Supplementary Information (SI) for New Journal of Chemistry.

Supporting Information

A Solvent-free Strategy to Synthesize WS_2/WC Embedded, N, S Co-Doped Mesoporous Carbon as Electrocatalysts for Hydrogen Evolution

Minghui Hu, Wan Jiang, Wenting Zhang*, Duihai Tang*, Zhen Zhao

Institute of Catalysis for Energy and Environment, College of Chemistry and Chemical Engineering, Shenyang Normal University, Shenyang 110034, China

*Corresponding authors.

Duihai Tang

E-mail: tangduihai@163.com

Wenting Zhang

E-mail: zhengwenting_1986@163.com

Characterization

The morphology, microstructure, and pore structure of the obtained sample were determined by transmission electron microscopy (TEM) FEI Tecnai G2 F20, and the crystal structure of the prepared sample was determined by powder X-ray diffraction Rigak Ultima IV (XRD). The cathode filament used copper target Kα - rays (λ=1.5418 Å), while the operating current and voltage were maintained at 30 mA and 40 kV, respectively. The specific surface area, pore volume, pore size, and pore volume distribution of porous carbon materials were measured using a Micrometeritics Tristar II 3020 physical analyzer. The degree of graphitization of porous carbon materials was evaluated using a Raman spectrometer LabRAM HR Evolution. The ESCALAB 250Xi was used to determine the chemical composition and properties of the catalyst.

HER measurements

The HER performance of the catalyst was measured using a three-electrode system of an electrochemical workstation. The three-electrode system consists of working electrode, reference electrode, and counter electrode. The reference electrode is a mercury/mercury oxide electrode (alkaline condition) and a saturated calomel electrode (acidic and neutral conditions), the counter electrode is a carbon rod, and the working electrode is an electrocatalysts loaded glassy carbon electrode (GCE). The required preparation for testing is to grind 50 mg of dried electrocatalyst in a mortar, add 80 μL of isopropanol and 2.0 μL of Nafion solution to the catalyst, and sonicate the resulting mixture for 40 minutes to form catalyst ink. Use a pipette to drop 4.5 μL of catalyst ink onto the working electrode. After the isopropanol on the catalyst surface has completely evaporated, use a pipette to drop 4.5 μL of a mixed solution of isopropanol and Nafion onto the working electrode. After approximately 5 mins, use an electrochemical workstation to perform electrochemical performance tests on the sample. Linear sweep voltammetry (LSV) was tested in alkaline electrolyte 1 M KOH (pH=14) at a rate of 5 mV^{-1}.

Hg/HgO and RHE potentials for saturated calomel electrodes:

$E_{(vs.RHE)}=E_{(vs.Hg/HgO)}+E^{\theta}_{Hg/HgO}+0.059pH$ (25°C)

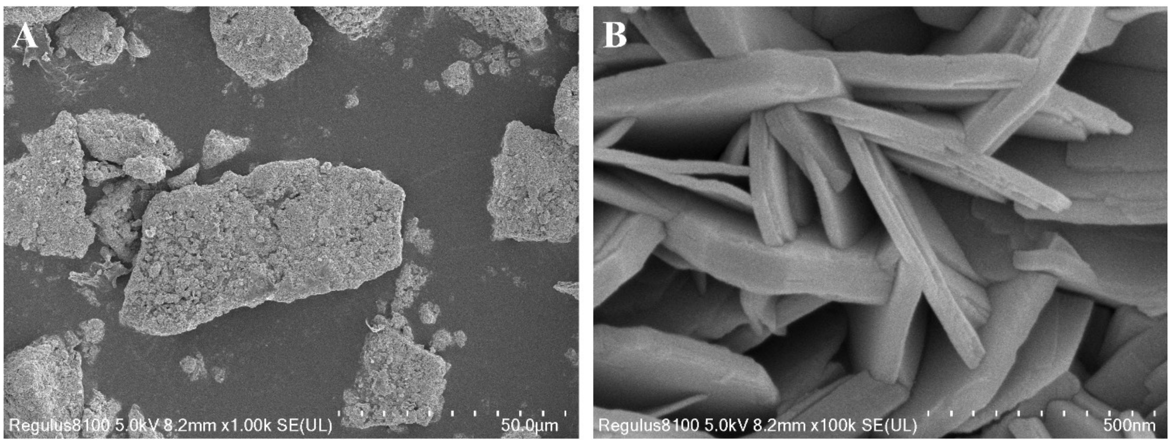

Fig. S1. SEM images of 2MF-2S-1W.

