Low-cost non-fluorinated membranes for fuel cells

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INTRODUCTION

Energy is one of the most important factors that will influence the shape of society in the 21st century. Fuel cells are electrochemical energy converters, transforming chemical energy directly into electricity. Fuel cells are the main zero emission energy converters fed with hydrogen or renewable fuels like methanol and ethanol to power vehicles, portable devices or to supply electricity to buildings. Fuel cell technology will forever change our concept of alternative energy systems and will become the driver of the next growth wave of the world’s economy.

A proton conductive membrane is the core of the polymer electrolyte membrane fuel cell (PEMFC). Presently, Nafion® membranes are widely used in PEMFC. However, the high cost, low operation temperature (<80°C), propensity for dehydratation, high methanol crossover, and environmental recycling uncertainties of Nafion® and other similar fluorinated membranes are limiting their widespread commercial application in PEMFC and DMFC [1-3]. Therefore, developing cheaper membranes with low methanol crossover have become an active area of research.

We developed low-cost proton conductive membranes based on non-fluorinated polymer. The membranes are thermally and chemically stable, mechanically strong, highly proton conductive and have low fuel crossover.

EXPERIMENTAL

The starting material, sulfonated-sulfonated poly (2,3-phthalido-p-phenylene-oxy-p-phenylene-oxy-phenylene) (SsPEEK) was prepared by reducing sulfonated-chlorosulfonated PEEK-Wc (ScPEEK-Wc).

PEEK-Wc solution in NMP with magnetic stir. The solution was cast on a glass Petri dish. The solvent was then removed in a vacuum oven. The membranes were peeled off from the Petri dish. An uncross-linked membrane was also prepared, but was water soluble.

Results and discussion

After cross-linking, the membranes become water insoluble. The water uptake of the cross-linked membrane was 44% at room temperature and reached 110% at 80°C. Although, the value of water uptake at 80°C was tolerant to reduce the value of water uptake is indispensable for the membrane used in DMFC at higher temperature such as 80°C. The cross-linked membrane can be reduced by reducing the thickness due to its extremely low methanol permeability.

The proton conductivity of covalent-ionically cross-linked PEEK-Wc membrane was 2.1×10⁻² cm⁻¹ at 20°C and reached to 4.1×10⁻² cm⁻¹ at 80°C. The proton conductivity of the cross-linked membrane is lower than that of Nafion® 117 which was measured at the same condition, however, the resistance of the cross-linked membrane can be reduced by reducing the thickness due to its extremely low methanol permeability.

Figure 1: ScPEEK-Wc and SsPEEK-Wc

Conveniently cross-linked membrane. The cross-linker was added to the ScPEEK-Wc solution in NMP with magnetic stir. The solution was cast on a glass Petri dish. The solvents were then removed in a vacuum oven. The membranes were peeled off from the Petri dish. An uncross-linked membrane was also prepared, but was water soluble.

Table 1: the comparative properties of the cross-linked membranes

<table>
<thead>
<tr>
<th>Membrane</th>
<th>Water uptake 20°C (cm² s⁻¹)</th>
<th>Methanol permeability 1 atm (cm² s⁻¹ cm⁻³)</th>
<th>Conductivity 30°C (S cm⁻¹)</th>
<th>Methanol permeability 80°C (cm² s⁻¹ cm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-linking</td>
<td>23</td>
<td>2×10⁻²</td>
<td>2×10⁻²</td>
<td>5×10⁻³</td>
</tr>
<tr>
<td>Ionically cross-linked</td>
<td>44</td>
<td>110</td>
<td>2×10⁻²</td>
<td>5×10⁻³</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The low-cost cross-linked membrane shows reduced water uptake, reduced methanol permeability and enhanced thermal stability, but slightly-reduced proton conductivity compared with that of covalent cross-linked PEEK-Wc.

REFERENCES