

Supporting Information for

Atomically dispersed Co-based species containing electron withdrawing groups for electrocatalytic oxygen reduction reactions

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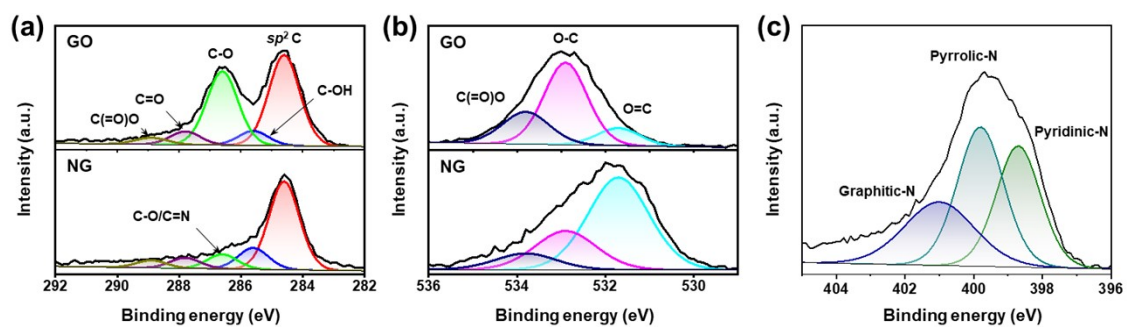


Fig. S1 (a) Deconvoluted XPS C 1s spectra of GO and NG. (b) Deconvoluted XPS O 1s spectra of GO and NG. (c) Deconvoluted XPS N 1s spectrum of NG.

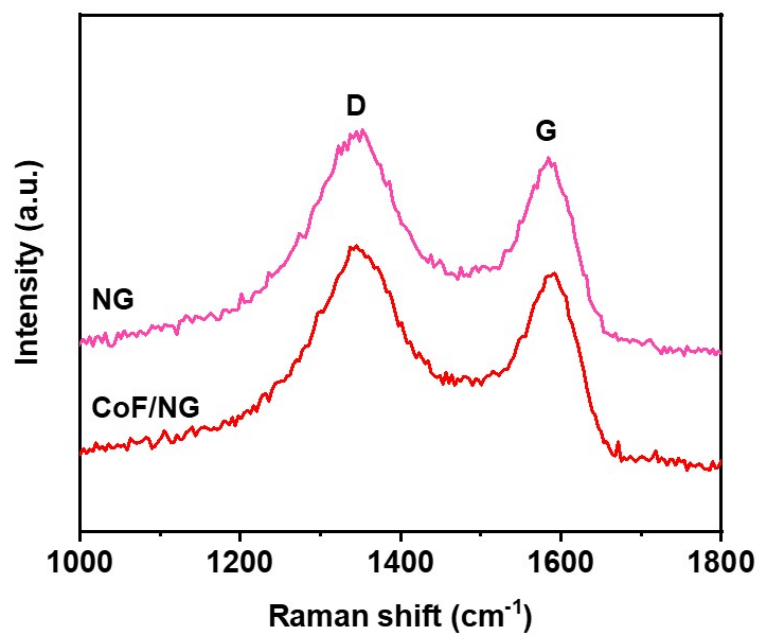


Fig. S2 Raman spectra of NG and CoF/NG.

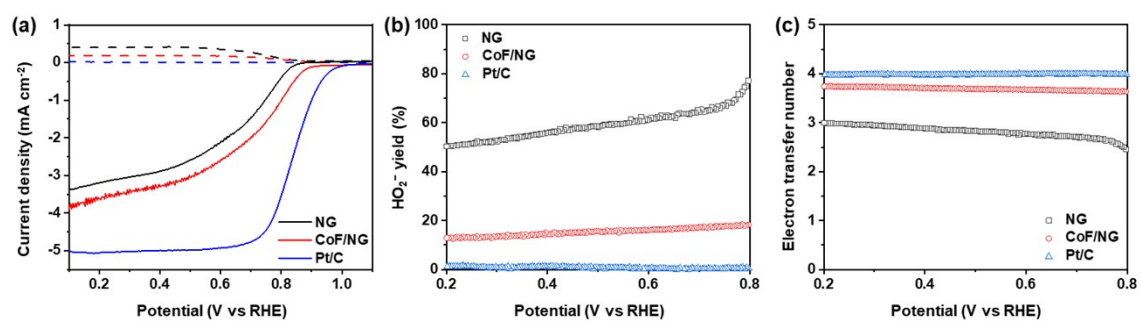


Fig. S3 Electrocatalytic ORR properties of NG, CoF/NG, and Pt/C using an RRDE system. (a) LSV polarization curves, (b) calculated HO₂⁻ yields, and (c) calculated electron transfer numbers.

