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Constructing Novel Heterostructure of $NiSe_2/CoSe_2$ Nanoparticles with Boosted Sodium Storage Properties for Sodium-Ion Batteries

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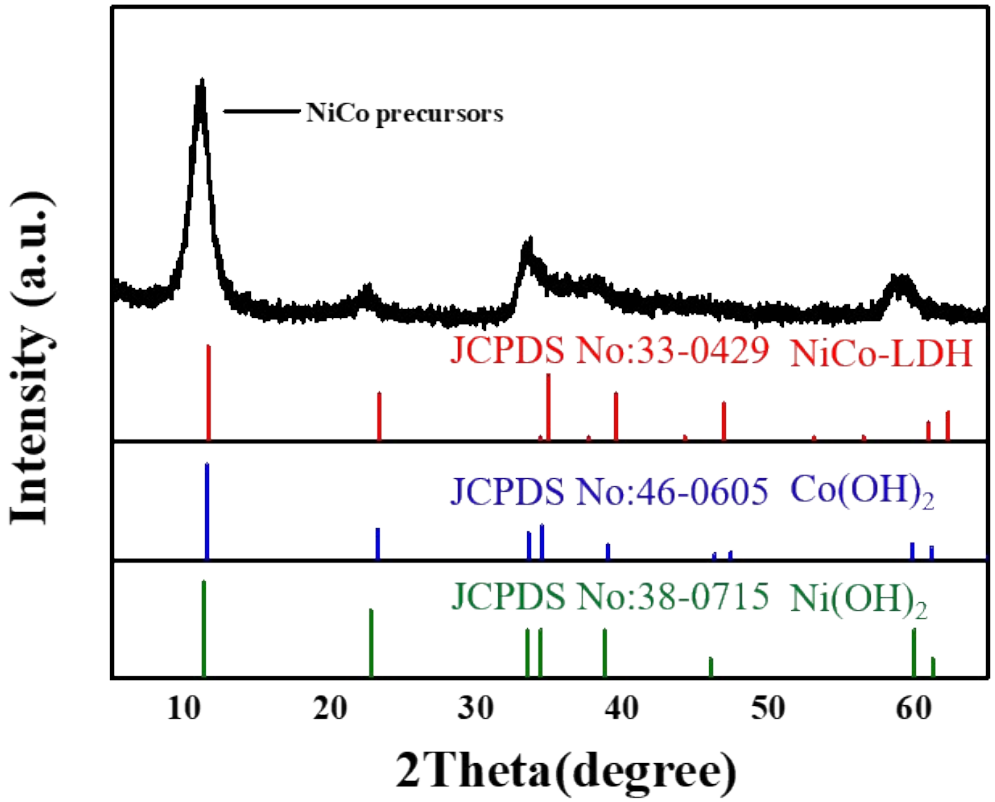

Fig. S1. XRD pattern of NiCo precursor.

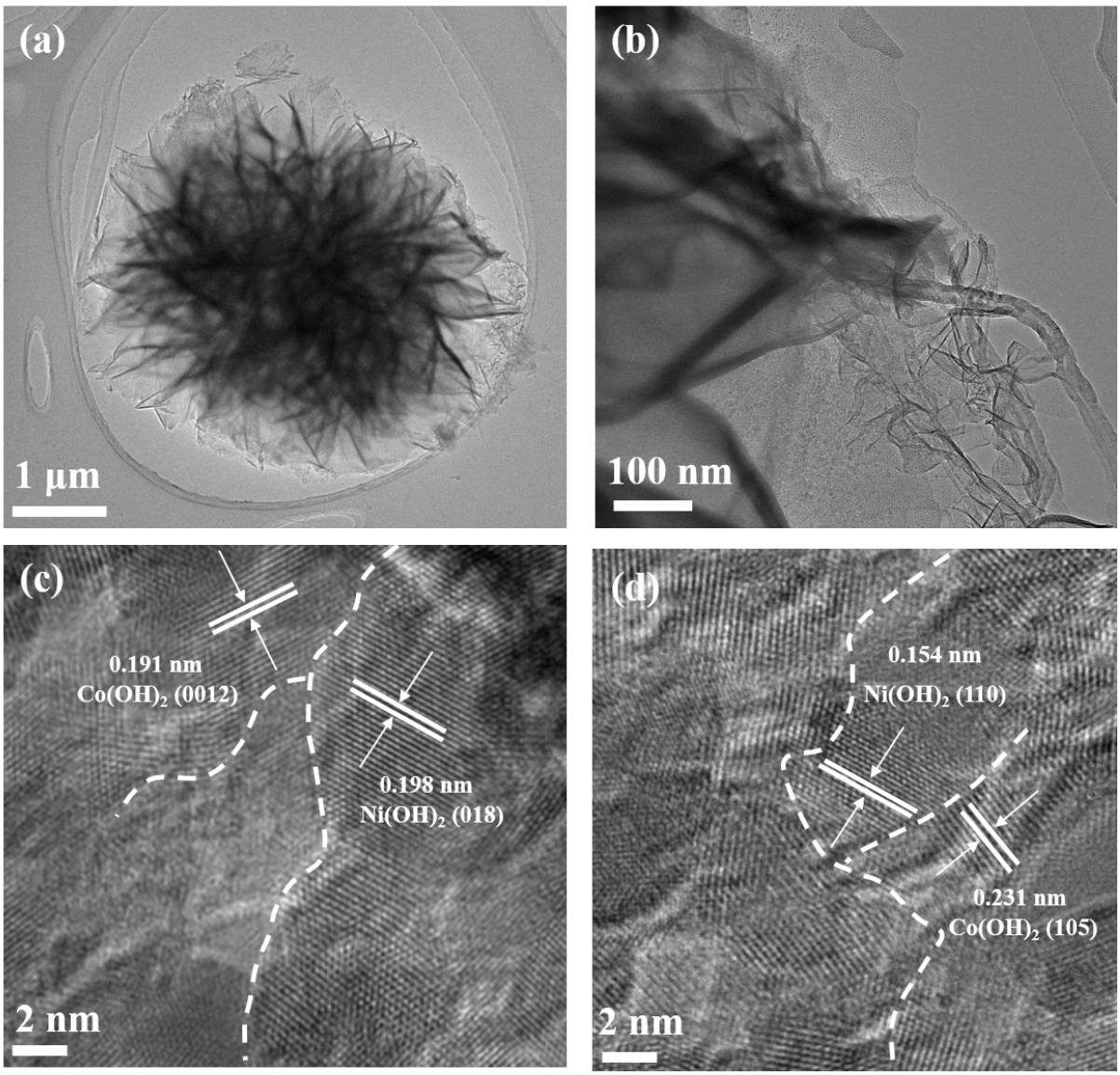

Fig. S2. (a-b) TEM and (c-d) HRTEM images of NiCo precursor.

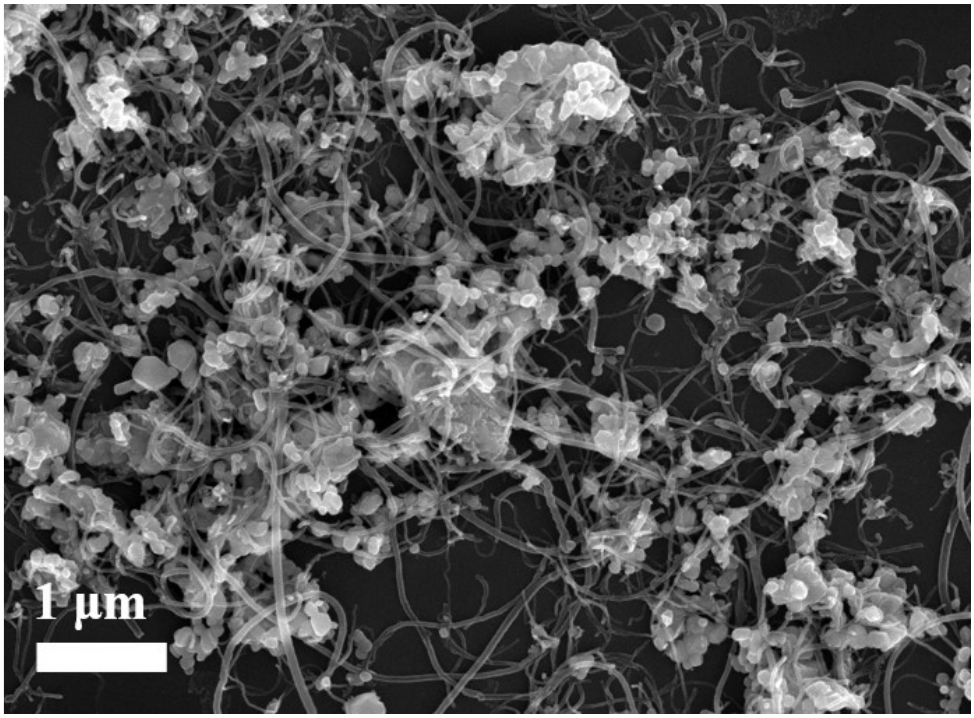

Fig. S3. SEM image of selenized NiCo precursor.

