ADVANCED ENERGY MATERIALS

Supporting Information

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Novel $K_3V_2(PO_4)_3$/C Bundled Nanowires as Superior Sodium-Ion Battery Electrode with Ultrahigh Cycling Stability

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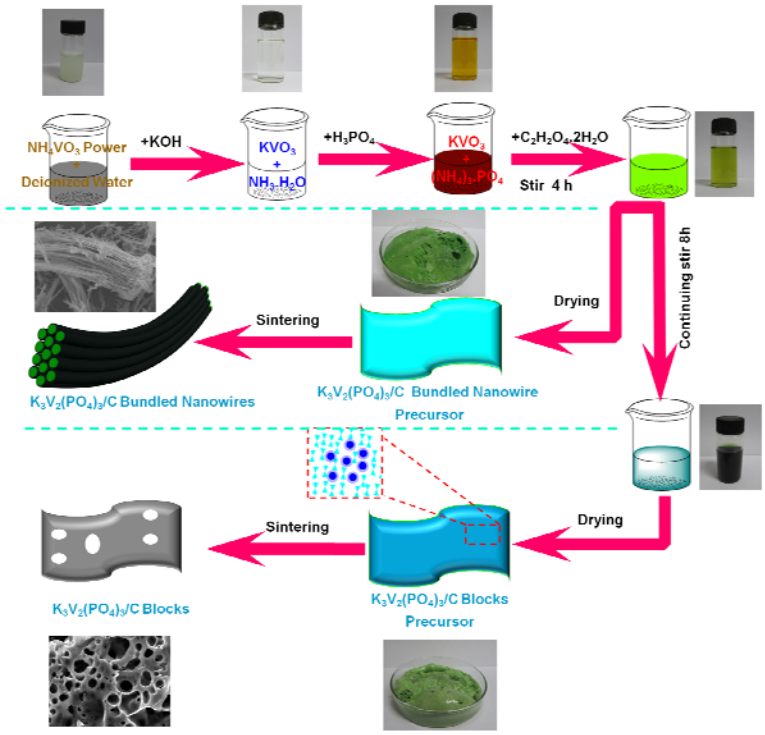

Figure S1. Schematic illustration for the fabrication process and proposed formation mechanism of the $K_3V_2(PO_4)_3$/C bundled nanowires and blocks.

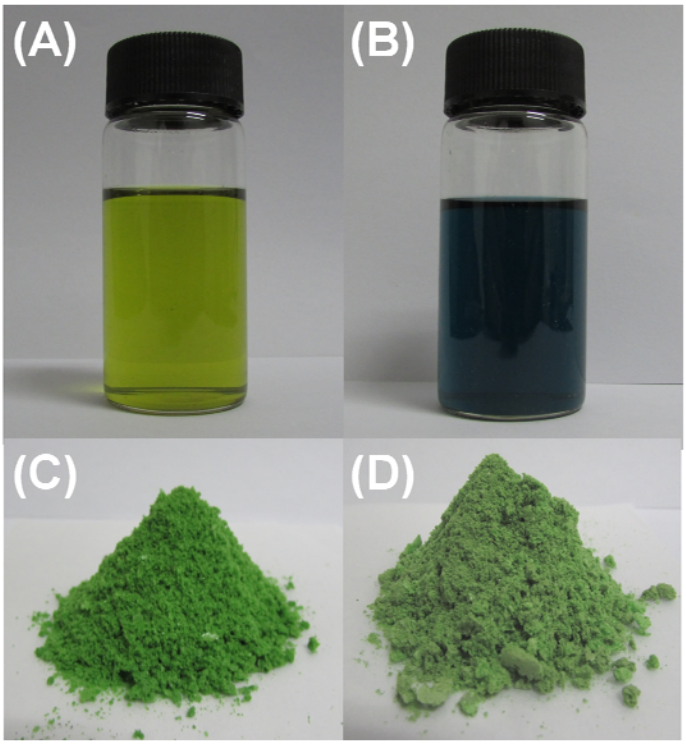

Figure S2. The photos for solution precursor of $K_3V_2(PO_4)_3$ bundled nanowires (A) and blocks (B). The photos for dried precursor of $K_3V_2(PO_4)_3$ bundled nanowires (C) and blocks (D).

