polymers

Supporting information

A composite anion conducting membrane based on quaternized cellulose and poly(phenylene oxide) for alkaline fuel cell application

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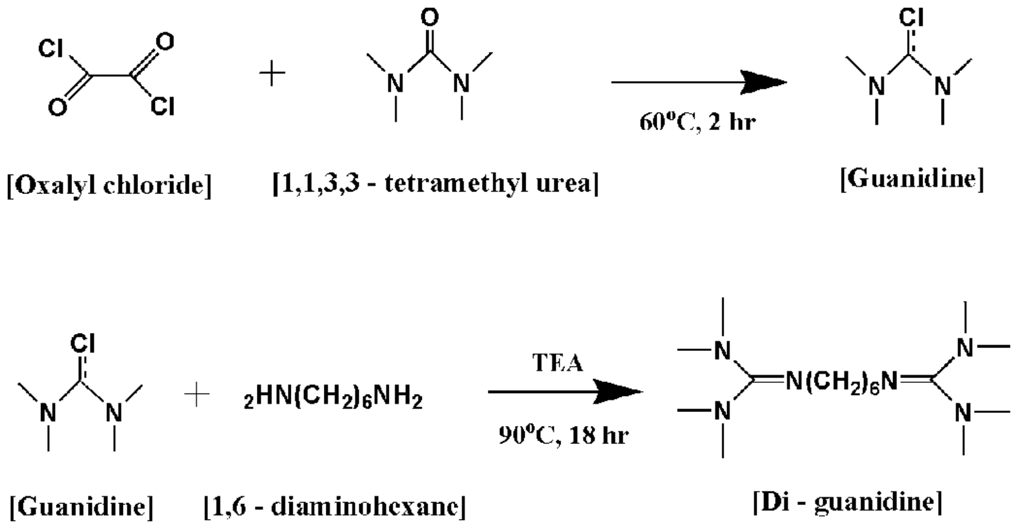

Scheme S1. Synthesis of guanidine and di-guanidine

Table S1. Composition in various membrane samples

Membrane	qPPO, g	D-Cel, g	DG-Cel, g
qPPO	1	-	-
qPPO/D-Cel3	1	0.03	-
qPPO/D-Cel5	1	0.05	-
qPPO/D-Cel7	1	0.07	-
qPPO/D-Cel10	1	0.10	-
qPPO/D-Cel15	1	0.15	-
qPPO/DG-Cel3	1	-	0.03
qPPO/DG-Cel5	1	-	0.05
qPPO/DG-Cel7	1	-	0.07
qPPO/DG-Cel10	1	-	0.10
qPPO/DG-Cel15	1	-	0.15

