Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Design of SnO_2/C Hybrid Triple-layer Nanospheres as Li-Ion Battery Anodes with High Stability and Rate Capability

Hao Hu, Haoyan Cheng, Guojian Li, Jinping Liu and and Ying Yu*

Institute of Nanoscience and Nanotechnology, College of Physical Science and Technology, Central China Normal University, Wuhan 430079, P.R. China

* Corresponding author. Tel: 86-27-67867037; Email: yuying01@mail.ccnu.edu.cn

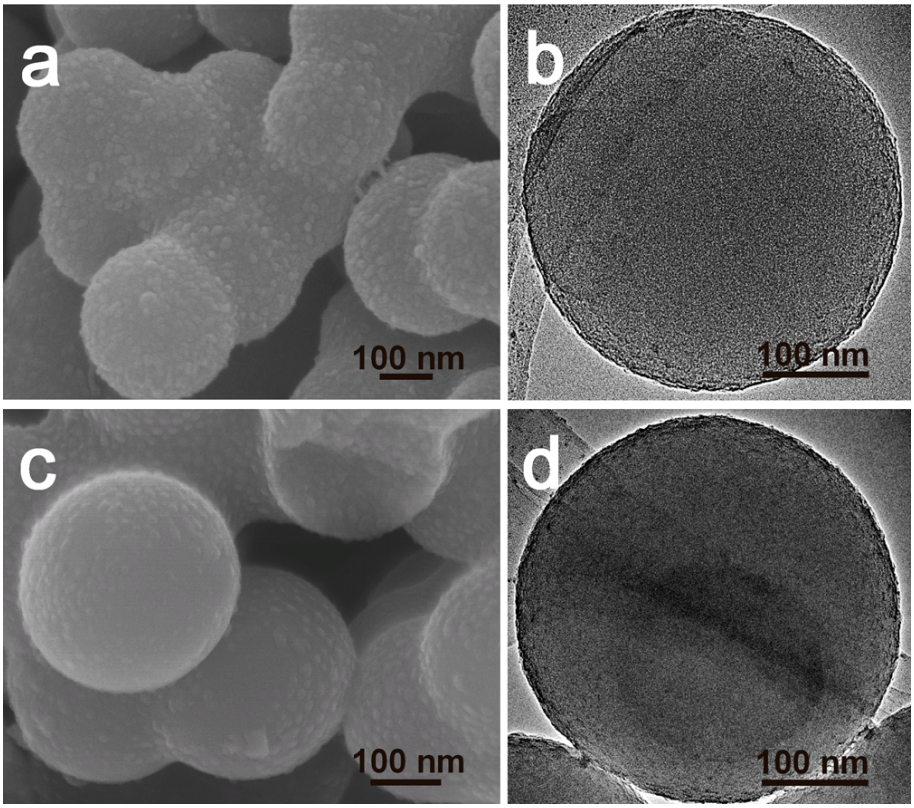

Fig. S1 SEM and TEM images for SnO_2/C nanospheres synthesized in only deionized water (a, b), and in mixture solution of ethanol and water (c, d) respectively after ultrasonic treatment for 1.5 h.

