Supporting Information

Macroscale Preparation of CoS_2 Nanoparticles for Ultra-High Fast-Charging Performance in Sodium-Ion Batteries

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Experimental

Synthesis of materials

CoS_2 was prepared by the co-precipitation method by first adding 2 mol of $CoSO_4$ (SCR) to 500 mL of water (solution A) while 16 mol of $C_2H_2O_4$ (Innochem 99.5%) was dissolved in 500 mL of anhydrous ethanol (SCR) (solution B). Solution A was then injected into solution B at a titration rate of 200 mL·min⁻¹. When the titration was completed, the pink slurry product obtained was immediately centrifuged and washed three times each with water and ethanol, and then the product was dried, with the temperature conditions set at 100 °C for 12 h. The CoC_2O_4 was then dried in a tube furnace. After drying, the sample was calcined in a tube furnace to obtain the Co_3O_4, and its calcination conditions were set at 350 °C for 2 hours. Finally, the precursor cooled to room temperature was injected with single sulfur powder, the mass ratio of sulfur powder (Innochem 99.95%) to precursor was 4:1, and CoS_2 was obtained by

sulfuring the sample with a tube furnace at 500 °C for 2 h under nitrogen atmosphere. The formation process is shown schematically in Fig. S1. For comparison, the preparation method of commercial CoS_2 was prepared using a similar method.

Material characterization

SEM (TESCAN MIRA LMS Scanning Electron Microscope) to observe the morphology of materials, TF20 Transmission Electron Microscope (TEM) to observe the fine morphology, X-ray diffraction pattern (XRD) (Japan SmartLab-SEX) with Cu Kα radiation to analyse the content of the internal physical phases and the crystalline condition, X-ray photoelectron spectroscopy (XPS) test to analyse the chemical composition of the samples, and the molecular structure of the materials are analysed accurately and non-destructively using Raman Spectroscopic Instruments.

Electrochemical performance tests

In the slurry composition, the mass ratio of the active substance was 70%, and the remaining superconducting carbon black (MJS) and binder (CMC, MJS) were 20% and 10%, respectively, then the coated copper foil was dried in vacuum ovens at 80 °C for 12 h. The slurry was then coated onto copper foil using a doctor blade and then dried under vacuum to form the working electrode (thickness of 10 μm), and mass loading of active material was 1.2 mg·cm^{-2}. And the composite electrodes were not compressed. Coin cells (CR2032) were assembled with a sodium foil counter and reference electrode, a polypropylene membrane (GLASS MICROFIBER FILTERS) separator. The electrolyte (MJS) was 1 mol/L $NaPF_6$ in a mixture of DEG/DME (v/v=1:1). the coated copper foil was cut into a 12 mm diameter electrode disks. Coin cell was

assembled in a glovebox with ultra-argon ($H_2O < 0.01$ ppm, $O_2 < 0.01$ ppm). The electrochemical reaction kinetics of the obtained electrode was studied by cyclic voltammetry (CV). The scanning rate was 0.1 mV·s^{-1}, within the potential range of 0.01 to 2.8 V. In addition, the galvanostatic charge/discharge measurements were tested at room temperature between 0.01 and 2.8 V on LAND CT2010. AC impedance testing (EIS) determined on electrochemical workstation (IviumStat), electrochemical workstation in the frequency range from 0.1Hz to 10 kHz and amplitude was 0.005 V. The Galvanostatic Intermittent Titration Technique (GITT) was used to analyze the diffusion of Na$^+$ on the electrode.
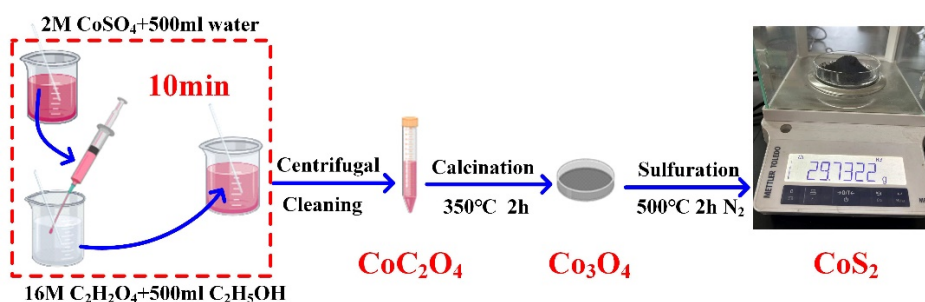

