Supplementary information

**Co₃O₄ nanosheet on zeolite-templated carbon as an efficient oxygen electrocatalyst for zinc-air battery**

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**Fig. S1** Scanning electron microscope (SEM) image of Co₃O₄ nanosheet grown on zeolite-templated carbon (Co₃O₄ NS/ZTC) at low magnification.
Fig. S2 Thermogravimetric analysis profile of Co₃O₄ NS/ZTC.
Fig. S3 Powder X-ray diffraction (XRD) pattern and SEM image of $\text{Co}_3\text{O}_4$ NS/ZTC after HCl treatment. During HCl treatment, $\text{Co}_3\text{O}_4$ removed from $\text{Co}_3\text{O}_4$ NS/ZTC and the XRD peak intensity and morphology of ZTC recovered indicating the retention of ZTC framework in $\text{Co}_3\text{O}_4$ NS/ZTC.
Fig. S4 The X-ray photoelectron spectroscopy (XPS) elemental survey of Co$_3$O$_4$ NS/ZTC.
Fig. S5 SEM images of (a) Co$_3$O$_4$, (b) Co$_3$O$_4$/carbon nanotube (CNT), and (c) Co$_3$O$_4$/activated carbon (AC) nanostructure.
**Fig. S6** UV-vis absorption spectra of CoCl$_2$ solution used and extracted after mixing and stirring with ZTC. The extracted CoCl$_2$ solution shows a decrease in the absorbance by 8% because of the absorption of Co$^{2+}$ on ZTC surface.
Fig. S7 XRD pattern of AC that did not possess ordered microporous structure.
(a) Oxygen reduction reaction (ORR) polarization curves of ZTC at different rotation speeds and (b) the corresponding Koutecký-Levich plots at different potential reveals the average number of electron transfer is 2.4.
Fig. S9 SEM images of Co$_3$O$_4$ NS/ZTC with (a) 20% and (b) 50% of Co$_3$O$_4$ content.
**Fig. S10** (a) ORR polarization curves and (b) variation of onset potential and diffusion limiting current density at 0.6 V of Co$_3$O$_4$ NS/ZTC with different Co$_3$O$_4$ contents.
Fig. S11 N$_2$ adsorption-desorption isotherm of Co$_3$O$_4$ NS/ZTC with different Co$_3$O$_4$ contents.
Fig. S12 Bifunctional oxygen electrocatalytic activity of Co$_3$O$_4$ NS/ZTC, RuO$_2$, and Pt/C in a 0.1 M KOH solution.
**Fig. S13** (a) Oxygen electrocatalytic activity of different material, (b) SEM image of commercial Co$_3$O$_4$, and XPS of (c) commercial Co$_3$O$_4$, (d) Co$_3$O$_4$/CNT, and (e) Co$_3$O$_4$/AC. O$_L$, O$_V$, and O$_W$ represent lattice, vacancy, and water oxygen, respectively.
**Fig. S14** Energy density of a Zinc-air battery assembled with Co$_3$O$_4$ NS/ZTC at a current density of 5 mA cm$^{-2}$. 
Table S1. Comparison of bifunctional oxygen electrocatalytic activity of Co₃O₄ NS/ZTC with the recently reported Co₃O₄ NS based electrocatalysts.

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>ORR</th>
<th>OER</th>
<th>ΔE ⁴</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co₃O₄ NS/Carbon cloth</td>
<td>E₁/₂= ~ 0.8 V vs RHE in 0.1 M KOH</td>
<td>Eₗ = 10 mA cm⁻² ³ = 1.71 V vs RHE in 0.1 M KOH</td>
<td>~ 0.91 V</td>
<td>ACS Appl. Mater. Interfaces 2017, 9, 22694</td>
</tr>
<tr>
<td>Co₃O₄ NS/nitrogen-doped reduced graphene oxide</td>
<td>E₁/₂ = 0.79 V vs RHE in 0.1 M KOH</td>
<td>Eₗ = 10 mA cm⁻² ³ = 1.72 V vs RHE in 0.1 M KOH</td>
<td>0.93 V</td>
<td>Adv. Mater. 2018, 30, 1703657</td>
</tr>
<tr>
<td>Co₃O₄ NS/carbon black</td>
<td>E₁/₂ = ~ 0.35 V vs, SCE in 0.1 M KOH</td>
<td>Eₗ = 10 mA cm⁻² ³ = ~ 0.73 V vs SCE in 0.1 M KOH</td>
<td>~ 1.08 V</td>
<td>Small 2018, 1702987</td>
</tr>
<tr>
<td>Co₃O₄ NS/carbon powder (Super P)</td>
<td>Eₗ= 1 mA cm⁻² ³ = -0.213 V vs Hg/HgO in 0.1 M KOH</td>
<td>Eₗ = 10 mA cm⁻² ³ = 0.843 V vs Hg/HgO in 0.1 M KOH</td>
<td>1.056 V</td>
<td>Nanoscale, 2018, 10, 10221</td>
</tr>
<tr>
<td>Co₃O₄ NS/ZTC</td>
<td>Eₗ= 3 mA cm⁻² ³ = 0.7 V vs RHE in 0.1 M KOH</td>
<td>Eₗ = 10 mA cm⁻² ³ = 1.69 V vs RHE in 0.1 M KOH</td>
<td>0.99 V</td>
<td>In this report</td>
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</table>

¹NS represents nanosheet. ²E₁/₂ is half-wave potential for ORR. ³Oxygen evolution reaction (OER) activity at Eₗ= 10 mA cm⁻². ⁴ΔE is the potential gap between Eₗ=10 mA cm⁻² for OER and E₁/₂/Eₗ =1 mA cm⁻²/Eₗ =3 mA cm⁻² for ORR.