Supporting Information

One-pot synthesis of N,S-doped pearl chain tube-loaded Ni_3S_2 composite materials for high-performance lithium-air batteries

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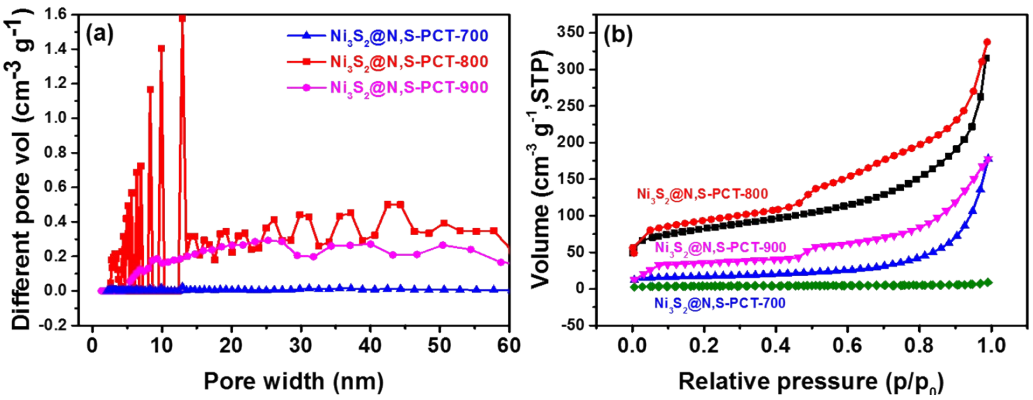

Figure S1 Under different temperature gradients (a) Ni_3S_2@N,S-PCT of pore size distribution; (b) Ni_3S_2@N,S-PCT of adsorption isotherm

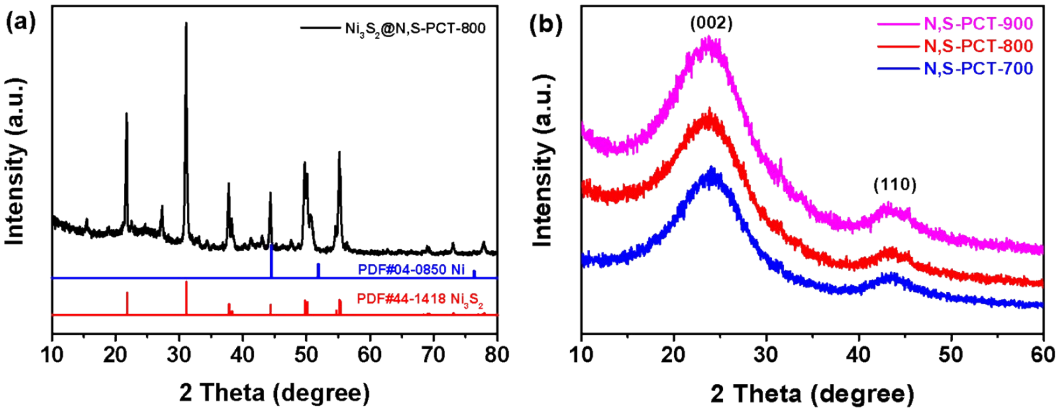

Figure S2 (a) XRD of material sample coated on carbon paper; (b) XRD of N,S-PCT at different temperatures

