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Support information

Cobalt doped JUC-160 Derived Functional Carbon Superstructures with Synergetic Catalyst Effect for Li-SeS₂ Batteries

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Keywords: Cobalt-doped, ZIF, Self-assembled, Crystal-shape engineering, Li-SeS₂

Table S1. List of abbreviations	
ZIF	Zeolitic imidazolate frame-work (ZIF), a subfamily of metal organic framework (MOF) generated from an assembly of transition metal ions (i.e., Zn(II), Co(II)) and N-rich imidazolate linkers
JUC-160	A ZIF material with zinc ion as the central ion
CJ-n	Cobalt doped ZIF prepared by adding $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ in the synthesis of JUC-160, and based on the addition amount of $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ (0.03,0.05 and 0.07g), the cobalt doped JUC-160 is named as CJ-n (n=0.03,0.05 and 0.07)
PCJ-m	Cobalt doped JUC-160 was prepared by mixing 0.06g $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ and a certain amount of JUC-160, and based on the addition amount of JUC-160 (0.5,0.8 and 1.1 g), the cobalt doped JUC-160 is named as PCJ-m (m=0.5,0.8 and 1.1)
CNC-n	The carbonization products of CJ-n
PCNC-m	The carbonization products of PCJ-m
CNC-n/ SeS_2	Selenium sulfide-impregnated CNC-n
PCNC-m/ SeS_2	Selenium sulfide-impregnated PCNC-m

In order to better show the relationship between MOF, JUC-160, mixed linker ZIF and Zn-based ZIF, the following figure is drawn with the concept of aggregate in mathematics.

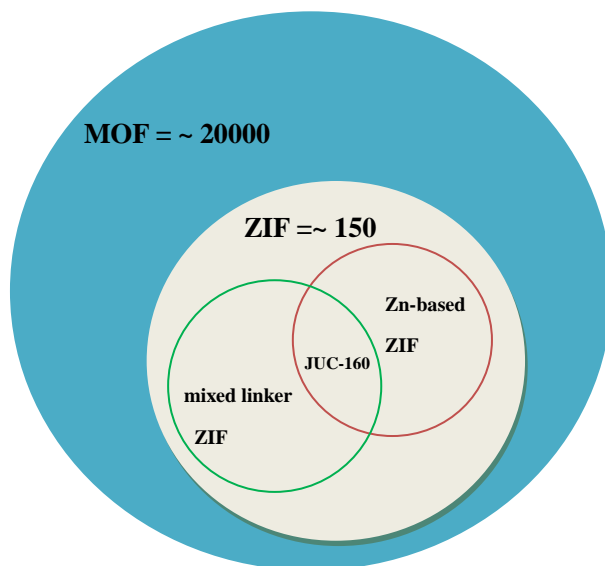


Fig.S1. the relationship between MOF, JUC-160, mixed linker ZIF and Zn-based ZIF.

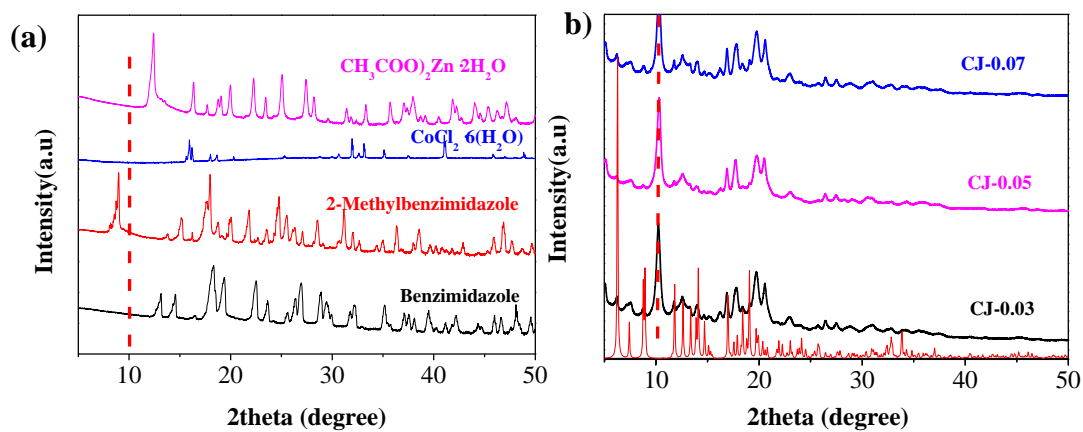


Fig.S2.(a)The chemical used in the experiment and its XRD characteristic peak; (b) X-ray diffraction (XRD) patterns of calculated the JUC-160 and CJ-n.

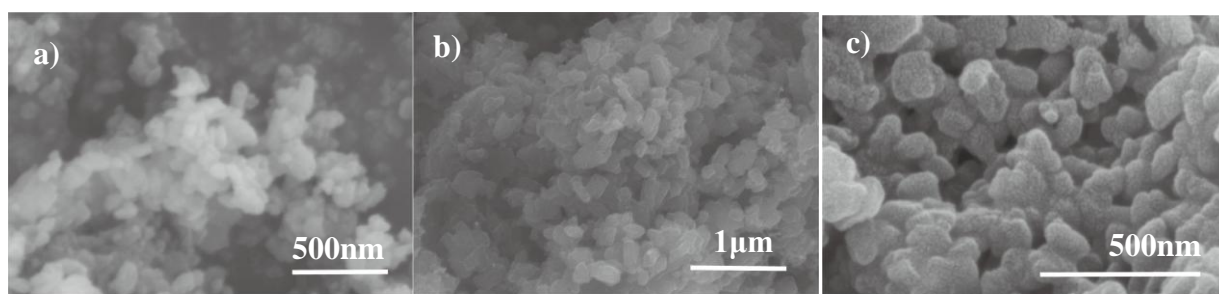


Fig.S3. JUC-160 (a) and their derived carbon materials (b,c).

