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

Supplementary Information

The high-performance and mechanism of P-doped activated carbon as a catalyst for air-cathode microbial fuel cells

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Text 1. Pretreatments of AC

Step one: The AC powders (2132 m^2 g^{-1}, Yihuan Carbon Co. Ltd., Fujian, China) were impregnated with 1 M H_3PO_4 solutions and stirred with a magnetic stirrer at a room temperature for 5 hours in order to achieve a complete loading/adsorption of H_3PO_4 solution on AC.

Step two: The mixture was dried in an vacuum oven at 100 ℃ for 24 h.

Step three: the samples were placed in a vacuum tube furnace for a heat-treatment in a flow of N_2 (flow rate=100 mL min^{-1}) at a given temperature.[1] The samples were heated in the range from room temperature to 200 ℃, 400 ℃, 600 ℃, 800 ℃ and 1000 ℃ respectively with a heating rate 10 ℃ min^{-1} and maintained at the control temperature for 40 min.

Step four: The resultant carbon sample was thoroughly washed with distilled water several times until the pH of washings filtrate was close to neutral and oven-dried at 110 ℃ overnight.[2]

Text 2. The composition of PBS

The PBS contained NH_4Cl (0.31 g L^{-1}), KCl (0.13 g L^{-1}), $NaH_2PO_4 \cdot 2H_2O$ (3.321 g L^{-1}), Na_2HPO_4 (4.090 g L^{-1}), trace mineral (12.5 mL L^{-1}), and a vitamin (5 mL L^{-1}) solution.[3]

Text 3. Electrochemical and material analysis

FTIR

The surface functionalities of AC were qualitatively revealed on Fourier transform infrared spectroscopy (FTIR). The FTIR spectra of the samples were recorded between 400 cm^{-1} and 4000 cm^{-1} in a Bio-Rad FTS 6000 spectrometer. Sample-KBr pellets were prepared by mixing powder with KBr before measurement.

SEM

Scanning electron microscope (SEM) equipped with an energy-dispersive X-ray spectrometer (S-3500N, Hitachi) was performed to observe the morphology of the samples. The microstructures and shapes with a magnification of 1000 times were respectively observed.

Text 4. The result and discussion of FTIR

As shown in Fig. S4, the FTIR spectra reflected the functional groups and structures of the treated ACs, together with that of RAW-SP. It was observed that notable new peaks appeared in treated samples compared to RAW-SP. For the original AC, the major bands at 1154 cm^{-1} and 1216 cm^{-1} were attributed to the stretching of C-O [4]. The band at 1561 cm-1 was attributed to the C=C stretch.[5] All treated samples revealed almost similar trends. The strongest absorption shoulders present at around 1152 cm-1, 1210 cm-1, 1536 cm-1, and 1633 cm-1 were assigned to stretching vibration of the C-O, C=C, and C=O [6], respectively. The weak peak at around 1029 cm^{-1} was due to the P-O stretching vibration of the P modified AC.[4, 7] A new band near 3292 cm-1 was discerned in SP-1000, which was corresponded to O-H.[6, 8] The intensity of the bands at 1633 cm^{-1} and 3292 cm^{-1}, corresponding to oxygen-containing groups [9], increased slightly after P modification.

