

## Supporting Information

### Unprecedented low energy losses in organic solar cells with high external quantum efficiencies by employing non-fullerene electron acceptors

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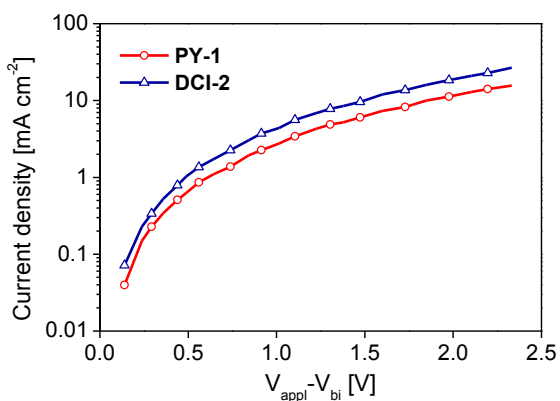
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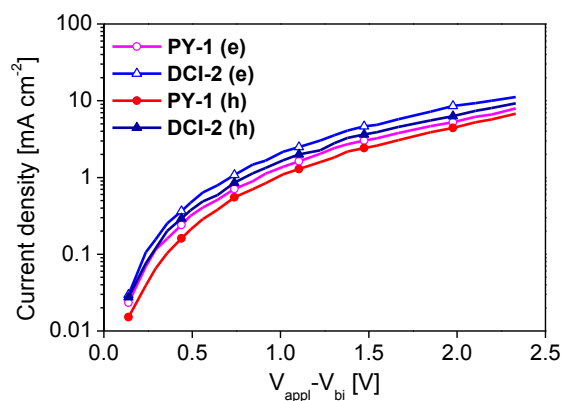
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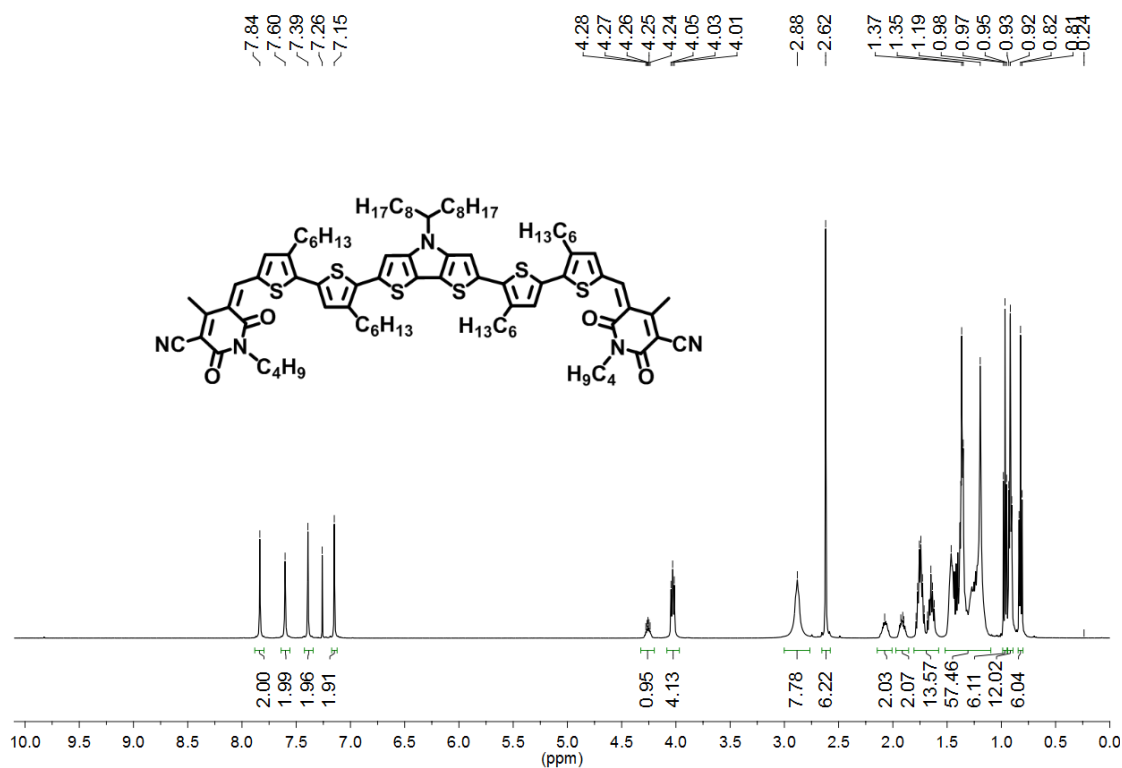
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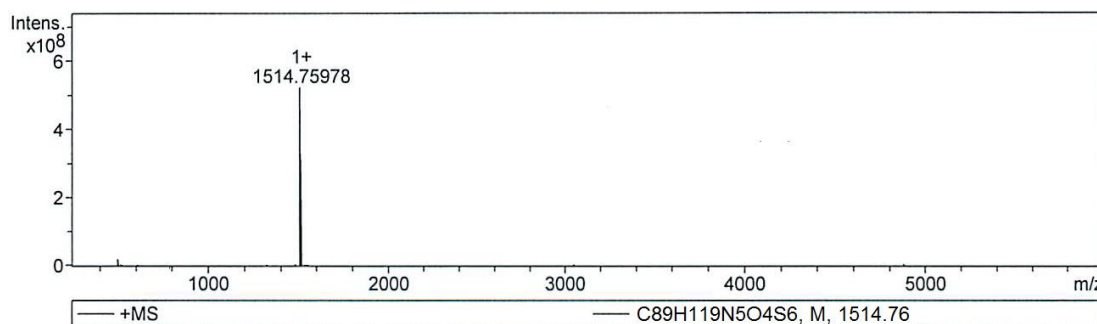
**Figure S1.** Current voltage characteristics in dark for ITO-Al/ PY-1 or DCI-2/Al devices to measure the electron mobility, Solid lines are SCLC fitting.



