

# Porous hollow carbon nanofibers derived from multi-walled carbon nanotubes and sucrose as anode materials for lithium-ion batteries

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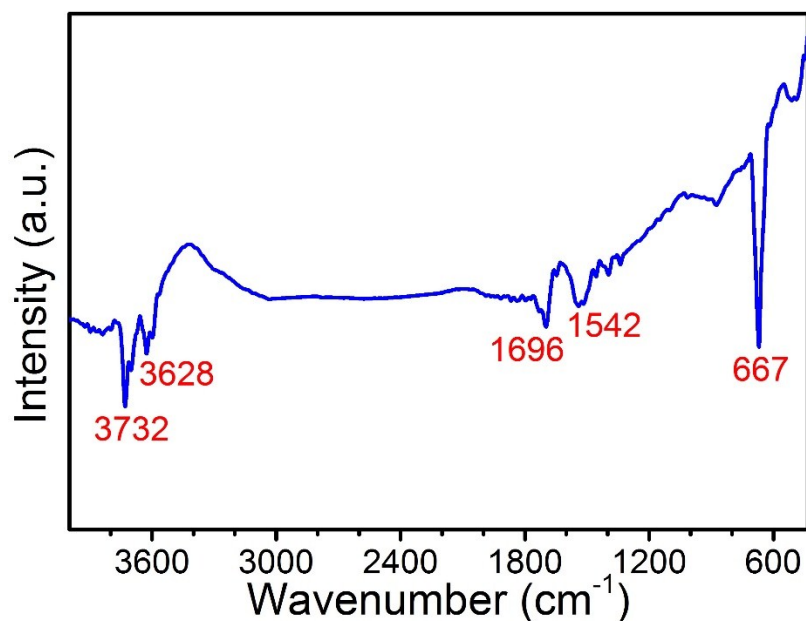
## 1. Calculation of lithium ion diffusion coefficients $D_{Li}$ by EIS method

The lithium ion diffusion coefficients  $D_{Li}$  in all the samples are evaluated by EIS method, which may differ from CV or other more accurate direct methods, like potentiometric intermittent titration (PITT) or galvanostatic intermittent titration (GITT) techniques. Herein, the  $D_{Li}$  values can be calculated from the following formula [*Electrochimica Acta* **2008**, 53, 2238-2244; *Chem. Mater.* **2008**, 20, 6829-6839.]:

