Electronic Supplementary Material

2D holey cobalt sulfide nanosheets derived from metal organic frameworks for high-rate sodium ion batteries with superior cyclability

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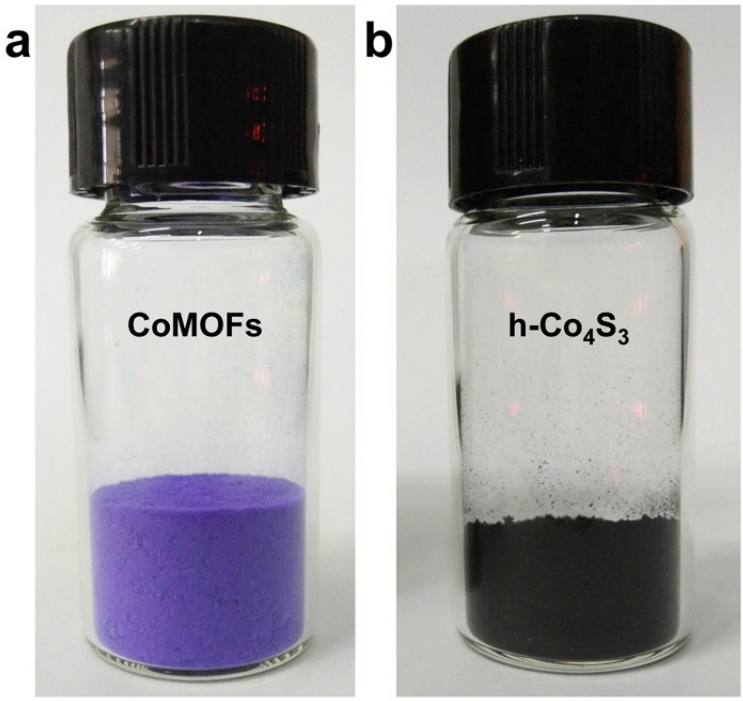

Figure S1. Photos of (a) CoMOFs and (b) h-Co_4S_3 samples.

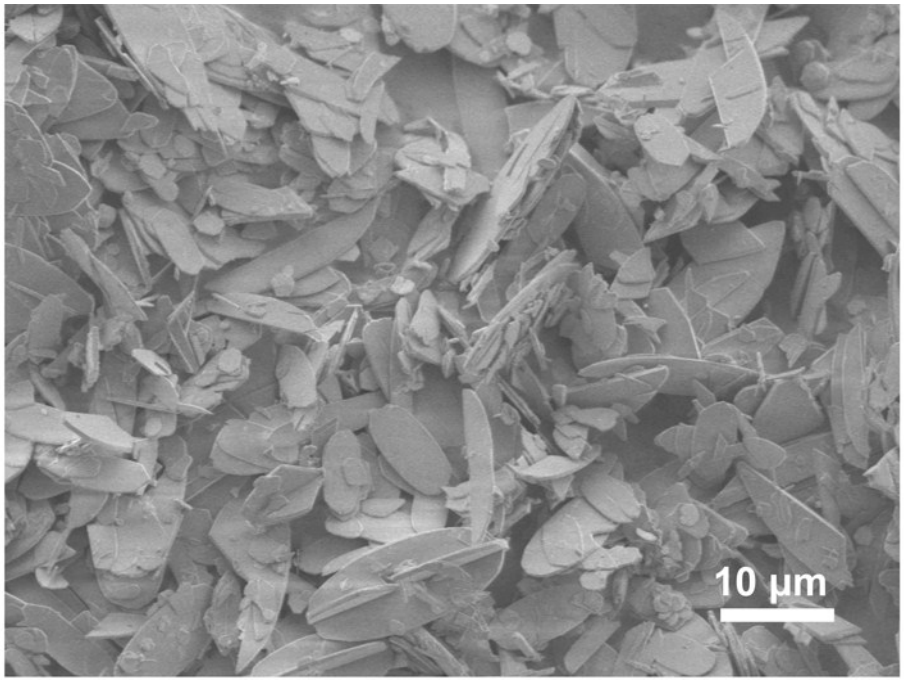

Figure S2. SEM image of CoMOFs.

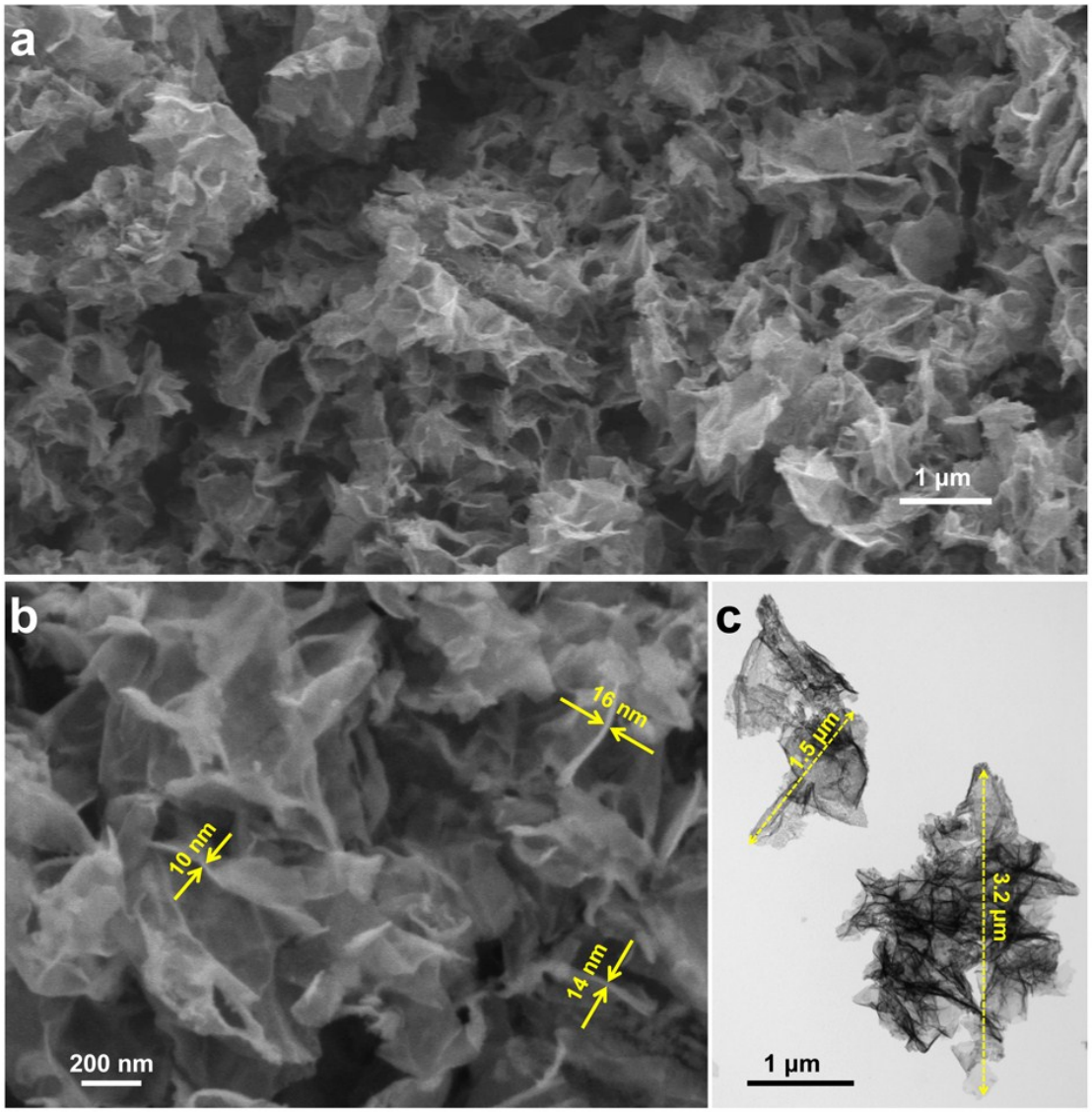

Figure S3. (a) Low-magnification and (b) high-magnification SEM images, and (c) TEM image of CoS_x nanosheets.