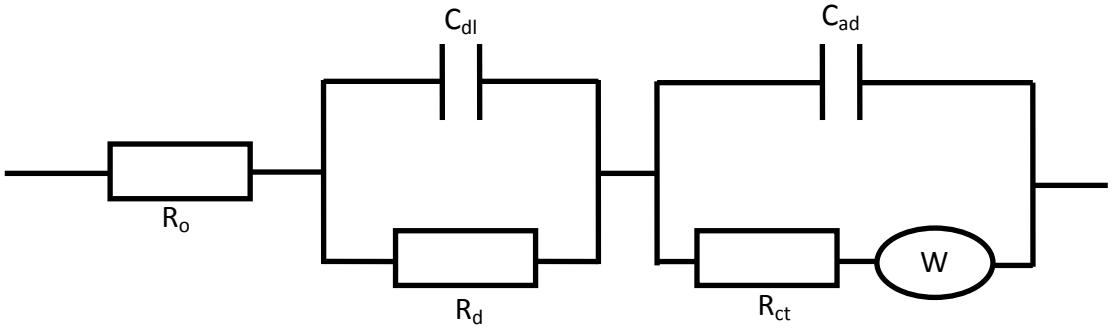

Figure S1. Equivalent circuits for modeling the EIS of air cathodes.