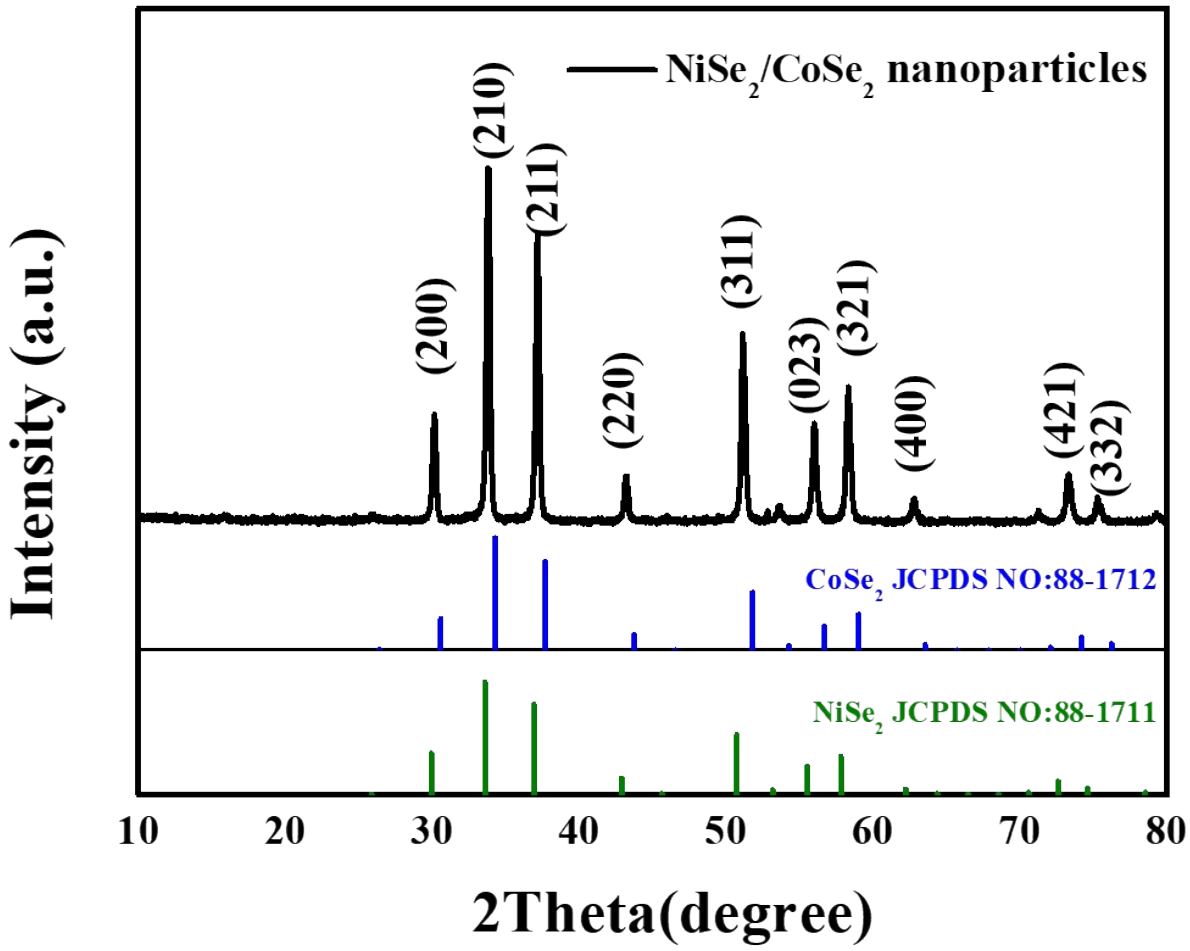

Fig. S4. XRD pattern of $NiSe_2/CoSe_2$ nanoparticles.

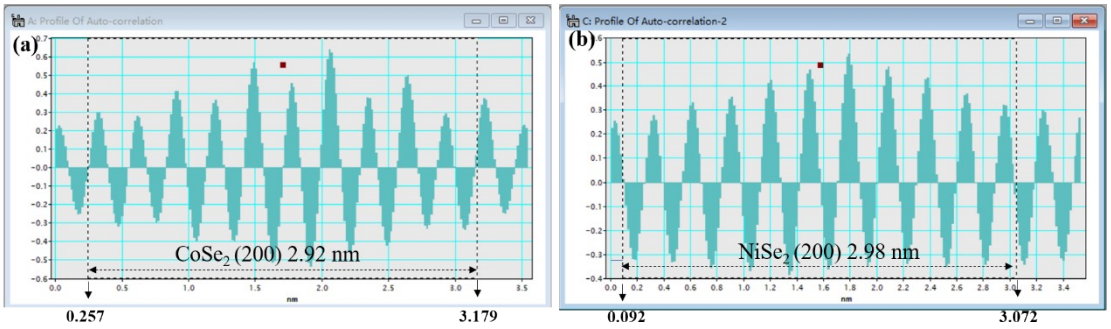

Fig. S5. Inverse FFT liner profiles of $NiSe_2/CoSe_2$ nanoparticles.

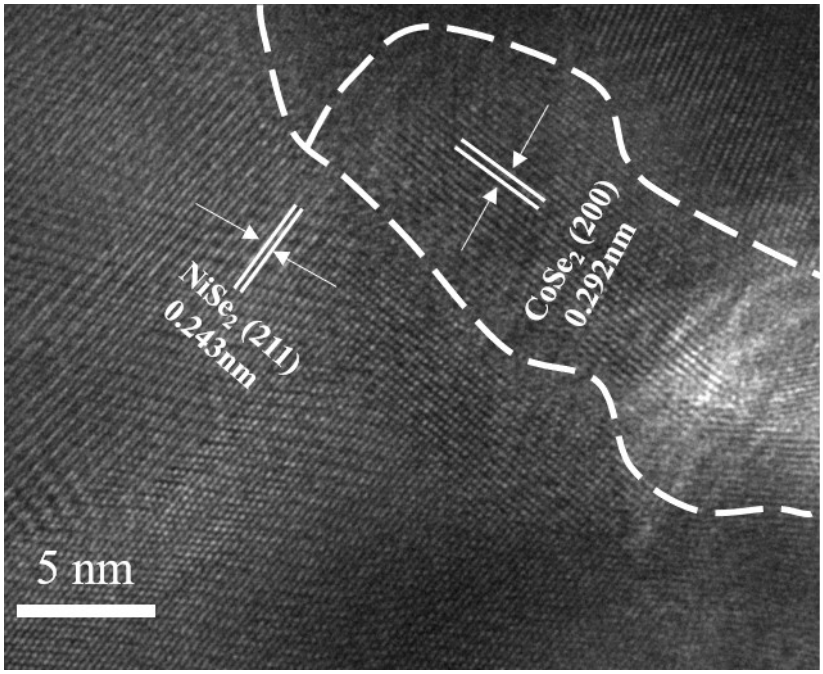

Fig. S6. HRTEM image of NiSe2/CoSe2 nanoparticles.

