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

Supporting Information

Guided Crystallization of P3HT in Ternary Blend Solar Cell Based on P3HT:PCPDTBT:PCBM

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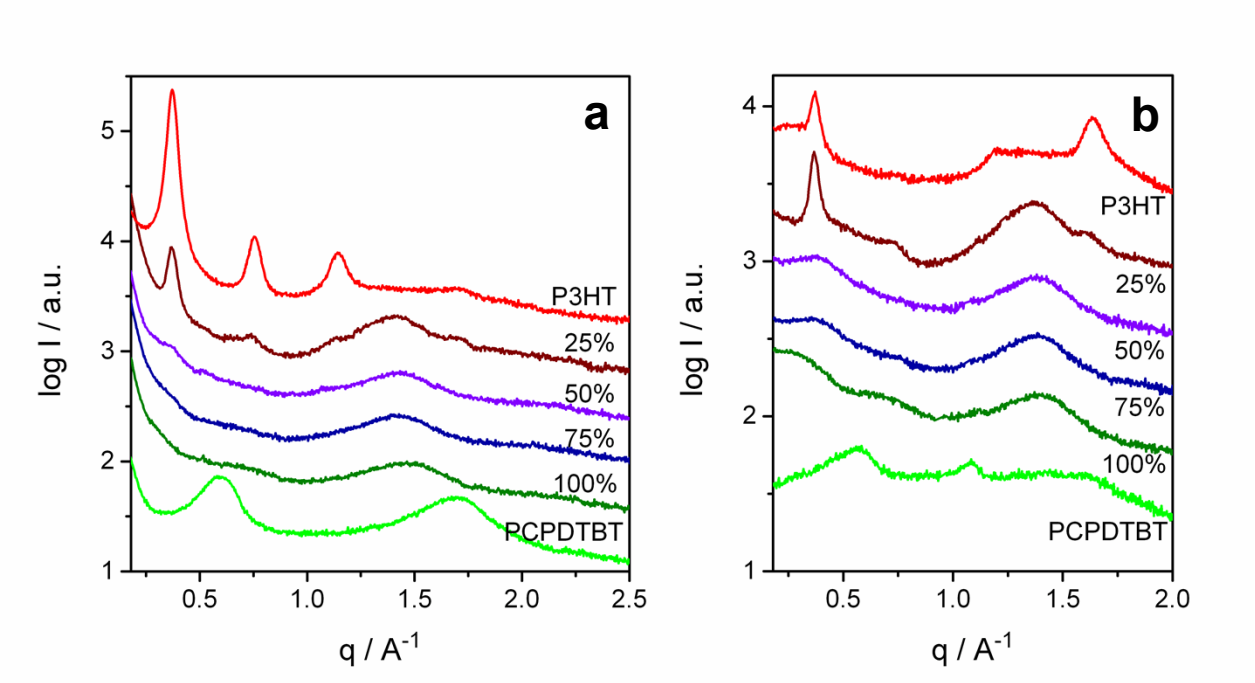


Figure S1. GIXD (a) OOP or (b) IP profiles for P3HT-32k:PCPDTBT:$PC_{61}BM$ ternary blend thin films with different PCPDTBT contents and pure P3HT or PCPDTBT films.

