Controllable Synthesis of Hollow Copper Oxide Encapsulated into N-doped Carbon Nanosheets as High-Stability Anodes for Lithium-Ion Batteries

Zhiqing Jia [ab], Yingbin Tan [a], Xiangxin Guo [ac]

[a]*State Key Laboratory of High Performance Ceramics and Superfine Microstructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China.*
[b]*University of Chinese Academy of Sciences, Beijing 100039, China.*
[c]*College of Physics, Qingdao University, Qingdao 266071, China.*

E-mail: jiazhiqing@student.sic.ac.cn

The surging demand for high-performance and long-life LIBs has stimulated great interest in exploring novel electrode materials with the capability to deliver increased energy. Among the available materials, transition metal oxides (TMOs) have been considered as promising substitutes for the traditional graphite anode due to their high theoretical capacity. [1] However, performance of the bulk TMOs is far below the expectations, resulting from the large volume expansion during lithiation process and the intrinsically low electronic conductivity. Recently, the well-designed carbon-based nanostructured materials have been received considerable attention. [2] Carbonaceous materials with structural flexibility and high electrical conductivity can buffer the severe mechanical strain during cycling, and maintain the integrity of whole electrode. Moreover, nanostructured materials would also accommodate the huge volume variation during lithiation and delithiation.

Hollow nanostructures with the large surface area, large internal space and low density have been received considerable attention. [3] The nanostructure provides extremely short transport length for Li^+ ions and electrons. Meanwhile, the favorable hollow architecture offers extra space for accommodating the large volume variation upon cycling. [4] However, construction of complex hollow structures usually suffers disadvantages like high cost and tedious synthetic process, which makes it difficult to apply in large-scale production.

Herein, we report the synthesis of N-doped carbon nanosheets decorated with hollow copper nanoparticles (Cu@NCSs) by chemical vapor and solid deposition methods using polyvinylpyrrolidone (PVP) as the carbon source on a Cu foil. Afterwards, the Cu@NCSs composites are successfully oxidized by thermal annealing process to obtain the hollow copper oxide encapsulated into N-doped carbon nanosheets (CuO@NCSs). The obtained hollow CuO@NCSs composites inherit all advantages of complex hollow structures, including the flexible carbon matrix to improve the electrical conductivity, the void space to accommodate the volume expansion upon cycling and the thin shells to reduce the electron and Li^+ diffusion pathway. Thus, the CuO@NCSs electrode delivers high reversible capacity, excellent rate capacity and extremely long cycle life for lithium storage. The synthesis method can be potentially scalable to large quantities for mass production with low cost.

References:

[1] M. Armand, J.-M. Tarascon, Nature 451 (2008) 652-657.
[2] G. D. Park and Y. Chan Kang, *Chem. Eur. J.*, 2015, **21**, 9179-9184.
[3] H. T. Sun, G. Q. Xin, T. Hu, M. P. Yu, D. L. Shao, X. Sun and J. Lian, *Nat. Commun.*, 2014, **5**, 4526-4534.
[4] J. S. Cho and Y. C. Kang, *Small* 2015, **11**, 4673-4681.