

WSe₂ Nanoflowers Grown on Ti₃C₂Cl₂ MXene for Energy Applications and Sensing

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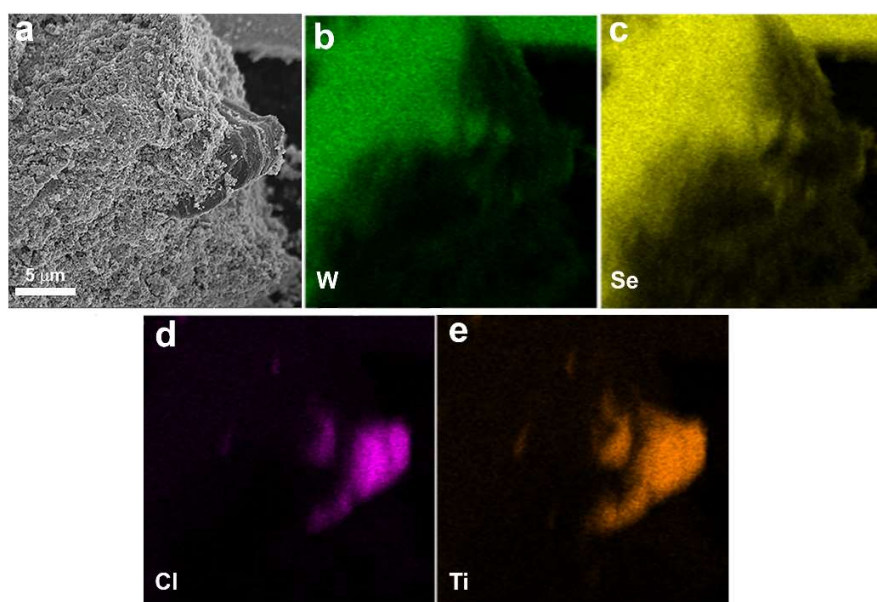


Figure S1. EDS elemental maps for (a) w-WSe₂/Ti₃C₂Cl₂ hybrid showing the distribution of (b) W, (c) Se, (d) Cl, and (e) Ti.

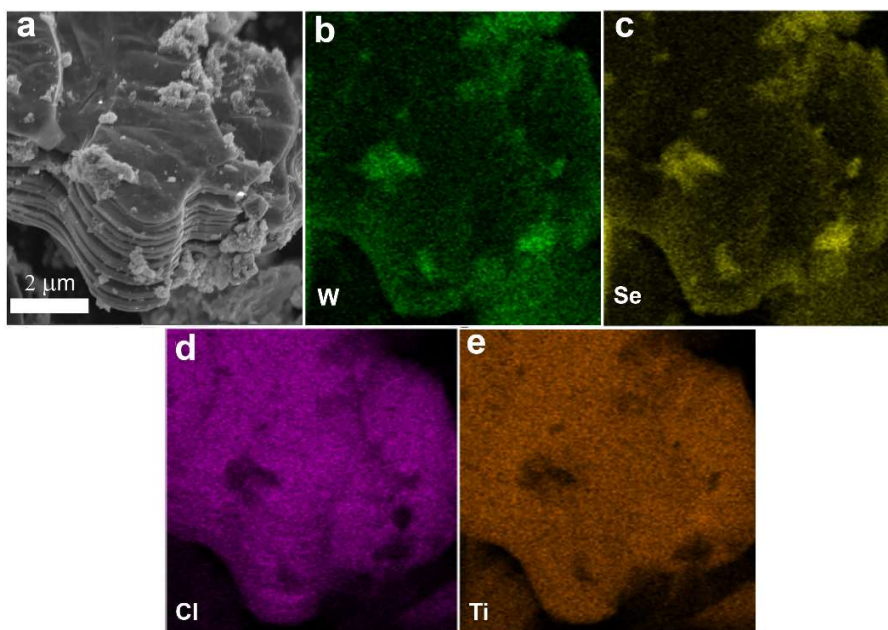


Figure S2. EDS elemental maps for (a) m-WSe₂/Ti₃C₂Cl₂ hybrid showing the distribution of (b) W, (c) Se, (d) Cl, and (e) Ti.

