Supporting information

High-Yielding Preparation of Hierarchically Branched Carbon Nanotubes Derived from Zeolitic Imidazolate Frameworks for Enhanced Electrochemical K^+ Storage

Dongbo Yu[a,b,c], Fei Wang[a], Jie Wang[a], Qingliang Gao[a], Jiaqin Liu[b,c,], Gang Qian[d,*], Yong Zhang[a,b,c], Yucheng Wu[a,b,c], Jiewu Cui[a,b,c,*]*

[a] School of Materials Science and Engineering, Hefei University of Technology, Hefei 230009, Anhui, China

[b] China International S&T Cooperation Base for Advanced Energy and Environmental Materials & Anhui Provincial International S&T Cooperation Base for Advanced Energy Materials, Hefei 230009, Anhui, China

[c] Key Laboratory of Advanced Functional Materials and Devices of Anhui Province, Hefei 230009, Anhui, China

[d] Instrumental Analysis Center, Hefei University of Technology, Hefei 230009, Anhui, China

Email Address: jqliu@hfut.edu.cn (Jiaqin Liu); qiangang.qg@163.com (Gang Qian); jwcui@hfut.edu.cn (Jiewu Cui);

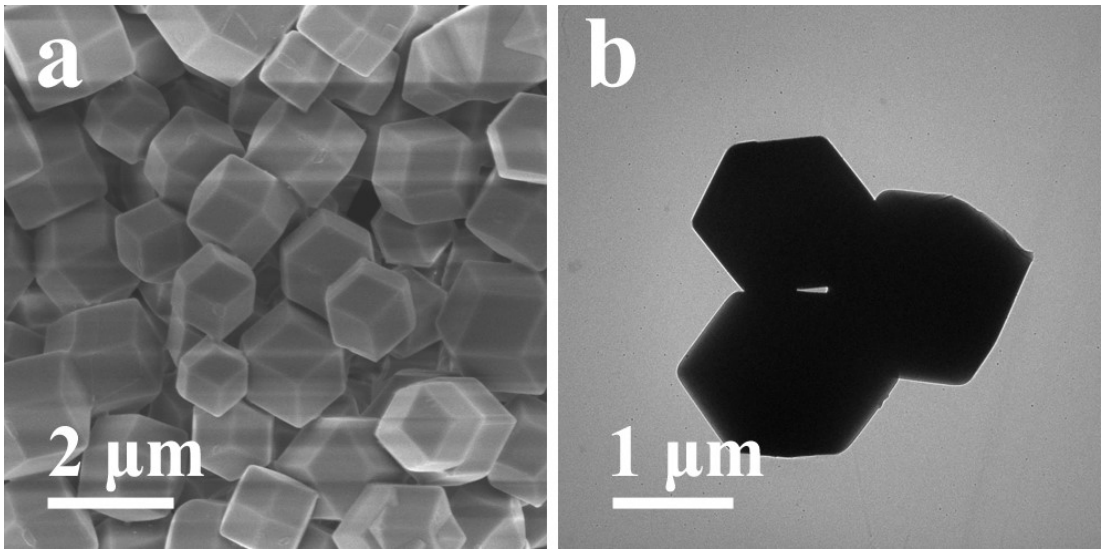

Fig. S1 SEM (a) and TEM (b) images of ZnCo-ZIF particles.

