Supplementary Information for

Non-fullerene Acceptor with Low Energy loss and High External Quantum Efficiency: towards High Performance Polymer Solar Cells

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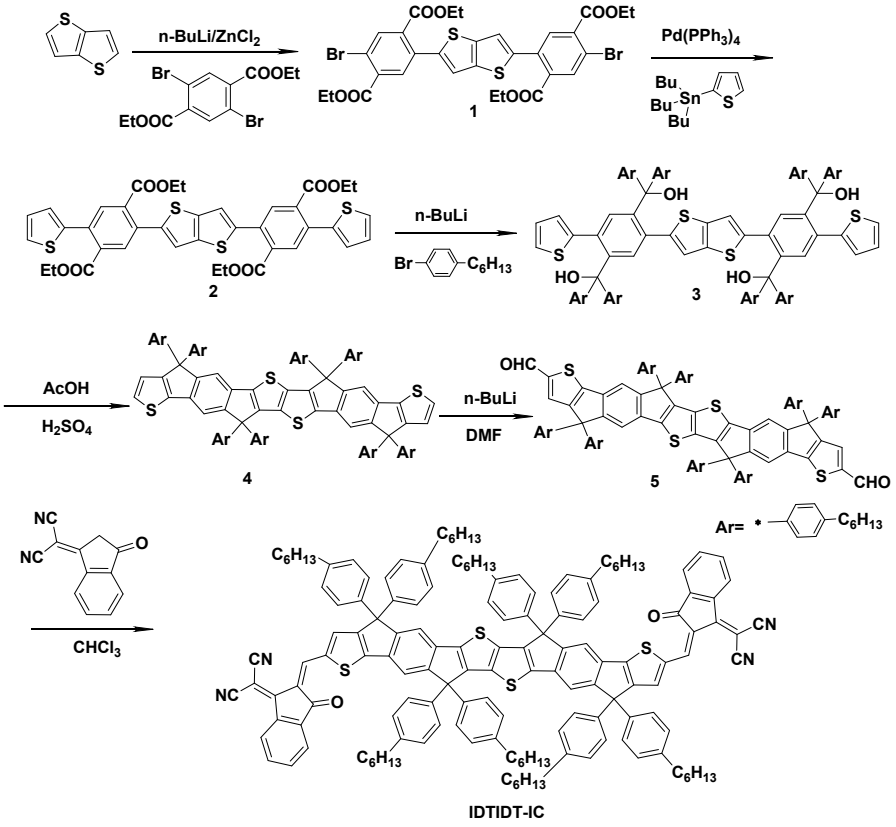
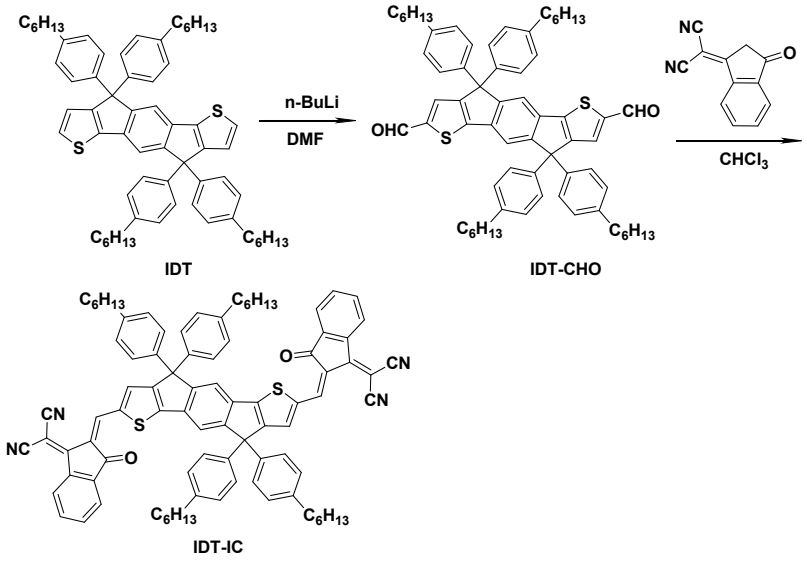
Contents for Supplementary Information:

