Electronic Supplementary Information

Nanoporous Carbon through Direct Carbonization of Zeolitic Imidazolate Framework for Supercapacitor Electrodes

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Experimental Section

Synthesis of nanoporous carbon: Nanoporous carbons were synthesized by carbonization of commercially available zeolitic imidazolate framework ZIF-8 (Basolite Z1200, purchased from Aldrich) under a flow of nitrogen gas at different temperature ranging from 600 to 1000 °C. Typically, about 500 mg of well ground ZIF-8 was homogeneously dispersed in a ceramic boat. The ceramic boat was then put into a tube furnace. The sample was exposed to a flow of nitrogen (~45 $mL \cdot min^{-1}$) at room temperature for an hour and afterward the furnace was heated to the targeted carbonization temperature with a heating rate of 5 $°C \cdot min^{-1}$. After reaching the targeted temperature, it was held for 5 h and then cooled down to room temperature. The resultant black powder was collected and then washed with a 10 wt% HF aqueous solution. The sample was stirred in the HF solution for 24 h and then collected by centrifugation. The washing process was repeated twice. Finally, the carbon sample was rinsed with a copious amount of distilled water and then dried at 60 °C overnight. The obtained nanoporous carbons are denoted as Z-*n*, where *n* is the carbonization temperature.

Characterization: Scanning electron microscopy (SEM) images were obtained with a Hitachi S-4800 instrument. Raman spectra were recorded on a Photon Design spectrometer using an argon ion laser with an excitation wavelength of 514 nm. Pore characteristics of the materials were assessed from nitrogen adsorption–desorption isotherms measured at -196 °C on a Micromeritics TriStar II 3020. Before the measurement, the samples were degassed at 180 °C under vacuum for 12 h. Thermogravimetric and differential thermal analysis (TG-DTA) was performed on an SII NanoTechnology TG/DTA 6200 instrument using pure nitrogen as a carrier gas with a heating rate of 5 $°C \cdot min^{-1}$.

Electrochemical test: Cyclic voltammograms (CVs) were obtained from an ALS/CH Instruments electrochemical analyzer (model 611B) using a standard three-electrode cell at ambient temperature. The working electrodes were fabricated as follow. First, 2.0 mg of the

carbon sample was added to 1000 μL of water and then subjected to ultrasonication for an hour. The suspension was dropped onto a glassy carbon electrode. After drying, a 0.5 wt% Nafion solution was coated on the sample. A platinum wire and an Ag/AgCl electrode were used as the counter and reference electrodes, respectively. For all electrochemical measurements, 0.5 M H_2SO_4 was used as the electrolyte and the experiments were done within a potential range of -0.2 to 1.0 V (vs. Ag/AgCl) at different scan rates.

