In-situ Laser Synthesis of SiOx Quantum Dots-Graphene Anodes for High Energy Density Li-ion Batteries

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Abstract

The need to develop higher energy-density lithium-ion batteries to meet the demands of transport and grid electrification is growing. A promising solution is to utilize the high-capacity silicon as the anode. However, the poor cycling performance caused by substantial volume change and low conductivity of silicon anodes hinder its commercial applications. Here, we show that laser irradiation of silicon-carbon composite is a practical approach to enhancing Li-ion storage through structural engineering. This novel laser synthesis generates SiOx quantum dots embedded within a highly-graphitic carbon matrix. Moreover, this approach has an important environmental impact by upcycling the carbon waste of fossil fuels burning (flay ash carbon or FAC) into a high-value functional material consisting of silicon oxide quantum dots embedded in lasered-irradiated fly ash carbon (SiOxQDs-LFAC) in one step without using binders or conductive additives. With only 10%w of Si, the laser-treated anodes exhibit a high first-cycle discharge specific capacity of 1588.9 mAh g–1 at 0.1 A g–1, whereas the untreated anodes exhibit 936.2 mAh g–1. The SiOxQDs-LFAC anodes deliver three times higher reversible capacity than the untreated material, 1033.3 mAh g−1 at the current density of 0.1 A g−1 after 250 cycles. This excellent performance shows slow capacity degradation of 0.03% decay per cycle after the initial reduction and a high coulombic efficiency of 98.1%. In contrast, Si-FAC electrodes demonstrate a low reversible capacity of 335.6 mAh g−1 at a current density of 0.1 A g−1 and capacity degradation of 0.19% decay per cycle after 250 cycles.