Supporting Information

Cobalt nanoparticles embedded in N-doped carbon as an efficient bifunctional electrocatalyst for oxygen reduction and evolution reactions

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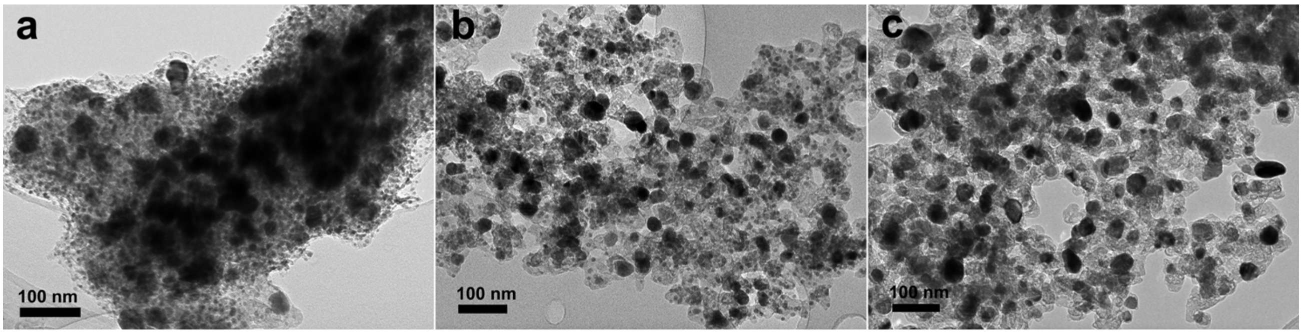

Figure S1. TEM images of (a) Co/N-C-700, (b) Co/N-C-800, and (c) Co/N-C-900.

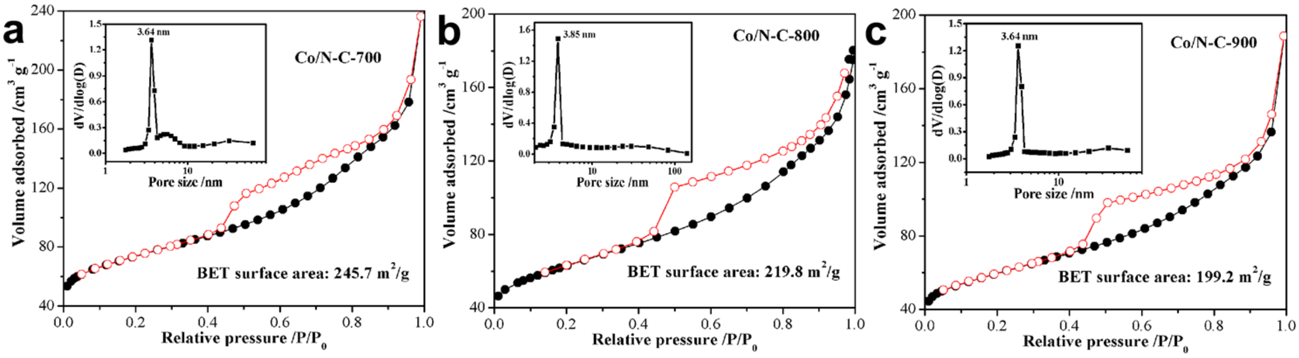

Figure S2. Nitrogen absorbtion and desorption isotherms of (a) Co/N-C-700, (b) Co/N-C-800, and (c) Co/N-C-900, the insets show the corresponding BJH pore distributions.

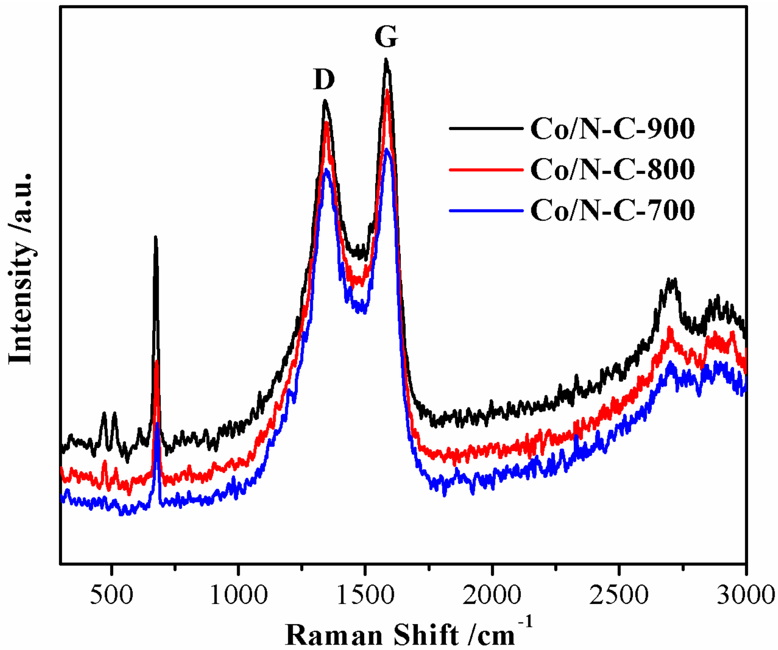

Figure S3. Raman spectra for Co/N-C samples carbonized under different temperatures.

