

Supporting Information

General Preparation of Three-dimensional Porous Metal Oxide Foams Coated with Nitrogen-doped Carbon for Enhanced Lithium Storage

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KEYWORDS. Porous structure · metal oxide foam · nitrogen-doped carbon · lithium storage · surfactant

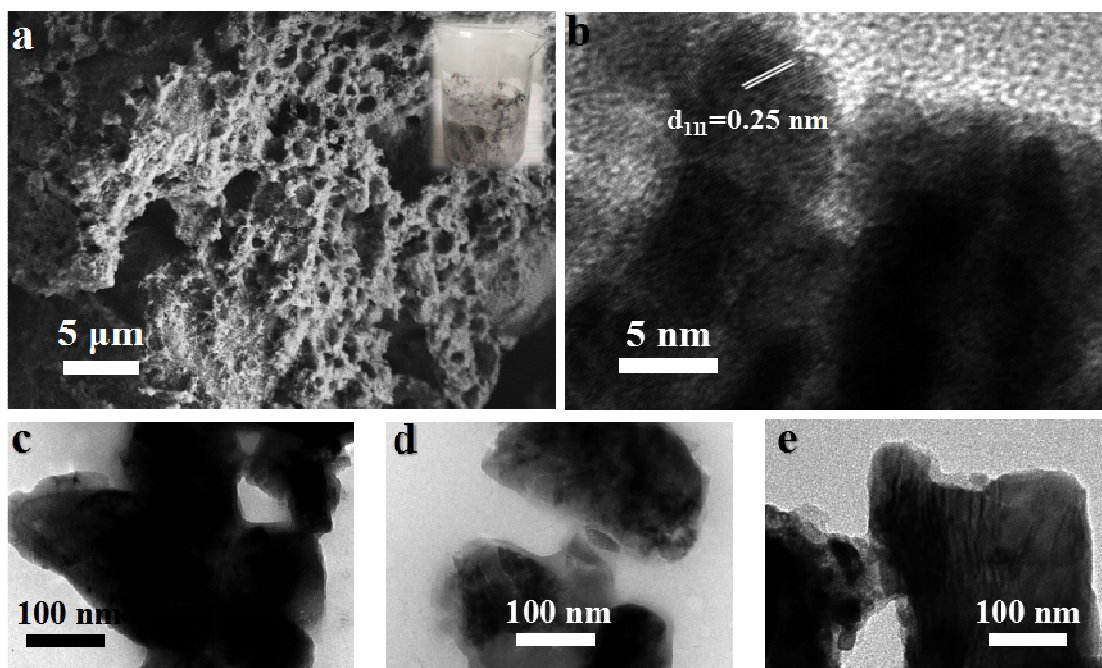


Figure S1. SEM images (a) and HRTEM images (b) of the MnO@N-C foam. Inset is the digital photo image of MnO₂ foam. The exposed lattice fringes (b) exhibit a spacing of 0.25 nm, corresponding to the (111) plane of MnO. TEM images of MoO₂@N-C (c), VO₂@N-C (d), and MnO@N-C (e).

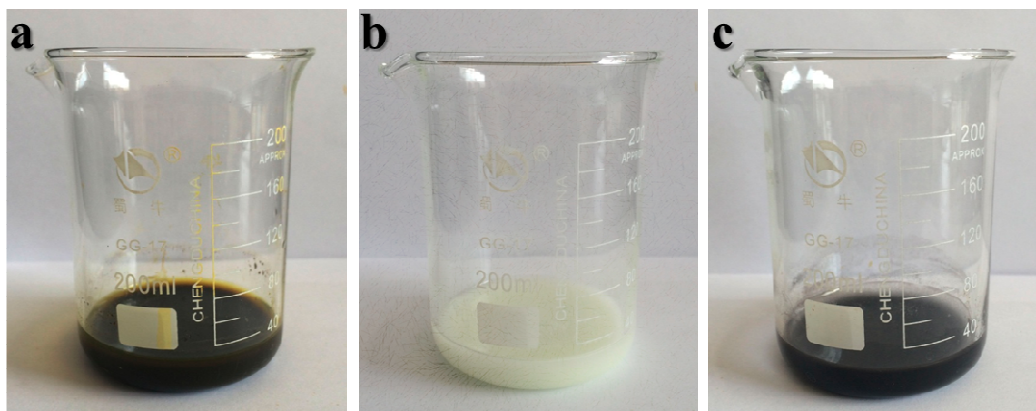


Figure S2. Digital photo images of (a) V_2O_5 , (b) MoO_3 , and (c) MnO_2 synthesized without the addition of HDA. It can be seen that metal oxide foams cannot be formed in the absence of surfactant.

