

Supplementary information

One-step pyrolysis synthesis of ternary (P, S, N)-doped graphene as an efficient metal-free electrocatalyst for oxygen reduction reaction

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The MB absorption technique

Firstly, the ethanol solution (150 mL) which includes a known mass of sample PSN-G3 (4 mg) and excessive amount of MB (10 mg) was handled by sonication adequately. Later, the ethanol solvent was evaporated in the vacuum oven. Subsequently, the free MB was dissolved in a specific amount of water (1000 mL) and determined by a UV-visible spectrophotometer at $\lambda = 664$ nm based on the standard concentrations of MB. Herein, the standard curve of MB based on Table S1 is indicated in the equation 1 in supplementary information. Consequently, the specific surface area of the sample PSN-G3 was calculated according to the mass and specific surface area literature value ($2540 \text{ m}^2 \text{ g}^{-1}$) of adsorbed MB. In this work, the value of A is 0.8071 for PSN-G3, thus the specific surface area value of PSN-G3 is $1868 \text{ m}^2 \text{ g}^{-1}$.

The standard curve of MB based on Table S1 is as follows:

$$A=0.1148c-0.0032 (R^2=0.9992) \quad (1)$$

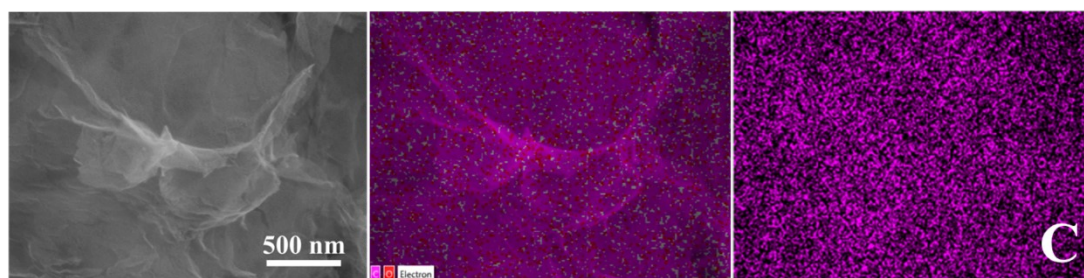


Fig. S1 FESEM images and corresponding EDS mapping images of G.

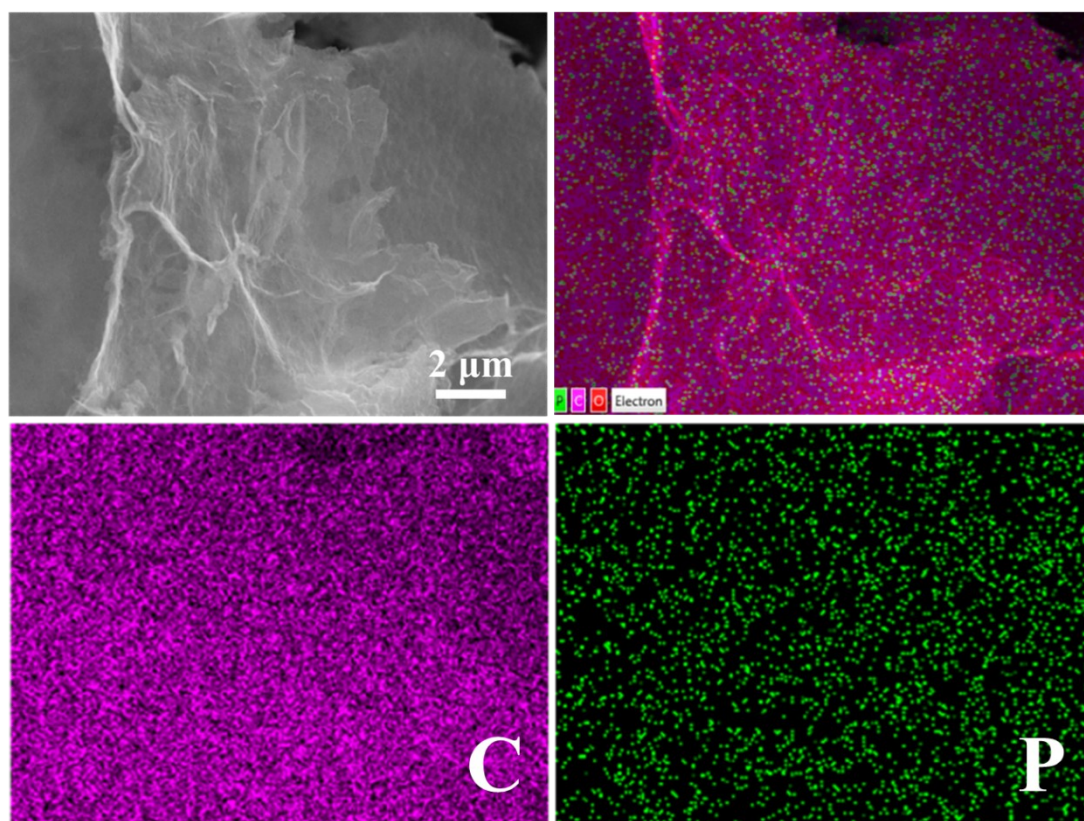


Fig. S2 FESEM images and corresponding EDS mapping images of P-G.

