

**Hierarchically porous  $\text{Zn}_{0.76}\text{Co}_{0.24}\text{S}/\text{CoS}$  heterostructures confined in N, S-co-doped carbon as high-performance anodes for sodium-ion batteries**

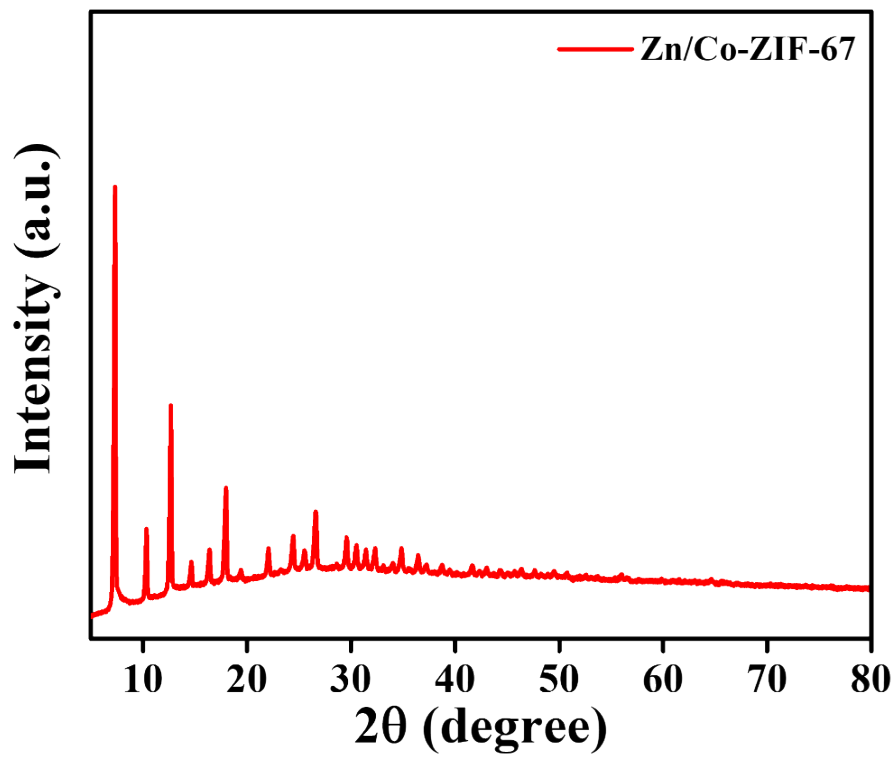
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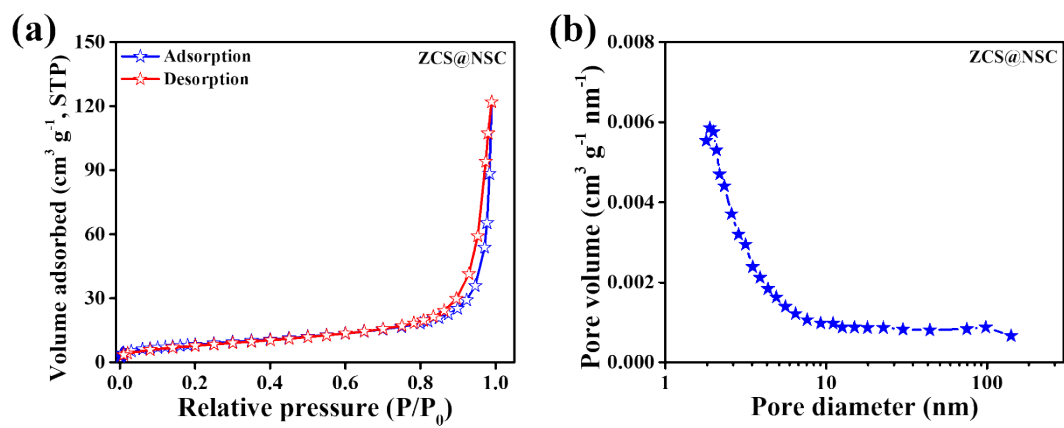
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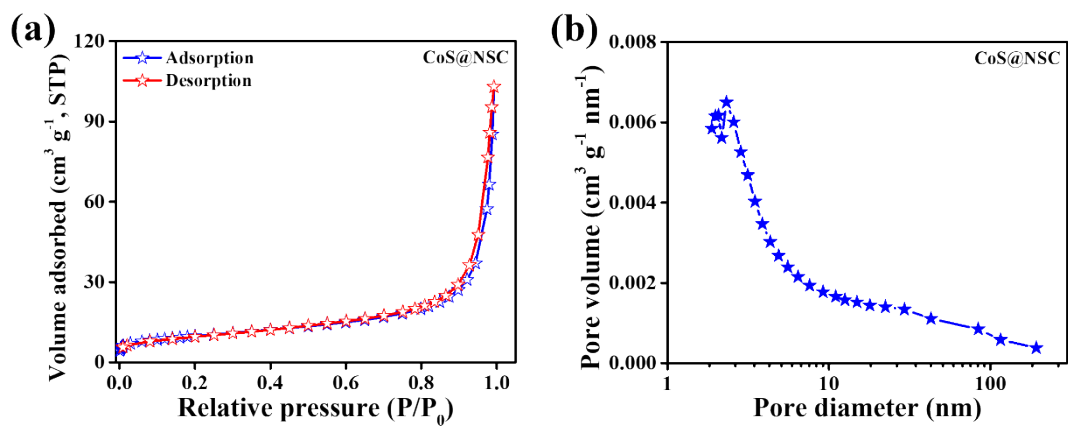
Email:lichao98.3.6@163.com; caokangzhe01@xynu.edu.cn