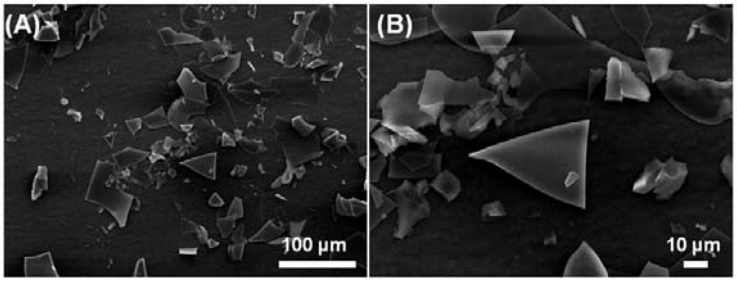

Figure S3. (A, B) SEM images of the $K_3V_2(PO_4)_3$ precursor baked at 180 °C for 2h.

Table S1. The ICP test results of the $K_3V_2(PO_4)_3$/C bundled nanowires.

Temperature	K: V: P
700 °C	**3.0 : 2.04 : 2.97**
800°C	**3.0 : 2.06 : 3.04**
900 °C	**3.0 : 1.99 : 3.08**

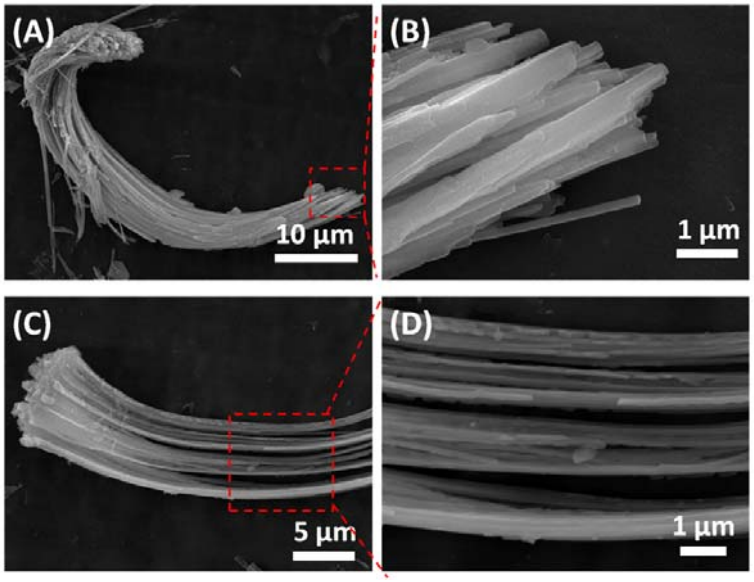

Figure S4. SEM images of the $K_3V_2(PO_4)_3$/C bundled nanowires sintered at 800 °C.

Table S2. The ICP test results of the $K_3V_2(PO_4)_3$/C blocks sintered at 800 °C.

	Temperature	**K: V: P**
Blocks	800 ºC	3.00 : 2.03 : 3.01

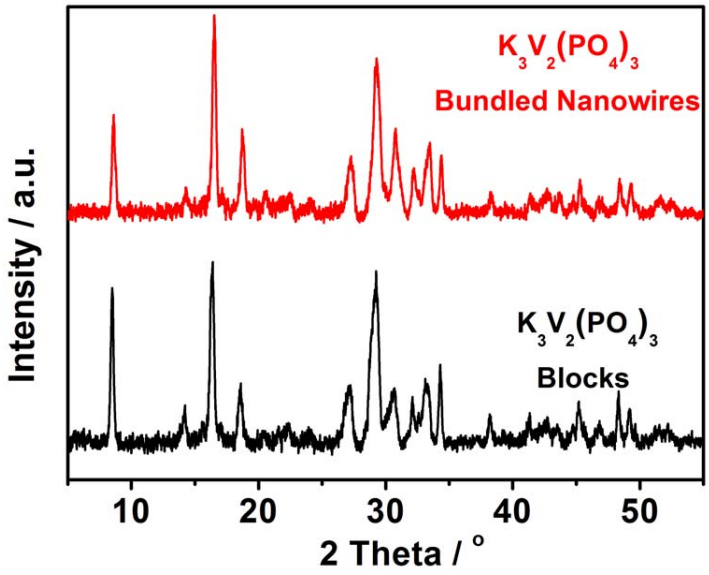

Figure S5. XRD patterns of the $K_3V_2(PO_4)_3$/C bundled nanowires and blocks sintered at 800 °C.

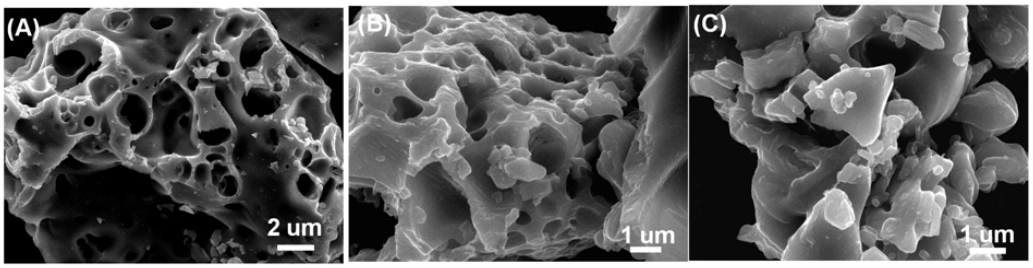

Figure S6. (A-C) SEM images of the $K_3V_2(PO_4)_3$/C blocks sintered at 800 °C.

