Carbon-coated silicon particles with micro/nano hierarchical architecture as anode material for lithium-ion batteries

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The low energy density (372 mAh•g^{-1}) of the traditional graphite anode in lithium-ion batteries (LIB) is hard to meet the requirements of the commercial application, especially the electric vehicles for high capacity and long cycle life. Si has a large theoretical specific capacity of 4200 mAh•g^{-1}. However, the application of silicon in LIB is hampered due to its large volume variation during the charge/discharge cycles. Although many efforts have been made to handle this problem, it is still a challenge to further enhance the performance of silicon anode materials to realize the large-scale commercial applications. In this study, we designed and prepared the carbon-coated silicon particles (CHS) (Fig. 1g, 1h and 1i) as anode material for LIB. The CHS was fabricated by the facile metal-assisted chemical etching process, low-temperature solution process and thermal carbonization process, as shown in Fig. 1a. The low-cost metallurgical silicon powders (MS) (Fig. 1b and 1c) and pitch were utilized as the raw materials. The single silicon particle (Fig. 1d, 1e and 1f) has micro/nano hierarchical architecture, i.e. numerous porous silicon nanowires are radially distributed over the silicon core. Such architecture can accommodate volume expansion and release the mechanical stress during the charge/discharge processes. In addition, the tight connection between the silicon nanowires and the core inhibits aggregation of the nanowires. Furthermore, the carbon layer coated on the micro/nano hierarchical silicon particle would prevent direct contact between the electrolyte and silicon, resulting in the formation of stable SEI films and integrity of the structure. Utilized as anode material for LIB, the carbon-coated silicon particles with micro/nano hierarchical architecture exhibit improved cycle stability and higher initial coulombic efficiency, which results are shown in Fig. 2.

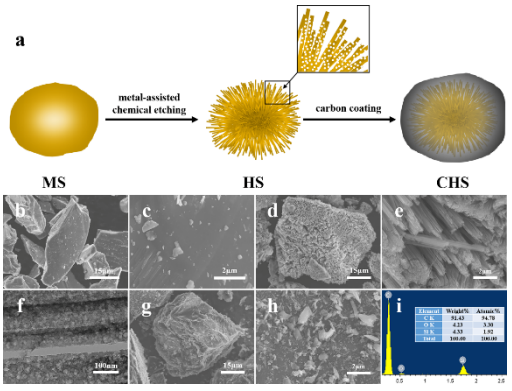

Fig. 1 Schematic diagram for the preparation of CHS (a), SEM images of MS (b,c), HS (d,e) and CHS (g,h), TEM image of the silicon nanowires on HS (f), EDS spectrum of CHS (i).

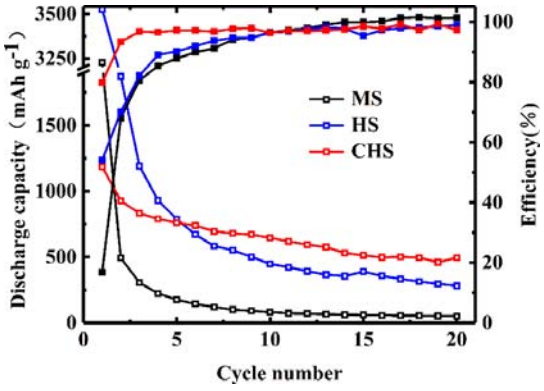

Fig. 2 Cycling stability of MS, HS and CHS