Electronic Supporting Information (ESI)

Designing a Carbon Nanotubes Interconnected ZIF-derived Cobalt Sulfide Hybrid Nanocage for Supercapacitors

Siou-Ling Jian,[a,§] Li-Yin Hsiao,[a,§] Min-Hsin Yeh,[b]* and Kuo-Chuan Ho[a,c,d]*

[a] *Department of Chemical Engineering, National Taiwan University, Taipei 10617, Taiwan*

[b] *Department of Chemical Engineering, National Taiwan University of Science and Technology, Taipei 10607, Taiwan*

[c] *Institute of Polymer Science and Engineering, National Taiwan University, Taipei 10617, Taiwan*

[d] *Advanced Research Center for Green Materials Science and Technology, National Taiwan University, Taipei 10617, Taiwan*

§ *The authors contributed equally to this work.*

Table S1 A list of [a] MOF-derived cobalt sulfide and [b] carbon/cobalt sulfide materials in the application of supercapacitors, compared to that obtained in this work. [c] Co_9S_8 embedded in carbon co-doped with N and S. [d] Co_9S_8@S, N-doped carbon cuboid. [e] CoS-nanoparticle-assembled nanoboxes surrounded by outer CoS-nanosheet-constructed shells. [f] Co_xS@porous carbon/RGO. [g] conductive polymer/rGO/Co_9S_8.

Materials	Electrolyte	Gravimetric capacitance (F g^{-1}) (Potential range *vs*. Hg/HgO)	Capacitance retention	Ref.
Co_9S_8-nanosheet array [a]	1.0 M KOH	1,098.8 (0.15 – 0.55 V, 0.5 A g^{-1})	1,000 (87.4%)	1
CoS nanocages [a]	1.0 M KOH	1,475 (-0.15 – 0.35 V, 1 A g^{-1})	3,000 (70.3%)	2
Co_9S_8/NS-C [a, b, c]	6.0 M KOH	734.09 (0 – 0.5 V, 1 A g^{-1})	140,000 (99.8%)	3
Co_9S_8@SNCC [a, b, d]	6 M KOH	429 (-1.1 – -0.6V, 1 A g^{-1})	2,000 (98%)	4
Zn-Co-S [a]	6.0 M KOH	1,266 (0.15 – 0.65 V, 1 A g^{-1})	10,000 (91%)	5
CoS-NP/CoS-NS [a, e]	2.0 M KOH	980 (0.15 – 0.70 V, 1 A g^{-1})	10,000 (89%)	6
CoS-N-doped carbon [a, b]	2.0 M KOH	360.1 (0.1 – 0.7 V, 1.5 A g^{-1})	2,000 (90%)	7
Co_xS@PC/RGO [a, b, f]	1.0 M KOH	455 (0.15 – 0.65 V, 2 A g^{-1})	4,000 (99.7%)	8
CoS_x/FMWCNTs [b]	2.0 M KOH	334 (-0.15 – 0.60 V, 0.4 A g^{-1})	1,000 (95%)	9
CNT/CoS [b]	1.0 M KOH	1,332.8 (0.15 – 0.65 V, 217.4 A g^{-1})	1,500 (91%)	10
CoS/CNT [b]	6.0 M KOH	804 (0.15– 0.65 V, 0.5 A g^{-1})	1,000 (93.4%)	11