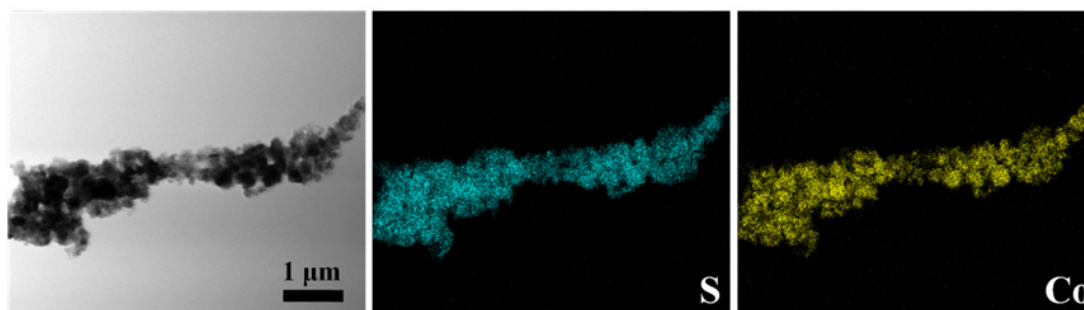**Fig. S1** Schematic illustration of the formation of CoS$_2$.

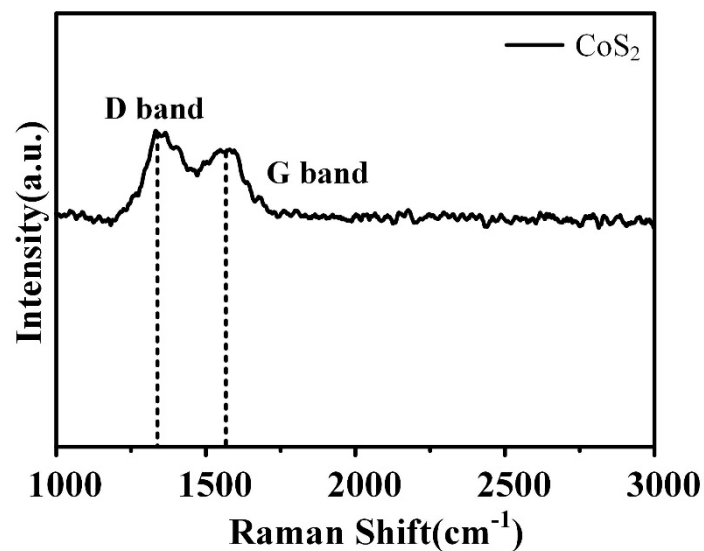**Fig. S2** EDX element distribution maps of Co (yellow) and S (blue).
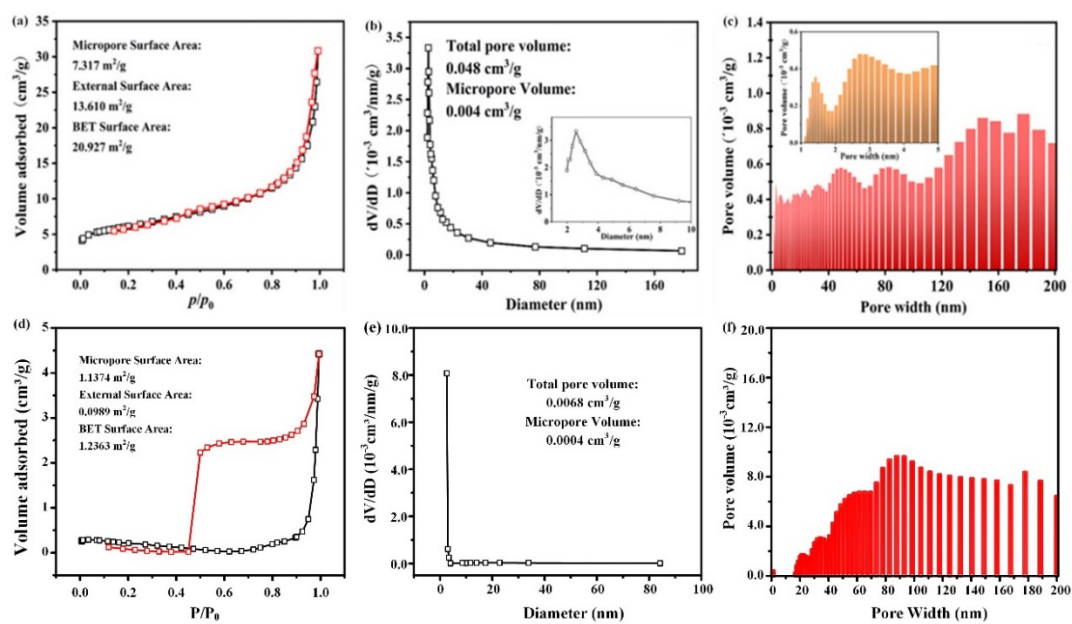
Fig. S3 Raman spectra of CoS_2

Fig. S4 (a) N_2 desorption/adsorption isotherm of CoS_2 and (b), (c) their pore size;

(d) N_2 desorption/adsorption isotherm of commercial CoS_2 and (e), (f) their pore size.

