Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Nitrogen-doped graphene encapsulated cobalt iron sulfide as an advanced electrode for high-performance asymmetric supercapacitors

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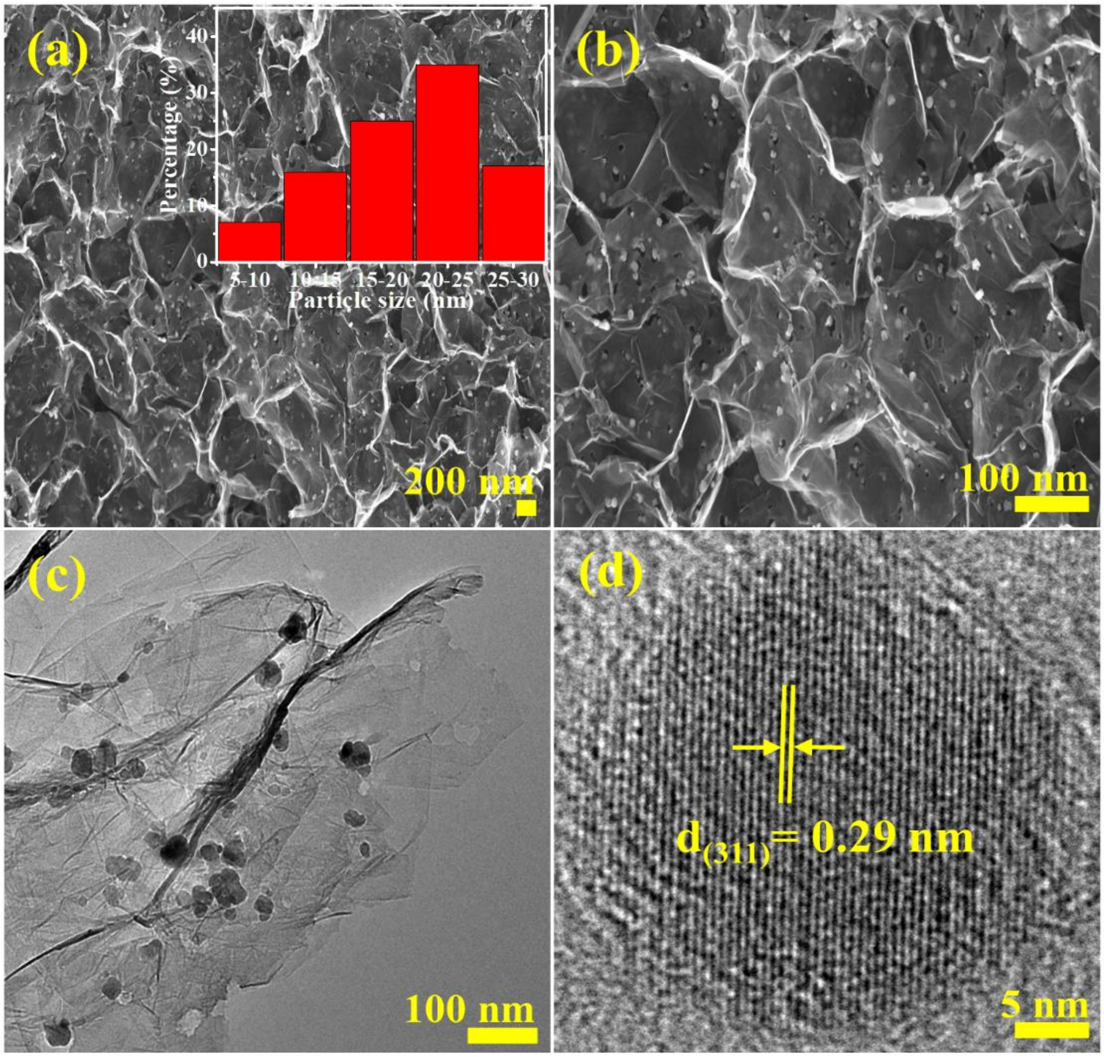

Fig. S1 (a and b) FE-SEM images with different magnifications (inset shows the particle size distribution), (c) TEM image, and (d) HR-TEM image of Co_8FeS_8/NG.

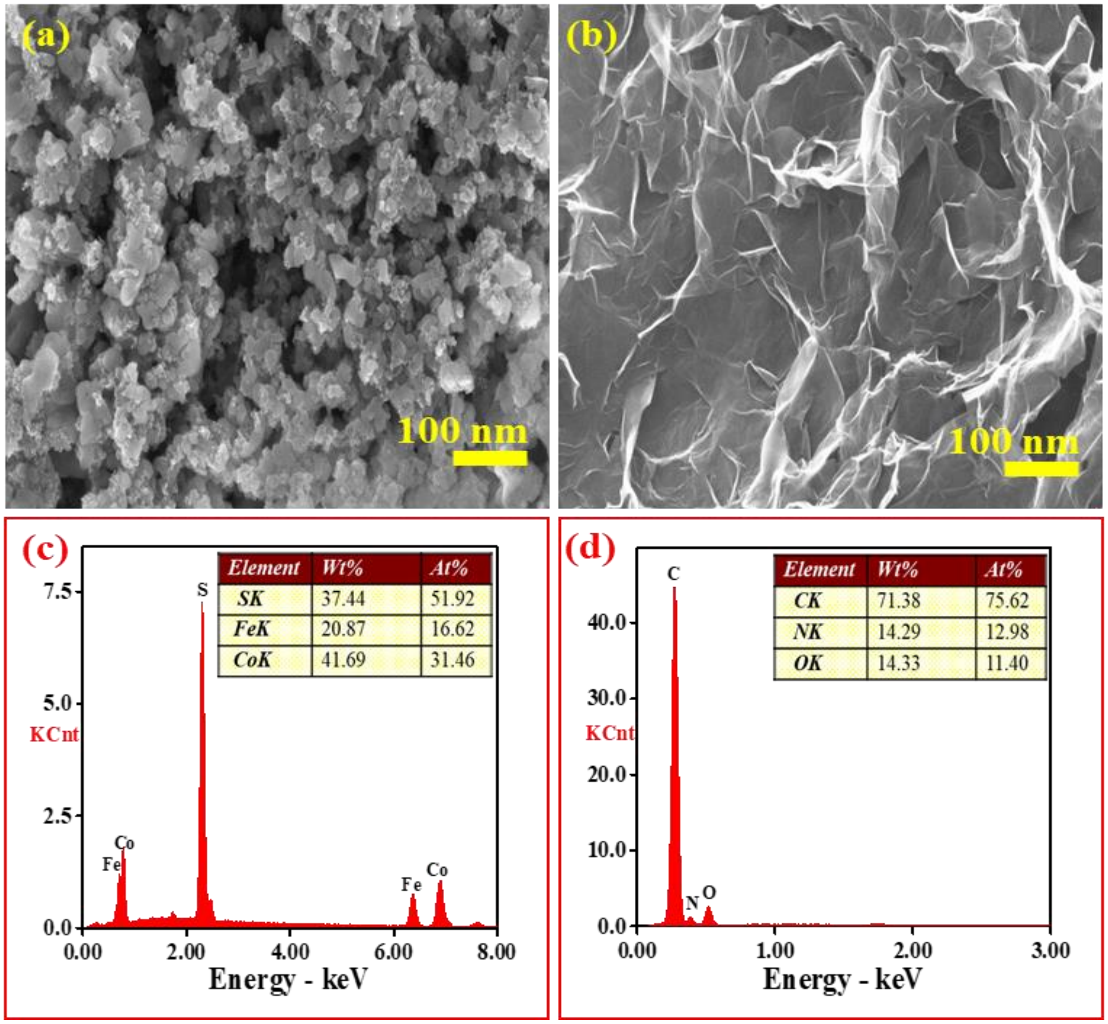

Fig. S2 (a and b) FE-SEM images, and (c and d) EDAX spectra of pristine Co_8FeS_8 and pristine NG, respectively.