rGO_{100}-CNT_{50}-Co_3S_4 [b]	6.0 M KOH	977 (0.15 – 0.65 V, 1 A g^{-1})	3,000 (90%)	12
RGO/CoS [b]	6.0 M KOH	1,130 (0.15 – 0.65 V, 0.5 A g^{-1})	1,000 (92.1%)	13
cP/rGO/Co_9S_8 [b, g]	2.0 M KOH	788.9 (0.1 – 0.55 V, 1 A g^{-1})	10,000 (over 100%)	14
CoS@rGO [b]	2.0 M KOH	849 (0 – 0.55 V, 5 mA cm^{-2})	3,000 (90.5%)	15
Co_3S_4/rGO [b]	2.0 M KOH	675.9 (0 – 0.5 V, 0.5 A g^{-1})	1,000 (over 100%)	16
CoS/rGO [b]	6.0 M KOH	550 (0.15 – 0.55 V, 1A g^{-1})	5,000 (95%)	17
Co_3S_4-rGO [b]	2.0 M KOH	2314 (-0.15 – 0.75 V, 2 mV/s)	1,000 (92.6%)	18
Co_9S_8/reduced graphene [b]	6.0 M KOH	728 (0.15 – 1.15 V, 2 A g^{-1})	1,000 (97%)	19
Co_9S_8/RGO [b]	6.0 M KOH	616 (0 – 0.8 V, 4.4 A g^{-1})	1,000 (98%)	20
PANI-rGO-CoS [b]	1.0 M H_2SO_4	431 (0.15 – 0.95 V, 0.5A g^{-1})	1,000 (90.1%)	21
CoS/graphene [b]	2.0 M KOH	3,386 (0.05– 0.55 V, 1 A g^{-1})	2,500 (31.1%)	22
CoS/graphene [b]	6.0 M KOH	564 (0.1 – 0.55 V, 1 A g^{-1})	2,000 (94.8%)	23
CoS/graphene [b]	6.0 M KOH	2,423.3 (-0.7 – 0.1 V, 5 mV/s)	-	24
Co_9S_8/3D graphene [b]	1.0 M KOH	2,317 (0.1 – 0.55 V, 1 A g^{-1})	6,000 (90%)	25
3D graphene/CoS_x [b]	1.0 M KOH	443 (0 – 0.6 V, 1 A g^{-1})	5,000 (86%)	26

Co_3S_4-N-doped graphene [b]	6.0 M KOH	2,245 (0.05– 0.3 V, 3 A g^{-1})	-	27
g-C_3N_4/CoS [b]	3.0 M KOH	668 (0.15 – 0.55 V, 2 A g^{-1})	1,000 (98%)	28
Hybrid CNT/CoS nanocage [a, b]	6.0 M KOH	2,173.1 (0.08 – 0.48 V, 5 A g^{-1})	1,000 (91.1%)	This work

Table S2 A list of asymmetric supercapacitor [a] and symmetric supercapacitor [b] composed of cobalt sulfide as the electrode (AC=Activated carbon; rGO=reduced graphene oxide).

Electrodes	Electrolyte	Energy density (Wh kg^{-1})/ Power density (W kg^{-1})	Capacitance retention	Ref.
Co_3S_4//Co_3S_4-rGO [a]	PVA/KOH	1.09/398 & 0.31/750 (0 – 1.5 V)	5,000 (89.56%)	18
CoS@eRG//AC [a]	2 M KOH	29/800 & 11/4,000 (0 – 1.6 V)	3,000 (70.3%)	22
Co_9S_8 nanoflakes//AC [a]	6 M KOH	31.4/2,000 & 26.3/4,000 (0 – 1.6 V)	5,000 (89.5%)	29
Co_9S_8//rGO [a]	6 M KOH	68.6/1,319 (0 – 1.2 V)	1,000 (96%)	30
CNT/CoS nanocage [b]	6 M KOH	62.4/674.6 & 23.3/3,382.2 (0 – 1.35 V)	5,000 (96.6%)	This work

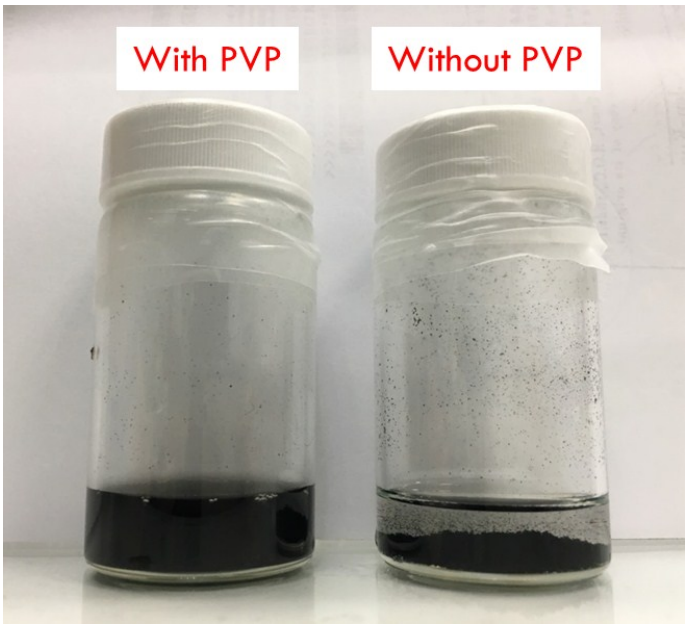

Figure S1 CNT dispersed in methanol with (left) and without (right) PVP.