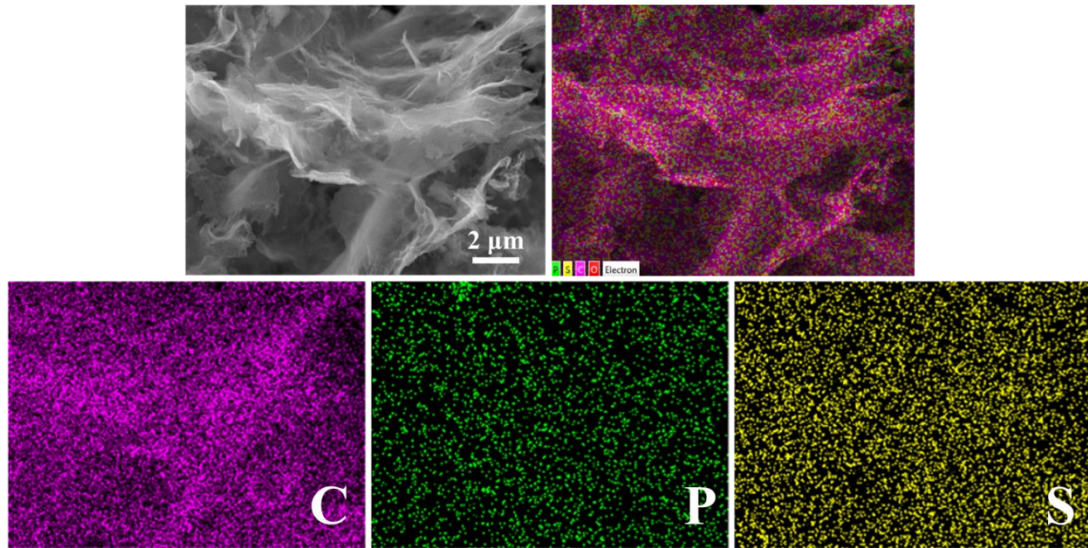


Fig. S3 FESEM images and corresponding EDS mapping images of PS-G.

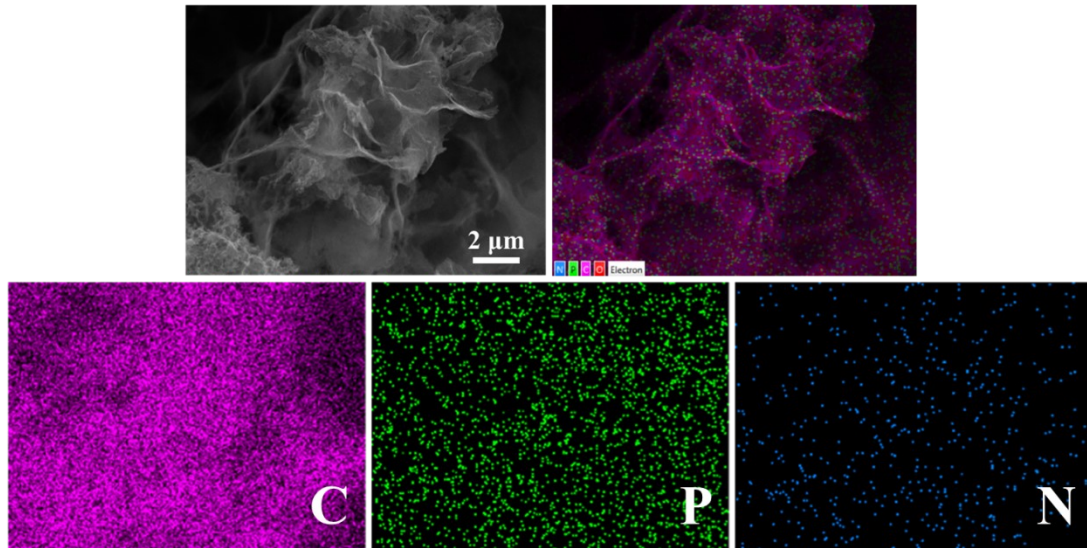


Fig. S4 FESEM images and corresponding EDS mapping images of PN-G.