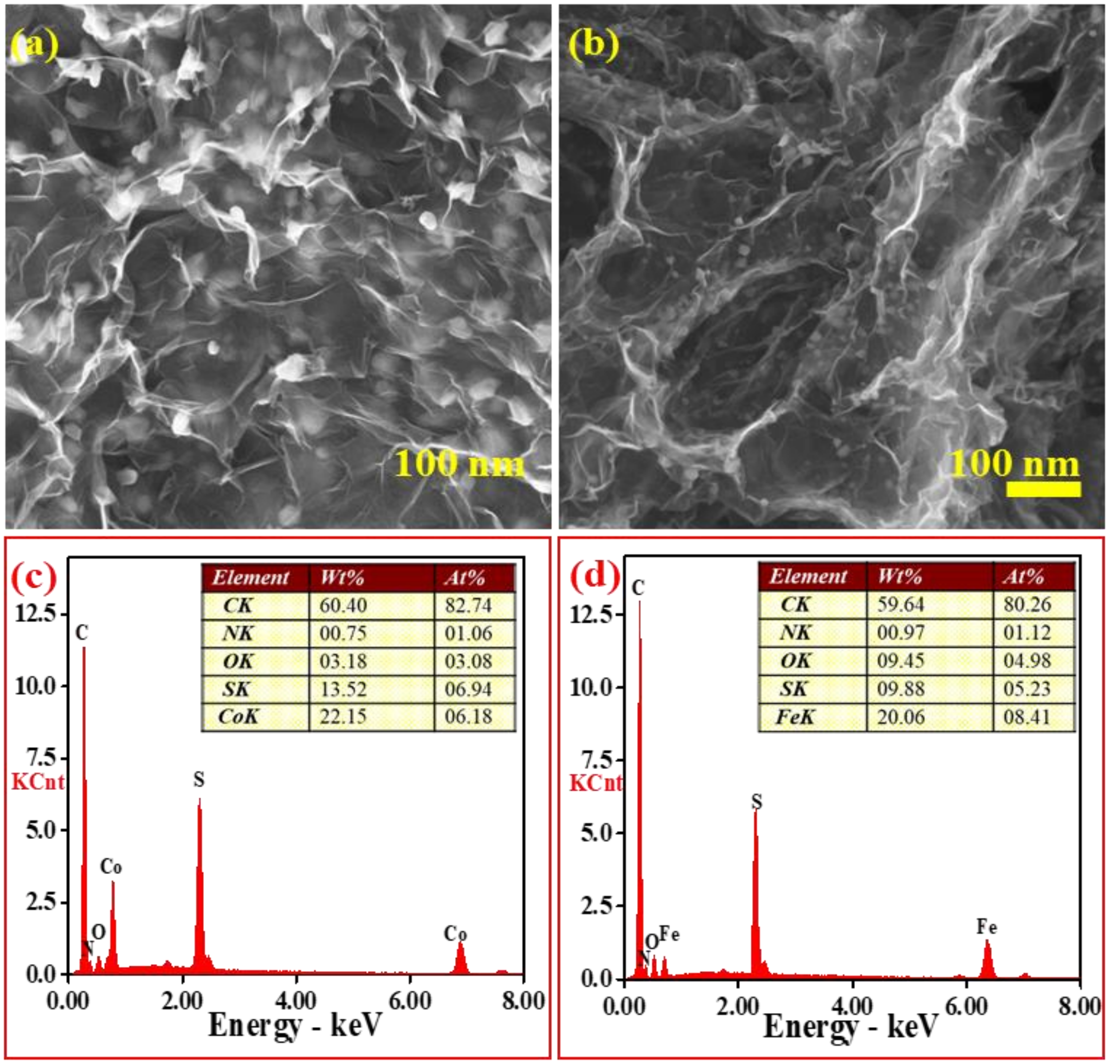

Fig. S3 (a and b) FE-SEM images, and (c and d) EDAX spectra of pristine Co_9S_8@NG and FeS@NG, respectively.

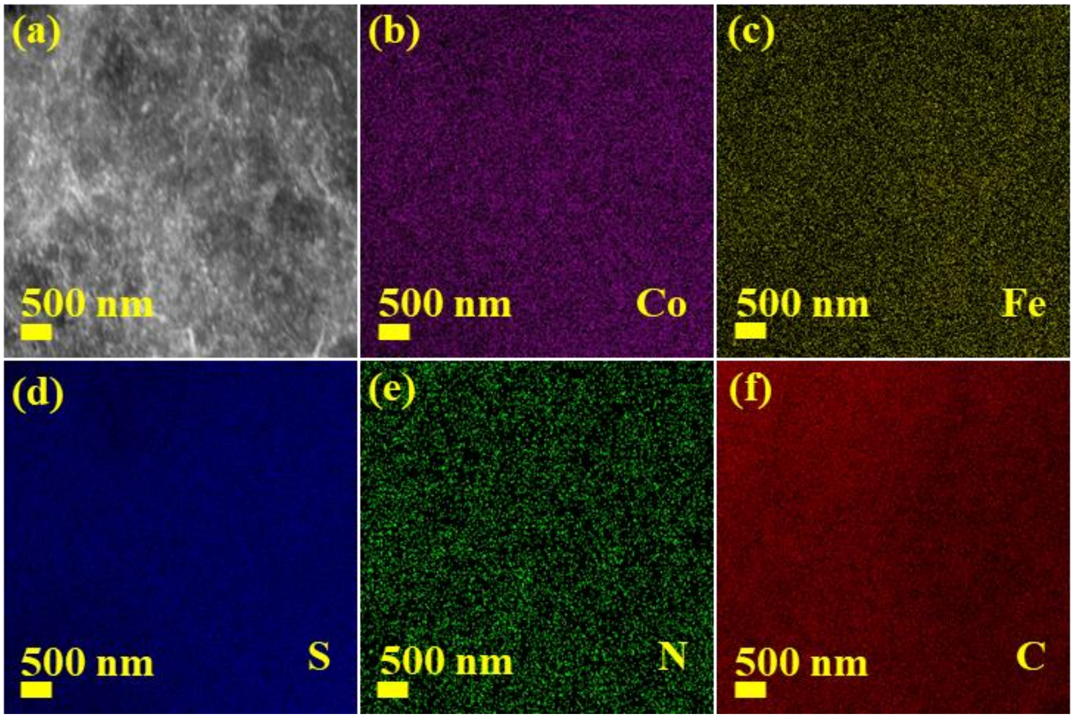

Fig. S4 SEM-EDS color mapping of cobalt, iron, sulfur, nitrogen, and carbon in the core-shell Co_8FeS_8@NG hybrid.