Fig. S1

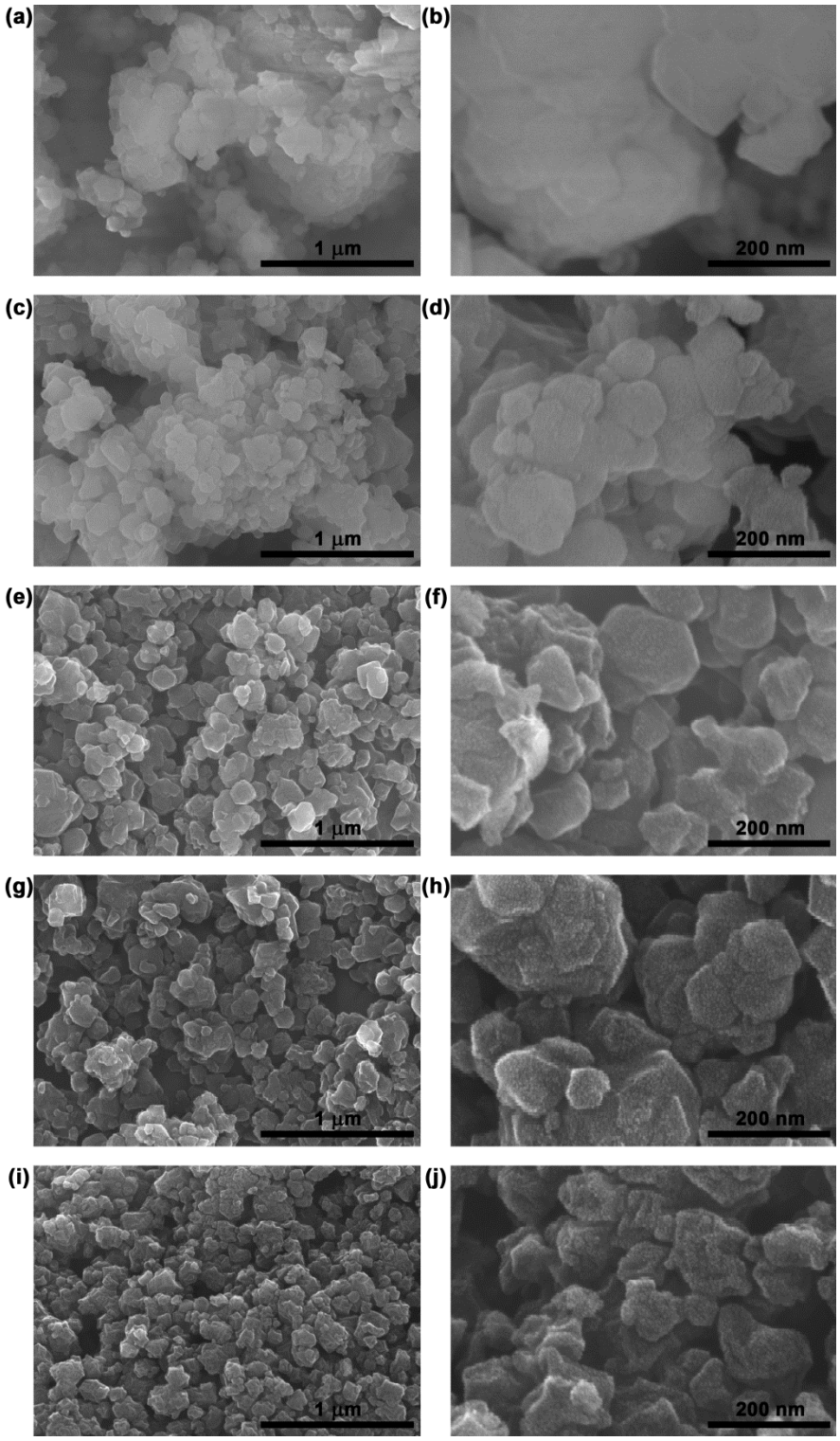

Fig. S1 SEM images of (a, b) ZIF-8, (c, d) Z-700, (e, f) Z-800, (g, h) Z-900, and (i, j) Z-1000.

