Supplementary Information

Dual-Phase MoS_2 as a High-Performance Sodium-Ion Battery Anode

Junxiong Wu,[a] Jiapeng Liu,[a] Jiang Cui,[a] Shanshan Yao,[a] Muhammad Ihsan-Ul-Haq,[a] Nauman Mubarak,[a] Emanuele Quattrocchi,[a] Francesco Ciucci,[*abc] and Jang-Kyo Kim[*a]

[a] Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China.

[b] Department of Chemical and Biological Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China

[c] Guangzhou HKUST Fok Ying Tung Research Institute, China

* Corresponding author: francesco.ciucci@ust.hk, mejkkim@ust.hk

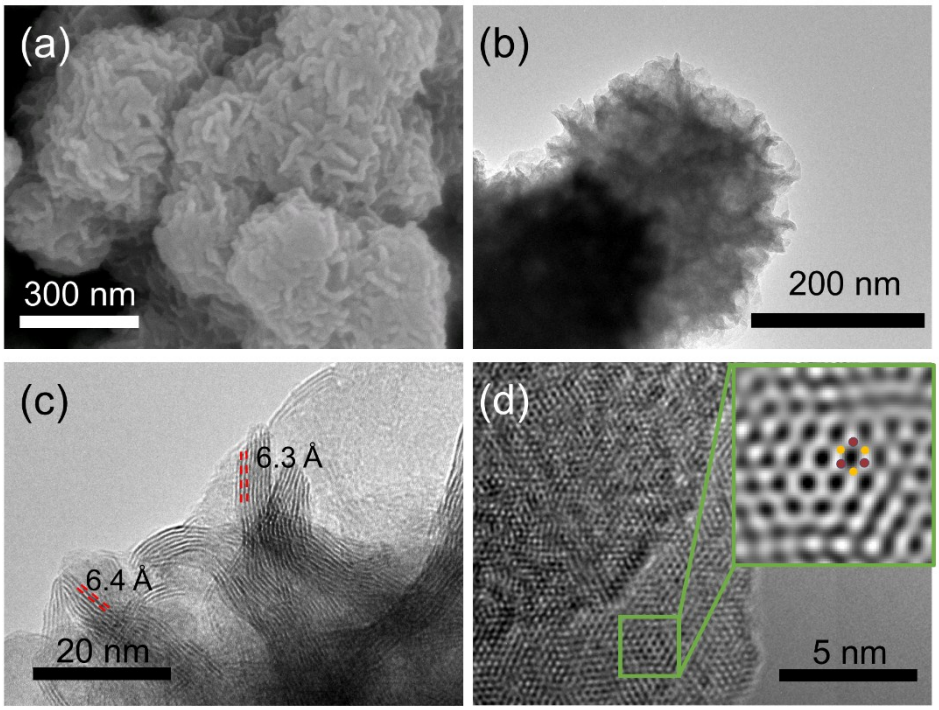

Figure S1. (a) SEM, (b) low-, and (c) high-magnification TEM and (d) HRTEM images of 2H-MoS_2.

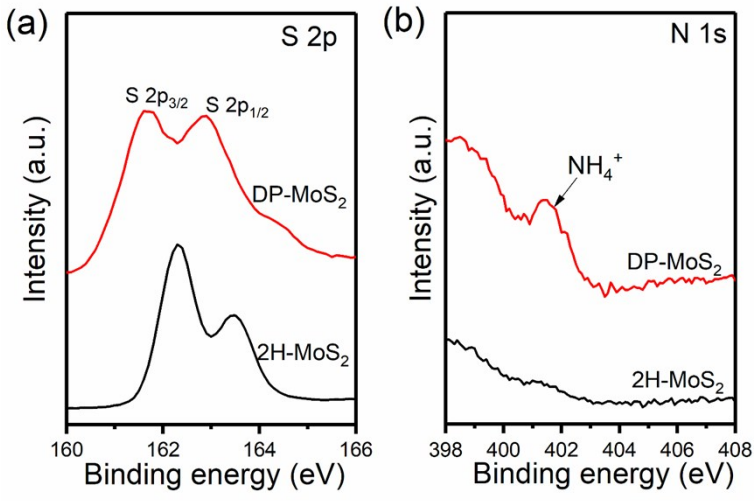

Figure S2. High resolution S 2p (a) and N 1s (b) XPS spectra of DP-MoS_2 and 2H-MoS_2.