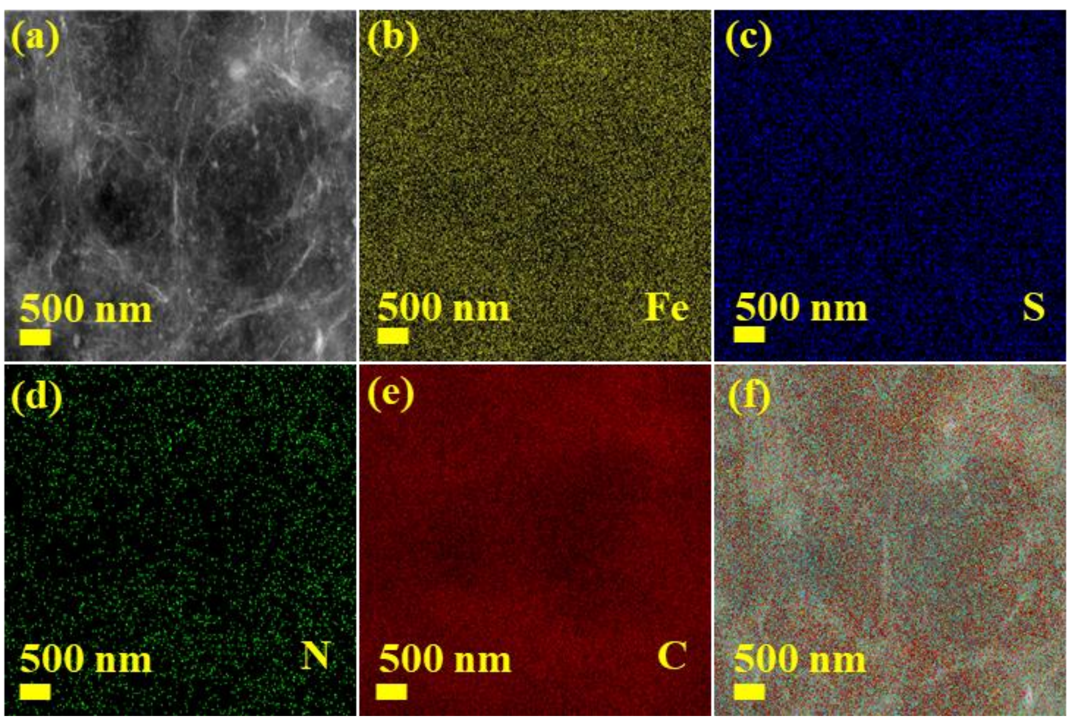

Fig. S5 SEM-EDS color mapping of iron, sulfur, nitrogen, and carbon, in the FeS@NG hybrid.

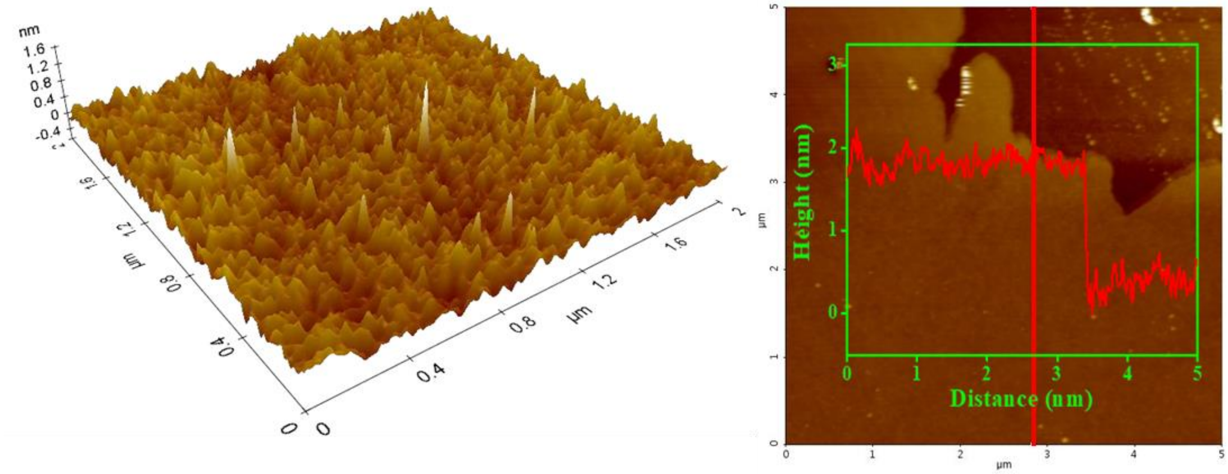

Fig. S6 AFM images of the core-shell Co_8FeS_8@NG hybrid.

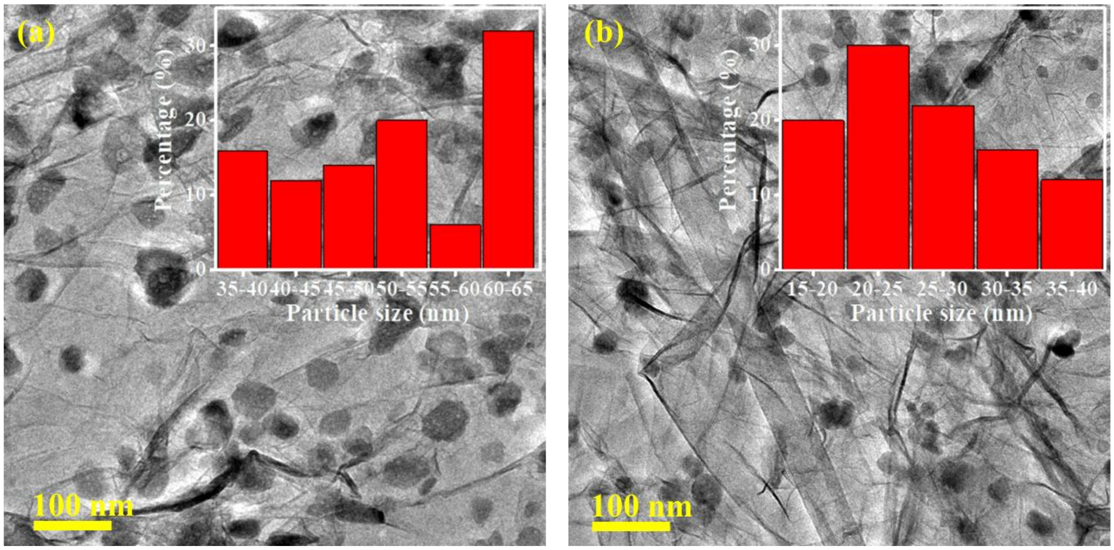

Fig. S7 (a and b) TEM images of the Co_9S_8@NG and FeS@NG hybrids (inset shows their corresponding particle size distributions).

