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Silicon-based anode materials for high capacity lithium ion batteries

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Abstract

Developing an anode material with high-energy capacity is crucial to improve the performance of rechargeable batteries. Si is an important anode candidate because of its large lithium storage capacity (4200 $mAhg^{-1}$, about 10 times higher than graphite, 372$mAhg^{-1}$), low lithium alloying/dealloying potential, long discharge plateau, and abundance. However, the huge volume expansion/shrinkage of Si particles during charge/discharge cycles results in the pulverization of electrode structure and causes considerable capacity decay. The lack of electronic contacts between Si particles or between active coating materials and current collectors reduces its capacity. Many investigations have been carried out to accommodate this severe volume expansion including novel nanostructured Si, such as Si wires, Si tubes, porous thin films, and nest-like Si nanospheres, and multiphase composites with active Si and other active/inactive phases. However, the nano-sized Si particles would agglomerate during cycling which will decrease the cycling performance, due to high electrochemical activity. In this presentation, micro-sized polycrystalline Si particles have reduced agglomeration effect compared to nano-sized ones. We find that the electrochemical performances can be improved greatly by introducing proper binder to protect the electrode from cracking and using suitable conductive agent to provide an efficient conductive channel. By introducing nano-porous structures through chemical etching, the huge volume expansion can be effectively relieved by maintaining the complete structure of Si particles during charge/discharge cycles. Moreover, combined with carbon coating which is attractive owing to the conductive and ductile features of carbon, the conductivity can be improved and the volume expansion/shrinkage of Si can be further decreased. Developing nano-porous structure combining with pyrolyzed polyacrylonitrile could form a novel composite electrode. The electrochemical performance can be considerably improved with a conductive carbon network and nano-porous structure together with carbon layer accommodate the volume expansion/shrinkage during charge/discharge cycles.