Supporting information

P-N Heterojunction-Enhanced Structural Stability of Tungsten Disulfide Nanosheets for Highly Efficient, Stable Alkaline Water Electrolysis

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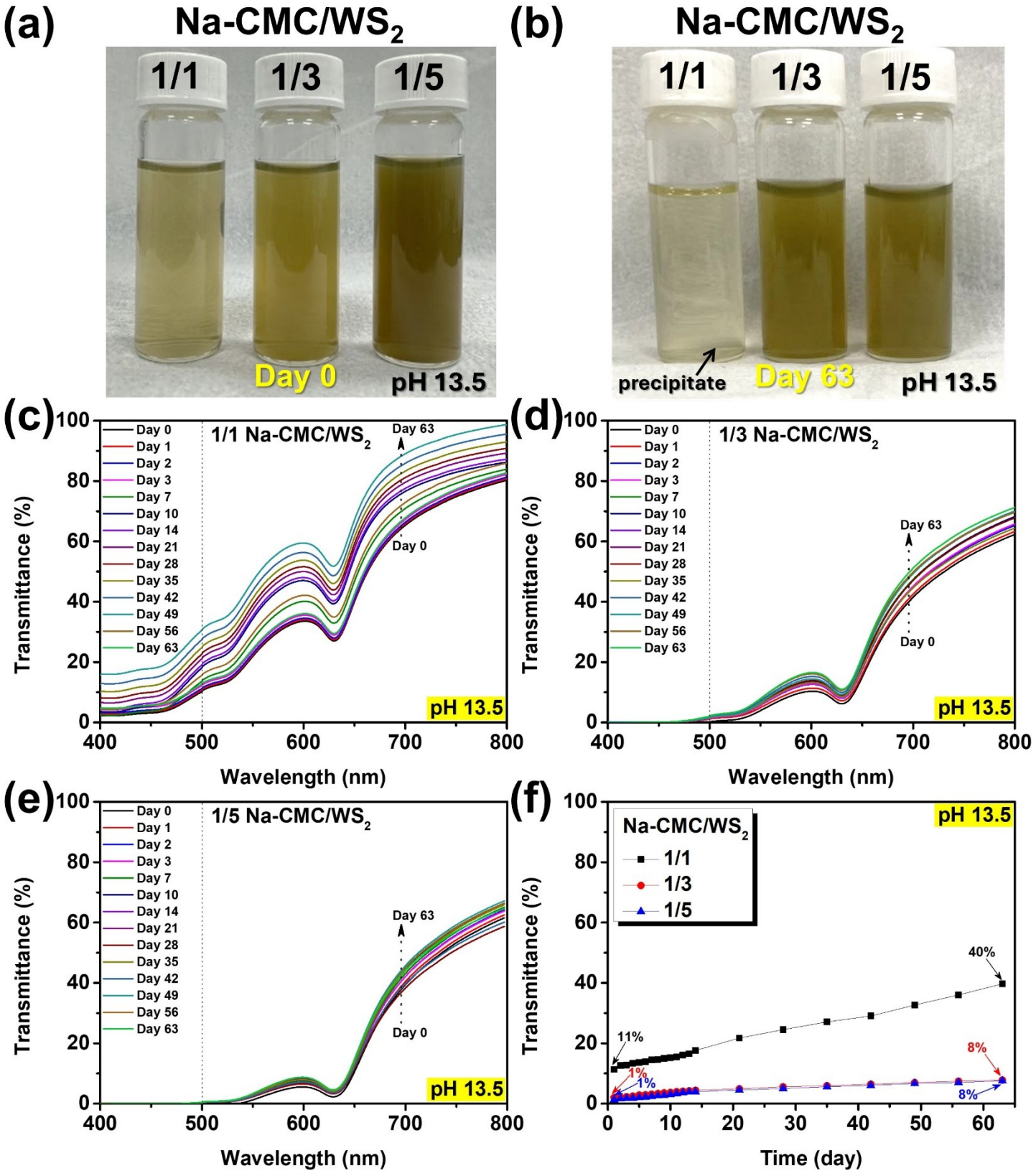

Fig. S1: Photographs of 1/1, 1/3, and 1/5 Na-CMC/WS_2 nanosheets in water at pH 13.5 on **(a)** day 0 and **(b)** day 63. Time-dependent transmittance (%) at 500 nm of **(c)** 1/1, **(d)** 1/3, and **(e)** 1/5 Na-CMC/WS_2 nanosheets in water at pH 13.5 recorded at 25 °C. **(f)** Summary plot of time-dependent transmittance at 500 nm for 1/1, 1/3, and 1/5 Na-CMC/WS_2 nanosheets in water at pH 13.5 over a 63-day monitoring period at 25 °C.

