Electronic supplementary information (ESI)

W_2C nanodots decorated CNT networks as highly efficient and stable electrocatalyst for hydrogen evolution in acidic and alkaline media†

Yang Hu,[a] Bo Yu,[a] Wenxin Li,[a] Manigandan Ramadoss,[a] Yuanfu Chen*[a]

[a] School of Electronic Science and Engineering, and State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China, Chengdu 610054, PR China

*Corresponding authors, emails: yfchen@uestc.edu.cn, Tel.: +86 028 83202710.

Address: State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China, Chengdu 610054, PR China

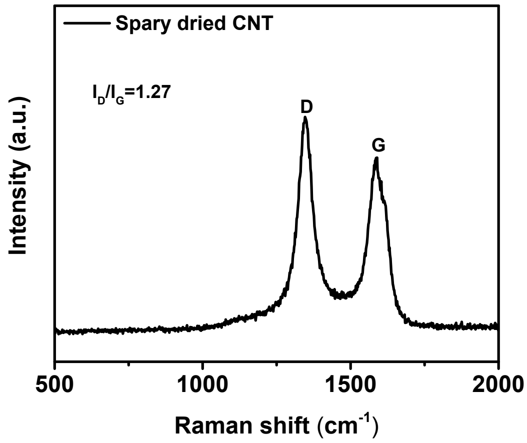


Fig. S1 Raman spectra of spray-dried CNT.

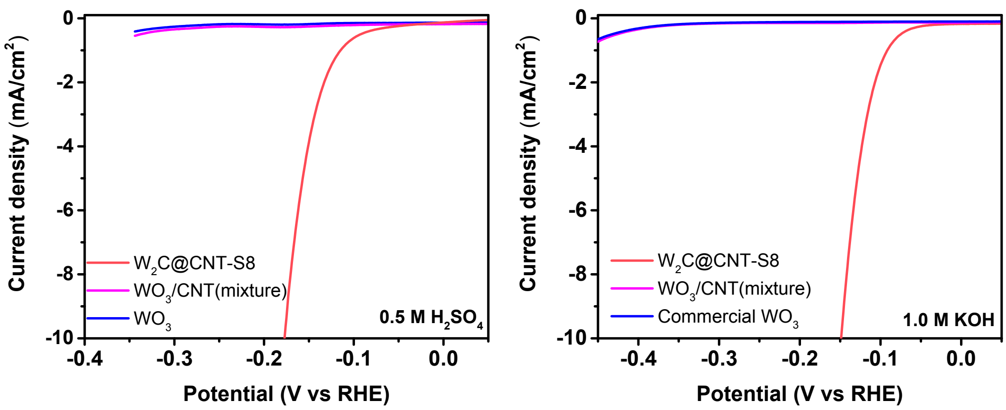
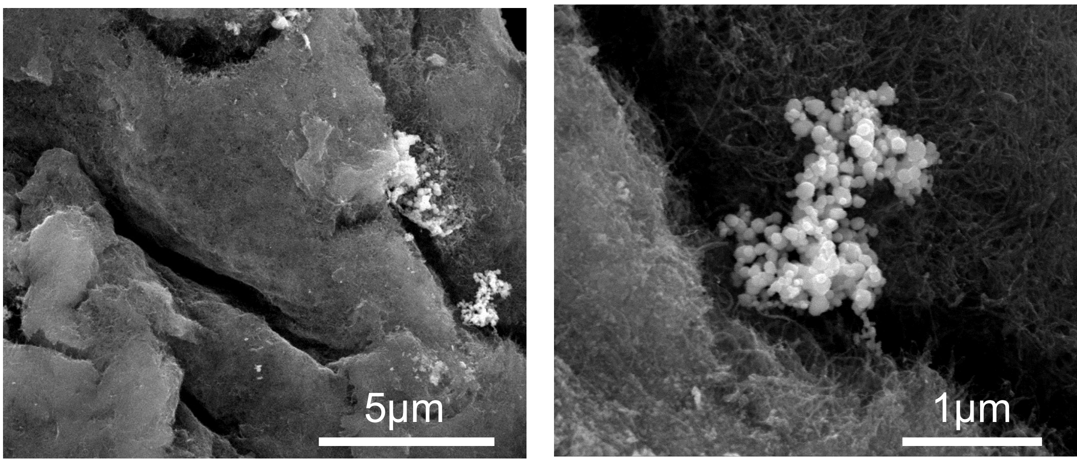