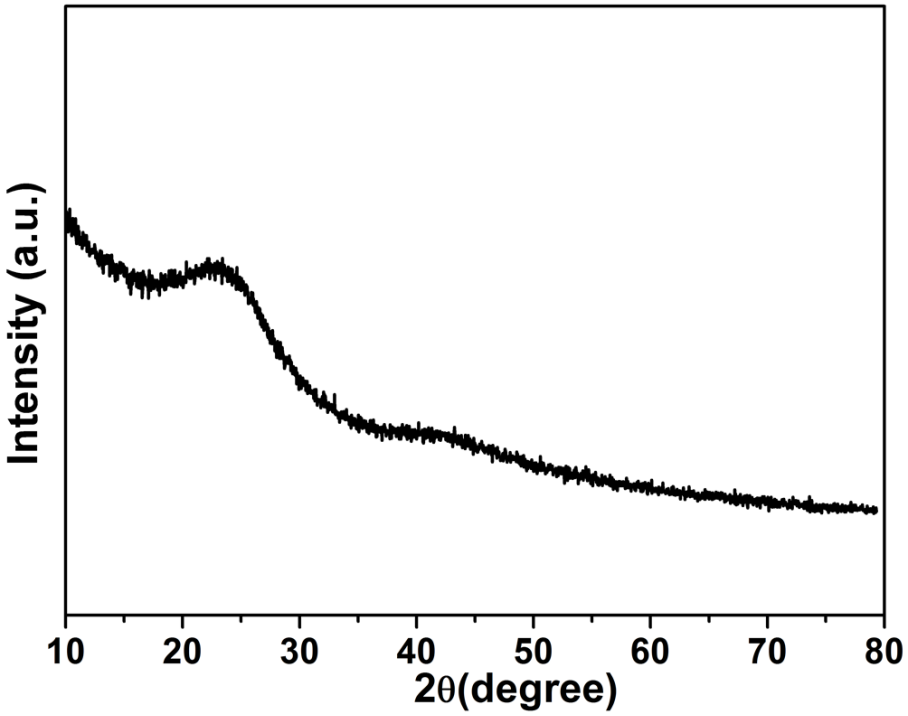

Fig. S2 XRD pattern of carbonized colloidal carbon spheres (CCs).

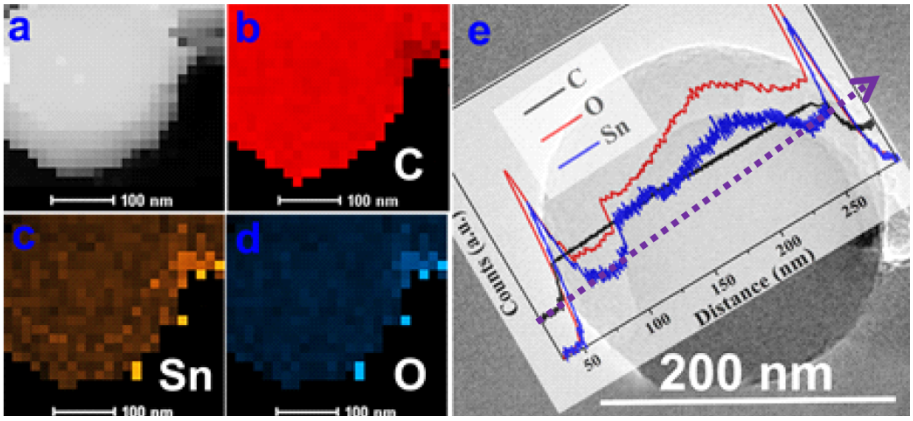

Fig. S3 DF-STEM images of SnO_2/C hybrid triple-layer nanospheres (STN) (a) and elemental mapping images for STN of carbon (b), tin (c) and oxygen (d) by energy-dispersive X-ray spectroscopy (EDX). And EDX profiles for C, O and Sn along purple dotted arrow across STN (e). These images were collected with an instrument of Titan G2 60-300 (Netherland).

