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

Supporting Information

1T-rich 2D-WS_2 as Interfacial Agent to Escalate Photo-induced Charge Transfer Dynamics in a Dopant-free Perovskite Solar Cells

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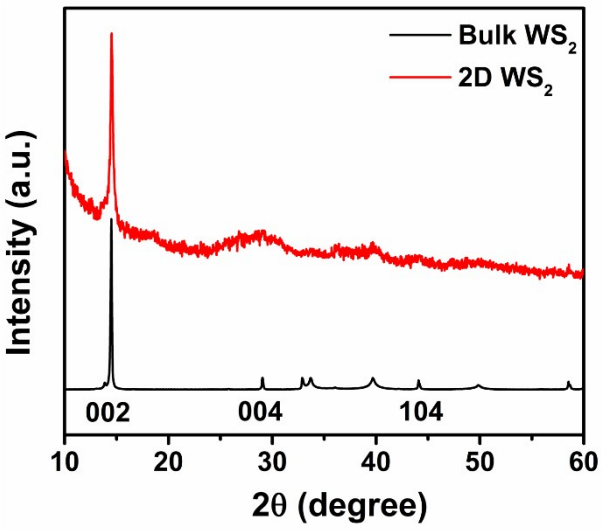

Figure S1. XRD patterns of bulk and 2D-WS_2.

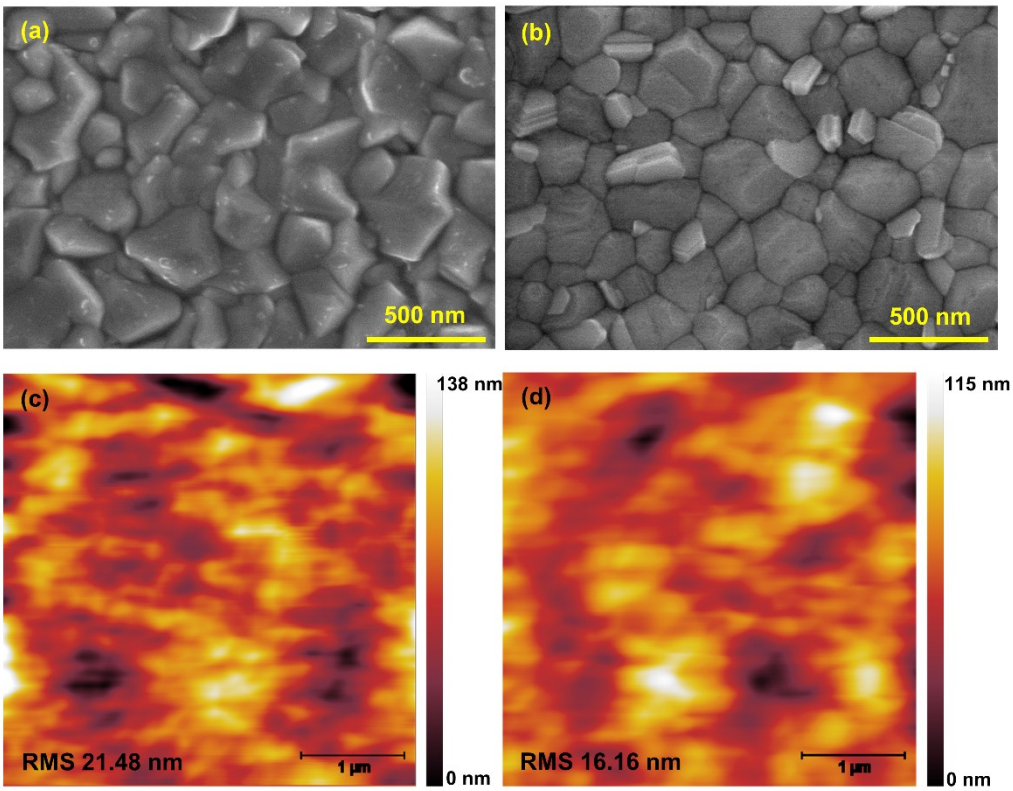

Figure S2. SEM images of (a) SnO_2-QD layer on c-TiO_2/FTO, and (b) the triple cation perovskite was grown on SnO_2-QD/c-TiO_2/FTO. AFM topography images of (c) CsFAMA film, (d) 2D-WS_2/CsFAMA layers.

