Supplementary data

Sustainable carbon-sheets and their MnO-C hybrid for Li-ion batteries

Shengbin Wang,[a] Yalan Xing,[a] Xin Liu,[a] Huaizhe Xu,[b] and Shichao Zhang*[a]

Experimental

Synthesis of CSs

The dried and cleaned sugarcane-stalk are initially processed into slices. 2 g of prepared sugarcane-stalk is immersed in a Teflon-lined stainless steel autoclave where 70 mL of 2 M KOH solution is contained, then the autoclave is heated at 150 °C for 4 h. When cooled down to room temperature, the samples are collected and washed, then dried at 80 °C. The following high temperature pyrolysis and chemically activation is carried out at 800 °C for 2 h under N_2 atmosphere to achieve the carbonaceous product.

Synthesis of MnO-C

The 0.1g as-made CSs and 1g $Mn(Ac)_2$•$4H_2O$ are dispersed in 70ml of water. The suspension is then sealed in Teflon lined stainless steel autoclaves for hydrothermal reaction at 180°C for 10 hours. The product is collected by vacuum filtration, washing with water. The resulting sample is heated to 700°C with following N_2, and kept at this temperature for 2 h. The obtained composite was denoted as MnO-C.

Characterization

Material Characterization: The obtained samples are characterized by scanning electron microscope (SEM, Hitachi S-4800), high-resolution transmission electron microscopes (HRTEM, JEOL JEM-2010), X-ray diffraction (XRD, Rigaku D/Max-2400, Cu Kα), Raman spectra (labRAM ARAMIS, λ=532 nm), Thermogravimetric analysis (TGA, NETZSCH STA 449C). The specific surface area determination, pore volume and size analysis are determined by nitrogen adsorption−desorption at 77 K

using a Quantachrome Autosorb-1C-VP analyzer. Powder electronic conductivity investigation at the pressure of 4 MPa was performed on Powder Resistivity Meter (FZ-2010,Changbao Analysis Co., Ltd, Shanghai, China).

Electrochemical Characterization: The working electrode is fabricated by 90% active material and 10% PVDF binder on copper-foil collector， with around 2 mg cm^{-2} active material loading. The electrode, separator and Li foil are assembled into a 2032 type coin cell filled with electrolytes (1 M $LiPF_6$ in EC-DEC-DMC) in Ar filled glove box. Electrochemical data are recorded using LAND CT2001A test system within the potential range of 0.01–3.0 V vs. Li/Li^+. Cyclic voltammograms (CVs) at a scan rate of 0.2 mV s^{-1} between 0.01 and 3.0 V, and Electrochemical impedance spectroscopy (EIS) after different cycles with the frequency range of 10 mHz to 0.1 MHz are collected by Zahner IM6e electrochemistry workstation, respectively.

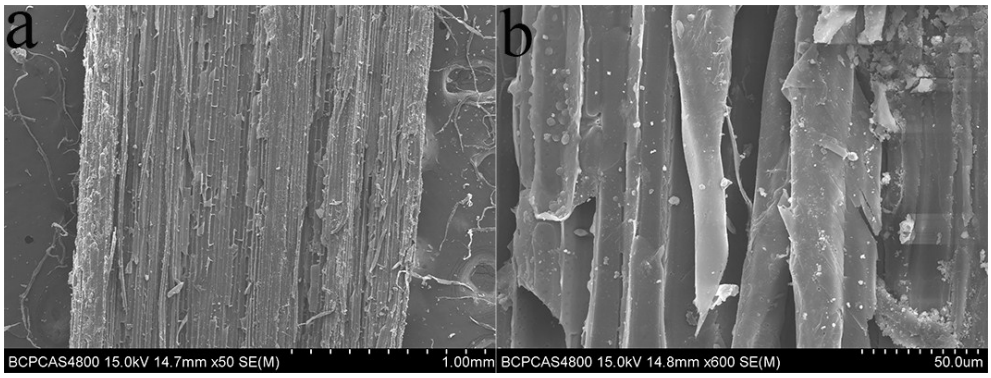

Fig. S1 SEM images of the sugarcane-stalk.

