Abstract #956, 224th ECS Meeting, © 2013 The Electrochemical Society

Three-Dimensional Silicon Anode Architectures via Electrodeposition on Copper Foam Current Collectors

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The search for an alternative anode materials to replace graphite in lithium-ion batteries has been underway for many years. Silicon anodes have become attractive alternatives to carbon because of its very high specific capacity (gravimetric, >3500 mAh/g; volumetric, >8200 mAh/cm^3) and low charge/discharge voltage at room temperature. Unfortunately, silicon suffers from poor capacity retention due to large volume expansion and contraction (~300 % with full lithiation) during lithiation/(de)lithiation. Various approaches has been proposed including new binder systems, capacity/voltage cutoffs, composite electrode formulations as well as different electrode designs.

In this study, three dimensional microporous copper current collectors are used to combine the duties of the electrodes conductive additive and the binder matrix concept into one electrode structure providing a sufficiently large void volume to accommodate the volume expansion. The active material silicon is electrodeposited into copper foam structures. Because the synthetic process based on electrochemical deposition is an inherently complex method, we have identified several variables to incorporate higher levels (> 2 mAh/cm^2) of active Si into three-dimensional electrode structures and assessed the effect of loading level, morphology and long range order of the product formed on its electrochemical properties. The local environment of electrodeposited silicon, its interaction with the surrounding copper foam and interfacial regions within the electrode are studied by various characterization tools such as solid state NMR and synchrotron tomography.

Figure 1 shows the SEM image of silicon electrodeposited into copper foam structures and Figure 2 highlights the performance of electrodeposited amorphous silicon. The cell showed > 2000 mAh/g and >99.7% cycling efficiency over the first 125 cycles (formation cycle not shown). The electrochemical curves and powder X-Ray diffraction studies are consistent with the deposited Si film (on Cu foam) being amorphous.

References:

1) Chan, C. K., Zhang, X. F., Cui, Y. *Nano Lett*, 2008, *8*, 307.
2) Beaulieu, L. Y., Eberman, K. W., Turner, R. L., Krause, L. J., Dahn, J. R. *Electrochemical Solid State Lett*, 2001, *4*, A137.
3) Joyce C., Trahey L., Bauer S., Dogan F., Vaughey J.T., *J. Electrochem. Soc*., 2012, 159, A909.
4) Nishimura Y., Fukunaka Y., *Electrochimica Acta*, 2007, 53, 111-116.

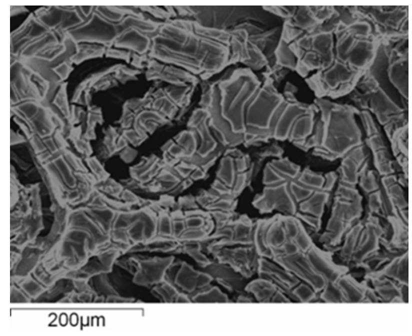

Figure 1. SEM image of electrodeposited silicon on copper foams.

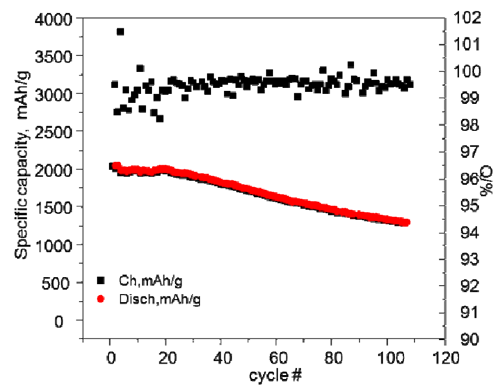

Figure 2. Cycle performance of electrodeposited silicon on copper foams.