

Supplementary Information

Spinel CoMn_2O_4 Nanoparticles Supported on Nitrogen and Phosphorus Dual Doped
Graphene Aerogel as Efficient Electrocatalysts for the Oxygen Reduction Reaction

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Supplementary data

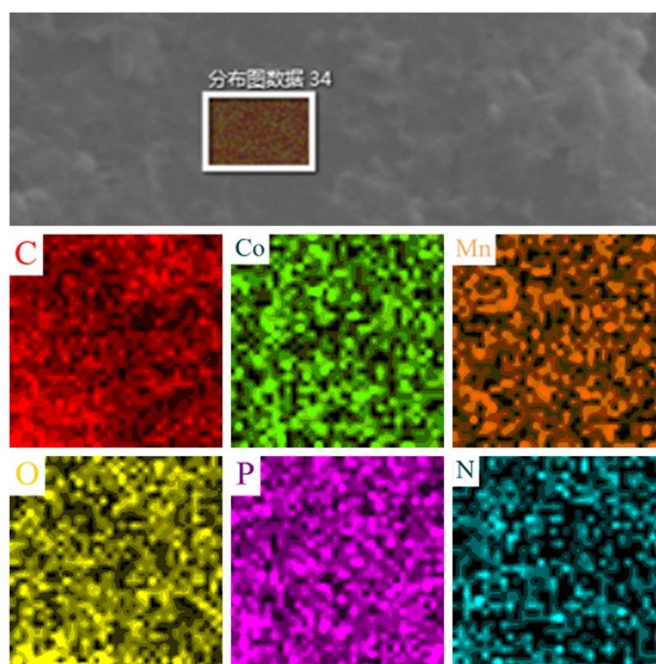


Fig. S1. The EDS of the selected region of the CoMn₂O₄/NPGA is shown.

The EDS shows the presence of C, Co, Mn, O, P and N (Fig. S1). All doping elements were homogeneously distributed throughout the whole carbon matrix.

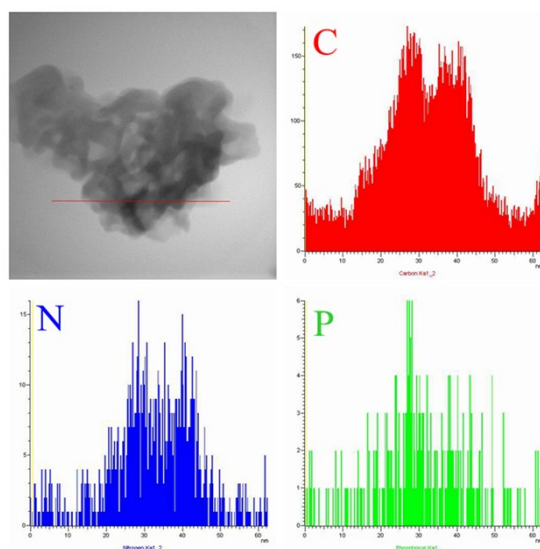


Fig. S2. The EDS of the selected line of the NPGA is shown

The EDS shows the presence of C, N and P of NPGA (Fig. S2).

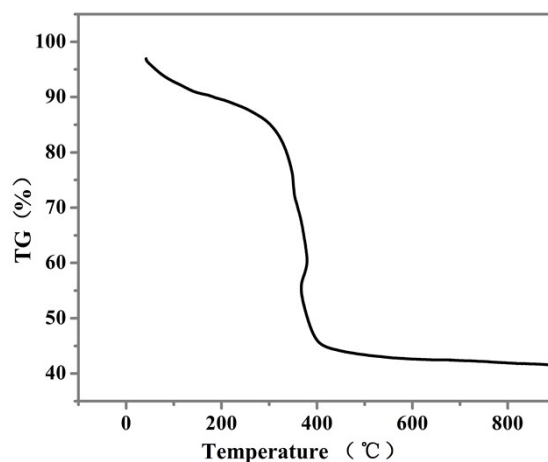


Fig. S3. TGA curve of the CoMn₂O₄/NPGA.

Table S1: Relative surface concentrations of nitrogen and phosphorus species obtained by N1s high-resolution XPS and P2p high-resolution XPS spectra of CoMn₂O₄/NPGA.

Element	Peak	Surface concentrations
N	pyrrolic N	69.3%
	pyridinic N	30.7%
P	C-O-PO ₃	26.52%
	P-N	47.91%
	P-C	25.57%

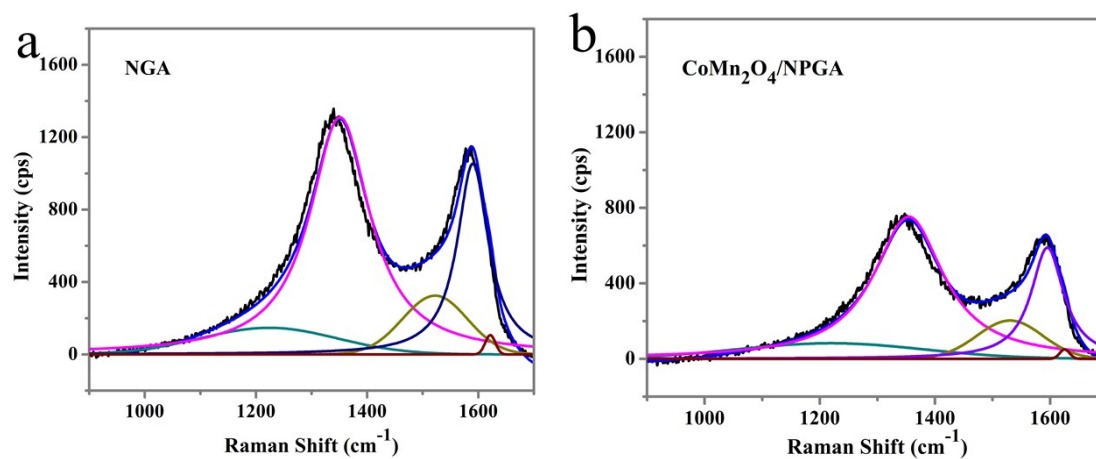


Fig. S4. Raman spectra of NGA (a) and CoMn₂O₄/NPGA (b).