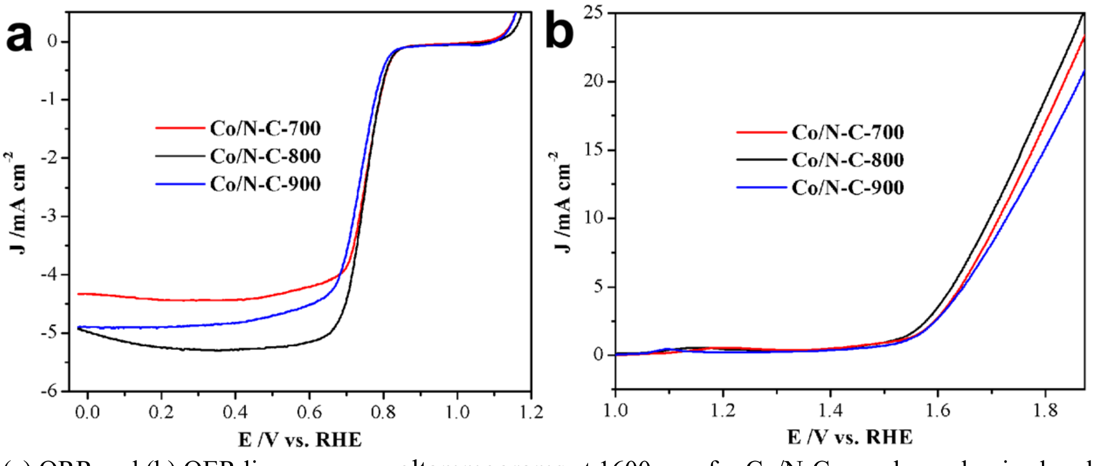

Figure S4. (a) ORR and (b) OER linear sweep voltammograms at 1600 rpm for Co/N-C samples carbonized under different temperatures in O_2-saturated 0.1 M KOH.

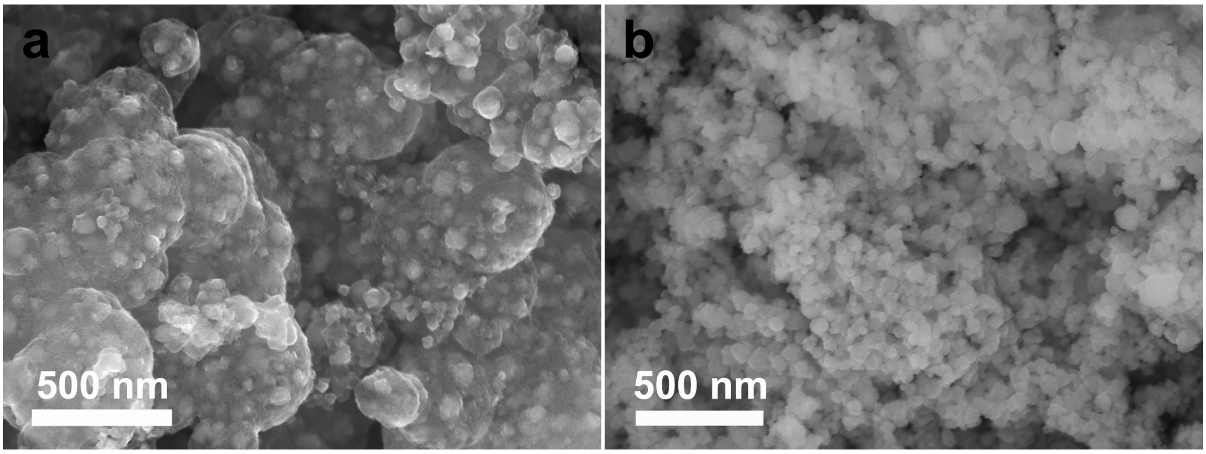

Figure S5. SEM images of (a) Co/N-C-800-250 and (b) Co/N-C-800-450.