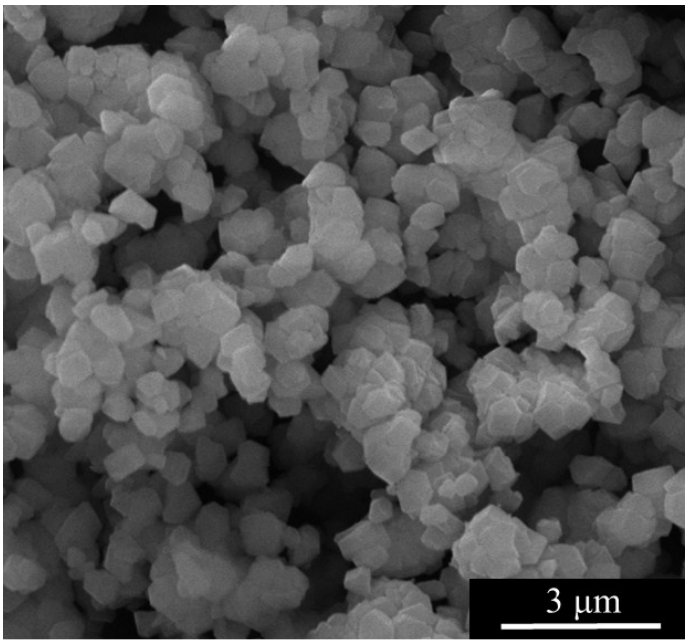

Figure S2 FE-SEM images of ZIF-67 nanoparticles synthesized with PVP.

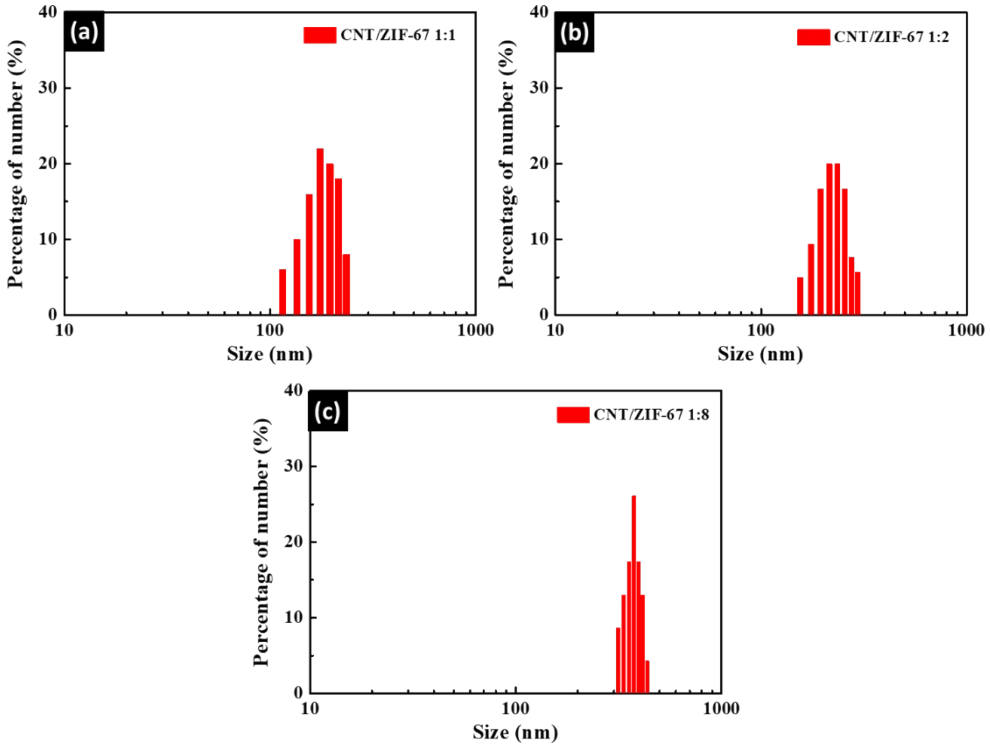

Figure S3 Particle size distributions of (a) CNT/ZIF-67 1:1, (b) CNT/ZIF-67 1:2, and (c) CNT/ZIF-67 1:8.

