Electronic Supplementary Information

In situ growth of free-standing perovskite hydroxide electrocatalysts for efficient overall water splitting

Shanlin Li[a,b], Ruguang Ma[b,c*], Yue Lu[a], Yu Pei[b], Minghui Yang[c,d], Jiacheng Wang[b,c,*], Danmin Liu[a,*]

[a] Beijing Key Laboratory of Microstructure and Properties of Solids, Institute of Microstructure and Property of Advanced Materials, Beijing University of Technology, Beijing 100124, China

[b] The State Key Laboratory of High Performance Ceramics and Superfine Microstructure, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai 200050, China

[c] Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences, 100049 Beijing, China

[d] Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo 315201, China.

Corresponding authors.
E-mail addresses: maruguang@mail.sic.ac.cn (R. Ma); dmliu@bjut.edu.cn (D. Liu); jiacheng.wang@mail.sic.ac.cn (J. Wang).

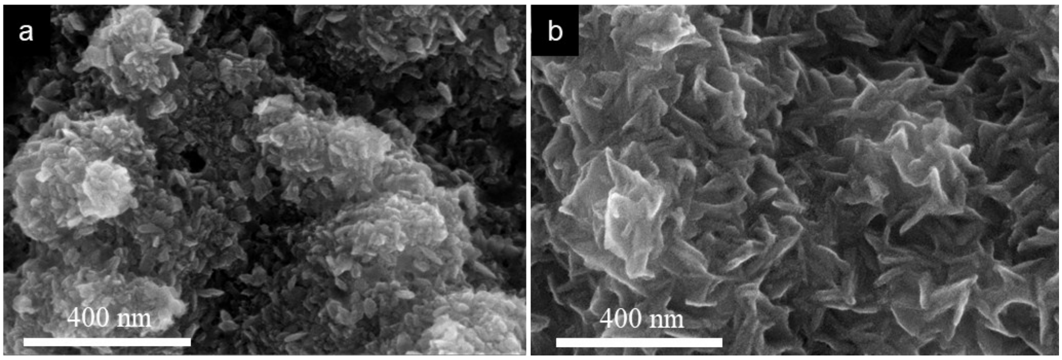

Fig. S1 SEM images of (a-b) SnFeNi/CF and (c-d) Pt-SnFeNi/CF.