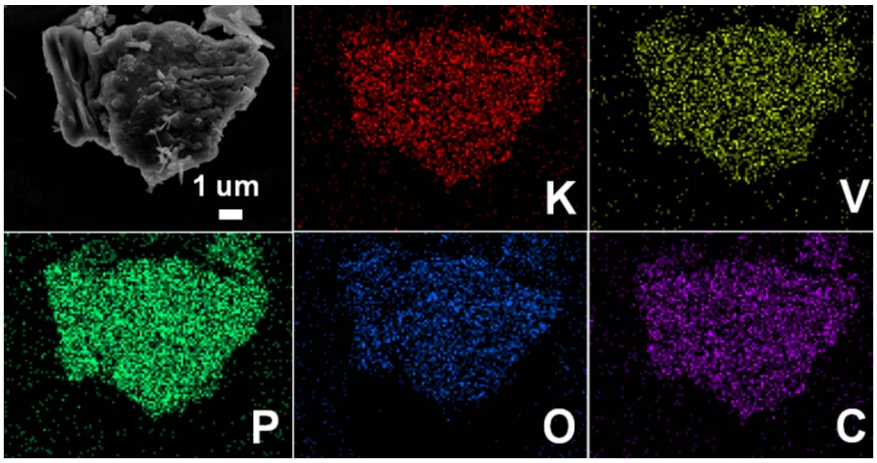

Figure S7. Elemental mapping images of the $K_3V_2(PO_4)_3$/C blocks sintered at 800 °C.

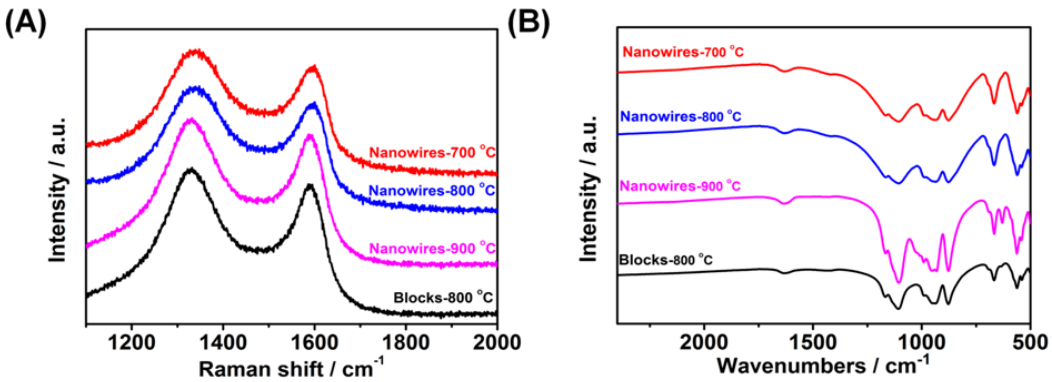

Figure S8. Raman spectra (A) and FT-IR spectra (B) of the $K_3V_2(PO_4)_3$/C samples.

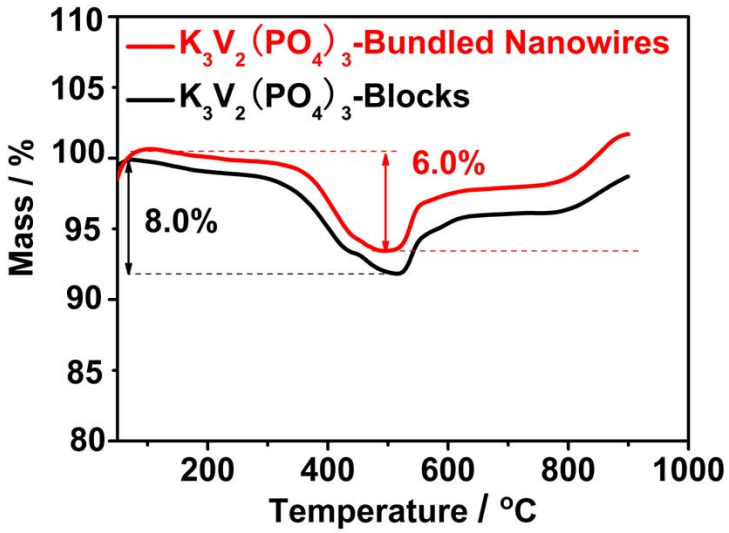

Figure S9. TGA curves of the $K_3V_2(PO_4)_3$/C bundled nanowires and blocks sintered at 800 °C.