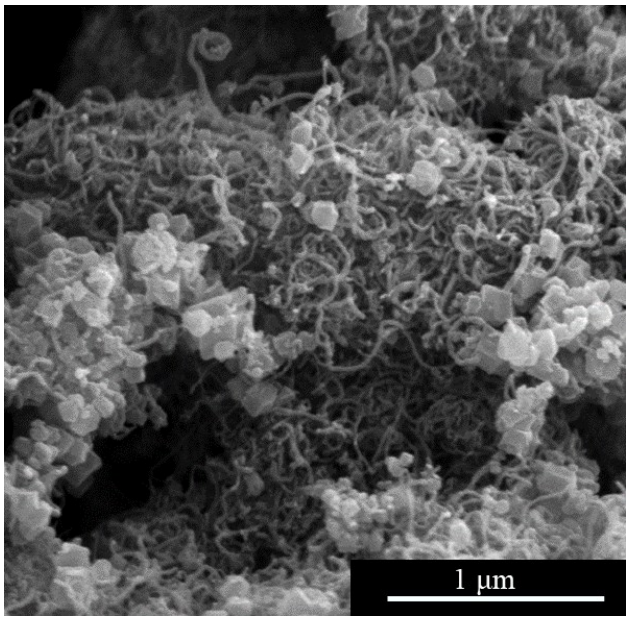

Figure S4 FE-SEM images of CNT/ZIF-67 composites with unfunctionalized CNTs.

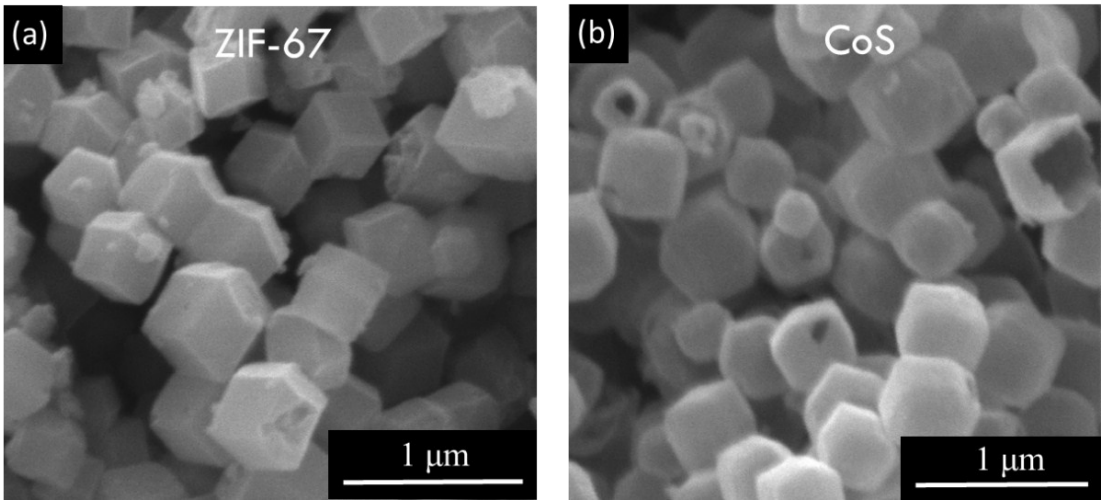

Figure S5 FE-SEM images of (a) ZIF-67 nanoparticles, and (b) CoS nanocages.