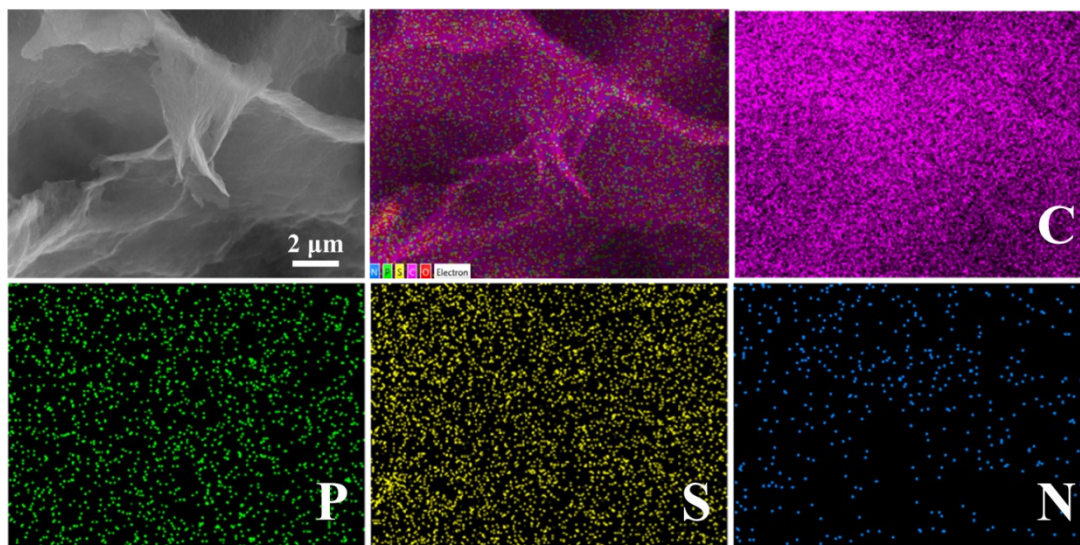


Fig. S5 FESEM images and corresponding EDS mapping images of PSN-G1.

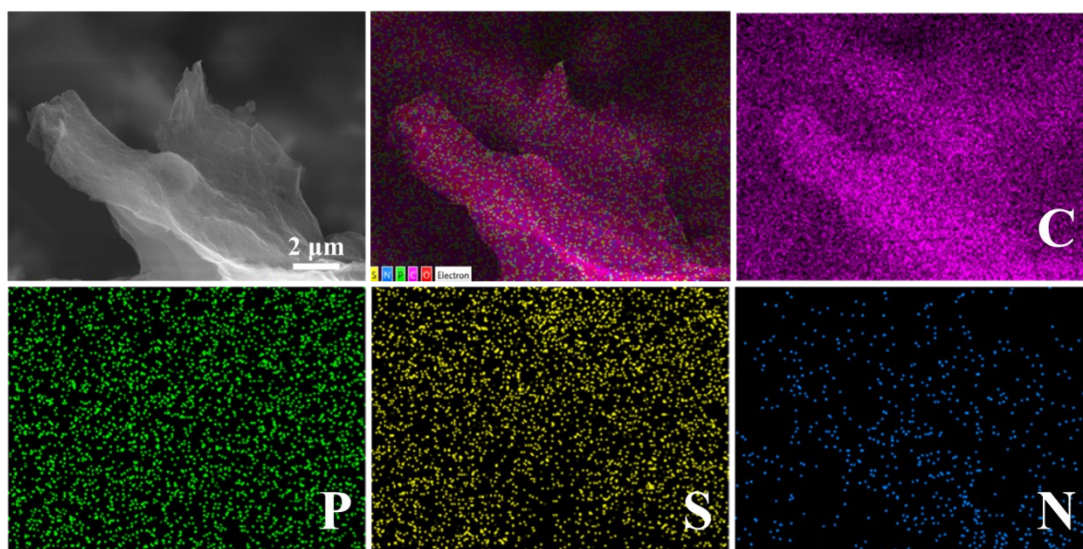


Fig. S6 FESEM images and corresponding EDS mapping images of PSN-G2.

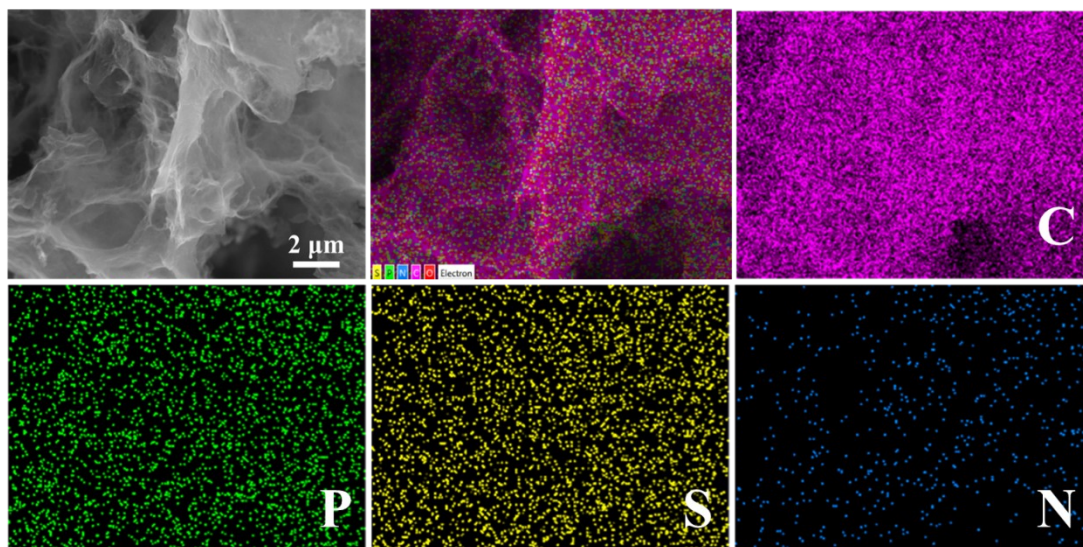


Fig. S7 FESEM images and corresponding EDS mapping images of PSN-G4.

