Supplemental Information

Light-weight 3D Co-N-doping hollow carbon spheres as efficient electrocatalyst for zinc-air battery

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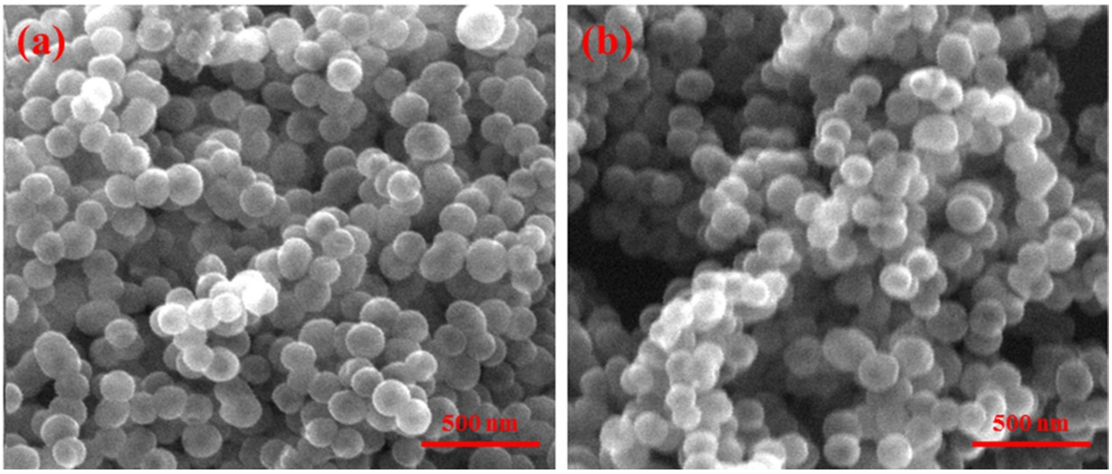

Fig. S1 (a) SEM image of 0.05-Co-NHCs; (b) SEM image of 0.15-Co-NHCs.

