Electronic Supplementary Material (ESI) for Energy & Environmental Science.

Electronic supplementary Information

Ternary Solar Cells with a Mixed Face-On and Edge-On Enable an Unprecedented Efficiency of 12.1%.

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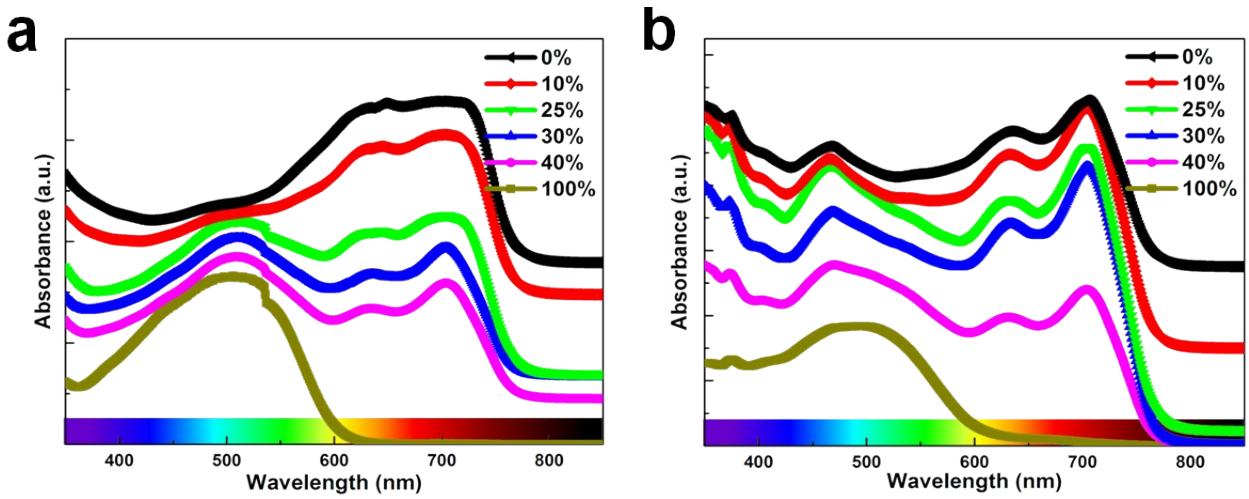

Figure S1. a) Absorption spectra of two donors' blend solutions. b) Absorption spectra of ternary blend solutions. Absorption graphs are plotted in stacked format for the ease in viewing the differences.

