Electronic Supplementary Materials

Engineering Hollow Polyhedrons Structured from Carbon-Coated $CoSe_2$ Nanospheres Bridged by CNTs with Boosted Sodium Storage Performance

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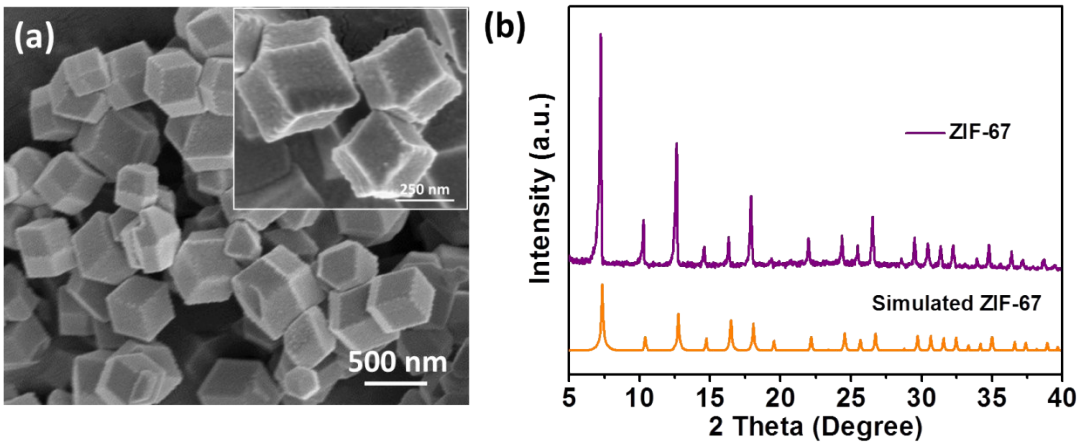

Fig. S1 (a) FE-SEM images of well-defined ZIF-67 particles; inset is magnified FE-SEM image of ZIF-67 particles. (b) XRD pattern of ZIF-67 particles.

