Supplementary Information

Efficient Co-N/PC@CNT bifunctional electrocatalytic material for oxygen reduction and oxygen evolution reactions based on metal-organic framework

Jinjin Ban[a,b,c], Guancheng Xu[a,b,c,*], Li Zhang[a,b,c], Gui Xu[a,b,c], Lijuan Yang[a,b,c], Zhipeng Sun[a,b,c], Dianzeng Jia[a,b,c,*]

[a] Key Laboratory of Energy Materials Chemistry, Ministry of Education;

[b] Key Laboratory of Advanced Functional Materials, Autonomous Region;

[c] Institute of Applied Chemistry, Xinjiang University, Urumqi, 830046 Xinjiang, P. R. China.

* Corresponding author. E-mail: xuguancheng@163.com

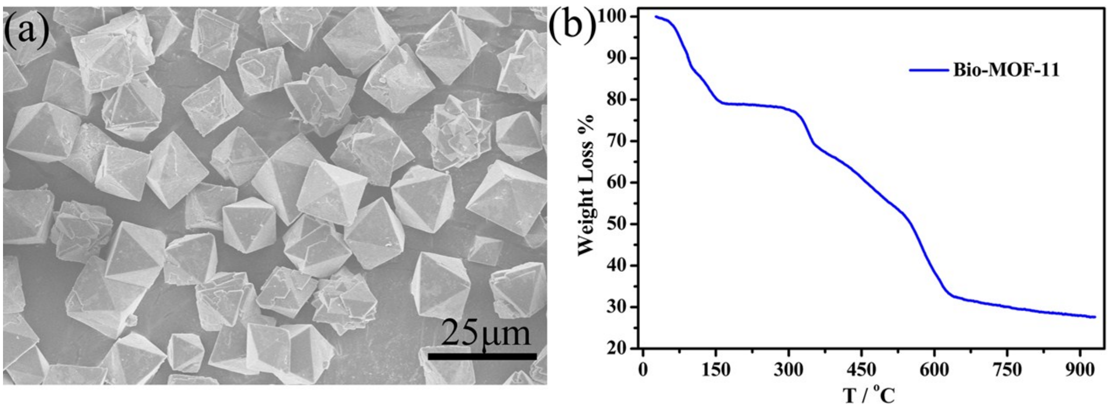

Fig. S1 SEM images (a) and TG curve (b) of Bio-MOF-11 precursor.

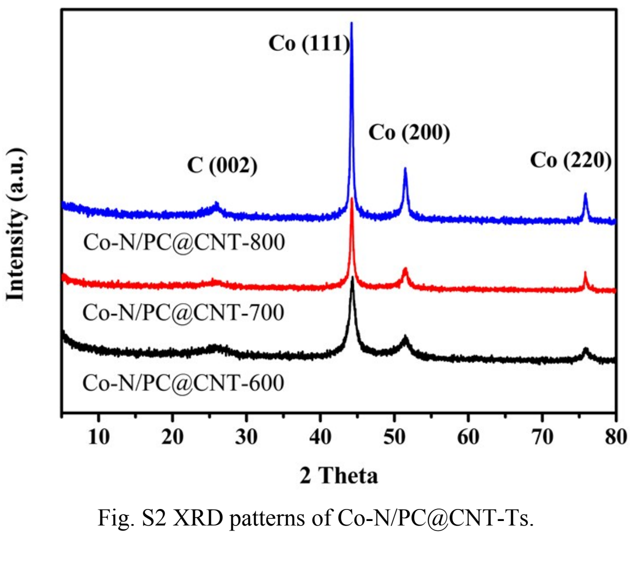

Fig. S2 XRD patterns of Co-N/PC@CNT-Ts.