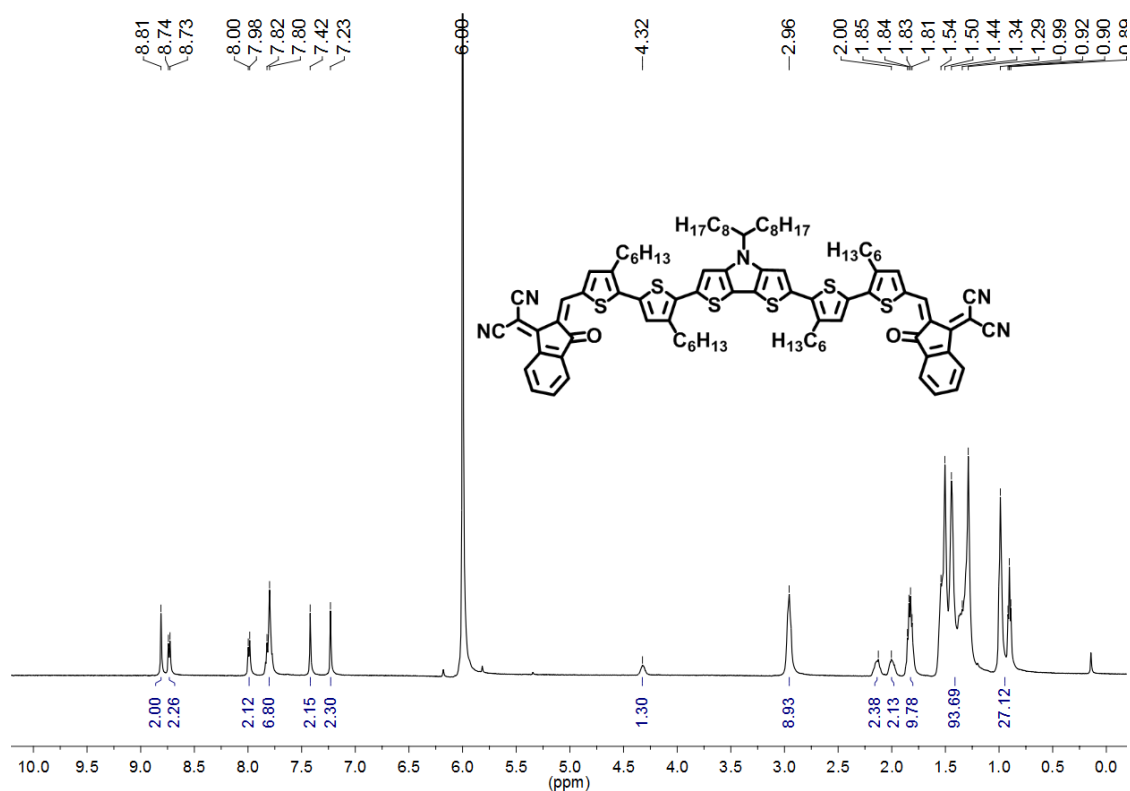
**Figure S2.** Current voltage characteristics in dark for hole only ITO:PEDOT/**P1:PY-1** or **DCI-2**/Au hole only devices and ITO-Al/**P1:PY-1** or **DCI-2**/Al electron only devices. Solid lines are SCLC fitting.



