Electronic Supplementary Material (ESI) for New Journal of Chemistry.

Polypyrrole nanocomposites doped by functional ionic liquids for high performance supercapacitors

Peng Cao,[1] Yuxia Fan,[1] Junrui Yu,[1] Rongmin Wang,[1] Pengfei Song,[1] Yubing Xiong[*1,2]

[1] College of Chemistry and Chemical Engineering, Northwest Normal University, Lanzhou 730070, China

[2] Department of Chemistry, Zhejiang Sci-Tech University, Hangzhou 310018, China

[*] Author to whom correspondence should be addressed; E-Mail: yubing_xiong@163.com; Tel.: +86-931-7970-358; Fax: +86-931-7970-075.

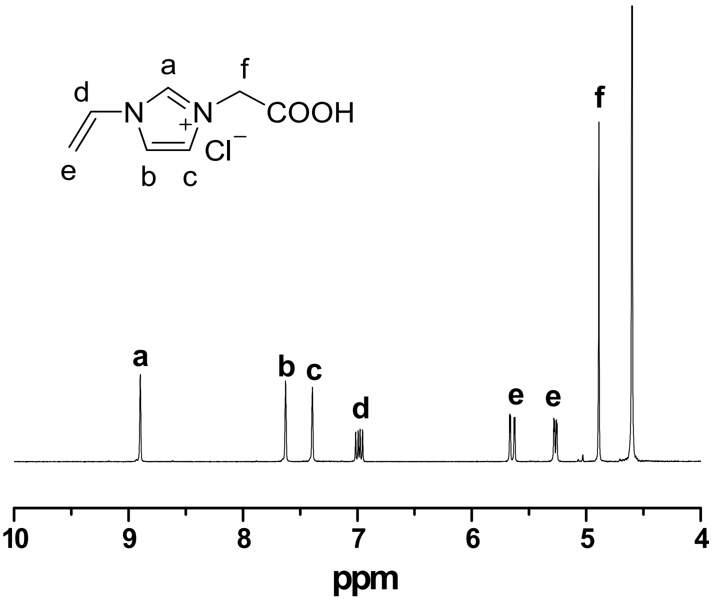

Figure S1 ^{1}H NMR spectrum of [VCMIm]Cl in D_2O.

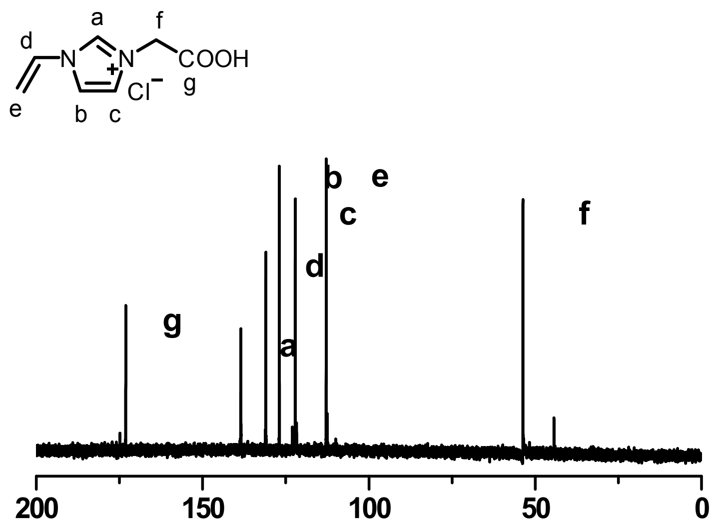

Figure S2 ^{13}C NMR spectrum of [VCMIm]Cl in D_2O.

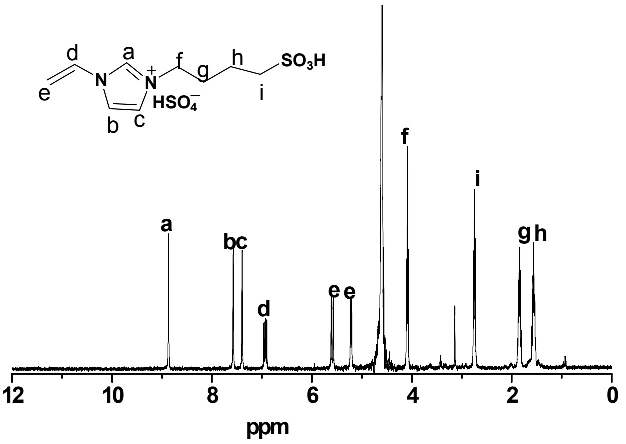

Figure S3 ^{1}H NMR spectrum of [SBVIm][HSO_4] in D_2O.

