Supporting Information

Weakened Charge Trapping at the Electrode/Active Layer Interface in Bulk Heterojunction based Organic Phototransistor for Quick Photomultiplication

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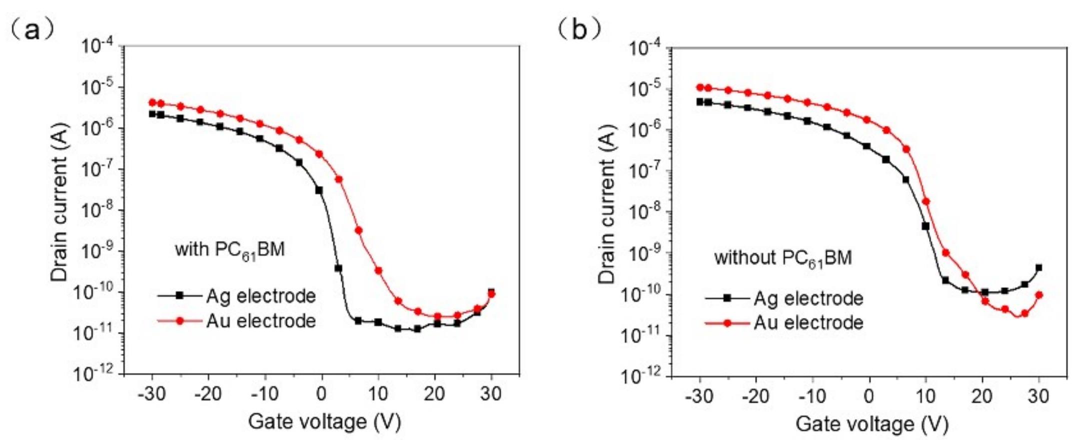


Fig. S1 Transfer characteristics curves of Ag electrode device and Au electrode device in dark, (a)with $PC_{61}BM$, (b)without $PC_{61}BM$. the drain voltage is set to −60 V.

Table S1 Field effect performance parameters of different electrode devices

	μ (× 10^{-2} $cm^2 \cdot V^{-1} \cdot s^{-1}$)	I_{on}/I_{off} (× 10^5)	V_{on}(V)	I_{off} (A)
Ag electrode device with $PC_{61}BM$	3.08	1.76	6.5	1.24×10^{-11}
Au electrode device with $PC_{61}BM$	4.21	1.61	13	2.58×10^{-11}
Ag electrode device without $PC_{61}BM$	3.38	0.43	13	1.12×10^{-10}
Au electrode device without $PC_{61}BM$	9.66	2.58	19.5	4.21×10^{-11}