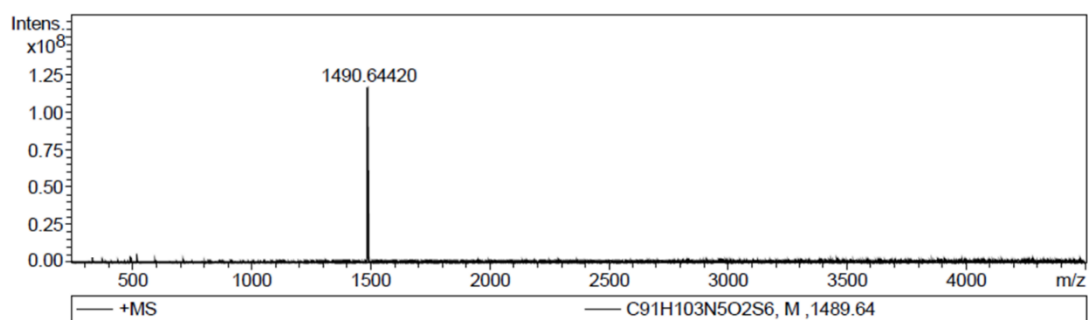
**Figure S3.**  $^1\text{H-NMR}$  spectrum of **PY-1** in  $[\text{D}]\text{CDCl}_3$  (400 MHz).



**Figure S4.** High resolution MALDI mass spectrum of **PY-1** (matrix: trans-2-[3-(4-tert-butylphenyl)-2-methyl-2-propenylidene]malononitrile (DCTB)).



**Figure S5.**  $^1\text{H-NMR}$  spectrum of DCI-2 in  $[\text{D}_2]\text{TCE}$  (400 MHz).



**Figure S6.** High resolution MALDI mass spectrum of DCI-2 (matrix: trans-2-[3-(4-tert-butylphenyl)-2-methyl-2-propenylidene]malononitrile (DCTB)).

**Table S1.** Photovoltaic results of recent high performance (PCE >5%) devices based on polymer donor and PC<sub>71</sub>BM acceptor. EQE<sub>max</sub> of the lowest energy band.

Polymer	$E_g$ [eV]	$V_{oc}$ [V]	$E_g - eV_{oc}$ [eV]	EQE <sub>max</sub> [%]	PCE [%]	Reference
PTB7-Th	1.59	0.82	0.77	0.80	10.8	1
PDPP2TzDTP	1.28	0.69	0.59	0.52	5.6	2
PDPP2Tz2T	1.37	0.92	0.55	0.40	5.1	2
PBDTSe-TT	1.60	0.82	0.78	0.60	8.0	3
PDBT-T1	1.85	0.92	0.93	0.77	9.7	4
PBDT-BT	1.75	0.92	0.83	0.80	9.4	5
BBTI-1	1.50	0.80	0.70	0.60	8.3	6
PNOz4T	1.52	0.96	0.56	0.75	8.9	7
PTB7-Th	1.59	0.83	0.76	0.80	10.6	8
PIPCP	1.47	0.86	0.61	0.58	6.1	9
PTTDPS <sub>e</sub>	1.28	0.58	0.70	0.60	5.7	10
PiITVT	1.61	0.91	0.70	0.70	7.1	11
PffBT4T-2OD	1.63	0.77	0.86	0.84	10.5	12
PIDTT-DFBT-TT	1.81	0.96	0.85	0.70	7.2	13
PPDT2FBT	1.76	0.79	0.97	0.83	9.4	14
PBDTTT-CT	1.55	0.78	0.77	0.78	8.6	15
PBDTT-S-TT	1.57	0.84	0.73	0.72	8.4	16
PBDTT-O-TT	1.53	0.73	0.80	0.70	7.1	16
PBTI3T	1.81	0.86	0.95	0.75	8.7	17
PThTPTI	1.86	0.92	0.94	0.72	7.2	18
TQ1	1.70	0.91	0.79	0.66	7.1	19
PR2	1.40	0.77	0.63	0.55	6.0	20
PMDPP3T	1.30	0.60	0.70	0.55	7.0	21
DT-PDPP4T	1.43	0.64	0.79	0.60	7.1	22
PDPP3T	1.33	0.67	0.66	0.49	7.1	23
PDTP-DFBT	1.38	0.70	0.68	0.63	8.0	24
PBDTDPP	1.31	0.82	0.49	0.45	5.2	25
PDTTDPP	1.22	0.66	0.56	0.55	6.1	26
PBDTT-DPP	1.44	0.73	0.71	0.50	6.6	27
PNDTDPP	1.36	0.76	0.60	0.52	6.9	28
PDTG-TPG	1.68	0.86	0.82	0.74	8.5	29
PTB7	1.60	0.74	0.86	0.80	9.2	30
PDPP2FT-C <sub>14</sub>	1.37	0.65	0.72	0.48	6.5	31
PDPPP5T	1.46	0.56	0.90	0.65	5.8	32
PDPP4TP	1.54	0.67	0.87	0.63	5.5	32
PBDTSTPD	1.73	0.88	0.85	0.65	7.3	33
TPD-P3	1.73	0.85	0.88	0.80	6.8	34

