Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

The electronic supplementary information for：

Efficient ORR Electrocatalytic Activity of Peanut Shell-Based Graphitic Carbon Microstructures

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Fig. S1-S19, Table S1-S3

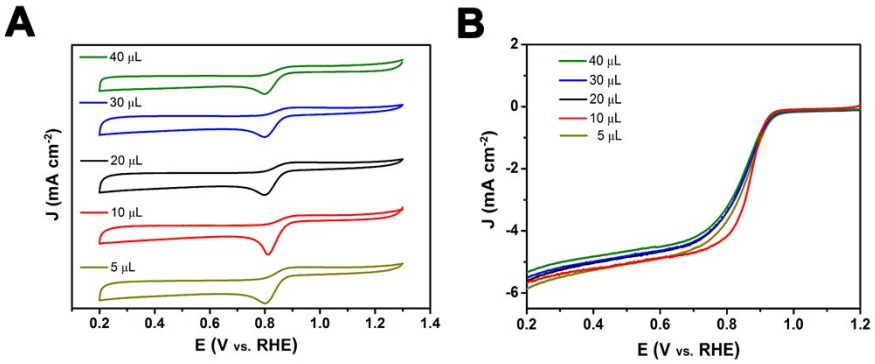

Fig. S1 (A) CVs of the CoOP@bio-C catalyst under different quantities of Nafion in O_2-saturated 0.1 M KOH electrolyte; (B) LSV curves of CoOP@bio-C under different quantities of Nafion at 10 mV s^{-1} and a rotating speed of 1600 rpm, respectively.

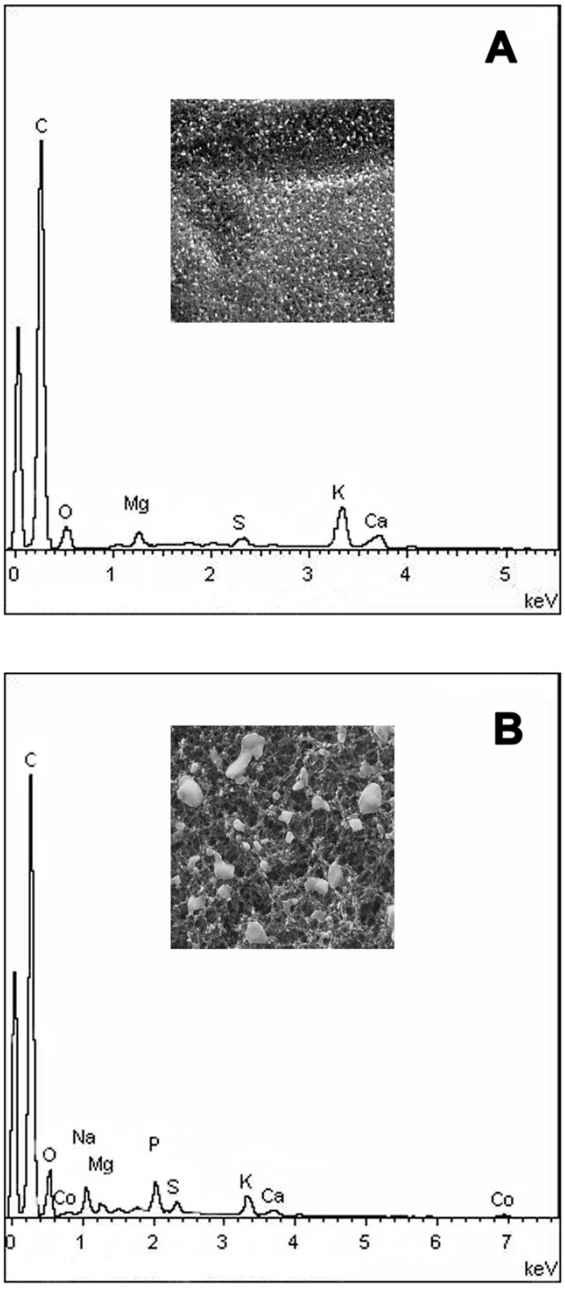

Fig. S2 SEM and the corresponding EDS image of (A) bio-C-800 and (B) CoOP@bio-C, respectively.

