Three-dimensional hierarchical Co$_3$O$_4$@MnO$_2$ core-shell nanoneedle arrays: morphology control and energy storage

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Abstract:

The growth and morphology control of nanoarchitecture materials is a crucial issue in the exploitation of their novel properties and applications. Herein, a highly ordered three-dimensional (3D) hierarchical porous Co$_3$O$_4$@MnO$_2$ core/shell arrays (CMNAs) on nickel foam have been fabricated by a stepwise, seed-assisted, hydrothermal approach and further investigated as the electrode materials for both supercapacitors and Li-ion batteries (LIBs). Based on the morphology evolution upon reaction time, a possible formation process is proposed. This unique structure significantly enhances the electroactive surface areas of the Co$_3$O$_4$ nanoneedle arrays (CNAs), leading to a better interfacial/chemical distribution at the nanoscale, fast ion and electron transfer and good strain accommodation. Thus, when it is used for supercapacitor testing, specific capacitances of 932.8 F g$^{-1}$ at 10 mV s$^{-1}$ and 1693.2 F g$^{-1}$ at 1 A g$^{-1}$ was obtained. Even after more than 5000 cycles at various large current densities, a capacitance of 1388 F g$^{-1}$ at 2 A g$^{-1}$ with 89.8% retention can be achieved, which are better than those of the reported Co$_3$O$_4$ or MnO$_2$ based electrode materials, and thus could be considered as perspective materials for high-performance electrochemical capacitors. The Co$_3$O$_4$@MnO$_2$ core/shell arrays are also tested as anode material for lithium-ion batteries (LIBs), which presents a high reversible capacity of 1060 mA h g$^{-1}$ at a rate of 120 mA g$^{-1}$ with good cycling stability and rate capability. It is also worth emphasizing that the Ni foam substrates present many potential virtues for supercapacitors and LIBs as flexible electronic devices owing to the flexible and lightweight properties. The fabrication strategy presented here is facile, cost-effective, and scalable, which opens new avenues for the design of electrochemical energy applications.