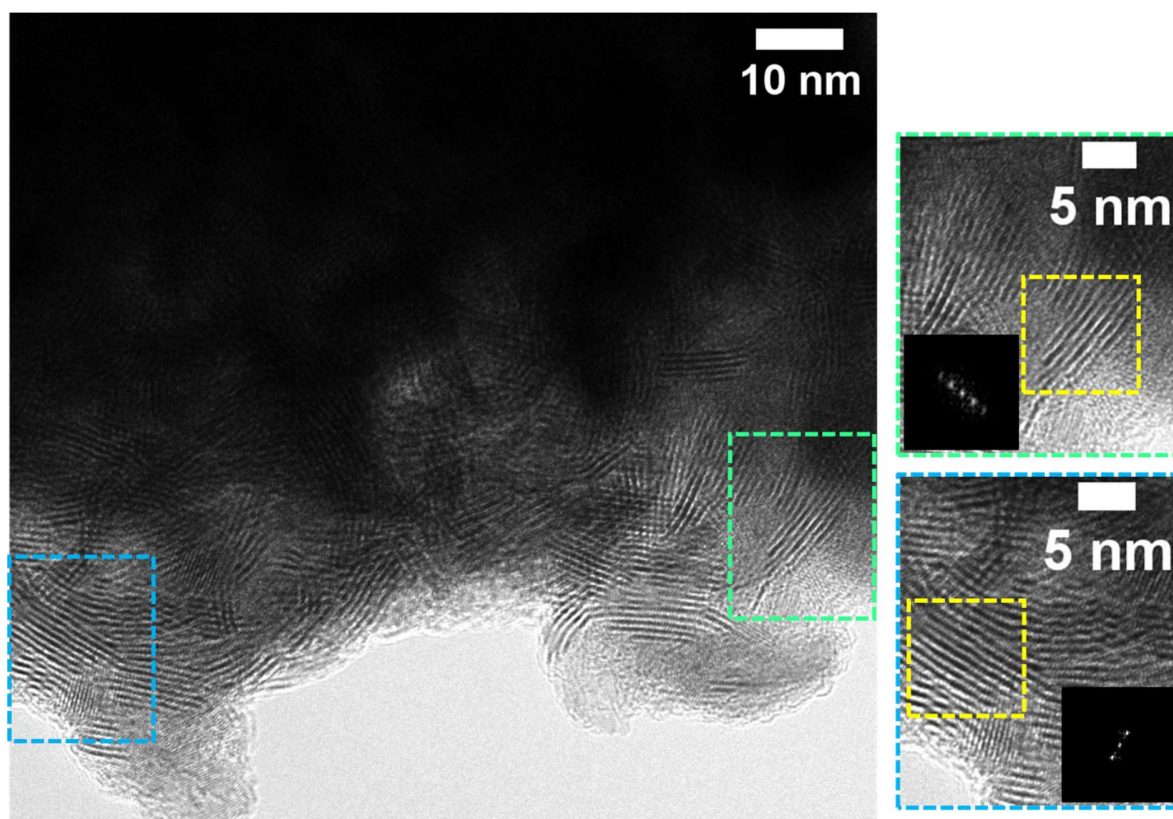


Figure S3. Representative HR-TEM image of w-WSe₂/Ti₃C₂Cl₂, with zoomed-in images of the marked areas and respective FFT patterns.

Table S1. Quantification of elements (atomic %) by SEM/EDS.

