Development of high-performance anion exchange membrane fuel cell using poly(isatin biphenylene) with flexible heterocycle quaternary ammonium cations

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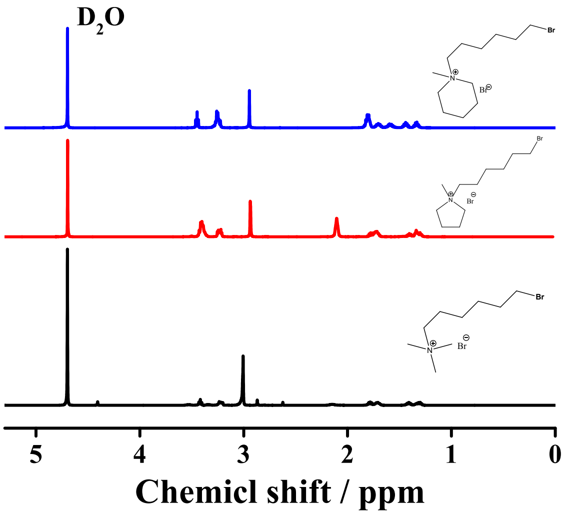


Fig.S1 ^{1}H-NMR spectra of QA, Pyr and Pip (Br^- form)

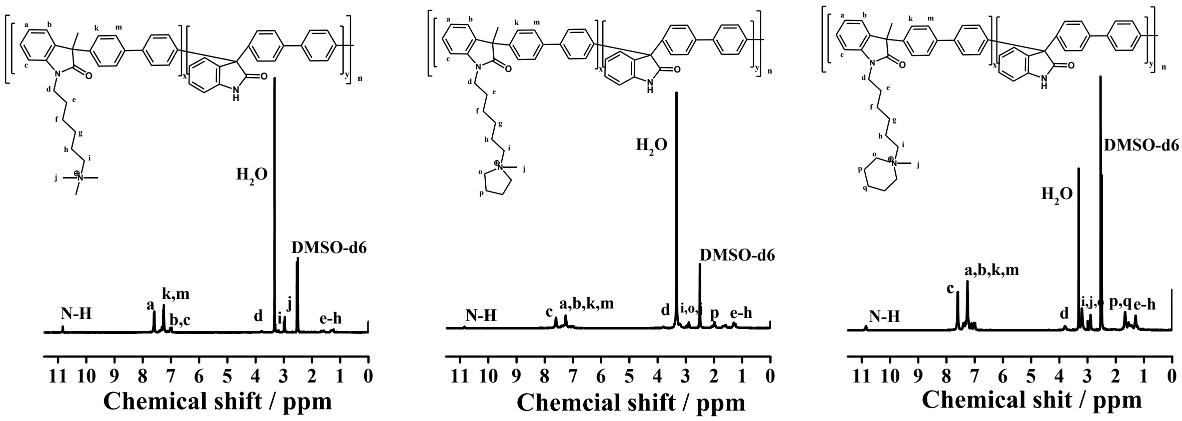


Fig.S2 ^{1}H-NMR spectra of QAPIB, PyrPIB and PipPIB (Br^- form)

Peaks a, b, c, k and m correspond to the protons on aromatic ring. Peaks d correspond to the $-CH_2-$ which is close to the N-H of isatin. Therefore, the degree of grafting for F-PIBs was calculated by using equation:

$$\frac{Area_d}{Area_{(a+b+c+k+m)}}/0.1667 \qquad \text{...} \qquad (1)$$

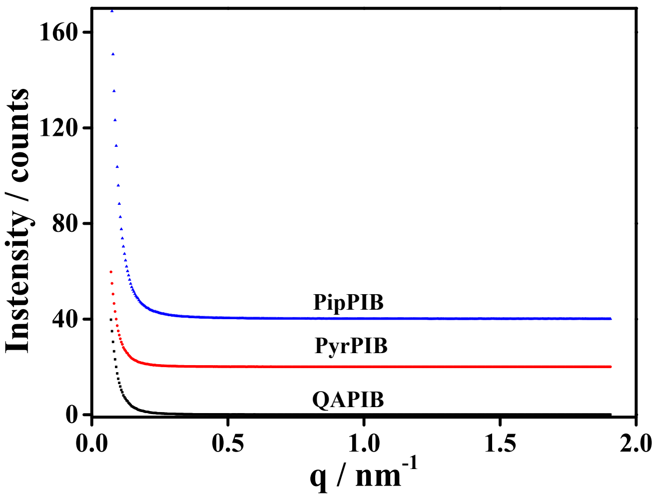
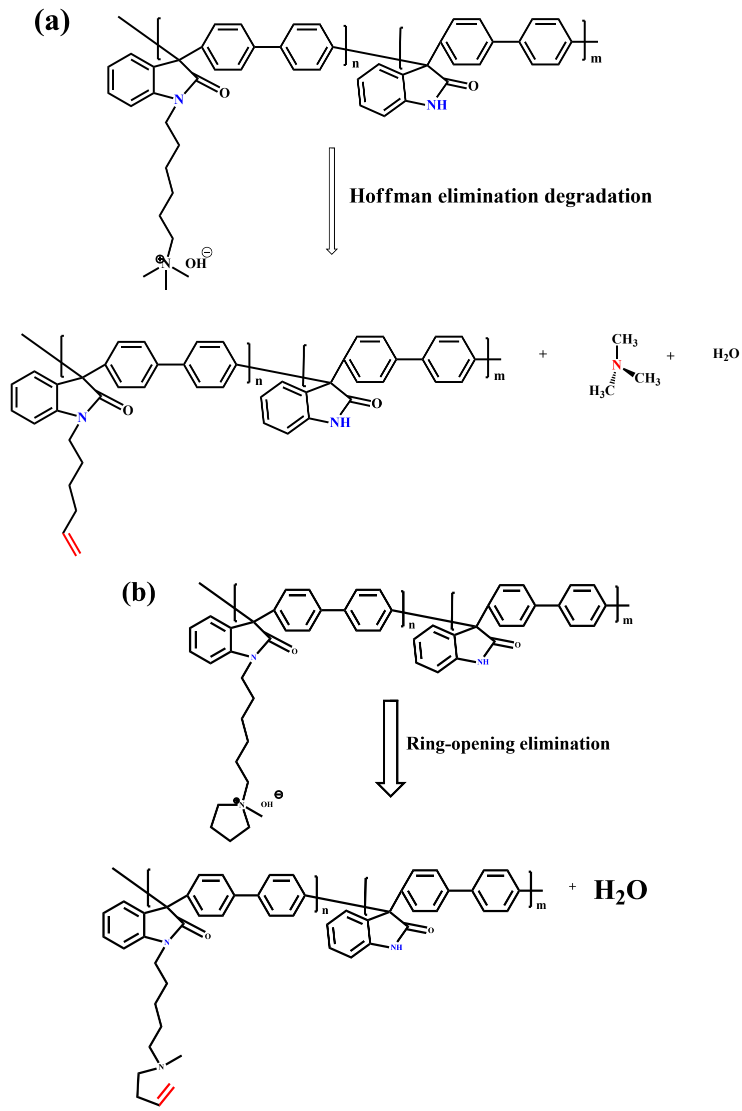


Fig.S3 SAXS profiles of the PIB-based AEMs



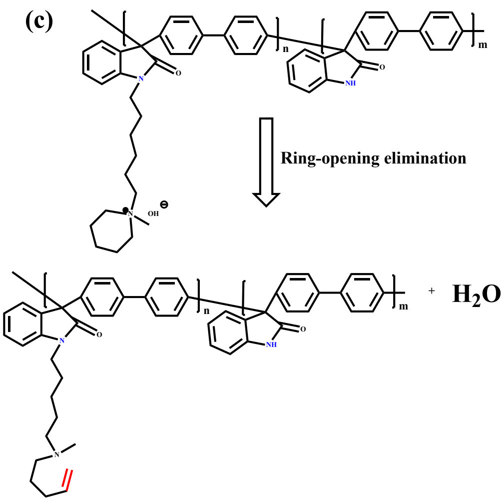


Fig.S4 Proposed degradation mechanism of PIB-based AEM (a) QAPIB, (b) PyrPIB and (c) PipPIB