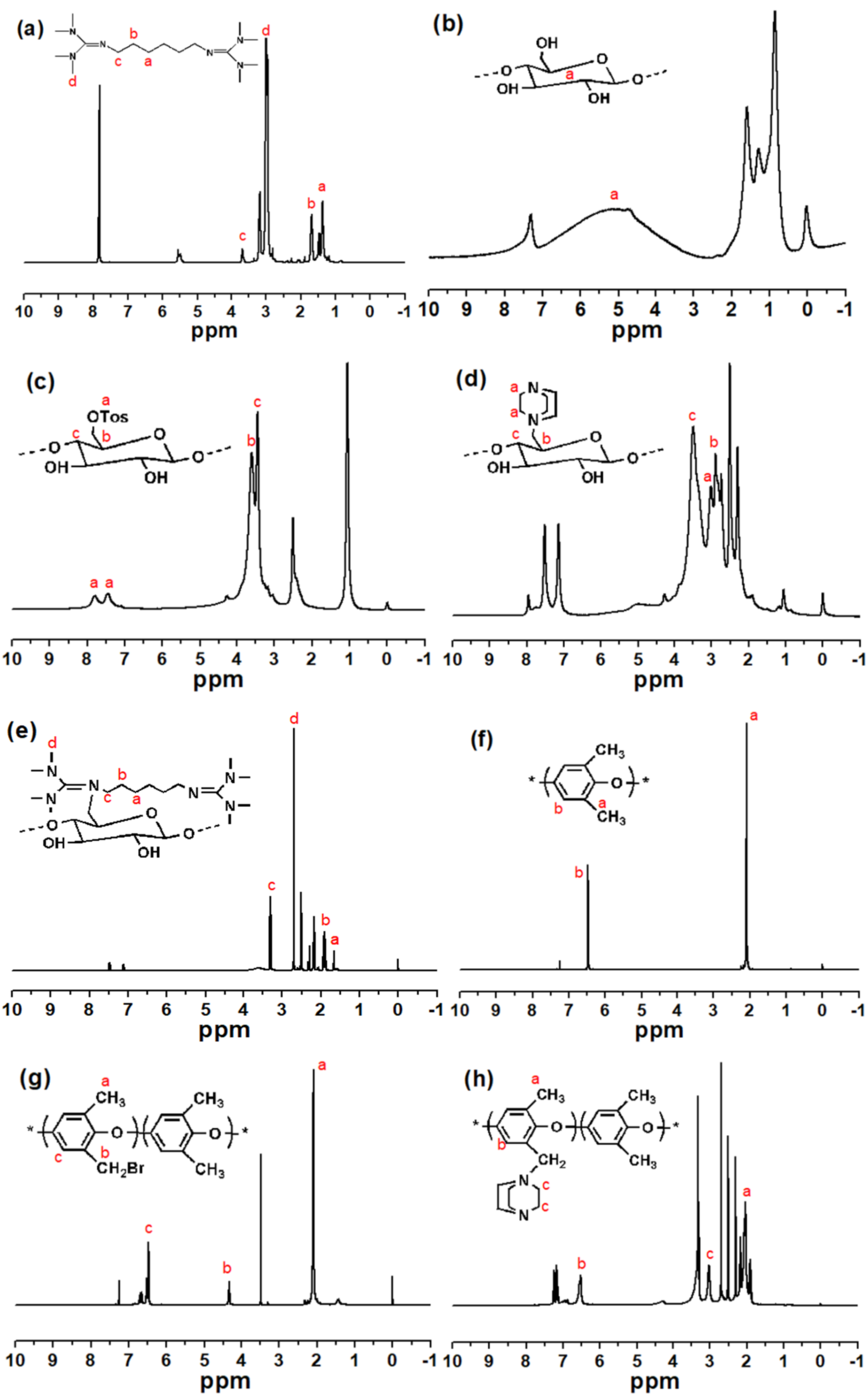

Figure S1. ^{1}H-NMR spectra of (a) DG, (b) Cel, (c) t-Cel, (d) D-Cel, (e) DG-Cel, (f) PPO, (g) bPPO, and (h) qPPO.

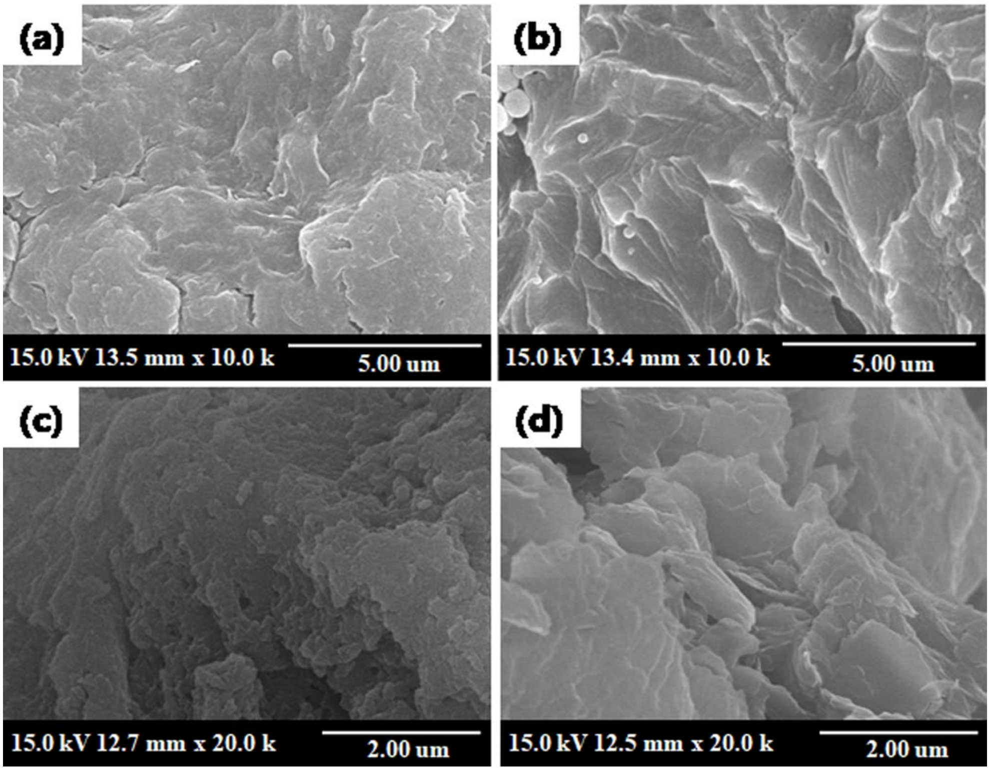

Figure S2. SEM images of (a) Cel, (b) t-Cel, (c) D-Cel, and (d) DG-Cel.