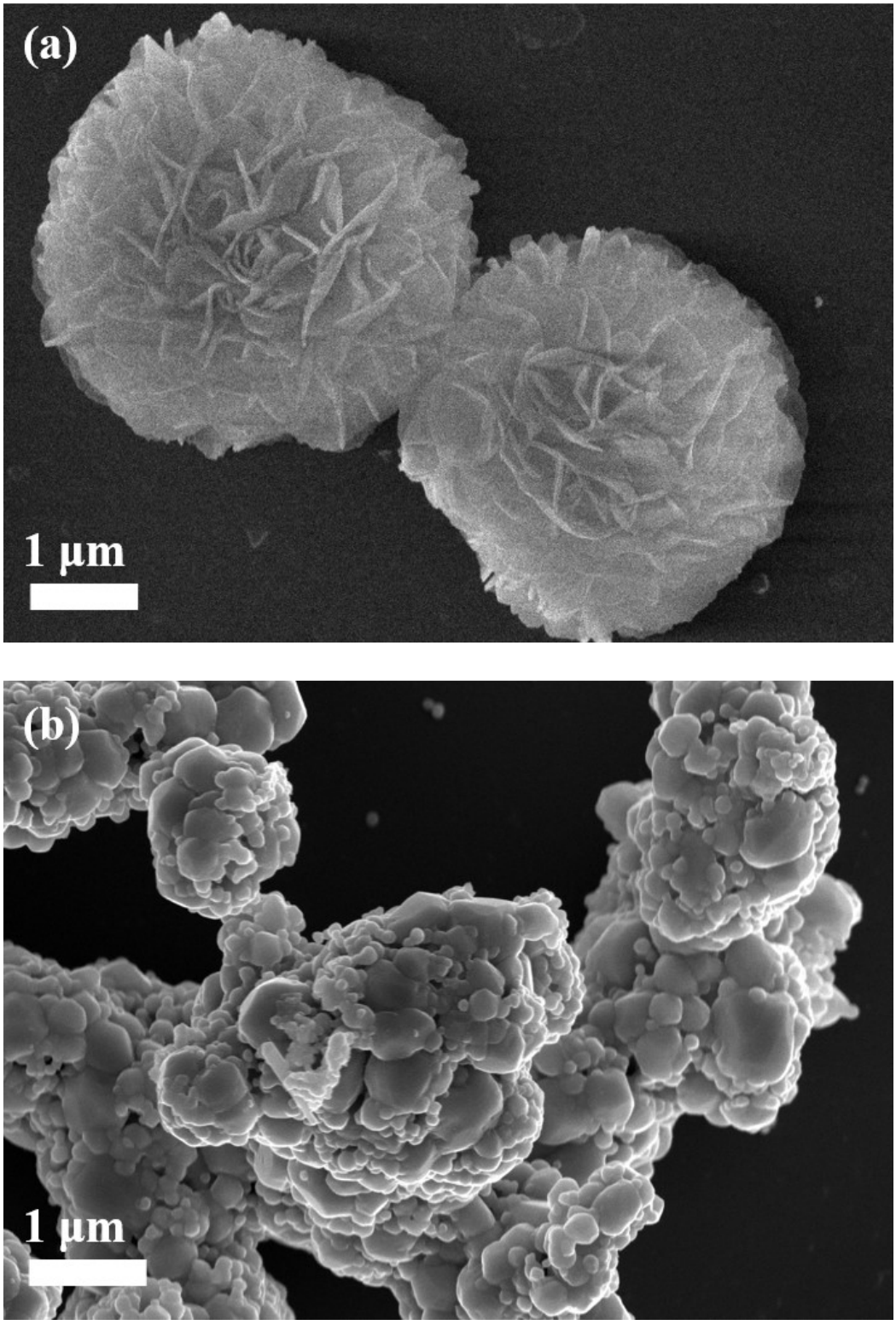

Fig. S7. (a) SEM image of NiCo precursor without MWCNTs; (b) SEM image of selenized NiCo precursor without MWCNTs.

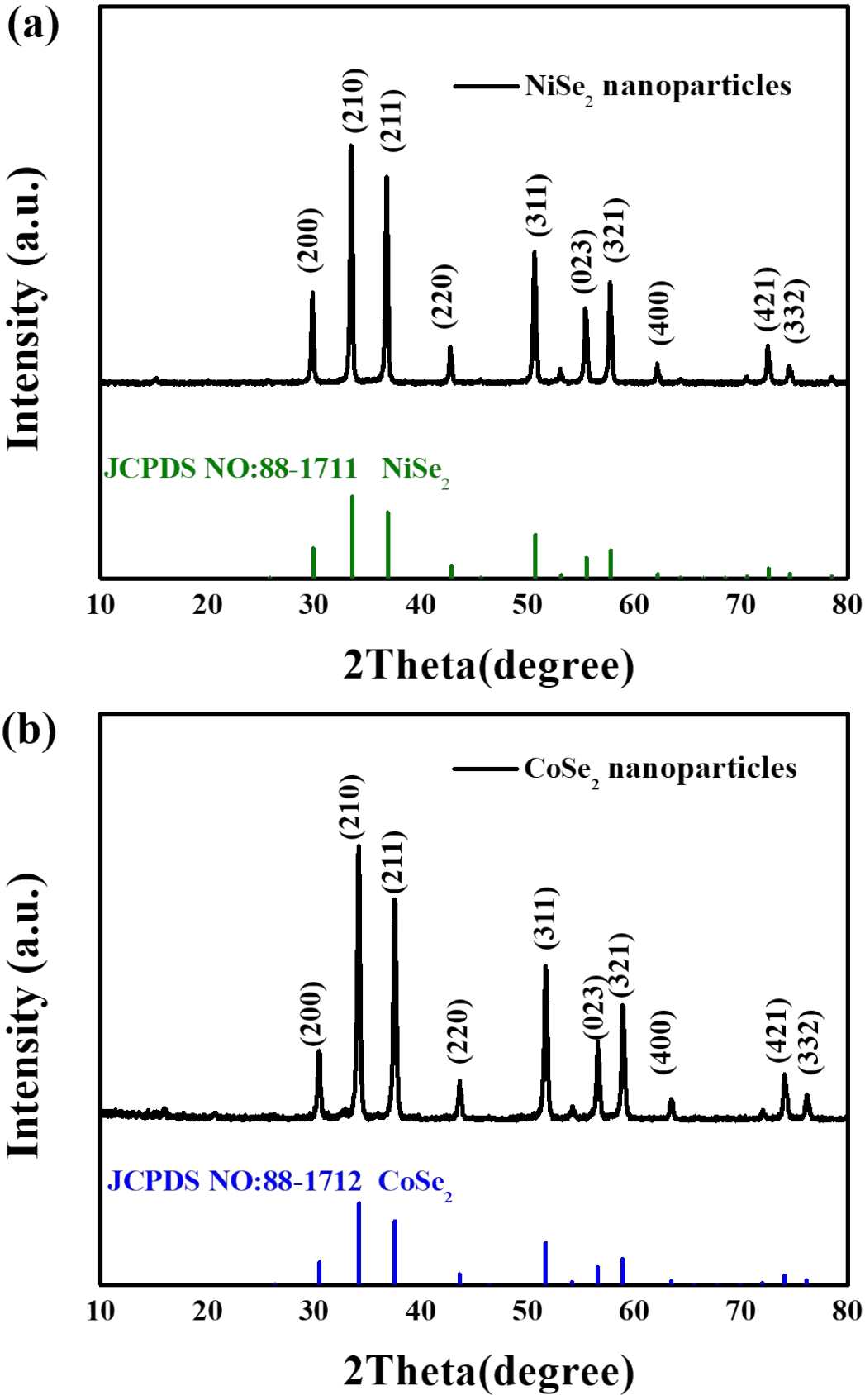

Fig. S8. XRD patterns of (a) $NiSe_2$ and (b) $CoSe_2$ nanoparticles.