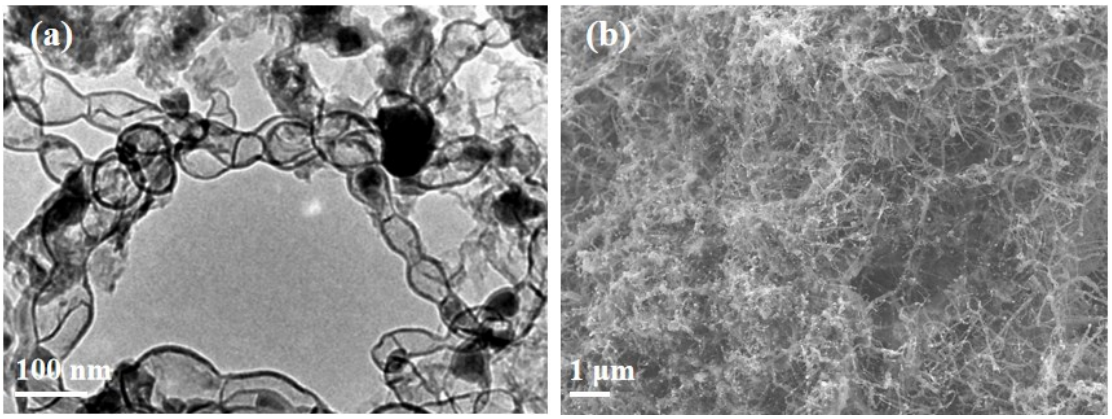

Figure S3 (a) Mapping the diameter of the carbon layer of N,S-PCTs; (b) the whole frame of Ni_3S_2@N,S-PCT-800

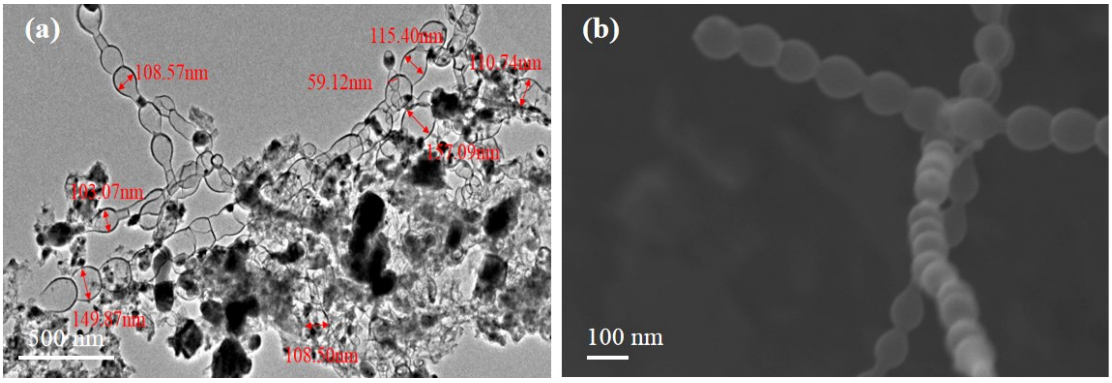

Figure S4 (a) Mapping the diameter of Ni_3S_2@N,S-PCT-800; (b) SEM images of N,S-PCT-800 . The N,S-PCT-800 obtained, the morphology of the carbon tube presents a pearl chain shape.