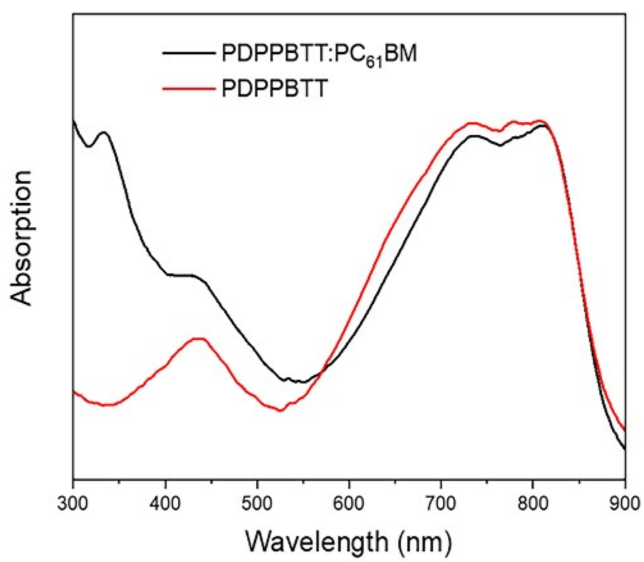


Fig. S2 Optical absorption spectra of PDPPBTT and PDPPBTT:$PC_{61}BM$ films

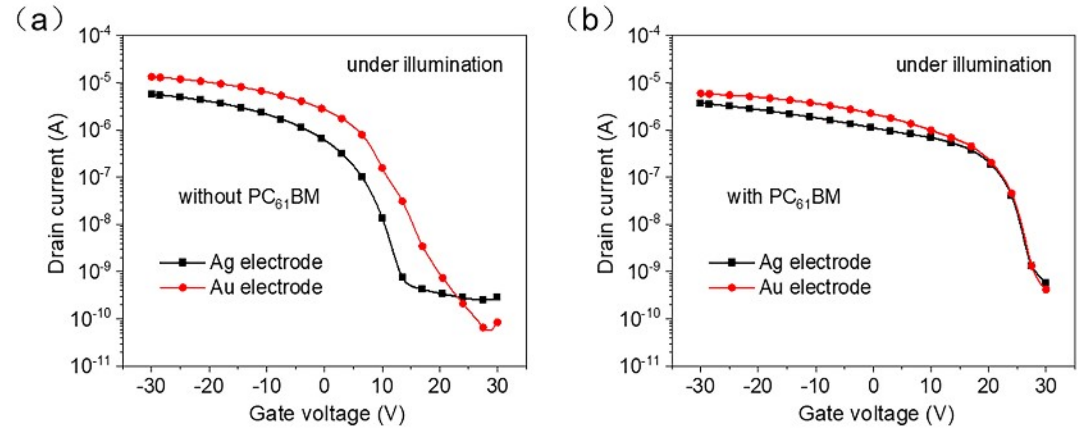


Fig. S3 Transfer characteristics curves of different devices under illumination at 810@0.011 mW·cm^{-2} nm, the drain voltage is set to −60 V. PDPPBTT as active layer.(a) without $PC_{61}BM$, (b) with $PC_{61}BM$

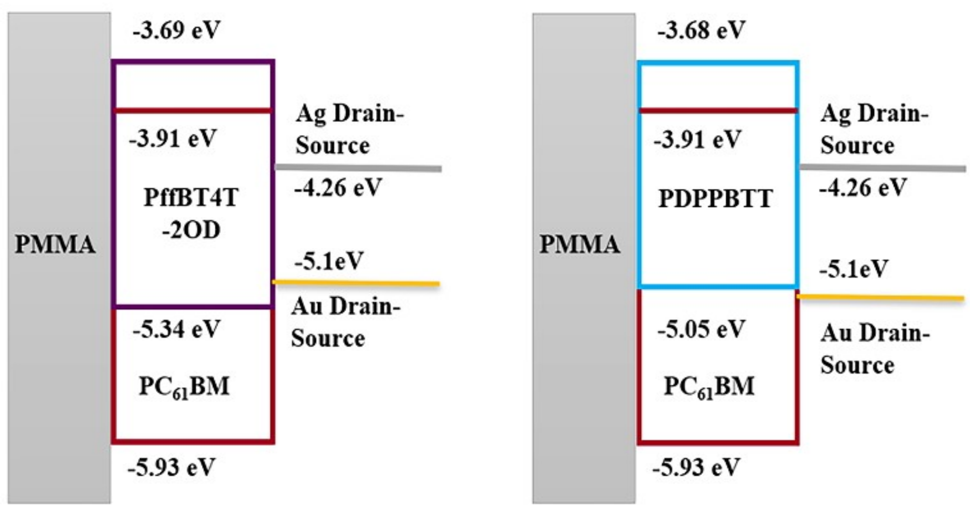


Fig. S4 The energy level structure diagram of PffBT4T-2OD:$PC_{61}BM$ and PDPPBTT:$PC_{61}BM$