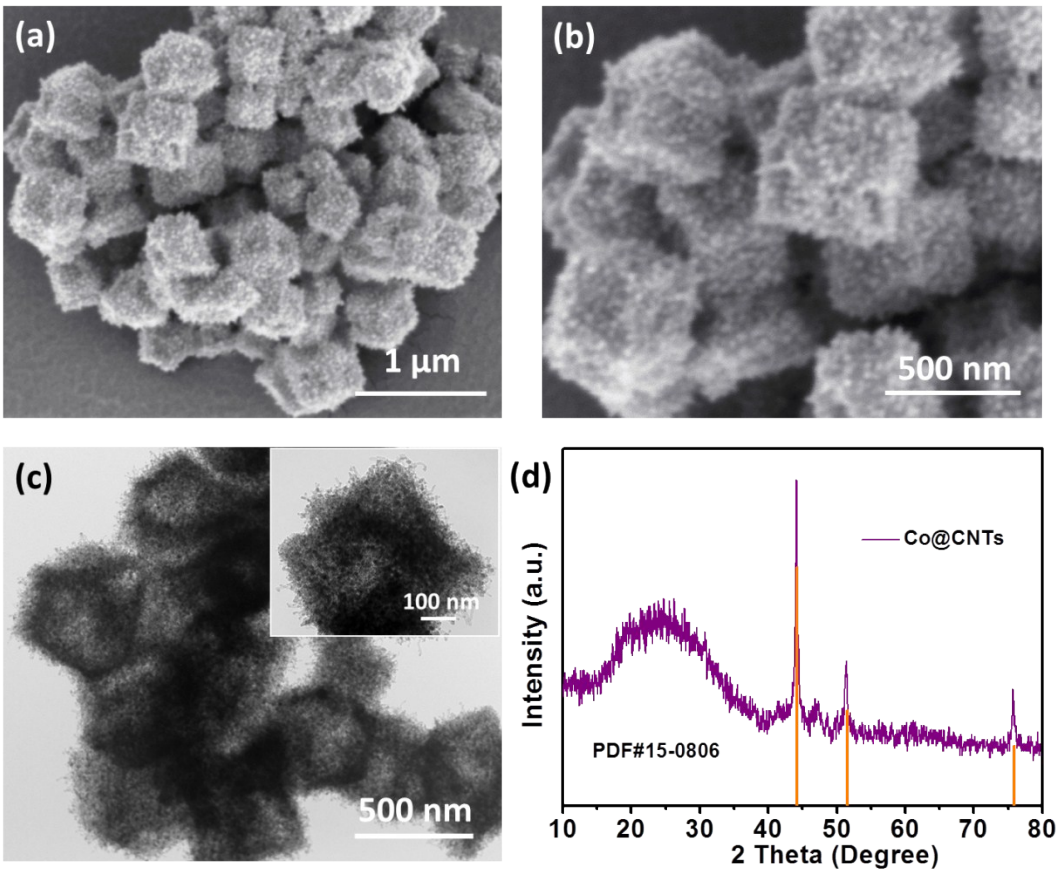

Fig. S2 (a)-(b) FE-SEM image of Co@C/CNTs hybrid polyhedron converted from ZIF-67 particles; (c) TEM images with various magnifications of the Co@C/CNTs hybrid polyhedron; (d) XRD pattern of the Co@C/CNTs hybrid polyhedron.

