

Electronic Supplementary Information

Twin-like Ternary PtCoFe alloy in Nitrogen-doped Graphene Nanopores as a Highly Effective Electrocatalyst for Oxygen Reduction

Xing Zhong,^a Wenlei Xu,^a lei Wang,^a Yingying Qin,^a Guilin Zhuang,^a Xiaonian Li,^a Jianguo Wang^{*a}

Supplementary Results

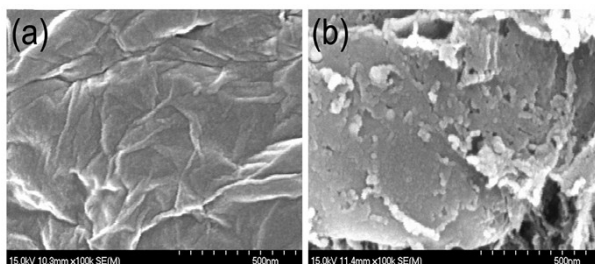


Figure S1. (a) SEM image of pristine graphene. Scale bar is 500 nm. (b) SEM image of PtCoFe/NPG 700. Scale bar is 500 nm.

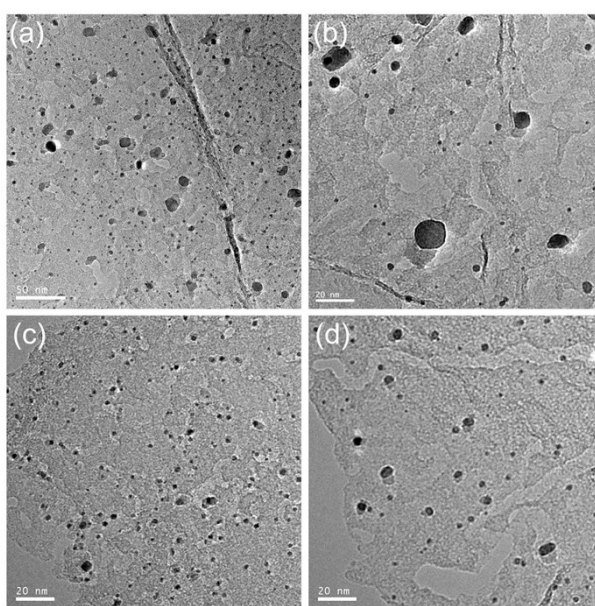


Figure S2. (a-b) TEM image of PtCoFe/NPG 700. Scale bars in (a) and (b) is 50 nm and 20 nm, respectively. (c) TEM image of PtNiFe/NPG. Scale bar is 20 nm. (d) TEM image of PtCoNi/NPG. Scale bar is 20 nm.

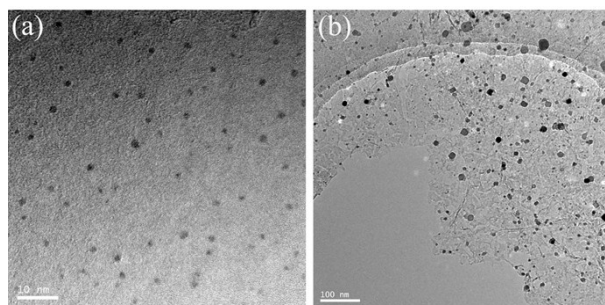


Figure S3. (a) TEM images of PtCoFe/NPG 600. Scale bar is 10 nm. (b) TEM images of PtCoFe/NPG 800. Scale bar is 100 nm.

Table S1: The calculated species concentrations (atomic %) of different atoms in G, PtCoFe/NPG 600, PtCoFe/NPG 700 and PtCoFe/NPG 800 based XPS results.

	%C	%N	%O	%Pt	%Co	%Fe
G	95.43	0.06	0.05	-	-	-
PtCoFe/NPG 600	85.76	7.74	4.66	0.58	0.66	0.59
PtCoFe/NPG 700	89.88	5.25	3.42	0.6	0.42	0.43
PtCoFe/NPG 800	91.81	3.56	3.13	0.58	0.39	0.52
Pt/NPG 700	94.43	1.04	3.63	0.9	-	-

Table S2: The calculated species concentrations (atomic %) of different atoms in PtFeCu/NPG.

	%C	%N	%O	%Pt	%Cu	%Fe
PtFeCu/NPG	89.48	4.56	4.35	0.66	0.3	0.64

Table S3: The calculated species concentrations (atomic %) of different atoms in PtFeNi/NPG.