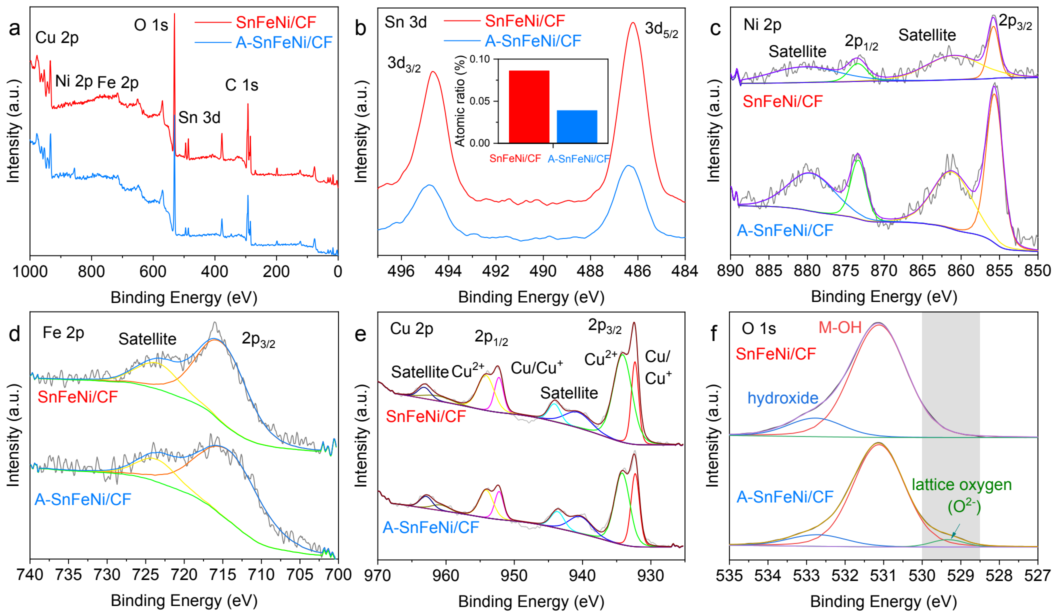

Fig. S2 High-resolution full spectra of SnFeNi/CF and A-SnFeNi/CF. (a−f) High-resolution full spectra of XPS, Sn 3d, Ni2p, Fe 2p, Cu 2p, O 1s.

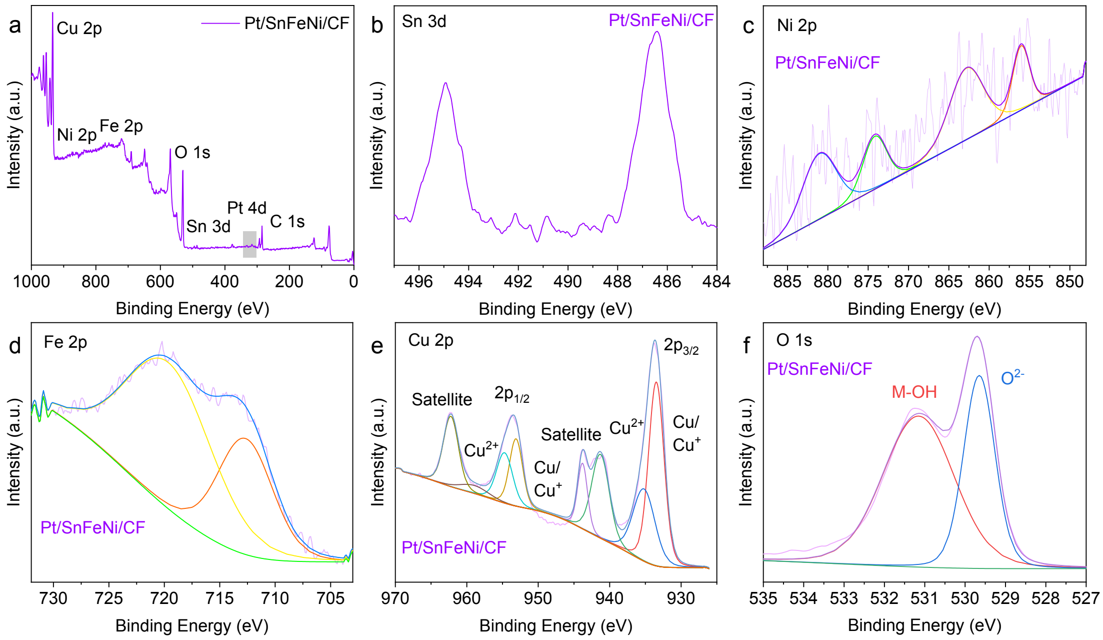

Fig. S3 High-resolution full spectra of Pt-SnFeNi/CF. (a–f) High-resolution full spectra of XPS, Sn 3d, Ni2p, Fe 2p, Cu 2p, O 1s.

