Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Supplementary Information:

Noble metal free hierarchical VS_2 onto WO_3 nanoflakes as an effective hetero junction strategy for enhanced photoelectrochemical water oxidation

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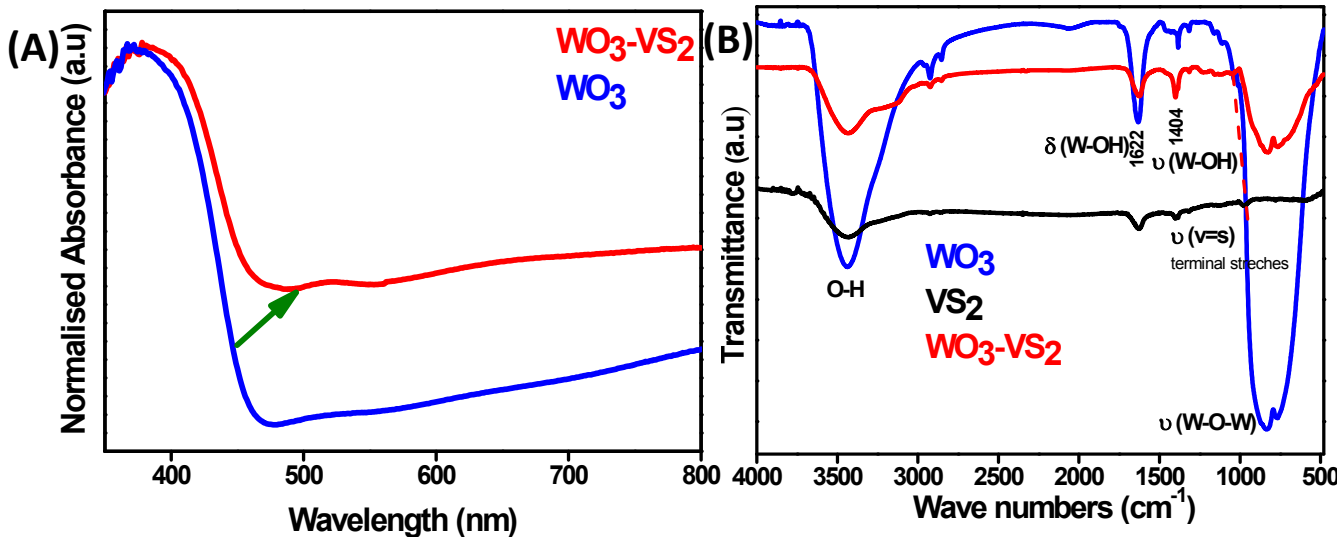

Fig. S1 (A) UV-Vis absorption spectra and (B) Fourier transforms infrared (FTIR) spectra of WO_3, VS_2 and WO_3-VS_2 composites.

Fourier transforms infrared (FTIR) spectra was obtained to characterize the surface functional groups in Fig. S1 (B). Monoclinic WO_3 exhibited three distinct peaks at the

wavelengths of 1622, 1405, and 804 cm^{-1}, which correspond to W-OH bending vibration mode as a result of adsorbed water molecules, W-O stretching vibration and O-W-O stretching mode respectively.[1] The broad absorption bands at 3450 cm^{-1} was associated with weakly bound surface hydroxyl from ethanol/water. VS_2 shows characteristic band centered at 986 cm^{-1} in the low-frequency region, which can be assigned to υ (V=S) terminal S stretches.[2] In WO_3-VS_2, the corresponding terminal S stretch of VS_2 was observed at 1020 cm^{-1} which is slightly blue shifted compared to VS_2, which implies an interaction between the components in the composite.