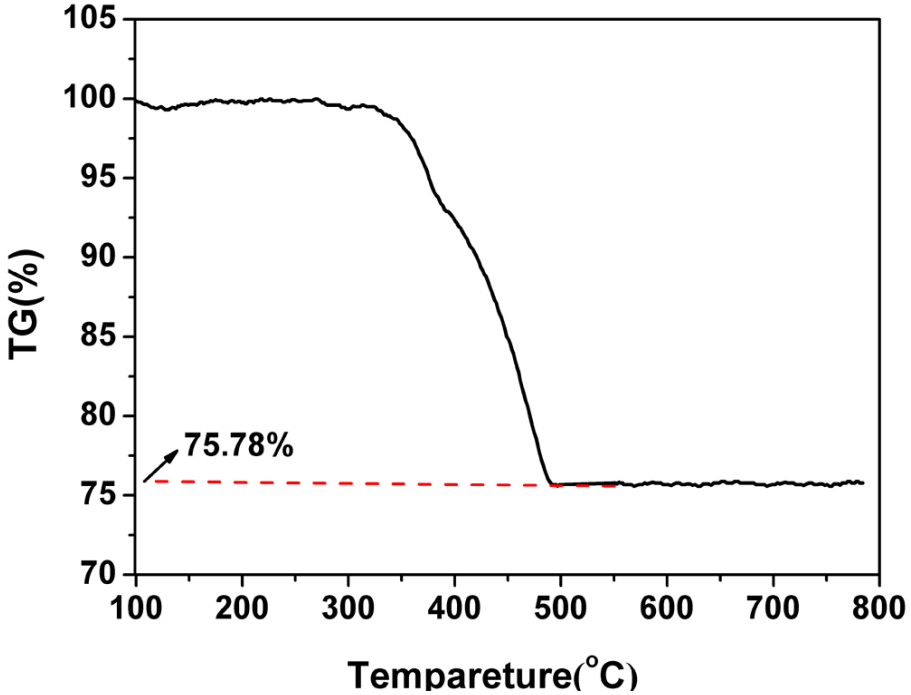

Fig. S4 TGA curve of SnO_2/C hybrid triple-layer nanospheres (STN).

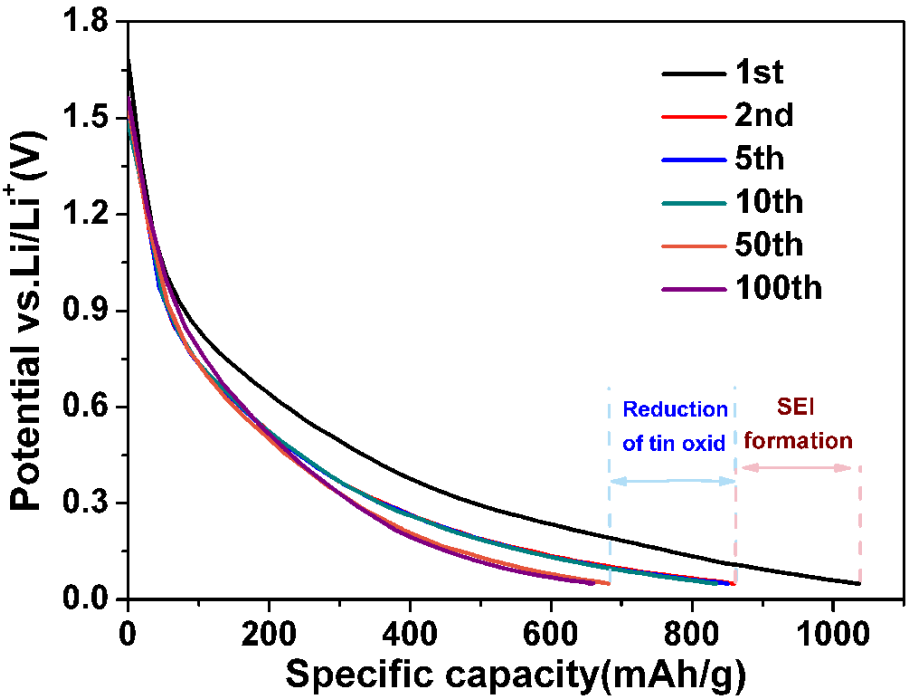

Fig. S5 Discharge voltage profiles of STN for 1st, 2nd, 5th, 10th, 50th and 100th cycles at current density of 300 mA/g with a voltage window of 0.05 ~2.5 V.

