Supplementary Information

Preparation of Hybrid Molybdenum Disulfide/Single Wall Carbon Nanotube–n-Type Silicon Solar Cells

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Materials and Methods

The Four-Point Probe (Conductivity measurements)

The conductivity test done using the four-point probe (KeithLink), an average of three readings were taking by measuring (the sheet resistance and conductivity) for the film mounted on a glass substrate by changing the orientation of the glass substrate.

UV-Visible NIR Spectroscopy (Transmittance measurements)

The MoS_2/SWCNTs films on glass substrates were scanned over (UV visible spectrophotometer Cary50, Varian) 350-1000nm to test the films' transparency. The transparency calculated from the transparency data using the average at (450–850 nm) using the equation.

Properties of the Reference Cell

A standard cell was made with just CNTs in the top layer. The detail characteristics of these cells are provided in Figures S1–S3 (UV-vis spectra of the films, dark and light curves at different treatment stages) and Table S1. The average efficiency of this cell was 6.83 ±0.76 % and other cells made containing MoS_2 will be compared to this value.

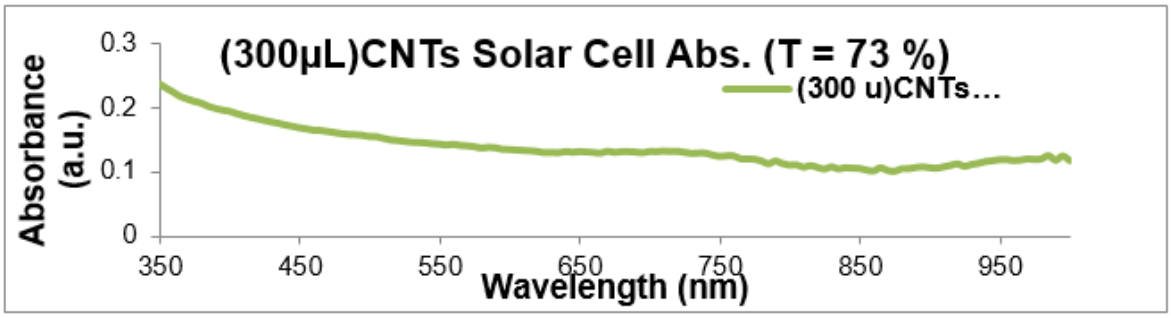

Figure S1. The absorption spectrum for the 300 µL SWCNTs-dispersion.

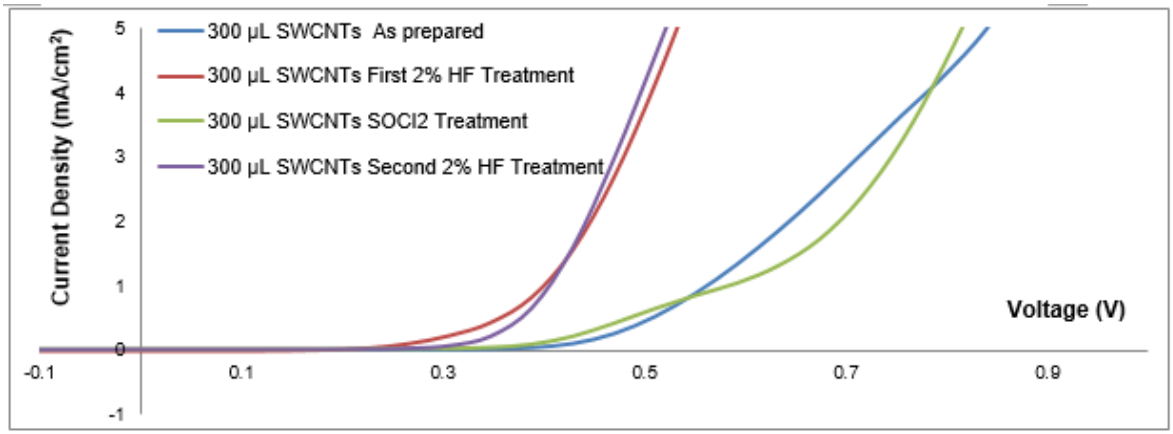

Figure S2. Dark curves for the SWCNTs-n-Silicon based solar cell at different stages of treatment made using 300 µL of the SWCNT dispersions.

