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# Polypyrrole nanoparticles embedded nitrogen-doped graphene composites as novel cathode for long life cycles and high-power zinc-ion hybrid supercapacitors

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**Table S1** the lists of ZICs/ZHSCs reports

| Materials | Electrolyte | Specific capacitance | Specific capacity | Energy/Power density | Retention | Ref. |
|---|---|---|---|---|---|---|
| Hollow carbon spheres | $ZnSO_4$ PAM | - | 86.8 mA h $g^{-1}$ at 0.5 A $g^{-1}$ | 59.7 Wh $kg^{-1}$ at 447.8 W $kg^{-1}$ | 98% after 15000 cycles at 1.0 A $g^{-1}$ | 1 |
| Coconut shells derived activated carbon | 1.0 M $Zn(CF_3SO_3)_2$ in AN | 170 F $g^{-1}$ at 0.1 A $g^{-1}$ | - | 52.7 Wh $kg^{-1}$ at 1725 W $kg^{-1}$ | 85% after 22000 cycles at 2.0 A $g^{-1}$ | 2 |
| Kelp-Carbon | $Zn(CF_3SO_3)_2$ PAM | 445 F $g^{-1}$ at 0.1 A $g^{-1}$ | 196.7 mAh $g^{-1}$ at 0.1 A $g^{-1}$ | 111.5 Wh $kg^{-1}$ at 1300 W $kg^{-1}$ | 88% after 4000 cycles at 0.1 A $g^{-1}$ | 3 |
| Activated graphene | 3.0 M $Zn(CF_3SO_3)_2$ | 210 F $g^{-1}$ at 0.1 A $g^{-1}$ | - | 31.4 kW $kg^{-1}$ at 106.3 Wh $kg^{-1}$ | 93% after 80000 cycles at 8.0 A $g^{-1}$ | 4 |
| $ZnMn_2O_4$/carbon | 3.0 M $Zn(CF_3SO_3)_2$ | - | 120 mAh $g^{-1}$ at 0.05 A $g^{-1}$ | ~202 Wh $kg^{-1}$ | 94% after 500 cycles at 0.5 A $g^{-1}$ | 5 |
| Nanostructured PPy composite | 2.0 M $ZnCl_2$ +3.0 M $NH_4Cl$ | - | 151.1 mAh $g^{-1}$ at 0.05 A $g^{-1}$, 125 mAh $g^{-1}$ at 0.1 A $g^{-1}$ | 11.7 kW $kg^{-1}$ at 64.0 Wh $kg^{-1}$ | 76.7% after 1000 cycles at 8.0 A $g^{-1}$ | 6 |
| Hollow mesoporous-carbon nanospheres | 2.0 M $ZnSO_4$ +1.0 M $Na_2SO_4$ | 212.1 F $g^{-1}$ at 0.2 A $g^{-1}$ | - | 75.4 Wh $kg^{-1}$ at 0.16 kW $kg^{-1}$ | 99.4% after 2500 cycles at 2.0 A $g^{-1}$ | 7 |
