Fish scale based hierarchical lamellar porous carbons obtained by natural template for high performance electrochemical capacitors

Weixin Chen, [a] Hao Zhang[b,c] , Yaqin Huang*[a] and Weikun Wang [b]

[a]State Key Laboratory of Chemical Resource Engineering, The Key Laboratory of Beijing City on Preparation and Processing of Novel Polymer Materials, Beijing University of Chemical Technology, 15 BeiSanhuan East Road, Beijing 100029, P. R.China,

[b]Research Institute of Chemical Defense, West Building, Number 35 Huayuanbei Road, Beijing 100191, P. R.China

[c]University of Science & Technology Beijing, 30 Xueyuan Road, Haidian District, Beijing 100083, P. R.China

*Corresponding author: Yaqin Huang , Fax: +86-10-6443-8266
E-mail: huangyaqin9@gmail.com

Supporting Information

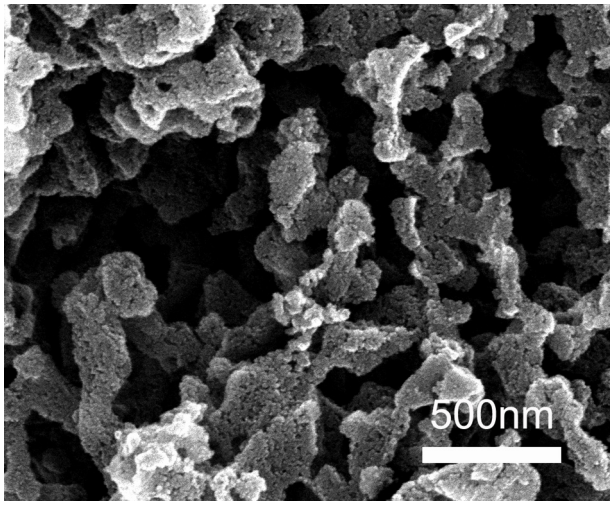

Figure S1. SEM image of FHLC

The main carbon skeleton and lamellar structure are kept after activation and removal of the inorganic composition. Meanwhile the etched part is hollowed into intersection path way and form macro/mesopores. Further, the activation process led to the porous structure in the sheet.

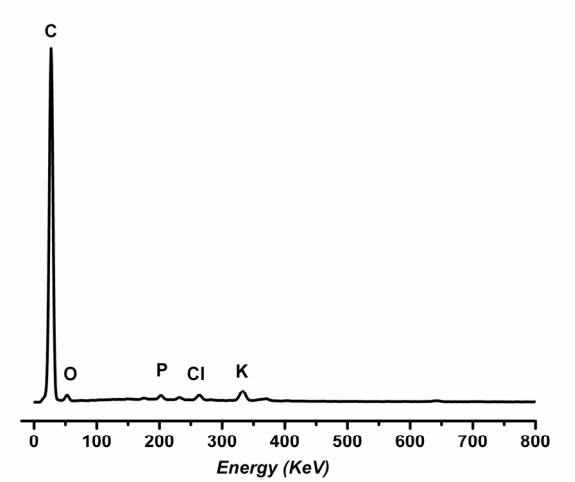

Figure S2. EDX image of FHLC.

The carbon content is high compared with other element such as oxygen, phosphor, chlorin and potassium.

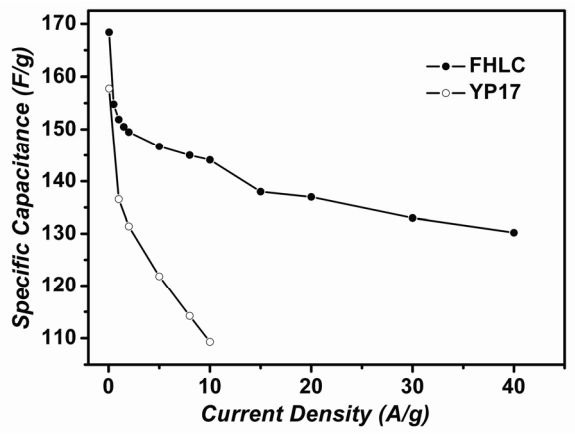

Figure S3. Galvanostatic charge/discharge data at different current densities of FHLC and YP17.

