Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

1D transition-metal dichalcogenides/carbon core-shell composites for Hydrogen Evolution Reaction

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Tables

Table S1: XPS Peak table for all the carbon-coated samples along with pristine WS_2.

Samples	WS_2	A-WS_2/C	O-WS_2/C	R-WS_2/C
Carbon	33.18	40.21	41.74	31.85
C-C	22.48	33.64	26.15	15.85
C-O	9.35	4.84	12.52	13.55
C=O	2.19	1.88	3.86	2.01
Oxygen (O1s)	14.64	5.49	9.01	21.65
Sulphur (s2p)	11.41	7.04	2.87	6.84
Tungsten (W4f)	4.82	3.32	1.79	4.77
Nitrogen (N1s)	2.46	3.58	2.07	3.5

Table S2: Atomic % of WS_2 ($4f_{7/2}+4f_{5/2}$) and WO_3 ($4f_{7/2}+4f_{5/2}$) content in the catalysts compared with total atomic % of W**,** obtained in XPS.

Samples	Atomic % of WS_2 or WO_2 ($4f_{7/2}+4f_{5/2}$)/W	Atomic % of WO_3 ($4f_{7/2}+4f_{5/2}$)/W	Total atomic % of W
WS_2	95	0	7.67
A-WS_2/C	89	0	3.17
O-WS_2/C	53.73	44.17	3.35
R-WS_2/C	35.61	61.75	8.76

Table S3: Comparison of electrochemical performances of similar electrocatalysts

Catalysts	Current density, mA cm^{-2}	Overpotential (mV vs. RHE)	Journal, Year of Publication	Ref.
2D graphene/WS_2 nanosheet	10	180	ACS *Appl. Energy Mater.*, 2021	42
WS_2/C	10	179	Journal of Fuel Chemistry and Technology, 2021	43
WS_2/OCF	10	278	Applied Surface Science, 2017	44
WS_2/rGO	10	170	Nanoscale, 2015	45
hierarchical triple-shelled (WS2-C-WS2) hollow nanospheres	10	175	Journal of Material Chemistry A, 2018	46
Carbon foam-N-doped Graphene-@ MoS2	10	170	Journal of Material Chemistry A, 2013	47
N-enriched C foam@WS_2	10	153	Applied Surface Science, 2019	48
N,S doped graphene	10	390	Angewandte Chemie, 2014	49
N, P co-doped carbon-encapsulated CoP/MoP hybrid	10	183	Journal of Colloid and Interface Science, 2023	50
WS_2 Nanoribbons	10	225	Advanced Energy Materials, 2014	17
MoS_2–WS_2	10	129	ACS *Sustainable Chem. Eng.*, 2018	51
R-WS_2/C	10	172		This work

Table S4: Values of resistances and capacitances from EIS spectra in 0.5 M H_2SO_4

	R_s (Ohm)	R_1 (Ohm)	CPE_1(μF)
WS_2	3.48	56.7	6.25
Carbon	2.71	9.01	8.08
A-WS_2/C	4.13	13.77	242
O-WS_2/C	2.78	11.21	7605
R-WS_2/C	4.8	8.87	1642

The equivalent circuit contains a resistor (Rs) connected with two parallel units in series: a constant phase element and a resistor (CPE_1-R_{ct}). The R_s represents the solution resistance, and the CPE_1- R_{ct} pair is equivalent to resistor and capacitor in parallel combination related to the charge transfer.