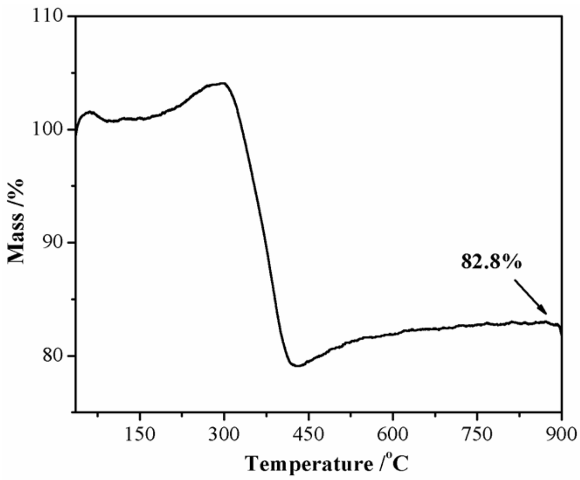

Figure S6. TG analysis of Co/N-C-800.

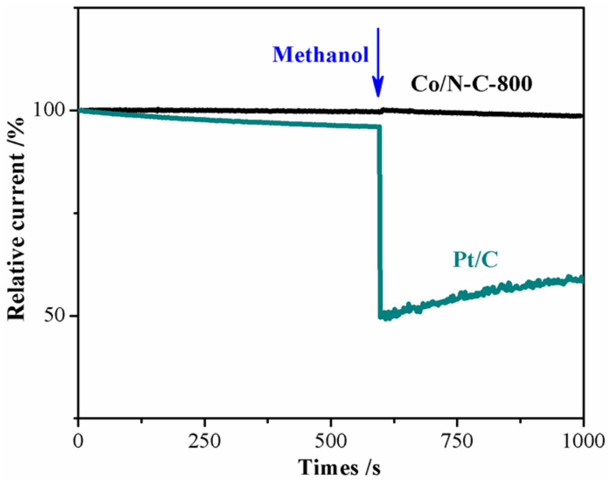

Figure S7. I-t plots of Co/N-C-800 and Pt/C at 0.55 V (vs. RHE) with a rotation rate of 900 rpm in O_2-saturated 0.1 M KOH with the adding of methanol (1.0 M).

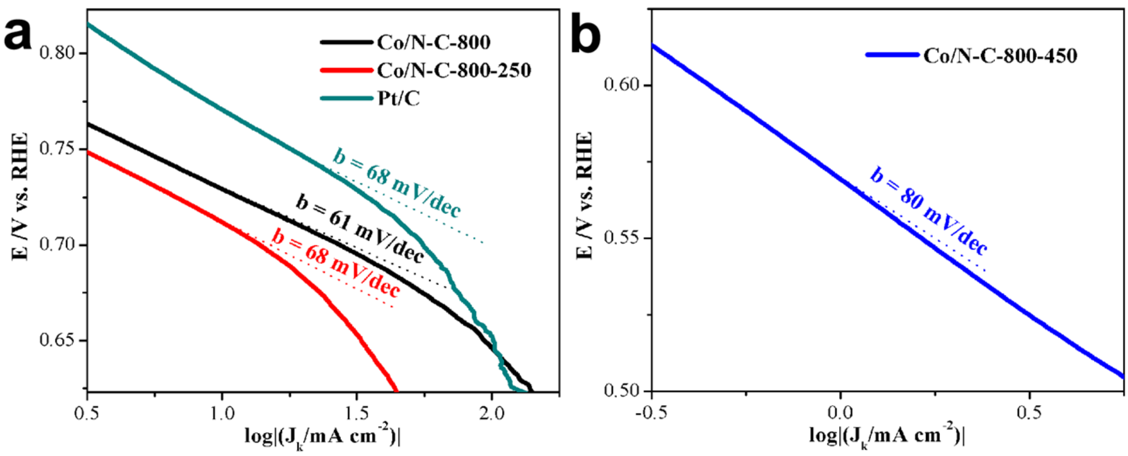

Figure S8. Tafel plots obtained from the RDE measurements at 1600 rpm for (a) Co/N-C-800, Co/N-C-800-250 and Pt/C, and (b) Co/N-C-800-450.