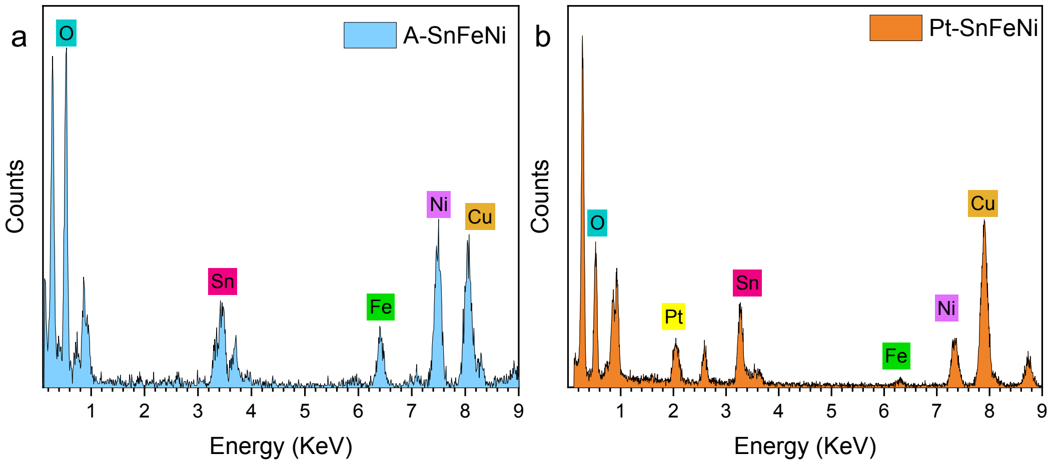

Fig. S4 EDS spectrum of (a) A-SnFeNi and (b) Pt-SnFeNi.

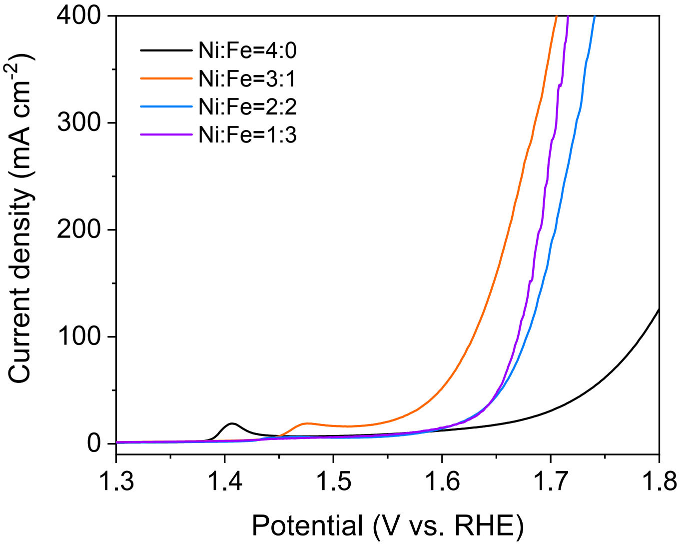

Fig. S5 Effect of Ni:Fe in perovskite hydroxides on the catalytic activity.

