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Production of Nano-Composite Si Powders By Plasma Spraying for Negative Electrode of Li Ion Batteries

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It is know that the storage capacity of lithium-ion batteries can be theoretically increased by a factor of 10 if one replaces the materials for negative electrode from graphite to silicon. This is made possible in a way that silicon accommodates lithium ions to form Si-Li alloy phases with larger crystal volume. As a result, during charge-discharge processes, silicon particles experiences the maximum 400% volume change and therefore get cracked and pulverized gradually, leading to a significant capacity fade with cycles. Various material structuring, such as porous and nano-sized composites, have been reported as effective approaches to cope with this issue. However, the throughput for the processing of the nano-structured materials is also equally important when considering the technology transfer to industry. With these in mind, we have employed plasma spraying in which nano-particles are in principle produced at reasonably high throughputs through the rapid condensation of high temperature Si vapors after the complete evaporation of metallurgical-grade low-cost silicon powders as feedstock. If one introduces the second element together with Si, we can expect composite powder formation through co-condensation of high temperature vapor mixtures. In fact, nano sized Si powders with amorphous Si-Cx coating have been produced. In this work, expecting further modification of the nanoparticle structures, we have attempted the plasma spraying under the different input power density and quenching conditions. It is found that the nano-sized silicon particles with 30 ~ 40 nm in diameter are produced somewhat equally for all the conditions. However, the powders produced at the low input power and with the quenching devices are identified to have smaller BET surface area. This suggests that the powders are fundamentally the multi-order composite having porous regions within the agglomerated nano-sized primary particles. These powders have exhibited the increased capacity and improved initial efficiency and the cycle performance. This may be attributed to the simultaneous attainment of the reduced specific surface area that consumes less Li for SEI formation and of the nano-sized Si particles with the porous structures that may mitigate the influence of the Si volume expansion.