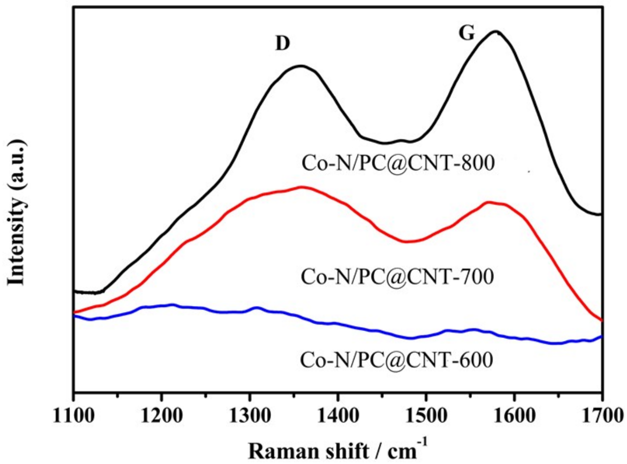

Fig. S3 Raman spectra of Co-N/PC@CNT-Ts.

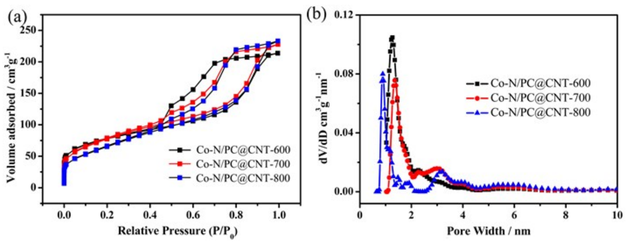

Fig. S4 N_2 adsorption-desorption isotherms (a) and pore size distributions (b) of Co-N/PC@CNT-Ts.

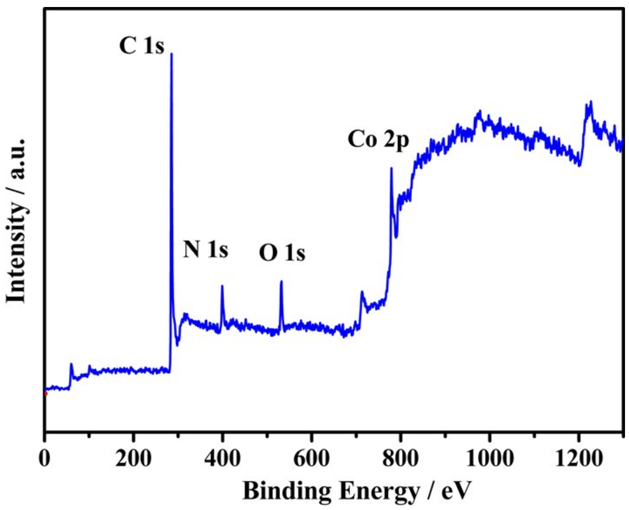

Fig. S5 Overall spectrum of Co-N/PC@CNT-700.

