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Development of Si-Based High-Capacity Anodes

Introduction

Si has a very high theoretical capacity of ~4200 mAh/g and great potential to be used as a Li-ion battery anode for high energy EV batteries. However, the large volume expansion that occurs during the lithiation process often leads to a rapid capacity loss and has hindered the practical applications of Si-based anodes. The project is to understand the fading mechanism of Si anodes and develop stable high capacity Si anodes with low cost production methods.

Projects Objectives

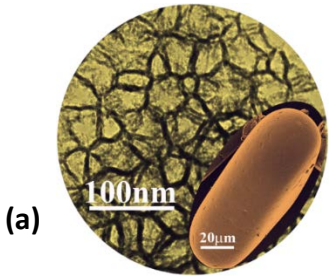
- Develop high-capacity, low-cost silicon (Si)-based anodes with good cycle stability and rate capability.
- Reduce the first cycle irreversible capacity loss and improve Coulombic efficiencies during cycling.
- Advance the fundamental understanding of the degradation mechanism of Si-based anodes, including the mechanical and electrochemical stability.

Main Achievement of the Project

Several low cost approaches have been developed to improve the long term cyclability of Si based anode. These approaches include:

- CVD coated micron-sized Si particles with nano-pore structures are investigated as an anode material for Li-ion batteries.
- Vapor-Induced Solid-Liquid-Solid Process for Silicon-Based Nanowire Growth.
- Conductive Rigid Skeleton Supported Silicon as High-Performance Li-Ion Battery Anodes.
- Reduction and Polymerization of Fluoroethylene Carbonate for Stable SEI via an Alternative Ring Opening Mechanism.
- Mesoporous silicon sponge as an anti-pulverization structure for high-performance lithium-ion battery anodes.

Fig. 1a shows the typical morphology of mesoporous Si sponge in different scales. This electrode demonstrates high capacity and good cycling stability



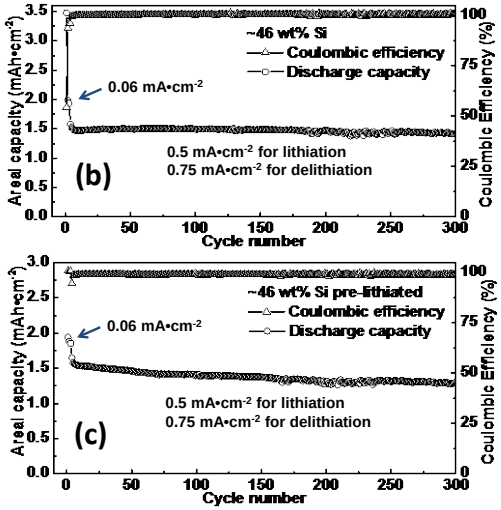


Figure 1(a) the appearance morphology and microstructure of porous Si. (b) Cycling performance of a porous Si electrode. (c) Cycling performance of a prelithiated porous Si electrode.

even at an areal capacity loading of ~1.5 mAh/cm^2 (Figure 1b). The first cycle Coulombic efficiency can be >95% after prelithiation (Figure 1c).

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Selected Publications

1. Xiaolin Li, Pengfei Yan, Bruce W Arey, Wei Luo, Xiulei Ji, Chongmin Wang, Jun Liu, Ji-Guang Zhang, "A stable nanoporous silicon anode prepared by modified magnesiothermic reactions." Nano Energy 2016, 20, 68-75.
2. Xiaolin Li, Meng Gu, Shenyang Hu, Rhiannon, Kennard, Pengfei Yan, Xilin Chen, Chongmin Wang, Michael Sailor, Ji-Guang Zhang, Jun Liu, "Mesoporous silicon sponge as an anti-pulverization structure for high performance lithium-ion battery anodes," Nat. Commun. 2014, 5, 4105
3. Xilin Chen, Xiaolin Li, Fei Ding, Wu Xu, Jie Xiao, Yuliang Cao, Praveen Meduri, Jun Liu, Gordon L. Graff, Ji-Guang Zhang, "Conductive rigid skeleton supported silicon as high-performance Li-ion battery anodes," Nano Lett., 2012, 12, 4124-4130.
4. Xiaolin Li, Praveen Meduri, Xilin Chen, Wen Qi, Mark H. Engelhard, Wu Xu, Fei Ding, Jie Xiao, Wei Wang, Chongmin Wang, Ji-Guang Zhang, Jun Liu Hollow core-shell structured porous Si-C nanocomposites for Li-ion battery anodes. J. Mater. Chem., 2012, 22, 11014-11017.
5. Xilin Chen, Xiaolin Li, Donghai Mei, Ju Feng, Mary Y. Hu, Jianzhi Hu, Mark Engelhard, Jianming Zheng, Wu Xu, Jie Xiao, Jun Liu, and Ji-Guang Zhang, "Reduction Mechanism of Fluoroethylene Carbonate for Stable Solid–Electrolyte Interphase Film on Silicon Anode," ChemSusChem, 7(2), 549–554 (2014).