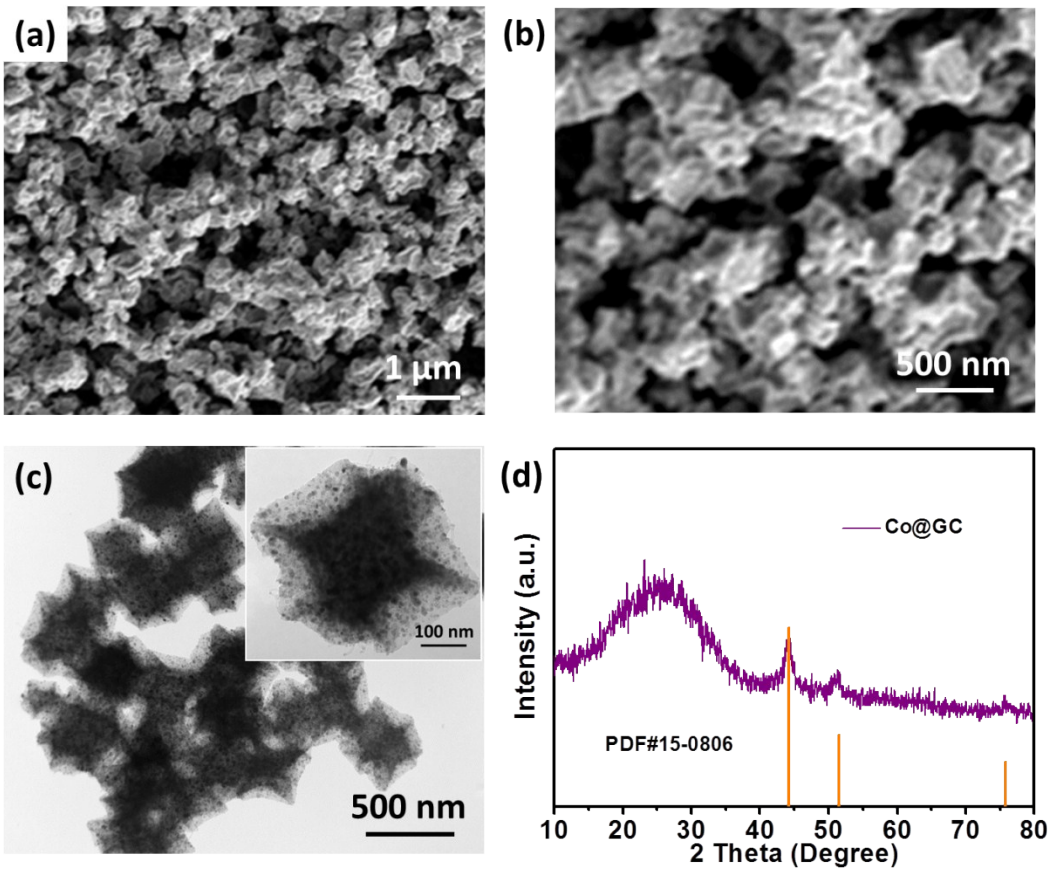

Fig. S3 (a)-(b) FE-SEM image of Co@GC hybrid polyhedron converted from ZIF-67 particles; (c) TEM images with various magnifications of the Co@GC hybrid polyhedron; (d) XRD profile of the Co@GC hybrid polyhedron.

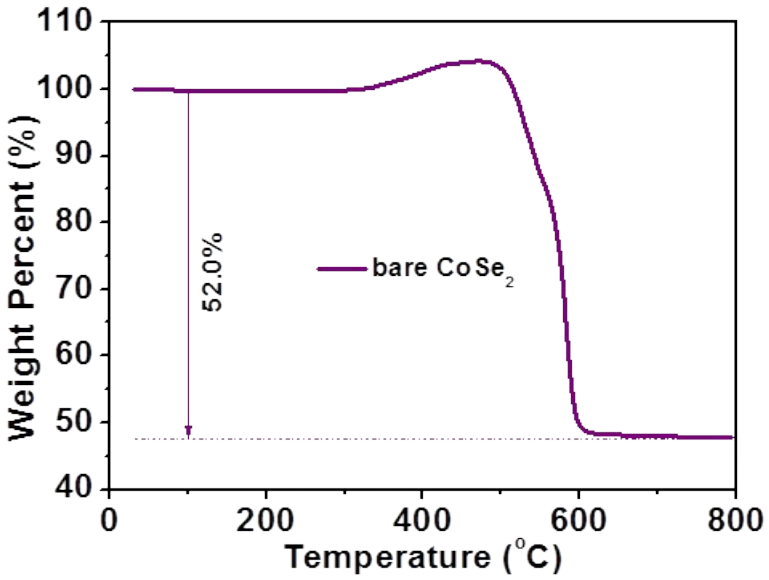

Fig. S4 TGA of bare $CoSe_2$ shows a weight loss of 52.0% in air atmosphere.

