Supplementary Information

Controllable formation of multilayered SnO_2@Fe_2O_3 sandwich cubes as high-performance anode for Li-ion batteries

Yi Zeng,[*,a] Jingze Luo,[a] Yanzhe Wang,[a] Liang Qiao,[b] Bo Zou[a] and Weitao Zheng[*,a]

a College of Materials Science and Engineering, Key Laboratory of Automobile Materials of Ministry of Educations (MOE), and State Key Laboratory of Superhard Materials, Jilin University, Changchun 130012, P.R. China

b College of Science, Changchun University, Changchun 130022, P.R. China

E-mail: zengyi@jlu.edu.cn, wtzheng@jlu.edu.cn;

Fax: +86-431-85168246; Tel: +86-431-85168246.

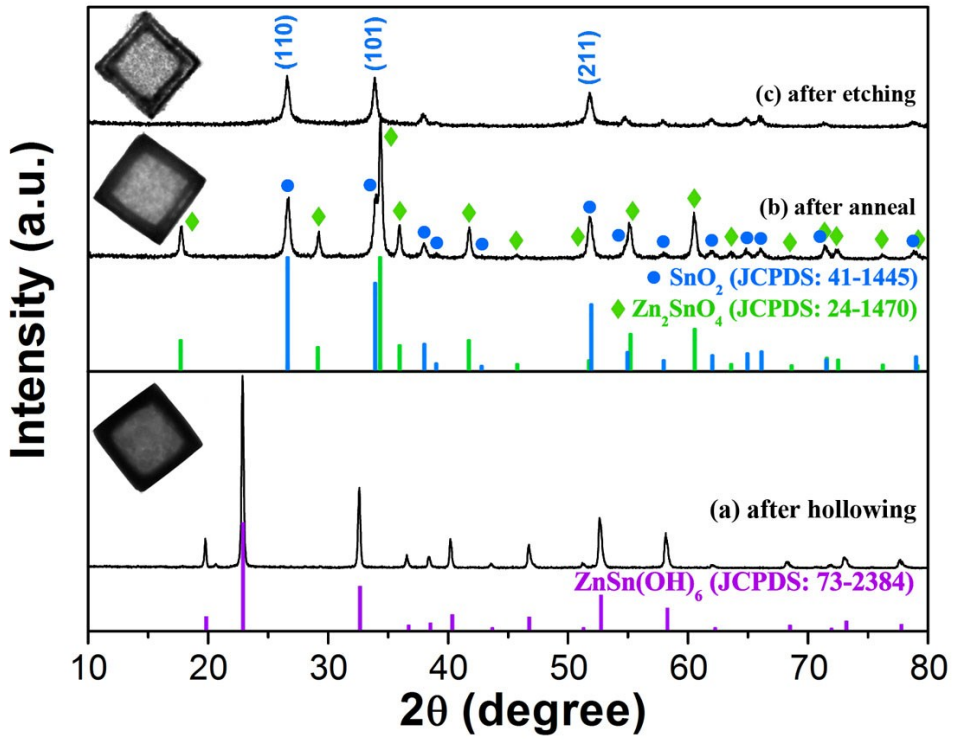

Figure S1. XRD patterns of the as-obtained products after (a) fast precipitation, (b) anneal, and (c) etching steps, respectively.

