Mechanical properties of uncoated silicon nanowire arrays and core-shell silicon nanowire arrays for the application of Lithium Ion Batteries

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Abstract

Lithium ion batteries (LIB) are the power sources for many electronic devices, including smartphones, laptops and electric vehicles. It is predicted that the market share of LIB will increase to $40 billion by 2021. However, it has long been identified that the graphite anodes are subjected to several mechanical and electromechanical issues, such as volume expansion, solid electrolyte interphase formation and capacity fading, during charging and discharging cycles. Hence, the goal of this work was to look for an appropriate type of core-shell silicon nanowire arrays that exhibits superior stiffness and strain-to-failure to cope with these issues in order to improve the performance and lifetime of LIB.

Three types of silicon nanowires arrays: 1) Uncoated silicon nanowires; 2) Alumina-coated silicon nanowires and 3) Polymer-coated silicon nanowires have been studied with regards to their mechanical properties with a newly developed Atomic Force Microscopy (AFM) based mechanical testing protocol. Three main properties were investigated with the use of AFM nanoindentation, including: i) stress-strain slope (or slope of stress-strain curve); ii) energy dissipation and iii) strain-to-failure.

It is found that the alumina-coated silicon nanowires possessed the highest stress-strain slope, energy dissipation and strain-to-failure. The high stress-strain slope was attributed to the dominating elastic properties of the alumina coating, whereas the high energy dissipation and strain-to-failure were very likely to be due to the shearing of the alumina-silicon interface as well as the high friction coefficient of the alumina coating. In addition, shorter alumina-coated silicon nanowires tended to show a higher stress-strain slope. Therefore, it is concluded that short alumina-coated SiNW was the most suitable material to be used as LIB anode among the three materials tested since it can potentially tackle the mechanical issues during charging and discharging cycles.