Material	W	Se	Ti	Al	Cl
WSe ₂	30.2	69.8	-	-	-
Ti ₃ C ₂ Cl ₂	-	-	65.2	6.9	27.9
w-WSe ₂ /Ti ₃ C ₂ Cl ₂	16.2	41.7	12.1	1.7	6.2
m-WSe ₂ /Ti ₃ C ₂ Cl ₂	1.9	5.7	55.1	3.3	34.0

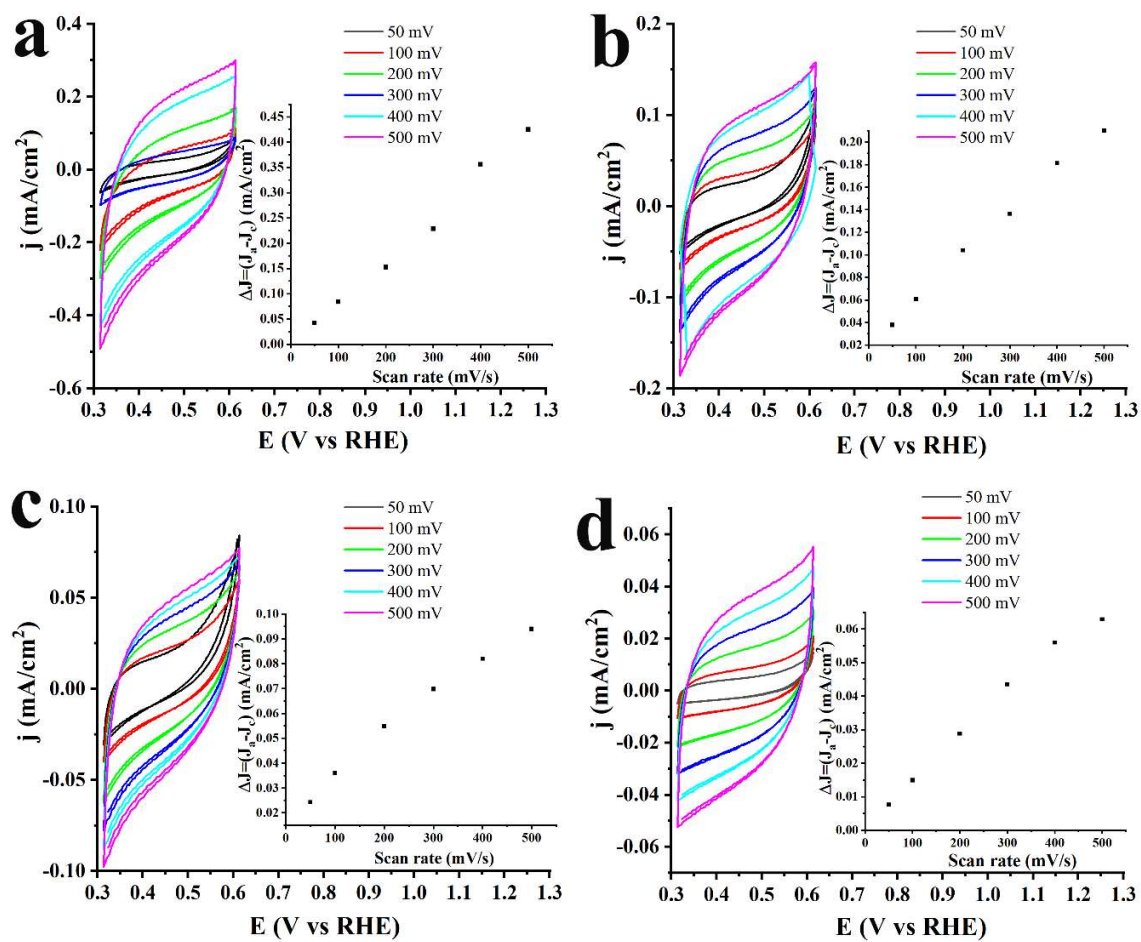


Figure S4. Cyclic voltammograms of (a) $w\text{-WSe}_2/\text{Ti}_3\text{C}_2\text{Cl}_2$, (b) $m\text{-WSe}_2/\text{Ti}_3\text{C}_2\text{Cl}_2$, (c) WSe_2 and (d) $\text{Ti}_3\text{C}_2\text{Cl}_2$ MXene in a nitrogen saturated aqueous 0.5 M H_2SO_4 electrolyte, at a rotation speed of 1600 rpm and scan rates from 50 to 500 mV/s. Inset: Scan rate dependence of the current densities for the corresponding materials.