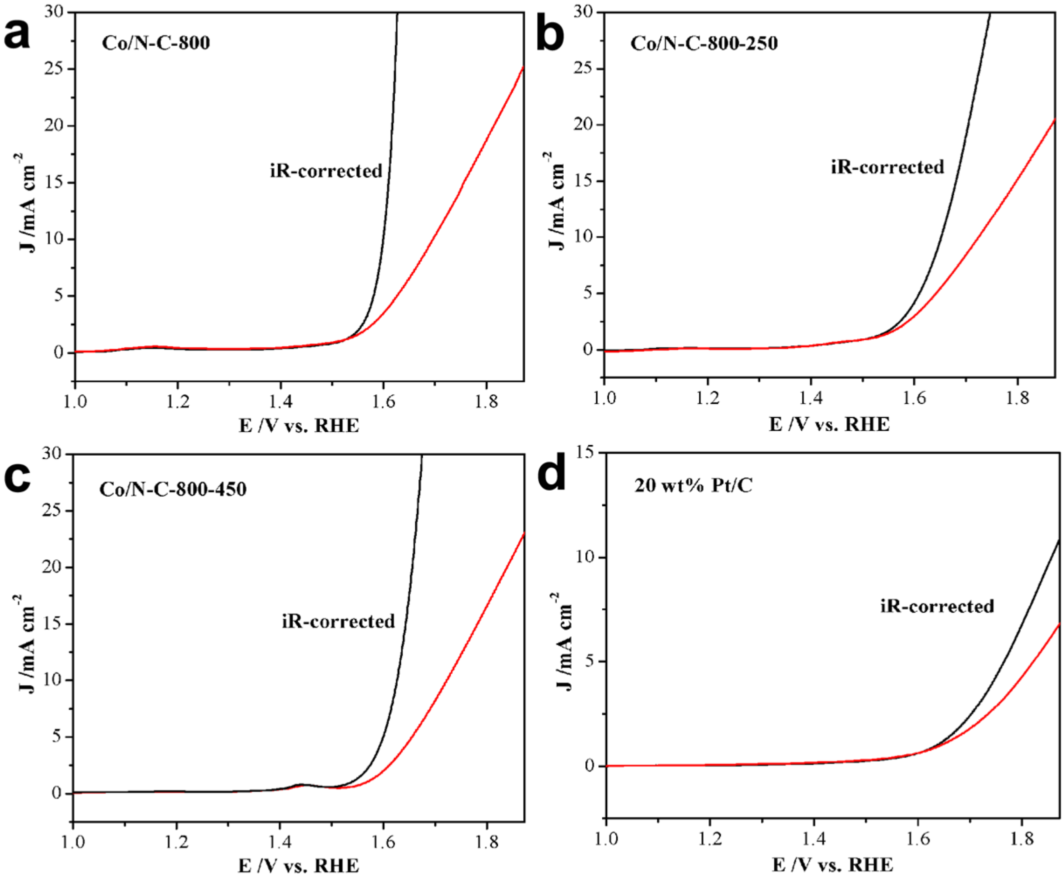

Figure S9. OER polarization curves for modified GC electrodes comprising the (a) Co/N-C-800, (b) Co/N-C-800-250, (c) Co/N-C-800-450, and (d) 20 wt% Pt/C with (black) and without (red) correction for iR losses. The ionic resistance (~45 Ω) from the solution was determined by the EIS technique.

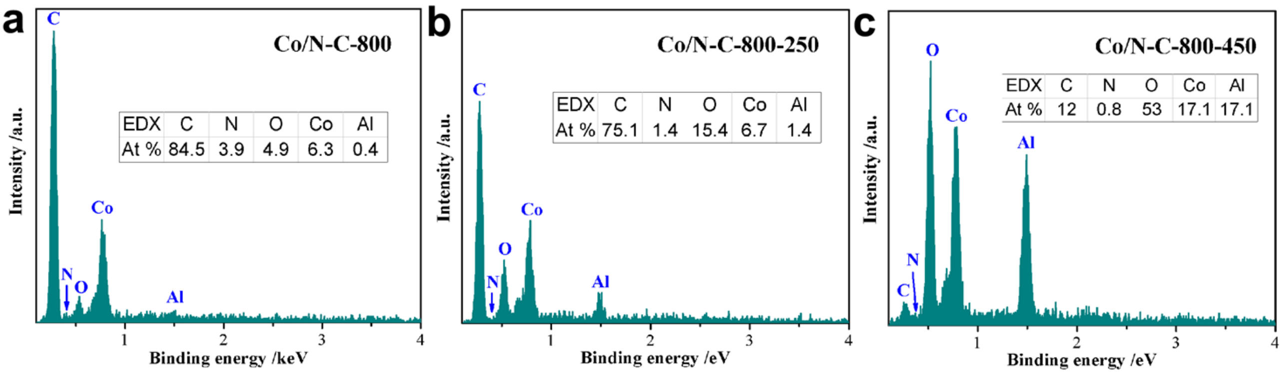

Figure S10. EDX spectra and the content of C, N, Co and O in (a) Co/N-C-800, (b) Co/N-C-800-250 and (c) Co/N-C-800-450, the signal of Al is from the Al substrates.