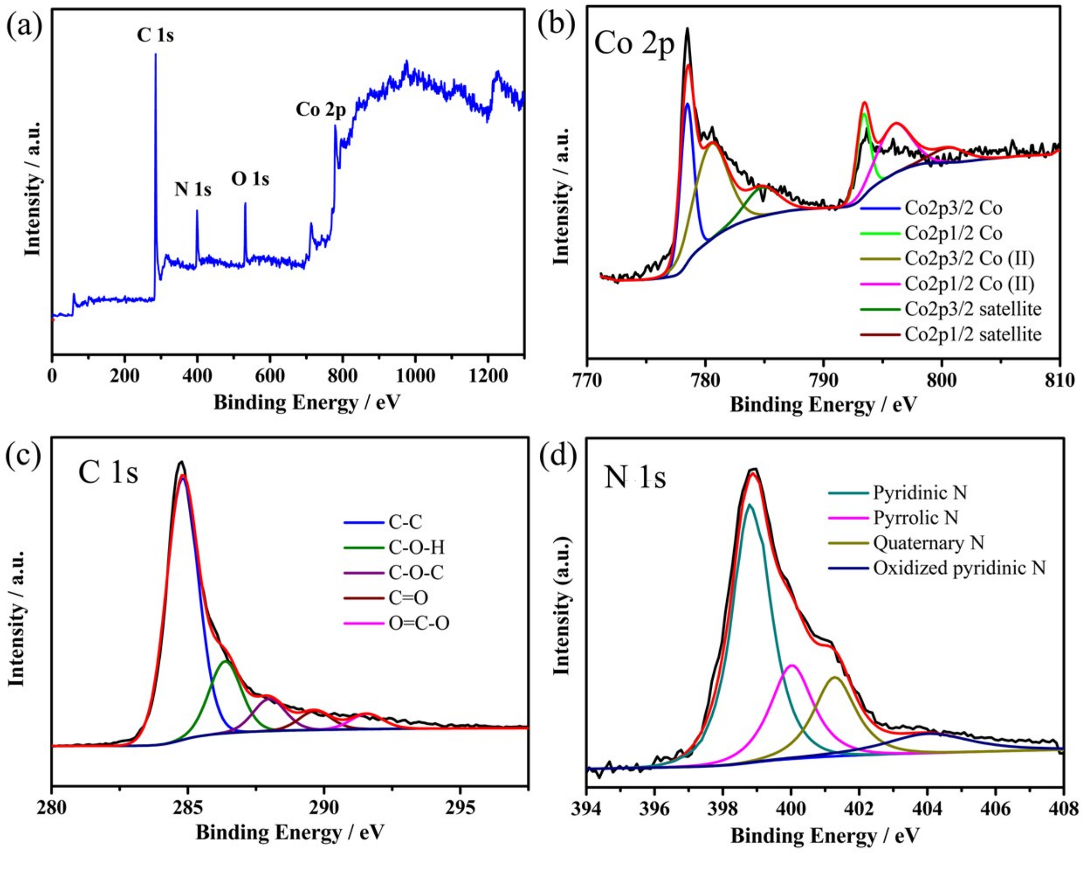

Fig. S6 Overall spectrum (a), Co 2p spectrum (b), C 1s spectrum (c) and N 1s spectrum (d) of Co-N/PC@CNT-600.

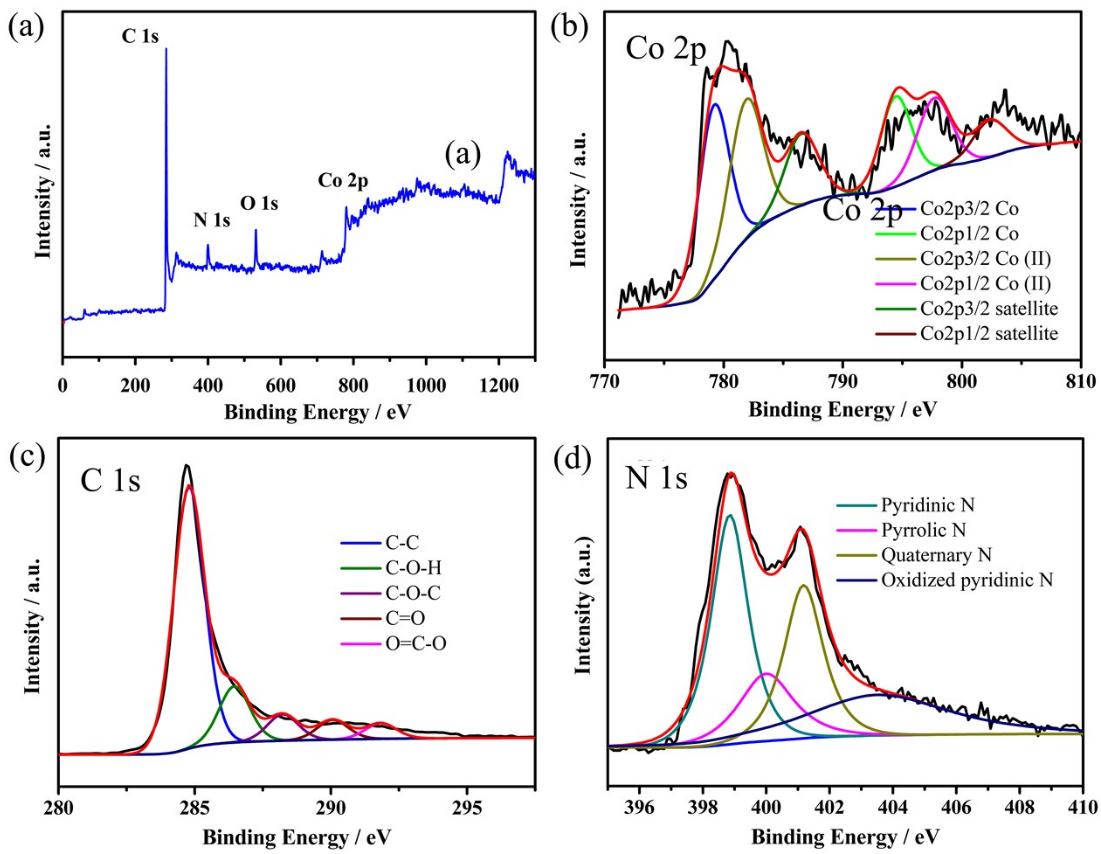

Fig. S7 Overall spectrum (a), Co 2p spectrum (b), C 1s spectrum (c) and N 1s spectrum (d) of Co-N/PC@CNT-800.

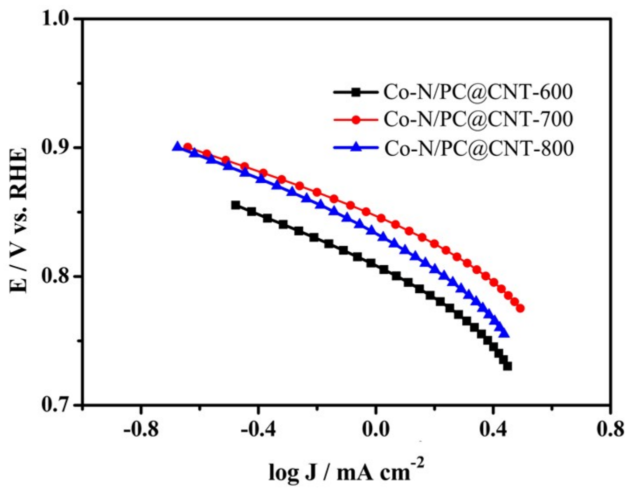

Fig. S8 Tafel curves of Co-N/PC@CNT-T electrocatalysts.

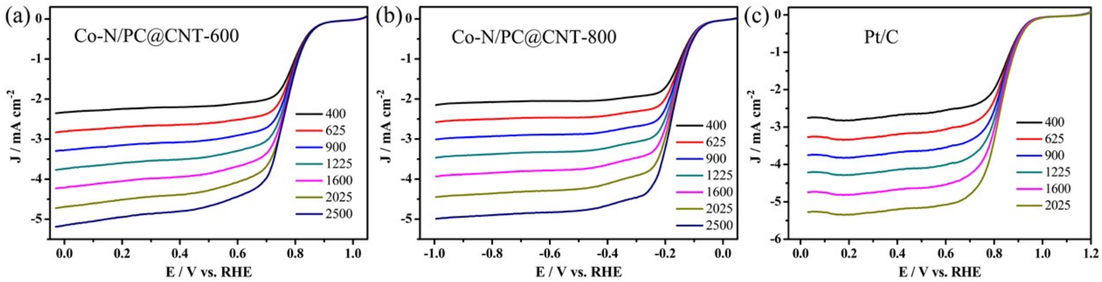

Fig. S9 LSV curves of Co-N/PC@CNT-600 (a), Co-N/PC@CNT-800 (b) and commercial Pt/C (c) electrocatalysts at rotation speeds from 400 to 1600 rpm with a scan rate of 5 mV s^{-1} in 0.1 M O_2-saturated KOH.