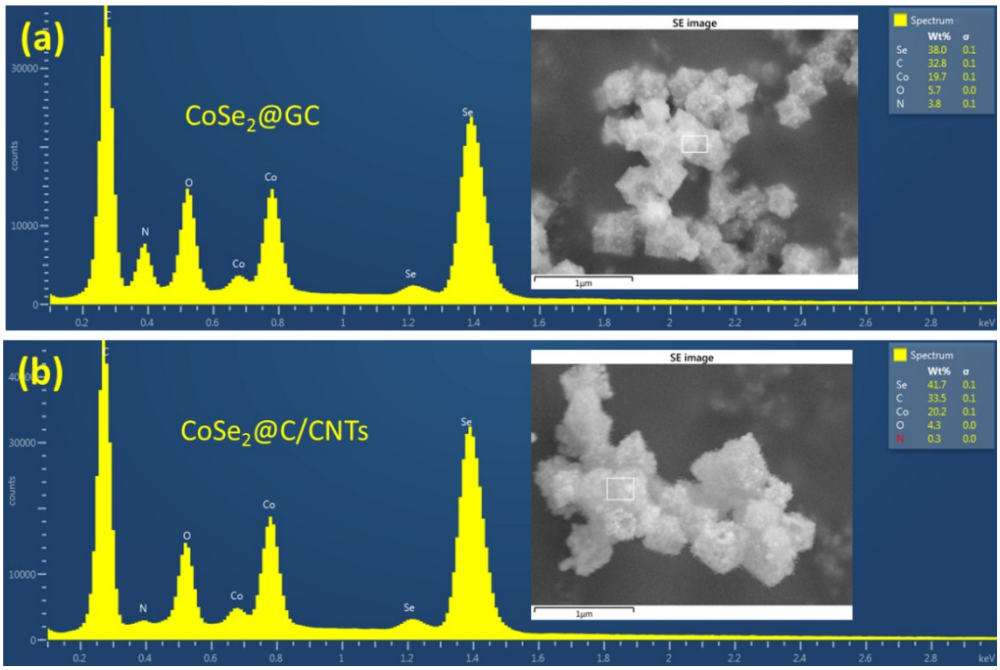

Fig. S5 EDS spectra and elements percentage of $CoSe_2$@C/CNTs and $CoSe_2$@GC.

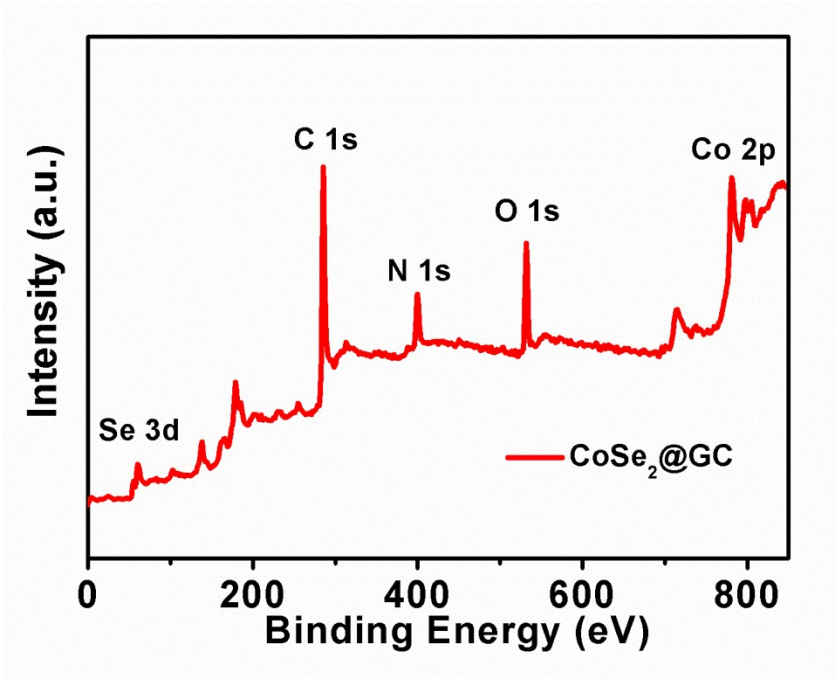

Fig. S6 XPS survey scan spectrum of $CoSe_2$@GC mainly composed of C, Co, Se, N, and O elements.

Table S1. Element contents (atomic ratio %) of the composite materials obtained from XPS analysis.

Elements / Samples	C	Co	Se	O	N
$CoSe_2$@C	74.26%	1.74%	3.90%	10.69%	9.41%
$CoSe_2$@C/CNTs	81.38%	2.06%	4.74%	10.45%	1.38%

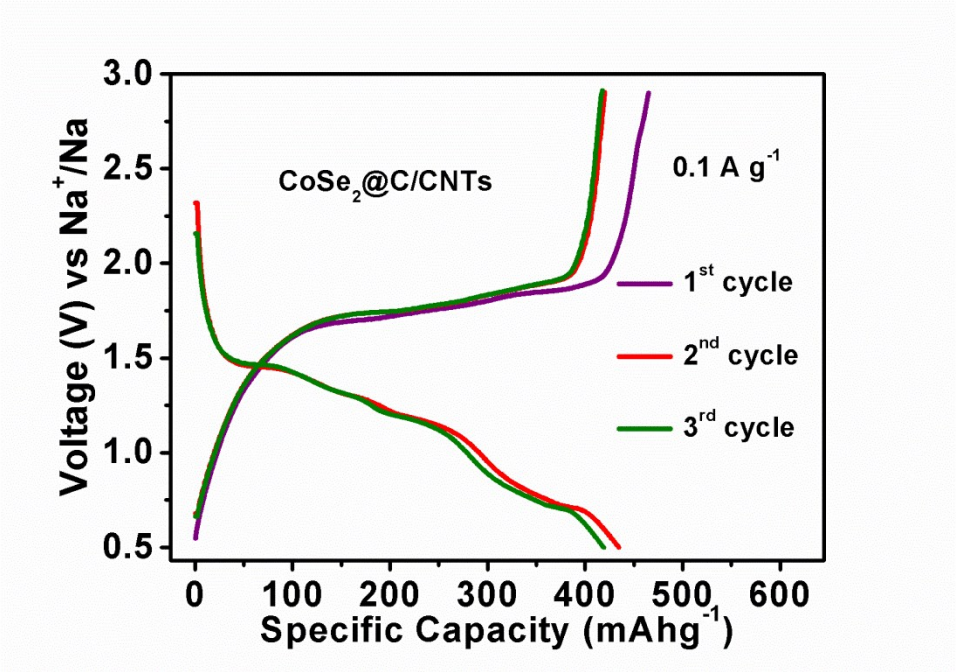

Fig. S7 Discharge-charge curves of $CoSe_2$@C/CNTs anode at a current density of 0.1 A g^{-1}.

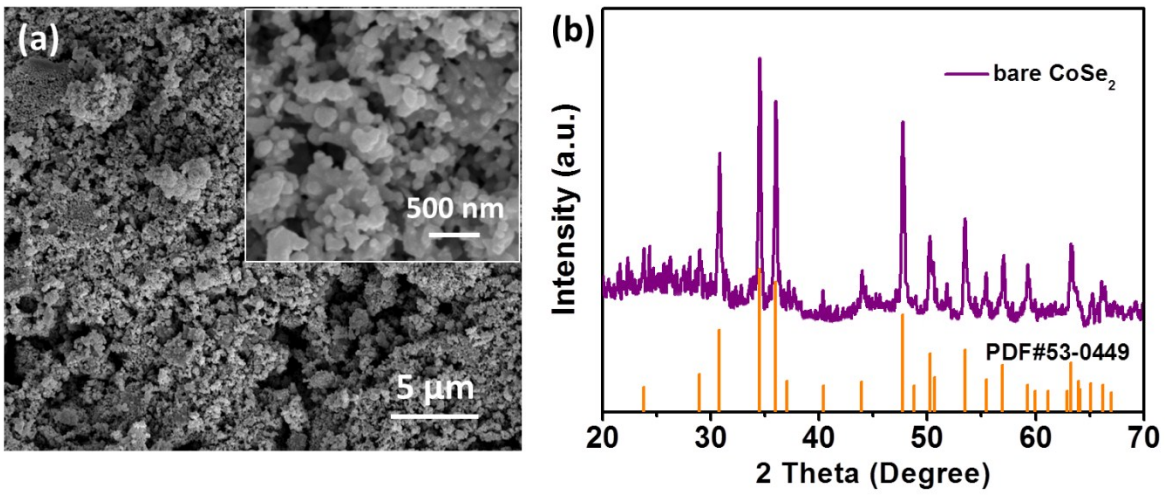

Fig. S8 FE-SEM image (a) and XRD patterns (b) of bare $CoSe_2$ showing its particle morphology and

orthorhombic structure .

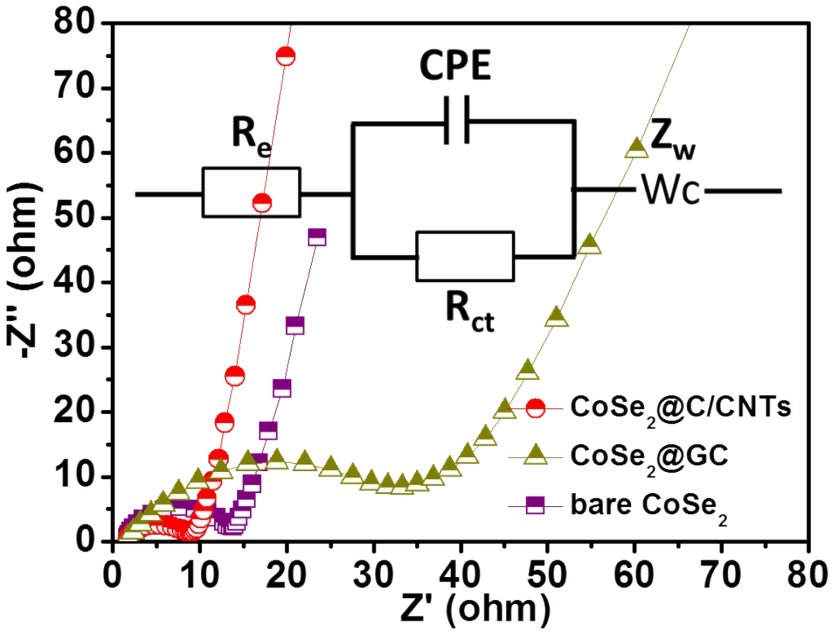

Fig. S9 EIS tests of $CoSe_2$@C/CNTs, $CoSe_2$@GC, and bare $CoSe_2$ anodes. In the equivalent circuit model, the Re, Rct, Zw, and CPE represent the ohm resistance of the electrolyte and electrode in high frequency region, charge transfer resistance in middle frequency region, and Warburg impedance related to the ionic diffusion in low frequency region, and double layer capacitance and passivation film capacitance, respectively.

