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Electronic Supplementary Information

Cobalt and nitrogen-codoped ordered mesoporous carbon as highly efficient bifunctional catalysts for oxygen reduction and hydrogen evolution reactions

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Table S1. Comparison of ORR activity of different samples

Sample	Onset potential (V vs RHE)	Half wave potential (V vs RHE)	Limiting current density at +0.4 V (mA cm^{-2})	Electron transfer number (n, 0 to +0.9 V))
Co,N-C700	+0.82	+0.65	2.79	1.0-3.1
Co,N-C800	+0.94	+0.83	4.86	2.8-3.8
Co,N-C900	+0.97	+0.85	5.82	3.7-4.0
Co,N-C1000	+0.92	+0.81	4.64	3.0-3.8
Pt/C	+0.97	+0.88	5.68	3.8-3.9

Table S2. Comparison of catalytic performances of Co,N-C900 and Co-based carbon materials in the literature

Catalysts	Catalyst loading (mg cm^{-2})	BET area (m^2 g^{-1})	E_{onset} (V)^a	n (at E/V)^b	$E_{1/2}$ (V)^c	i_l (mA cm^{-2})^d
This work	0.24	413.0	+0.97	3.71-3.99 (0 ~ 0.90)	0.85	5.82
rGO/ cobalt porphyrin [1]	0.10	na	-0.18^e	~3.85 (-0.3 ~ -0.5)	-0.22^e	4.0
CoP-CMP800[2]	0.60	~480	-0.12^e	~3.85 (-0.45 to -0.55)	-0.18^e	4.6
$Co@Co_3O_4@C$ core@bishell nanoparticles [3]	0.10	~616	+ 0.93	~3.96 (+0.35 to +0.75)	0.81	4.7
Nitrogen-doped graphene/cobalt-embedded porous carbon [4]	0.70	375	+ 0.97	3.90–3.94 (+0.4 to +0.6)	na	na

Co_xZn_{100-x}–ZIF-8 [5]	0.28	~1700	-0.05[e]	3.8-4.0 (-0.3 ~ -0.6)	-0.12[e]	5.0
N,Co,P-codoped porous carbon [6]	0.10	1225	-0.04[e]	~3.9 (-0.25 ~ -0.45)	-0.12[e]	6.0
Co/CoO nanoparticles immobilized on Co–N-doped carbon [7]	0.60	647.7	-0.05[e]	~3.8 (-0.3 to -0.45)	-0.17[e]	5.5
Cobalt-embeded N-doped graphene aerogel [8]	0.28	466.6	+ 0.90	3.99 (+0.3 to +0.6)	0.81	6.0
Co-N-doped mesoporous carbon hollow spheres [9]	0.28	342.3	+ 0.94	3.7 (+0.6 to +0.75)	0.85	4.7

a. Onset potential in V vs RHE, unless otherwise noted
b. Number of electron transfer at the specified potential range. The potential scale is identical to the E_{onset}.
c. Half wave potential in V vs RHE, unless otherwise noted.
d. Limiting current density
e. V vs Ag/AgCl

