Supplementary Information

A low crystallinity tungsten supported palladium catalyst and its electrochemical hydrogen evolution activity

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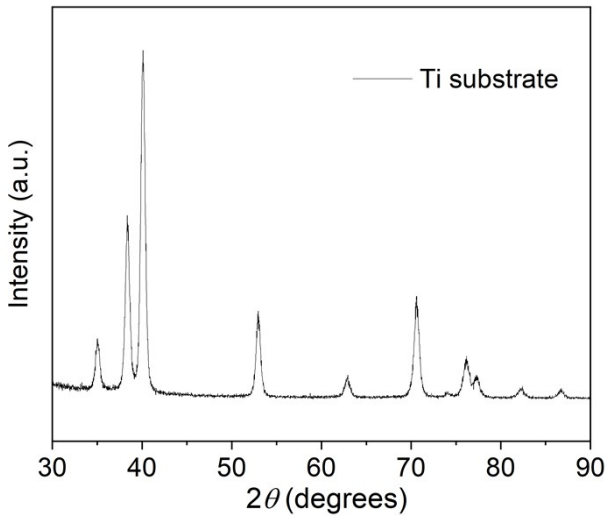

Figure S1 X-ray diffraction pattern of Ti substrate.

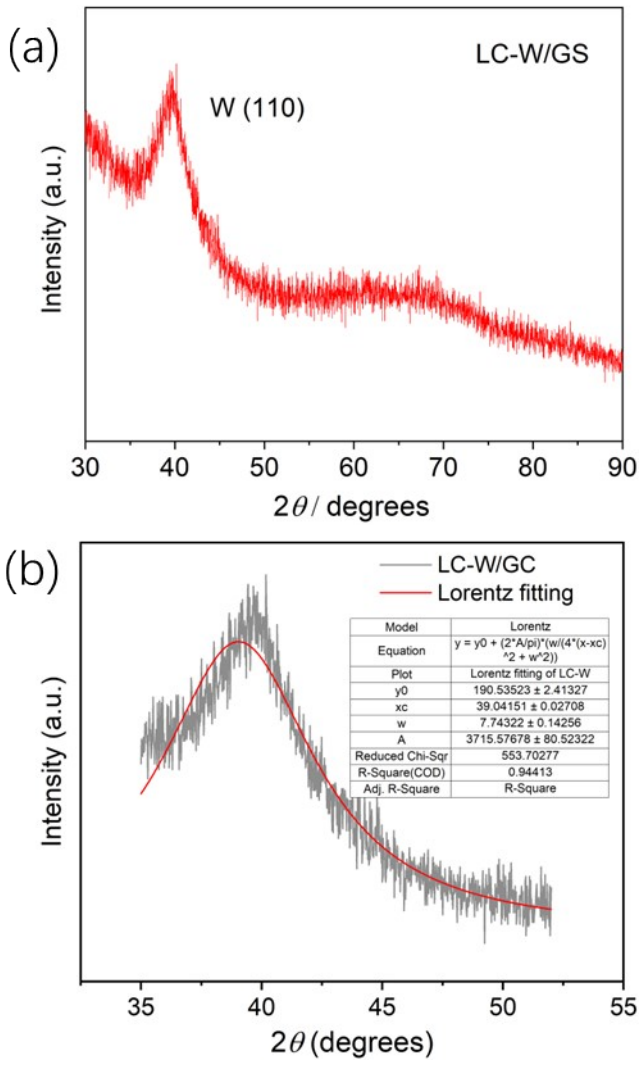

Figure S2 X-ray diffraction pattern (a) and fitting curve (b) of LC-W/GS.

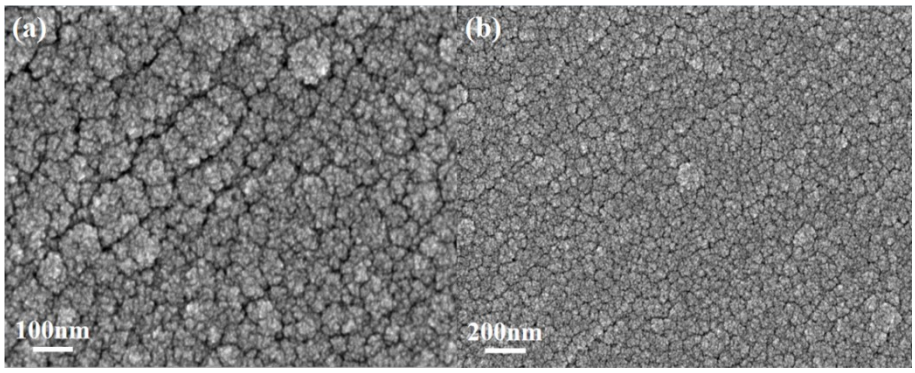

Figure S3 SEM images of LC-W/Ti.

