Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Porous tremella-like NiMoP/CoP network electrodes as an efficient electrocatalyst

Jianzhi Wang[#], Jie Yang[#], Fuhua Huang, Yuru Li, Yu Luo, Yanan Xue, Ning Cai, Hui Li*, Faquan Yu*

Key Laboratory for Green Chemical Process of Ministry of Education,

Hubei Key Laboratory for Novel Reactor and Green Chemistry Technology

Hubei Engineering Research Center for Advanced Fine Chemicals

School of Chemical Engineering and Pharmacy,

Wuhan Institute of Technology, Wuhan 430073, China

#These authors contributed to the work equllly and should be regarded as co-first authors.

*Corresponding author:

Hui Li, PhD; Faquan Yu, Professor, PhD

Wuhan Institute of Technology

LiuFang Campus, No.206, Guanggu 1st road, Wuhan 430205, Hubei, China

E-mail address: sodium2008@163.com; fyu@wit.edu.cn

Tel: (86-27) 87194980; Fax: (86-27) 87194465

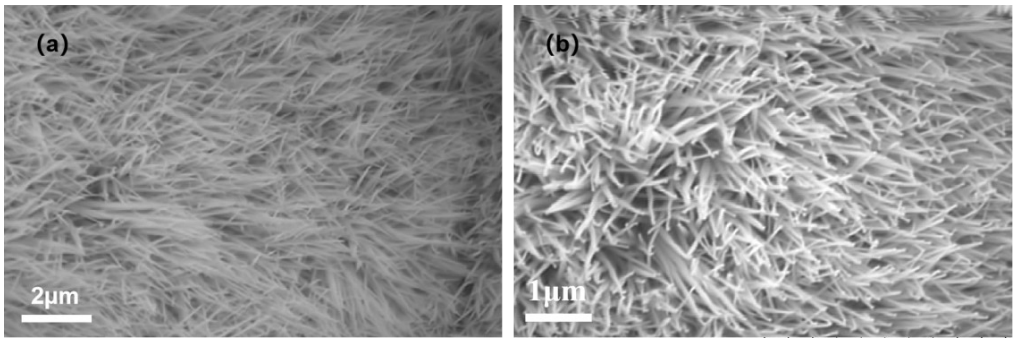

Figure S1. SEM images of $Co(OH)_2$/NF nanostructures at different magnifications.

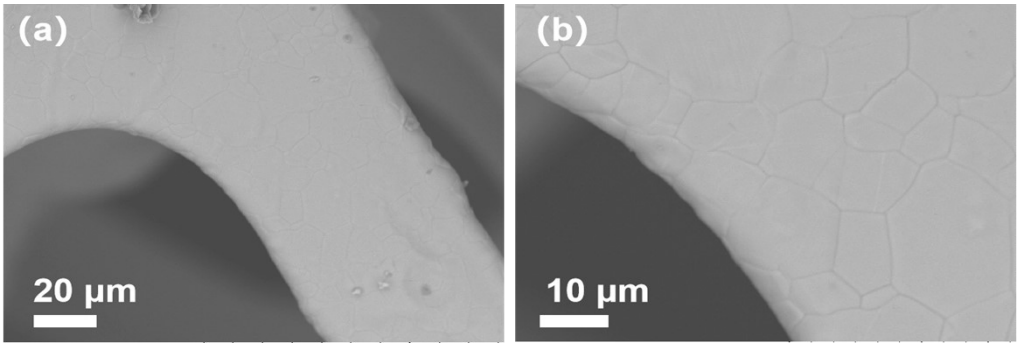

Figure S2. (a, b) SEM images of NF at different magnifications.