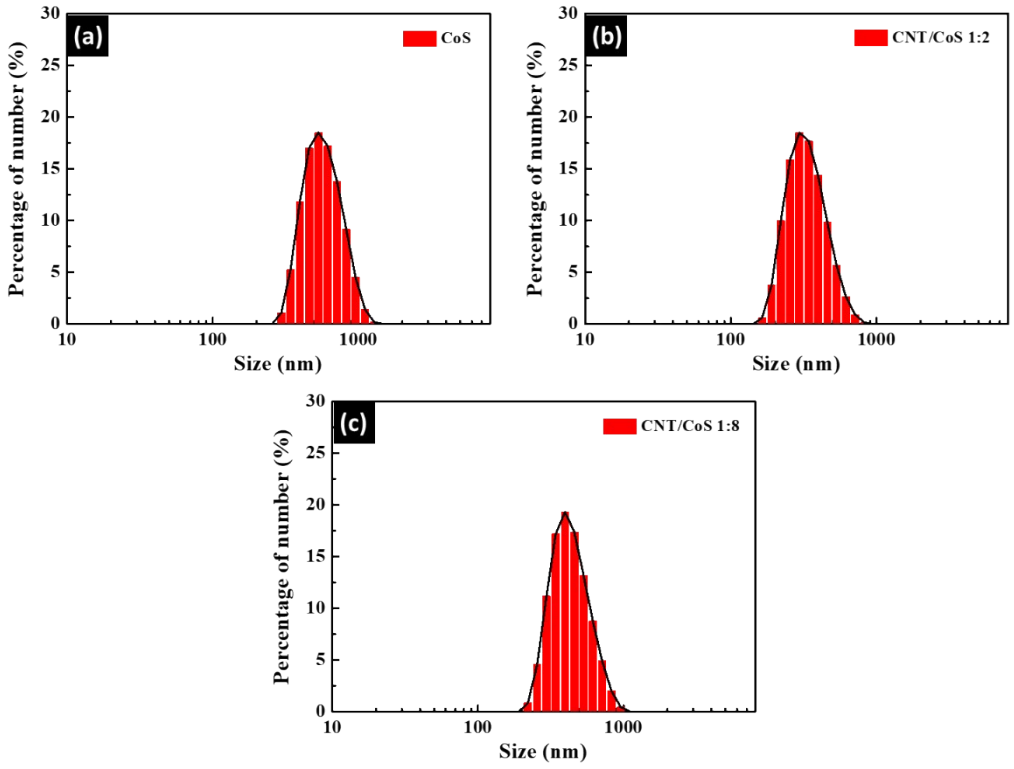

Figure S6 Particle size distributions of (a) CoS, (b) CNT/CoS 1:2 and (c) CNT/CoS 1:8.

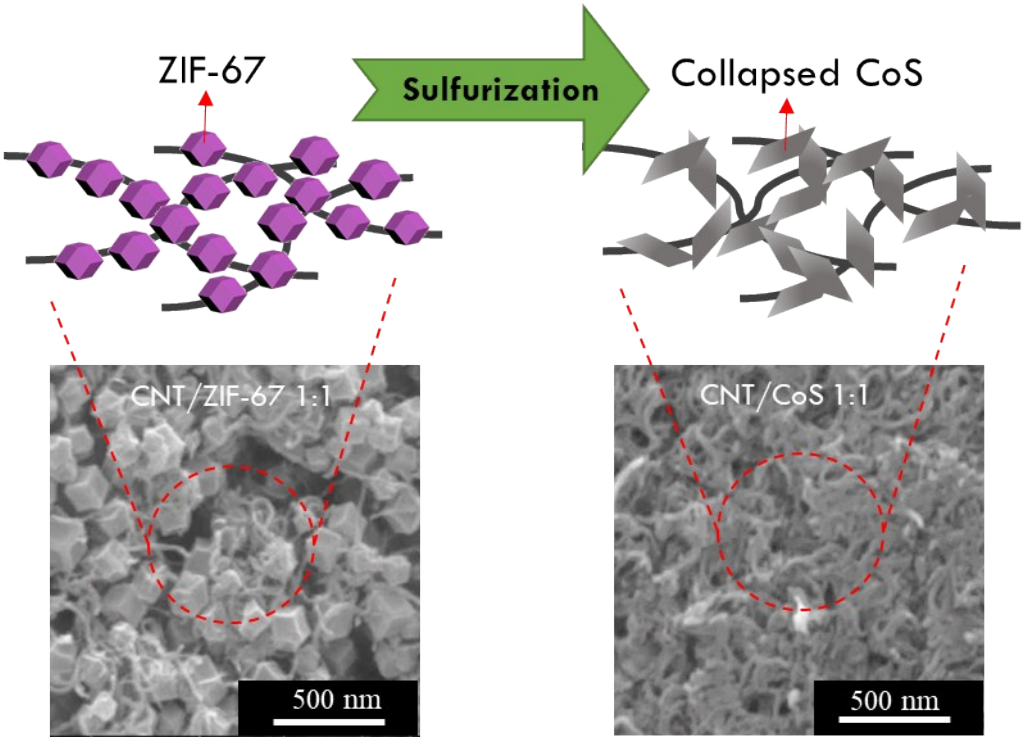

Figure S7 FE-SEM images of CNT/ZIF-67 1:1, CNT/CoS 1:1 and the schematic illustration of the collapsed CoS *via* sulfurization.

