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Oxygen-incorporated induced C@MoS_2-CoS_2-O@C nanocomposites with improved electronic structure as high-performance anode for sodium-based dual-ion batteries

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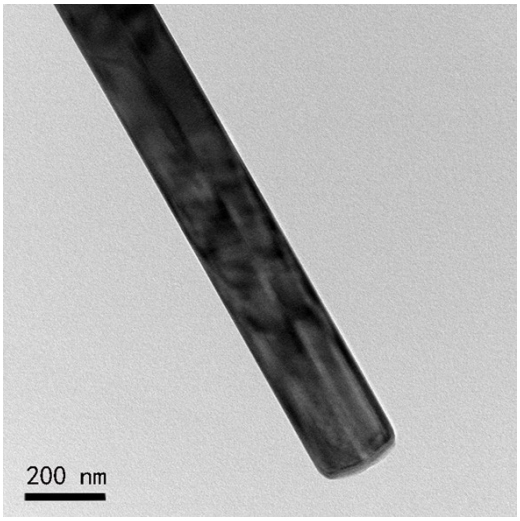

Fig. S1 TEM of MoO_3 nanorod.

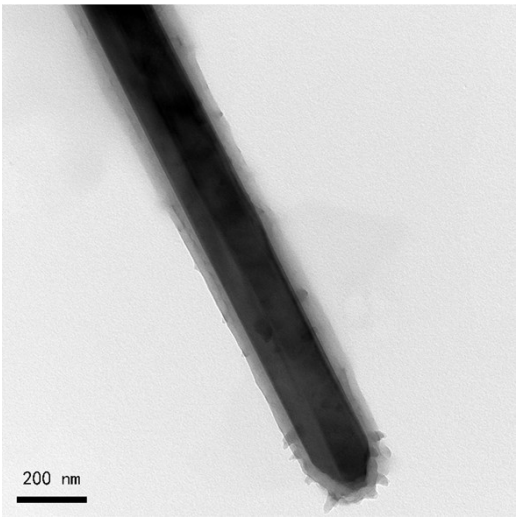

Fig. S2 TEM of MoO_3@PPY nanorod.

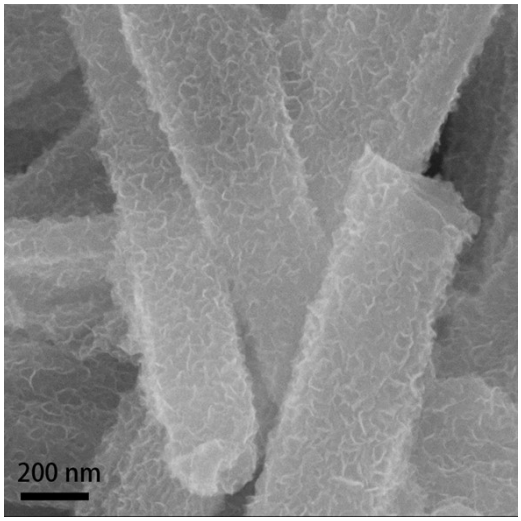

Fig. S3 SEM image of C@MoS_2-CoS_2.

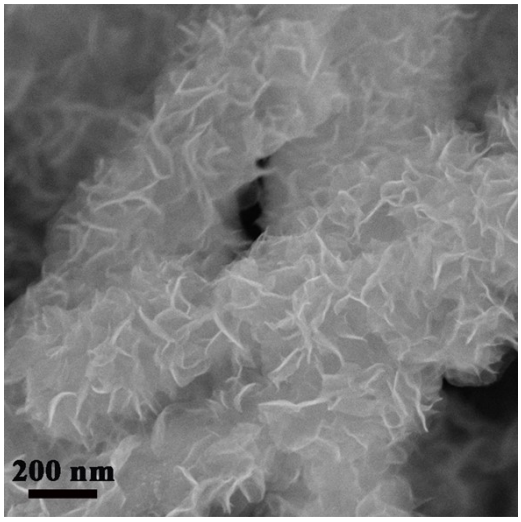

Fig. S4 SEM image of C@MoS_2.