The capacitance retention of FHLC is better than the YP17 sample. The capacitance of FHLC is 168 F/g at the current density of 0.05 A/g. Its specific capacitance could be kept at 130 F/g even at the current density of 40 A/g, while the commercial

activated carbon YP17 (Kuraray Chemical) is 158 F/g at 0.05 A/g and 109 F/g at 10 A/g.

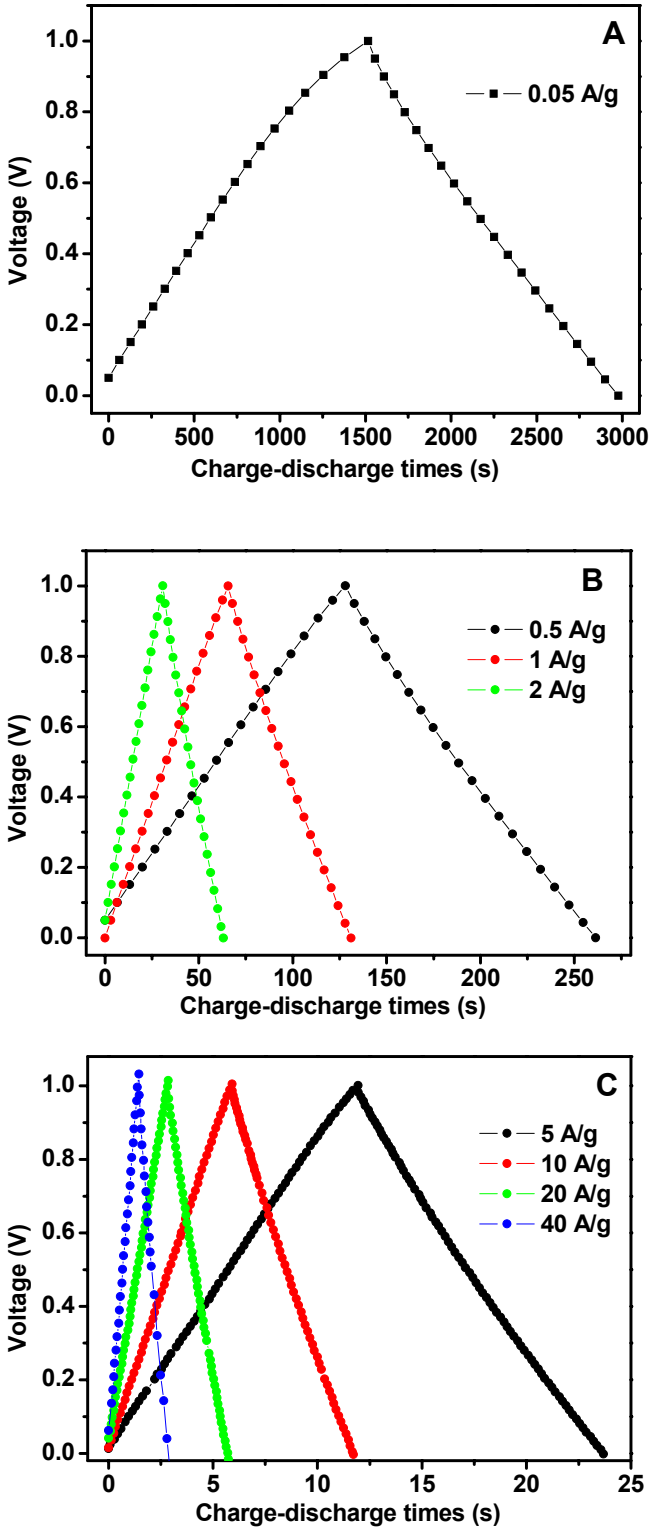

Figure S4. Charge-discharge curves of FHLC at different current density

The charge-discharge curves remain the linear shape at different current densities, indicating the good rapid discharge capability of FHLC as the electrode materials for EDLC.