1. Supplementary Schemes

Scheme S1. The synthesis route of IDTIDT-IC



Scheme S2. The synthesis route of IDT-IC



2. Supplementary Figures

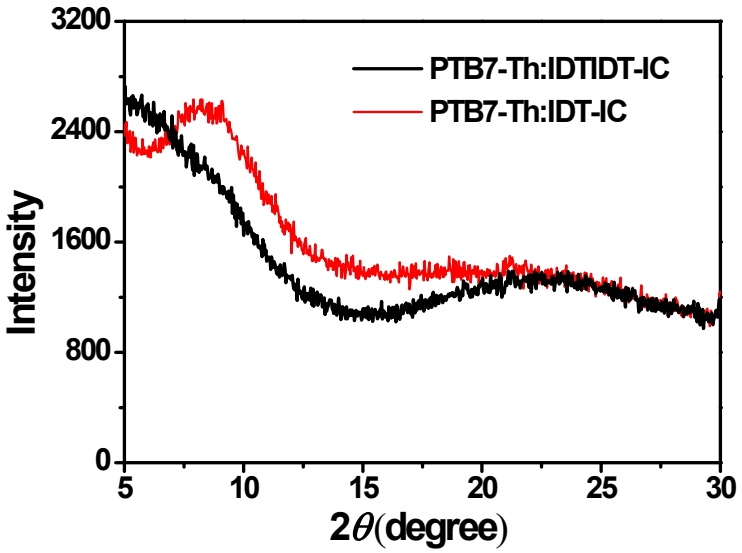


Figure S1. The XRD pattern of the PTB7-Th:IDTIDT-IC and PTB7-Th:IDT-IC films spin-coated on ITO/PEDOT:PSS substrates

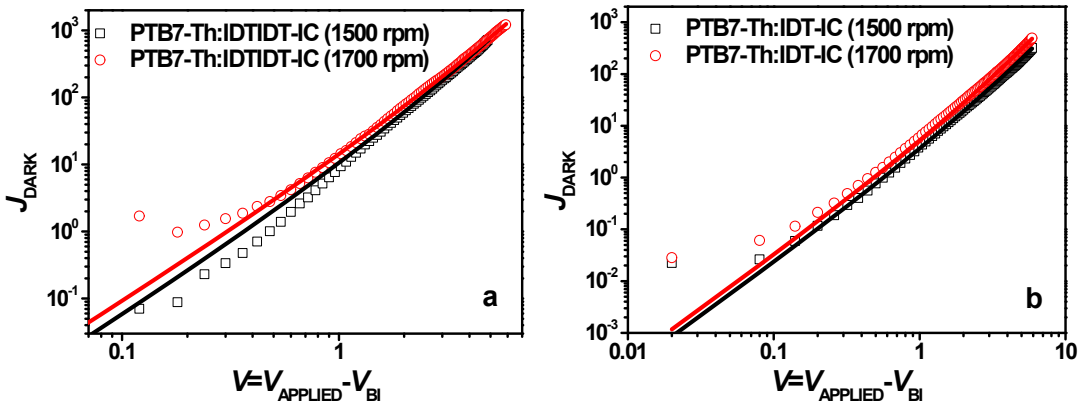


Figure S2. The (a) *J-V* characteristics under dark of the electron-only devices with the structure of ITO/Cs_2CO_3/PTB7-Th:IDTIDT-IC (1500 and 1700 rpm)/Ca (16 nm)/Al and (b) *J-V* characteristics under dark of the electron-only devices with the structure of ITO/Cs_2CO_3/PTB7-Th:IDT-IC (1500 and 1700 rpm)/Ca (16 nm)/Al. (The symbols represent experimental data, and the solid lines are the fit to the experimental data by the SCLC model. The applied voltage is corrected for the built-in potential due to the work function difference of the two electrodes.)