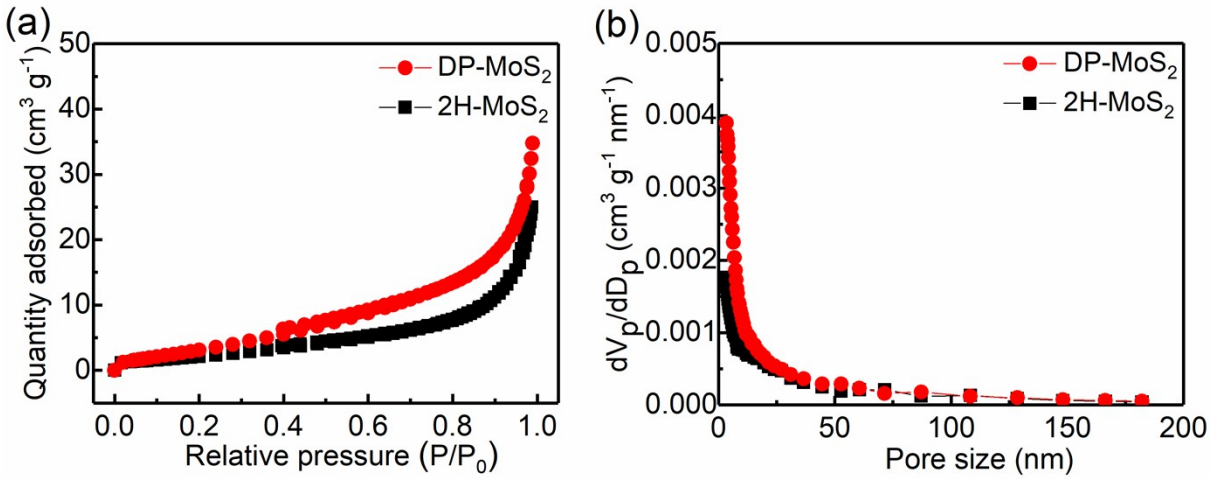

Figure S3. (a) N_2 adsorption/desorption isotherms and (b) pore size distribution curves of DP-MoS_2 and 2H-MoS_2.

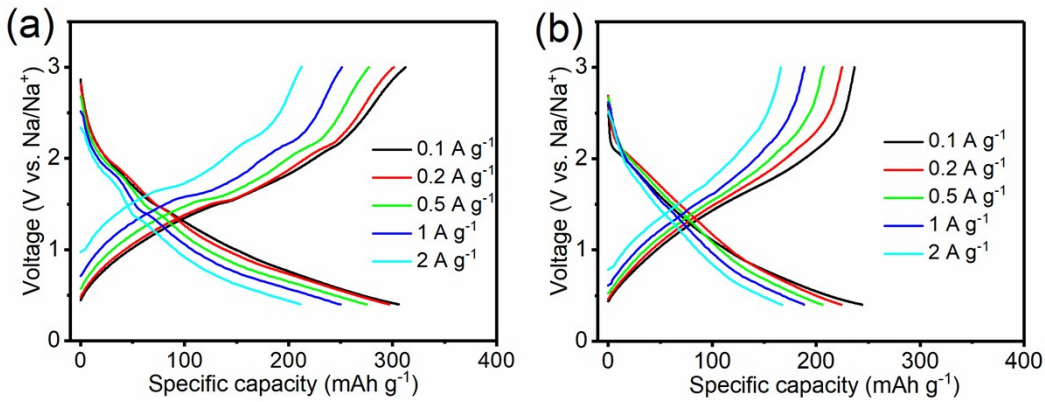

Figure S4. Charge/discharge curves of (a) the DP-MoS_2 and (b) 2H-MoS_2 electrodes at current densities varying from 0.1 A g^{-1} to 2 A g^{-1}.