Fig. S2 Polarization curves of the W_2C@CNT-S8, commercial WO_3/CNT mixture and commercial WO_3 in 0.5 M H_2SO_4 and 1.0 M KOH.

In order to further check the HER activity of WO_3, the HER performance in both acidic and alkaline media of commercial WO_3 and commercial WO_3/CNT mixture has been performed, as shown in the Fig. S2. From Fig. S2, compared to W_2C@CNT-S8, the WO_3/CNT mixture and commercial WO_3 show much worse HER catalytic activities.



Fi

g. S3 SEM images of the W_2C/CNT.

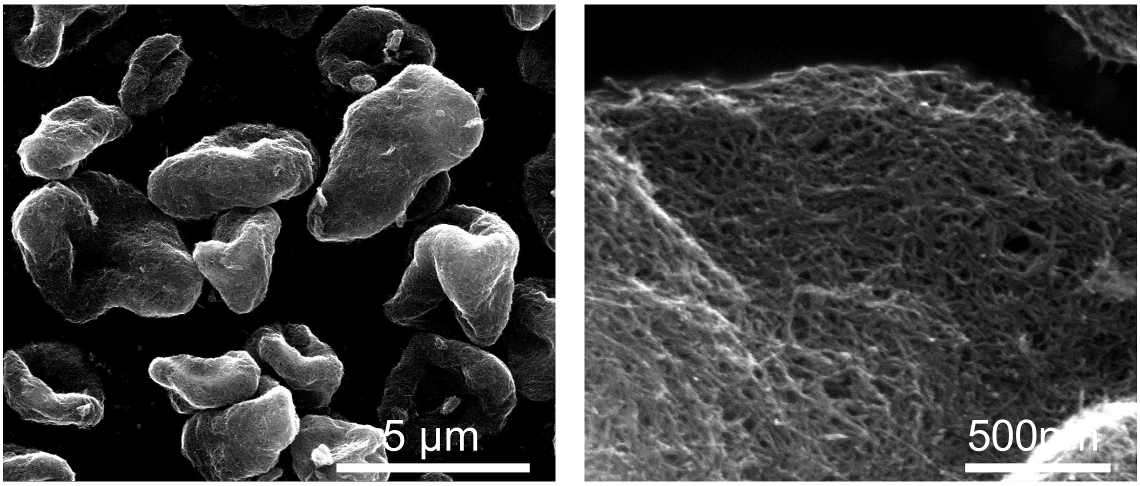


Fig. S4 SEM images of the pure CNT networks.

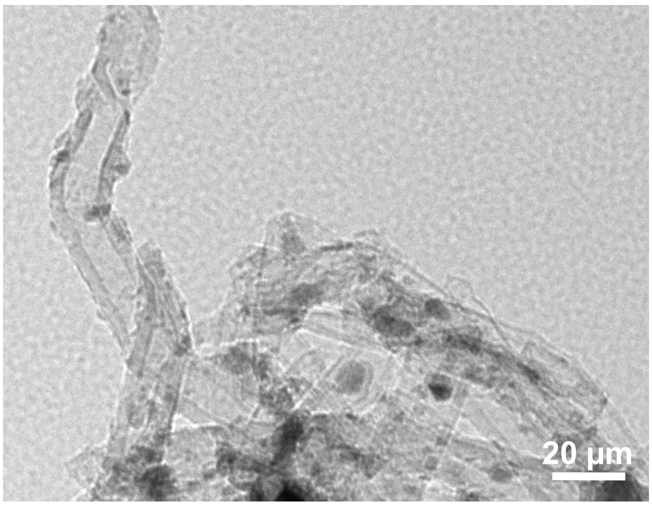


Fig. S5 TEM image of W_2C@CNT-S8.

