Porous SWNT-PPy Sheets and Fibers for Supercapacitor Applications

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ABSTRACT

Nanocomposite electrodes for supercapacitors in the form of sheets and fibers were prepared by i) vacuum filtration of SWNT-PPy methanol dispersion and ii) wet-spinning of SWNT-PPy aqueous dispersion, respectively. Electrochemical properties of prepared materials were investigated using cyclic voltammetry method in aqueous 1M NaCl and $NaPF_6$ electrolytes. The capacitance of the SWNT-PPy sheet was about 5 times higher than that of pristine SWNT paper. The capacitance of SWNT-PPy fibers reached record 200 F/g value. Prospective applications of prepared materials range from supercapacitors to electrodes for batteries and electromechanical actuators.

Keywords: carbon nanotubes, polypyrrole, supercapacitor, capacitance

1. INTRODUCTION

Carbon nanotubes are attractive materials for electrodes of electrochemical energy storage devices due to their high surface area, chemical stability, high conductivity and low mass density. The performance of conventional carbon nanotube mats (buckypaper) is limited by the effective surface area so that observed capacitance values normally do not exceed 15-40 F/g [1, 2]. Achieving higher capacity requires improvement of electrode materials.

Properties of carbon nanotube electrodes can be modified by addition of a conducting polymer such as doped polypyrrole (PPy). In Ref. [3] we reported an efficient, easily scalable method for preparation of highly porous SWNT-PPy nanocomposite electrodes suitable for industrial supercapacitor applications. This method is based on the vacuum filtration of SWNT-PPy methanol dispersion and is an extension of conventional buckypaper fabrication technique on the multi-component system. Using similar approach we prepared and report here SWNT-PPy fibers that can be considered an extension of the SWNT wet spinning method [4] on the multi-component system.

2. EXPERIMENTAL

As produced HiPco SWNT (CNI), doped PPy (Aldrich Inc.) [5], and methanol (99.8% grade, Aldrich Inc.) were used in this work. Pristine SWNT and SWNT-PPy methanol dispersions with 2:1 SWNT to PPy ratio (33 wt. % PPy) were prepared by probe sonication [3]. SWNT-PPy fibers were spun from similar 2:1 SWNT-PPy aqueous dispersion as described in [4]. The dispersion for fiber spinning was prepared with the aid of lithium dodecyl sulfate (LDS) surfactant.

Cyclic voltammetry experiments were performed with a Gamry Instruments potentiogalvanostat in 1M NaCl and $NaPF_6$ aqueous electrolytes using a conventional three-electrode cell. A platinum mesh served as a counter electrode and saturated calomel electrode (SCE) was used as a reference electrode.

3. RESULTS AND SISCUSSION

Comparative CV measurements of pristine SWNT

paper, SWNT-PPy sheet, and SWNT-PPy fiber acquired at scan rate of 10 mV/s in 1 M NaCl and $NaPF_6$ electrolytes are shown in Figure 1.

The voltammogram of the SWNT paper had rectangular shape typical of double layer charging. CVs of SWNT-PPy nanocomposite electrodes look quite similar if measured in the same voltage range except for onsets of two current peaks at +0.5 V and -0.5 V. The peaks can be attributed to a Faradaic redox reaction of PPy.

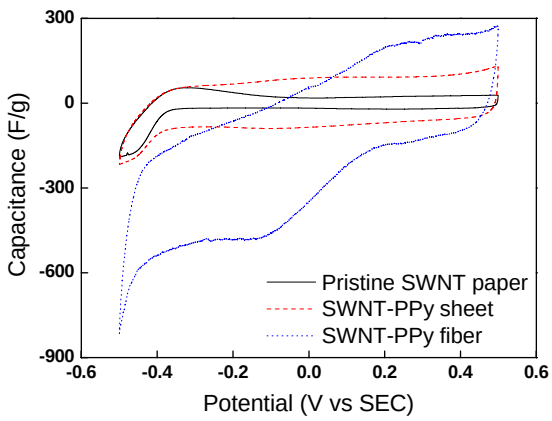

Figure1: Cyclic voltammograms of pristine SWNT paper, SWNT-PPy sheet (33 wt.% PPy), and SWNT-PPy fiber (33 wt.% PPy) at scan rate of 10 mV/s in 1 M $NaPF_6$ electrolyte.

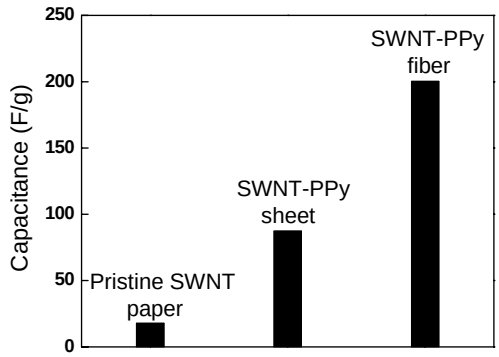

Figure2: The comparison of specific capacitance of pristine SWNT paper, SWNT-PPy sheet (33 wt.% PPy), and SWNT-PPy fiber (33 wt.% PPy) determined by CV in 1 M $NaPF_6$ electrolyte.

Specific capacitance values for the electrodes calculated using the CV data in the vicinity of 0 V, are shown in Figure 2. One can see that the capacitance of SWNT-PPy sheets is significantly about 5 times higher than that for pristine SWNT paper. This is in good agreement with [3] and can be associated with the Faradaic contribution coming from nanostructured PPy. The capacitance of SWNT-PPy fiber reached record 200 F/g value in $NaPF_6$ electrolyte. The dramatic increase in capacitance of fiber as compared with SWNT-PPy sheets of the same composition is probably because of much higher electrolyte accessible surface area of the fibrillose material.

4. CONCLUSIONS

Significant increase in capacitance of SWNT-PPy sheets and fibers as compared with pristine carbon nanotube assemblies has been observed. The capacitance of SWNT-PPy fibers reached record 200 F/g value. The SWNT-PPy sheet and fiber technologies are easily scalable for device fabrication on an industrial scale.

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