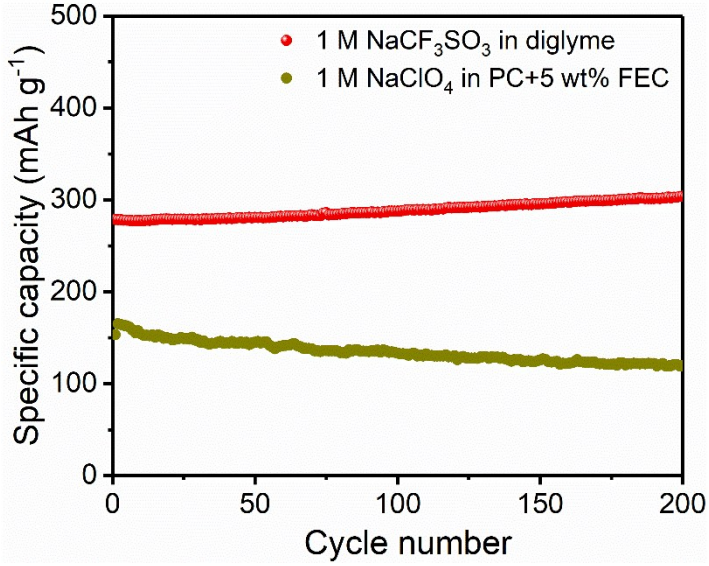

Figure S5. Cyclic performance of the DP-MoS_2 electrode in ether- and ester-based electrolytes.

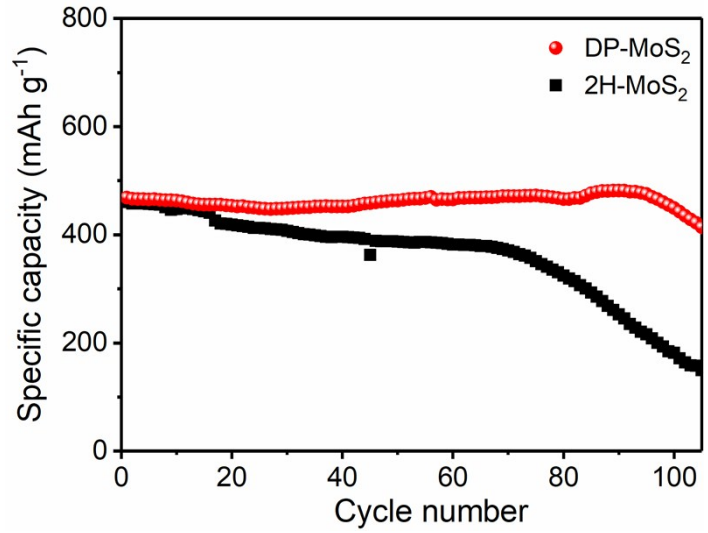

Figure S6. Cyclic performance of the DP-MoS_2 and 2H-MoS_2 electrodes at 0.5 A g^{-1} in the voltage range from 0.01 to 3 V (vs. Na/Na^+).

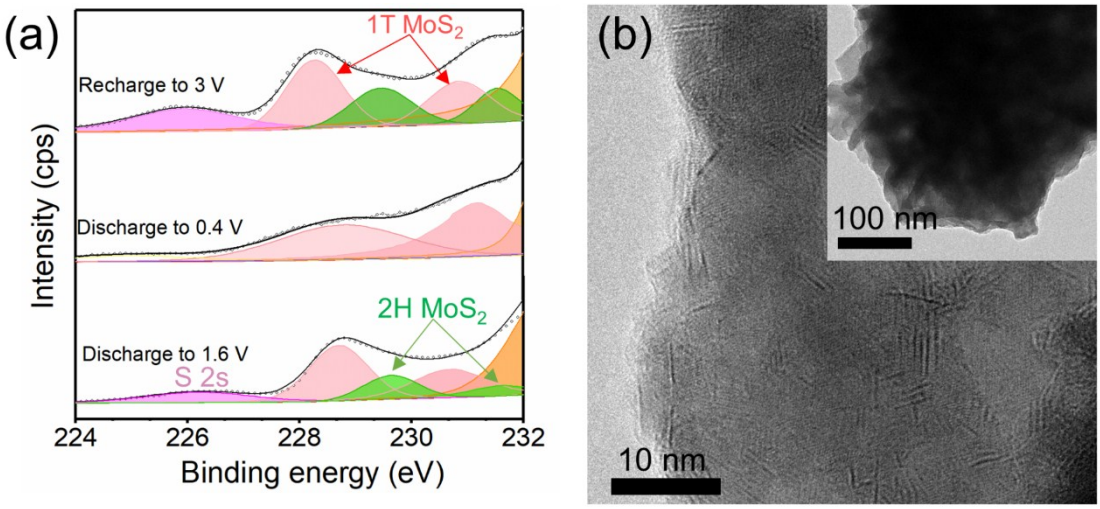

Figure S7. (a) *Ex-situ* XPS of DP-MoS_2 at different potentials; (b) HRTEM images of DP-MoS_2 taken after discharging to 0.4 V in the 100th cycle.