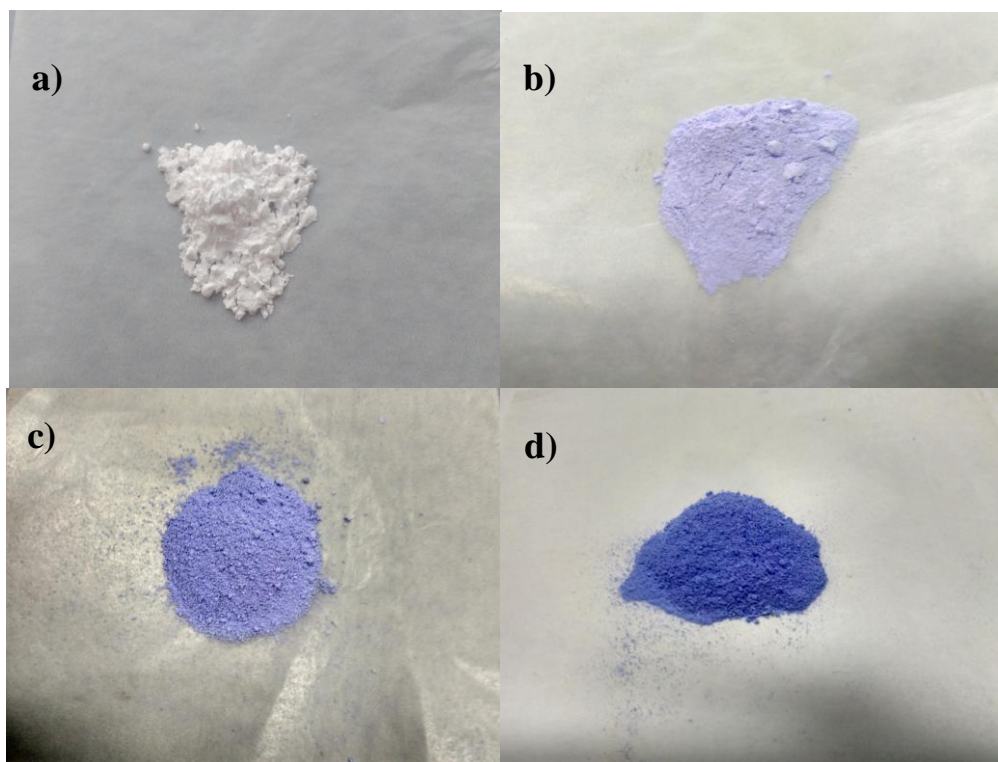


Fig.S4. The photographs of (a) JUC-160, (b) CJ-0.03, (c) CJ-0.05 and (d) CJ-0.07.

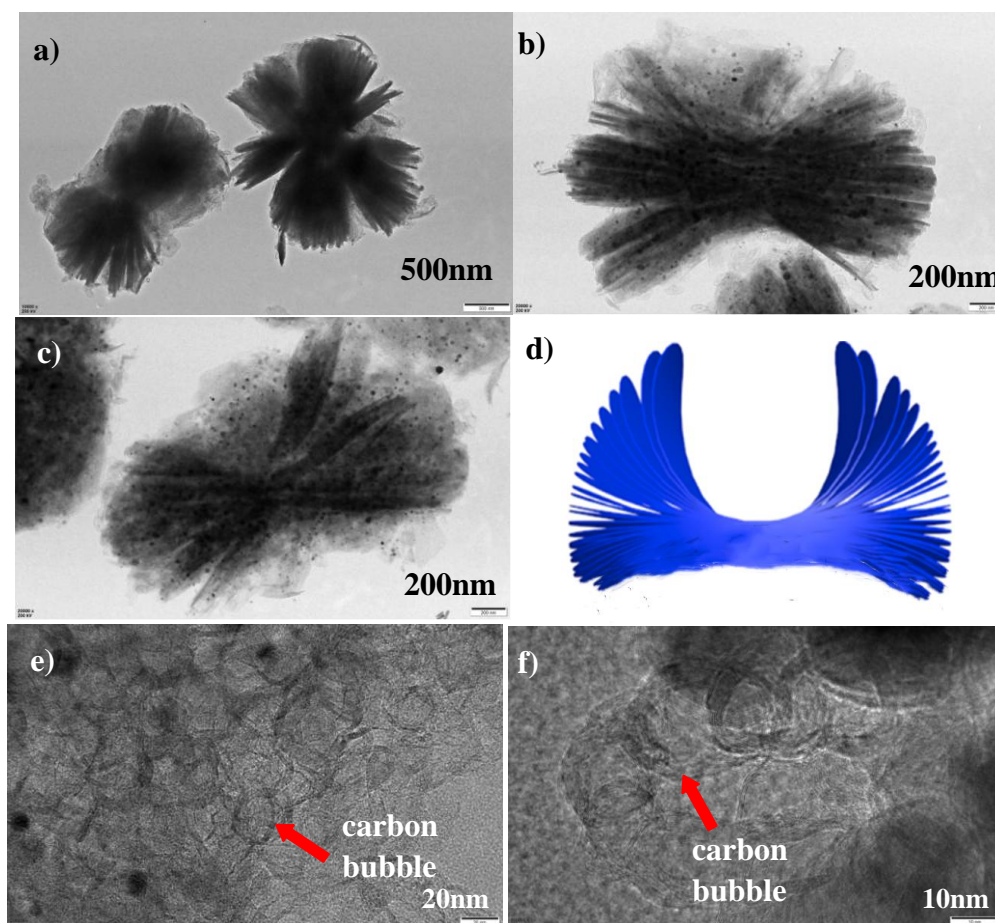


Fig.S5. TEM images of the CNC-0.05 (a-c) and the open-book-like model (d); The hollow carbon bubble structures of CNC-0.05(e-f).