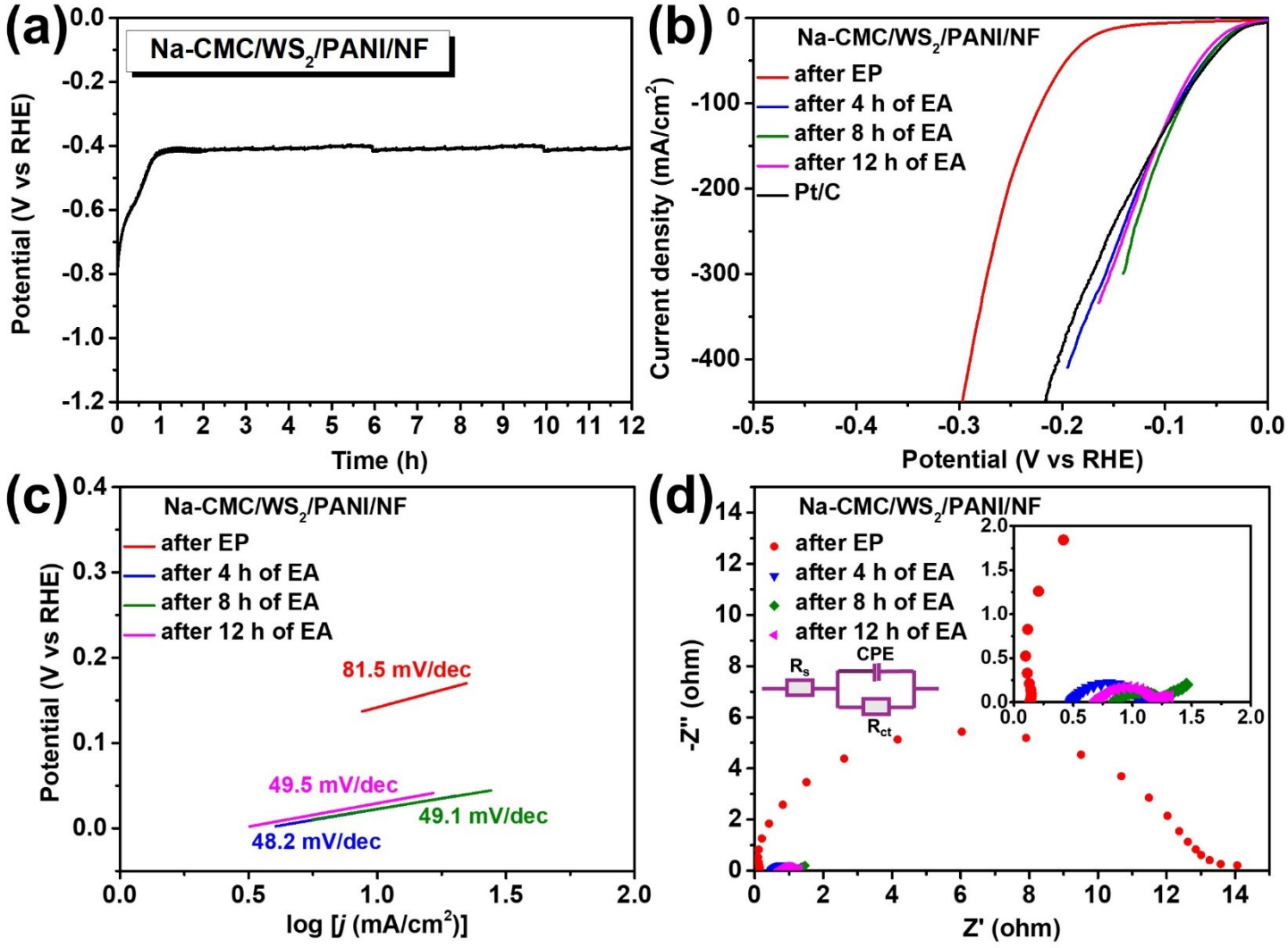

Fig. S2: (a) Chronopotentiometric curve for the EP-treated Na-CMC/WS_2/PANI/NF electrode at a constant current density of 500 mA cm^{-2} in 1.0 M KOH electrolyte for 12 h. **(b)** LSV curves, **(c)** Tafel plots, and **(d)** EIS Nyquist plots of Pt/C, EP-treated Na-CMC/WS_2/PANI/NF, and Na-CMC/WS_2/PANI/NF electrodes subjected to EA treatment for various durations in 1.0 M KOH electrolyte. **(d)** The inset on the left shows the equivalent circuit model used to fit the experimental data.

