Electronic Supplementary Information for:

Carbon-Sandwiched Perovskite Solar Cell

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1. Chemical Capacitance Analysis

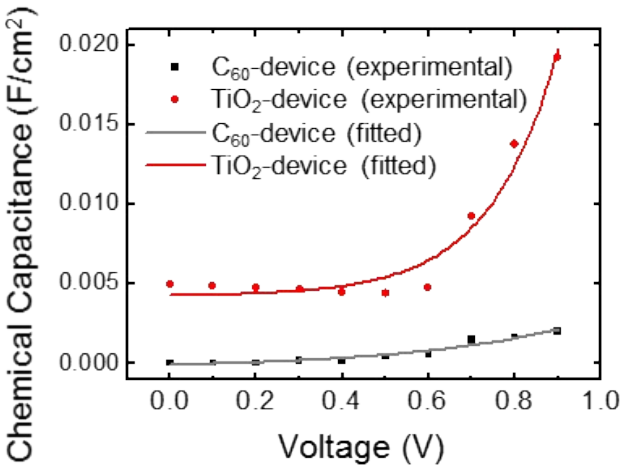
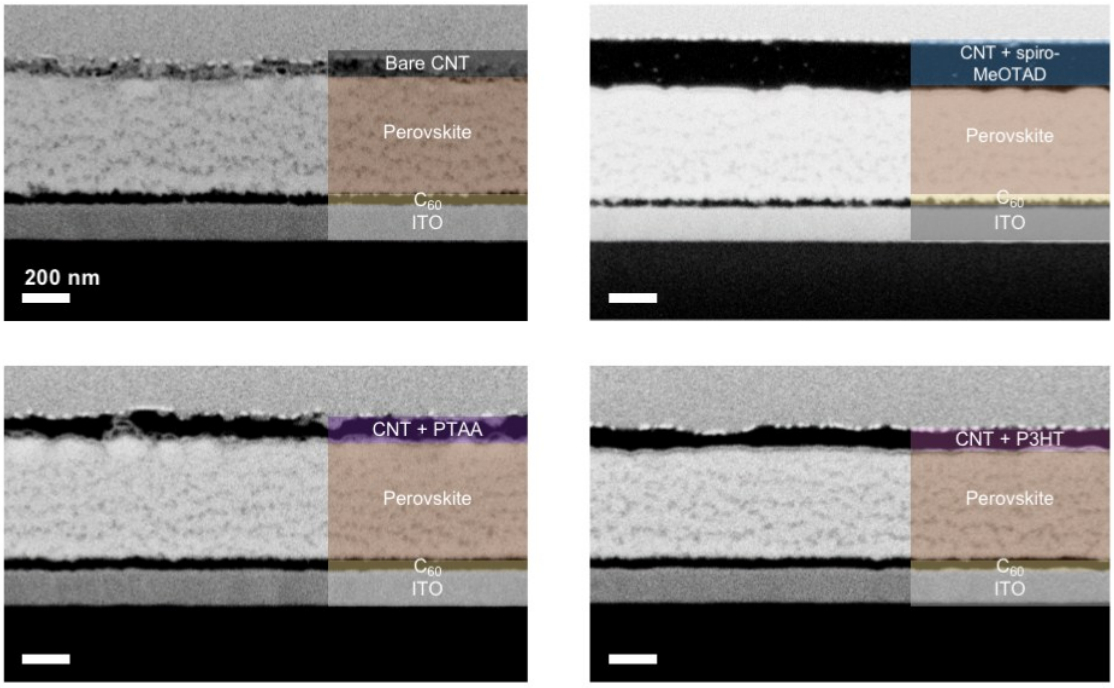


Figure S1. Chemical capacitance of C_{60} (black) and TiO_2 (red) based device with CNT , respectively.

2. SEM Analysis



Scale bar: 200 nm

Figure S2. Cross-sectional SEM images of the CNT-based devices with different HTMs.

3. WVTR Measurement

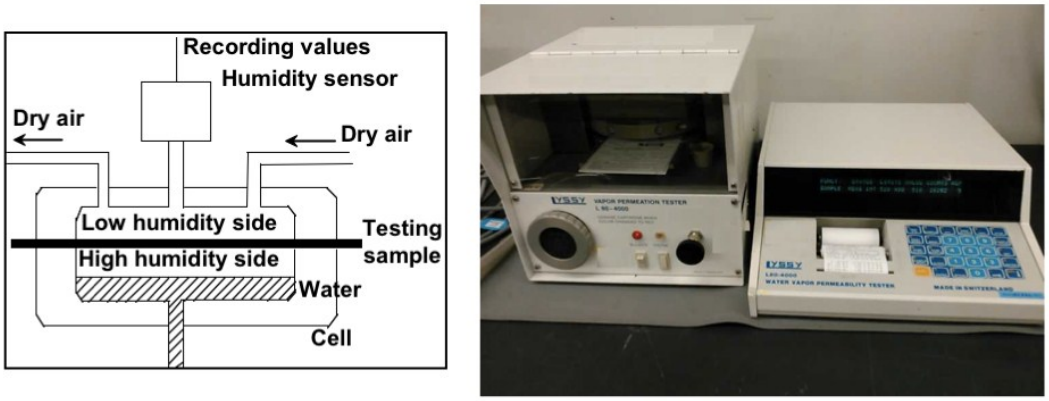


Figure S3. WVTR machine used in this work (right) and its schematic diagram (left).