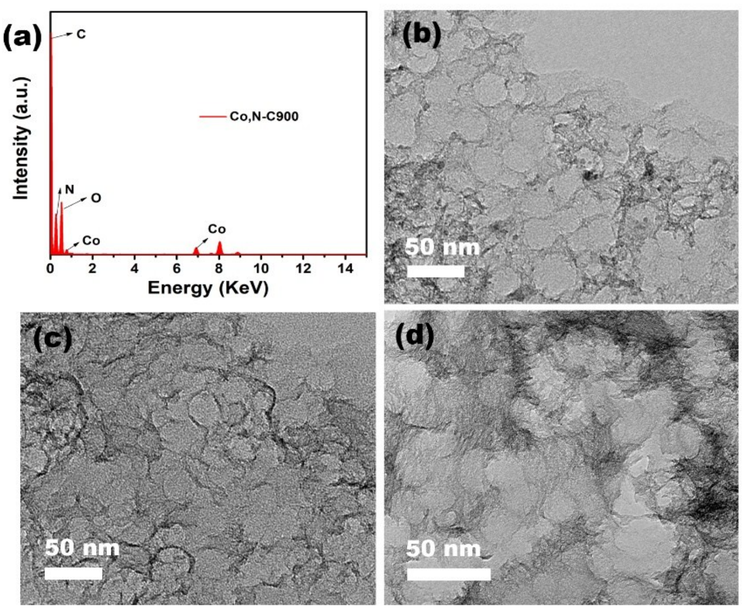

Figure S1. (a) Corresponding EDS of Co,N-C900 and TEM images of (b) Co,N-C700, (c) Co,N-C800 and (d) Co,N-C1000.

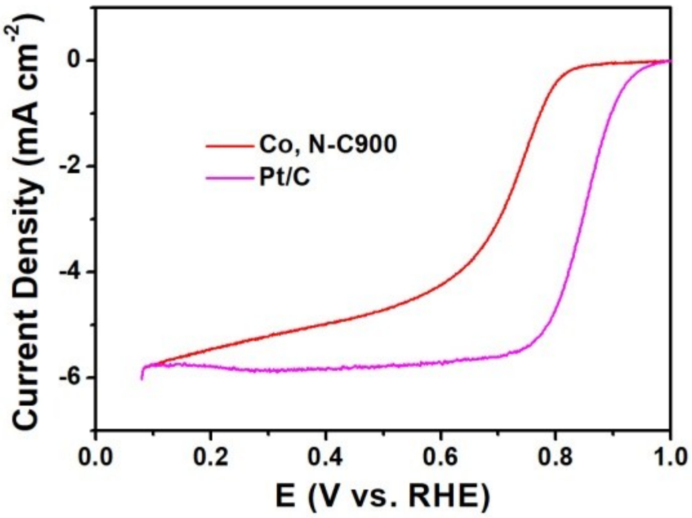

Figure S2. RDE voltammograms for ORR of Co,N-C900 and 20 wt% Pt/C at 1600 rpm with a scan rate of 10 mV s^{-1} in O_2 -saturated 0.1 M $HClO_4$.

Table S3. BET specific surface area and total pore volume of N,Co-codoped porous carbon prepared at different heat treatment temperatures.

Sample	S_{BET}(m^2 g^{-1})	Pore volumes (cm^3 g^{-1})
Co,N-C700	173.8	1.61
Co,N-C800	326.6	2.69
Co,N-C900	413.1	5.32
Co,N-C1000	274.5	1.93

Table S4. BET specific surface area and total pore volume of Co,N-NTC900, Co,N-C900 and N-C900.

Sample	S_{BET}(m^2 g^{-1})	Pore volumes (cm^3 g^{-1})
Co,N-NTC900	90.2	0.65
Co,N-C900	413.1	5.32
N-C900	361.3	3.26

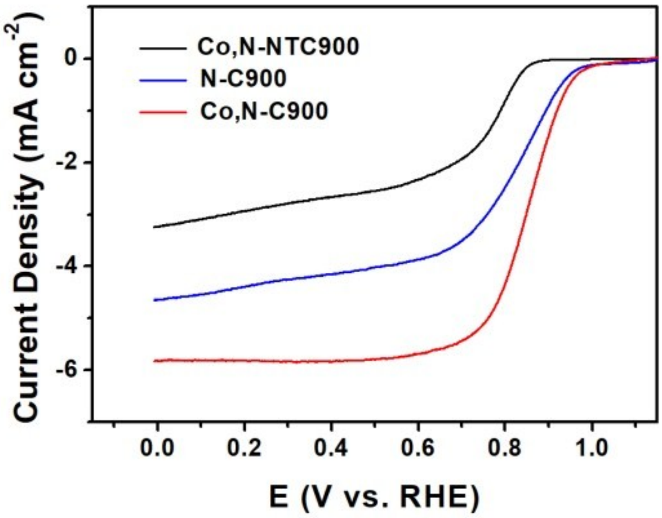

Figure S3. RDE voltammograms for ORR of Co,N-NTC900, N-C900 and Co,N-C900 in O_2-saturated 0.1 M KOH at the electrode rotation rate of 1600 rpm and potential scan rate of 10 mV s^{-1}.