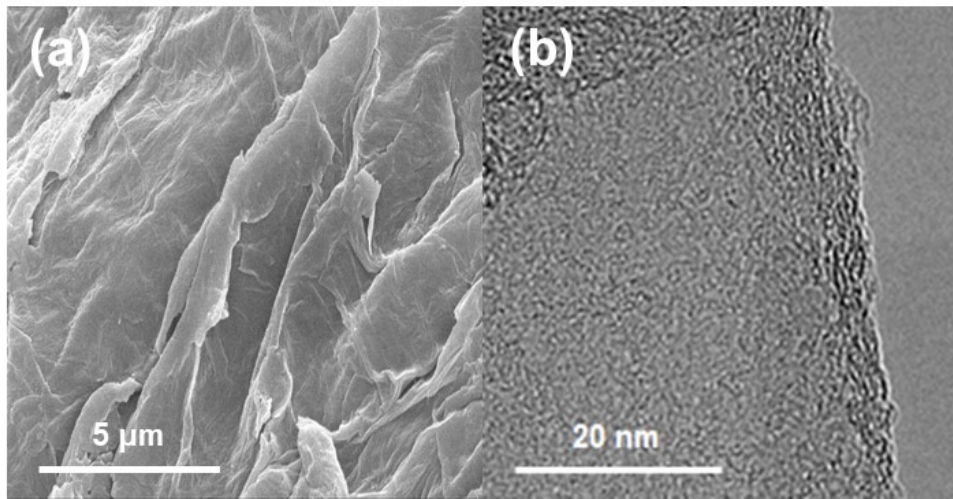


Fig. S4 (a) SEM and (b) TEM images of CoF/ReG.

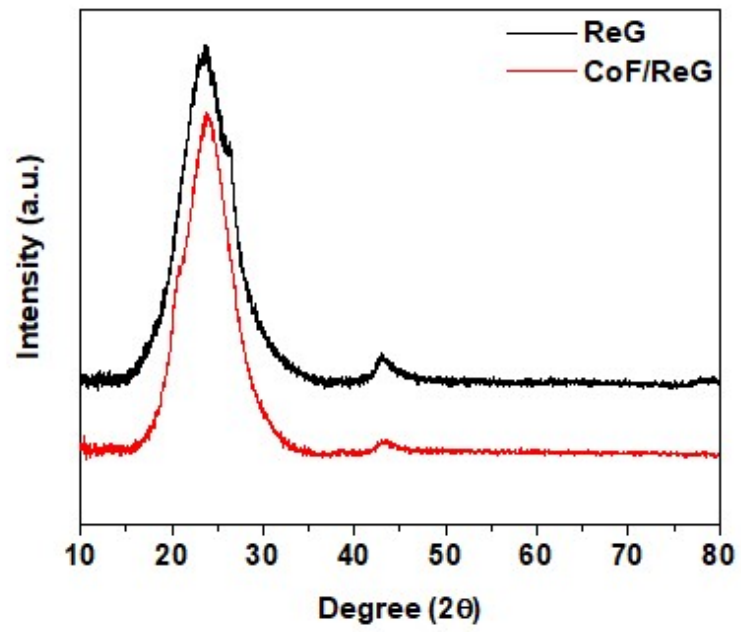


Fig. S5 XRD patterns of ReG and CoF/ReG.

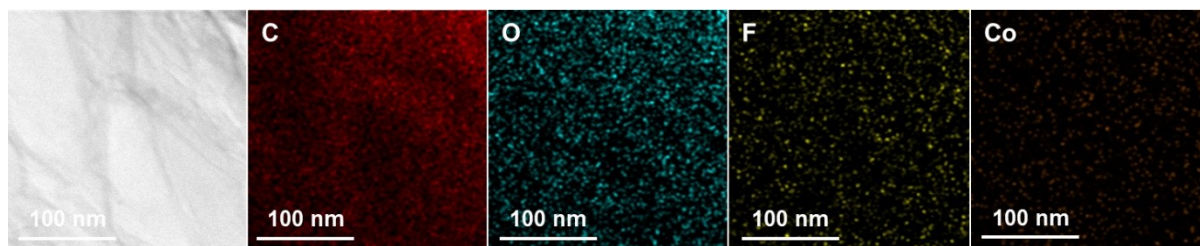


Fig. S6 TEM elemental mapping images of CoF/ReG.