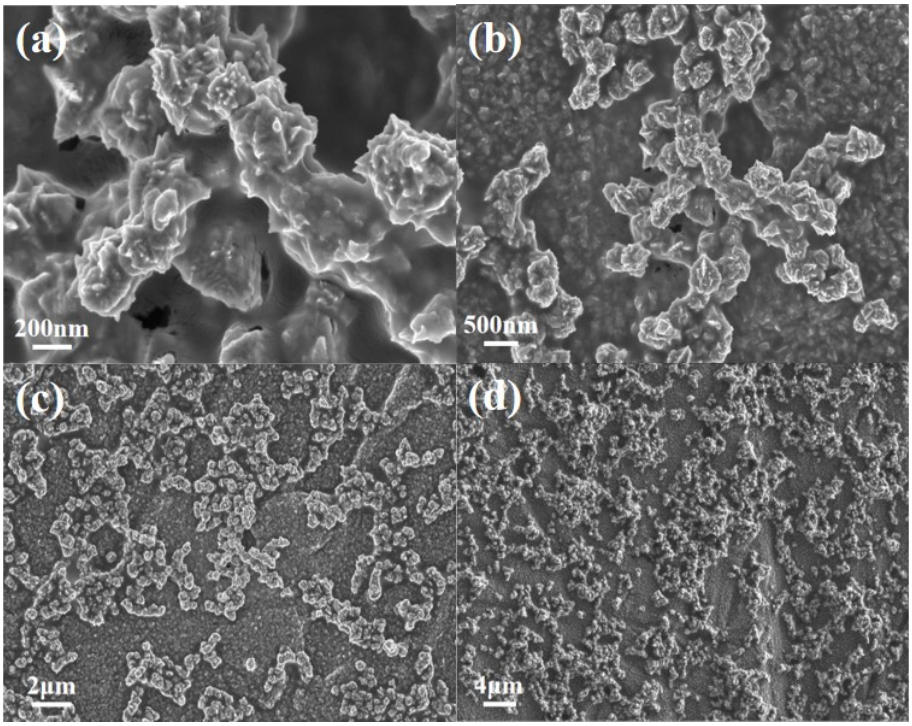

Figure S4 SEM images of Pd@LC-W/Ti.

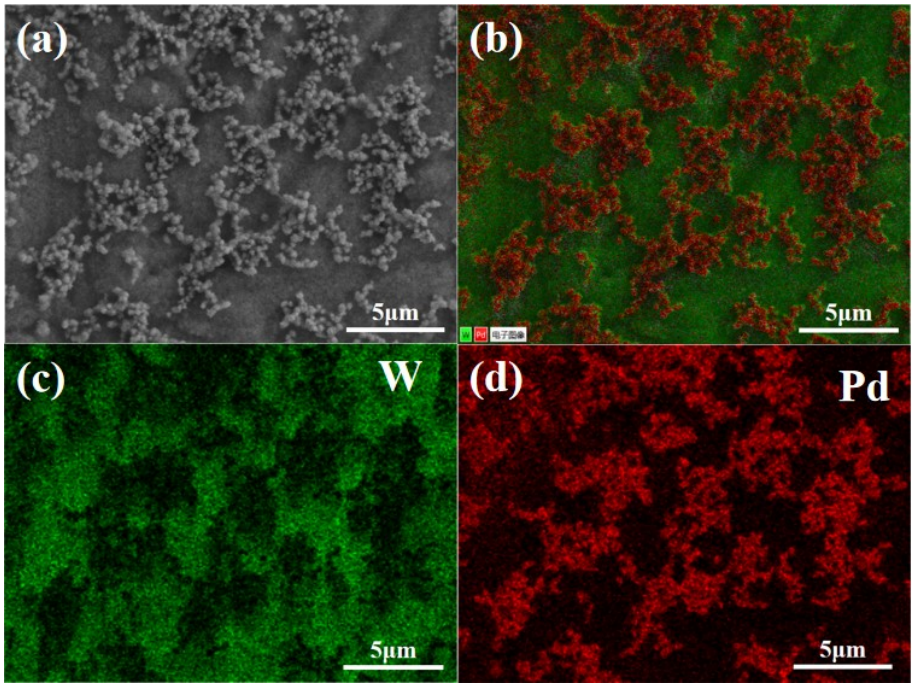

Figure S5 SEM-mapping of Pd@LC-W/Ti.