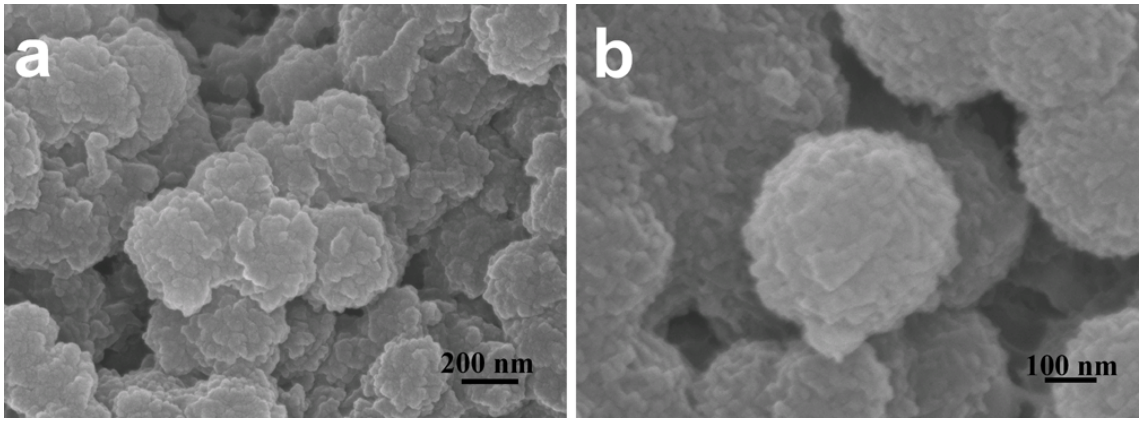

Fig. S6 SEM images of STN electrodes after 350th cycle at 300 mA/g (a), after 1000th cycle at 20 C (b).