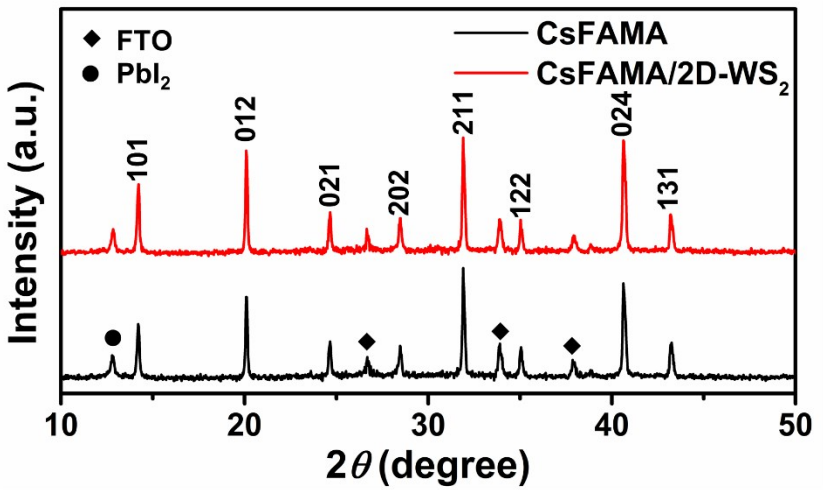

Figure S3. XRD patterns of CsFAMA and 2D-WS_2/CsFAMA layers.

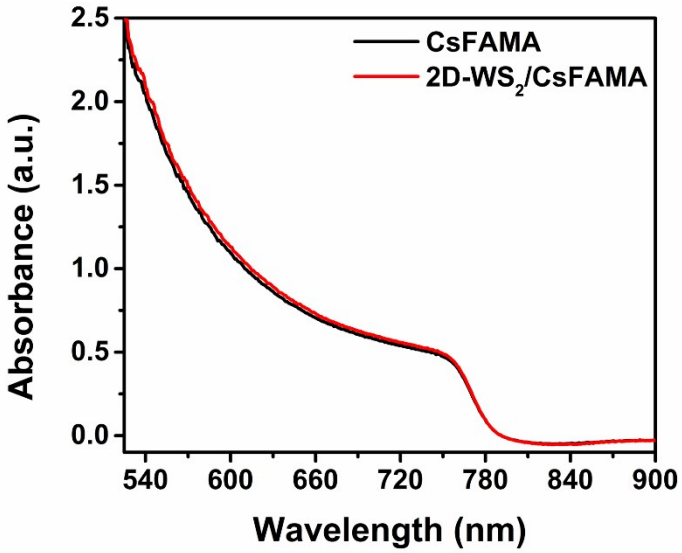

Figure S4. UV-Vis absorption spectrum of perovskite and 2D-WS_2/perovskite.

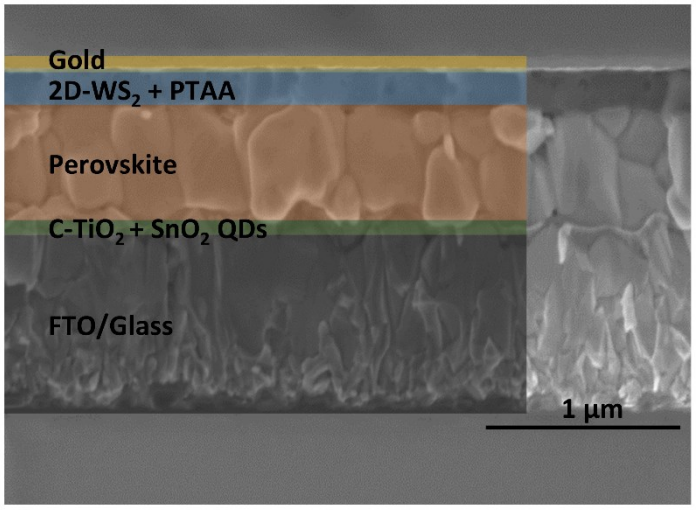

Figure S5. Cross-sectional SEM image of the PSC with 2D-WS_2 interface layer.

