Molybdenum Oxide/Carbon Composite Electrodes as Electrochemical Supercapacitors

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Electrochemical supercapacitors are candidates for high power density devices used in energy storage systems. High surface ares carbon, polymers or metal oxides have been proposed as possible materials and have been widely studied. We recently reported that nanosize ruthenium or molybdenum oxide produces extremely large pseudo-capacitance when highly dispersed on non-porous carbon [1,2]. Increase in the supercapacitive behavior of porous carbon by loading with ruthenium oxide has also been reported [3,4]. We report here, the enhancement in the charge storage capability of high surface area carbon material by loading with an inexpensive oxide.

The MoO_3/C composite materials were prepared by a simple impregnation method. High surface area carbons (Activated Carbon Mitsubishi Chemicals Capacitor Grade) were stirred in methanolic solutions of $MoCl_5$, followed by drying and pyrolysis. Electrode materials for electrochemical characterization were prepared following a method described by Schmidt et al.[5] for the characterization of PtRu/C electrocatalysts. Briefly, 20 mg of MoO_3/C was dispersed in 10 mL distilled water and was subject to ultrasonification for 30 min. The pH of the solution was adjusted with dil. NaOH to obtain a stable dispersion. 20 mL of the MoO_3/C dispersion was then pipetted onto a mirror finished Glassy Carbon substrate. After drying, 20 mL of a 1 wt% Nafion® ionomer solution was further dropped onto the electrode surface. Cyclic voltammetry was conducted in 1 M NaOH or 0.5 M H_2SO_4 electrolyte with a typical scan rate of 50 mV s^{-1} between 0.2-1.2 V (*vs.* RHE) at 25°C.

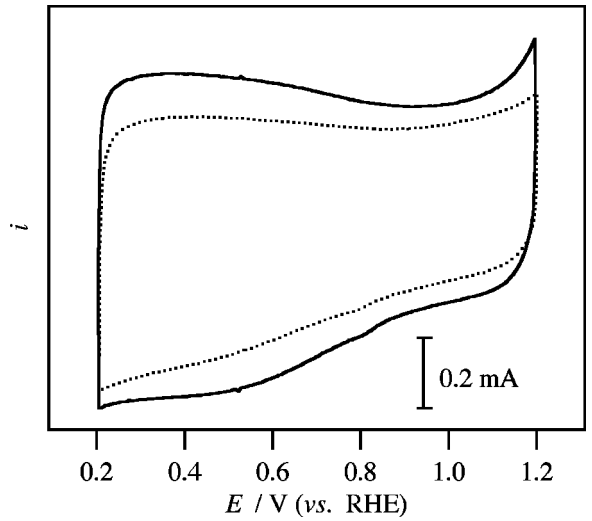

Fig.1. Cyclic voltammorgams of high surface area activated carbon (dotted line) and activated carbon loaded with 1.4 mass% MoO_3 (solid line). Measured in 1 M NaOH at 25°C (50 mV s^{-1}, 100th cycle).

Figure 1 shows typical cyclic voltammograms in 1 M NaOH electrolyte of activated carbon (S_{BET} = *c.a.* 2000 m^2 g^{-1}) and the MoO_3/C composite electrode with 1.4 mass% loading. The specific capacitance of MoO_3/C was appoximately 177±5 F g^{-1}, which is 34% higher than that of pristine activated carbon (132±4 F g^{-1}). An increase in capacitance of 29% was also obtained an 0.5 M H_2SO_4 electrolyte (136 → 176 F g^{-1} for 0.85 mass% loading).

As shown in Fig. 2, The increase in the specific capacitance was observed up to a few mass% loading, with a maxima at approximately 1.4 mass%. When the loading amount of MoO_3 is high, the specific capacitance became lower than that of pristine activated carbon.

The present results shows that the MoO_3/C composite electrodes are candidates as high energy density electrochemical supercapacitors. The specific capacitance of high surface area carbon based electrochemical supercapacitors can be enhanced by sufficient alloying with electroactive oxide material even with poor electrical conductivity.

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[2] Y. Takasu *et al.*, *Electrochemistry*, **67**, 1187 (1999).
[3] J.M.. Miller *et al.*, *J. Electrochem. Soc.*, **144**, L306 (1997).
[4] Y. Sato *et al.*, *Electrochem. Solid-State Lett.*, **3**, 113 (2000).
[5] T.J. Schmidt *et al.*, *J. Electrochem. Soc.*, **145**, 2354 (1998).

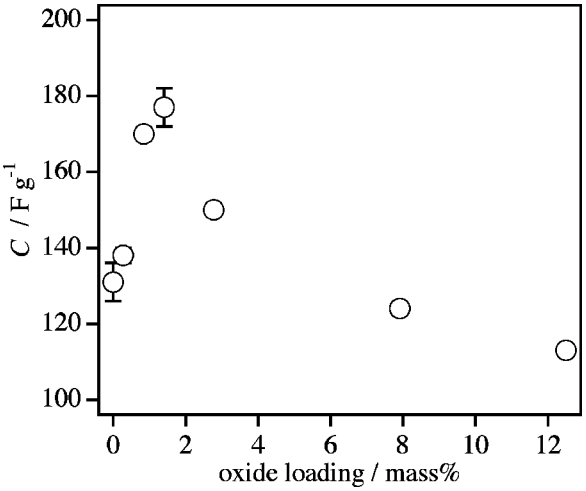

Fig.2. Relationship between the capacitance and the amount of MoO_3 loading in MoO_3/C composite electrodes. Measured in 1 M NaOH at 25°C (50 mV s^{-1}, 100th cycle).