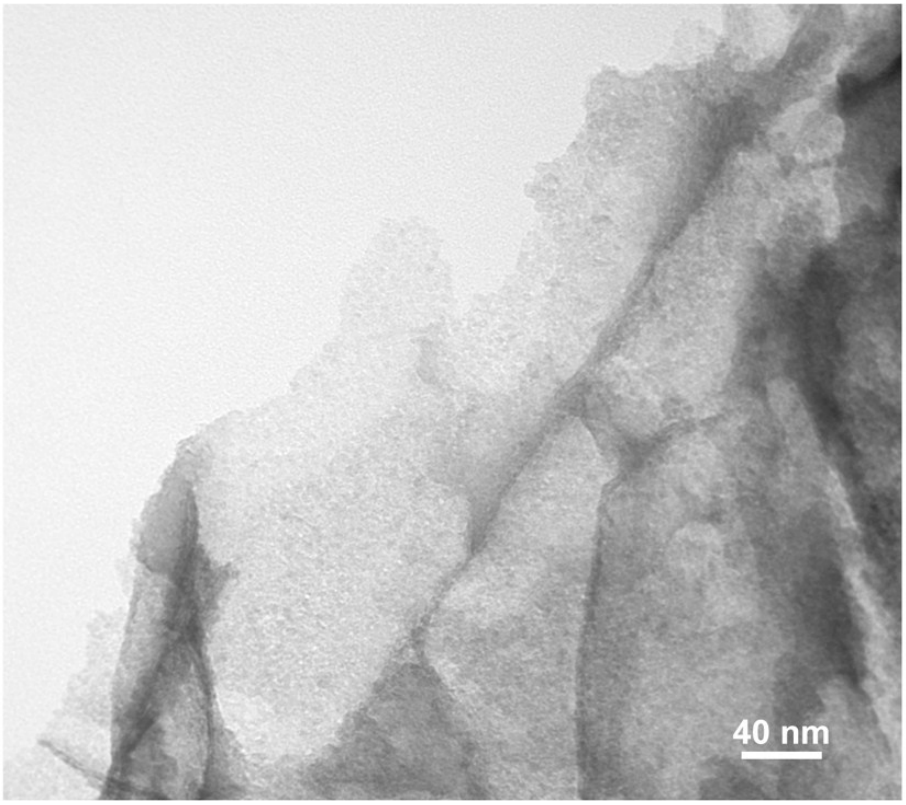

Figure S4. TEM image of CoS_x nanosheets.

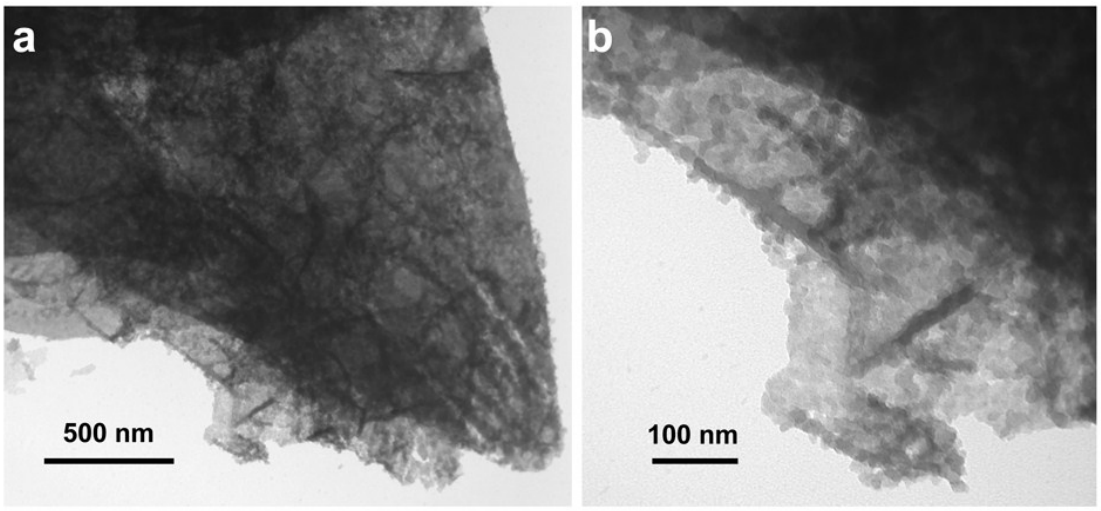

Figure S5. (a) TEM and (b) HRTEM images of the CoS_x products obtained after a sulfuration reaction time of 10 min.

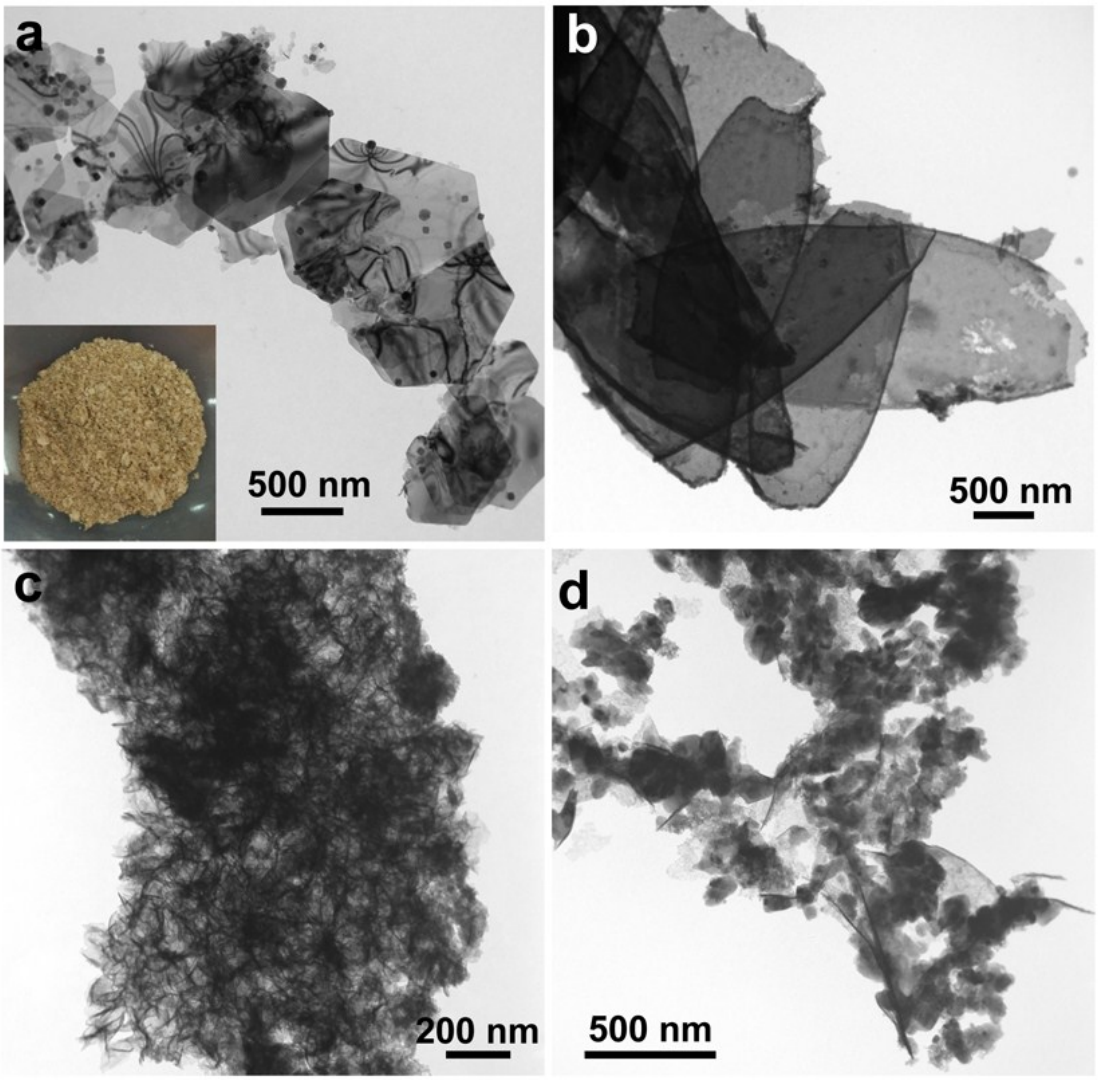

Figure S6. (a) TEM image of $Co(OH)_2$ nanosheets synthesized at 85 ^oC in H_2O without TAA. Inset: the photograph of $Co(OH)_2$ nanosheets. (b,c) TEM images of CoS_x products prepared in alcohol (b) and mixed reaction solution of H_2O (40 mL) and alcohol (140 mL) (c). (d) TEM imge of CoS_x product prepared with the sulfuration reagent of Na_2S. The CoMOFs were unstable at 85 ^oC in H_2O without TAA, and would release the Co^{2+} ions, resulting in the generation of $Co(OH)_2$ nanoplates (Figure S6a). While in alcohol, the growth of CoS_x would surpass the dissolution of the CoMOFs, therefore, the sulfuration reaction between S^{2-} ions from TAA and Co^{2+} ions from CoMOFs occurred at the surface of CoMOFs. With the