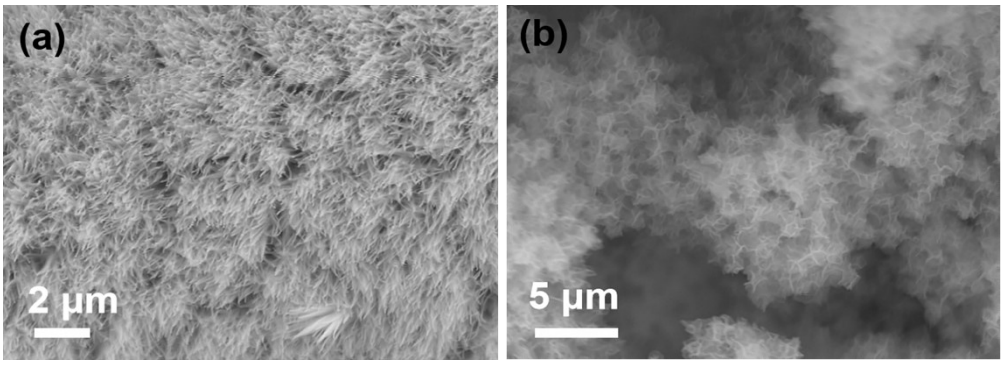

Figure S3. (a) SEM image of Co_3O_4/NF and (b) SEM image of $NiMoO_4$/NF.

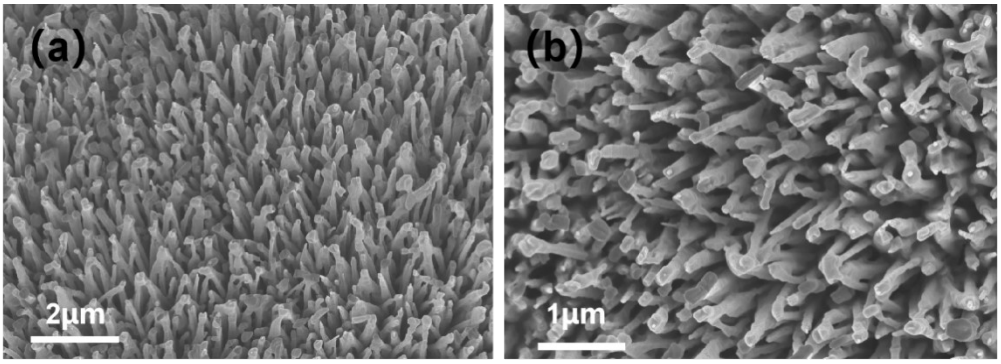

Figure S4. SEM images of CoP/NF nanostructures at different magnifications.

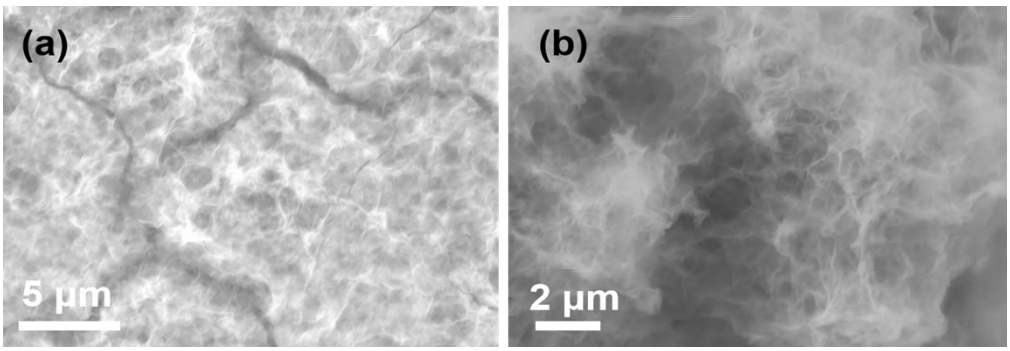

Figure S5. SEM images of NiMoP/NF nanostructures at different magnifications.