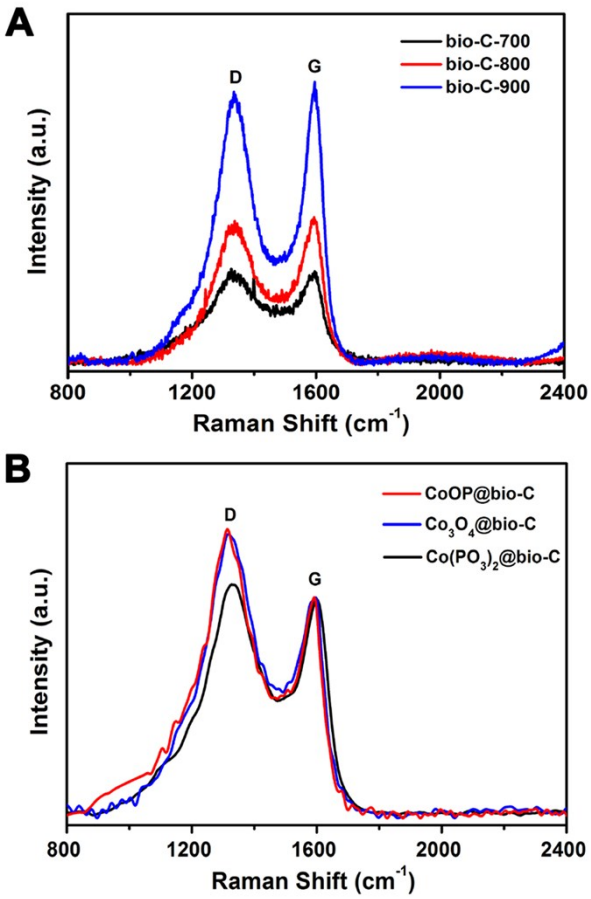

Fig. S3 Raman spectra of (A) the bio-C-700, bio-C-800, bio-C-900 and (B) CoOP@bio-C, Co_3O_4@bio-C, $Co(PO_3)_2$@bio-C, respectively.

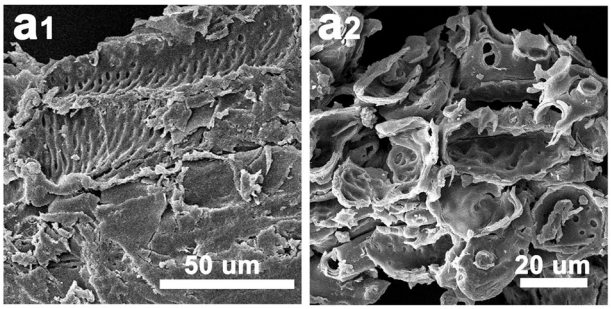

Fig. S4 SEM image of the blank peanut shell power.

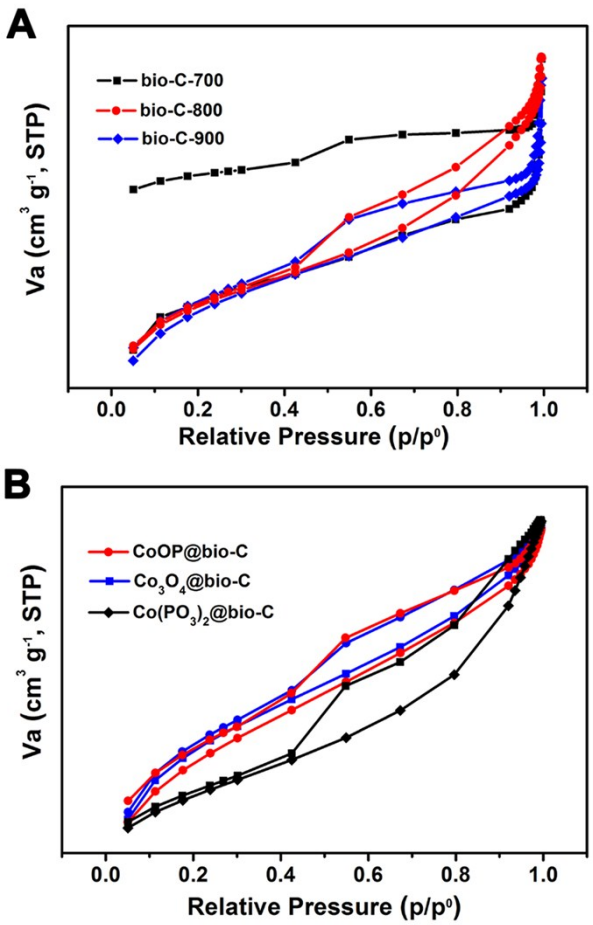

Fig. S5 N_2 adsorption/desorption isotherms of (A) the bio-C-700, bio-C-800, bio-C-900 and (B) the CoOP@bio-C, Co_3O_4@bio-C, $Co(PO_3)_2$@bio-C, respectively.