**Fig. S1** XRD pattern for Zn/Co-ZIF-67.



**Fig. S2** (a)  $N_2$  adsorption-desorption isotherms and (b) pore size distribution for ZCS@NSC.



**Fig. S3** (a) N<sub>2</sub> adsorption-desorption isotherms and (b) pore size distribution for CoS@NSC.

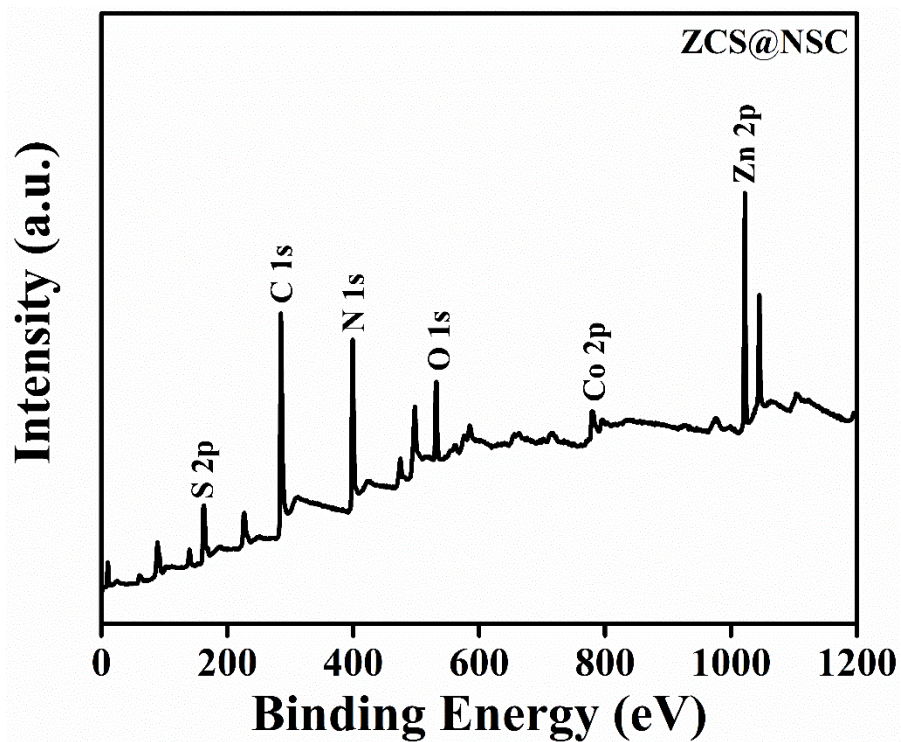
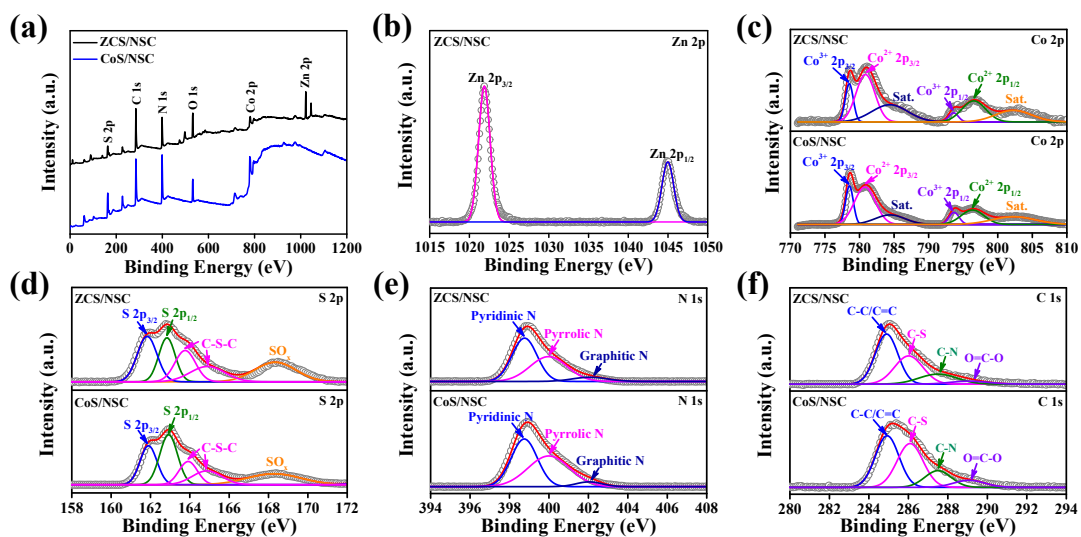


Fig. S4 The survey spectrum for ZCS@NSC.



**Fig. S5** (a) The survey spectrum for ZCS/NSC and CoS/NSC; High-magnification XPS spectra of (b) Zn 2p, (c) Co 2p, (d) S 2p, (e) N 1s, and (f) C 1s.

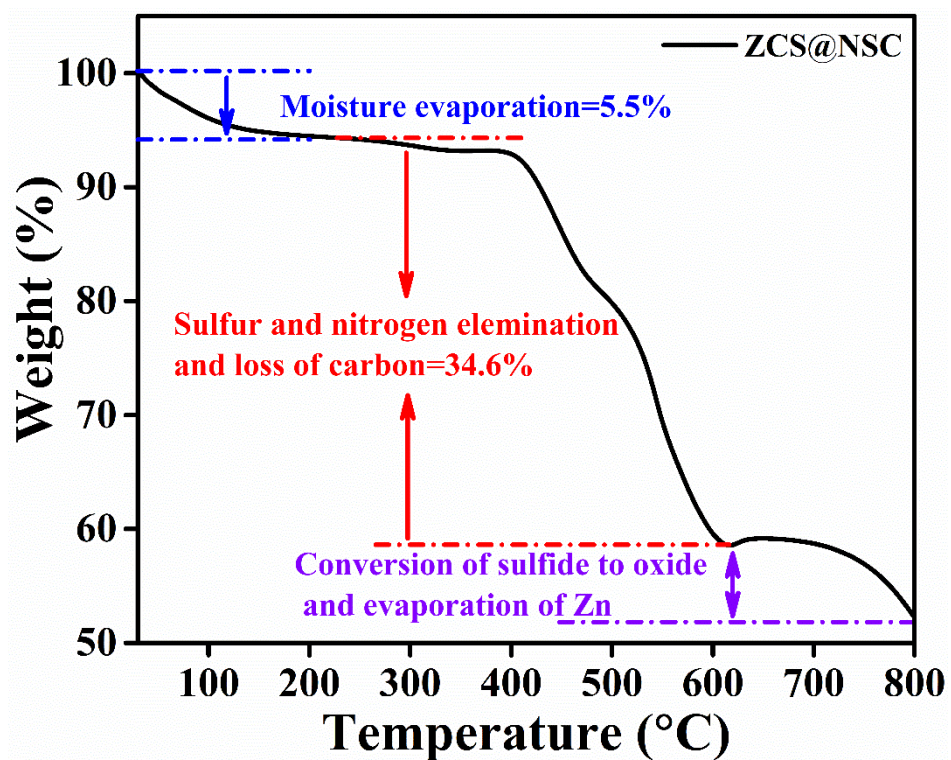
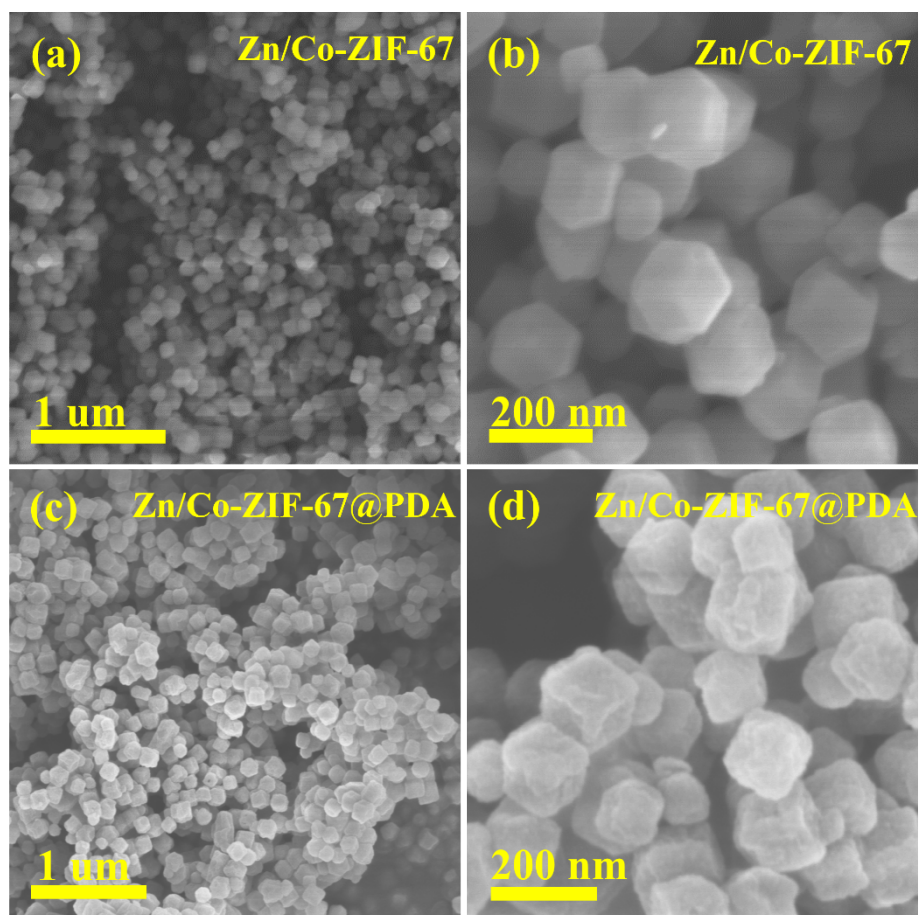
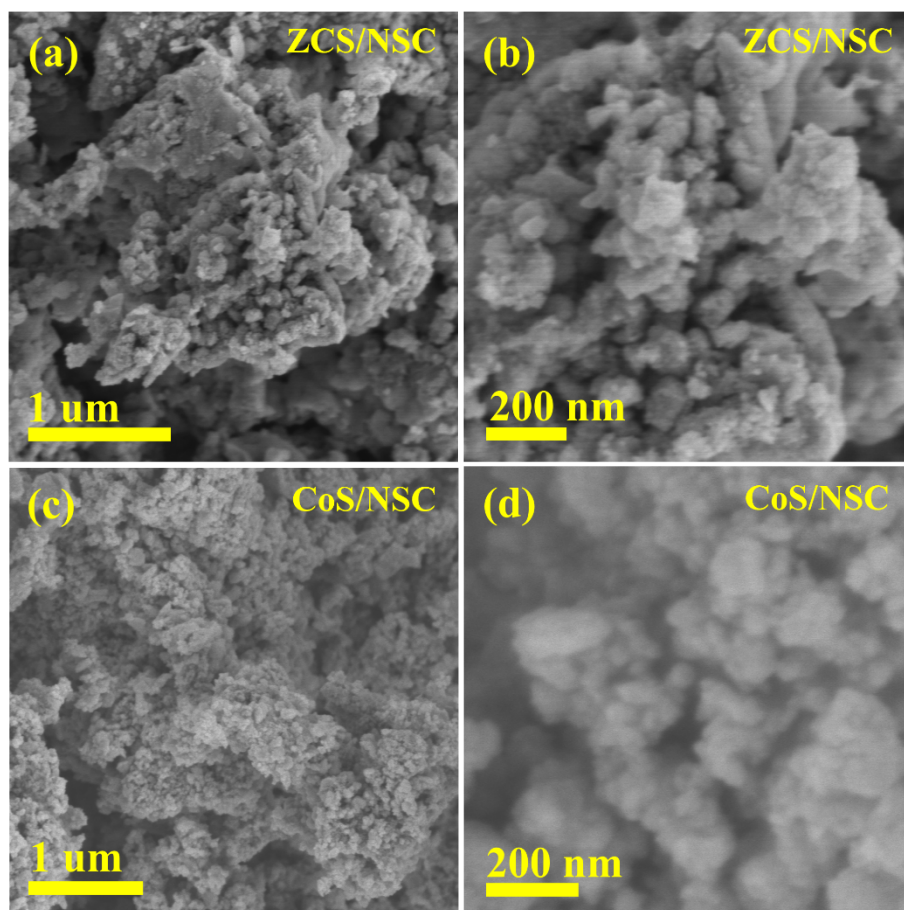


Fig. S6 TGA curve for ZCS@NSC.

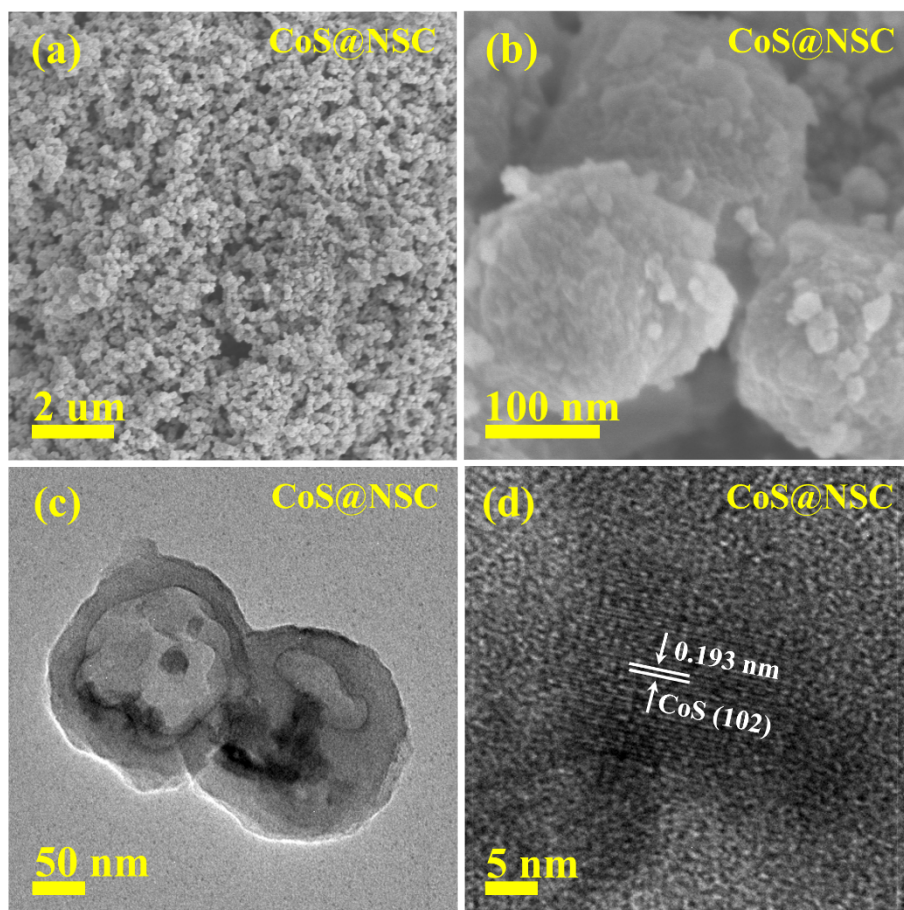


**Fig. S7** (a) low- and (b) high-resolution SEM images for Zn/Co-ZIF-67; (c) low- and (d) high-resolution SEM images for Zn/Co-ZIF-67@PDA.





**Fig. S8** (a) low- and (b) high-resolution SEM images for ZCS/NSC; (c) low- and (d) high-resolution SEM images for CoS/NSC.