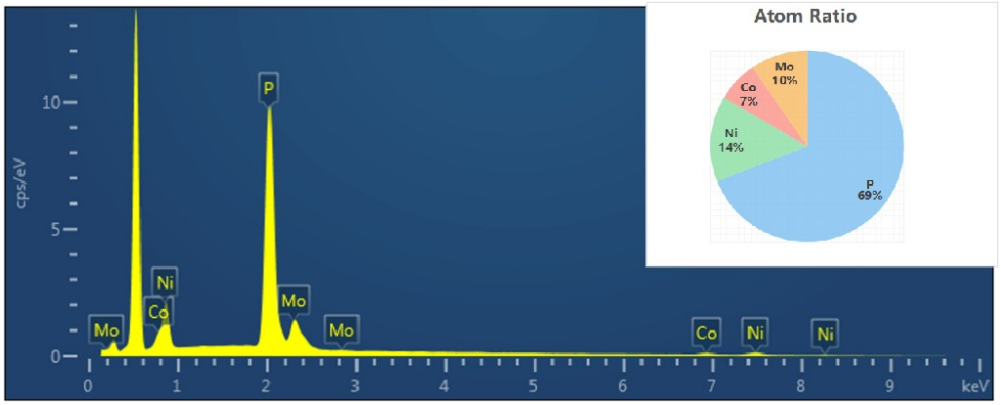

Figure S6. Energy dispersive spectrum of NiMoP/CoP/NF and the atomic ratio (Co, Mo, Ni and P) of NiMoP/CoP/NF (inset).

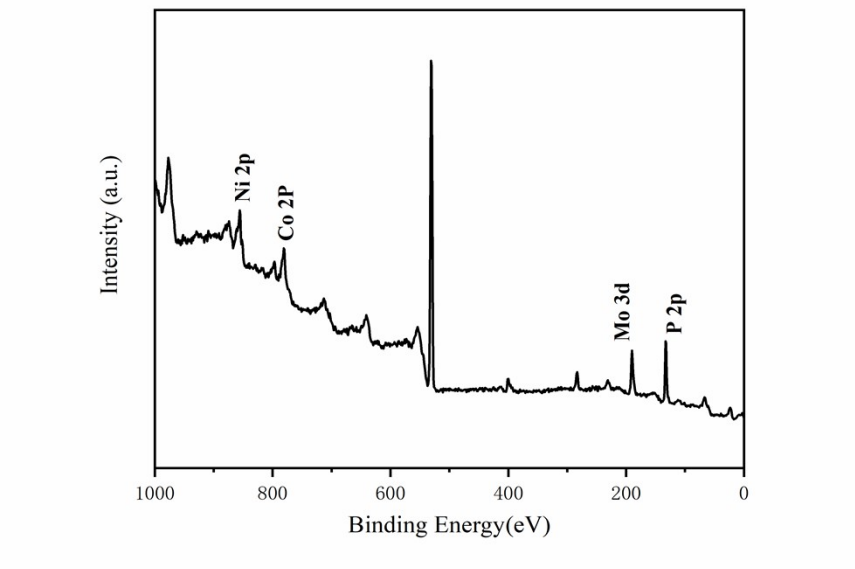

Figure S7. XPS spectra of survey scan of NiMoP/CoP /NF.