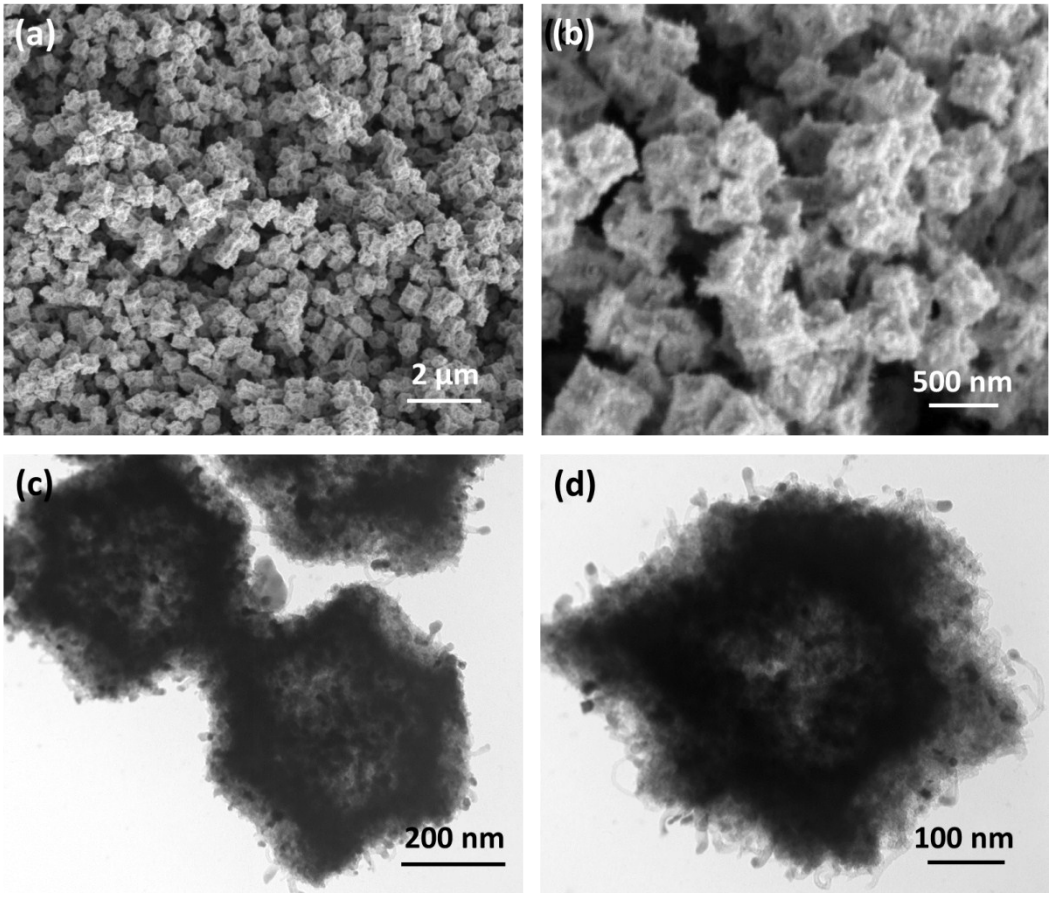

Fig. S10 Morphological features of $CoSe_2$@C/CNTs with CNTs growth time of 1 h: (a-b) FE-SEM images; and (c-d) TEM images.