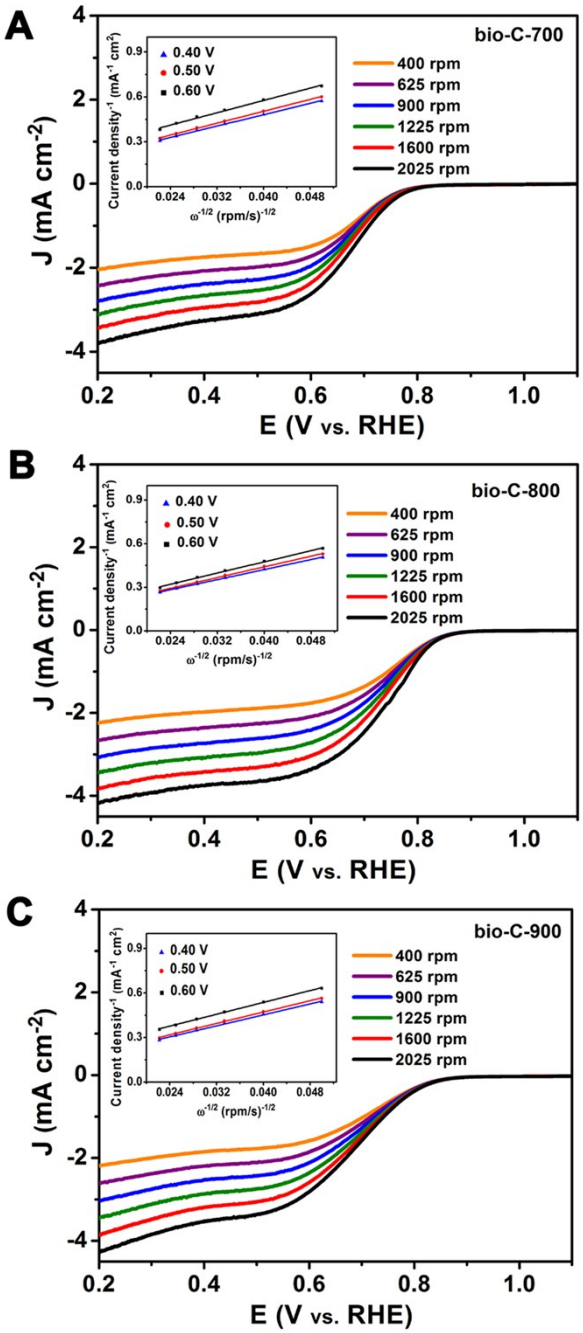

Fig. S6 LSV curves at various rotating rates of the (A) bio-C-700, (B) bio-C-800 and (C) bio-C-900 in O_2-saturated 0.1 M KOH electrolyte with a sweep rate of 10 mV s^{-1}, respectively. (inset: corresponding K–L plots at various potentials)

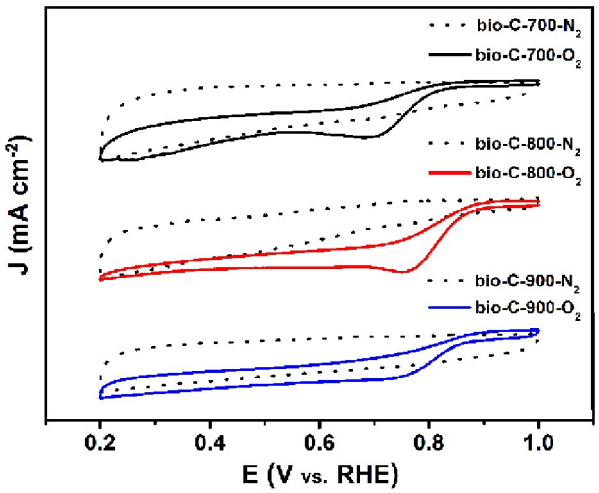

Fig. S7 CVs of the bio-C-700, bio-C-800 and bio-C-900 catalysts in O_2-saturated (solid lines) and N_2-saturated (dot lines) 0.1 M KOH at 10 mV s^{-1}, respectively.

