All solid-state flexible supercapacitors based on titanium dioxide@polypyrrole core–shell nanowires

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The fast growth of flexible devices such as portable electronics, roll-up display, paper-like personal gadgets, and miniature biomedical devices has stimulated the development of flexible, lightweight and environmentally friendly energy storage devices. 1 As a new kind of energy storage devices, flexible solid-state supercapacitors (SCs) have received increasing attention due to their high power density, fast charge/discharge rate, excellent cycling stability and safety. 2 Moreover, in comparison to conventional SCs, flexible solid-state SCs have remarkable advantages such as small-size, high-flexibility, light-weight, ease of handling, excellent reliability, and wider range of operation temperature. 3 The performance of SCs strongly depends on the electrode materials. 4 In the past few decades, carbon materials such as activated carbon (AC), 5 carbon nanotubes (CNTs), 6 graphene 7 have been extensively studied as electrode materials for SCs due to their high surface area and excellent conductivity. However, their low energy density severely limits their practical application. 8 In comparison to carbon materials, pseudo-capacitive materials that utilize Faraday redox reactions for charge storage exhibit higher energy density, and have attracted increasing interest as electrode materials. 9

Figure 1. (a) Schematic diagram of the solid-state SC device based on TiO$_2$@PPy NWs with PVA/H$_2$SO$_4$ gel polymer as electrolyte and filter paper as separator. Inset: Photomages of the fabricated TiO$_2$@PPy-SC device. (b) CV curves of the fabricated solid-state fabricated TiO$_2$@PPy-SC device collected at a scan rate of 100 mV s$^{-1}$ in different bending states. (C) Galvanostatic charge/discharge curves of the TiO$_2$@PPy-SC device collected at different current densities. (d) Cycling performance of the fabricated the TiO$_2$@PPy-SC device collected at 100 mV s$^{-1}$ under normal, bent and twisted states. Insets are the pictures of the device under normal, bent and twisted states.

Among various pseudo-capacitive materials, Polyppyrrole (PPy) has been emerged as a kind of promising electrode material for SCs because it has many significant advantages such as high specific capacitance, good conductivity, outstanding mechanical property and biocompatibility. 11 Recent reports have shown that nanostructured electrode can remarkably improve the electrochemical performance of electrode materials. 12 In this regard, considerable efforts have been devoted to the design and synthesis of nanostructured PPy electrodes with rational architectures. 13 In recent years, multifarious PPy nanostructures such as nanotubes, nanoplates, 14 nanofibers 15 have been developed as electrodes for SCs. Nevertheless, the development of PPy nanostructures with excellent electrochemical property is still highly desirable.

In this work, we reported the facile synthesis and improved electrochemical performance of the TiO$_2$@PPy core-shell nanowires (NWs). Electrochemical measurements show that the TiO$_2$@PPy core-shell NWs grown on carbon cloth by a two-step method exhibit a high areal capacitance of 64.6 mF cm$^{-2}$ at a scan rate of 10 mV s$^{-1}$. Moreover, NWs grown directly on carbon cloth not only provide a high surface area and strain accommodation, but also enable the fabrication of flexible SC devices without the need of a binder. The solid-state SC device based on the as-prepared TiO$_2$@PPy core-shell NW electrodes exhibits good flexibility and achieves a maximum energy density of 0.013 mWh cm$^{-2}$.

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References: