Combination of a SnO$_2$-C hybrid anode and a tubular mesoporous carbon cathode in a high energy density non-aqueous lithium ion capacitor

Wen-Hui Qu, Fei Han, An-Hui Lu, Chao Xing, Mo Qiao, Wen-Cui Li*
State Key Laboratory of Fine Chemicals, School of Chemical Engineering, Dalian University of Technology, Dalian 116024, P. R. China
E-mail: wencuili@dlut.edu.cn

Dramatic increases in the energy storage of supercapacitors can be achieved by using asymmetric combinations of different cathodes and anodes in non-aqueous electrolytes which produce a higher working voltage. The lithium ion capacitor (LIC), bridging supercapacitors and lithium ion batteries (LIBs), has recently drawn considerable attention. Herein, a non-aqueous LIC was fabricated using tubular mesoporous carbon as cathode and a SnO$_2$-C hybrid (ultrafine SnO$_2$ encapsulated in the tubular mesoporous carbon) as anode.

SnO$_2$-C hybrids with nanosized SnO$_2$ particles encapsulated in a tubular mesoporous carbon were used as anode materials for the LIC and three porous carbons were investigated as the cathode in order to achieve an optimum match between cathode and anode. We demonstrated that the porous carbon with a high area surface and easy accessible pore channels produces the highest capacitance and good rate capability. The combination of a SnO$_2$-C hybrid anode and a porous carbon cathode can produce a superior performance LIC with a maximum energy density of 110 Wh kg$^{-1}$ and a maximum power density of 2960 W kg$^{-1}$. These are higher or at least equal to those of recent reported non-aqueous lithium ion capacitors. The capacitance retention is fairly stable and remains at 80% of its initial value after 2000 cycles.

This unique performance arises because of the highly conductive tubular mesoporous carbon matrix and fast charge/ion diffusion in the SnO$_2$-C hybrid anode. It is shown that the SnO$_2$ loading in the anode has a great influence on the stability of the SnO$_2$ nano-structure and the kinetics for lithium ion transfer. Electrochemical impedance spectroscopy (EIS) was used to evaluate the charge transfer resistance and the ionic diffusion resistance before and after long-term cycling. The diffusion coefficient was also calculated to verify the good rate and cycling capability. It is found that the charge/ion transfer efficiency and the cycle stability of the nano-structured SnO$_2$-C hybrid are closely related to the loading ratio of active SnO$_2$, which determines the energy/power density and long-term cycling capability of the LIC.