Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Novel Ionic Liquid-based Electrolyte Assisting the High Performance of Low-temperature Supercapacitors

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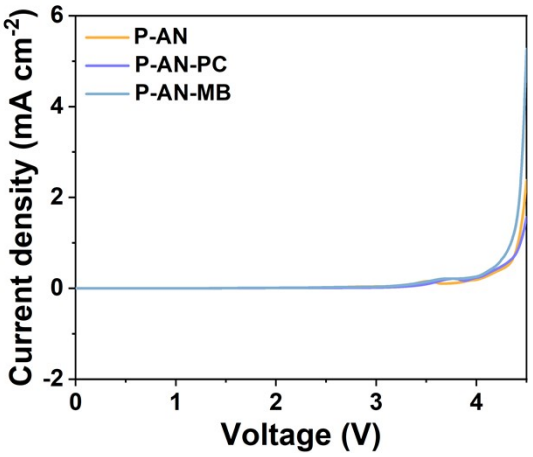

Fig. S1. The LSV curves of the P-AN, P-AN-PC and P-AN-MB at a scan rate of 2 mV s^{-1}.

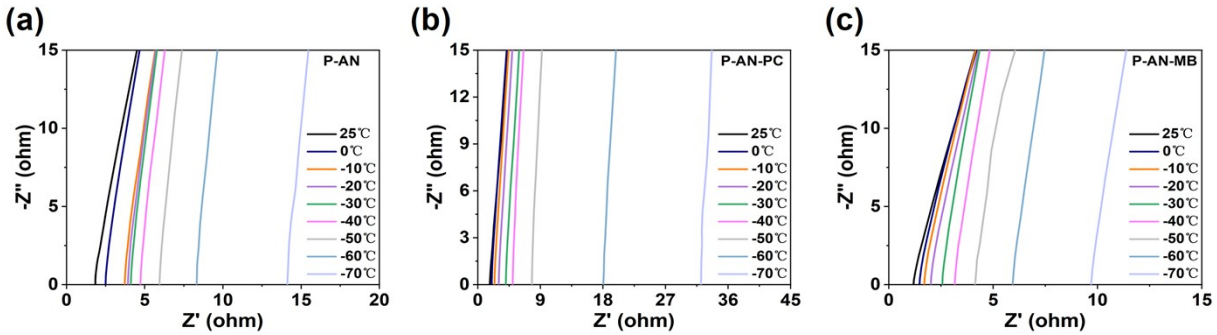

Fig. S2. Nyquist plots of the SCs based on (a) P-AN, (b) P-AN-PC, and (c) P-AN-MB obtained from the EIS at a temperature range from 25°C to -70°C.

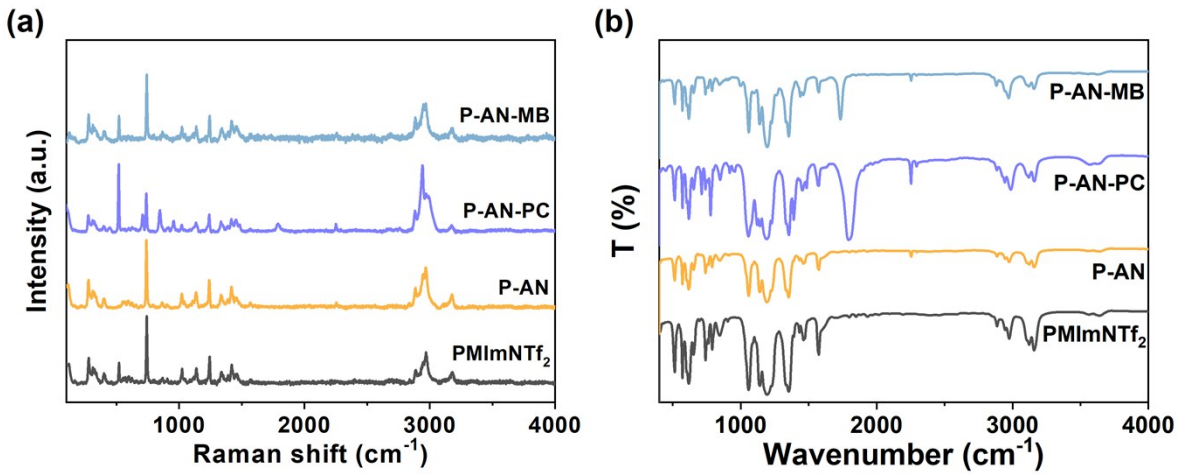

Fig. S3. (a) Raman and (b) FTIR spectra of $PMImNTf_2$, P-AN, P-AN-PC, and P-AN-MB.