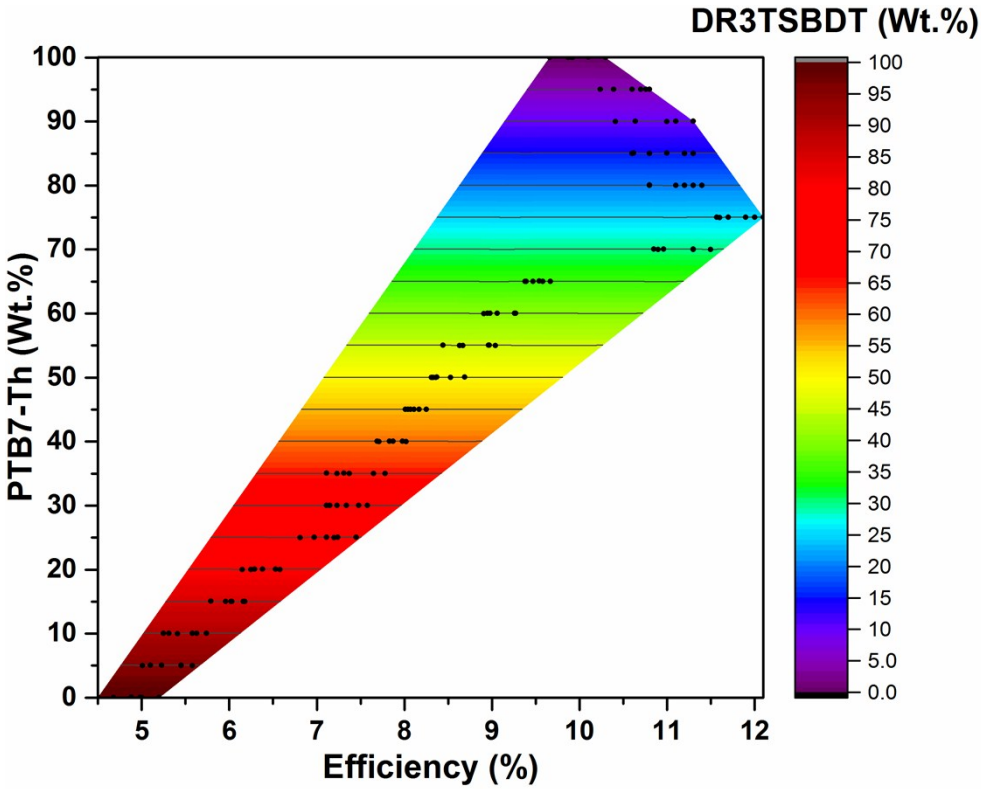

Figure S2. Contour plot showing the experimental power conversion efficiency (PCE) versus the wt.% of PTB7-Th (contour lines) and DR3TSBDT (colors) as two donor materials in the optimized ternary blends. Plotted for 6 devices in each case with maximum and minimum efficiency.

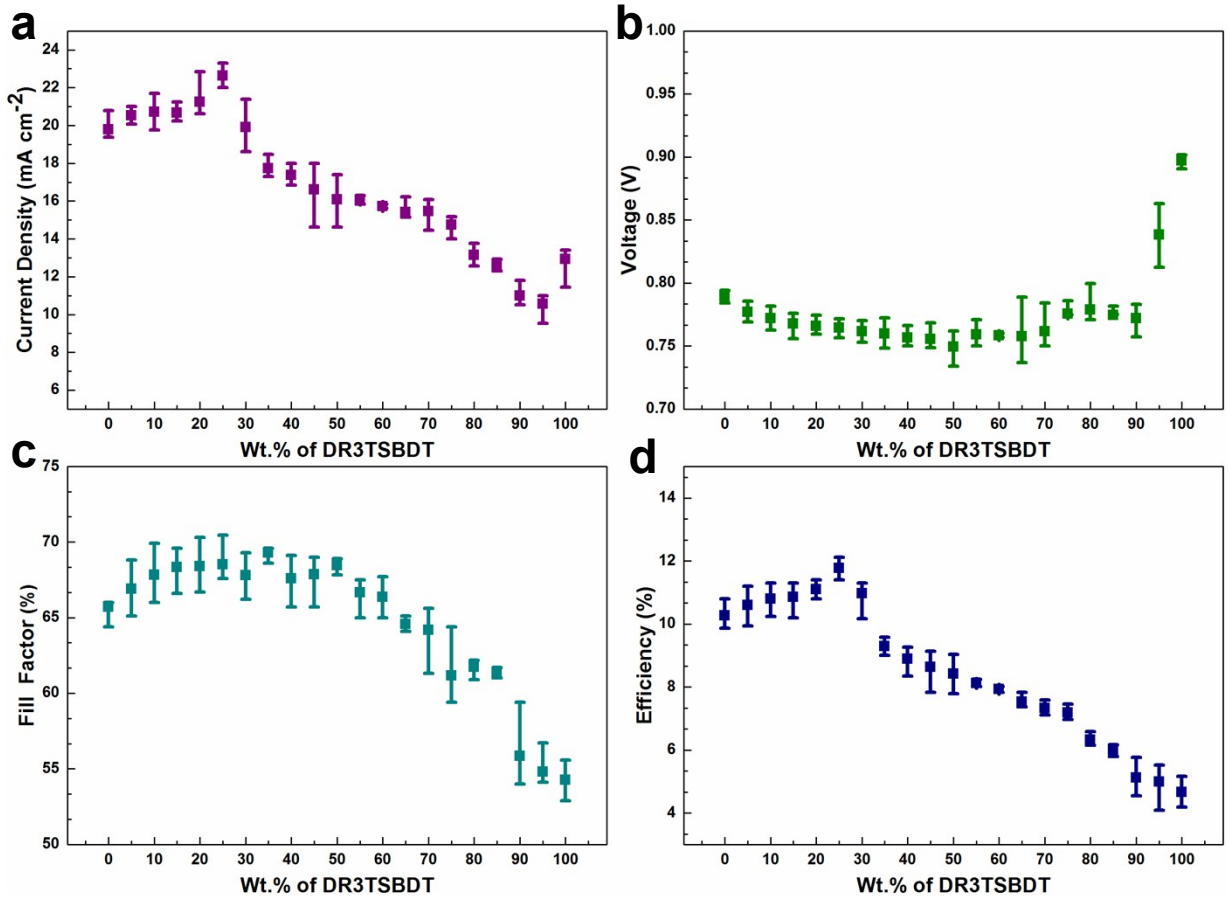

Figure S3. a) Current density. b) Voltage. c) Fill factor. d) Efficiency versus wt.% of DR3TSBDT used in the ternary blends.