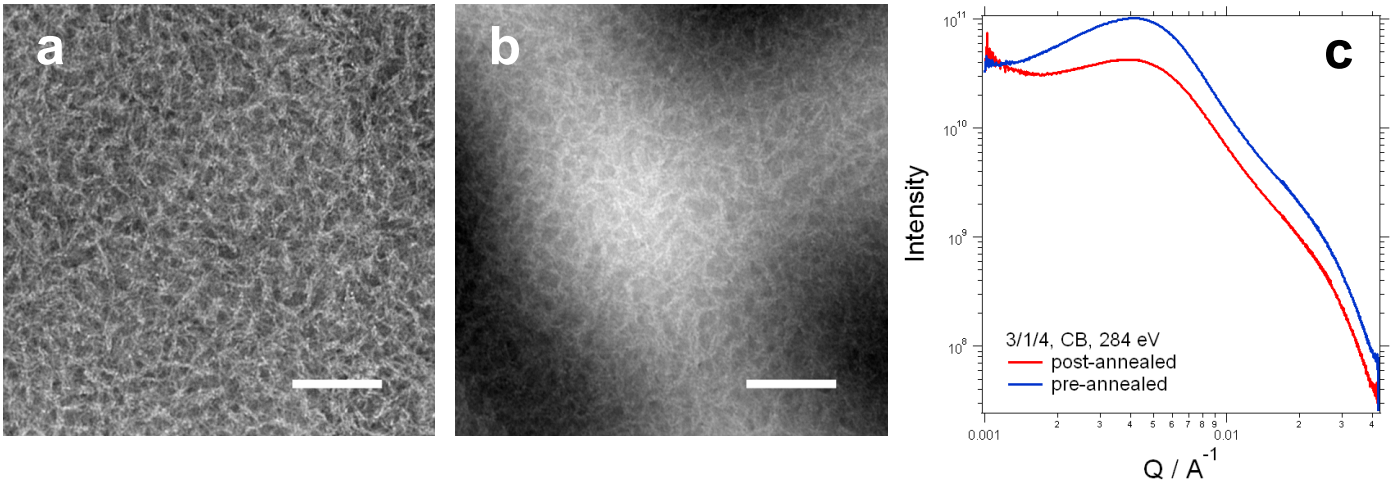


Figure S2. BF-TEM images for ternary blend thin films of P3HT-32k:PCPDTBT:$PC_{61}BM$ with weight ratio of 3/1/4 (25 wt% of PCPDTBT), spin-coated by CB, pre-annealed (a) or post-annealed (b). The scale bar is 500 nm. P-RSoXS profiles for the pre-annealed and post-annealed samples (c).