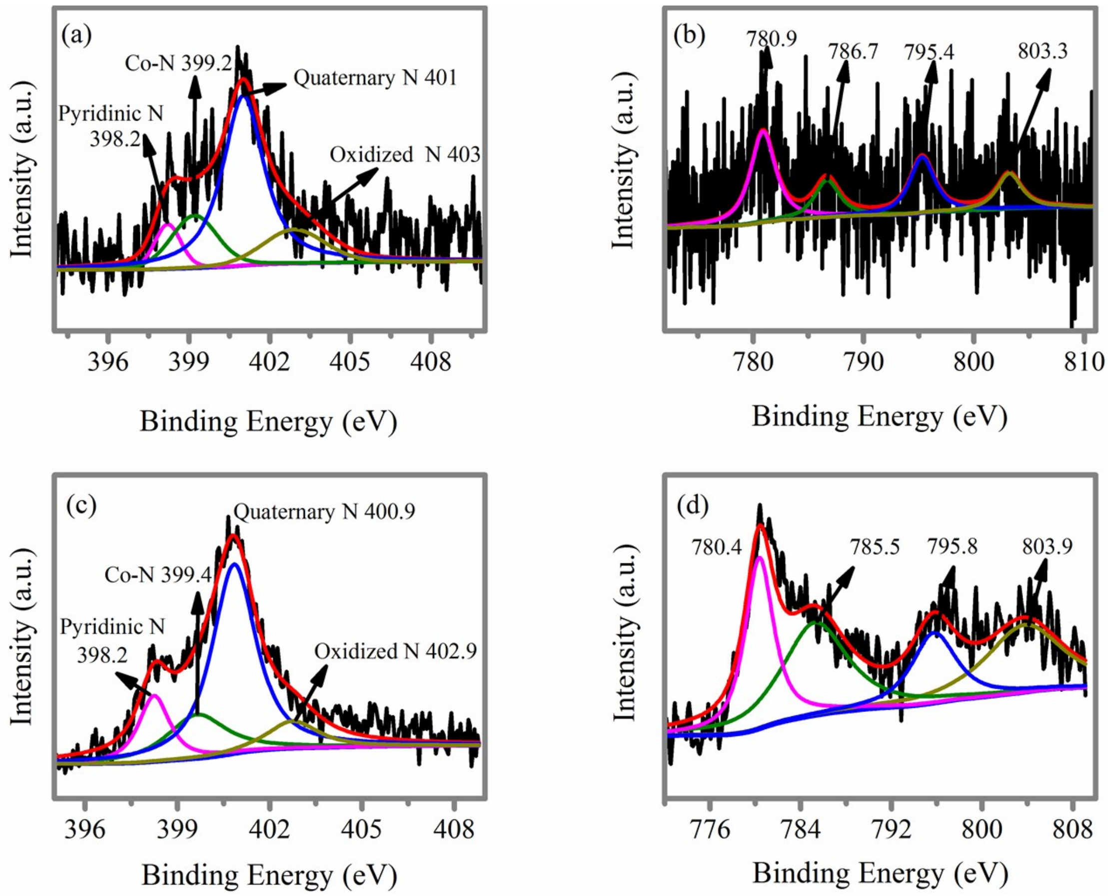

Fig. S2 High-resolution XPS N 1s (a, c) and Co 2p (b, d) of 0.05-Co-NHCs and 0.15-Co-NHCs.

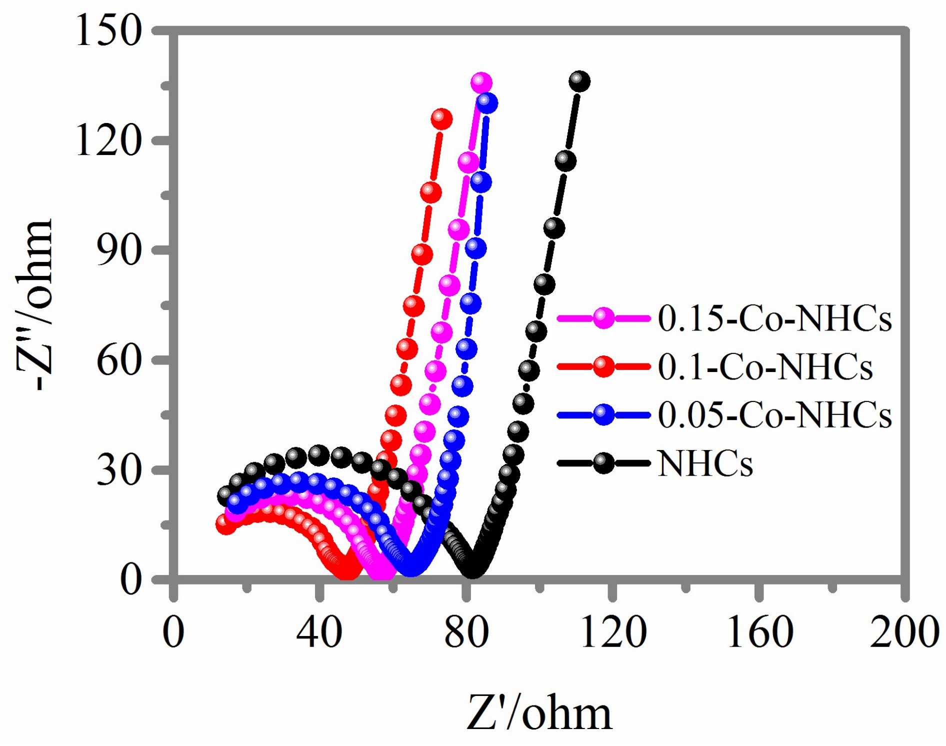

Fig. S3 The A.C impedance plots of catalysts NHCs, 0.05-Co-NHCs, 0.1-Co-NHCs and 0.15-Co-NHCs.