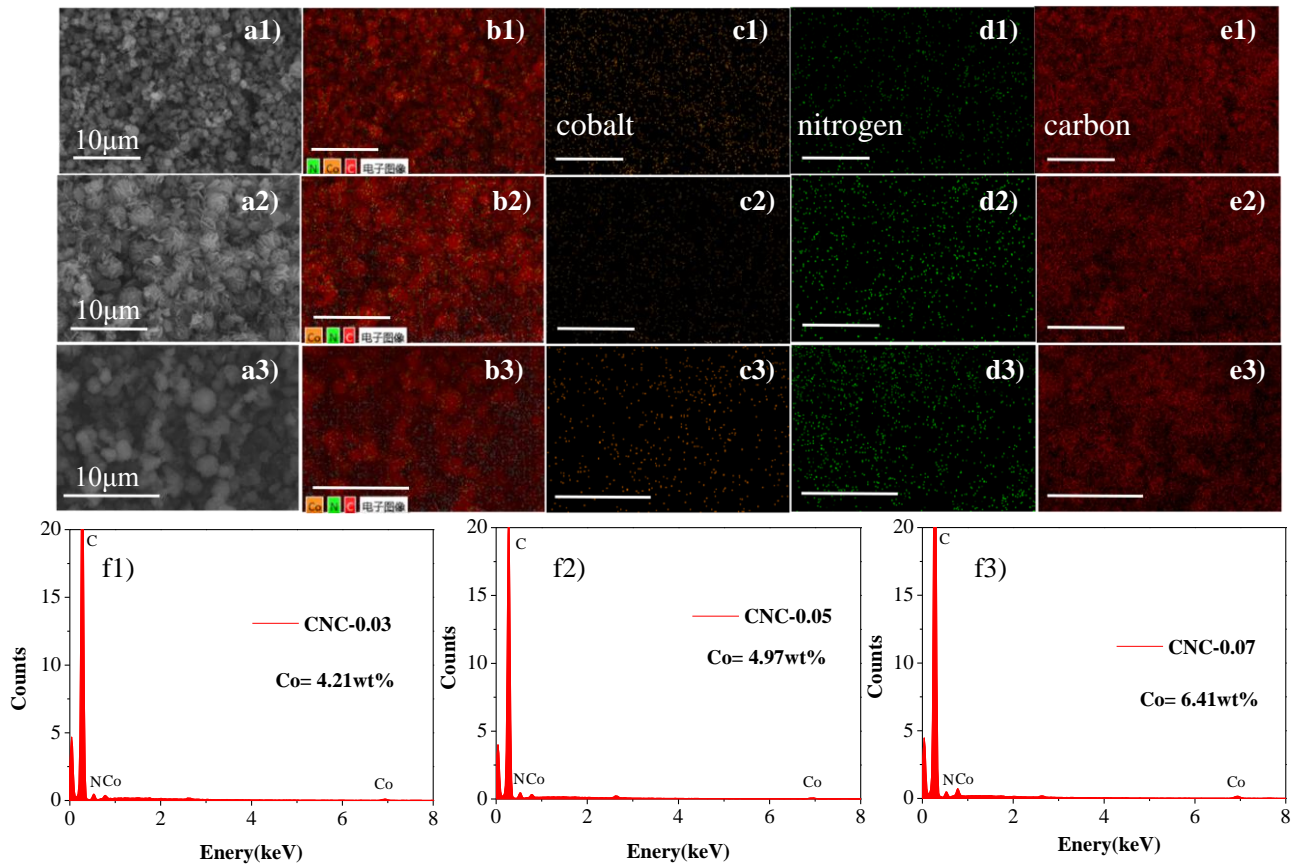


Fig.S6. SEM image of (a1~a3) CNC-n and the corresponding EDS elemental maps for cobalt(c1~c3), nitrogen (d1~d3), carbon(e1~e3) and all elements combined (b1~b3). The scale bar is 10 μ m; elemental spectrum(f1~f3).

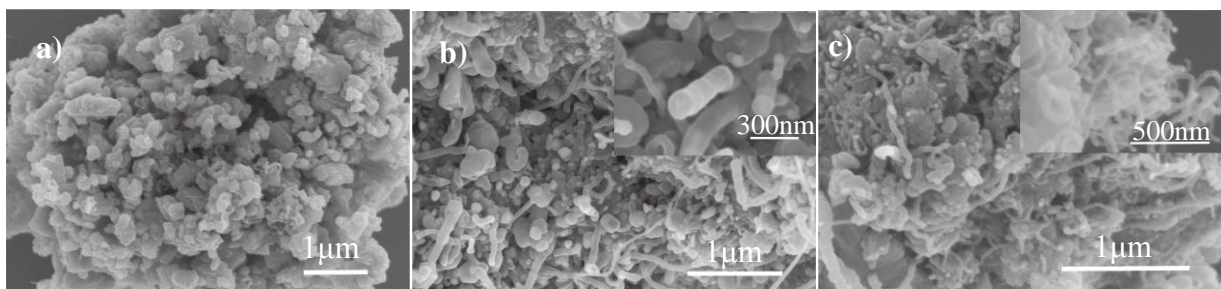


Fig.S7. SEM image of (a) PCNC-1.1, (b) PCNC-0.8 and (c) PCNC-0.5.

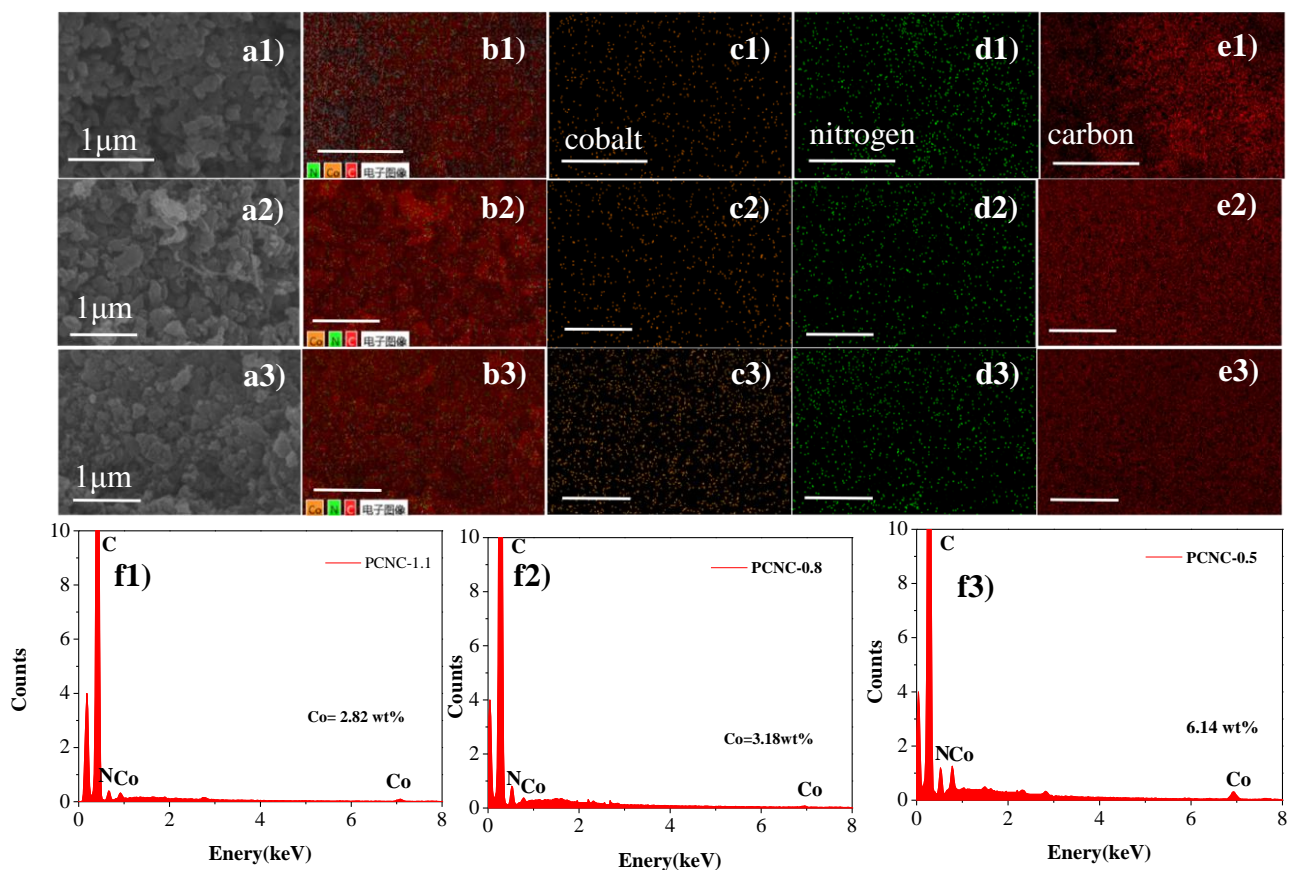


Fig.S8. SEM image of (a1~a3) PCNC-m and the corresponding EDS elemental maps for cobalt(c1~c3), nitrogen (d1~d3), carbon(e1~e3) and all elements combined (b1~b3). The scale bar is 1 μ m; elemental spectrum(f1~f3).