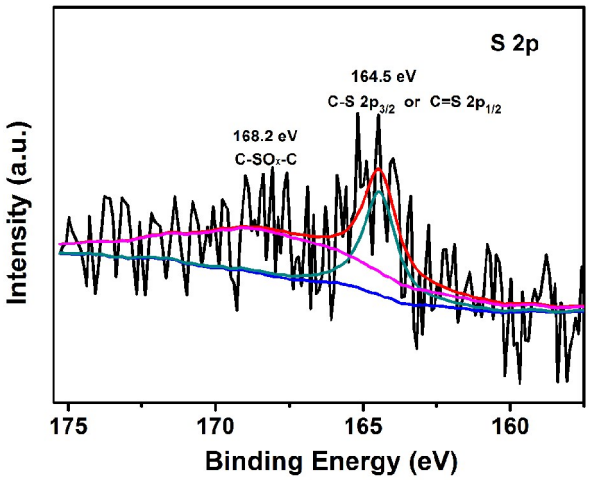

Fig. S8 High-resolution XPS spectra of the S 2p core level for CoOP@bio-C.

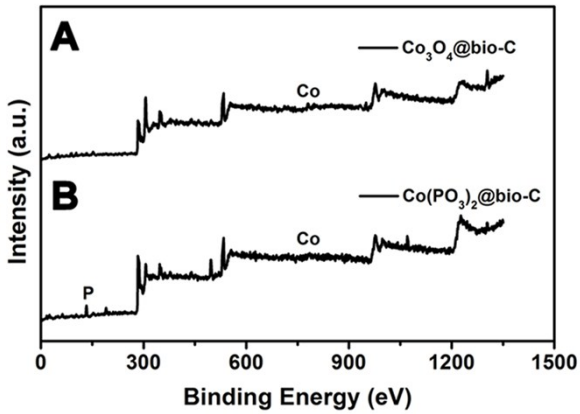

Fig. S9 XPS survey spectra of the (A) Co_3O_4@bio-C and (B) $Co(PO_3)_2$@bio-C composites.