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시험보고서

보고서번호: 16S-1629

1. 의 뢰 자
   기 관 명: Ulsan National Institute of Science and Technology
   주　　소: 50, UNIST-gil, Ulsan 44919, Republic of Korea

2. 시료 설명: Organic Thin-Film Solar Cells

3. 시험기간: 16.10.27 (1일간)

4. 시험방법: 시험 장비의 측정 방법에 의함.

5. 시험결과

시험항목	결과	비고
태양전지평가시스템 기본사용 (Solar Simulator - 1kW)	Note the test results	-

이 시험보고서의 내용은 의뢰자가 제시한 시료에 한하며 용도이외의 사용을 금합니다.

확인	작성자		팀장	
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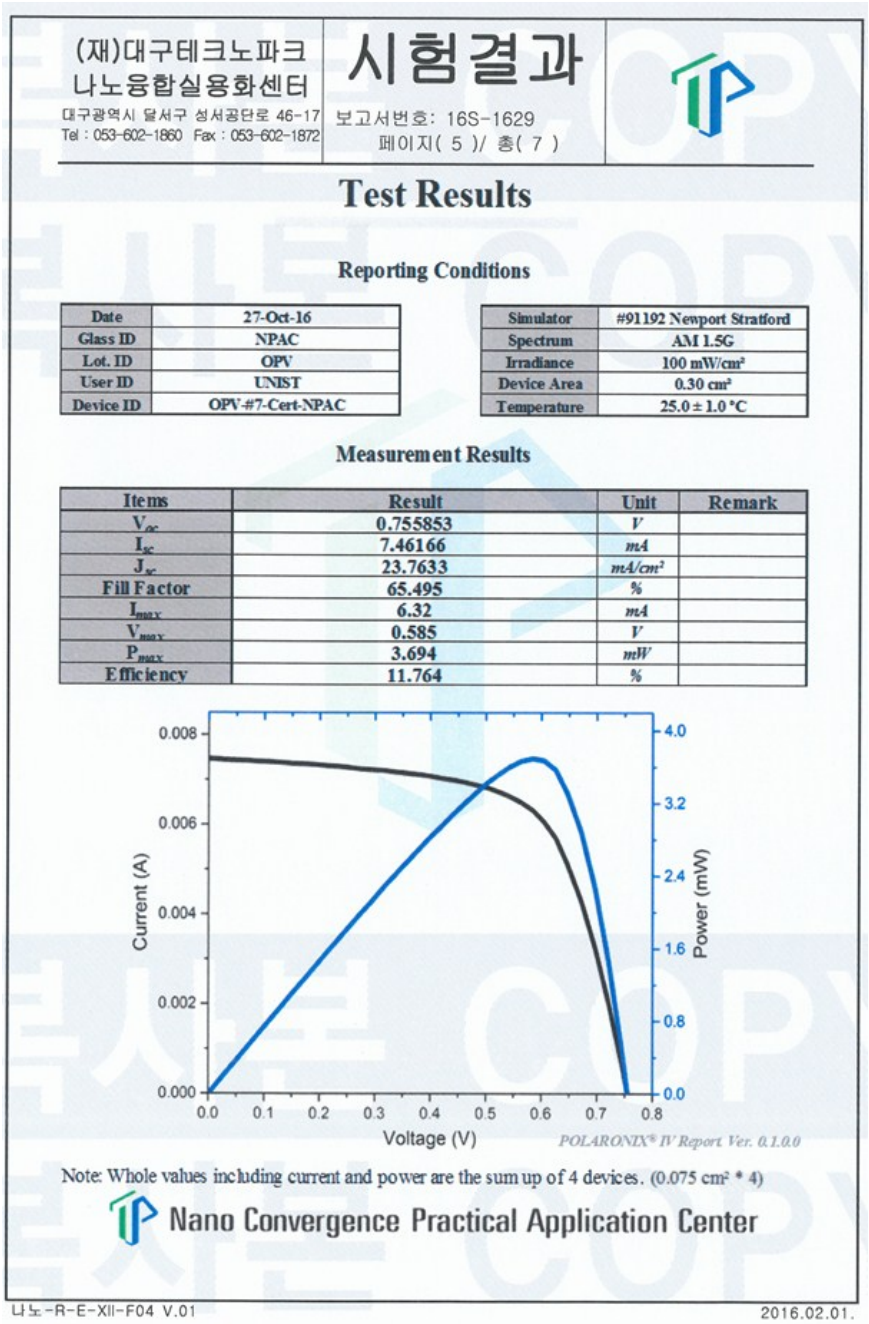
2016. 10. 31.

