Candidate organic electrolytes for electric double-layer capacitor application

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Abstract : Electrolytic conductivity , viscosity and electrochemical behavior were investigated for organic electrolytes based on PC (Propylene carbonate) , MAN(Methoxy acetonitrile) and GBL(γ-Butyrolactone) solvents. It was found that 1 mol/ L Et_4NBF_4-MAN had the highest conductivity , lowest viscosity and acceptable potential window. The specific capacitance and energy density obtained from the capacitor using 1 mol/ L Et_4NBF_4-MAN as electrolyte were the highest among all the tested electrolytes. 1 mol/ L Et_4NBF_4-GBL also seemed promising to be used in electric double-layer capacitor (EDLCs).

Key words : electric double-layer capacitor ; organic electrolytes ; methoxy acetonitrile ; propylene carbonate ; activated carbon

中图分类号 : TM533 文献标识码 : A 文章编号 :1001 - 1579(2004) 05 - 0337 - 03

Electric double-layer capacitor(EDLC) is a unique electrochemical energy storage device which exhibits much greater capacitance than conventional capacitors. It also offers much higher power density than conventional batteries. $(C_2H_5)_4NBF_4$-PC is frequently used as electrolyte in EDLCs for its relatively high electrochemical and thermal stability[1-2]. However, the conductivity of $(C_2H_5)_4NBF_4$-PC is rather low and the viscosity is quite high. Acetonitrile has a high conductivity and has already been used as solvent in the European market for capacitors[3]. However, this solvent is toxic and prohibited in the United States, Japan and some other countries. Although MAN is a acetonitrile-based compound, it is far less toxic than acetonitrile and is possible to be used in some areas. An organic electrolyte based on GBL solvent had relatively high conductivity and low viscosity[4] was also evaluated for the application in EDLCs.

1 Experimental

All chemicals used were reagent grade from Wako Pure Chemical Industries, Ltd. They were used as received without any further purification. Electrolyte solutions were prepared in a glove box, which had been evacuated and filled with inert gas (N_2).

Electrolytic conductivity of the electrolyte solutions was measured with a conductivity meter (Model SC 82, Yokogawa Electric. Corp.). Viscosity of the electrolyte solutions was measured with a viscometer (Model VM-1G, CBC Materials Co., Ltd.).

Performance of the test capacitors using various electrolytes was investigated by constant-current charge-discharge, cyclic voltammetry and electrochemical impedance spectrum(EIS) techniques(frequency varied from 100 kHz to 1 Hz). The activated carbon electrodes (including Al foil current collector) used in the test capacitors were from Hohsen Corp., 16 mm in diameter and weighed 0.032 g each. The mass of carbon at each electrode was 0.017 5 g. 300 ml of electrolyte solution was used in a test capacitor. Constant-current charge-discharge tests were carried out with a battery test system HJ1010SM8 (Hokuto Denko Corp.). Capacitance of the cell (capacitor) was calculated according to the equation $C = 2E/\Delta V^2$, where E stood for the energy delivered and ΔV for the usable voltage during the period of discharge. Specific capacitance was calculated as the capacitance of the electrode divided by the mass of active material, i.e., activated carbon. Energy density was defined as the energy delivered divided by the total mass of electrodes. For cyclic voltammetry measurements, a glassy carbon electrode (3 mm in diameter) was used as the working electrode, a Pt disc (3 mm in diameter) as the counter electrode and Ag/ AgCl as the reference electrode. The instruments employed for EIS measurements were: Model S-5720C frequency response analyzer(NF Electronics Instruments), Model PS 2000 potentiostat/ galvanostat and Model FG-02 function generator(TOHO Technical Research).

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