Electronic Supplementary Information

Recent advances in cobalt phosphides based materials for energy-related applications

Jianmei Wang,‡[a,b] Zhen Liu,‡[b] Yiwei Zheng,[a] Liang Cui,[c] Wenrong Yang*[b, d] and Jingquan Liu*[a,c]

[a] College of Materials Science and Engineering, Institute for Graphene Applied Technology Innovation, Qingdao University, Qingdao, 266071, China

[b] School of Life and Environmental Sciences, Deakin University, Geelong, VIC 3217, Australia

[c] College of Materials Science and Engineering, Linyi University, Linyi 276000, China

[d] Shandong Provincial Key Laboratory of Detection Technology for Tumor Markers, College of Chemistry and Chemical Engineering, Linyi University, Linyi 276005, China.

‡ These authors contributed equally to this work.

* E-mail: jliu@qdu.edu.cn (Jingquan Liu); wenrong.yang@deakin.edu.au (Wenrong Yang);

Table S1. Compilation of overall water splitting performance for various cobalt phosphide catalysts

Materials	Loading density (mg cm^{-2})	P source	Electrolytes	$\eta_{10\ mA\ cm^{-2}}$	Ref.
CoP/Ti	2.1	NaH_2PO_2	1.0 M KOH	1.64	1
$Cu_{0.3}Co_{2.7}P$/NC	0.4	$NaH_2PO_2 \cdot H_2O$	1.0 M KOH	~1.63	2
CoP_2/RGO	0.285	NaH_2PO_2	1.0 M KOH	1.56	3
Co_2P/Co-foil	~	$NaH_2PO_2 \cdot H_2O$	1.0 M KOH	1.71	4
Co-Ni-P NWs/NiF	6.0	Red phosphorous	1.0 M KOH	~1.62	5
yolk-shelled $Ni_{0.69}Co_{0.31}$–P	3.5	NaH_2PO_2	1.0 M KOH	1.59	6
$Co_{0.7}Fe_{0.3}P$/CNT	8	$NaH_2PO_2 \cdot H_2O$	1.0 M KOH	1.50	7
Co-Pi/CoP/Ti	2	NaH_2PO_2	1.0 M KOH	1.6	8
NiCoP/NF	~1.6	PH_3 gas plasma	1.0 M KOH	1.58	9
CoP-MNA	6.2	NaH_2PO_2	1.0 M KOH	1.62	10
$Ni_{0.51}Co_{0.49}P$ film/NF	~	NaH_2PO_2	1.0 M KOH	1.57	11
CoP NS/C	0.71	$NaH_2PO_2 \cdot H_2O$	1.0 M KOH	1.54	12
CoP NW/CoF	~	Red phosphorus	1.0 M KOH	1.58	13
Co-Fe-P-1.7	0.424	$NaH_2PO_2 \cdot H_2O$	1.0 M KOH	1.60	14
CoFePO	2.187	TPP	1.0 M KOH	1.563	15
CoP/rGO-400	0.42	NaH_2PO_2	1.0 M KOH	1.71	16

Table S2. Compilation of borohydrides hydrolysis performance for various cobalt phosphide catalysts

Catalyst	Form	Activity (mL H_2 min^{-1} g_{cat}^{-1})	$NaBH_4$/NaOH (conc. wt%)	T/K	Year	Reference
Co-P	Electroplated on copper	954	10/1	303	2007	[17]
Co-P/Cu	Electroless deposition	3300	10/1	303	2008	[18]
Co-P-B	Powder	2120	0.95/1	298	2009	[19]
Co-Ni-P	Electrodeposited	2479	10/10	303	2009	[20]
Co-Ni-P-B	Powder	2400	0.95/1	298	2009	[21]
Co-P-B	Plused laser deposited film	4320	0.95/1	298	2010	[22]
Co-P/Ni	Electrolessly plated	3854	10/1	303	2010	[23]
Co-P/Cu	Electrolessly plated	1846	5/1	298	2010	[24]
Co-Ni-P/Pd-TiO_2	Electrolessly plated	460	1.13/10	298	2011	[25]
Co-P/Ni	Coating film	1490	15/5	303	2012	[26]
Co-W-P	Electrodeposited	5000	10/10	303	2012	[27]
Co-P	Electrodeposition	5965	10/10	303	2013	[28]
Co-P/Cu	Electrolessly plated	2275	5/1	303	2016	[29]
CoP	Nanosheet Nanoarray	6100	1/2	298	2016	[30]
CoP	Nanowire Nanoarray	6500	1/1	293	2017	[31]
Fe-CoP	Nanowire Nanoarray	6060	1/1	298	2017	[32]
Co-P	Electroplating	3750	2 wt% NH_3BH_3	303	2010	[33]
Co-P	Powder	1820	1 wt% NH_3BH_3	298	2014	[34]
Co-P-B	deposition	2020	0.025 M NH_3BH_3	298	2012	[35]
Co-Mo-B-P	Powder	2750	0.025 M NH_3BH_3	298	2012	[36]
CoP	Nanosheet array	42.8 (TOF)	1 wt% NH_3BH_3	298	2017	[37]