Figures

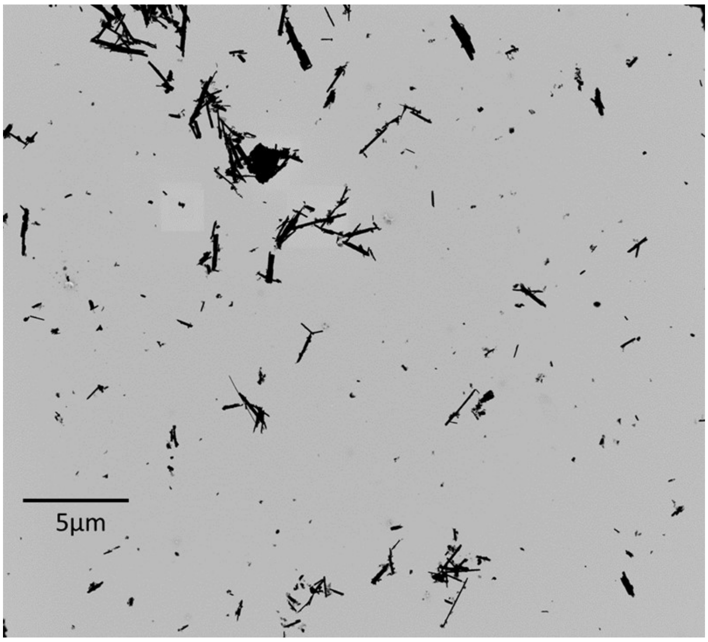

Figure S1: Low magnification STEM image of WS_2 NTs/carbon composite showing the NTs are well dispersed throughout the grid.

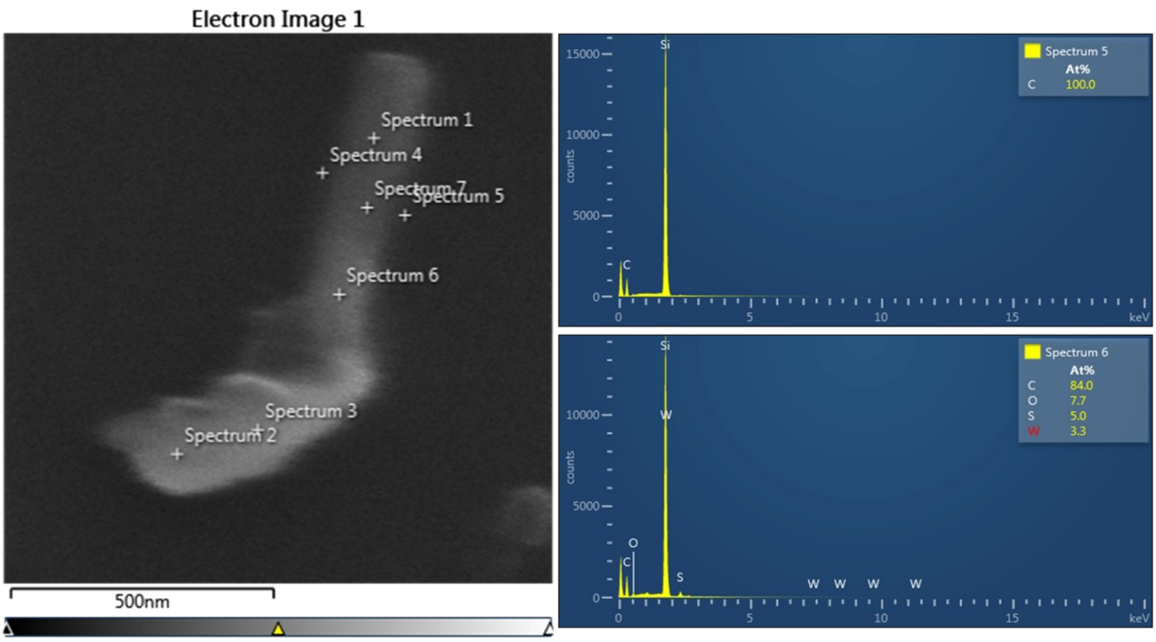

Figure S2: *left*. Low voltage SEM image of the carbon-coated WS_2 tube on silicon wafer. *Right*. EDS analysis of different points on the nanotube shown, revealing 100% carbon adjacent to the wall of the tube (point #5) as compared to elements content in the middle of the tube (point #6). The high content carbon proves that the carbon efficiently wraps all over the nanotube.