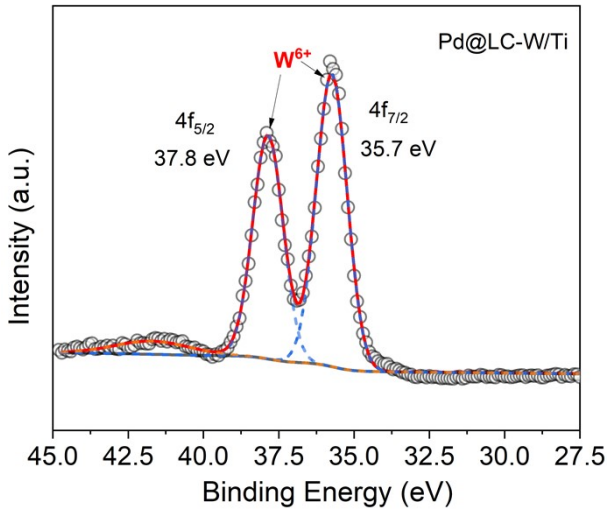

Figure S6 XPS core-level spectra of W 4f obtained from Pd@LC-W/Ti.

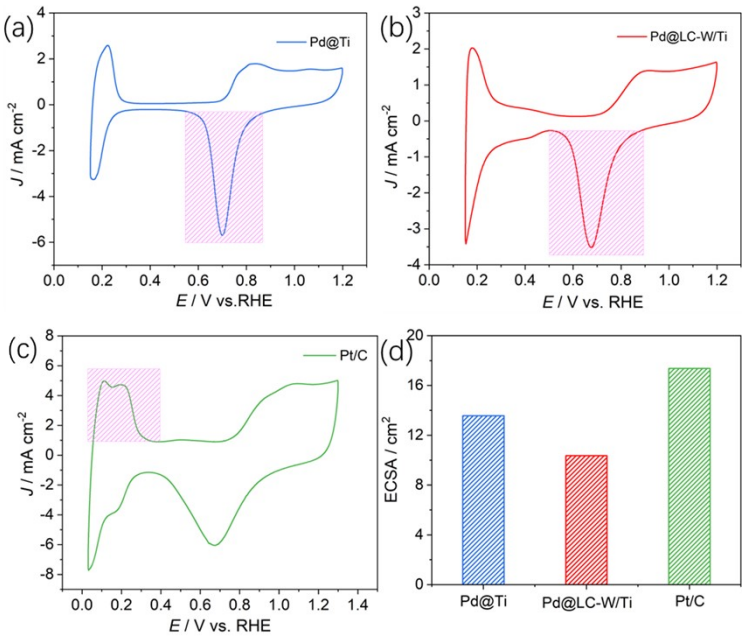

Figure S7 Electrochemical surface areas (ECSAs) of Pd@Ti, Pd@LC-W/Ti and Pt/C.

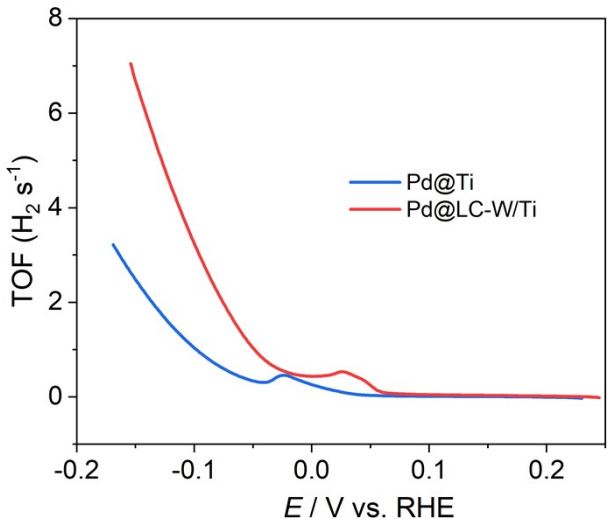

Figure S8 The turnover frequencies (TOFs) of Pd@Ti and Pd@LC-W/Ti.