Table S1. Photovoltaic statistics of the PSCs with 2D-WS_2 interfacial layer.

Device	V_{oc} (mV)	J_{sc} (mAcm^{-2})	FF (%)	PCE (%)
1	1034.21	23.83	76.99	18.98
2	1049.61	22.98	77.85	18.78
3	1043.02	23.16	75.87	18.32
4	1029.25	23.50	77.79	18.82
5	1051.63	23.59	76.69	19.02
6	1051.07	22.89	77.60	18.67
7	1053.26	23.05	76.79	18.64
8	1029.81	24.09	76.49	18.98
9	1032.49	22.96	75.84	17.96

10	1056.85	23.07	76.68	18.70
Statistics	1043.12 ± 10.15	23.31 ± 0.39	76.86 ± 0.68	18.69 ± 0.31

Table S2. Photovoltaic statistics of the PSCs without 2D-WS_2 interface layer.

Device	V_{oc} (mV)	J_{sc} (mAcm^{-2})	FF (%)	PCE (%)
1	963.42	23.53	68.20	15.46
2	979.52	21.84	73.04	15.63
3	976.73	23.40	68.88	15.74
4	960.96	22.90	70.69	15.56
5	967.65	21.47	71.94	14.94
6	971.38	22.59	71.72	15.74
7	953.88	23.66	64.97	14.66
8	987.65	21.27	72.00	15.13
9	976.93	23.25	68.60	15.58
Statistics	970.90 ± 9.89	22.66 ± 0.86	70.01 ± 2.41	15.38 ± 0.36

Table S3. Electrochemical impedance spectroscopy data at an applied voltage of 0.95V in dark conditions.

Device parameters	Without 2D-WS_2	With 2D-WS_2
R_s (Ω)	15.58	12.33
R_{ctr} (Ω)	169.1	42.39
R_{rec} (Ω)	210.6	682.5
CPE1 (F)	94.9×10^{-9}	15.15×10^{-6}
CPE2 (F)	0.1389×10^{-6}	64.88×10^{-9}

Table S4. Photoelectrical dynamics of the devices.

Device parameters	Without 2D-WS_2	With 2D-WS_2
Ideality factor, n_{id}	2.69	2.47
Saturation current density, J_0 (mAcm^{-2})	4.834×10^{-6}	2.109×10^{-7}
Effective voltage, V_{eff} (V)	0.3	0.58
Saturation photocurrent density, J_{sat} (mA)	23.39	23.60
Maximum excitation generation rate, G_{max} (s^{-1})	3.65×10^{21}	3.68×10^{21}