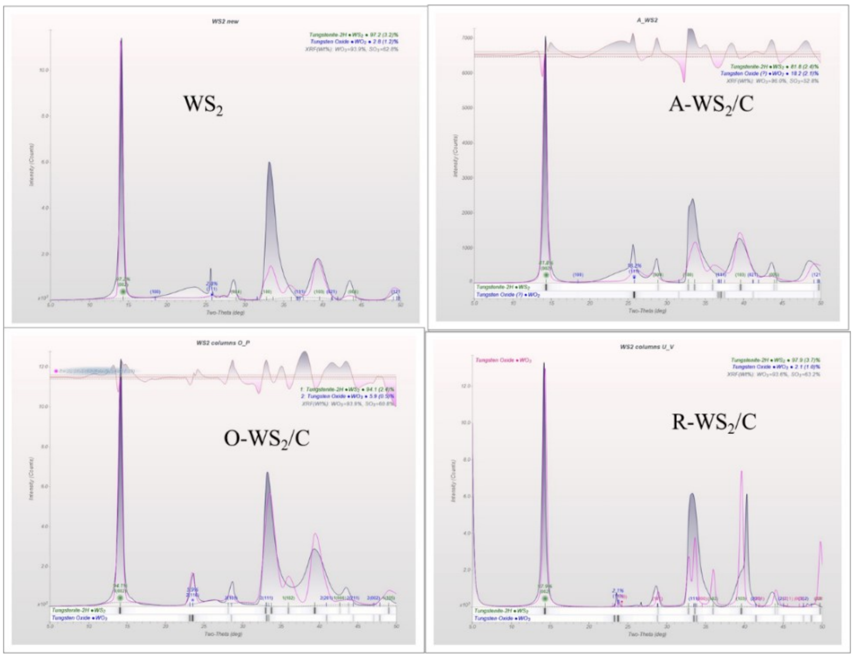

Figure S3. XRD analysis of three different samples with pristine WS_2 shows the presence of WO2 oxide phase in pristine and first annealed (A-WS_2/C) sample whereas the other two samples (O-WS_2/C AND R-WS_2/C) contain WO_3 phase. Importantly, for every sample WS_2 (002) peak at 2Θ=14.5 remains a higher percentage proving the unharmed crystallinity.

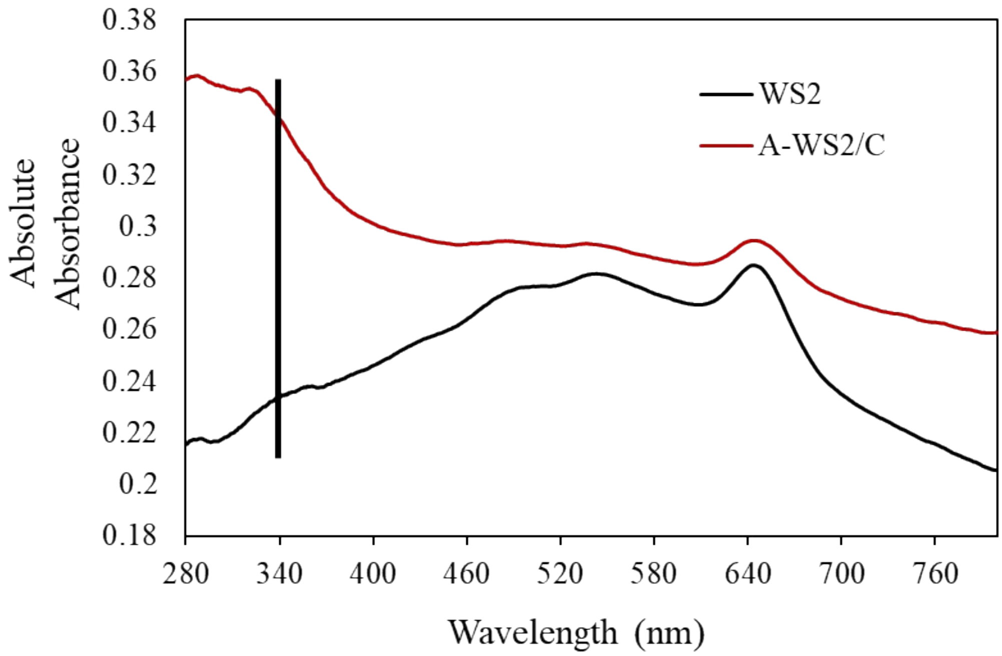

Figure S4: Absolute absorption spectra of prepared A-WS_2/C showing no shift at the exciton of the nanotube. An additional peak near 340 nm appears due to the attachment of carbon with the nanotube.