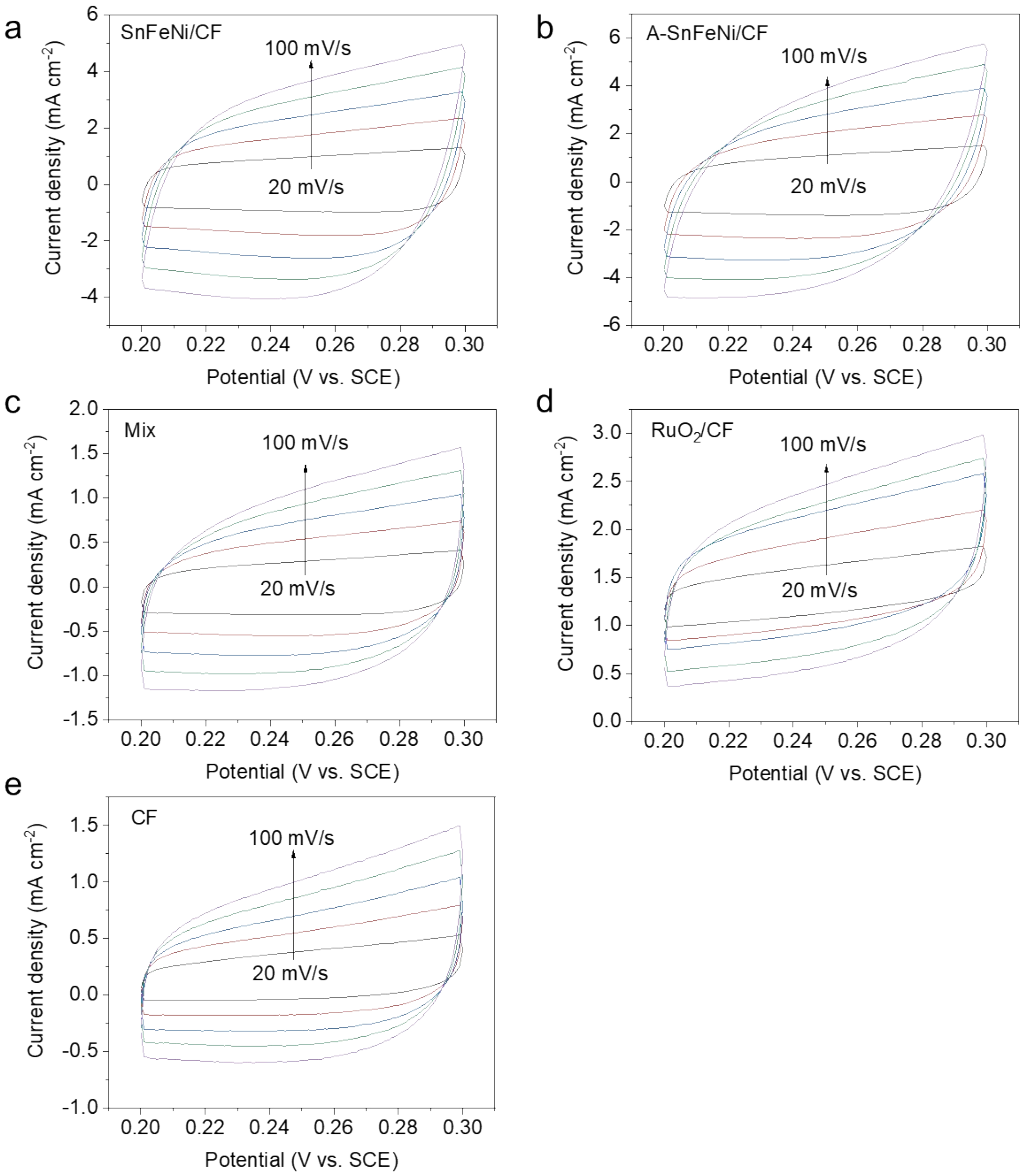

Fig. S6 Cyclic voltammetry curves of (a) SnFeNi/CF, (b) A-SnFeNi/CF, (c) Mix, (d) RuO_2/CF, and (e) CF at different scan rates.

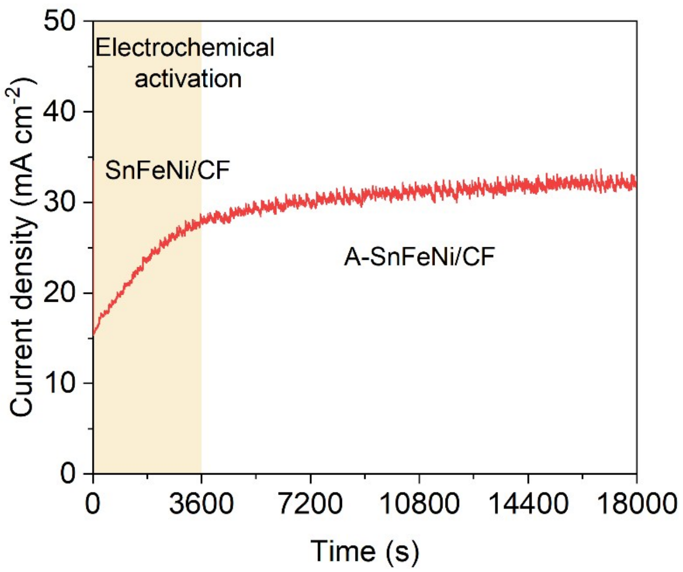

Fig. S7 Long-term stability of SnFeNi/CF.