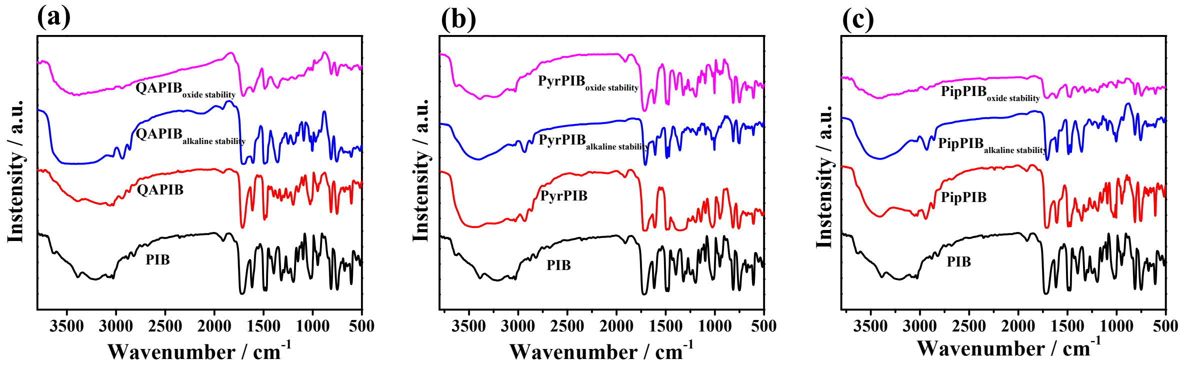


Fig.S5 the FT-IR spectra of QAPIB, PyrPIB and PipPIB after alkaline treatment and Fenton's test

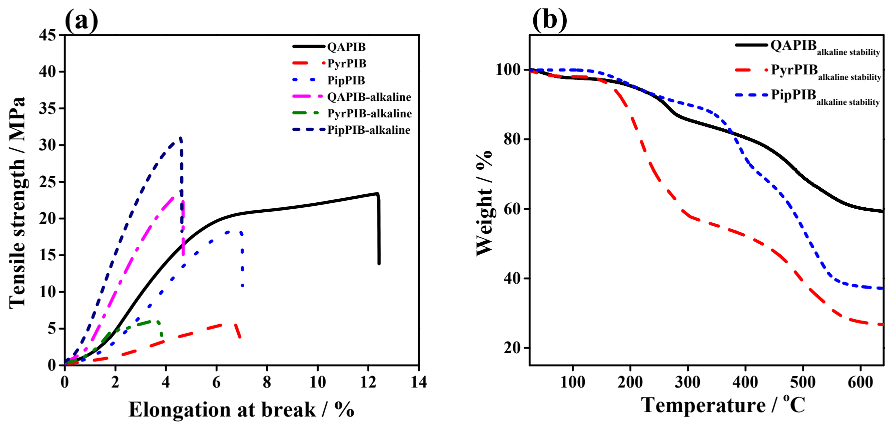


Fig.S6 the strain-stress curves of wet membranes (a) and TGA curves of AEMs after alkaline stability test (b).

Table S1 The mechanical properties of wet membranes before and after alkaline test

Samples	Tensile strength (MPa)	Young's Modulus (MPa)	Elongation at break (%)
QAPIB	23.36	497.42	12.37
PyrPIB	5.63	114.37	6.89
PipPIB	18.45	419.34	7.0
QAPIB-alkaline	23.81	718.33	4.61
PyrPIB-alkaline	6.06	423.18	3.76
PipPIB-alkaline	31.02	973.12	4.59

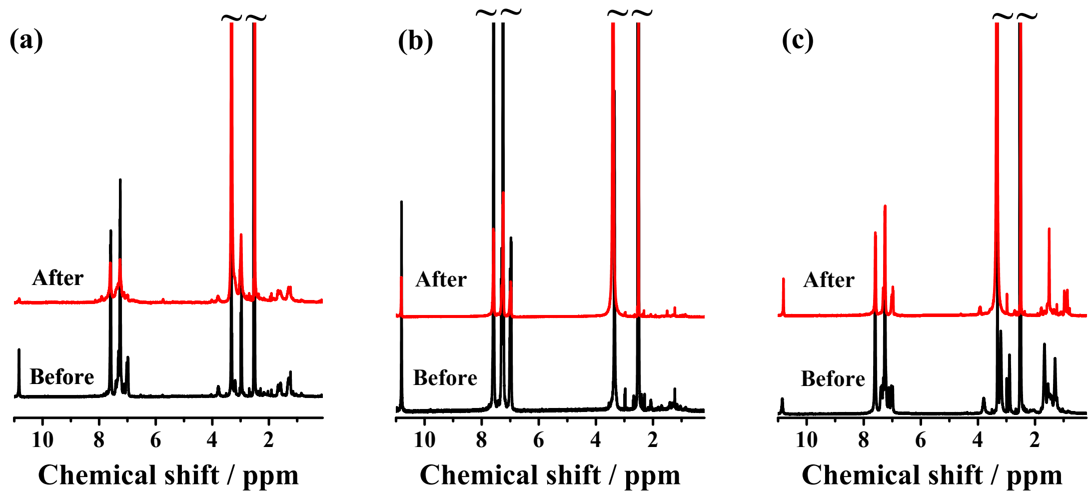


Fig.S7 the ^{1}H-NMR spectra of (a) QAPIB, (b) PyrPIB and (c) PipPIB after oxidative stability test

