Electronic Supplementary Material (ESI) for Inorganic Chemistry Frontiers.

Supporting Information for

Synthesis of Cobalt-doped Nickel Sulfide Nanomaterials with Rich Edge Sites as High-performance Supercapacitor Electrode materials

Shengli Xie[ab], Jianxia Gou[b], Bin Liu[a] and Chenguang Liu[a*]

a State Key Laboratory of Heavy Oil Processing, China University of Petroleum (East China), Qingdao 266580, PR China

b College of Chemistry & Chemical Engineering, Binzhou University, Binzhou 25660 3, PRChina

* Corresponding author

E-mail addresses: shenglixie@126.com (S. Xie), cgliu@upc.edu.cn (C. Liu).

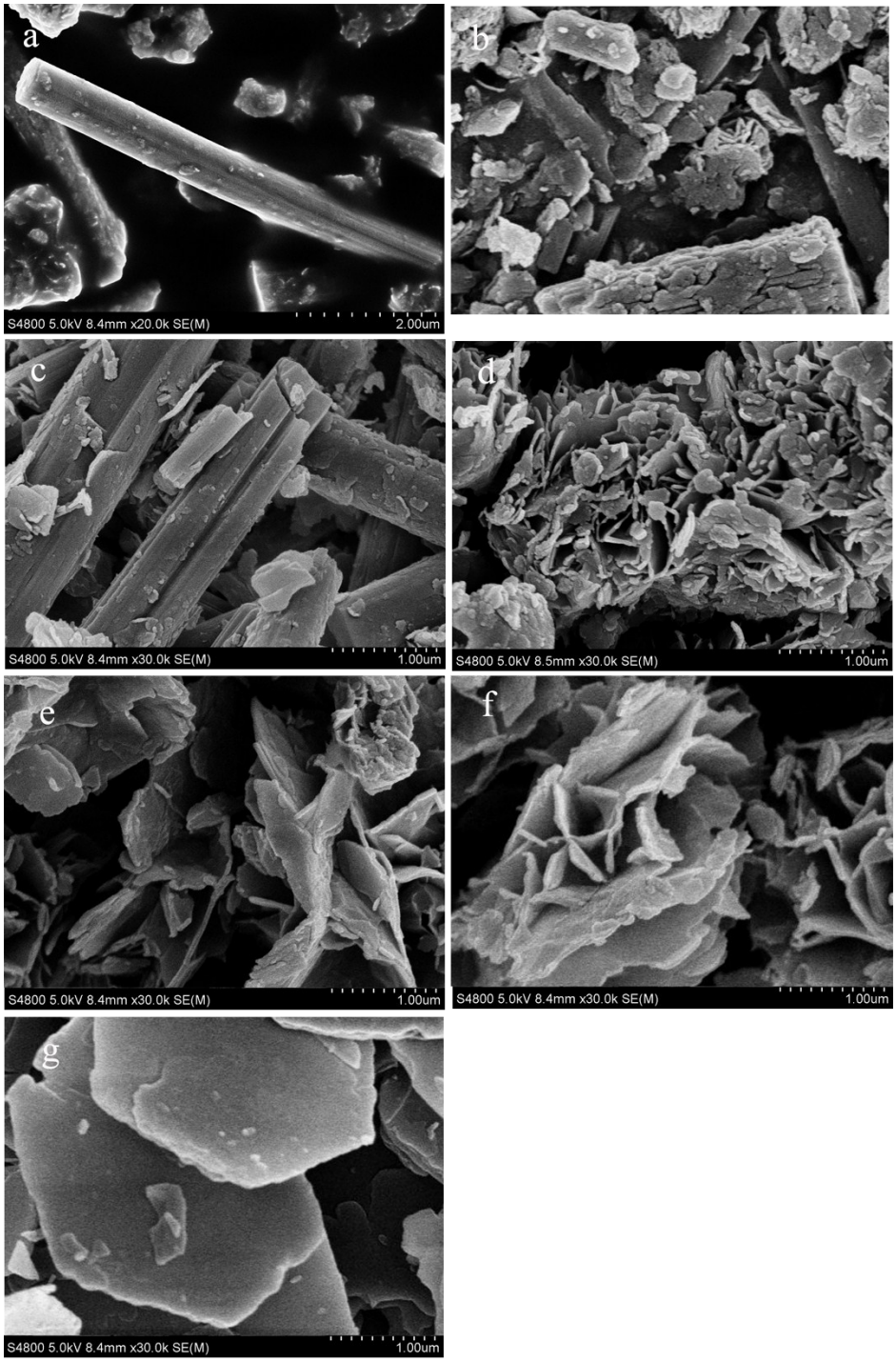

Figure S1. SEM images of precursors: (a) Ni/Co=1/0, (b) Ni/Co=4/1, (c) Ni/Co=3/1, (d) Ni/Co=1/1, (e) Ni/Co=1/3, (f) Ni/Co=1/4, and (g) Ni/Co=0/1

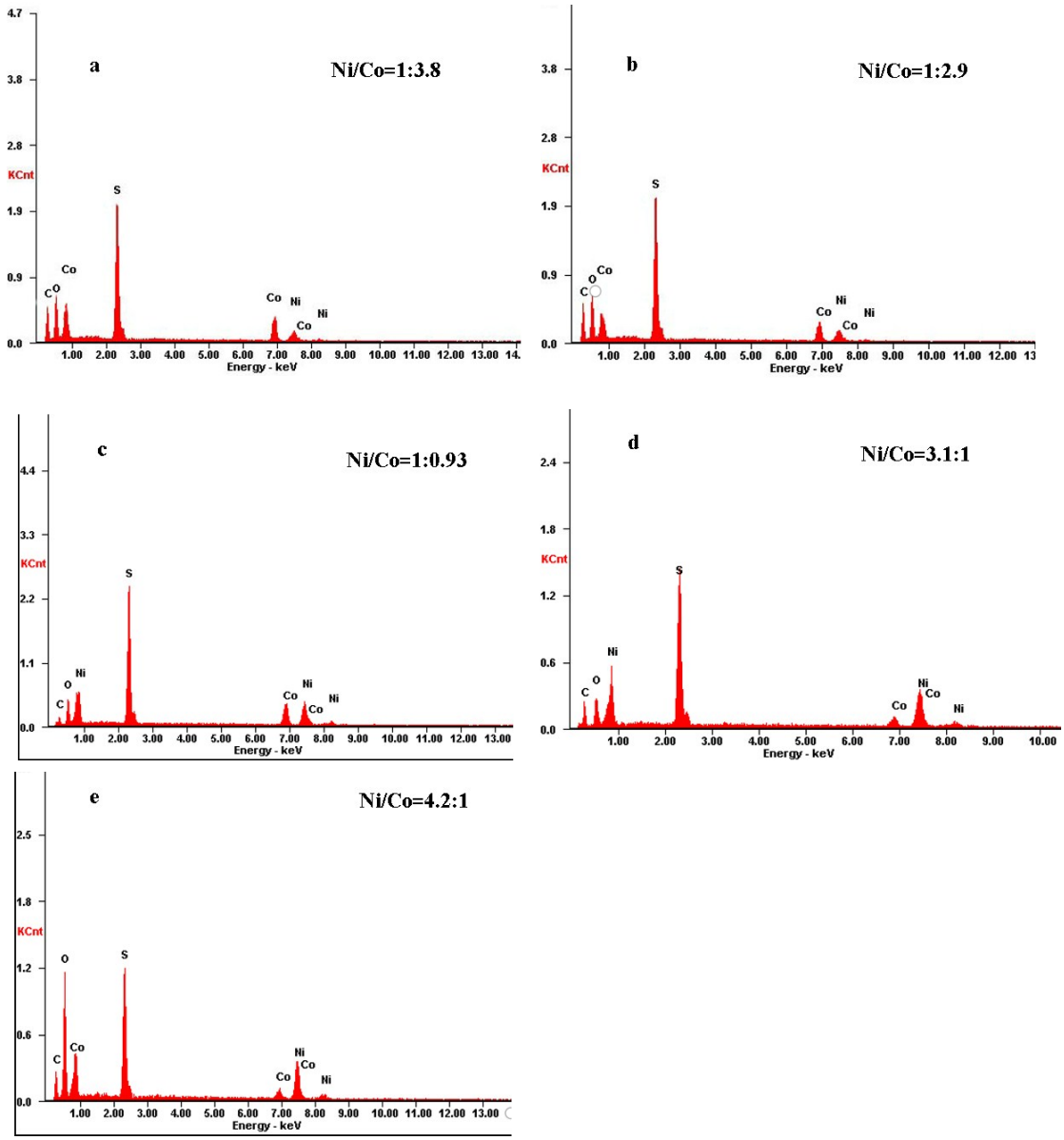

Figure S2. EDS spectra of samples: (a) $Ni_{0.2}Co_{0.8}S_2$, (b) $Ni_{0.25}Co_{0.75}S_2$, (c) $Ni_{0.5}Co_{0.5}S_2$, (d) $Ni_{0.75}Co_{0.25}S_2$ and (e)$Ni_{0.8}Co_{0.2}S_2$.

