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# Effect of increasing hydrophilic–hydrophobic block length in quaternary ammonium-functionalized poly(ether sulfone) block copolymer for anion exchange membrane fuel cells

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## ABSTRACT

Quaternary ammonium-functionalized poly(ether sulfone) (QA-PES) block copolymers with different block chain lengths were prepared as anion exchange membranes. Copolymers with similar hydrophilic/hydrophobic block ratios and hence similar IEC values, but with various oligomer block chain lengths were synthesized to investigate, for the first time, how the length of each oligomer included in the block copolymers affected the chemophysical and electrical properties of the obtained QA-PES anion exchange membranes. The copolymer with the optimal hydrophilic:hydrophobic block chain length (QA-PES-16-30) showed good phase separation. This led to the optimal formation of ionic clusters, and the highest ion conductivity of  $81.01 \text{ mS cm}^{-1}$  at  $80^\circ\text{C}$ , as well as excellent physicochemical stability even after alkaline treatment in 1 M NaOH at  $60^\circ\text{C}$  for 500 h, due to strengthening of the hydrophobic regions, strongly suggesting that the block chain length of each of the hydrophilic and hydrophobic blocks can affect the physicochemical properties of the polymer membranes. The  $\text{H}_2/\text{O}_2$  single cell performance using the QA-PES-16-30 membrane showed a maximum power density of  $260 \text{ mW cm}^{-2}$ , much higher than that obtained from the Tokuyama A201.

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## Introduction

Increasing air pollution and global warming, resulting from the consumption of fossil fuels, has stimulated studies to develop alternative energy sources. Fuel cells in particular have attracted attention because they generate electricity via the reaction of hydrogen and oxygen, leaving water as the only byproduct. In recent decades, numerous studies have investigated the proton exchange membrane-based fuel cell (PEMFC), and relevant technologies have already advanced to commercialization stage. However, the PEMFC still has many technological limitations, including the high price of the preferred Pt catalyst and the inevitable decline in performance produced by so-called ‘CO-poisoning’ which results from the accumulation of carbon

monoxide (CO) generated during the process to obtain hydrogen gas [1,2].

Recent reports have highlighted the anion exchange membrane-based alkaline fuel cell (AEMFC), which conducts hydroxide ions ( $\text{OH}^-$ ) instead of the  $\text{H}^+$  ion (proton) using an anion exchange membrane (AEM). The AEMFC can also use Ni or Ag, which are less expensive metals than Pt, as catalysts [3–8]. However, AEMFC still has disadvantages: the ion conductivity of the AEM is low, primarily because hydroxide ions are much larger than protons, and the high nucleophilicity of the hydroxide ions can degrade the polymer backbone or the ion-conducting groups, reducing the cell performance. AEM degradation by  $\text{OH}^-$  is further accelerated under actual AEMFC working conditions: high temperature (above  $80^\circ\text{C}$ ) and high pH (alkaline). The present goal is to develop an AEM with high ion conductivity as well as high alkaline stability.

The polymers typically employed as the AEM are composed of an ion-conducting (or ion exchange) group and a polymer backbone. The most commonly used ion-conducting groups include quaternary ammonium [9–12], imidazolium [13,14], piperidinium [14,15], morpholinium [14,16], sulfonium [17],

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