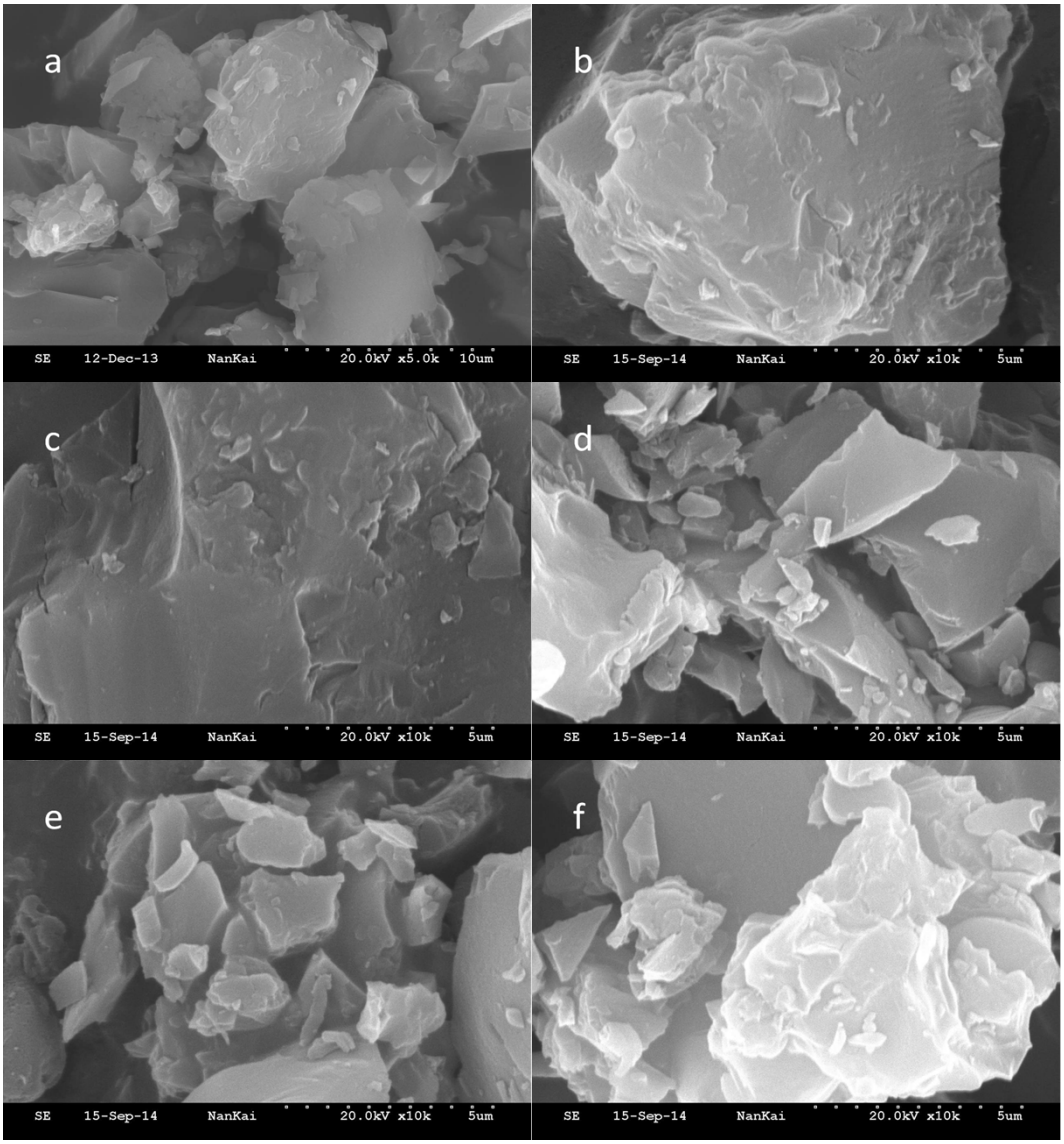

Figure S2. SEM images of catalyst layers of six air-cathodes magnified 5000 and 10000 times, which was the graph of (a)RAW-SP (bare AC), (b) SP-200 (AC treated at 200 ℃), (c) SP-400 (AC treated at 400 ℃), (d) SP-600 (AC treated at 600 ℃), (e) SP-800 (AC treated at 800 ℃) and (f) SP-1000 (AC treated at 1000 ℃) respectively.