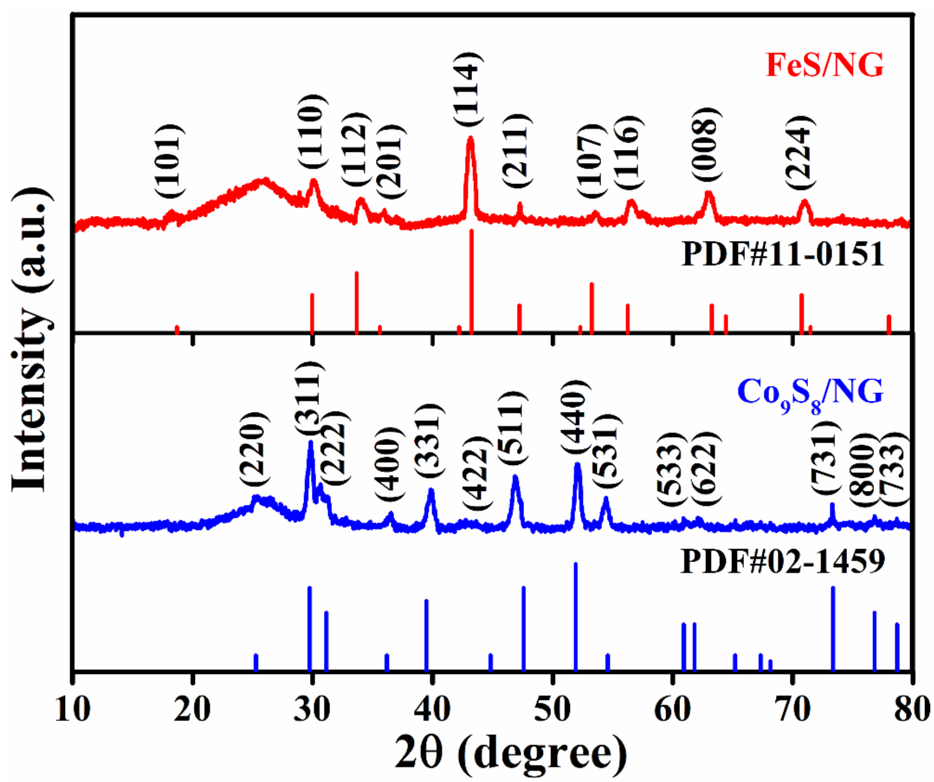

Fig. S8 XRD pattern of the Co_9S_8@NG and FeS@NG hybrids.

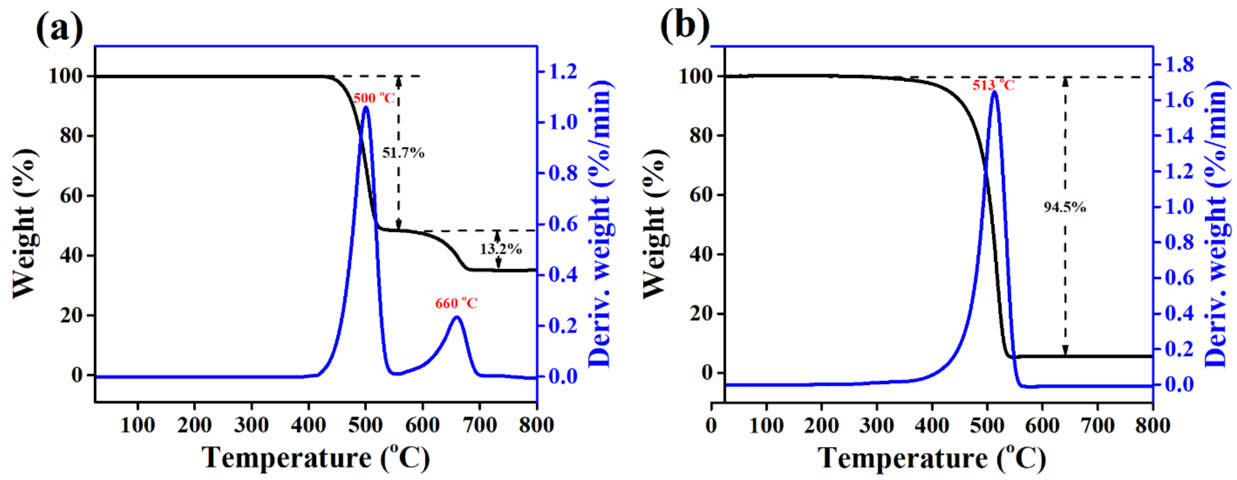

Fig. S9 TGA-DTA analysis curves of (a) the core-shell Co_8FeS_8@NG hybrid and (b) Pristine NG.

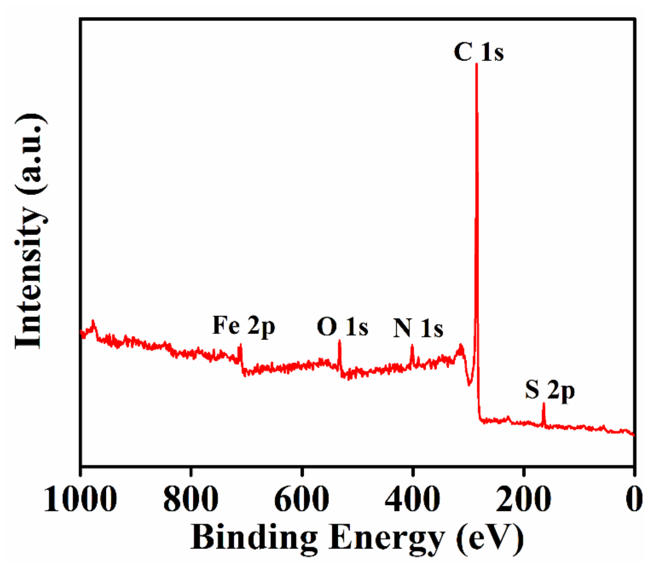

Fig. S10 XPS survey spectra of the FeS@NG hybrid (negative electrode).