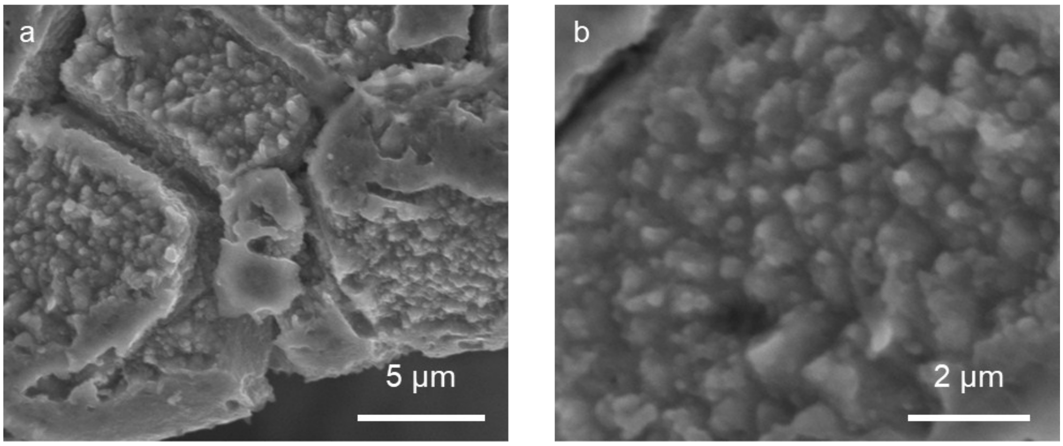

Fig. S8 SEM images of A-SnFeNi/CF electrocatalysts after durability tests.

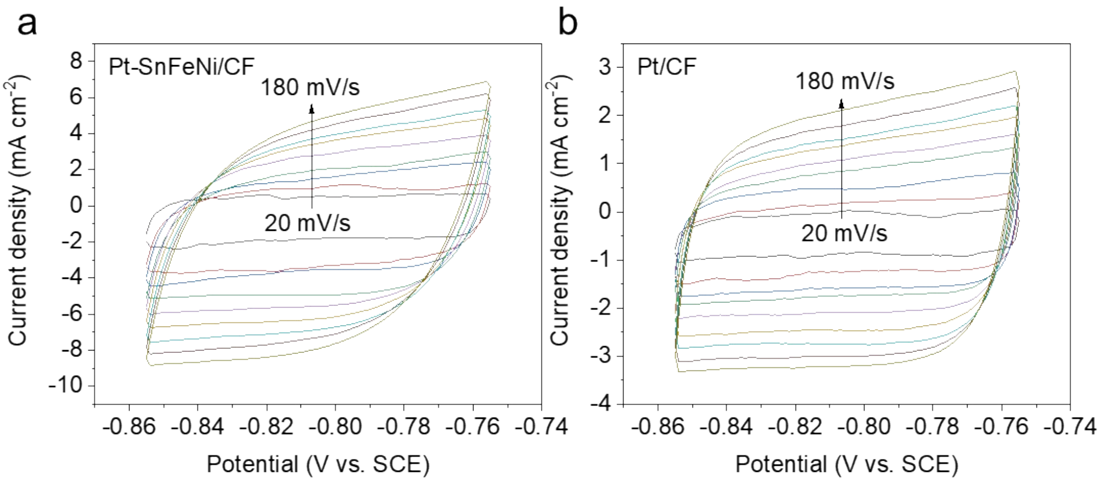

Fig. S9 Cyclic voltammetry curves of (a) Pt-SnFeNi/CF and (b) Pt/CF at different scan rates.

