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Supporting Information

Solar-Driven Alkaline Water Electrolysis with Multifunctional Catalysts

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Fig. S1 (a) Raman spectrum of the *p*-NiO@NC; (b) pore distribution of the *p*-NiO@NC; (c) XPS spectrum of the *p*-NiO@NC; High- resolution XPS spectrum of N 1s (d) and O 1s (e).

Fig. S2 (a, b) SEM images of the $p\text{-NiFe}_2\text{O}_4@\text{NC}$; (c, d) TEM images of the $p\text{-NiFe}_2\text{O}_4@\text{NC}$.

Fig. S3 Elemental mapping of $p\text{-NiFe}_2\text{O}_4@\text{NC}$.

Fig. S4 (a, b) SEM images of the $p\text{-CoFe}_2\text{O}_4\text{@NC}$; (c, d) TEM images of the $p\text{-CoFe}_2\text{O}_4\text{@NC}$.

Fig. S5 Elemental mapping of $p\text{-CoFe}_2\text{O}_4@\text{NC}$.

Fig. S6 (a, b) SEM images of the $p\text{-NiCo}_2\text{O}_4@\text{NC}$; (c, d) TEM images of the $p\text{-NiCo}_2\text{O}_4@\text{NC}$.

Fig S7 Elemental mapping of $p\text{-NiCo}_2\text{O}_4@\text{NC}$.

Fig. S8 BET surface area and pore distribution of $p\text{-NiFe}_2\text{O}_4\text{@NC}$ (a, b), $p\text{-CoFe}_2\text{O}_4\text{@NC}$ (c, d), and $p\text{-NiCo}_2\text{O}_4\text{@NC}$ (e, f).

Fig. S9 Charge-discharge profiles of the *p*-NiO@NC electrode ranging from 0.5 A g⁻¹ to 8 A g⁻¹.

Fig. S10 Electrochemical performance of $p\text{-NiFe}_2\text{O}_4\text{@NC}$.

Fig. S11 Electrochemical performance of $p\text{-CoFe}_2\text{O}_4@\text{NC}$.

Fig. S12 Electrochemical performance of $p\text{-NiCo}_2\text{O}_4@\text{NC}$.

Fig. S13 (a, b) SEM images of LiCoO_2 . (c, d) electrochemical performance of LiCoO_2 . (e, f) electrochemical performance of the full lithium ion battery.

Fig. S14 (a) The digital image of the LIB full cell. The open-circuit potential of full cell is about 3.33V. The LIB full cell can drive the 2V LED lights, (b) red, (c) green, and (d) yellow.

Fig. S15 SEM images of NiO after heat treatment of *p*-NiO@NC in air atmosphere.

Fig. S16 (a) *p*-NiO@NC; (b) NiO/NC mixture; (c) NiO; (d) NC.

Fig. S17 OER performance of $p\text{-NiFe}_2\text{O}_4\text{@NC}$.

Fig. S18 OER performance of $p\text{-NiCo}_2\text{O}_4@\text{NC}$.

Fig. S19 OER performance of $p\text{-CoFe}_2\text{O}_4@\text{NC}$.

Fig. S20 Electronic structure of the NiO and N-doped NiO.

Fig. S21 XRD pattern of $p\text{-Ni}_2\text{P@NC}$.

Fig. S22 (a, b) SEM images of $p\text{-Ni}_2\text{P@NC}$; (c-d) TEM images of $p\text{-Ni}_2\text{P@NC}$.

Fig. S23 Elemental mapping of $p\text{-Ni}_2\text{P@NC}$.

Fig. S24 (a) HER polarization curves of $p\text{-Ni}_2\text{P@NC}$ and commercial Pt/C in 1.0 M KOH at 5 mV s^{-1} . (b) Tafel plots of $p\text{-Ni}_2\text{P@NC}$ and commercial Pt/C catalysts. (c) LSV curves of $p\text{-Ni}_2\text{P@NC}$ before and after the acceleration durability test for 5000 cycles.

Fig. S25 (a) CV curves of the $p\text{-Ni}_2\text{P@NC}$; (b) C_{dl} of the $p\text{-Ni}_2\text{P@NC}$.

Fig. S26 (a) HER and OER curves of the *p*-NiO@NC and *p*-Ni₂P@NC electrodes. (b) Polarization curves of the electrolyzer using *p*-NiO@NC and *p*-Ni₂P@NC as cathode and anode, respectively.

