Atomic Layer Deposited Cu_2S as a Superior Electrode Material with High Capacity and Excellent Cycleability for Lithium-ion Batteries

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Introduction

In the search for new materials enabling high energy density and exceptional cycling stability in lithium-ion batteries (LIBs), metal sulfides represent an important class of electrode materials undergoing intensive investigation [1]. To date, a large variety of metal sulfides have been investigated, such as Al_2S_3, SnS_2, FeS_2, and CuS.

Previously, solution-based methods (e.g. electrodeposition) dominated the fabrication of metal sulfides. Recently there has been increasing interest in atomic layer deposition (ALD) for growing extremely uniform and conformal thin films of metal sulfides. Among them, a successful case was reported with ALD-Cu_2S [2] by our group. In our recent effort, we investigated the performance of the ALD-Cu_2S in a LIB. We found that the ALD-Cu_2S provides excellent cycling stability and high areal capacity.

Experimental

ALD-Cu_2S was deposited on 2-dimensional (2D) planar Cu foils and 3D networked Cu foams (see figure 1(a) and (b)) at 130 °C, using $(Cu(^sBu\text{-}amd))_2$ and H_2S as precursors. The Cu_2S film thickness can be precisely controlled at the sub-nanometer level, and the Cu foil and foam substrates were conformally coated to three different thickness: 50, 75, and 100 nm (see figure 1(c) and (d)). The ALD-coated Cu foils and foams as LIB electrodes were electrochemically tested in lithium half cells.

Results

The ALD-Cu_2S on Cu foil and Cu foam shows superior electrochemical performance, as seen in Figure 2 and 3. The 50-nm ALD-Cu_2S coated 2D planar Cu foils show extremely reliable cycleability over 400 charge-discharge cycles with no capacity fading after the first 20 cycles (see figure 2). Figure 3 exemplifies that 100-nm ALD-Cu_2S coated Cu foams as LIB electrodes show continuously increasing capacity after a drop in the first 10 cycles, going higher than 300μA/cm^2. In particular, in both cases the Coulombic efficiencies are excellent, accounting for a value of over 99%. These factors indicate that ALD-Cu_2S is a promising electrode material for LIBs.

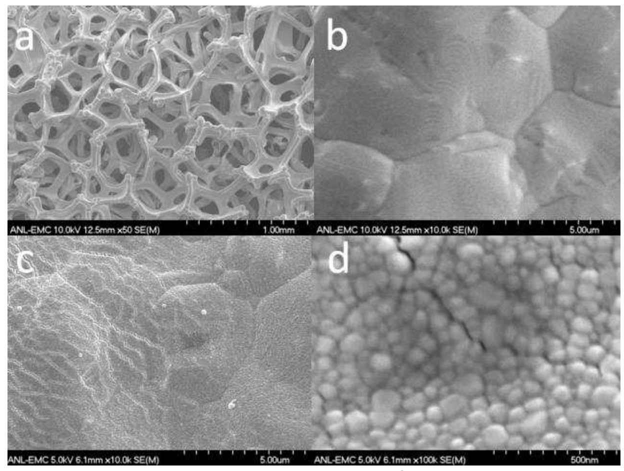

Figure 1. SEM images: (a). bare Cu foam, (b) a local area of bare Cu foam, (c, d) local areas of Cu foam coated with 100-nm Cu_2S.

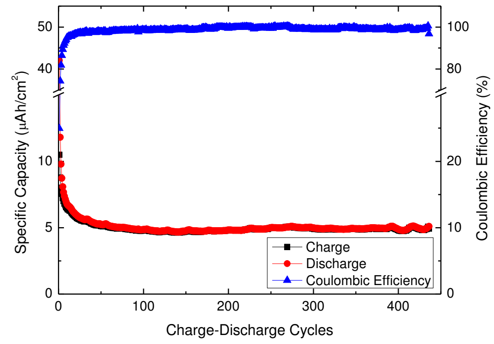

Figure 2. The superior cyclability and Coulombic efficiency of 50-nm thick ALD-Cu_2S on Cu foil as LIB electrode. (current density = 10 μA/cm^2, voltage = 0.01 - 2.00 V)

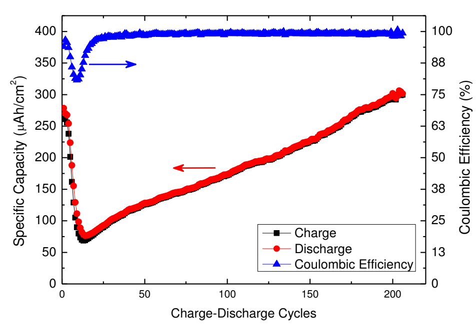

Figure 3. The superior cyclability and Coulombic efficiency of 100-nm thick ALD-Cu_2S on Cu foam as LIB electrode. (current density = 100 μA/cm^2, voltage window = 0.01 - 3.00 V)

References:

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