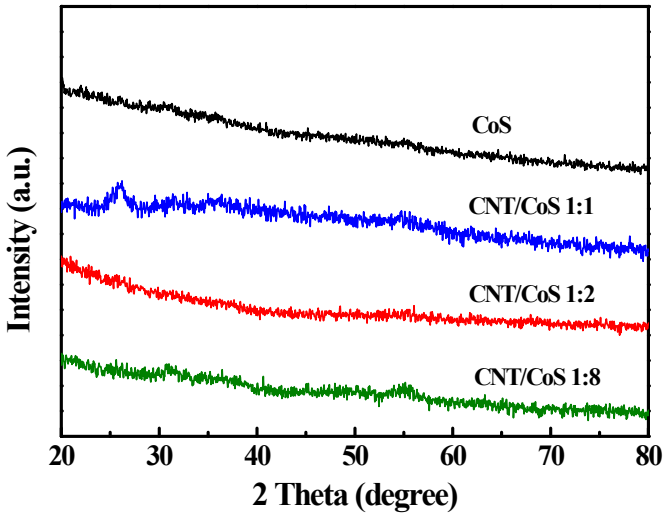

Figure S8 XRD patterns of CoS cage and hybrid CNT/CoS nanocages with various sizes of ZIF-67 as templates.

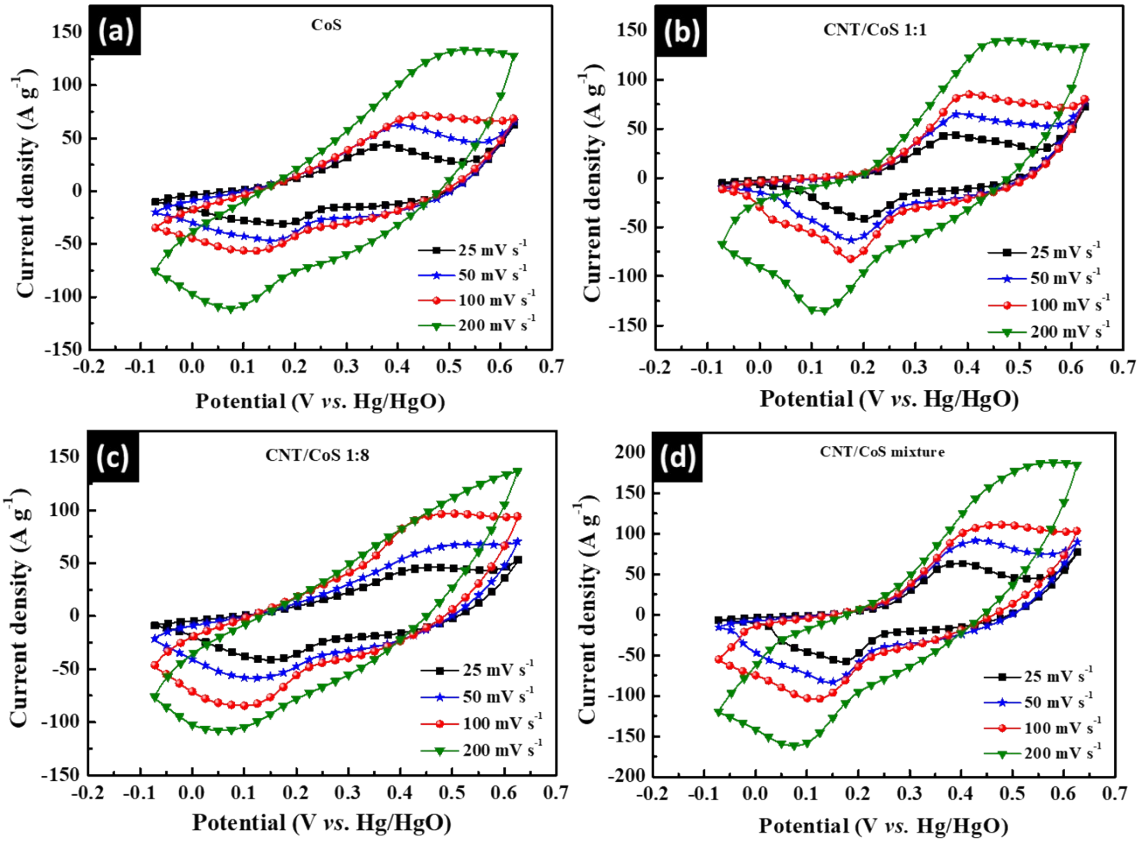

Figure S9 CVs of (a) CoS nanocage, (b) CNT/CoS 1:1 nanocage, (c) CNT/CoS 1:8 nanocage, and (d) CNT/CoS mixture electrodes at different scan rates.