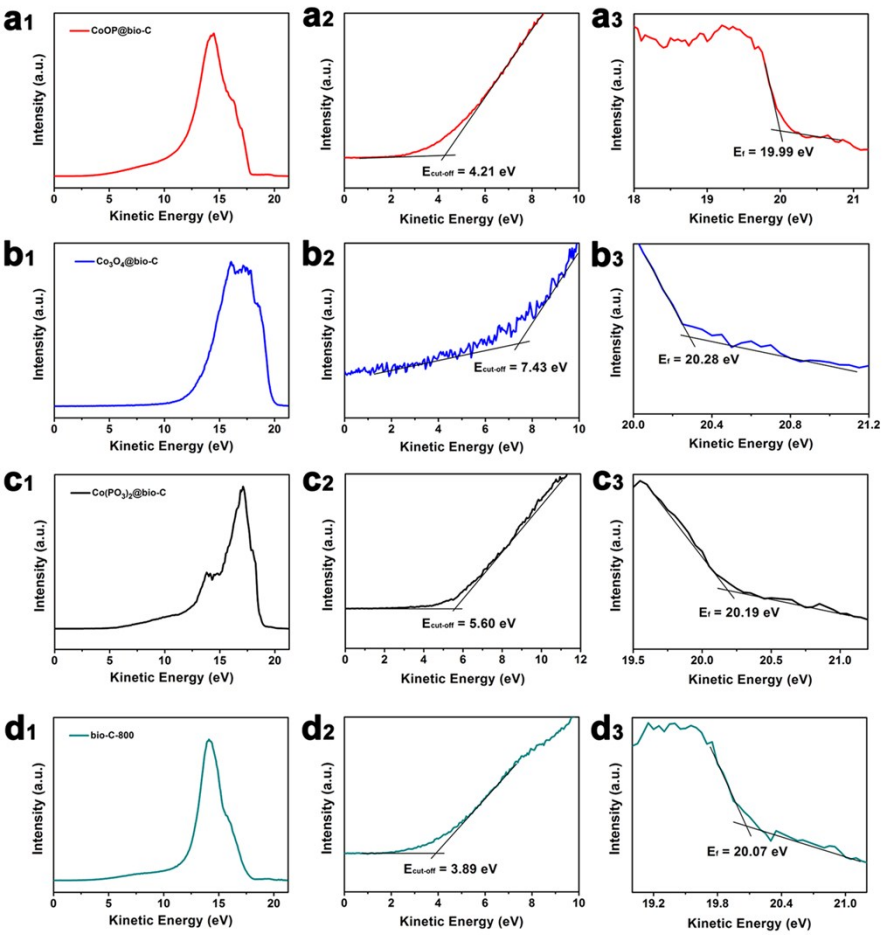

Fig. S10 Ultraviolet photoelectron spectroscopy (UPS) measurements of CoOP@bio-C (a_1, a_2 and a_3), Co_3O_4@bio-C (b_1, b_2 and b_3), $Co(PO_3)_2$@bio-C (c_1, c_2 and c_3) and bio-C-800 (d_1, d_2 and d_3) (UV excitation by He I = 21.2 eV). The sample for UPS measurement was prepared by depositing a thin film (8 nm) on a small plate of SiO_2/Si substance (size: 1.5 cm × 1.5 cm). The work function of samples can be calculated by using the following equation.

$$\Phi \text{ (work function)} = h\nu - |E_{cut\text{-}off} - E_f| \quad (3)$$

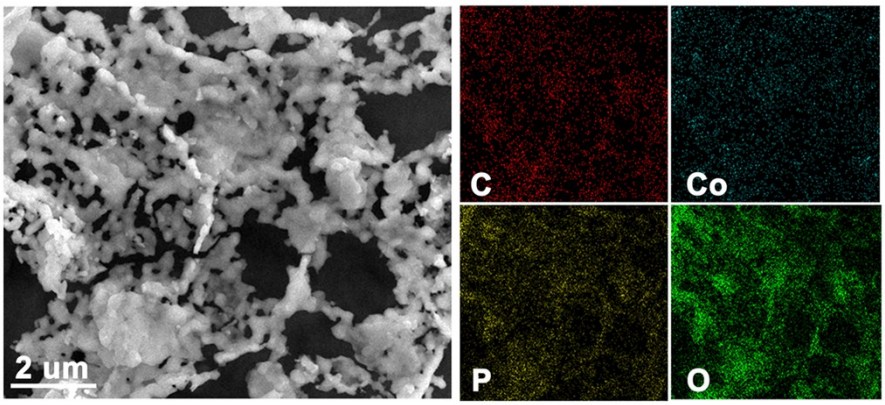

Fig. S11 SEM image of CoOP@bio-C used in the EDS mapping revealing the elemental distribution of C, Co, P and O.

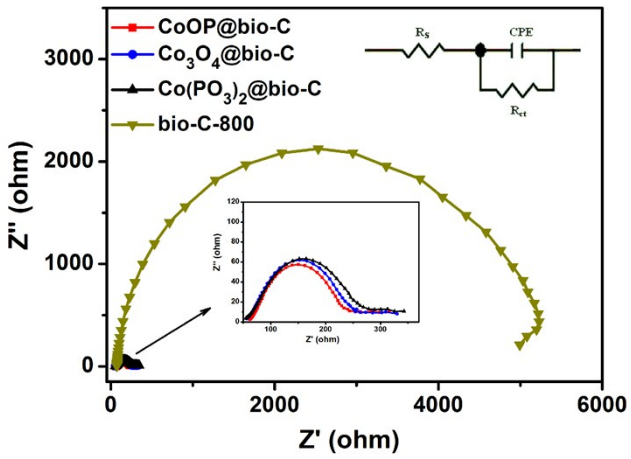

Fig. S12 Nyquist plots of CoOP@bio-C, Co_3O_4@bio-C, $Co(PO_3)_2$@bio-C and bio-C-800 catalysts-modified electrodes in 0.1 M KOH solution in the frequency range of 0.1–10000 Hz, respectively. (inset: corresponding equivalent circuit)