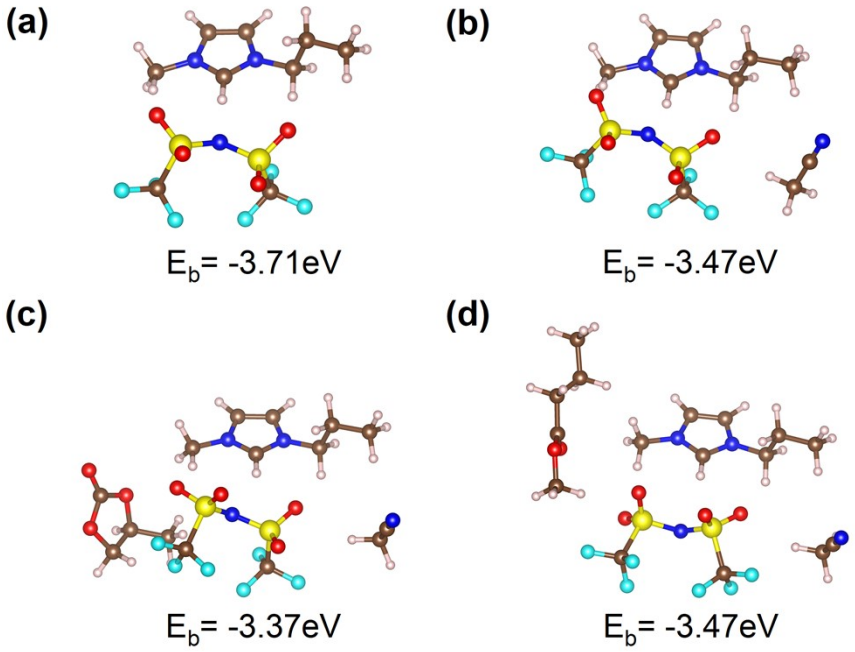

Fig. S4. Binding energies for (a) $PMImNTf_2$, (b) P-AN, (c) P-AN-PC, and (d) P-AN-MB systems obtained from DFT calculation. (Atom color: C, brown; N, blue; H, light pink; O, red; S, yellow; and F, aquamarine blue)

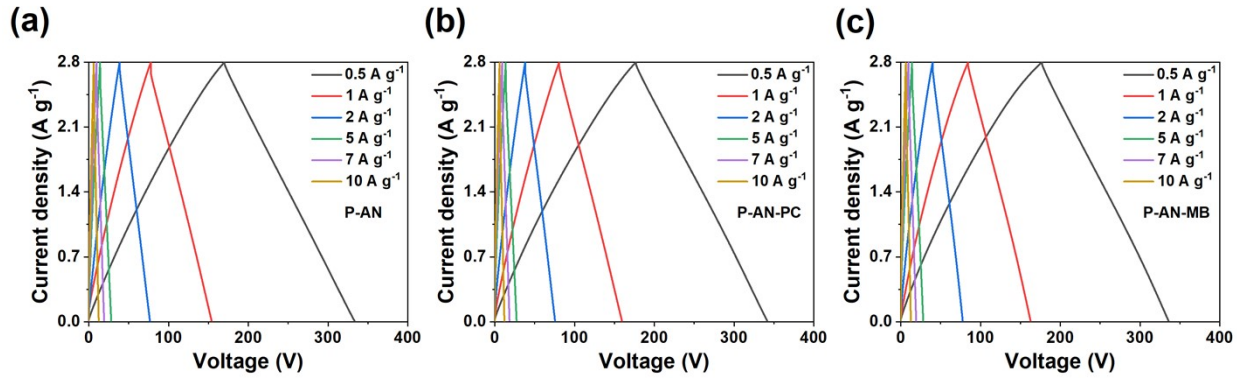

Fig. S5. GCD curves of the SCs at 25 ℃ based on (a) P-AN, (b) P-AN-PC, and (c) P-AN-MB.