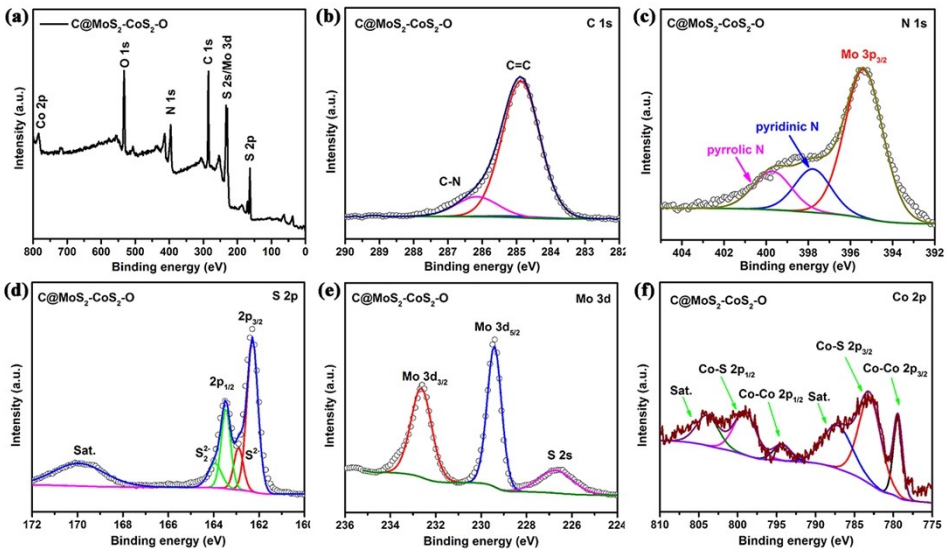

Fig. S5 XPS spectra of C@MoS_2-CoS_2-O. (a) survey spectrum. (b) C 1s spectrum. (c) N 1s

spectrum. (d) S 2p spectrum. (e) Mo 3d spectrum. (f) Co 2p spectrum.

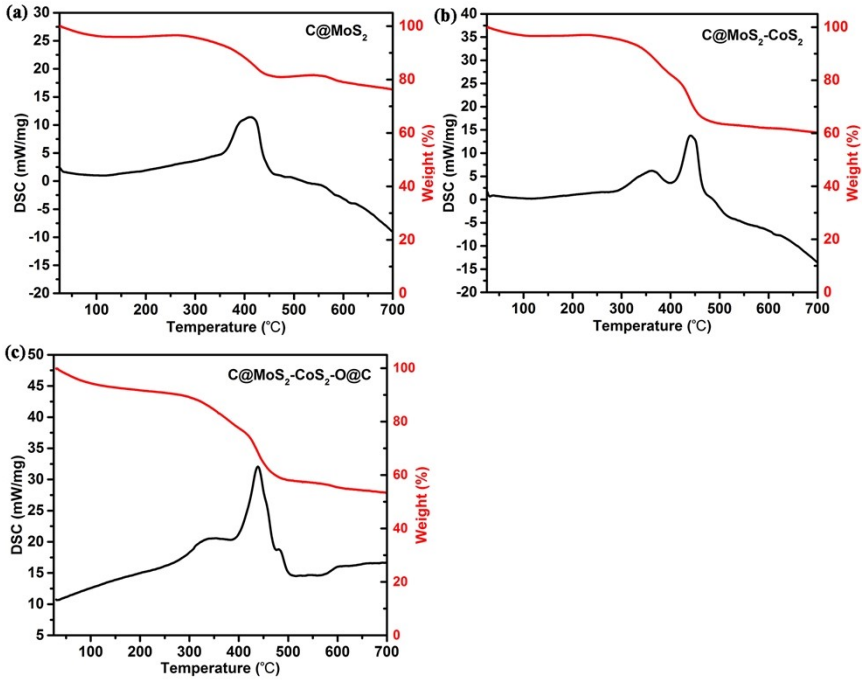

Fig. S6 DSC/TGA curves of (a) C@MoS_2, (b) C@MoS_2-CoS_2 and C@MoS_2-CoS_2-O@C nanocomposites.