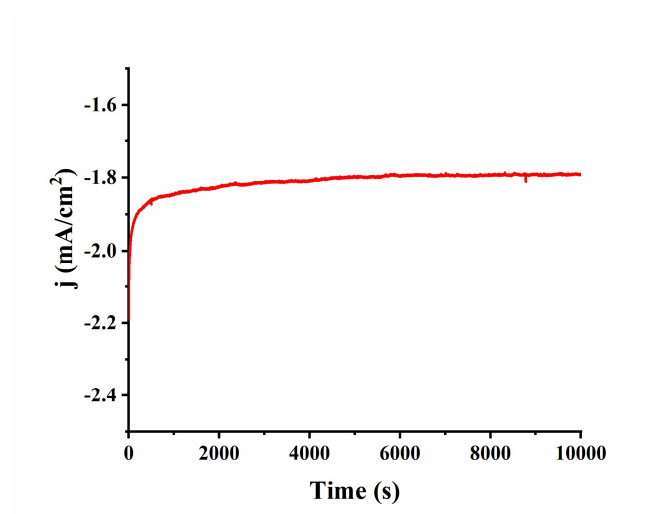


Figure S5. Chronoamperometric response at -0.16 V (versus RHE) for 10,000 s for w-WSe₂/Ti₃C₂Cl₂.

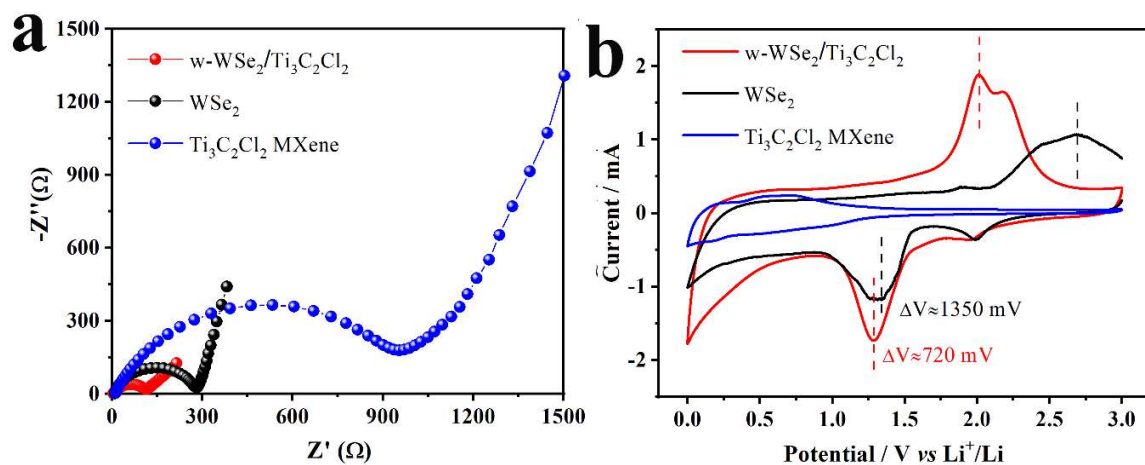


Figure S6. (a) Nyquist plots on PC voltage of Ti₃C₂Cl₂ MXene, WSe₂, and w-WSe₂/Ti₃C₂Cl₂ electrodes and the corresponding (b) CV curves at 1.0 mV s⁻¹.

Table S2. Electrocatalytic HER parameters for all tested materials in 0.5 M H₂SO₄.

