Nanocarbon Scaffold with Multi-Range Electron Pathways for Li-ion Batteries

Xin-Yan Liu, Hong-Jie Peng, Qiang Zhang, Jia-Qi Huang, Xiao-Fei Liu, Li Wang, Xiangming He, Wancheng Zhu, Fei Wei

a Beijing Key Laboratory of Green Chemical Reaction Engineering and Technology, Department of Chemical Engineering, Tsinghua University, Beijing 100084, China
b Department of Chemical Engineering, Qufu Normal University, Shandong 273165, P. R. China.
c Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing 100084, P. R. China.

Email: zhang-qiang@mails.tsinghua.edu.cn (Q. Zhang)

Chemical energy storages using rechargeable Li-ion batteries are becoming more and more important to meet the rapidly increasing demands from portable electronic devices, electrical vehicles, hybrid electrical vehicles, and so on. However, the cathode material based on traditional oxides/phosphates of transition metals such as olivine LiFePO$_4$ suppressed both low electronic and ionic conductivity, leading to initial capacity loss and poor rate capability. The nanoscale cathode material and utilization of conductive agents such as carbon blacks (CBs) and/or carbon nanotubes (CNTs) were effective solution, and however, also complicated and expensive for commercialization.

Herein, a hierarchical 3D scaffold consisting of CNTs and CBs was employed as conductive fillers in the cathode of Li-ion batteries. The as-obtained composite cathodes with hybridized CBs and CNTs possessed both short- and long-range electron pathways, which provided both surficial conductive layer with abundant contacting sites to LiFePO$_4$/C particles and interconnected continuous 3D networks. Therefore, the LiFePO$_4$/C cathode showed enhanced Li storage performance and ameliorative electrochemical kinetics.

With the construction of hierarchical CNT/CB conductive scaffolds, the LiFePO$_4$/C cathode exhibits enhanced Li storage performance and improved electrochemical kinetics. At a current density of 0.2 C, LiFePO$_4$/C cathode with such hierarchical CNT/CB network exhibited reversible discharge capacity of 156.9 mAh g$^{-1}$ over 50 cycles. When the current density was increased to 1.2 C, a capacity of 119.1 mAh g$^{-1}$ can still be preserved, and a capacity of 150.5 mAh g$^{-1}$ at 0.2 C rate was available after 1.2 C rate, indicating a high reversibility of the composite cathode.

Fig. 1 Hierarchical carbon nanotube/carbon black scaffolds were used to promote the short-/long-range electron pathways within the LiFePO$_4$ cathode.

This strategy to hybridize CNTs and CBs into a hierarchical 3D network has demonstrated its high efficiency to build LiFePO$_4$/C composite cathode with excellent Li storage performance and good economy. Such design can be easily extended to various cathode materials for Li-ion batteries, as well as super capacitors, redox flow batteries, Li/S as well as Li/O$_2$ batteries with extraordinary energy storage performance.

References