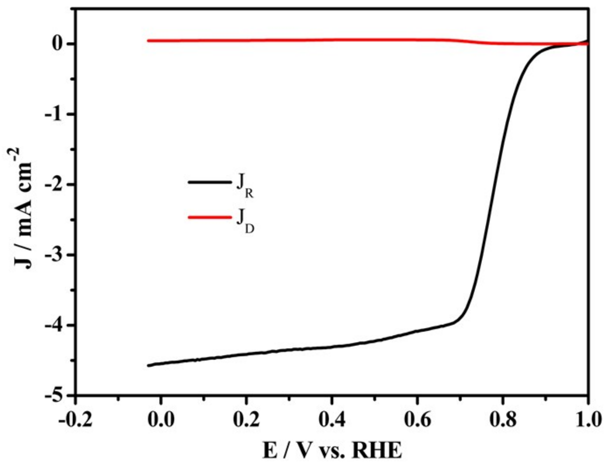

Fig. S10 RRDE curves of Co-N/PC@CNT-700 at a rotation speed of 1600 rpm with a scan rate of 5 mV s^{-1} in 0.1 M O_2-saturated KOH.

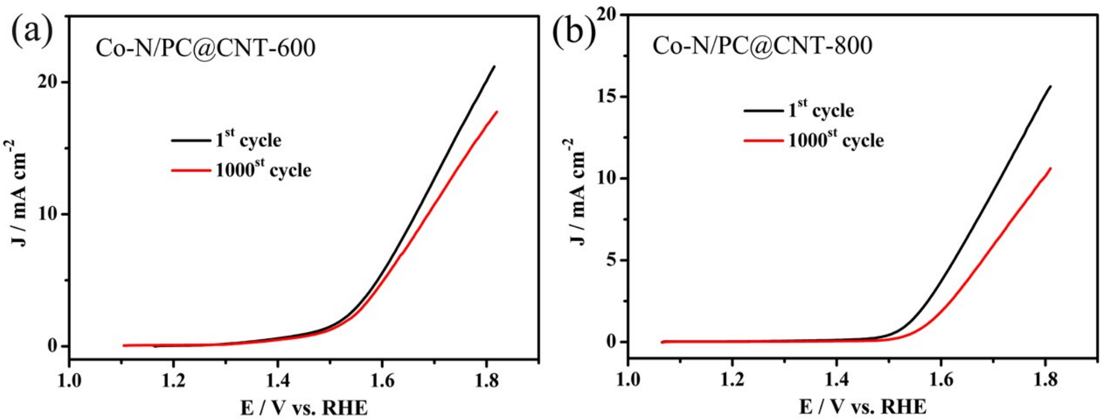

Fig. S11 Potential changes of Co-N/PC@CNT-600 (a) and Co-N/PC@CNT-800 (b) after 1000 cycles at a rotation speed of 1600 rpm with a scan rate of 5 mV s^{-1}.

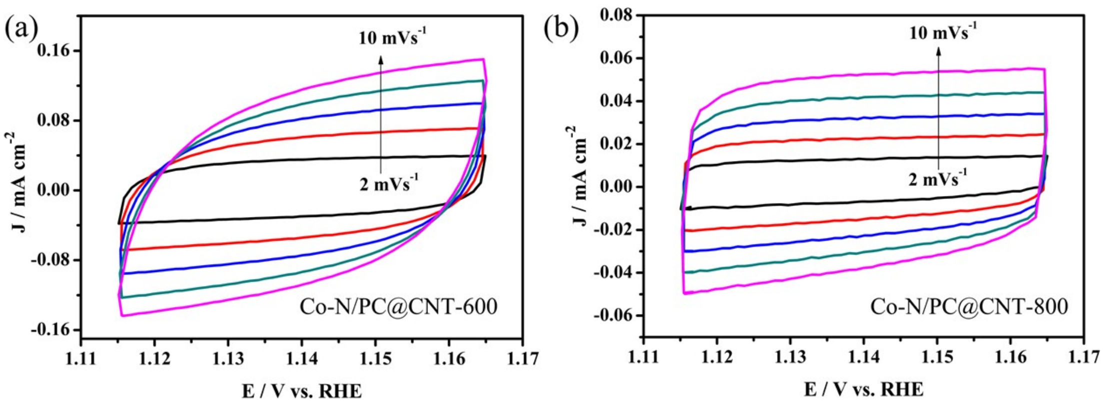

Fig. S12 CV curves of Co-N/PC@CNT-600 (a) and Co-N/PC@CNT-800 (b) recorded at 1.115-1.165 vs. RHE at scan rates from 2 to 10 mV s^{-1}.