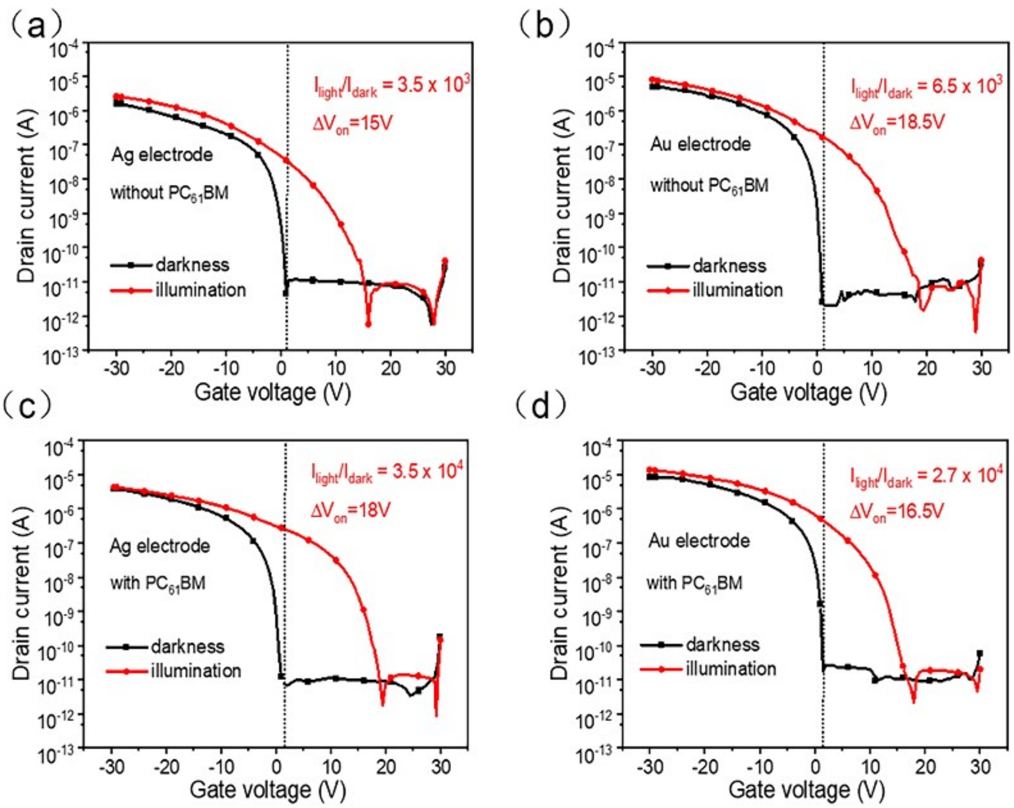


Fig. S5 (a) Transfer characteristics curves of different devices without illumination and in light intensity illumination of 702@0.011 mW·cm^{-2} nm, the drain voltage is set to −30 V.(a) Ag electrode without $PC_{61}BM$, (b) Au electrode without $PC_{61}BM$, (c) Ag electrode with $PC_{61}BM$, (d) Au electrode with $PC_{61}BM$.

As shown in Figure S5, when $PC_{61}BM$ is not added, Au electrode device exhibits a more pronounced turn-on voltage drift than Ag electrode device (18.5V of Au electrode device vs. 15 V of Ag electrode device), which indicates that more photogenerated electrons are trapped in the active layer, and the accumulated photogenerated electrons at the electrode/active layer interface can further reduce the hole injection barrier and promote more hole injection from the source into the active layer, further increasing the output photocurrent of the device. Meanwhile, the I_{light}/I_{dark} of Au electrode device under illumination is two times higher than that of Ag electrode device, indicating that the photocurrent of Au electrode device rises faster under the same light conditions. However, when $PC_{61}BM$ was added to form BHJ with PffBT4T-2OD, the turn-on voltage drift of Au electrode device (16.5V) was significantly smaller than that of Ag electrode device(18V), indicating that the number of photogenerated electrons captured in Au electrode device was lower than that of Ag electrode device. Meanwhile, the lower turn-on voltage drift made the I_{light}/I_{dark} of Au electrode device lower than that of Ag electrode device, indicating that the rise of photocurrent in Au electrode device becomes slower under the same light condition. Therefore，when $PC_{61}BM$ was added ，the enhancement effect of Au electrode on the photocurrent of OPTs is weakened.