Fig. S27 Schematic illustration of the reasons for enhanced electrochemical performance.

Fig. S28 (a) The schematic and the digital image of the PV-LIB system. (b) The schematic and digital image of the LIB-AWE system.

Fig. S29 (a) The digital image of the overall water splitting driven by the LIB-AWE system with different time.

Fig. S30 (a) The digital image of the overall water splitting driven by the LIB-AWE system with different time.

Table S1 Comparison of BET surface area of the as-prepared oxides

	Surface area (m ² g ⁻¹)
<i>p</i> -NiO@NC	115
<i>p</i> -NiFe ₂ O ₄ @NC	47
<i>p</i> -CoFe ₂ O ₄ @NC	79
<i>p</i> -NiCo ₂ O ₄ @NC	37

Table S2 Comparison of cycling stability of NiO-based materials for LIBs anode.

Anode materials	Cycling stability	Refs
<i>p</i>-NiO@NC	812.5 mA h g⁻¹ (350 cycles @ 2 A g⁻¹)	This work
Porous NiO/HMPC	863 mA h g ⁻¹ (83.6% after 100 cycles @ 0.1 A g ⁻¹)	Electrochimica Acta 274 (2018) 288–297
C-coated Ni/NiO nanofibers	1046 mA h g ⁻¹ (95.8% after 100 cycles @ 0.2 A g ⁻¹)	Journal of Alloys and Compounds 750 (2018) 17–22
NiO nano octahedron	803 mA h g ⁻¹ (67.6% after 200 cycles @ 0.14 A g ⁻¹)	Electrochimica Acta 231 (2017) 272–278
Egg shell-yolk NiO/C porous composites	603 mA h g ⁻¹ (50.8% after 100 cycles @ 0.1 A g ⁻¹)	Electrochimica Acta 245 (2017) 941–948
NiO nanosheets	599 mA h g ⁻¹ (66.6% after 50 cycles @ 0.144 A g ⁻¹)	Electrochimica Acta 245 (2017) 941–948
NiO@C/pRGO	1006 mA h g ⁻¹ (62.5% after 200 cycles @ 0.2 A g ⁻¹)	Chemical Engineering Journal 332 (2018) 479–485
Ni-NiO-CNT	750 mA h g ⁻¹ (75% after 50 cycles @ 0.2 A g ⁻¹)	Electrochimica Acta 230 (2017) 98–105
NiO hollow microspheres	650 mA h g ⁻¹ (93% after 100 cycles @ 1 A g ⁻¹)	RSC Adv., 2017, 7, 31287
Hollow cubic NiO	652 mA h g ⁻¹ (72.4% after 100 cycles @ 0.1 A g ⁻¹)	Electrochimica Acta 211 (2016) 207–216
Li-doped NiO	907 mA h g ⁻¹ (96.2% after 100 cycles @ 0.4 A g ⁻¹)	Ceramics International 42 (2016) 14565–14572
NiO/CNT composites	692.3 mA h g ⁻¹ (89.3% after 100 cycles @ 0.78 A g ⁻¹)	Electrochimica Acta 213 (2016) 75–82
Porous NiO nanorods	700 mA h g ⁻¹ (94.2% after 60 cycles @ 0.1 A g ⁻¹)	<i>Part. Part. Syst. Charact.</i> 2016 , 33, 764–770
NiO-graphene-carbon fiber mats	750 mA h g ⁻¹ (125% after 350 cycles @ 0.5 A g ⁻¹)	ACS Appl. Mater. Interfaces 2016, 8, 11507–11515

Table S3 Comparison of OER activity of various nonprecious catalysts in 1 M KOH.