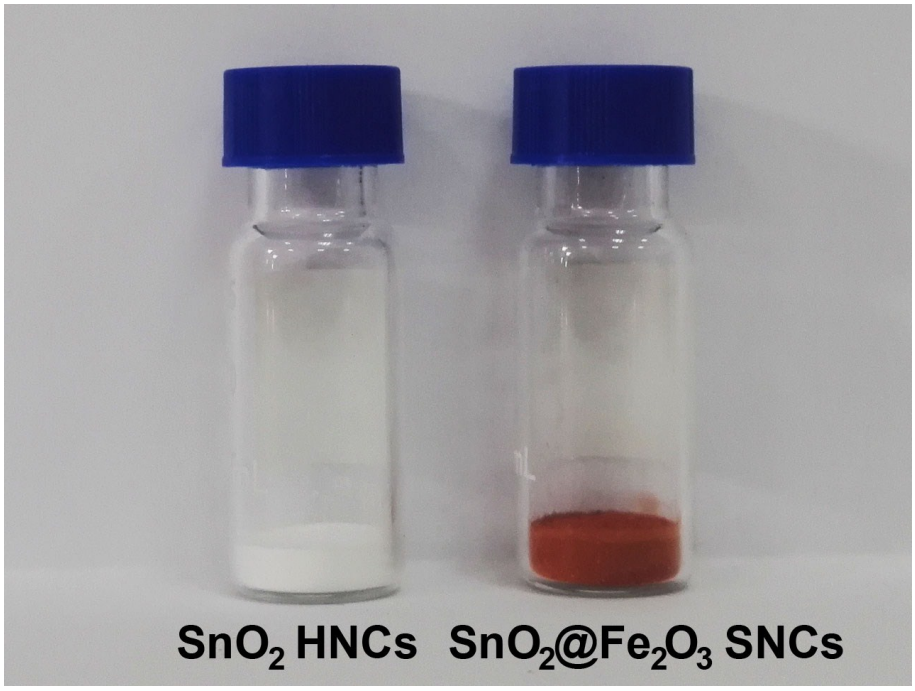

Figure S2. Digital photographs of (a) the pristine SnO_2 HNCs after the etching process and (b) final $SnO_2@Fe_2O_3$ SNCs.

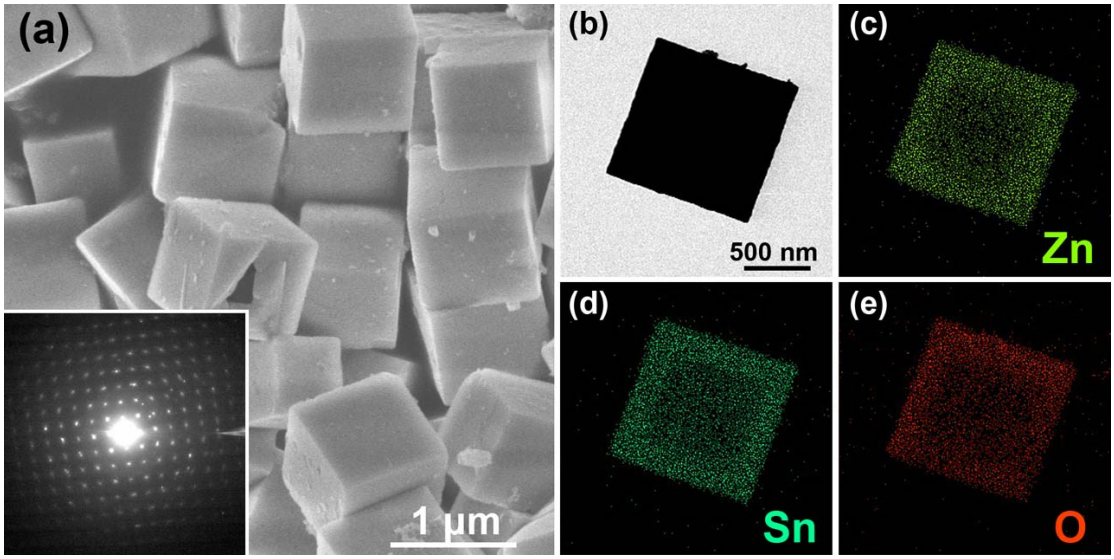

Figure S3. (a) Low-magnification FESEM image of the as-obtained ZHS single-shelled hollow precursor. (b-e) EDX mapping images of an individual ZHS single-shelled hollow cube. The inset of (a) is a typical SAED pattern taken from a ZHS cube.

