明志科技大學材料工程系 111學年四技頂石專題製作競賽

利用導入介面層與第三元材料提升有機太陽能電池和有機光電感測器之性能

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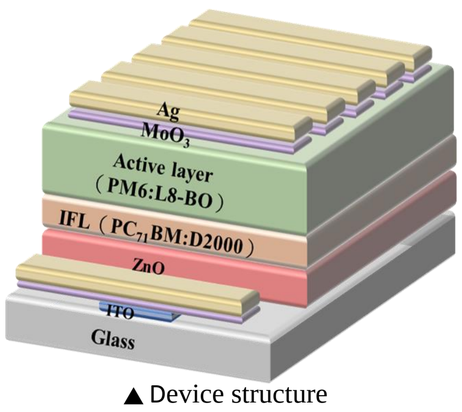
摘要

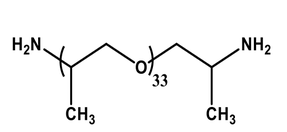
- 本實驗藉由導入介面層及第三元材料等工程的方式使OPV元件性能優化，提升光吸收、激子拆解與汲取、接收電子電洞等光電性質。
- 添加第三元非富勒烯小分子受體進入OPD系統，並透過調控主動層三元比例與厚度，使OPD元件在保有低暗電流情況，增加紅外光波段吸收，並表現擁有良好電性表現。

OPV Interfacial Layer

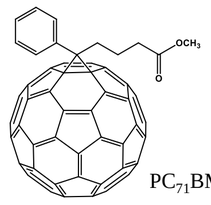


▲ Device structure

IFL

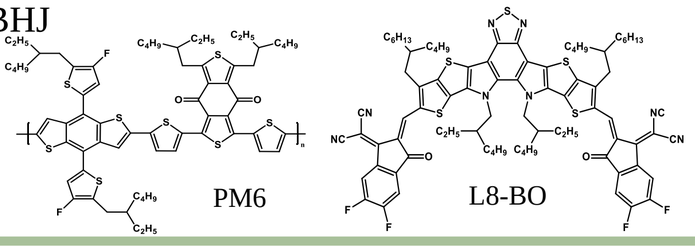


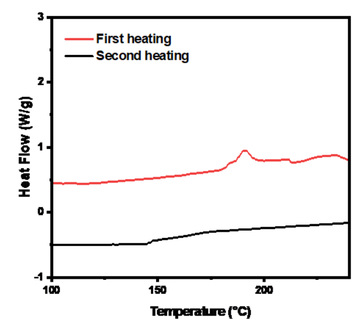
Jeffamines-D2000



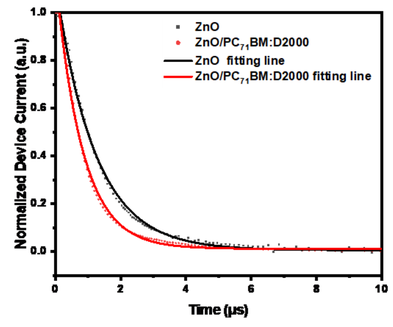
$PC_{71}BM$

BHJ

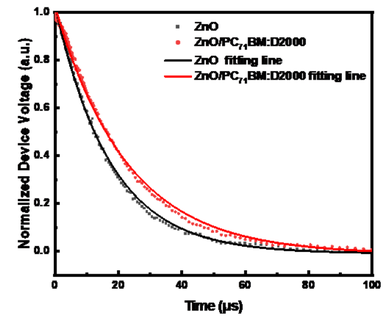




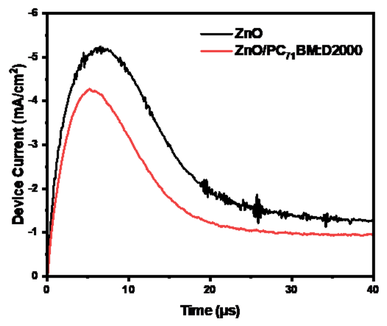
▲ DSC



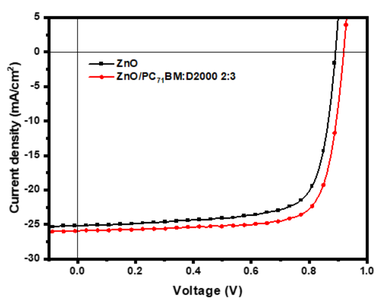
▲ TPC



▲ TPV



▲ Photo CELIV



▲ J-V curve

▼ Summary of device parameters of the optimized OSCs.

