SnO$_2$ nanocrystals stored in carbonaceous matrix: cycle durable anode materials for Lithium ion batteries

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Lithium ion batteries (LIBs) have been considered as attractive power sources for upcoming electric/hybrid vehicles and smart grids due to their potential for high power and high energy density. To meet the challenges of LIBs used in electric/hybrid vehicles and so forth, great efforts are being made to explore new electrode materials with novel structures and higher specific capacities. Accordingly, different kinds of materials, such as transition-metal oxides (Fe$_2$O$_3$, Co$_3$O$_4$, and MnO$_2$, etc), and alloy-based materials (Si, Sn, Al, and Sb, etc) have been studied for the alternative anode materials. Among them, SnO$_2$-based materials are widely interested because their low toxicity, widespread availability, and especially their total theoretical capacity can reach as high as 1494 mAh/g (including 711 mAh/g for the conversion reaction, and 783mAh/g for the alloying reaction), which is four times higher than that of the currently used graphite (372 mAh/g). However, the great challenge for practical application of SnO$_2$-based anodes is the severe pulverization and capacity fading problems caused by the extremely large volume change of Sn during cycling.

To overcome these problems, many methods have been studied to reduce the absolute volume change and cracking of active materials by the nanosize effects, especially via nano-architected materials, such as nanoparticles, nanowires, and nanotubes, and so on. However, limited cycleability improvement has been obtained by simply nano-modifying the pure SnO$_2$, because the agglomeration of nano-sized SnO$_2$ and/or Sn is still unavoidable unless there is an extra confining buffer. In contrast, the nanopainting of SnO$_2$ with various carbonaceous materials has recently been found effective for improving the cycleability of SnO$_2$-based anodes, because the carbonaceous materials not only enhance the electrical conductivity but also act as buffering layers for the large volume change of SnO$_2$. And thus, the SnO$_2$-carbon (graphite, MCMB, CNTs, amorphous carbon, graphene, etc) composite anodes with various microstructures have been designed and prepared by different strategies in the last decades.

Although some properties of these complex designed SnO$_2$-carbonaceous anodes far exceed those of the conventional graphitic anode materials and demonstrated very high capacity and good stability, overall performance (especially the output of materials, the electrode loading or the capacity per unit area), as well as those rather complicated processes of the SnO$_2$-based anode materials still far from practical applications. Therefore, it is still desirable to develop simple and more efficient way to mass produce prepare composites with nano-sized SnO$_2$ stored in the carbon matrix, which not only preserves high-dispersion state of the active SnO$_2$ but also achieves high capacity together with enhanced cyclic performance.

Recently, we have developed several facile strategies, which are cost-effective and have a good potential for large scale applications, to synthesize SnO$_2$-based carbonaceous nanocomposite as anodes for LIBs. Unique structures, with homogeneous dispersion of SnO$_2$ nanocrystals (~5nm) in amorphous carbon matrix (see Fig.1)[1], and CNTs filled with amorphous-nanocrystalline SnO$_2$ [2], have been achieved. In the presentation, another new facile way, via simply boiling and following heating of Sn together with sugar, has been developed to fabricate cycle durable anode materials for LIBs (see Fig.2). The origin of the enhanced anode performance of the SnO$_2$/sugar nanocomposite has been analyzed by microstructure observations combining with electrochemical characterizations.

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References