**Fig. S9** (a) Low- and (b) high-resolution SEM images for CoS@NSC; (c) TEM and (d) HRTEM images for CoS@NSC.

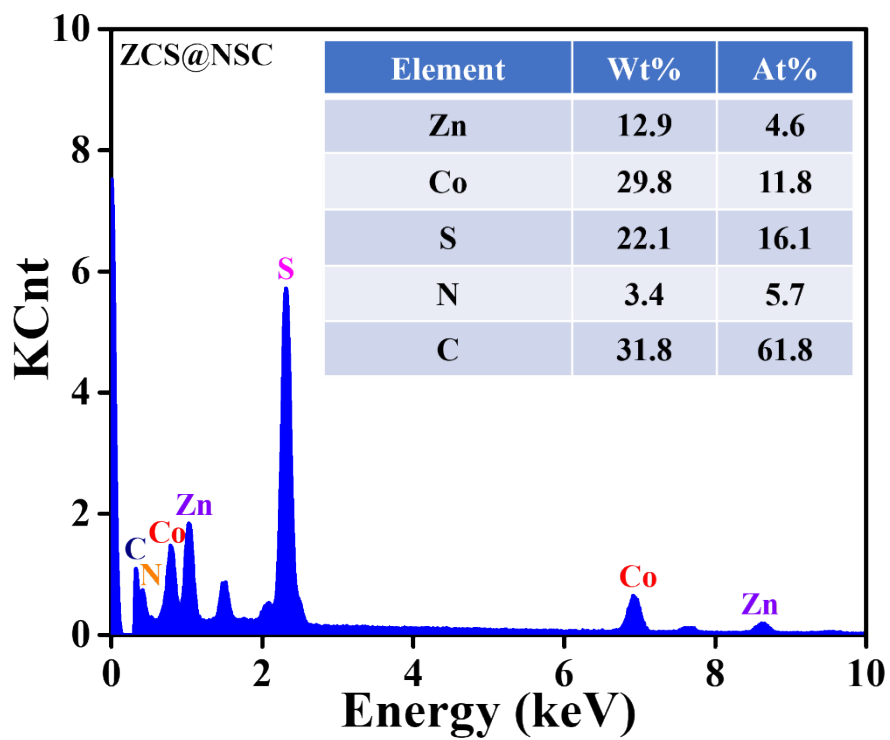
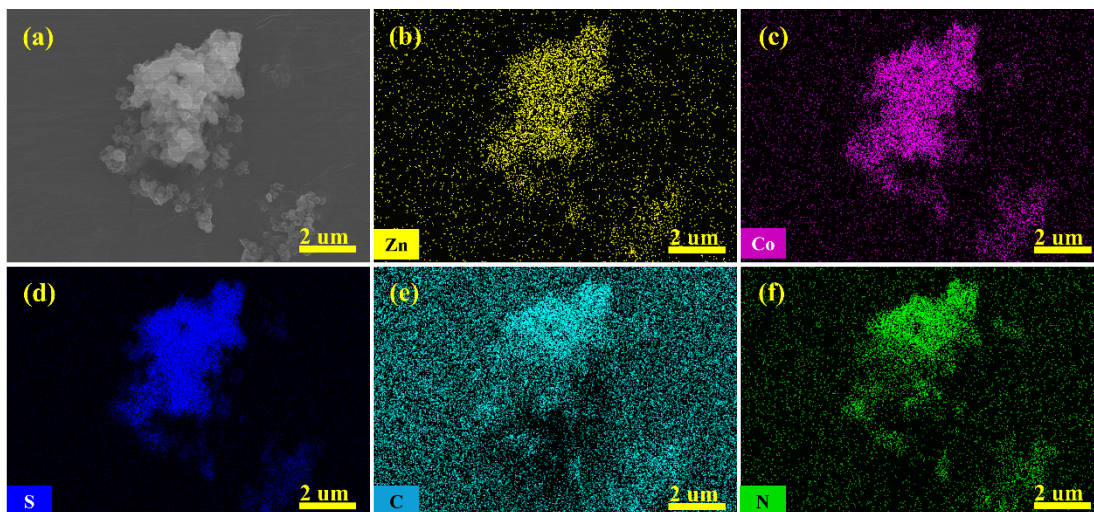


Fig. S10 EDS spectrum for ZCS@NSC.



**Fig. S11** SEM-EDS mapping spectra for ZCS@NSC.

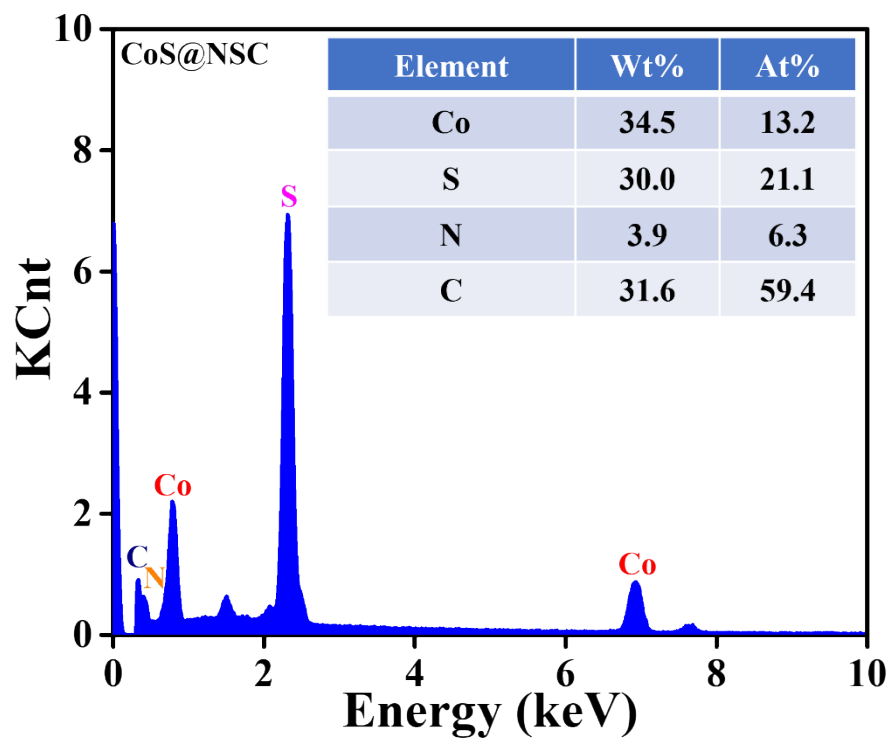
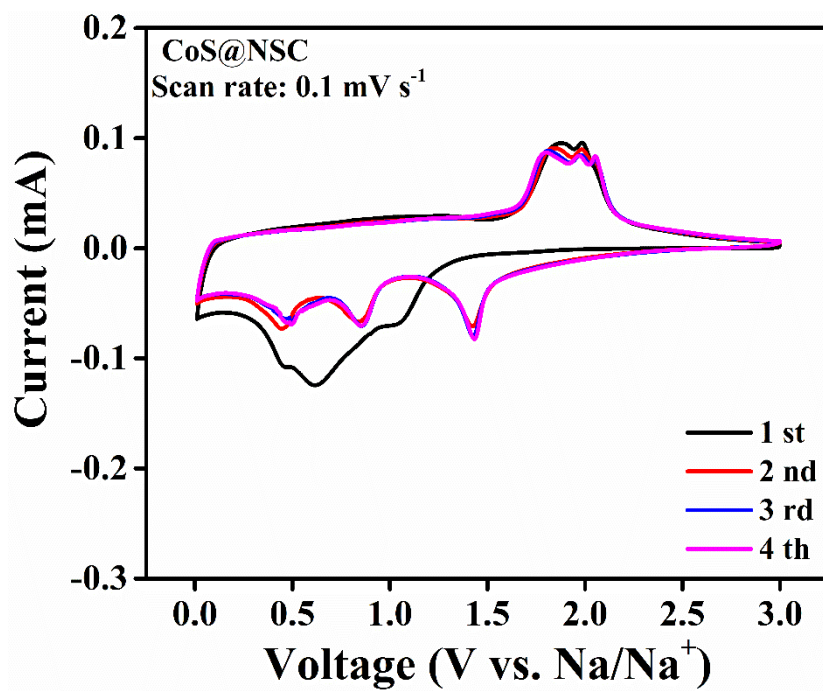
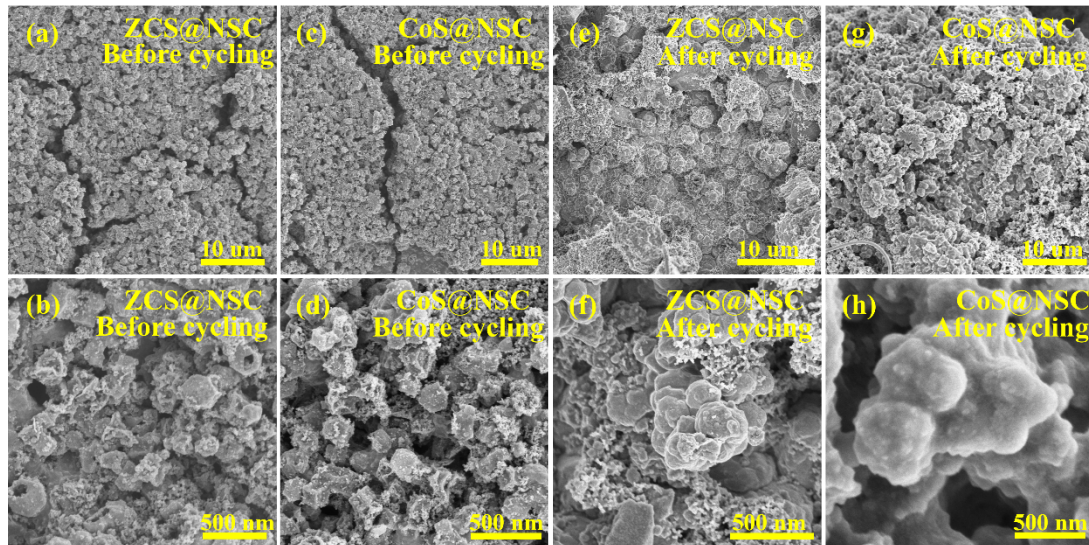