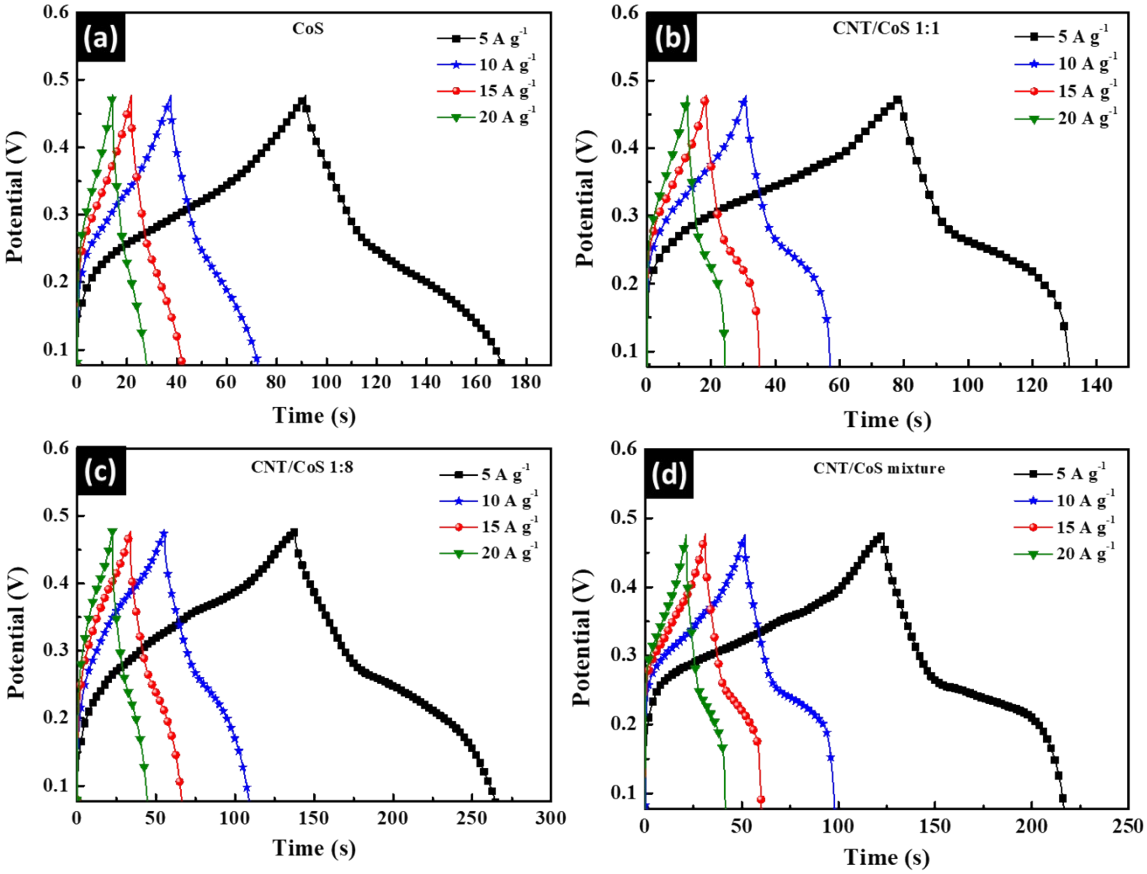

Figure S10 GCD curves of (a) CoS nanocage, (b) CNT/CoS 1:1 nanocage, (c) CNT/CoS 1:8 nanocage, and (d) CNT/CoS mixture electrodes at different current densities.