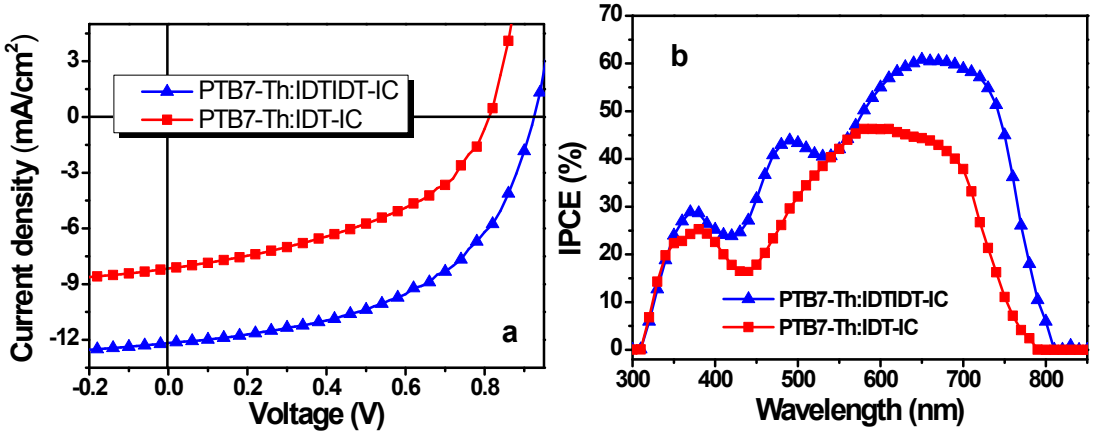


Figure S3. The (a) *J-V* characteristics and (b) IPCE spectra of the PTB7-Th:IDTIDT-IC and PTB7-Th:IDT-IC (1:1.5, w/w) with Ca as cathode interlayer.

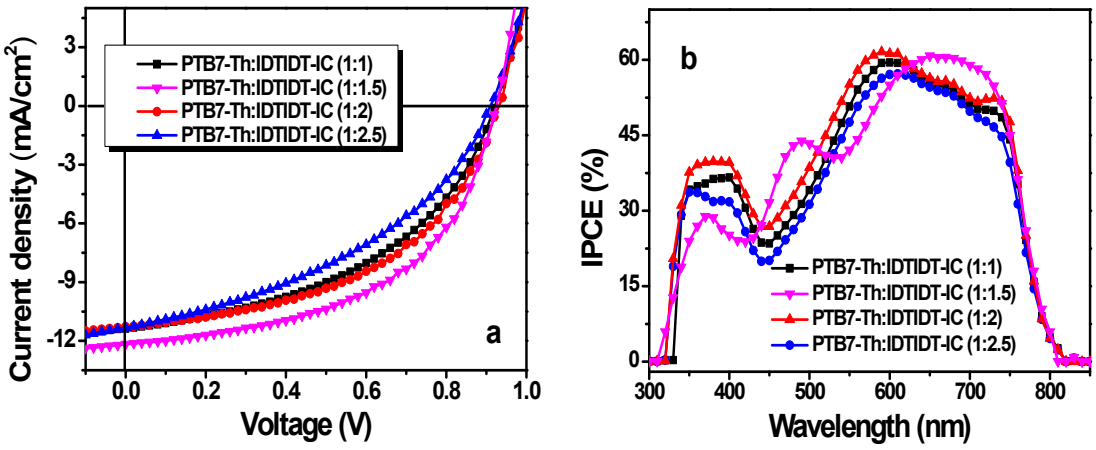


Figure S4. The (a) J-V characteristics and (b) IPCE spectra of the devices with different PTB7-Th:IDTIDT-IC weight ratios with Ca as cathode interlayer (total concentration of 25 mg mL^{-1}).

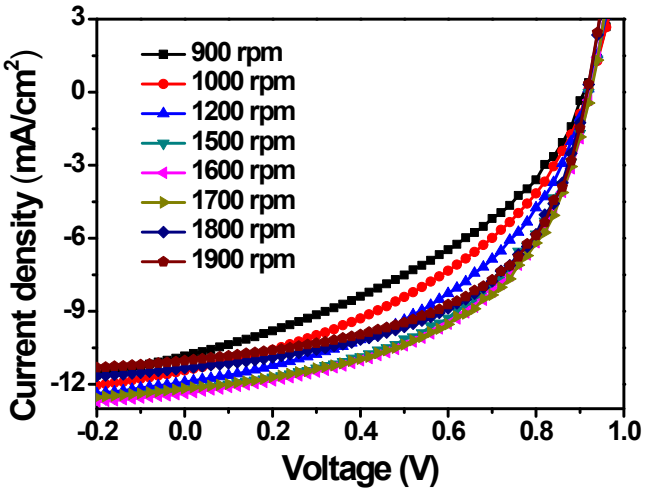


Figure S5. The *J-V* characteristics of the PTB7-Th:IDTIDT-IC (900, 1000, 1200, 1500, 1600, 1700, 1800 and 1900 rpm) based devices with Ca as cathode interlayer.