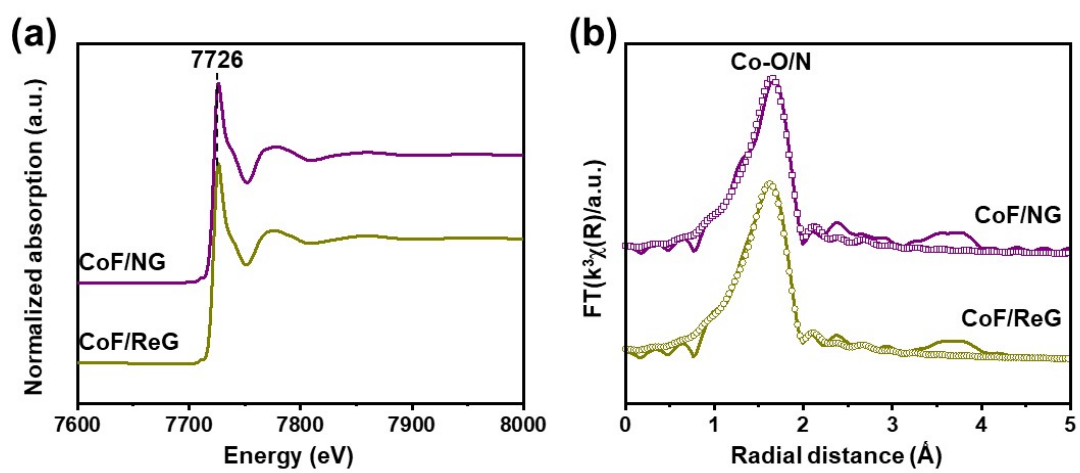


Fig. S7 (a) XANES and (b) EXAFS fitting spectra of CoF/NG and CoF/ReG.

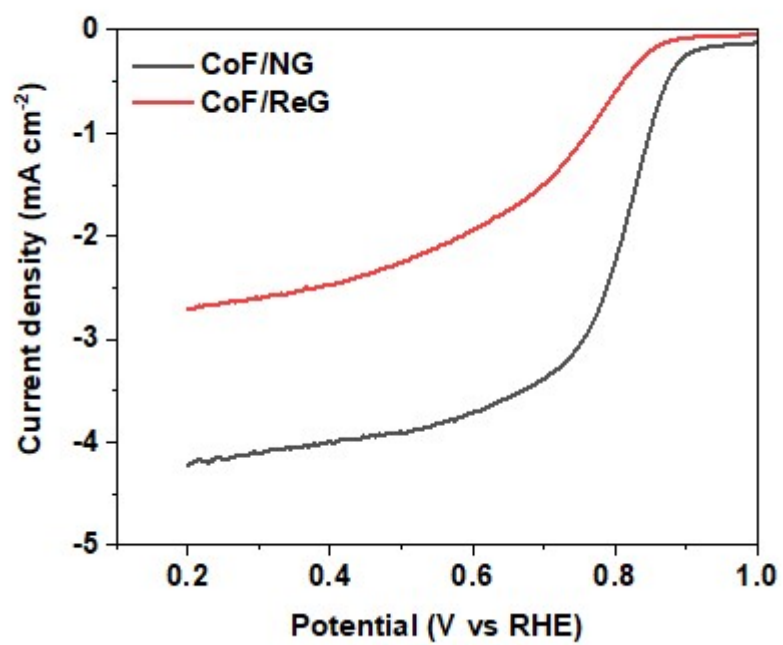


Fig. S8 LSV polarization curves of CoF/NG and CoF/ReG.