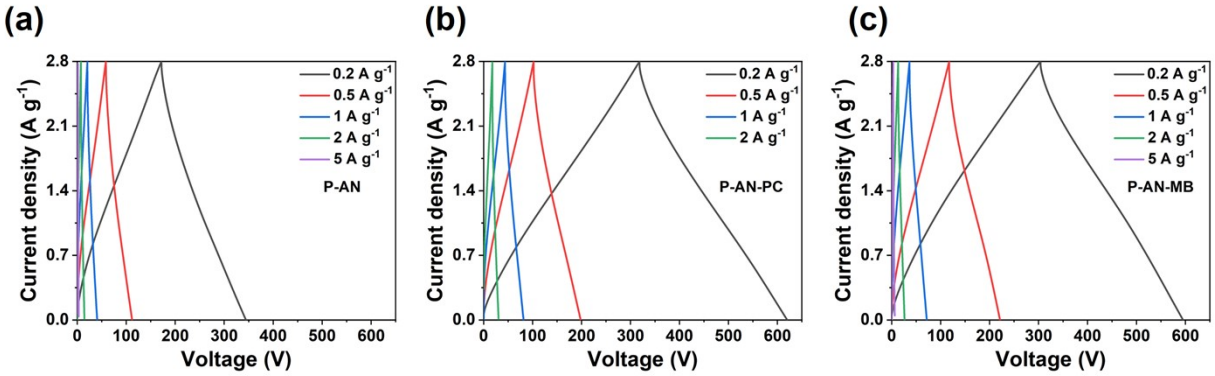

Fig. S6. GCD curves of the SCs at -50 ℃ based on (a) P-AN, (b) P-AN-PC, and (c) P-AN-MB.

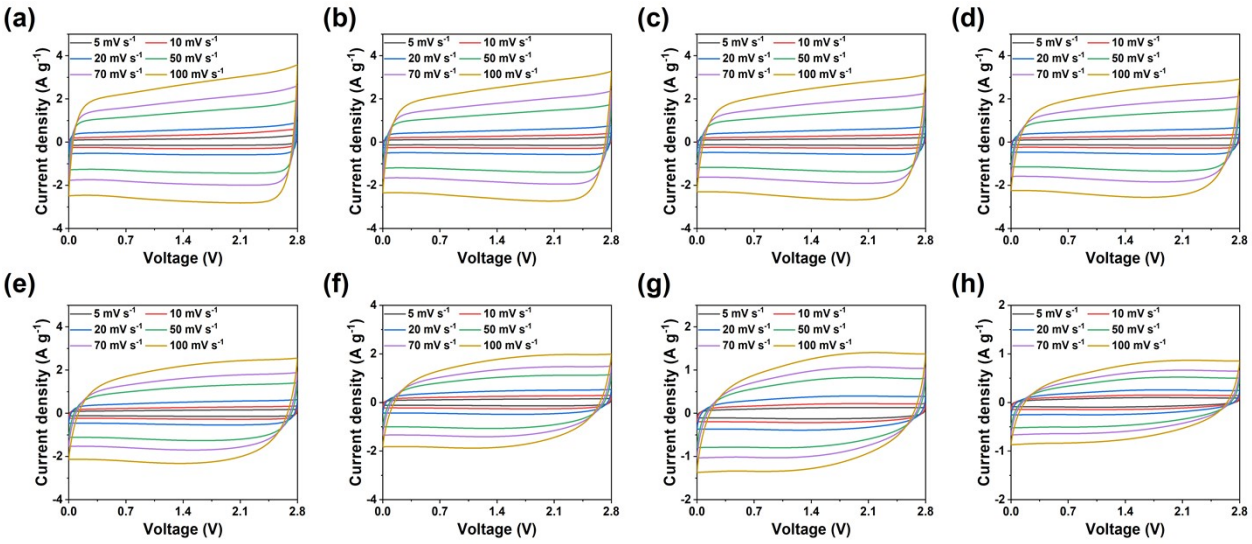

Fig. S7. CV curves of the P-AN-MB-based SCs at (a) 25 °C, (b) 0 °C, (c) -10 °C, (d) -20 °C, (e) -30 °C, (f) -40 °C, (g) -50 °C, (h) -60 °C.