(재)대구테크노파크 나노융합실용화센터장 (인)



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시험결과

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페이지(5)/ 총(7)

Test Results

Reporting Conditions

Date	27-Oct-16
Glass ID	NPAC
Lot. ID	OPV
User ID	UNIST
Device ID	OPV-#7-Cert-NPAC

Simulator	#91192 Newport Stratford
Spectrum	AM 1.5G
Irradiance	100 mW/cm²
Device Area	0.30 cm²
Temperature	25.0 ± 1.0 °C

Measurement Results

Items	Result	Unit	Remark
V_{oc}	0.755853	V	
I_{sc}	7.46166	mA	
J_{sc}	23.7633	mA/cm²	
Fill Factor	65.495	%	
I_{max}	6.32	mA	
V_{max}	0.585	V	
P_{max}	3.694	mW	
Efficiency	11.764	%	

Note: Whole values including current and power are the sum up of 4 devices. (0.075 cm² * 4)

Nano Convergence Practical Application Center

나노-R-E-XII-F04 V.01 2016.02.01.

Figure S4. Independent certification confirming a power conversion efficiency of 11.76% by Nano Convergence Practical Application Center, South Korea.

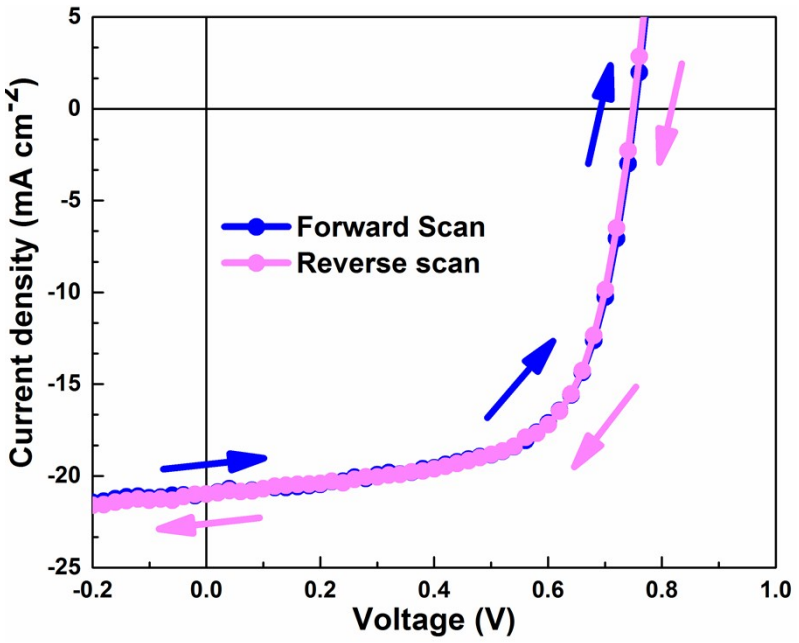

Figure S5. Hysteresis free *J-V* curve of one of the best performing ternary device (25 wt.% of DR3TSBDT loading)**.**

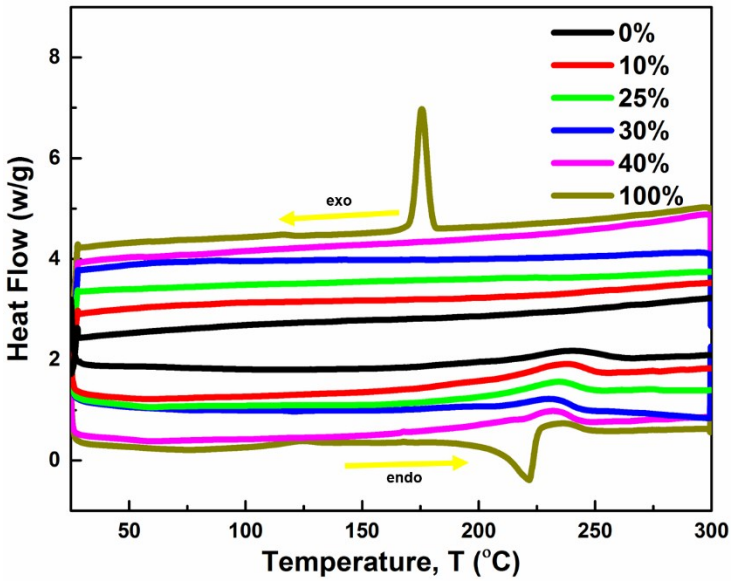

Figure S6. Differential scanning calorimetry (DSC) curves for the two donors' blend at different wt.% of DR3TSBDT loading.