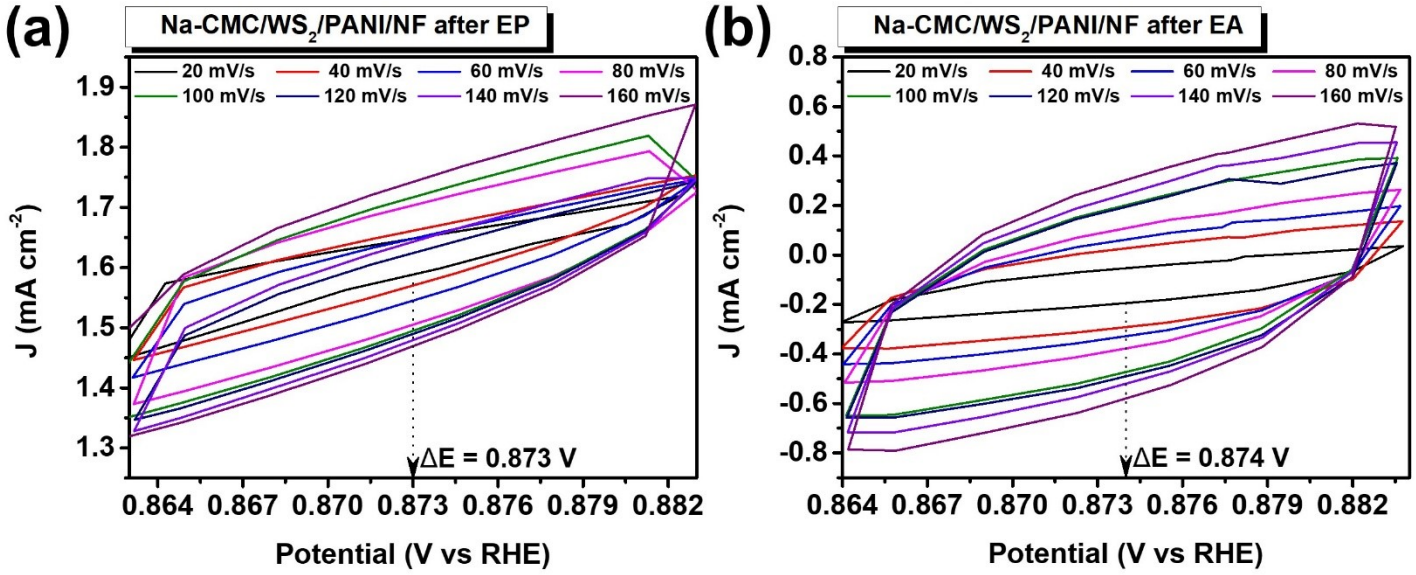

Fig. S3: Measurement of C_{dl} CV curves of the **(a)** EP-treated and **(b)** EA-treated Na-CMC/WS_2/PANI/NF electrodes in 1.0 M KOH aqueous solution at different scan rates.