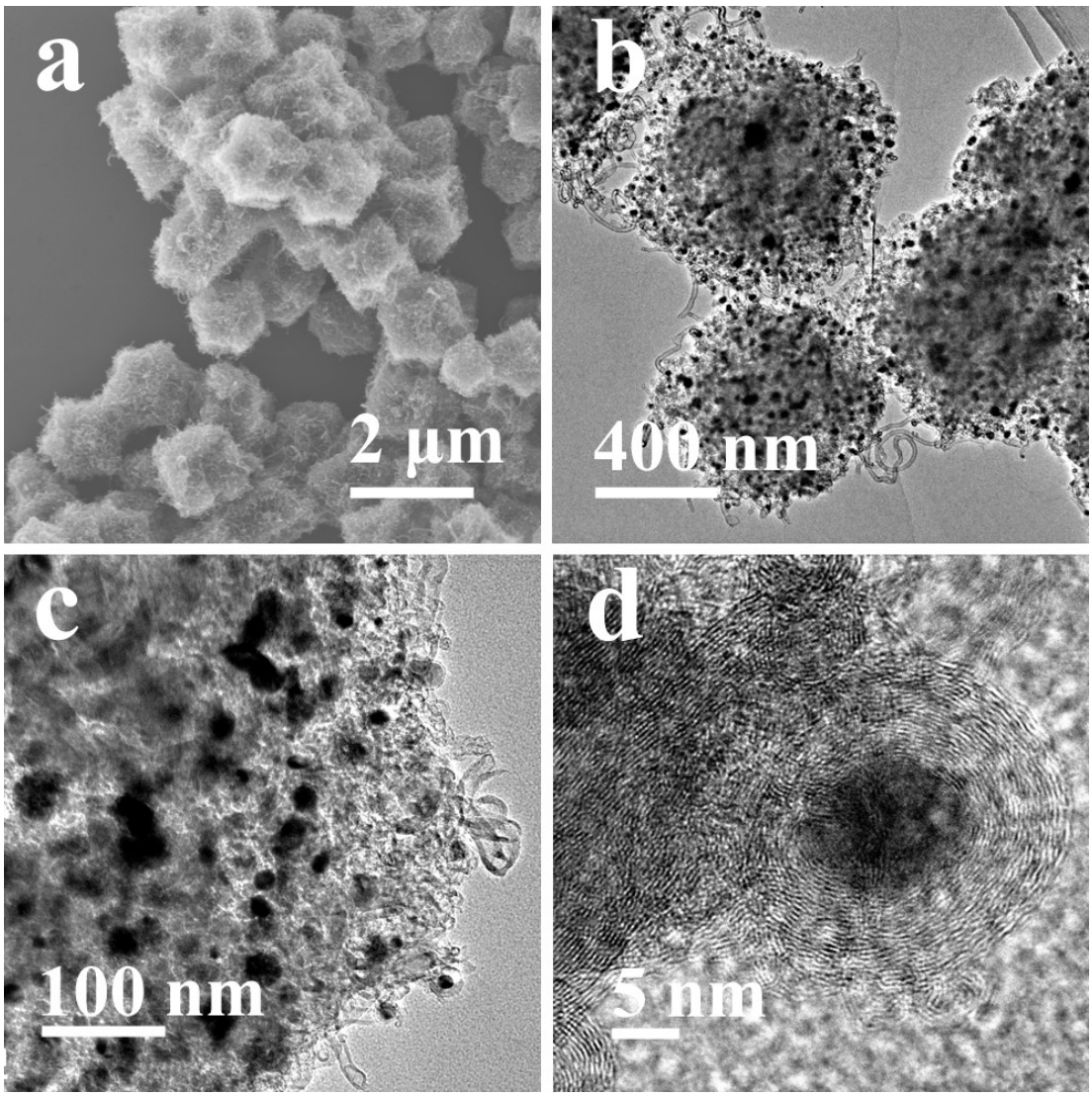

Fig. S2 SEM (a), TEM (b, c) and HRTEM (d) images of ZnCo-ZIF particle-derived urchin-like carbon (u-CPs).