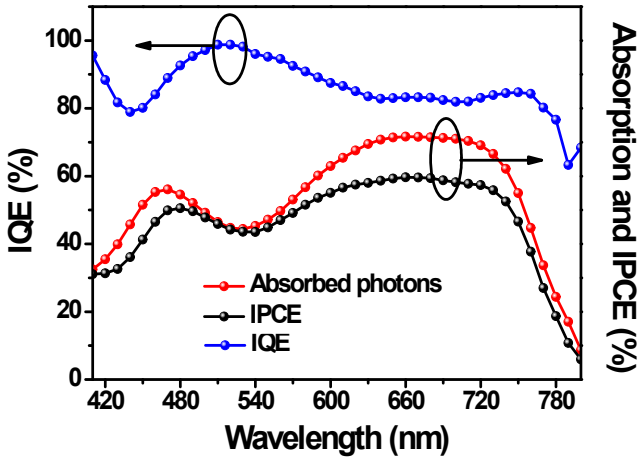


Figure S6. Internal quantum efficiency (IQE) of the device with PTB7-Th:IDTIDT-IC and PDINO as the active layer and cathode interlayer, respectively. The red line shows the total absorption of the device, and the black line the EQE (also called IPCE).

Table S1. Photovoltaic properties of PSCs based on the PTB7-Th as the donor and IDTIDT-IC as the acceptor with the different blending ratio and Ca as cathode interlayer.

	Active layer	J_{sc} (mA/cm²)	V_{oc} (V)	FF (%)	PCE (%)	J_{sc}^{IPCE} (mA/cm²)
Ca	PTB7-Th:IDTIDT-IC (1:1)	11.33	0.91	41.2	4.25	12.41
	PTB7-Th:IDTIDT-IC (1:1.5)	12.17	0.93	52.1	5.87	12.12
	PTB7-Th:IDTIDT-IC (1:2)	11.37	0.92	46.1	4.83	11.74

	PTB7-Th:IDTIDT-IC (1:2.5)	11.28	0.93	49.0	5.15	11.07

Table S2. The Photovoltaic performance of the polymer solar cells based on PTB7-Th:IDTIDT-IC (900, 1000, 1200, 1500, 1600, 1700, 1800 and 1900 rpm) with Ca as cathode interlayer.

	Active layer	Thickness (nm)	J_{sc} (mA/cm^2)	V_{oc} (V)	FF (%)	PCE (%)
Ca	PTB7-Th:IDTIDT-IC (900 rpm)	197.0	10.83	0.91	39.4	3.88
	PTB7-Th:IDTIDT-IC (1000 rpm)	186.1	11.43	0.92	42.0	4.40
	PTB7-Th:IDTIDT-IC (1200 rpm)	138.0	11.91	0.92	45.7	4.99
	PTB7-Th:IDTIDT-IC (1500 rpm)	115.9	12.24	0.92	50.2	5.65
	PTB7-Th:IDTIDT-IC (1600 rpm)	109.7	12.37	0.92	50.9	5.82
	PTB7-Th:IDTIDT-IC (1700 rpm)	94.2	12.17	0.93	52.1	5.87
	PTB7-Th:IDTIDT-IC (1800 rpm)	84.2	11.33	0.92	52.6	5.46
	PTB7-Th:IDTIDT-IC (1900 rpm)	77.1	11.02	0.92	53.6	5.42

Table S3. SCLC device characteristics of PTB7-Th:IDTIDT-IC and PTB7-Th:IDT-IC with different film thicknesses.

Active layer	L (nm)[a]	Electron mobility (cm^2 V^{-1} s^{-1})[b]
PTB7-Th:IDTIDT-IC (1500 rpm)	116	4.54×10^{-5}
PTB7-Th:IDTIDT-IC (1700 rpm)	94	3.04×10^{-5}
PTB7-Th:IDT-IC (1500 rpm)	127	2.09×10^{-5}
PTB7-Th:IDT-IC (1700 rpm)	110	1.86×10^{-5}

[a] L is the thickness of the film, measured by Dektak surface profiler
[b] At the electric field of 10^7 V m^{-1}

E_g vs V_{oc} and E_{loss} vs EQE of recent high performance narrow band gap polymers

Table S4. E_g vs eV_{oc} and E_{loss} vs EQE of recent high performance narrow band gap polymers.

