Supporting Information for

Alumina stabilized ZnO-graphene anode for lithium ion batteries via atomic layer deposition

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1. Thermal atomic layer deposition (ALD) of ZnO and Al_2O_3 onto G-aerogel

ZnO film was deposited onto G-aerogel by using an ALD system of SUNALE R200 (Picosun). Typically, a piece of G-aerogel was placed in the ALD chamber where zinc diethyl ($Zn(C_2H_5)_2$, 99.9999%, Jiangsu Nata Opto-electronic Material Co. Ltd) reacted with H_2O to form ZnO for 60 ALD cycles. Then, trimethyaluminium ($Al(CH_3)_3$, 99.9999%, Jiangsu Nata Opto-electronic Material Co. Ltd) reacted with H_2O to form Al_2O_3 via "x" ALD cycles, x= 0, 4, 10 or 20, respectively. The operational pressure of the ALD system was maintained at about 1800-2000 Pa throughout the deposition. Vapors of the two precursors for forming each oxide were alternately carried by N_2 gas into the reaction chamber and the temperature was kept at 150°C. The as-obtained ZnO-G-x (x refers to the number of ALD cycles used for depositing Al_2O_3) samples were treated by heating at 100°C under vacuum for 12 h before characterizations.

2. Supplementary figures

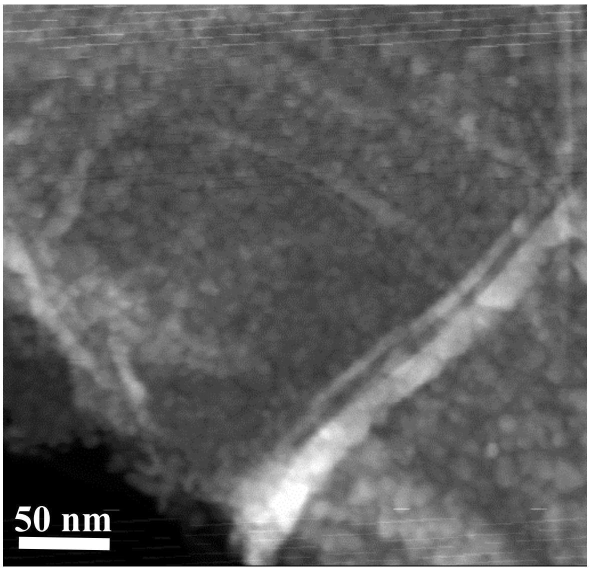

Fig. S1 STEM image of ZnO-G-0 composite.

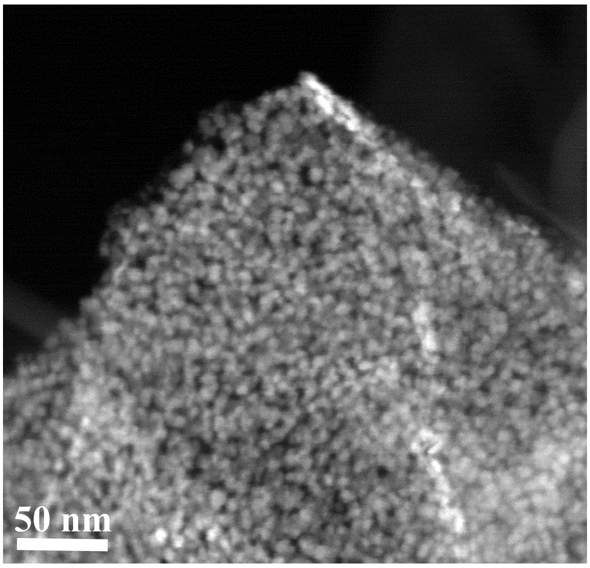

Fig. S2 STEM image of ZnO-G-5 composite.

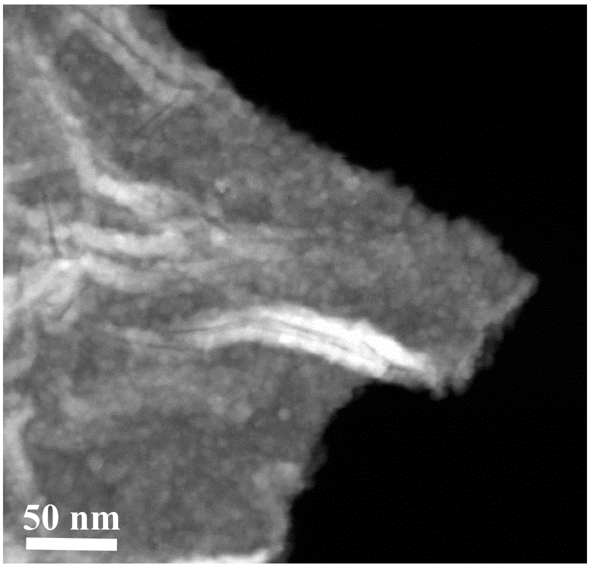

Fig. S3 STEM image of ZnO-G-20 composite.

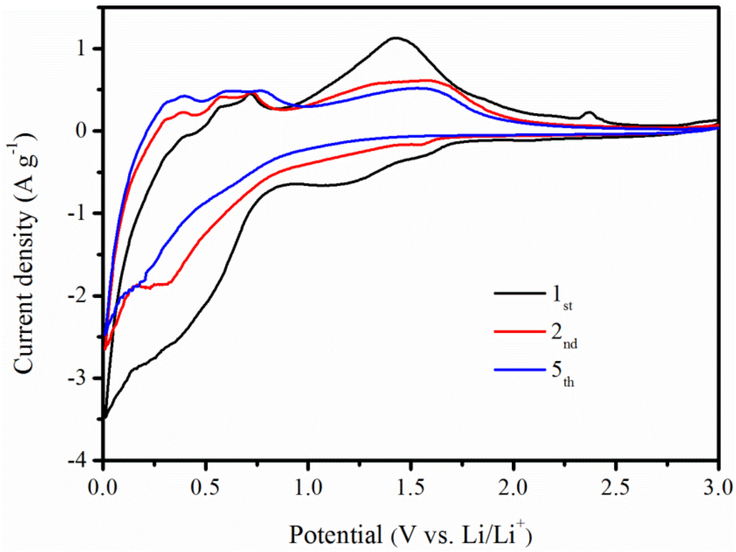

Fig. S4 CV curves of ZnO-G-0 composite at 0.1 mV s^{-1}.

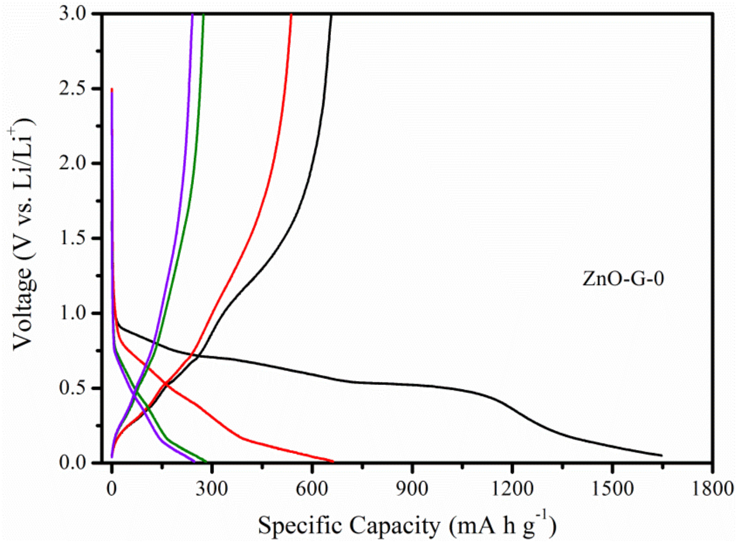

Fig. S5 Galvanostatic charge/discharge curves of ZnO-G-0 composite at a current density of 100 mA g^{-1}.