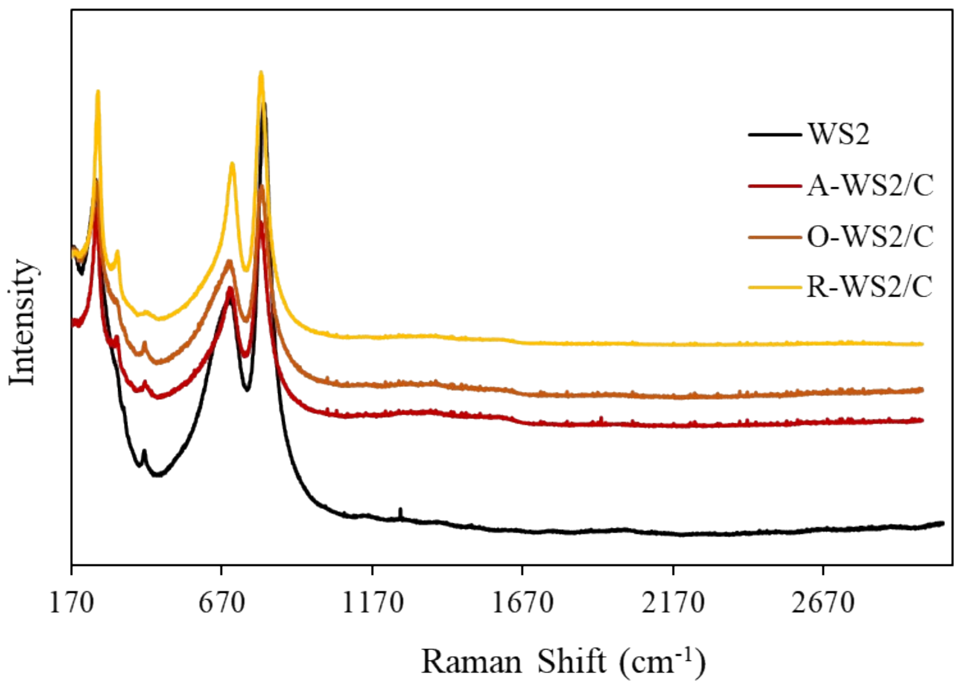

Figure S5: Raman spectroscopy of the WS_2/C composites.

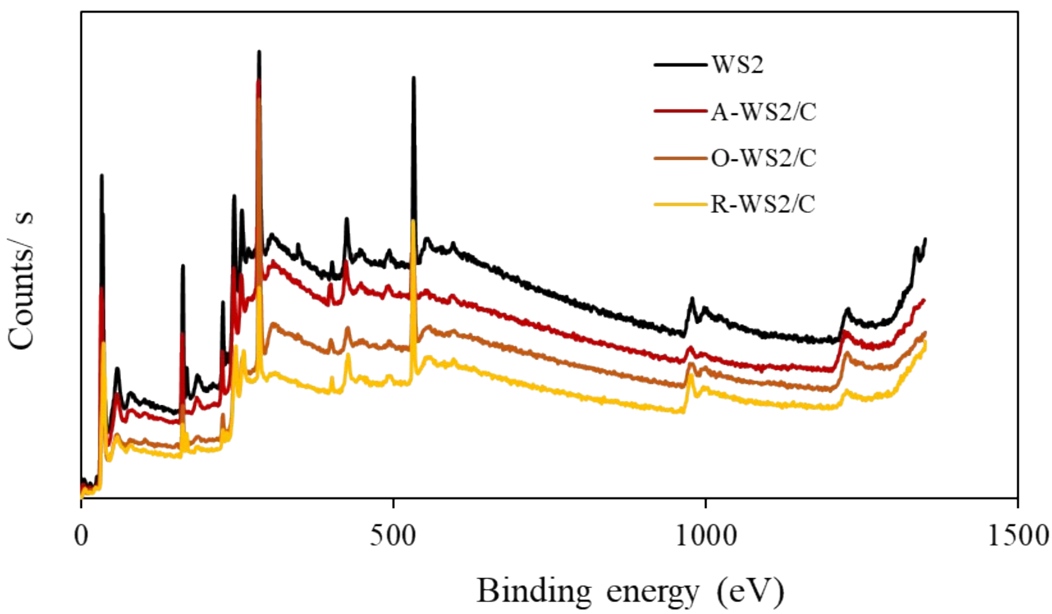

Figure S6: Full XPS spectrum of the WS_2, A-WS_2/C, O-WS_2/C, R-WS_2/C.