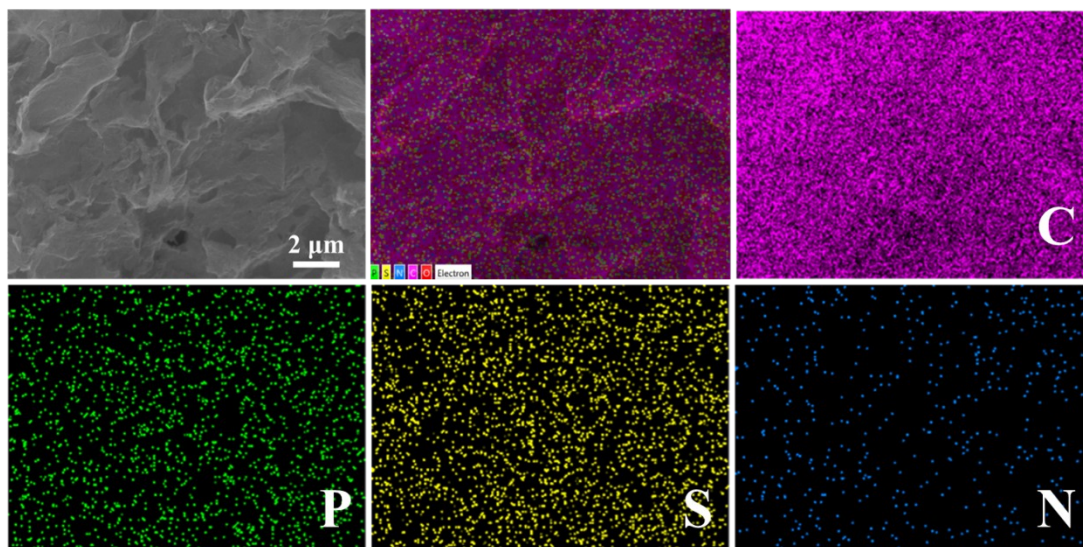


Fig. S8 FESEM images and corresponding EDS mapping images of PSN-G5.

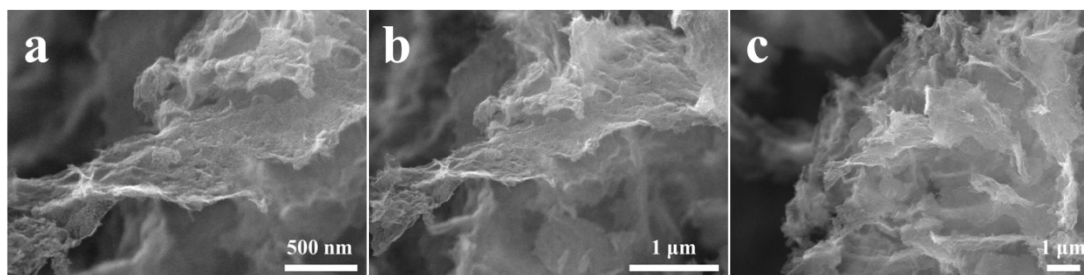


Fig. S9 FESEM images of PSN-G3-1000-10 at different magnifications.

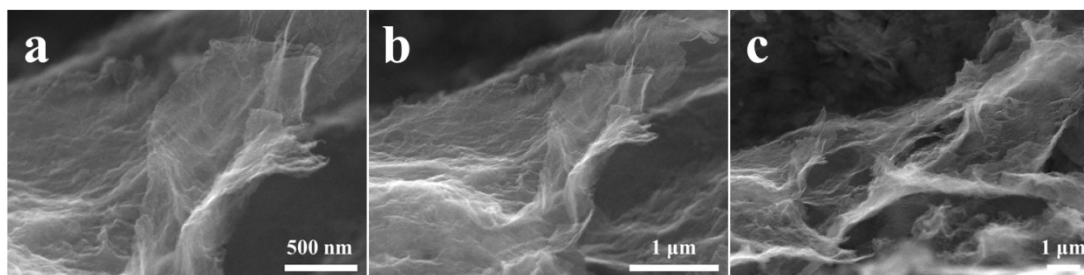


Fig. S10 FESEM images of PSN-G3-900-10 at different magnifications.