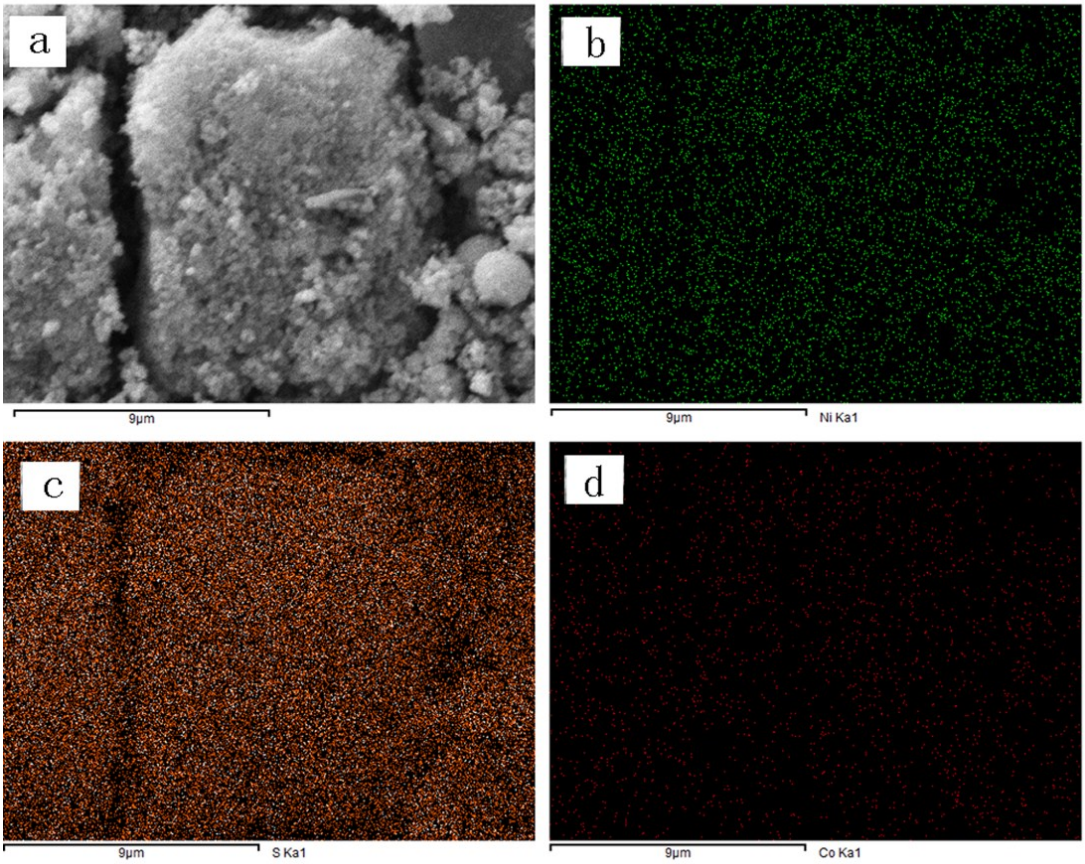

Figure S3. Elemental mapping of the $Ni_{0.75}Co_{0.25}S_2$.

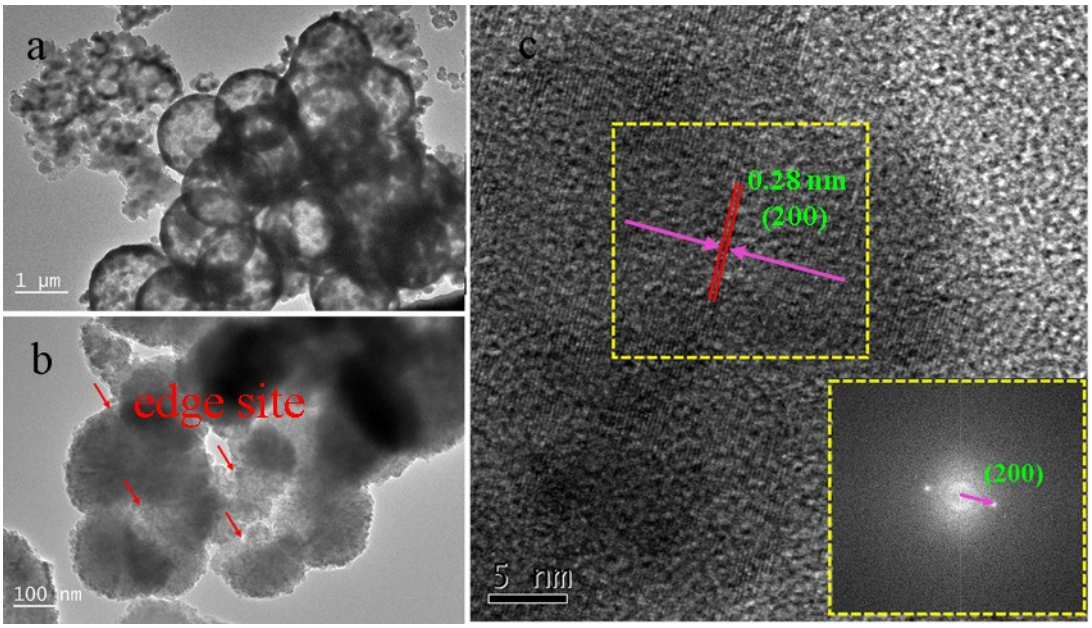

Figure S4. TEM images (a and b) and HRTEM image (c) of the NiS_2, and the inset is FFT (fast-Fourier transform) image obtained from the yellow square region.