Fig. S2

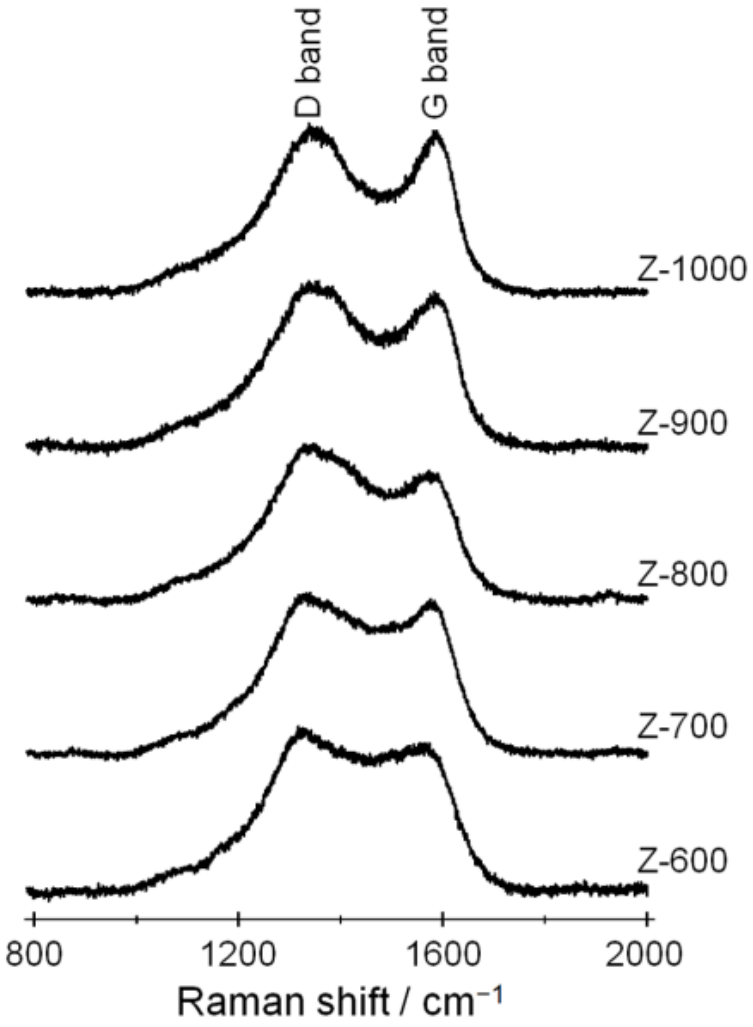

Fig. S2 Raman spectra of the obtained nanoporous carbon samples.

Fig. S3

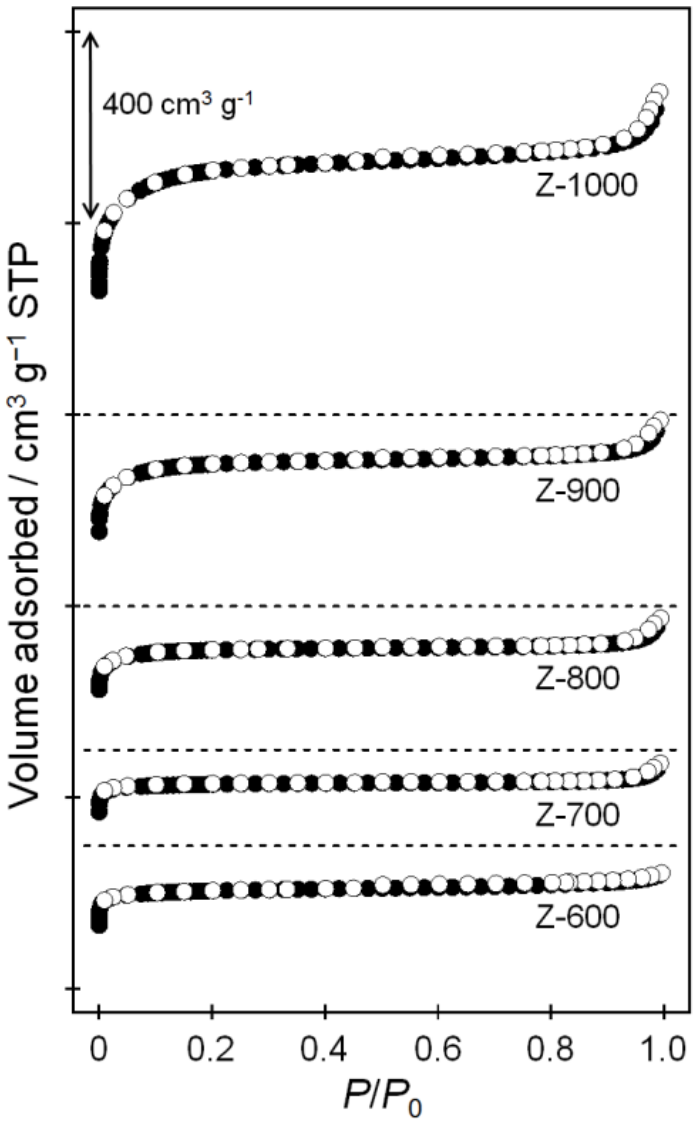

Fig. S3 Nitrogen adsorption-desorption isotherms (solid and open symbols represent adsorption and desorption isotherms respectively) of the carbon samples *before acid washing*. The isotherms of Z-700, Z-800, Z-900, and Z-1000 are shifted vertically by 300, 500, 800, and 1200 $cm^3\ g^{-1}$ STP, respectively.

