

Attachment of Nickel Nanoparticles on Carbon Nanotube Electrodes for Enhancement of Electrochemical Capacitance

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1. Summary

A chemical impregnation led to homogeneously disperse Ni particles onto the surface of CNTs, which were oxidized by nitric acid treatment. The Ni particles were found to be an average size of 30–50 nm. CV measurements showed that the presence of Ni particles significantly enhances the electrochemical capacitance. The Faradaic current (i.e., peak current) linearly increased with the Ni loading, indicating that the population of Ni coverage promotes the redox process. This indicates that attached nickel can be served as a redox site in facilitating an excess specific capacitance, i.e., pseudocapacitive behavior. Equivalent circuit analysis on the ac impedance results showed that the total resistance of CNT electrodes was mainly attributed to the charge transfer and the electrical connection resistances. Both of the two resistances were found to decrease upon the introduction of nickel. This indicated that the Ni attachment would improve not only the conductivity of CNT electrodes but also the charge transfer of redox reaction.

Keywords: carbon nanotubes; electric double-layer capacitance; nickel nanoparticle; Pseudocapacitance; ac impedance

2. Extended Abstract

Attachment of nickel particles on carbon nanotubes (CNTs) was conducted to explore the influence of Ni loading on the electrochemical capacitance of Ni-attached CNT electrodes. A chemical impregnation led to homogeneously disperse Ni particles onto the surface of CNTs, which were oxidized by nitric acid treatment. The Ni particles were found to be an average size of 30–50 nm. The capacitive behavior of the CNT electrodes was investigated in 6 M KOH, by using cyclic voltammetry (CV) and ac impedance spectroscopy. CV measurements showed that the Faradaic current was found to increase with the Ni coverage, indicating the presence of Ni would enhance the redox process. Equivalent circuit analysis indicated that both of electrical connection and charge transfer resistances accounted for the major proportion of the overall resistance and were found to decrease with the amount of nickel. A linearity relationship between the total capacitance and the Ni population reflected that each Ni particle exhibits an identical electrochemical activity in enhancing the electrochemical capacitance.

Table 1. Components of the equivalent circuit fitted for the impedance spectra of Ni-CNT electrodes.

CNT sample	R_s (Ω)	R_c (Ω)	C_c ($\mu\text{F cm}^{-2}$)	R_F (Ω)	$C_{dl} + C_p$ (F g^{-1})
CNT-Ni5	1.41	8.17	25.9	59.1	141
CNT-Ni10	1.37	3.55	33.0	25.2	198
CNT-Ni14	1.22	1.82	55.1	15.7	237

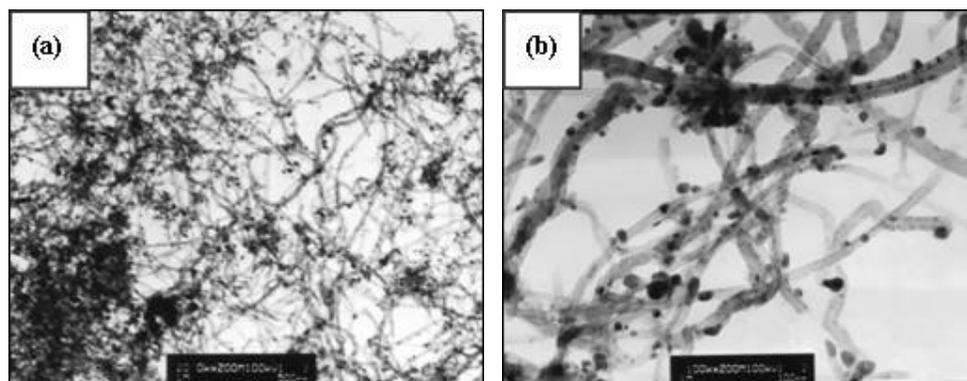


Figure 1. TEM images at different magnifications: (a) $\times 20$ k and (b) $\times 100$ k, for Ni particles deposited on CNTs.

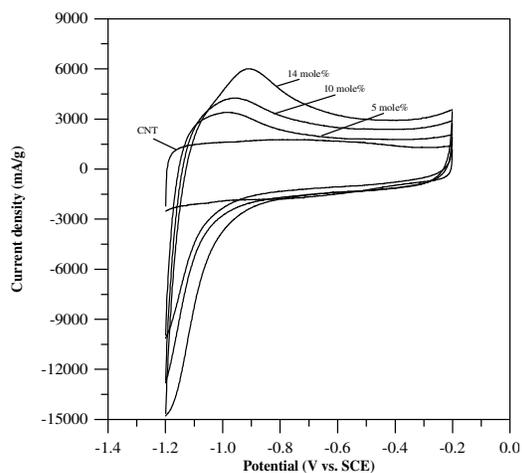


Figure 2. Cyclic voltammograms of the CNT electrodes in 6 M KOH at a scan rate of 30 mV/sec.

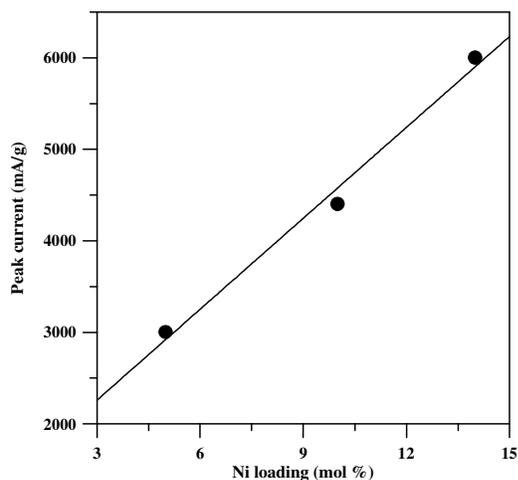


Figure 3. Variation of anodic peak current at -0.9 V vs. Hg/HgO with Ni loading for different CNT electrodes.

References

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