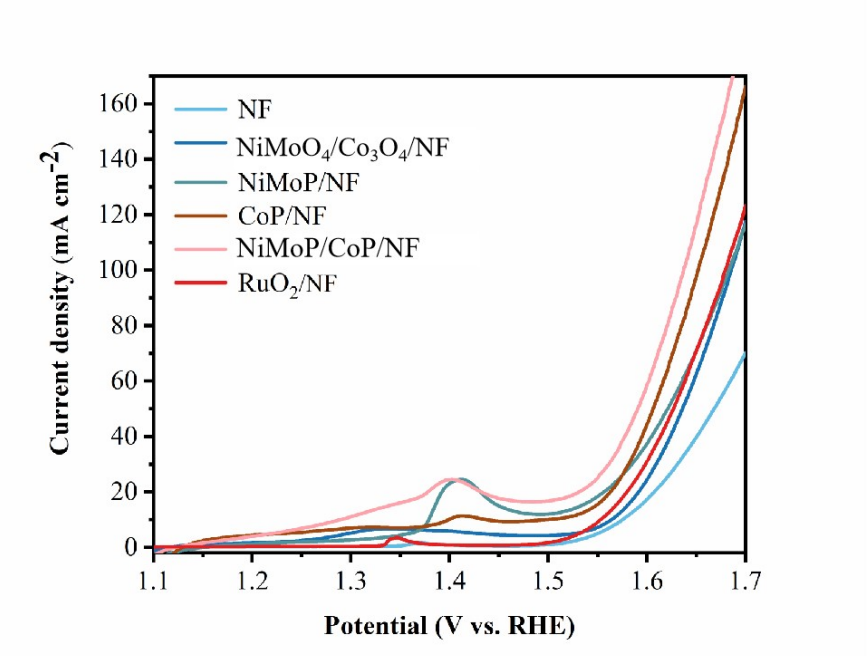

Figure S8. Linear sweep polarization curves of the catalysts in 1M KOH.