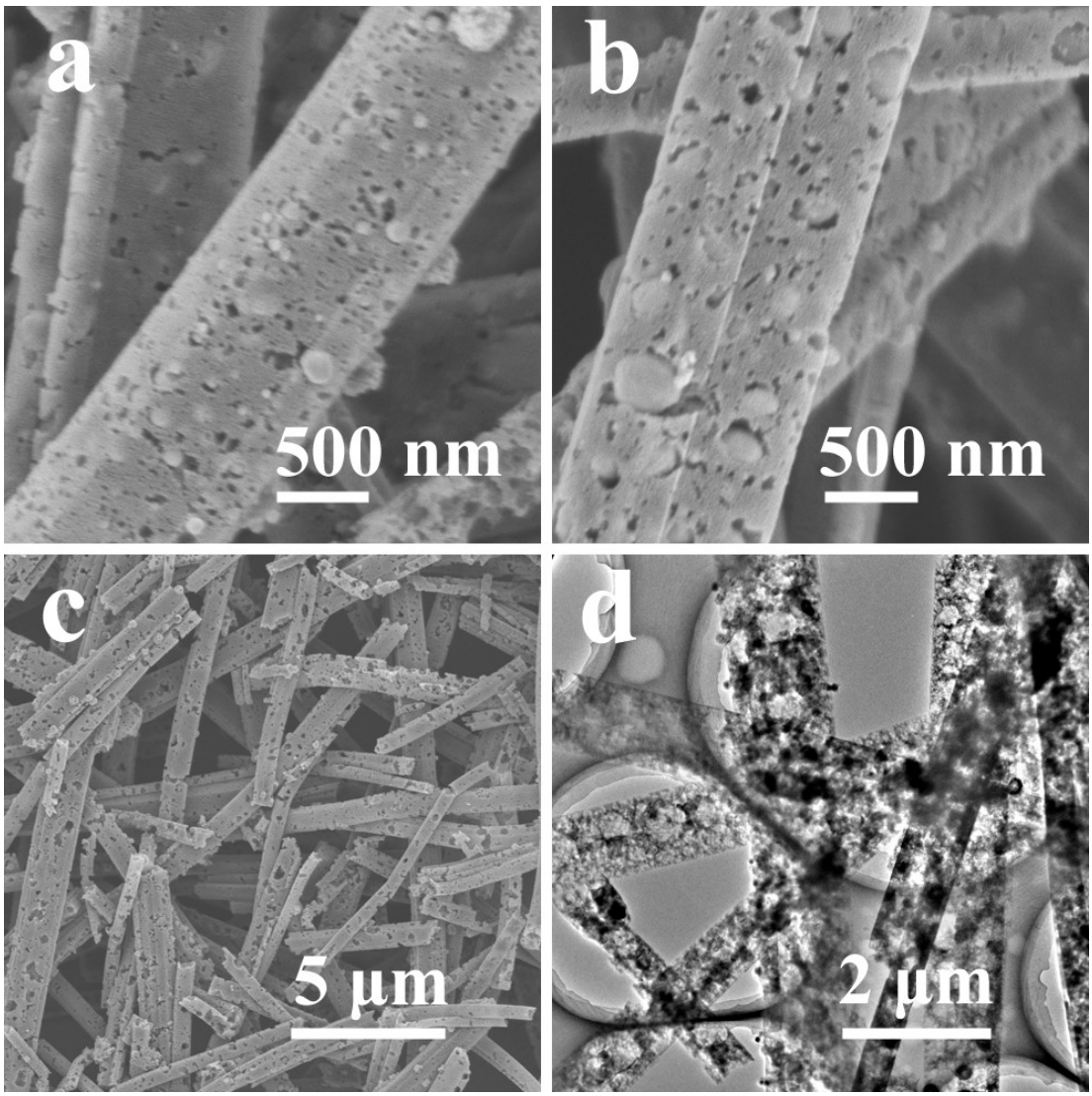

Fig. S3 SEM images of ZnCo-BTC NW after carbonization treatment but before nitrate acid etching (a, b); SEM (c) and TEM (d) images of ZnCo-BTC NW-derived carbon nanowires (CNWs) after nitrate acid etching.

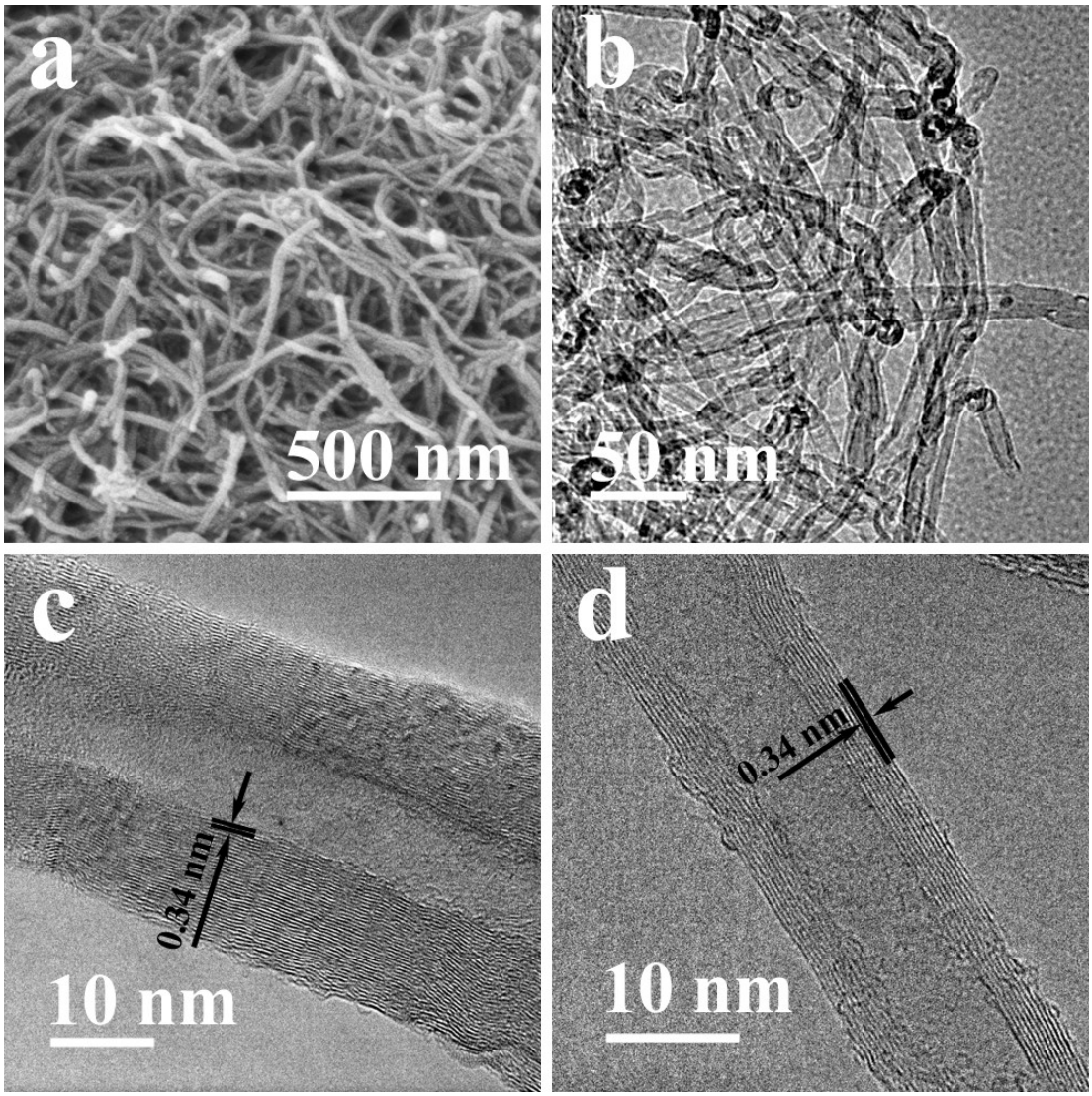

Fig. S4 SEM (a), TEM (b) and HRTEM (c, d) images of commercial carbon nanotubes (c-CNTs).