The DSC/TGA measurements were conducted in air atmosphere to test the carbon contents of C@MoS_2, C@MoS_2-CoS_2 and C@MoS_2-CoS_2-O@C, as shown in Fig. S6. The clear weight-loss takes place from 300 to 700 °C, which is attributed to the process of MoS_2 oxidized to MoO_3, CoS_2 oxidized to Co_3O_4 and C oxidized to CO_2. The mass loss of C@MoS_2, C@MoS_2-CoS_2 and C@MoS_2-CoS_2-O@C is 23.7%, 39.7% and 46.6%.

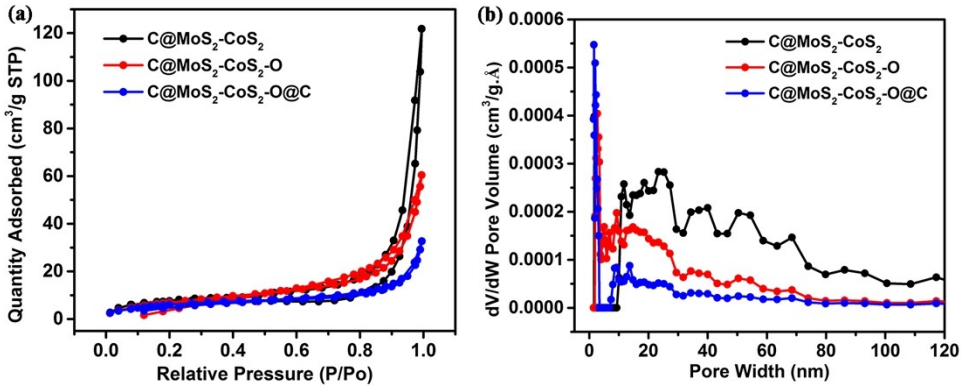

Fig. S7 (a) Nitrogen adsorption/desorption isotherms and (b) the pore distribution of C@MoS_2-CoS_2, C@MoS_2-CoS_2-O and C@MoS_2-CoS_2-O@C.

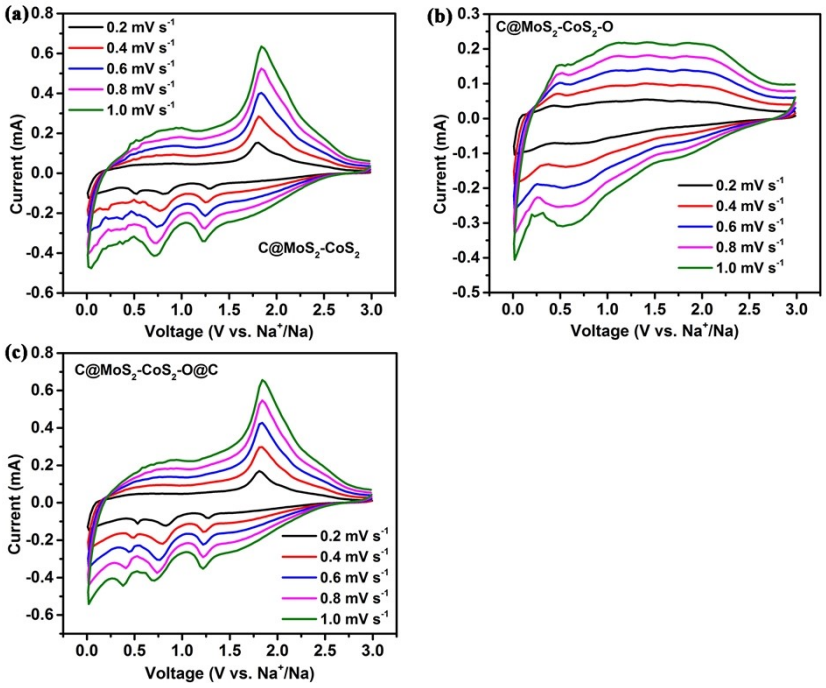

Fig. S8 (a) CV curves of the C@MoS_2-CoS_2 as SIBs anode at different scanning rates. (b) CV curves of the C@MoS_2-CoS_2-O as SIBs anode at different scanning rates. (c) CV curves of the C@MoS_2-CoS_2-O@C as SIBs anode at different scanning rates.