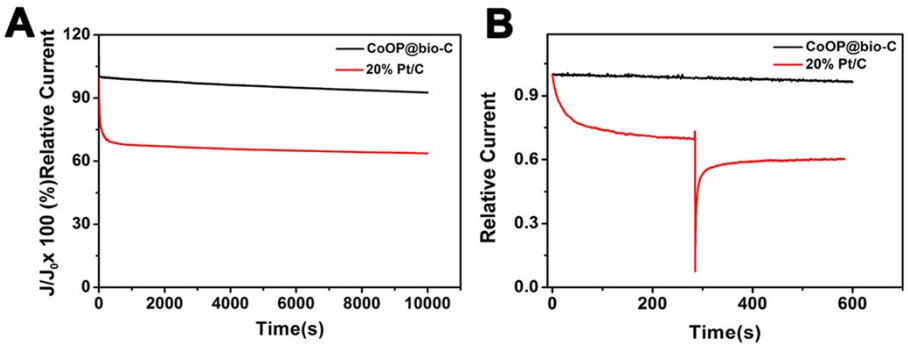

Fig. S13 (A) Amperometric i–t curves of CoOP@bio-C and 20 wt% Pt/C and (B) upon the addition of 3 M methanol in O_2-saturated 0.1 M KOH solution with the rotation speed of 1600 rpm.

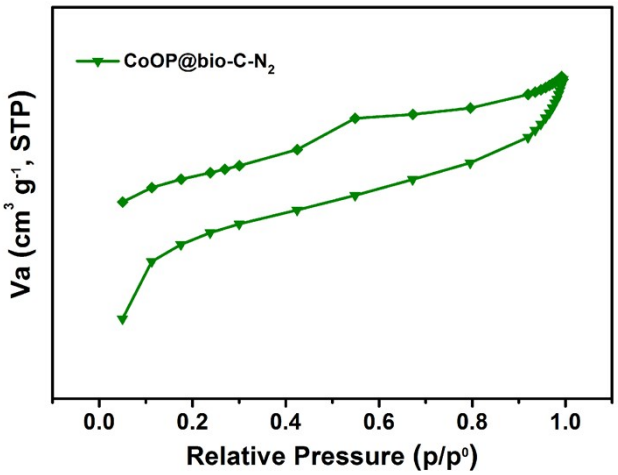

Fig. S14 N_2 adsorption/desorption isotherms of the CoOP@bio-C-N_2.

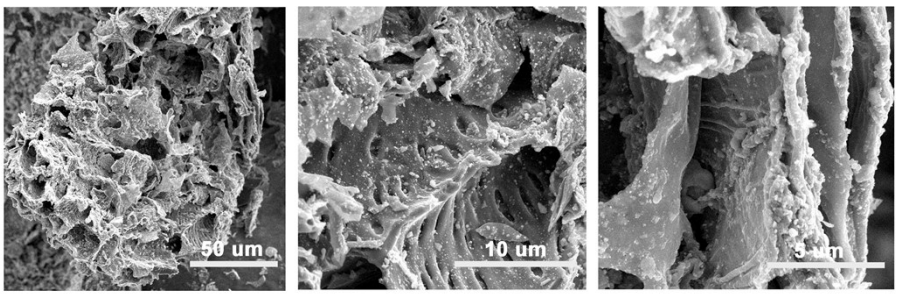

Fig. S15 SEM images of the CoOP@bio-C-N_2 sample observed at the different amplification times.

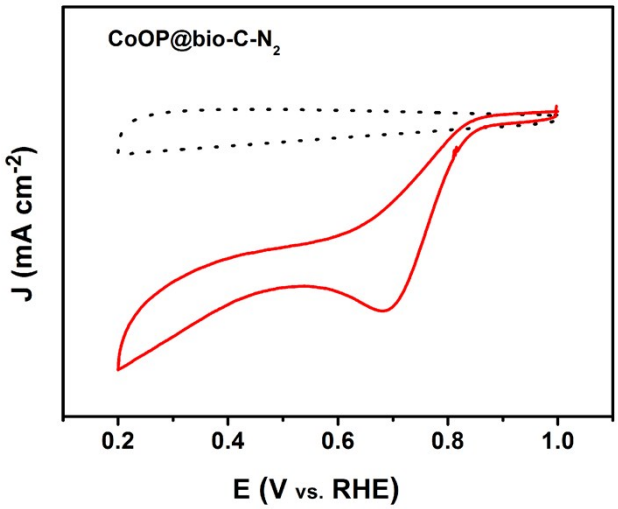

Fig. S16 CV curve of the CoOP@bio-C-N_2 catalyst in O_2-saturated (solid line) and N_2-saturated (dot line) 0.1 M KOH electrolyte.