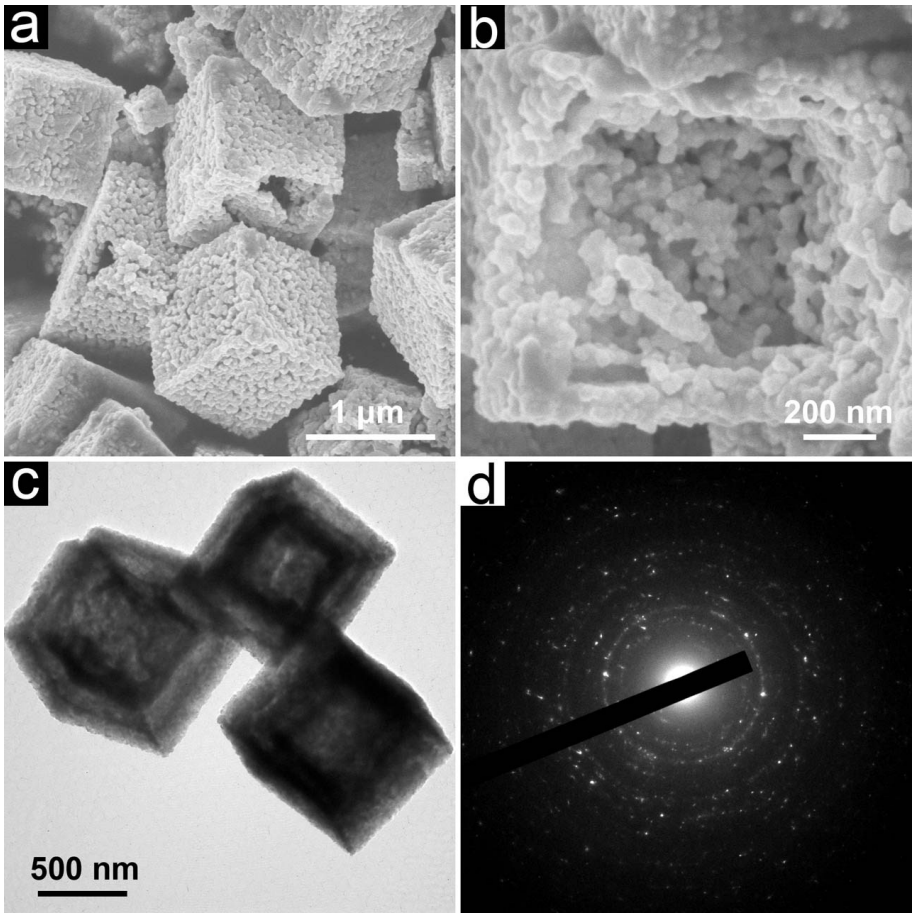

Figure S4. (a) Low-magnification FESEM and (c) TEM images of Zn_2SnO_4/SnO_2 double-shelled hollow cubes, (b) enlarged FESEM image of a broken Zn_2SnO_4/SnO_2 hollow cube, and (d) typical SAED pattern from a Zn_2SnO_4/SnO_2 hollow cube.