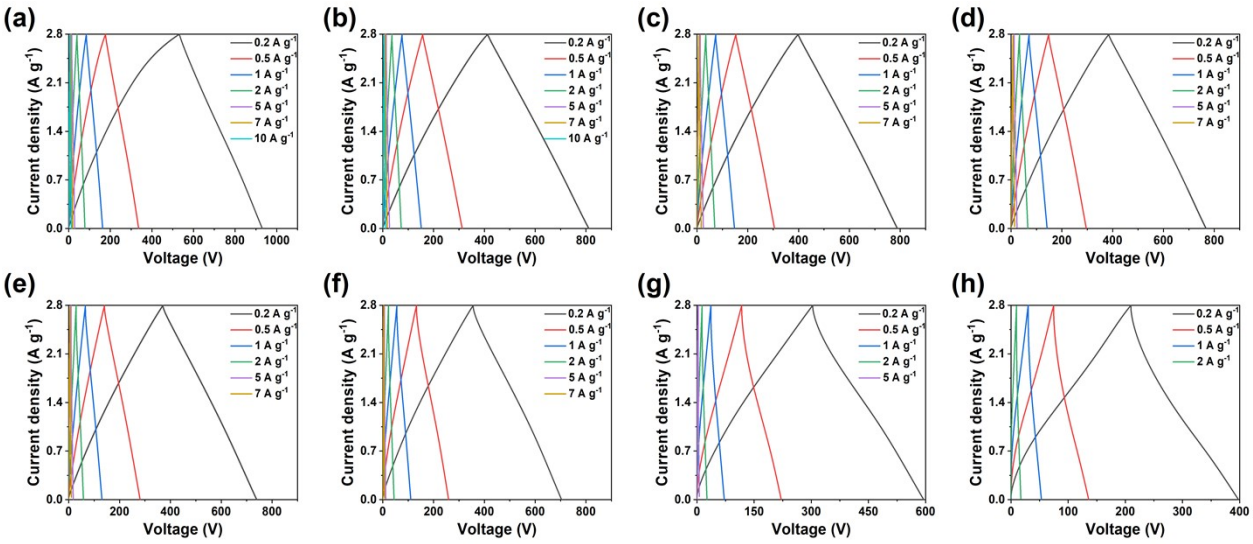

Fig. S8. GCD curves of the P-AN-MB-based SCs at (a) 25 °C, (b) 0 °C, (c) -10 °C, (d) -20 °C, (e) -30 °C, (f) -40 °C, (g) -50 °C, (h) -60 °C.