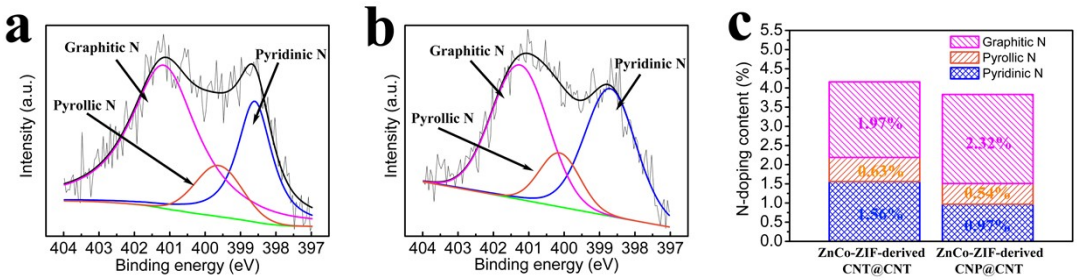

Fig. S5 The high-resolution XPS spectra of N 1s of u-CPs (a) and br-CNTs (b); the specific N-doping contents of u-CPs and br-CNTs (c).

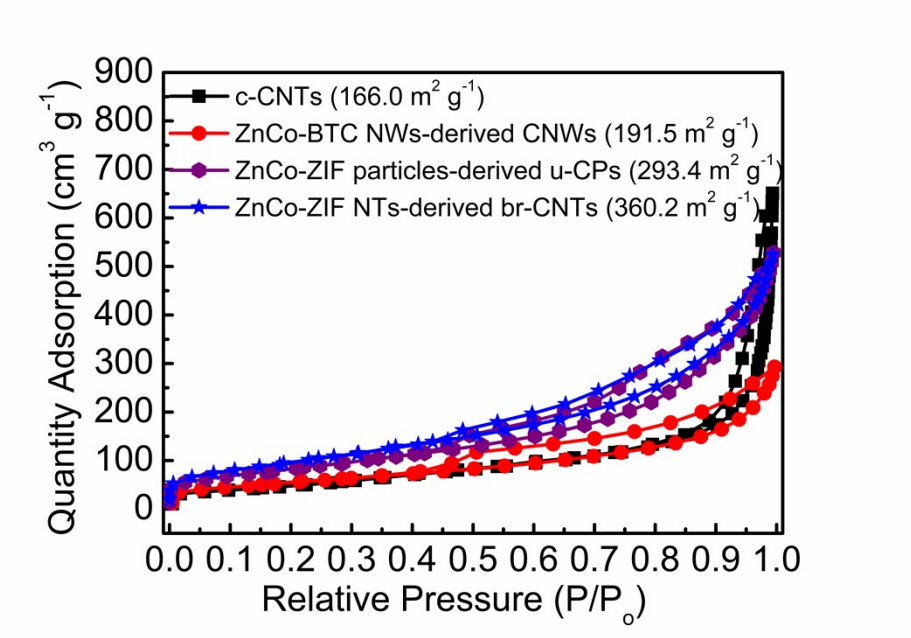

Fig. S6 Nitrogen adsorption-desorption isotherms of c-CNTs (a), CNWs (b), u-CPs (c) and br-CNTs (d).

Table S1 Percentage of pores in different size range for c-CNTs, CNWs, u-CPs and br-CNTs.

Materials	≤ 2 nm	2 ~ 5 nm	5 ~ 10 nm	10 ~ 50 nm	> 50 nm
c-CNTs	0.44%	11.14%	6.79%	22.26%	59.37%
CNWs	2.14%	22.78%	15.50%	33.04%	26.54%
u-CPs	1.42%	18.01%	18.47%	39.67%	22.43%
br-CNTs	1.19%	22.84%	19.79%	36.89%	19.30%

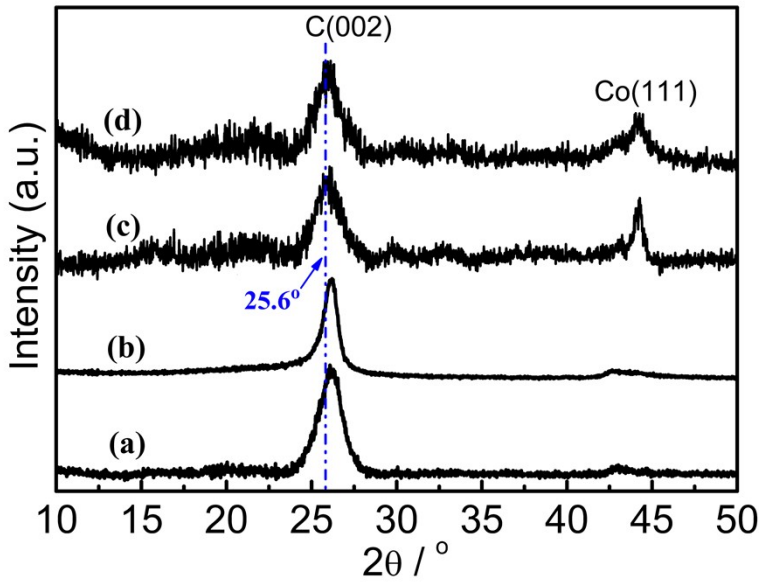

Fig. S7 XRD patterns of c-CNTs (a), CNWs (b), u-CPs (c) and br-CNTs (d).

