Supporting Information

Keratin-derived S/N co-doped graphene-like nanobubble and nanosheet hybrids for highly efficient oxygen reduction

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Table S1 The content of C, N, O and S in GLBS and GLBS-1000.

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Fig. S1 TEM images of hybridized graphene-like nanobubbles and nanosheets (GLBS).

Fig. S2 XRD patterns of GLBS, GLBS-1000 and graphite.
Fig. S3 The pore size distribution of GLBS and GLBS-1000.

Fig. S4 TEM image of the flake-shaped carbon.
Fig. S5 The optical photo of the residual carbon.

Fig. S6 SEM, TEM, N$_2$ adsorption-desorption isotherms and pore size distribution of keratin derived carbon (KDC) without KOH activation.
The Koutecky-Levich (K-L) equation as given below:

\[
\frac{1}{J} = \frac{1}{J_L} + \frac{1}{J_K} = \frac{1}{B\omega^{1/2}} + \frac{1}{J_K} \tag{1}
\]

\[
B = 0.62nF C_0 (D_0)^{2/3} \nu^{-1/6} \tag{2}
\]

where J denotes the measured current density, J_K is the kinetic current density, J_L is the diffusion-limited current density, \( \omega \) is the electrode rotation rate, F is the Faraday constant (96485 C mol\(^{-1}\)), C_0 is the bulk concentration of O\(_2\) (1.2 \times 10^{-3} \text{ mol L}^{-1} ), D_0 is the diffusion coefficient of O\(_2\) (1.9 \times 10^{-5} \text{ cm}^2 \text{ s}^{-1} ) and \( \nu \) is the kinetic viscosity of the electrolyte (1.0 \times 10^{-2} \text{ cm}^2 \text{ s}^{-1} ).
Fig. S8 LSV curves for GLBS-800, GLBS-900, GLBS-1000 and GLBS-1000 catalyst.

Fig. S9 The K-L plots at the range potential from 0.2 to 0.6 V.
**Fig. S10** The stability of Pt/C catalyst before and after accelerated durability test (ADT) of 3,000 cycles from 0.4 to 1.0 V.

**Fig. S11** LSV curves of GLBS-1000 and Pt/C catalysts in acidic media (a); i–t chronoamperometric response of GLBS-1000 and Pt/C catalysts in acidic media under a constant potential at 0.3 V at a rotation rate of 1600 rpm; inset: the ratio of J/J₀ (b).
Table S1 The content of C, N, O, S and the possible metal in GLBS and GLBS-1000.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Content (%)</th>
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<tr>
<td></td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>S</td>
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<tr>
<td>GLBS</td>
<td>75.4</td>
<td>4.9</td>
<td>19.2</td>
<td>0.5</td>
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<tr>
<td>GLBS-1000</td>
<td>95.9</td>
<td>1.5</td>
<td>2.5</td>
<td>0.1</td>
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Table S2 Comparison of the Tafel slopes between GLBS-1000 and other reported carbon based catalysts under 0.1 M KOH conditions in literature.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Tafel slope (mV per decade)</th>
<th>Catalyst name</th>
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<tbody>
<tr>
<td>This work</td>
<td>68</td>
<td>GLBS-1000</td>
</tr>
<tr>
<td>1</td>
<td>72</td>
<td>N-PANn-1000</td>
</tr>
<tr>
<td>2</td>
<td>69</td>
<td>(GO 8 wt%) Cu.MOF</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>Fe/N-gCB</td>
</tr>
<tr>
<td>4</td>
<td>75</td>
<td>Co SAs/N-C(900)</td>
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<tr>
<td>5</td>
<td>103</td>
<td>WHC-700</td>
</tr>
<tr>
<td>6</td>
<td>85</td>
<td>BP350@C-1000</td>
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<tr>
<td>7</td>
<td>67</td>
<td>Fe3C/NG-800</td>
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<tr>
<td>8</td>
<td>105</td>
<td>Fe/C-SOYB</td>
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<tr>
<td>9</td>
<td>84</td>
<td>BP1000</td>
</tr>
</tbody>
</table>
Reference