Table S2, Synthesis conditions of CJ-n

CJ-n	Derived carbon	Benzimidazole (g)	2-methylbenzimidazole (g)	Zn(Ac) ₂ ·2H ₂ O (g)	CoCl ₂ ·6H ₂ O (g)
CJ-0.03	CNC-0.03	0.29539	0.26432	0.49394	0.03399
CJ-0.05	CNC-0.05	0.29541	0.26439	0.49357	0.05558
CJ-0.07	CNC-0.07	0.29543	0.26435	0.494071	0.07131

Table S3, Synthesis conditions of PCJ-m

PCJ-(JUC-160(g)/ CoCl ₂ .6H ₂ O=0.06g)	Derived carbon	JUC-160 (g)	CoCl ₂ .6H ₂ O (g)	ethanol (ml)
PCJ-0.5	PCNC-0.5	0.50722	0.06973	40ml
PCJ-0.8	PCNC-0.8	0.82162	0.06979	40ml
PCJ-1.1	PCNC-1.1	1.182	0.06970	40ml

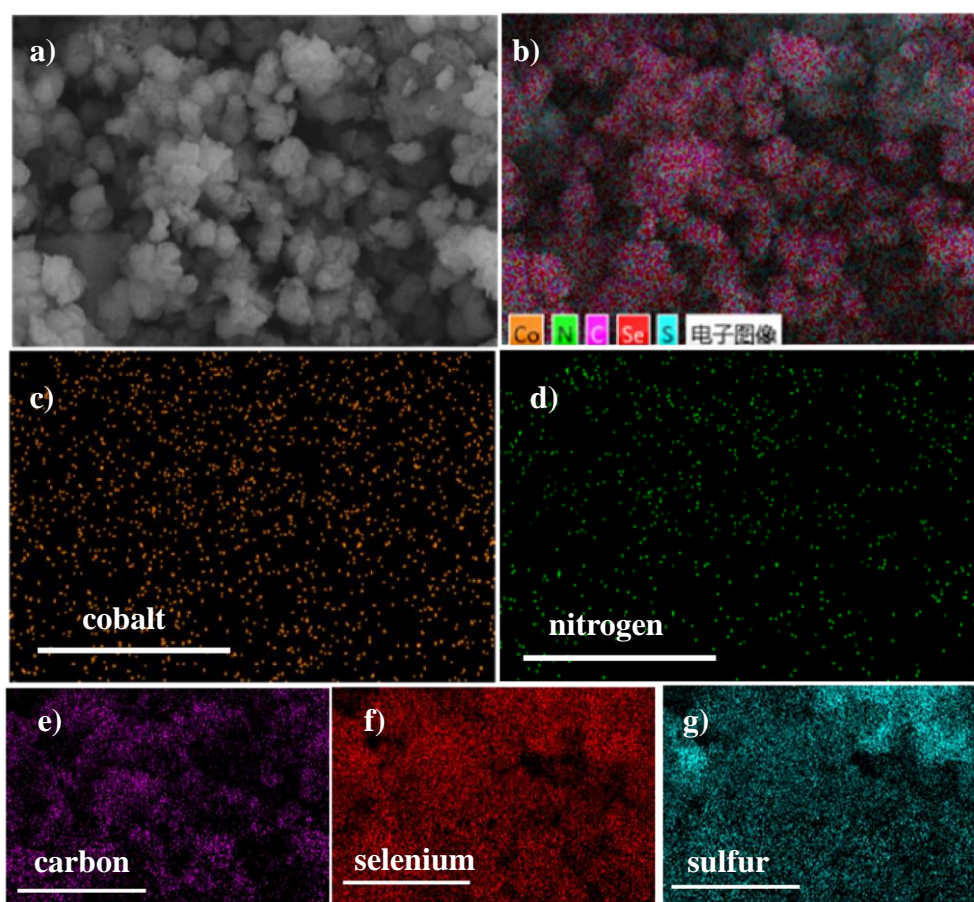


Fig. S9 . SEM image of (a) CNC-0.05/SeS₂ and the corresponding EDS elemental maps for cobalt(c), nitrogen (d), carbon (e), selenium (f) , sulfur (f) and all elements combined (b). The scale bar is 10μm.

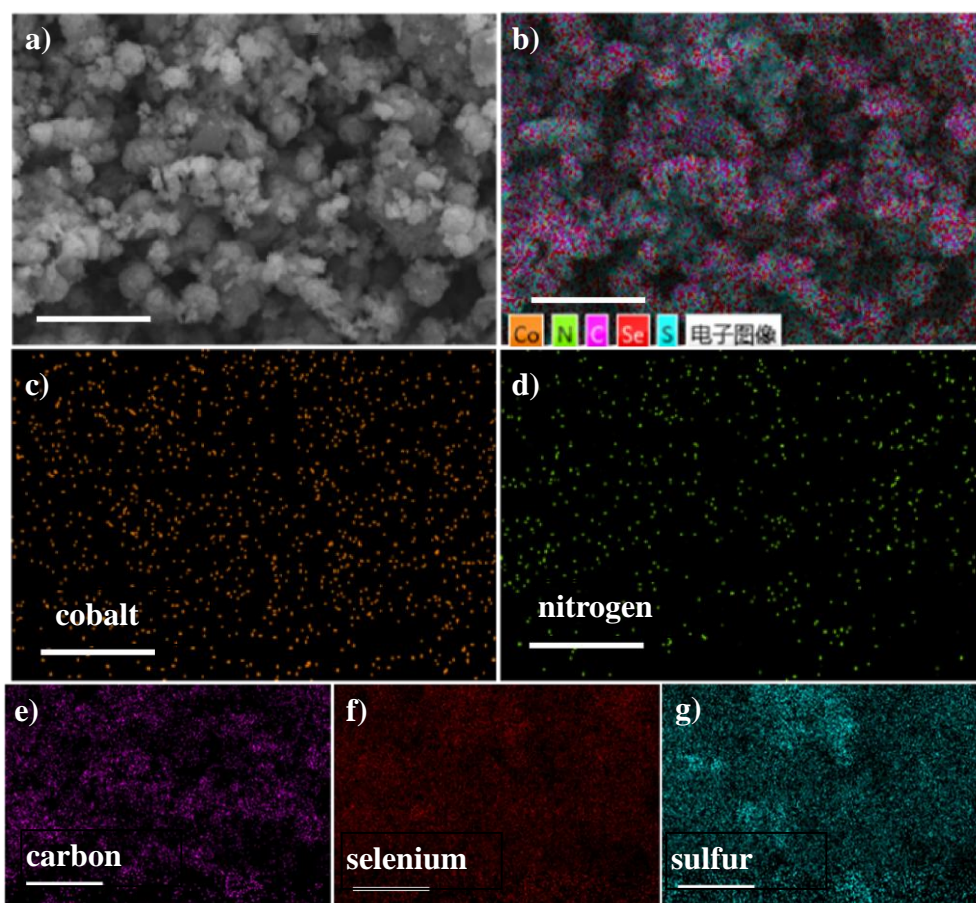


Fig. S10 . SEM image of (a) CNC-0.07/SeS₂ and the corresponding EDS elemental maps for cobalt(c), nitrogen (d), carbon (e), selenium (f) , sulfur (f) and all elements combined (b). The scale bar is 10 μ m.