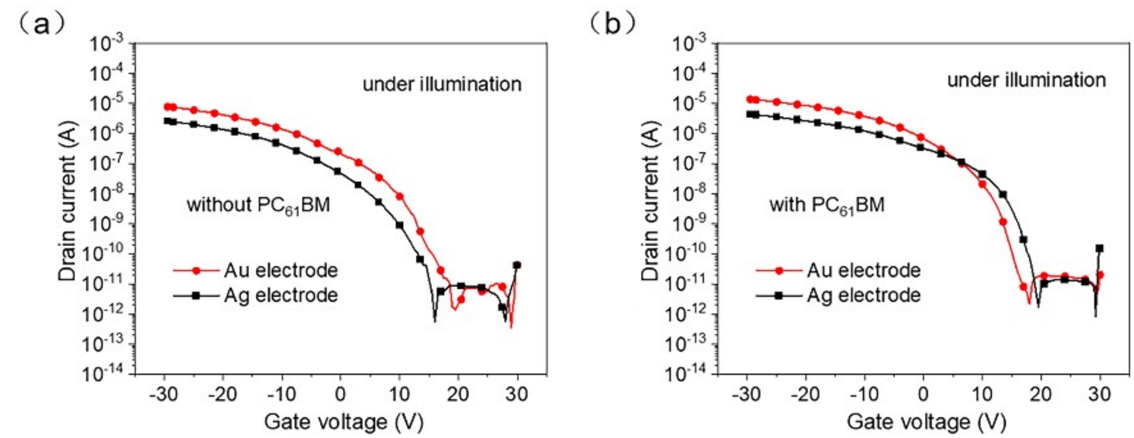


Fig. S6 Transfer characteristics curves of different devices under illumination at 702@0.011 $mW\cdot cm^{-2}$ nm, the drain voltage is set to −30 V. PffBT4T-2OD as active layer.(a) without $PC_{61}BM$, (b) with $PC_{61}BM$

Table S2. The photodetection performance parameters of OPTs.

PffBT4T-2OD	V_{on} (V) in dark	ΔV_{on} (V)	I_{light}/I_{dark}	R ($A \cdot W^{-1}$)	D^* (Jones)
Ag electrode device without $PC_{61}BM$	1	15	3.5×10^3	93.6	1.5×10^{15}
Au electrode device without $PC_{61}BM$	1	18.5	6.5×10^3	330.7	9.7×10^{15}
Ag electrode device with $PC_{61}BM$	1.5	18	3.5×10^4	684	7.4×10^{15}
Au electrode device with $PC_{61}BM$	1.5	16.5	2.7×10^4	1052.2	1.0×10^{16}

under 702 nm@0.011 mW · cm^{-2} illumination at -30 V source drain voltage.

As shown in Table S2. When PffBT4T-2OD is used as a separate active layer, it can be seen that Au electrode device exhibits significant higher *R* and *D** values than Ag electrode device. The *R* and *D** values of Au electrode device at the turn-on voltage (V_g = 1V) are 330.7 A · W^{-1} and 9.7×10^{15} Jones, respectively. Compared with Ag electrode device, the *R* value (93.6 A · W^{-1}) and *D** value (1.5×10^{15} Jones) at the turn-on voltage (V_g = 1V) are increased by 3.5 times and 6 times, respectively. As mentioned earlier, when constructing OPTs with a single p-type material, since the Au electrode has a smaller hole injection barrier than the Ag electrode, it is beneficial for holes to inject from the electrode into the active layer, thereby obtaining a larger photocurrent and improving the photodetection performance of OPTs.

It is worth noting that Au electrode device does not exhibit significantly higher *R* and *D** values than Ag electrode device when $PC_{61}BM$ is added to form a native heterojunction (BHJ) with PffBT4T-2OD as the active layer. When V_g = 1.5 V (turn-on voltage), Au electrode device obtains the maximum *D** value of 1.0×10^{16} Jones, and the corresponding *R* value is 1052.2 A · W^{-1}. Although these two parameters are still larger than Ag electrode device (*R* = 684 A · W^{-1}, *D ** = 7.4×10^{15} Jones, V_g = 1.5 V), *R* and *D** are only increased by 1.5 times and 1.3 times, respectively. The advantage of Au electrode is no longer obvious compared to Ag electrode devices without $PC_{61}BM$. The above experimental results are consistent with the results of Table 1, which again prove that our previous conclusion is correct.