	%C	%N	%O	%Pt	%Ni	%Fe
PtFeNi/NPG	89.1	4.31	5.05	0.62	0.47	0.46

Table S4: The calculated species concentrations (atomic %) of different atoms in PtNiCo/NPG.

	%C	%N	%O	%Pt	%Ni	%Co
PtNiCo/NPG	88.5	5.47	4.53	0.58	0.48	0.44

Table S5: The calculated species concentrations (atomic %) of different atoms in PtNiCu/NPG.

	%C	%N	%O	%Pt	%Ni	%Cu
PtNiCu/NPG	89.73	4.8	4.24	0.58	0.43	0.23

Table S6: Relative ratios of the deconvoluted peak areas of the N 1s XPS spectra.

	Pyridinic N	N-M	Pyrrolic N	Graphitic N	N ⁺ -O ⁻
PtCoFe/NPG 600	64.45	-	21.75	13.8	-
PtCoFe/NPG 700	42.05	28.17	18.98	8.93	1.87
PtCoFe/NPG 800	23.12	28.48	27.3	14.56	6.54
Pt/NPG 700	36.72	-	38.66	15.04	9.58
G	61.45	-	16.92	16.1	5.54

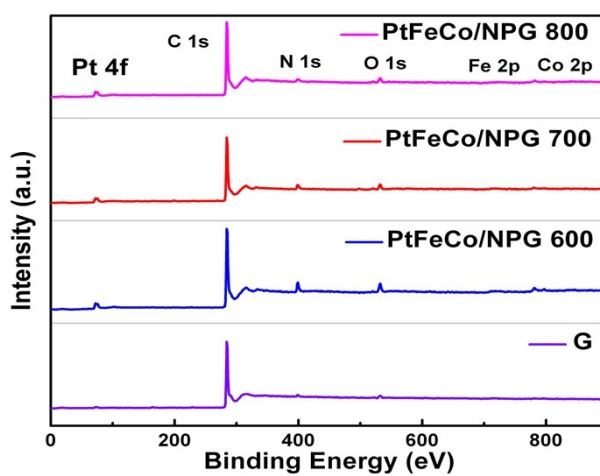


Figure S4. XPS survey spectra of PtCoFe/NPG 800, PtCoFe/NPG 700, PtCoFe/NPG 600 and G.

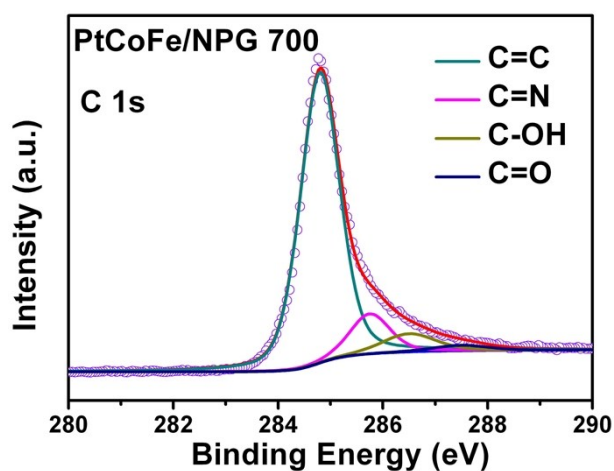


Figure S5. The high-resolution C1s XPS spectra of PtCoFe/NPG 700.

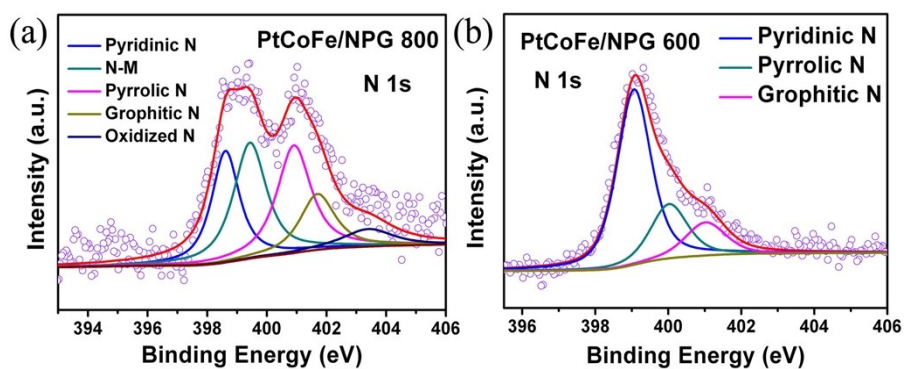


Figure S6. The high resolution N1s XPS spectra of (a) PtCoFe/NPG 800 and (b) PtCoFe/NPG 600.