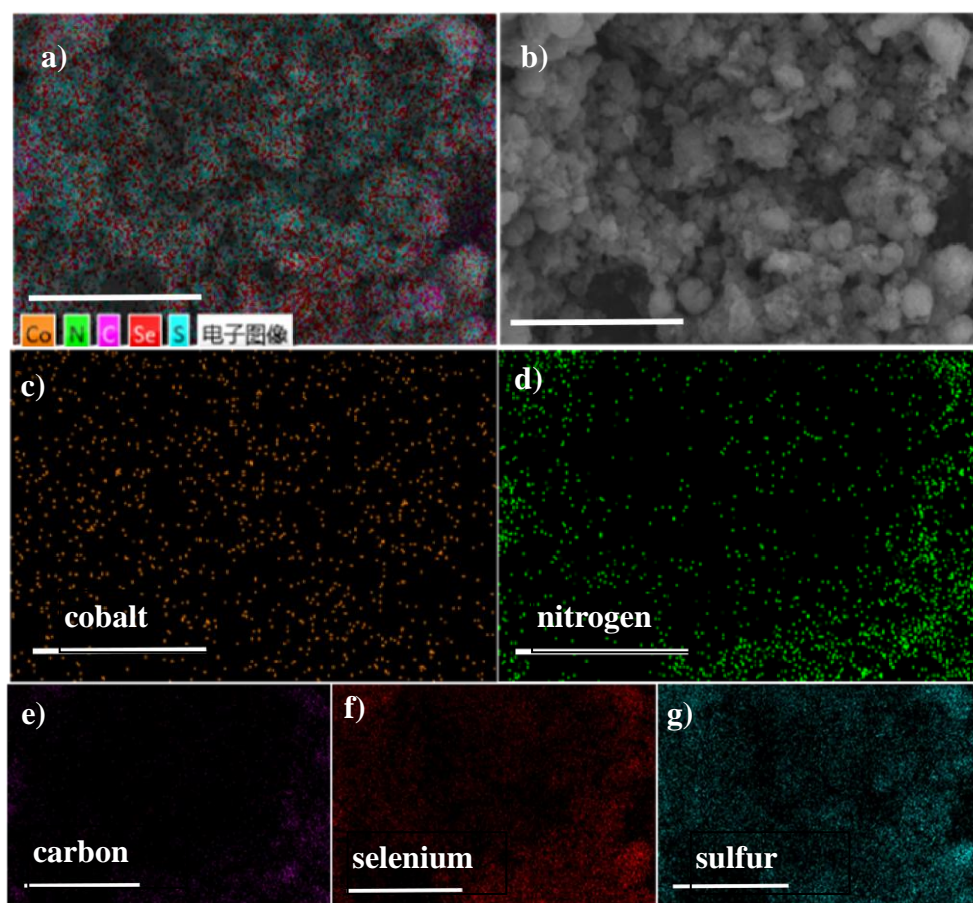


Fig. S11. SEM image of (a) CNC-0.03/SeS₂ and the corresponding EDS elemental maps for cobalt(c), nitrogen (d), carbon (e), selenium (f) , sulfur (f) and all elements combined (b). The scale bar is 10 μ m.

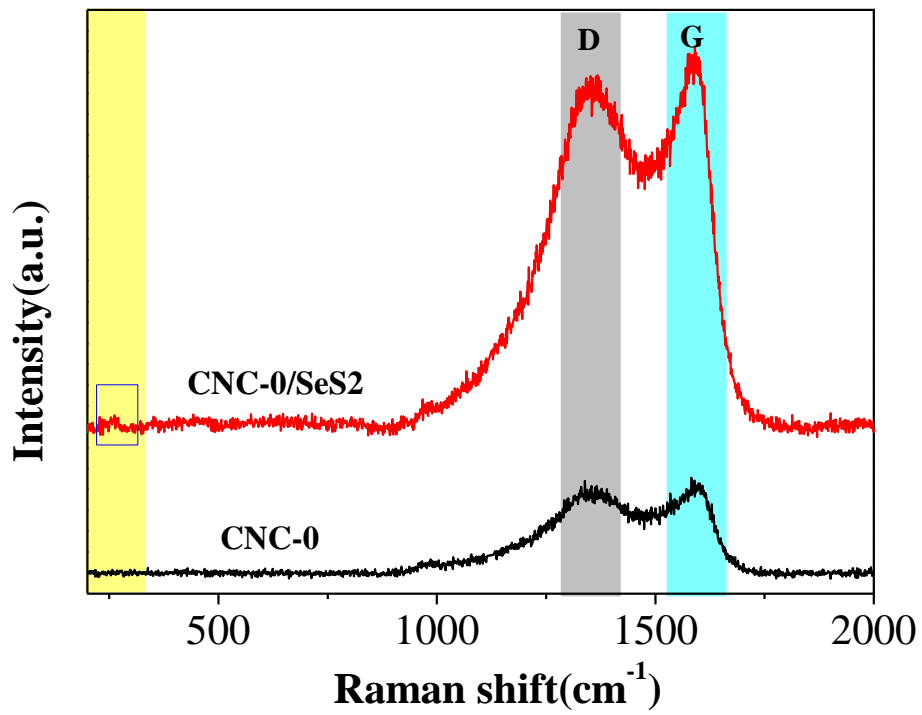


Fig.S12. Raman spectra of CNC-0 and CNC-0/SeS₂.