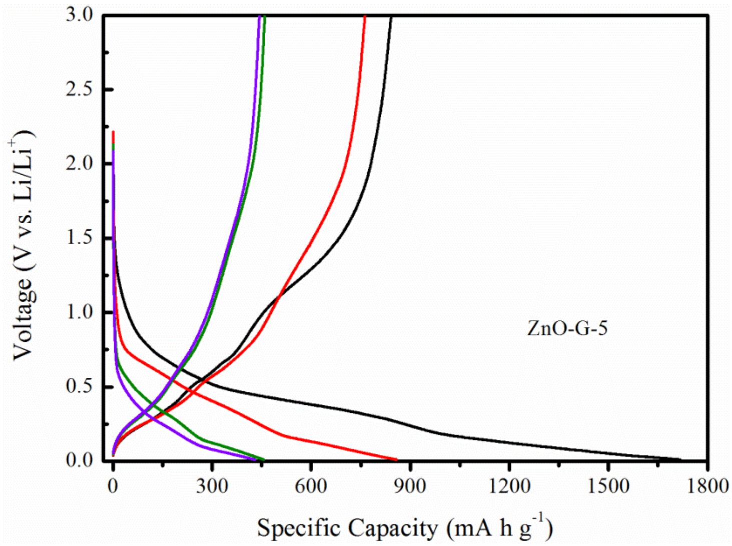

Fig. S6 Galvanostatic charge/discharge curves of ZnO-G-5 composite at a current density of 100 mA g^{-1}.

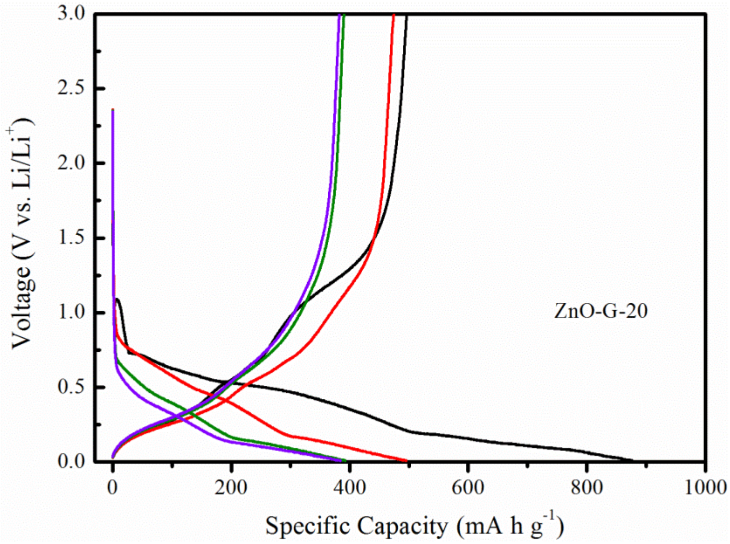

Fig. S7 Galvanostatic charge/discharge curves of ZnO-G-20 composite at a current density of 100 mA g^{-1}.

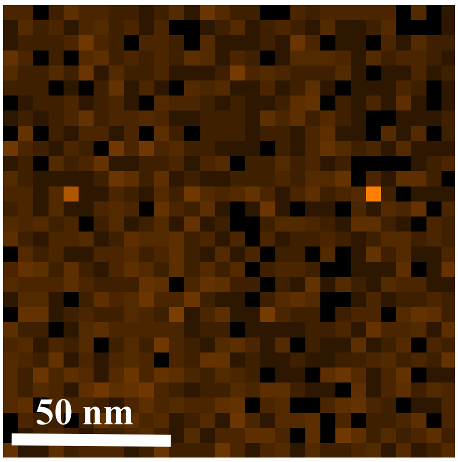

Fig. S8 EDS mapping of Al element in ZnO-G-10 composites after 100 cycles of charging/discharging at 100 mA g^{-1}.

Table S1 Comparison of the electrochemical performances of different ZnO anode materials (1 C= 978 mA g^{-1}, C_{dis}=discharge capacity, C_{char}=charge capacity, C_{rev}= Reversible capacity).