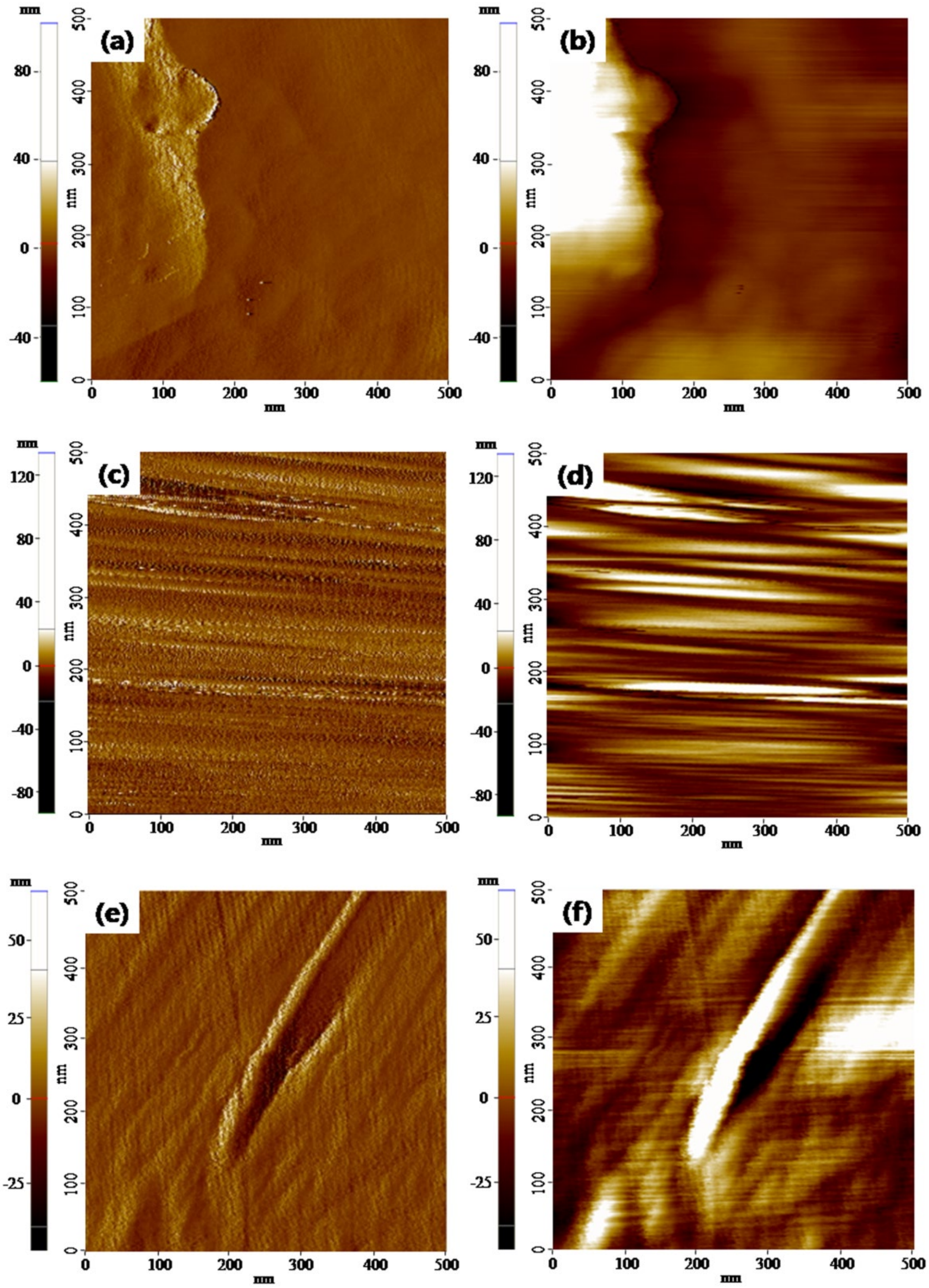

Figure S3. AFM image of (a, b) qPPO, (c, d) qPPO/D-Cel7, (e, f) qPPO/DG-Cel7.

