Supporting Information

Easy conversion of protein-rich enoki mushroom biomass to nitrogen-doped carbon nanomaterial as a promising metal-free catalyst for oxygen reduction reaction

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Figure 1S The particle-size distribution of the N-C-900 sample.

Figure 2S Nitrogen adsorption/desorption isotherms of N-C-900 and its corresponding pore size distribution (inset).
Figure 3S Nitrogen adsorption/desorption isotherms of N-C@CNT-900 and its corresponding pore size distribution (inset).

Figure 4S Amperometric current–time (i–t) responses for ORR at +0.7 V vs. RHE in an O₂-saturated 0.1 M KOH electrolyte at N-C-900 and N-C@CNT-900 modified electrodes with a rotation speed of 1600 rpm.
Figure 5S Amperometric current–time (i–t) responses for ORR at +0.5 V vs. RHE in an O₂-saturated 0.5 M H₂SO₄ electrolyte at N-C-900 and N-C@CNT-900 modified electrodes with a rotation speed of 1600 rpm.
Table 1S. N 1s XPS results from Fig. 4 and ORR activity data from Fig. 5 and 6 for EM, N-C-900, N-C@CNT-900, and 20 wt.% Pt/C catalyst.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total N content [%][a]</th>
<th>Nitrile N [%]</th>
<th>Pyrrolic N [%]</th>
<th>Graphitic N [%]</th>
<th>Oxidized N [%]</th>
<th>$E_{\text{ORR}}$ / V[b]</th>
<th>$E_{\text{ORR}}$ / V[c]</th>
<th>$E_{1/2}$ / V[b]</th>
<th>$E_{1/2}$ / V[c]</th>
<th>$j$ / mA cm$^{-2}$ @ +0.5 V[b]</th>
<th>$j$ / mA cm$^{-2}$ @ +0.5 V[c]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM material</td>
<td>5.27</td>
<td>100.0</td>
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<tr>
<td>N-C-900</td>
<td>3.43</td>
<td>26.6</td>
<td>43.3</td>
<td>30.1</td>
<td>---</td>
<td>0.87</td>
<td>0.77</td>
<td>0.73</td>
<td>0.46</td>
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<td>N-C@CNT-900</td>
<td>3.20</td>
<td>25.5</td>
<td>33.3</td>
<td>41.2</td>
<td>---</td>
<td>0.94</td>
<td>0.81</td>
<td>0.81</td>
<td>0.60</td>
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<tr>
<td>20 wt.% Pt/C</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
<td>0.98</td>
<td>0.93</td>
<td>0.86</td>
<td>0.82</td>
<td>5.02</td>
<td>3.74</td>
</tr>
</tbody>
</table>

[a] The total N content (at.%) was determined by XPS analysis in Figure 4a.
[b] The ORR activity data from Fig. 5 were obtained in O$_2$-saturated alkaline electrolyte.
[c] The ORR activity data from Fig. 6 were obtained in O$_2$-saturated acidic electrolyte.