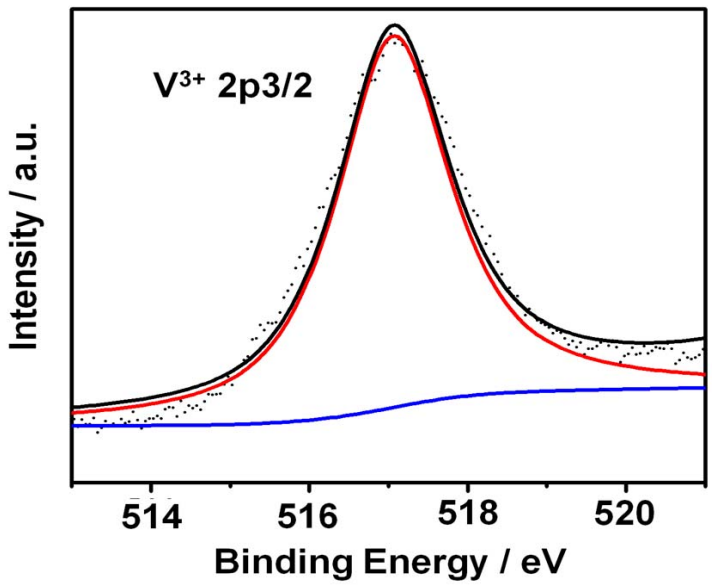

Figure S10. XPS spectra of the V 2p3/2 core level region of the $K_3V_2(PO_4)_3$/C bundled nanowires.

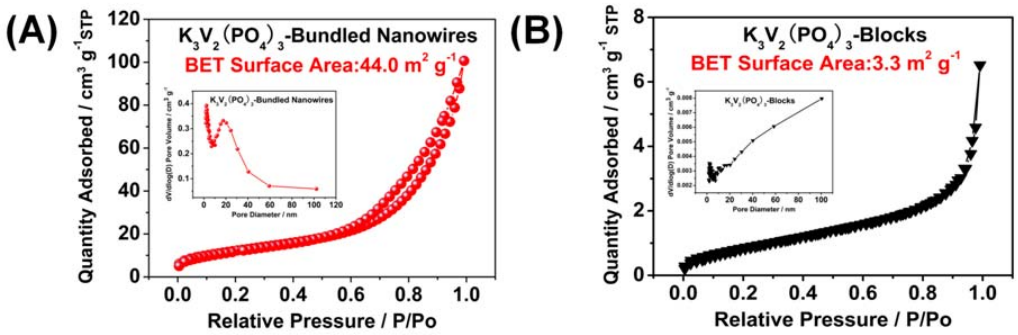

Figure S11. The nitrogen adsorption-desorption isotherms of the $K_3V_2(PO_4)_3$/C bundled nanowires (A) and blocks (B). The pore size distribution of the $K_3V_2(PO_4)_3$/C bundled nanowires (inset of A) and blocks (inset of B).