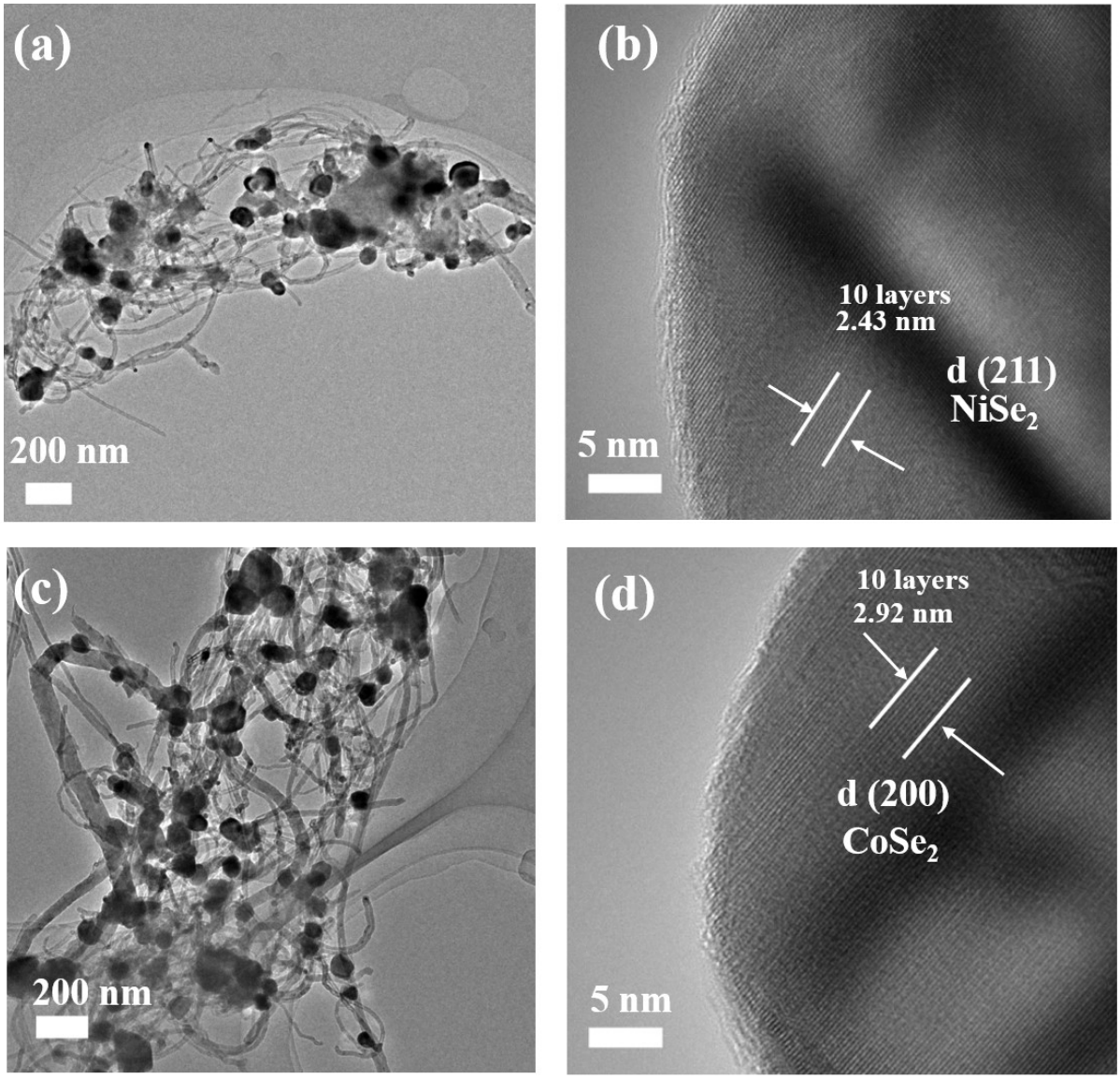

Fig. S9. (a) TEM and (b) HRTEM images of $NiSe_2$ nanoparticles; (c) TEM and (d) HRTEM images of $CoSe_2$ nanoparticles.

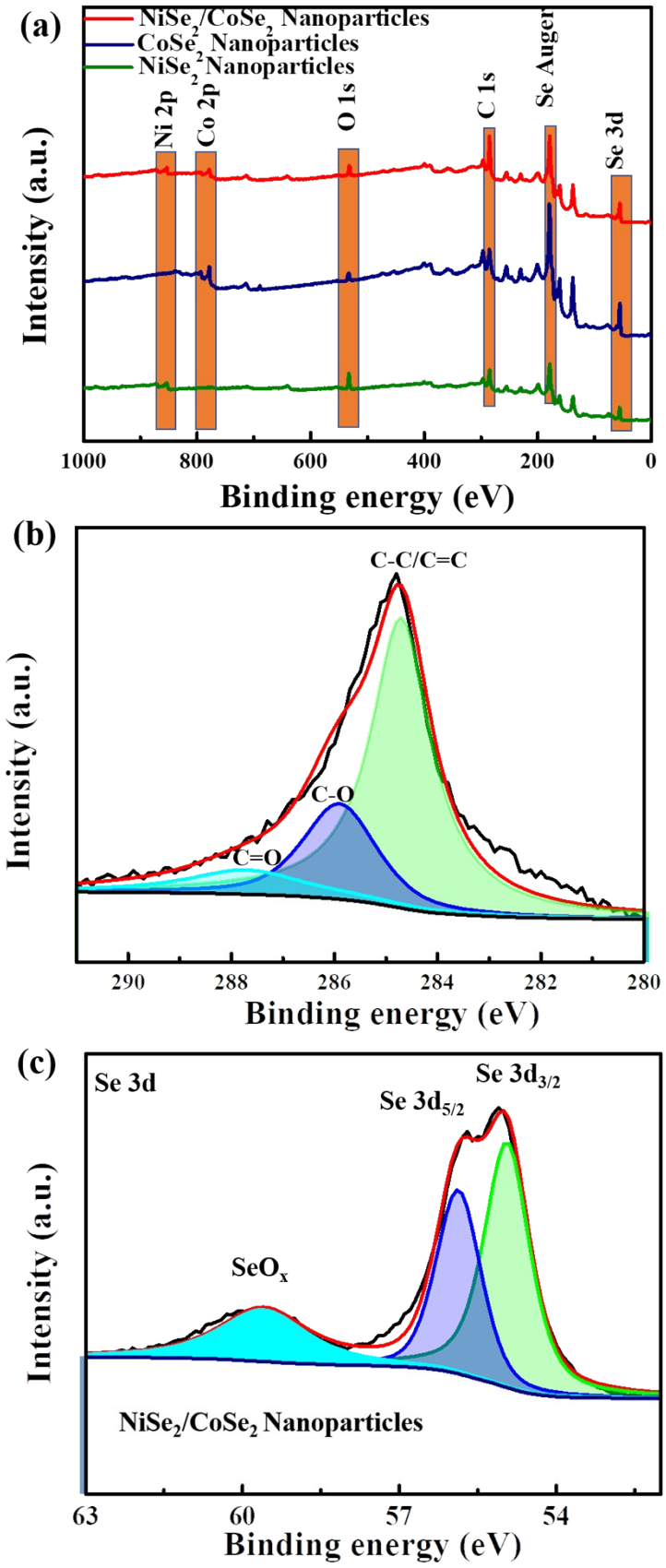

Fig. S10. (a)XPS survey spectra of $NiSe_2$, $CoSe_2$ and $NiSe_2/CoSe_2$ nanoparticles; (b-c) High-resolution C1s and Se 3d XPS spectrum of $NiSe_2/CoSe_2$ nanoparticles.

