Macroporous Silicon as Highly Stable Anodes for Lithium Rechargeable Batteries

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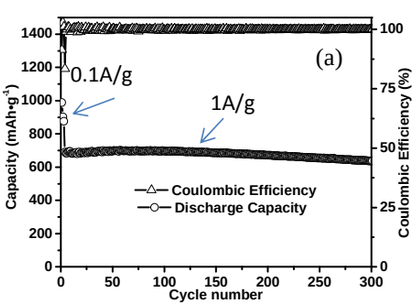
Introduction

Because of its high theoretical capacity (ca. 4200 mAh/g), silicon has been regarded as one of the best anode materials for the next generation lithium ion batteries.[1] However, the practical application of the silicon based anode has been largely hindered by the poor overall performance and/or high fabrication cost. Recently, significantly improved performance has been demonstrated using silicon with hollow/porous structures to accommodate the volume changes during charging/discharging.[2-11] However, sacrificial template methods with silicon synthesized from solution phase reactions or chemical vapor deposition (CVD) were used in the preparation of the porous structured silicon. [3-5, 8, 11] Cost-effective and scalable methods for porous silicon synthesis still needs to be developed. In this work, we adapted an electrochemical etching method and synthesized macroporous Si with > ~50 nm etched channels. This macroporous Si exhibits less than 30% overall volume change during charge/discharge process because the internal opening of the channels can accommodate most of volume expansion. The macroposous Si has demonstrated a very stable cycling performance with the capacity of ~600 mAh/g (based on the whole electrode weight) and >90% capacity retention over 300 cycles at a current density of 1A/g (based on the weight of Si).

Results and Discussion

Macroporous silicon was coated with a thin layer of conductive carbon by CVD method. CVD-coated macroporous silicon was then mixed with conductive carbon and binder and casted on a copper substrate and tested in coin cells. In-situ transmission electron microscopy (TEM) study on the charged samples shows that the big macroporous silicon particles with the size up to 20 microns are like sponges soaked in water and exhibit relatively small volume change on their outside dimension. The macroposous Si has demonstrated a very stable cycling performance with the capacity of ~700 mAh/g (based on the whole electrode weight) and >90% capacity retention over 300 cycles at a current density of 1A/g (based on the weight of Si). It also shows good rate performance with the capacity >600 mAh/g at 2A/g (based on the weight of Si) current density.



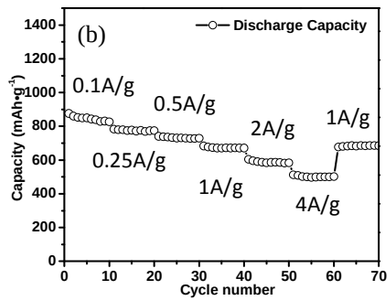


Fig. 1. (a) Cycling performance of the macroporous silicon. (b) Rate performance of the macroporous silicon.

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