

Conductivity measurements of a radiation grafted anion exchange membrane in hydroxides, bicarbonates and carbonates forms for fuel cell applications

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Introduction

Recently, anion exchange membrane (AEM) fuel cells have gained interest from many researchers as an alternative to proton exchange membrane (PEM) fuel cells. The use of AEM in fuel cells has shown to reduce fuel crossing-over, provide fuel flexibility, eliminate the requirement of precious metal as catalyst due to high reaction kinetics at basic conditions, and decrease cost [1–3]. However, compared to PEMs such as Nafion®, AEMs still need performance optimization. There are still many areas that need investigation to make them viable for fuel cell applications. One of the major debatable issues is the stability and performance of alkaline AEMs when exposed to atmospheric carbon dioxides. This report compared the conductivity performance of alkaline to carbonates or bicarbonates forms of AEMs as a function of temperature at static %RH when exposed to atmospheric CO₂.

Experimental

Electrochemical Impedance spectra for radiation grafted AEMs, provided by John Varcoe from University of Surrey, were measured using a 4-probe test cell with Pt electrodes connected to a BioLogic VMP3 Potentiostat over a 1 Hz - 100 kHz frequency range. The cell was placed in a TestEquity®(Solatron 1007H Model) environmental chamber to control the temperature and %RH of a sample. The spectra were fitted to Nyquist plot in EC-Lab software to get a membrane resistance which was used to calculate in-plane conductivity using the following relation:

$$\sigma = \frac{l}{R w t}$$

where l is the distance between two electrodes, R is the membrane impedance, w and t are the width and thickness of the membrane.

Results and conclusions

We observed that the conductivity of an alkaline AEM suffers dramatically when exposed to atmospheric CO₂. The conductivity of the alkaline AEM is lower compared to the conductivity of both the carbonates and the bicarbonates forms of the AEM (Figure 1). This reduced conductivity performance could be because of the increased effective anionic size of carbonates and bicarbonates anion coexistence in the membrane. This acid base interplay reaction between carbonates and bicarbonates ions in the AEM hinders the anionic transport. This compromises the conductivity of AEM in hydroxides form. This study correlates with previous study done by Yanagi et al[4]. A slight higher activation energy, calculated using the Arrhenius equation, for ion transport in OH⁻ form compared to HCO₃⁻ form, shown in Table 1, indicates a greater energy barrier for ionic transport when alkaline forms of AEMs is exposed to atmospheric CO₂.

Conductivity dependency study on a relative humidity at a constant temperature (Figure 2) showed a strong conductivity correlation to the presence of water. The conductivity difference between alkaline and bi/carbonates forms of AEMs at constant temperature increased with increased in water content in the membrane.

Table 1. Activation energies calculated using Linear regression

Anions	HCO ₃ ⁻	CO ₃ ²⁻	OH ⁻
Ea(kJ/mol)	23.1 ± 1.9	23.3 ± 2.7	24.2 ± 0.1

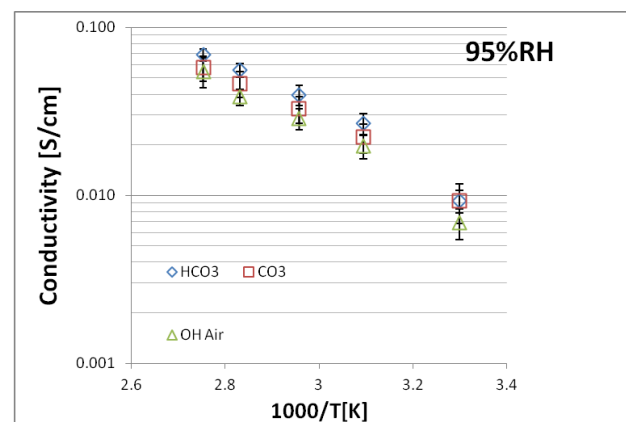


Figure 1. In-plane conductivity of AEMs in HCO₃⁻, CO₃²⁻ and OH⁻ forms at static humidity of 95%

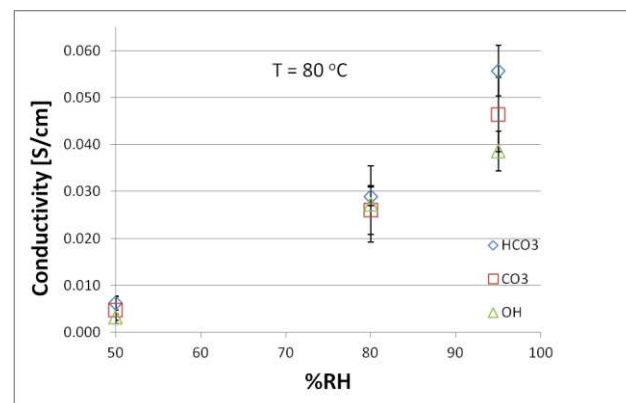


Figure 2. In-plane conductivity of AEMs in HCO₃⁻, CO₃²⁻ and OH⁻ forms as a function of %RH at 80 °C

References

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