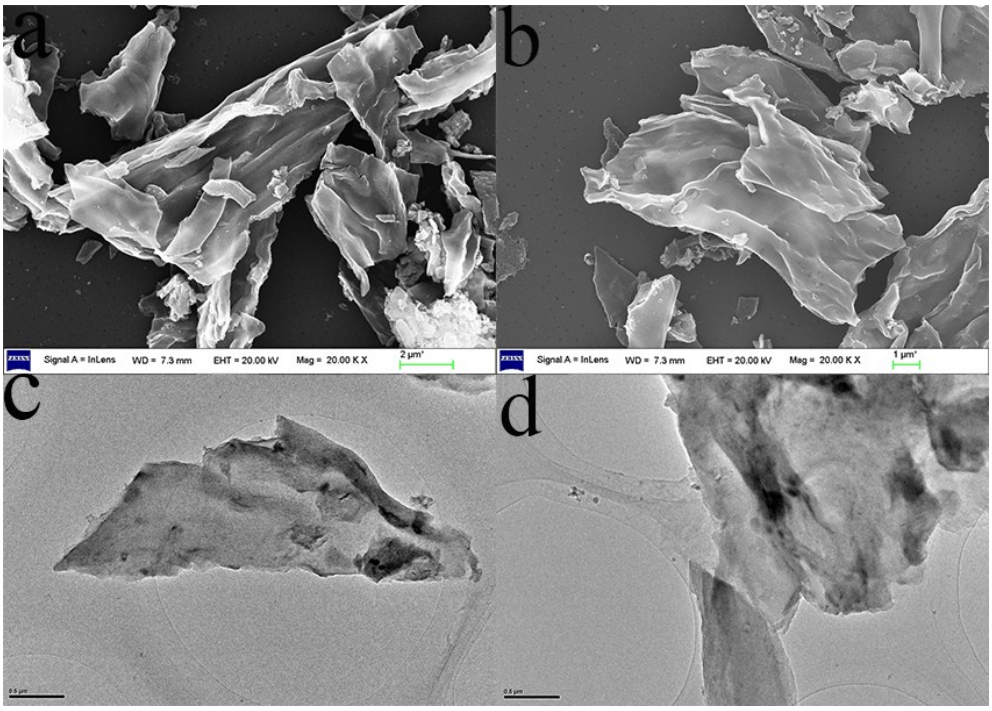

Fig. S2 SEM and TEM images of the CSs.

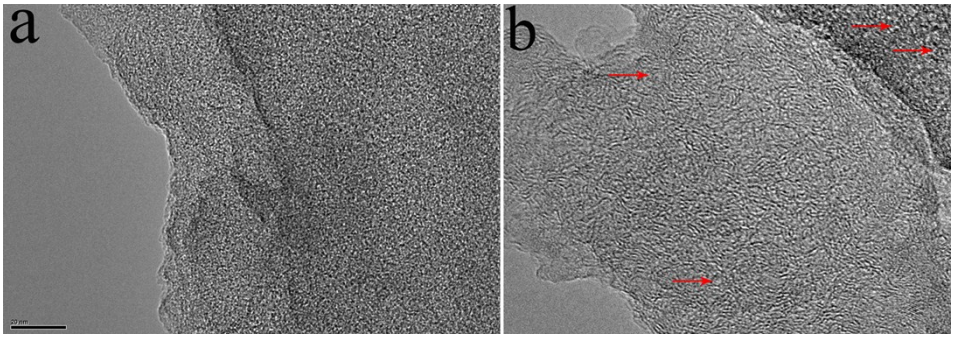

Fig. S3 HRTEM images of the CSs.

Table S1 Electrical conductivity of different carbonaceous materials.	
Materials	Conductivity [S cm^{-1}]
CSs	1.82
Activated Carbon	0.08
Acetylene Black	7.1

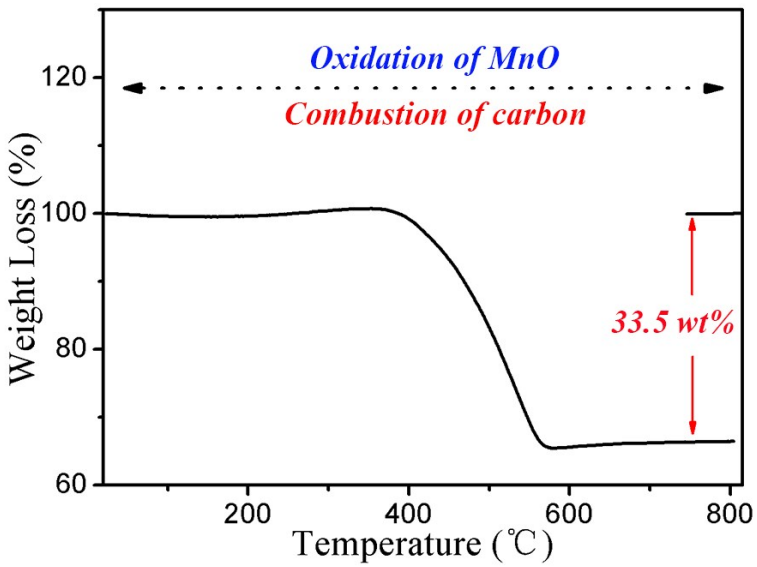

Fig. S4 TGA pattern of MnO-C.

A weight loss of 33.5 wt% between 100 and 800 °C can be detected, which is attributed to the integrative effect of the weight loss (combustion of carbon to CO_2) and the weight gain (oxidation of MnO). Based on the theoretical value (11.3%) of the weight increase from MnO to Mn_2O_3, the carbon content in the MnO-CSs is evaluated to be about 44.8 wt %.