$$D_{Li} = Z''2\pi fL^2/(3R_L)$$

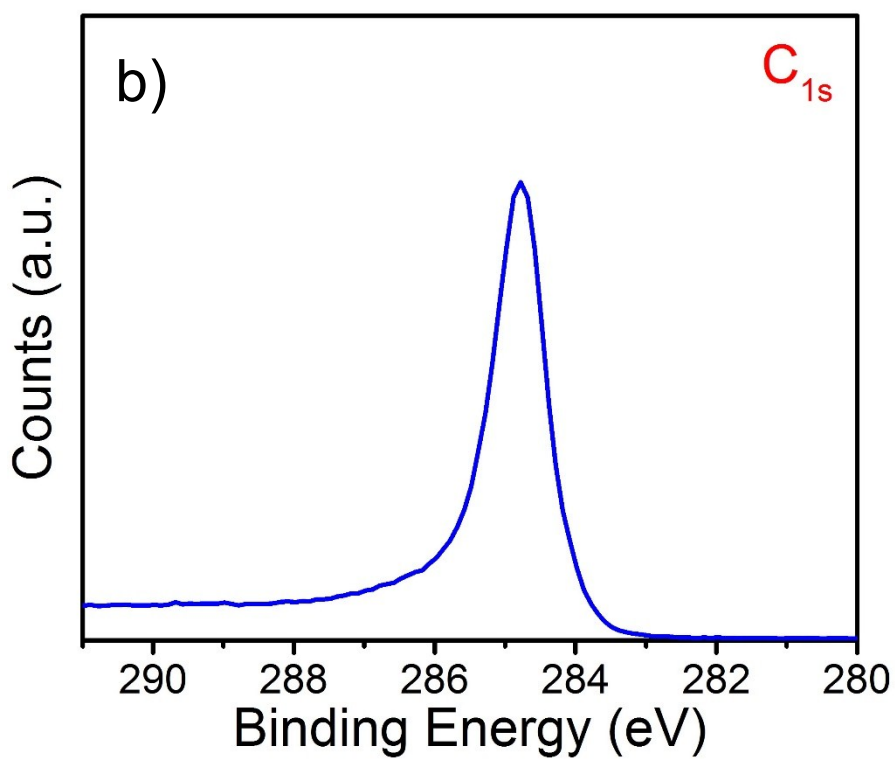
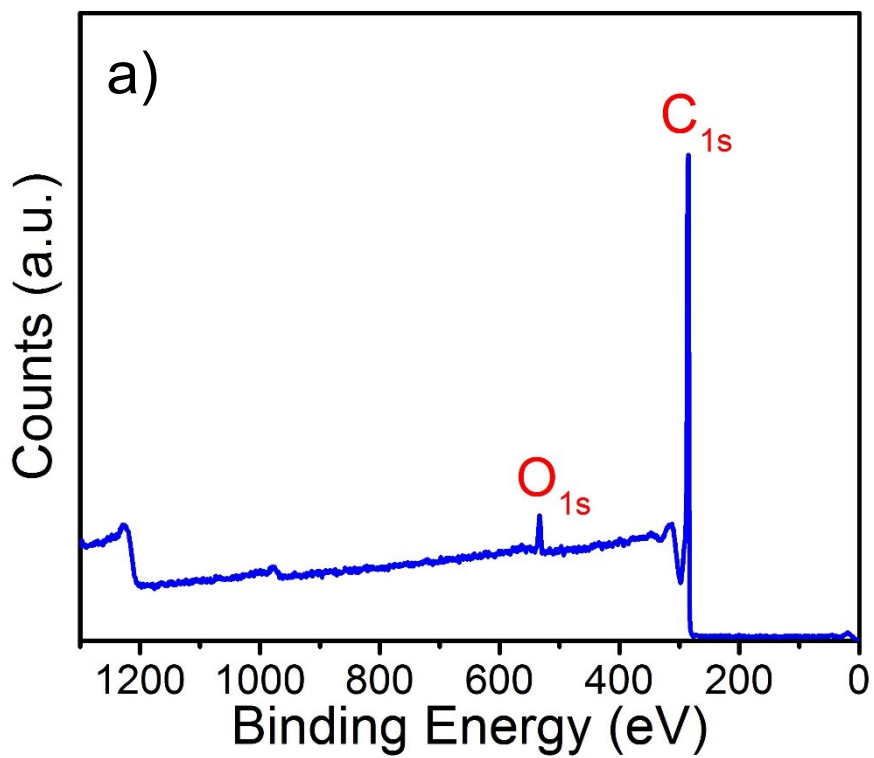
Where  $Z''$  is the imaginary part of the impedance at a frequency  $f$ ;  $R_L$ , limiting resistance, is obtained taking into account the abscissa of the intersection of the two straight lines fitting the 45° slope of the spectrum and the finite diffusion part at low frequency;  $L$  is the maximum diffusion length. Assuming lithium ion diffusion parallels to the carbon nanotube bundle, in that case, the maximum diffusion pathway  $L$  is about 10  $\mu\text{m}$  (length of MWCNTs).