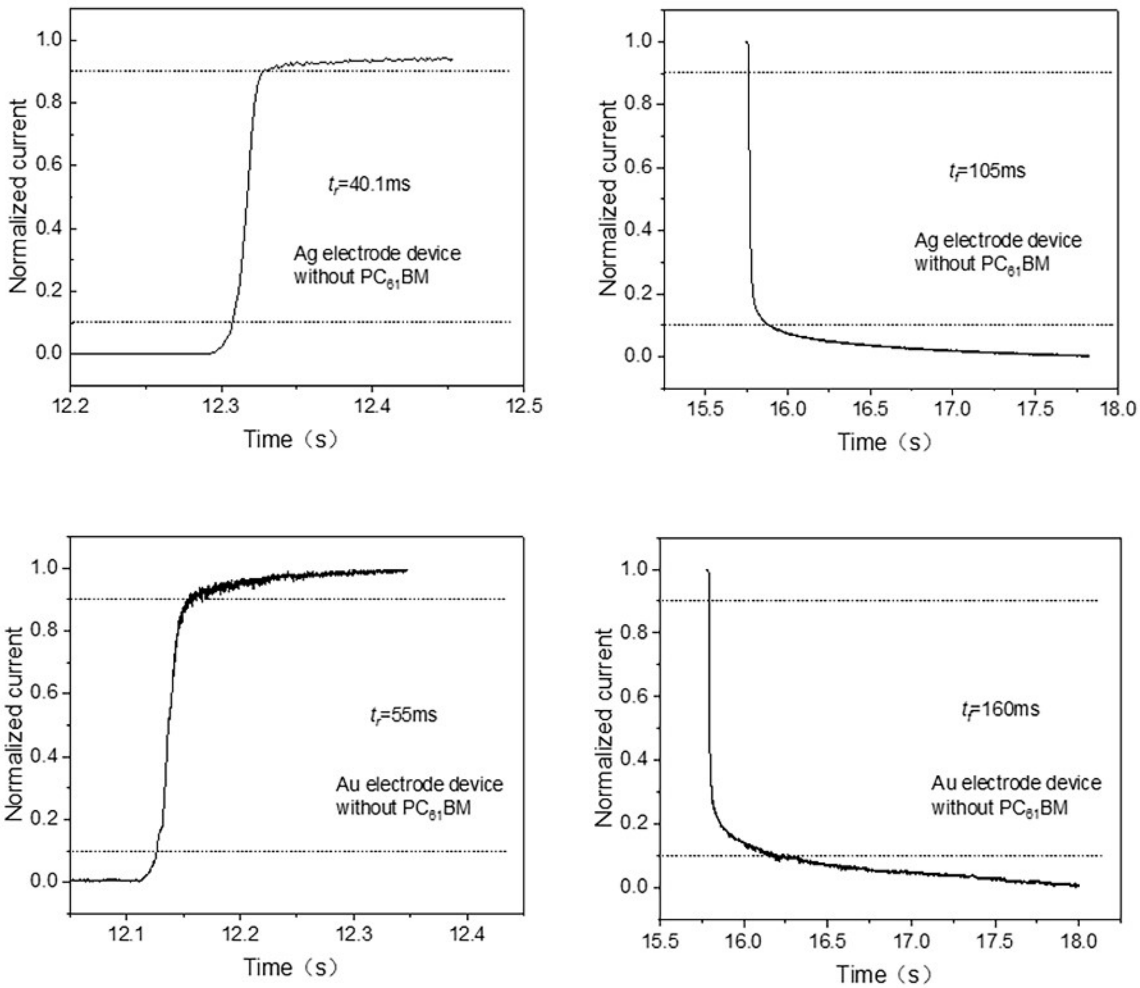


Fig. S7 Response time of different electrode devices without $PC_{61}BM$ in PDPPBTT:$PC_{61}BM$

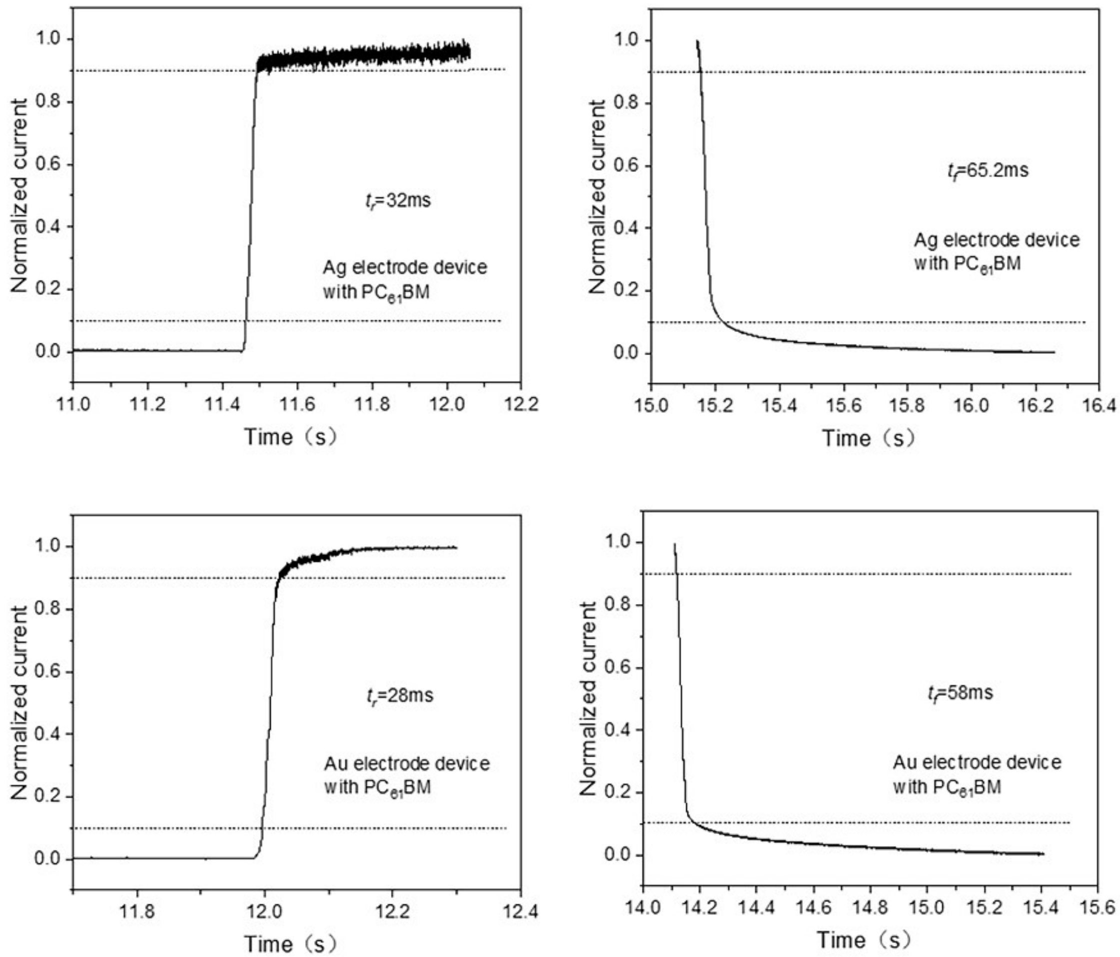
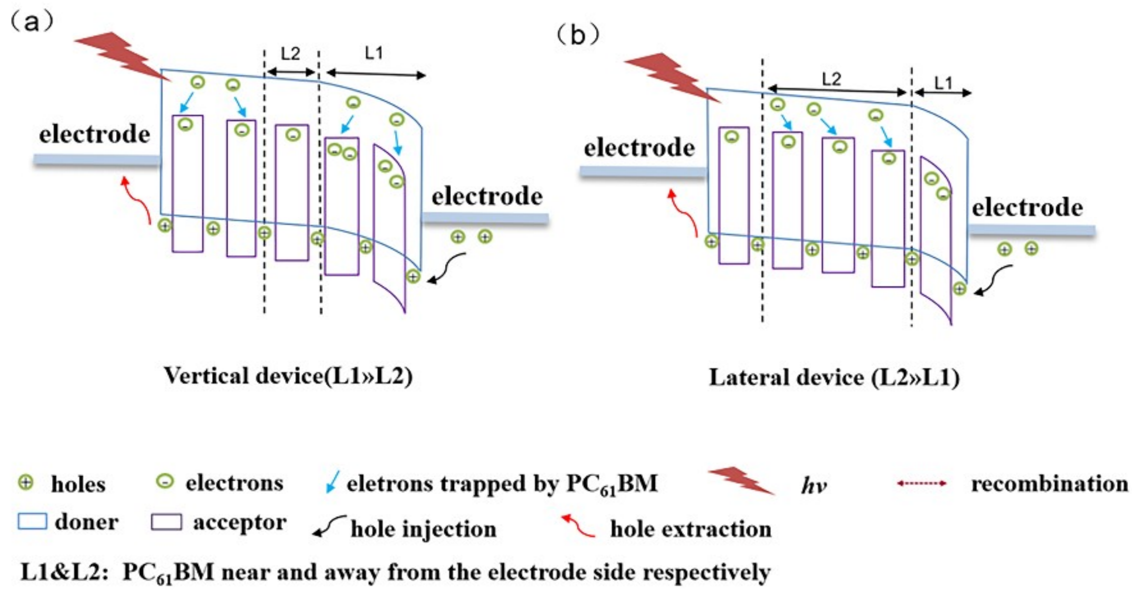


Fig. S8 Response time of different electrode devices with PC$_{61}$BM in PDPPBTT:PC$_{61}$BM



FigureS9. Comparison of charge trapping mechanism between lateral device and vertical device

The contact resistances of the Au electrodes are R_{Au1} and R_{Au2}, respectively. Therefore, the total resistance formulas of the following four devices are obtained.

