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3D Porous $LiFePO_4$ and its carbonaceous composites (graphene, N-CNTs and CNTs) as Cathode Materials for Lithium Ion Batteries

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Introduction

$LiFePO_4$ has attracted much attention as a promising cathode material for lithium ion battery applied for electric vehicle (EV) and hybrid electric vehicle (HEV) [1]. However, its poor conductivity limits its practical applications. Significant progresses have been made in understanding and controlling phase purity, particle size and carbon coating of the C/$LiFePO_4$ composite material. Down-sizing strategy to nanoscale is an effective way to improve the performance of the electrode, but it accompanies with low tap density and a low volumetric capacity in practical battery application. Developing a three dimensional (3D) porous $LiFePO_4$ architecture is a feasible strategy to solve the problem and achieve fast electronic and ion conduction [2-3].

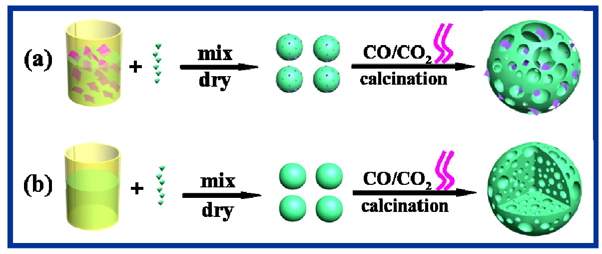
Considering the importance of carbon in the composite, the choice of a more appropriate carbon material such as carbon nanotubes (CNTs), nitrogen doped carbon nanotubes (N-CNTs) and graphene is important for high-performance of the composite. N-CNTs could enhance the electronic conductivity because the additional electrons contributed by the nitrogen atom provide electron carriers for the conduction band. Graphene could offer a superior conductivity and flexible structure, and more importantly, high surface area (theoretical value of 2630 m^2/g). Such promising advantages make N-CNTs and graphene great potential in Li-ion battery applications. In this presentation, we will report the roles of N-CNTs and graphene with $LiFePO_4$ [2-4].

Experimental

In this presentation, 3D porous $LiFePO_4$ and carbonaceous composites including $LiFePO_4$/N-CNTs, $LiFePO_4$/Graphene with hierarchical structure were prepared by sol-gel method independent of templates. Detailed procedures are shown in Scheme 1. The impact of stacked graphene and unfolded graphene on the morphology and electrochemical performance of $LiFePO_4$ were investigated specifically.

Results and Conclusions

3D porous $LiFePO_4$/N-CNTs, $LiFePO_4$/graphene composites were successfully fabricated by a facile template-free sol-gel approach. As shown in Figure 1, the obtained $LiFePO_4$/graphene delivered a capacity of 146 mA h g^{-1} at 0.1 C after 100 cycles, which is over 1.4 times the capacity (104 mA h g^{-1}) of porous LFP (Figure 1a). And N-CNTs and CNTs modified composites delivered the capacities of 138 and 113 mA h g^{-1}, respectively (Figure 1b). The use of unfolded graphene enables better dispersion of $LiFePO_4$ and restricts the $LiFePO_4$ particles size at nanoscale (Figure 2). More importantly, as shown in the scheme, it makes each particle attached on the conducting layer, which could greatly enhance the electronic conductivity, hence realizing the full potential of active materials. Based on the superior structure, the $LiFePO_4$/unfolded graphene nanocomposites deliver a high and stable discharge capacity of 166.2 mA h g^{-1} (98% of the theoretical capacity) and excellent rate performance up to 15 C. All these results demonstrate that highly conductive and uniformly dispersed N-CNTs and graphene modified composites can act as a promising cathode for high-performance lithium-ion batteries.



Scheme 1. Scheme of 3D porous (a) $LiFePO_4$/graphene and (b) $LiFePO_4$ formation process.

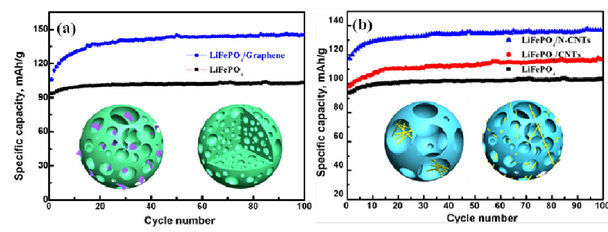


Figure 1. Electrochemical performance of (a) $LiFePO_4$/graphene composite and (b) $LiFePO_4$/N-CNTs composite.

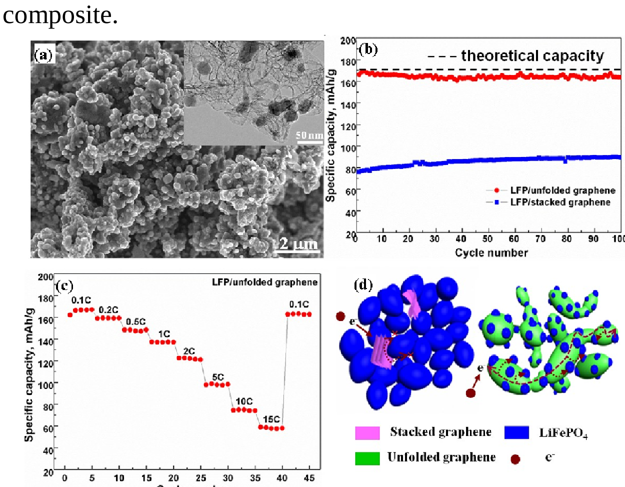


Figure 2. Characterization of $LiFePO_4$/unfolded graphene composite: (a) SEM and TEM images; (b) Cycle performance; (c) Rate performance and (d) Scheme representation of electron-transfer pathway.

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