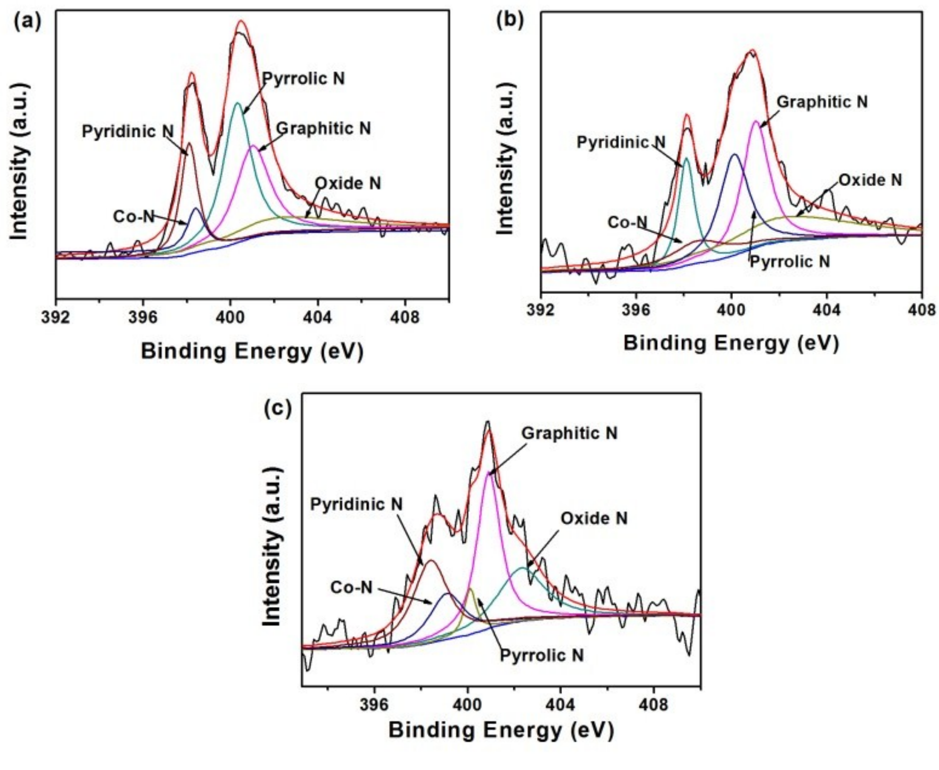

Figure S4. Peak deconvolutions of the N1s spectra of (a) Co, N-C700, (b) Co, N-C800 and (c) Co, N-C1000.

Table S5. Elemental contents and concentrations of N species in carbon catalysts determined by XPS measurements

sample	C (at.%)	O (at.%)	N (at.%)	Co (at.%)	Pyrinidic N	Co-N	Pyrrolic N	Graphitic N	Oxide N
Co,N-C700	77.63	10.77	10.9	0.70	2.25	0.66	3.97	2.98	1.04
Co,N-C800	80.86	9.51	8.62	1.01	1.61	0.82	2.49	3.05	0.65
Co,N-C900	84.71	7.80	6.37	1.12	1.29	0.97	0.50	3.40	0.61
Co,N-C1000	87.09	7.44	4.26	1.21	0.97	0.63	0.29	1.39	0.98

Table S6. Comparison of HER performances of Co,N-C900 and Co-based carbon materials in literature