References

1 L. Yang, H. Qi, C. Zhang and X. Sun, *Nanotechnology*, 2016, **27**, 23LT01.
2 J. Song, C. Zhu, B. Z. Xu, S. Fu, M. H. Engelhard, R. Ye, D. Du, S. P. Beckman and Y. Lin, *Adv. Energy Mater.*, 2017, **7**, 1601555.
3 J. Wang, W. Yang and J. Liu, *J. Mater. Chem. A*, 2016, **4**, 4686-4690.
4 C.-Z. Yuan, S.-L. Zhong, Y.-F. Jiang, Z. K. Yang, Z.-W. Zhao, S.-J. Zhao, N. Jiang and A.-W. Xu, *J. Mater. Chem. A*, 2017, **5**, 10561-10566.
5 W. Li, X. Gao, X. Wang, D. Xiong, P.-P. Huang, W.-G. Song, X. Bao and L. Liu, *J. Power Sources*, 2016, **330**, 156-166.
6 Z. Yin, C. Zhu, C. Li, S. Zhang, X. Zhang and Y. Chen, *Nanoscale*, 2016, **8**, 19129-19138.
7 X. Zhang, X. Zhang, H. Xu, Z. Wu, H. Wang and Y. Liang, *Adv. Funct. Mater.*, 2017, **27**, 1606635.
8 L. Ai, Z. Niu and J. Jiang, *Electrochim. Acta*, 2017, **242**, 355-363.
9 H. Liang, A. N. Gandi, D. H. Anjum, X. Wang, U. Schwingenschlogl and H. N. Alshareef, *Nano Lett.*, 2016, **16**, 7718-7725.
10 Y.-P. Zhu, Y.-P. Liu, T.-Z. Ren and Z.-Y. Yuan, *Adv. Funct. Mater.*, 2015, **25**, 7337-7347.
11 J. Yu, Q. Li, Y. Li, C.-Y. Xu, L. Zhen, V. P. Dravid and J. Wu, *Adv. Funct. Mater.*, 2016, **26**, 7644-7651.
12 J. Chang, L. Liang, C. Li, M. Wang, J. Ge, C. Liu and W. Xing, *Green Chem.*, 2016, **18**, 2287-2295.
13 W. Li, X. Gao, D. Xiong, F. Xia, J. Liu, W. G. Song, J. Xu, S. M. Thalluri, M. F. Cerqueira, X. Fu and L. Liu, *Chem. Sci.*, 2017, **8**, 2952-2958.
14 T. Zhang, J. Du, P. Xi and C. Xu, *ACS Appl. Mater. Interfaces*, 2017, **9**, 362-370.
15 J. Duan, S. Chen, A. Vasileff and S. Z. Qiao, *ACS Nano*, 2016, **10**, 8738-8745.
16 L. Jiao, Y.-X. Zhou and H.-L. Jiang, *Chem. Sci.*, 2016, **7**, 1690-1695.
17 K. W. Cho and H. S. Kwon, *Catal. Today*, 2007, **120**, 298-304.
18 K. Eom, K. Cho and H. Kwon, *J. Power Sources*, 2008, **180**, 484-490.
19 N. Patel, R. Fernandes and A. Miotello, *J. Power Sources*, 2009, **188**, 411-420.
20 D.-R. Kim, K.-W. Cho, Y.-I. Choi and C.-J. Park, *Int. J. Hydrogen Energy*, 2009, **34**, 2622-2630.
21 R. Fernandes, N. Patel and A. Miotello, *Int. J. Hydrogen Energy*, 2009, **34**, 2893-2900.
22 N. Patel, R. Fernandes, N. Bazzanella and A. Miotello, *Thin Solid Films*, 2010, **518**, 4779-4785.
23 K. S. Eom and H. S. Kwon, *Int. J. Hydrogen Energy*, 2010, **35**, 5220-52263.
24 X. Zhang, J. Zhao, F. Cheng, J. Liang, Z. Tao and J. Chen, *Int. J. Hydrogen Energy*, 2010, **35**, 8363-8369.
25 M. Rakap, E. E. Kalu and S. Özkar, *J. Alloys Compd.*, 2011, **509**, 7016-7021.
26 T. H. Oh and S. Kwon, *Int. J. Hydrogen Energy*, 2012, **37**, 15925-15937.
27 Y. Guo, Z. Dong, Z. Cui, X. Zhang and J. Ma, *Int. J. Hydrogen Energy*, 2012, **37**, 1577-1583.
28 Y. Guo, Q. Feng, Z. Dong and J. Ma, *J. Mol. Catal. A: Chem.*, 2013, **378**, 273-278.
29 Y. Wang, Y. Shen, K. Qi, Z. Cao, K. Zhang and S. Wu, *Renewable Energy*, 2016, **89**, 285-294.
30 T. Liu, K. Wang, G. Du, A. M. Asiri and X. Sun, *J. Mater. Chem. A*, 2016, **4**, 13053-13057.
31 L. Cui, Y. Xu, L. Niu, W. Yang and J. Liu, *Nano Res.*, 2017, **10**, 595-604.
32 C. Tang, R. Zhang, W. Lu, L. He, X. Jiang, A. M. Asiri and X. Sun, *Adv. Mater.*, 2017, **29**, 1602441-n/a.
33 K. Eom, K. Cho and H. Kwon, *Int. J. Hydrogen Energy*, 2010, **35**, 181-186.
34 H. Guo, X. Liu, Y. Hou, Q. S. Xie, L. Wang, H. Geng and D. L. Peng, *J. Power Sources*, 2014, **260**, 100-108.
35 N. Patel, A. Kale and A. Miotello, *Appl. Catal. B*, 2012, **111**, 178-184.
36 R. Fernandes, N. Patel, A. Miotello and L. Calliari, *Top. Catal.*, 2012, **55**, 1032-1039.
37 C. Tang, F. Qu, A. M. Asiri, Y. Luo and X. Sun, *Inorg. Chem. Front.*, 2017, **4**, 659-662.