**Table S2.** Photovoltaic results of recent high performance (PCE >5%) devices based on molecular/oligomer donor and PC<sub>71</sub>BM acceptor. EQE<sub>max</sub> of the lowest energy band.

Oligomer	$E_g$ [eV]	$V_{oc}$ [V]	$E_g - eV_{oc}$ [eV]	EQE <sub>max</sub> [%]	PCE [%]	Reference
BDTT-S-TR	1.73	0.97	0.76	0.75	9.2	35
BIT6F	1.79	0.89	0.90	0.70	9.1	36
DTP-6T-DCV	1.59	0.87	0.72	0.56	7.0	37
DTP-6T-IN	1.54	0.84	0.70	0.62	7.5	37
DTP-6T-DCV	1.58	0.83	0.75	0.60	7.1	38
DTG(FBT <sub>2</sub> Th <sub>2</sub> ) <sub>2</sub>	1.62	0.79	0.83	0.82	9.1	39
PE-T-Rh	1.48	0.99	0.49	0.56	6.6	40
PE-TVT-Rh	1.44	0.94	0.50	0.60	7.2	40
DPP-DPP	1.54	0.79	0.75	0.58	5.3	41
DPP-T-DPP	1.62	0.91	0.71	0.61	5.5	41
DRCN7T	1.62	0.91	0.71	0.75	9.3	42
DRCN5T	1.6	0.92	0.68	0.74	10.1	43
DR3TSBDT	1.74	0.92	0.82	0.78	9.9	44
SMPV1	1.77	0.94	0.83	0.64	8.1	45
BDT-2DPP	1.65	0.84	0.81	0.68	5.8	46
p-DTS(FBTTh <sub>2</sub> ) <sub>2</sub>	1.55	0.81	0.74	0.67	7.0	47