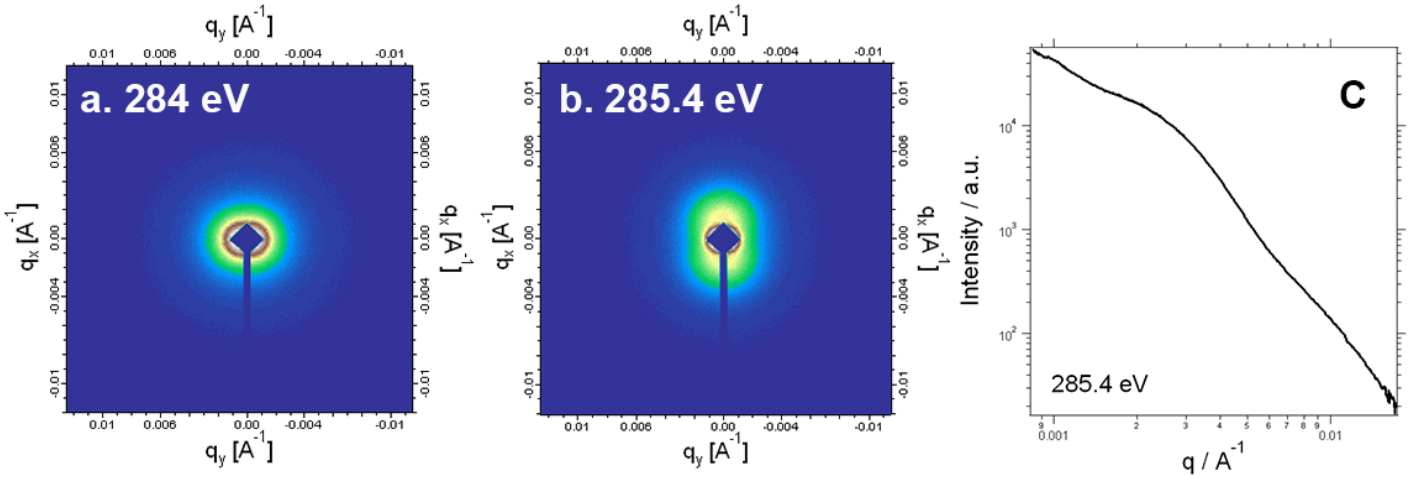
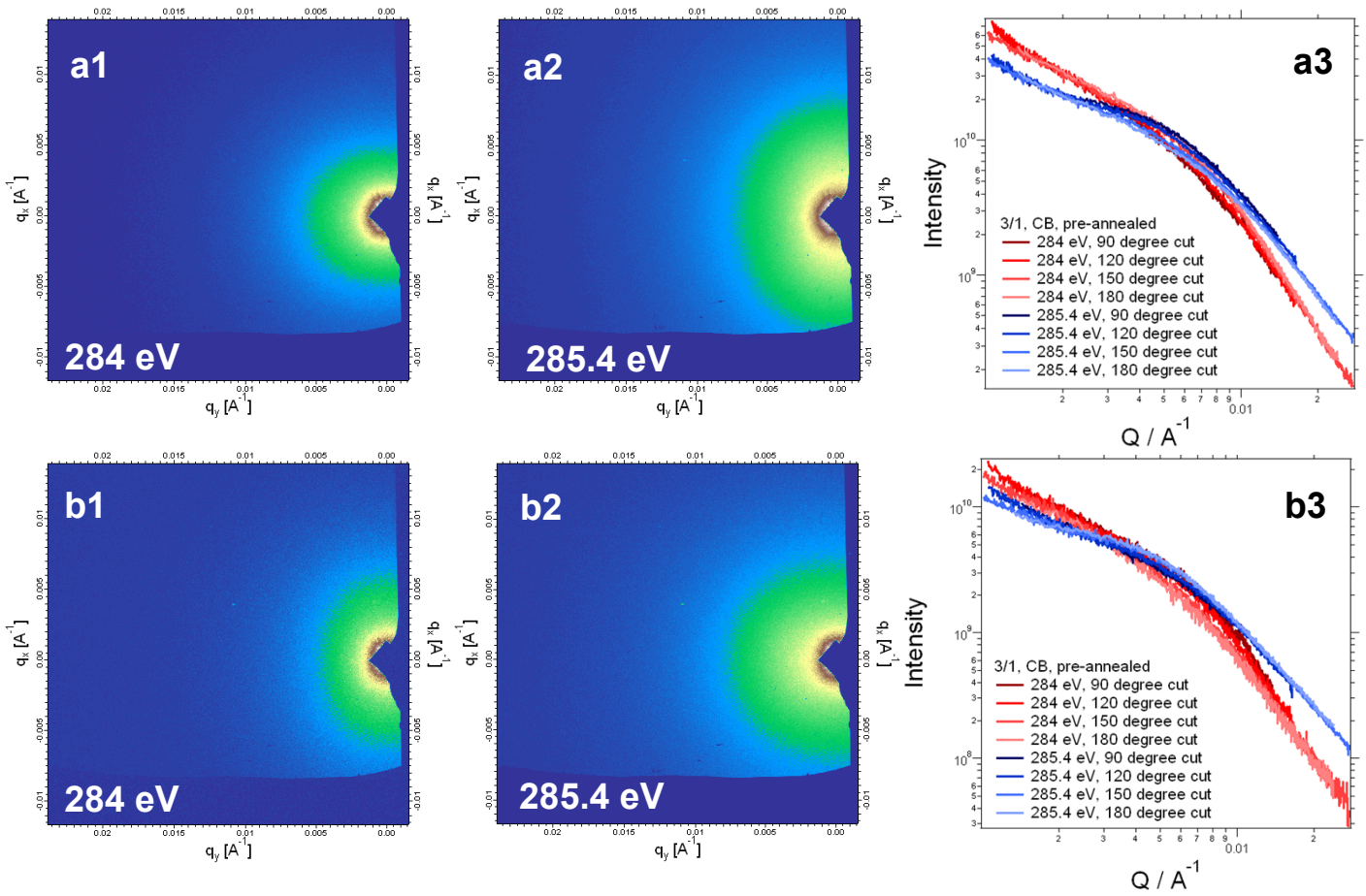


Figure S3. P-RSoXS patterns (a, b) and circularly averaged profile (c) for regio-random P3HT:PCPDTBT thin film (1/1 wt/wt, spin-coated by CB, pre-annealed at 150°C for 10 minutes) at horizontally polarized x-ray beam.