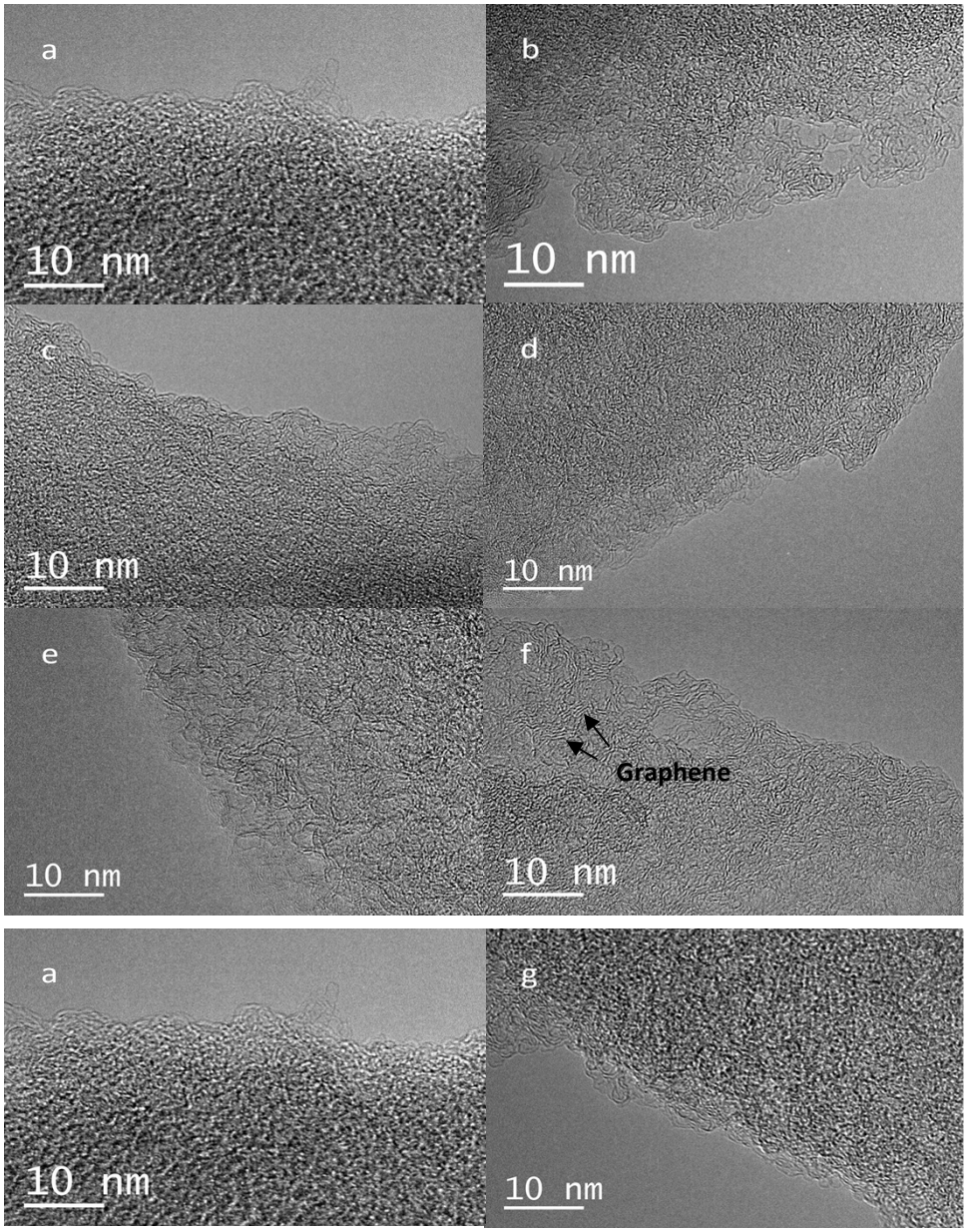

Figure S3. TEM images of catalyst layers of air-cathodes, which was the graph of (a) RAW-SP, (b) SP-200, (c) SP-400, (d) SP-600, (e) SP-800, (f) SP-1000and (g) RAW-800 respectively.

Figure S4. X-ray photoelectron spectroscopy (XPS) survey spectra of RAW-SP, SP-200 , SP-400, SP-600, SP-800 and SP-1000.

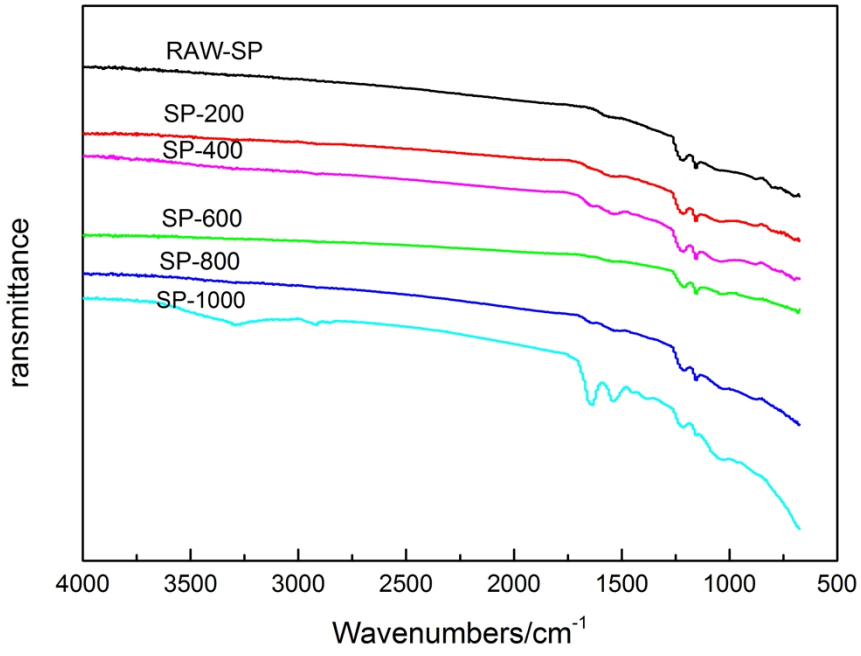

Figure S5. Fourier transform infrared (FTIR) spectra of RAW-SP, SP-200, SP-400, SP-600, SP-800 and SP-1000.

Table S1. The position of the D-band peaks and the G-band peaks for all samples.

	RAW-SP	RAW-800	SP-200	SP-400	SP-600	SP-800	SP-1000
D-band peak	1355	1356	1347	1346	1346	1345	1350
G-band peak	1593	1593	1599	1599	1596	1600	1600

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