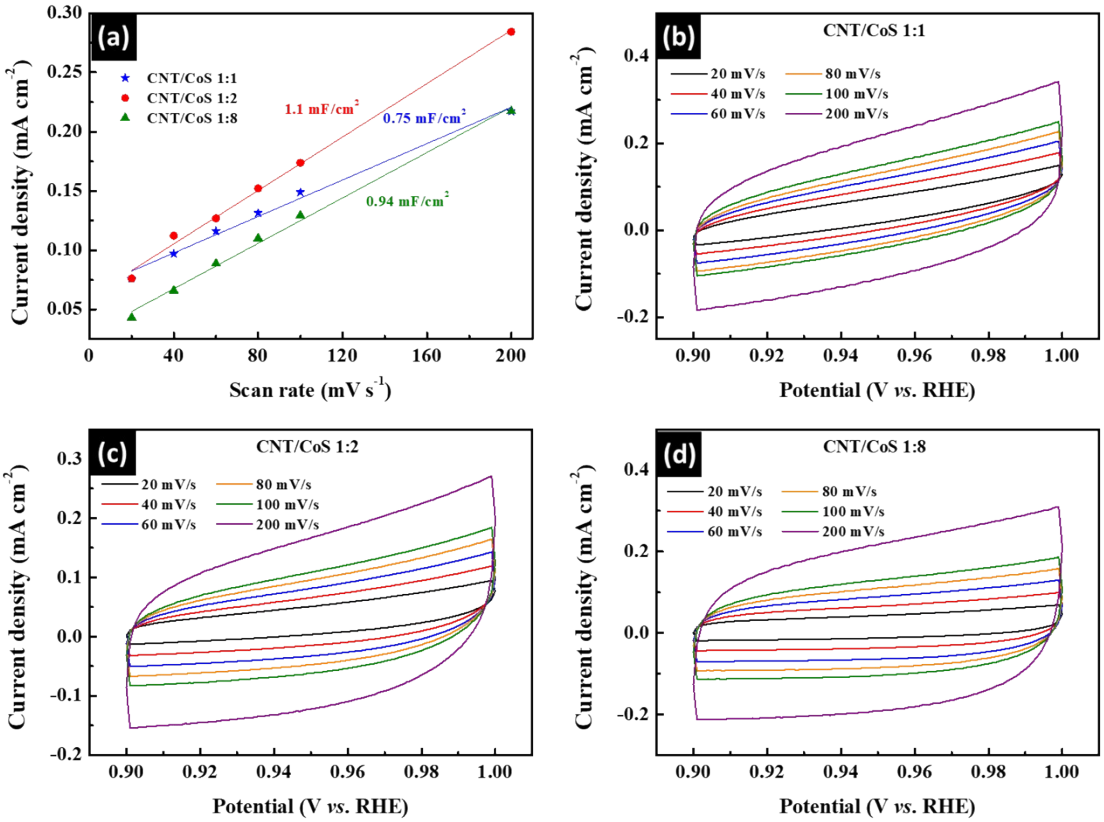

Figure S11 Electrochemical active surface area using CVs recorded in non-faradic region at different scan rates. (a) Linear fits of anodic current density measured at 0.95 V (*vs.* RHE) versus scan rate plots. (b) CNT/CoS 1:1 nanocage, (c) CNT/CoS 1:2 nanocage and (d) CNT/CoS 1:8 nanocage.

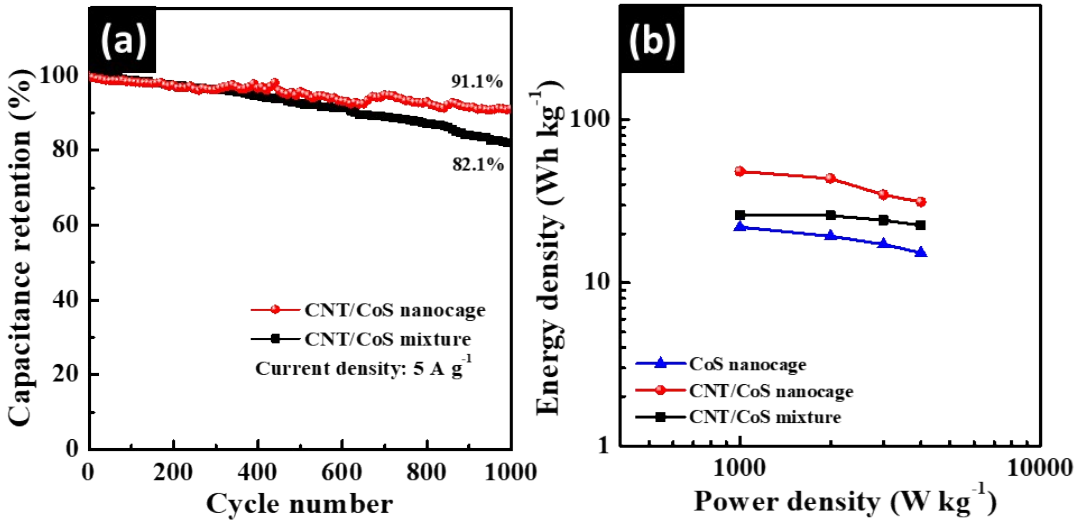

Figure S12 (a) Cycling performance of hybrid CNT/CoS nanocage and CNT/CoS mixture, and (b) Ragone plot of CoS nanocage, hybrid CNT/CoS nanocage and CNT/CoS mixture under various current densities in three-electrode system.

Figure S13 A photograph of the symmetric supercapacitor of hybrid CNT/CoS nanocage as electrodes.

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