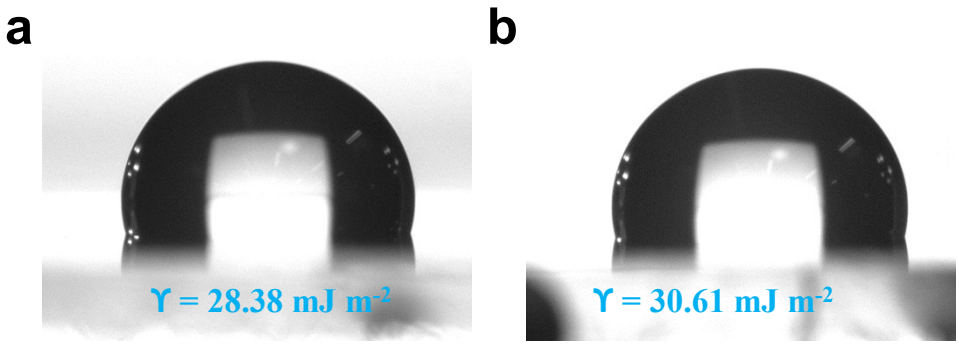

Figure S7. Surface energy measurement. Photographs of the drop of water on the surface of a) DR3TSBDT and b) PTB7-Th:$PC_{71}BM$ films on a glass substrate.

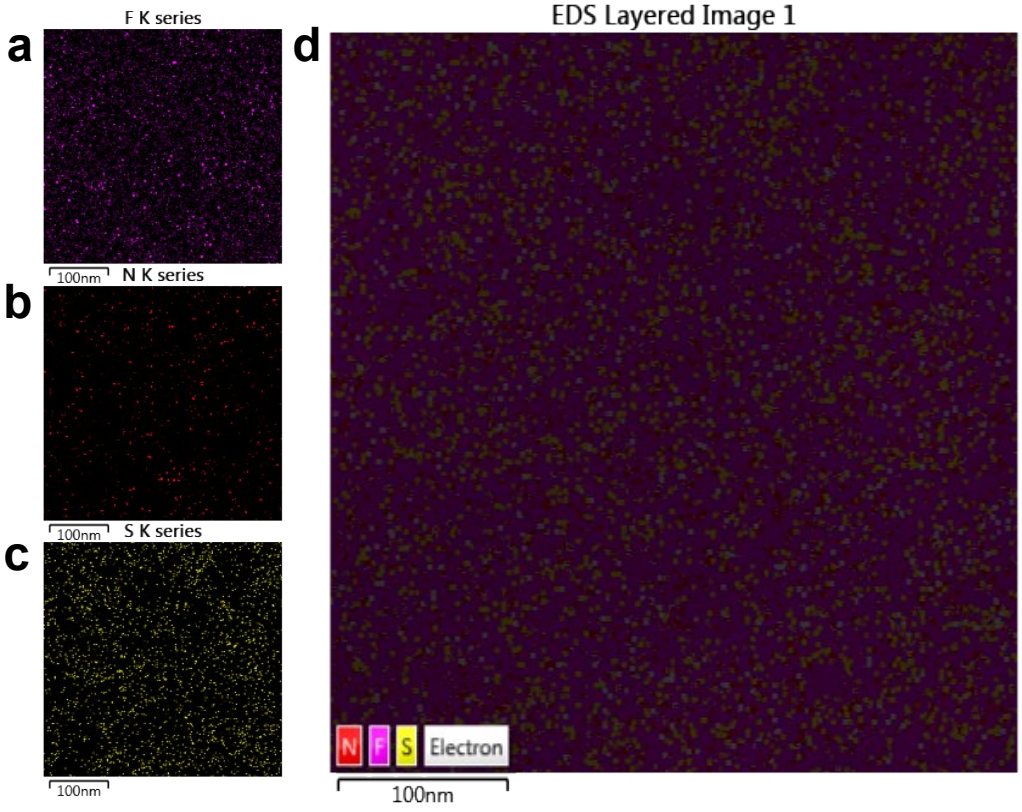

Figure S8. Energy dispersive X-ray elemental mapping; the fluorine (purple dots) and nitrogen (red dots) indicate PTB7-Th and DR3TSBDT, respectively in ternary blend for 25 wt.% of DR3TSBDT at higher resolution of 100 nm using HR-TEM equipped with an energy dispersive X-ray spectrometer.

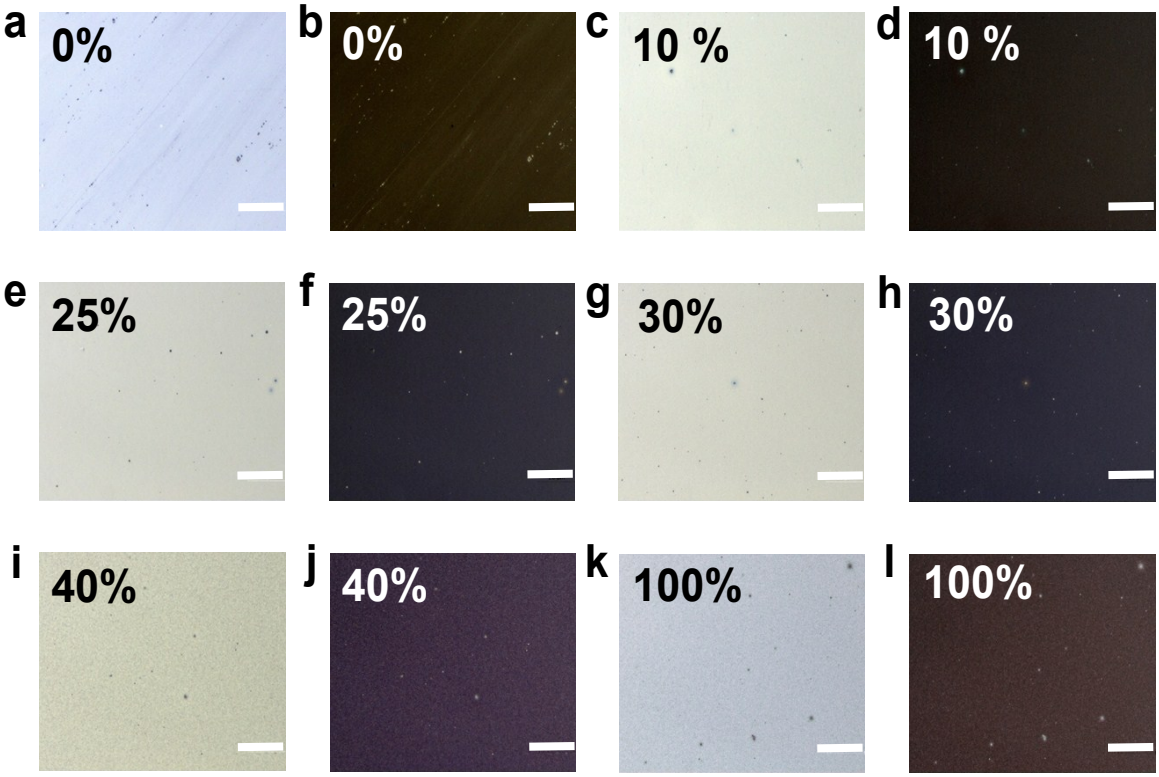

Figure S9. Optical microscopic images of ternary blends in normal and inverse color mode. a), b) 0%. c), d) 10%. e), f) 25%. g), h) 30%. i), j) 40%. k), l) 100% of DR3TSBDT in ternary blends. Scale bar is 20 µm.

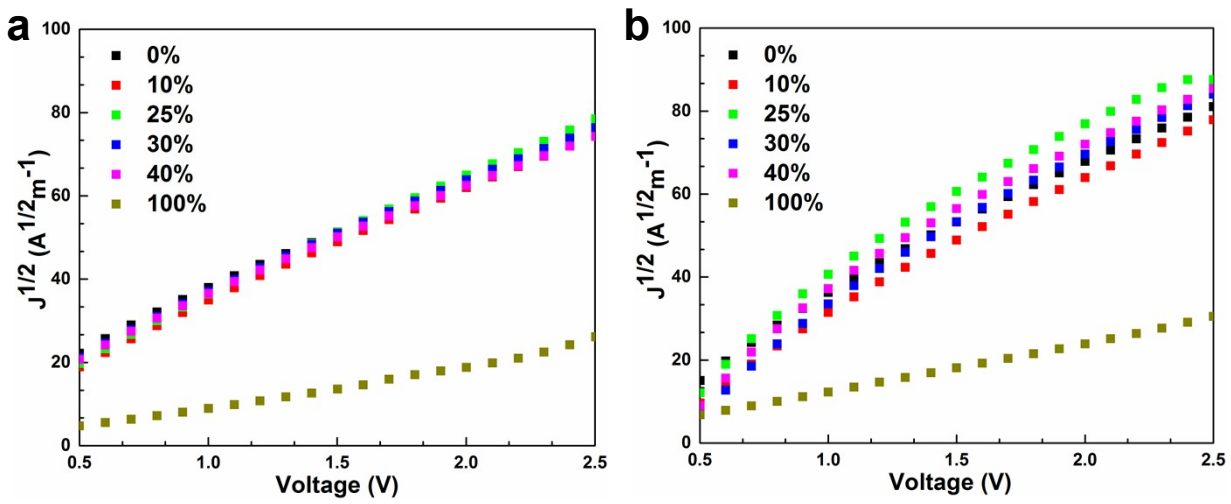

Figure S10. a) Hole mobility. b) Electron mobility of OSCs.