| AC raw material | 2.0 M $ZnSO_4$ | - | 121 mAh $g^{-1}$ | 84 Wh $kg^{-1}$ at 14.9 kW $kg^{-1}$ | 91% after 10000 cycles at 1.0 A $g^{-1}$ | 8 |
| Bamboo-derived porous carbons | 2.0 M $ZnSO_4$ | - | 51.4 mA h $g^{-1}$ | 12.1 Wh $kg^{-1}$ at 993.4 W $kg^{-1}$ | 99 % after 2500 cycles at 1.0 A $g^{-1}$ | 9 |
| Mesoporous structured activated carbon | 2.0 M $ZnSO_4$ (two electrode testing) | - | 176 mAh $g^{-1}$ at 0.5 A $g^{-1}$, 80 mAh $g^{-1}$ at 7.0 A $g^{-1}$ | 188 Wh $kg^{-1}$ at 533 W $kg^{-1}$ | 78% after 40000 cycles 10.0 A $g^{-1}$ | 10 |
| Porous carbon nanosheets | $ZnCl_2$ deep-eutectic-solvent electrolyte | - | 78.6 mAh $g^{-1}$ at 0.5 A $g^{-1}$ | 52.8 W h $kg^{-1}$ at 384.8 W $kg^{-1}$ | - | 11 |
| Three-dimensional (3D) graphene | 1.0 M $ZnSO_4$ electrolyte | 222.03 F $g^{-1}$ at 0.5 A $g^{-1}$ | - | 118.42 Wh $L^{-1}$ at 24.00 kW $L^{-1}$ | 80% after 30000 cycles at 10 A $g^{-1}$ | 12 |
| Hierarchically porous carbon | 3.0 M $Zn(CF_3SO_3)_2$ | 44.3 F $g^{-1}$ at 0.5 A $g^{-1}$ | - | 6.2 W h $kg^{-1}$ at 250 W $kg^{-1}$ | > 98% after 10000 cycles at 2.0 A $g^{-1}$ | 13 |
| ZN@graphene /AC cathodes | 2.0 M $ZnSO_4$ electrolyte | 186 F $g^{-1}$ at 0.1 A $g^{-1}$ | - | 78.32-30.26 Wh $kg^{-1}$ at 30.26- 8010 W $kg^{-1}$ | > 80 % after 10000 cycles 0.1 A $g^{-1}$ | 14 |
| 3D MXene (Ti3C2Tx)-reduced graphene oxide | $ZnSO_4$ | 128.6 F $g^{-1}$ 0.4 A $g^{-1}$ | - | 34.9 Wh $kg^{-1}$ at 279.9 W $kg^{-1}$ | 95 % after 75000 at 5.0 A $g^{-1}$ | 15 |
| Oxygen-enriched porous carbon | gelatin/$ZnSO_4$ | - | 132.7 mAh $g^{-1}$ at 0.2 A $g^{-1}$ | 38.6 W h $kg^{-1}$ at 3760 W $kg^{-1}$ | - | 16 |
| N-rGO/PPy | 2.0 M $ZnSO_4$ | 385 F $g^{-1}$ at 0.1 A $g^{-1}$ | 145.32 mA h $g^{-1}$ at 0.1 A $g^{-1}$, 69 mAh $g^{-1}$ at 7.0 A $g^{-1}$ | 232.50 - 110.40 W h k $g^{-1}$ at 160 - 11200 W k $g^{-1}$ | 82.5% after 10000 cycles at 7.0 A $g^{-1}$ | (This work) |