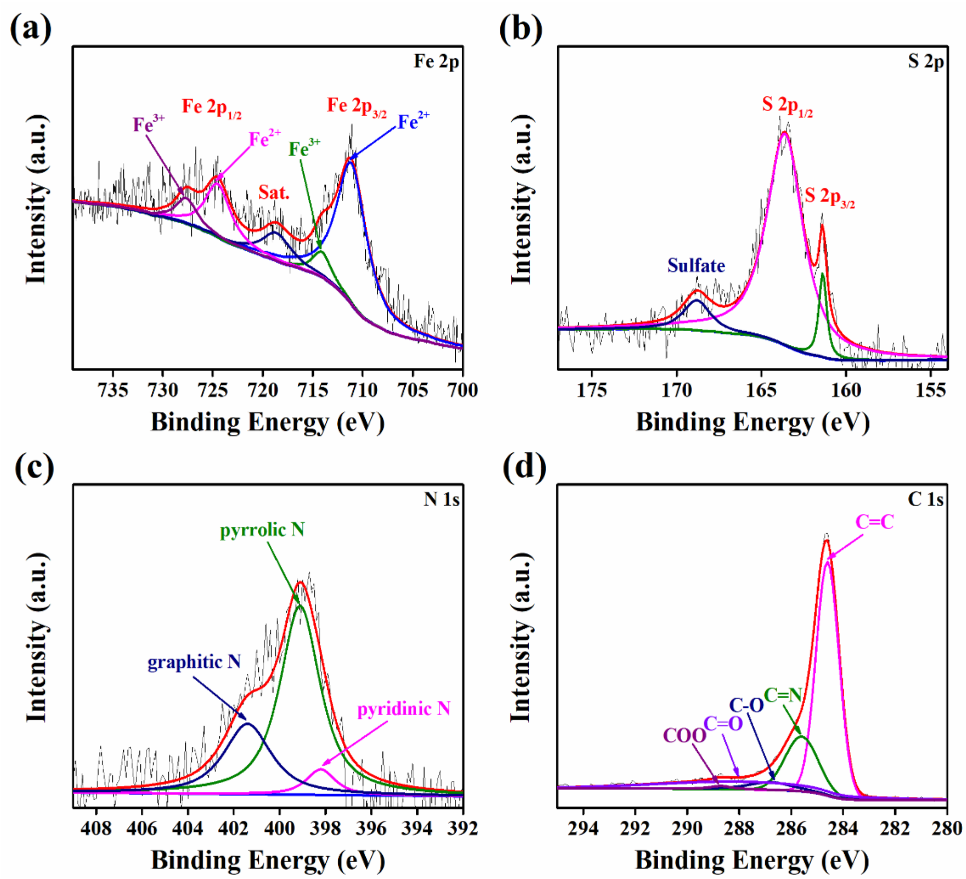

Fig. S11 High-resolution XPS spectra of a) Fe 2p, b) S 2p, c) N 1s, and c) C 1s, for the FeS@NG hybrid (negative electrode).

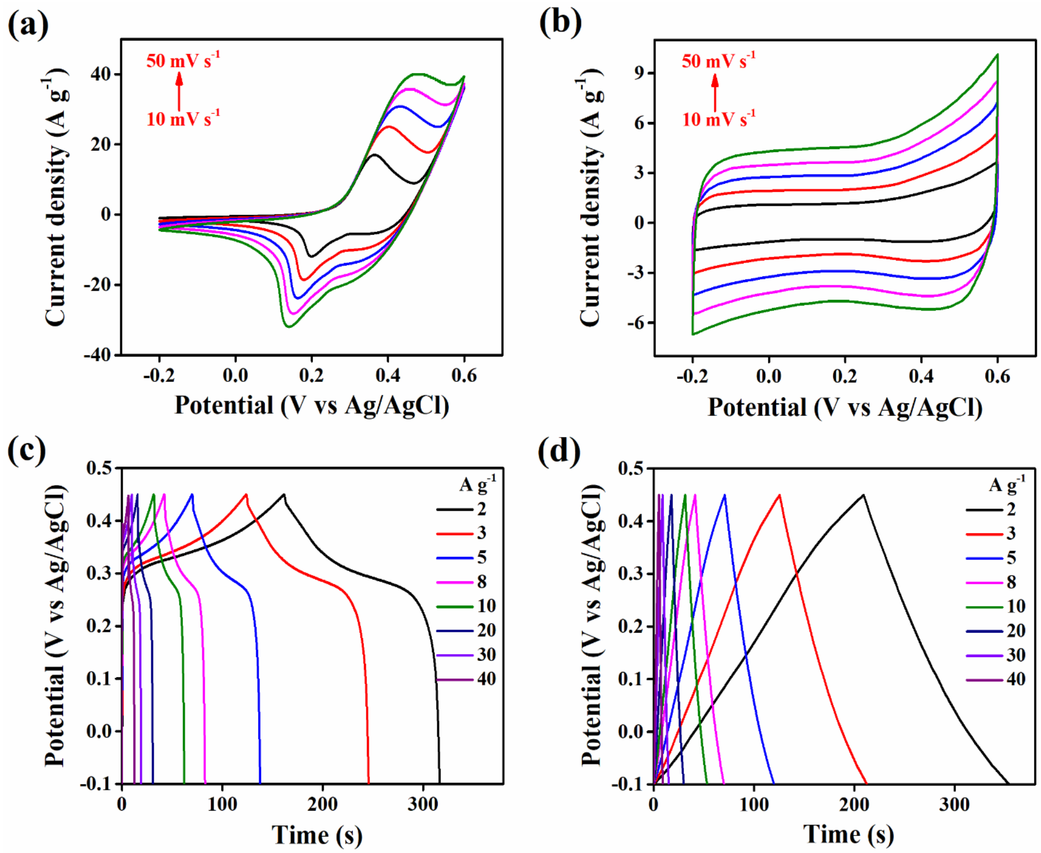

Fig. S12 CV curves of (a) Pristine Co_8FeS_8 and (b) Pristine NG electrodes with different scan rates from 10 to 50 mV s^{-1}. GCD curves of (c) Pristine Co_8FeS_8 and (d) Pristine NG electrodes with various current densities from 2 to 40 A g^{-1}.