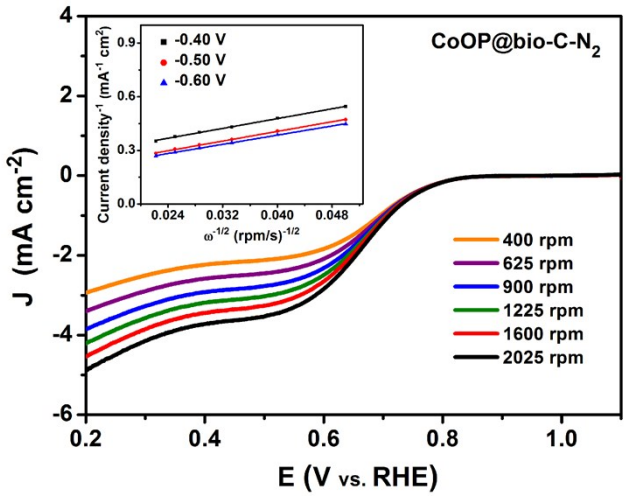

Fig. S17 LSV curves at various rotating rates of the CoOP@bio-C-N_2 catalyst in O_2-saturated 0.1 M KOH electrolyte. (inset: corresponding K–L plots at various potentials)

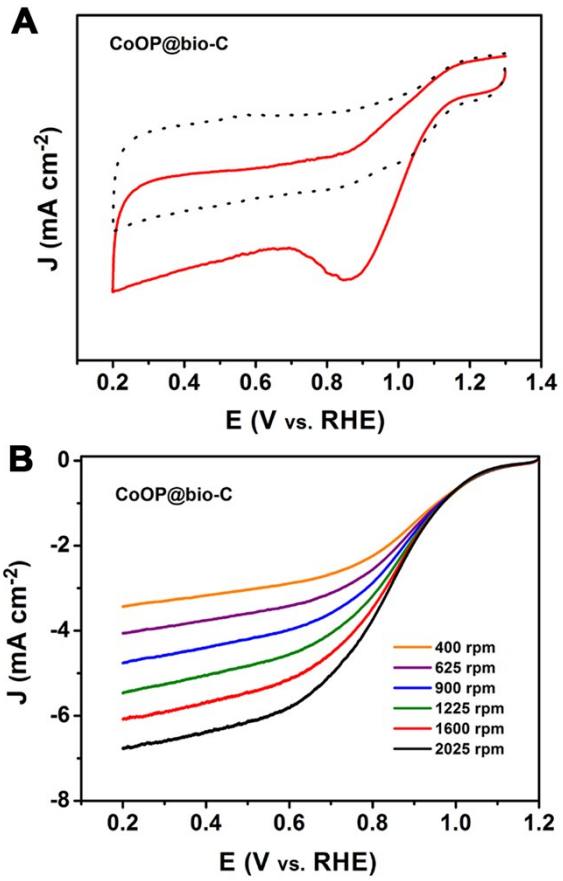

Fig. S18 (A) CVs of CoOP@bio-C in O_2-saturated (solid lines) and N_2-saturated (dash lines) PBS solution at 10 mV s^{-1}. (B) LSV curves of CoOP@bio-C at various rotating speeds.

