Carbon Derived from Plasma Methane Pyrolysis as an Anode Material for Li-Ion Batteries

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Abstract

While natural gas remains abundant, it can be transformed into a hydrogen energy source without carbon dioxide emissions through methane pyrolysis a process that decomposes methane into hydrogen gas and solid carbon. Taking into account carbon taxes and energy consumption, direct methane pyrolysis presents a more economical method for producing both hydrogen and solid carbon compared to conventional hydrogen production techniques such as steam methane reforming (SMR), which emits CO_2, and water electrolysis, which is highly energy-intensive. Beyond serving as a clean energy source, the solid carbon byproduct of methane pyrolysis holds considerable industrial value. This study investigates the potential of carbon produced via plasma-assisted methane pyrolysis as a high-value additive for lithium-ion batteries, particularly as an anode material or conductive agent. Raman spectroscopy and differential capacity analyses reveal that this carbon contains a higher proportion of graphitic structures. These graphitic carbons demonstrate excellent electrochemical performance, achieving reversible capacities of up to 450 $mAhg^{-1}$ of 80th cycles when used as anode material (80% plasma carbon) half-cell configuration. Likewise, the carbon displayed the charging capacity 230 $mAhg^{-1}$ in the first cycle to 460 $mAhg^{-1}$ for 100th cycle when it is used as the conducting material (10% plasma carbon). A comprehensive characterization using TEM indicates the presence of disordered carbon domains and residual metal species. These structural imperfections and metallic residues negatively impact electrochemical activity, reducing reversibility and rate performance relative to commercial carbon anodes. The electronic conductivity of the pyrolyzed carbon is found to be strongly influenced by residual metal content, with the purest samples approaching the conductivity levels of commercial carbon additives. Overall, these findings highlight the promising financial and technical potential of solid carbon derived from plasma methane pyrolysis as a next-generation anode material for lithium-ion batteries.

Keywords

Carbon, hydrogen energy, plasma methane pyrolysis, Li-ion anode.