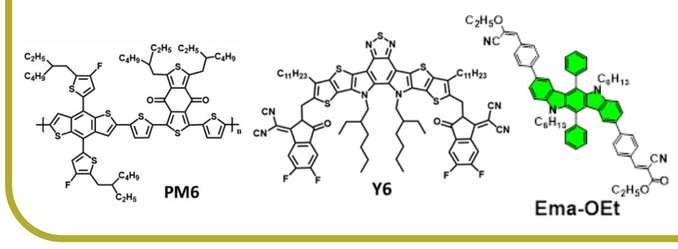
	TPC Time(μs)	TPV Time(μs)	Photo-CELIV mobility ($cm^2 V^{-1} s^{-1}$)
ZnO	1.19	17.35	$5.257x10^{-5}$
$ZnO/PC_{71}BM$:D2000	0.81	22.67	$8.187x10^{-5}$

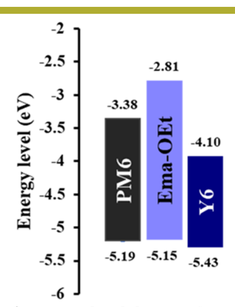
▼ Summary of device parameters of the optimized OSCs.

	J_{sc}(mA/cm^2)	V_{oc}(V)	FF(%)	PCE(%)	PCE_{best}(%)
ZnO	25.5 ± 1.23	0.88 ± 0.01	73.8 ± 1.70	16.6 ± 0.50	17.2
$ZnO/PC_{71}BM$:D2000	25.9 ± 0.45	0.91 ± 0.02	74.7 ± 1.04	17.5 ± 0.41	18.2