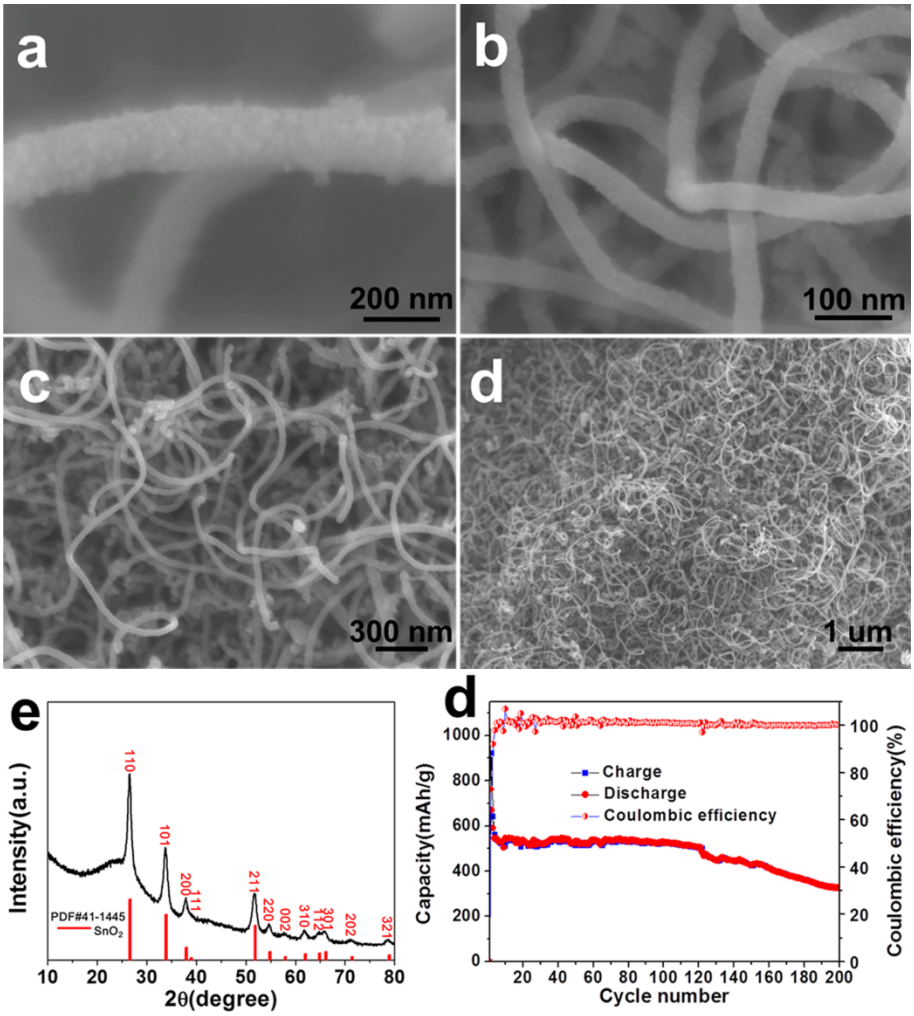

Fig. S7 SEM images of raw SnO_2@CNT (carbon nanotubes) with different magnifications (a), (b), (c) and (d), XRD pattern of raw SnO_2@CNT (e), and cycling performance of SnO_2@CNT at a current density of 300 mA/g within a voltage window of 0.05~2.5 V (f). For comparison, the composite of SnO2@ CNT was prepared. The process is as follow. 0.1 g CNT in 80 ml (water/ethanol = 1:3, v：v) 0.5 M $SnCl_2$ solution and then stirring at 50 °C in a water bath for 8h. The as-prepared products were collected after several rinse-centrifugation cycles. The annealing of raw of SnO2@CNT was first carried out at 500 °C for 3h in argon atmosphere with heating rate of 15 °C/min, and then in air at 250 ºC for 1.5h with the rate of 5 °C/min.

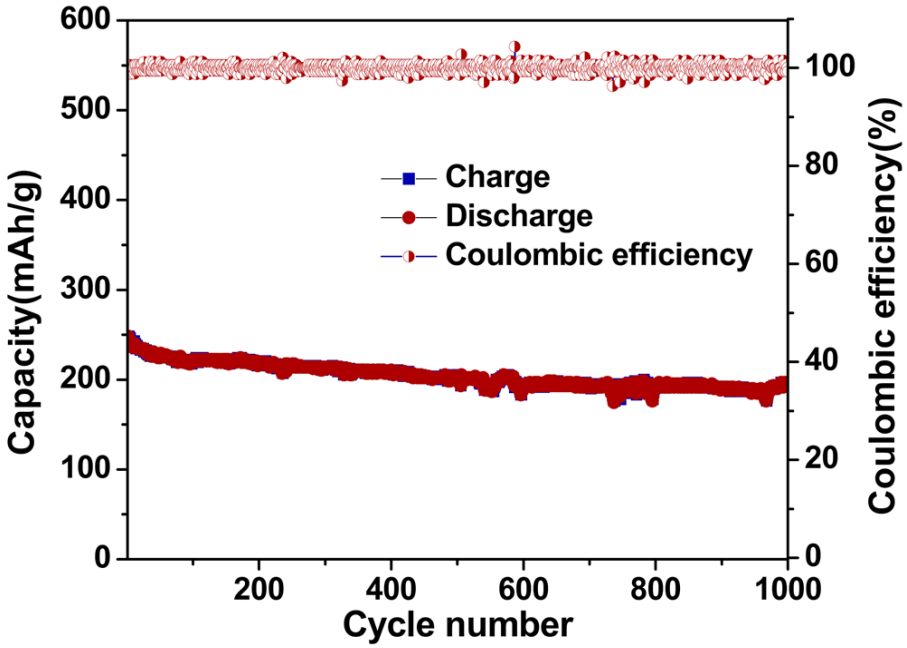

Fig. S8 Cycling performance of STN at a current rate of 20 C (C = 690 mA/g) within a voltage window of 0.05~2.5 V.