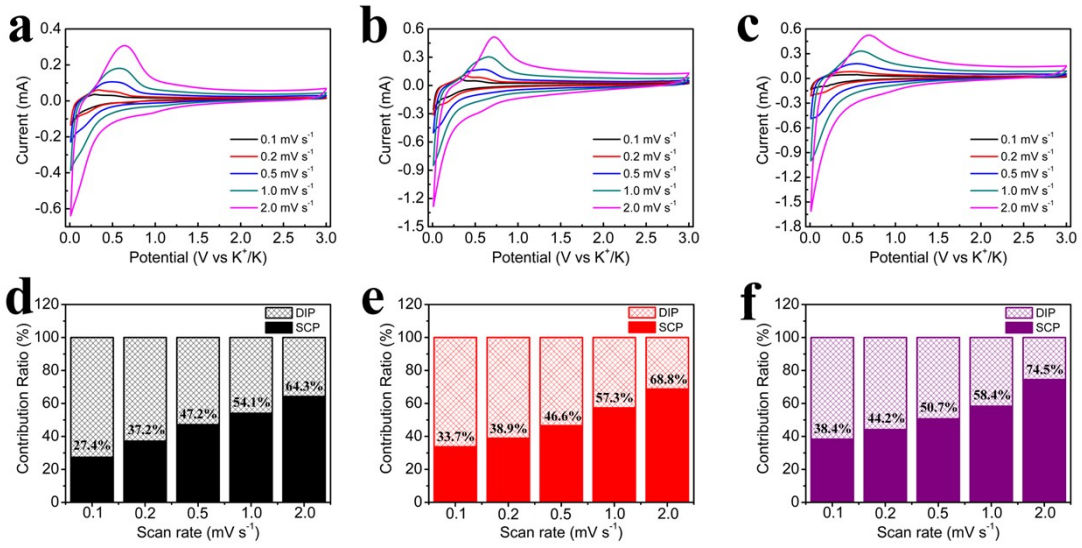

Fig. S8 CV plots of c-CNTs (a), CNWs (b) and u-CPs (c) at different scan rates; the corresponding contribution ratio of DIP and SCP versus scan rate calculated from CV plots of c-CNTs (d), CNWs (e) and u-CPs (f).

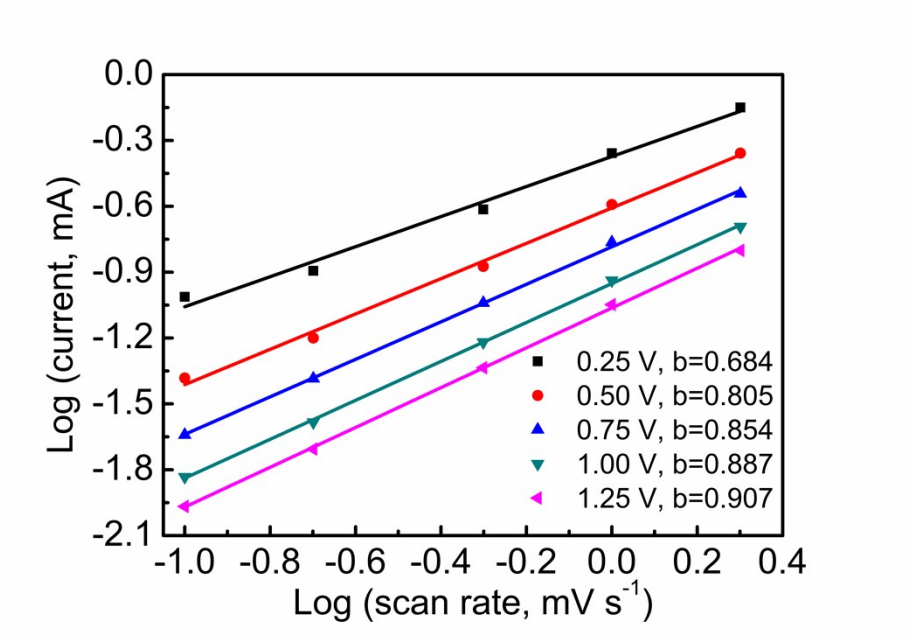

Fig. S9 The linear relationships between the logarithm current and logarithm scan rate calculated from CV curves of br-CNTs in Fig. 3d.

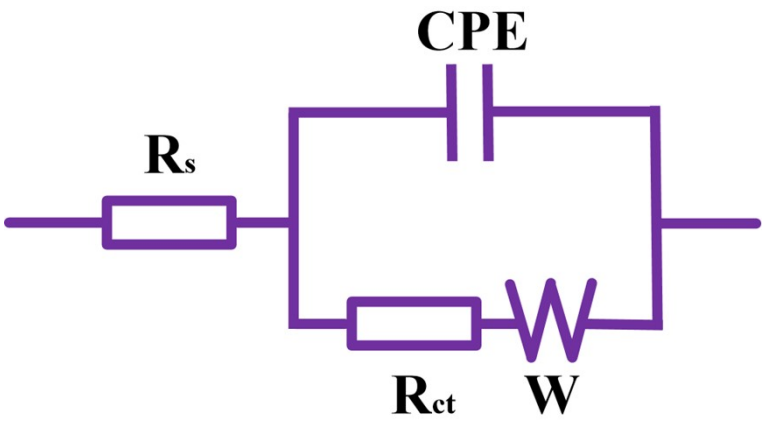

Fig. S10 The fitting equivalent circuit of Nyquist plots in Fig. 3f, where R_s, R_{ct}, CPE and W corrsponded to series resistance, charge transfer resistance, constant phase element and Warburg impedance, respectively.