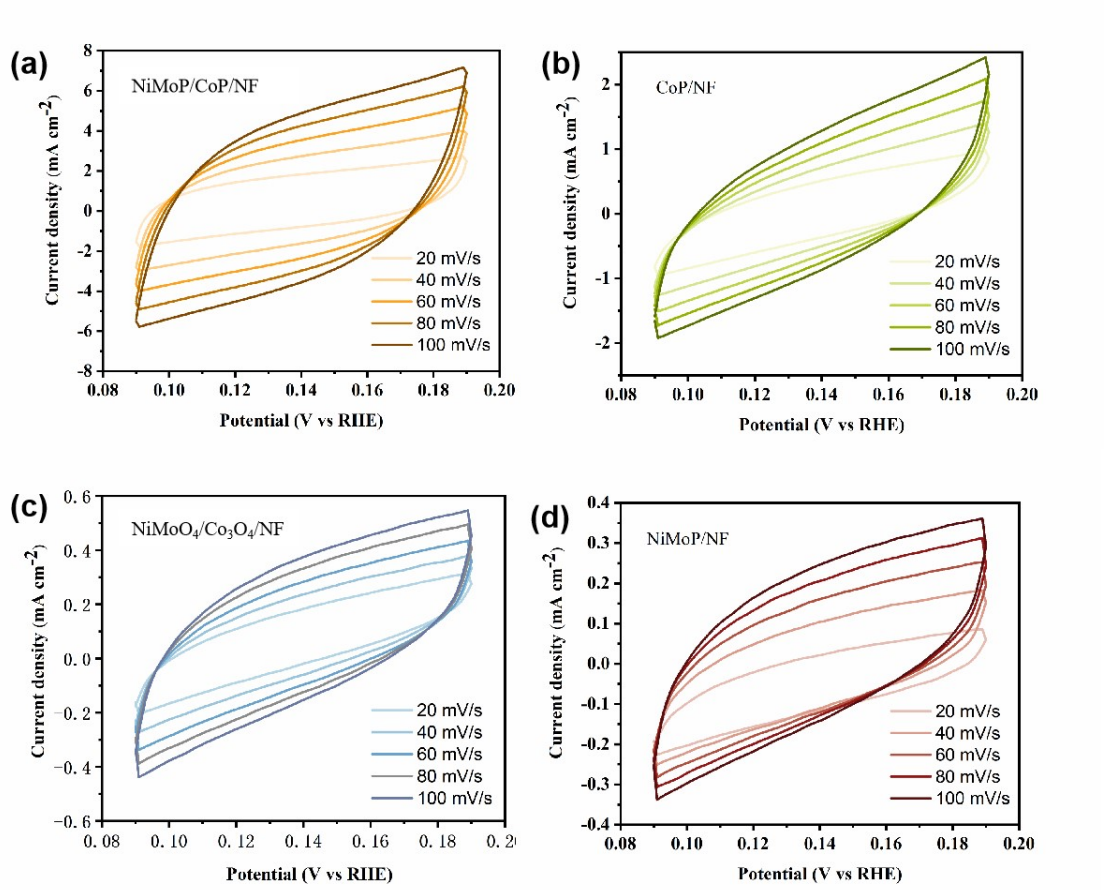

Figure S9. Cyclic voltammetry curves of various catalysts in the region of 0.09~0.19 V vs. RHE at different scan rates: (a) NiMoP/CoP /NF, (b) CoP/NF, (c) $NiMoO_4/Co_3O_4$/NF and (d) NiMoP/NF.

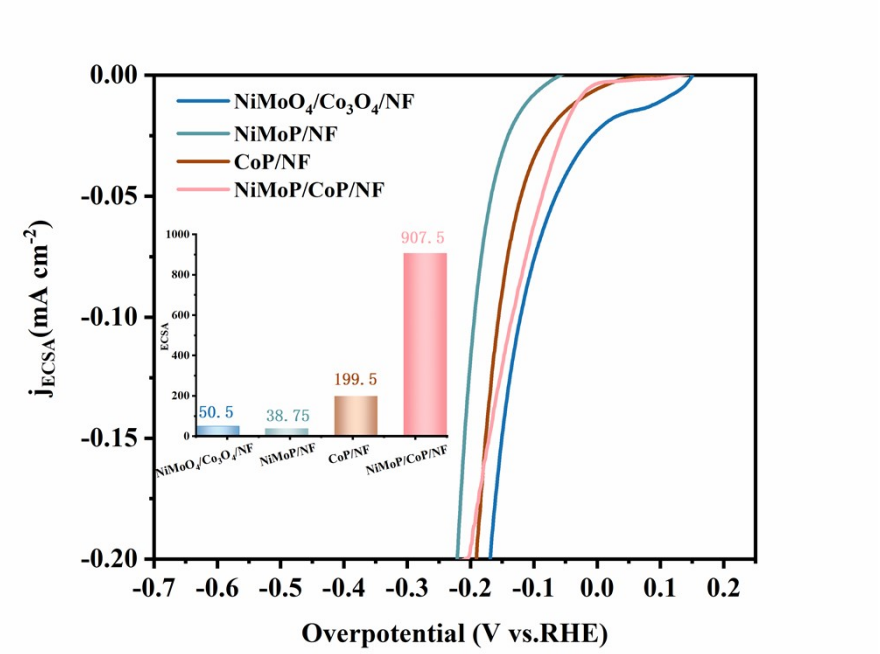

Figure S10. ECSA-normalized LSV curves (Inset: a bar chart of the ECSA).

