Polybenzimidazole membranes for zero gap alkaline electrolysis cells

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Citation (APA):
Membranes of m-PBI doped in KOH (aq), 15-35 wt%, show high ionic conductivity in the temperature range 20-80 °C. In electrolysis cells with nickel foam electrodes m-PBI membranes provide low internal resistance. With a 60 µm membrane thickness, m-PBI membranes of aqueous KOH at varying temperatures are used to demonstrate m-PBI in zero gap electrolysis cells. Membranes provide low internal resistance, which is achieved at 2.25 mS/cm for 20 wt% KOH at room temperature [1].

Current-voltage-curves are presented in Figure 4. Data were recorded by scanning the potential from 1.2 to 2.5 V at 2.5 mV/s. The cells were operated at 80 °C. The cell house and external setup is displayed in Figure 5, on the right. Aqueous KOH with concentration identical to the doping solution is circulated on both sides.

Novel electrode concepts

Hydrogen evolution

Increasing the active surface area of nickel catalysts is an efficient way to improve the hydrogen evolution activity. This is commonly done by using Raney catalysts, or by immobilizing nickel powder through the use of a binder, e.g. PTFE, or both [3].

We are using m-PBI polymer as a binder to make porous electrodes. The good adhesion stability and hydrophilic properties make this an interesting binder for alkaline electrolysis in particular.

So far, we have prepared electrodes by first dissolving ~5 wt% Fe-doped nickel hydroxide and adding nickel powder to form a viscous mixture. The mixture was applied by a dip-coating procedure, in which nickel foam pieces were briefly submerged and otherwise left to dry in air.

A polarization curve for such an electrode is presented in Figure 6, compared to a non-coated nickel foam electrode.

Oxygen evolution

Increasing the active surface area of nickel does not seem to have the same effect on the OER compared to the HER, and stability issues are more severe for OER. However, recent research have shown that Fe-doped nickel hydroxide is a very active OER catalyst [4].

Electrodes can be made in various ways, here, Figure 7, an electrode prepared by a hydro thermal process using urea, and nickel and iron nitrates is presented. This demonstrates a huge potential for overall cell improvements.

Cell polarization

For zero gap electrolysis cell measurements, m-PBI membranes were equilibrated in aqueous KOH at a given concentration over night prior to cell assembly. Electrodes used were pressed (thickness ~ 210 µm) nickel foam. Figure 3.

Current-voltage-curves are presented in Figure 4. Data were recorded by scanning the potential from 1.2 to 2.5 V at 2.5 mV/s. The cells were operated at 80 °C. The cell house and external setup is displayed in Figure 5, on the right. Aqueous KOH with concentration identical to the doping solution is circulated on both sides.

Figure 3. Cell polarization at 80 °C with m-PBI membranes at different KOH (aq) concentrations. Membrane thickness: 30 µm. Thickness of Zrfilm is about 500 µm.

Figure 4. Cell polarization at 80 °C with m-PBI membranes at different KOH (aq) concentrations. Membrane thickness: 500 µm.

Figure 5. Cell polarization at 80 °C with m-PBI membranes at different KOH (aq) concentrations. Membrane thickness: 30 µm. Thickness of Zrfilm is about 500 µm.

Oxygen evolution polarization curves. Conditions: 20 wt% KOH and room temperature. Scan rate 2 mV/s.

Figure 6. Oxygen evolution polarization curves. Conditions: 20 wt% KOH and room temperature. Scan rate 2 mV/s.

Figure 7. Oxygen evolution polarization curves. Conditions: 20 wt% KOH and room temperature. Scan rate 2 mV/s.

Table 1: Comparison of different PBI membranes for alkaline electrolysis.

<table>
<thead>
<tr>
<th>Membrane Type</th>
<th>KOH Concentration</th>
<th>Conductivity (mS/cm)</th>
<th>Stability (h)</th>
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</thead>
<tbody>
<tr>
<td>m-PBI</td>
<td>15  wt% KOH</td>
<td>148</td>
<td>&gt;18000</td>
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<td>&gt;12000</td>
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<td>&gt;6000</td>
</tr>
<tr>
<td>m-PBI</td>
<td>35  wt% KOH</td>
<td>160</td>
<td>&gt;4000</td>
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References