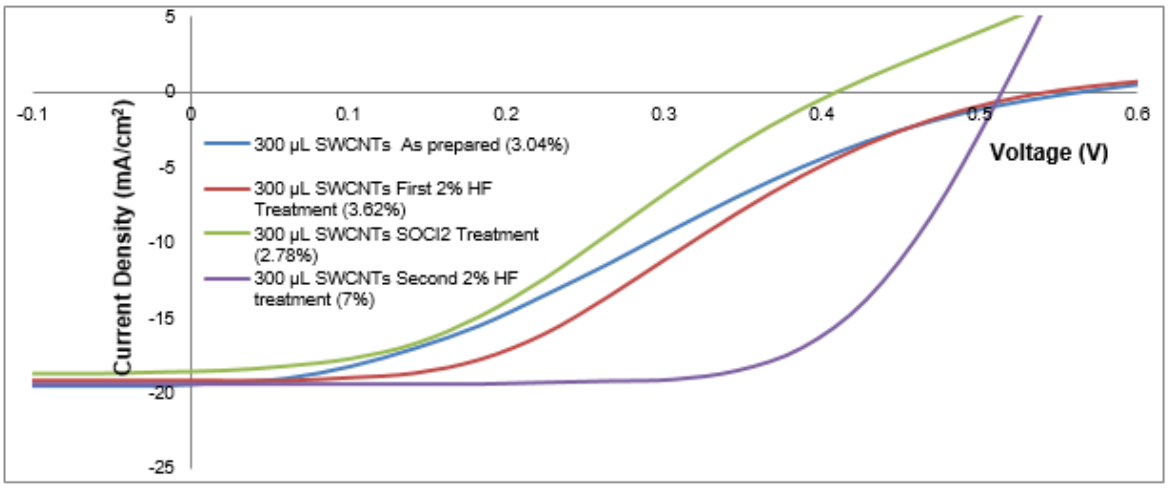

Figure S3. Light curves for the SWCNTs-n-Silicon based solar cell at different stages of treatment made using 300 µL of the SWCNT dispersions.

Table S1. The cell parameters for the reference SWCNTs-n-Si solar cell made with 300µL of SWCNT dispersion.

Cell	Transmittance (T %)	Sheet Resistivity (Ω cm^{-1})	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	R_{shunt} (Ω)	R_{series} (Ω)	Cell Efficiency (%)
1	73.4	192	22.029	0.501	0.53	4.81×10^3	75.3	6
2	73.2	188.3	19.387	0.515	0.66	6.75×10^4	69.2	7
3	72	187	24.114	0.515	0.6	5.29×10^3	1.05×10^2	7.5

Cells made using MoS_2

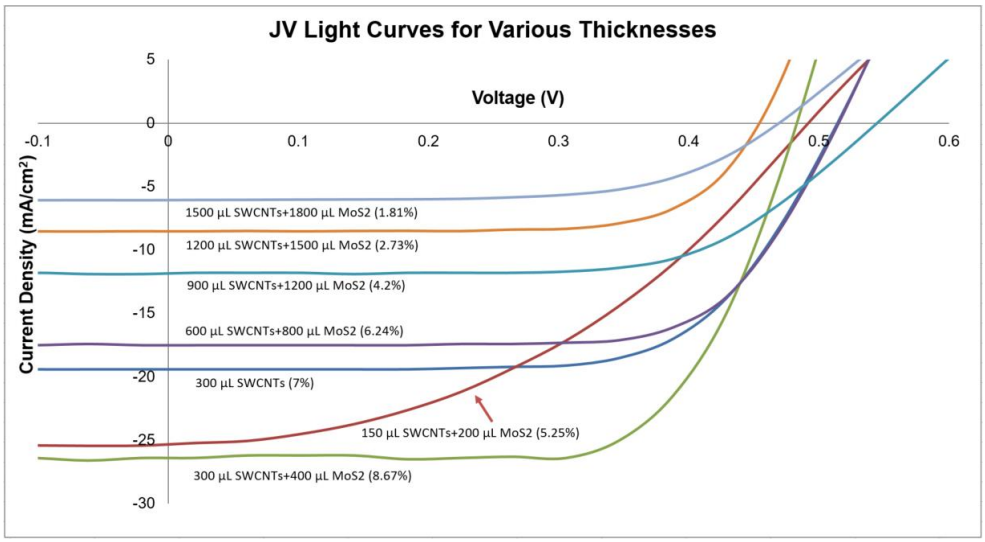

Figure S4. Light curves for the cells made with MoS_2/SWCNT hybrid films of various thicknesses.