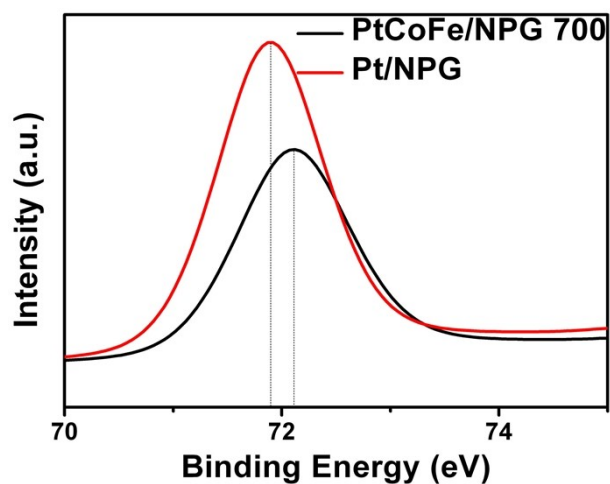


Figure S7. Comparison of the sub-spectra of Pt $4f_{7/2}$ corresponding to Pt⁰ entities for PtCoFe/NPG 700 and Pt/NPG.

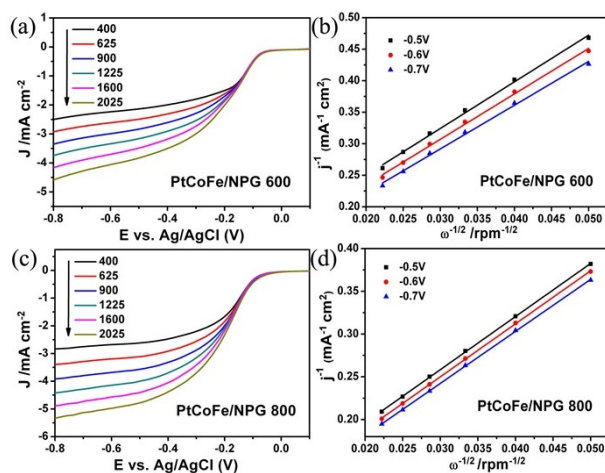


Figure S8. LSV of (a) PtCoFe/NPG 600, (c) PtCoFe/NPG 800 on RDE at different rotating rates (400 to 2,025 rpm). Corresponding Koutecky–Levich plot of (b) PtCoFe/NPG 600, (d) PtCoFe/NPG 800 at different potentials.

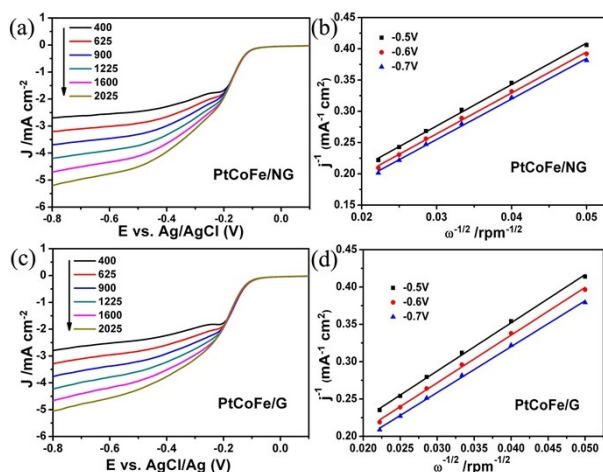


Figure S9. LSV of (a) PtCoFe/NG, (c) PtCoFe/G on RDE at different rotating rates (400 to 2,025 rpm). Corresponding Koutecky–Levich plot of (b) PtCoFe/NG, (d) PtCoFe/G at different potentials.