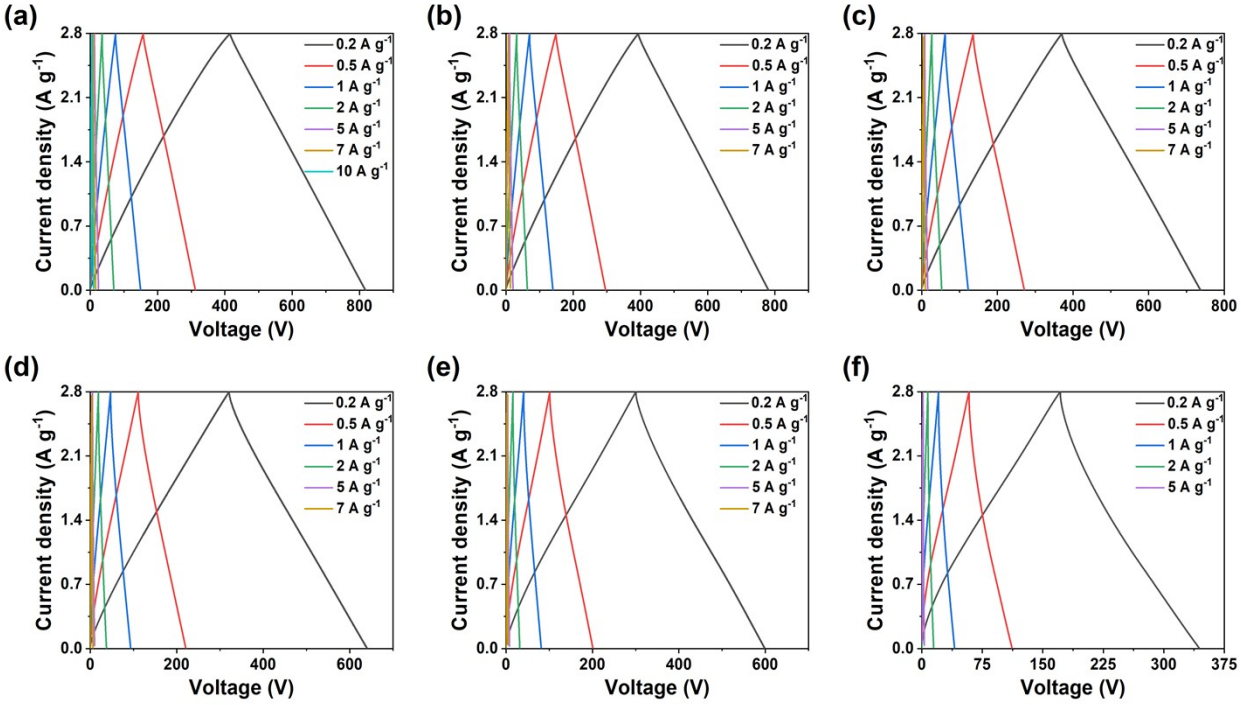

Fig. S9. GCD curves of the P-AN-based SCs at (a) 0 °C, (b) -10 °C, (c) -20 °C, (d) -30 °C, (e) -40 °C, (f) -50 °C.

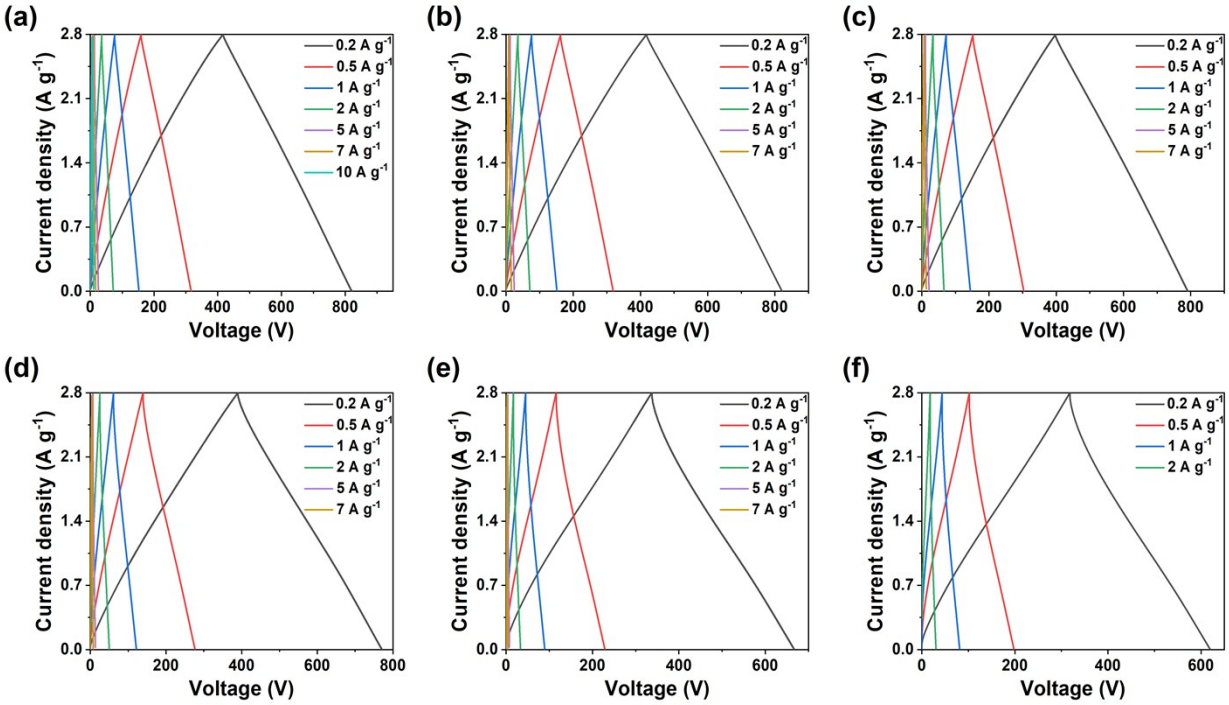

Fig. S10. GCD curves of the P-AN-PC-based SC at (a) 0 °C, (b) -10 °C, (c) -20 °C, (d) -30 °C, (e) -40 °C, (f) -50 °C.