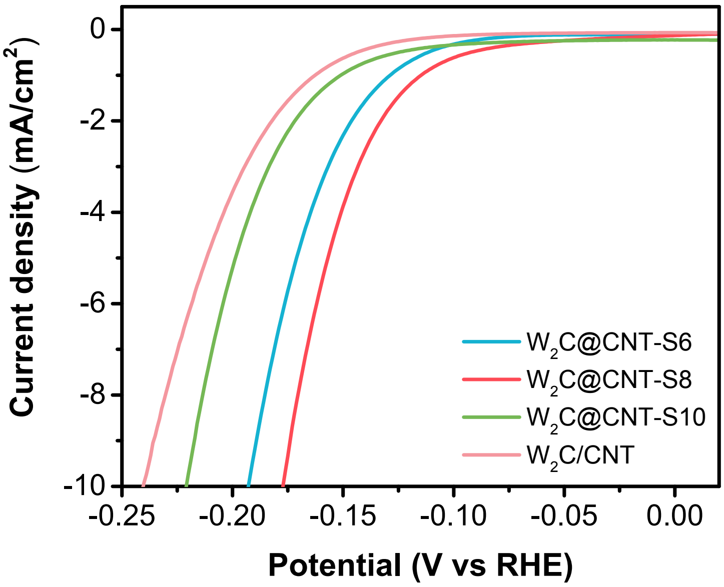


Fig. S6 Polarization curves for W_2C/CNT-S6, W_2C/CNT-S8, W_2C/CNT-S10 and W_2C/CNT in 0.5 M H_2SO_4 with a scan rate of 5 mV s^{-1}.