Table S2 IEC, water uptake, swelling ratio and hydroxide conductivity of the AEMs and reported AEMs

Membranes	IEC (mmol·g^{-1})	WU (wt%)	SW (%)	σ_{OH^-}(mScm^{-1})	Reference
PTPipQ6	2.08	44^{a}	-	47.9^{a}	1
PES-MPRD	1.42	36.5^{b}	17.2^{b}	60.4 (Br^- 80 °C)	2
PPO-7Q-1.8	1.8	42^{a}	-	33^{a}	3
PPO-5Q1	1.5	39^{a}	-	14^{a}	4
PES-6-QA	1.48	77.5^{b}	22^{b}	30^{b}	5
D-SC-paAE100%	2.41	30.4^{b}	0^{b}	58^{b}	6
ABA-TQA-44	1.93	58.6^{a}	18.9^{a}	58.7^{a}	7
8C-SfPAES-ImOH	1.49	70^{b}	28^{a}	38^{a}	8
QAPIB	1.23	32^{b}	9.5^{b}	33.5^{b}	This work
PyrPIB	1.11	40^{b}	8.2^{b}	25.8^{b}	This work
PipPIB	1.26	15^{b}	5.1^{b}	24.6^{b}	This work

^{a} Measured at 20 °C

^{b} Measured at 30 °C

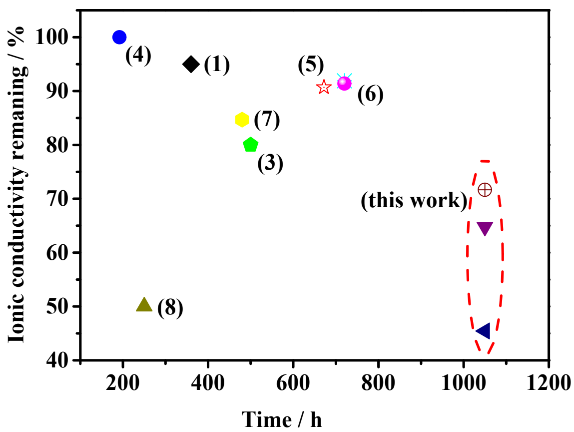


Fig.S8 Hydroxide conductivity of the F-PIBs membranes compared with that of other AEMs with long side chain. (The number in brackets is represented for reference)

Reference

1. J. S. Olsson, T. H. Pham and P. Jannasch, *Adv. Funct. Mater.*, 2018, **28**, 1702758.

2. F. H. Liu, C. X. Lin, E. N. Hu, Q. Yang, Q. G. Zhang, A. M. Zhu and Q. L. Liu, *J. Membrane Sci.*, 2018, **564**, 298-307.

3. H. S. Dang, E. A. Weiber and P. Jannasch, *J. Mater. Chem. A*, 2015, **3**, 5280-5284.

4. H. S. Dang and P. Jannasch, *Macromolecules*, 2015, **48**, 5742-5751.

5. C. X. Lin, X. L. Huang, D. Guo, Q. G. Zhang, A. M. Zhu, M. L. Ye and Q. L. Liu, *Journal of Materials Chemistry A*, 2016, **4**, 13938-13948.

6. J. Ran, L. Ding, C. Chu, X. Liang, T. Pan, D. Yu and T. Xu, *J. Mater. Chem. A*, 2018, **6**, 17101-17110.

7. C. X. Lin, H. Y. Wu, L. Li, X. Q. Wang, Q. G. Zhang, A. M. Zhu and Q. L. Liu, *ACS Appl. Mater. Inter.*, 2018, **10**, 18327-18337.

8. X. Yan, B. Zhao, J. Liu, X. Zhang and G. He, *Journal of Membrane Science*, 2018, **564**, 436-443.