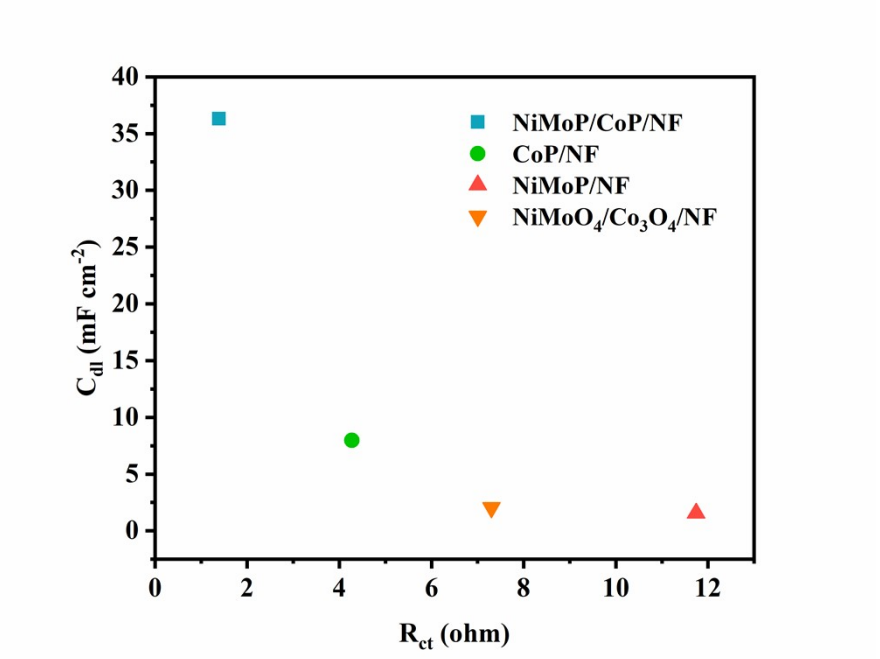

Figure S11. The trend in C_{dl} compared to the trend in R_{ct} of various catalysts.

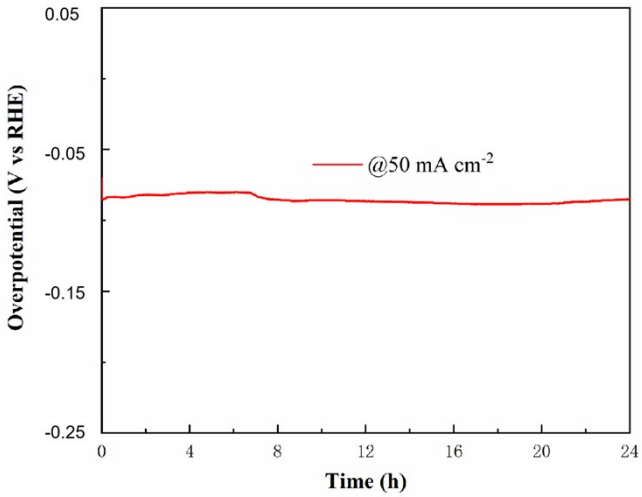

Figure S12. Chronopotentiometry curve of at a constant current density of 50 mA cm^{-2} for 24 h in 1.0 M KOH.

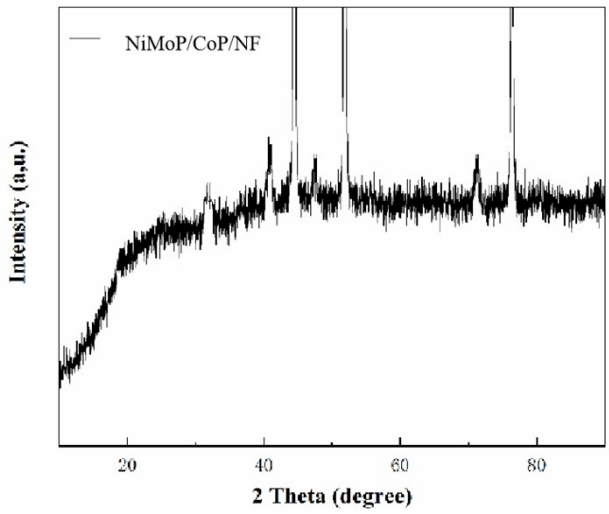

Figure S13. The XRD patterns of NiMoP/CoP/NF after durability test.

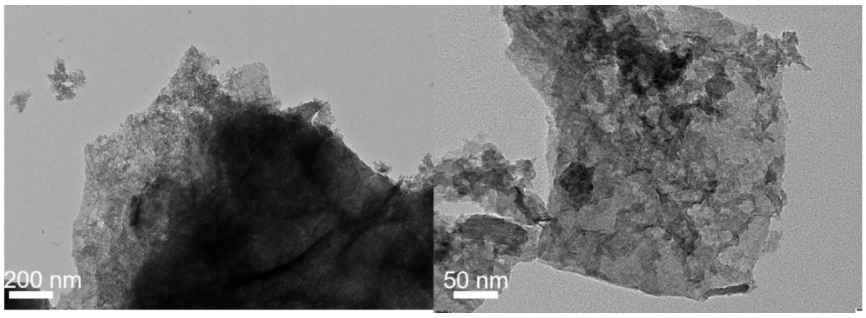

Figure S14. TEM image of NiMoP/CoP/NF after durability test.