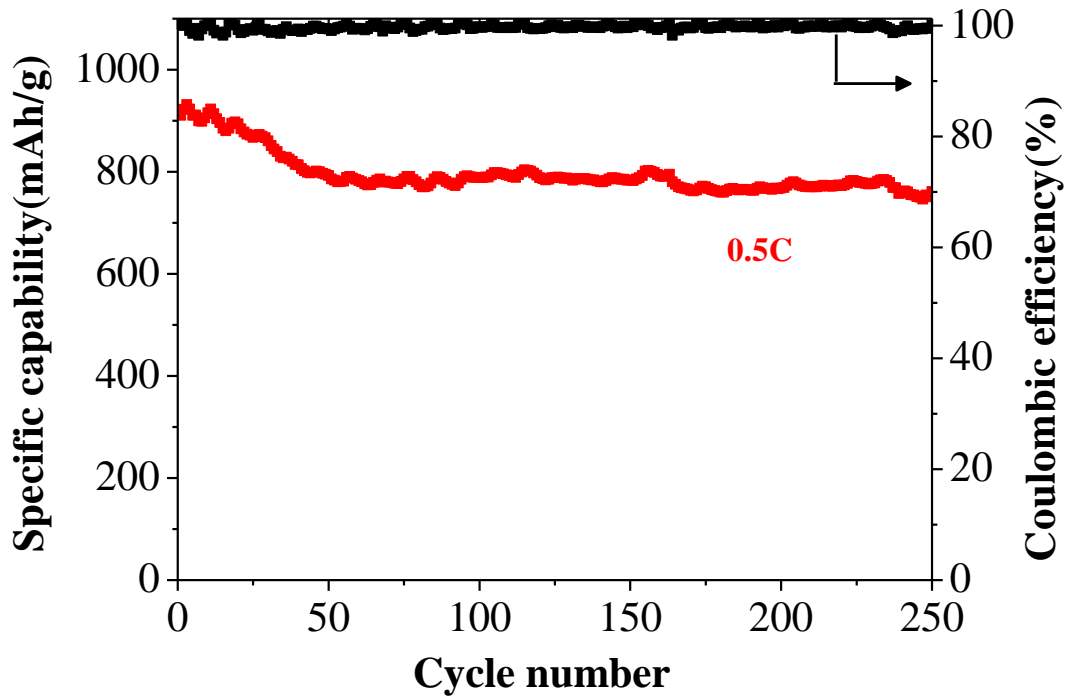


Fig.13. Cycle performance of the CNC-0.05/SeS₂ at 0.5C.

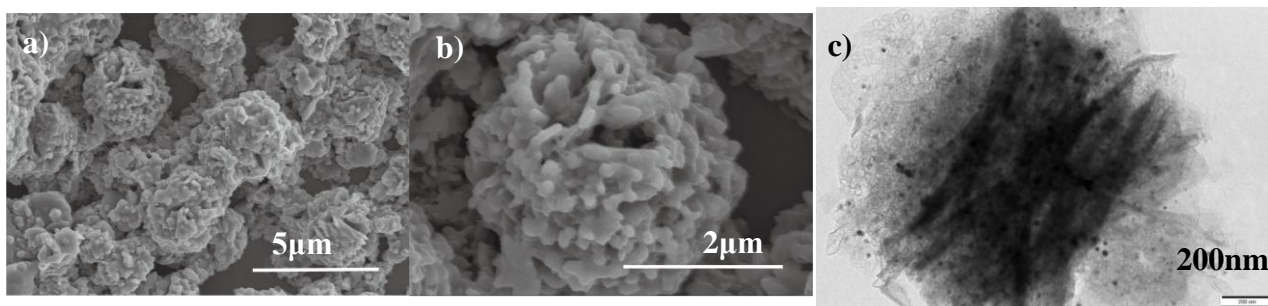


Fig.S14. (a-b) FESEM and (c) TEM images of the CNC-0.05/SeS₂ electrode after 100 cycles at a current density of 0.2C.

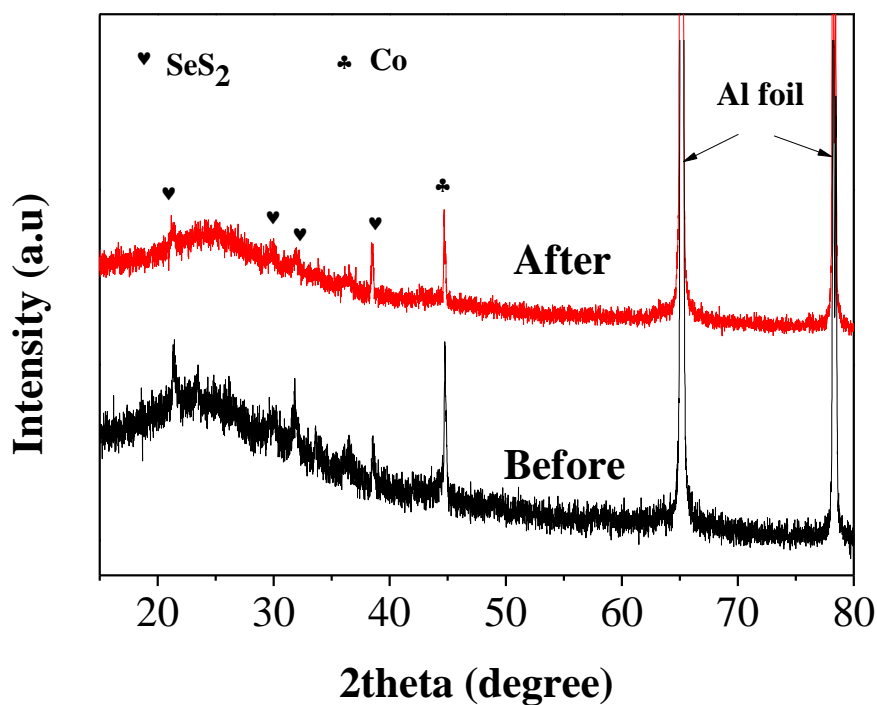


Fig.S15. XRD patterns of CNC-0.05/SeS₂ electrode on Al foil before and after 100 cycles at 0.2C.

