·**Supplementary Materials for**

Three-Dimensional NiCoS Nanotubes@NiCo-LDH Nanosheets Core-Shell Heterostructure for High-Rate Capability Alkaline Zinc-Based Batteries

*Linxi Dai, Shangshu Peng, Xinhai Wang, Bo Chen, Yang Wu, Quan Xie, Yunjun Ruan**

Institute of Advanced Optoelectronic Materials and Technology, College of Big Data and Information Engineering, Guizhou University, Guiyang 550025, China.

**Corresponding author E-mail: yjruan@gzu.edu.cn (Yunjun Ruan)*

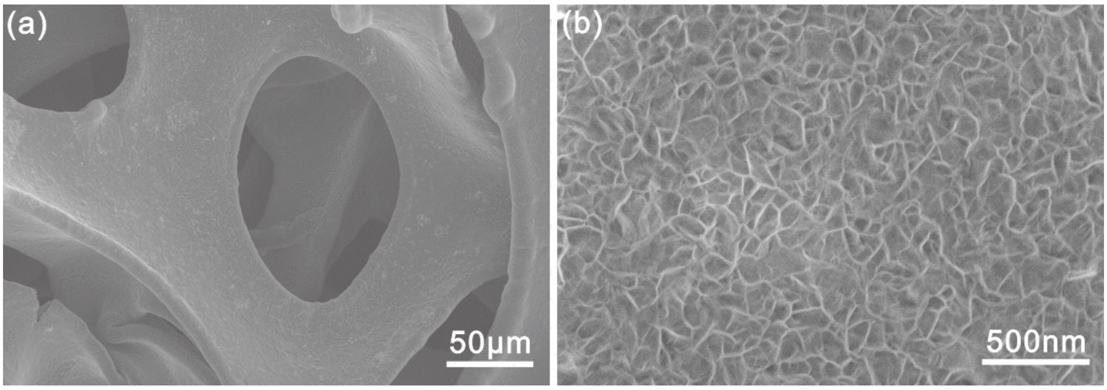

Figure S1. SEM image of (a)NF and (b)NiCo-LDH nanosheets on Ni foam.

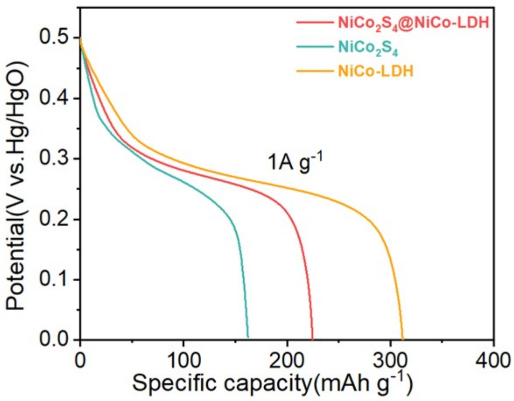

Figure S2. GCD curves of the NiCoS@NiCo-LDH, NiCoS, and NiCo-LDH at 1 A g^{-1}.