Table S2: Raman parameters obtained after curve fitting all the investigated samples. ν_D and ν_G respectively correspond to D and G bands positions. $\omega_{1/2D}$ and $\omega_{1/2G}$ respectively correspond to full width at half-maximum (FWHM) of D and G bands. L_a represents the in-plane crystallite size determined from L_a (nm) = $2.4 \times 10^{-10} \lambda^4_{\text{laser}} \times$

I_G/I_D .

	NGA	CoMn ₂ O ₄ /NPGA
ν_D (cm ⁻¹)	1342	1345
$\omega_{1/2D}$ (cm ⁻¹)	132	148
ν_G (cm ⁻¹)	1585	1591
$\omega_{1/2G}$ (cm ⁻¹)	71	72
I_D/I_G	1.24	1.28
L_a (nm)	15.5	15.0

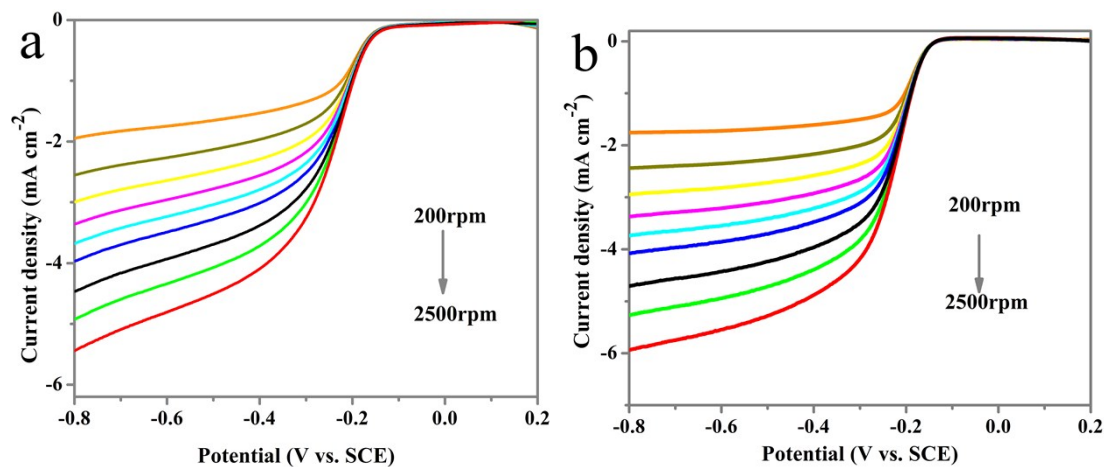


Fig. S5. LSV curves for ORR on (a) NGA and (b) NPGA at different rotation speeds from +0.2 to -0.8 V in O₂-saturated 0.1 M KOH with the scan rate of 10 mV s⁻¹.

Fig. S5 shows the RDE measurements obtained on NGA and NPGA with the rotation rate from 200 to 2500 rpm in O₂-saturated 0.1M KOH solution. The ORR potential of NGA began at about -0.147 V vs. SCE and was kept under different rotation speeds. The ORR

potential of NPGA began at about -0.142 V vs. SCE. With increase of the rotation speed, the current density of NGA and NPGA were distinctly enhanced.

Table S3: All values were obtained in alkaline conditions with 0.1 M KOH.

Electrocatalyst	$E_{\text{onset}}^{\text{a,c}}$	$J_L^{\text{b,c}}$	Reference electrode	Tafel slope	Catalyst loading per area	Ref.
	V	mA cm^{-2}		mV decade^{-1}	$\mu\text{g cm}^{-2}$	
CoMn ₂ O ₄ /NPGA	-0.094	-5.39	SCE	77	280	In this work
FCO/HrGOS	-0.09	~ -5.80	Ag/AgCl	56	1006	1
NiCo ₂ O ₄ -G	-0.12	~ -4.10	SCE	37	407	2
CoFe ₂ O ₄ /rGO	-0.136	~ -6.40	Ag/AgCl	67	1006	3
Co ₃ O ₄ /tmGO	~ 0.93	~ -5.00	RHE	42	Not mentioned	4
CMO/NGA	0.10	~ -4.20	Ag/AgCl	Not mentioned	250	5
CFO/RC-400	-0.1	-4.86	Ag/AgCl	Not mentioned	320	6
NiCo ₂ O ₄ /PGR-110	-0.12	~-3.00	Ag/AgCl	Not mentioned	140	7
NiCo ₂ O ₄ /CMK-3	-0.09	~2.80	Ag/AgCl	Not mentioned	210	8

^a Represents the onset potential of various catalysts.

^b Represents the diffusion-limited current density of the various catalysts at a rotation speed of 1600 rpm and 0.8V.

^c The onset potential (E_{onset}) and diffusion-limited current density (J_L) were obtained from the homologous literature and the corresponding figures in the present study.

References

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