$R_a= R_{Ag1}+R_1$ Ag electrode，without $PC_{61}BM$ (S1)

$R_b= R_{Ag2}+R_2$ Ag electrode，with $PC_{61}BM$ (S2)

$R_c= R_{Au1}+R_1$ Au electrode，without $PC_{61}BM$ (S3)

$R_d= R_{Au2}+R_2$ Au electrode，with $PC_{61}BM$ (S4)

The above formula is transformed to obtain:

$R_{Ag1}-R_{Au1}= R_a-R_c$ (S5)

$R_{Ag2}-R_{Au2}= R_b-R_d$ (S6)

Based on $R=V_d/I_d$ (S7)

we calculated R_a, R_b, R_c, and R_d, and finally obtained the variation of contact resistance of different electrodes with and without $PC_{61}BM$ after deducting the channel resistance (Table S3).

Table S3. Contact resistance different between Ag and Au electrode in OPTs under illumination

	PDPPBTT（Ω）	PffBT4T-2OD（Ω）
R_{Ag1}-R_{Au1} (without $PC_{61}BM$)	5.89×10^6	7.86×10^6
R_{Ag2}-R_{Au2} (with $PC_{61}BM$)	5.94×10^6	4.77×10^6

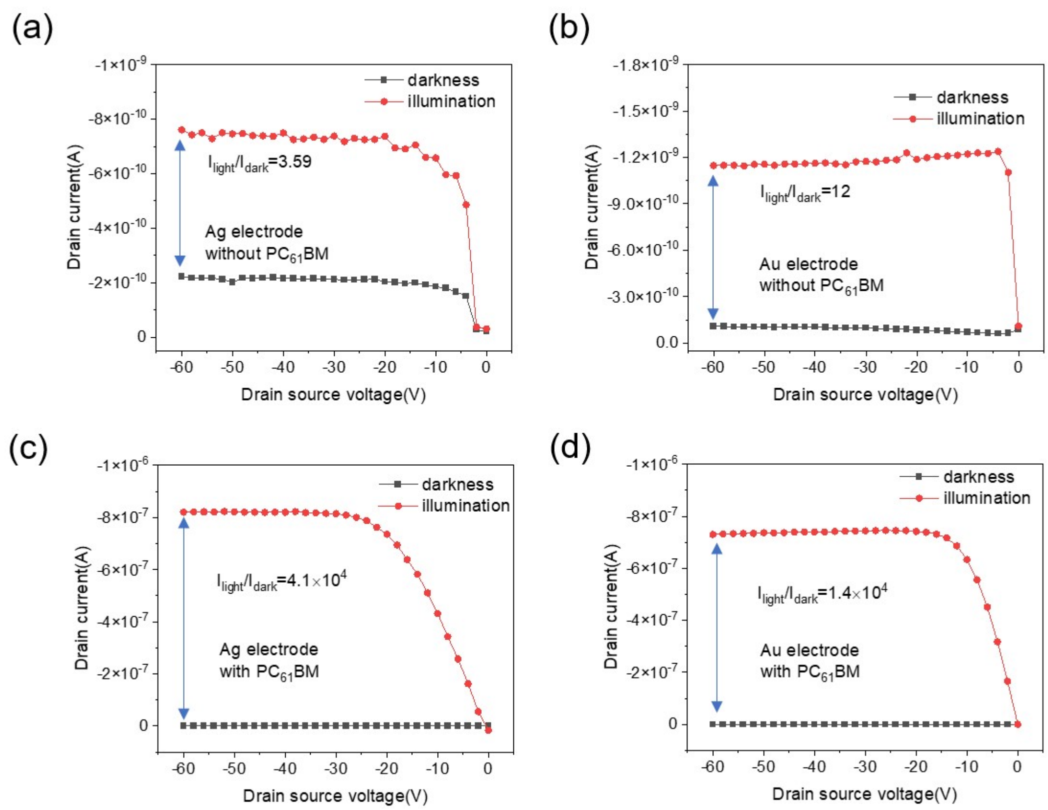


Figure S10. Output characteristics curves of different PDPPBTT:$PC_{61}BM$ devices without illumination and in light intensity illumination of 810@0.037 mW·cm^{-2} nm, the gate voltage is set at turn-on voltage. (a) Ag electrode device without $PC_{61}BM$, (b) Au electrode device without $PC_{61}BM$, (c) Ag electrode device with $PC_{61}BM$, (d) Au electrode device with $PC_{61}BM$.