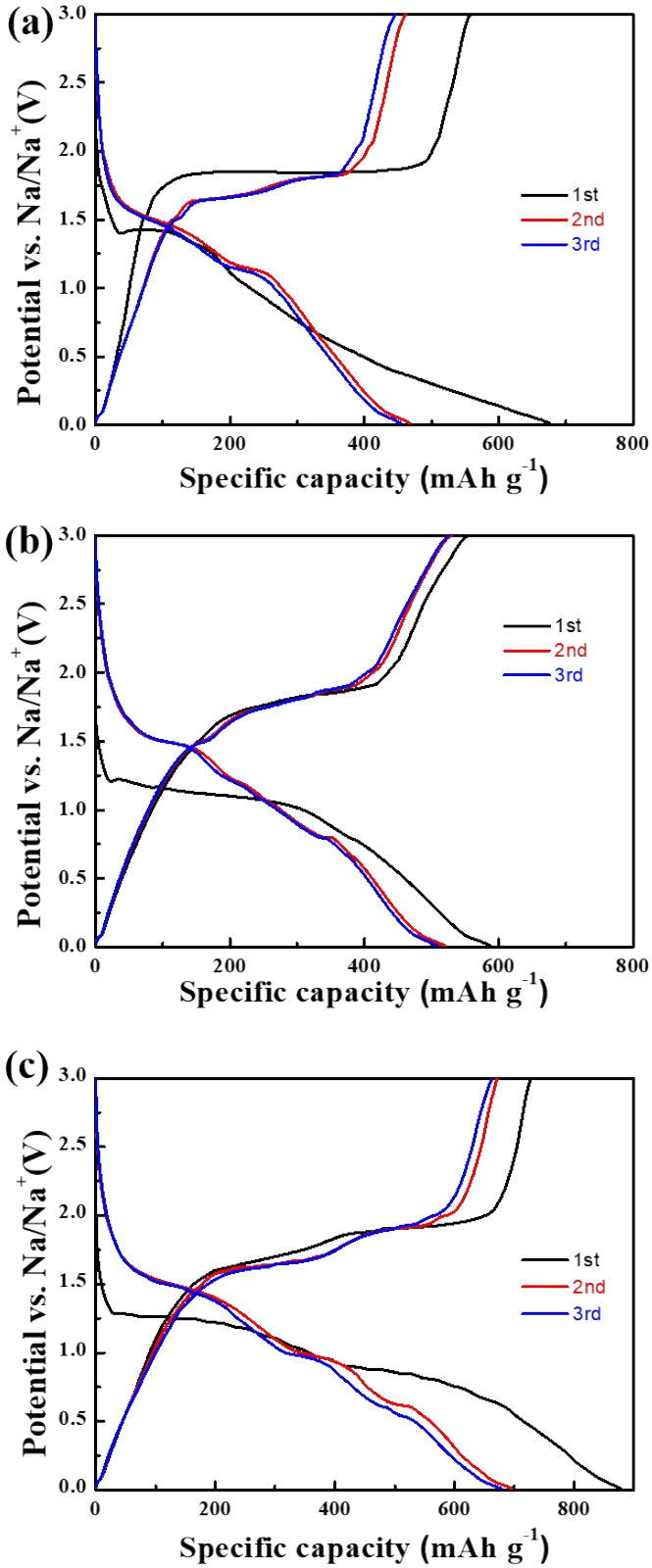

Fig. S11. The charge/discharge curves of the (a) $NiSe_2$, (b) $CoSe_2$ and (c) $NiSe_2/CoSe_2$ nanoparticles at 0.1 A g^{-1}.

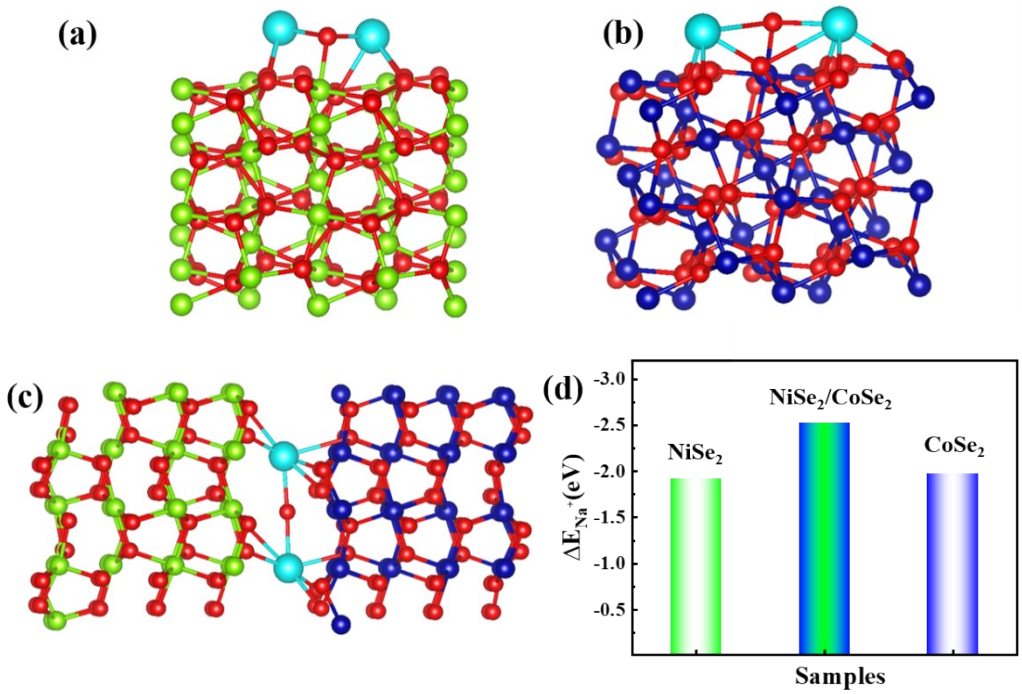

Fig. S12. The optimized structures of Na_2Se adsorption on (a) $NiSe_2$, (b) $CoSe_2$ and (c) $NiSe_2$ (200)/$CoSe_2$ (200); (d) The adsorption energies of Na_2Se on $NiSe_2$, $CoSe_2$ and $NiSe_2$ (200)/$CoSe_2$ (200).