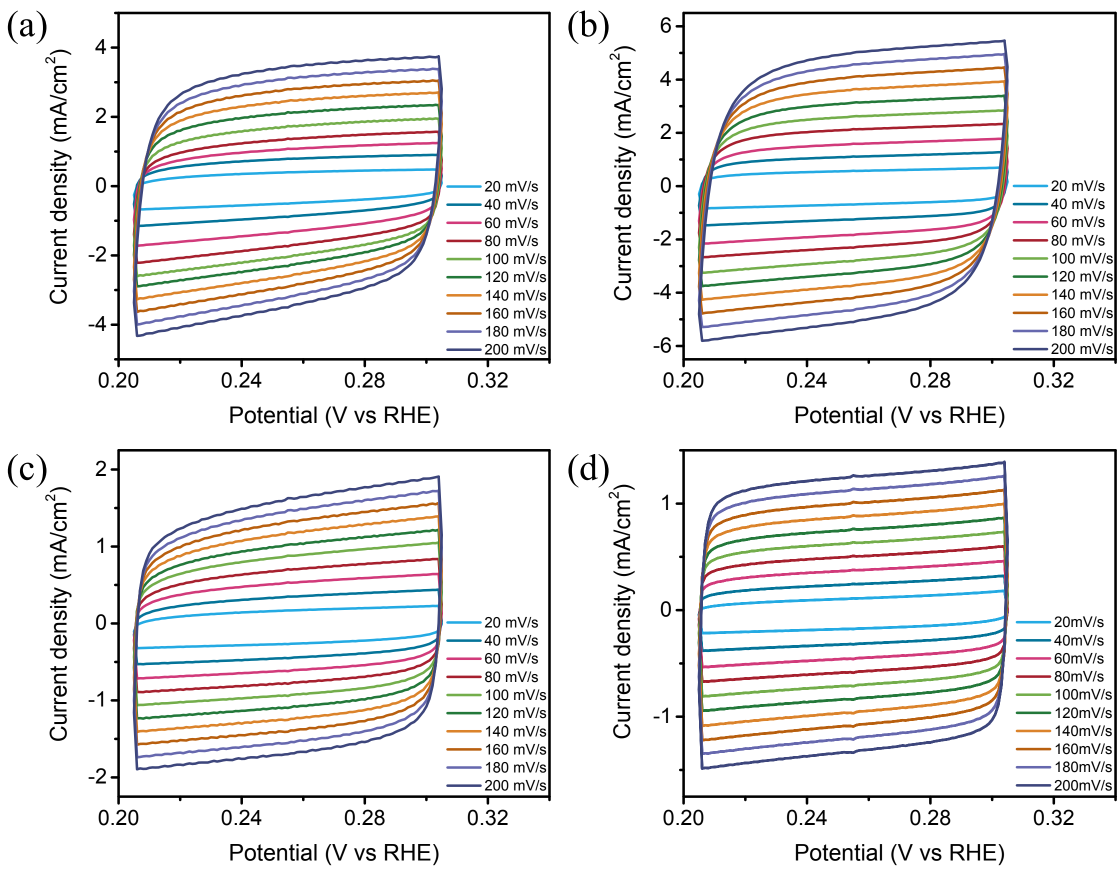


Fig. S7 The cyclic voltammograms (CV) of W_2C@CNT-S6 (a), W_2C@CNT-S8 (b), W_2C@CNT-S10 (c) and W_2C/CNT (d) are measured at various scan rates range from 0.205-0.305 V (vs. RHE) in 0.5 M H_2SO_4 solution.

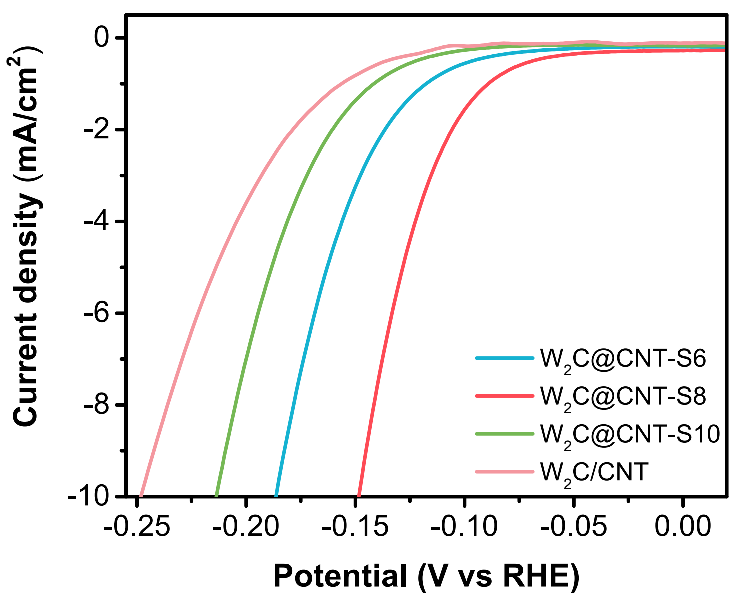


Fig. S8 Polarization curves for W_2C/CNT-S6, W_2C/CNT-S8, W_2C/CNT-S10 and W_2C/CNT in 1 M KOH with a scan rate of 5 mV s^{-1}.