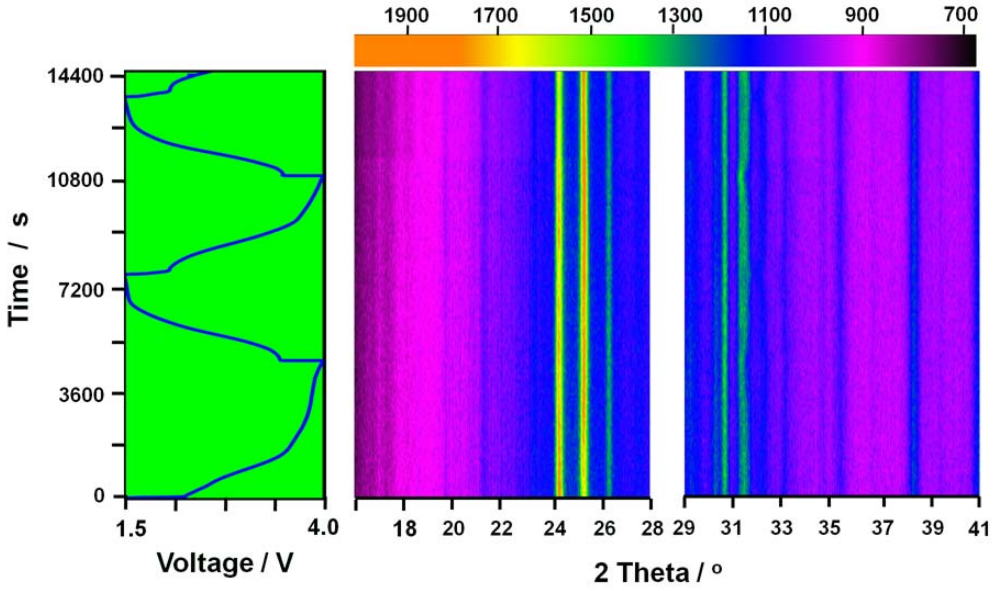

Figure S12. *In situ* X-ray diffraction patterns during galvanostatic charge and discharge of the $K_3V_2(PO_4)_3$/C bundled nanowires at 100 mA g^{-1}.

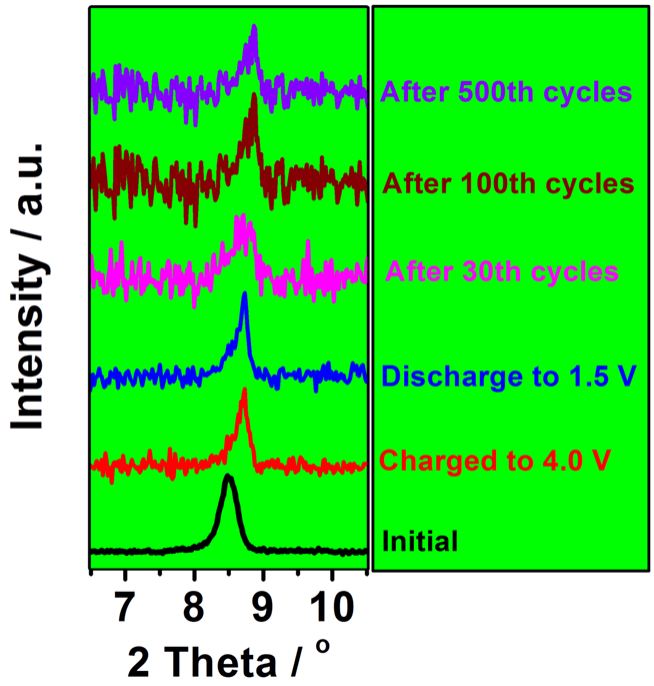

Figure S13. *Ex situ* XRD patterns of the $K_3V_2(PO_4)_3$/C bundled nanowires.

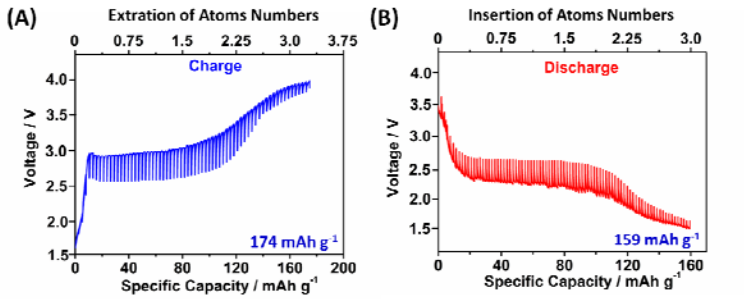

Figure S14. The galvanostatic intermittent titration technique (GITT) for $K_3V_2(PO_4)_3$ bundled nanowires.