The ratio of capacitive (k1v) and diffusion control contributions can be quantitatively divided by the formula:[1]

$$i(V) = k1v + k2v^{1/2}$$

where k1 and k2 are a constant at certain potentials and would be calculated by linear plotting $i/v^{1/2}$ versus $v^{1/2}$. V is the specified voltage. i is the current at a given voltage. And v is the scanning rate.

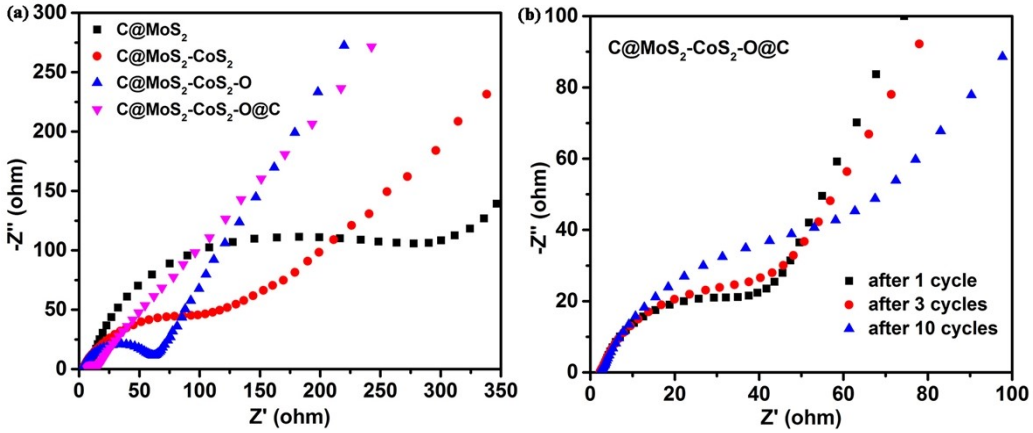

Fig. S9 (a) Electrochemical impedance spectra of C@MoS_2, C@MoS_2-CoS_2, C@MoS_2-CoS_2-O and C@MoS_2-CoS_2-O@C for sodium storage. (b) Electrochemical impedance spectra of C@MoS_2-CoS_2-O@C after 1 cycle, 3cycles and 10 cycles.

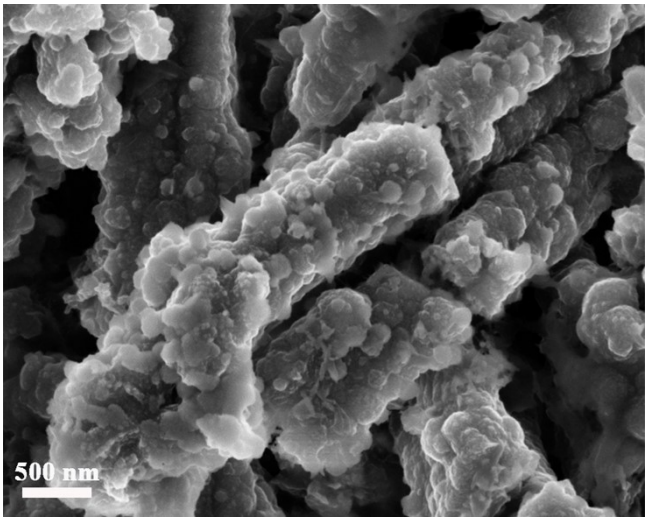

Fig. S10 SEM image of C@MoS_2-CoS_2-O@C after 150 cycles at 1A g^{-1} for S-DIBs.