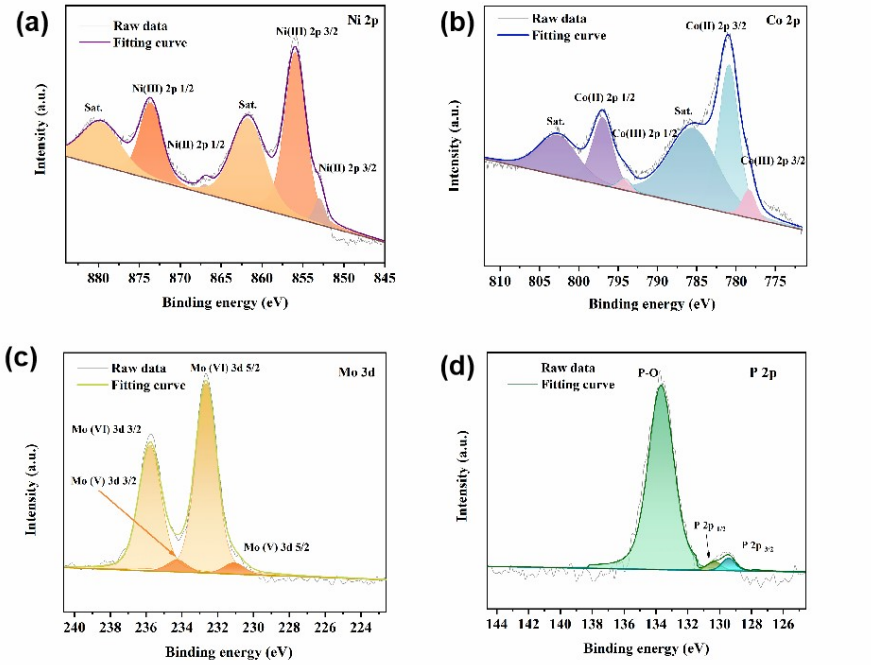

Figure S15. XPS spectra of NiMoP/CoP/NF catalyst after durability test: (a) Ni 2p, (b) Co 2p, (c) Mo 3d and (d) P 2p.

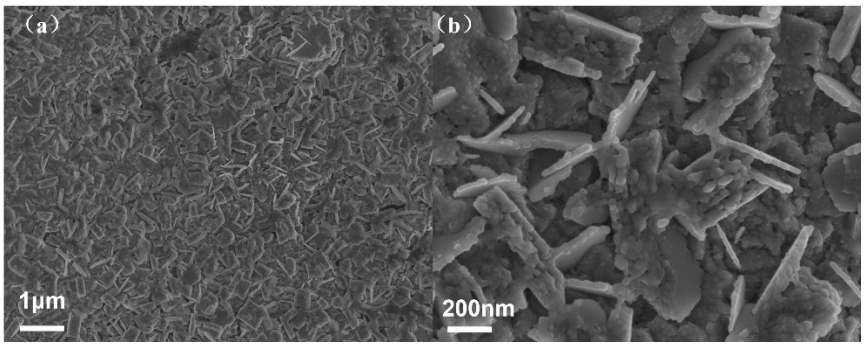

Figure S16. SEM of NiMoP/CoP catalyst after durability test.

Table S1. XPS analysis of Mo species.