4. Molecular Computation

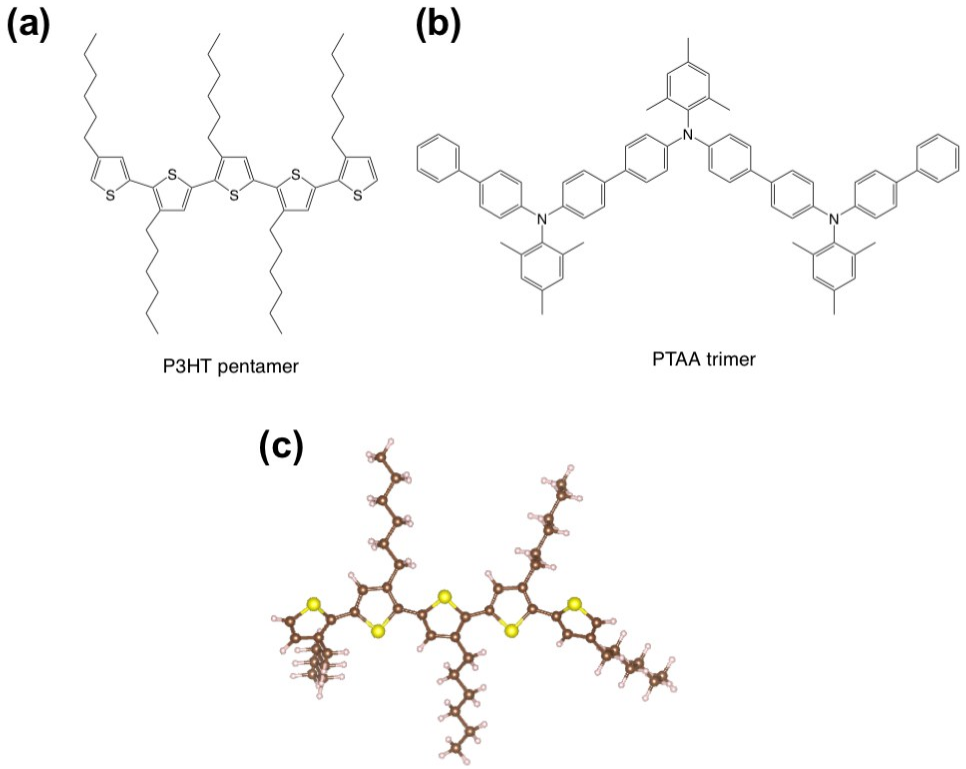


Figure S4. Molecular structures of (a) P3HT pentamer and (b) PTAA trimer used in the computational calculation in Figure. 4a, and (c) P3HT molecular configuration before hexyl bond rotation optimization.

5. Photovoltaic Performance and Hysteresis

Electrode type	Scan direction	V_{OC} (V)	J_{SC} (mA/cm^2)	FF	PCE (%)	Hysteresis Index
CNT + spiro-MeOTAD	Reverse	1.08	23.8	0.66	17.0	0.023
	Forward	1.07	23.7	0.66	16.6	
CNT + PTAA	Reverse	0.98	22.9	0.68	15.2	0.007
	Forward	0.98	23.0	0.68	15.3	
CNT + P3HT	Reverse	0.88	21.4	0.66	12.5	0.016
	Forward	0.88	21.5	0.65	12.3	
Bare CNT	Reverse	0.93	21.8	0.65	13.2	0.038
	Forward	0.92	21.8	0.63	12.7	

Table S1. Photovoltaic data of the solar cell devices with different cathode types under one sun (AM1.5G illumination, 100 mW cm^{-2}) and their hysteresis indices.

