A high conductivity ultrathin anion-exchange membrane with 500+ h alkali stability for use in alkaline membrane fuel cells that can achieve 2 W cm⁻² at 80 °C

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This document provides additional data in support of the main article

**Fig. S1** The 4-probe (in-plane) conductivities of LDPE15-AEM and LDPE25-AEM on the chloride anion forms submerged in water. Error bars are from measurements on \( n = 3 \) samples of each anion form of the AEM (some error bars are smaller than the symbols).

**Fig. S2** A 500 h ex situ stability test where LDPE15-AEM was maintained in the OH⁻ form at 80 °C in a N₂ (CO₂-free, RH = 100%) gas flow. The extended linear regression to 3500h is shown (dotted line) with the best- and worst-case scenarios donated with the dashed lines (based on the standard errors of the linear regression).
Fig. S3 The scanning electron microscope image (SEM) and energy-dispersive X-ray spectroscopy (EDX) maps of a sample of the surface of the cathode electrode containing the Pt/C electrocatalyst (40% wt. metal content, 0.40 mg cm\(^{-2}\) metal loading) and the ETFE-based radiation grafted AEI ionomer powder (20% wt. in electrode, IEC = 1.26 ± 0.06 mmol g\(^{-1}\)). These were recorded using a Noran system seven (ver. 3.1) ultradry SSD X-ray detector coupled to a JSM-7100F Field Emission SEM. Magnification = 1000×.
Fig. S4 The scanning electron microscope image (SEM) and energy-dispersive X-ray spectroscopy (EDX) maps of a sample of the surface of the cathode electrode containing the Ag/C electrocatalyst (40% wt. metal content, 0.86 mg cm\(^{-2}\) metal loading) and the ETFE-based radiation grafted AEI ionomer powder (20% wt. in electrode, IEC = 1.26 ± 0.06 mmol g\(^{-1}\)). These were recorded using a Noran system seven (v. 3.1) ultradry SSD X-ray detector coupled to a JSM-7100F Field Emission SEM. Magnification = 1000×.
Fig. S5 The scanning electron microscope image (SEM) and energy-dispersive X-ray spectroscopy (EDX) maps of a sample of the surface of the cathode electrode containing the FeCoPc/C electrocatalyst (3% wt. metal content, <0.01 mg cm\(^{-2}\) metal loading) and the ETFE-based radiation grafted AEI ionomer powder (20% wt. in electrode, IEC = 1.26 ± 0.06 mmol g\(^{-1}\)). These were recorded using a Noran system seven (v. 3.1) ultradry SSD X-ray detector coupled to a JSM-7100F Field Emission SEM. Magnification = 1000×. Note that the Fe-based EDX map does reliably detect the presence of Fe in the electrode but the presence of Fe was previously proven by XANES and EXAFS [1].
Fig. S6 Surface SEM for a sample of LDPE15-AEM recorded before and after the 500 h 80 °C ex situ stability test (presented in Fig. 3 in the main article). A 2 nm Au coating (75 mA) was applied to the surface of each sample. The scale bars represent 1 μm.

Table S1 Comparison of the key grafting conditions used to synthesise LDPE15-AEM and LDPE25-AEM.

<table>
<thead>
<tr>
<th>AEM</th>
<th>LDPE15-AEM</th>
<th>LDPE25-AEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafting mixture temperature / °C</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>Grafting time / h</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>IEC / mmol g⁻¹</td>
<td>2.54 ± 0.21</td>
<td>2.87 ± 0.05</td>
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</table>

Table S2 EDX data for a sample of LDPE15-AEM (average of \( n = 3 \) EDX spectra on different areas of the same sample) recorded before and after the 500 h 80 °C ex situ stability test (presented in Fig. 3 in the main article). The post-degradation AEM was converted back the Cl⁻ form before EDX analysis to allow comparison with the Cl⁻ form pre-degraded AEM. The data was corrected by removal of Au contents from the percentages in the table (a 2 nm Au coating was applied to the surface of each sample for SEM/EDX). These EDX experiments were not sensitive enough to detect the amine-related N content in these AEMs. Note that unlike the (bulk) conductivity, IEC and Raman data presented in the main text, EDX data is biased towards the surface of the AEMs, where a higher level of degradation is expected.

<table>
<thead>
<tr>
<th>Element Line</th>
<th>Weight %</th>
<th>Atom %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start (0 h)</td>
<td>End (500 h)</td>
</tr>
<tr>
<td>Cₖ</td>
<td>72.4 ± 1.2</td>
<td>80.7 ± 0.8</td>
</tr>
<tr>
<td>Clₖ</td>
<td>27.6 ± 2.9</td>
<td>19.3 ± 3.1</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

References to ESI: