Electronic Supplementary Information

Coaxial Nickel Cobalt Selenide/Nitrogen-doped Carbon Nanotube Array as a Three-Dimensional Self-Supported Electrode for Electrochemical Energy Storage

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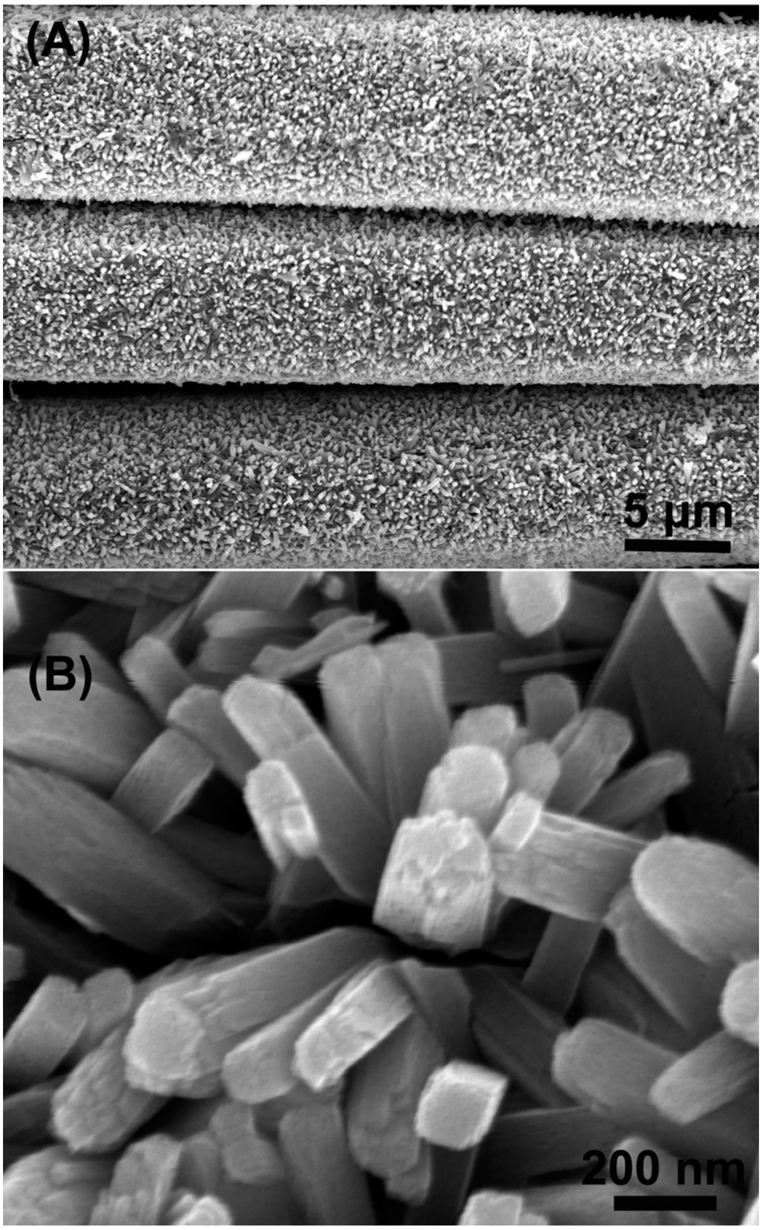

Figure S1. (A) Low and (B) high magnified SEM images of FeOOH nanoarray grown on carbon fiber paper via a hydrolysis of $FeCl_3$.

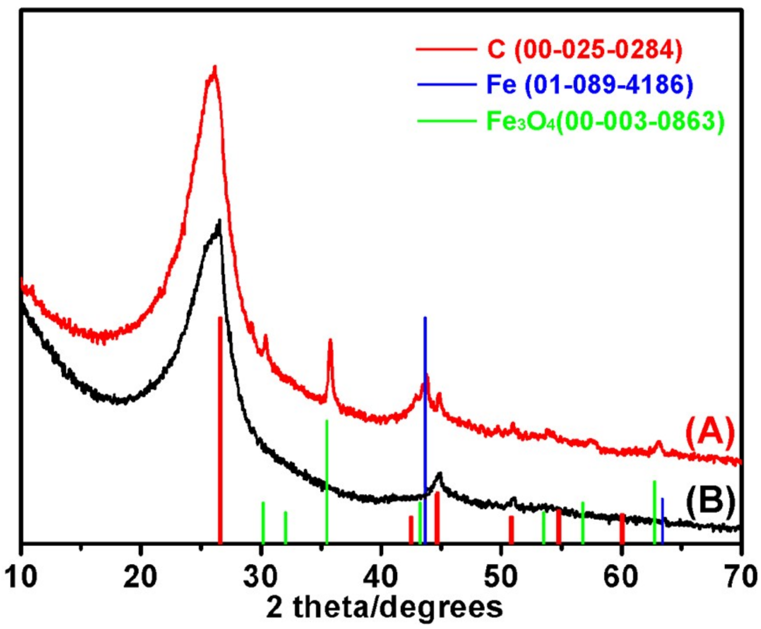

Figure S2. XRD pattern of (A) Fe/Fe_3O_4/NCNT and (B) NCNT array.

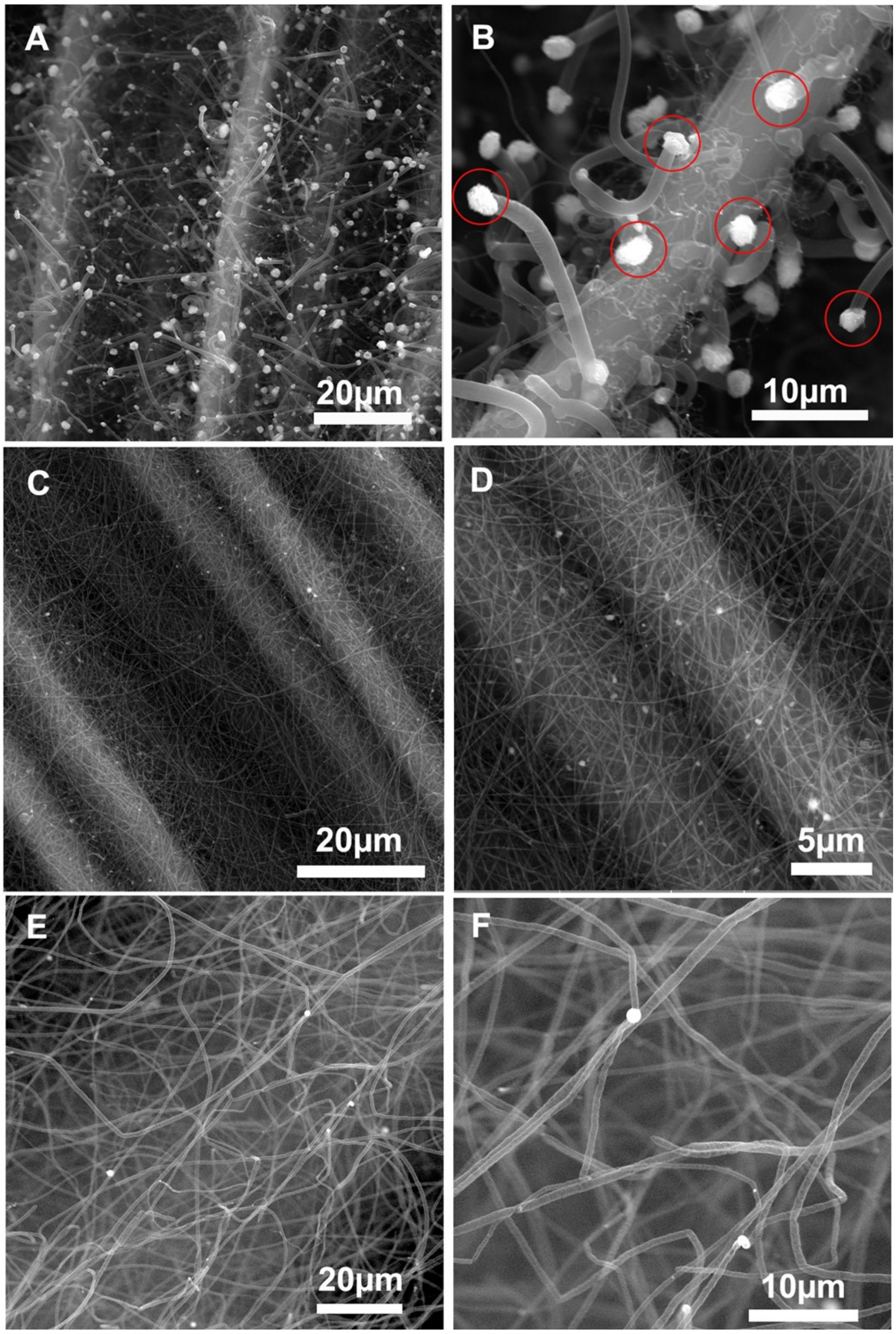

Figure S3. SEM images of Fe/Fe_3O_4/NCNT array formed after different pyrolysis times: (A, B) 10 min, (C, D) 30 min, and (E, F) 60 min.

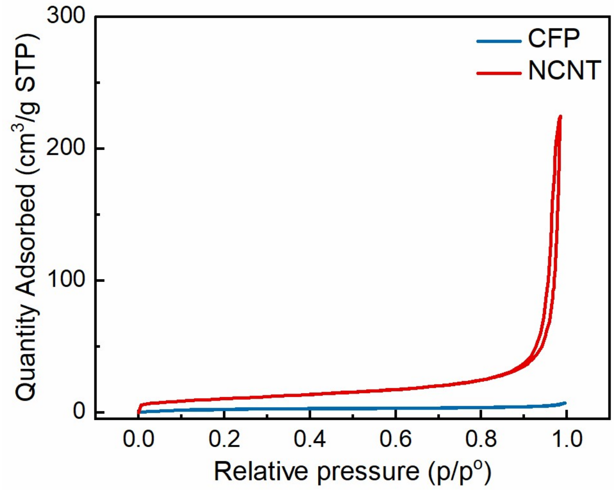

Figure S4. N_2 sorption isotherms of carbon fiber paper (CFP) and NCNT array.

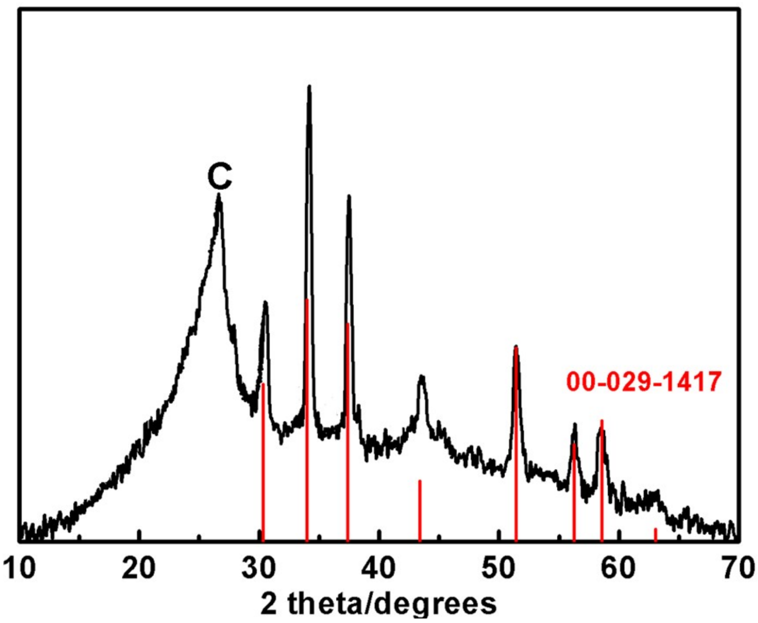

Figure S5. XRD pattern of $Co_{0.5}Ni_{0.5}Se_2$/NCNT, which is in consistent with the standard pattern of $CoSe_2$ (JCPDS 00-029-1417).

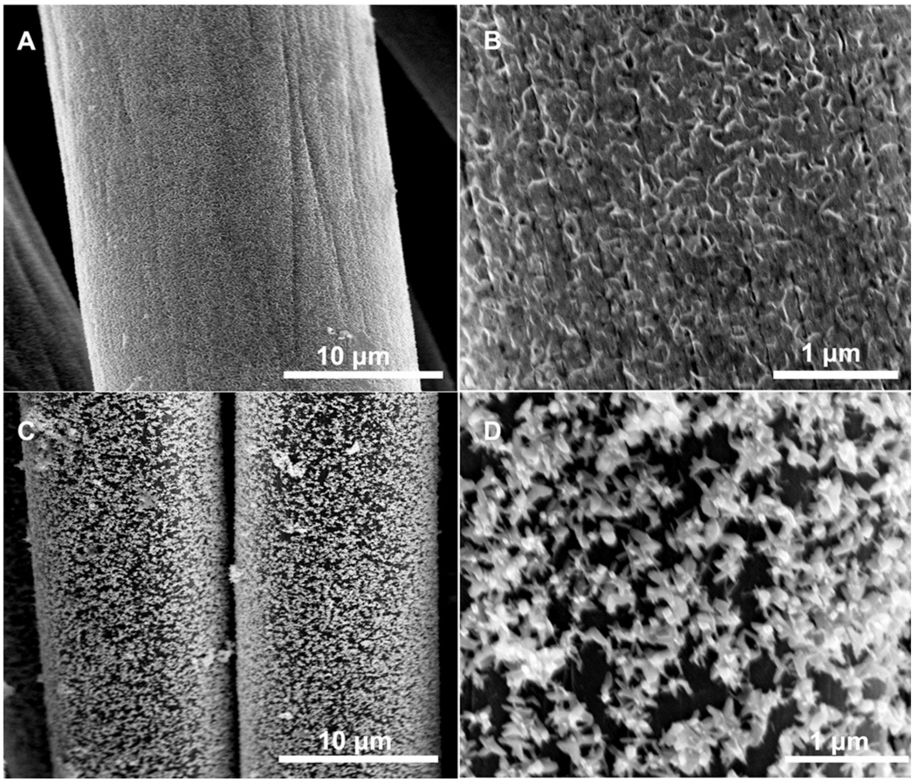

Figure S6. SEM images of (A, B) $Co_{0.5}Ni_{0.5}(OH)_2$/CFP and (C, D) $Co_{0.5}Ni_{0.5}Se_2$/CFP.

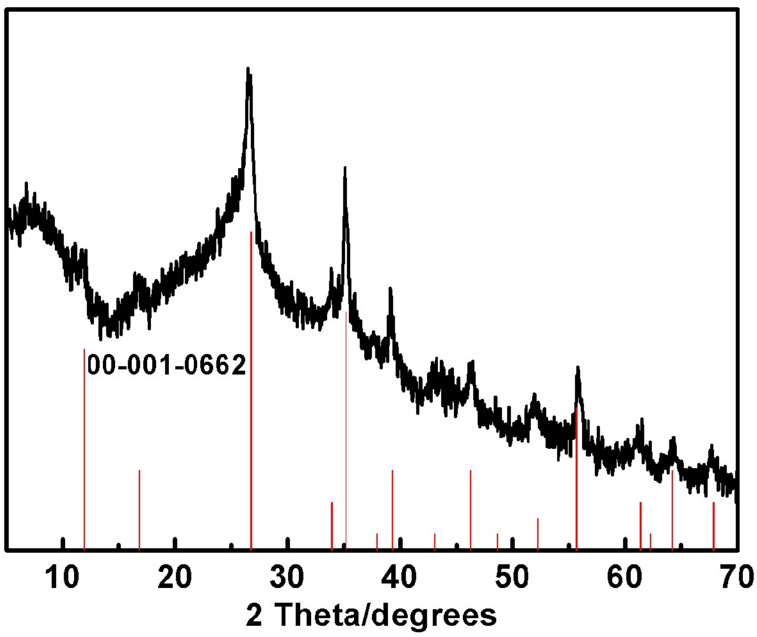

Figure S7. XRD pattern of the coaxial FeOOH/NCNT array, which is in accordance with the standard pattern of FeOOH (JCPDS 00-001-0662).

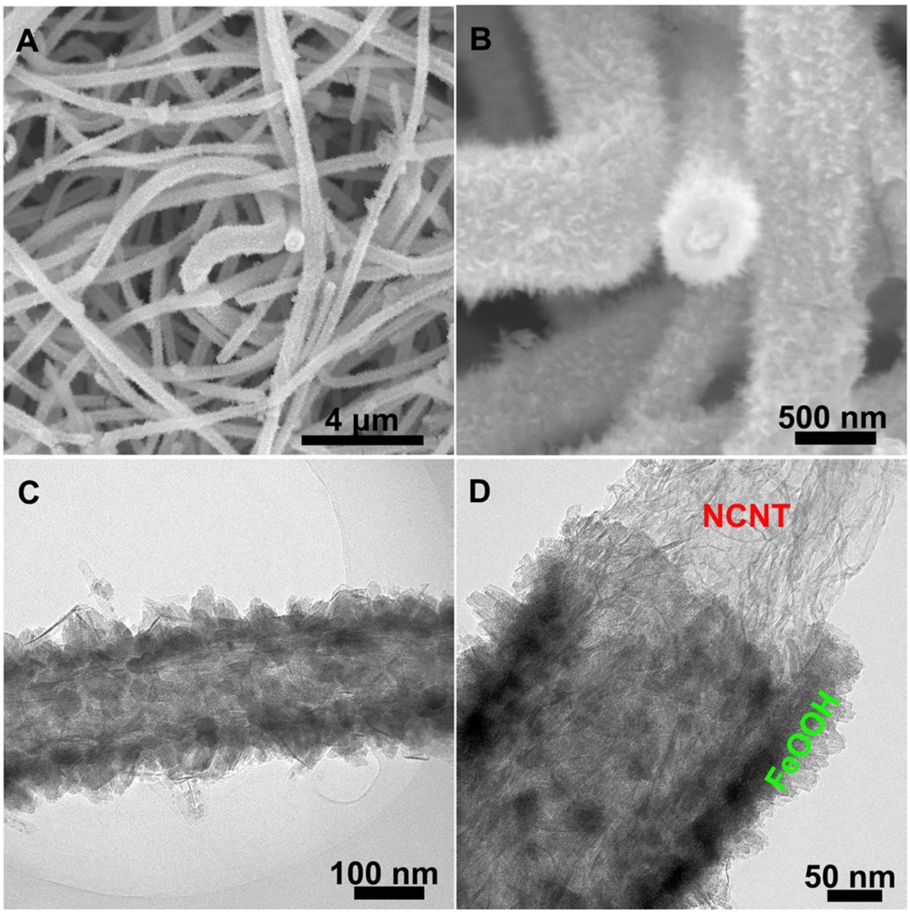

Figure S8. (A, B) SEM and (C, D) TEM images of the coaxial FeOOH/NCNT array.

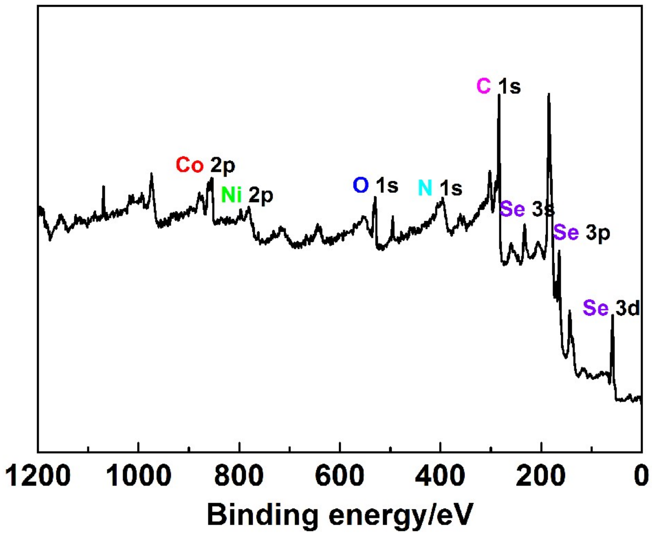

Figure S9. The XPS full spectrum of $Co_{0.5}Ni_{0.5}Se_2$/NCNT.

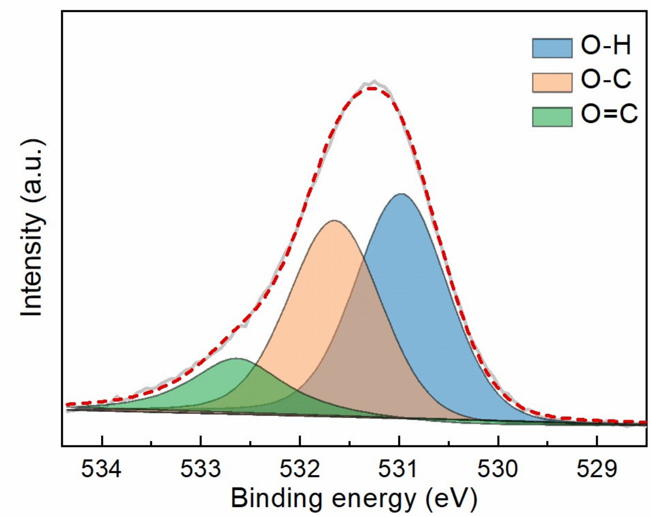

Figure S10. The O 1s XPS fine spectrum for $Co_{0.5}Ni_{0.5}Se_2$/NCNT.

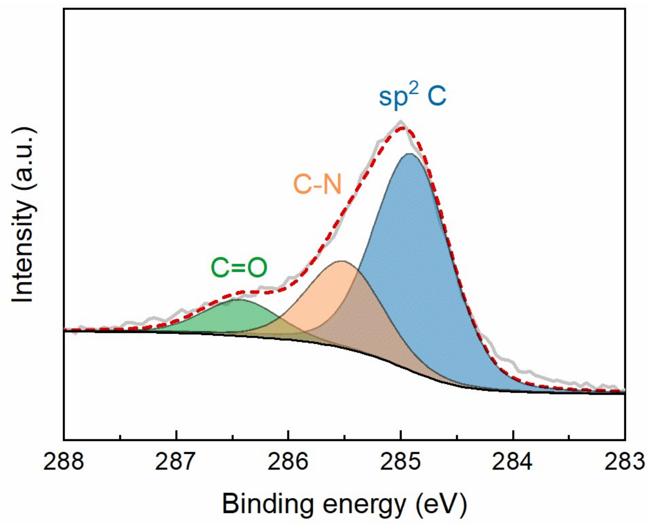

Figure S11. The C 1s XPS fine spectrum for $Co_{0.5}Ni_{0.5}Se_2$/NCNT.

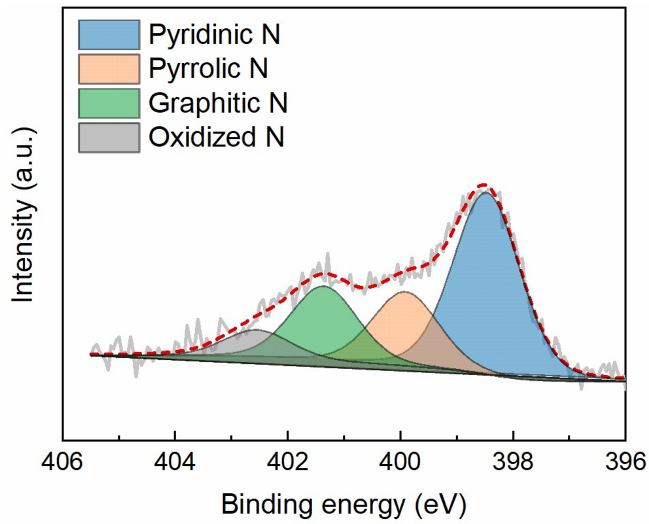

Figure S12. The N 1s XPS fine spectrum for $Co_{0.5}Ni_{0.5}Se_2$/NCNT.

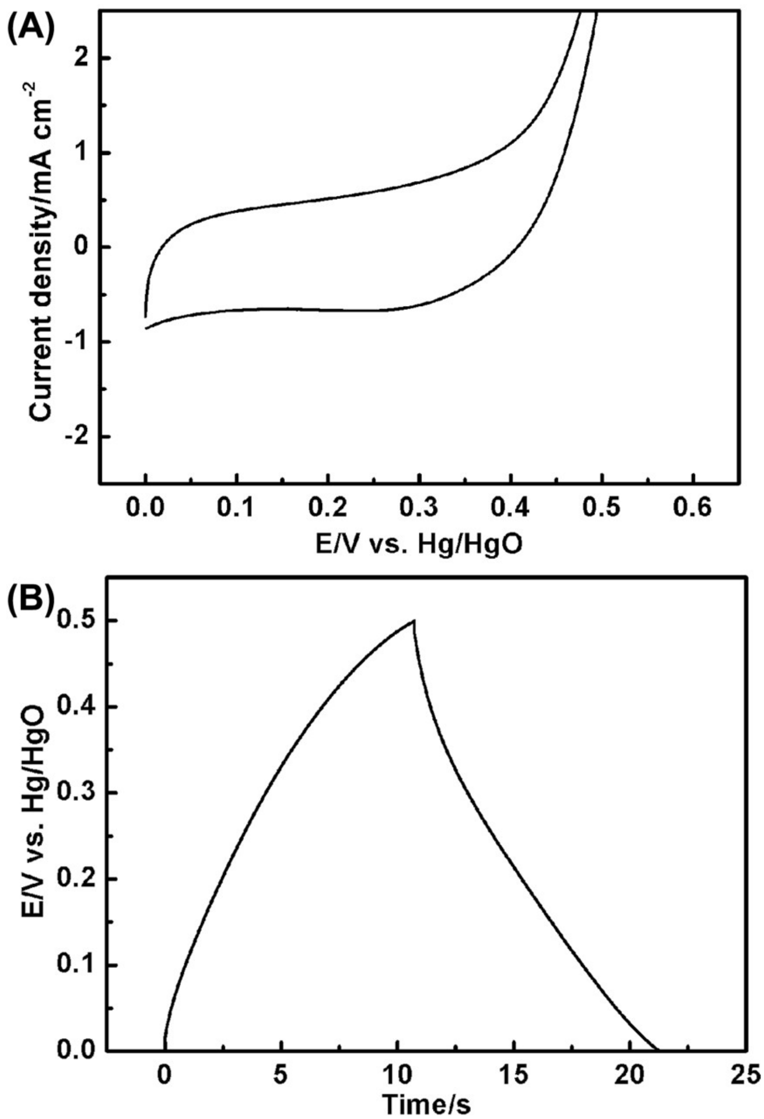

Figure S13. (A) CV curve (10 mV s^{-1}) and (B) galvanostatic charge/discharge curves at 4 mA cm^{-2} of NCNT. The areal capacity is 21.0 mC cm^{-2} at 4 mA cm^{-2}.

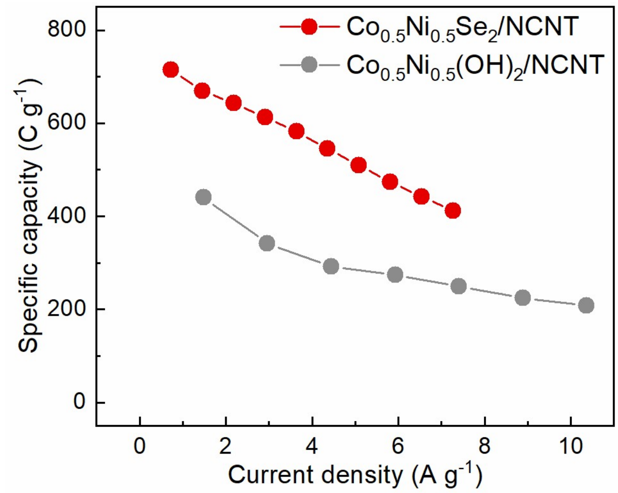

Figure S14. Specific capacity of $Co_{0.5}Ni_{0.5}(OH)_2$/NCNT and $Co_{0.5}Ni_{0.5}Se_2$/NCNT electrodes.

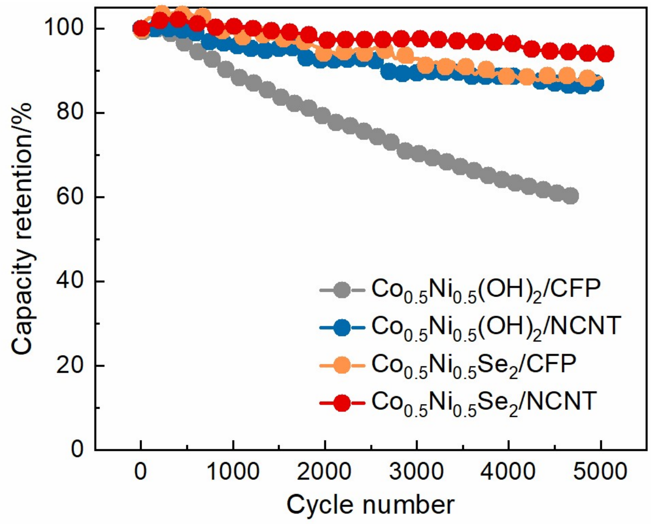

Figure S15. The long-term cycling performances of $Co_{0.5}Ni_{0.5}(OH)_2$/CFP, $Co_{0.5}Ni_{0.5}(OH)_2$/NCNT, $Co_{0.5}Ni_{0.5}Se_2$/CFP, and $Co_{0.5}Ni_{0.5}Se_2$/NCNT at a charging/discharging current of 20 mA cm^{-2}.