Donor	Acceptor	V_{oc}	J_{sc}	FF	PCE	E_g	E_{loss}	EQE_{max}
		(V)	(mA cm^{-2})	(%)	(%)	(eV)	(V)	(%)
P3HT	PCBM	0.64	11.30	69.0	5.0	1.91	1.27	70
P3HT	ICBA	0.84	12.10	72.3	7.3	1.91	1.07	85
PBnDT-FTAZ	PCBM	0.79	11.80	73.0	6.8	1.91	1.12	75
PBDTPD	PC71BM	0.92	13.10	61.0	7.3	1.84	0.92	70
PFDCTBT-C8	PC71BM	0.83	12.60	66.8	7.0	1.75	0.92	70
PTB7	PC71BM	0.76	15.80	70.2	8.4	1.65	0.89	70
PBnDT-DTffBT	PCBM	0.91	12.90	61.2	7.2	1.71	0.80	64
PIDTT-DFBT	PC71BM	0.96	12.20	61.0	7.0	1.76	0.80	65
PDTG-TPD	PC71BM	0.86	14.00	67.3	8.1	1.65	0.79	65
PBDT-DTNT	PC71BM	0.80	11.70	61.0	6.0	1.55	0.75	65
PDPP2FT-C14	PC71BM	0.65	14.80	64.0	6.2	1.36	0.71	50
PCPDT-FBT	PC71BM	0.77	15.60	50.0	5.8	1.46	0.69	65
PBDTDPP	PC71BM	0.82	10.50	60.0	5.2	1.31	0.49	45
pDPP5T-2	PC71BM	0.56	15.90	64.0	5.7	1.41	0.85	
PR2	PC71BM	0.77	13.50	58.0	6.0	1.40	0.63	55
PBDTP-DPP	PC71BM	0.76	13.60	60.0	6.2	1.46	0.70	50
PDPT-DFBT	PC71BM	0.70	18.00	63.0	8.0	1.38	0.68	63
PDPP2Tz2T	PC71BM	0.92	8.80	63.0	5.1	1.47	0.55	40
PDPP2TzDTP	PC71BM	0.69	14.90	54.0	5.6	1.28	0.59	52
PDPP5T	PCBM	0.58	14.00	65.0	5.3	1.46	0.88	65
C2	PC71BM	0.61	18.60	64.0	7.3	1.40	0.79	70
PIPCP	PC71BM	0.86	13.00	55.0	6.2	1.47	0.61	60
PNOz4T	PC71BM	0.96	14.5	64.0	8.9	1.52	0.56	63
PBDTT-FTTE	PNDIS-HD	0.81	18.80	51.0	7.7	1.59	0.78	90
PBDTT-TT	PDI1	0.80	13.30	55.0	6.1	1.59	0.79	61
PBDTT-TT-F	P(NDIDT-FT2)	0.81	13.53	62.0	6.7	1.59	0.78	65
PSEHTT	DBFI- DMT	0.92	12.56	55.0	6.4	1.82	0.90	80
PTB7-Th	HPDI4	0.80	15.10	68.0	8.3	1.59	0.79	80
PDBT-T1	SdiPBI-S	0.90	11.98	66.1	7.2	1.82	0.92	70
PBDTT-F-TT	tetra-PDI	0.86	8.25	48.1	3.5	1.59	0.73	45
PTB7-TH	ITIC	0.81	14.21	59.1	6.8	1.59	0.78	70
PBDTT-F-TT	TPE-PDI4	0.91	11.70	52.0	5.5	1.59	0.68	55
PBDT-TS1	PPDI	0.82	12.51	53.0	5.4	1.55	0.73	65
PffBT4T-2DT	SF-PDI2	0.98	10.70	57.0	6.0	1.65	0.67	55
P3HT	SF(DPPB)4	1.14	8.29	55.0	5.2	1.77	0.63	48
PDBT-T1	SdiPBI-Se	0.95	12.48	69.7	8.2	1.80	0.85	70
PPDT2FBT	NIDCS-HO	1.03	11.88	63.0	7.6	1.80	0.67	72

PffT2-FTAZ-2DT	IEIC	1.0	12.20	59.0	7.3	1.57	0.57	56
PBDTT-F-TT	di-PBI	0.80	11.68	55.0	5.3	1.59	0.79	50