Effect of phosphorus functionalities on the supercapacitive properties of nonporous carbon nanofibers

Xiaodong Yan, Jinle Lan, Yuan Liu, Yunhua Yu*, Xiaoping Yang
State Key Laboratory of Organic-Inorganic Composites, Beijing University of Chemical Technology, Beijing, 100029, E-mail: yuyh@mail.buct.edu.cn

Supercapacitors have attracted tremendous attention due to their moderate energy densities and high power densities which can bridge the gap between batteries and conventional electrolytic capacitors [1]. Carbon materials are the most widely used and studied electrode materials. However, the limited specific capacitance of activated carbons and the high cost of templated carbons force us to develop a more effective and simple method to fabricate high-capacitance carbons. Heteroatom doping seems to be one of the most promising strategies to simplify the preparation processes, and meantime endow the carbons with high capacitances. Recently, the incorporation of nitrogen and phosphorus atoms into carbon scaffolds or onto the surface of carbons has attracted much interest [2, 3]. However, the function of phosphorus groups is not defined definitely. Herein, the phosphorus doped carbon nanofibers (P-CNFs) were conveniently fabricated through electrospinning of the precursor solution containing polyacrylonitrile and phosphoric acid and subsequent heat treatments without any additional activation. The effect of phosphorus groups on the supercapacitive performance and the mechanism of phosphorus groups in enhancing the capacitance of the carbon materials were investigated.

The cyclic voltammetry (CV) measurement indicates that the electrical double layer (EDL) characteristics of P-CNFs are greatly promoted due to the presence of the phosphorus groups on the surface of the CNFs, as the CV curve of P-CNFs shows a typical rectangular shape (Fig. 1). This can be ascribed to the oxygen-rich phosphorus functionalities which could improve the wettability between the electrode materials and the electrolyte as well as enhance the adsorption of protons in the electrolyte. The electrochemical impedance spectroscopy indicates fast ion transfer from the electrolyte to the electrode materials as the slope of the linear part in the Nyquist plot of P-CNFs moves towards vertical (Fig. 2).

In conclusion, the P-CNFs demonstrate excellent electrochemical performance. The phosphorus groups have a positive effect on the formation of EDL by enhancing the wettability and adsorption of ions in the electrolytes. The phosphorus doping can be a promising strategy to fabricate high-capacitance carbon-based electrode materials for supercapacitors with a simple preparation process.

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References