Table S1 Comparison of Sodium Storage Properties of anode materials.

Electrode materials	Preparation method /yield	Current density	Cyclability(mAh·g^{-1})	Electrode materials
CoS$_2$ nanoparticles	co-precipitation	0.1A·g^{-1}	970 (150th cycles)	**This work**
		1A·g^{-1}	760 (400th cycles)	
		5A·g^{-1}	685.5 (400th cycles)	
N–C/CoS$_2$	one-pot solvothermal	1A·g^{-1}	704 (400th cycles)	[S1]
CoS$_2$/C/C	solvothermal	0.1A·g^{-1}	712 (100th cycles)	[S2]
CoS$_2$/C	solution precipitation	0.1A·g^{-1}	510 (100th cycles)	[S3]
Co$_9$S$_8$-HB	solvothermal	0.5A·g^{-1}	550 (100th cycles)	[S4]
CoS$_2$@MCNFs	solvothermal	1A·g^{-1}	620 (900th cycles)	[S5]
NiS$_2$@CoS$_2$@C@C	co-precipitation	1A·g^{-1}	600 (250th cycles)	[S6]
CoO/Co$_3$S$_4$@N-C-36	one-pot solvothermal	0.1A·g^{-1}	577.3 (60th cycles)	[S7]
CoS$_2$/rGO	solvothermal	1A·g^{-1}	192(1000th cycles)	[S8]
f-Ti$_3$C$_2$/CoS$_2$@NPC		2A·g^{-1}	200.6(1500th cycles)	[S9]
CoS$_2$/NGC-1:30		1A·g^{-1}	341(1000th cycles)	[S10]
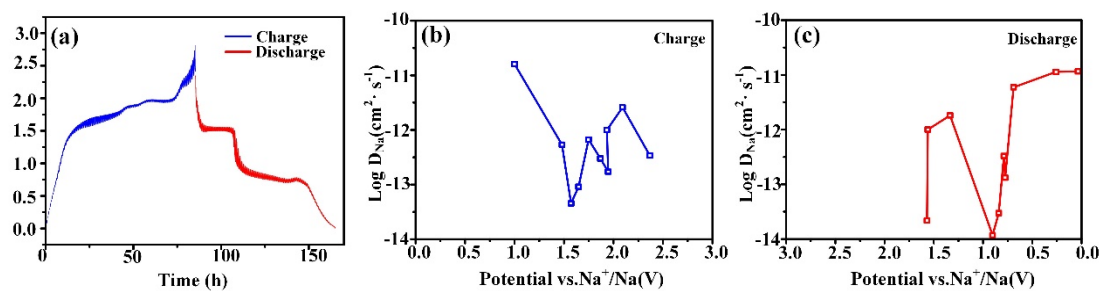
Fig. S5 GITT test curve of commercial CoS$_2$ (a), LogD$_{Na}$ values during charging (b) and discharging (c).
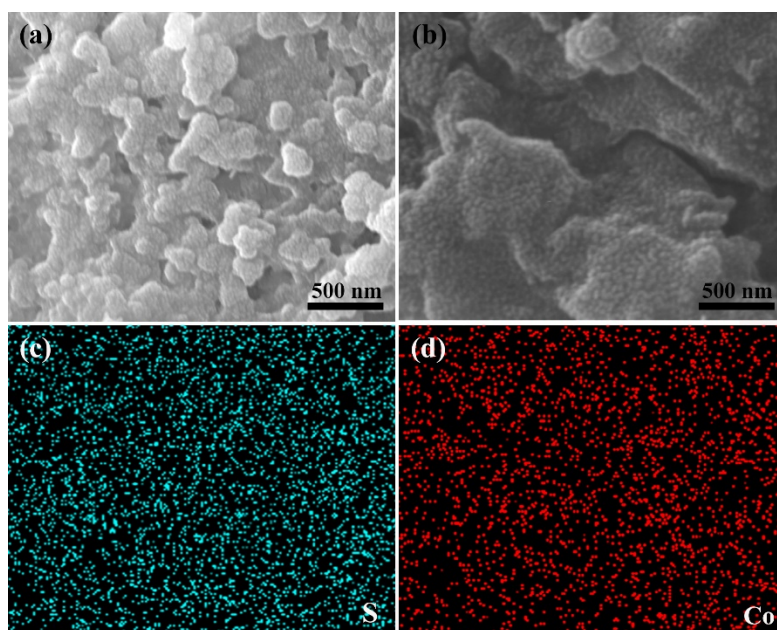
Fig. S6 (a) SEM images of the CoS$_2$ after 30 cycles at 0.1 A·g^{-1}. (b, c, d) EDX element distribution maps of S (blue) and Co (red).

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