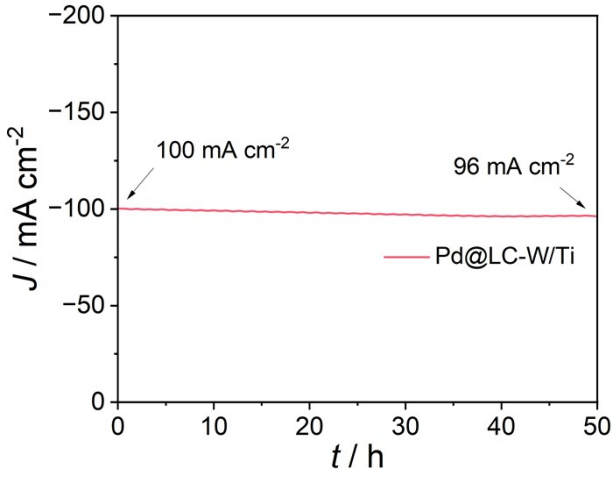

Figure S9 The stability of Pd@LC-W/Ti electrode.

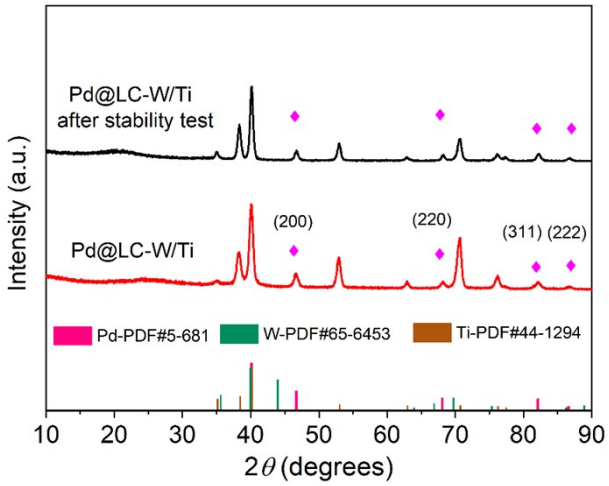

Fig. S10 X-ray diffraction patterns of Pd@LC-W/Ti before and after stability test.

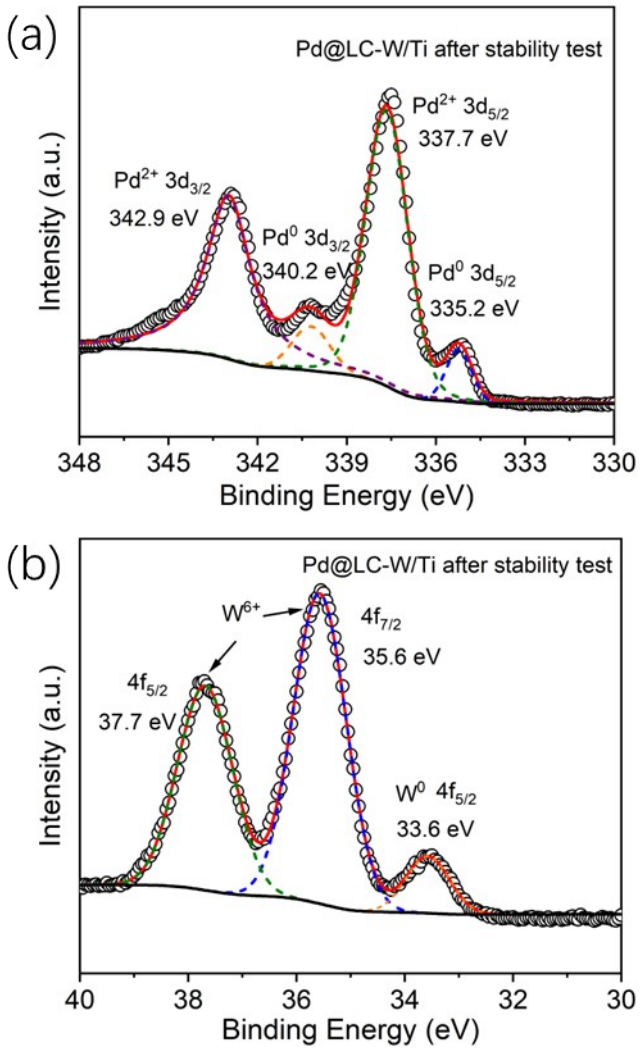

Fig. S11 XPS core-level spectra of Pd 3d (a) and W 4f (b) obtained from Pd@LC-W/Ti after stability test.