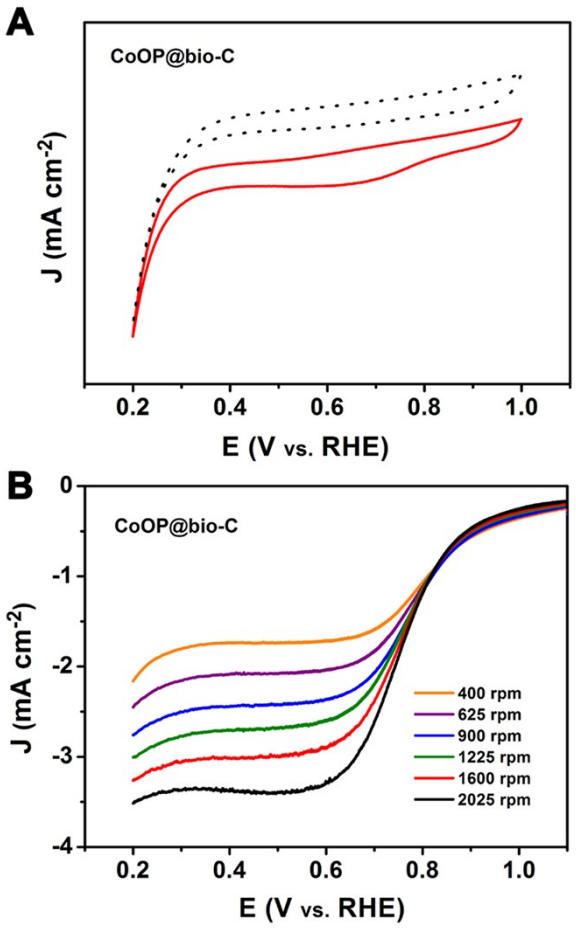

Fig. S19 (A) CVs of CoOP@bio-C in O_2-saturated (solid lines) and N_2-saturated (dash lines) 0.5 M H_2SO_4 media at 10 mV s^{-1}. (B) LSV curves of CoOP@bio-C at various rotating speeds.

Table S1 Comparison of the ORR performance for CoOP@bio-C catalysts at 1600 rpm in 0.1 M KOH.

Catalysts	Half-wave potential (V)	Current densityJ (mA cm^{-2})	Onset potential (V)	Tafel slope (mV/dec^{-1})	Electron transfer number	Reference
CoOP@bio-C	0.81	5.67	0.91	57	3.93	This work
urchin-like CoP NCs	0.70	4.50	0.80	--	--	*Nano Lett.*, 2015 [1]
Co-NC@CoP-NC	0.78	--	0.89	--	--	*J. Mater. Chem. A*, 2016 [2]
NCS-800	0.75	4.60	0.82	--	--	*Energy Environ. Sci.*, 2014 [3]
N-CNAs	0.79	4.35	0.92	--	--	*Small*, 2014 [4]
$Co_3(PO_4)_2C$-N	0.84	3.75	0.96	--	--	*Energy Environ. Sci.*, 2016 [5]
Co@Co_3O_4@C	0.81	4.65	0.93	--	--	*Energy Environ. Sci.*, 2015 [6]
WHC-700	0.88	4.40	0.98	--	--	*Nanoscale*, 2015 [7]
NPC-800	0.76	5.30	0.94	--	--	*Phys. Chem. Chem. Phys.*, 2016 [8]
Co_9S_8@CNS900	0.83	5.60	0.95	--	--	*Adv. Mater.*, 2016 [9]
3D-HPG	0.84	5.50	0.93	--	--	*Nano Energy*, 2016 [10]
Cal-CoZIF-VXC72	-0.16	5.92	--	35	4.0	*Adv. Mater.*, 2017 [12]
AC-U-P	-0.21	5.40	0.98	--	3.7	*Appl. Catal.B Environ.*, 2017 [13]
NC@CoPx/PyCNTs-900	-0.20	5.50	0.92	85	3.8	*Carbon*, 2018 [14]

Table S2 Surface areas of the bio-C-700, bio-C-800, bio-C-900, CoOP@bio-C, CoOP@bio-C-N_2, Co_3O_4@bio-C and $Co(PO_3)_2$@bio-C, respectively.

Sample	BET surface area (m^2 g^{-1})
bio-C-700	95.6
bio-C-800	653.9
bio-C-900	461.7
CoOP@bio-C	**671.4**
CoOP@bio-C-N_2	248.9
Co_3O_4@bio-C	366.2
$Co(PO_3)_2$@bio-C	324.4

Table S3 The ORR performance of the bio-C-700, bio-C-800, bio-C-900, CoOP@bio-C, CoOP@bio-C-N_2, Co_3O_4@bio-C and $Co(PO_3)_2$@bio-C in alkaline media at 1600 rpm, respectively.

Sample	Onset potential (V)	Half wave potential (V)	Current density J (mA cm^{-2})	Tafel slope (mV dec^{-1})	Electron transfer number
bio-C-700	0.73	0.71	3.43		2.95
bio-C-800	0.83	0.75	3.84		3.23
bio-C-900	0.81	0.69	3.86		3.02
CoOP@bio-C	**0.91**	**0.81**	**5.70**		**3.93**
CoOP@bio-C-N_2	0.79	0.68	4.49		3.19
Co_3O_4@bio-C	0.86	0.78	5.20		3.86
$Co(PO_3)_2$@bio-C	0.85	0.77	4.14		3.47
Pt/C	0.97	0.83	4.28		3.94 [15]

Notes and references

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