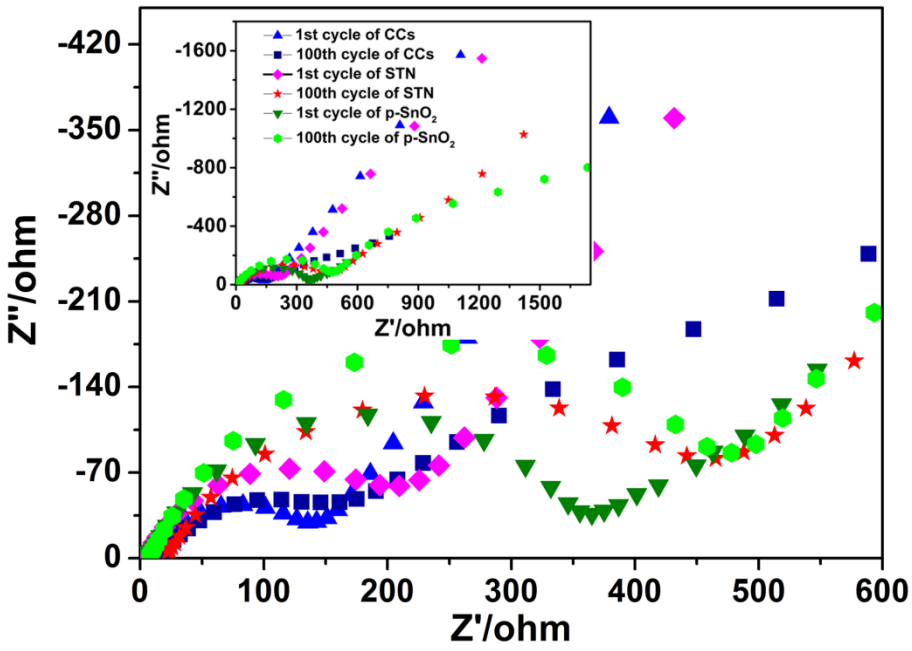

Fig. S9 Nyquist plots of CCs, STN and p-SnO_2 electrodes at first and 100th charge/discharge cycles with an amplitude of 5.0 mV in the frequency range from 100 kHz to 10 mHz. The inset exhibits amplified spectra within high frequency region.

Table S1. Summary of the discharge performance (irreversible and reversible capacity) for variously typical SnO_2-based anodes. (The irreversible capacities are resulted from irreversible cycling of reduction of tin oxide.)

Structure	**Current density (voltage window)**	**Cycling number**	**Irreversible cycling number (irreversible capacity percentage)**	**Reversible capacity (mAh/g)**	**Ref.**
SnO_2/C hybrid triple-layer nanospheres	300 mA/g (0.05-2.5 V)	350	80 (19%)	653	Our work
	20 C (C=690 mA/g) (0.05-2.5 V)	1000 (after rate cycling)	_	260	
SnO_2@CNT	300 mA/g (0.05-2.5 V)	200	5 (35%)	325	Our work
Ultrasmall SnO_2 in carbon	1400 mA/g (0.01-1.5 V)	2000	30 (44%)	443	1
CNTs@SnO_2@Carbon coaxial	400 mA/g (0.01-2.5 V)	60	20 (35%)	505	2

nanocables					
SnO_2@carbon nanocluster	100 mA/g (0.01-2.5 V)	200	10 (~25%)	852	3
SnO_2 nanoboxes	~150 mA/g (0.01-2.0 V)	40	15 (~45%)	570	4
SnO_2/graphene	400 mA/g (0.01-2.0 V)	50	6 (~26%)	590	5

References:

1 A. Jahel, C. M. Ghimbeu, L. Monconduit, C. Vix-Guterl, *Adv. Energy Mater.*, 2014, **4**, 1400025.

2 S. Ding, J. S. Chen, X. W. Lou, *Chem. Asian J.*, 2011, **6**, 2278.

3 M. He, L. Yuan, X. Hu, W. Zhang, J. Shu, Y. Huang, *Nanoscale*, 2013, **5**, 3298.

4 Z. Y. Wang, D. Y. Luan, F. Y. C. Boey, X. W. Lou, *J. Am. Chem. Soc.*, 2011, **133**, 4738.

5 X. Wang, X. Zhou, K. Yao, J. Zhang, Z. Liu, *Carbon*, 2011, **49**, 133.