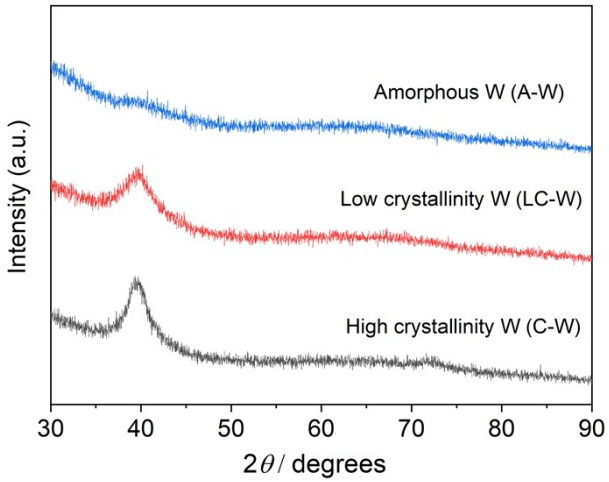

Figure S12 X-ray diffraction patterns of A-W, LC-W and C-W.

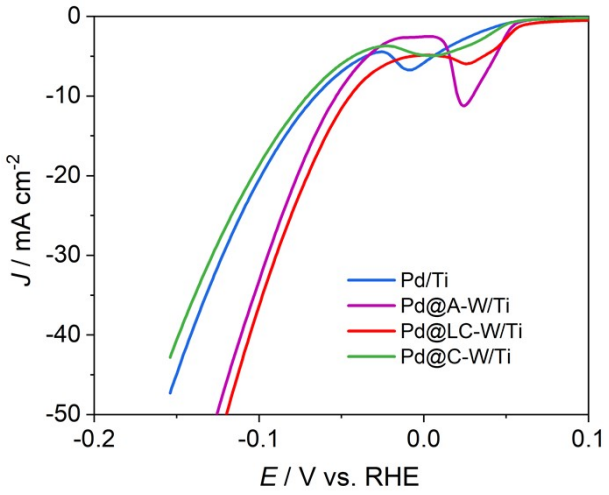

Figure S13 HER activities of Pd/Ti, Pd@A-W/Ti, Pd@LC-W/Ti and Pd@C-W/Ti.

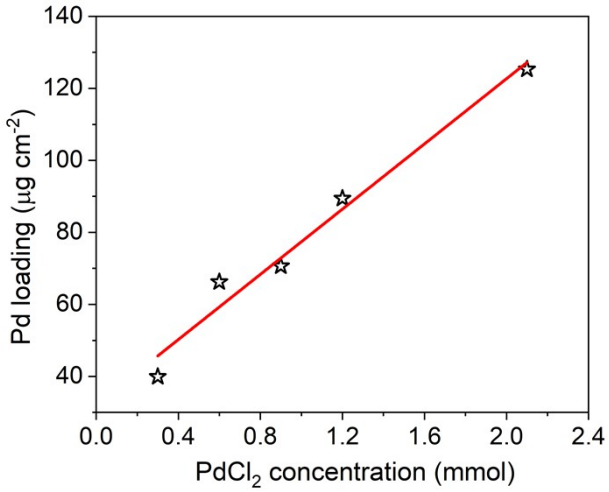

Figure S14 Relationship between $PdCl_2$ concentration and Pd loading.

