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Study of the structure-properties relations of carbon spheres affecting electrochemical performances of EDLCs

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ABSTRACT

For high performance of electrical double layer capacitors (EDLCs), a high specific surface area (SSA) and N-doping level, and small particle size of carbonaceous materials, have been believed to be crucial factors. However, there have been few reports on simultaneous study of the structure-properties relations of carbons and the electrochemical performances of EDLCs. Herein, we report the relationship between the structural properties of carbons, such as the SSA, N-doping, and particle size, and the electrochemical properties of EDLCs by using a series of well-defined carbons. Monodisperse and size-tunable resorcinol-formaldehyde carbon (RFC) spheres were synthesized and activated by hot CO_2 treatment to increase the SSA up to 3958 m^2/g (RFC_C390 sample). When the specific capacitances of the RFC spheres were plotted in terms of their SSAs, an almost perfect correlation ($R^2 = 0.99$) was observed, which confirmed the linear relationship between the specific capacitance and the SSA. In addition, N-doped melanin C (MC) spheres were synthesized and subsequently activated for N-doping effect. Activated MC (MC_C130), which exhibited similar SSA (2618 m^2/g) and size (301 nm) but a different N-doping level (3.1%) compared with those (2793 m^2/g, 312 nm, and 1.3%, respectively) of the activated RFC spheres (RFC_C120), displayed higher specific capacitance (288 F/g), capacitance retention (64%), and long term stability over 5000 cycles (93%) compared with those (260 F/g, 58%, and 90%, respectively) of the RFC counterparts. To observe the particle size effect, different sizes (98, 280, and 579 nm) of RFC spheres with similar SSAs (3981, 3958, and 3898 m^2/g, respectively) and pore size distributions were prepared, such that the smallest RFC revealed the best EDLC performance in terms of specific capacitance (360 F/g), capacitance retention (70%), and long term stability over 5000 cycles (98%), all of which could be compared with the values reported in the literature. Furthermore, all of the Carbon samples were analyzed by using electrochemical impedance spectroscopy for confirming the structure-properties relations of carbon spheres with the electrochemical performances of EDLCs.

1. Introduction

Owing to increasing energy demand due to rapid industrialization, the development of efficient and eco-friendly energy conversion and storage devices is urgently required. As emerging energy storage devices, the class of electrochemical capacitors called supercapacitors (SCs) has attracted high interest owing to their outstanding properties such as fast charging-discharging, high power density, and excellent long term stability, which are crucial factors for electric vehicles, smart grids, and high-power electric devices [1–6]. Electrical energy is stored in an electric double layer (EDL), where electrolytes are adsorbed on oppositely charged electrodes. Carbonaceous materials with high specific surface area (SSA) and good electrical conductivity have

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