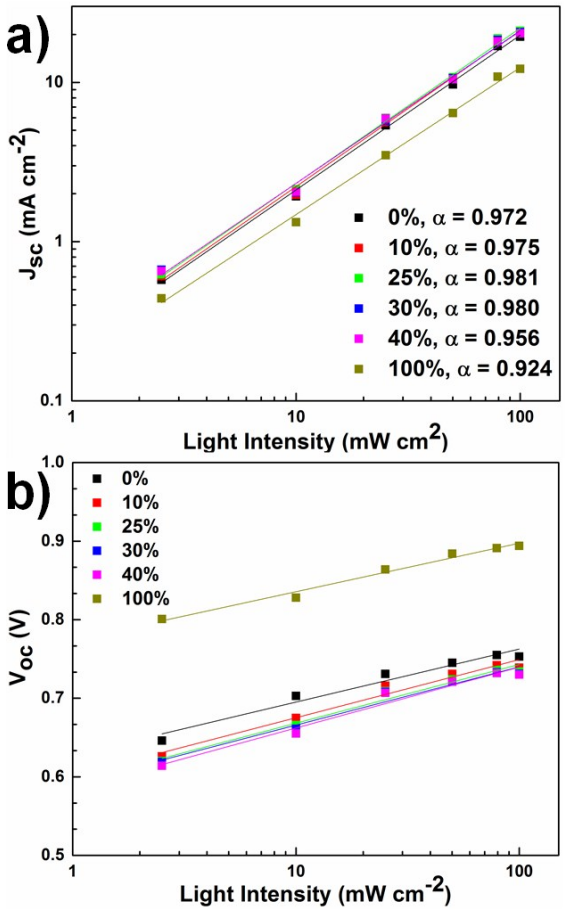

Figure S11. a) Dependence of current density (J_{SC}) and b) V_{OC} on light intensity of OSCs.

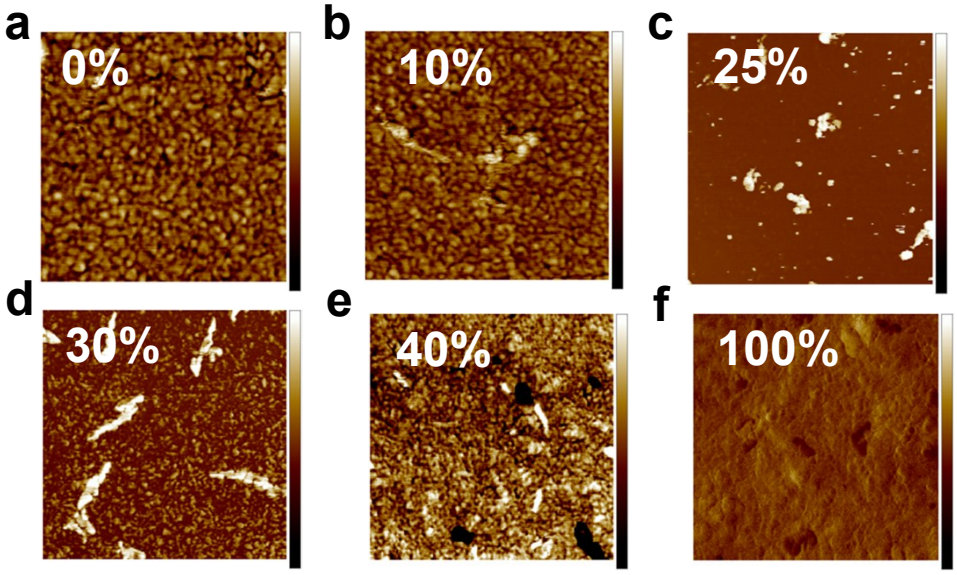

Figure S12. a) 0%, b) 10%, c) 25%, d) 30%, e) 40%, and f) 100% AFM phase images (scan size 1 × 1 µm). Different color bars are used for the phase variance.