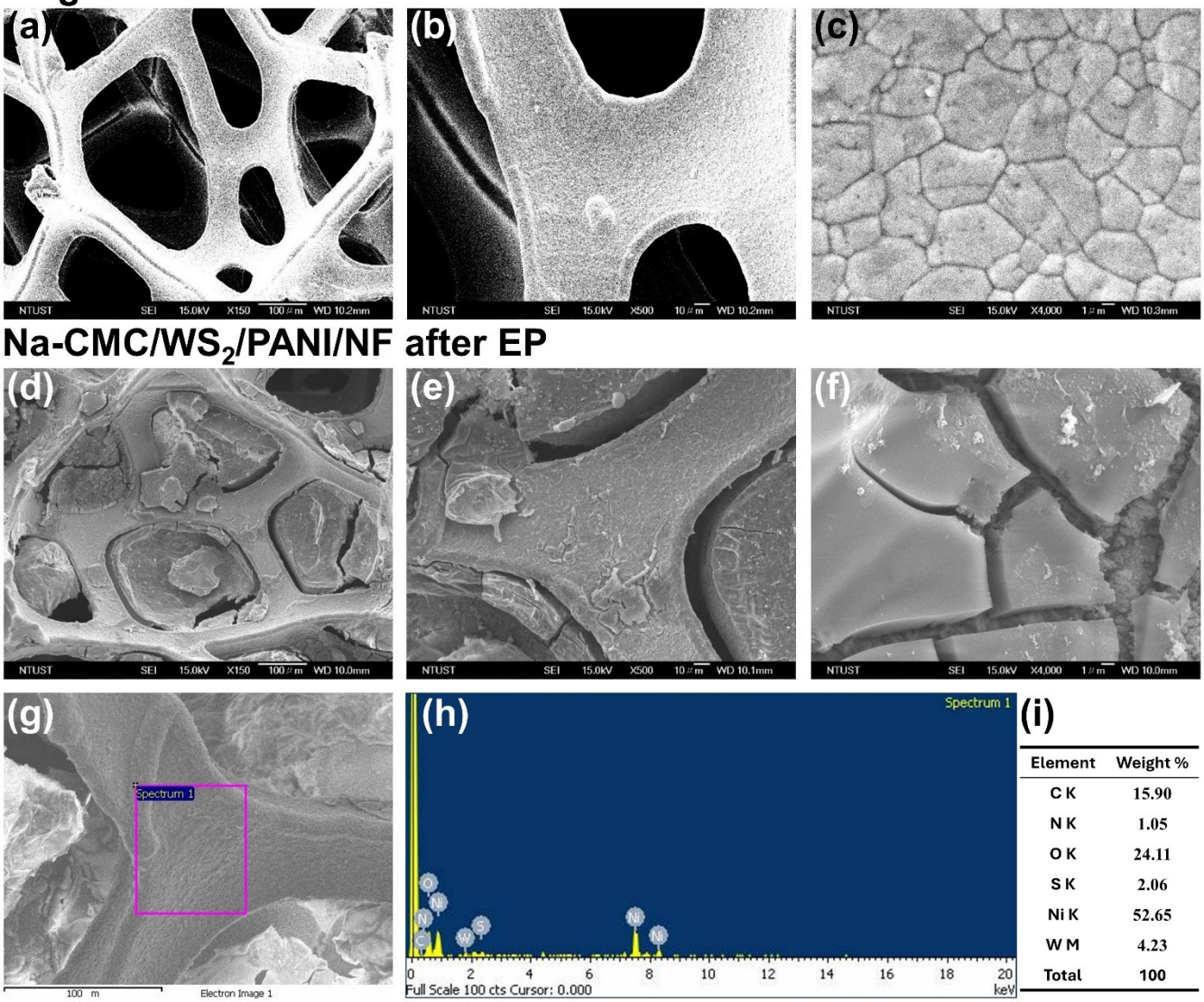

Fig. S4: SEM images of pristine NF at magnifications of **(a)** ×150, **(b)** ×500, and **(c)** ×4,000. SEM images of the EP-treated Na-CMC/WS_2/PANI/NF electrode at magnifications of **(d)** ×150, **(e)** ×500, and **(f)** ×4,000. **(g)** SEM image of the EP-treated Na-CMC/WS_2/PANI/NF electrode, along with **(h)** the corresponding EDX spectrum and **(i)** the elemental weight percentage composition.