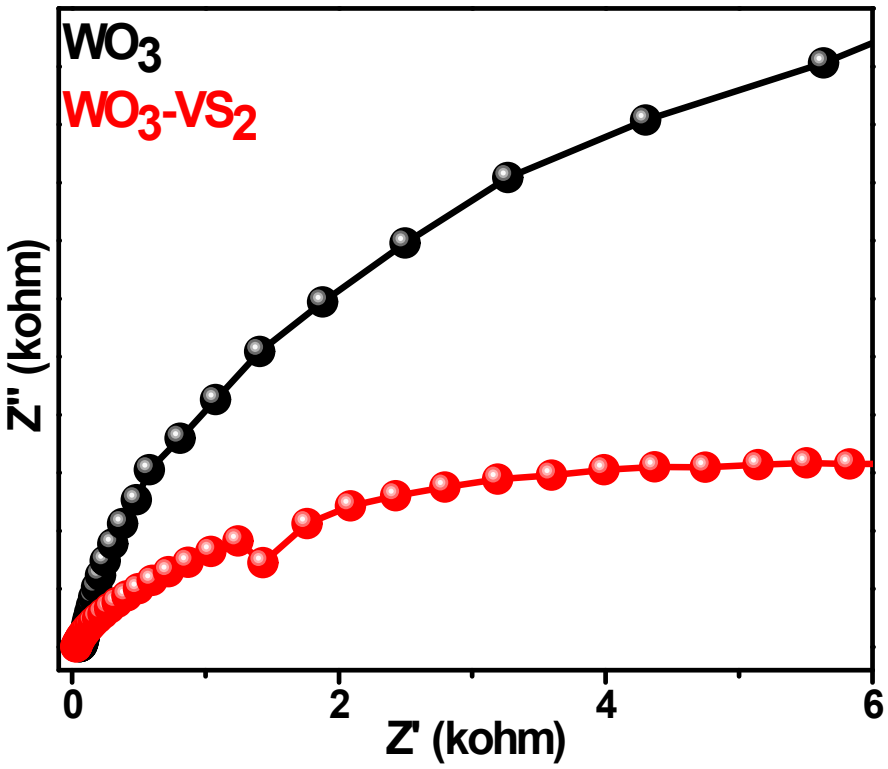

Fig. S2 Nyquist plots of WO_3 and WO_3-VS_2 photoanode under light illumination in 0.1M Na_2SO_4