Table S2. The cell parameters for devices made with MoS_2/SWCNT hybrid films of various thicknesses.

Cell Name	Transmittance (T%)	Sheet Resistivity (Ω sq^{-1})	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	R_{shunt} (Ω)	R_{series} (Ω)	Average Cell Efficiency (%)	Highest Cell Efficiency (%)
300 µL SWCNTs	73.2	188.3	19.387	0.515	0.66	6.75 x 10^4	69.2	6.83 ± 0.63	7.5
150 µL SWCNTs + 200 µL MoS_2	88.5	708.1	26.497	0.551	0.35	7.69 x 10^2	190	5.04 ± 0.17	5.25
300 µL SWCNTs + 400 µL MoS_2	65	436.1	26.38	0.487	0.67	1.16 x 10^4	49.5	8.08 ± 0.47	8.67
600 µL SWCNTs + 800 µL MoS_2	46	168.1	17.489	0.516	0.69	6.87 x 10^4	69.0	5.98 ± 0.23	6.24
900 µL SWCNTs + 1200 µL MoS_2	30	107	11.846	0.545	0.65	1.63 x 10^4	141	3.83 ± 0.36	4.17
1200 µL SWCNTs + 1500 µL MoS_2	24	76	8.516	0.451	0.71	6.02 x 10^4	77.3	2.39 ± 0.34	2.73
1500 µL SWCNTs + 1800 µL MoS_2	21	50.2	6.05	0.47	0.64	2.28 x 10^4	200	1.76 ± 0.04	1.81

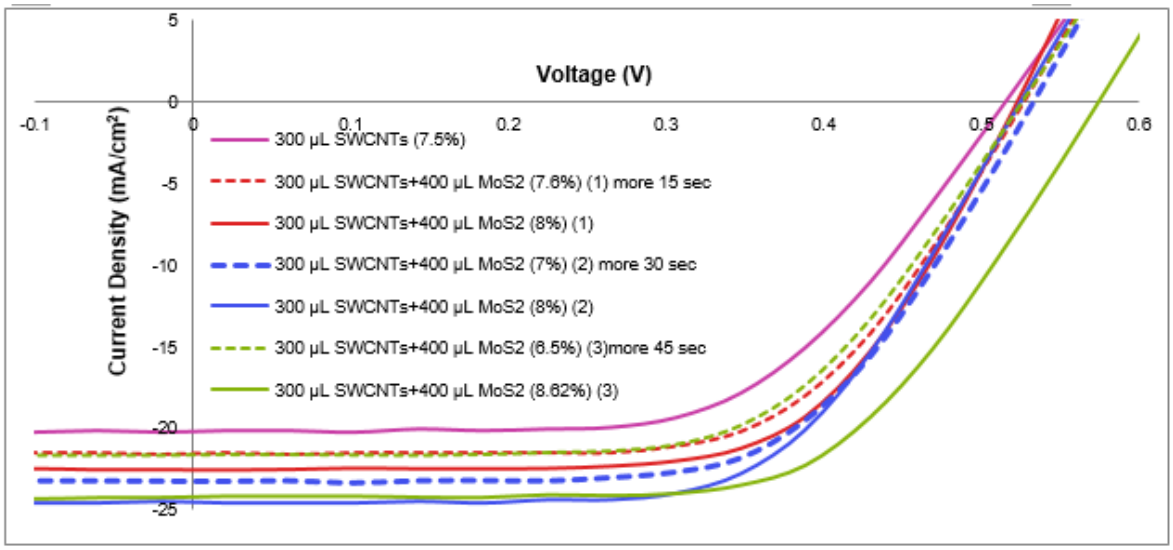

Figure S5. Light curves for the SWCNTs-n-Silicon reference solar cell and cells made with MoS_2/SWCNT hybrids after various HF etching times.

TableS 3. Parameters for the reference SWCNTs-n-Si solar cell made with 300µL SWCNT dispersion and cells made with MoS_2/SWCNT hybrids after various HF etching times.

Cell Name	Transmittance (T%)	Sheet Resistivity (Ω sq^{-1})	Normal Etching Cell Efficiency (%)	Extra Etching Cell Efficiency (%)
300 µL SWCNTs	72	187	7.5	
300 µL SWCNTs + 400 µL MoS_2	65	376	8	7.6 (15 sec)
300 µL SWCNTs + 400 µL MoS_2	65	351.2	8	7 (30 sec)
300 µL SWCNTs + 400 µL MoS_2	67	297	8.62	6.5 (45 sec)

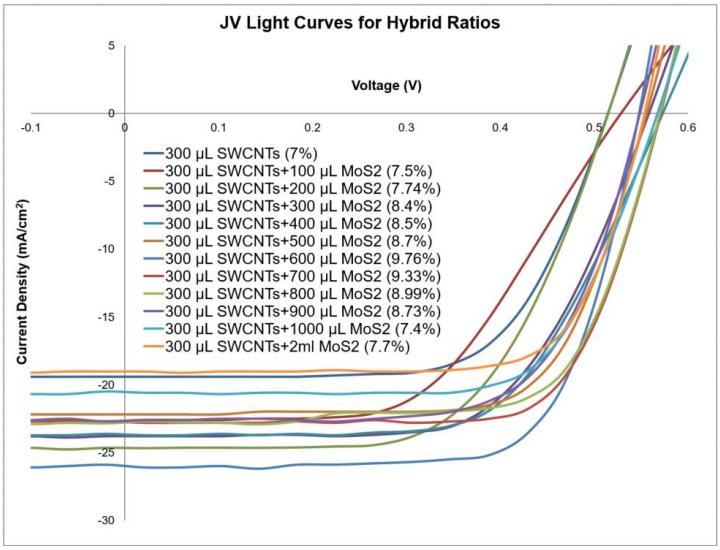

Figure S6. Light curves for the SWCNTs-n-Silicon reference solar cell and cells made with MoS_2/SWCNT hybrids using various ratios of dispersions.

Table S4. The cell parameters for the reference SWCNTs-n-Si solar cell and cells made with MoS_2/SWCNT hybrids using various ratios of dispersions.

Cell Name	Transmittance (T%)	Sheet Resistivity (Ω sq^{-1})	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	R_{shunt} (Ω)	R_{series} (Ω)	Average Cell Efficiency (%)	Highest Cell Efficiency (%)
300 µL SWCNTs	73.4	192	22.029	0.501	0.53	4.81 x 10^3	75.3	7 ±0.63	7.5
300 µL SWCNTs + 100 µL MoS_2	75	460.1	22.615	0.527	0.54	7.31 x 10^3	118	7.4 ±0.07	7.5
300 µL SWCNTs + 200 µL MoS_2	75	407	24.642	0.515	0.61	1.89 x 10^4	65.6	7.51 ± 0.18	7.74
300 µL SWCNTs + 300 µL MoS_2	73	386	23.803	0.559	0.63	2.39 x 10^4	71.5	8.3 ±0.18	8.4
300 µL SWCNTs + 400 µL MoS_2	67	289	23.629	0.573	0.63	6.72 x 10^3	80.1	8.13 ± 0.45	8.5
300 µL SWCNTs + 500 µL MoS_2	70	286	22.199	0.556	0.7	2.55 x 10^4	56.0	8.53 ± 0.17	8.7
300 µL SWCNTs + 600 µL MoS_2	66.3	231.1	25.544	0.522	0.61	7.57 x 10^3	58.4	9 ±0.58	9.8
300 µL SWCNTs + 700 µL MoS_2	53	295	22.743	0.575	0.71	3.80 x 10^3	59.1	9.23 ±0.09	9.33
300 µL SWCNTs + 800 µL MoS_2	52	266.2	22.771	0.574	0.69	3.73 x 10^3	59.8	8.33 ± 0.47	8.99
300 µL SWCNTs + 900 µL MoS_2	50	348	22.62	0.548	0.68	4.53 x 10^3	51.7	8.2 ± 0.15	8.73
300 µL SWCNTs + 1000 µL MoS_2	49.5	352.1	20.55	0.575	0.7	2.41 x 10^4	71.6	8.15±0.54	7.4
300 µL SWCNTs + 2 mL MoS_2	34	233.3	19.031	0.554	0.73	4.62 x 10^4	53.3	7.3 ±0.29	7.7

