

Anion exchange polymer electrolyte membranes for alkaline fuel cells and water electrolyzers

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Introduction

Research and development directed towards anion exchange membranes (AEMs) has grown substantially over the past decade for polymer electrolyte membrane alkaline fuel cells (AEMFCs). (1) Non-platinum group metal catalyst can be utilized under alkaline conditions making AEMFCs an attractive proposition. (2, 3) Although most recent research applied to AEMs has focused on AFCs, there are other applications for incorporating AEMs into other electrochemical energy technologies. For example, water electrolyzers operated in alkaline environments can utilize non-platinum based electrocatalysts (e.g., metal oxide pyrochlores) for the oxygen evolution reaction (OER). (4, 5) The AEM based membrane electrode assembly for water electrolysis eliminates the need for feed water streams containing alkali. Also, operating the electrolyzer in alkaline environments allows for the use of stainless steel hardware.

This talk will discuss our work on improving ionic conductivity and alkaline stability for polysulfone (PSF) and polyphenylene oxide (PPO) type AEMs. Specifically, 2D NMR will be showcased as a powerful tool for elucidating cation chemistry and polymer backbone degradation in alkaline media. Rotating disk electrode ORR and OER results for different types of pyrochlore electrocatalysts will be discussed, and alkaline fuel cell and water electrolyzer performance will be presented.

Experimental

Preparation of PSF based AEMs and ionic conductivity and fuel cell testing are reported in our previous work. (6)

Preparation of PPO AEMs was carried out via free radical bromination of PPO. 8 wt% of PPO in chlorobenzene was added to a round bottom flask equipped with an egg stir bar and reflux condenser. The temperature of the solution was raised to 130 °C. N-bromosuccinimide (NBS) was added to the bulb flask followed by a subsequent addition of azobisisobutyronitrile (AIBN) (5% weight equivalent to dissolved PPO). NBS amount was varied to control the degree of bromomethylation of the PPO backbone. The brominated PPO (BrPPO) was dissolved in dry n-methyl-2-pyrrolidone with an organic base reagent (like quinuclidine - ABCO) to prepare quaternary ammonium groups. The AEM solution was casted on to a glass plate and the solvent was evaporated at 70 °C for 24 hours to attain a thin film.

Preparation of the pyrochlore based materials was done following the alkaline solution technique of Horowitz and coworkers. (8) Precipitation and recrystallization at moderate temperatures results in mixed metal oxide materials with relatively high surface areas (20-90 m² g⁻¹).

Water electrolyzer testing was conducted at 50 °C using a 25 cm² active cell area. The anode graphite plate was replaced by a titanium plate to avoid carbon corrosion. The electrolyzer was operated using ultrapure

deionized water (18 MΩ) circulated through the anode side via a peristaltic pump (at 50-100 mL min⁻¹).

Results

Figure 1 presents the hydroxide ionic conductivity of PPO-ABCO AEMs. The IEC for PPO-ABCO AEM was 1.5 mmol g⁻¹. The relatively high conductivity for this homogenous AEM at this IEC was ascribed to the high basicity of the ABCO and the electron donating characteristics of the PPO backbone.

Figure 2 provides water electrolyzer performance using an AEM separator and electrode binder. The AEM was PSF with quaternary benzyl trimethylammonium cations. The MEA for the electrolyzer used a platinum black anode and lead ruthenate pyrochlore for the cathode (~2.5 mg catalyst cm⁻²). Adequate electrolyzer performance was attained with a non-optimized AEM electrolyte.

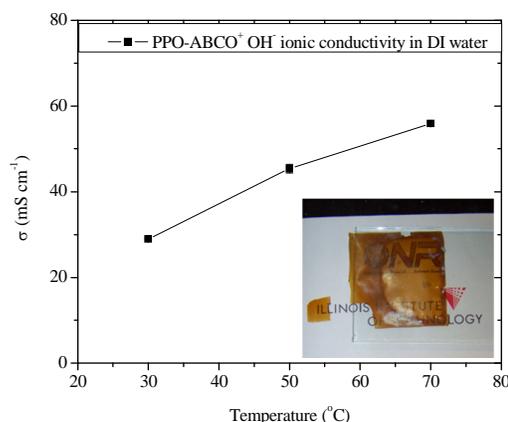


Figure 1: Hydroxide ion conductivity of PPO-ABCO⁺ AEM with a picture of the PPO-ABCO⁺ membrane.

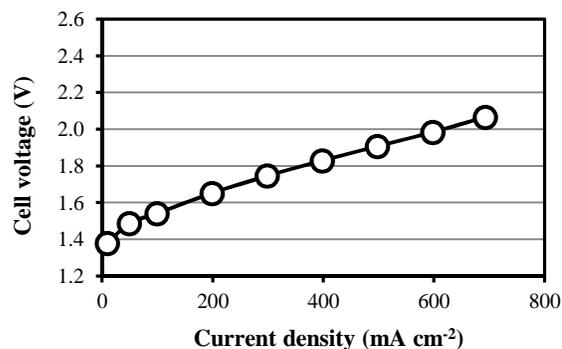


Figure 2: Water electrolyzer polarization curve using an AEM based MEA

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