Electrochemical Behaviors of Polyaniline-Implanted Porous Carbon Electrode for Supercapacitors

Wei-Chih Chen and Ten-Chin Wen
Department of Chemical Engineering, NCKU
Tainan, 701, TAIWAN
E-mail: n3889109@ccmail.ncku.edu.tw

Introduction

Supercapacitors have attracted considerable attention as an intermediate power source between conventional capacitors and rechargeable batteries. In recent years, porous carbon is the most frequently used electrode material for electric double-layer capacitors (EDLCs) [1-2].

Sometimes, a supercapacitor of large specific capacitance forms from an electrode material not only possessing large specific surface area but also coupling with active species, like conducting polymers and metal oxides, that can be reversibly oxidized or reduced over a potential range.

The objective of the present research work is to enhance the capacitance of an EDLC through introduction of the conducting polymer, polyaniline (PANI) which provides pseudocapacitance, to the carbon electrodes. The electrochemical characteristics of electrodes and the performances of the resulting supercapacitors are examined by using cyclic voltammetry (CV), AC impedance, and galvanostatic charge-discharge, in the attempt to clarify the contribution of PANI to the overall capacitance.

Results and Discussion

Porous carbon powders serving as the main electrode material have a high specific surface area of 1778 m^2/g. Bare-carbon (BC) electrodes were fabricated by coating carbon slurry consisting of 20 wt% PVdF as binder. PANI-implanted carbon (PC) electrodes were made by the electrochemical loading of PANI on BC substrates via CV between -0.2 and 0.8 V, with a slow scan rate, 0.3 mV/s, for 5 cycles only.

The voltammograms of the BC electrode with various sweep rates are shown in Fig. 1. This figure reveals that the electrode is stable in acid solution within the applied potential range. It can be seen that a wide bending of voltammograms appears just after the reversal of the potential sweep before reaching to the plateau. The voltammograms show a slight deviation from the rectangular form. Also, increasing the scan rate enhances the delay of the current to reach a constant value. These are arisen from the distributed capacitance effects in porous electrodes and the effects are enhanced upon increasing the potential sweep rate [3].

The voltammograms of the PC electrode are shown in Fig. 2. In comparison with the BC electrode, PC not only presents a higher background current in the voltammograms but also displays faradaic currents, which are likely to arise from the contribution of the deposited PANI. It can be seen from the voltammograms of Fig. 2 that, during the anodic potential sweep, the current significantly increases with the potential for the sweep beyond 0.2 V and reaches a maximum at 0.6 V. This is attributable to the addition of faradaic current from PANI, which is in its conducting emeraldine state at this potential range, 0.2–0.6 V. On the other hand, while the potential below 0.2 V, PANI exists in the insulated leucoemeraldine state that could not contribute faradaic current. In the reversal cathodic potential scan, the current was enhanced by the reduction of PANI. However, the redox transitions within PANI would not be as reversible and fast as the double layer formation, and this leads to a more serious delay of current to reach the plateau.

From the charge-discharge cycling tests, the PC electrode exhibits a large specific capacitance of 180 F/g, much higher than the BC electrode exhibiting a value of 92 F/g. The high specific capacitance of PC electrodes was concluded as the combination of double-layer capacitance and pseudocapacitance.

References

[1] M. Endo, Y.J. Kim, T. Takeda, T. Maeda, T. Hayashi, K. Koshiba, H. Hara, M.S. Dresselhaus, J. Electrochem. Soc. 148 (2001) A1135.
[2] T.C. Weng, H. Teng, J. Electrochem. Soc. 148 (2001) A368.
[3] I. Tanahashi, A. Yoshida, A. Nishino, J. Electrochem. Soc. 137 (1990) 3052.

Acknowledgments— The authors are grateful to the National Science Council in Taiwan for its financial support through NSC 91-2214-E-006-028.

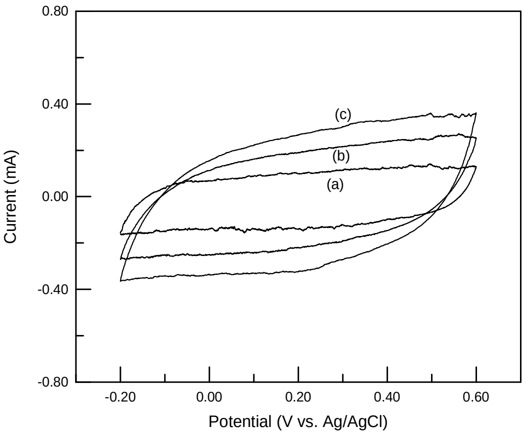

Fig. 1. Cyclic voltammograms of the BC electrode in 1 M H_2SO_4 at different sweep rates: (a) 0.3; (b) 0.6 and (c) 1.0 mV/s.

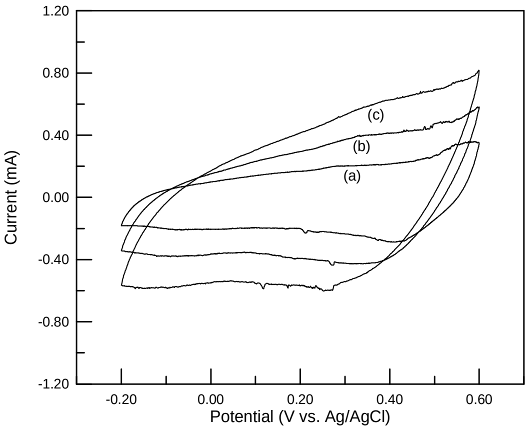

Fig. 2. Cyclic voltammograms of the PC electrode in 1 M H_2SO_4 at different sweep rates: (a) 0.3; (b) 0.6 and (c) 1.0 mV/s.