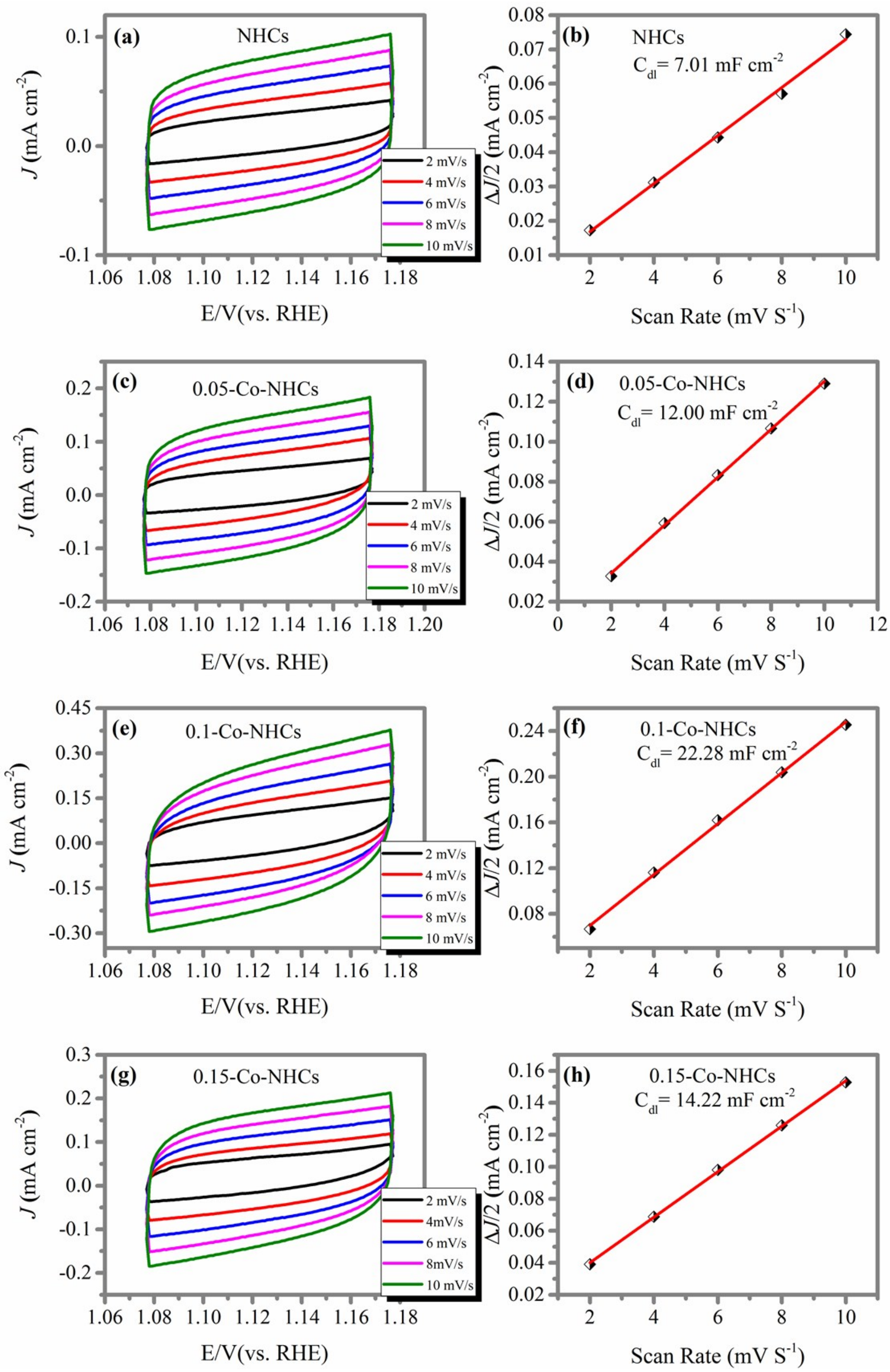

Fig. S4 CV curves in the region of 0.1-0.2 V at scan rate from 2 to 10 mVs^{-1} and corresponding liner fitting capacitive current vs. scan rates to estimate the C_{dl}: 7.01 mF cm^{-2} for NHCs (a, b), 12.00 mF cm^{-2} for 0.05-Co-NHCs (c, d), 22.28 mF cm^{-2} for 0.1-Co-NHCs (e, f) and 14.22 mF cm^{-2} for 0.15-Co-NHCs (g, h).