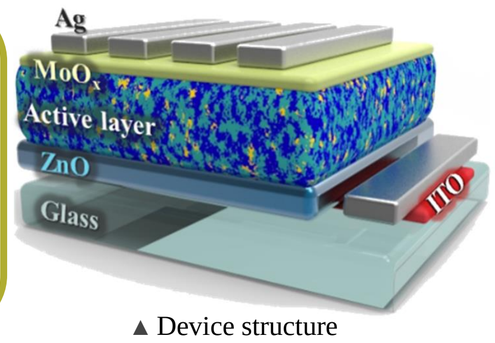
Ternary OPV

Ternary OPV BHJ



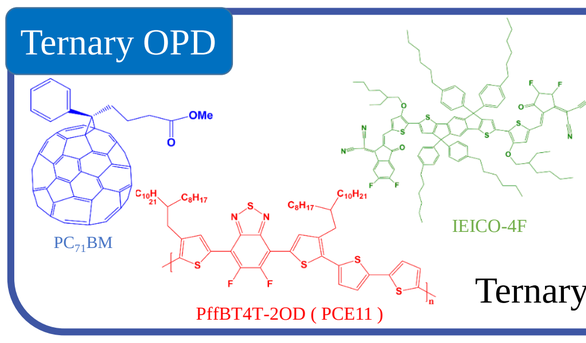


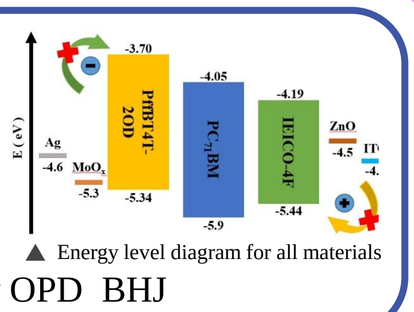
▲ Energy level diagram for materials



▲ Device structure

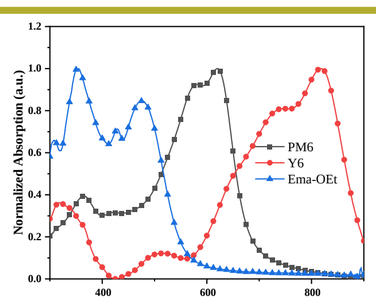
Ternary OPD



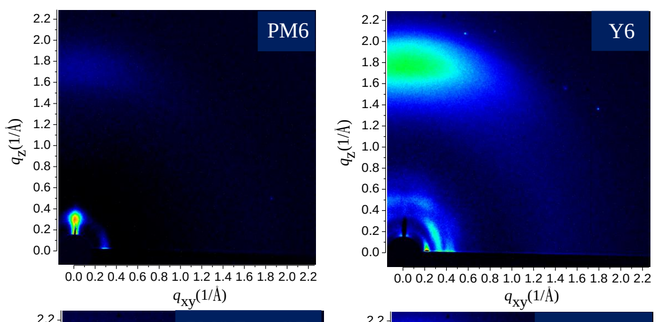


▲ Energy level diagram for all materials

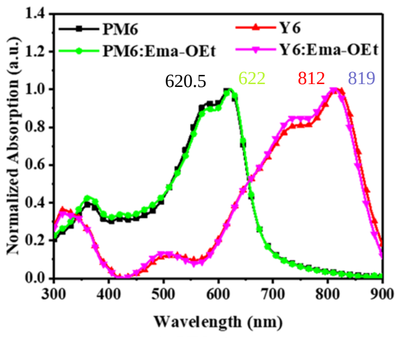
Ternary OPD BHJ



▲ UV-vis



▲ GIWAXS

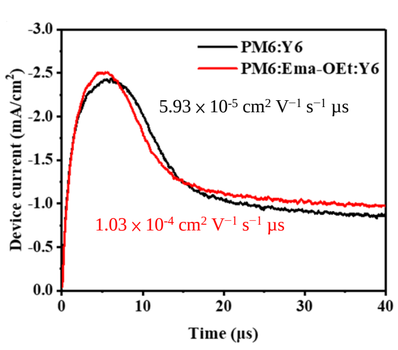


▲ UV-vis

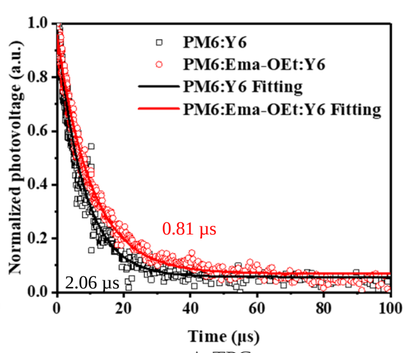
▼ Photovoltaic parameters of ternary OPVs fabricated same condition

Active layer (1:0.07:1.2)	J_{SC} ($mA \cdot cm^{-2}$)	V_{OC} (V)	FF (%)	η (%) average	η (%) best
PM6:Y6	25.18±0.24	0.865±0.002	71.08±0.81	15.51±0.19	15.71
PM6:**Ema-OEt**:Y6	25.84±0.60	0.891±0.003	74.60±0.65	17.17±0.28	17.64

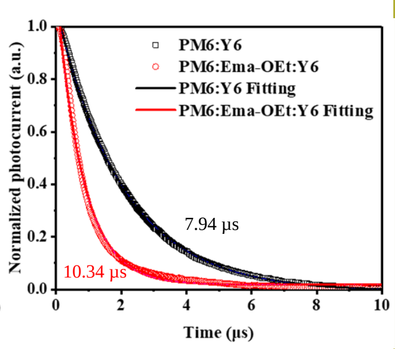
Weight ratio. Average OPV performance determined from at least six individual cells.



▲ Photo CELIV



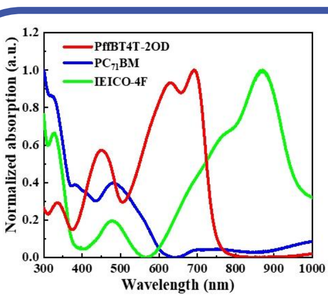
▲ TPC



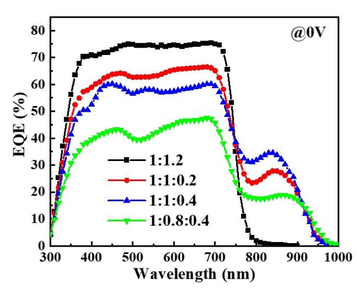
▲ TPV

▼ Detailed Energy loss parameters of the binary and ternary OPVs.

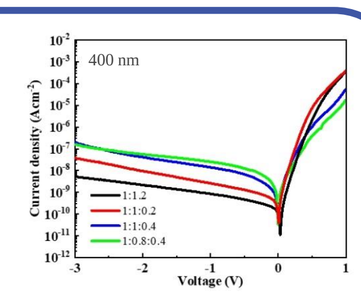
Blend	E_g [eV]	qV_{OC} [eV]	E_{loss} [eV]	E_{CT} [eV]	ΔE_{rad} [eV]	ΔE_{CT} [eV]	$\Delta E_{non\text{-}rad}$ [eV]	EQE_{EL}
PM6:Y6	1.433	0.865	0.568	1.388	0.266	0.045	0.257	4.6×10^{-5}
PM6:**EmaOEt**:Y6	1.431	0.891	0.540	1.400	0.263	0.031	0.246	7.0×10^{-5}