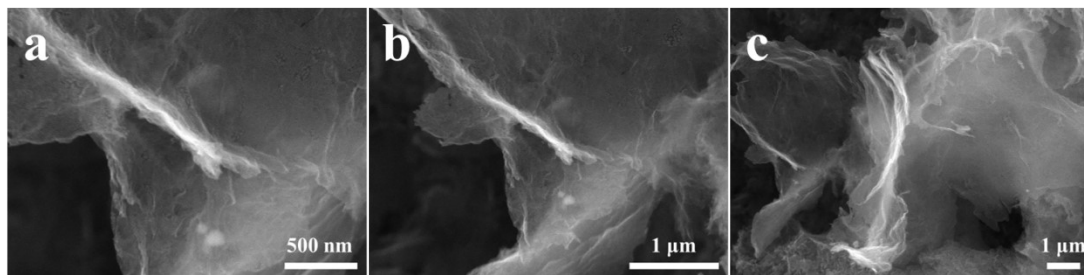


Fig. S11 FESEM images of PSN-G3-950-30 at different magnifications.

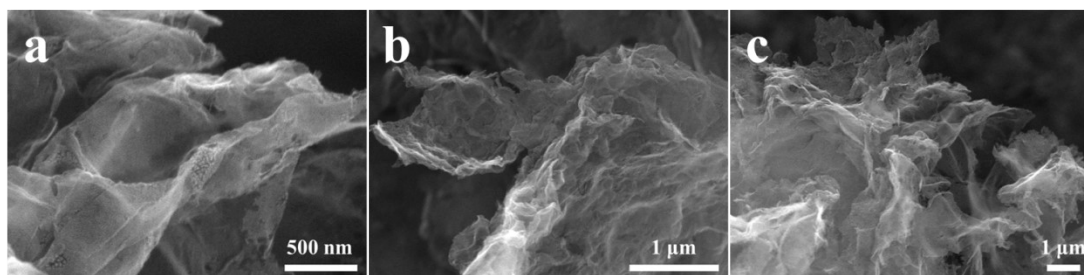


Fig. S12 FESEM images of PSN-G3-950-60 at different magnifications.

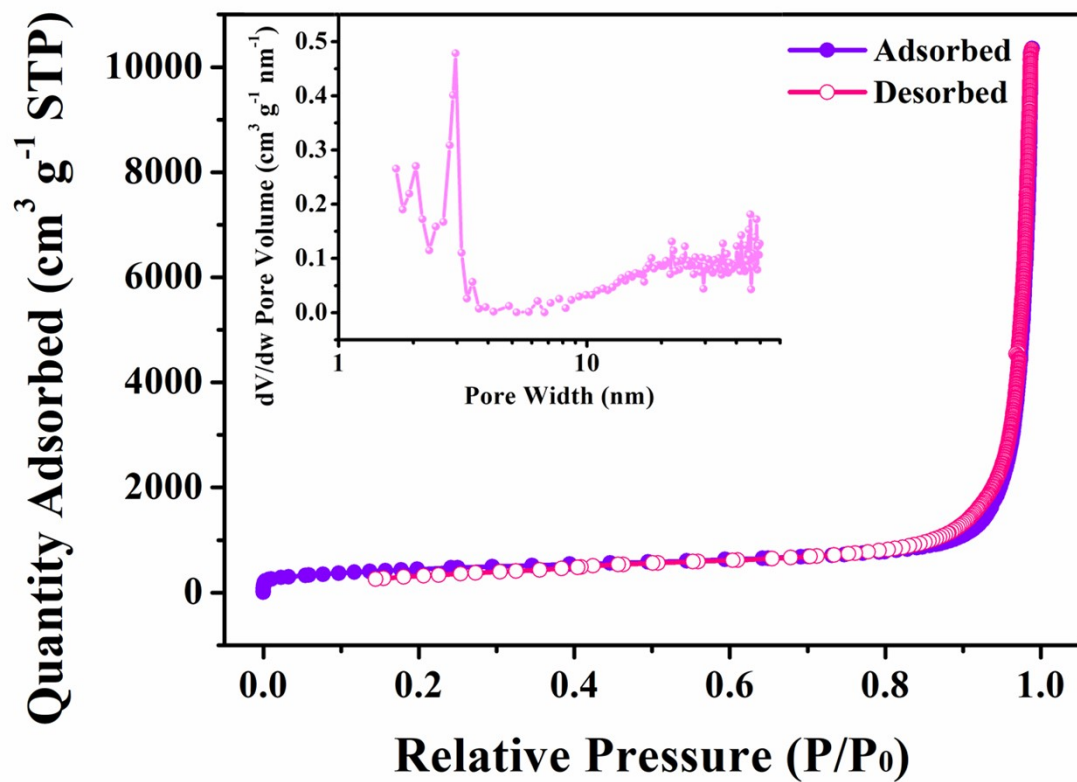


Fig. S13 N_2 adsorption–desorption isotherms and an inset showing the corresponding pore size distributional details of PSN-G3.