Table S1. Comparison of the specific capacity and rate capability of the $Co_{0.5}Ni_{0.5}Se_2$/NCNT coaxial electrode with the Ni-Co-Se electrodes reported before.

Samples	Current density	Specific capacity	Rate capability	Ref.
$Co_{0.5}Ni_{0.5}Se_2$/NCNT	4.0 mA cm^{-2}	3.9 C cm^{-2} (714.5 C g^{-1})	57.6% (4-40)	This work
$Ni_{0.34}Co_{0.66}Se_2$	4.0 mA cm^{-2}	1.31 C cm^{-2}	75% (4-20)	[1]
Ni-Co-Se	1 A g^{-1}	333.0 C g^{-1}	40.6% (1-20)	[2]
Ni-Mn-Se	2 A g^{-1}	1221.1 C g^{-1}	78.8% (2-32)	[3]
$NiCo_{2.1}Se_{3.3}$	1 mA cm^{-2}	371.2 C g^{-1}	63.5% (1-10)	[4]
$NiCoSe_2$	3 A g^{-1}	375 C g^{-1}	88.0% (3-10)	[5]
$(Ni_xCo_{1-x})_9Se_8$	5 A g^{-1}	1692.9 C g^{-1}	91.8% (5-30)	[6]
$NiCoSe_4$	0.5 A g^{-1}	504 C g^{-1}	85.2% (0.5-20)	[7]
$Ni_{0.5}Co_{0.5}Se_2$	1 A g^{-1}	262 C g^{-1}	56.0% (1-50)	[8]
$(Ni_{0.33}Co_{0.67})Se_2$	1 A g^{-1}	414.0 C g^{-1}	78.0% (1-30)	[9]
$NiCoSe_2$	1 A g^{-1}	150.1 C g^{-1}	63.3% (1-20)	[10]
$NiCoSe_2$	1 A g^{-1}	520 C g^{-1}	53.7% (1-30)	[11]

References

1. P. Xu, W. Zeng, S. Luo, C. Ling, J. Xiao, A. Zhou, Y. Sun and K. Liao, *Electrochim. Acta*, 2017, **241**, 41-49.
2. Y. L. Liu, C. Yan, G. G. Wang, F. Li, Q. Kang, H. Y. Zhang and J. C. Han, *Nanoscale*, 2020, **12**, 4040-4050.
3. A. Mohammadi Zardkhoshoui, B. Ameri and S. S. Hosseiny Davarani, *Nanoscale*, 2021, **13**, 2931-2945.
4. Y. Wang, W. Zhang, X. Guo, K. Jin, Z. Chen, Y. Liu, L. Yin, L. Li, K. Yin, L. Sun and Y. Zhao, *ACS Appl. Mater. Interfaces*, 2019, **11**, 7946-7953.
5. L. Hou, Y. Shi, C. Wu, Y. Zhang, Y. Ma, X. Sun, J. Sun, X. Zhang and C. Yuan, *Adv. Funct. Mater.*, 2018, **28**, 1705921.
6. P. Yang, Z. Wu, Y. Jiang, Z. Pan, W. Tian, L. Jiang and L. Hu, *Adv. Energy Mater.*, 2018, **8**, 1801392.
7. Z. Xie, D. Qiu, J. Xia, J. Wei, M. Li, F. Wang and R. Yang, *ACS Appl. Mater. Interfaces*, 2021, **13**, 12006-12015.
8. X. Song, C. Huang, Y. Qin, H. Li and H. C. Chen, *J. Mater. Chem. A*, 2018, **6**, 16205-16212.
9. L. Quan, T. Liu, M. Yi, Q. Chen, D. Cai and H. Zhan, *Electrochim. Acta*, 2018, **281**, 109-116.
10. Y. Miao, Y. Sui, D. Zhang, J. Qi, F. Wei, Q. Meng, Y. He, Z. Sun and Y. Ren, *Mater. Lett.*, 2019, **242**, 42-46.
11. L. Wang, Z. Feng, H. Zhang, D. Li and P. Xing, *Nanotechnology*, 2020, **31**, 125403.