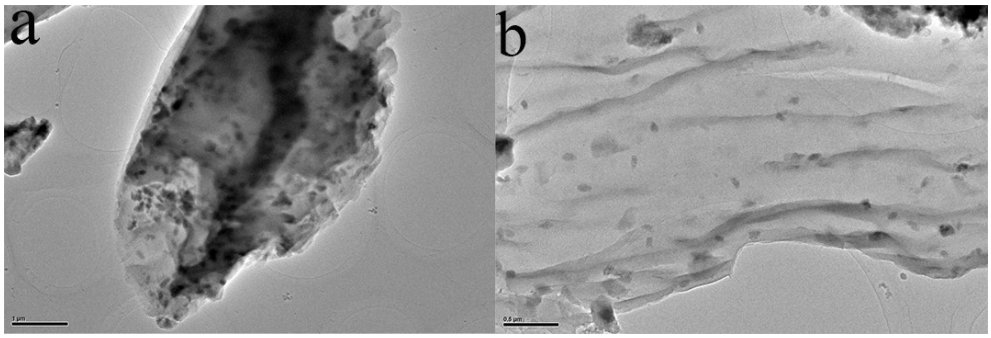

Fig. S5 TEM images of the MnO-C

Table S2. Performances comparison of CSs and MnO-C with some other carbon and MnO/C materials						
	BET surface area (m^2 g^{-1})	Active material loading (mg cm^{-2})	Reversible capacity (mAh g^{-1})		Rate-retention (%)	Ref.
CSs	182	2	479 at 0.1 A g^{-1}	136 at 3 A g^{-1}	28	This work
Hollow Carbon-Nanotube/	1840	-	913 at 0.1 A g^{-1}	268 at 3 A g^{-1}	29	1

Nanofiber						
Mesoporous carbon	800	1	1780 at 0.1 A g^{-1}	205 at 4 A g^{-1}	11	2
Bamboo-derived carbon fibers	808	2.5-4.0	353 at 0.17 A g^{-1}	137 at 4.6 A g^{-1}	38	3
MnO-C	275	2	646 at 0.1 A g^{-1}	354 at 3 A g^{-1}	55	This work
MnO/C-N nanorods	-	1	828 at 0.2 A g^{-1}	372 at 5 A g^{-1}	45	4
Hollow MnO/C	77	1.4-2.1	741 at 0.1 A g^{-1}	234 at 3 A g^{-1}	31	5
MnO/C Nanopeapods	103	0.6	845 at 0.185 A g^{-1}	463 at 5A g^{-1}	55	6

References:

[1] Y. Chen, X. Li, K. Park, J. Song, J. Hong, L. Zhou, Y.-W. Mai, H. Huang and J. B. Goodenough, *J. Am. Chem. Soc.*, 2013, **135**, 16280.

[2] Z. Li, Z. Xu, X. Tan, H. Wang, C. M. B. Holt, T. Stephenson, B. C. Olsen and David Mitlin, *Energy Environ. Sci.*, 2013, **6**, 871.

[3] J. Jiang, J. Zhu, W. Ai, Z. Fan, X. Shen, C. Zou, J. Liu, H. Zhang and T. Yu, *Energy Environ. Sci.*, 2014, **7**, 2670.

[4] X. Gu, J. Yue, L. Chen, S. Liu, H. Xu, J. Yang, Y. Qian and X. Zhao, *J. Mater. Chem. A,* 2015, **3**, 1037.

[5] Y. Xia, Z. Xiao, X. Dou, H. Huang, X. Lu, R. Yan, Y. Gan, W. Zhu, J. Tu, W. Zhang and X. Tao, *ACS Nano*, 2013, **7**, 7083.

[6] H. Jiang, Y. Hu, S. Guo, C. Yan, P. S. Lee and C. Li, *ACS Nano*, 2014, **8**, 6038.

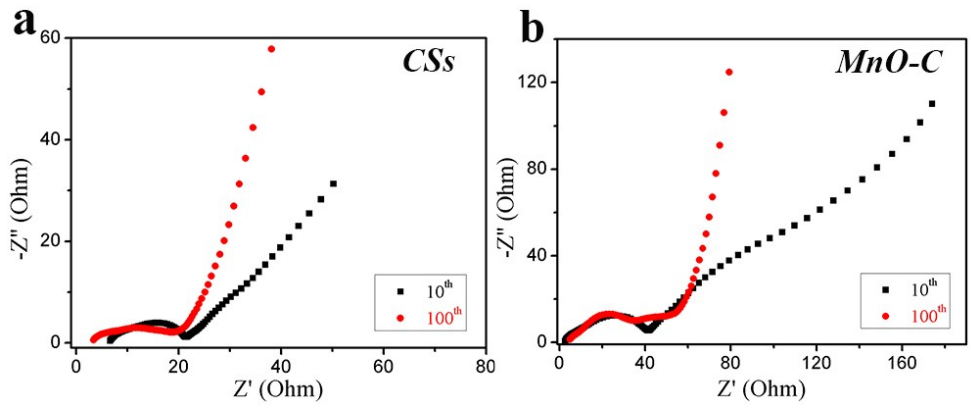

Fig. S6 EIS of CSs and MnO-C at different cycles.