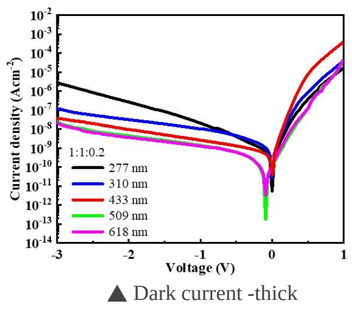
▲ UV-vis



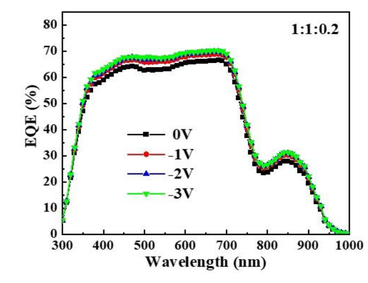
▲ EQE-ratio



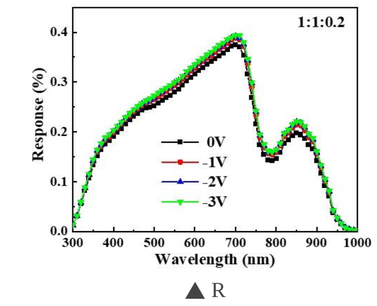
▲ Dark current -ratio



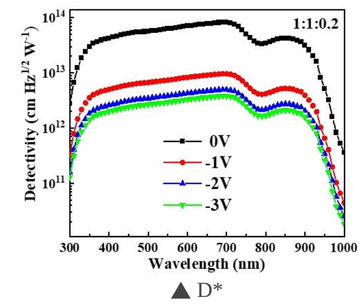
▲ Dark current -thick



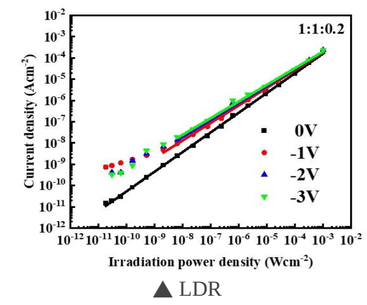
▲ EQE



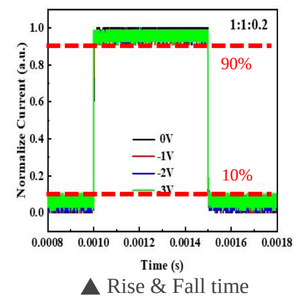
▲ R



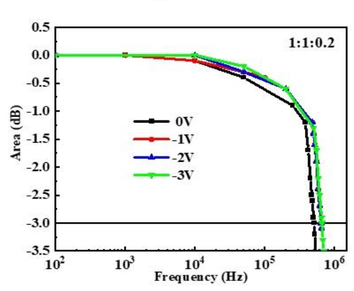
▲ D*



▲ LDR



▲ Rise & Fall time



▲ Cut-off

▲Contact angle

▼ Performances of OPD devices

1:1:0.2	J_{dark} ($A\ cm^{-2}$)	EQE_{680nm} (AW^{-1})	R_{680nm} (AW^{-1})	D^*_{680nm} (cm $Hz^{1/2}$ W^{-1})	dB_{530nm}	Rise/Fall time	Cut-off -3dB
0V	6.09×10^{-11}	66.5	0.36	8.2×10^{13}	142	310/220 ns	510 kHz
-1V	2.62×10^{-9}	68.9	0.38	9.6×10^{12}	110	270/175 ns	640 kHz
-2V	9.43×10^{-9}	69.6	0.38	5.0×10^{12}	84	240/154 ns	640 kHz
-3V	3.73×10^{-8}	70.1	0.39	3.8×10^{12}	82	210/135 ns	660 kHz

結論

- 導入介面層作為電子傳輸層的修飾層後，發現其電子傳輸能力有明顯的上升，使其載子在傳遞過程更加順利，減少再結合的現象，這也使元件光電轉換效率提升。
- Ema-OEt的添加，藉而改善元件的能階匹配、表面型態故優化分子堆積和能量損失，從而得到高效率的三元有機太陽能電池。
- 導入第三元非富勒烯小分子受體進入OPD系統後，得到可偵測紅外光波段之感測器，並且擁有良好電性表現。