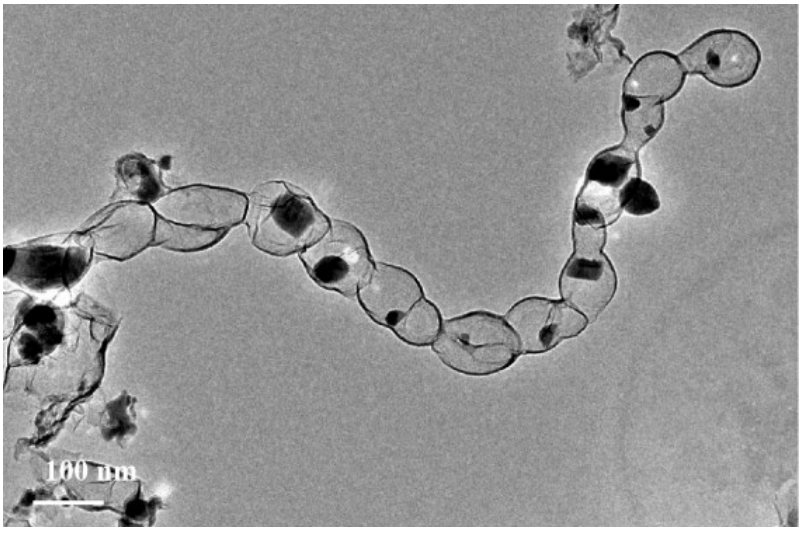

Figure S5. HRTEM images of Ni_3S_2@N,S-PCT-800

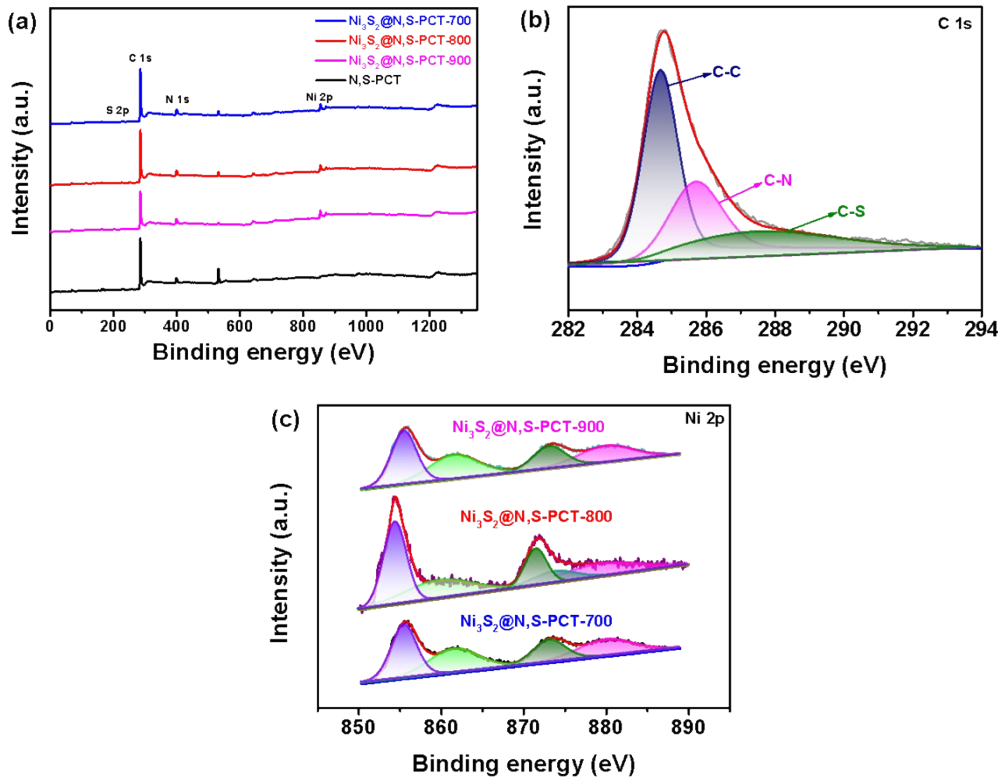

Figure S6 (a) XPS analysis of the samples in different temperatures; (b) XRD pattern of C 1s; (c) XRD pattern of Ni 2p from 700℃ to 900℃