a1
284 eV
a2
285.4 eV
a3
3/1, CB, pre-annealed
284 eV, 90 degree cut
284 eV, 120 degree cut
284 eV, 150 degree cut
284 eV, 180 degree cut
285.4 eV, 90 degree cut
285.4 eV, 120 degree cut
285.4 eV, 150 degree cut
285.4 eV, 180 degree cut
Intensity
Q / A-1
b1
284 eV
b2
285.4 eV
b3
3/1, CB, pre-annealed
284 eV, 90 degree cut
284 eV, 120 degree cut
284 eV, 150 degree cut
284 eV, 180 degree cut
285.4 eV, 90 degree cut
285.4 eV, 120 degree cut
285.4 eV, 150 degree cut
285.4 eV, 180 degree cut
Intensity
Q / A-1
qx [A-1]
qy [A-1]

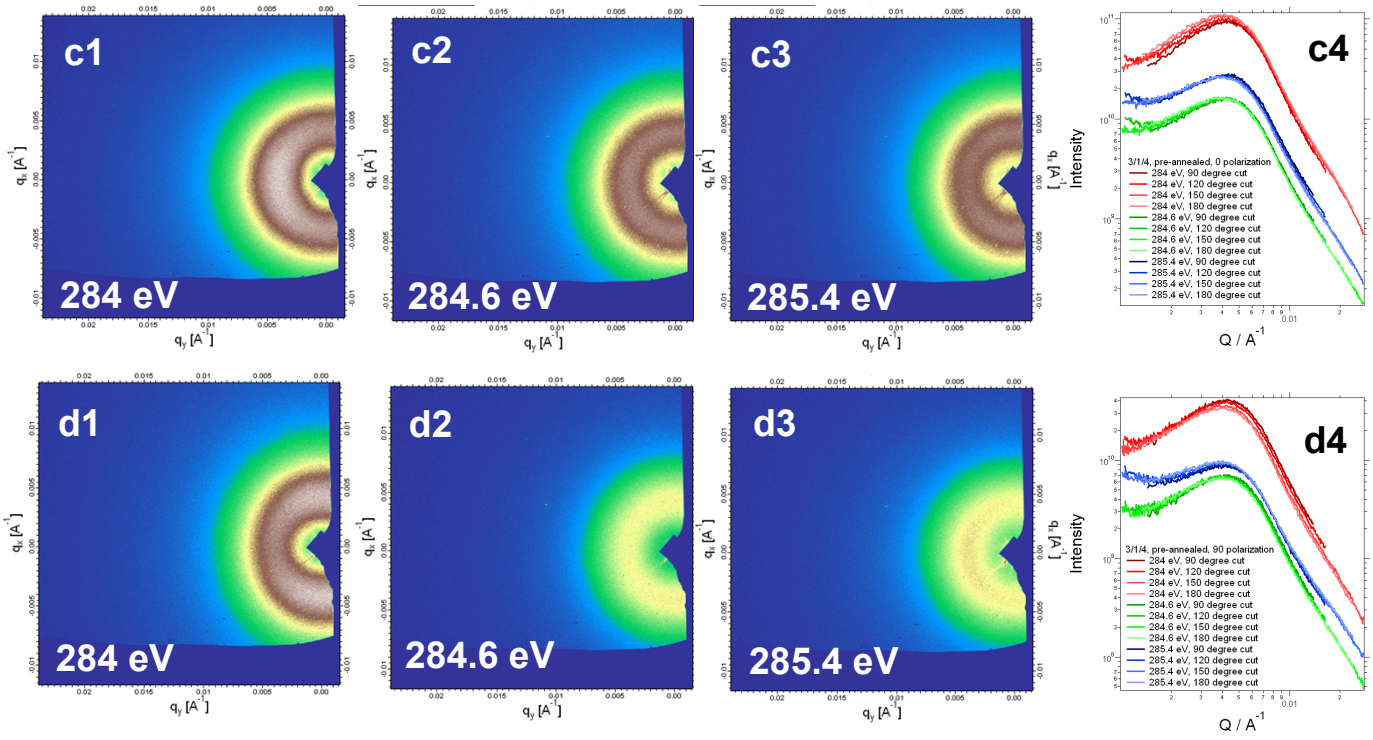

c1
284 eV
c2
284.6 eV
c3
285.4 eV
c4
3/1/4, pre-annealed, 0 polarization
284 eV, 90 degree cut
284 eV, 120 degree cut
284 eV, 150 degree cut
284 eV, 180 degree cut
284.6 eV, 90 degree cut
284.6 eV, 120 degree cut
284.6 eV, 150 degree cut
284.6 eV, 180 degree cut
285.4 eV, 90 degree cut
285.4 eV, 120 degree cut
285.4 eV, 150 degree cut
285.4 eV, 180 degree cut
Intensity
Q / A-1
d1
284 eV
d2
284.6 eV
d3