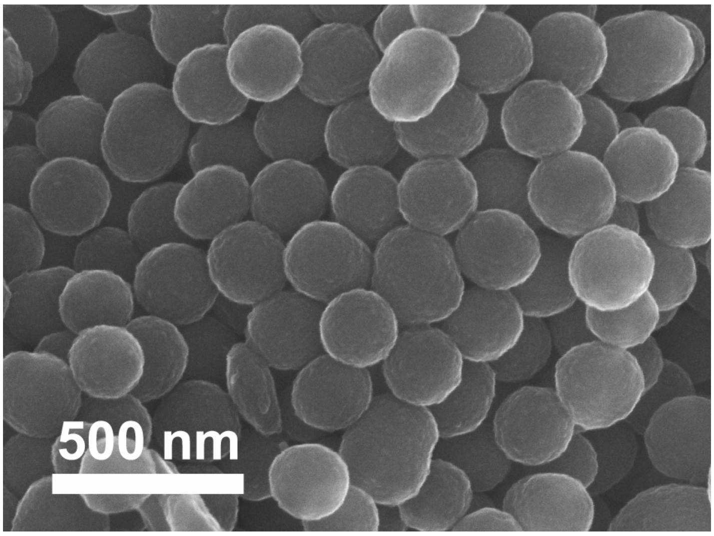

Figure S11. SEM image of N-doped carbon.

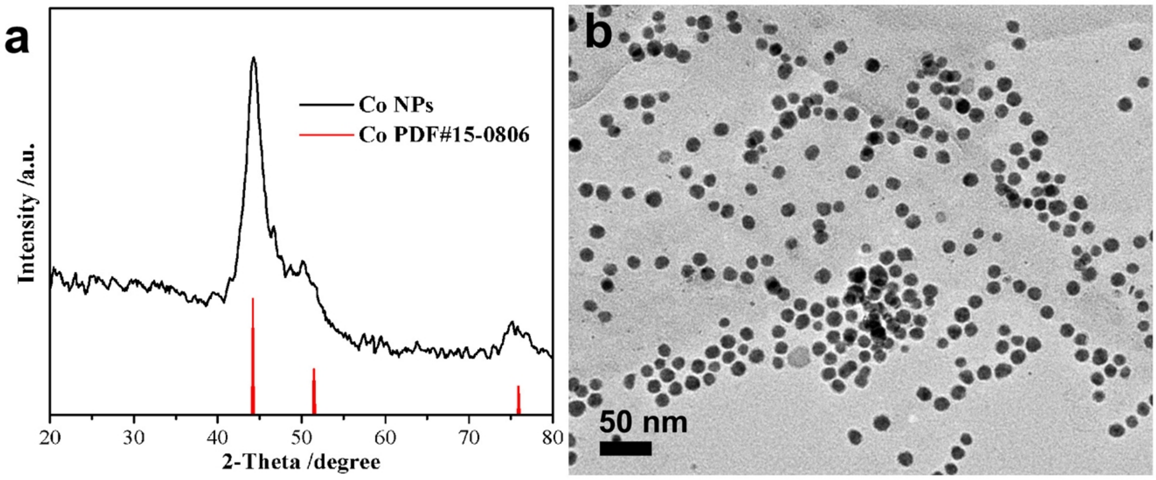

Figure S12. (a) XRD pattern and (b) TEM image of pristine Co NPs.

Table S1. Elemental composition by XPS (at %).

Sample	C 1s	N 1s	O 1s	Co 2p
Co/N-C-800	88.5	2.7	6.3	2.5

Table S2. Comparison of bifunctional oxygen electrode activities of Co/N-C-800 with various precious metal and non-precious metal catalysts in previous literatures.

Catalysts	E_{ORR} (V) at J = -3 mA cm^{-2}	E_{OER} (V) at J = 10 mA cm^{-2}	Oxygen electrode ΔE (V) = E_{OER} - E_{ORR}	Refs.
Co/N-C-800	0.74	1.60	0.86	In this study[a]
20 wt% Ir/C	0.69	1.61	0.92	[1]
20 wt% Ru/C	0.61	1.62	1.01	[1]
20 wt% Pt/C	0.86	2.02	1.16	[1]
Mn-oxide	0.73	1.77	1.04	[1]
$LaNiO_3$/NC	0.64	1.66	1.02	[2]
$NiCo_2S_4$@N/S-rGO	0.76	1.70	0.94	[3]
Co_3O_4/2.7Co_2MnO_4	0.68	1.77	1.09	[4]
$NiCo_2O_4$/G	0.54	1.67	1.13	[5]
$NiCo_2O_4$	0.75	1.72	0.97	[6]
NCO-N_1	0.72	1.64	0.92	[7]
NCO-N_2	0.76	1.62	0.86	[7]
NCO-A_1	0.78	1.62	0.84	[7]

[a] Here all the potential values from this study and the references were converted to vs. RHE for comparison.