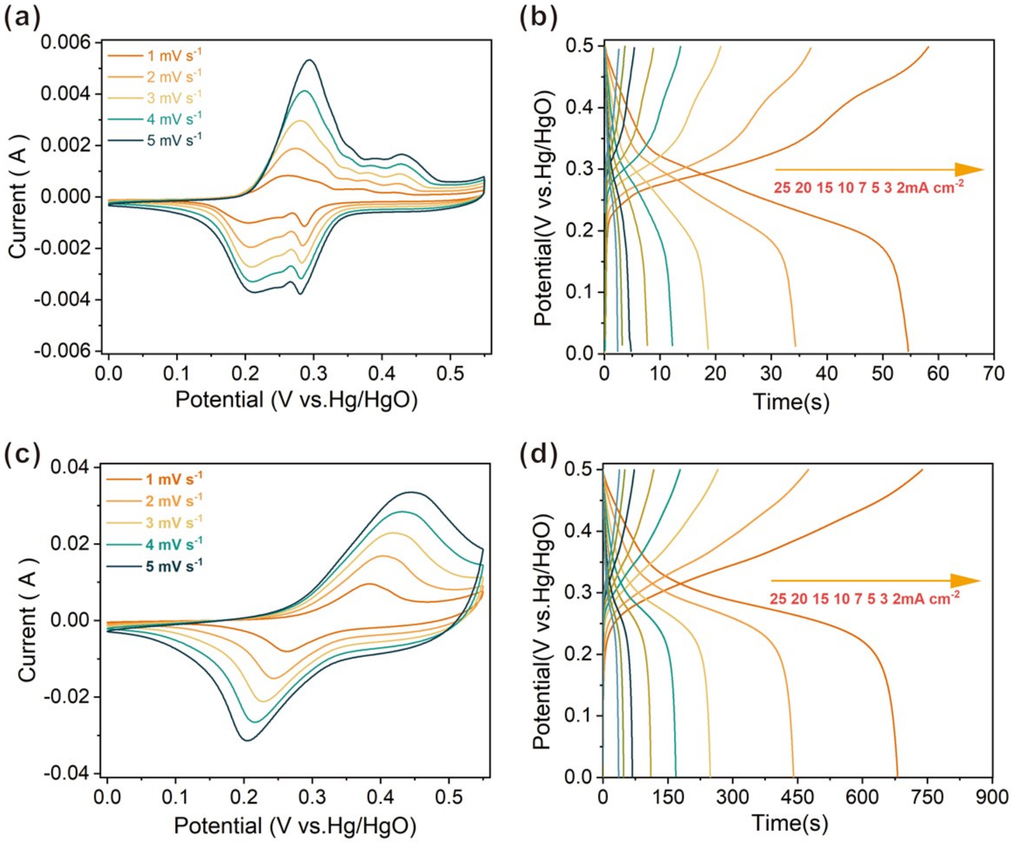

Figure S3. (a) CV curves and (b) GCD curves of NiCo-LDH. (c) CV curves and (d) GCD curves of NiCoS.

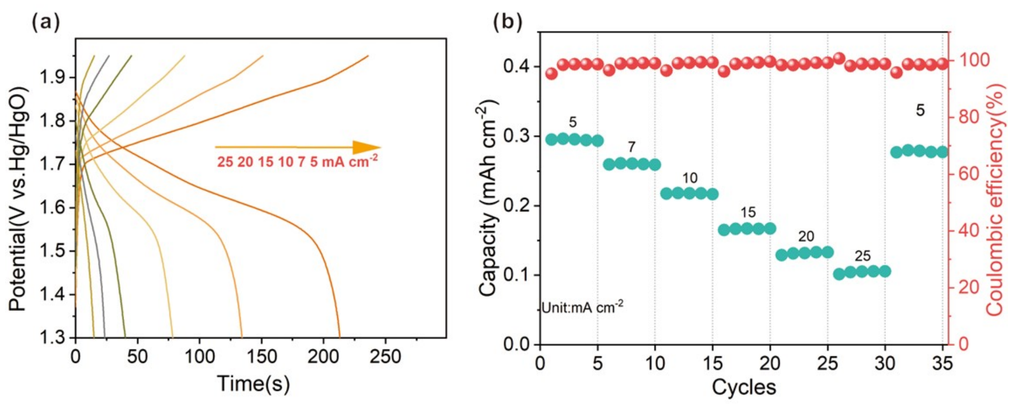

Figure S4.(a) GCD curves for various current densities of NiCoS//Zn battery.(b) Rate performance and coulombic efficiency of NiCoS//Zn battery

Table S1. Comparison of area capacity of alkaline Zn-based batteries.

Battery	Area capacity	Reference
NiCoS@NiCo-LDH//Zn	0.54 mAh cm^{-2} (5 mA cm^{-2})	This work
FCO//Zn	0.24 mAh cm^{-2} (4 mA cm^{-2})	1
COHF//Zn	0.265 mAh cm^{-2} (4 mA cm^{-2})	2
CNF@$NiCo_2S_4$//Zn	0.32 mAh cm^{-2} (2 mA cm^{-2})	3
NiCo LDH@Ag NW//Zn	0.12 mAh cm^{-2} (0.1 mA cm^{-2})	4
P-$NiCo_2O_{4-x}$//Zn	0.24 mAh cm^{-2} (2 mA cm^{-2})	5
Ni@NiO//Zn	0.112 mAh cm^{-2} (4 mA cm^{-2})	6
CC-CF@NiO//CC-CF@ZnO	0.39 mAh cm^{-2} (0.5 mA cm^{-2})	7

Table S2. Cycling performance of different alkaline Zn-based batteries.