285.4 eV
d4
3/1/4, pre-annealed, 90 polarization
284 eV, 90 degree cut
284 eV, 120 degree cut
284 eV, 150 degree cut
284 eV, 180 degree cut
284.6 eV, 90 degree cut
284.6 eV, 120 degree cut
284.6 eV, 150 degree cut
284.6 eV, 180 degree cut
285.4 eV, 90 degree cut
285.4 eV, 120 degree cut
285.4 eV, 150 degree cut
285.4 eV, 180 degree cut
Intensity
Q / A-1
qx [A-1]
qy [A-1]

Figure S4. P-RSoXS scattering patterns and sector averaged profiles for P3HT-32k:PCPDTBT thin film (3/1 wt/wt, spin-coated by CB and pre-annealed) at horizontally polarized x-ray beam (a1-a3) or at vertically polarized x-ray beam (b1-b3). P-RSoXS scattering patterns and sector averaged profiles for P3HT-32k:PCPDTBT:$PC_{61}BM$ thin film (3/1/4, spin-coated by CB and pre-annealed) at horizontally polarized x-ray beam (c1-c4) or at vertically polarized x-ray beam (d1-d4).

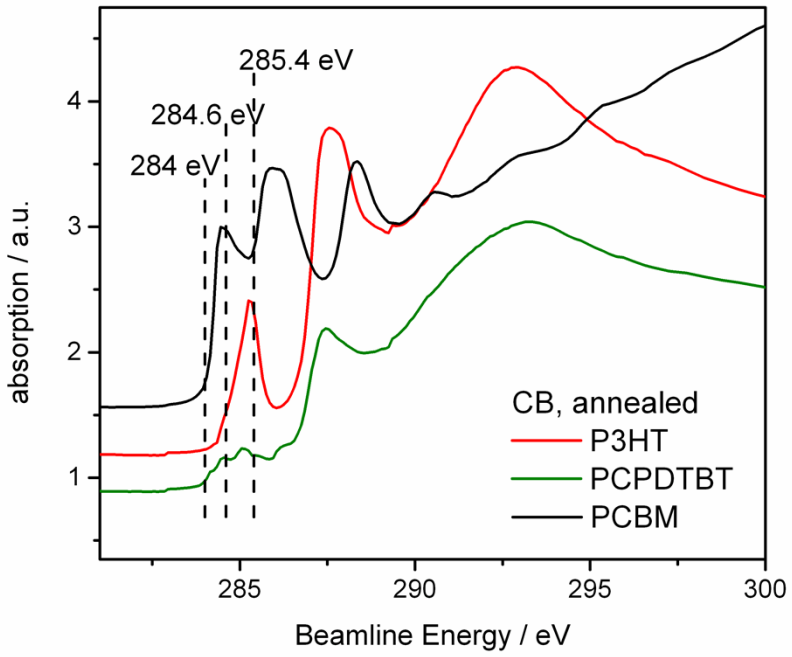


Figure S5. NEXAFS profiles for P3HT, PCPDTBT and PCBM spin-coated by CB and annealed.