Material	Onset overpotential (mAcm ⁻²)	Overpotential at -10 (mA/cm ²)	Tafel slope (mV/dec)	R _{ct} (Ω)	ECSA (cm ²)	Cdl (μF)
w-WSe ₂ /Ti ₃ C ₂ Cl ₂	-0.14	-0.19	50	18.6	21.7	868
w-WSe ₂ /Ti ₃ C ₂ Cl ₂ *	-0.15	-0.21	61	-	-	-
m-WSe ₂ /Ti ₃ C ₂ Cl ₂	-0.19	-0.35	144	141.1	9.0	360
m-WSe ₂ /Ti ₃ C ₂ Cl ₂ *	-0.25	-0.36	136	-	-	-
WSe ₂	-0.25	-0.46	186	74.6	3.8	152
WSe ₂ *	-0.36	-0.50	177	-	-	-
Ti ₃ C ₂ Cl ₂ MXene	-0.21	-0.40	112	177.5	3.1	124
Ti ₃ C ₂ Cl ₂ MXene*	-0.27	-0.45	114	-	-	-
Pt/C (20 wt.%)	0.01	-0.031	42	30	-	-

*after 10000 cycles

Table S3. Comparison of w-WSe₂/Ti₃C₂Cl₂ with reported 2D-Based electrochemical sensors for H₂O₂ detection in Terms of LOD and LOQ.

Modifier/ Electrode	Technique	Polarization Potential (V)	Linear Range (μ M)	LOD (μ M)	Ref.
graphene– AuNPs/GC	Amperometry (N ₂ saturate solution)	-0.4 V	20-280	6.00	1
MoS ₂ /C _N - NWs/GC	Amperometry	-0.1	2-500	0.73	2
m- MoS ₂ @CNS/GC	Amperometry (N ₂ -saturated 0.1 M NaOH)	-0.35	100-1000 2000-20000	7.50	3
MoS ₂ /GC	CV	-	10-100	1.13	4
WS ₂ /GC	CV	-	10-90	0.88	5
CuO- CeO ₂ /MXene/GC	Amperometry	-0.3	5-100	1.67	6
Pd-Ti ₂ NT _x MXene/GC	Amperometry	-0.4	1-300	0.72	7
TiO _{2-x} /Ti ₃ C ₂ /FTO	Amperometry	0.45	10-5310	1.38	8
WSe ₂ /Ti ₂ C ₂ Cl ₂ /GC	Amperometry	-0.3	1-88	0.60	This work

References

1. Hu, J. *et al.* One-step synthesis of graphene-AuNPs by HMTA and the electrocatalytical application for O₂ and H₂O₂. *Talanta* **93**, 345–349 (2012).
2. Dai, H. *et al.* Molybdenum sulfide/nitrogen-doped carbon nanowire-based electrochemical sensor for hydrogen peroxide in living cells. *Sens Actuators B Chem* **276**, 65–71 (2018).
3. Cho, I. W., Son, S. U., Yang, M. H. & Choi, J. Preparation of microporous MoS₂@carbon nanospheres for the electrochemical detection of hydrogen peroxide. *Journal of Electroanalytical Chemistry* **876**, (2020).
4. Haritha, V. S., Vijayan, A., Sarath Kumar, S. R. & Rakhi, R. B. Voltammetric determination of hydrogen peroxide using MoS₂ modified glassy carbon electrodes. *Mater Lett* **301**, (2021).
5. Haritha, V. S., Sarath Kumar, S. R. & Rakhi, R. B. Non-enzymatic electrocatalytic detection of hydrogen peroxide using Tungsten disulphide nanosheets modified electrodes. *Materials Science and Engineering: B* **285**, (2022).

6. Zhou, K. *et al.* A novel electrochemical sensor based on CuO-CeO₂/MXene nanocomposite for quantitative and continuous detection of H₂O₂. *Journal of Electroanalytical Chemistry* **921**, (2022).
7. Zhang, Y., He, L., Sun, X., Yang, C. & Li, J. A Sensitive H₂O₂ Electrochemical Sensor Based on Pd Nanoparticles Decorated Ti₂NT_x MXene. *ChemistrySelect* **9**, (2024).
8. Li, Q. *et al.* Cu/Cu₂O nanoparticles modified Ti₃C₂ MXene with in-situ formed TiO₂-X for detection of hydrogen peroxide. *Ceram Int* **49**, 9632–9641 (2023).