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

Electronic Supplementary Information (ESI) for

Efficiency improvement for perovskite-inspired $Cs_3Sb_2I_9$ solar cells using P3HT as the hole transport material

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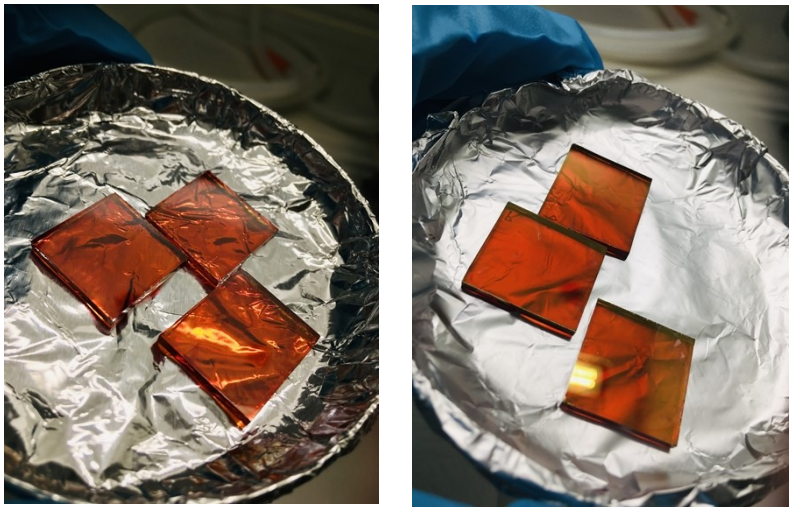

Figure S1. Photographs of the films of $Cs_3Sb_2I_9$ (left). On the right, films with P3HT coating atop $Cs_3Sb_2I_9$.

Table S1. Comparison of the photovoltaic parameters in this work with those of the closest state-of-the-art solar cell structures.

	PCE (%)	FF (%)	J_{SC} (mA/cm^2)	V_{OC} (V)
$Cs_3Sb_2I_9$ with no HTM (**this work**)	1.19	47.70	4.70	0.52
$Cs_3Sb_2I_9$ with P3HT as HTM (**this work**)	2.48	54.90	5.40	0.80
$Cs_3Sb_2I_9$ with no HTM[1]*	1.21	55.85	3.55	0.61
$Cs_3Sb_2Cl_3I_6$ with LZ-HTL-1-1 as HTM[2]	2.15	56	6.46	0.60

*Device area = 0.09 cm^2 (vs. 0.2 cm^2 in this work).

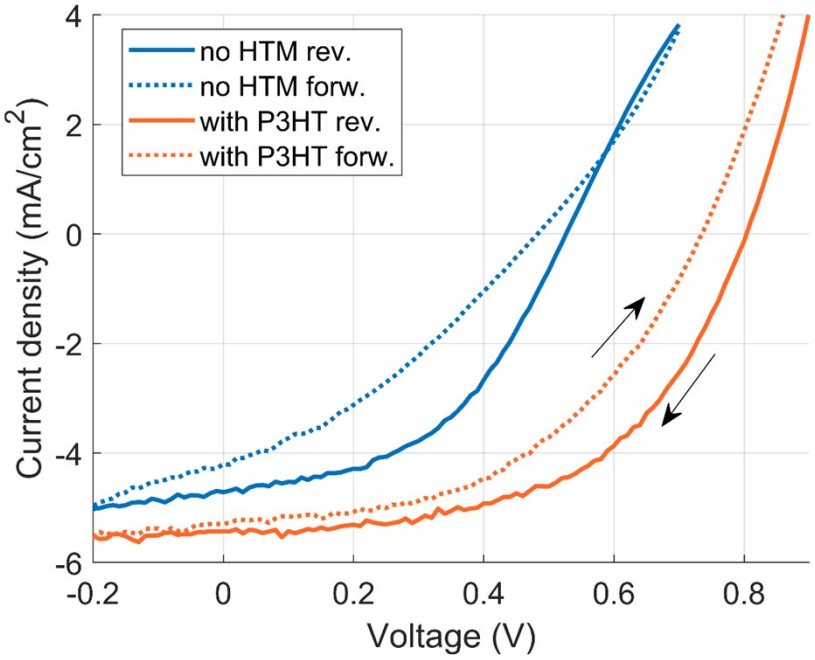

Figure S2. Forward and reverse scans for the solar cells. In the forward direction with P3HT the figures of merit are PCE = 1.9 %, FF = 49 %, Jsc = 5.3 mA/cm^2 Voc = 0.73 V, and without P3HT PCE = 0.68 %, FF = 33 %, Jsc = 4.3 mA/cm^2, and Voc = 0.48 V.