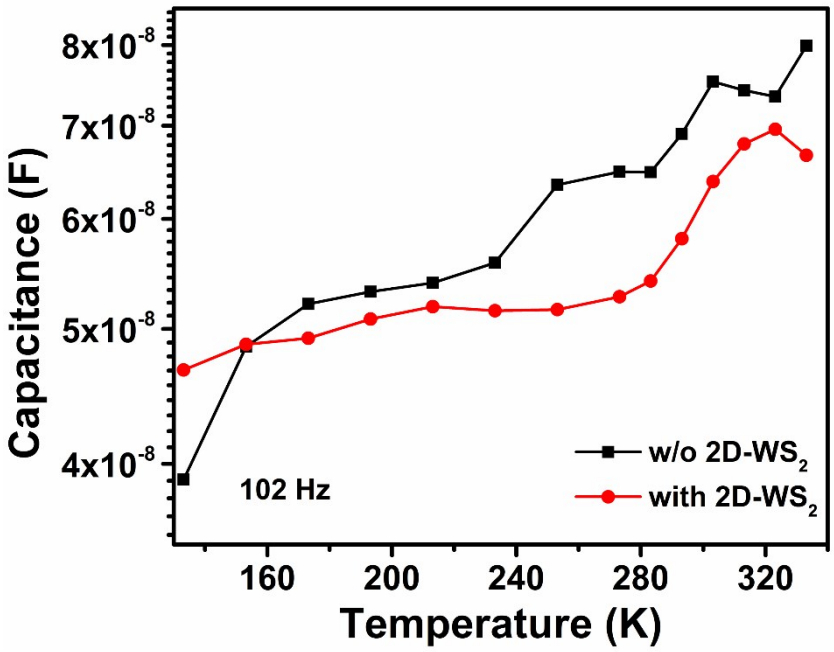

Figure S6. Temperature-dependent low-frequency capacitance variation of the devices with and without 2D-WS_2.

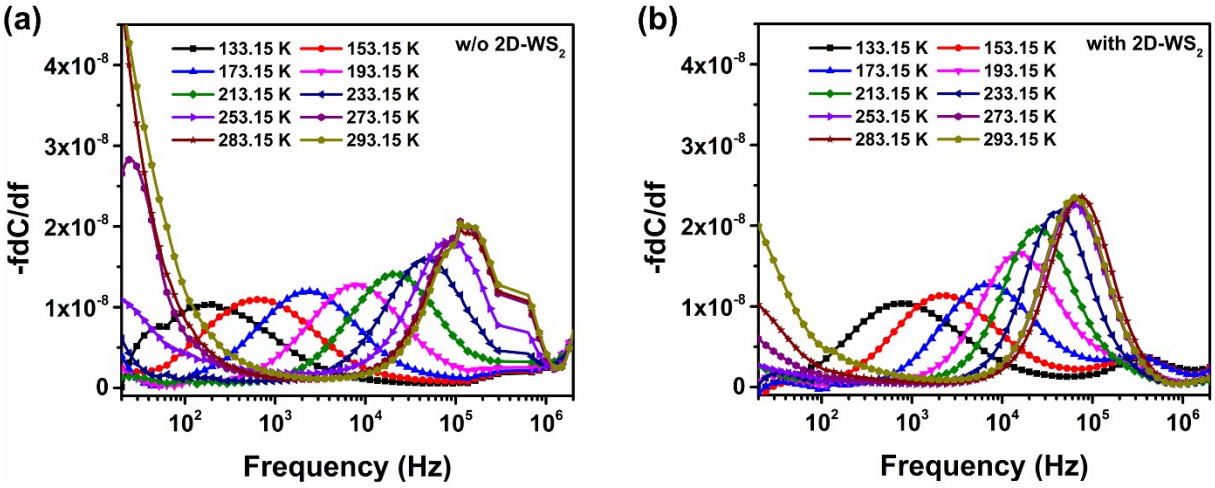

Figure S7. –fdC/df vs. frequency variation at low temperature for the devices without (a) and with (b) 2D-WS_2 interface layer.

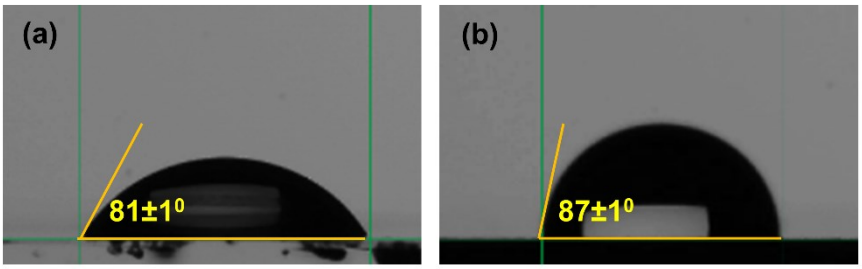

Figure S8. The water contact angle of (a) perovskite and with (b) 2D-WS_2/perovskite layer.