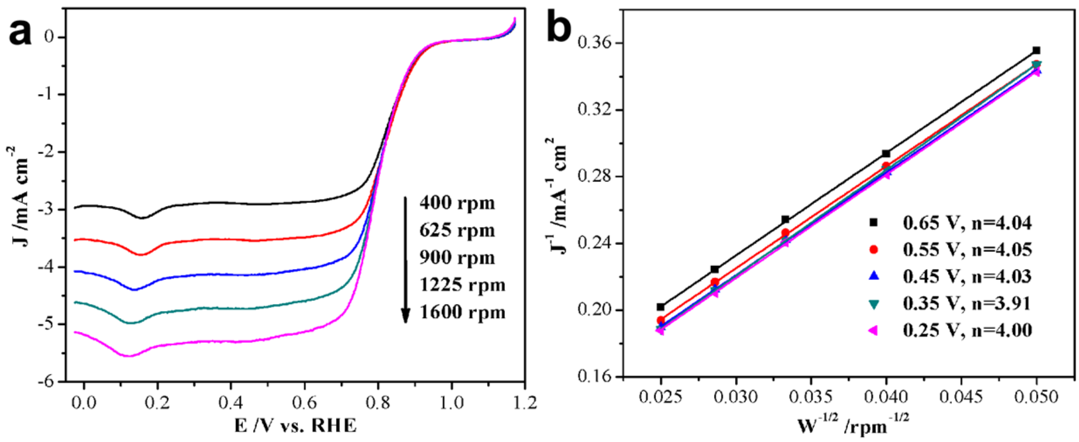

Figure S13. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for Pt/C catalyst in O_2-saturated 0.1 M KOH solution.

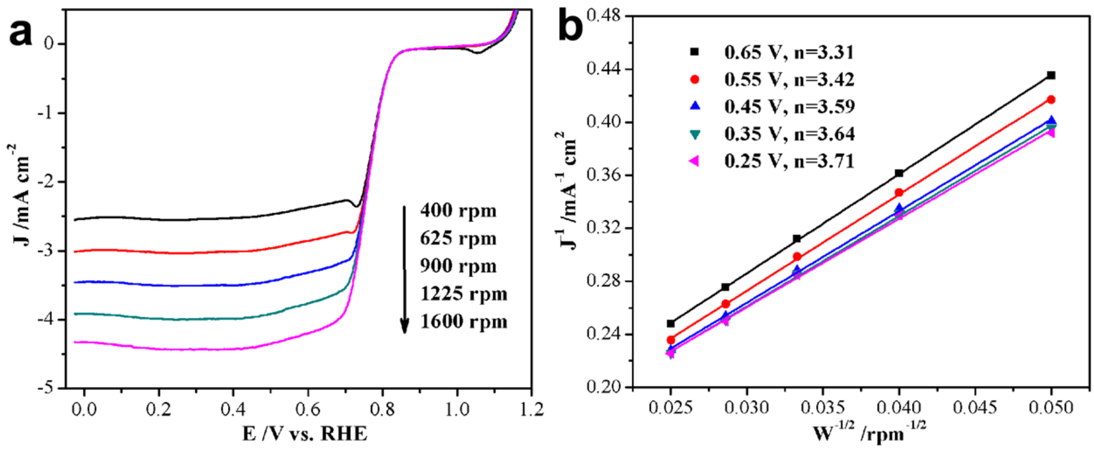

Figure S14. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for Co/N-C-700 in O_2-saturated 0.1 M KOH solution.