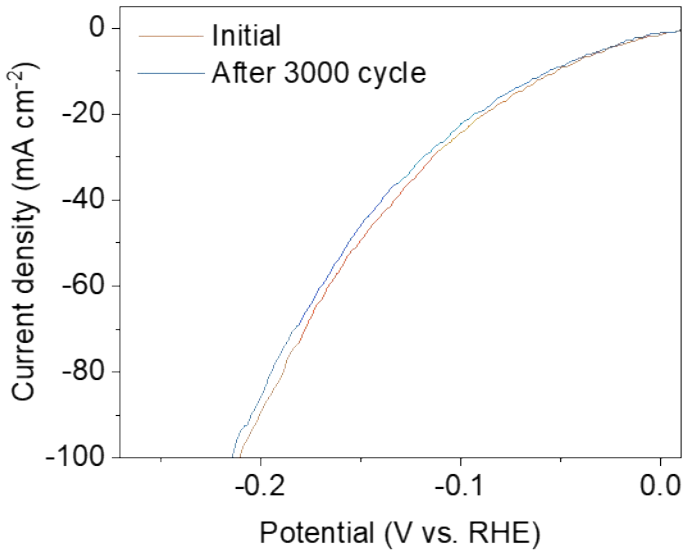

Fig. S10 The Pt-SnFeNi/CF polarization curves before and after 3000 CV cycles between -0.15 and +0.1 V vs. RHE at 100 mV s^{-1}.

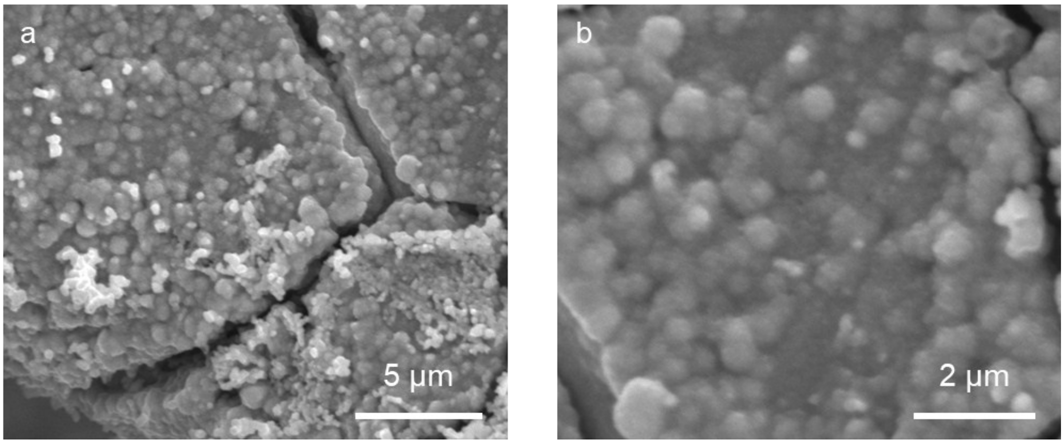

Fig. S11 SEM images of Pt-SnFeNi/CF catalyst after 3000 CV cycles.

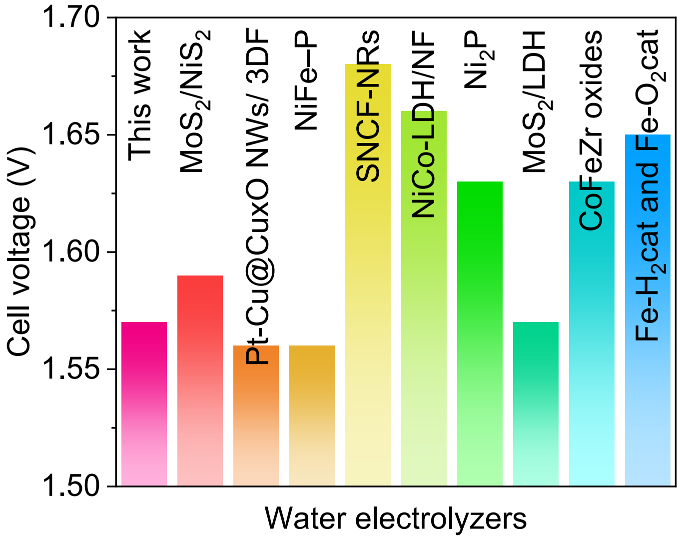

Fig. S12 Comparison of the cell voltages to achieve 10 mAcm−2 among different water alkaline electrolyzers.