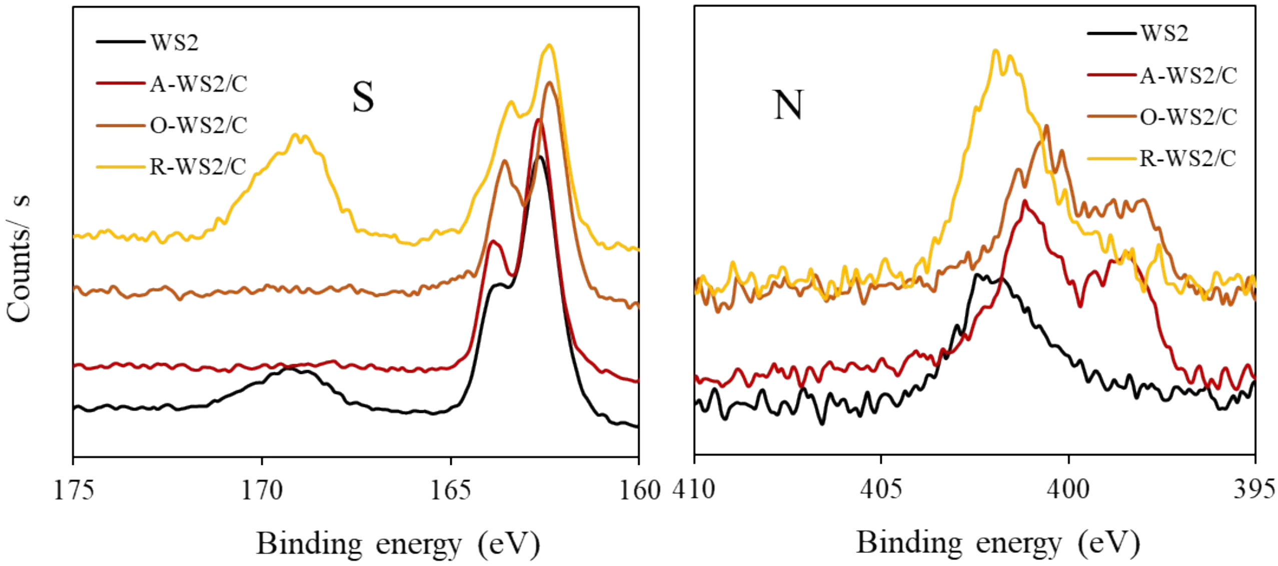

Figure S7: XPS of S2p and N1s for all samples.

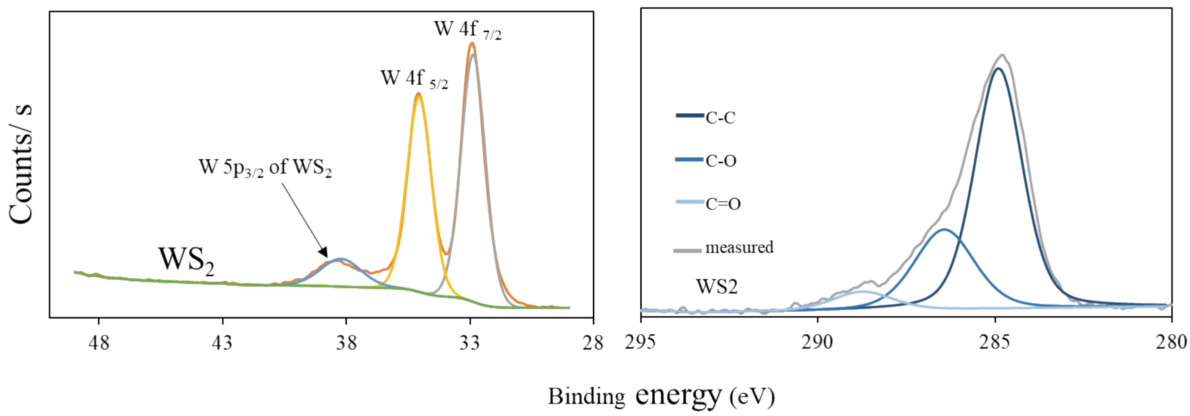

Figure S8: XPS spectrum of pristine WS2 after peak splitting of W4f and C1s scan.