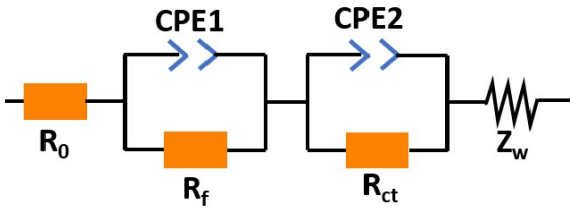

Figure S8. Equivalent circuit used for fitting the EIS data.

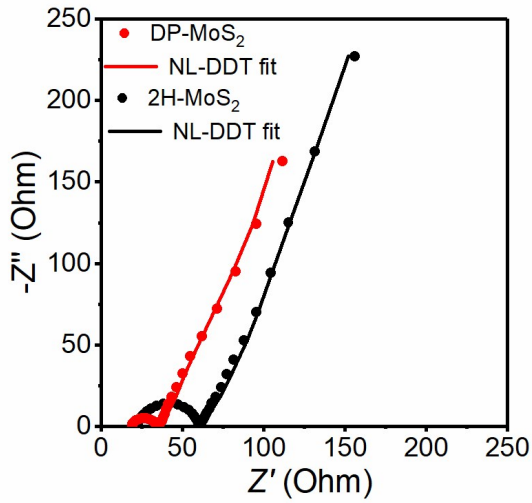

Figure S9. Nyquist plots with NL-DDT fit of Na//DP-MoS_2 and Na//2H-MoS_2 batteries.

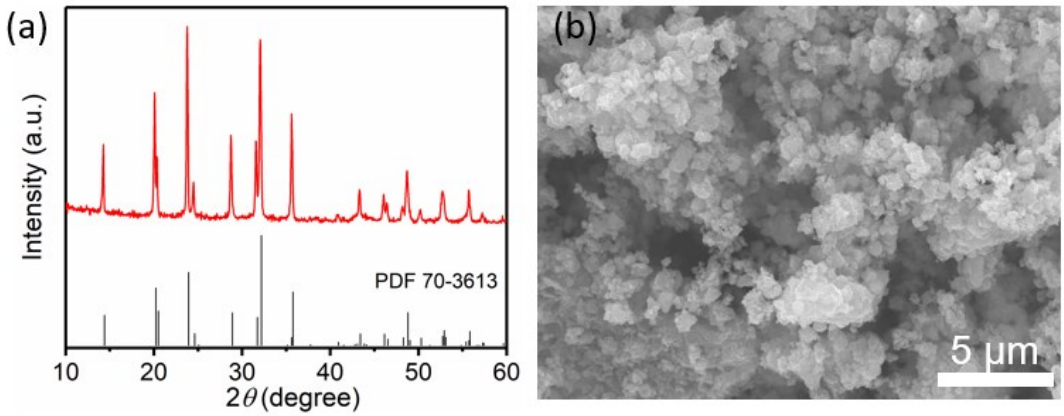

Figure S10. (a) XRD pattern and (b) SEM image of NVP cathode.

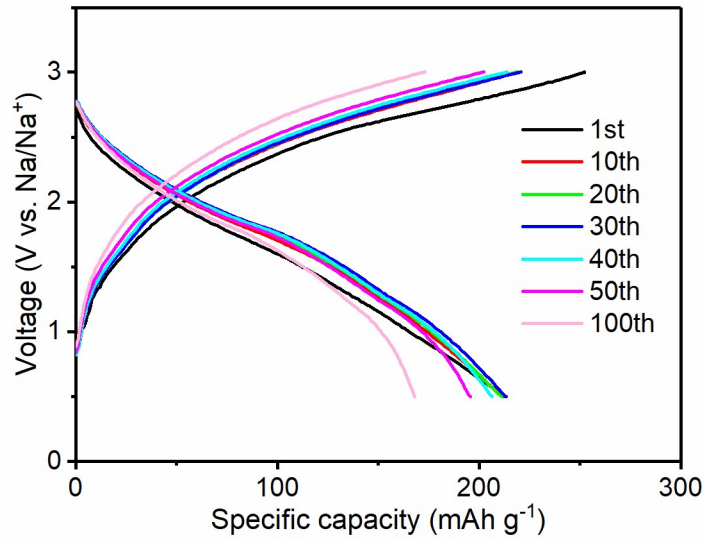

Figure S11. Charge/discharge curves of the DP-MoS_2//NVP full cell at a current density of 0.5 A g^{-1}.

Table S1. Impedance parameters predicted from the Nyquist plots using the equivalent circuit shown in Figure S7.