processing of the sulfuration reaction, the hollow leaf-like nanostructures were obtained (Figure S6b). It is noted that the kinetics between the dissolution of the CoMOFs and the growth of the CoS_x could be well controlled by employing mixed reaction solution of H_2O and alcohol, and ultra-thin wrinkle CoS_x nanosheets were prepared (Figure S6c). While Na_2S was used as sulfuration agent instead of TAA, the rate of the CoS_x growth would be too fast due to the excessed release of S^{2-} ions, thereby the product displayed the existence of particles on nanosheets (Figure S6d).

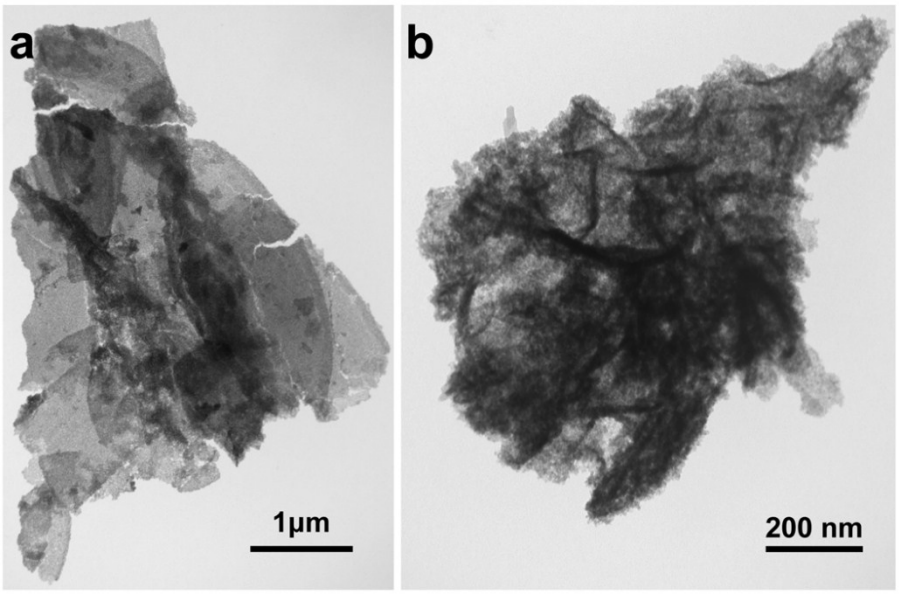

Figure S7. TEM images of (a) Zn MOFs derived product and (b) ZnCo MOFs derived product synthesized under the same procedures with CoS_x nanosheets except for the use of ZnMOFs and ZnCoMOFs precursors, indicating the unqiue roles of CoMOFs precursor in forming large-area CoS_x nanosheets