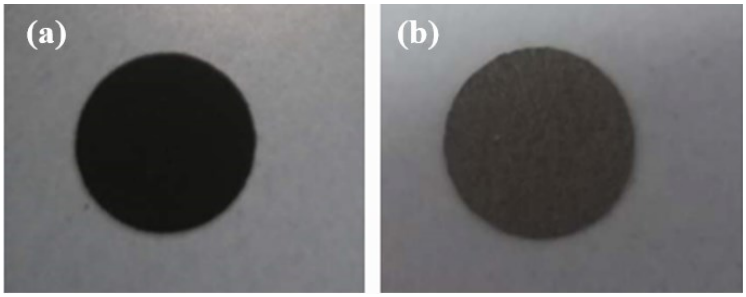

Figure S7. (a) loaded carbon paper (b) Original carbon paper

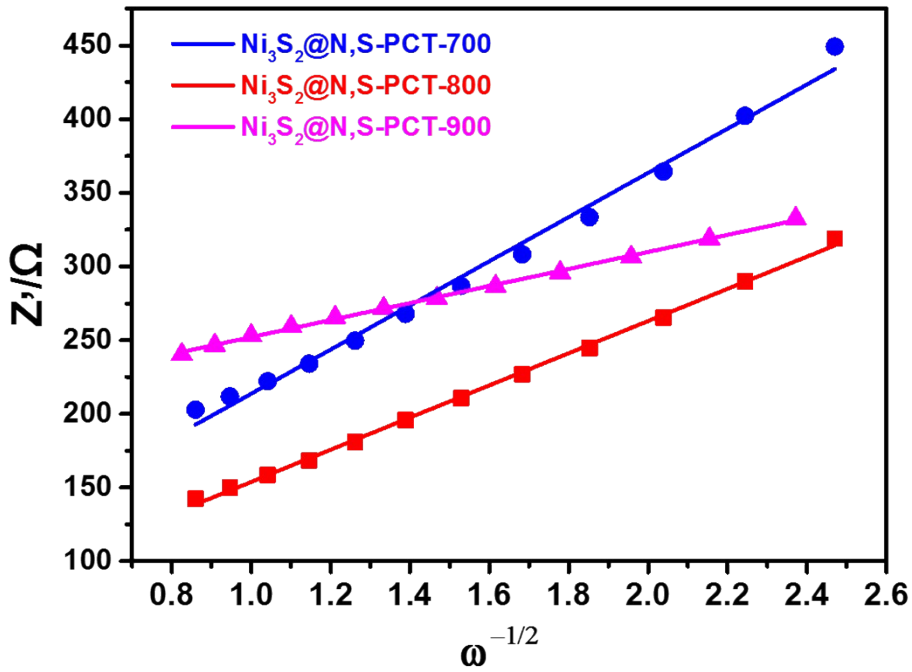

Figure S8. The relationship between Z´and $\omega^{-1/2}$ of O_2 electrode

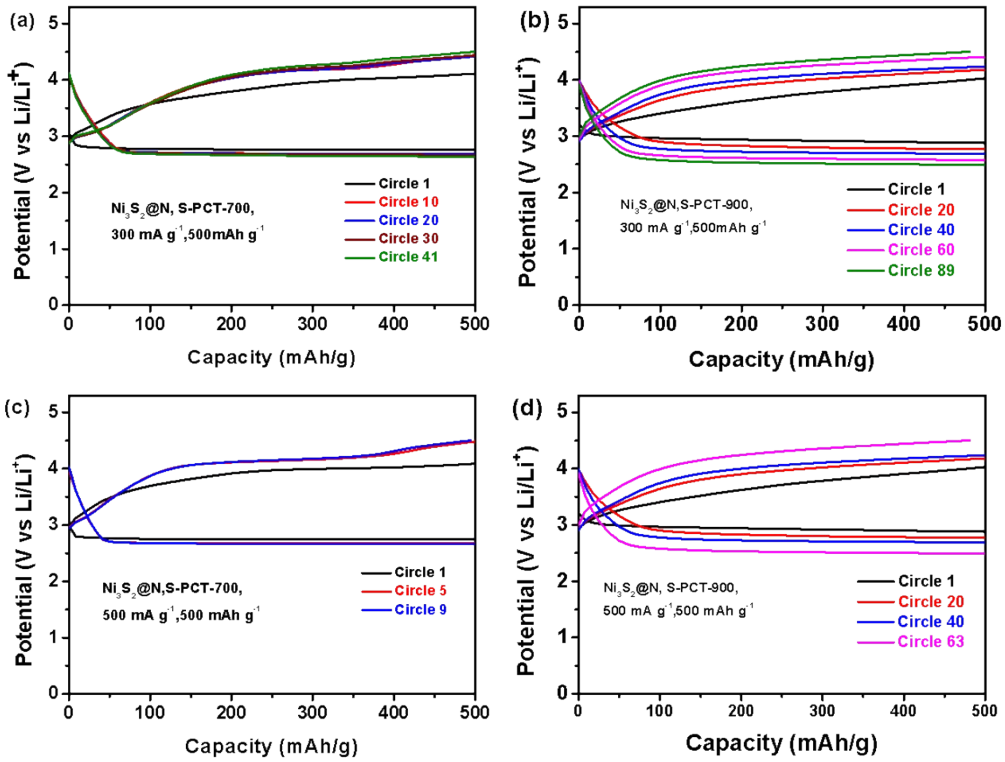

Figure S9. The discharge/charge profiles of (a) Ni_3S_2@N,S-PCT-700 and (b) Ni_3S_2@N,S-PCT-900, at a current density of 300 mA g^{-1} with a limited capacity of 500 mAh g^{-1}. The discharge/charge profiles of (c) Ni_3S_2@N,S-PCT-700 and (d) Ni_3S_2@N,S-PCT-900, at a current density of 500 mA g^{-1} with a limited capacity of 500 mAh g^{-1}