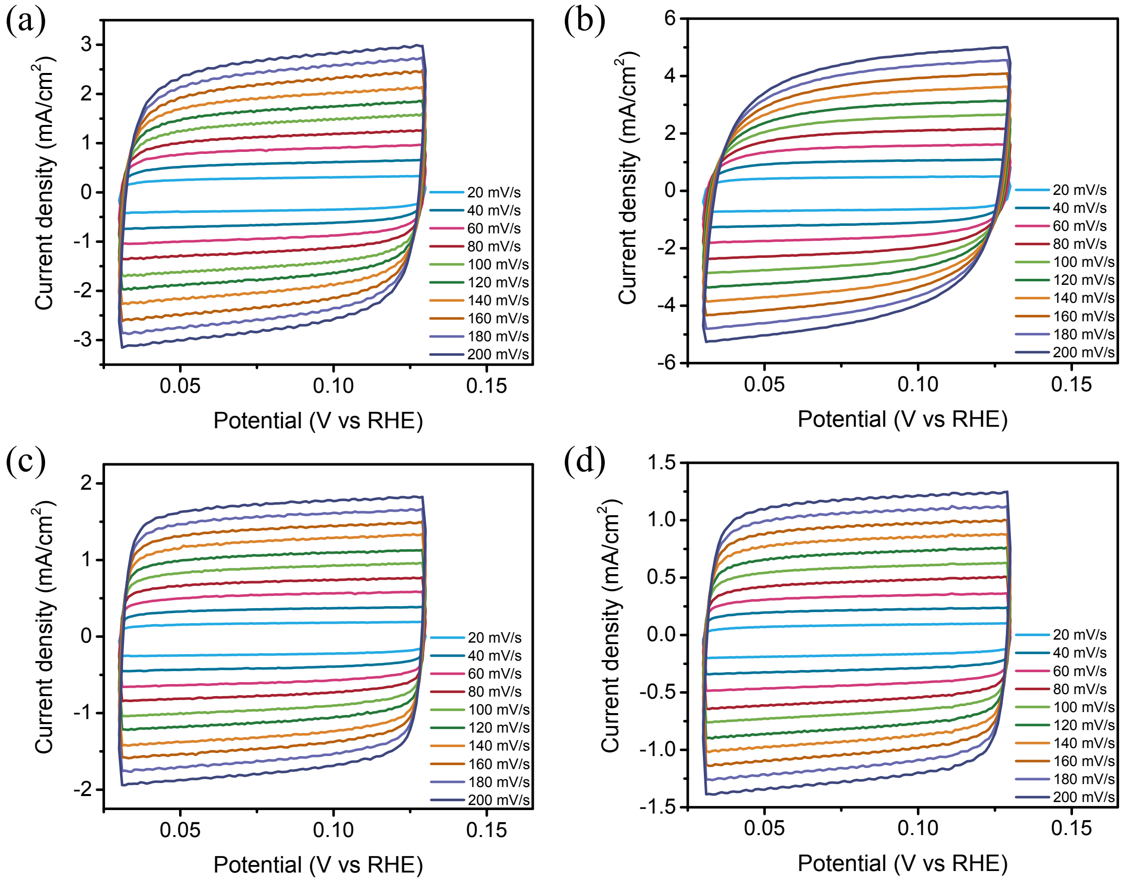


Fig. S9 The cyclic voltammograms (CV) of W_2C@CNT-S6 (a), W_2C@CNT-S8 (b), W_2C@CNT-S10 (c) and W_2C/CNT (d) are measured at various scan rates range from 0.205-0.305 V (vs. RHE) in 1 M KOH solution.