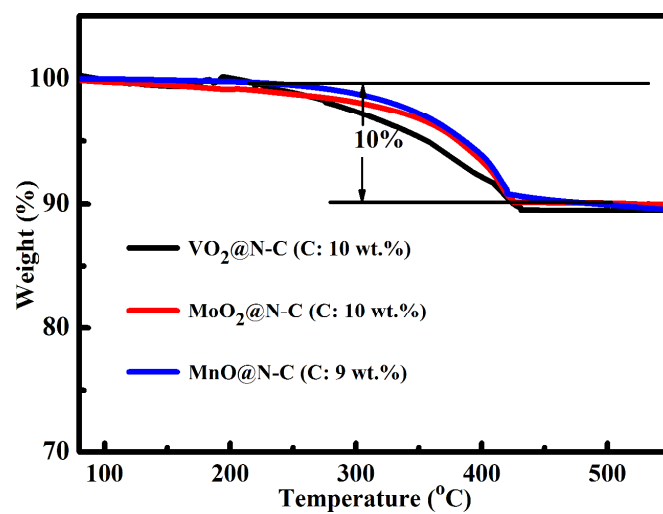


Figure S3. Thermal gravimetric analysis for VO₂@N-C, MoO₂@N-C and MnO@N-C.

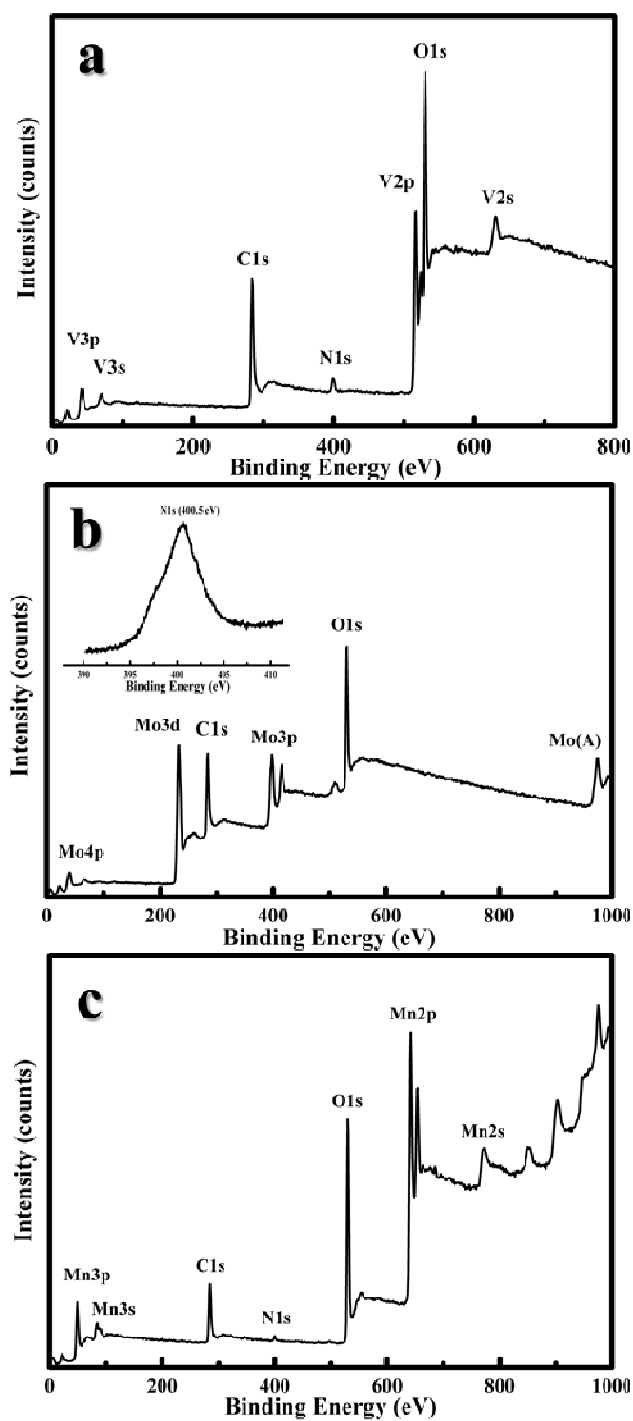


Figure S4. XPS survey spectra of VO₂@N-C (a), MoO₂@N-C (b) and MnO@N-C (c).

