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High-performance multiblock PEMs containing a highly acidic fluorinated-hydrophilic domain for water electrolysis

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ABSTRACT

The present paper describes the design and evaluation of novel hydrophilic–hydrophobic poly(arylene ether sulfone) (PAES) multiblock copolymers for their synergistic effects upon transport properties and their potential use in proton exchange membrane water electrolysis. The multiblock copolymers are prepared via a coupling reaction between (i) a hydrophilic segment consisting of a disulfonated quinone fluorinated biphenyl group that contains fluorine moieties next to the sulfonated groups to increase the acidity, and (ii) hydrophobic segments composed of non-sulfonated biphenyl sulfone to provide dimensional stability. Two different lengths (molecular weights; 5 k and 10 k, where k represents 10^3 g mol^{-1}) of hydrophobic segments are used to investigate the effects of the membrane properties compared with those of Nafion® and PAES random copolymer (i.e., BPSH40). Atomic force microscopy images of the BPSH40 and multiblock membranes are shown to agree closely with a mesoscale simulation, thus confirming the importance of the morphological effect upon the transport properties. Moreover, the multiblock copolymer with a higher proportion of hydrophilic segments (10 k–5k) was shown to provide enhanced performance (3.41 A cm^{-2} at 1.9 V) compared to the multiblock copolymer with equal proportions of hydrophilic and hydrophobic segments (10 k–10 k) due to the greater continuity of nano-sized ionic channels.

1. Introduction

Hydrogen (H_2) is a promising future energy carrier or fuel with a high energy density per unit mass relative to other energy storage materials such as methane, diesel, and several types of battery [1]. Although water electrolysis (WE) is an eco-friendly technology for producing high-purity H_2, the cost of electricity needed for water splitting has impeded its large-scale development. The most economically viable way to produce H_2 while reducing fossil fuel consumption and CO_2 emissions would use renewable energy sources such as solar panels and wind turbines, referred to as the "power-to-gas" approach. Due to its high current density, proton exchange membrane water electrolysis (PEMWE) is the only technology with a sufficiently fast transaction for coupling with renewable energy production devices and is a relatively compact electrolysis technology [2,3]. Thus, H_2 production via the PEMWE process using emission-free renewable power sources holds promise for advancing the emerging hydrogen economy and promoting its efficiency and economic viability in the near future. However, the cost of PEMWE system components and materials must be overcome.

The principle of PEMWE operation is that the water supplied to the anode is oxidized by a catalyst such as iridium (IV) oxide (IrO_2) to separate the protons (H^+) and electrons and, thus, generate oxygen (O_2) gas. The generated H^+ ions pass to the cathode along the proton exchange membrane (PEM) and react with electrons to produce hydrogen gas (H_2), as shown schematically in Fig. 1a. In the PEMWE system, the PEM functions as a proton conductor for H_2 production and as a separator for preventing the crossover of the different gases generated on

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