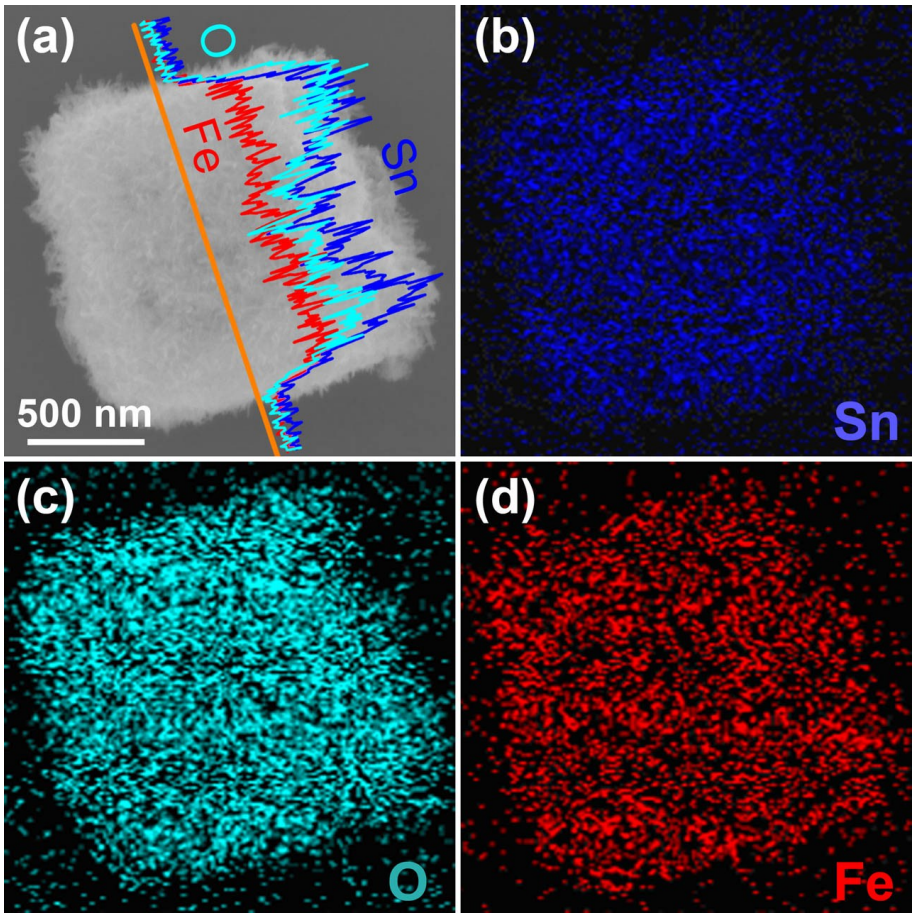

Figure S5. (a) FESEM image of single SnO_2@Fe_2O_3 particle, and (b-d) the corresponding elemental mapping showing the dispersion of Sn, O, and Fe elements in SnO_2@Fe_2O_3 particle.

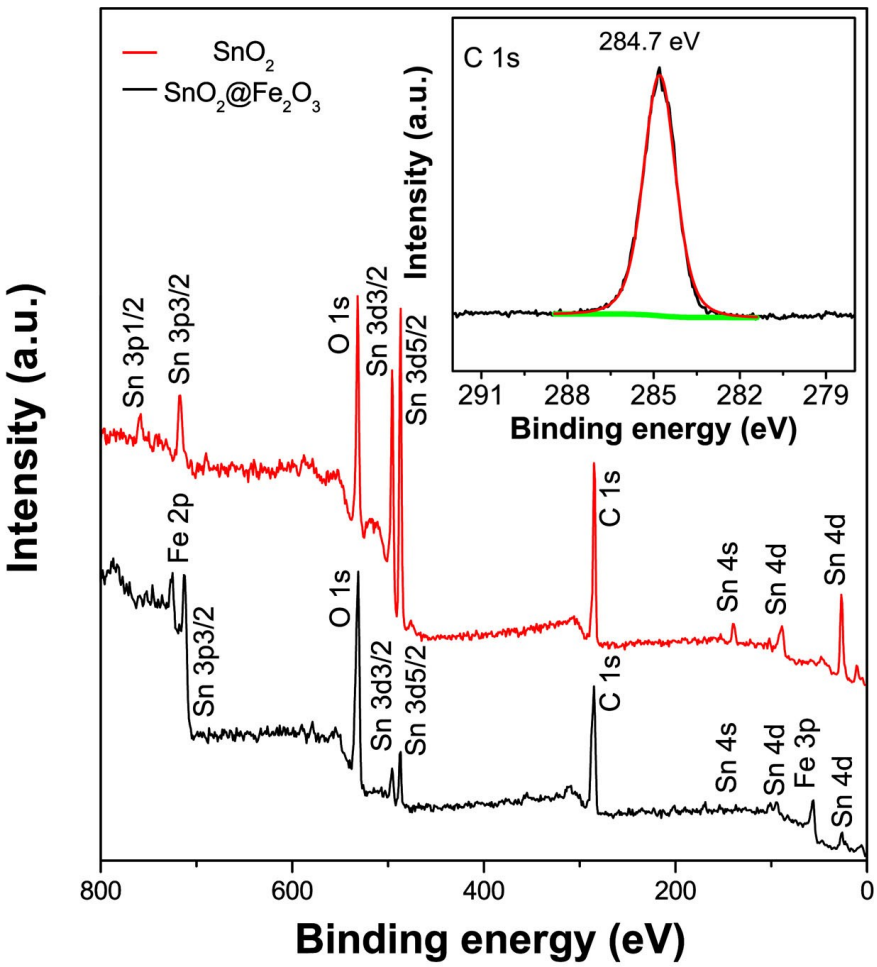

Figure S6. XPS survey spectra of the as-prepared SnO_2 HNCs and $SnO_2@Fe_2O_3$ SNCs. The upper inset is the typical high-resolution C 1s XPS spectra of SnO_2 HNCs.

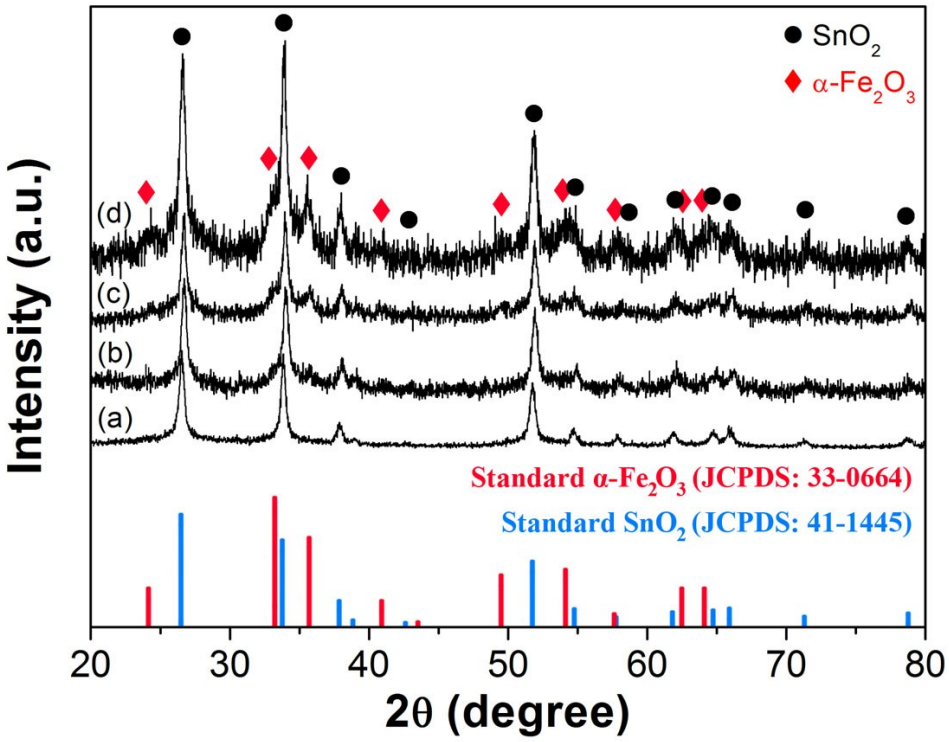

Figure S7. XRD patterns of the as-prepared samples without hydrothermal process (a) and within the time-dependent hydrothermal process of (b) 0.5 h, (c) 1.0 h, and (d) 1.5 h, respectively.

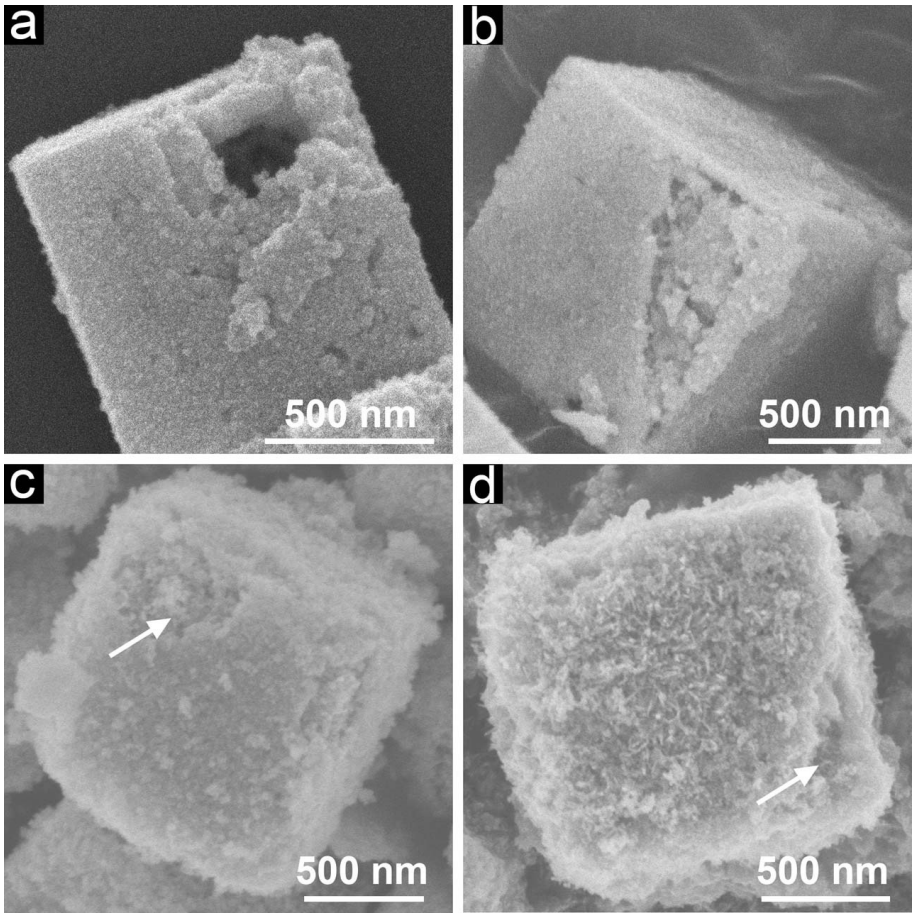

Figure S8. FESEM images of (a,b) the as-prepared SnO_2 HNCs without hydrothermal process and (c,d) SnO_2@Fe_2O_3 SNCs after the Fe_2O_3-loaded hydrothermal process.

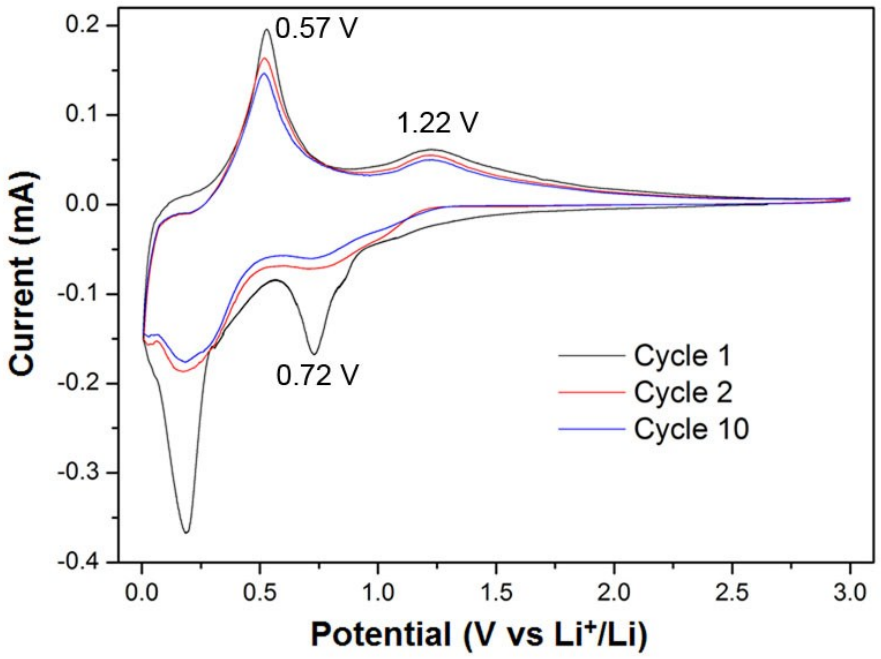

Figure S9. The following figure shows the CV curves of SnO_2 HNCs electrode. There exists a large cathodic peak at 0.72 V at the first scan, which can be attributed to the typical voltage trend of SnO_2 during the lithium intercalation, as shown in the following irreversible reaction (1). The discriminable anodic peaks centered at 0.57 V and 1.22 V could be identified for the lithium extraction in Sn materials, as shown in the reaction (2). The obvious difference between the first and subsequent cycles could be attributed to the irreversible reaction and the formation of SEI layer. In addition, it is clearly discerned after the first cycle that the CV curves with peak intensity and integrated area during the reductive and oxidative polarization processes are clearly reduced, indicating an unsatisfied reversibility of lithium insertion/extraction reaction. The main electrochemical processes of SnO_2 electrode can be described as follows [1-3].

