Bismuth Nanorod Networks Confined in Robust Carbon Matrix as

Long-Cycling and High-Rate Potassium-Ion Battery Anodes

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Figure S1. Schematic illustration of the synthesis process of $Bi \in NS-C$.



Figure S2. (a) SEM image and (b) XRD pattern of Bi_2S_3 nanorods.



Figure S3. SEM elemental mapping image and EDX analysis of the Bi∈NS-C samples.



Figure S4. TG curve of $Bi \in NS-C$. The calculated content of Bi in the composite structure was based on the following equation:

 $Bi (wt\%) = \frac{molecular \ weight \ of \ Bi}{molecular \ weight \ of \ Bi_2O_3} \times final \ weight \ percent \ of \ Bi_2O_3$



Figure S5. Raman spectrum of the carbon matrix.



Figure S6. N₂ absorption-desorption isotherms of Bi \in NS-C.



Figure S7. High-resolution XPS spectra of (c) N 1s and (d) S 2p and Bi 4f.



Figure S8. Electrochemical performances of the N, S-doped carbon matrix: (a) rate capability, (b) and galvanostatic charge/discharge curves at the current densities from 0.2 to 6 A g⁻¹ and (c) cycling stability at 1 A g⁻¹.



Figure S9. The electrochemical performances of $Bi \in NS-C$ electrodes without adding conventional carbon additives (acetylene black): (a) rate performance and cycling

stability and (b) galvanostatic charge/discharge curves at different scan rates.



Figure S10. TEM images of the PPy-shelled Bi nanorods after annealing at 550 $^\circ\mathbb{C}$.



Figure S11. XRD pattern of the PPy-shelled Bi_2S_3 after annealing.



Figure S12. CV curves of (a) Bi powders and (b) $Bi \in NS-C$ at different scan rates, plots of log (peak current) *vs* log (scan rates) of (c) Bi powders and (d) $Bi \in NS-C$, and calculated b values for (e) Bi powders and (f) $Bi \in NS-C$.



Figure S13. Comparison of the GITT profiles of (a) discharging and (b) charging processes. The K^+ diffusion coefficients obtained in (c) discharging and (d) charging processes.

The diffusion coefficient of K⁺ ions was measured by using galvanostatic intermittent titration technique (GITT), and the diffusion coefficient was calculated based on the following equation:

$$D_{K^{+}} = \frac{4}{\pi\tau} \left(\frac{m_B V_M}{M_B A} \right) \left(\frac{\Delta E_S}{\Delta E_{\tau}} \right)$$

where A is the geometric area of electrode, M_B , V_M , and m_B are molecular weight, molar volume, and mass of electrode material, respectively. ΔE_S and $\Delta E\tau$ represent the changes of quasi-equilibrium potential and battery voltage, respectively.



Figure S14. Enlarged plots of Coulombic efficiencies of Bi powders, Bi@C, and

 $Bi \in NS-C$ electrodes measured at 1 A g⁻¹.



Figure S15. SEM images of the pristine (a) Bi powders; (b) Bi@C and (c) $Bi \in NS-C$ electrodes.



Figure S16. (a) TEM image and (b) XRD pattern of the KMnHCFe.



Figure S17. Typical cyclic voltammogram curve of full KMnHCFe/Bi∈NS-C battery.

Samples	Electrochemical stability	Reference
Commercial Bi	\sim 97% capacity retention after 100 cycles at 0.4 A g $^{-1}$	31
Bi nanoparticle@C	91 mAh g $^{-1}$ (74.8% capacity retention) after 700 cycles at 1 A g $^{-1}$	34
Bi nanoparticles embedded in 3D graphene	164 mAh g ⁻¹ after 400 cycles at 1 A g ⁻¹	35
Porous Sb	318 mAh g $^{\rm 1}$ (62.35% capacity retention) after 50 cycles at 0.1 A g $^{\rm 1}$	28
Sb@C	247 mA h g $^{-1}$ after 600 cycles at 0.2 A g $^{-1}$	46
Sn_4P_3 @carbon fiber	160.7 mAh g $^{\rm 1}$ (\sim 53% capacity retention) after 1000 cycles at 0.5 A g $^{\rm 1}$	25
Sulfur-grafted hollow carbon spheres	\sim 150 mAh g^-1 (93% capacity retention) after 1000 cycles at 3 A g^-1	44
Hard–Soft composite carbon	200 mAh $g^{\rm -1}$ (93% capacity retention) at 0.279 A $g^{\rm -1}$ after 200 cycles	8
Mesoporous carbon	146.5 mAh g $^{\rm -1}$ (70% capacity retention) after 1000 cycles at 1 A g $^{\rm -1}$	47
Hierarchical carbon nanotube	210 mAh g $^{-1}$ (90% capacity retention) after 500 cycles at 0.1 A g $^{-1}$	48
VSe ₂ @C	${\sim}150$ mAh $g^{\text{-}1}$ (87.3% capacity retention) after 500 cycles at 2 A $g^{\text{-}1}$	11
Sb ₂ S ₃ /graphene	404 mAh g ⁻¹ after 200 cycles at 0.5 A g ⁻¹	49
MoSe ₂ @C	226 mAh g $^{-1}$ (83.5% capacity retention) after 1000 cycles at 1 A g $^{-1}$	21
SnS₂@rGO	205 mAh g $^{\rm -1}$ (73% capacity retention) after 300 cycles at 1 A g $^{\rm -1}$	50
CoSe₂@CNT	173 mAh g $^{\rm -1}$ (97% capacity retention) after 600 cycles at 2 A g $^{\rm -1}$	51
Titania sheets	\sim 75 mAh g $^{\rm -1}$ (70% capacity retention) after 1000 cycles at 1 A g $^{\rm -1}$	15
CuO nanoplates	206 mAh g ⁻¹ after 100 cycles at 1A g ⁻¹	16
Ti ₆ O ₁₁ @CNT	$\sim\!80$ mAh g^{-1} (76% capacity retention) over 500 cycles at 2 A g^{-1}	52
FeP@C nanoboxes	205 mAh g $^{-1}$ after 300 cycles at 0.1 A g $^{-1}$	53
This work	320 mAh g ⁻¹ (90% capacity retention) after 100 cycles at 0.2 A g ⁻¹ 285 mAh g ⁻¹ (91% capacity retention) after 1000 cycles at 5 A g ⁻¹	

 Table S1. Comparision of cycling stabilities of KIBs anodes.