Direct Spark Plasma Erosion Synthesis of High Performance Tin and Silicon Alloy Nano-Particulate Materials for Lithium Ion Batteries

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Lithium ion batteries presently offer the highest energy density of any portable energy storage technology, but are not being used to their full potential due to the capacity limitations of currently used materials. One material, silicon, has a theoretical lithium capacity (4200 mAh/g) over ten times higher than commercial graphitic anode materials (372 mAh/g). Alternatives to silicon that also have exceptional capacity for lithium include tin with a theoretical capacity (990 mAh/g) of nearly three times that of graphite. However, silicon and tin (to a lesser extent) must be scaled down to the nano-level to mitigate the pulverization that occurs in the anode due to drastic volume changes in the structure during lithium ion insertion/extraction.

The available synthesis techniques for silicon and tin nano-particles for anodes are overly-complicated and costly to scale-up for commercial production. A unique one-step process for synthesizing Si-Sn alloy and Sn nano-particles via spark plasma erosion is being developed to achieve the ideal nano-particulate size and carbon coating architecture. The spark erosion method produces unique particle characteristics and morphologies, shown to be beneficial for high capacity and good reversibility in a lithium ion battery. The resulting spherical nano-particles are crystalline and amorphous, averaging 5-200nm in diameter. The nano-particles have been characterized using TEM, SEM, XPS, Auger, EDS, and NMR spectroscopy. Anode (half cell) performance measurements, thus far, display significant reversible capacities for over 100 cycles at a C/10 rate and initial capacities approaching theoretical values. Several compositions of tin and silicon alloys have been spark eroded and characterized, and the resulting nano-particles show improved performance as anode materials over current commercial materials.

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