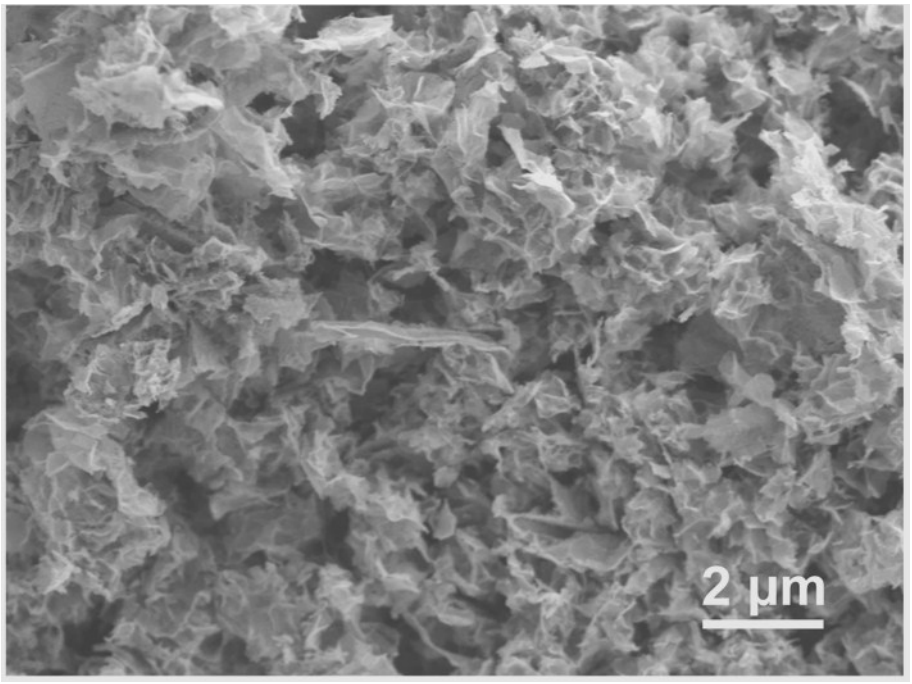

Figure S8. Low-magnification SEM image of h-Co_4S_3 nanosheets.

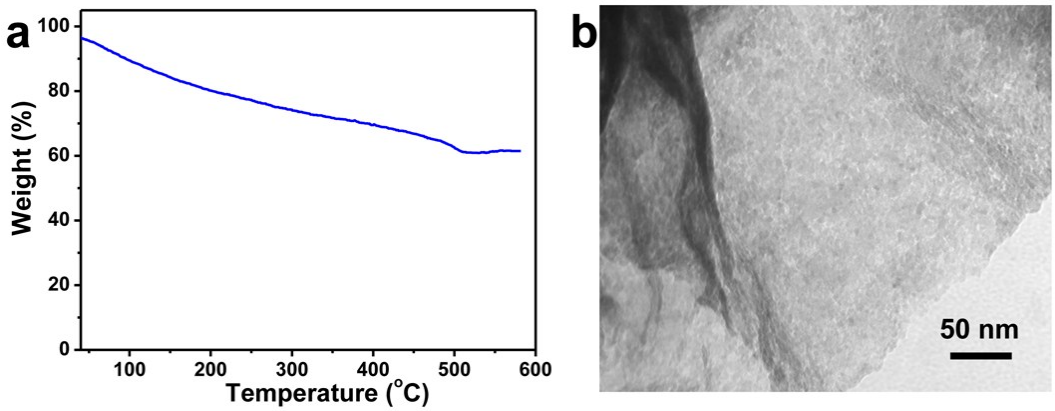

Figure S9. (a) Thermogravimetric analysis of CoS_x nanosheets conducted in nitrogen atmosphere. (b) TEM image of the sample (detonated as CoS_x-350 °C) synthesized by annealing treatment of CoS_x nanosheets at lower temperature of 350 °C in nitrogen atmosphere.