Table S1 Summary of ORR/OER activity MOF-derived catalysts in 0.1M KOH at 1600 rpm.

Catalysts	MOF	heat treatment	Loading/ mg cm^{-2}	ORR		OER		ΔE	Ref.
				E_{onset}	$E_{1/2}$	E_{onset}	$E_{j=10}$		
Co-N/PC@CNT	Bio-MOF-11	700 °C N_2	0.25	0.92 V vs RHE	0.78 V vs RHE	1.45 V vs RHE	1.63 V vs RHE	0.86 V vs RHE	Our work
NGPC-800-5	ZIF-8	800 °C N_2	0.10	-0.16 V vs Ag/AgCl	-0.41 vs Ag/AgCl				Nanoscale 2014, 6, 6590-6602
CNP-800	MIL-88B-NH_3	800 °C Ar	0.39	0.90 V vs RHE	0.76 V vs RHE				ACS Nano 2014, 12660-12668
CIRMOF-3-600	IRMOF-3	600 °C Ar	0.10	-0.23 V vs Ag/AgCl					Electrochimica Acta 2015, 178, 287-293
Co-CNT/PC	ZIF-67	800 °C N_2	1	0.91 V vs RHE					Chem. Commun. 2016, 52, 9727-9730
N-Fe-MOF	Fe-MOF	1000 °C N_2	1		0.88V vs RHE				Adv. Mater. 2014, 26, 1378-1386
Carbon-L	ZIF-7	950 °C Ar	0.1	0.86 V vs RHE	0.69 V vs RHE				Energy Environ. Sci. 2014, 7, 442-450
Co-C@Co_9S_8 DSNCs	ZIF-67	600 °C N_2	0.375	0.96 V vs RHE					Energy Environ. Sci. 2016, 9, 107-111

N-doped Fe/Fe_3C@C/RGO	Prussian blue	800 ^{o}C Ar	0.714	1 V vs RHE	0.93 V vs RHE				Adv. Energy Mater. 2014, 1400337
BNPC	MC-BIF-1S	1000 ^{o}C H_2/Ar	0.4	0.86 V vs RHE	0.74 V vs RHE	1.41 V vs RHE			Carbon 2017, 111, 641-650
NCNTF	ZIF-67	700 ^{o}C Ar/H_2	0.2				1.60 V vs RHE		Nature Energy 2016, 1, 15006
N-PC	ZIF-67	800 ^{o}C Ar	0.35			1.65 V vs RHE			Nano Energy 2015, 12, 1-8
Co_3O_4	UTSA-16	450 ^{o}C air	0.35			1.64 V vs RHE			ACS Appl. Mater. Interfaces 2017, 9 7193-7201
Co/NC	ZIF-67	800 ^{o}C He/H_2	0.210		0.83 V vs RHE		1.69 V vs RHE	0.86 V vs RHE	Angew. Chem. Int. Ed. 2016, 55,4087-4091
Co@Co_3O_4/NC-2	ZIF-67	800 ^{o}C He/H_2 250 O_2	0.210		0.74 V vs RHE		1.64 V vs RHE	0.90 V vs RHE	Angew. Chem. Int. Ed. 2016, 55,4087-4091
Co@NPC	Co-MOFs	800 ^{o}C N_2	0.407	0.89 V vs RHE			1.68 V vs RHE	0.98 V vs RHE	Applied Surface Science 2017, 392, 402-409
Co_3O_4@C-MWCNTs	Co-ZIF-9	700 Ar 250 air	0.325	0.89 V vs RHE	0.81 V vs RHE	1.50 V vs RHE	1.55 V vs RHE		J. Mater. Chem. A 2015, 3, 17392-17402