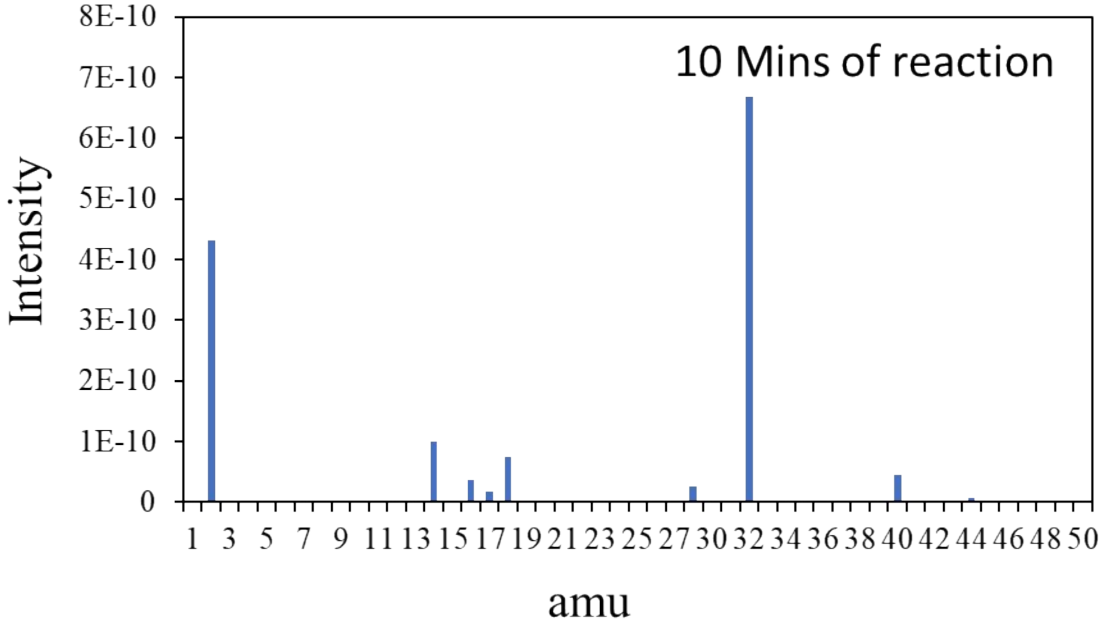

Figure S9. Mass spectroscopy (MS) was collected from A-WS2/C after 10 minutes of CA at its overpotential, confirming hydrogen production.

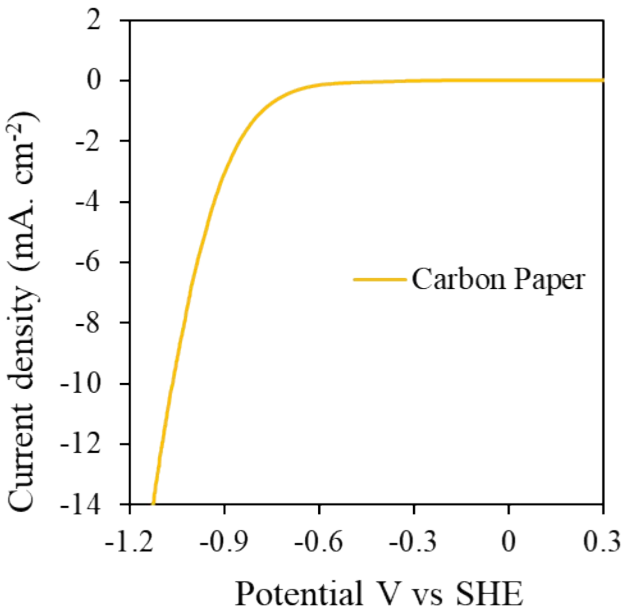

Figure S10: LSVs of the Toray carbon paper showing a negligible effect on the catalytic performance.