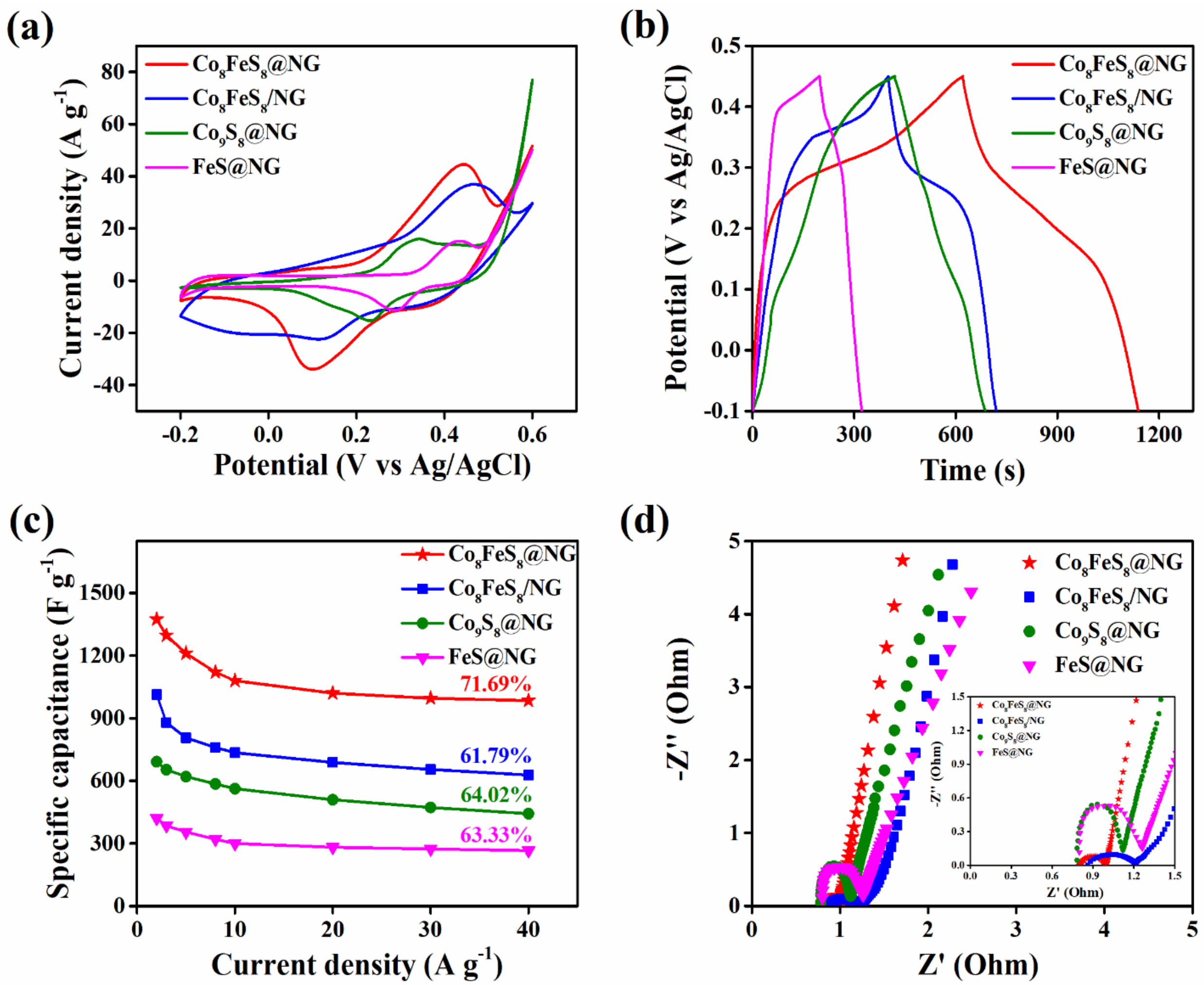

Fig. S13 (a) CV curves of Co_8FeS_8@NG, Co_8FeS_8/NG, Co_9S_8@NG, and FeS@NG electrodes at a scan rate of 20 mV s^{-1}, (b) GCD curves of Co_8FeS_8@NG, Co_8FeS_8/NG, Co_9S_8@NG, and FeS@NG electrodes at a current density of 2 A g^{-1}, (c) Specific capacitance vs. current density of Co_8FeS_8@NG, Co_8FeS_8/NG, Co_9S_8@NG, and FeS@NG electrodes, and (d) EIS spectrum of Co_8FeS_8@NG, Co_8FeS_8/NG, Co_9S_8@NG, and FeS@NG electrodes.

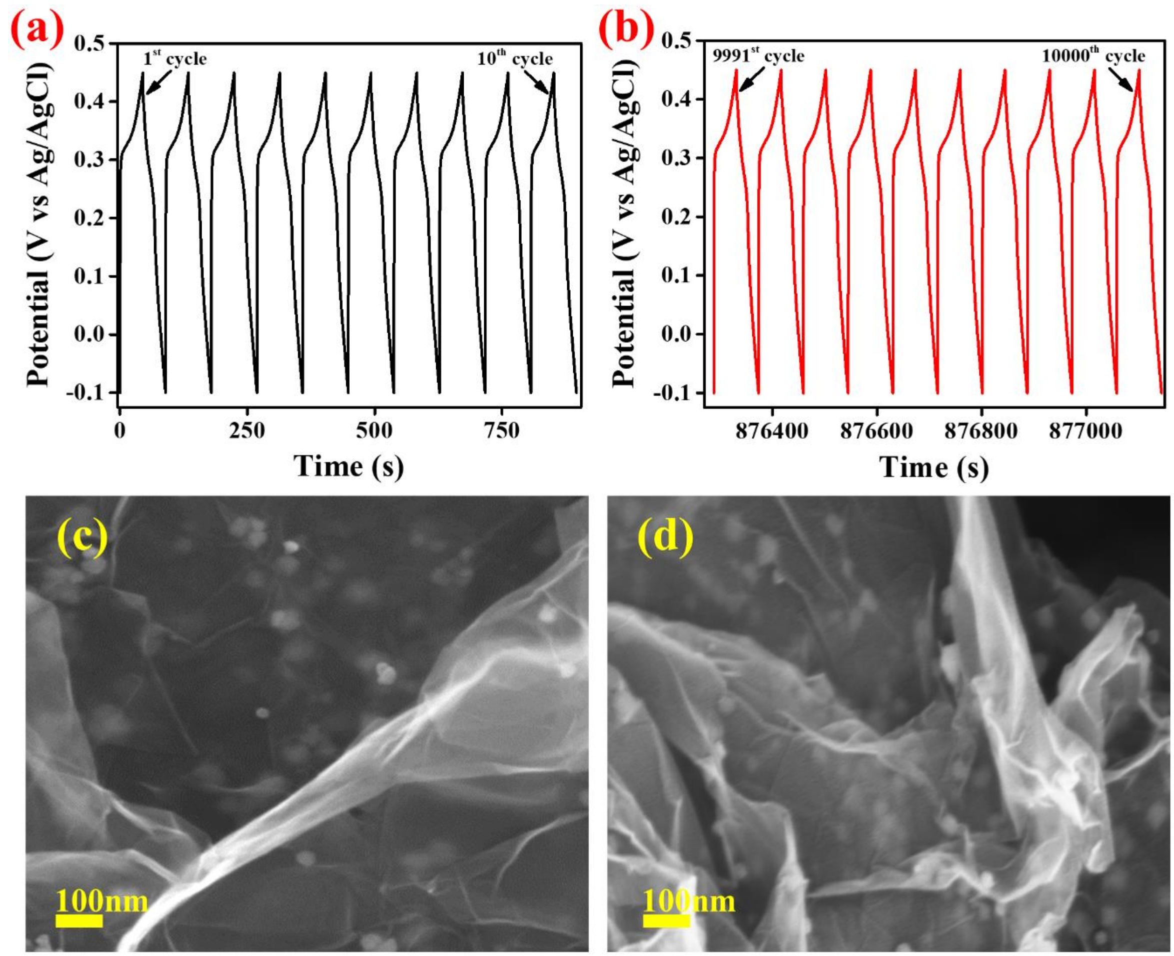

Fig. S14 GCD curves of Co_8FeS_8@NG electrode: (a) From 1st to 10th cycle, (b) From 9991st to 10 000th cycle, and (c and d) FE-SEM image of core-shell Co_8FeS_8@NG hybrid before and after 10 000 GCD cycles test, respectively.

