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N3-butyl imidazolium-based anion exchange membranes blended with Poly(vinyl alcohol) for alkaline water electrolysis

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ABSTRACT

Blended membranes composed of a series of N3-butyl-substituted imidazolium-based poly(1-vinyl-3-imidazole-co-styrene) (PIS), prepared via radical polymerization, and poly(vinyl alcohol) (PVA), were used as anion exchange membranes (AEM) for alkaline water electrolysis (AWE). PISPVAx blend membranes (where x denotes the ratio of imidazolium group and styrene in PIS being 4:6, 3:7, and 2:8) were doped with 6 M KOH solution to prepare OH⁻ conductive AEMs and their thermal and mechanical properties, chemical stabilities, and hydration properties were analyzed. With increasing imidazolium (PIS) ratio, the PISPVAx blend membranes show phase separation between the hydrophobic and hydrophilic polymer chains, and thus, feature well-connected hydrophilic channels. The highest ionic conductivity of 89.7 mS cm⁻¹ was observed for the PISPVA46 membrane when using with 0.5 M KOH solution at 60 °C. The outstanding electrochemical performance of the PISPVA46 membrane, compared with those of PISPVA37 and PISPVA28, was reflected in a current density of 547.7 mA cm⁻² at a cell voltage of 2.0 V. The higher imidazole ratio in the blend membrane produced an increase in the elongation at break and hydration property, such as water uptake and IEC, that obviously enhances the ion conducting capability of the resulting AEMs. Additionally, the KOH molecules were introduced into the membrane through PVA, resulting in high KOH uptake. Therefore, the PISPVAx blend membranes are useful candidates for anion exchange membrane water electrolysis (AEMWE) systems.

1. Introduction

Water electrolysis (WE) is a well-developed technology for the conversion of water into hydrogen (H₂) and oxygen (O₂). WE technology can be classified as conventional alkaline water electrolysis (CAWE) and polymer membrane electrolysis which uses proton exchange membranes (PEMs) or anion exchange membranes (AEMs) [1–3]. The CAWE can employ inexpensive, non-precious metals as catalysts, showing long-term stability and high electrochemical efficiency (Fig. 1(a)) [1,4]. The CAWE commonly uses a high liquid electrolyte concentration of 30–40% KOH and a porous separator to isolate the O₂ and H₂ gases and prevent intermixing of the catholyte and anolyte to obtain high gas purities and high current efficiencies. The porous separator consists of ceramic oxides like asbestos and potassium titanate or polymers like polysulfone, poly(phenylene sulfide), and poly(tetra fluoroethylene) [5,

6]. The CAWE is very sensitive to atmospheric CO₂ and reacts easily with a hydroxyl ion (OH⁻) to form K₂CO₃, which can block the holes in the gas diffusion layer (GDL) to reduce the ion conduction and cell performance in anion exchange membrane fuel cell (AEMFC) as well as anion exchange membrane water electrolysis (AEMWE) [1,7–9].

Replacing the porous separator with a polymer membrane offers various advantages, such as eliminating problems caused by fuel gas crossover, area resistances, and bubble formation [6]. WE based on polymer membrane, such as PEMs or AEMs, can be operated with distilled water (DI) because these electrolyzers comprise an ion-exchange membrane, in contrast to a porous separator electrolyzer. Proton exchange membrane water electrolysis (PEMWE) performs the same function as combining the KOH electrolyte with the porous separator (Fig. 1(b)). The electrochemical performance of PEMWE is advantageous over CAWE, as its theoretical efficiency reaches 80–90%.

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