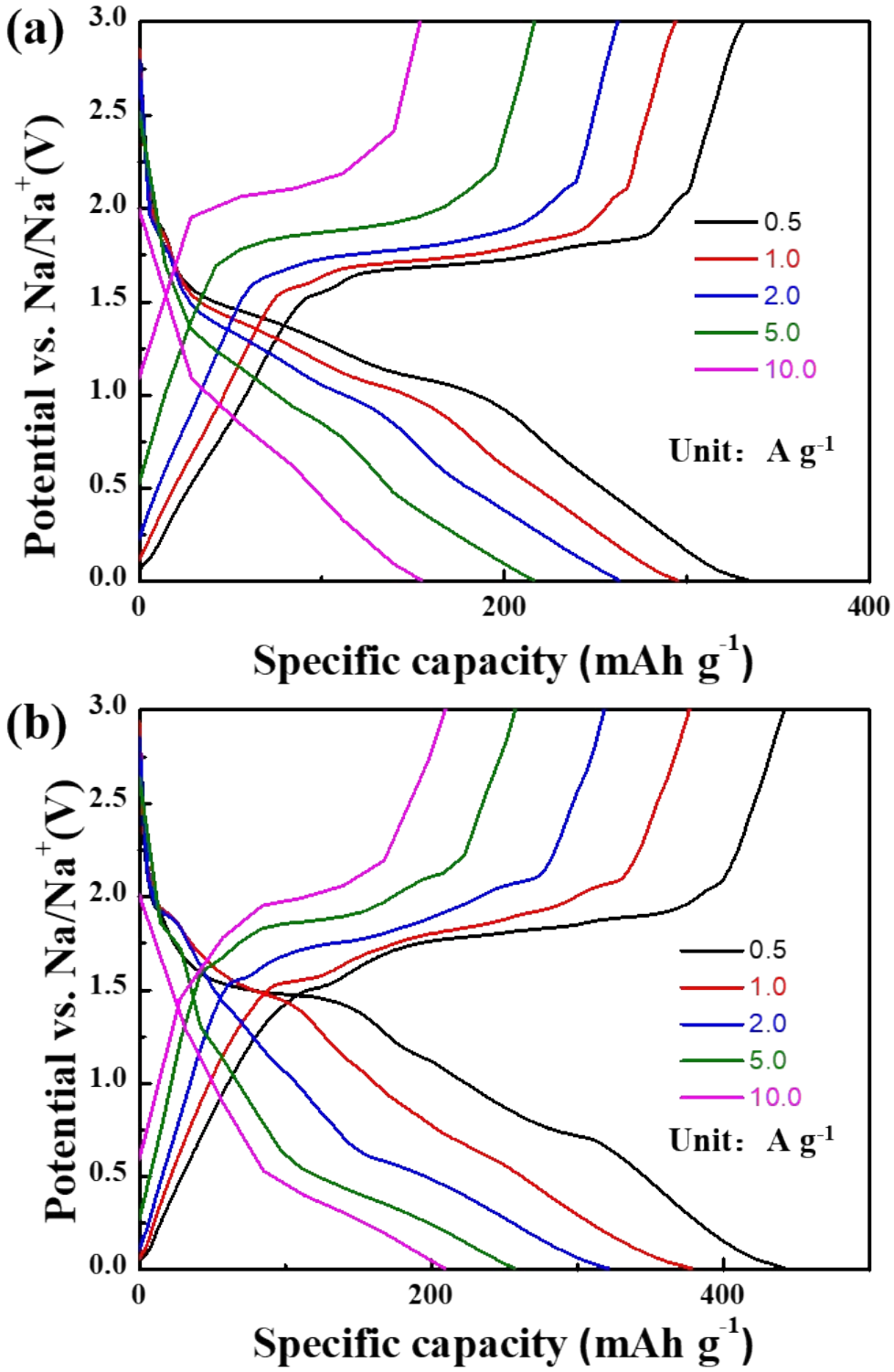

Fig. S13. The charge/discharge curves of (a) $NiSe_2$ and (b) $CoSe_2$ nanoparticles at different current densities.

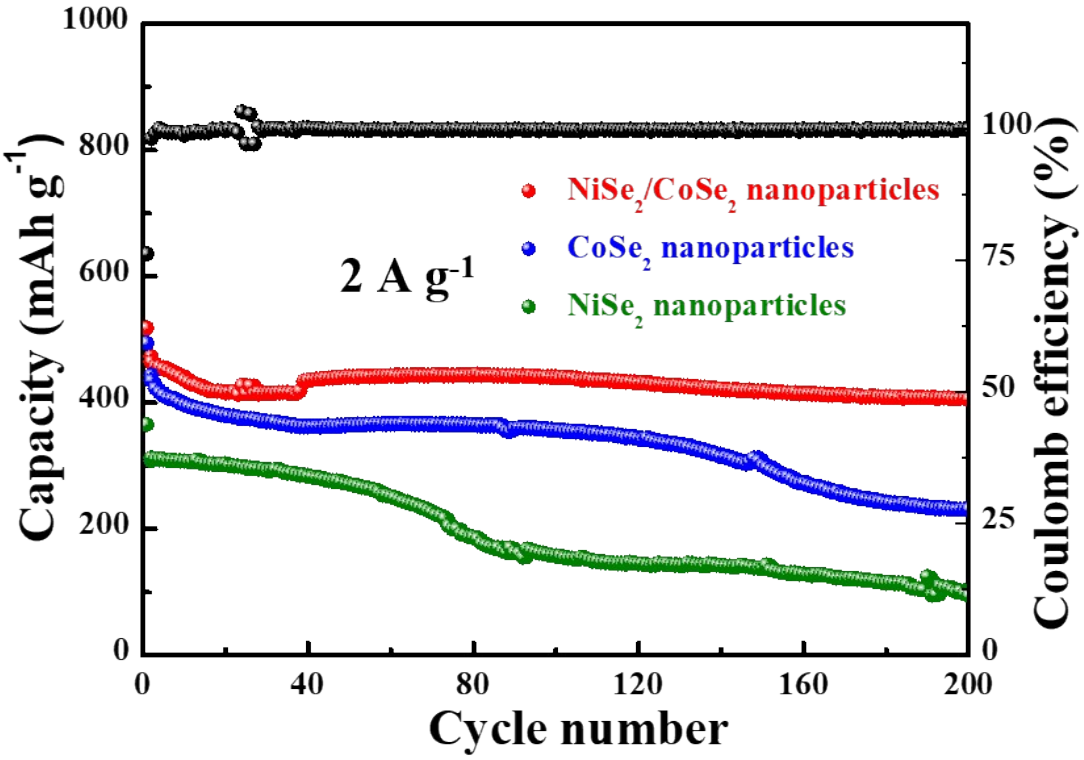

Fig. S14. The cycling performances of $NiSe_2$, $CoSe_2$ and $NiSe_2/CoSe_2$ nanoparticles at 2 A g^{-1}.

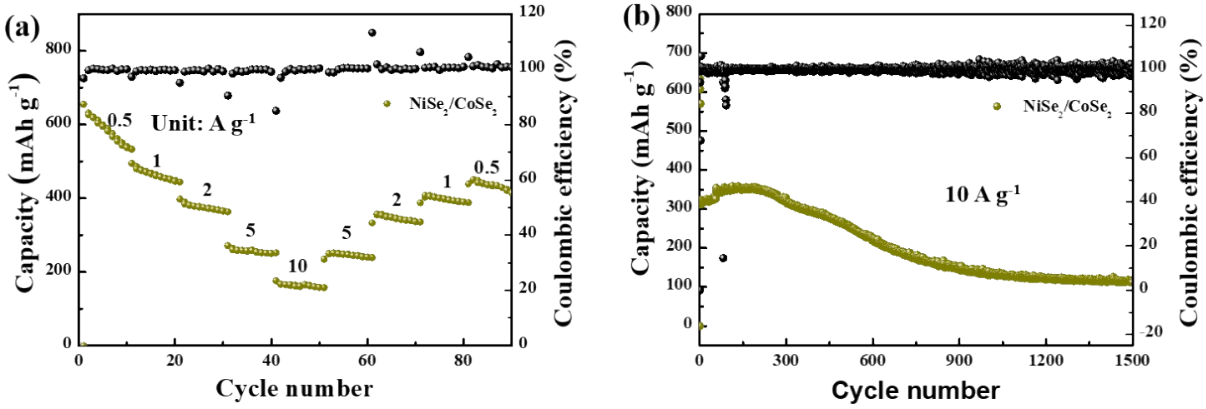

Fig. S15. (a) Rate performance and (b) cycling performance of selenized NiCo precursor without MWCNTs.