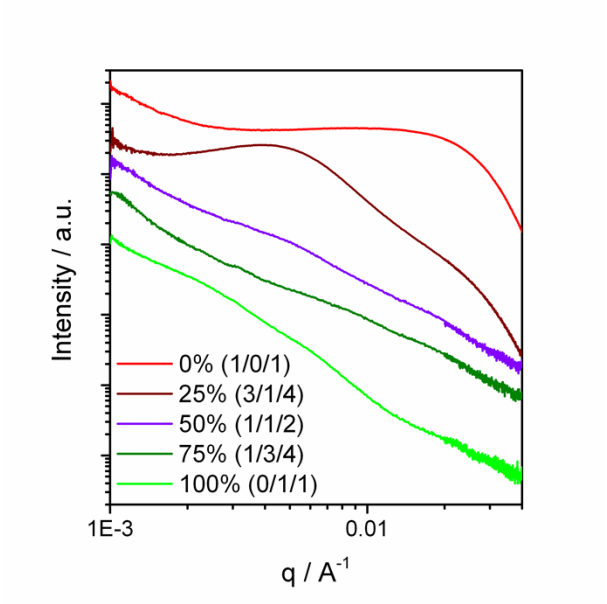
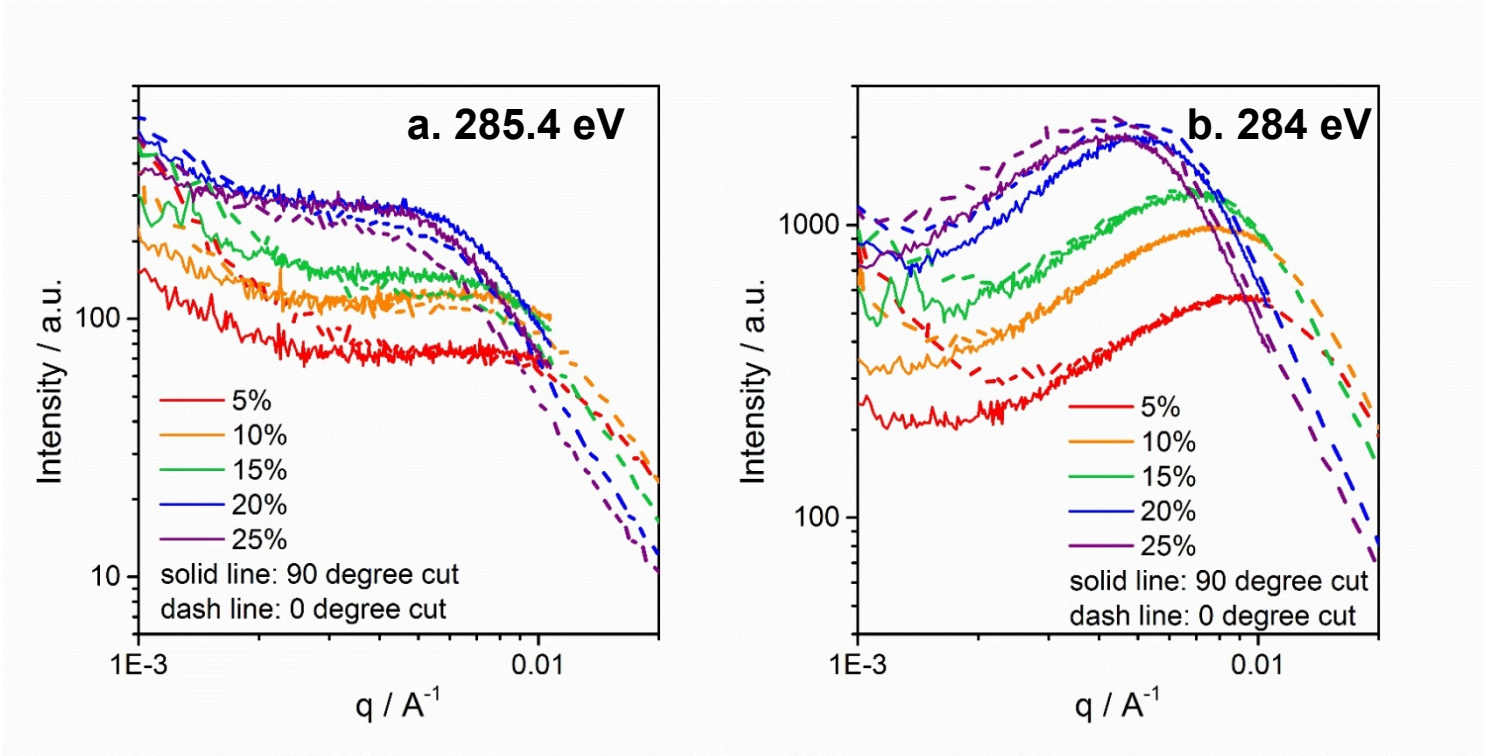


Figure S6. Circularly averaged P-RSoXS profiles for ternary blend thin film of P3HT-32k : PCPDTBT:$PC_{61}BM$ or binary references at 284 eV horizontally polarized x-ray beam. The



profiles are shifted to show each curve clearly.