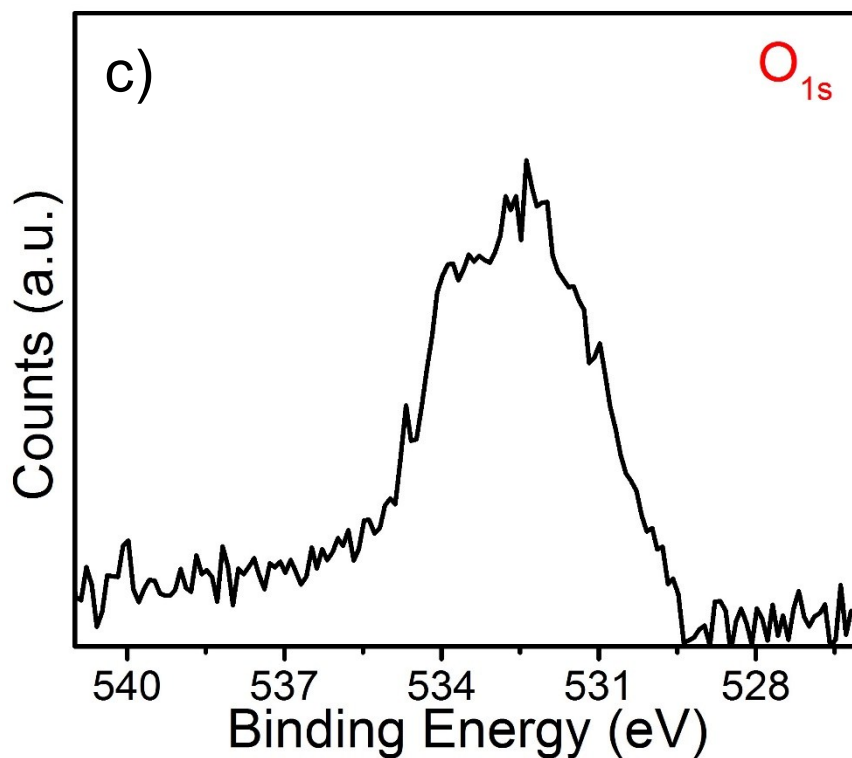
As calculated from EIS,  $D_{Li}$  values of MWCNTs, PHCNF-1, PHCNF-2, and PHCNF-3 are estimated to be  $4.36 \times 10^{-11}$ ,  $2.51 \times 10^{-11}$ ,  $1.79 \times 10^{-10}$ , and  $3.82 \times 10^{-11}$   $\text{cm}^2 \text{s}^{-1}$ , respectively. That is, the electrodes of MWCNTs, PHCNF-1 and PHCNF-3 have the comparable  $D_{Li}$  values (the same order of -11), except that the electrode of PHCNF-2 shows a much higher  $D_{Li}$  value (the order of -10). The improved  $D_{Li}$  value of PHCNF-2 can be attributed to the mesoporous structural advantages of the non-graphitic carbon shell, which favors electrolyte diffusion, as well as lithium-ion intercalation and diffusion.



**Fig. S1** FT-IR spectrum of PHCNF-2.

The weak bands at 1696 and 1542 cm<sup>-1</sup> can be attributed to the C=O stretching vibration of non-aromatic carboxyl groups resulting from the partial dehydrogenation during hydrothermal reactions. The sharp peak at 667 cm<sup>-1</sup> is attributed to skeletal C=C stretching vibrations, and the bands at 3732, 3628 cm<sup>-1</sup> correspond to stretching vibrations of O-H (hydroxyl, carboxyl, or H<sub>2</sub>O), respectively [*Chem. Eng. J.* **2013**, 228, 824-833; *Carbohydr. Res.* **2011**, 346, 999-1004; *Chem. Eng. J.* **2016**, 286, 476-484]. Based on these results, hydroxyl and carboxylic groups are the main oxygen surface functional groups. Except oxygen, no other heteroatoms such as nitrogen, sulfur, or phosphorus are discovered in the carbon shells.





**Fig. S2** XPS spectra of PHCNF-2: (a) a survey spectrum, (b) C 1s spectrum, and (c) O 1s spectrum.

A survey spectrum (Fig. S2a) shows the existence of carbon and oxygen elements without any other impurities, and the elements' atomic ratios are 95.96 and 4.04%, respectively. The asymmetric C 1s spectrum (Fig. S2b) displays a peak at the binding energy of 284.8 eV, indicative of  $sp^2$  C=C or  $sp^3$  C-C; and a shoulder peak at around 285.8 eV resulted from C-O [*Physica E* **2013**, 53, 155-160]. The O 1s spectrum (Fig. S2c) displays a peak at the binding energy of about 532.4 eV, ascribed to various oxygen functional groups such as C=O.