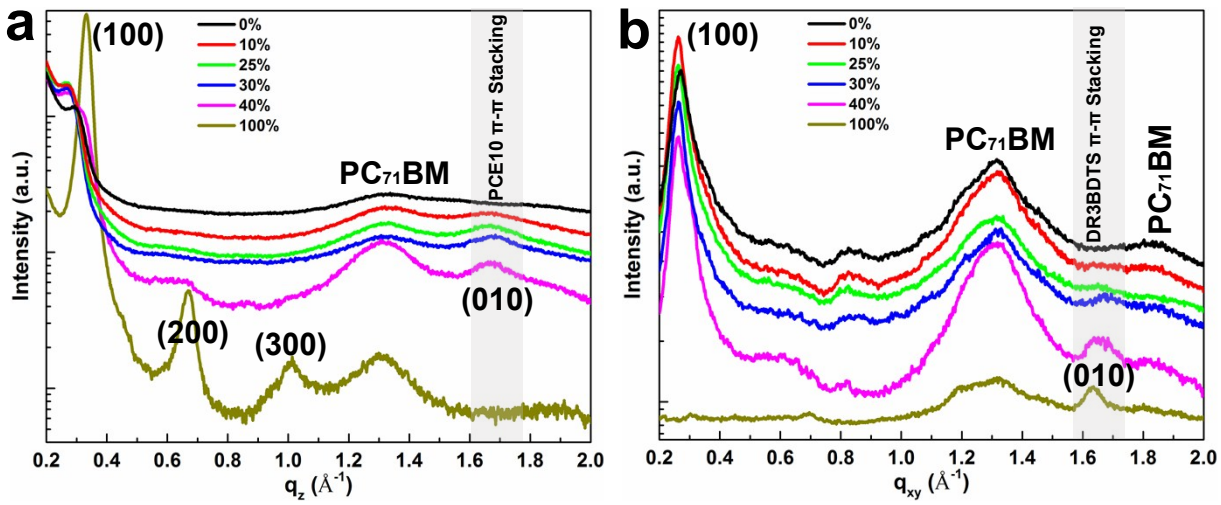

Figure S13. a) Out-of-plane. b) In-plane line cut profiles obtained from GIWAXS data.

Table S1. Lattice parameters in out-of-plane and in-plane direction for ternary system with different DR3TSBDT loading ratios.

Active layer	Unit cell long axis (100) ($Å^{-1}$)	d_{100} (Å)	π-π stacking cell axis (010) ($Å^{-1}$)	d_{010} (Å)
Out of plane				
0 %	0.2960	21.22	1.689	3.719
10 %	0.2793	22.50	1.677	3.747
25 %	0.2795	22.48	1.675	3.752
30 %	0.2748	22.86	1.674	3.753
40 %	0.2788	22.53	1.672	3.758
100 %	0.3202	19.62		
In plane				
0 %	0.2999	20.95		
10 %	0.2912	21.58	1.652	3.804
25 %	0.2881	21.81	1.648	3.813
30 %	0.2881	21.81	1.669	3.765
40 %	0.3043	20.65	1.650	3.808
100 %	0.3064	20.51	1.632	3.849

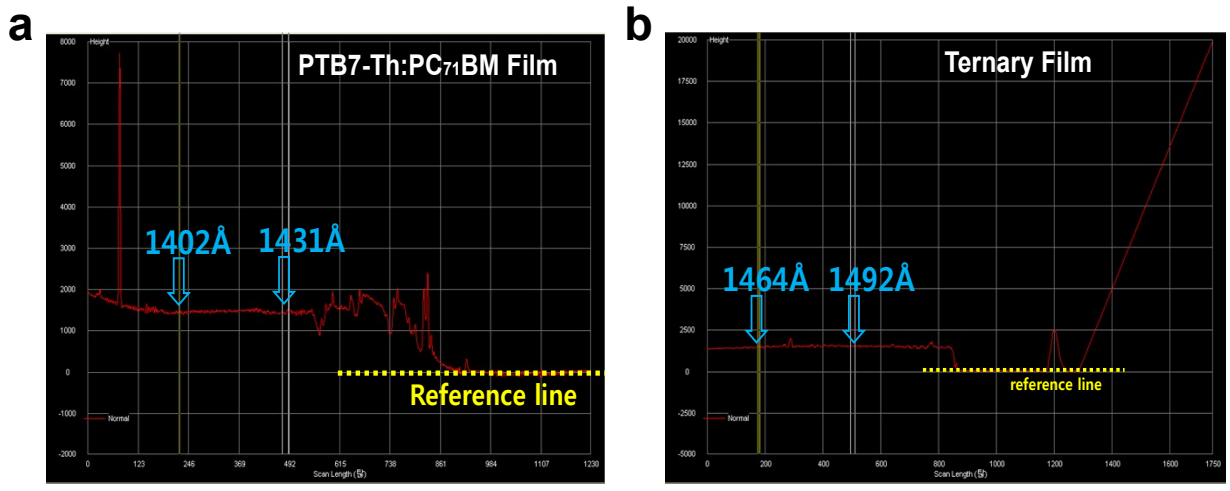

Figure S14. Thickness of optimized films in the range of 140-150 nm. a) PTB7-Th:PC_{71}BM binary film. b) Ternary film.