Hierarchical carbon nanofiber electrodes with integrated tin nanoparticles

Martin K. Dufficy, Saad A. Khan, and Peter S. Fedkiw

Department of Chemical and Biomolecular Engineering, North Carolina State University, Raleigh, North Carolina 27695

Since commercialization of lithium-ion batteries two decades ago, carbon-based anodes are still highly regarded as one of the more stable anodes due to the formation of a passivating solid-electrolyte interface [1]. However, because of lithium loss upon the initial charge, carbon electrodes, and more specifically graphite (372 mAh/g), suffer from a relatively low-charge capacity when compared to reversible lithium-alloying metals such as tin (992 mAh/g). On the other hand, these metals are subject to high strain and subsequent pulverization due to the large volume expansions during lithium intercalation. Here we examine novel anode materials that incorporate both carbon and tin within a fiber matrix. By coupling carbon fibers with graphene, which has attracted attention due to its 2D structure and high conductivity, and the high- charge capacity of tin, an enhanced performance can be observed with respect to the rate capability and charge capacity of lithium-ion anodes.

Carbon nanofibers (CNFs) provide many beneficial characteristics including an increased surface area for lithium alloying while negating the necessity for a binder due to their nonwoven characteristics. Electrospinning is chosen for the fiber extrusion process in this work as it allows for the continuous and uniform integration of composite fiber mats in a single step. Further, electrospinning provides a facile means to modify fiber functionalization, porosity, conductivity, etc through the addition of a secondary component.

Novel composite nanofibers composed of tin and graphene oxide integrated into a polyacrylonitirile (PAN) polymer matrix are produced. The composite nanofiber mats as well as the filler containing the tin-graphene sheets are pictured in Figures 1 and 2, respectively. These fiber mats are heat treated and placed as the positive electrode in lithium half-cells where we examine the capacity, life, and columbic efficiency of the fiber electrode mats. Graphene-containing nanofiber mats display a large reversible charge capacity of 560 mAh/g (Figure 3) after SEI formation, which is expected to increase with addition of tin. Our work correlates the electrochemical functionality—cycling performance—with physical functionalization—the attributes that give the system its unique performance.

.

References

[1] JB Goodenough, Y Kim, Chem. Mater. 2010. 22, 587-603

.

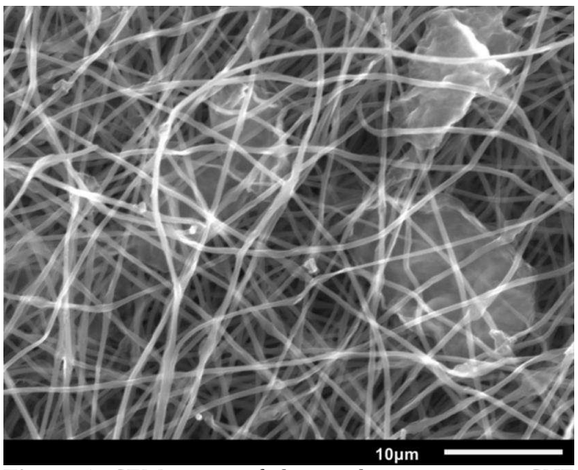

Figure 1: SEM image of the graphene-containing CNF mats with an average fiber diameter of 550 nm.

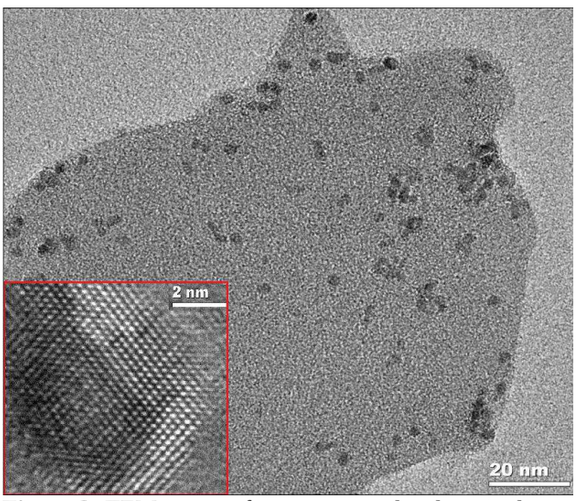

Figure 2: TEM image of tin nanoparticles deposited on a graphene sheet, which are to be used as the composite component in the nanofiber matrix. The inset HR-TEM image shows the atomic lattice of the tin nanoparticle.

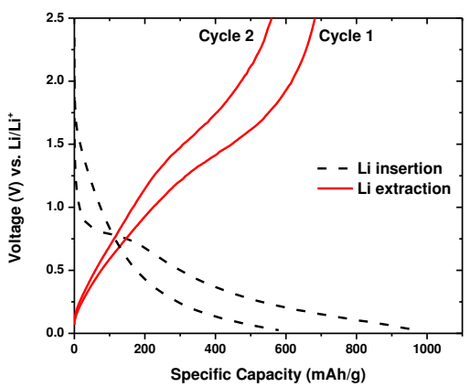

Figure 3: Charge/discharge curve for the first two cycles of graphene containing CNFs. The electrode exhibits a reversible charge capacity of 680 mAh/g after the first cycle and 560 mAh/g after the second when cycled from 0.025 V to 2.5 V at a rate of C/24 (~15mA/g).