$$SnO_2 + 4Li^+ + 4e^- \rightarrow Sn + 2Li_2O \qquad (1)$$

$$Sn + xLi^+ + xe^- \leftrightarrow Li_xSn\ (0 \leqslant x \leqslant 4.4) \qquad (2)$$

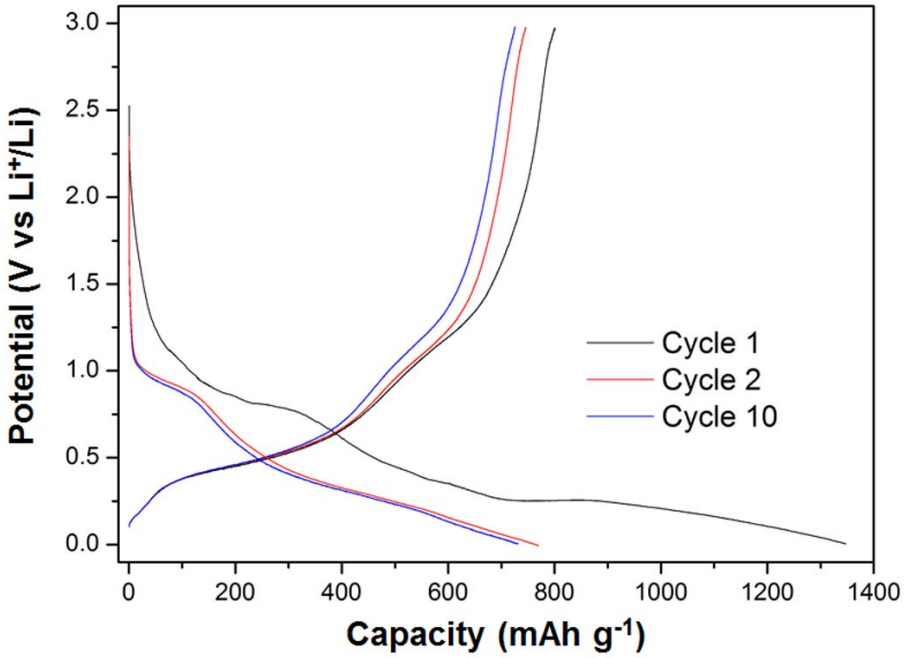

Figure S10. Galvanostatic discharge-charge voltage profiles of SnO_2 HNCs for the 1st, 2nd and 10th cycles at a current density of 100 mA g^{-1}.

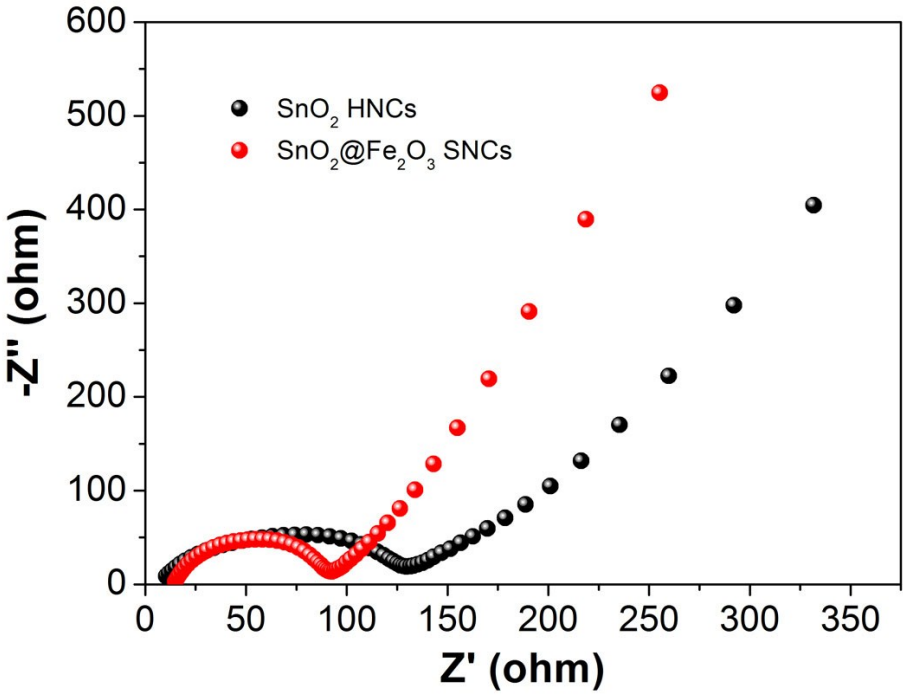

Figure S11. Nyquist plots of SnO_2 HNC and $SnO_2@Fe_2O_3$ SNC electrodes after 5 cycles.