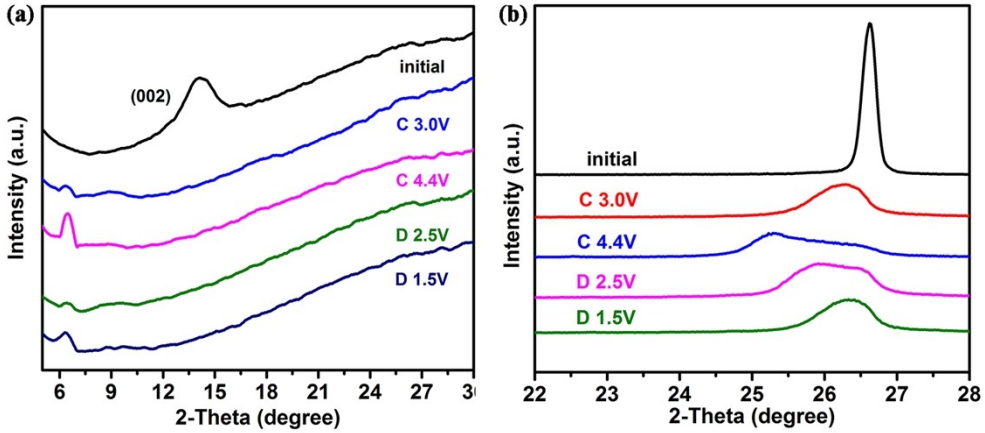

Fig. S11 Ex situ XRD patterns of (a) C@MoS_2-CoS_2-O@C anode and (b) the graphite cathode at different charge/discharge voltages.

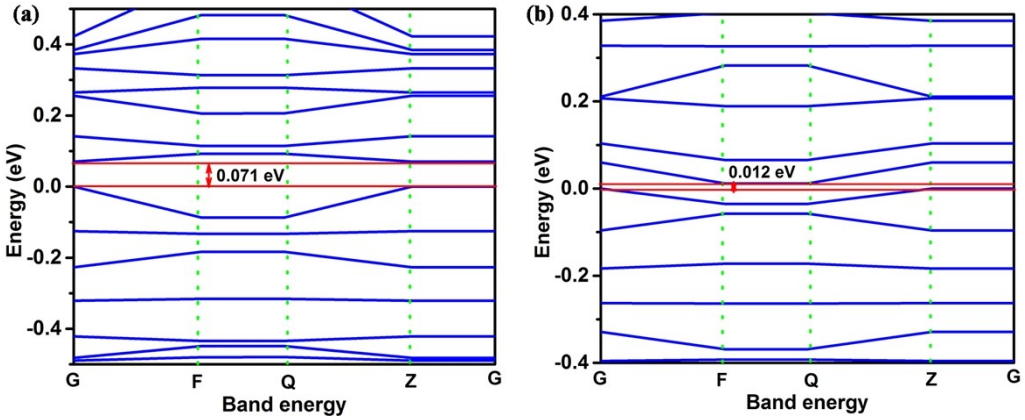

Fig. S12 (a) Calculated band structure of MoS_2-CoS_2. (b) Calculated band structure of MoS_2-CoS_2-O.

Table. S1 ICP-MS analysis of C@MoS_2-CoS_2.

sample	Co	Mo
	mg/g	mg/g
C@MoS_2-CoS_2	165	681

Table. S2 Energy spectrum analysis of C, N, O, S, Mo and Co atomic percentages for C@MoS_2-CoS_2, C@MoS_2-CoS_2-O and C@MoS_2-CoS_2-O@C.

samples	C At%	N At%	O At%	S At%	Co At%	Mo At%
C@MoS_2-CoS_2	35.82	4.52	31.43	18.21	1.50	8.53
C@MoS_2-CoS_2-O	39.64	4.93	35.61	11.52	1.65	6.65
C@MoS_2-CoS_2-O@C	55.92	9.88	18.18	9.66	1.84	4.54

Reference:

1 K. Zhang, M. Park, L. Zhou, G.-H. Lee, J. Shin, Z. Hu, S.-L. Chou, J. Chen and Y.-M. Kang, *Angew. Chem*, 2016, **128**, 13014.