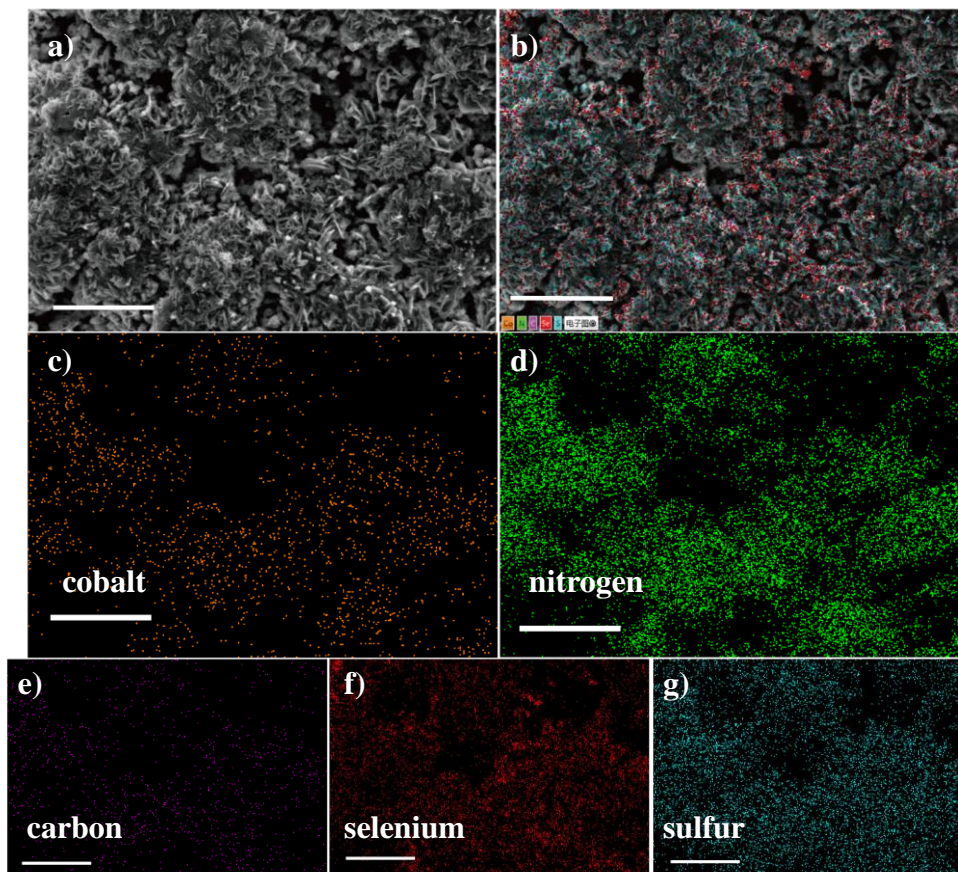


Fig. S16. SEM image of (a) CNC-0.03/SeS₂ and the corresponding EDS elemental maps for cobalt(c), nitrogen (d), carbon (e), selenium (f) , sulfur (f) and all elements combined (b). of CNC-0.05/SeS₂ electrode after 100 cycles at 0.2C. The scale bar is 25μm.

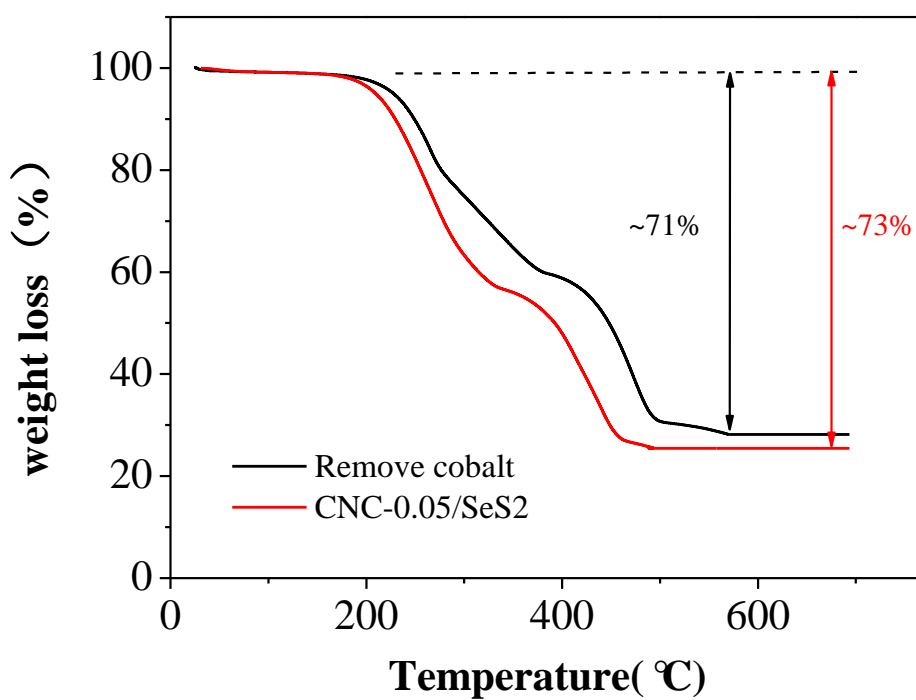


Fig.S17. TGA curves of the CNC-0.05/SeS₂ and the samples of remove cobalt.

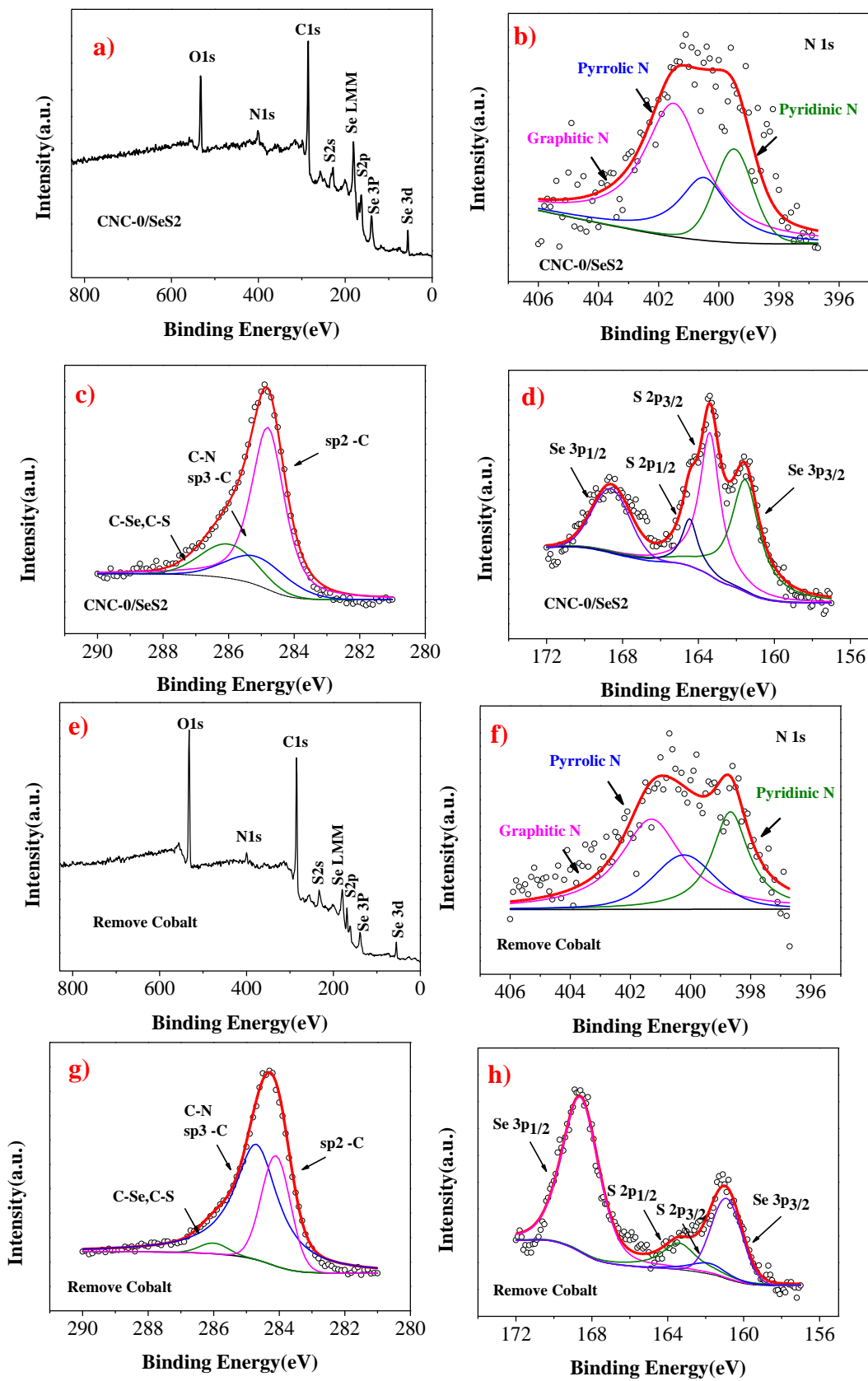


Fig.S18, (a) XPS survey spectrum of CNC-0/SeS₂, (b-d) the corresponding high-resolution XPS

