Assembly and Electric Double-Layer Capacitive Behavior of Three-Dimensional Carbon Nanocluster Electrodes

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1. Summary

We have investigated nickel nanoparticles on catalytically grown multi-walled carbon nanotubes (CNTs) as well as the generation of secondary nanotubes by resubmitting the decorated nanotubes to the chemical vapor deposition process. N_2 physisorption indicated that the specific surface area is found to increase after the growth of secondary nanotubes. The electrochemical behavior of carbon electrodes in H_2SO_4 was examined using ac impedance spectroscopy. The specific double-layer capacitance was significantly enhanced due to the presence of secondary nanotubes. The pore resistance for ion migration was low for these carbon nanostructures. The electrical connection resistance between the CNTs and the backing plate accounted for the major proportion of the overall resistance and was shown to decrease due to the growth of secondary CNTs. There is ca. 204 % capacitance increase achieved through the introduction of secondary nanotubes. This fact that the presence of secondary on the primary CNT enhances the double layer capacitance and the responding rate has a great enhancement on the energy storage devices and semiconductor-type gas sensors.

Keywords: carbon nanotubes, chemical vapor deposition, electric double-layer capacitance

2. Extended Abstract

A chemical vapor deposition used for growing the secondary nanotubes decorated with primary multi-walled carbon nanotubes (CNTs) was investigated. Low (700 °C) and high (900 °C) growth temperatures lead to grow different shapes of 3-D carbon cluster. This can be attributed from the fact that at the elevated temperature, the small Ni particles start to merge into isolated large clusters due to the increased mobility and mass transport, thus resulting in the morphology transformation of carbon network. N_2 physisorption indicated that the growth of secondary nanotubes improves both of specific surface area and micropore fraction. The electrochemical behavior of carbon electrodes in H_2SO_4 was examined using ac impedance spectroscopy. Equivalent circuit analysis indicated that both of the specific double-layer capacitance electrical connection resistance between the CNTs and the backing plate were found to significantly enhance due to the presence of secondary nanotubes.

Table 1. Components and Related Parameters of the Equivalent Circuit (Figure 1(c): i) for the CNT Electrodes in 1 M H_2SO_4 within High Frequency Region.

Carbon Electrode	R_s (Ω)	R_b (Ω)	C_b (μF/cm^2)
Primary CNT	1.67	18.0	36.8
3-D cluster	1.52	4.95	43.1

Table 2. Components and Related Parameters of the Equivalent Circuit (Figure 1(c): ii) for the CNT Electrodes in 1 M H_2SO_4 within Low Frequency Region.

Carbon Electrode	C_d (F/g)	R_{es} (Ω)	R_P (Ω)	τ_0 (sec)
Primary CNT	39.3	20.3	0.63	1.51
3-D cluster	119.5	7.15	0.68	1.52

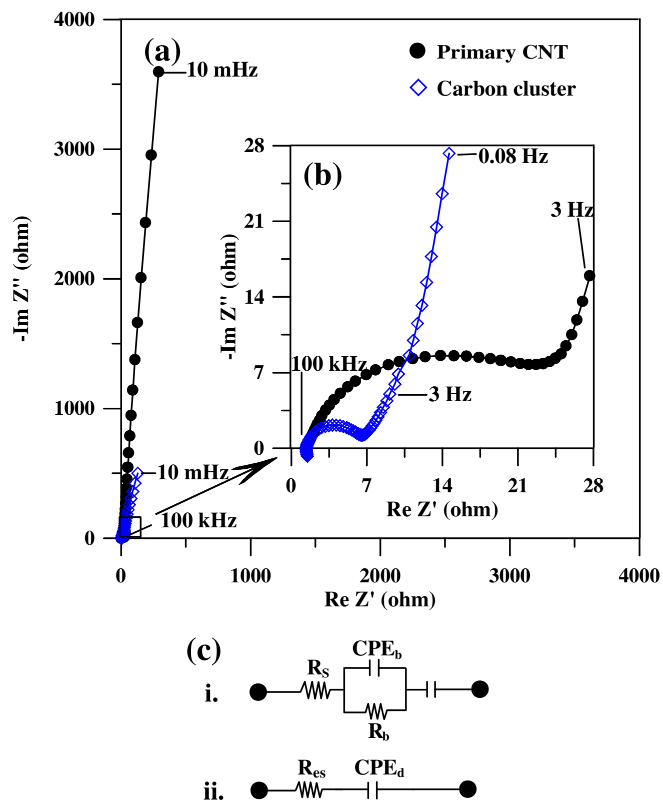

Figure. 1. Nyquist plots of carbon electrodes operated within (a) 10 mHz–100 kHz and (b) 3 Hz–100 kHz. (c) Equivalent circuits for carbon electrodes at (i) high and (ii) low frequencies.

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