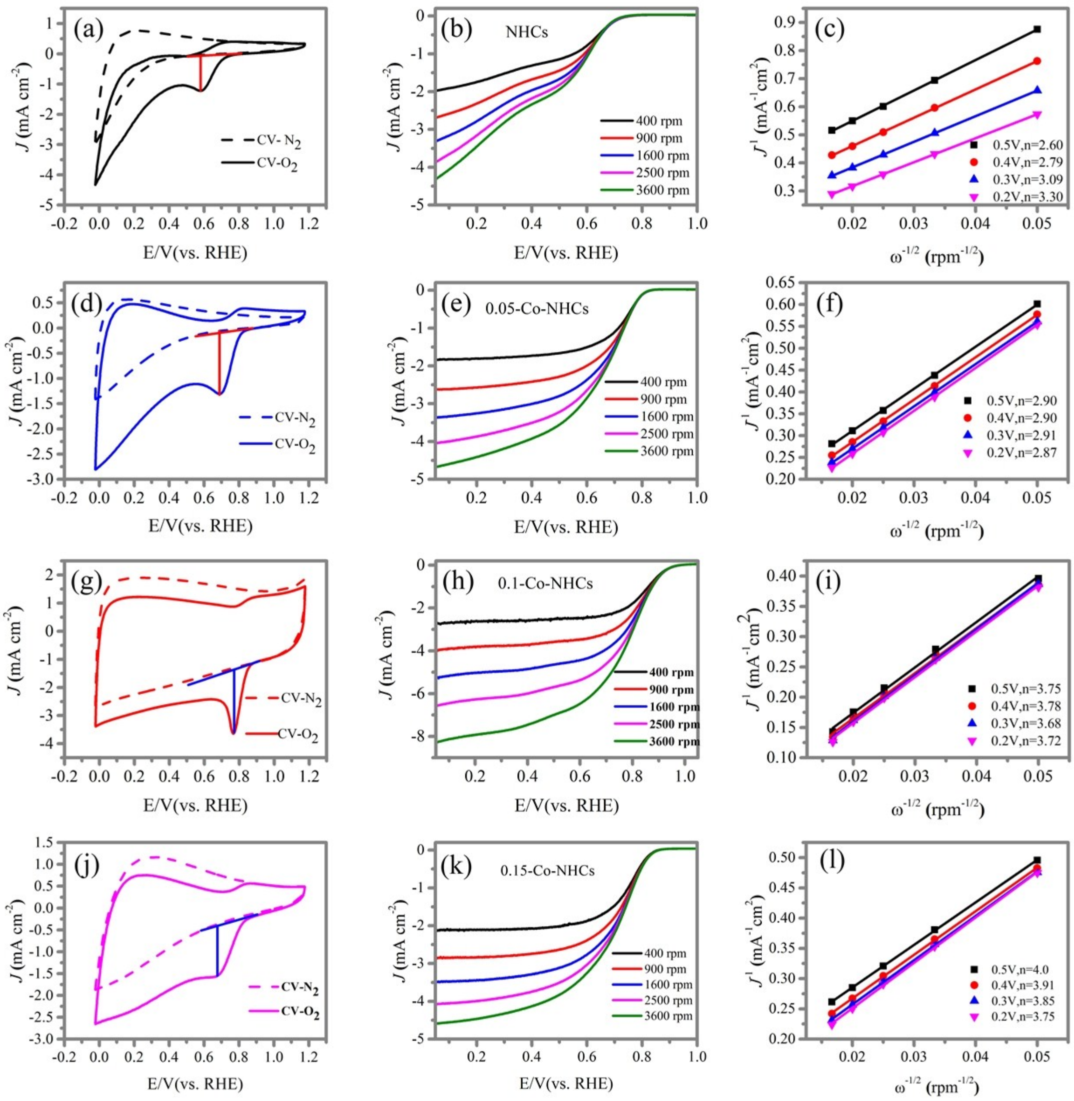

Fig. S5 (a, d, g, j) CV curves of different catalysts recorded at 100 mV s^{-1} in N_2 and O_2 saturated 0.1 M KOH solution; (b, e, h, k) LSV curves of different catalysts at different rotation speeds; (c, f, i, l) K-L plots of different catalysts at different potentials with corresponding electron transfer number.