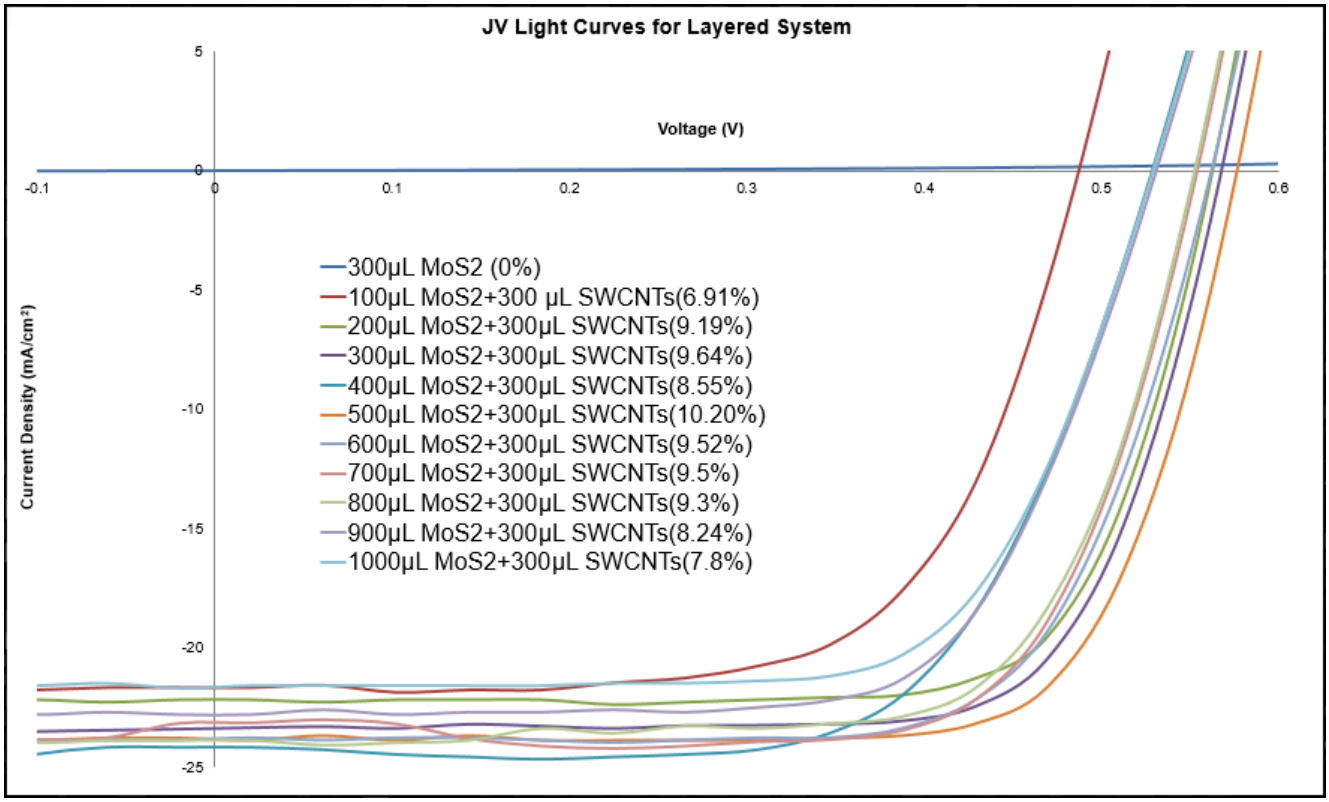

Figure S7. Light curves for the cells made with a layer structure with the Si first covered a MoS_2 layer which is then covered by a SWCNT layer.

Table S5. The parameters for cells made with a layer structure with the Si first covered a MoS_2 layer which is then covered by a SWCNT layer.

Cell Name	Transmittance (T%)	Sheet Resistivity (Ω sq^{-1})	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	R_{shunt} (Ω)	R_{series} (Ω)	Average Cell Efficiency (%)	Highest Cell Efficiency (%)
300 µL MoS_2	85	192	-0.001	-0.007	0	8.51×10^4	8.92×10^4	0	0
100 µL MoS_2 + 300 µL SWCNTs	66	192	21.673	0.494	0.65	1.35×10^5	62.8	6.84 ± 0.06	6.91
200 µL MoS_2 + 300 µL SWCNTs	61.3	282.5	22.203	0.567	0.73	1.44×10^4	49.7	8.4 ± 0.58	9.19
300 µL MoS_2 + 300 µL SWCNTs	65.3	128.8	24.207	0.532	0.66	3.10×10^4	62.7	9.09 ± 0.95	9.64
400 µL MoS_2 + 300 µL SWCNTs	62.2	157.8	23.206	0.572	0.72	3.40×10^6	51.4	8.26 ± 0.21	8.55
500 µL MoS_2 + 300 µL SWCNTs	62.2	132.6	23.838	0.565	0.71	2.07×10^4	52.4	10.04 ± 0.23	10.2
600 µL MoS_2 + 300 µL SWCNTs	64	178.4	23.841	0.575	0.74	4.95×10^3	36.6	9.27 ± 0.34	9.52
700 µL MoS_2 + 300 µL SWCNTs	58	191	23.144	0.555	0.74	2.75×10^4	46.4	9.47 ± 0.05	9.5
800 µL MoS_2 + 300 µL SWCNTs	56	208.4	23.894	0.553	0.7	9.01×10^3	45.8	9.16 ± 0.18	9.28
900 µL MoS_2 + 300 µL SWCNTs	56	210.4	22.762	0.535	0.68	5.06×10^4	64.2	7.67 ± 0.74	8.24
1000 µL MoS_2 + 300 µL SWCNTs	55	283.1	21.609	0.533	0.68	4.51×10^3	64.3	7.0 ± 0.75	7.87