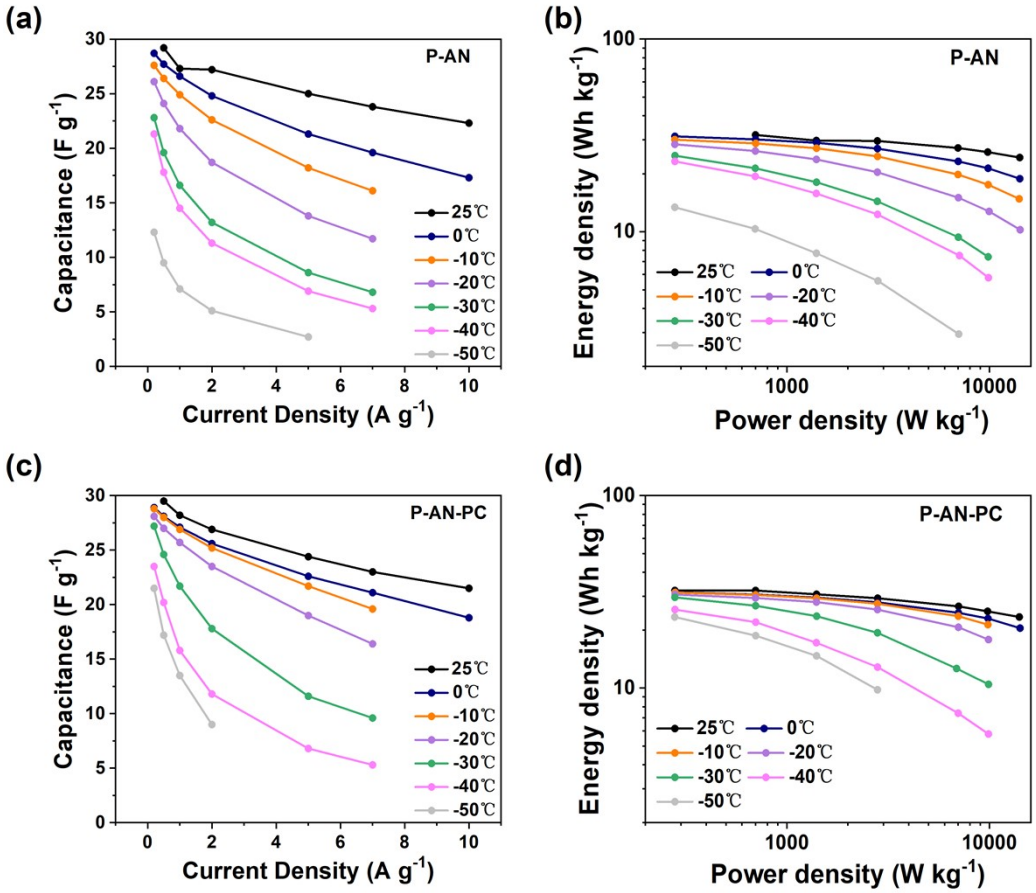

Fig. S11. Specific capacitances as a function of current density of the SCs based on (a) P-AN and (c) P-AN-PC at different temperatures; Ragone plots of the SCs based on (b) P-AN and (d) P-AN-PC at different temperatures.

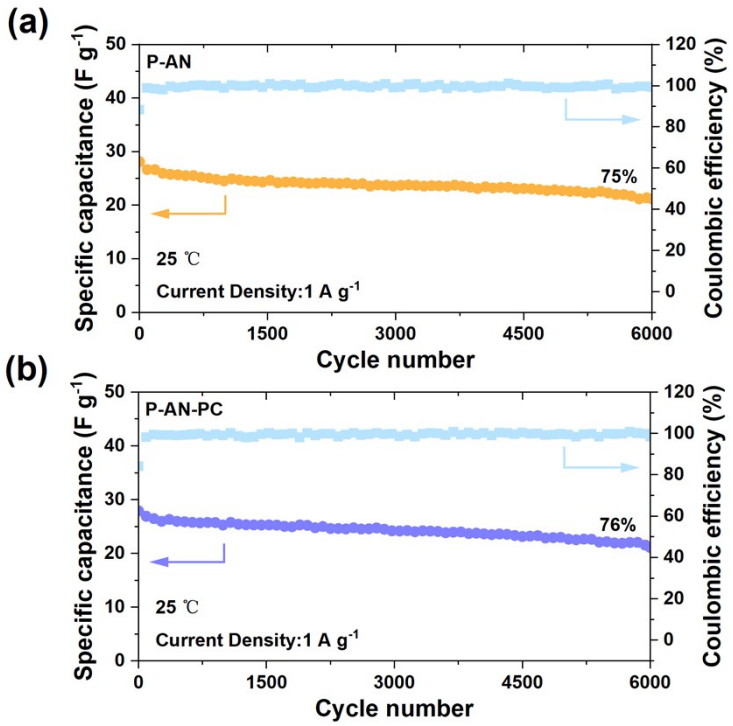

Fig. S12. Cycling performance of the SCs based on (a) P-AN and (b) P-AN-PC at 25 °C and a current density of 1 A g^{-1}.