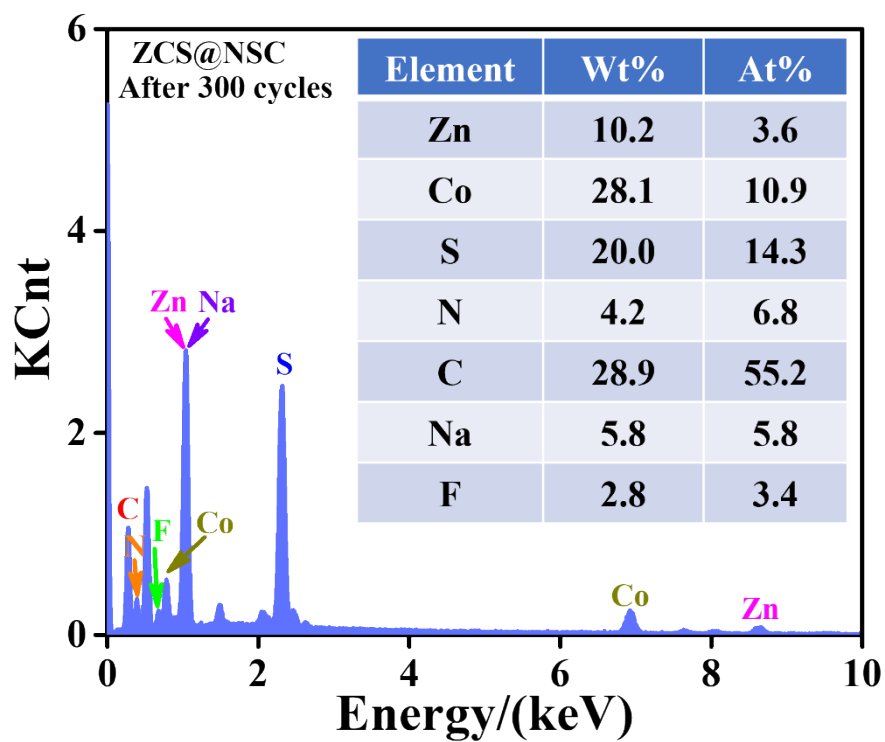
Fig. S12 EDS spectrum for CoS@NSC.