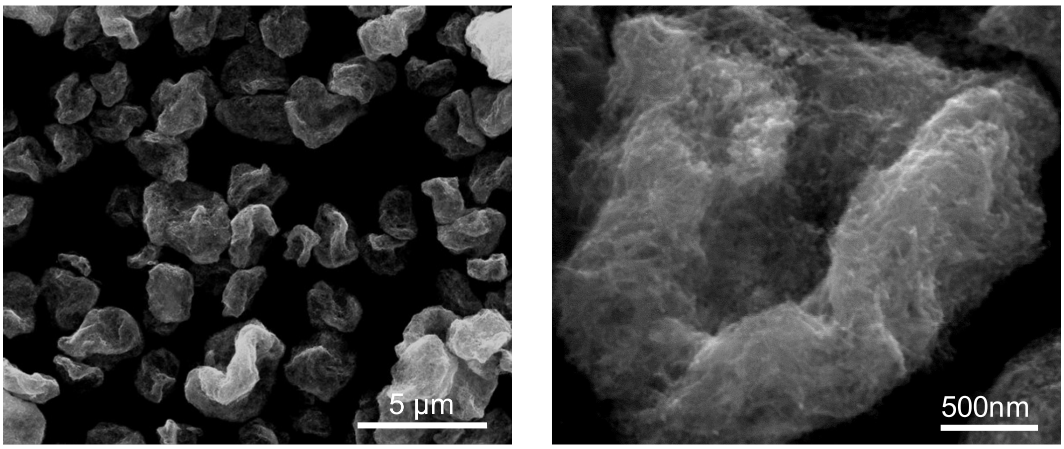


Fig. S10 (a, b) SEM images of the W_2C@CNTS8 after the HER stability test in 0.5 M H_2SO_4.

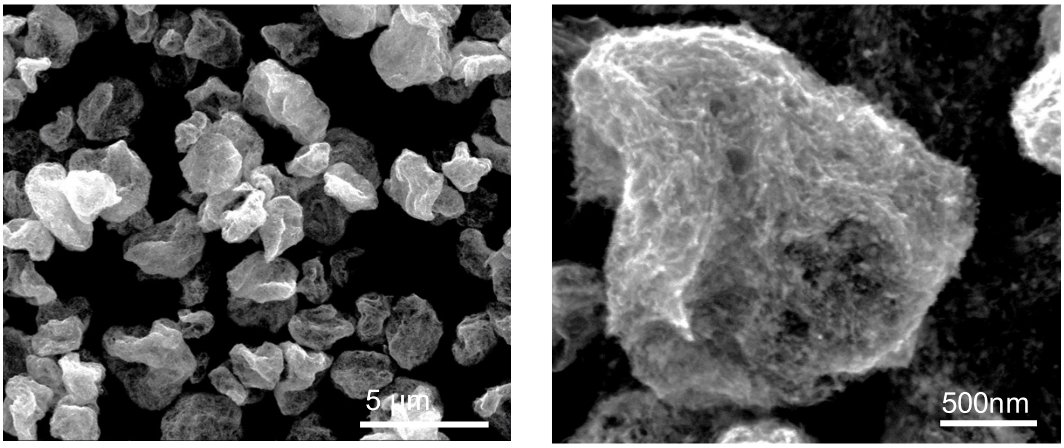


Fig. S11 (a, b) SEM images of the W_2C@CNTS8 after the HER stability test in 1.0 M KOH.

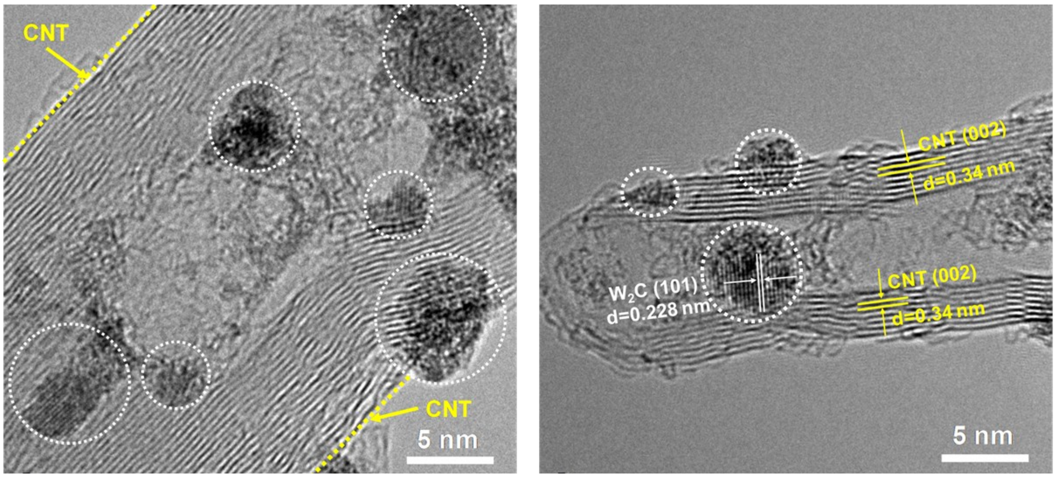


Fig. S12 (a, b) TEM images of the W_2C@CNTS8 after the HER stability test in 0.5 M H_2SO_4.