6. Cost Analysis

Material		Supplier	Amount used per device	Price	Cost (¥)
Electron-transporting Layer	TiO_2	Sigma-Aldrich	6 μL	¥18,600/L	0.1
	Ethanol		42 μL	¥25,900/L	1.1
	mesoporous-TiO_2	Solaronix	2.4 mg	¥700/g	1.7
	1-butanol	Sigma-Aldrich	20 μL	¥9,000/L	0.2
	C_{60}		0.002 g	¥15,000/g	3.0
Active Layer	PbI_2	TCI	0.015 g	¥2,200/g	33.0
	MAI	TCI	0.005 g	¥3,400/g	17.0
	DMSO	TCI	2.367 μL	¥64/g	0.0
	DMF	Sigma-Aldrich	0.019 mL	¥5,600/L	0.1
	Diethyl ether		0.100 mL	¥10,380/L	1.0
Hole-transporting Layer	Spiro-MeOTAD	Merck	1.446 mg	¥113,638 /g	164.3
	PTAA	EM index	0.250 mg	¥150,200 /g	37.6
	P3HT	Sigma-Aldrich	0.365 mg	¥88,600/g	32.3
	CB		0.025 mL	¥10,900/L	0.3
	TBP		0.576 μL	¥756/mL	0.4
	acetonitrile		0.35 μL	¥5,900/mL	2.1
Anode	Au		0.06 g	¥24,600/g	1,476.0
	CNT*	Canatu	1 cm^2	<¥65/9cm^2	<7.2

Table S2. Cost analysis of the materials used for the fabrication of lab-scale PSCs in this work. The price corresponds to the fabrication of one substrate (1 cm × 1 cm) which accommodates four solar devices.

Note: Cathode has not been included as all the devices can adopt either ITO or FTO.
High temperature annealing process cost has been excluded to give less leverage to our devices.
Vacuum process cost has been excluded for all the devices equally require vacuum once during the process.
All the prices have been cited and estimated as of 2016.12.16.
*Canatu cannot disclose the price. However, a spokesperson stated that the price will be lower than that of FTO or ITO substrates in the market.

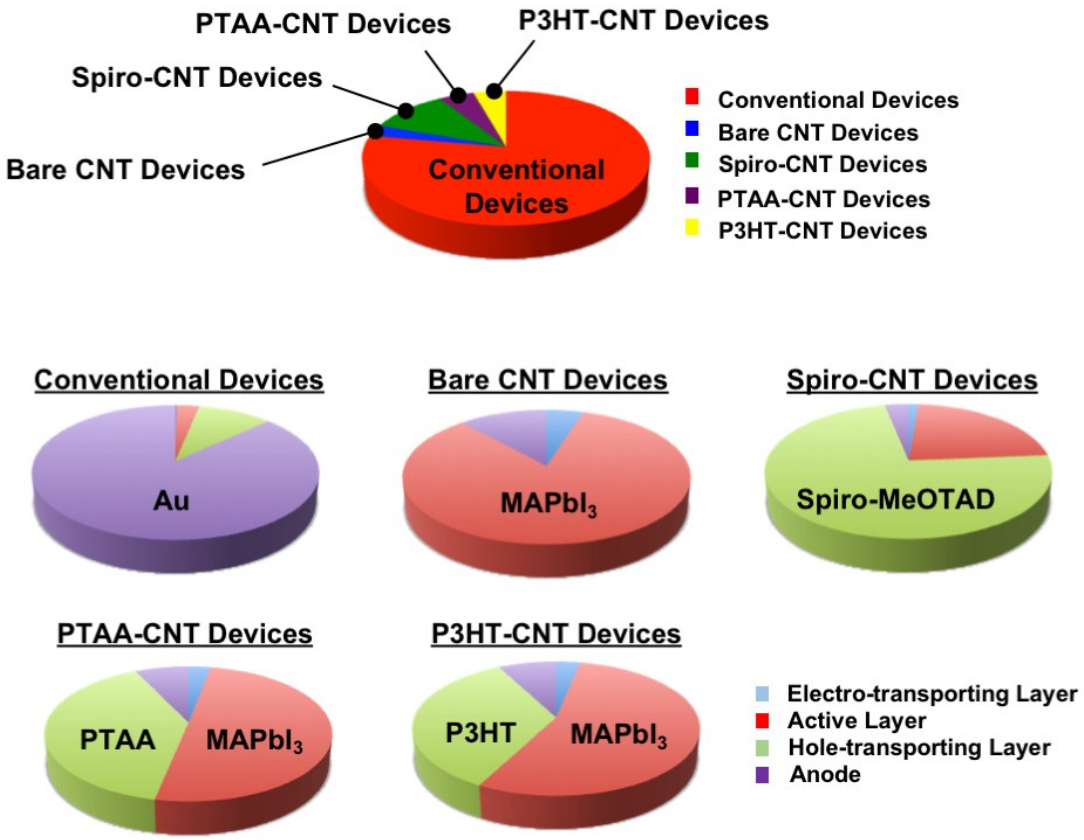


Figure S5. Cost analysis pie charts derived from Supplementary Table S2. Comparison of different devices and their price compositions.