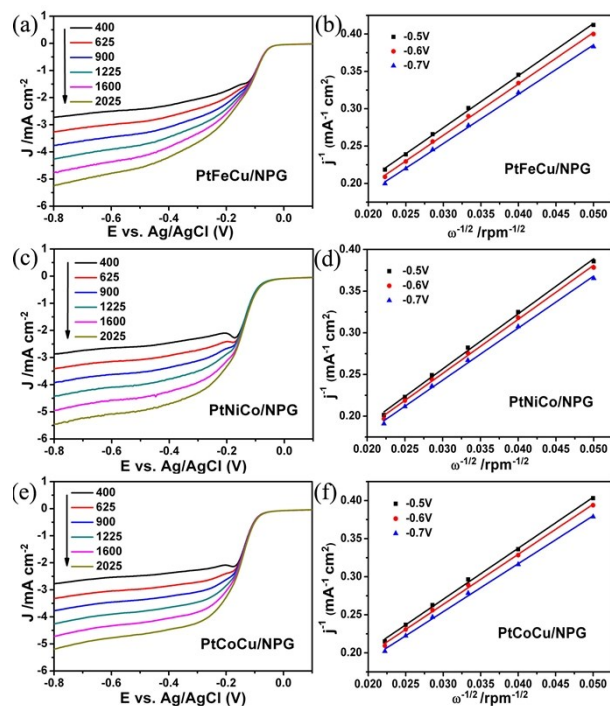


Figure S10. LSV of (a) PtFeCu/NPG, (c) PtNiCo/NPG, (e) PtCoCu/NPG on RDE at different rotating rates (400 to 2025 rpm). Corresponding Koutecky-Levich plot of (b) PtFeCu/NPG, (d) PtNiCo/NPG, (f) PtCoCu/NPG at different potentials.

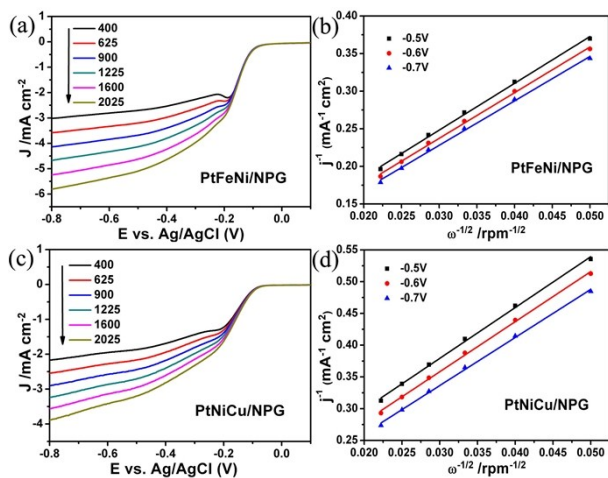


Figure S11. LSV of (a) PtFeNi/NPG, (c) PtNiCu/NPG on RDE at different rotating rates (400 to 2025 rpm). Corresponding Koutecky-Levich plot of (b) PtFeNi/NPG, (d) PtNiCu/NPG at different potentials.

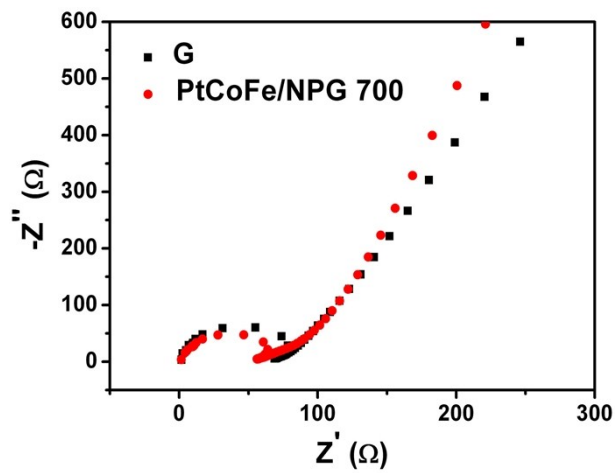


Figure S12. (a) Nyquist curves of G and PtCoFe/NPG 700.

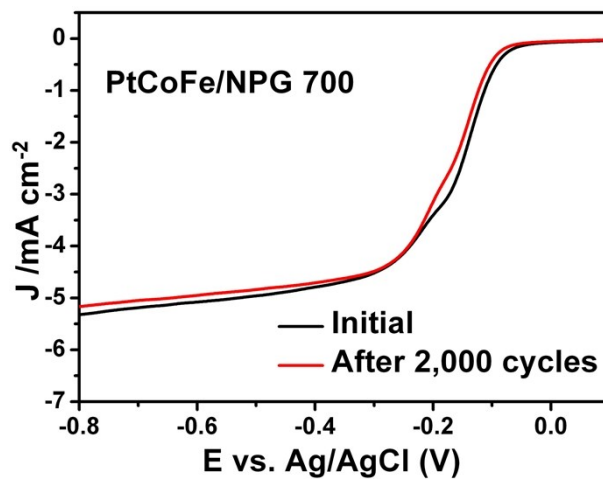


Figure S13. RDE curves of PtCoFe/NPG before and after 2000 cycles on an RDE (1600 rpm) in an O_2 -saturated 0.1 M KOH solution.