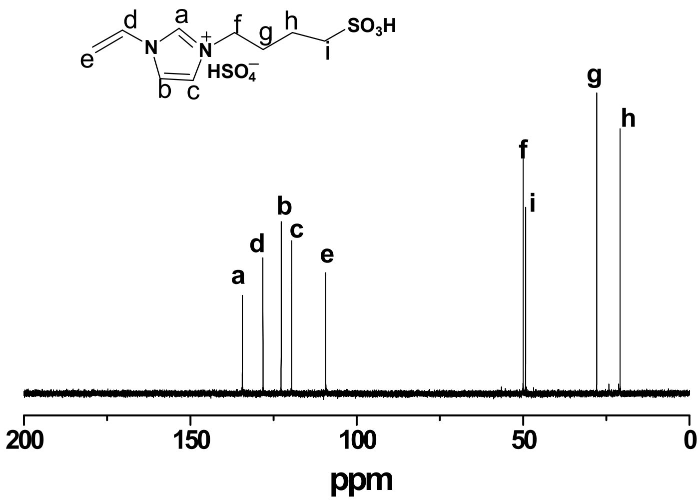

Figure S4 ^{13}C NMR spectrum of [SBVIm][HSO_4] in D_2O.

Table S1 Element composition of IL@PPy nanocomposites measured by energy dispersive spectrometer (EDS).

Entry	[VCMIm]Cl : Py : $FeCl_3$	C %	N%	O %	Cl%
1V1P1F	1:1:1	62.31	17.57	11.77	7.39
3V1P1F	3:1:1	64.65	15.95	12.01	7.66
4V1P1F	4:1:1	65.07	15.63	11.64	8.35
3S1P1F	3:1:1 ([SBVIm][HSO_4] : Py : $FeCl_3$)	59.01	16.20	19.10	5.69 (S%)

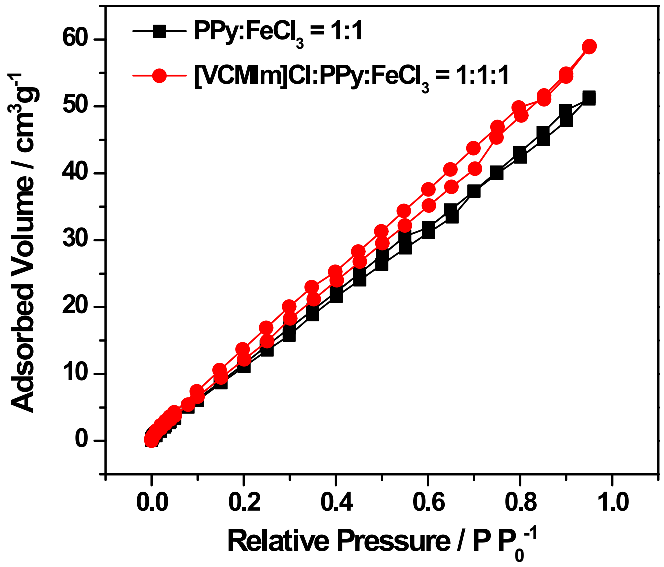

Figure S5. N_2 absorption-desorption isotherms of pure PPy nanoparticles and IL@PPy nanocomposites. The specific surface areas of PPy:$FeCl_3$=1:1 and [VCMIm]Cl:PPy:$FeCl_3$=1:1:1 are 73.8 $m^2\ g^{-1}$ and 80.1 $m^2\ g^{-1}$ respectively.