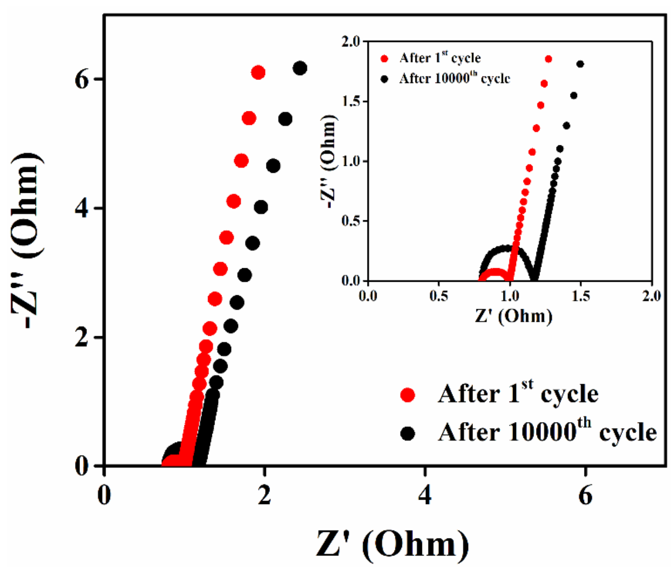

Fig. S15 EIS spectrum of the Co_8FeS_8@NG electrode after 1st GCD cycle and after the 10 000th GCD cycle.

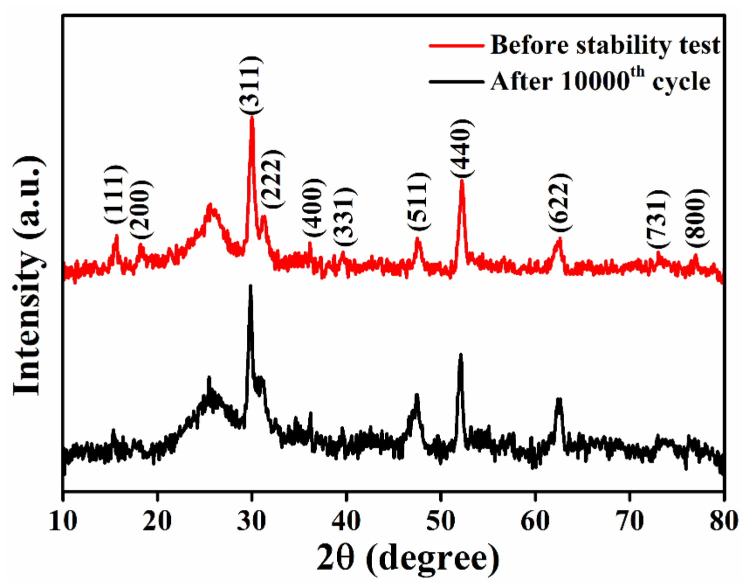

Fig. S16 XRD pattern of the core-shell Co_8FeS_8@NG hybrid before and after cyclic stability test.

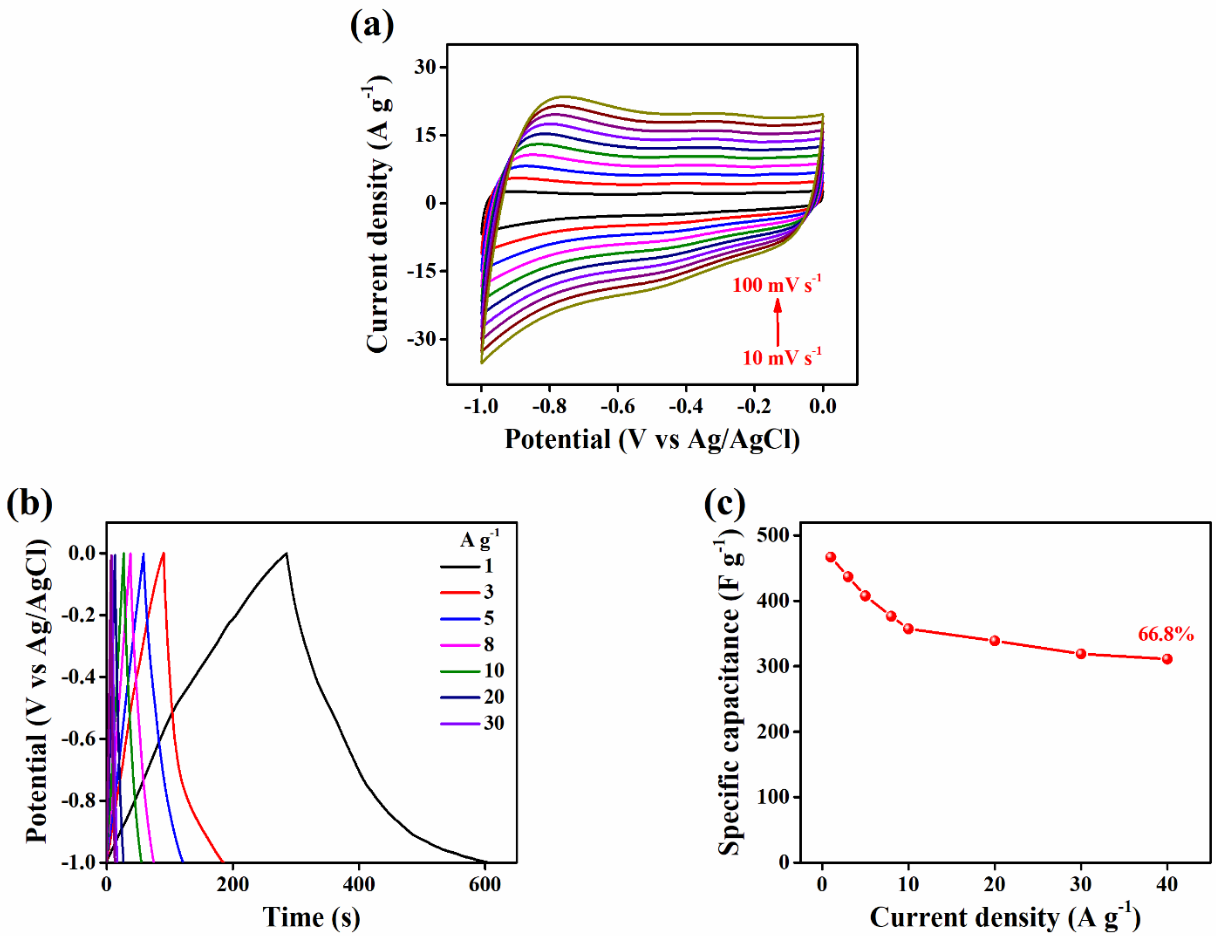

Fig. S17 (a) CV curves of the FeS@NG electrode at different scan rates from 10 to 100 mV s^{-1}, (b) GCD curves of FeS@NG electrode at various current densities from 1 to 30 A g^{-1}, and (c) Specific capacitance *vs*. current density of FeS@NG electrode.