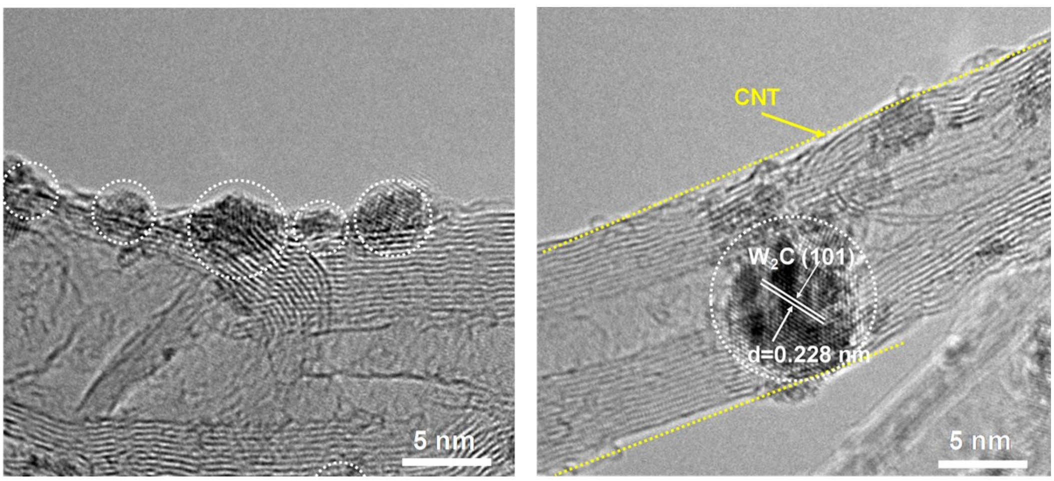


Fig. S13 (a, b) TEM images of the W_2C@CNTS8 after the HER stability test in 1.0 M KOH.

Table S1. Comparison of HER performance for W_2C@CNT-S, W_2C/CNT and other non-noble metal-based electrocatalysts.

Catalyst	Electrolyte	η_{onset}（mV）	η_{10}（mV）	Tafel slope (mV dec^{-1})	Reference
W_2C@CNT-S6	0.5 M H_2SO_4	70	192	59.8	This work
	1 M KOH	60	186	60.7	
W_2C@CNT-S8	0.5 M H_2SO_4	60	176	57.4	
	1 M KOH	40	148	56.2	
W_2C@CNT-S10	0.5 M H_2SO_4	90	220	68.6	
	1 M KOH	80	213	63.8	
W_2C/CNT	0.5 M H_2SO_4	110	240	72.3	
	1 M KOH	100	248	88.6	
W_2C/WC NPs	0.5 M H_2SO_4	N/A	310	108	1
W NPs	0.5 M H_2SO_4	N/A	295	156	
W_2C@WC_{1-x}	0.5 M H_2SO_4	N/A	240	86	2
W_2C-WN/GnP	0.5 M H_2SO_4	N/A	120	64.7	3
WC-CNT	0.5 M H_2SO_4	15	145	72	4
	1 M KOH	16	137	106	
W@WC	0.5 M H_2SO_4	N/A	264	85	5
WC nanowall	0.5 M H_2SO_4	52	160	67	6
C-WP/W	0.5 M H_2SO_4	N/A	109	79.8	7
W_xC@WS_2	0.5 M H_2SO_4	70.3	146	61	8
WS_2/WO_2	0.5 M H_2SO_4	90	160	63	9
WSe_2/CNT	0.5 M H_2SO_4	~120	230	59.7	10
P-WN/rGO	0.5 M H_2SO_4	46	85	54	11
$CoWS_x$	0.5 M H_2SO_4	95	N/A	78	12
WC	0.5 M H_2SO_4	~120	~270	69	13
WS_2/rGO	0.5 M H_2SO_4	150	300	58	14
CoW/CN	1 M KOH	31	98	125	15
WS_2/WC_2@NSPC	1 M KOH	80	205	72	16
p-WC_x NWs	1 M KOH	56	122	56	17
$MoSe_2$-$CoSe_2$	1 M KOH	127	237	79	18
NiS_2/MoS_2	1 M KOH	69	204	65	19

