Several sandwich types of membranes involving SPEEK, polypropylene, tungstophosphoric acid have been prepared and tested in VRB, which showed promising performances.[12] However, their permeation of vanadium ions is still serious although not so high as in Nafion. This is because vanadium cations carry the same charge as protons, and their permeation through sulfonated membrane is inevitable. In this context, anion exchange membranes (AEMs), which are positively charged, can better restrict permeation of vanadium ions because of the Donnan exclusion effect. However, low ionic conductivity of AEMs often led