Fig. S4

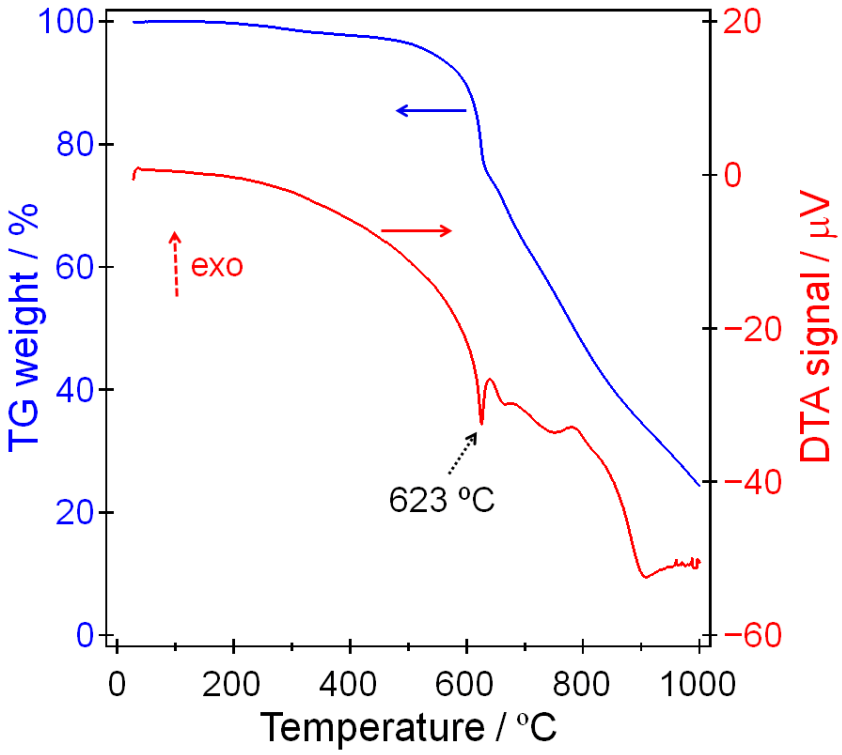

Fig. S4 TG-DTA curves of ZIF-8 under nitrogen with a heating rate of 5 °C·min^{-1}.

Table S1 Capacitances in aqueous electrolytes of various porous carbons reported in the representative literatures.

Material	Electrolyte	Potential range/ V	Scan rate/ $mV \cdot s^{-1}$	Particle density[a]/ $g \cdot cm^{-3}$	Capacitance[b]			Ref.
					$F \cdot g^{-1}$	$\mu F \cdot cm^{-2}$	$F \cdot cm^{-3}$	
MOF-derived carbon								
Z-900	0.5 M H_2SO_4	−0.2 to 1.0	5	0.93	214	20	200	This work
NPC	1 M H_2SO_4	−0.5 to 0.5	5	0.39	204	7	80	S1
NPC_{650}	1 M H_2SO_4	−0.5 to 0.5	5	0.51	167	11	84	S2
C800	1 M H_2SO_4	−0.5 to 0.5	5	0.50	188	9	94	S3
C1000	1 M H_2SO_4	−0.5 to 0.5	5	0.32	161	5	52	S3
MC-A	6 M KOH	−1.0 to 0	2	0.55	208	12	114	S4
MPC-A	6 M KOH	−1.0 to 0	2	0.41	196	15	81	S4
MAC-A	6 M KOH	−1.0 to 0	2	0.61	271	12	165	S4
Templated porous carbon by nanocasting								
Y-AN	1 M H_2SO_4	0 to 0.6	2	0.74	340	20	250	S5
BMC-I	1 M H_2SO_4	0 to 0.8	2	0.96	112	17	108	S6
BMC-II	1 M H_2SO_4	0 to 0.8	2	1.01	99	21	100	S6
Carbon aerogel-derived carbon								
CA1-800	2 M H_2SO_4	0 to 1.2	2	0.50	225	31	111	S7
COU-2	1 M H_2SO_4	−0.2 to 0.8	2	0.86	184	27	159	S8
K-COU-2	1 M H_2SO_4	−0.2 to 0.8	2	0.57	244	14	139	S8
AMC-6	0.1 M NaCl	−0.4 to 0.6	1	0.48	188	10	91	S9
Carbide-derived carbon								
TiC-CDC	1 M H_2SO_4	−0.5 to 0.5	5		190	12[c]	140[c]	S10
Carbon fiber-based material								
ACF4	6 M KOH	0 to 1.0	1	0.38	371	11	139	S11

[a] Particle density = [Total pore volume + $1/\rho_{carbon}$]$^{-1}$, where ρ_{carbon} is the true density of carbon (2 $g \cdot cm^{-3}$)[S12].
[b] Gravimetric capacitances in $F \cdot g^{-1}$ were taken from the references; interfacial capacitances in $\mu F \cdot cm^{-2}$ were normalized to the BET surface area; volumetric capacitances in $F \cdot cm^{-3}$ were calculated from the particle density of carbon materials.
[c] Taken from the reference.

References

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