Catalysts	Loading amount (mg cm $^{-2}$)	Onset potential (V)	Overpotential @10mA cm $^{-2}$ (V)	Tafel slope
This work	0.28	-0.04	-0.106	49
N-graphene/ cobalt-embedded porous carbon [4]	0.357	−0.058	-0.229	126
Co-embedded Nitrogen-rich carbon nanotubes [10]	0.28	-0.05	-0.26	69
Fe and Co Encapsulated N doped carbon nanotube [11]	0.32	-0.07	-0.28	72
CoS_2 microwires [12]	unknown	-0.075	-0.158	58
CoS_2 nanowires [13]	unknown	-0.075	-0.145	51.6
Co_2P nanorods [14]	1.02	-0.07	-0.134	71
$CoSe_2$ nanowires	1.30	-0.085	-0.130	32
$CoSe_2$ film [15]	0.037	-0.045	-0.17	40
MoS_2/reduced graphene [16]	0.285	-0.010	-0.16	41
MoS_2 /$CoSe_2$ hybrid[17]	0.28	-0.011	-0.068	36

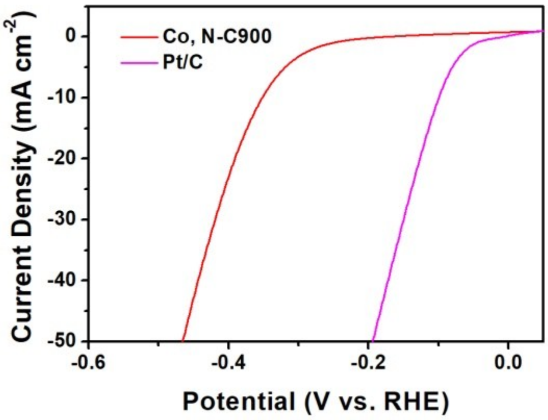

Figure S5. Polarization curves for HER in 0.1 M KOH at Co,N-C900 and 20 wt% Pt/C. Potential sweep rate 5 mV s^{-1}.

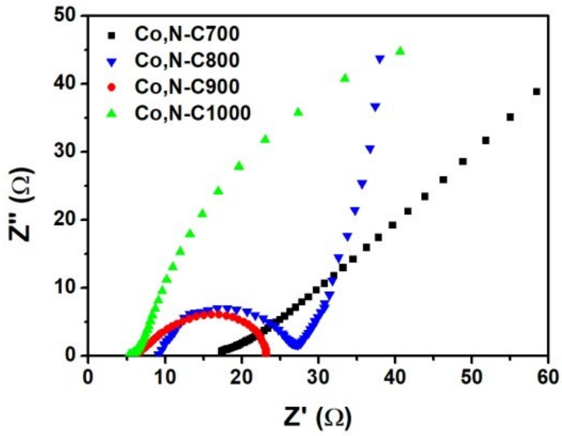

Figure S6. Electrochemical impedance spectra of Co, N-C700, Co, N-C800, Co, N-C900 and Co, N-C1000 for HER in 0.5 M H_2SO_4 at −0.2 V.

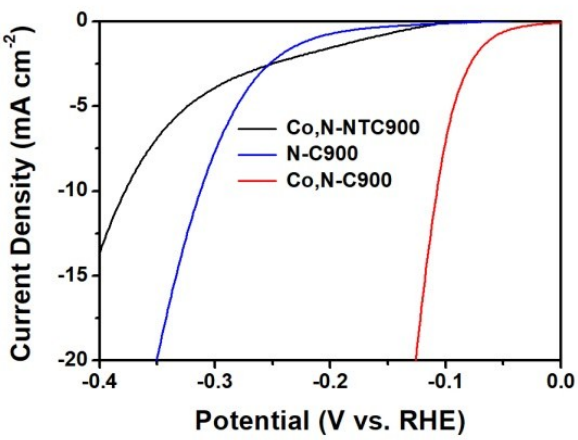

Figure S7. LSV curves of Co,N-NTC900, N-C900 and Co,N-C900 for HER in 0.5 M H_2SO_4. Potential sweep rate: 5 mV s^{-1}.

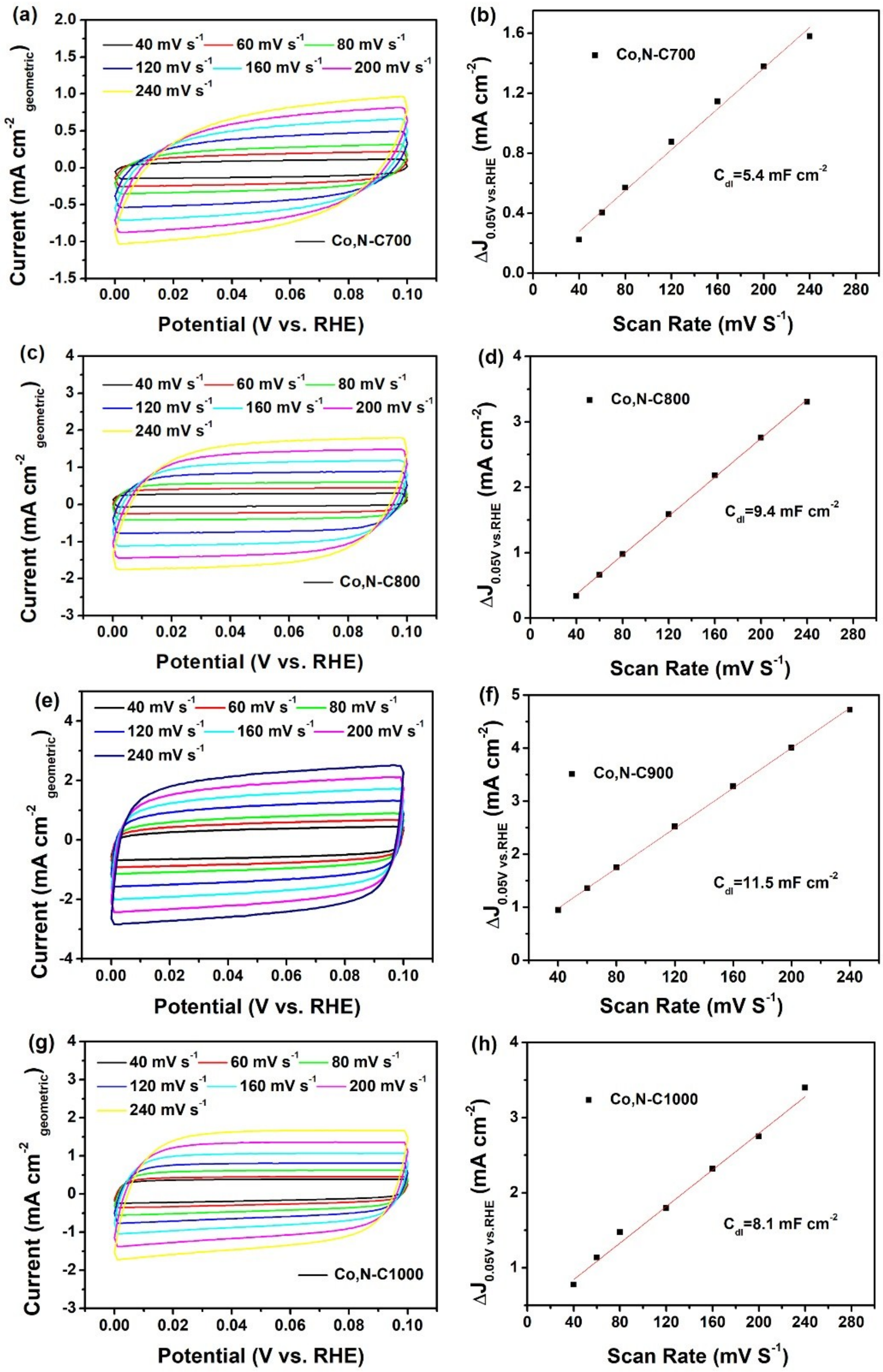

Figure S8. Cyclic voltammograms of (a) Co, N-C700, (c) Co, N-C800, (e) Co, N-900 and (g) Co, N-C1000 taken in N_2-saturated 0.5 M H_2SO_4 and the capacitive currents at 0.05 V vs. RHE as a function of scan rate for (b) Co, N-C700, (d) Co, N-C800, (f) Co, N-900 and (h) Co, N-C1000.

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