spectra for N 1s and C 1s, S 2p/Se 3p, respectively; (e) XPS survey spectrum of the removing cobalt samples, (f–h) the corresponding high-resolution XPS spectra for N 1s and C 1s, S 2p/Se 3p, respectively.

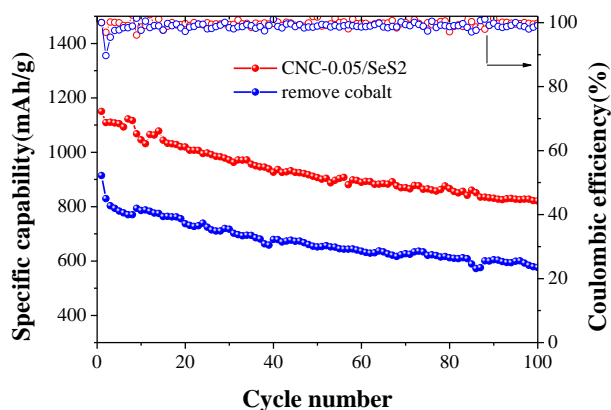


Fig.S19, Cycle performance of the CNC-0.05/SeS₂ and remove cobalt at 0.2 C.

Table S4. A survey of electrochemical properties of the comparisons of cathode materials for Li-SeS₂ batteries.

Category	Carbon SSA* (m ² g ⁻¹)	Precursor	SeS ₂ content	Cycling stability	C-Rate-performance
CNC-0.05/SeS ₂ (This work)	416	Cobalt doped JUC-160 (Template-free)	~73%	820.87 mAh g ⁻¹ after 100 cycles at 0.2C/0.22 A g ⁻¹ 760.93 mAh g ⁻¹ after 250 cycles at 0.5C/0.56 A g ⁻¹	1067 mAh g ⁻¹ (0.1C/0.11 A g ⁻¹), 927 mAh g ⁻¹ (0.2C/0.22 A g ⁻¹), 822mAh g ⁻¹ (0.5C/0.56 A g ⁻¹), 733 mAh g ⁻¹ (1C/1.12 A g ⁻¹), 634mAh g ⁻¹ (2C/2.24 A g ⁻¹), 262mAh g ⁻¹ (5C/5.61 A g ⁻¹), 158 mAh g ⁻¹ (10C/11.23 A g ⁻¹)
MYS-Co ₄ N@C/SeS ₂ (Ref. ¹)	142	ZIF-67 (Template-free)	70%	996 mA h.g ⁻¹ after 100 cycles at 0.22 A g ⁻¹ 669 mA h.g ⁻¹ after 300 cycles at 0.56 A g ⁻¹	962 mAh g ⁻¹ (0.22 A g ⁻¹), 866 mAh g ⁻¹ (0.56 A g ⁻¹), 735 mAh g ⁻¹ (1.12 A g ⁻¹), 610mAh g ⁻¹ (2.24 A g ⁻¹), 460 mAh g ⁻¹ (3.36 A g ⁻¹)

Co-N-C/SeS ₂ (Ref. ²)	296	ZIF-67 (Template-free)	66.5%	970.2 mAh g ⁻¹ after 200 cycles at 0.26 A g ⁻¹	1193.5 mAh g ⁻¹ (0.13 A g ⁻¹), 1080.7 mAh g ⁻¹ (0.26 A g ⁻¹), 928.2 mAh g ⁻¹ (0.67 A g ⁻¹), 760 mAh g ⁻¹ (1.34 A g ⁻¹), 604.1 mAh g ⁻¹ (2.69 A g ⁻¹), 439.7mAh g ⁻¹ (5.38 A g ⁻¹), 300.3 mAh g ⁻¹ (8.07 A g ⁻¹), 138.1 mAh g ⁻¹ (10.76 A g ⁻¹)
NiCo ₂ S ₄ @NC /SeS ₂ (Ref. ³)	44.5	Dopamine hydrochloride (NiCo ₂ S ₄ template)	66.7 %	556.45 mAh g ⁻¹ after 800 cycles at 1.34 A g ⁻¹	1205.1 mAh g ⁻¹ (0.13 A g ⁻¹), 1021.2 mAh g ⁻¹ (0.26 A g ⁻¹), 871.6 mAh g ⁻¹ (0.67 A g ⁻¹), 776.6 mAh g ⁻¹ (1.34 A g ⁻¹), 673.5 mAh g ⁻¹ (2.69 A g ⁻¹),
SeS ₂ @MCA (Ref. ⁴)	—	mesoporous carbon aerogels (Template-free)	49.3 %	308 mAh g ⁻¹ after 130 cycles at 0.2 A g ⁻¹	1074 mAh g ⁻¹ (0.25A g ⁻¹), 731 mAh g ⁻¹ (0.5A g ⁻¹), 371mAh g ⁻¹ (2A g ⁻¹),
CMK-3/SeS ₂ @PDA: (Ref. ⁵)	—	CMK-3/SeS ₂ @PDA (Core-shell structure)	70%	783 mAh g ⁻¹ after 150 cycles at 0.2 A g ⁻¹	1005 mAh g ⁻¹ (0.2A g ⁻¹), 864 mAh g ⁻¹ (0.5A g ⁻¹), 787mAh g ⁻¹ (1A g ⁻¹), 702mAh g ⁻¹ (2A g ⁻¹), 645mAh g ⁻¹ (3A g ⁻¹), 584mAh g ⁻¹ (4A g ⁻¹) 535mAh g ⁻¹ (5A g ⁻¹)
CoS ₂ @LRC/SeS ₂ (Ref. ⁶)	77.6	Co(Ac) ₂ /PAN/PS paper	70%	745 mAh g ⁻¹ after 100 cycles at 0.2A g ⁻¹	1096 mA hg ⁻¹ (0.1A g ⁻¹), 1038mA hg ⁻¹ (0.2A g ⁻¹), 846mA hg ⁻¹ (0.5A g ⁻¹), 686 mA hg ⁻¹ (1A g ⁻¹), 526mA hg ⁻¹ (2A g ⁻¹),

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