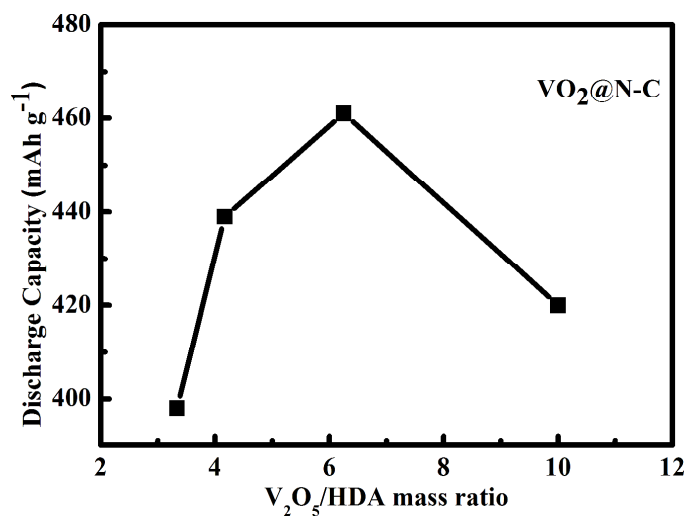


Figure S5. Capacities calculated from the discharge curves as a function of V₂O₅/HDA mass ratio at 30 mA g⁻¹.

To optimize the capacity performance, the VO₂@N-C samples were prepared by changing the mass ratio of vanadium oxide to HDA. It can be seen that the maximal capacity is achieved at the ratio of 6.25.