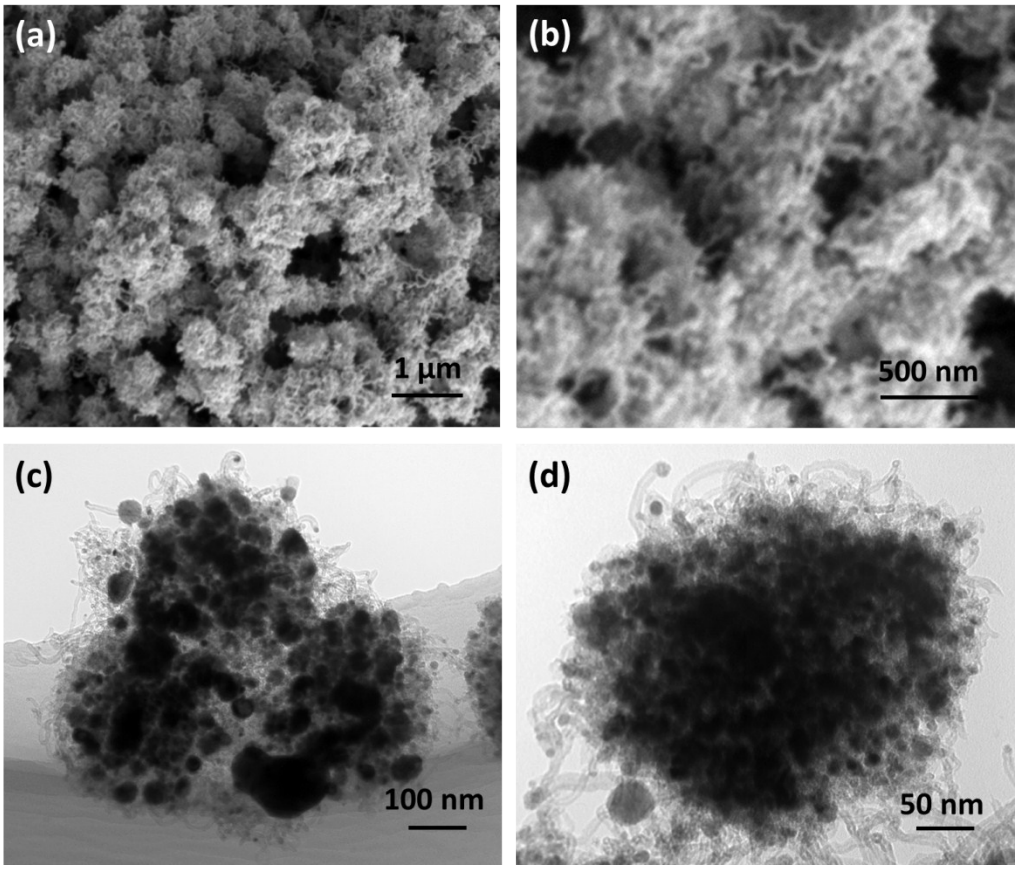

Fig. S11 Morphological features of $CoSe_2$@C/CNTs with CNTs growth time of 3 h: (a-b) FE-SEM images; and (c)-(d) TEM images.

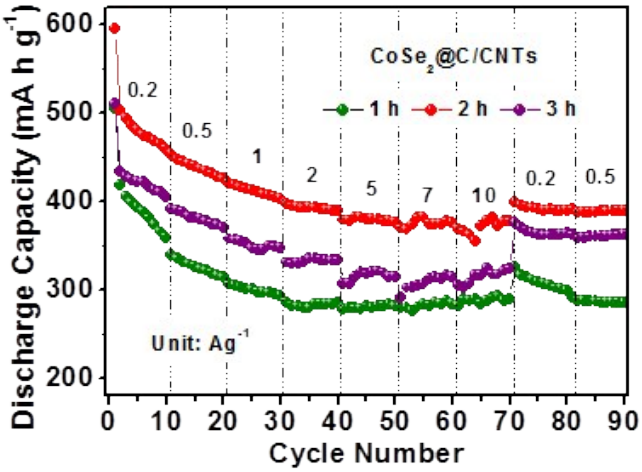

Fig. S12 Rate capability comparison of $CoSe_2$@C/CNTs with different CNTs growth time.

Table S2 Rate capability comparison of various transition metal chalcogenide/oxide based anodes.

Current density ($A\ g^{-1}$)	$CoSe_2$@C/CNTs (This work)	GF+V_2O_3/CNTs [1]	Urchin-like $CoSe_2$ [2]	Hollow $CoSe_2$ [3]	$SnSe_2$/RGO [4]	SnSSe [5]	SnS/SnO_2 [6]
	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)	Capacity ($mA\ h\ g^{-1}$)
0.09							620
0.1		600	434	521	528		
0.2	470	550	422		504		
0.27							590
0.3				490	485		
0.5	435	500	403		440		
0.6				471			
0.81							500
0.9				446			
1	410	450	397		398	500	
2	393	400	390		365		
2.43							420
2.5						400	
3							
5	381	325	378			320	
7	375	200					
7.29							300
7.5						200	
10	373	150	354			150	
30			163				
50			97				

References

1. X. Xia, D. Chao, Y. Zhang, J. Zhan, Y. Zhong, X. Wang, Y. Wang, Z. X. Shen, J. Tu and H. J. Fan, *Small*, 2016, **12**, 3048-3058.
2. K. Zhang, M. Park, L. Zhou, G.-H. Lee, W. Li, Y.-M. Kang and J. Chen, *Adv. Funct. Mater.*, 2016, **26**, 6728-6735
3. Y. N. Ko, S. H. Choi and Y. C. Kang, *ACS Appl. Mater. Interfaces*, 2016, **8**, 6449-6456.
4. F. Zhang, C. Xia, J. Zhu, B. Ahmed, H. Liang, D. B. Velusamy, U. Schwingenschlögl and H. N. Alshareef, *Adv. Energy Mater.*, 2016, **22**, 1601188.
5. X. Wang, D. Chen, Z. Yang, X. Zhang, C. Wang, J. Chen, X. Zhang and M. Xue, *Adv. Mater.*, 2016, **28**, 8645-8650.
6. Y. Zheng, T. Zhou, C. Zhang, J. Mao, H. Liu and Z. Guo, *Angew. Chem. Int. Ed.*, 2016, **55**, 3408-3413.