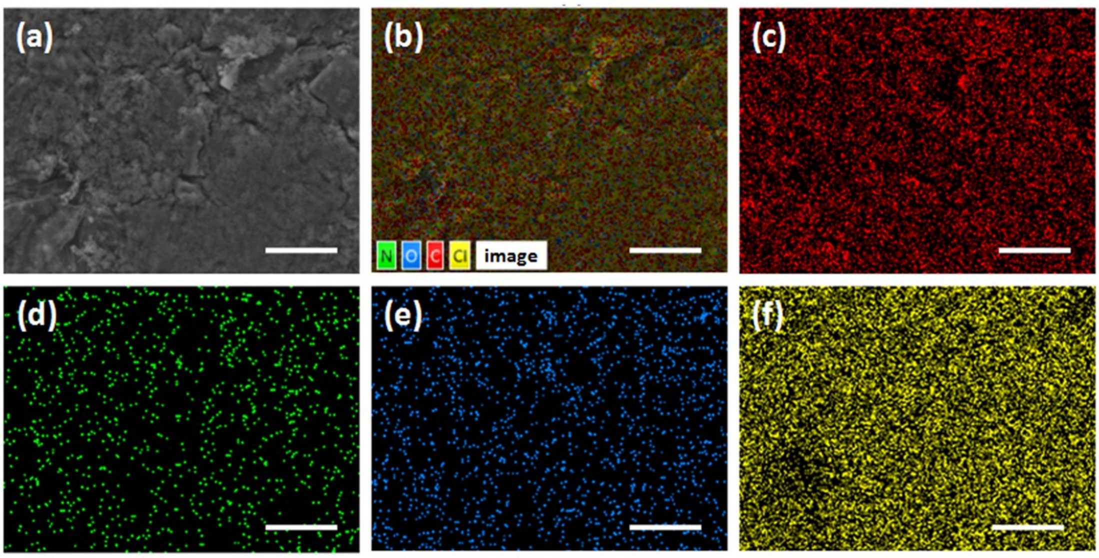

Figure S6. SEM mapping photograph of C, N, O and Cl elements within [VCMIm]Cl@PPy (3:1:1) All the scale bars are 50 μm.

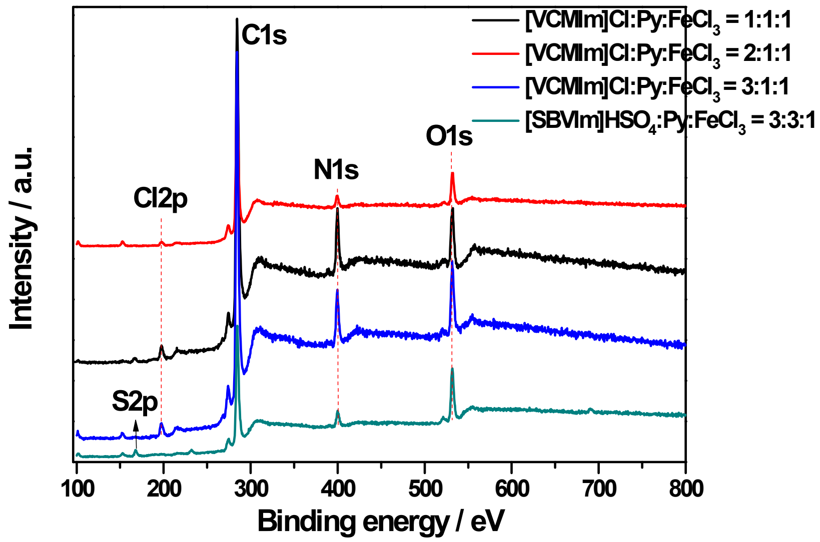

Figure S7. XPS survey scans of IL@PPy nanocomposites indicating the existence of carbon, oxygen, nitrogen, chlorine and sulfur.

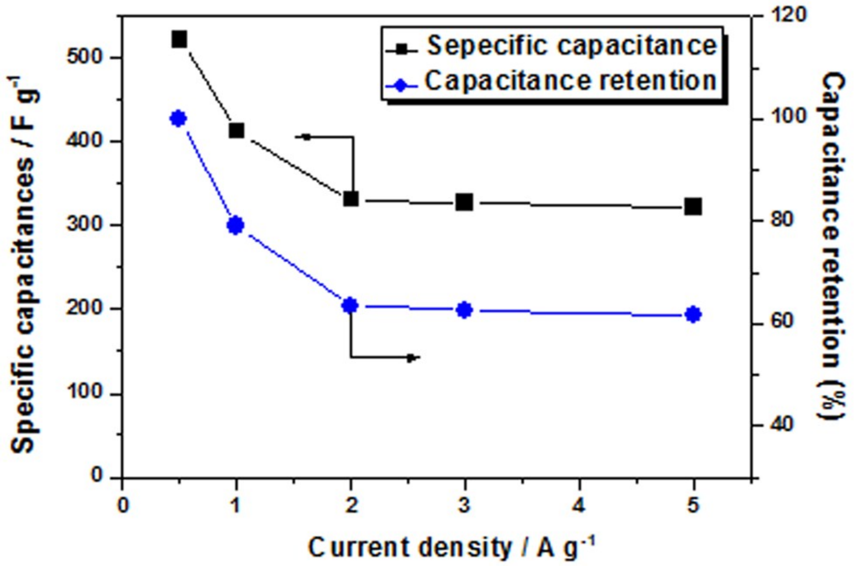

Figure S8. Specific capacitances and capacitance retention at various current densities.