Battery	Electrolyte	Cycle performance	Reference（
NiCoS@NiCo-LDH//Zn	6M KOH + sat. ZnO	95.9% after 3000cycles	This work
Ni–NiO/CC//Zn	6M KOH+0.5M $ZnAc_2$	87.5% after 2000cycles	8
$NiCo_2O_4$//Zn plate	6M KOH+0.1M $ZnAc_2$	63.2% after 1000cycles	9
Ni_2P//Zn@CF	1M KOH + 20mM $ZnAc_2$	80.0% after 1500cycles	10
NiCo-90//Zn foil	2.5M KOH + sat. ZnO	73.0% after 850cycles	11
Co-Ni_3Se_2//Zn foil	1M KOH	77.9% after 100cycles	12
FNCP//Zn	1M KOH	90.6% after 2000cycles	13
Al-CoNiDH-5%//Zn	2.5M KOH + sat. ZnO	64.4% after 2000cycles	14
Ni_3S_2/Ov-$Ni(OH)_2$//Zn	1M KOH + 20mM $ZnAc_2$	93.2% after 3000cycles	15
CNF@$NiCo_2S_4$//Zn	3M KOH+0.1M $ZnAc_2$	83.0% after 2000 cycles	3
Ni_3S_2@PEDOT//Zn	1M KOH+20mM $ZnAc_2$	97.3% after 2000 cycles	16
Co_3O_4@NiO//Zn@Cu foil	6M KOH	89% after 500cycles	17
CC-CF@NiO//CC-CF@ZnO	2M KOH + sat. ZnO	72.9% after 2400cycles	7

Table S3. Electrochemical performance of different alkaline Zn-based batteries.

Battery	Electrolyte	Energy density /Wh kg^{-1}	Power density /kW kg^{-1}	Reference
NiCoS@NiCo-LDH//Zn	6M KOH + sat. ZnO	435.3	4.1	This work
Ni_3S_2/OV-$Ni(OH)_2$//Zn	1M KOH+20mM $ZnAc_2$	384.6	1.73	15
$Ni_{12}P_5$//Zn	1M K_2CO_3+2M kF+4M KOH + sat. ZnO	287.9	5.1	18
NCS@NCH//Zn	2M KOH+0.02M $Zn(CH_3COO)_2 \cdot 2H_2O$	194.2	0.72	19
Ni/NiO-BCF//Zn	6M KOH + 0.5mM $Zn(Ac)_2$	313.4	0.66	20
$Ni(OH)_2$/CNFs//Zn	6M KOH+1M LiOH,and PAAS saturated with ZnO gel.	325	1.23	21
R-Co_3O_4//Zn	6M KOH saturated with $Zn(Ac)_2$	295.5	0.84	22
$NiCo_2O_4$//Zn	1M KOH and 20mM $Zn(Ac)_2$	248.3	2.2	23
Ni_3S_2@PANI//Zn	6M KOH + 0.2M $Zn(CH_3COO)_2$	308	6.9	24
CC-CF@NiO//CC-CF@ZnO	2M KOH + sat. ZnO	355.7	0.46	7
Co_3O_4@NiO//Zn	6M KOH sat. ZnO	215.5	3.45	17

References

1 J. Xie, H. Zhang, F. Yang, X. Cao, X. Liu and X. Lu, *Chemical Communications*, 2022, **58**, 3977-3980.

2 J. Wu, Y. Lin, R. Qin, Y. Zeng and X. Lu, *ACS Sustainable Chemistry & Engineering*, 2020, **8**, 1464-1470.

3 Z. Cui, S. Shen, J. Yu, J. Si, D. Cai and Q. Wang, *Chemical Engineering Journal*, 2021, **426**, 130068.

4 X. Xuan, M. Qian, L. Pan, T. Lu, Y. Gao, L. Han, L. Wan, Y. Niu and S. Gong, *JOURNAL OF ENERGY CHEMISTRY*, 2022, **70**, 593-603.

5 Y. Zeng, Z. Lai, Y. Han, H. Zhang, S. Xie and X. Lu, *ADVANCED MATERIALS*, 2018, **30**, 1802396.

6 F. Wang, Y. Lu, S. Zeng, Y. Song, D. Zheng, W. Xu and X. Lu, *CHEMELECTROCHEM*, 2020, **7**, 4572-4577.

7 J. Liu, C. Guan, C. Zhou, Z. Fan, Q. Ke, G. Zhang, C. Liu and J. Wang, *ADVANCED MATERIALS*, 2016, **28**, 8732-8739.

8 L. Li, L. Jiang, Y. Qing, Y. Zeng, Z. Zhang, L. Xiao, X. Lu and Y. Wu, *Journal of Materials Chemistry A*, 2020, **8**, 565-572.

9 W. Shang, W. Yu, P. Tan, B. Chen, H. Xu and M. Ni, *JOURNAL OF POWER SOURCES*, 2019, **421**, 6-13.

10 J. Wen, Z. Feng, H. Liu, T. Chen, Y. Yang, S. Li, S. Sheng and G. Fang, *Applied Surface Science*, 2019, **485**, 462-467.

11 H. Chen, Z. Shen, Z. Pan, Z. Kou, X. Liu, H. Zhang, Q. Gu, C. Guan and J. Wang, *ADVANCED SCIENCE*, 2019, **6**, 1802002.

12 D. A. Reddy, H. Lee, M. Gopannagari, D. P. Kumar, K. Kwon, H. D. Yoo and T. K. Kim, *INTERNATIONAL JOURNAL OF HYDROGEN ENERGY*, 2020, **45**, 7741-7750.

13 W. Liu, Y. Chen, Y. Wang, Q. Zhao, L. Chen, W. Wei and J. Ma, *ENERGY STORAGE MATERIALS*, 2021, **37**, 336-344.

14 X. Zhu, Y. Wu, Y. Lu, Y. Sun, Q. Wu, Y. Pang, Z. Shen and H. Chen, *JOURNAL OF COLLOID AND INTERFACE SCIENCE*, 2021, **587**, 693-702.

15 X. Wang, Z. Yang, P. Zhang, Y. He, Z.-A. Qiao, X. Zhai and H. Huang, *JOURNAL OF ALLOYS AND COMPOUNDS*, 2021, **855**, 157488.

16 Y. He, P. Zhang, H. Huang, X. Li, X. Zhai, B. Chen and Z. Guo, *ELECTROCHIMICA ACTA*, 2020, **343**, 136140.

17 Z. Lu, X. Wu, X. Lei, Y. Li and X. Sun, *INORGANIC CHEMISTRY FRONTIERS*, 2015, **2**, 184-187.

18 Z. Wang, P. Shi, Q. Liu, J. Li, Y. Gan, J. Yao, J. Xia, X. Liu, X. Chen, K. Qian, X. Liu, L. Lv, G. Ma, L. Tao, J. Zhang, H. Wang, H. Wan and H. Wang, *Journal of Power Sources*, 2022, **550**, 232170.

19 M. Cui, X. Bai, J. Zhu, C. Han, Y. Huang, L. Kang, C. Zhi and H. Li, *ENERGY STORAGE MATERIALS*, 2021, **36**, 427-434.

20 L. Jiang, L. Li, S. Luo, H. Xu, L. Xia, H. Wang, X. Liu, Y. Wu and Y. Qing, *NANOSCALE*, 2020, **12**, 14651-14660.

21 Y. Jian, D. Wang, M. Huang, H.-L. Jia, J. Sun, X. Song and M. Guan, *ACS SUSTAINABLE CHEMISTRY & ENGINEERING*, 2017, **5**, 6827-6834.

22 Y. Lu, J. Wang, S. Zeng, L. Zhou, W. Xu, D. Zheng, J. Liu, Y. Zeng and X. Lu, *JOURNAL OF MATERIALS CHEMISTRY A*, 2019, **7**, 21678-21683.

23 H. Z. Zhang, X. Y. Zhang, H. D. Li, Y. F. Zhang, Y. X. Zeng, Y. X. Tong, P. Zhang and X. H. Lu, *GREEN ENERGY & ENVIRONMENT*, 2018, **3**, 56-62.

24 L. Zhou, X. Zhang, D. Zheng, W. Xu, J. Liu and X. Lu, *JOURNAL OF MATERIALS CHEMISTRY A*, 2019, **7**, 10629-10635.