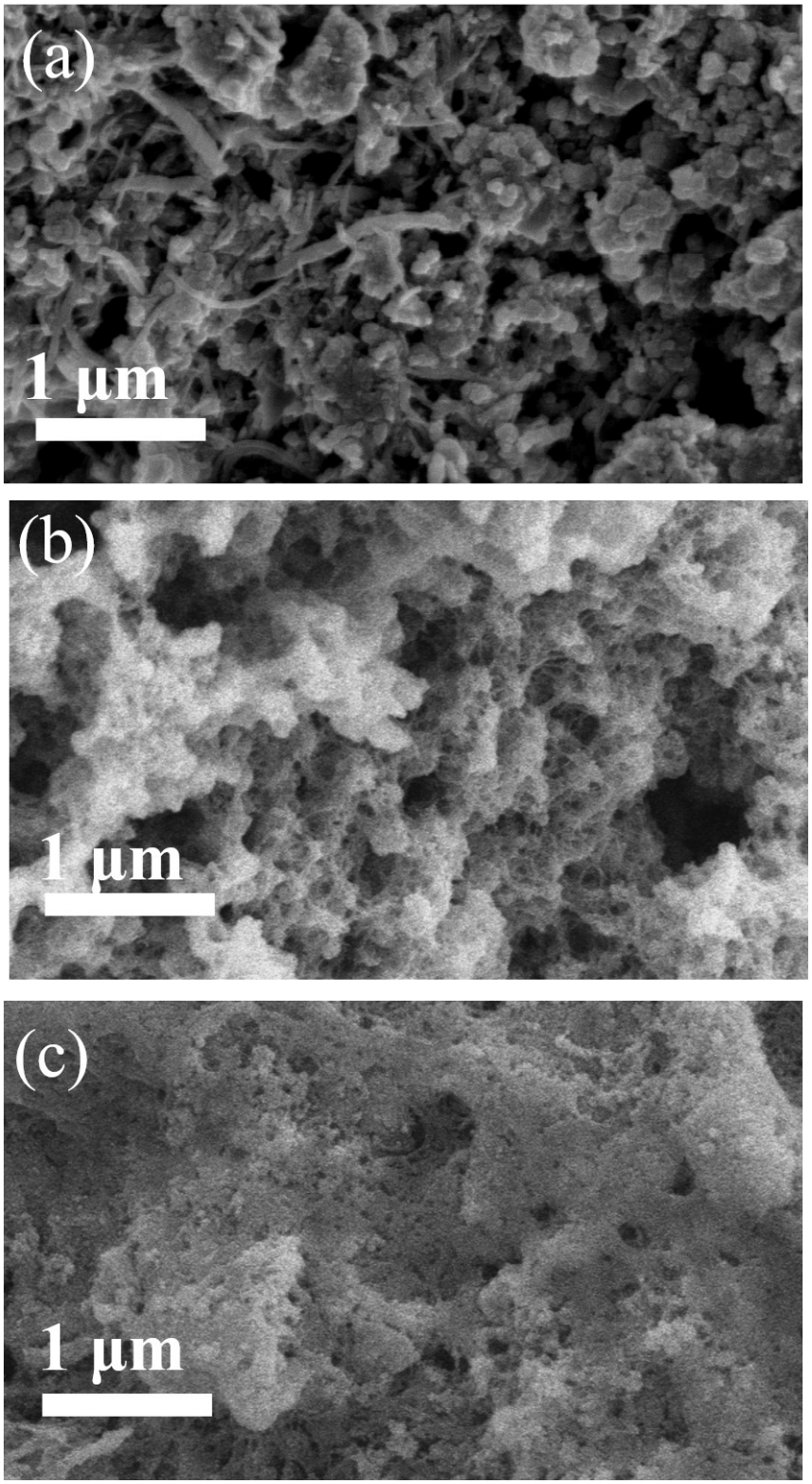

Fig. S16. SEM images of (a) $NiSe_2$; (b) $CoSe_2$ and (c) $NiSe_2/CoSe_2$ nanoparticles after 800 charge/discharge cycles at 10 A g^{-1}.

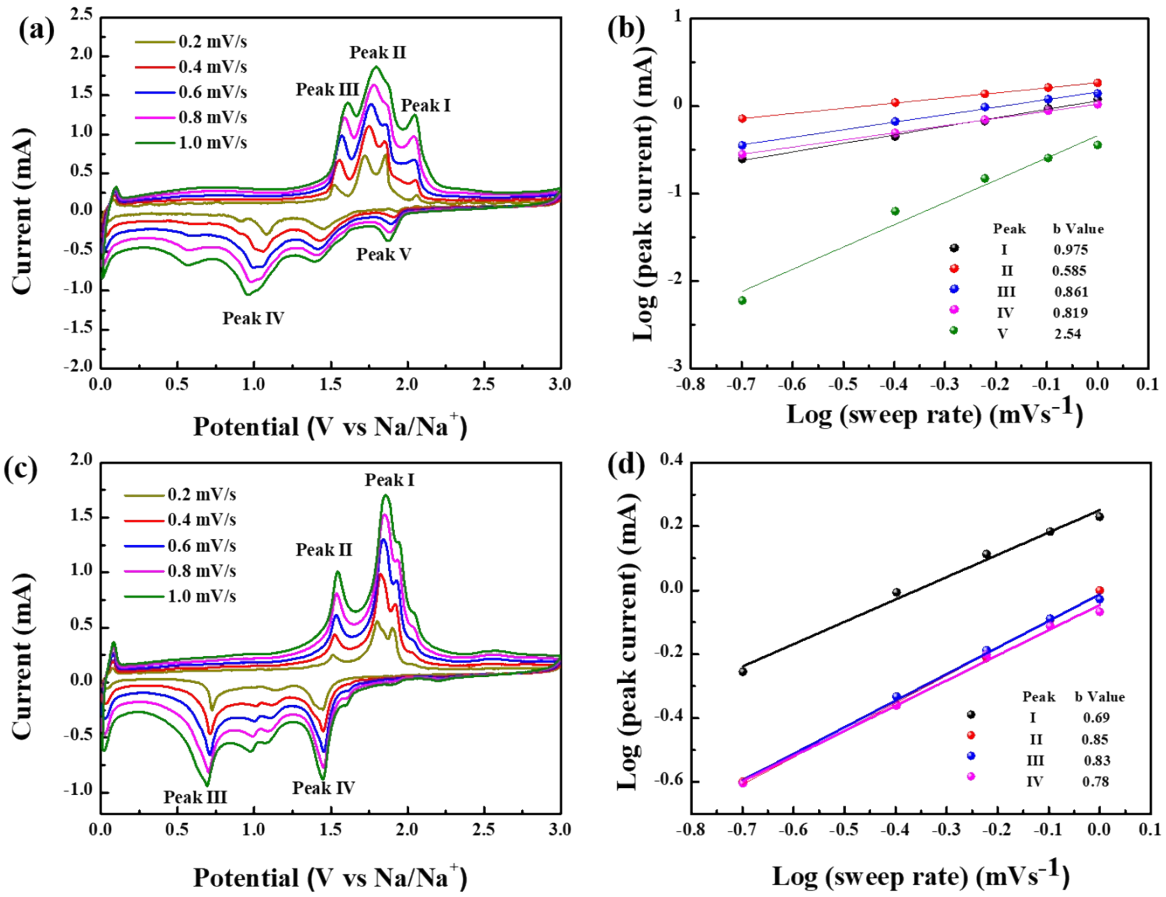

Fig. S17. (a) CV curves of $NiSe_2$ nanoparticles at different scan rates; (b) The b value after fitting at three specific redox peaks for $NiSe_2$ nanoparticles electrode; (c) CV curves of $CoSe_2$ nanoparticles at different scan rates; (d) The b value after fitting at three specific redox peaks for $CoSe_2$ nanoparticles electrode.