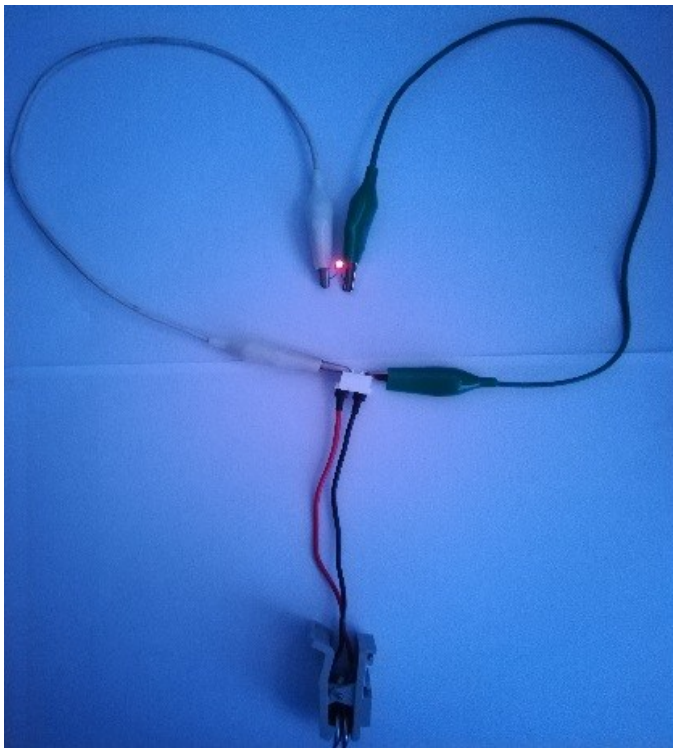

Figure S5. A photograph of a red LED lighted up by two supercapacitors in series

III. Tables

Table S1. The full width at half maximum (FWHM) of Ni 2p XPS of NiS_2 and $Ni_{0.75}Co_{0.25}S_2$.

Sample	Position (eV)	FWHM (eV)	Position (eV)	FWHM (eV)
NiS_2	853.8	1.77	871.2	2.52
$Ni_{0.75}Co_{0.25}S_2$	853.9	2.21	871.6	3.44

Table S2. Performance comparison of the nickel sulfide-based electrode materials in three-electrode configuration with previously published results[1-30]