	Mo^{4+}		Mo^{5+}		Mo^{6+}	
	3d 5/2	**3d 3/2**	**3d 5/2**	**3d 3/2**	**3d 5/2**	**3d 3/2**
FWHM	1.23	1.23	1.41	1.41	1.5	1.5
Area%	23.57	15.62	11.87	7.92	24.62	16.41
B.E. (eV)	230.4	233.5	231.6	234.7	232.97	236.1

Table S2. XPS analysis of Co species.

	Co^{2+}		Co^{3+}		sat	
	2p 3/2	2p 1/2	2p 3/2	2p 1/2		
FWHM	2.41	2.52	1.68	1.53	6.82	5.75
Area %	24.25	12.21	3.75	1.47	41.69	16.69
B.E. (eV)	781.3	797.5	777.7	792.7	784.5	802.2

Table S3. XPS analysis of Ni species.

	Ni^{2+}		Ni^{3+}		sat	
	2p 3/2	2p 1/2	2p 3/2	2p 1/2		
FWHM	1.59	1.76	2.50	2.50	5.59	5.38
Area %	8.4	4.4	30.72	13.14	27.37	17.97
B.E. (eV)	852.5	869.7	856.2	874.2	861.0	879.1

Table S4. Comparison of the HER activity of the NiMoP/CoP/NF with other reported TMPs catalysts in 1 M KOH.

Electrocatalyst	Overpotential (mV) (η@10mA cm^{-2})	Tafel slope (mV dec^{-1})	Electrolyte	Reference
NiMoP/CoP/NF	38	83.0	1.0 M KOH	this work
CoP/NF	121	116.0	1.0 M KOH	this work
NiMoP/NF	231	91.0	1.0 M KOH	this work
$NiMoO_4/Co_3O_4$/NF	169	154.0	1.0 M KOH	this work
Cu_3P NW/CF	143	67.0	1.0 M KOH	[1]
CoP/CNT	122	54.0	1.0 M KOH	[2]
CoP_3/CoMoP/NF	125	61.1	1.0 M KOH	[3]
NiCoP-CoP/NF	73	91.3	1.0 M KOH	[4]

V-Ni_2P NSAs/CC	85	95.0	1.0 M KOH	5
Ni_2P/Ni/NF	98	72	1.0 M KOH	6
NiCoP/CC	62	66.5	1.0 M KOH	7
NiS/Ni_2P	111	45.4	1.0 M KOH	8
CoP-FeP	71	42	1.0 M KOH	9

Reference

1 J. Tian, Q. Liu, N. Cheng, A. M. Asiri and X. Sun, *Angew Chem*, 2014, **126**, 9731–9735.

2 Q. Liu, J. Tian, W. Cui, P. Jiang, N. Cheng, A. M. Asiri and X. Sun, *Angew Chem Int*, 2014, **53**, 6710–6714.

3 D. Jiang, Y. Xu, R. Yang, D. Li, S. Meng and M. Chen, *ACS Sustain Chem Eng*, 2019, **7**, 9309–9317.

4 R. Boppella, J. Tan, W. Yang and J. Moon, *Adv Funct Mater*, 2019, **29**, 1807976.

5 L. Wen, J. Yu, C. Xing, D. Liu, X. Lyu, W. Cai and X. Li, *Nanoscale*, 2019, **11**, 4198–4203.

6 M. Wang, C. Ye, H. Liu, M. Xu and S. Bao, *Angew Chem*, 2018, **130**, 1981–1985.

7 C. Wang, J. Jiang, T. Ding, G. Chen, W. Xu and Q. Yang, *Adv Mater Interfaces*, 2016, **3**, 1500454.

8 X. Xiao, D. Huang, Y. Fu, M. Wen, X. Jiang, X. Lv, M. Li, L. Gao, S. Liu and M. Wang, *ACS Appl Mater Interfaces*, 2018, **10**, 4689–4696.

9 Z. Niu, C. Qiu, J. Jiang and L. Ai, *ACS Sustain Chem Eng*, 2018, **7**, 2335–2342.