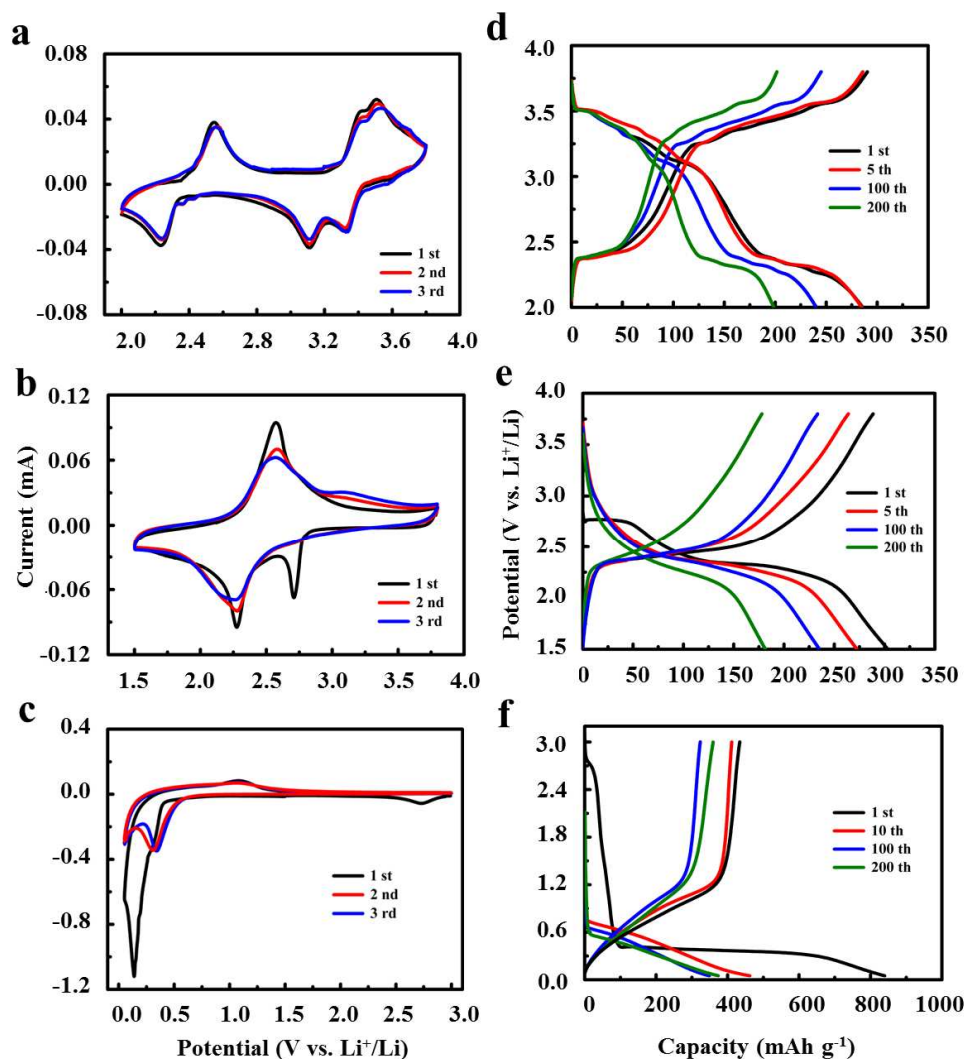


Figure S6. Cyclic voltammogram curves of (a) V₂O₅, (b) MoO₃, and (c) MnO₂ at a scan rate of 0.1 mV s⁻¹. Galvanostatic charge/discharge curves (d) V₂O₅, (e) MoO₃, and (f) MnO₂ foam materials (for V₂O₅ and MoO₃, the current density: 30 mA g⁻¹, for MnO₂ current density: 100 mA g⁻¹).

The CV curves of the as-prepared MoO₃ foam show the substantial variation of redox peaks in comparison with the initial cycle. Typically, the absence of the peak at around 2.75 V due to the irreversible lithium insertion suggests the phase transformation to a favorable one with the highly reversible redox peaks at 2.26/2.57 V in the subsequent cycles. In good agreement with the CV curves, the initial discharge curve with two plateau regions gives a capacity of as high as 302 mA h g⁻¹.

It can be seen that the discharge and charge plateaus generally remain stable over the repeated cycles, indicating the good structural reversibility.

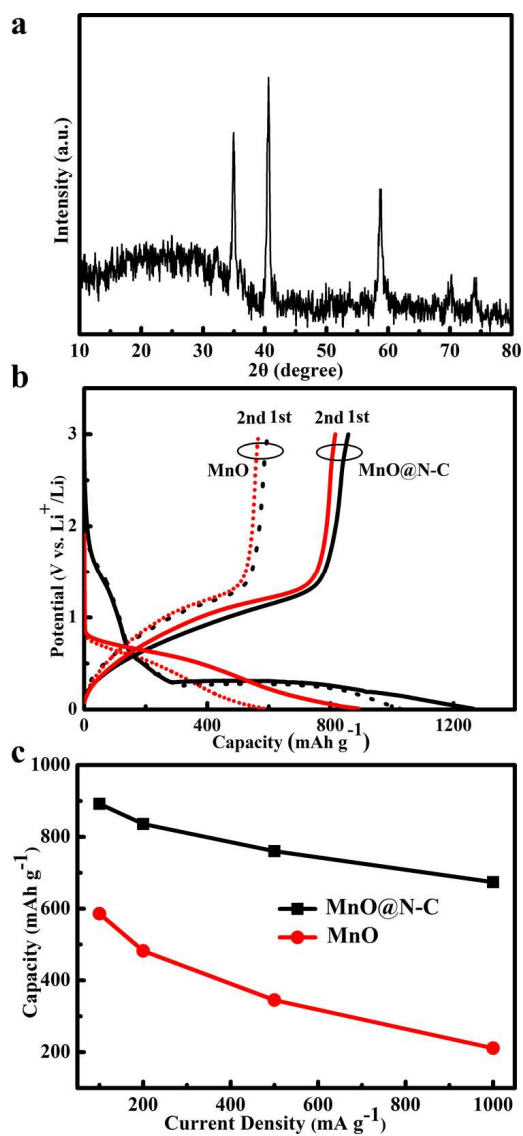


Figure S7. XRD pattern of MnO (a). Galvanostatic discharge/charge curves of MnO@N-C and MnO (b). Capacity calculated from the charge/discharge curves at various current densities (c).

To demonstrate of the crucial role of carbon networks for Li storage, pure MnO foam was prepared by reduction of MnO_2 foam in the presence of hydrogen (7 vol%). The XRD pattern (Figure S7a) can be indexed to the face-centered cubic MnO (JCPDS no. 07-0230). It can be seen that the performance of MnO can be enhanced in the presence of carbon coating.