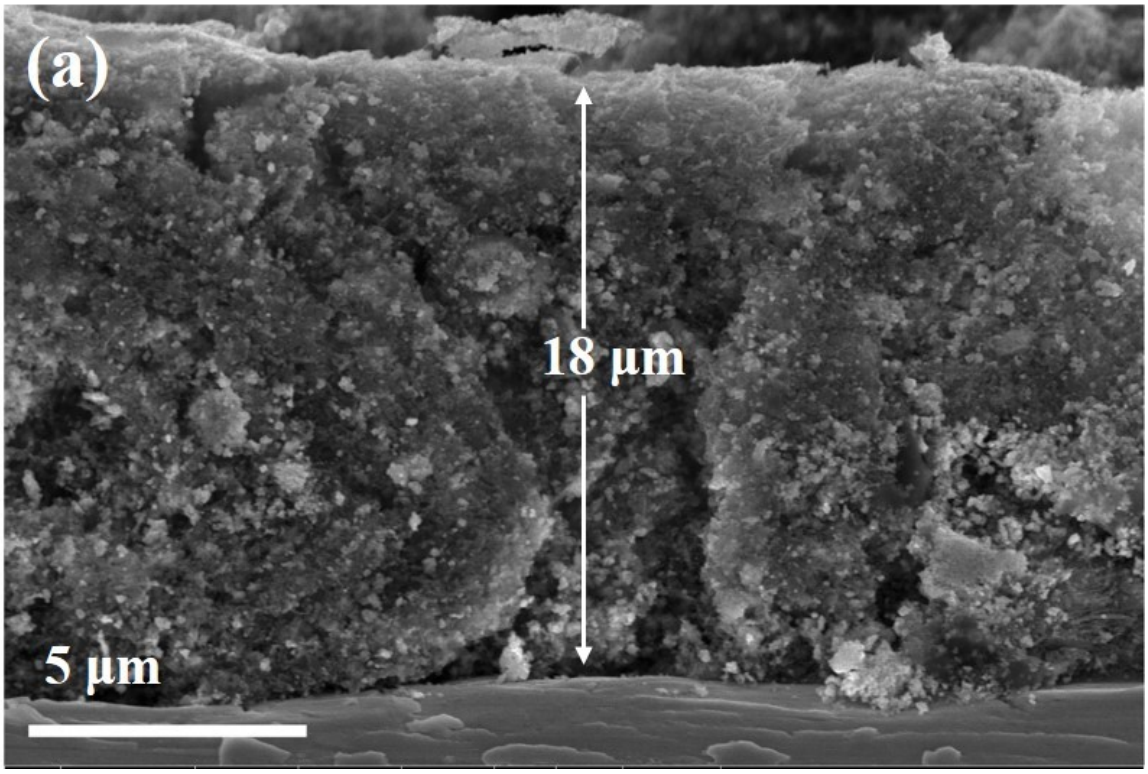

Fig. S18. The thickness of $NiSe_2/CoSe_2$ nanoparticles composite on the copper foil.

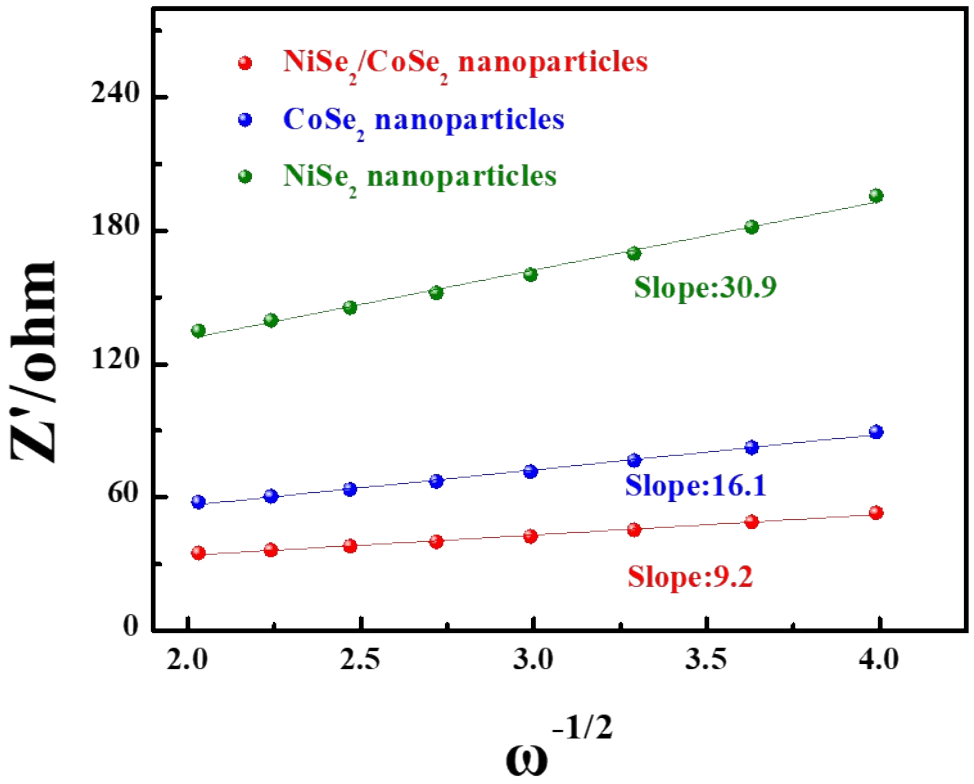

Fig. S19. The fitting lines between Z' and $\omega^{-1/2}$ for three electrodes.

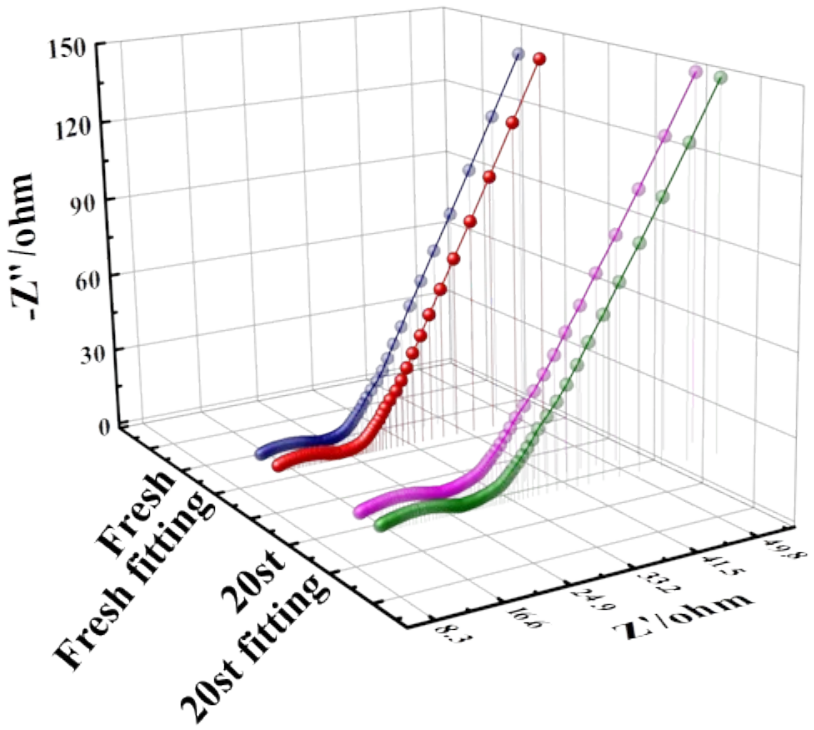

Fig. S20. the fitting EIS curves of $NiSe_2/CoSe_2$ NPs before and after cycling.

Table S1. The atomic ratio of $NiSe_2/CoSe_2$ nanoparticles

Measurements	Atomic ratio
	$NiSe_2/CoSe_2$ nanoparticles
ICP	Ni: Co: Se =1:1:4

Table S2. The cycling performance comparisons of $NiSe_2/CoSe_2$ Nanoparticles with other with previously reported TMSe.

Materials	Current Density ($A\ g^{-1}$)	Specific Capacity ($mA\ h\ g^{-1}$)	Cycle number	Ref.
$CoSe_2$-CNS	10	250	2000	[1]
3DOHP ZnSe@N,C	10	233.1	800	[2]
$NF_{11}S/C$	8	208.8	2000	[3]
$Ni_xCo_{1-x}Se_2$	10	324.5	675	[4]
In_2Se_3-$CoIn_2$-$CoSe_2$	10	205.5	2000	[5]
$NiSe_2/CoSe_2$ nanoparticles	10	296.4	1500	This work

Table S3. Fitting parameters of sodium ion batteries of electrodes at the fresh state

Samples	R_s (Ω)	R_{ct} (Ω)	σ (Ω $cm^2 \cdot s^{-1/2}$)	D_{Na^+} (cm^2 s^{-1})
$NiSe_2$ nanoparticles	17.4	77.2	30.9	1.1×10^{-11}
$CoSe_2$ nanoparticles	14.6	20.1	16.1	4.2×10^{-11}
$NiSe_2/CoSe_2$ nanoparticles	14.1	8.6	9.2	1.3×10^{-10}

The diffusion coefficients of the Na^+ ions (D_{Na^+}) of the three electrodes can be calculated from the following equations:

$$Z' = R_s + R_{ct} + \sigma\,\omega^{-1/2} \qquad (S1)$$

$$D = R^2T^2/2A^2n^4F^4C^2\sigma^2 \qquad (S2)$$

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