Polybenzimidazole membranes for zero gap alkaline electrolysis cells

Kraglund, Mikkel Rykær; Aili, David; Christensen, Erik; Jensen, Jens Oluf

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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 in the temperature range 20-80 °C, 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 at 80 °C, conductivity is achieved at 2.25 mS/cm at 80 °C. While the uncertainty is largest in the 15-35 wt% KOH concentration range where the conductivity peaks, there is a trend that conductivity peaks near 20-25 wt%, which is lower than for bulk solution. A polarization curve for such an electrode is presented in Figure 6, compared to a non-coated nickel foam electrode. Figure 6.

A promising ion-solvating polymer is poly(2,2’-(m-phenylene)dicarboxylate) (m-PBI). When equilibrated in aqueous KOH solution the polymer deprotonizes, and at >15 wt% KOH (aq) the potassium form predominates [1]. Deprotonization of m-PBI happens at high pH and the potassium form is predominantly in KOH (aq) solutions of more than 15 wt% KOH.

Figure 3 shows measured conductivity of m-PBI membranes in a 210 µm thick porous PTFE cell with 2 expanded nickel mesh electrodes. Figure 2. Temperature was controlled by placing the assembly in a heating cabinet. Electrochemical impedance spectra were recorded, and the resistance taken as $R_{\text{ct}} = R_{\infty} - 0.02$. Membrane conductivity, $\sigma$, was found by subtracting a blank sample measurement.

![Image](image-url)

**Figure 3**. Measured conductivity, $\sigma$, of m-PBI and bulk solution at different concentrations of aqueous KOH at varying temperatures [1].

Conductivity of the m-PBI membranes were measured in a laboratory PTFE cell with 2 expanded nickel mesh electrodes. Temperature was controlled by placing the assembly in a heating cabinet. Electrochemical impedance spectra were recorded, and the resistance taken as $R_{\text{ct}} = R_{\infty} - 0.02$. Membrane conductivity, $\sigma$, was found by subtracting a blank sample measurement.

While the uncertainty is large in the 15-35 wt% KOH concentration range where the conductivity peaks, there is a trend that suggests a conductivity peak near 20-25 wt%, which is lower than for bulk solution. At 25 wt%, we measure 146 mS/cm at room temperature and 255 mS/cm at 80 °C.

Previous measurements have shown a peak conductivity of 130 mS/cm for 20 wt% KOH at room temperature [1].

![Image](image-url)

**Figure 4**. Membrane conductivity at 80 °C with m-PBI membranes at different KOH (aq) concentrations. Lines are predictions of a proton solubility model. Membrane thickness in the range 80-160 µm. Thickness of Zirfon is about 950 µm.

Novel electrode concepts

**Hydrogen evolution**

Increasing the active surface area of nickel catalysis 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 alkaline stability and hydrophilic properties makes this an interesting binder for alkaline catalysis in particular.

So far, we have prepared electrodes by first dissolving ~5 wt% m-PBI and 5 wt% ZrO$_2$-PBI membranes at different KOH (aq) concentrations. The mixture was applied by a dip-coating procedure, in which nickel foam pieces was briefly submerged and otherwise left to dry in air.

A polarization curve for such an electrode is presented in Figure 7, compared to a non-coated nickel foam electrode.

![Image](image-url)

**Figure 5**. Oxygen evolution polarization curves. Conditions: 20 wt% KOH and room temperature. Scan rate 2 mV/s. CE: Large nickel mesh surrounding the WE and RE. WE: Biscrystal Hydrogen Electrode.

### Hydrogen evolution

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 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.

### Oxygen evolution

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

![Image](image-url)

**Figure 6**. Hydrogen evolution polarization curves. Conditions: 20 wt% KOH and room temperature. Scan rate 2 mV/s. CE: Large nickel mesh surrounding the WE and RE. WE: Biscrystal Hydrogen Electrode.

### References