Catalysts	Loading (mg cm ⁻²)	η (mV) at 10 mA cm ⁻²	Tafel slop (mV dec ⁻¹)	Reference
<i>p</i> -NiO@NC	0.3	289	73.2	This work
<i>p</i> -NiFe ₂ O ₄ @NC		290	51.0	
<i>p</i> -CoFe ₂ O ₄ @NC		284	53.7	
<i>p</i> -NiCo ₂ O ₄ @NC		295	46.7	
CoP@3D Ti ₃ C ₂ -Mxene	0.20	298	51	ACS Nano 2018, 12, 8017–8028
NPC-CP	0.60	310	87.4	<i>Adv. Energy Mater.</i> 2017 , 1602928
Co-C ₃ N ₄ /CNT	0.41	>370	68.4	J. Am. Chem. Soc. 2017, 139, 3336–3339
NiCo-HS@G	0.12	302	49.6	Adv. Funct. Mater. 2017, 1704594
BP nanosheets	0.02	>500	88	Adv. Energy Mater. 2017, 1700396
N, S enriched carbon	0.42	350	273	<i>Energy Environ. Sci.</i> , 2017, 10, 742--749
Porous CoO-MoO ₂ nanocages	0.5	312	69	<i>Adv. Funct. Mater.</i> 2017 , 27, 1702324
CuO nanoparticles	0.28	290	64	Angew. Chem. Int. Ed. 2017, 56, 4792 –4796
Co ₃ O ₄ -NP/N-rGO	0.15	380	62	<i>Adv. Energy Mater.</i> 2017 , 1702222
CoO/hi-Mn ₃ O ₄	0.255	378	61	Angew. Chem. Int. Ed. 2017, 56, 1 – 6
NiCo ₂ Se ₄ -based holey nanosheets	0.285	300	53	ACS Nano 2017, 11, 9550–9557
Hollow Iron-Vanadium composite spheres	0.143	390	36.7	Angew. Chem. Int. Ed. 2017, 56, 1 – 6
CoO _x -ZIF/C	0.3	318	70.3	Adv. Funct. Mater. 2017, 1702546
C ₃ N ₄ -Ni(OH) ₂	0.2	290	77	Adv. Funct. Mater. 2017, 1705583
CoZn-NC	0.24	390	69	<i>Adv. Funct. Mater.</i> 2017 , 1700795
CuCo ₂ S ₄ nanosheets	0.7	310	86	ACS Catal. 2017, 7, 5871–5879
CCS Ni-Co NW	0.3	302	43.6	<i>Adv. Energy Mater.</i> 2017 , 7, 1601492
Ni-P porous nanoplates	0.35	300	64	<i>Energy Environ. Sci.</i> , 2016, 9, 1246--1250

Fe ₃ O ₄ @Co ₉ S ₈ /rGO	0.25	340	65.5	Adv. Funct. Mater. 2016, 26, 4712–4721
Cu ₂ O-Cu hybrid foams	5.5	350	67.52	ACS Catal. 2017, 7, 986–991
CoMnP	0.25	330	61	J. Am. Chem. Soc. 2016, 138, 4006–4009

Table S4 Comparison of HER activity of various nonprecious catalysts in alkaline solutions

Catalysts	Loading (mg cm ⁻²)	η_{10} (mV)	Tafel slop (mV dec ⁻¹)	Reference
<i>p</i>-Ni₂P@NC	0.3	115	88.2	This work
NiFe@N-doped porous carbon	0.5	130	84	Adv. Energy Mater. 2017, 1700220
N,S-CN	N/A	380	103	ACS Nano 2017, 11, 7293–7300
CuCo@NC	N/A	145	79	Adv. Energy Mater. 2017, 1700193
NiMoN	1.1	109	95	Adv. Energy Mater. 2016, 6, 1600221
CoMn-S@NiO/CC	6.9	150	147.3	ACS Catal. 2016, 6, 2797–2801
o-CoSe ₂ /CC	N/A	190	85	Adv. Mater. 2016, 28, 7527–7532
S-600	0.285	262	74	Energy Environ. Sci., 2015, 8, 3563–3571
CoNi@NC	0.32	142	104	Angew. Chem. Int. Ed. 2015, 54, 2100–2104
Co-NRCNTs	0.28	370	N/A	Angew. Chem. 2014, 126, 4461–4465
Co ₁ Mn ₁ CH/NF	5.6	180	N/A	J. Am. Chem. Soc. 2017, 139, 8320.
Ni ₂ P NPA/NF	N/A	152	86	Angew. Chem. Int. Ed. 2016, 55, 9913.
CoO _x /CN	0.42	232	N/A	J. Am. Chem. Soc. 2015, 137, 2688.
MoC _{0.654} @CNS	0.785	220	N/A	J. Am. Chem. Soc. 2015, 137, 5480.