ZnO anode material	1st C_{dis} (mA h g^{-1})	1st C_{char} (mA h g^{-1})	C_{rev} (mA h g^{-1})	Ref
ZnO/graphene	1235	420	300, 25 cycles at 50 mA g^{-1}	[1]
Nanosized ZnO/Carbon	1550	900	700 after100 cycles at 100 mA g^{-1} (based on ZnO)	[2]
ZnO nanorod/Carbon	1150	640	330, 50 cycles at 0.25 C	[3]
ZnO nanorod arrays	1461	980	310, 40 cycles at 0.1 mA cm^{-2}	[4]
ZnO films	900	400	220, 40 cycles at 20 μA cm^{-2}	[5]
ZnO/Ni	1048	786	490, 30 cycles at 80 mA g^{-1}	[6]
ZnO-C microsphere	1432	798	520,150 cycles at 100 mA g^{-1}	[7]
ZnO nanotube	932	621	386, 50 cycles at 0.5 C	[8]
ZnO nanosheets	1120	750	400,100 cycles at 0.5 mA g^{-1}	[9]
ZnO/Se	703	505	400, 100 cycles at 5 μA cm^{-2}	[10]
ZnO/Au	1280	660	392, 50 cycles at 120 mA g^{-1}	[11]
ZnO/NiO/C	1235	805	488, 50 cycles at 0.5 C	[12]
ZnO nangrains/graphene/Al_2O_3	1513	803	490,100 cycles at 100 mA g^{-1}	This work

[1] W. T. Song, J. Xie, S. Y. Liu, Y. X. Zheng, G. S. Cao, T. J. Zhu, X. B. Zhao, Graphene decorated with ZnO nanocrystals with improved electrochemical properties prepared by a facile in situ hydrothermal route, Int. J. Electrochem. Sci, 7 (2012) 2164–2174.
[2] O. B. Chae, S. Park, J. H. Ryu, S. M. Oh, Performance Improvement of Nano-Sized Zinc Oxide Electrode by Embedding in Carbon Matrix for Lithium-Ion Batteries, Journal of The Electrochemical Society, 160 (2013) A11–A14.
[3] J. Liu, Y. Li, R. Ding, J. Jiang, Y. Hu, X. Ji, Q. Chi, Z. Zhu, X. Huang, Carbon/ZnO Nanorod Array Electrode with Significantly Improved Lithium Storage Capability, The Journal of Physical Chemistry C, 113 (2009) 5336–5339.

[4] H. Wang, Q. Pan, Y. Cheng, J. Zhao, G. Yin, Evaluation of ZnO nanorod arrays with dandelion-like morphology as negative electrodes for lithium-ion batteries, Electrochimica Acta, 54 (2009) 2851–2855.
[5] Z. W. Fu, F. Huang, Y. Zhang, Y. Chu, Q. Z. Qin, The electrochemical reaction of zinc oxide thin films with lithium, Journal of The Electrochemical Society, 150 (2003) A714–A720.
[6] C. Zhang, J. Tu, Y. Yuan, X. Huang, X. Chen, F. Mao, Electrochemical performances of Ni□coated ZnO as an anode material for lithium-ion batteries, Journal of The Electrochemical Society, 154 (2007) A65–A69.
[7] Q. Xie, X. Zhang, X. Wu, H. Wu, X. Liu, G. Yue, Y. Yang, D. L. Peng, Yolk-shell ZnO-C microspheres with enhanced electrochemical performance as anode material for lithium ion batteries, Electrochimica Acta, 125 (2014) 659–665.
[8] K. T. Park, F. Xia, S. W. Kim, S. B. Kim, T. Song, U. Paik, W. I. Park, Facile synthesis of ultrathin ZnO nanotubes with well□organized hexagonal nanowalls and sealed layouts: applications for lithium ion battery anodes, The Journal of Physical Chemistry C, 117 (2013) 1037–1043.
[9] X. H. Huang, X. H. Xia, Y. F. Yuan, F. Zhou, Porous ZnO nanosheets grown on copper substrates as anodes for lithium ion batteries, Electrochimica Acta, 56 (2011) 4960–4965.
[10] Y. N. Zhou, W. J. Li, Z. W. Fu, Electrochemical reactivity of nanocomposite ZnO–Se for lithium-ion batteries, Electrochimica Acta, 59 (2012) 435–440.
[11] M. Ahmad, S. Yingying, A. Nisar, H. Sun, W. Shen, M. Wei, J. Zhu, Synthesis of hierarchical flower-like ZnO nanostructures and their functionalization by Au nanoparticles for improved photocatalytic and high performance Li-ion battery anodes, Journal of Materials Chemistry, 21 (2011) 7723–7729.
[12] Q. Pan, L. Qin, J. Liu, H. Wang, Flower like ZnO-NiO-C films with high reversible capacity and rate capability for lithium ion batteries, Electrochimica Acta, 55 (2010) 5780–5785.