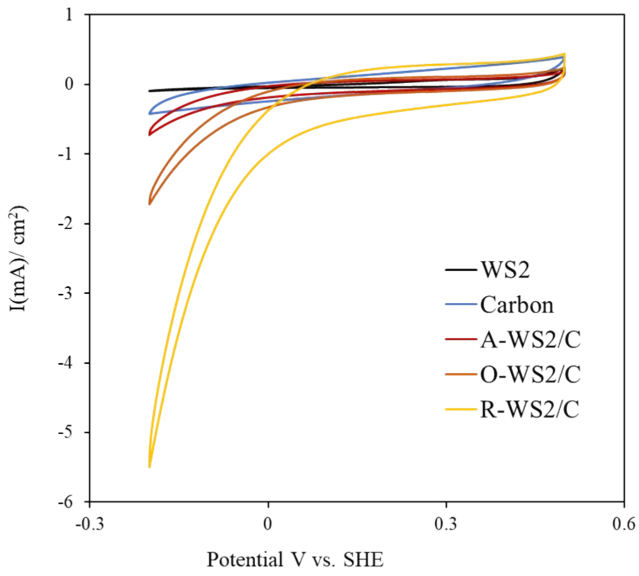

Figure S11: CV for all the samples in 0.5 M H_2SO_4.

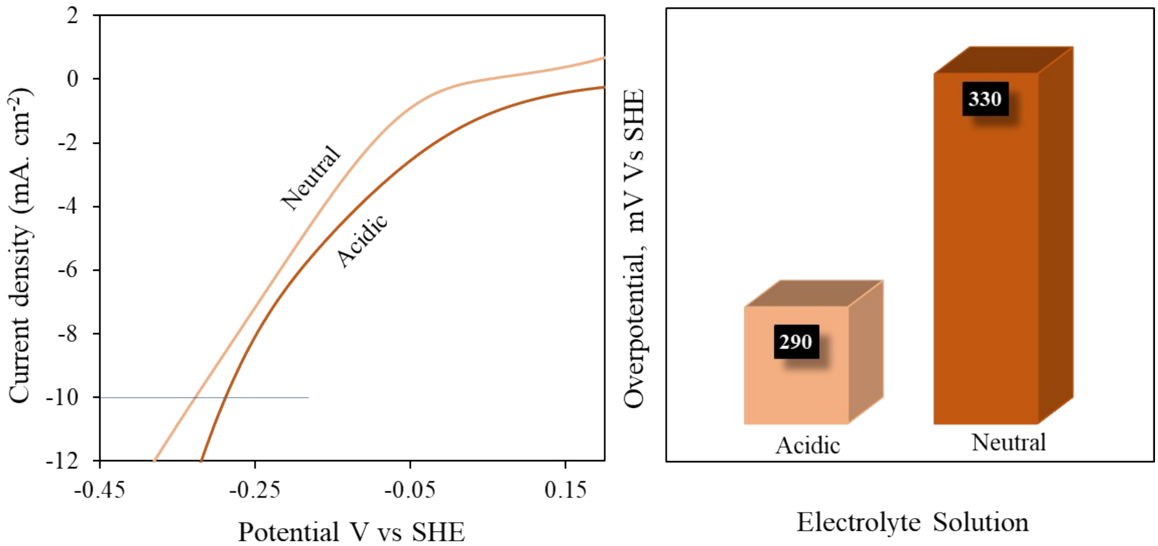

Figure S12: Onset potential at a current density of -10 $mAcm^{-2}$ of O-WS_2/C at acidic and neutral solutions.