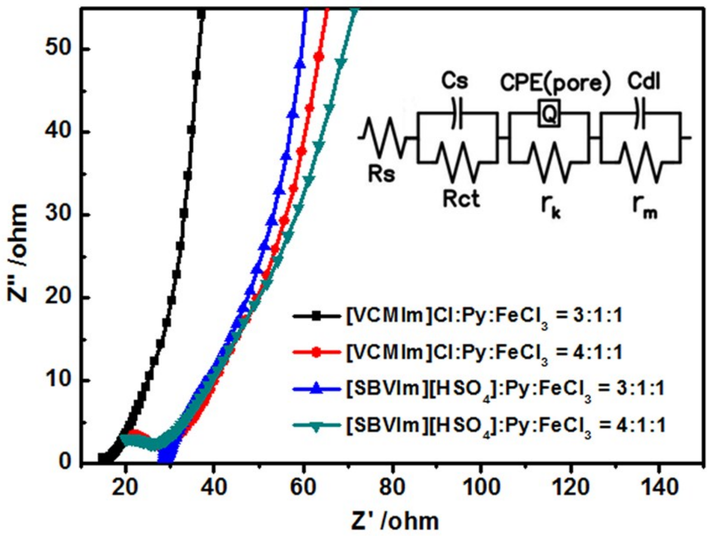

Figure S9. Nyquist plots of the IL-doped PPy. Inset: equivalent circuit used to fit the impedance spectrum.

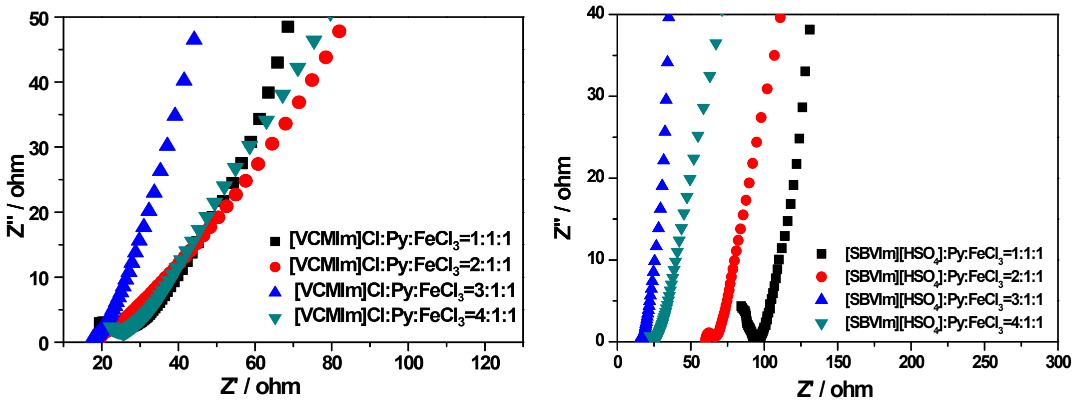

Figure S10. EIS curves of IL@PPy electrode materials with different composition.

Table S2 Fitted EIS parameters of symmetric supercapacitors based on the IL-doped PPy electrodes.

Electrode materials	Ratio	Rs (Ω)	Rct (Ω)
[VCMIm]Cl:Py:$FeCl_3$	3:1:1	1.03	0.09
[VCMIm]Cl:Py:$FeCl_3$	4:1:1	1.38	0.42
[SBVIm][HSO_4]:Py:$FeCl_3$	3:1:1	2.04	0.43
[SBVIm][HSO_4]:Py:$FeCl_3$	4:1:1	1.32	0.40

Table S3 Power and energy density of the electrode materials based PPy composites

CPs-based composites	Power density W Kg^{-1}	Energy density Wh Kg^{-1}	Reference
PPy-MnO_2	901.7	25.8	1
CNT-PPy-MnO_2-AC	100	38.42	2
PPy/MO-2h	467.0	19.4	3
PPy-LGS	-	20.6	4
PPy coated fabric	799.2	11.1	5
Ag-PPy	500	30	6
GF-CNTs-PPy	2700	6.2	7
PPy-Graphene	3200	8.4	8
[VCMIm]Cl-PPy(3:1)	2226	40.2	**This work**

Table S4 Specific capacitance of IL@PPy in this work, in comparison with several representative results with different dopants from recent publications.