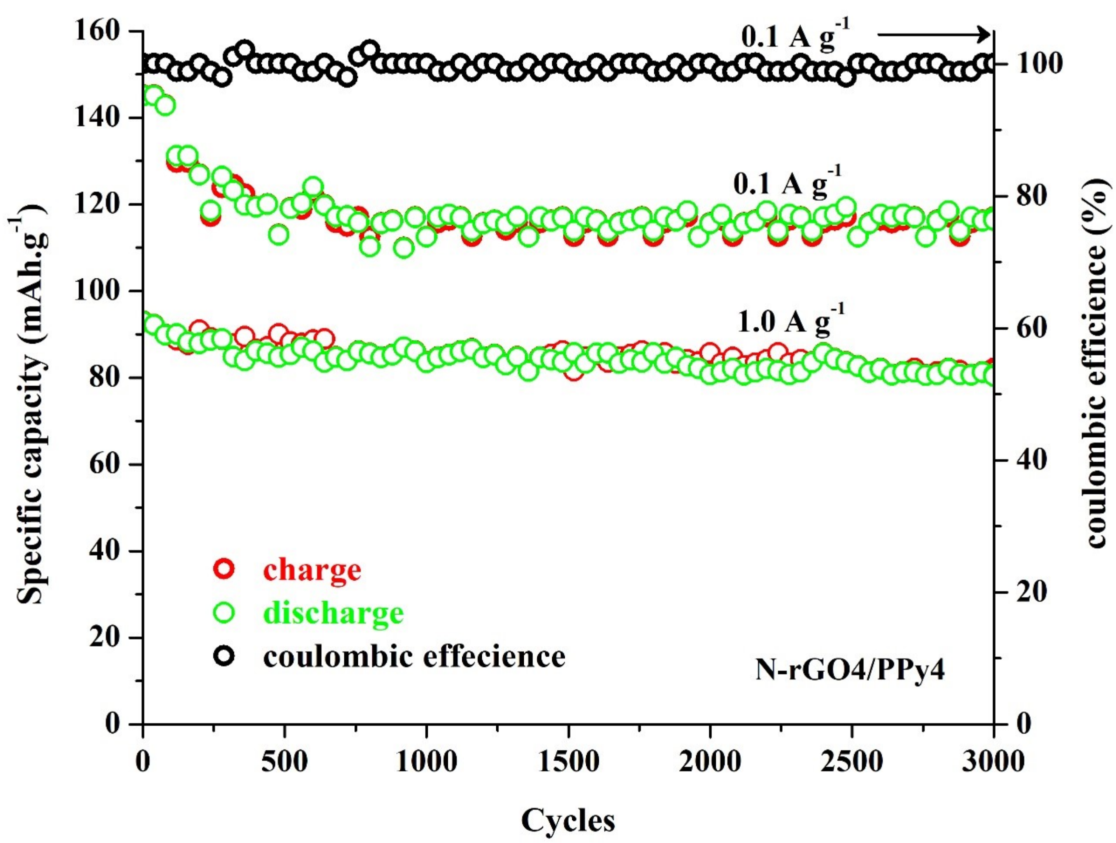


**Fig. S1** The rate capacity of N-rGO4/PPy4 at 0.1 and 1.0 A $g^{-1}$ for 3000 cycles

## References


1. S. Chen, L. Ma, K. Zhang, M. Kamruzzaman, C. Zhi and J. A. Zapien, *Journal of Materials Chemistry A*, 2019, **7**, 7784-7790.
2. H. Wang, M. Wang and Y. Tang, *Energy Storage Materials*, 2018, **13**, 1-7.
3. J. Zeng, L. Dong, L. Sun, W. Wang, Y. Zhou, L. Wei and X. Guo, *Nano-Micro Letters*, 2020, **13**, 19.
4. S. Wu, Y. Chen, T. Jiao, J. Zhou, J. Cheng, B. Liu, S. Yang, K. Zhang and W. Zhang, *Advanced Energy Materials*, 2019, **9**, 1902915.
5. N. Zhang, F. Cheng, Y. Liu, Q. Zhao, K. Lei, C. Chen, X. Liu and J. Chen, *Journal of the American Chemical Society*, 2016, **138**, 12894-12901.
6. X. Li, X. Xie, R. Lv, B. Na, B. Wang and Y. He, *Energy Technology*, 2019, **7**, 1801092.
7. S. Chen, G. Yang, X. Zhao, N. Wang, T. Luo, X. Chen, T. Wu, S. Jiang, P. A. van Aken, S. Qu, T. Li, L. Du, J. Zhang, H. Wang and H. Wang, *Frontiers in Chemistry*, 2020, **8**, 663.
8. L. Dong, X. Ma, Y. Li, L. Zhao, W. Liu, J. Cheng, C. Xu, B. Li, Q.-H. Yang and F. Kang, *Energy Storage Materials*, 2018, **13**, 96-102.
9. H. Chen, Y. Zheng, X. Zhu, W. Hong, Y. Tong, Y. Lu, G. Pei, Y. Pang, Z. Shen and C. Guan, *Materials Research Bulletin*, 2021, **139**, 111281.
10. G.-H. An, *Applied Surface Science*, 2020, **530**, 147220.
11. H. Tian, R. Cheng, L. Zhang, Q. Fang, P. Ma, Y. Lv and F. Wei, *Materials Letters*, 2021, **301**, 130237.
12. L. Zhang, D. Wu, G. Wang, Y. Xu, H. Li and X. Yan, *Chinese Chemical Letters*, 2021, **32**, 926-931.
13. H. Li, J. Wu, L. Wang, Q. Liao, X. Niu, D. Zhang and K. Wang, *Chemical Engineering Journal*, 2022, **428**, 131071.
14. X. Zhang, C. Chen, S. Gao, X. Luo, Y. Mo, B. Cao and Y. Chen, *Journal of Energy Storage*, 2021, **42**, 103037.
15. Q. Wang, S. Wang, X. Guo, L. Ruan, N. Wei, Y. Ma, J. Li, M. Wang, W. Li and W. Zeng, *Advanced Electronic Materials*, 2019, **5**, 1900537.
16. Y. Zheng, W. Zhao, D. Jia, Y. Liu, L. Cui, D. Wei, R. Zheng and J. Liu, *Chemical Engineering Journal*, 2020, **387**, 124161.