Table S2 R_s, R_{ct} and CPE values fitted from Nyquist plots according to the equivalent circuit in Figure S10.

Materials	R_s (Ω)	R_{ct} (Ω)	CPE (F)
c-CNTs	17.01	6043	0.000020068
CNWs	8.087	4370	0.000040941
u-CPs	7.317	3249	0.000048539
br-CNTs	6.667	2255	0.000029429

Table S3 K^+ storage properties of MOF-derived materials in recent literature.

Materials	Specific Capacity	Rate Capability	Cycling Stability	References
Cu-MOF-derived hollow porous carbon	370 mAh g^{-1} at 0.1 A g^{-1}	190 mAh g^{-1} at 1 A g^{-1}	100 % after 3000 cycles at 1 A g^{-1}	*Small*, **2021**, 17, 2100538
Mn-BDC MOFs-derived carbon	266.4 mAh g^{-1} at 0.05 A g^{-1}	93 mAh g^{-1} at 2 A g^{-1} ; 57.2 mAh g^{-1} at 5 A g^{-1}	100% after 1000 cycles at 0.2 A g^{-1}	*Adv. Funct. Mater.*, **2020**, 30, 2006561
Cu-MOF-derived N-doped porous carbon nanosheets	276 mAh g^{-1} at 50 mA g^{-1}	184 mAh g^{-1} at 1 A g^{-1} ; 157 mAh g^{-1} at 2 A g^{-1}	94.5% after 6000 cycles at 1 A g^{-1}	*Angew. Chem. Int. Ed.*, **2020**, 59, 19460
LDH/ZIF-67-derived honeycomb-like carbon	367.1 mAh g^{-1} at 0.05 A g^{-1}	162.7 mAh g^{-1} at 2 A g^{-1}	67.9% after 200 cycles at 1 A g^{-1}	*Chem. Eng. J.*, **2020**, 384: 123328
Macroporous ZIF-8 single crystal-derived N-doped carbon	345 mAh g^{-1} at 0.1 A g^{-1}	180 mAh g^{-1} at 1 A g^{-1} ; 94 mAh g^{-1} at 10 A g^{-1}	105.4% after 12000 cycles at 2 A g^{-1}	*Nano Lett.*, **2019**, 19, 4965
MIL-100-derived S/N co-doped thin carbon	320 mAh g^{-1} at 50 mA g^{-1}	91.2 mAh g^{-1} at 2 A g^{-1}	71.3% after 900 cycles at 2 A g^{-1}	*Adv. Mater.*, **2019**, 31, 1805430
ZIF-8-derived N-doped meso-macro porous carbon	312 mAh g^{-1} at 0.2 C	117 mAh g^{-1} at 21 C	93.2 % after 2000 cycles at 2 A g^{-1}	*J. Mater. Chem. A*, **2019**, 7, 21966
Cu-BTC-derived N/O co-doped carbon	354 mAh g^{-1} at 50 mA g^{-1}	110 mAh g^{-1} at 1 A g^{-1}	90.9% after 1300 cycles at 1 A g^{-1}	*J. Mater. Chem. A*, **2019**, 7, 12317
Co-HMT-derived carbon nanosheets	311 mAh g^{-1} at 0.1 A g^{-1}	168 mAh g^{-1} at 2 A g^{-1}	96% after 10000 cycles at 5 A g^{-1}	*J. Mater. Chem. A*, **2019**, 7, 18499
MIL-101-derived N/O-doped hard carbon	365 mAh g^{-1} at 25 mA g^{-1}	118 mAh g^{-1} at 3 A g^{-1}	69.5% after 1100 cycles at 1.05 A g^{-1}	*Adv. Mater.*, **2018**, 30, 1700104
ZIF-67-derived high pyridine N-doped porous carbon	359.6 mAh g^{-1} at 0.2 A g^{-1}	207.8 mAh g^{-1} at 2 A g^{-1}	≈ 71% after 2000 cycles at 0.5 A g^{-1}	*J. Mater. Chem. A*, **2018**, 6, 17959
ZIF-67-derived porous carbon	587.6 mAh g^{-1} at 50 mA g^{-1}	186.2 mAh g^{-1} at 2 A g^{-1}	39.4% after 2000 cycles at 0.5 A g^{-1}	*J. Mater. Chem. A*, **2018**, 6, 17959
Zn-MOF@Co-MOF nanosheet-derived	310 mA h g^{-1} at 100 mA g^{-1}	170 mAh g^{-1} at 2 A g^{-1}; 120 mAh g^{-1} at 5 A g^{-1}	89.3% after 5200 cycles at 1 A g^{-1}	*J. Mater. Chem. A*, **2019**, 7, 19929

carbon				
Al-MIL-NH_2 nnaorod-derived N-doped carbon	305 mA h g^{-1} at 100 mA g^{-1}	202 mAh g^{-1} at 1 A g^{-1}; 162 mAh g^{-1} at 6 A g^{-1}	~ 100% after 500 cycles at 6 A g^{-1}	*Small*, **2021**, 17, 2100135
MIL-88A-derived S-doped carbon	358.4 mAh g^{-1} at 50 mA g^{-1}	192.6 mAh g^{-1} at 2 A g^{-1}	90.9% after 700 cycles at 1 A g^{-1}	*ACS Appl. Energy Mater.*, **2021**, 4, 2282
ZIF-67-derived N-doped carbon nanotubes	254.7 mAh g^{-1} at 50 mA g^{-1}	180 mAh g^{-1} at 0.5 A g^{-1}; 131 mAh g^{-1} at 2 A g^{-1}	77.86% after 500 cycles at 2 A g^{-1}	*ChemSusChem*, **2018**, 11, 202
Bi-MOF-derived carbon film@carbon nanorods@Bi nanoparticle	425 mAh g^{-1} at 0.1 A g^{-1}	140 mAh g^{-1} at 1 A g^{-1}	74.8% after 700 cycles at 1 A g^{-1}	*ACS Appl. Energy Mater.*, **2019**, 11, 22474
ZIF-67-derived open ZnSe/C nanocages	318 mAh g^{-1} at 0.05 A g^{-1}	205 mAh g^{-1} at 0.5 A g^{-1}	92.19% after 400 cycles at 0.5 A g^{-1}	*J. Mater. Chem. A*, **2020**, 8, 779
ZIF-8@ZIF-67-derived N-doped CoP/C polyhedron	310 mAh g^{-1} at 0.1 A g^{-1}	220 mAh g^{-1} at 1A g^{-1}	70% after 800 cycles at 0.5 A g^{-1}	*Small*, **2020**, 16, 1906566
ZIF-67-derived N-doped carbon/CoSe nanocubes	388.7 mAh g^{-1} at 0.1 A g^{-1}	365.9 mAh g^{-1} at 2 A g^{-1}	84.6% after 500 cycles at 2 A g^{-1}	*J. Colloid Interf. Sci.*, **2021**, 604, 157
ZIF-67-derived $Co_{0.85}Se$@C nanofibers	364 mAh g^{-1} at 0.2 A g^{-1}	303 mAh g^{-1} at 2 A g^{-1}	87.42% after 400 cycles at 1 A g^{-1}	*Energy Storage Mater.*, **2020**, 24, 167
ZIF-67-derived CoP/ reduced graphene oxide	360 mAh g^{-1} at 0.1 A g^{-1}	189 mAh g^{-1} at 1 A g^{-1} ; 155 mAh g^{-1} at 2 A g^{-1}	93.65% after 2800 cycles at 1 A g^{-1}	*J. Colloid Interf. Sci.*, **2021**, 604, 319
ZnCo-ZIF-derived branched carbon nanotubes	**450.2 mAh g^{-1} at 0.05 A g^{-1}; 348.0 mAh g^{-1} at 0.1 A g^{-1}**	**199.5 mAh g^{-1} at 1 A g^{-1} ; 147.2 mAh g^{-1} at 2 A g^{-1}**	**91.6%, 86.9% and 84.5% after 500, 1000 and 1300 cycles at 2 A g^{-1}**	**This work**

Table S4 K^+ storage properties of other carbon materials in recent literature.

Materials	Specific Capacity	Rate Capability	Cycling Stability	References
N-doped carbon spheres	363.7 mAh g^{-1} at 0.05 A g^{-1}	107.9 mAh g^{-1} at 5 A g^{-1}	56.8 % after 3600 cycles at 1 A g^{-1}	*Nano-Micro Lett.*, **2021**, 13, 174
Gelatin-derived carbon	132 mAh g^{-1} at 0.1 A g^{-1}	53.8 mAh g^{-1} at 1 A g^{-1}	89.3 % after 300 cycles at 0.2 A g^{-1}	*Carbon*, **2021**, 178, 775-782
O-rich carbon nanosheets	392 mAh g^{-1} at 0.05 A g^{-1}	174 mAh g^{-1} at 2 A g^{-1}	≈ 128.5 % after 2500 cycles at 2 A g^{-1}	*Nanoscale*, **2021**, 13, 2389
P/N co-doped porous carbon monoliths	437 mA h g^{-1} at 0.05 A g^{-1}	205 mA h g^{-1} at 2 A g^{-1}	84.2 % after 3000 cycles at 1 A g^{-1}	*ACS Nano*, **2020**, 14, 14057
N/O dual-doped hard carbon	439.1 mAh g^{-1} at 100 mA g^{-1}	254.4 mAh g^{-1} at 1 A g^{-1} ; 223.4 mAh g^{-1} at 2 A g^{-1}	74.5% after 5000 cycles at 1 A g^{-1}	*Adv. Sci.*, **2020**, 7, 1902547
N/S dual-doped graphitic hollow architectures	≈ 220 mAh g^{-1} at 500 mA g^{-1}	192 mAh g^{-1} at 1 A g^{-1} ; 155 mAh g^{-1} at 2 A g^{-1}	90.2% after 5000 cycles at 5 A g^{-1}	*Adv. Energy Mater.*, **2020**, 10, 2001161
Polyaniline-*co*-polypyrrole-derived N-doped carbon	423 mAh g^{-1} at 50 mA g^{-1}	195 mAh g^{-1} at 1 A g^{-1} ; 148 mAh g^{-1} at 2 A g^{-1}	93.8% after 660 cycles at 0.2 A g^{-1}	*Angew. Chem. Int. Ed.*, **2020**, 59, 4448
Superabsorbent polymers-derived porous carbon	291.9 mAh g^{-1} at 50 mA g^{-1}	151.4 mAh g^{-1} at 1 A g^{-1} ; 136.7 mAh g^{-1} at 2 A g^{-1}	106.8% after 2000 cycles at 1 A g^{-1}	*J. Power Sources*, **2020**, 451, 227727
Nitrogen-doped turbostratic carbon	518 mAh g^{-1} at 50 mA g^{-1}	212 mAh g^{-1} at 2 A g^{-1} ; 119 mAh g^{-1} at 5 A g^{-1}	93.1% after 500 cycles at 1 A g^{-1}	*Adv. Mater.*, **2020**, 32, 2000732
Crustacean-derived porous hard carbon nanobelts	468 mAh g^{-1} at 50 mA g^{-1}	235 mAh g^{-1} at 1.6 A g^{-1}	≈ 100% after 1600 cycles at 1 A g^{-1}	*Nano Energy*, **2020**, 77, 105018
Silicon carbide - derived carbon	289.9 mAh g^{-1} at 100 mA g^{-1}	197.3 mAh g^{-1} at 1 A g^{-1}	89.3% after 1000 cycles at 1 A g^{-1}	*Adv. Funct. Mater.*, **2020**, 30, 2004348
Pitch-derived carbon	290 mAh g^{-1} at 0.1 A g^{-1}	146 mAh g^{-1} at 2 A g^{-1}	80 % after 2000 cycles at 1 A g^{-1}	*Carbon*, **2021**, 176, 383