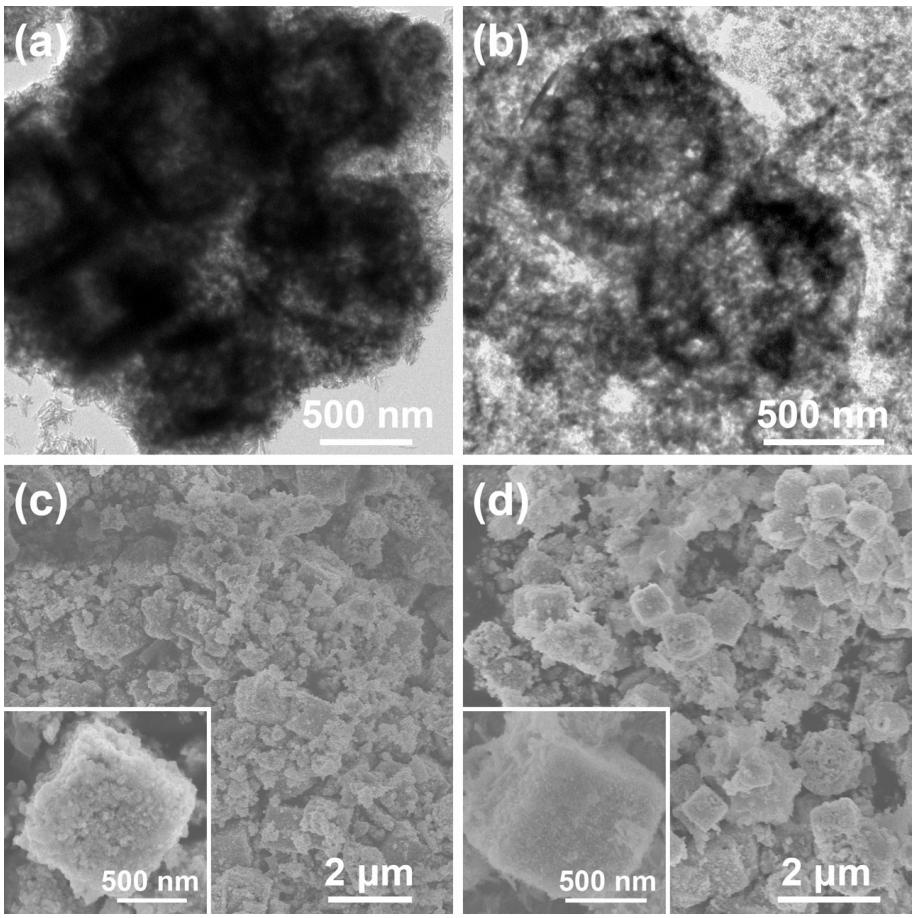

Figure S12. TEM and FESEM images of (a,c) SnO_2 HNC and (b,d)SnO_2@Fe_2O_3 SNC electrodes after 20 cycles at a current density of 100 mA g^{-1}.

Notes and references

1 Y. L. Wang, J. J. Xu, H. Wu, M. Xu, Z. Peng and G. F. Zheng, *J. Mater. Chem.*, 2012, **22**, 21923.

2 S. J. Ding, D. Y. Zhang, H. B. Wu, Z. C. Zhang and X. W. Lou, *Nanoscale*, 2012, **4**, 3651.

3 R. Z. Hu, D. C. Chen, G. Waller, Y. P. Ouyang, Y. Chen, B. Zhao, B. Rainwater, C. H. Yang, M. Zhu and M. L. Liu, *Energy Environ. Sci.*, 2016, **9**, 595.