Figure S7. Sector averaged (±2°) P-RSoXS profiles for ternary blend thin film of P3HT-32k : PCPDTBT:$PC_{61}BM$ with different PCPDTBT weight fractions at (a) 285.4 eV or (b) 284 eV horizontally polarized x-ray beam.

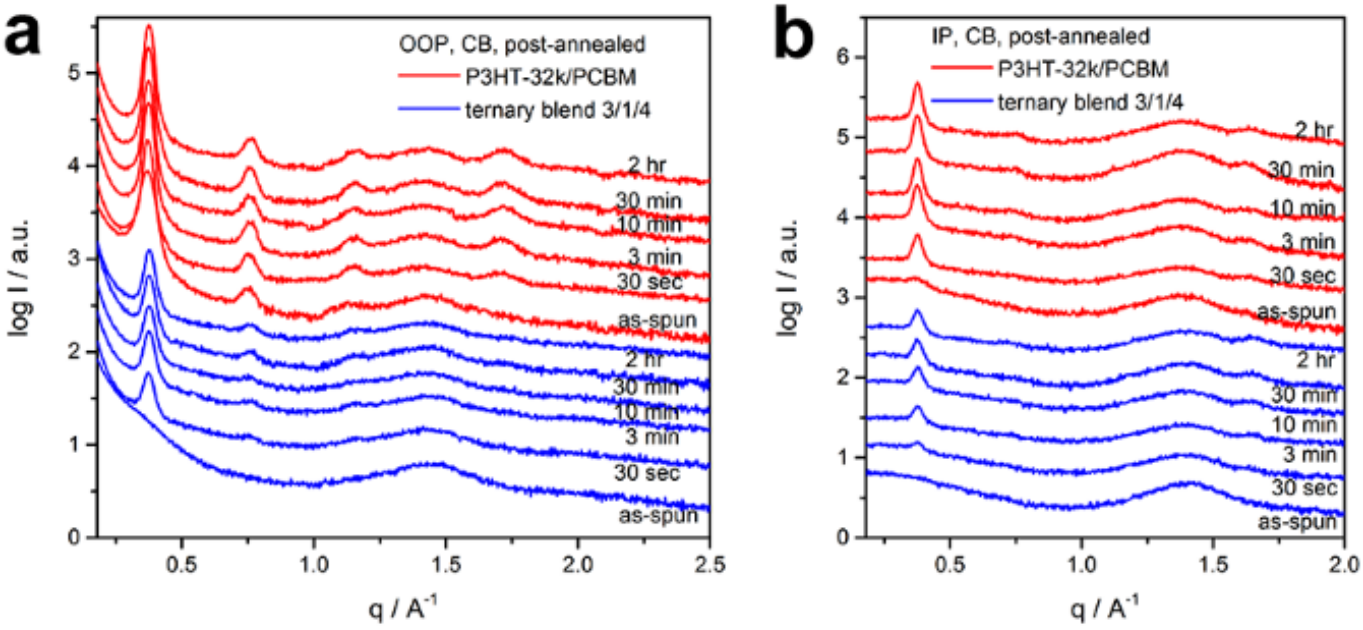


Figure S8. GIXD OOP (a) or IP (b) profiles for thin film of P3HT-32k:PCBM (1/1) and P3HT-32k:PCPDTBT:$PC_{61}BM$ (3/1/4) spin-coated by CB and post-annealed for a different time.