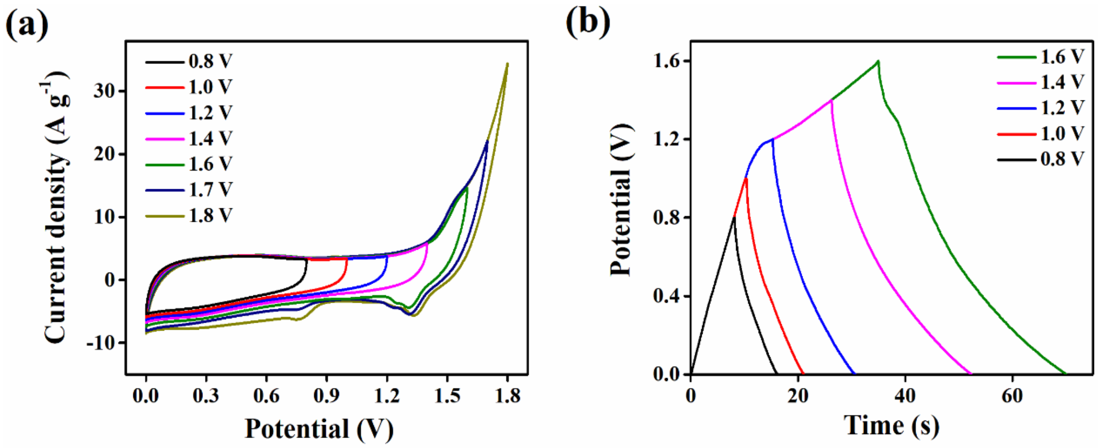

Fig. S18 (a) CV curves (at a sweep rate of 20 mV s^{-1}) of the Co_8FeS_8@NG//FeS@NG ASC device with different operating potential window from 0.8 to 1.8 V and (b) GCD curves (at a current density of 10 A g^{-1}) of the Co_8FeS_8@NG//FeS@NG ASC device at different operating potential window from 0.8 to 1.6 V.

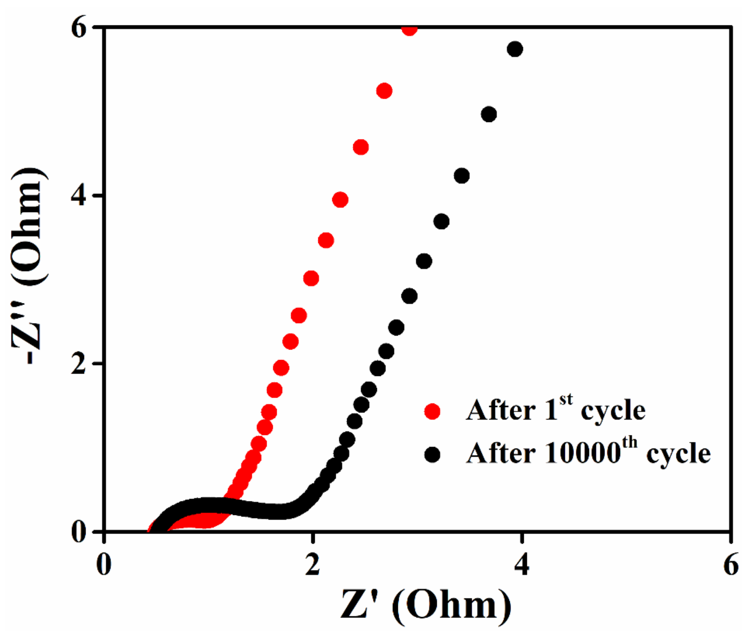

Fig. S19 EIS spectrum of the Co_8FeS_8@NG//FeS@NG ASC after the 1st and 10 000th cycles test.

Table S1. Elemental composition of the core-shell Co_8FeS_8@NG and FeS@NG hybrids measured by XPS analysis.

Sample	Co (at. %)	Fe (at. %)	S (at. %)	N (at. %)	C (at. %)	O (at. %)
Co_8FeS_8@NG	4.11	1.12	5.49	6.26	76.10	6.92
FeS@NG	-	3.88	3.41	6.12	79.2	7.39

Table S2. Electrochemical properties of the Co_8FeS_8@NG electrode comparison with reported literature.

Materials	**Specific capacitance ($F\ g^{-1}$)**	**Current density**	**Electrolyte**	**Potential window (V)**	**Stability (Cycles)**	**References**
Co_8FeS_8@NG	1374	2 $A\ g^{-1}$	2 M KOH	−0.1-0.45	96.1% (10 000)	This work
GNS/NiS	775	0.5 $A\ g^{-1}$	6 M KOH	0.0-0.4	88.1% (1000)	1
$NiCo_2S_4$-g-MoS_2	1002	5 $A\ g^{-1}$	6 M KOH	0-0.3	94.8% (4000)	2
GN-$CoMoS_4$@rGO	774	1 $A\ g^{-1}$	3 M KOH	0.0-0.55	94.49% (6000)	3
$Ni_xCo_{1-x}S_{1.987}$ microspheres/rGO	1152	0.5 $A\ g^{-1}$	2 M KOH	0.0-0.5	-	4
CGH	564	1 $A\ g^{-1}$	6 M KOH	−0.05-0.4	94.8% (2000)	5
$CoMoS_4$	661	1 $A\ g^{-1}$	1 M KOH	0.0-0.6	86% (10 000)	6
$ZnCo_{1-x}S$ nanoartichokes	486	2 $A\ g^{-1}$	1 M KOH	0.0-0.45	86.4% (2000)	7
CdS/NF	909	2 $mA\ cm^{-2}$	6 M KOH	0.0-0.4	104% (5000)	8
Co_2CuS_4/NG	1005	1 $A\ g^{-1}$	6 M KOH	−0.1-0.5	96.3% (5000)	9
Ni_3S_2@$Ni(OH)_2$/3D GN	1277	5.1 $A\ g^{-1}$	3 M KOH	−0.15-0.55	99.1 (2000)	10

CGH: 3D CoS/graphene composite hydrogel

Table S3. ASCs device performance comparison with previously reported literature.

Reported ASC Devices	Electrolyte	Device window (V)	Energy density (Wh kg^{-1})	Power density (kW kg^{-1})	Stability (Cycles)	References
Co_8FeS_8@NG//FeS@NG	PVA-KOH	0-1.6	70.4	0.59	93.7% (10 000)	This work
Ni-Co-S/G//PCNS	KOH	0-1.6	43.3	0.8	85% (10000)	11
ZICO//NG	PVA-KOH	0-1.5	40.5	0.75	95% (5000)	12
GN-$CoMoS_4$@rGO//AC	PVA-KOH	0-1.8	42.8	0.9	93.2% (8000)	3
$CuCo_2S_4$@NiMn-LDH//AC	KOH	0-1.5	45.8	1.49	87.6% (10 000)	13
Fe_3O_4@Fe_2O_3//Fe_3O_4@MnO_2	Na_2SO_4	0-2.0	26.6	0.5	92% (5000)	14
CC@$CoMoO_4$@NiCo-LDH	PVA-KOH	0-1.6	59.5	0.8	89.7% (5000)	15
MnO_2NS-CC//FeOOH NS-CC	Li_2SO_4	0-1.85	37.4	16	-	16
MoO_2@NC//$CuCo_2S_4$	PVA-KOH	0-1.6	65.1	0.8	90.6% (5000)	17
Co_2CuS_4/NG//NG	KOH	0-1.6	53.3	0.79	92.2% (4000)	9
NiNTAs@MnO_2//NiNTAs@Fe_2O_3	PVA-Na_2SO_4	0-1.6	34.1	3.19	79.3% (5000)	18
$NiCo_2S_4$//AC	KOH	0-1.5	28.3	0.24	91.7% (5000)	19

Notes and References

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