Table S1. Physical properties of ILs

ILs	Melting points (℃)	Viscosities (cP)
1-ethyl-3-methylimidazolium tetrafluoroborate ($EMImBF_4$)	11	45
1-ethyl-3-methylimidazolium bis((trifluoromethyl)sulfonyl)imide ($EMImNTf_2$)	-15	32
1-propyl-3-methylimidazolium tetrafluoroborate ($PMImBF_4$)	-17	103
1-propyl-3-methylimidazolium bis((trifluoromethyl)sulfonyl)imide ($PMImNTf_2$)	-87	44
1-butyl-3-methylimidazolium tetrafluoroborate ($BMImBF_4$)	-81	140
1- butyl-3-methylimidazolium bis((trifluoromethyl)sulfonyl)imide ($BMImNTf_2$)	-4	69

Table S2. Physical characteristics of the solvents involved in this work

Solvents	Melting points (℃)	Dielectric constants	Viscosities (cP)
AN	-45.7	37.5	0.34
PC	-47.0	64.4	2.53
MB	-85.8	5.48	0.54

Table S3. FTIR information of the electrolytes

Electrolytes	Wavenumbers of Peak (cm^{-1})		
	υ(Alkyl C-H)	υ(C2-H)	υ(C4,5-H)
$PMImNTf_2$	2885.9, 2944.8, 2975.1	3122.2	3158.3
P-AN	2885.5, 2945.2, 2975.1	3121.2	3158.3
P-AN-PC	2884.0, 2943.3, 2987.2	3119.8	3159.8
P-AN-MB	2881.6, 2944.3, 2970.8	3120.3	3156.9

Table S4. The average numbers of hydrogen bonds for $PMImNTf_2$, P-AN, P-AN-PC, and P-AN-MB systems

Systems	H-O	H-N	H-F	Sum
$PMImNTf_2$	31	99	22	152
P-AN	28	99	14	141
P-AN-PC	53	80	14	147
P-AN-MB	46	83	12	141

Table S5. Comparison of binding energy obtained from DFT calculation

Systems	Total	Cation	Anion	E_b (Ha)	E_b (eV)
$PMImNTf_2$	-2210.12	-383.45	-1826.53	-0.14	-3.71
P-AN	-2342.75	-383.45	-1959.17	-0.13	-3.47
P-AN-PC	-2724.18	-383.45	-2340.60	-0.12	-3.37
P-AN-MB	-2689.45	-383.45	-2305.87	-0.13	-3.47

Table S6. Voltage drops of the SCs based on P-AN, P-AN-PC, and P-AN-MB at -50 ℃

SCs	0.2 A g^{-1}	0.5 A g^{-1}	1 A g^{-1}	2 A g^{-1}	5 A g^{-1}
P-AN	0.042 V	0.100 V	0.199 V	0.389 V	0.943 V
P-AN-PC	0.045 V	0.111 V	0.222 V	0.439 V	-
P-AN-MB	0.036 V	0.085 V	0.171 V	0.338 V	0.827 V

Table S7. The R_i of the SCs based on P-AN, P-AN-PC, and P-AN-MB at different temperatures

SCs	25 ℃	0 ℃	-10 ℃	-20 ℃	-30 ℃	-40 ℃	-50 ℃	-70 ℃
P-AN	1.8 Ω	3.9 Ω	4.5 Ω	5.6 Ω	7.0 Ω	9.6 Ω	14.1 Ω	70.2 Ω
P-AN-PC	2.7 Ω	3.8 Ω	4.6 Ω	5.7 Ω	7.4 Ω	15.5 Ω	16.6 Ω	71.3 Ω
P-AN-MB	3.3 Ω	5.2 Ω	5.8 Ω	7.1 Ω	8.4 Ω	11.1 Ω	15.4 Ω	41.6 Ω