Advanced Designs of Silicon Anodes for High Energy Lithium-Ion batteries

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Achieving a high energy density of lithium-ion batteries (LIBs) has been urgently required for forthcoming applications. Silicon anodes stand out as one of the promising candidates due to its high capacity and low working potential, while a structural failure from large expansion upon lithiation/delithiation poses a significant challenge [1]. The extensive efforts over the past has been devoted to addressing this issue by employing nanostructures, binder designs, and compositing methods.

In this respect, we adopted multiple strategies, such as introducing multifunctional coating layers and separately realizing unique structures prepared via thermochemical reduction process of either inexpensive clay minerals or metal-organic-frameworks (MOFs), which demonstrate a great feasibility of their synthesis and electrochemical properties, thus satisfying a strict requirement for practical application (Figure 1).

Multifunctional layers composed of lithium silicate (Li_2SiO_3) and lithium titanate ($Li_4Ti_5O_{12}$) on nano-Si, provide structural robustness and effective lithium ion pathway for Si anode, which also promote a formation of stable/uniform SEI layers [2]. The unconventionally structured Si materials are available through utilization of clay minerals and MOFs for ultrathin nanosheet, hyperporous flake, and hollow nanocubes, respectively, which is enabled by salt-assisted or templated thermochemical reduction [3-5]. The presented here, exhibited exceptional electrochemical properties (e.g., cycling stability over hundreds of cycles and durability toward high current density) along with effective accommodation of huge volume change of silicon anodes. These advanced and rational designs can render the silicon anodes much stable and durable for high energy density LIBs.

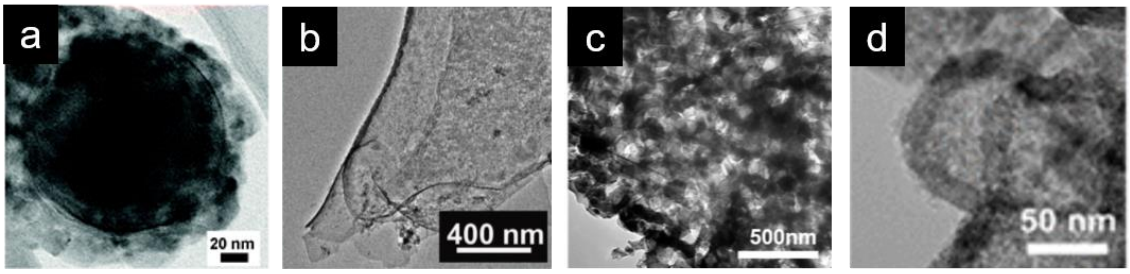

Figure 1. Multiple strategies for silicon anodes. (a) $Li_2SiO_3/Li_4Ti_5O_{12}$ multifunctional layers on nano-Si, (b) Si nanosheet, (c) hyperporous Si flake and (d) mesoporous Si hollow nanocube.

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