Table S2. Elemental analysis of D-Cel and DG-Cel

Name	N (%)	C (%)	H (%)
D-Cel	5.19	47.91	6.825
DG-Cel	3.49	32.76	5.227

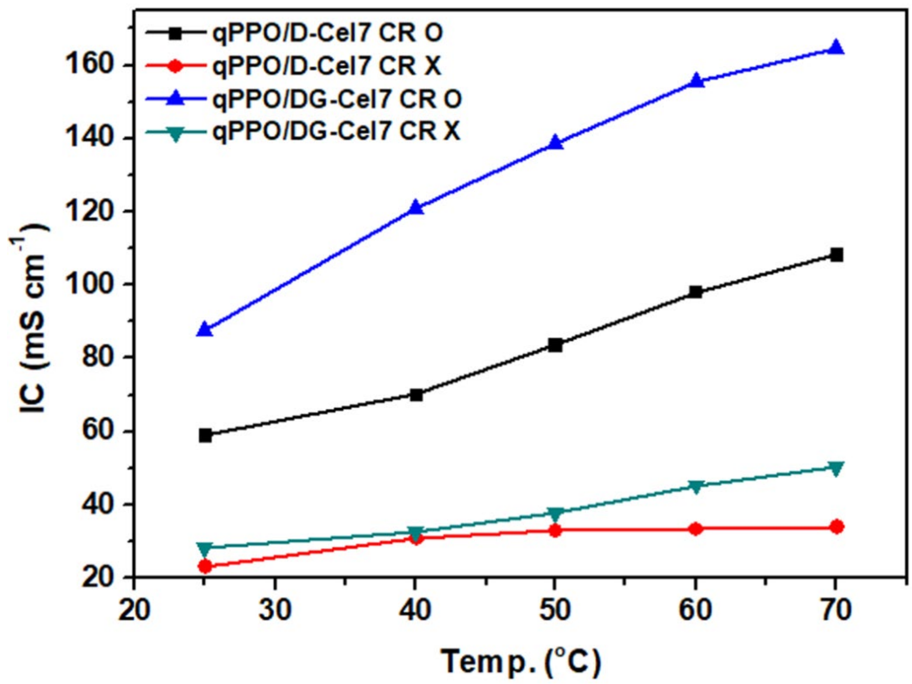

Figure S4. Effect of cross-linking on composite membranes.

Table S3. Comparative data of AEMs

Membrane	IC (RT), mS/cm	IC (>RT), mS/cm	IEC, mmol g^{-1}	WU, %	Ref.
PAES	~ 30	107 (80 °C)	2.2	50~60	[1]
Im-SiO_2/TA-PPO	~ 40	105 (80 °C)	3.15	145	[2]
PAES/Nano-ZrO_2	23.1	36.5 (80 °C)	1.82	28.1	[3]
CLQCPAES/nano-ZrO_2	16.2	55.2 (80 °C)	1.23	56.2	[4]
PSf/MMT	~ 15	47.3 (95 °C)	1.21	< 50	[5]
CS/QHNTs	5.56	17 (90 °C)	~0.4	79.2	[6]
QPSfDMC2	54	94 (70 °C)	2.34	124.72	[7]
QPPOQGO2	90.9	151 (80 °C)	2.25	74.28	[8]
QPSfQC15	74	128 (80 °C)	2.71	80.47	[9]
BG-BPS/PTFE	31	65 (60 °C)	1.14	29.4	[10]
Tri-QPESOH	45.9	130.9 (80 °C)	2.31	62	[11]
qPPO/D-Cel7	58.9	108.2 (70 °C)	1.66	67	This Work
qPPO/DG-Cel7	87.5	164.7 (70 °C)	1.24	91	This Work