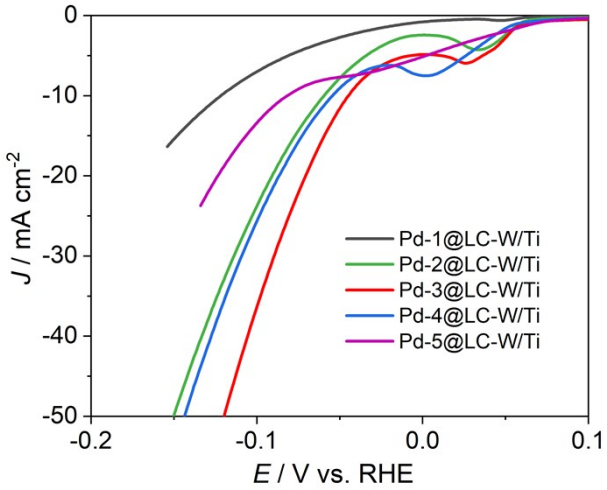

Figure S15 HER activities of Pd-x@LC-W/Ti with different Pd loadings.

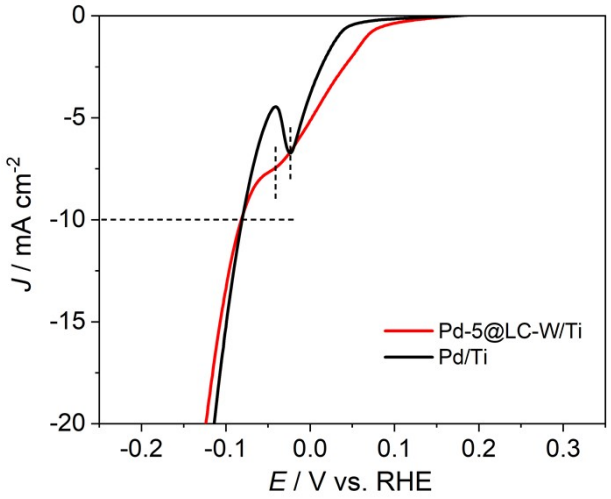

Figure S16 HER activities of Pd/Ti and Pd-5@LC-W/Ti.

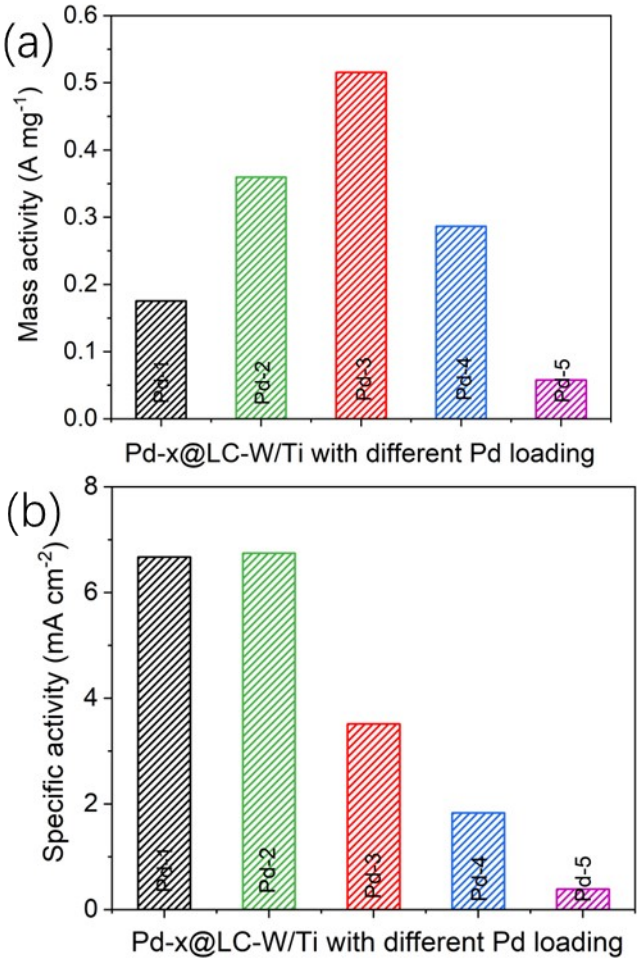

Figure S17 MA activities of Pd-x@LC-W/Ti with different Pd loadings.