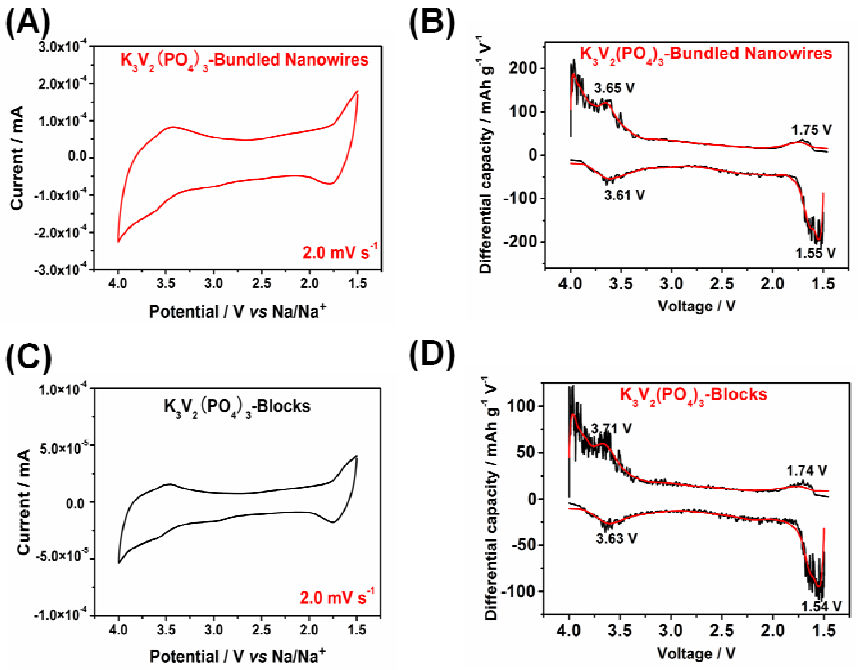

Figure S15. Cyclic voltammograms (CV) and corresponding dq/dv plots of the $K_3V_2(PO_4)_3$/C bundled nanowires (A and B) and blocks (C and D) at a scan rate of 2.0 mV s^{-1} in the electrochemical window of 1.5 to 4.0 V *vs.* Na/Na^+.

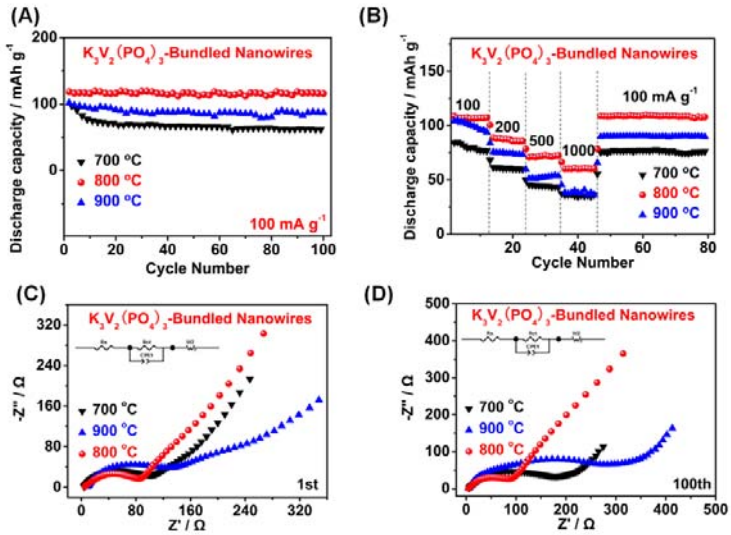

Figure S16. (A) Cycling performance of the three $K_3V_2(PO_4)_3$/C bundled nanowires at 100 mA g^{-1} in the electrochemical window of 1.5 – 4.0 V. (B) Rate performance of the three samples. (C, D) AC impedance plots of the three samples before and after 100^{th} cycles (from 0.1Hz to 100 kHz).

Table S3. The *ex situ* ICP test results of the $K_3V_2(PO_4)_3$/C bundled nanowires.

	K: Na: V
Before cycle	**3.02 : 0.81 : 2.00**
Charge to 4.0 V	**1.01 : 0.01 : 2.00**
Discharge to 1.5 V	**1.16 : 2.10 : 2.00**
After 2 cycles	**1.07 : 2.26 : 2.00**
After 30 cycles	**1.02 : 2.25 : 2.00**
After 100 cycles	**1.01 :2.24 : 2.00**
After 500 cycles	**1.02 : 2.25 : 2.00**

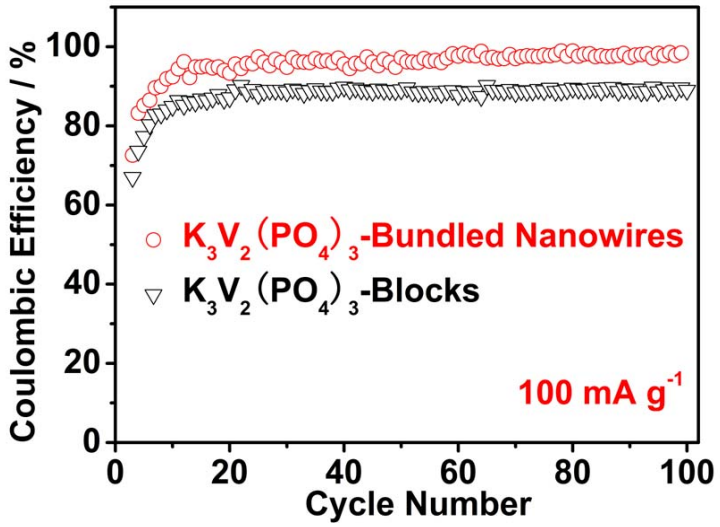

Figure S17. Columbic efficiency of the $K_3V_2(PO_4)_3$/C bundled nanowires and blocks at 100 mA g^{-1}.