Ref.	Electrode materials	Maximum capacitance	Cycle number	Capacitance retention ratio
1	Ni_3S_4	1213 F g^{-1} at 2 A g^{-1}	2000	60 % at 2 A g^{-1}
2	NiS	1636.4 F g^{-1} at 2 A g^{-1}	1000	102.8 % at 50 mv s^{-1}
3	NiS/rGO	905.2 F g^{-1} at 0.5 A g^{-1}	2000	88.3 % at 4 A g^{-1}
4	Ni_3S_2/carbon fiber	957 F g^{-1} at 1 A g^{-1}	1000	83.5 % at 4 A g^{-1}
5	NiS	857.76 F g^{-1} at 2 A g^{-1}	1000	41 % at 2 A g^{-1}
6	NiS_2	695 F g^{-1} at 1.25 A g^{-1}	3000	93.4 % at 1.25 A g^{-1}
7	Graphene/NiS_2 composite	478.1 F g^{-1} at 0.5 A g^{-1}	2000	89.3 % at 5 A g^{-1}
8	α-NiS	717.3 F g^{-1} at 0.6 A g^{-1}	1000	98.5 % at 20 A g^{-1}
9	NiS_2	1020.2 F g^{-1} at 1 A g^{-1}	1000	93.4 % at 2 A g^{-1}
10	NiS_2/NiO	2251 F g^{-1} at 1 A g^{-1}	2000	78 % at 5 A g^{-1}
11	NiS-NiS_2/rGO	1169 F g^{-1} at 5 A g^{-1}	3000	41.4 % at 10 A g^{-1}
12	NiS_2/ZnS	1198 F g^{-1} at 1 A g^{-1}	1000	87 % at 5 A g^{-1}
13	Ni_3S_2-NiS	1077.3 F g^{-1} at 5 A g^{-1}	10000	76.3 % at 20 A g^{-1}
14	NiS	1122.7 F g^{-1} at 1 A g^{-1}	1000	97.8 % at 10 A g^{-1}
15	NiS_2	1643 F g^{-1} at 1 A g^{-1}	1000	27.9 % at 1 A g^{-1}
16	NiS	1315.4 F g^{-1}at 1 A g^{-1}	5000	84.2 % at 10 A g^{-1}
17	Ni_xS_y@CoS	2291 F g^{-1}at 2 A g^{-1}	2000	37.6 % at 20 A g^{-1}
18	Co_9S_8/RGO/ Ni_3S_2 on Ni foam	13.53 F cm^{-2} at 20 mA cm^{-2}	1000	91.7% at 80 mA cm^{-2}
19	Nickel sulfides/MoS_2	757 F g^{-1} at 0.5 A g^{-1}	2000	100 % at 5 A g^{-1}
20	β-NiS	697.3 C g^{-1} at 2 A g^{-1}	2500	80 % at 10 A g^{-1}
21	Ni@rGO Ni_3S_2	987.8 F g^{-1} at 1 A g^{-1}	3000	97.9 % at 12 A g^{-1}
22	NiS	1897 F g^{-1} at 1 A g^{-1}		
23	NiS	718 F g^{-1} at 2 A g^{-1}	3000	82.6 % at 2 A g^{-1}
24	NiS/Ni Foam	2.64 F cm^{-2} at 2.5 mA cm^{-2}	2000	90 % at 2.5 mA cm^{-2}
25	α-NiS	1092 F g^{-1} at 1 A g^{-1}	2000	100 % at 5 A g^{-1}