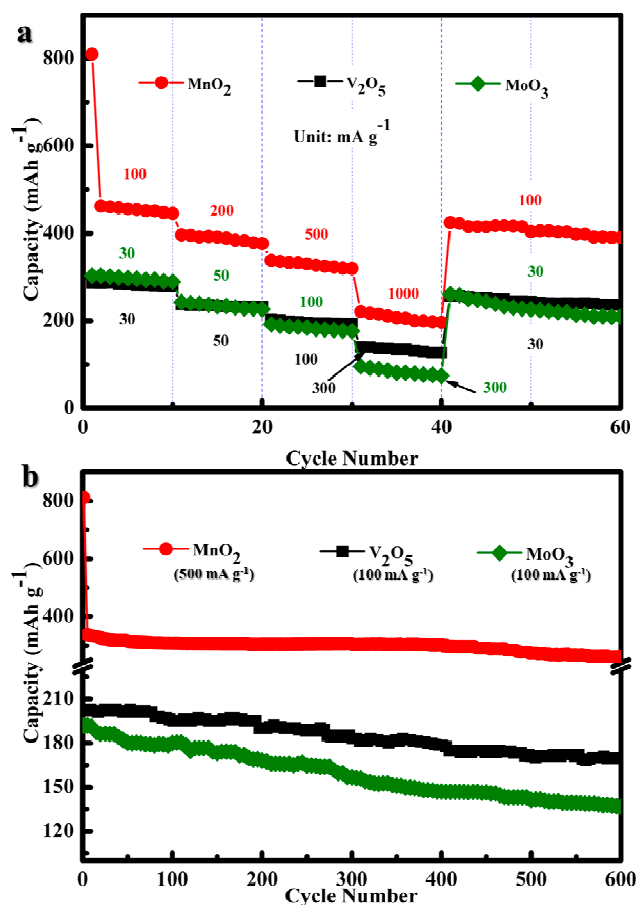


Figure S8. Rate (a) and cycling performances (b) of different materials.

The rate performance of the electrode materials was tested by varying the current density. When the current was restored to the initial current density after 40 cycles, around 89, 86, and 91% of the initial specific capacity for V₂O₅, MoO₃, and MnO₂ can be recovered. When the current density was increased by 10 times (30 to 300 mA g⁻¹ or 100 to 1000 mA g⁻¹), the capacity retention of V₂O₅, MoO₃, and MnO₂ were about 71, 63, and 72%, exhibiting a good high-rate performance. The reversible capacity of V₂O₅, MoO₃, and MnO₂ foams are 166.6, 135.9, and 257.5 mAh g⁻¹ after 600 cycles, with the capacity retention of around 82.5, 70.8, and 76.1% (for the second cycle), respectively.