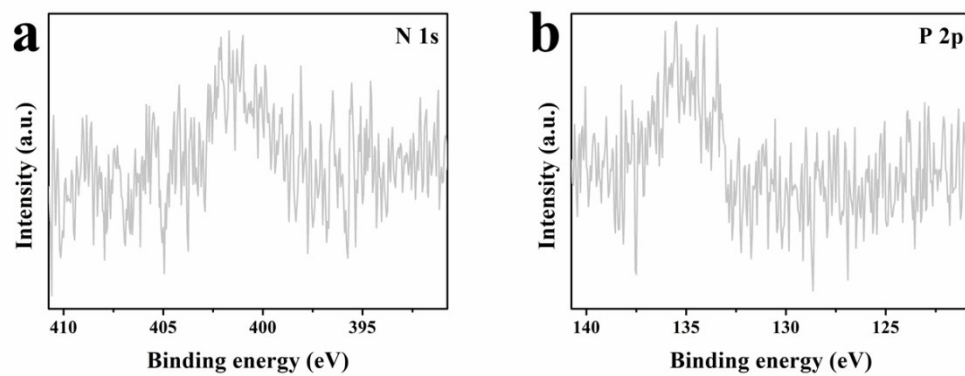


Fig. S14 High-resolution XPS spectra for (a) N 1s and (b) P 2p of PSN-G3.

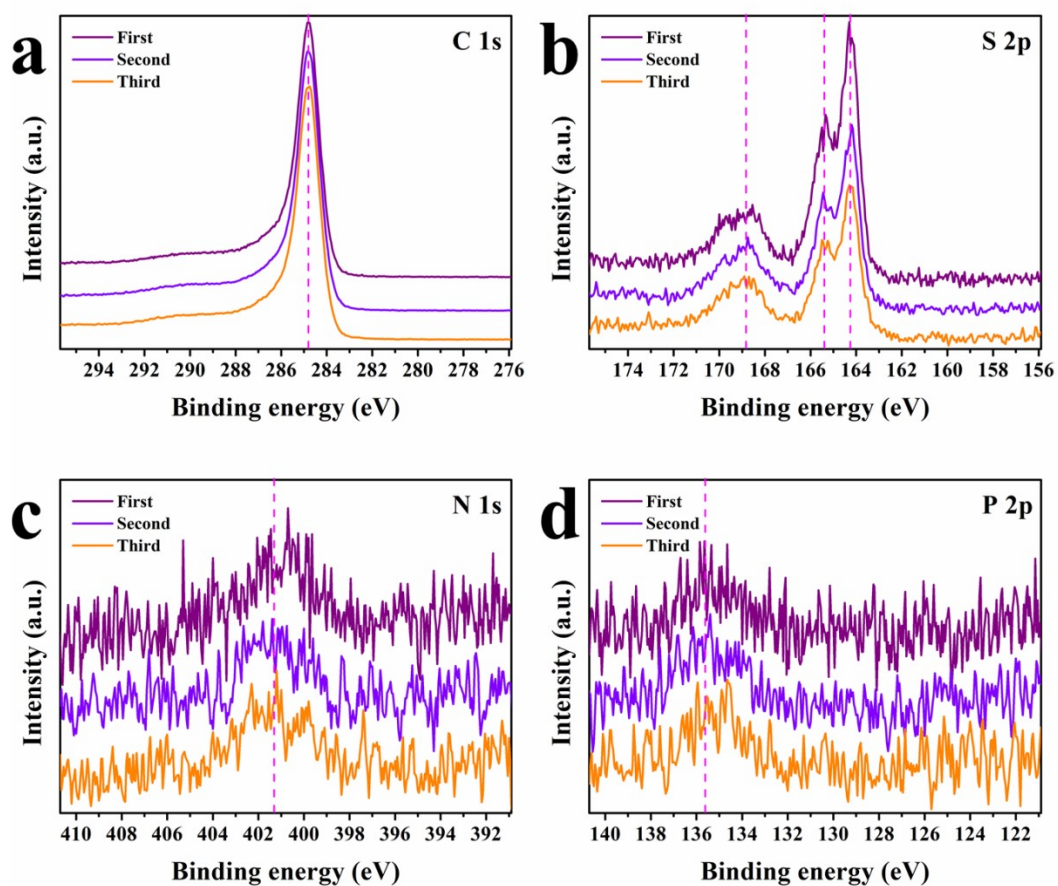


Fig. S15 The high-resolution XPS spectra for (a) C 1s, (b) S 2p, (c) N 1s and (d) P 2p of PSN-G3

for three parallel tests.

