Electronic supplementary information

Uniform nitrogen and sulphur co-doped hollow carbon nanospheres as efficient metal-free electrocatalysts for oxygen reduction

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**Fig. S1** SEM images: (a) SN; (b) MSN; (c) SN/PA; (d) PAC-S; (e) PAC-3S (f) PAC-7S.
a

Quality Absorbed (cm$^3$ g$^{-1}$ STP)

Relative Pressure ($P/P_0$)

b

Quality Absorbed (cm$^3$ g$^{-1}$ STP)

Relative Pressure ($P/P_0$)
C

Quality Absorbed (cm$^3$g$^{-1}$ STP)

Relative Pressure (P/P$_0$)

PAC-3S

D

Quality Absorbed (cm$^3$g$^{-1}$ STP)

Relative Pressure (P/P$_0$)

PAC-7S
Fig. S2 N$_2$ adsorption-desorption isotherms: (a) PAC; (b) PAC-S; (c) PAC-3S; (d) PAC-7S. Pore-size distributions and cumulative volumes: (e) PAC; (f) PAC-S; (g) PAC-3S; (h) PAC-7S.
Fig. S3 (a) XPS spectra of various catalysts. (b) N1s spectrum of PAC. (c) N1s spectrum of PAC-S. (d) N1s spectrum of PAC-3S. (e) N1s spectrum of PAC-7S. (f) S2p spectra of PAC-S. (g) S2p spectra of PAC-3S. (h) N1s spectrum of PAC-7S.
Fig. S4 Half-wave potential and current density of various catalysts.
Fig. S5 LSV curves of obtained catalysts under different rotation rates: (a) PAC; (b) PAC-S; (c) PAC-3S; (d) PAC-5S; (e) PAC-7S.
c) PAC-3S

\[ J^{-1} / \text{mA} \cdot \text{cm}^2 \]

\[ \omega^{-1/2} / \text{rps}^{-1/2} \]

-0.4 V
-0.45 V
-0.5 V
-0.55 V
-0.6 V
-0.65 V
-0.7 V

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d) PAC-5S

\[ J^{-1} / \text{mA} \cdot \text{cm}^2 \]

\[ \omega^{-1/2} / \text{rps}^{-1/2} \]

-0.4 V
-0.45 V
-0.5 V
-0.55 V
-0.6 V
-0.65 V
-0.7 V
Fig. S5  K-L plots of as-prepared catalysts: (a) PAC; (b) PAC-S; (c) PAC-3S; (d) PAC-5S; (e) PAC-7S.
Table S1 Comparison of ORR performances of PAC-5S with some doped carbon catalysts recently reported.

<table>
<thead>
<tr>
<th>No.</th>
<th>Catalyst</th>
<th>Half-wave potential* (E_{1/2})</th>
<th>Reference</th>
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<tr>
<td>1</td>
<td>PAC-5S</td>
<td>46 mV inferior</td>
<td>Our work</td>
</tr>
</tbody>
</table>

* compared with Pt/C catalyst.