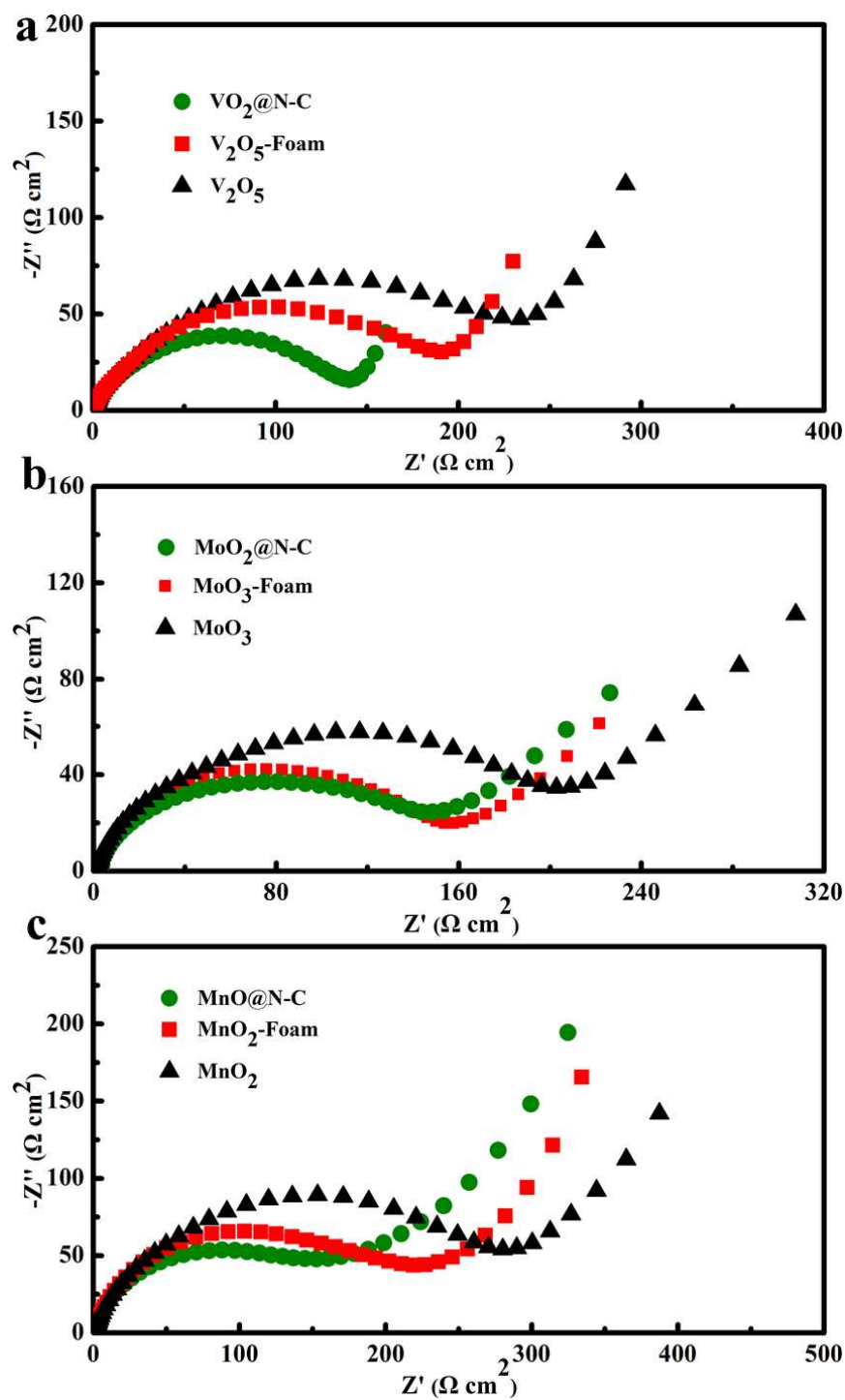


Figure S9. Nyquist plots of different electrode materials. (a) V-based metal oxide, (b) Mo-based metal oxide, and (c) Mn-based metal oxide materials.

Table S1. The capacities of metal oxides@N-C at various current densities.

Sample	Current density (mA g ⁻¹)	Capacity (mAh g ⁻¹)
VO ₂ @N-C	30	461
	50	437
	100	402
	200	369
	500	332.8
	1000	269
MoO ₂ @N-C	100	856 ^{1st} /613 ^{2nd}
	200	565
	500	520.5
	1000	465
MnO@N-C	100	1265 ^{1st} /892 ^{2nd}
	200	836
	500	760
	1000	674

Table S2. The comparison of vanadium oxides as active materials for Li storage.

Materials	Potential range (V vs. Li⁺/Li)	Capacity (mAh g⁻¹)/ current density (mA g⁻¹)	Cycling stability/cycles	Citation
VO ₂ /C	2-3	219/50	85%/100 (100 mA g ⁻¹)	S1
V ₂ O ₅	2-4	275/294	88.4%/200 (294 mA g ⁻¹)	S2
Microspheres				
N-G-VO ₂	1.5-4	418/50	60%/50 (50 mA g ⁻¹)	S3
V ₂ O ₅	2-4	256/100	89%/50 (100 mA g ⁻¹)	S4
V ₂ O ₅ /C	2-4	297/1000	97.3%/50 (1 A g ⁻¹)	S5
V ₂ O ₅	2.75-4	427/7.5	30%/20 (7.5 mA g ⁻¹)	S6
VO ₂ -Graphene	1.5-3.5	415/196	93%/1000 (37.2 A g ⁻¹)	S7
VO ₂ Hollow	2-3	203/100	90%/100 (100 mA g ⁻¹)	S8
Microspheres				
V ₂ O ₅ Foam		237/50	82.5%/600(100 mA g ⁻¹)	This work
VO ₂ @C Foam	2-3.8	438/50	87.5%/600 (100 mA g ⁻¹)	

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