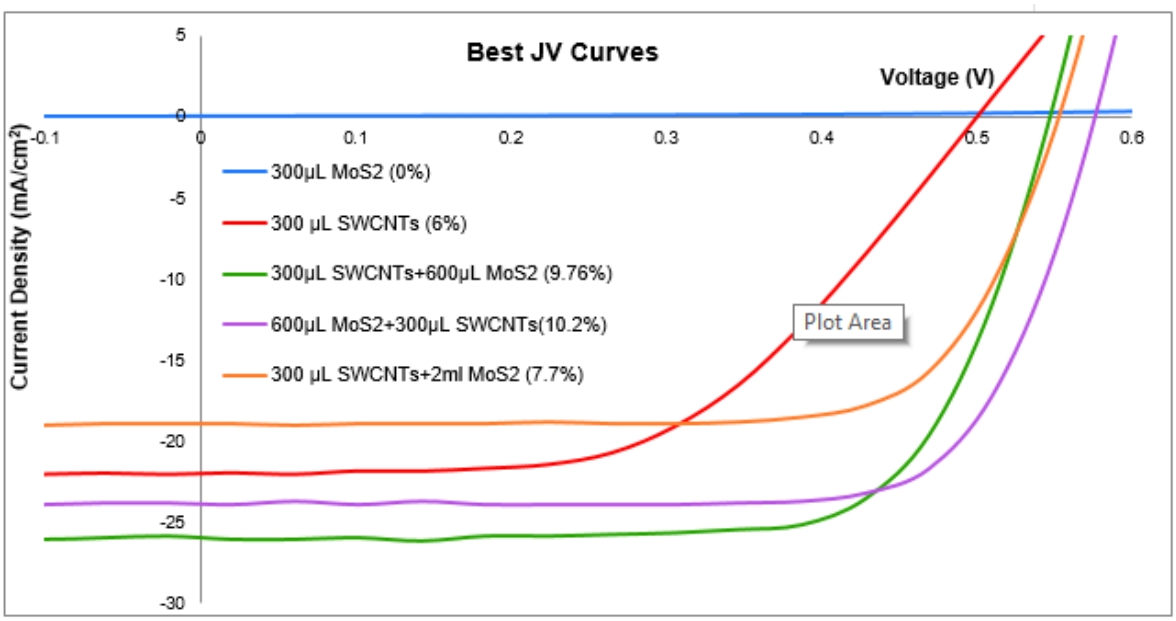

Figure S8. Representative light curves for the best average cells.

Table S6. The parameters for the best average cells.

Cell Name	Transmittance (T%)	Sheet Resistivity (Ω sq^{-1})	J_{sc} (mA cm^{-2})	V_{oc} (V)	FF	R_{shunt} (Ω)	R_{series} (Ω)	Average Cell Efficiency (%)	Highest Cell Efficiency (%)
300 µL MoS_2	85	192	−0.001	−0.007	0	8.51 x 10^4	8.92 x 10^4	0	0
300 µL SWCNTs	73.2	188.3	19.387	0.515	0.66	6.75 x 10^4	69.2	6.83 ±0.63	7.5
Layered 500 µL MoS_2 + 300 µL SWCNTs	64	178.4	23.841	0.575	0.74	4.95 x 10^3	36.6	10.04 ±0.22	10.2
Hybrid 300 µL SWCNTs + 700 µL MoS_2	53	295	22.743	0.575	0.71	3.80 x 10^3	59.1	9.23 ±0.09	9.33