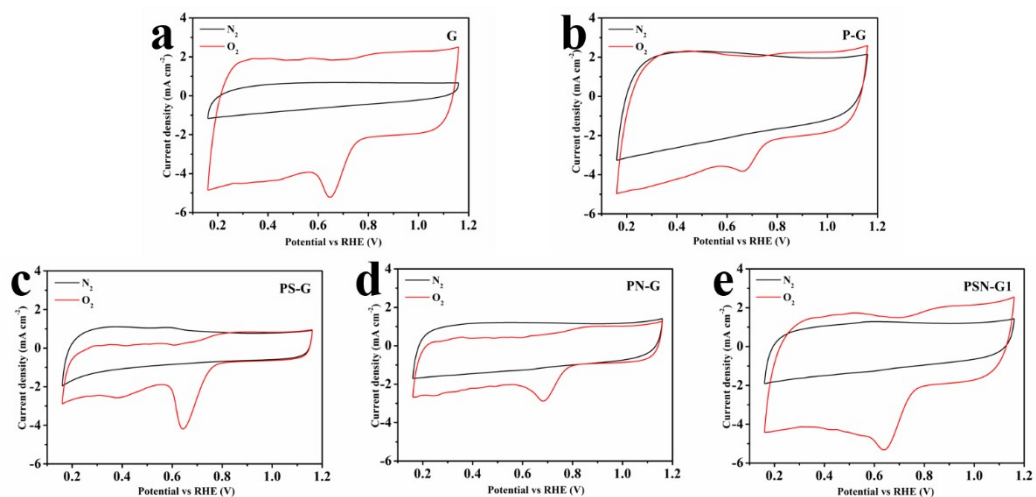


Fig. S16 Comparison of CV curves in the N₂-saturated and O₂-saturated 0.1 mol L⁻¹ KOH electrolyte of G, P-G, PS-G, PN-G and PSN-G1.

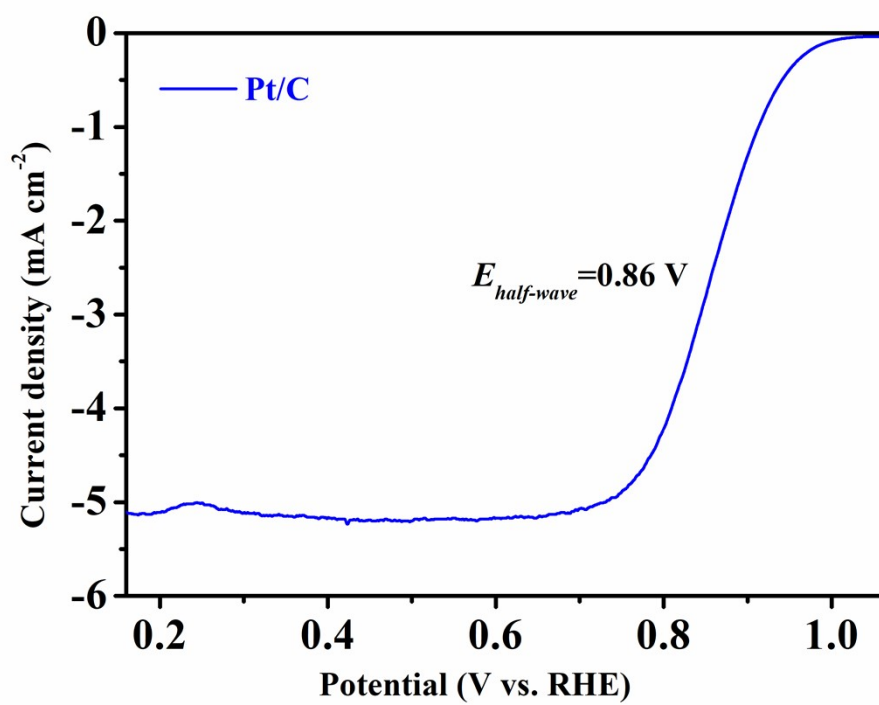


Fig. S17 Comparison of CV curves in the N₂-saturated and O₂-saturated 0.1 mol L⁻¹ KOH electrolyte of G, P-G, PS-G, PN-G and PSN-G1.