Table S1 Atomic ratio of Sn:Ni and Fe:Ni of SnFeNi/CF, A-SnFeNi/CF, and Pt-SnFeNi/CF electrocatalysts characterized by ICP.

Sample	Element	Loading (mg/kg)	Sn:Ni (atomic ratio)	Fe:Ni (atomic ratio)
SnFeNi/CF	Cu	Over	0.072	0.087
	Fe	107.33		
	Ni	1297.56		
	Sn	188.48		
A-SnFeNi/CF	Cu	Over	0.027	0.112
	Fe	129.32		
	Ni	1218.29		
	Sn	67.55		
Pt-SnFeNi/CF	Cu	Over	0.045	0.039
	Fe	50.09		
	Ni	1355.29		
	Pt	569.57		
	Sn	124.30		

Table S2 Comparison of the overall water splitting activities.

Catalyst	Cell voltages at 10 mA cm^{-2} (V)	Source
Pt-SnFeNi/CF and A-SnFeNi/CF	1.57	This work
MoS_2/NiS_2	1.59	J. Lin *et al.*, Defect-Rich Heterogeneous MoS2/NiS2 Nanosheets Electrocatalysts for Efficient Overall Water Splitting. *Advanced Science*, (2019).
Pt-Cu@CuxO NWs/ 3DF	1.56	D. T. Tran, H. T. Le, T. L. Luyen Doan, N. H. Kim, J. H. Lee, Pt nanodots monolayer modified mesoporous Cu@CuxO nanowires for improved overall water splitting reactivity. *Nano Energy* **59**, 216-228 (2019).
NiFe–P	1.56	J. Xing, H. Li, M. Ming-Cheng Cheng, S. M. Geyer, K. Y. S. Ng, Electro-synthesis of 3D porous hierarchical Ni–Fe phosphate film/Ni foam as a high-efficiency bifunctional electrocatalyst for overall water splitting. *Journal of Materials Chemistry A* **4**, 13866-13873 (2016).
SNCF-NRs	1.68	Y. L. Zhu *et al.*, A Perovskite Nanorod as Bifunctional Electrocatalyst for Overall Water Splitting. *Advanced Energy Materials* **7**, (2017).
NiCo-LDH/NF	1.66	W. Liu *et al.*, Nickel-cobalt-layered double hydroxide nanosheet arrays on Ni foam as a bifunctional electrocatalyst for overall water splitting. *Dalton Trans* **46**, 8372-8376 (2017).
Ni_2P	1.63	L.-A. Stern, L. Feng, F. Song, X. Hu, Ni2P as a Janus catalyst for water splitting: the oxygen evolution activity of Ni2P nanoparticles. *Energy & Environmental Science* **8**, 2347-2351 (2015).
MoS_2/LDH	1.57	P. Xiong *et al.*, Interface Modulation of Two-Dimensional Superlattices for Efficient Overall Water Splitting. *Nano Lett.*, (2019).
CoFeZr oxides	1.63	L. Huang *et al.*, Zirconium-Regulation-Induced Bifunctionality in 3D Cobalt-Iron Oxide Nanosheets for Overall Water Splitting. *Adv. Mater.*, e1901439 (2019).
Fe-H_2 cat and Fe-O_2 cat	1.65	X. Zou *et al.*, In Situ Generation of Bifunctional, Efficient Fe-Based Catalysts from Mackinawite Iron Sulfide for Water Splitting. *Chem* **4**, 1139-1152 (2018).