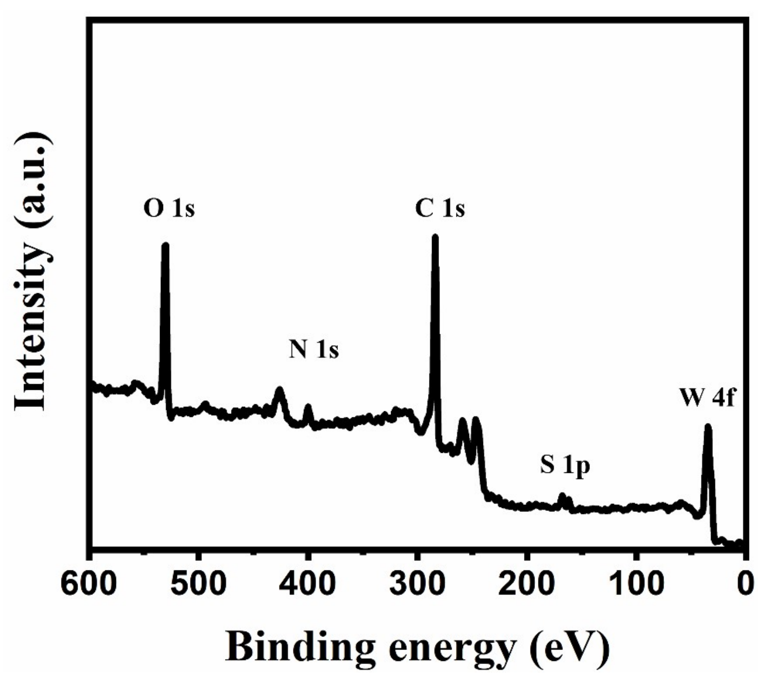

Fig. S2. XPS survey spectrum for 2MF-2S-1W.

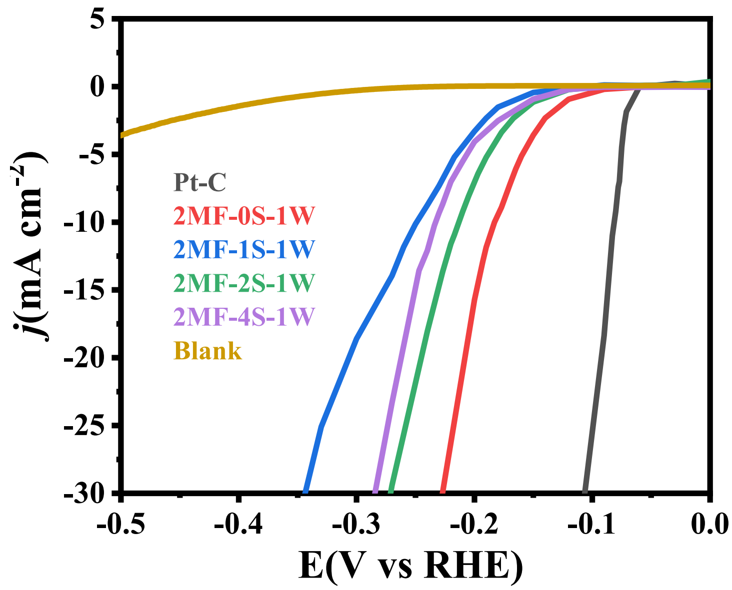

Fig. S3. (A) Polarization curves of Pt/C, the as-received electrocatalysts and blank GCE at pH 0.

Table S1 Electrocatalytic performances toward HER of various WS_2/WC composite reported in the representative literatures.