Electrode material	Specific Capacitance	Scan rate or current density	Electrolyte	reference
PPy-20 wt% MWNTs	506 F g^{-1}	5 mVs^{-1}	1 M H_2SO_4	9
RGO/PPy	352 F g^{-1}	1 A/g	1 M H_2SO_4	10
PPy/TSA	376 F g^{-1}	3 mA m^{-2}	0.5 M Na_2SO_4	11
PPy hydrogel-CC	400 F g^{-1}	0.2 A/g	1 M H_2SO_4	12

CTAB@PPy	305 F g^{-1}	0.5 A/g	1 M KCl	13
s-G/PPy	310 F g^{-1}	0.3 A/g	1 M KCl	14
AQDS/NDA	393 F g^{-1}	0.5 A/g	1 M H_2SO_4	15
PPy/GNS	298.2 F g^{-1}	0.5 A g^{-1}	1 M H_2SO_4	16
R-G/Pys	180 F g^{-1}	0.5 mA/g	1 M H_2SO_4	17
HNTs/PPy	522 F g^{-1}	5 mA cm^{-2}	0.5 M Na_2SO_4	18
PPy	533 F g^{-1}	5 mV s^{-1}	0.5 M H_2SO_4	19
GO/PPy	650 F g^{-1}	0.45 A g^{-1}	1 M H_2SO_4	20
GO/PPy	633 F g^{-1}	1 A g^{-1}	1 M KCl	21
IL@PPy	520 F g^{-1}	0.5 A/g	1 M KCl	**This work**

Reference

1. W. D. He, C. G. Wang, F. W.Zhuge, X. L. Deng, X. J. Xua, T.Y. Zhai. Nano Energy, 2017, **35**, 242–250.
2. Y. J. Zhou, H.Zhao, X.M. Mu, Nanoscale, 2015, **7**, 14697–14706.
3. J. Xu, D. X. Wang, L. L. Fan, Y. Yuan, W. Wei, R. N. Liu, S. J. Gu, W. L. Xu, Organic Electronics, 2015, **26**, 292–299
4. L. Zhu, L. Wu, Y. Sun, M. Li, J. Xu, Z. Bai, G. Liang, L. Liu, D. Fang, W. Xu, RSC Adv, 2014. **4** 6261–6266.
5. B. Yue, C. Wang, X. Ding, G.G. Wallace , Electrochimica Acta, 2012, **68**, 18–24
6. L.Yuan, C. Wan, X. Ye, Electrochimica Acta, 2016, **213**, 115–123.
7. Y. H. Lee, H.J. Choi, M.S. Kim, S. Noh, K. Ahn, K. Im, O. Kwon, H. Yoon, Scientific Reports, 2016, **6**, 19822.
8. L.J. Lei, Z.L. Li, W.H. Bin, L.J. Yi, S.Z. Xiang, L.X. David, Energy&Environmental Science, 2014, **7**, 3709–3719
9. V. Khomenko, E. Frackowiak, F.Beguin, Electrochimica Acta, 2005, **50**, 2499–2506.
10. H. H Chang, C. K. Chang, Y. C. Tsai, C. S. Liao, Carbon, 2012, **50**, 2331–2336.
11. Z. H. Dong, Y. Li. Wei, W. Shi, G. A. Zhang, Materials Chemistry and Physics, 2011, **131**, 529–534.

12. Y. Shi, L. J. Pan, B. R. Liu, Y. Q. Wang, Y. Cui , Z. A. Bao and G. H. Yu, Journal of Materials Chemistry A, 2014, **2**, 6086–6091.
13. Q.F. Wu, K.X. He, H.Y. Mi, X.G. Zhang, Materials Chemistry and Physics, 2007, **101**, 367–371.
14. X.P. Zuo, Y.L. Zhang, L. Si, B. Zhou, B. Zhao, L.H. Zhu, X.Q. Jiang, Journal of Alloys and Compounds, 2016, **688**, 140–148.
15. Y.Q. Han , X.X. Gao, T.Q. Wang, M.S. He, T.X. Li, W.J. Li, Synthetic Metals, 2016, **217**, 288–294.
16. D.C. Zhang, X. Zhang, Y. Chen, P. Yu, C.H. Wang, Y.W. Ma, Journal of Power Sources, 2011, **196**, 5990–5996.
17. Y.Q. Han, L. Hao, X.G. Zhang, Synthetic Metals, 2010, **160**, 2336–2340.
18. C. Yang, P. Liu, Y.Q. Zhao, Electrochimica Acta, 2010, **55**, 6857–6864.
19. D.P. Dubal, S.V. Patil, A.D. Jagadale, C.D. Lokhande, Journal of Alloys and Compounds, 2011, **509**, 8183–8188.
20. Y. Liu, H.H. Wang, J. Zhou, L.Y. Bian, E.W. Zhu, J.F. Hai, J. Tang, W.H. Tang, Electrochimica Acta, 2013, **112**, 44–52.
21. J. Li, H.Q. Xie, Materials Letters, 2012, **78**, 106–109.