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Elaboration and Characterization of Porous Silicon Nanowires Modified with Groups of CHx (PSiNWs/CHx) for Application Energy Storage

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ABSTRACT:

In this work, porous silicon nanowires of mesoporous types were developed by single-step metal-assisted chemical etching. These porous silicon nanowires have sufficient electronic conductivity along the longitudinal axis and can provide very high capacitance with the addition of carbon. The stability of porous silicon nanowires being the most difficult parameter to control during cycling, we opted for a new energy storage approach that consists of depositing a CHX hydrocarbon on the surface of the latter. The PSiNWs are covered with a CHX layer deposited by methane plasma created in a triode reactor at RF 13.5 MHZ, synchronized under an argon atmosphere on the surface of the porous silicon nanowires. The PSiNWs powder is recovered by ultrasound and then characterized by different characterization methods: FTIR, Ramon, BET, MEB and XPS. The morphological and structural characterization reveals that the powder of porous silicon nanowires modified by CHx can be used as an anode for lithium-ion batteries.

Keywords: Energy storage devices; Porous silicon nanowires; Lithium-ion battery.

1. Introduction

Silicon (Si) is considered the most attractive anode material due to its high theoretical specific capacity of 4000 mAh g^{-1} (estimated from $Li_{15}Si_4$ at room temperature), approximately ten times higher than that of graphite conventional (372 mAh g^{-1}) [1]. However, the extreme volume changes of silicon (up to 350–400%) remains the main challenge for the successful commercialization of LIBs. Volumetric changes typically cause rapid mechanical degradation (i.e., particle sputtering, electrode disintegration, and delamination) and significant irreversible side reactions with the organic electrolyte [2], leading to rapid capacity degradation and lower cycling performance. Various Si nanostructures have been designed to solve these problems, such as nanowires [3], nanosheets [6], and porous nanoparticles [7]. To further address this issue, hybridization of nanosilicon with reinforcing composites (inactive or conductive media) has been developed, as it can form a stable buffer to release stress [8, 9]. Various reinforced materials (graphene, carbon nanotubes, metal oxides, carbides, etc.) have been used to synthesize Si-based composite anodes with improved cyclic stability. This work, for the first time, demonstrated a simple method to synthesize carbon-coated silicon nanowires in situ. The PSiNWs/CHx nanocomposites retained nanowire morphology. Benefiting from the PSiNWs/CHx nanoparticles, the PSiNWs/CHx anodes exhibited improved stable cycling performance compared to the pure PSiNWs anodes used as anodes in LIBs.

2. Experimental

The PSiNWs are covered with a CHX layer deposited by methane plasma created in a triode reactor at RF 13.5 MHZ, synchronized under an argon atmosphere on the surface of the porous silicon nanowires.

3. Results and Discussion

Understand the composition of the interfacial layers formed after the development of the PSiNWs/CHx anode to design stabilized battery systems. X-ray photoelectron spectroscopy (XPS) can provide detailed information on the chemical state of surfaces as well as global characteristics when combined with ion sputtering to profile a sample. The high-resolution XPS spectrum survey of the PSiNWs/CHx displays

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peaks of C1s at 289 eV.

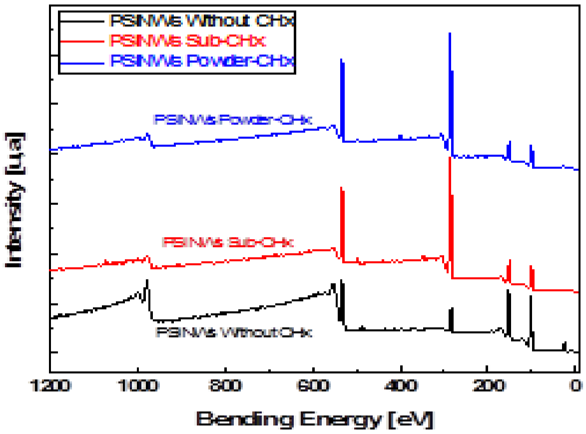

Figure 1: Survey XPS of anode porous silicon nanowires modifies with CHx (PSiNWs/CHx).

4. Conclusion

In conclusion, this work has successfully show a good electrochemical performance for both anodes with a remarkable improvement in the performance of the PSiNWs/CHx anode compared to the unmodified PSiNWs anode, and from there we show the role of added Chx groups to improve the capabilities of the anode.

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