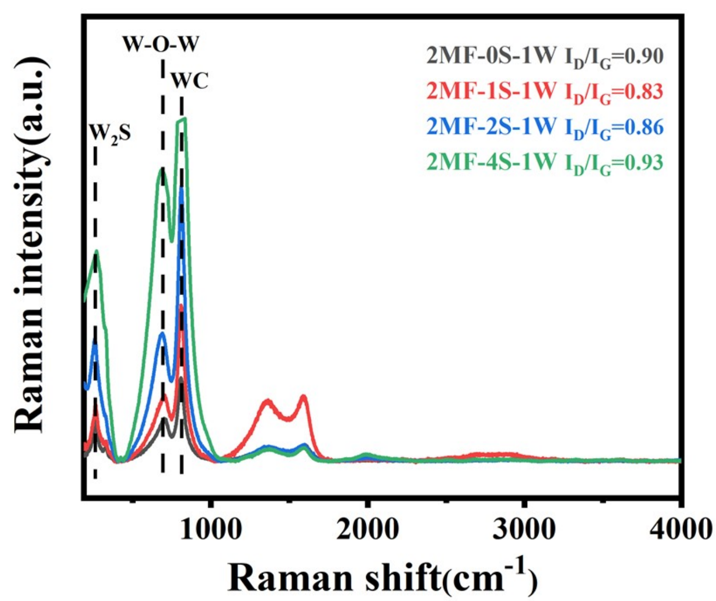

Fig. S4. Raman spectra of the electrocatalysts

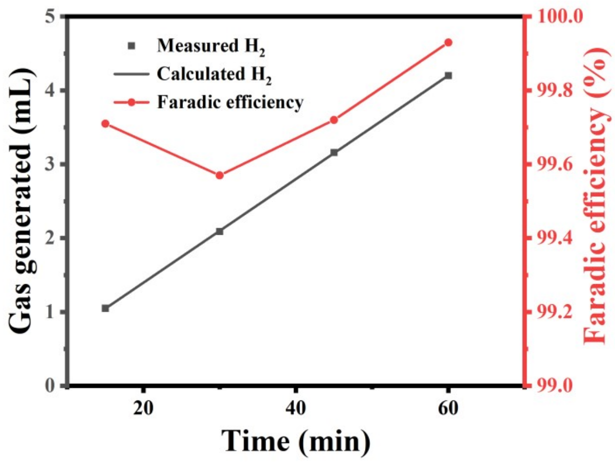

Fig. S5 Faraday efficiency of 2MF-2S-1W.

Table S1 Electrocatalytic performances toward HER of various WS_2/WC composite reported in the representative literatures.

No.	Composition of the catalyst	10mA cm^{-2}（overpotential）/mV	Tafel slope /mV dec^{-1}	Ref.
1	W_2S/WC	184(neutral) 98(alkaline)	81 94	This Work
2	N–W_2C/W	90（ neutral） 82（alkaline）	54.0 49.2	1
3	WS2/WN@CM	92（alkaline）	82.71	2
4	R-WS2/C	172（acidity）	234	3
5	WS2/Co9S8	192（alkaline）	72.9	4

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(2) J. Zhao, L. Li, H. Jiang, H. Tang, D. Chen, J. Yao, F. Du, G. Li, *Appl. Surf. Sci.*, 2025, **680**, 161466.

(3) A. Dutta, O. Breuer, M. Krishnappa, R. Minnes, A. Zak, A. Borenstein, *J. Mater. Chem.*, 2023, **11**, 21806-21816.

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Table S2 Faradaic efficiency (FE), Exchange current density (j_0), Turnover frequency (TOF), and Mass activity (A g^{-1}) data under neutral condition.

Neutral	2MF-0S-1W	2MF-1S-1W	2MF-2S-1W	2MF-4S-1W
Exchange current density (j_0)	0.378	0.286	0.085	0.170
Turnover frequency (TOF)	3.72	5.23	2.83	2.24
Mass activity (A g^{-1})	6.6	7	32	19

Table S3 Faradaic efficiency (FE), Exchange current density (j_0), Turnover frequency (TOF), and Mass activity (A g^{-1}) data under alkaline condition.

alkaline	2MF-0S-1W	2MF-1S-1W	2MF-2S-1W	2MF-4S-1W
Exchange current density (j_0)	0.485	0.527	0.919	0.682
Turnover frequency (TOF)	3.72	5.23	2.83	2.24
Mass activity (A g^{-1})	98	100	235	180