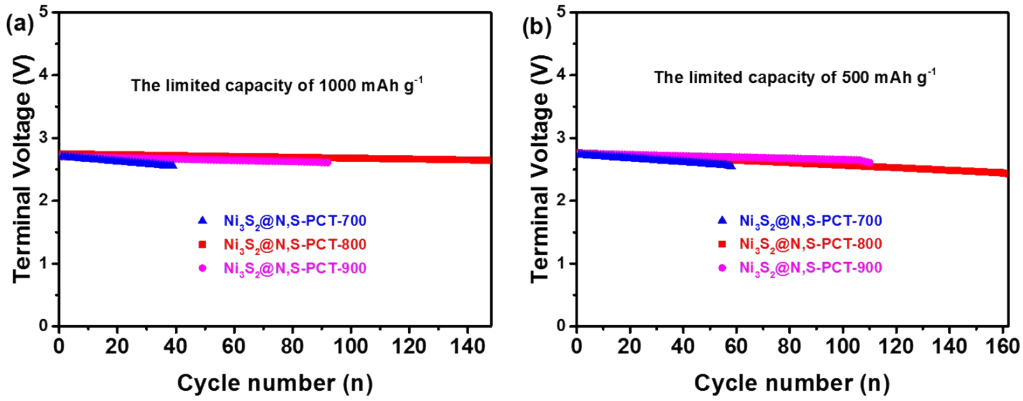

Figure S10. Cycle performance of the Ni_3S_2@N,S-PCT-900, Ni_3S_2@N,S-PCT-800 and Ni_3S_2@N,S-PCT-700 electrodes (a) at current density of 450 mA g^{-1} with limited capacity of 1000 mAh g^{-1} (b) at current density of 500 mA g^{-1} with limited capacity of 500 mAh g^{-1}

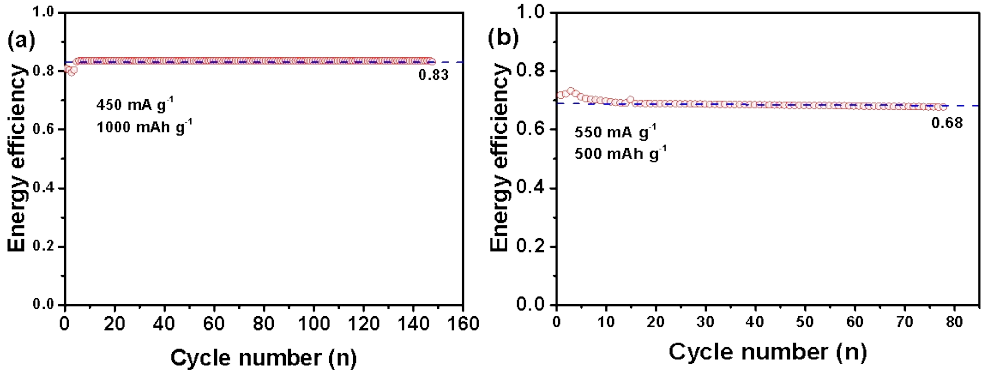

Figure S11. The cycle efficiency of Ni_3S_2@N,S-PCT-800 (a) the current density is 450 mA g^{-1} and the limited capacity is 1000 mA g^{-1} (b) the current density is 550 mA g^{-1} and the limited capacity is 500 mA g^{-1}