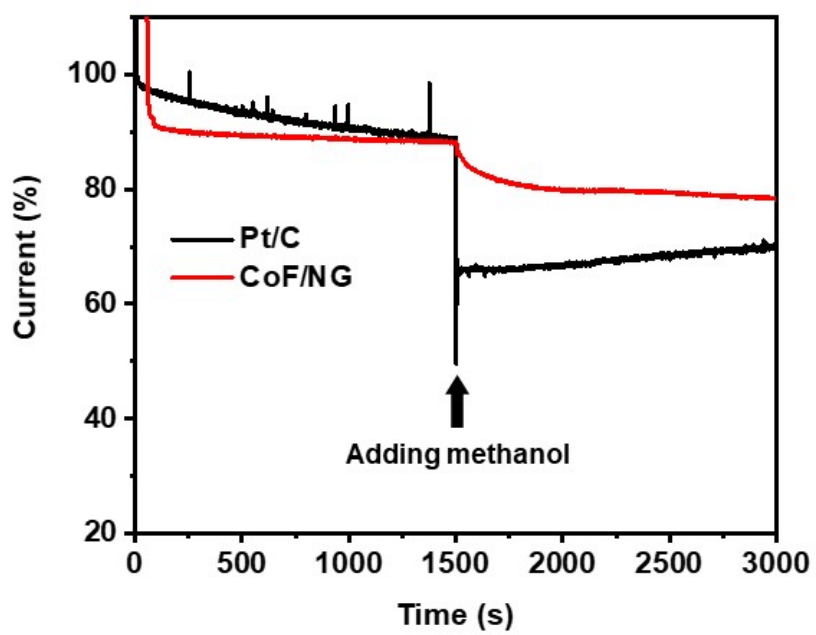


Fig. S9 Methanol tolerance tests for CoF/NG and Pt/C.

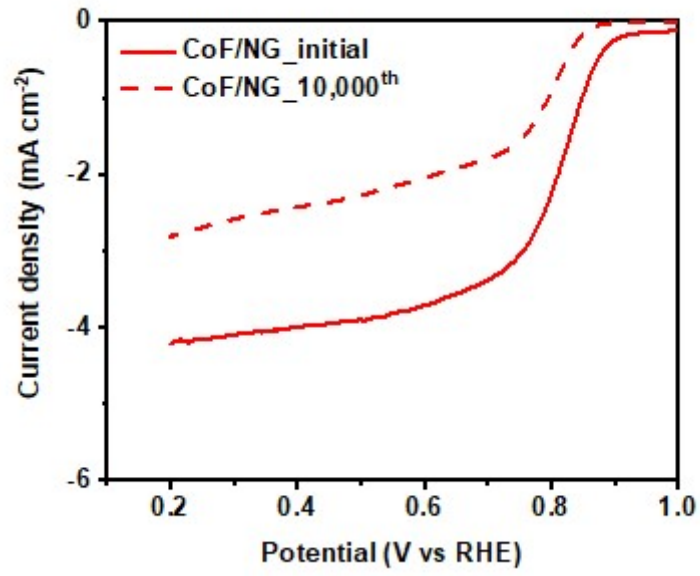


Fig. S10 LSV polarization curves of CoF/NG_initial and CoF/NG_10,000th.

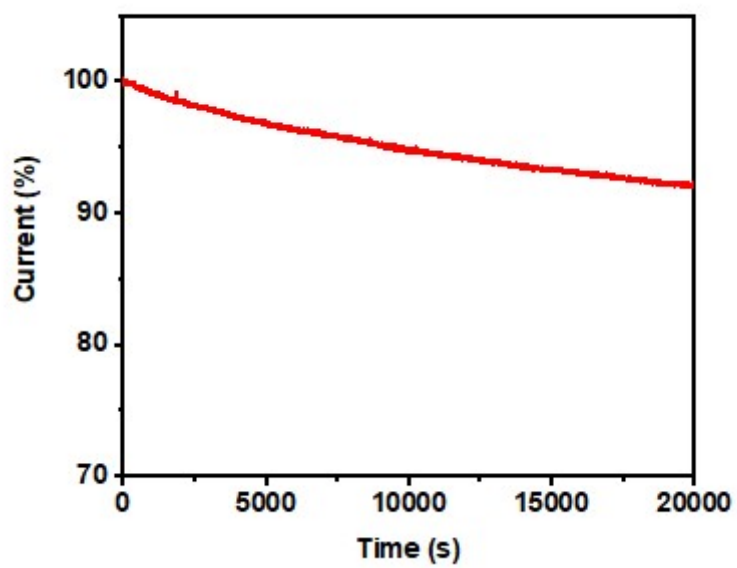


Fig. S11 I-t curves of CoF/NG until 20,000 s.