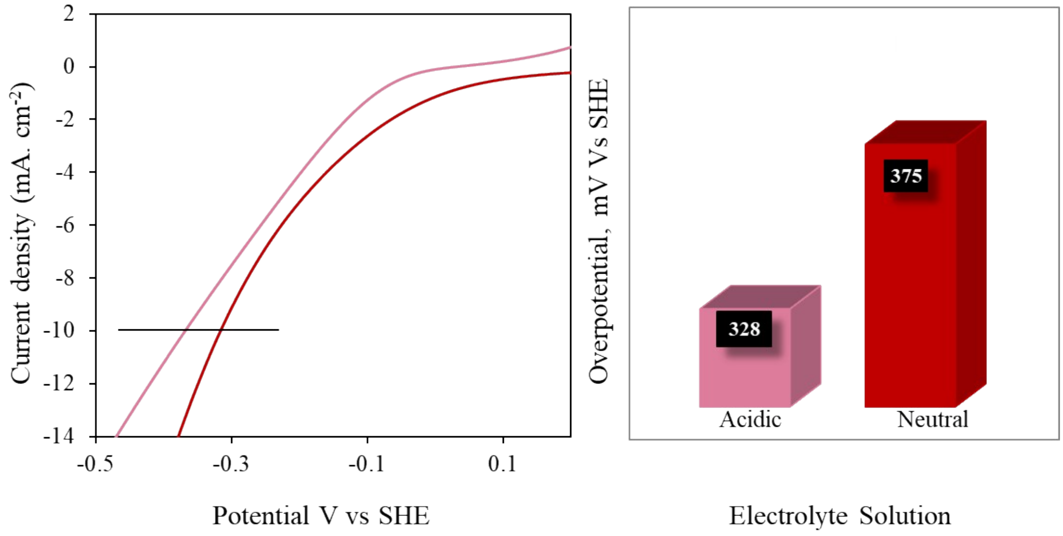

Figure S13: Onset potential at a current density of -10 $mAcm^{-2}$ of A-WS_2/C at acidic and neutral solutions

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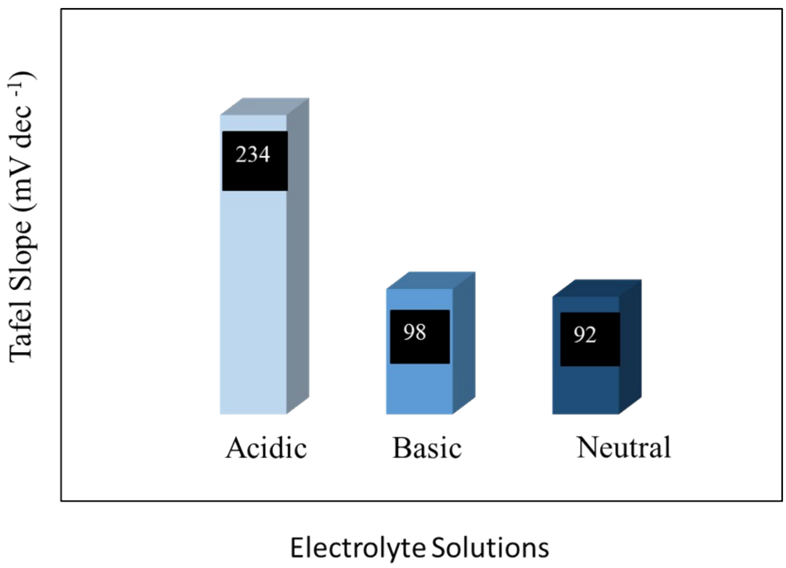

Figure S14: Tafel slope in different pH solutions.

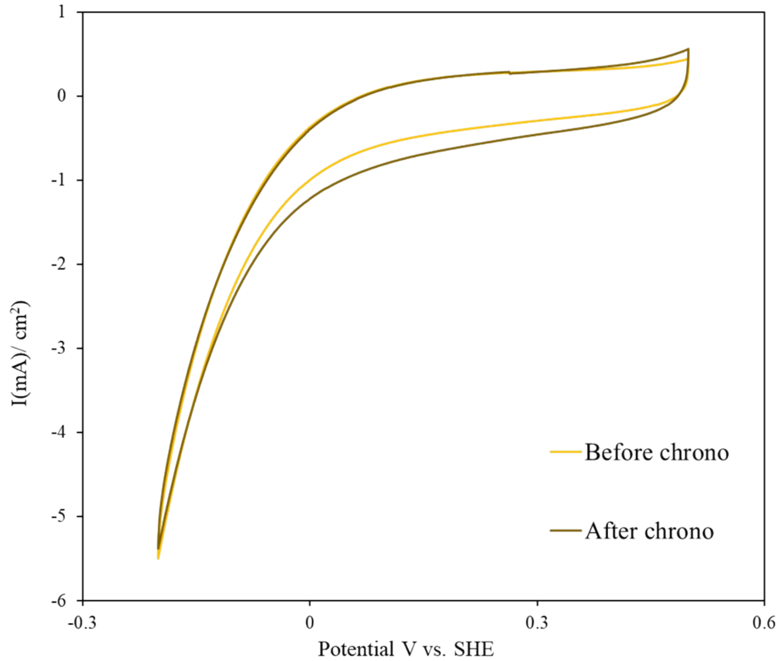

Figure S15: CV before and after the 12 h of chronoamperometry test with an applied voltage of -0.150V vs. RHE for the prepared WS_2/C catalyst indicates that the catalyst is stable even after a long duration of hydrogen production.