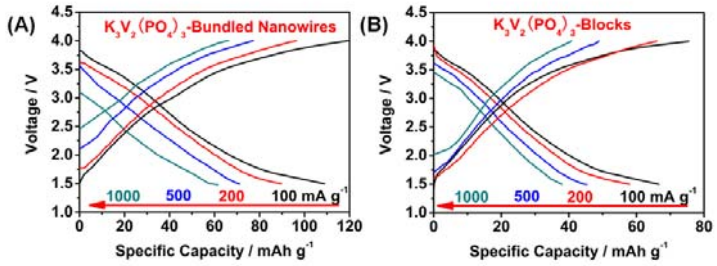

Figure S18. Charge-discharge curves of the $K_3V_2(PO_4)_3$/C bundled nanowires (A) and blocks (B), at various current densities from 100 to 1,000 mA g^{-1}.

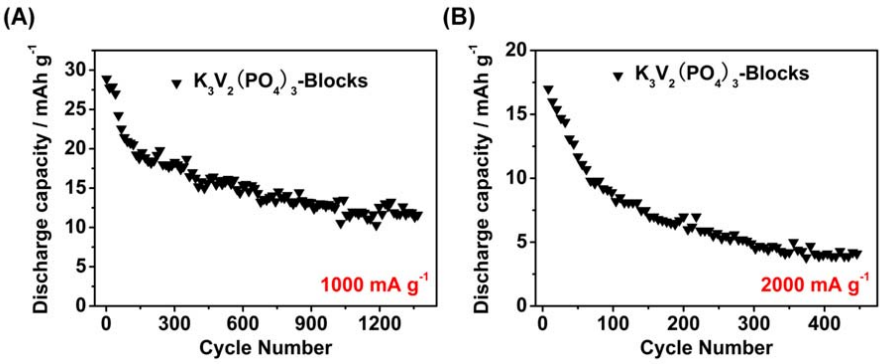

Figure S19. The cycle performances of the $K_3V_2(PO_4)_3$/C blocks at 1,000 (A) and 2,000 mA g^{-1} (B).

Table S4. Comparison of the electrochemical performance of phosphate based electrodes for sodium-ion batteries.

	Material	Current density (mA g^{-1})	Initial capacity (mAh g^{-1})	Cycle numbers	Per cycle decay (%)	Referance
1	**$K_3V_2(PO_4)_3$**	100	119	100	0.0213	**Our work**
		500	71.0	1,000	0.0026	
		1,000	66.0	2,000	0.0023	
		2,000	45.7	2,000	0.0016	
2		588	100.6	200	0.0015	**S1**
3		1,176	103	1,000	0.0029	**S2**
4		4,700	60	30,000	0.013	**S3**
5	**$Na_3V_2(PO_4)_3$**	1,176	86	300	0.023	**S4**
6		11.76	109	80	0.088	**S5**
7		588	95	700	0.0056	**S6**
8		5.88	50	50	0.146	**S7**

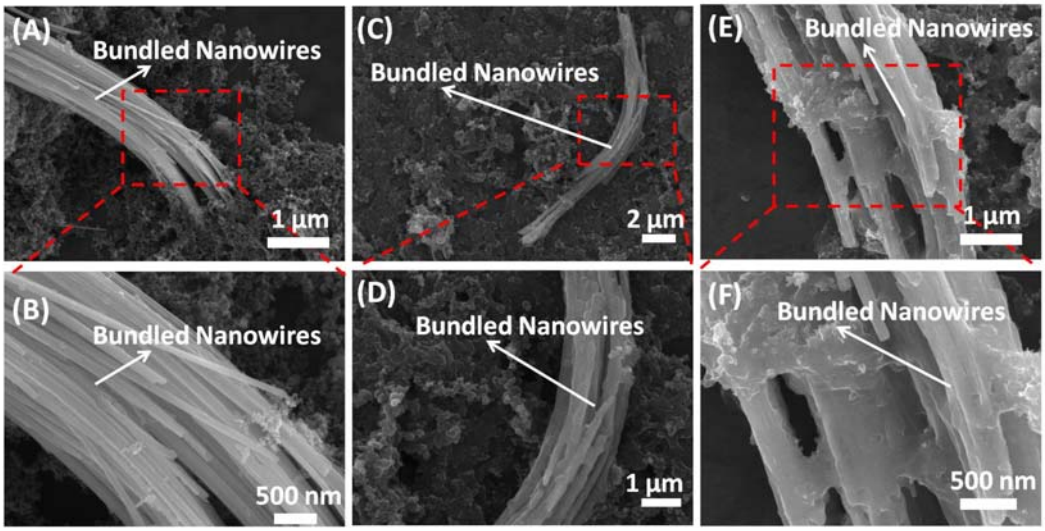

Figure S20. SEM images of the $K_3V_2(PO_4)_3$/C bundled nanowires before cycling (A, B), after 100 cycles at 100 mA g^{-1} (C, D), and after 2,000 cycles at 1,000 mA g^{-1} (E, F).