26	Ni_3S_2@β-NiS	1158 F g^{-1} at 2 A g^{-1}	2000	97.4 % at 15 A g^{-1}
27	NiS/CoO	1054 F g^{-1} at 6A g^{-1}	3000	91.7 % at 10 A g^{-1}
28	$Co_{1.5}Ni_{1.5}S_4$	1370.7 F g^{-1} at 0.5 A g^{-1}	2000	88.8 % at 0.5 A g^{-1}
29	$Ni_xCo_{3x}S_4$	1418 F g^{-1} at 5 A g^{-1}	/	/
30	$Ni_{0.31}Co_{0.69}S_2$ /graphene	1166 F g^{-1} at 1 A g^{-1}	1000	74.5 % at 5 A g^{-1}
This work	$Ni_{0.75}Co_{0.25}S_2$	238.0 mAh g^{-1} (equivalent to 2142.0 F	1000	81.8 % at 10 A g^{-1}
			2000	75.6 % at 10 A g^{-1}
			3000	75.3 % at 10 A g^{-1}

		g^{-1}) at 2 A g^{-1}		

As seen in the **Table S2**, the capacity values of $Ni_{0.75}Co_{0.25}S_2$ is somewhat inferior to that of Ni_xS_y@CoS [17], but the capacity retention ratio is significantly higher than that of it.

References

1. L. Wang, J. Liu, L. Zhang, B. Dai, M. Xu, M. Ji, X. S. Zhao, C. Cao, J. Zhang and H. Zhu, *RSC Adv.*, 2015, **5**, 8422-8426.
2. Z. Li, A. Gu, J. Sun and Q. Zhou, *New J. Chem*, 2016, **40**, 1663-1670.
3. J. Yang, X. Duan, W. Guo, D. Li, H. Zhang and W. Zheng, *Nano Energy*, 2014, **5**, 74-81.
4. W. Yu, W. Lin, X. Shao, Z. Hu, R. Li and D. Yuan, *J. Power Sources*, 2014, **272**, 137-143.
5. J. Yang, X. Duan, Q. Qin and W. Zheng, *J. Mater. Chem. A*, 2013, **1**, 7880-7884.
6. H. Pang, C. Wei, X. Li, G. Li, Y. Ma, S. Li, J. Chen and J. Zhang, *Sci. Rep.*, 2014, **4**, 3577.
7. X. Li, J. Shen, N. Li and M. Ye, *Mater. Lett.*, 2015, **139**, 81-85.
8. C. Wei, C. Cheng, Y. Cheng, Y. Wang, Y. Xu, W. Du and H. Pang, *Dalton T.*, 2015, **44**, 17278-17285.
9. Y. Ruan, J. Jiang, H. Wan, X. Ji, L. Miao, L. Peng, B. Zhang, L. Lv and J. Liu, *J. Power Sources*, 2016, **301**, 122-130.
10. D. Zhang, X. Zhou, K. Ye, Y. Li, C. Song, K. Cheng, D. Cao, G. Wang and Q. Li,

Electrochimi. Acta, 2015, **173**, 209-214.