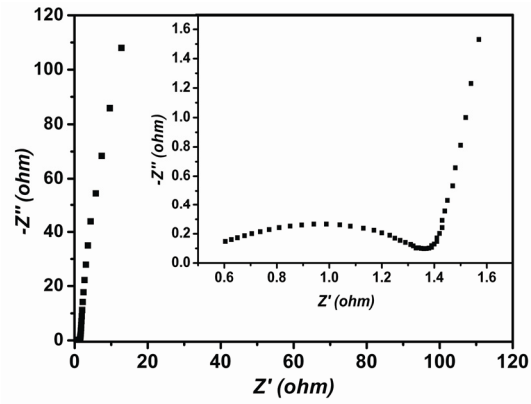

Figure S5. Nyquist plots(20k-0.1 Hz) of FHLC electrode

As the pore size of the FHLC is large enough as well as the hierarchical lamellar porous structure strongly enhanced the diffusion of ion, the sloping linear region at high-to-medium frequency related to diffusion resistance is not observed, which indicate that the diffusion is not the control factor in the kinetic of the electrode process.

Experimental Section:

FHLC were prepared from the herring fish scale which collected from food market at Dali, Yunnan province. The clean and dry fish scale was carbonization at 330 ºC for 3h in air atmosphere. Then the carbonization powder were mixed with KOH at a ratio of 1:1, followed by activation in an N_2 atmosphere at 950 ºC for 1h. The product

were washed with 5 M HCl and hot deioned water until the pH value become neutral. Then the product was heated in a vacuum oven at 120 ºC for 24 h to get FHLC.

FHLC was analyzed by adsorption/desorption measurement of nitrogen at 77 K (ASAP 2020, Micromeritics, USA). SEM and EDAX were tested by HITACHI S-4700, and XRD were recorded using D/max 2500V.

The working electrodes for electrochemical testing were prepared as reference [1]. The ratio of FHLC, acetylene black (Jinnpu Corp, Beijing, China) and PTFE (as a binder, FR301B, 3F Corp., Shanghai, China) is 87:10:3. The mixtures were dispersed in ethanol to allow a good homogenization of the binder suspension and then rolled to 0.40±0.01 mm thick films. These films were dried in air at 120 °C for 4 h and electrodes of 11mm in diameter were cut and used for the determination of the electrochemical performance. The 7M KOH was roled as electrolyte. Measurement of the gravimetric specific capacitance was performed by the galvanostatic charge-discharge using BT2000 (Arbin instruments) testing station. Cyclic voltammetry and electrochemical impedance spectrum were used in evaluation of the electrode electrochemical performance. The measurements were carried out using a Solartron 1280Z electrochemical test station controlled by CorrWare 2. Two–electrode-system was applied for all test. Current loads of 0.05, 0.5, 1.0, 1.5, 2.0, 5.0, 8.0, 10.0, 15.0, 20.0, 30.0, and 40 A/g were applied in GC measurements. The specific capacitances of the cells (C_{dll}) in Farads per gram were calculated from the discharge curve based on the equation

$C_{dll} = (I * \Delta t)/ \Delta V$

Where I in Amperes per gram of active material (including the binder and the acetylene black) is the discharge current, Δt in seconds is the discharge time, and ΔV in Volts is the voltage window from the end of the IR drop to the end of the discharge process.

The specific capacitances of single electrode were obtained by multiplying the C_{dll} by four [2]. All the capacitances cited in the paper were defined as specific capacitance of single electrode.

REFERENCES

[1] H. Zhang, W. F. Zhang, J. Cheng, G. P. Cao and Y. S. Yang, *Solid State Ionics.,* 2008, ***179,*** 1946.

[2] D. Qu and H. Shi, *J.Power Sources.,* 1998, ***74,*** 99.