**Fig. S13** First four CV curves for CoS@NSC at 0.1 mV s<sup>-1</sup>.

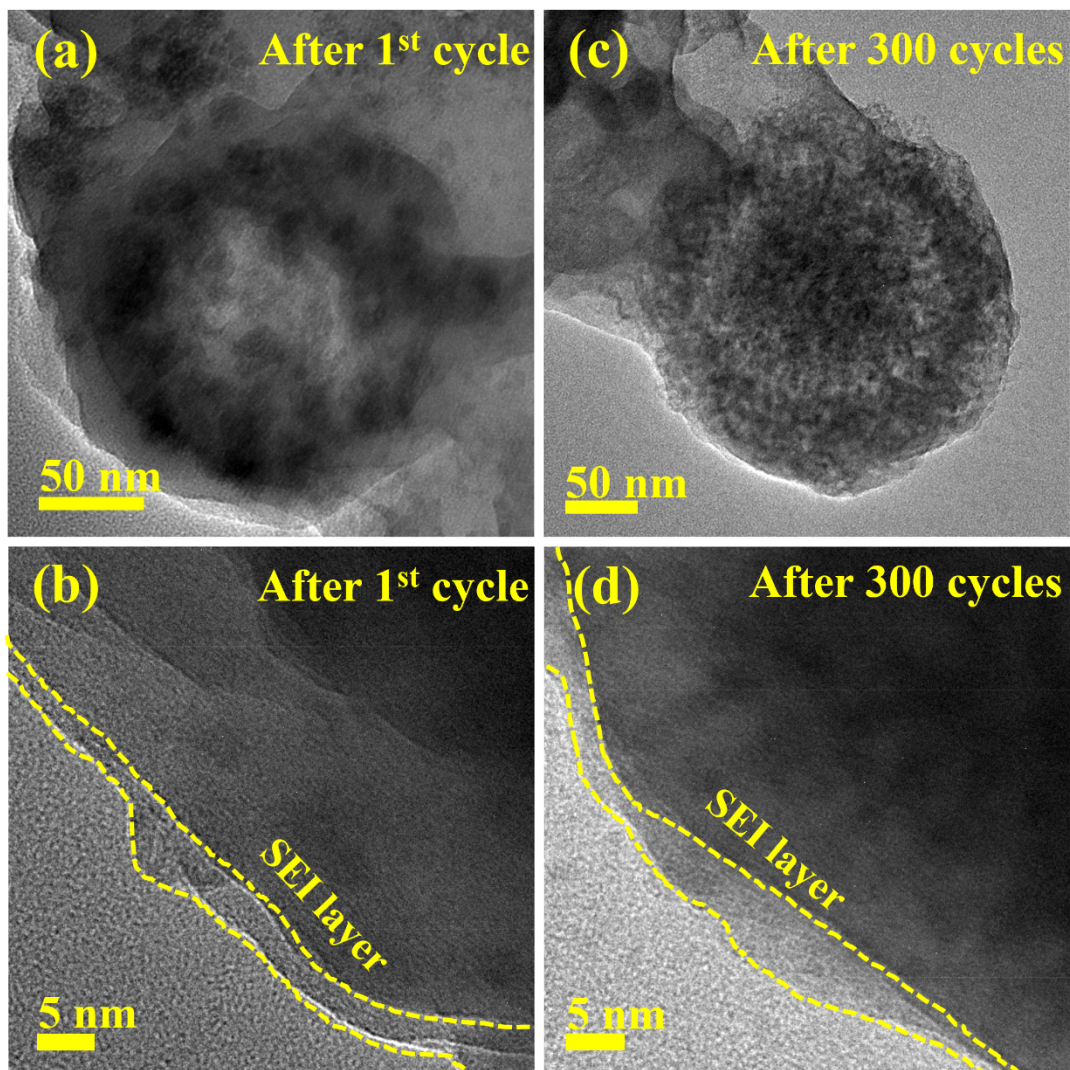


**Fig. S14** SEM images for the electrodes; (a-b) ZCS@NSC and (c-d) CoS@NSC before cycling test, (e-f) ZCS@NSC and (g-h) CoS@NSC after 300 GCD cycles.