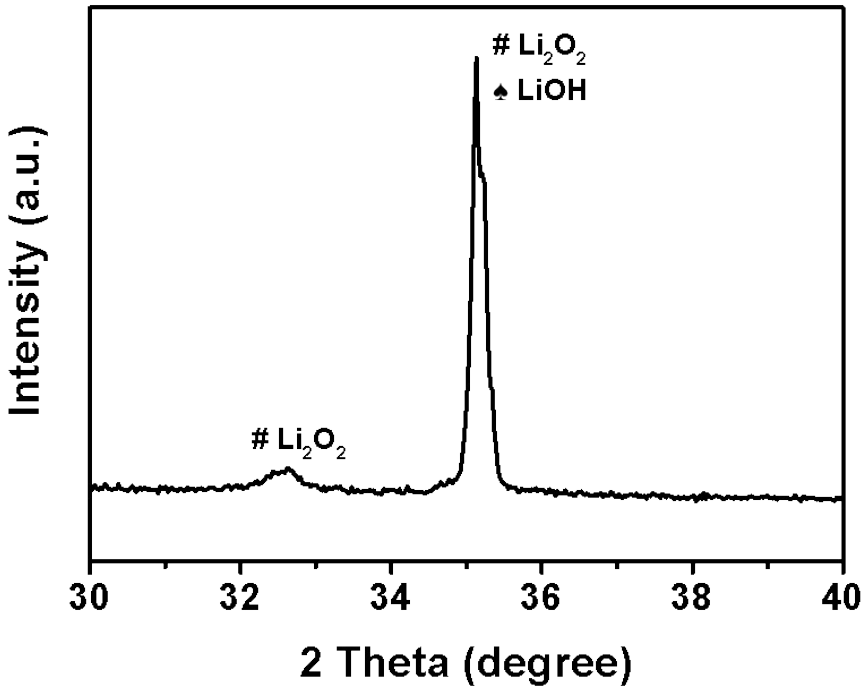

Figure S12. XRD analysis chart of discharge products in a certain range.

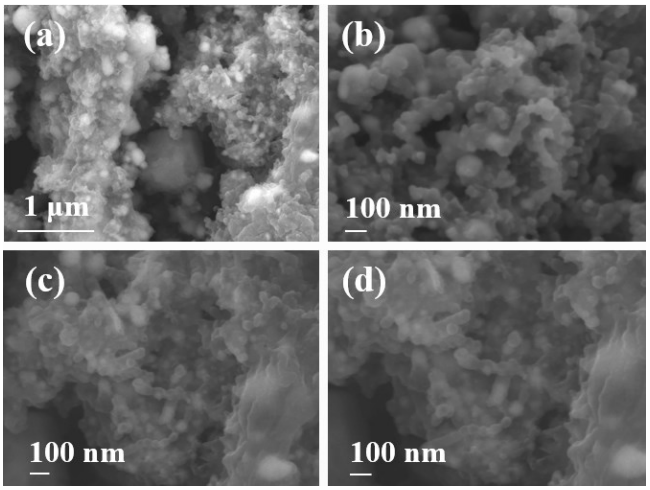

Figure S13. SEM image of materials after circulation in different positions (a) Magnification is 20,000; (b) Magnification is 50,000; (a) Magnification is 40,000; (a) Magnification is 50,000

