Hybrid Sn$_3$O$_2$(OH)$_2$/Graphene Nanoparticles as Anode for Lithium Ion Batteries

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Lithium ion batteries (LIBs) are the dominant rechargeable power source for portable and small scale electronic applications. In order for LIBs to be realistically and practically applied to large scale applications, primarily electric vehicles (EVs), significant improvement in overall capacity and energy density need to be achieved. This can be done through cell geometries, specific engineering of the applied system, or most importantly, the materials used within the battery. Use of Sn as an anode material can improve current anodes, typically carbon, three-fold (from theoretically 372 mAh/g for carbon to theoretically 994 mAh/g for Sn). However, structural stresses (up to 260% volumetric changes) during lithium intercalation/deintercalation create irreversible destruction of the anode which quickly reduces the overall capacity and efficiency. Two of the most popular techniques to mitigate this effect is to reduce particle size where the stress on the crystal is reduced and the addition of lithium-inactive elements to act as a buffer during volumetric changes. Oxygen will irreversibly react with lithium to create Li$_2$O, which will act as the volumetric stabilizer.

Our study uniquely deposited Sn$_3$O$_2$(OH)$_2$ nanoparticles on graphene nano-platelets (GnP) for use as an anode in LIBs. This solvothermal synthesis technique allows the overall synthesis to be scaled according to the required amount of Sn$_3$O$_2$(OH)$_2$/GnP, making it an attractive technique for large scale production. X-ray diffraction (XRD) and scanning electron microscopy (SEM) confirm Sn$_3$O$_2$(OH)$_2$ phase and 40-50 nm particle size of Sn$_3$O$_2$(OH)$_2$ on the surface of the larger GnP through both XRD peak broadening and visual inspection of SEM images. Cyclic voltammetry (CVs) and galvanostatic charge/discharge curves in LIB pouch cells show initial reversible capacity of ca. 680 mAh/g that retains 60% of the initial capacity after the 40th cycle.

In-situ x-ray absorption spectroscopy (XAS), specifically extended x-ray absorption fine structure (EXAFS) spectroscopy measurements were made to determine local structural changes around Sn during different points of charge/discharge. As expected, large structural changes occur during charging, and in a discharged state the particles show Sn in a more metallic crystal structure. In addition, the more it is charged/discharged, the more prominent this Sn-Sn metallic peak becomes. This suggests the destructive nature of cycling such anodes is the tendency of Sn to agglomerate to larger structures, particularly to the point where the volumetric instability of pure Sn metal once again takes over.