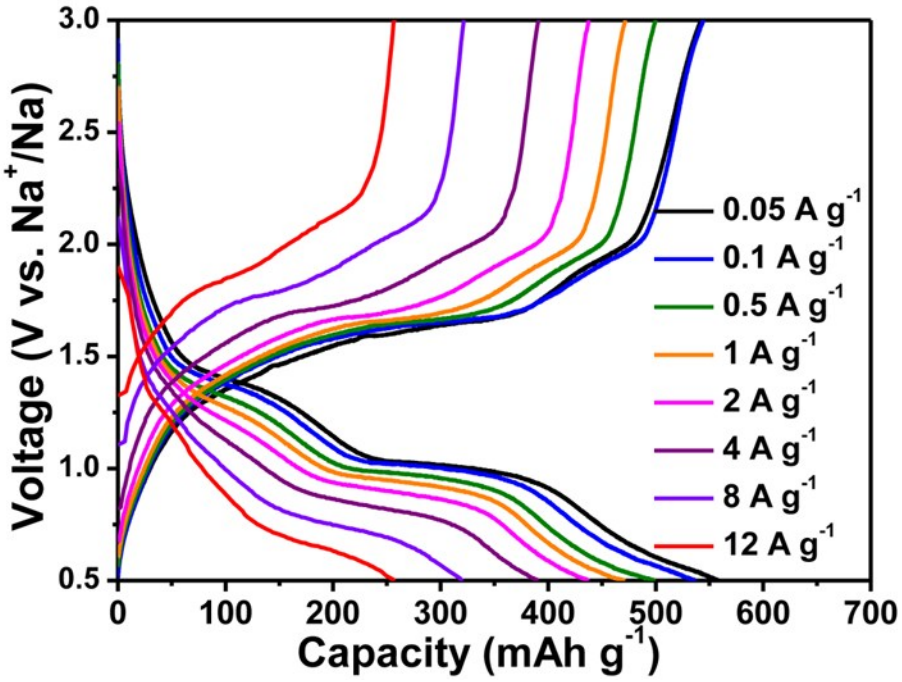

Figure S10. Galvanostatic charge and discharge profiles of h-Co_4S_3 anode cycled at different current densities from 0.05 to 12 A g^{-1}.

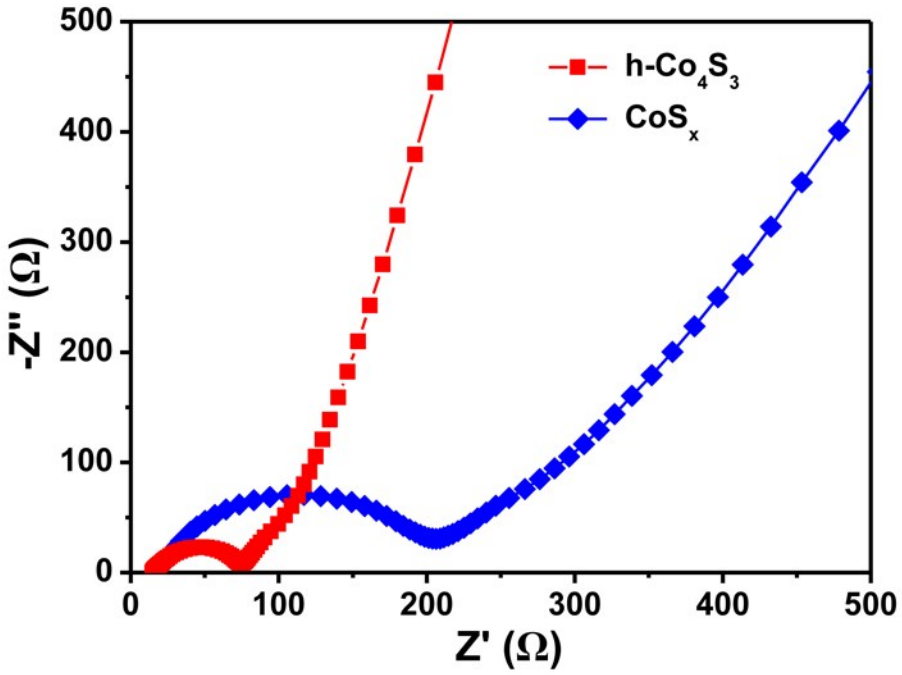

Figure S11. Electrochemical impedance spectroscopies of h-Co_4S_3 and CoS_x electrodes.