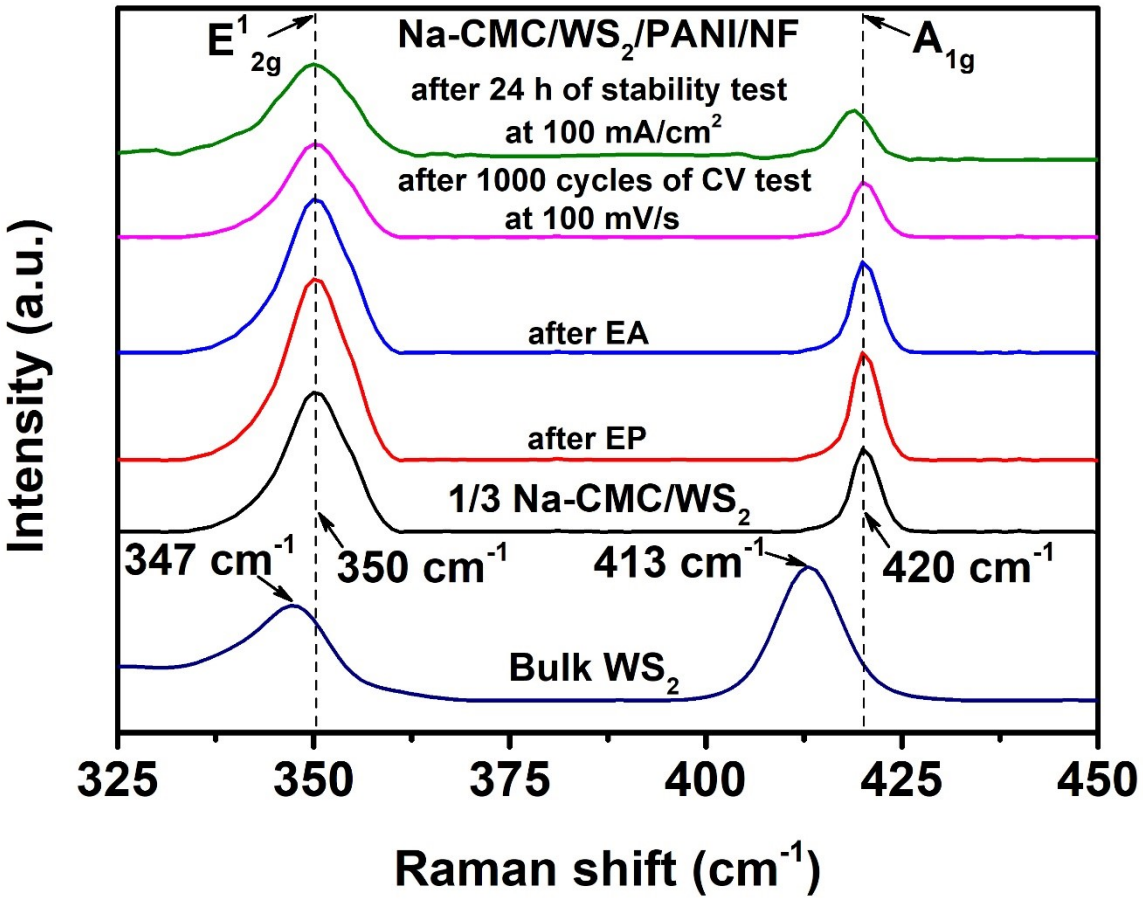

Fig. S5: Raman spectra recorded at 25 °C for bulk WS_2 crystals, the 1/3 Na-CMC/WS_2 composite, the EP-treated electrode, the EA-treated electrode, and the EA-treated Na-CMC/WS_2/PANI/NF electrode after a 24-h stability test at 100 mA cm^{-2} and 1000 CV cycles in 1 M KOH solution.

Table S1: Comparison of the HER performance of representative WS_2-based electrocatalysts in 1 M KOH solution.

Catalyst	Electrolyte	η at –10 mA cm^{-2} (mV vs. RHE)	Tafel slope (mV dec^{-1})	Ref.
WS_2@UiO-66/NF	1 M KOH	121	83	[28]
Exfoliated WS_2/NF	1 M KOH	153	283	[28]
WS_2/CC	1 M KOH	235	174	[36]
1T-WS_2|P-5@CFP	1 M KOH	190	92	[37]
WS_2/CoS_2/CC	1 M KOH	146	64	[38]
WS_2/CoS_2/Cu	1 M KOH	252	70	[39]
5% WS_2-MXene/NF	1 M KOH	66	47	[40]
CeO_2/WS_2/CC	1 M KOH	276	200	[41]
WS_2/CC	1 M KOH	340	174	[41]
EP-treated Na-CMC/WS_2/PANI/NF	1 M KOH	142	82	This work
EA-treated Na-CMC/WS_2/PANI/NF	1 M KOH	25	48	This work

CC: carbon close; CFP: carbon fiber paper; GC: glassy carbon; Cu: copper; NF: nickel foam; GF: graphite foam