* PAES = Poly(arylene ether sulfone), Im-SiO2/TA-PPO = Imidazolium-modified silica/Triple-ammonium side chain poly(phenylene oxide), CLQCPAES = Cross-linked multiblockcopoly(arylene ether sulfone), PSf = polysulfone, MMT = montmorillonite, CS = chitosan, QHNTs = Quaternized halloysite nanotubes, QPSfDMC = quaternized poly(sulfone) with N,N-dimethyl chitosan, QPPOQGO = quaternized poly(phenylene oxide) with modified graphene oxide, QPSfQC = DABCO polysulfone DABCO cellulose, BG-BPS = Bi-guanidinium bridged polysilsesquioxane, PTFE = poly tetra fluoro ethylene, QPESOH = quaternized poly (ether sulfone)

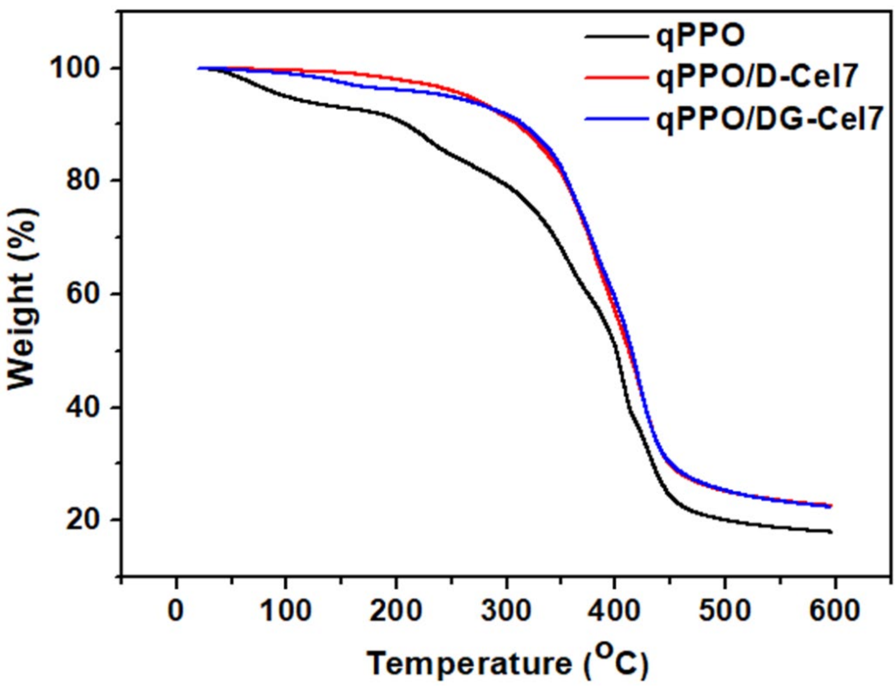

Figure S5. TGA graph of qPPO, qPPO/D-Cel7, and qPPO/DG-Cel7.

Table S4. Comparative data of direct urea fuel cell

Membrane	Fuel, Electrolyte	Catalyst (Anode-Cathode)	Power density (mW cm-2)	Ref
AMI-7001	0.33 mol L^{-1} Urea, 1 mol L^{-1} KOH	*Gr/Ni – Pt/C	4.06 x 10^{-3} (Room temperature)	[12]
Astom ACS A-5152	0.5 mol L^{-1} Urea	CuNi^PEDOT*PSS – Pt-B	1.88 (Room temperature)	[13]
FAA-3-50, Fumapem	0.33 mol L^{-1} Urea, 1 mol L^{-1} KOH	Pd-Ni/C – Pd/C	1.12 (Room temperature)	[14]
Fumasep FAA-3-50	0.33 mol L^{-1} Urea, 1 mol L^{-1} KOH	Ni/C – Mn_3O_4-Co_3O_4/MWCNT	0.4226 (50 °C)	[15]
QPSfDMC2	0.33 mol L^{-1} Urea, 1 mol L^{-1} KOH	Ni/C – PtRu/C	4.4 (70 °C)	[7]
QPPOQGO2	0.33 mol L^{-1} Urea, 1 mol L^{-1} KOH	Ni/C – PtRu/C	5.2 (60 °C)	[8]
qPPO/D-Cel7	0.33 mol L^{-1} Urea, 3 mol L^{-1} KOH	Ni/C – PtRu/C	8.36 (70 °C)	This work
qPPO/DG-Cel7	0.33 mol L^{-1} Urea, 3 mol L^{-1} KOH	Ni/C – PtRu/C	12.25 (70 °C)	This work

* Gr = graphene, MWCNT = multiwalled carbon nanotubes, AG = aerogel, PEDOT*PSS = poly(3,4-ethylenedioxythiophene) polystyrene sulfonate, Pt-B = Pt-Black

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