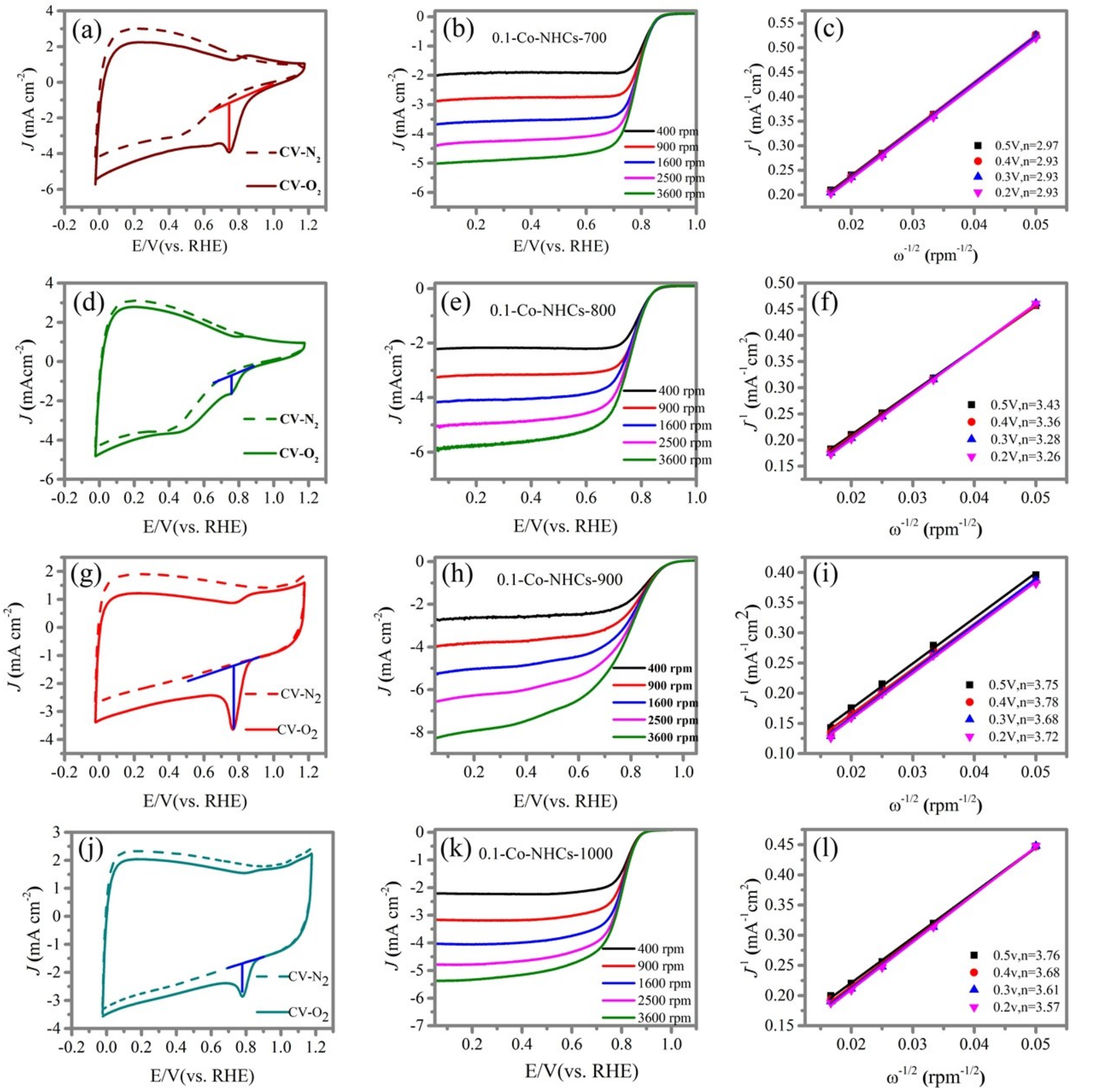

Fig. S6 (a, d, g, j) CV curves of different catalysts recorded at 100 mV s^{-1} in N_2 and O_2 saturated 0.1 M KOH solution; (b, e, h, k) LSV curves of different catalysts at different rotation speeds; (c, f, i, l) K-L plots of different catalysts at different potentials with corresponding electron transfer number.

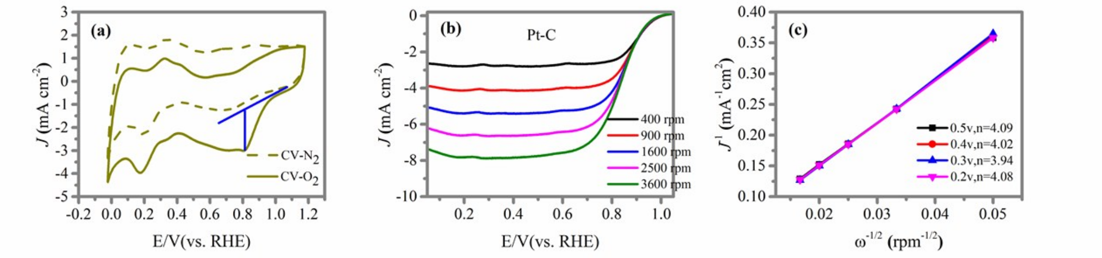

Fig. S7 (a) CV curves of commercial Pt-C catalyst recorded at 100 mV s^{-1} in N_2 and O_2 saturated 0.1 M KOH solution; (b) LSV curves of commercial Pt-C catalyst at different rotation speeds; (c) K-L plots of commercial Pt-C catalyst at different potentials with corresponding electron transfer number.