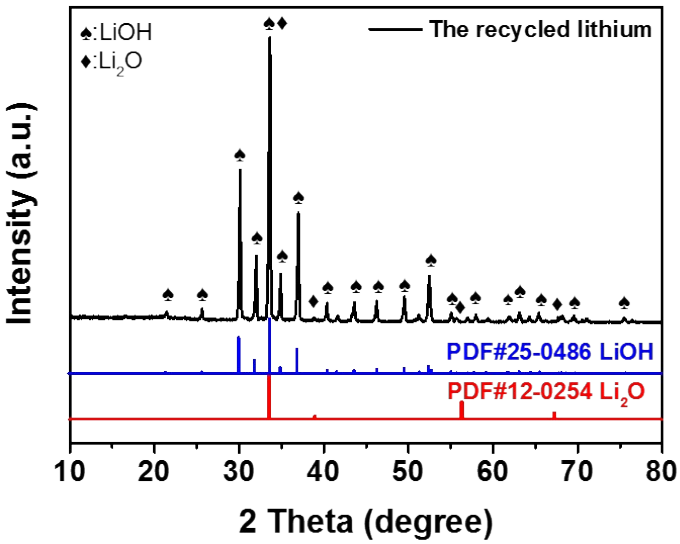

Figure S14. XRD patterns of the recycled lithium

Table S1. Elemental content percentage measured by XPS

Sample name	Ni (at. %)	O (at. %)	C (at. %)	N (at. %)	S (at. %)
Ni_3S_2@N,S-PCT-900	1.8	11.06	76.51	7.73	2.91
Ni_3S_2@N,S-PCT-800	3.24	2.98	81.95	10.63	1.34
Ni_3S_2@N,S-PCT-700	1.88	4	83.96	9.13	1.03
N,S-PCT	0.53	2.7	85.67	10.07	1.17

Table S2. Comparison of Li-O_2 battery properties of Ni_3S_2@N,S-PCT-800 cathode with those of representative state-of-the-art cathodes reported in literature.

Catalysts	Current Density（mA g^{-1}）	Overpotention (V)	Cycling Performance (Cycles/Limited Capacity)	First Discharge Capacity (mAh g^{-1})	Ref.
2D Co_3S_4 nanosheets	100	0.92	25/500	5917	1
Ni_3S_2	200	1.29	50/500	7478	2
MoS_2 nanoflakes	100	≥1.0	50/500	1250	3
Ni_3S_2/PBSC NFs	100	0.68	120/500	12874	4
Co_9S_8	100	1.37	100/500	3500	5
MoS_x/HRG	0.05	1.5	30/500	6678	6
TiC/MWNTs-Ru	250	0.49	90/1000	3841	7
GDP-Mo_2C@NCF	100	1.2	100/1000	7437	8
NCS/S-3DPG	150	1.38	102/1000	14,173	9
Co_2P/Ru/CNT	100	1.22	120/1000	12 800	10
Ni_3S_2@N,S-PCT-800	**450**	**1.45**	**148/1000**	**16733.7**	**This work**

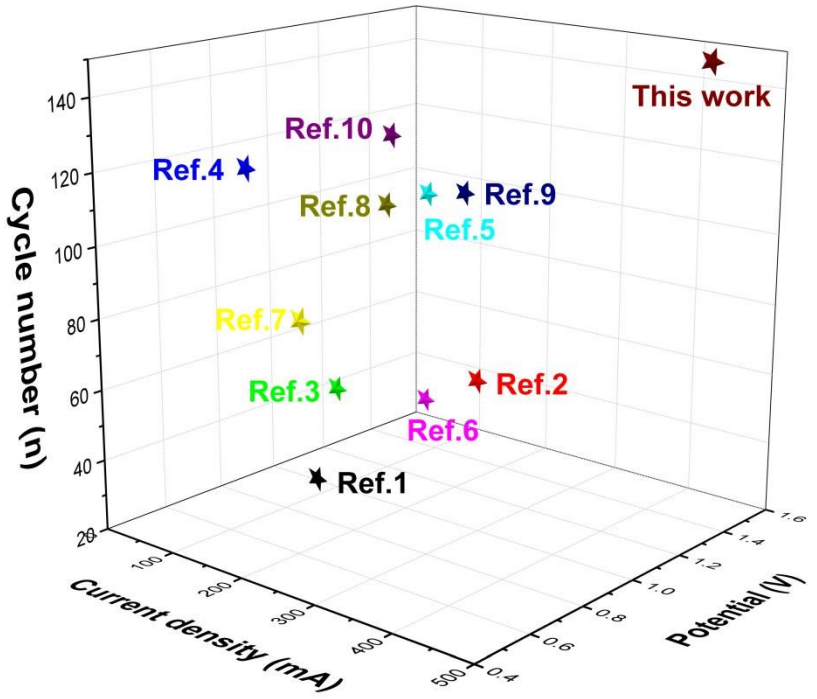

Figure S12 Lithium-air battery performance of different types of cathode materials

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