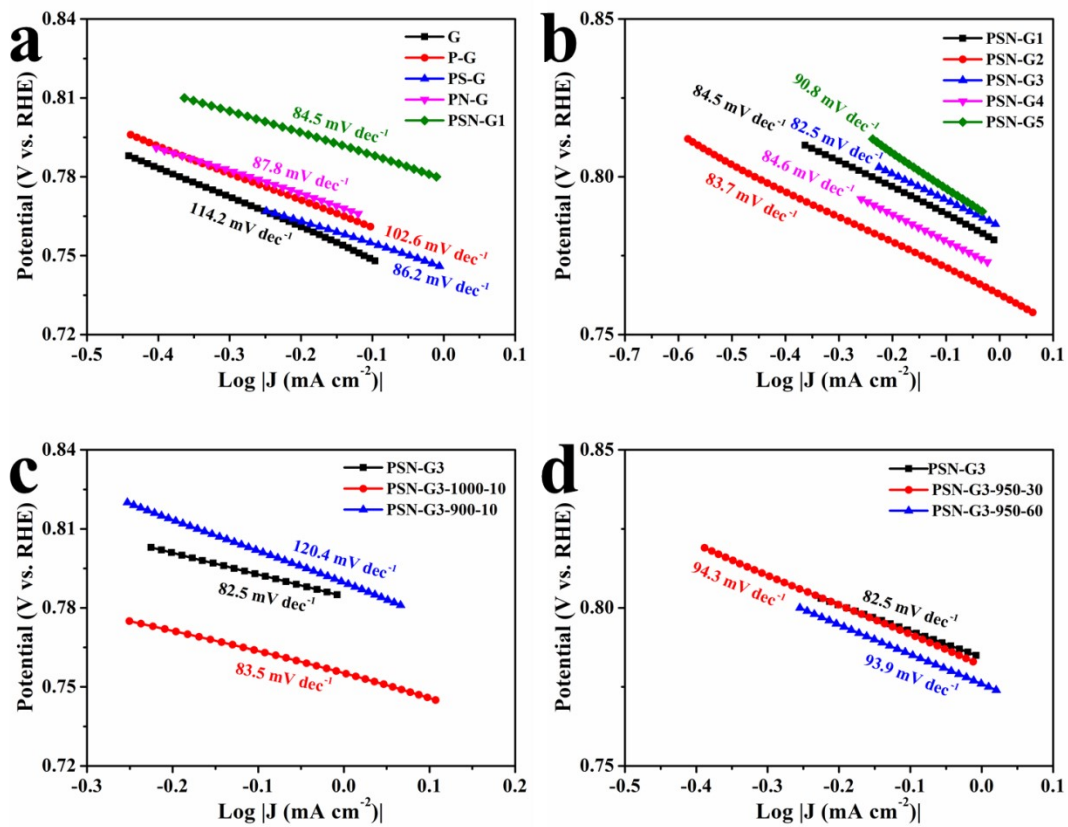


Fig. S18 Comparison of Tafel plots of (a) G, P-G, PS-G, PN-G and PSN-G1; (b) PSN-G1, PSN-G2, PSN-G3, PSN-G4 and PSN-G5; (c) PSN-G3, PSN-G3-1000-10 and PSN-G3-900-10; (d) PSN-G3, PSN-G3-950-30 and PSN-G3-950-60.

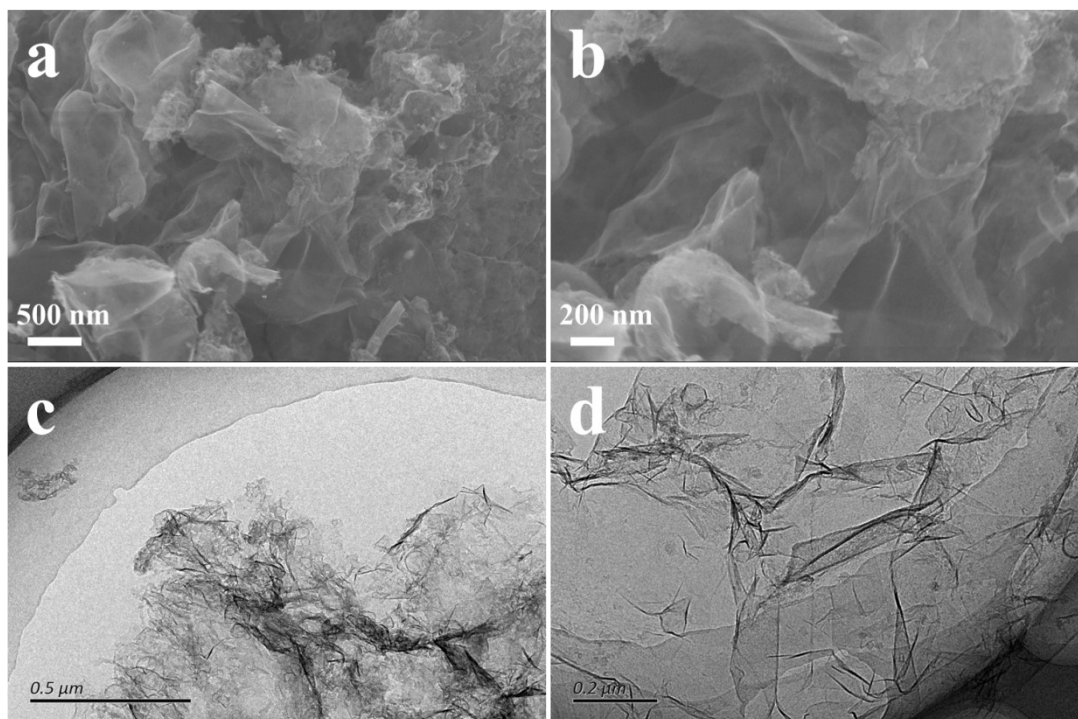


Fig. S19 (a-b) FESEM images of PSN-G3 after i-t test at different magnifications; (c-d) TEM images of PSN-G3 after i-t test at different magnifications.

Table S1 The standard curve values of MB by UV-visible spectrophotometer analysis

c (mg L⁻¹)	0	0.5	1	2	5	10
A	0	0.0535	0.1066	0.2145	0.5943	1.1364

Table S2 The concentration of chemical elements for PSN-G3 by XPS analysis

Chemical Elements	C	O	S	N	P
Concentration (at%)	94.12	5.00	0.52	0.28	0.08