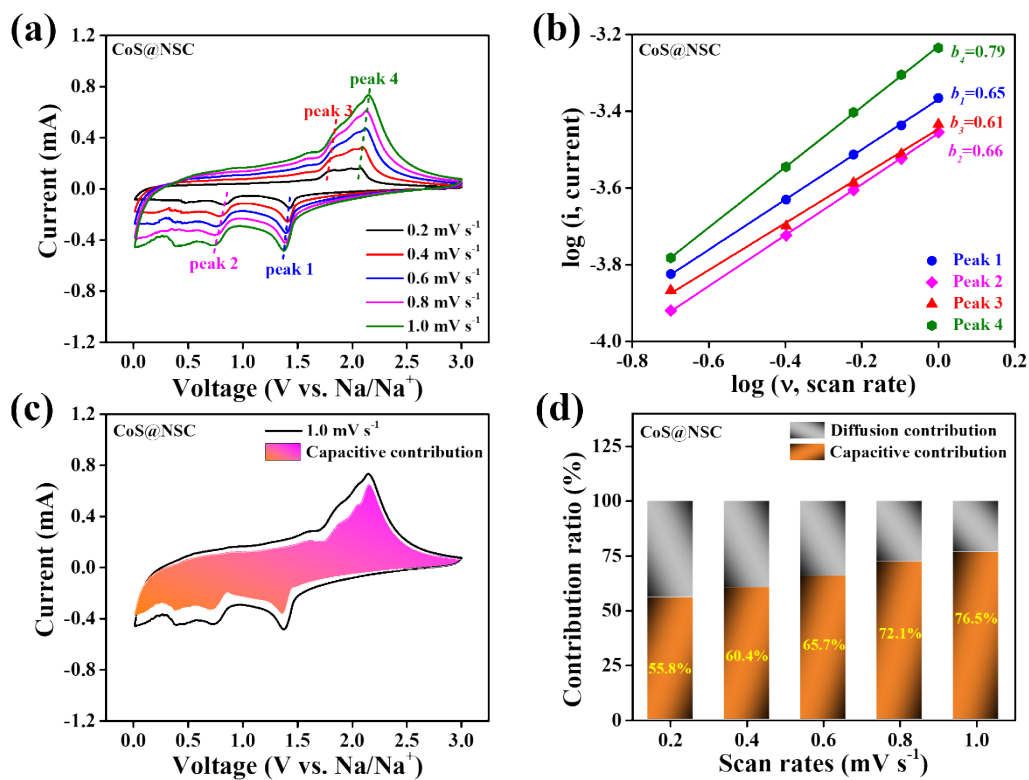


**Fig. S15** EDS spectrum for the ZCS@NSC after 300 GCD cycles.

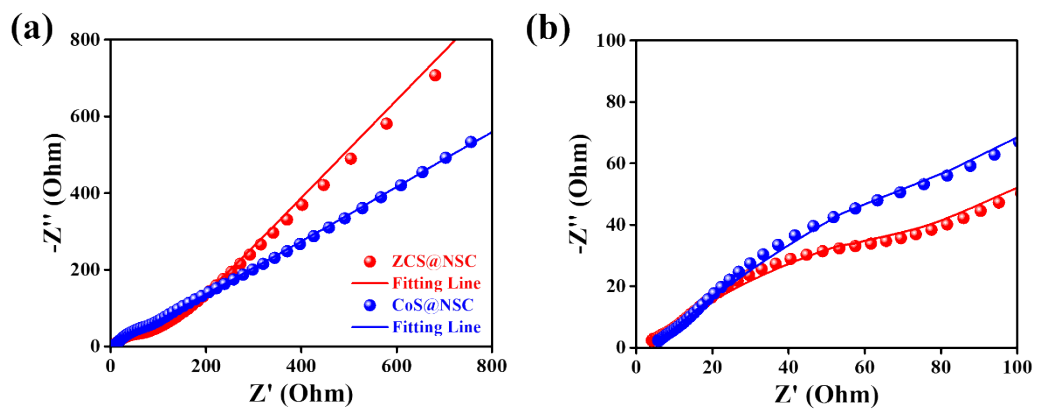




**Fig. S16** TEM and HRTEM images for ZCS@NSC, (a-b) after the first GCD cycle and (c-d) after 300 GCD cycles.



**Fig. S17** (a) CV plots from 0.2-1.0 mV s<sup>-1</sup>; (b)  $b$  values for the cathodic and anodic peaks; Capacitive contribution at (c) 1.0 mV s<sup>-1</sup> and (d) various scan rates for CoS@NSC.



**Fig. S18** (a) Nyquist plots for the ZCS@NSC and CoS@NSC anodes after 300 GCD cycles; (b) The enlarged Nyquist plots in the high-frequency regions.

**Table S1** ICP-OES results for ZCS@NSC and CoS@NSC.

<b>Samples</b>	<b>ZCS@NSC (at.%)</b>	<b>CoS@NSC (at.%)</b>
Zn	13.8	
Co	32.7	40.8
S	53.5	59.2
Total	100	100

**Table S2** Comparison of the Na<sup>+</sup>-storage performance of reported binary metal sulfides and the ZCS@NSC.

Electrode materials	Specific capacity (mAh g <sup>-1</sup> )	Rate capability (mAh g <sup>-1</sup> )	Capacity retention (mAh g <sup>-1</sup> )	Ref.
ZnS/CoS <sub>2</sub> @NC@NC	401 (0.1 A g <sup>-1</sup> )	170 (5.0 A g <sup>-1</sup> )	239 after 500 cycles (1.0 A g <sup>-1</sup> )	[1]
CuCo <sub>2</sub> S <sub>4</sub> /rGO	504 (0.05 A g <sup>-1</sup> )	336 (1.0 A g <sup>-1</sup> )	-	[2]
MnS/CoS@C	526 (0.1 A g <sup>-1</sup> )	273.7 (10 A g <sup>-1</sup> )	214.8 after 1000 cycles (5.0 A g <sup>-1</sup> )	[3]
NiS/MoS <sub>2</sub> /C	516 (0.1 A g <sup>-1</sup> )	398 (5.0 A g <sup>-1</sup> )	335 after 200 cycles (1.0 A g <sup>-1</sup> )	[4]
MoS <sub>2</sub> @NiS/rGO	289.5 (0.1 A g <sup>-1</sup> )	66.8 (5.0 A g <sup>-1</sup> )	131.3 after 800 cycles (1.0 A g <sup>-1</sup> )	[5]
CoS <sub>2</sub> /NiS <sub>2</sub> -RGO	475 (0.1 A g <sup>-1</sup> )	58.2 (5.0 A g <sup>-1</sup> )	127 after 200 cycles (1.0 A g <sup>-1</sup> )	[6]
FeS/ZnS	538.5 (0.1 A g <sup>-1</sup> )	207.6 (2.0 A g <sup>-1</sup> )	475.1 after 50 cycles (0.1 A g <sup>-1</sup> )	[7]
ZnS/CuS@C	454.4 (0.1 A g <sup>-1</sup> )	298.9 (10.0 A g <sup>-1</sup> )	387.4 after 700 cycles (2.0 A g <sup>-1</sup> )	[8]
ZnS/CoS@C/rGO	484.2 (0.1 A g <sup>-1</sup> )	308.0 (2.0 A g <sup>-1</sup> )	374.2 after 500 cycles (1.0 A g <sup>-1</sup> )	[9]
FeS/MoS <sub>2</sub>	457 (0.1 A g <sup>-1</sup> )	325 (5.0 A g <sup>-1</sup> )	331 after 200 cycles (2.0 A g <sup>-1</sup> )	[10]
ZCS@NSC	568.2 (0.1 A g <sup>-1</sup> )	224.1 (10.0 A g <sup>-1</sup> )	320.6 after 300 cycles (1.0 A g <sup>-1</sup> )	This work

**Table S3** EIS fitting results for the ZCS@NSC and CoS@NSC anodes before and after cyclic stability tests.

<b>Electrode materials</b>	<b><math>R_s</math> (<math>\Omega</math>)</b>	<b><math>R_{ct}</math> (<math>\Omega</math>)</b>
ZCS@NSC-before cycling	4.0	277.9
ZCS@NSC-after cycling	3.8	170.5
CoS@NSC-before cycling	6.9	401.9
CoS@NSC-after cycling	6.5	273.2

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