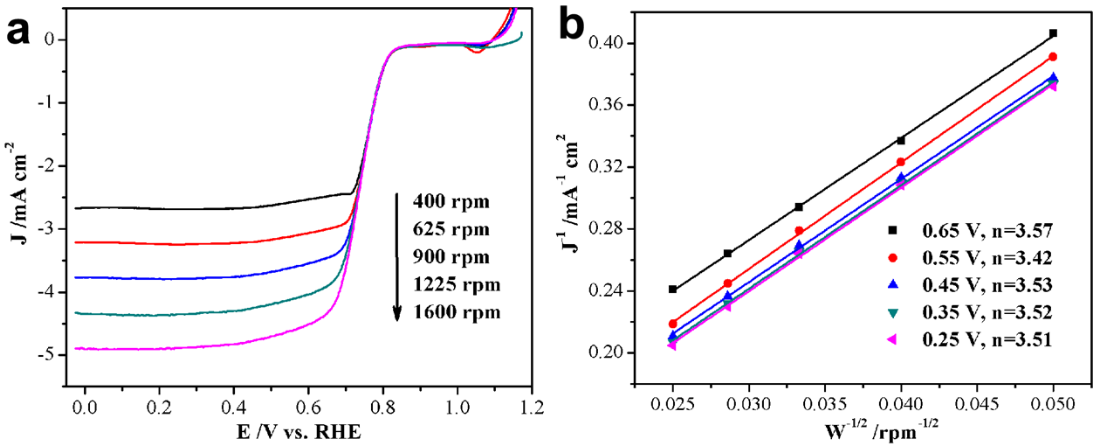

Figure S15. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for Co/N-C-900 in O_2-saturated 0.1 M KOH solution.

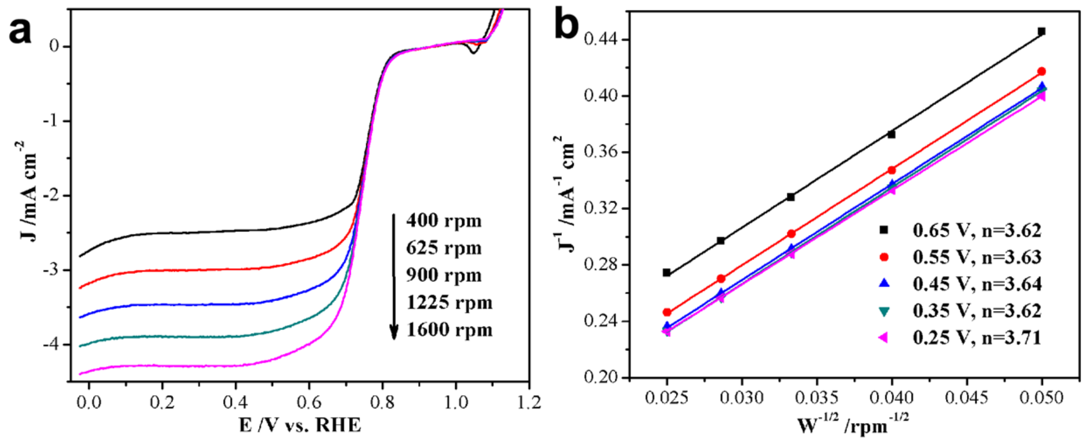

Figure S16. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for Co/N-C-800-250 in O_2-saturated 0.1 M KOH solution.

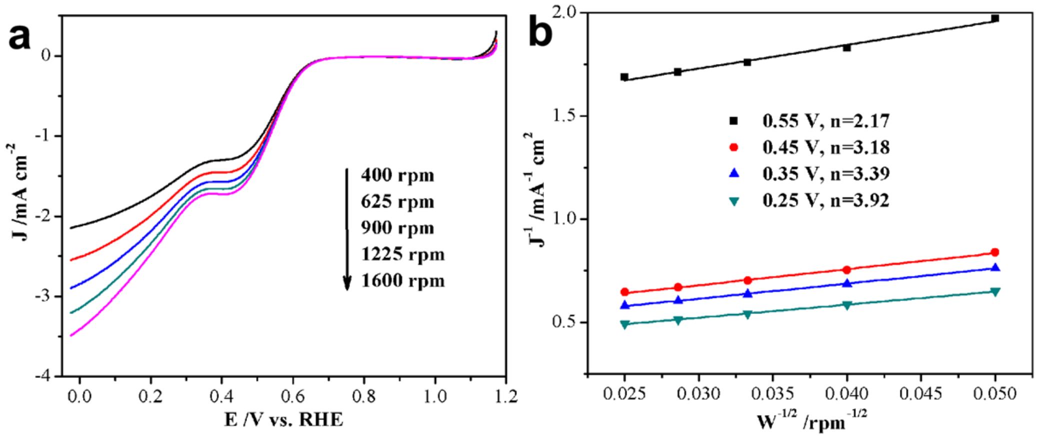

Figure S17. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for Co/N-C-800-450 in O_2-saturated 0.1 M KOH solution.