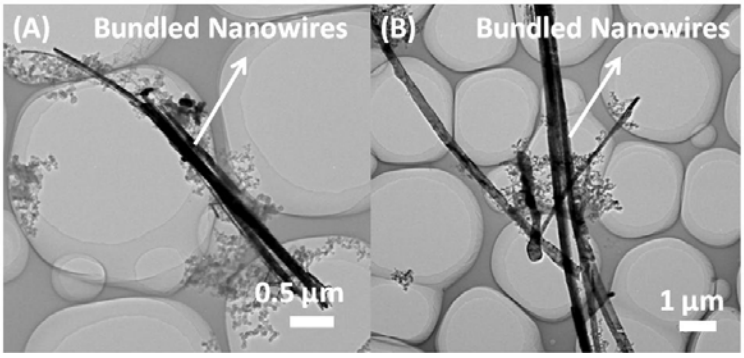

Figure S21. (A, B) TEM images of the $K_3V_2(PO_4)_3$/C bundled nanowires after 100 cycles at 100 mA g^{-1}.

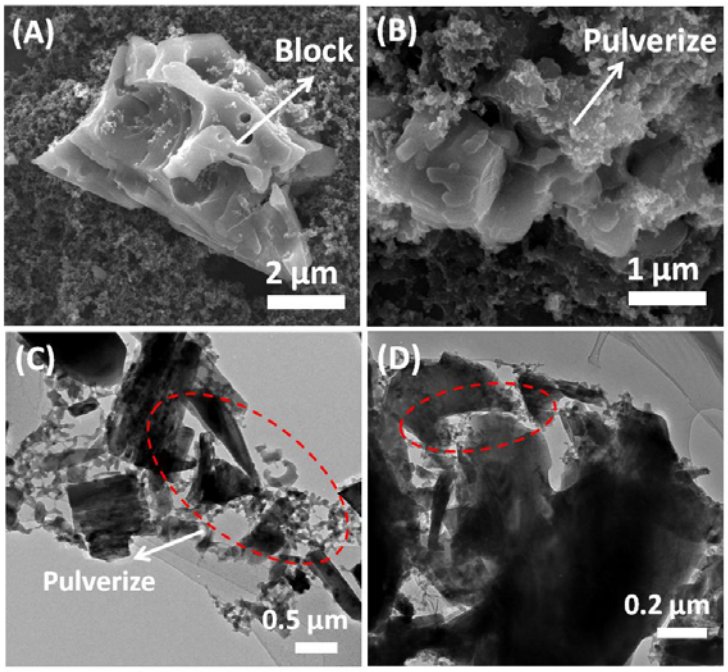

Figure S22. SEM images of the $K_3V_2(PO_4)_3$/C blocks before cycling (A) and after 100 cycles at 100 mA g^{-1} (B). TEM images of the $K_3V_2(PO_4)_3$/C blocks after 100 cycles at 100 mA g^{-1} (C, D).

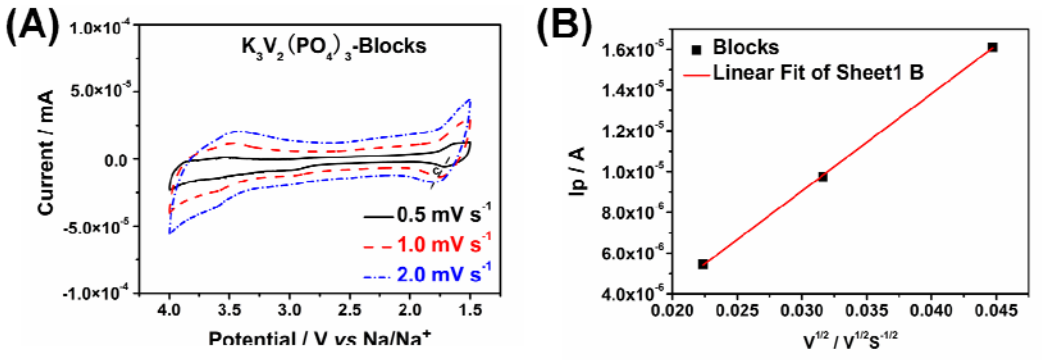

Figure S23. (A) CV curves of the $K_3V_2(PO_4)_3$/C blocks in the electrochemical window of 1.5 – 4.0 V at different scan rates. (B) Cycling response of the $K_3V_2(PO_4)_3$/C blocks analyzed by the Randles-Sevick equation.

Reference

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