11. Z. Xing, Q. Chu, X. Ren, J. Tian, A. M. Asiri, K. A. Alamry, A. O. Al-Youbi and X. Sun, *Electrochem. Commun.*, 2013, **32**, 9-13.

12. G.-C. Li, M. Liu, M.-K. Wu, P.-F. Liu, Z. Zhou, S.-R. Zhu, R. Liu and L. Han, *RSC Adv.*, 2016, **6**, 103517-103522.

13. X. Zang, Z. Dai, J. Yang, Y. Zhang, W. Huang and X. Dong, *ACS Appl. Mater. Inter.*, 2016, **8**, 24645-24651.

14. B. Guan, Y. Li, B. Yin, K. Liu, D. Wang, H. Zhang and C. Cheng, *Chem. Eng. J.*, 2017, **308**, 1165-1173.

15. M. Lu, X.-P. Yuan, X.-H. Guan and G.-S. Wang, *J. Mater. Chem. A*, 2017, **5**, 3621-3627.

16. J. Zhao, B. Guan, B. Hu, Z. Xu, D. Wang and H. Zhang, *Electrochimi. Acta*, 2017, **230**, 428-437.

17. R. Gao, Q. Zhang, F. Soyekwo, C. Lin, R. Lv, Y. Qu, M. Chen, A. Zhu and Q. Liu, *Electrochimi. Acta*, 2017, **237**, 94-101.

18. Z. Zhang, Q. Wang, C. Zhao, S. Min and X. Qian, *ACS Appl. Mater. Inter.*, 2015, **7**, 4861-4868.

19. X. Yang, L. Zhao and J. Lian, *J. Power Sources*, 2017, **343**, 373-382.

20. Y. Ruan, D. Zha, L. Lv, B. Zhang, J. Liu, X. Ji, C. Wang and J. Jiang, *Electrochimi. Acta*, 2017, **236**, 307-318.

21. D. Ghosh and C. K. Das, *ACS Appl. Mater. Inter.s*, 2015, **7**, 1122-1131.

22. Z. Li, X. Yu, A. Gu, H. Tang, L. Wang and Z. Lou, *Nanotechnology*, 2017, **28**,

065406.

23. X. Yan, X. Tong, L. Ma, Y. Tian, Y. Cai, C. Gong, M. Zhang and L. Liang, *Mater. Lett.*, 2014, **124**, 133-136.

24. L. Yu, B. Yang, Q. Liu, J. Liu, X. Wang, D. Song, J. Wang and X. Jing, *J. Electroanal. Chem*, 2015, **739**, 156-163.

25. C. Sun, M. Ma, J. Yang, Y. Zhang, P. Chen, W. Huang and X. Dong, *Sci. Rep.*, 2014, **4**, 7054.

26. W. Li, S. Wang, L. Xin, M. Wu and X. Lou, *J. Mater. Chem. A*, 2016, **4**, 7700-7709.

27. J. Wu, C. Ouyang, S. Dou and S. Wang, *Nanotechnology*, 2015, **26**, 325401.

28. Y. Tang, T. Chen, S. Yu, Y. Qiao, S. Mu, S. Zhang, Y. Zhao, L. Hou, W. Huang and F. Gao, *J. Power Sources*, 2015, **295**, 314-322.

29. W. Chen, C. Xia and H. N. Alshareef, *ACS Nano,* 2014, **8**, 9531-9541.

30. G. Li and C. Xu, *Carbon*, 2015, **90**, 44-52.