Acetonitrile-derived porous carbon	271 mAh g^{-1} at 50 mA g^{-1}	135 mAh g^{-1} at 1 A g^{-1} ; 98 mAh g^{-1} at 5 A g^{-1}	82% after 600 cycles at 0.1 A g^{-1}	*J. Power Sources*, **2020**, 466, 228303
N/F dual doped soft carbon nanofibers	262 mAh g^{-1} at 0.1 A g^{-1}	146 mAh g^{-1} at 5 A g^{-1}	78.5 % after 1000 cycles at 1 A g^{-1}	*Small,* **2021**, 17, 2101576
Ni-EDTA-derived N-doped carbon	369 mAh g^{-1} at 50 mA g^{-1}	152 mAh g^{-1} at 1 A g^{-1} ; 123 mAh g^{-1} at 2 A g^{-1}	82% after 200 cycles at 0.2 A g^{-1}	*Adv. Funct. Mater.*, **2019**, 29, 1903641
Gelatin-derived carbon	132 mAh g^{-1} at 0.1 A g^{-1}	53.8 mAh g^{-1} at 1 A g^{-1}	89.3 % after 300 cycles at 0.2 A g^{-1}	*Carbon*, **2021**, 178, 775
Amorphous ordered mesoporous carbon	286.4 mAh g^{-1} at 50 mA g^{-1}	144.2 mAh g^{-1} at 1 A g^{-1}	101.6% after 1000 cycles at 1 A g^{-1}	*Adv. Energy Mater.*, **2018**, 8, 1701648
Spent asphalt-derived mesoporous carbon	289 mAh g^{-1} at 0.1 A g^{-1}	197.3 mAh g^{-1} at 1 A g^{-1}	89.3 % after 1000 cycles at 1 A g^{-1}	*Adv. Funct. Mater.*, **2020**, 30, 2004348
Soybeans-derived hard carbon	175 mAh g^{-1} at 0.05 A g^{-1}	70 mAh g^{-1} at 0.8 A g^{-1}	≈ 100 % after 900 cycles at 0.05 A g^{-1}	*J. Power Sources*, **2020**, 463, 228172
PPy-derived N-doped carbon nanofiber	238 mAh g^{-1} at 100 mA g^{-1}	172 mAh g^{-1} at 1 A g^{-1} ; 153 mAh g^{-1} at 2 A g^{-1}	95.3% after 2000 cycles at 1 A g^{-1}	*Nat. Commun.*, **2018**, 9, 1720.
Pitch-derived soft carbon	461.2 mAh g^{-1} at 0.1 A g^{-1}	224 mAh g^{-1} at 1 A g^{-1}	70 % after 1000 cycles at 1 A g^{-1}	*Carbon,* **2019**, 155, 601
Sycamore leaves-derived carbon microtube	432 mAh g^{-1} at 0.2 A g^{-1}	273.6 mAh g^{-1} at 1 A g^{-1}	92.48 % after 100 cycles at 0.5 A g^{-1}	*J. Mater. Chem. A*, **2019**, 7, 25845
Hierarchically N-doped porous carbon	381.7 mAh g^{-1} at 0.05 A g^{-1}	185.0 mAh g^{-1} at 10 A g^{-1}	86.0% after 1000 cycles at 2.0 A g^{-1}	*Adv. Energy Mater.*, **2018**, 8, 1802386
ZnCo-ZIF-derived branched carbon nanotubes	**450.2 mAh g^{-1} at 0.05 A g^{-1}; 348.0 mAh g^{-1} at 0.1 A g^{-1}**	**199.5 mAh g^{-1} at 1 A g^{-1} ; 147.2 mAh g^{-1} at 2 A g^{-1}**	**91.6%, 86.9% and 84.5% after 500, 1000 and 1300 cycles at 2 A g^{-1}**	**This work**