Fig. S8 Digital image of assembled zinc-air battery using 0.1-Co-NHCs as catalyst to display open-circuit voltage and different color LED powered by two of the assembled zinc-air batteries in series.

Table S1 Ratio analysis of the peaks in XPS spectrum in NHCs and Co based NHCs catalysts

				% N				
	% C	% O	% Co	N total	Pyri-N	Co-N	Qua-N	Oxi-N
NHCs	91.23	4.07	0.00	4.68	24.59	0.00	73.79	1.62
0.05Co-NHCs	85.77	12.30	0.13	1.69	8.07	16.57	61.02	14.34
0.1 Co-NHCs	89.00	8.52	0.29	2.19	9.65	32.71	39.87	17.76
0.15Co-NHCs	91.05	6.51	0.39	2.26	14.24	18.20	57.71	9.85

Table S2 Comparison of the ORR performance between 0.1-Co-NHCs catalyst, commercial Pt-C and other reported catalysts in 0.1 M KOH electrolyte

Electrocatalyst	Onset potential (V vs. RHE)	Half-wave potential (V vs. RHE)	Loading mass (ug cm^{-2})	Reference
0.1-Co-NHCs	0.99	0.81	217	This work
Pt-C	1.02	0.83	140	This work
Fe-N/C-800	0.923	0.809	100	J. Am. Chem. Soc., 2014, 136, 11027.
N-doped carbon cubes	0.92	0.80	400	Nanoscale, 2017, 9, 1059.
CoO@Co/N-rGO	0.95	0.81	-	J. Mater. Chem. A, 2017,5,5865
N, S-doped Graphene sheets	0.92	0.77	200	Nano Energy, 2016, 19, 373
NCNT/CoO-NiO-NiCo	0.97	0.83	210	Angew.Chem. Int.Ed. 2015, 54,9654
Fe−N-Doped Carbon Capsules	0.94	0.83	100	ACS Nano, 2016, 10,5922
CF-NG-Co	0.97	0.85	140	J. Mater. Chem. A, 2018,6,489
N-CG–CoO	0.90	0.81	700	Energ Environ Sci 2014, 7, 609

Table S3 Comparison of the zin - air batteries performance between using 0.1-Co-NHCs catalyst, commercial Pt-C and other reported catalysts

Electrocatalyst	Loading mass ($g \cdot cm^{-2}$)	Power density ($mW \cdot cm^{-2}$)	Round-trip Efficiency	Stability	Reference
0.1-Co-NHCs	1	239.8	60.6%	11 min per cycle for 300 cycles; voltage gap increased ~0.1V	This work
Pt-C	1	156	59.8%	11 min per cycle for 300 cycles; voltage gap increased ~0.4V	This work
N-doped graphene	0.5	65	60%	60 min per cycle for 150 cycles; voltage gap increased ~0.2 V	Sci. Adv. 2016,2:e1501122.
FeCo-N-doped CNT	2	89.3	32.3%	10 min per cycle for 240 cycles; voltage gap increased ~0.03 V	Adv. Energy Mater. 2017, 1602420.
Co_3O_4-NCNT/SS	-	160.7	61%	20 min per cycle for 1500 cycles; voltage gap increased ~0.16 V	Adv. Mater. 2016, 28, 6421.
N, P-doped mesoporous carbon	0.5	55	59%	10 min per cycle for 180 cycles; voltage gap increased ~0.7 V	Nature Nanotech. 2015, 10, 444.
Atomically dispersed Fe-N	1.25	102.7	57%	After 100cycles; voltage gap increased ~0.2 V	Angew. Chem. Int. Ed. 2017, 56, 610.
Co_3O_4/NPGC	0.9	-	58.9%	After 85 hours; voltage gap increased ~0.05V	Angew.Chem .Int. Ed. 2016, 55, 4977
Co_4N/CNW/CC	-	174	61%	20 min per cycle for 408 cycles; voltage gap increased ~0.01 V	J. Am. Chem. Soc. 2016, 138, 10226.
N/S hierarchically porous carbon	1	151	61%	11 min per cycle for 300 cycles; voltage gap increased ~0.085V	Energy Environ. Sci., 2017, 10, 742