Electrochemical Properties and Applications of Carbon Nanotube Electrodes

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Carbon nanotubes, consisting of cylindrical graphene sheets with nanometer diameter, combine in a unique way high electrical conductivity, high chemical stability and extremely high mechanical strength and modulus. These special properties of both single-wall and multi-wall carbon nanotubes have attracted increasing interest as new applications for these materials are envisaged. Reports have described the evaluation of nanotubes for use in supercapacitors, chemical sensors and energy storage devices. A novel application of single-wall carbon nanotubes (SWNT) in electromechanical actuators has also been proposed [1]. These actuators undergo dimensional changes as a result of electrochemical charge injection.

We have previously described [2-4] the electrochemical properties of free-standing SWNT sheets or mats, in a range of aqueous and non-aqueous electrolytes. More recently several studies have been conducted to explore a range of new applications.

The basic properties of the NT mats were examined using cyclic voltammetry, chronoamperometry and electrochemical impedance spectroscopy. The effect of annealing, electrolyte type and concentration, applied potential, mat thickness and surface area on the electrochemical behaviour of the NT mats was investigated.

Cyclic voltammetry in aqueous solutions revealed redox responses which disappeared upon thermal annealing. Impedance spectroscopy produced spectra showing typical features of a porous electrode. The equivalent circuit contained a constant phase element to account for the distributed time constant (RC). A range of capacitance values was observed depending on the mat preparation conditions. In aqueous solutions these values varied between 15 to 40 F/g. Maximum capacitance was accessible up to around 10 Hz. Chronoamperometric and impedance data obtained to evaluate the rate of double layer charging indicated that the time constant increased linearly with the mat thickness.

Surface area measurements using the BET method yielded values ranging from 280 to 380 m^2/g. The capacitance was found to be proportional to the BET surface area.

The electromechanical actuation properties of the NT mats were found to be larger in non-aqueous solutions. Minimum actuation was observed around the potential of zero charge where the electrical capacitance is also minimum.

Surface properties were investigated using SEM, AFM and electric force microscopy (EFM). The latter technique, previously applied to conducting polymers, offers interesting possibilities in mapping surface potential.

Other applications investigated include the use o NT mats as electrodes for electrical energy generation in thermoelectrochemical cells. Initial current levels were around 10 A/kg using nitric acid as electrolyte.

The possibility of preparing mats from different NT dispersions has resulted in the testing of a range of aqueous stabilisers and the subsequent fabrication of composite materials with different electrochemical and mechanical properties.

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