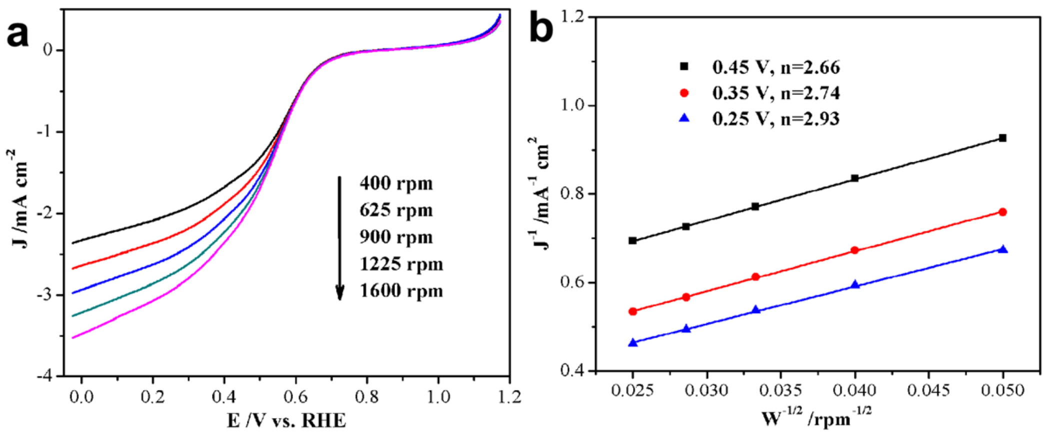

Figure S18. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for N-doped carbon in O_2-saturated 0.1 M KOH solution.

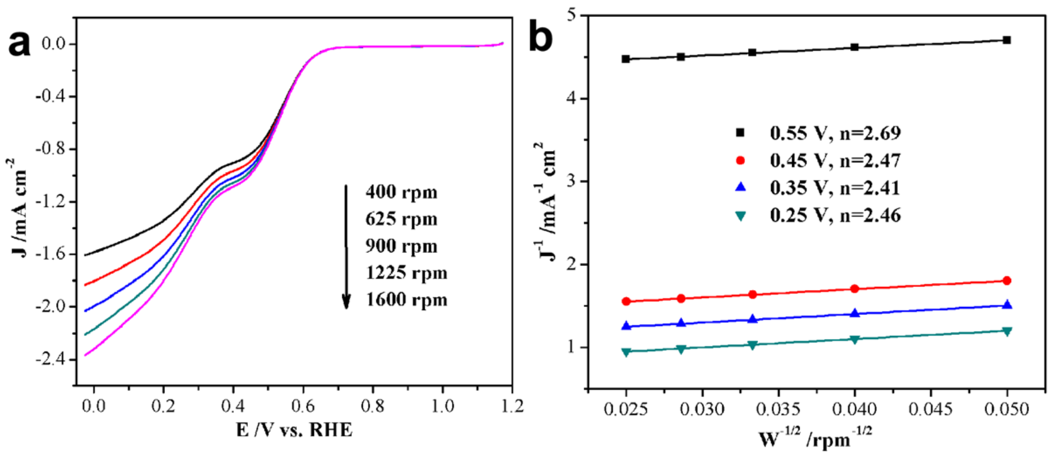

Figure S19. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for pristine Co NPs in O_2-saturated 0.1 M KOH solution.

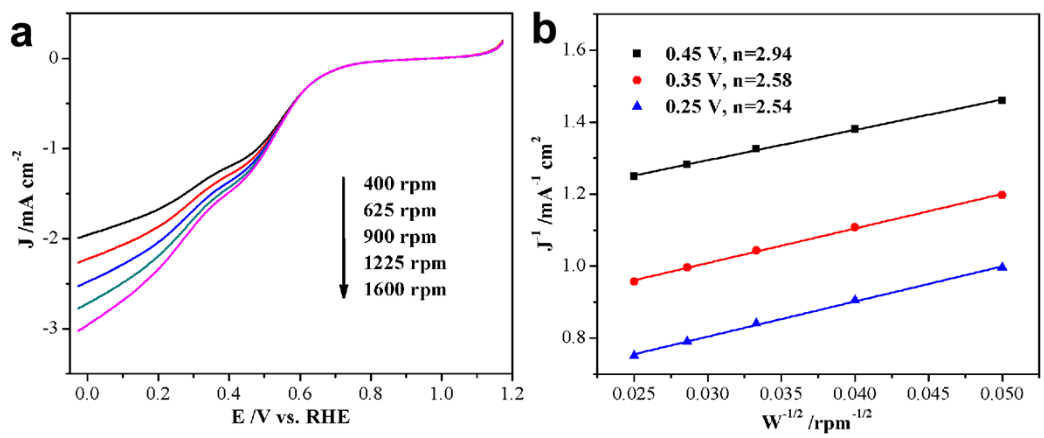

Figure S20. (a) Linear sweep voltammograms and (b) K-L plots at different potentials for the physical mixture of N-doped carbon and Co NPs in O_2-saturated 0.1 M KOH solution.

References:

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