Table S2. Summary of TRPL data.

Sample	[a)]A_1 (%)	τ_1 (ps)	A_2 (%)	τ_2 (ps)
glass/$Cs_3Sb_2I_9$	74.1	85.4	25.9	1025.2
glass/$Cs_3Sb_2I_9$/P3HT	83.3	50.9	16.7	73.5

[a)]Contribution factor, $A_1 + A_2 = 100\%$.

Table S3. Performance dependence on the HCl concentration x µl/ml in DMF.

	PCE (%)	FF (%)	J_{sc} (mA/cm2)	V_{oc} (V)
20 µl/ml	0.03	34.00	0.30	0.25
30 µl/ml	0.74	43.14	2.90	0.59
50 µl/ml	0.90	50.90	3.98	0.44

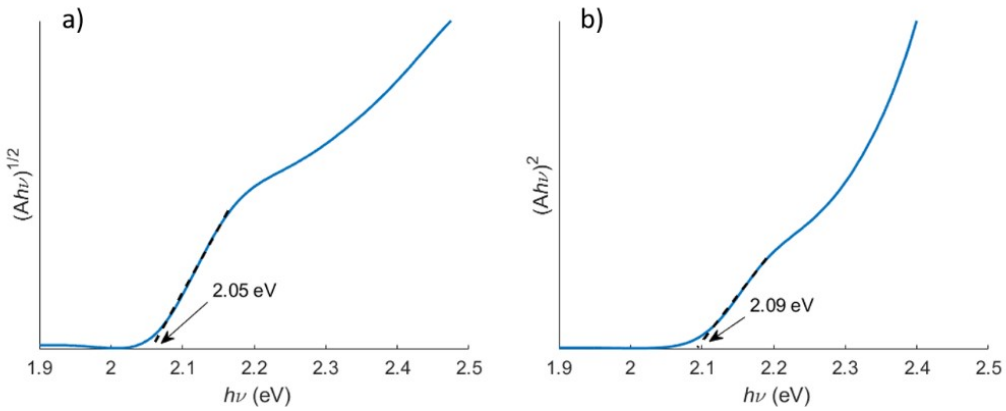

Figure S3. a) Indirect Tauc plot; b) direct Tauc plot

Table S4 Numerical presentation of data presented in Figure 5

No HTM	PCE (%)	FF (%)	J_{sc} (mA/cm2)	V_{oc} (V)
Day 1	0.46	37.36	2.46	0.44
st. dev.	0.35	6.77	1.33	0.05
Week 1	0.53	40.39	2.63	0.45
st. dev.	0.39	7.51	1.25	0.05
Week 2	0.47	43.47	2.36	0.43
st. dev.	0.30	4.60	1.13	0.05
Week 4	0.30	47.74	1.50	0.40
st. dev.	0.22	4.42	0.94	0.05

With P3HT	PCE (%)	FF (%)	J_{sc} (mA/cm2)	V_{oc} (V)
Day 1	1.17	50.03	3.82	0.60
st. dev.	0.33	3.63	0.57	0.08
Week 1	1.03	48.66	3.44	0.60
st. dev.	0.32	2.78	0.61	0.08
Week 2	0.69	48.32	2.71	0.52
st. dev.	0.18	2.85	0.52	0.05
Week 4	0.40	48.99	1.85	0.43
st. dev.	0.12	4.66	0.39	0.07

References

1. F. Umar, J. Zhang, Z. Jin, I. Muhammad, X. Yang, H. Deng, K. Jahangeer, Q. Hu, H. Song, J. Tang, F. Umar, J. Zhang, Z. Jin, I. Muhammad, X. Yang, H. Deng, K. Jahangeer, Q. Hu, H. Song, J. Tang, *Adv. Optical Mater.* **2019**, *7*, 1801368.
2. Y. Peng, F. Li, Y. Wang, Y. Li, R. L. Z. Hoye, L. Feng, K. Xia, V. Pecunia, *Appl. Mater. Today* **2020**, *19*, 21.