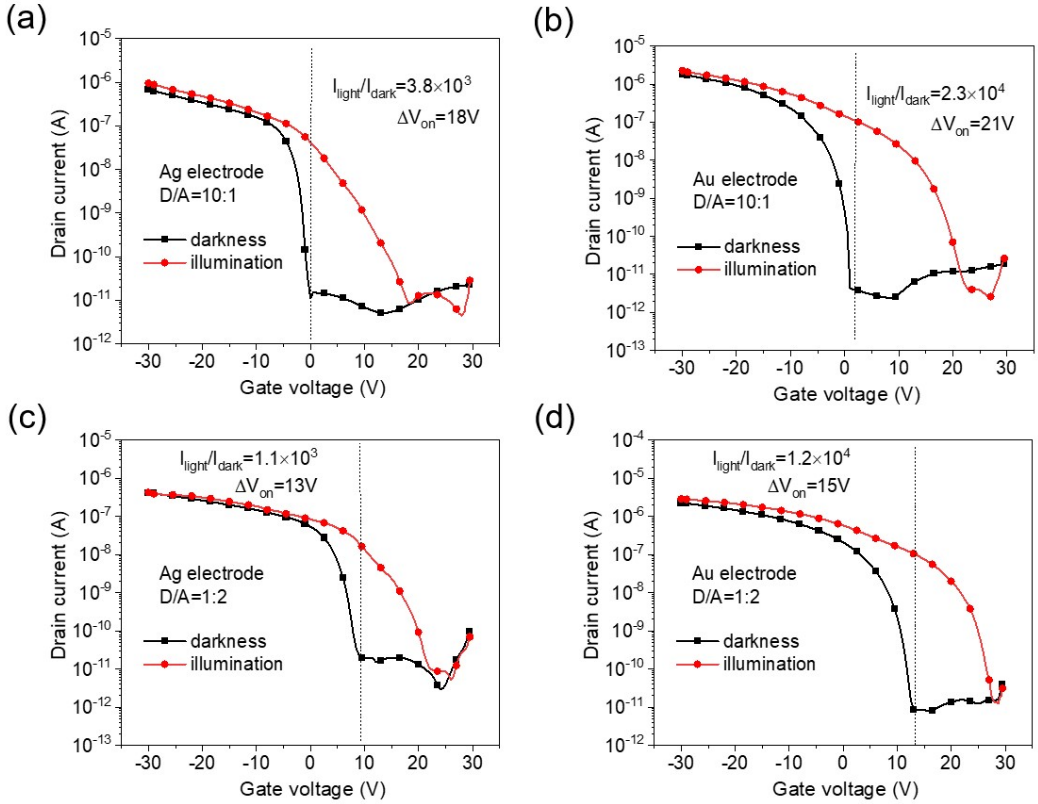


Fig. S11 Transfer characteristics curves of different PDPPBTT:$PC_{61}BM$ devices without illumination and in light intensity illumination of 810@0.037 mW·cm^{-2} nm, the drain voltage is set to −60 V. (a) D/A=10:1 of Ag electrode device, (b) D/A=10:1 of Au electrode device (c) D/A=1:2 of Ag electrode device, (d) D/A=1:2 of Au electrode device

Table S4. The photodetection performance parameters of different D/A ratio devices

PDPPBTT:PC61BM	V_{on} (V) in dark	ΔV_{on} (V)	I_{light}/I_{dark}	R ($A \cdot W^{-1}$)	D^* (Jones)
Ag electrode device D/A=10:1	0	18	3.8×10^3	133	3.1×10^{14}
Au electrode device D/A=10:1	2	21	2.3×10^4	552	9.8×10^{14}
Ag electrode device D/A=1:2	19	13	1.1×10^3	112	1.9×10^{14}
Au electrode device D/A=1:2	14	15	1.2×10^4	420	5.3×10^{14}

under 810nm@0.037 mW cm^{-2} illumination at -60 V source drain voltage.