Electrode	DP-MoS_2	2H-MoS_2
R_o (Ω)	18.9	22.3
R_f (Ω)	3.0	5.1
R_{ct} (Ω)	13.8	31.3

Table S2. Comparison of the electrochemical performance of published SIB anode against the current work

Material	Preparation method	Electrochemical performance		Ref.
		Cyclic performance	Rate performance	
DP-MoS_2	Solvothermal	220 mAh g^{-1} at 2A g^{-1} after 500 cycles	255 mAh g^{-1} at 1.0 A g^{-1}; 220 mAh g^{-1} at 2.0 A g^{-1}	Current work
1T MoS_2/GF	Solvothermal	313 mAh g^{-1} at 0.05 A g^{-1} after 200 cycles	208 mAh g^{-1} at 1.0 A g^{-1}; 175 mAh g^{-1} at 2.0 A g^{-1}	S1
1T-MoS_2	Li^+ intercalation assisted exfoliation	324 mAh g^{-1} at 1.0 A g^{-1} after 200 cycles	301 mAh g^{-1} at 1.0 A g^{-1}; 253 mAh g^{-1} at 2.0A g^{-1}	S2
MXene	HF etching	~140 mAh g^{-1} at 0.02 A g^{-1} after 100 cycles	113 mAh g^{-1} at 1.0 A g^{-1}; 90 mAh g^{-1} at 2.0 A g^{-1}	S3
Expanded graphite	Two-step oxidation-reduction	~180 mAh g^{-1} at 0.1 A g^{-1}	184 mAh g^{-1} at 0.1 mA g^{-1}; 91 mAh g^{-1} at 0.2 mA g^{-1}	S4
MoS_2–PEO composite	Exfoliation-restacking	148 mAh g^{-1} at 0.05 A g^{-1} after 70 cycles	127 mAh g^{-1} at 0.5 A g^{-1}; 112 mAh g^{-1} at 1.0A g^{-1}	S5
MoS_2/C	Hydrothermal and calcination	~120 mAh g^{-1} at 1.0 A g^{-1} after 800 cycles	125 mAh g^{-1} at 1.0 A g^{-1}; 100 mAh g^{-1} at 2.0 A g^{-1}	S6
$MoS_{2x}Se_x$/GF	Hydrothermal and calcination	~165 mAh g^{-1} at 0.2 A g^{-1} after 500 cycles	180 mAh g^{-1} at 1.0 A g^{-1}; 175 mAh g^{-1} at 2.0 A g^{-1}	S7
VO-MoS_2/N-RGO	Solvothermal	245 mAh g^{-1} at 1.0 A g^{-1} after 1300 cycles	248 mAh g^{-1} at 1.0 A g^{-1}; 243 mAh g^{-1} at 2.0 A g^{-1}	S8

References

[S1] X. Geng, Y. Jiao, Y. Han, A. Mukhopadhyay, L. Yang, and H. Zhu, *Adv. Funct. Mater.*, 2017, **27**, 1702998.

[S2] D. Sun, D. Huang, H. Wang, G.-L. Xu, X. Zhang, R. Zhang, Y. Tang, D. A. EI-Hady, W. Alshitari, and A. S. AL-Bogami, *Nano Energy*, 2019, **61**, 361-369.

[S3] X. Wang, S. Kajiyama, H. Iinuma, E. Hosono, S. Oro, I. Moriguchi, M. Okubo, and A. Yamada, *Nat. Commun.*, 2015, **6**, 6544.

[S4] Y. Wen, K. He, Y. Zhu, F. Han, Y. Xu, I. Matsuda, Y. Ishii, J. Cumings, and C. Wang, *Nat. Commun.*, 2014, **5**, 4033.

[S5] Y. Li, Y. Liang, F. C. Robles Hernandez, H. Deog Yoo, Q. An, and Y. Yao, *Nano Energy*, 2015, **15**, 453-461.

[S6] R. Wang, S. Wang, X. Peng, Y. Zhang, D. Jin, P. K. Chu, and L. Zhang, *ACS Appl. Mater. Interfaces*., 2017, **9**, 32745-32755

[S7] G. Jia, D. Chao, N. H. Tiep, Z. Zhang, and H. J. Fan, *Energy Storage Mater.*, 2018, **14**, 136-142.

[S8] P. Li, J. Y. Jeong, B. Jin, K. Zhang, and J. H. Park, *Adv. Energy Mater.*, 2018, **8**, 1703300.