References

1 S. Emin, C. Altinkaya, A. Semerci, H. Okuyucu, A. Yildiz, P. Stefanov, *Appl. Catal. B*, 2018, **236**, 147.

2 I. Kim, S. Park, D. Kim, *Nanoscale*, 2018, **10**, 21123.

3 W. Chen, J. M. Schneider, K. Sasaki, C. Wang, J. Schneider, S. Iyer, S. Iyer, Y. Zhu, J. T. Muckerman, E. Fujita, *Chemsuschem*, 2014, **7**, 2414.

4 X. Fan, H. Zhou, X. Guo, *ACS Nano*, 2015, **9**, 5125.

5 Z. Chen, L. Duan, T. Sheng, X. Lin, Y. Chen, Y. Chu, S. Sun, W. Lin, *ACS Appl. Mater. Inter.*, 2017, **9**, 20594.

6 Y. Ko, J. Cho, I. Kim, D. S. Jeong, K. Lee, J. Park, Y. Baik, H. Choi, W. Lee, *Appl. Catal. B*, 2017, **203**, 684.

7 L. Wu, Z. Pu, Z. Tu, I. S. Amiinu, S. Liu, P. Wang, S. Mu, *Chem. Eng. J.*, 2017, **327**, 705.

8 F. Wang, P. He, Y. Li, T. A. Shifa, Y. Deng, *Adv. Funct. Mater.*, 2017, **27**, 1605802.

9 J. Wang, W. Wang, Z. Wang, J. G. Chen, C. Liu, *ACS Catal.*, 2016, **6**, 6585.

10 X. Wang, Y. Chen, F. Qi, B. Zheng, J. He, Q. Li, P. Li, W. Zhang, Y. Li, *Electrochem. Commun.*, 2016, **72**, 74.

11 H. Yan, C. Tian, L. Wang, A. Wu, M. Meng, L. Zhao, H. Fu, *Angew. Chem. Int. Ed.*, 2015, **54**, 6325.

12 P. D. Tran, S. Y. Chiam, P. P. Boix, Y. Ren, S. S. Pramana, J. Fize, V. Artero, J. Barber, *Energy Environ. Sci.*, 2013, **6**, 2452.

13 H. Fei, Y. Yang, X. Fan, G. Wang, G. Ruan, J. M. Tour, *J. Mater. Chem. A*, 2015, **3**, 5798.

14 J. Yang, D. Voiry, S. J. Ahn, D. Kang, A. Y. Kim, M. Chhowalla, H. S. Shin, *Angew. Chem. Int. Ed.*, 2013, **52**, 13751.

15 H. Jin, J. Chen, S. Mao, Y. Wang, *ACS Appl. Mater. Inter.*, 2018, **10**, 22094.

16 Y. Li, X. Wu, H. Zhang, J. Zhang, *ACS Appl. Energy Mater.*, 2018, **1**, 3377.

17 B. Ren, D. Li, Q. Jin, H. Cui, C. Wang, *J. Mater. Chem. A*, 2017, **5**, 13196.

18 X. Wang, B. Zheng, B. Yu, B. Wang, W. Hou, W. Zhang, Y. Chen, *J. Mater. Chem. A*, 2018, **6**, 7842.

19 P. Kuang, T. Tong, K. Fan, J. Yu, *ACS Catal.*, 2017, **7**, 6179.