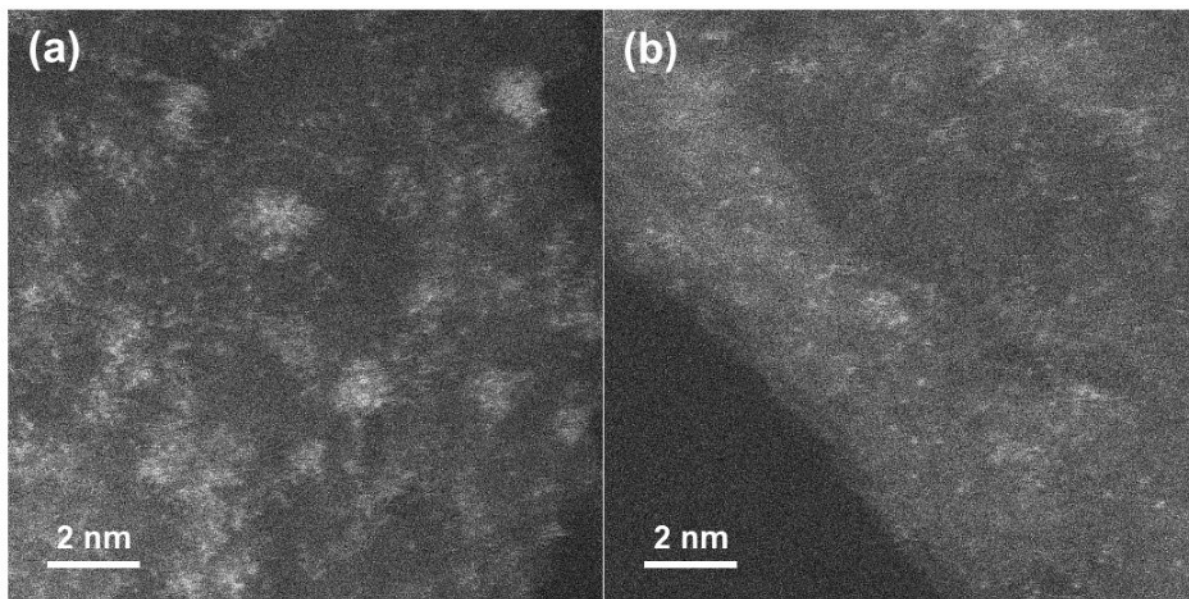


Fig. S12 STEM images (a) CoF/NG-after-cycle and (b) Co(acac)₂/NG-after-cycle.

Table S1. Atomic amounts of NG, ReG, CoF/NG, and CoF/ReG.

Sample	C (%)	O (%)	N (%)	F (%)	Co (%)
NG	78.7	13.9	7.4	-	-
ReG	81.2	18.8	-	-	-
CoF/NG	80.4	9.5	8.4	1.1	0.6
CoF/ReG	82.6	16.2	-	0.81	0.39

Table S2. Electrochemical performance of CoF/NG at RRDE system.

Sample	Onset Potential (V)	Half-wave Potential (V)	j_L (mA cm ⁻²)	HO ₂ ⁻ yield @ 0.3 V (%)	Electron transfer number @ 0.3 V
NG	0.86	0.66	3.50	48.24	2.77
CoF/NG	0.90	0.72	3.61	13.7	3.72
Pt/C	1.02	0.85	5.50	0.32	3.99

Table S3. EXAFS fitting results of CoF precursor, CoF/NG, and CoF/ReG.

Sample	Bond	N	So2	σ^2	C-N	R (Å)
CoF precursor	Co-O	1	4.330	0.00518	7.89	2.05
CoF/NG	Co-O(N)	1	3.801	0.00729	6.92	2.06
CoF/ReG	Co-O(N)	1	3.938	0.00724	7.17	2.06

Table S4. Electrochemical performance results of CoF/NG and CoF/ReG.

Sample	Onset Potential (V)	Half-wave Potential (V)	j_L (mA cm ⁻²)
CoF/NG	0.91	0.80	4.22
CoF/ReG	0.89	0.72	2.70