Microstructural Characterization of Silicon Thin Film Anodes for Lithium-Ion Batteries

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Reduction in the size of electronic components (due to improved integrated circuit technology and fabrication processes) has led to the miniaturization of electronic devices and related peripherals. This has resulted in a need for lightweight, compact power sources that would satisfy the demands of portable devices. One of the immediate consequences of this requirement is the need for higher capacity battery anode materials.

Although carbon based materials are still the accepted anode used in a majority of commercial lithium-ion batteries, intense research is currently ongoing to identify higher capacity anode materials for the next generation of lightweight and compact lithium-ion batteries. In the past few years, many researchers have focused on studying silicon or tin based bulk powder systems for the next-generation anodes in lithium-ion batteries.

Very few researchers have investigated thin or thick films of silicon or compounds in the silicon-tin system. Research on thin films of silicon or silicon-tin systems has shown some promise. More recently, Lee et al. studied the cycle related stress effects in sputtered silicon thin films. Reversible, large scale volume changes were seen in meso-scale sputtered Si-Sn films reported by Beaulieu et al. Research by Beaulieu et al. provided good insight into the nature of the electrochemical reaction of lithium with sputtered amorphous Si$_x$Sn$_{3-x}$ films. Several groups have also presented encouraging results of Si films deposited on Cu and Ni substrates at the 11th International Meeting on Lithium Batteries (IMLB11) 15-17

The promising results of sputtered films prompted the use of sputtering as a synthetic tool in this study to research the electrochemical behavior of amorphous silicon on an inactive, ductile copper foil substrate. Preliminary cycling data for the 250 nm Si films shows promising results for films cycled at both the C/2.5 and 2C rates with 30 cycles charge at C/2.5 rate. (c) after 30th charge at 2C rate (scale same in all images).

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References


Figure 1: SEM morphology of (a) as-deposited 250 nm Si film on Cu, and (b) after 30th charge at C/2.5 rate. (c) after 30th charge at 2C rate (scale same in all images).

Figure 2: AFM images of the 250 nm Si film on Cu foil, (a) before cycling, (b) after cycling 30 times at C/2.5, R$_x$ = 54.0 nm and (c) copper foil substrate prior to Si deposition, R$_x$ = 16.6 nm. (scale same in all images.)

Figure 3: Comparison of galvanostatic cycling of 250 nm and Si films on Cu foil at ~C/2.5 rate and ~2C rate between 0.02 V and 1.2 V.