**Table S3.** Photovoltaic results of polymer donor and non-fullerene acceptors (NF-A).

Polymer:NF-A	$E_g$ [eV]	$V_{oc}$ [V]	$E_g - eV_{oc}$ [eV]	EQE <sub>max</sub> [%]	PCE [%]	Reference
PPT:ITIC	1.55	0.90	0.65	0.48	5.4	48
PBT-S-TTz:ITIC	1.55	0.97	0.58	0.71	8.2	49
PDCBT2F:ITM	1.59	1.13	0.46	0.59	6.6	50
PTB7-Th:TPB	1.60	0.79	0.81	0.75	8.5	51
PDCBT:ITIC	1.57	0.94	0.63	0.72	10.2	52
PTB7::FITP	1.60	0.99	0.61	0.55	7.3	53
PDBTT1:ITICTh	1.60	0.88	0.72	0.80	9.6	54
PTB7:ITICTh	1.60	0.80	0.80	0.80	8.7	54
P3TEA:SF-PDI <sub>2</sub>	1.68	1.11	0.57	0.66	9.5	55
PDBTT1:SdiPBISe	1.80	0.96	0.84	0.73	8.4	56
PDBTT1:IC-C6IDT-IC	1.62	0.89	0.73	0.76	8.7	57
J5f:IDSe-T-IC	1.52	0.91	0.61	0.66	8.6	58
PBDBT:ITIC	1.57	0.90	0.67	0.75	11.2	59
PBDBT:IT-M	1.60	0.94	0.66	0.78	12.0	60
PBDBT:IT-DM	1.63	0.97	0.66	0.77	11.3	60
PTB7-Th:IDTIDT-IC	1.53	0.94	0.59	0.62	6.5	61
PBDTT-FTTE:DBFI-EDOT	1.57	0.95	0.62	0.72	6.7	62
PSEHTT:DBFI-EDOT	1.70	0.93	0.77	0.82	8.1	62
J51:ITIC	1.57	0.82	0.75	0.74	9.3	63
J60:ITIC	1.57	0.91	0.66	0.72	9.0	64
J61:ITIC	1.57	0.89	0.68	0.77	9.5	64
PBDTTT-ET:IEICO	1.34	0.82	0.52	0.66	8.4	65
PBDTTT-ET:IEIC	1.50	0.90	0.60	0.50	4.9	65
P3HT:SF(DPPB) <sub>4</sub>	1.75	1.14	0.61	0.48	5.2	66

BDT3TR:O-IDTBR	1.57	1.06	0.51	0.56	7.0	67
BDTS-2DPP:IEIC	1.65	0.93	0.72	0.45	5.3	68
PPDT2FBT:NIDCS-HO	1.76	1.03	0.73	0.70	7.6	69
PffBT4T-2DT:FBR	1.61	1.12	0.48	0.57	7.8	70
PffBT4T-2DT:IDTBR	1.61	1.07	0.53	0.76	10.0	70
PTB7-Th:ATT1	1.54	0.87	0.67	0.73	10.1	71
PffBT4T-2DT:SFPDI <sub>2</sub>	1.58	0.98	0.60	0.51	6.3	72
PffBT4T-2DT:diPDI	1.58	0.84	0.76	0.49	5.4	72
PDBT-T1:SdiPBI-S	1.82	0.93	0.89	0.70	7.2	73
PTB7-Th:IEIC	1.58	0.97	0.61	0.57	6.3	74
PTB7-Th:ITIC	1.59	0.81	0.78	0.73	6.8	75
PTB7-Th:TPE-PDI <sub>4</sub>	1.58	0.91	0.67	0.56	5.5	76
PffT2-FTAZ-2DT:IEIC	1.57	1.00	0.57	0.56	7.3	77
PTB7:DTDFBT(TDPP) <sub>2</sub>	1.52	0.81	0.71	0.68	5.0	78
p-DTS(FBTTh) <sub>2</sub> :NIDCS-MO	1.78	0.85	0.93	0.48	5.4	79
PBDTTT-EFT:IEICO-4F	1.24	0.74	0.50	0.75	10.0	80
PY-1	1.40	0.86	0.54	0.48	3.2	This work
DCI-2	1.23	0.84	0.39	0.56	4.6	This work
PY-1 (with DIO)	1.40	0.83	0.57	0.55	4.9	This work
DCI-2 (with DIO)	1.23	0.80	0.43	0.69	6.9	This work

**Table S4.** Photovoltaic devices using inorganic and perovskite solar cells.

Inorganic SCs	$E_g$ [eV]	$V_{oc}$ [V]	$E_g - eV_{oc}$ [eV]	Reference
GaAs	1.42	1.11	0.31	81,82
c-Si	1.12	0.71	0.41	
CIGS	1.15	0.72	0.43	
CdTe	1.45	0.84	0.61	
a-Si	1.73	0.88	0.85	
<b>Perovskite Solar Cells</b>				
CH <sub>3</sub> NH <sub>3</sub> PbI <sub>3-x</sub> Cl <sub>x</sub>	1.55	1.10	0.45	83
(FAPbI <sub>3</sub> ) <sub>0.85</sub> (MAPbBr <sub>3</sub> ) <sub>0.15</sub>	1.56	1.15	0.41	84
FA <sub>1-x</sub> MA <sub>x</sub> Pb(I <sub>1-y</sub> Br <sub>y</sub> ) <sub>3</sub>	1.60	1.18	0.42	85

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