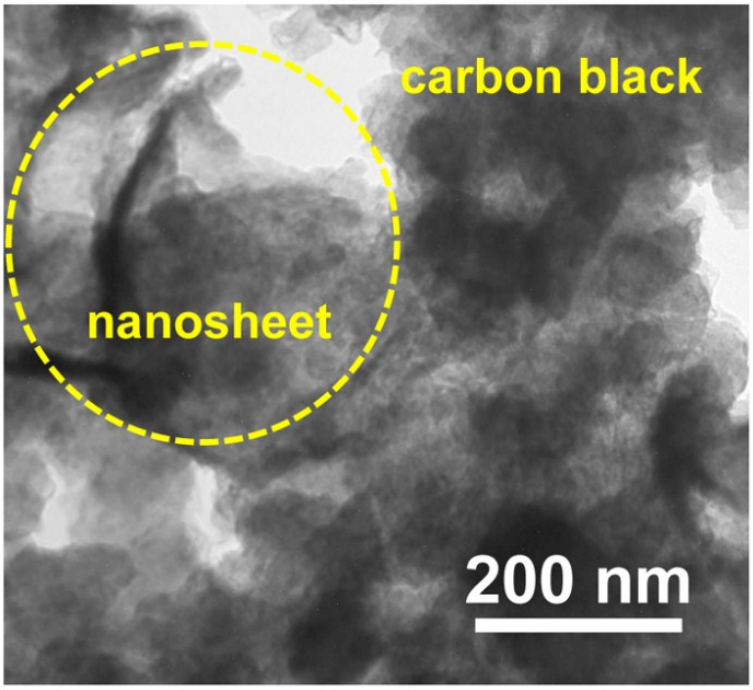

Figure S12. TEM image of cycled h-Co_4S_3, showing the nanosheets marked in the yellow circle were well kept without pulverization.

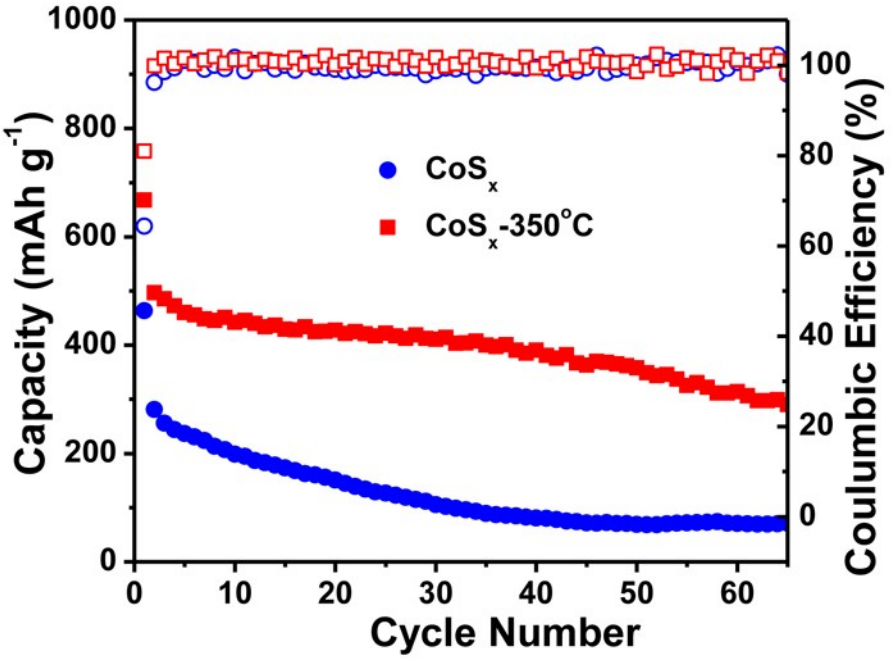

Figure S13. Cycling performance of CoS_x and CoS_x-350 °C electrodes in DGM-based electrolyte tested at 0.1 A g^{-1}.

Table S1 Comparison of the lateral size and thickness of MOFs derived nanosheets in this work and other reported Co based nanosheets

Materials	Preparation method	Lateral size (nm)	Thickness (nm)	Reference
CoS_x nanosheet	sulfuration of CoMOFs with TAA	micrometer scale(~1000-3000)	<16	**This work**
h-Co_4S_3 nanosheet	annealing treatment	micrometer scale(~1000-3000)	<30	**This work**
CoS nanosheet	sulfuration of $Co(OH)_2$ with Na_2S	<200	<25	Ref.[1]
CoS_x nanosheet	electrodeposition	<50	<20	Ref.[2]
nickel cobalt sulfide nanosheet	electrodeposition	<200	<25	Ref.[3]
$NiCo_2S_4$ nanosheets	sulfuration of NiCo-precursor with Na_2S	<500	<50	Ref.[4]
NiCo-layered double hydroxides	etching of ZIF67 with $Ni(NO_3)_2$	<300	<50	Ref.[5]
$Co(OH)_2$ flower-like nanosheets	hydrothermal treatment of MOF	~1000	<30	Ref.[6]
CoNi hydroxide nanosheets	in situ decomposition of Co-based acetate hydroxide MOFs	<100	<3	Ref.[7]
porous Co_3O_4 nanosheets	pyrolysis process of Co-based MOF nanoplates in air	micrometer scale	~30	Ref.[8]
holey Co_3O_4 nanosheets	GO templated synthesis	micrometer scale	~30	Ref.[9]

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