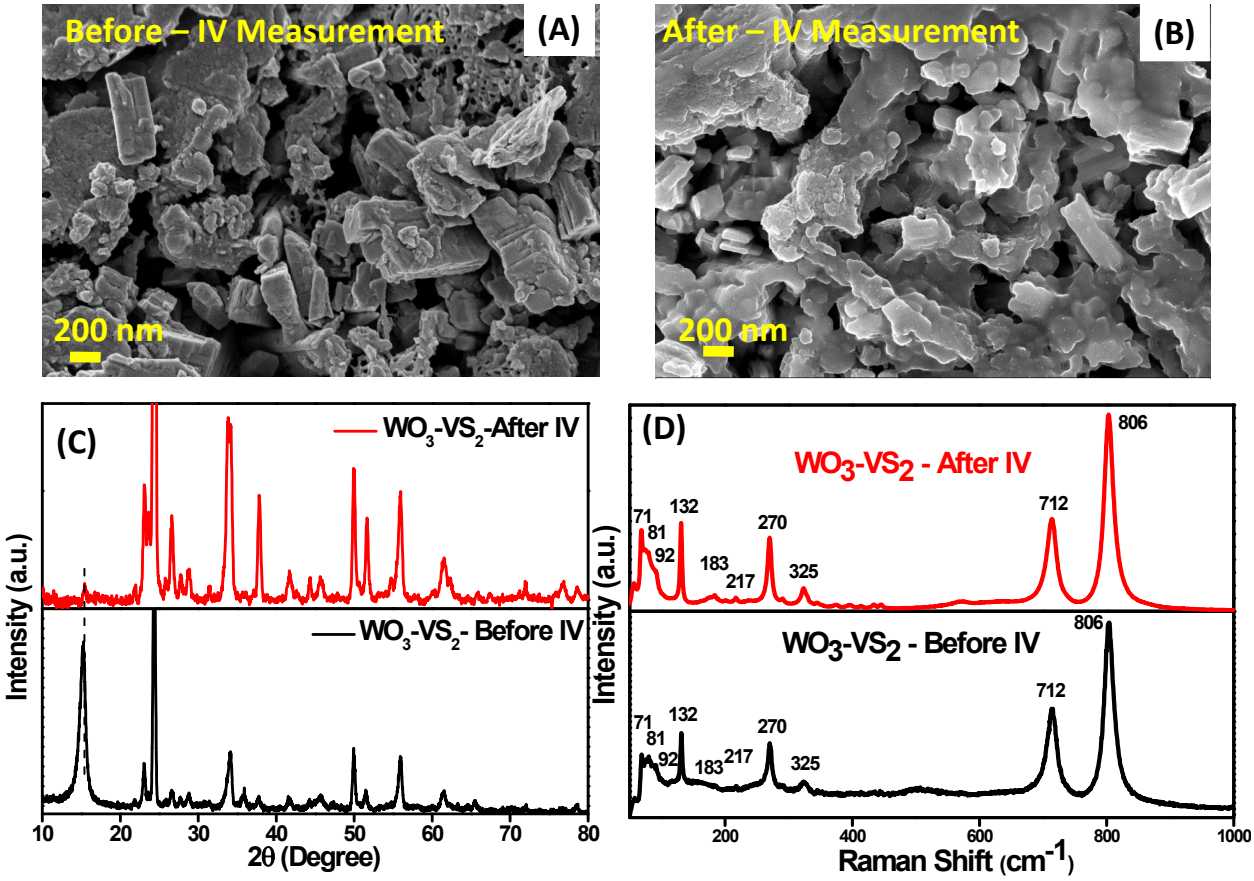

Fig. S3. (A) and (B) are FESEM image, (C) XRD and (D) Raman spectra of WO_3-VS_2 composite before and after the PEC measurement.

The solar-to-hydrogen (STH) efficiency was calculated from the following formula.[3,4]

$$STH = \frac{J_{SC}\left(\frac{mA}{cm^2}\right) \times 1.23\ V\ \times\ \eta_F}{P_{total}(mW/cm^2)}$$

Charge separation efficiency is calculated by using the following equation.[5]

$$\eta_{sep} = J_{sca} / J_{abs}$$

Where J_{abs} is the theoretical photo current density, J_{sca} is the photocurrent of the photoanode in the presence of scavengers as a function of applied bias.

Table S1: Tabulation of fitted parameters of Nyquist plot at open circuit potential.

	R_s	C_{bulk}	R_{trap}(bulk)	R_{ct} trap	C_{trap}
WO_3 Dark	61.29	1.02×10^{-5}	7.71×10^{5}	2.5×10^{4}	7.32×10^{-6}
WO_3 Light	65.71	1.02×10^{-5}	1.87×10^{4}	1.79×10^{4}	3.55×10^{-5}
WO_3-VS_2 Dark	32.36	1.15×10^{-5}	2.79×10^{3}	9073	2.34×10^{-5}
WO_3-VS_2 Light	32.44	1.20×10^{-5}	1.97×10^{3}	5504	3.25×10^{-5}

References

1. J. Wang, Z. Chen, G. Zhai and Y. Men, *Appl. Surf. Sci.* 2018, **462**, 760.
2. B. Pandit, L. K. Bommineedi and B. R. Sankapal, *J. Energy Chem.,* 2018, **0**, 1.
3. B. Pinaud, J. D. Benck , L. C. Seitz, A. J. Forman, Z. B. Chen, T. G. Deutsch, B. D. James, K. N. Baum, G. N. Baum, S. Ardo, H. L. Wang, E. Miller and T. F. Jaramillo, *Energy Environ. Sci*., 2013, **6**, 1983.
4. Z. Chen, H. Dinh and E. Miller, Photoelectrochemical Water Splitting, Springer, 2013.
5. T. K. Sahu, A. K. Shah, A. Banik, M. Qureshi, *ACS Appl. Energy Mater*. 2019, **2**, 4325.