Table S1 W Loading prepared at different sputtering times by XRF

Catalysts	Sputtering time (min)	W loading (μg cm^{-2})
A-W/Ti	10	55.20
LC-W/Ti	20	126.1
C-W/Ti	40	259.8

Table S2 Pd loading of Pd-x@LC-W/Ti with different concentrations of $PdCl_2$ by XRF

Catalysts	concentrations of $PdCl_2$ (mol L^{-1})	Pd loading (μg cm^{-2})	W loading (μg cm^{-2})
Pd-1@LC-W/Ti	0.3×10^{-3}	39.90	
Pd-2@LC-W/Ti	0.6×10^{-3}	66.21	
Pd-3@LC-W/Ti	0.9×10^{-3}	70.60	259.8
Pd-4@LC-W/Ti	1.2×10^{-3}	89.37	
Pd-5@LC-W/Ti	2.1×10^{-3}	125.3	

Table S3 Overpotentials of Pd@Ti, Pd@LC-W/Ti and Pt/C at different current densities

Catalysts	η_{10} (mV)	η_{20} (mV)	η_{40} (mV)
Pd@Ti	81	114	157
Pd@LC-W/Ti	45	71	106
Pt/C	33	48	76

Table S4 Comparison of HER activities between optimized Pd@LC-W/Ti and other Pd-based electrocatalysts in literatures. (0.5 M H_2SO_4)

Catalyst	η_{10} (mV)	Tafel slope (mV dec^{-1})	Pd loading (μg cm^{-2})	References
Cu@Pd	185	120	---	(1)
Pd–HPMo@GNP	94	90	15.5	(2)
Pd@MoS_2/$Mo_2TiC_2T_x$	92	60	---	(3)
Pd-PCNFs-800	93.1	88	71.4	(4)
$NiCo_2S_4$/Pd	87	70	43.0	(5)
$Pd_{63}Ni_{16}Fe_{21}$	83	52	---	(6)
$Pd_{83.5}Ir_{16.5}$	73	43.6	75.2	(7)
PdKMX	72	69	8.8	(8)
Pd SA/WO_{3-x}	70	68	13.8	(9)
Pd-MoS_2	70	43	---	(10)
Ni-Pd/rGO	63	116	---	(11)
PdCo/SNC	58	75	70.0	(12)
Pd1-Rh1/MoS_2	46	31	---	(13)
Pd, Re-MoS_2	46	72	11.1	(14)
PdCuNi	45	33	---	(15)
$PdRu_x$ alloy	35.6	57	---	(16)
N-PdIr bimetallene	26	30.3	143	(17)
Pd_3Sn/Ru	20	14	21.1	(18)
Pd@LC-W/Ti	45	82.9	70.6	This work

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Table S5 Comparison of HER activities between optimized Pd@LC-W/Ti and other Ti-based electrocatalysts in literatures.

Catalyst	Electrolyte	η_{10} (mV)	Tafel slope (mV dec^{-1})	Reference s
Pd-WO_3/W/Ti	0.5 M H_2SO_4	52	80.6	(1)
(Pt_ac-O-Au)-1/Ti	0.5 M H_2SO_4	41	28.6	(2)
N-MXene-35/Ti	0.5 M H_2SO_4	162	69	(3)
MoS_2/$MnMoO_4$@Ti	0.5 M H_2SO_4	153	80	(4)
GNWs/Mo-MXene/Ti	0.5 M H_2SO_4	132	178	(5)
TiH_2/Ti	0.5 M H_2SO_4	224	202.4	(6)
Pt@$Ti_3C_2T_x$	0.5 M H_2SO_4	60.8	59.2	(7)
core-shell VS_2/Ti_3C_2	0.5 M H_2SO_4	59	38.42	(8)
Ru/Ni-NiO/$Mo_2TiC_2T_x$	0.5 M H_2SO_4	49	62	(9)
CoP/$Ti_3C_2T_x$	0.5 M H2SO4	135	48	(10)
Pd@LC-W/Ti	0.5 M H_2SO_4	45	82.9	This work

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Table S6 Fitting parameters in the equivalent circuit of Pd@Ti and Pd@LC-W/Ti

Catalysts	R_s / Ω cm^2	R_{ct} / Ω cm^2	C_{dl} / mC cm^{-2}
Pd@Ti	0.306	16.430	0.576
Pd@LC-W/Ti	0.300	4.388	0.412

Table S7 Pd loading of Pd@LC-W/Ti before and after stability test

Catalysts	Stability test	Pd loading (μg cm^{-2})
Pd@LC-W/Ti	/	70.60
Pd@LC-W/Ti	100 mA cm^{-2} 50 h test	65.17