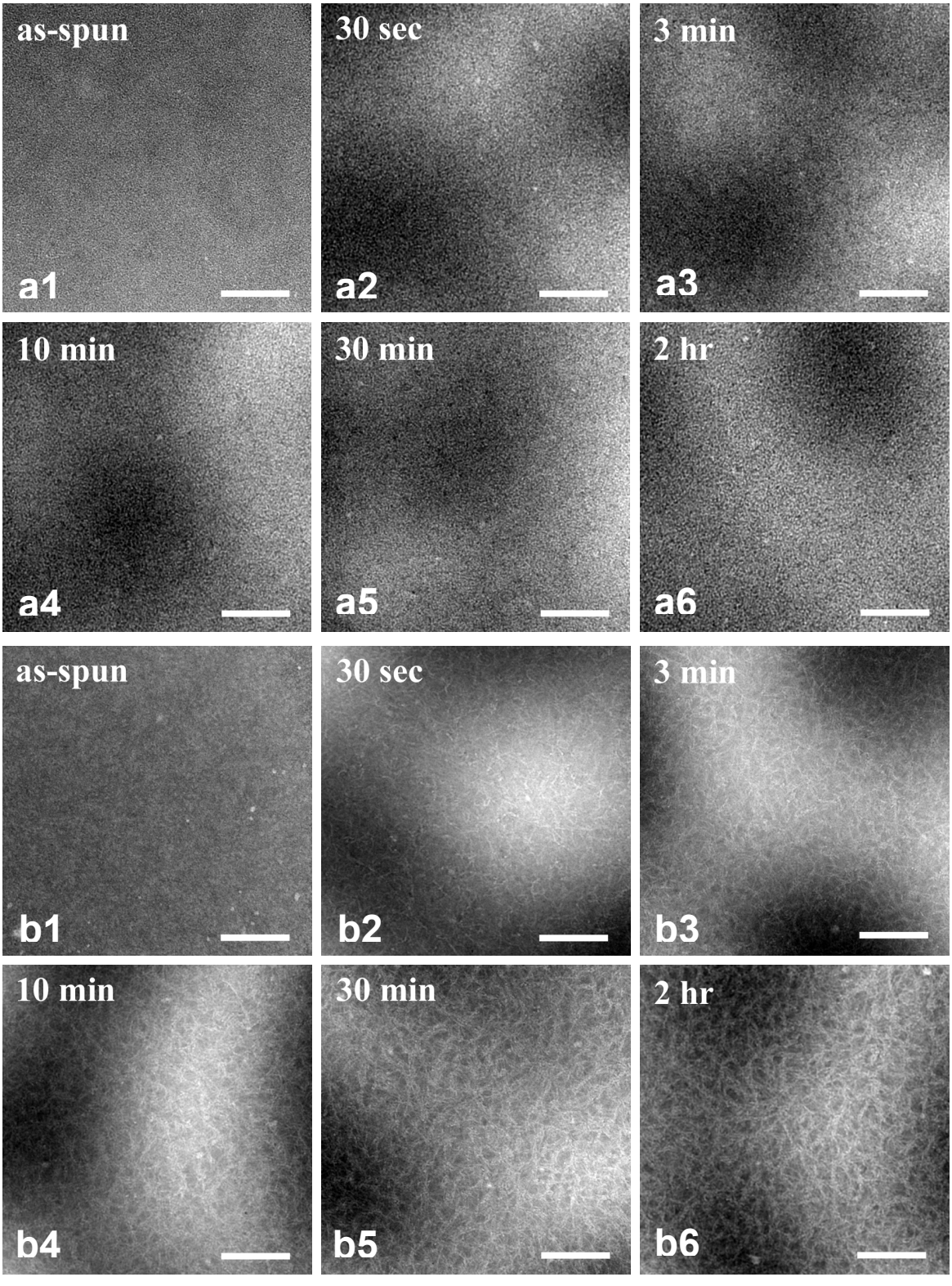

as-spun
a1
30 sec
a2
3 min
a3
10 min
a4
30 min
a5
2 hr
a6
as-spun
b1
30 sec
b2
3 min
b3
10 min
b4
30 min
b5
2 hr
b6

Figure S9. BF-TEM images for thin films of P3HT-32k:PC_{61}BM (1/1) (a1-a6) or P3HT-32k:PCPDTBT:PC_{61}BM (3/1/4) (b1-b6) post-annealed for a different time. The scale bar is 500 nm.

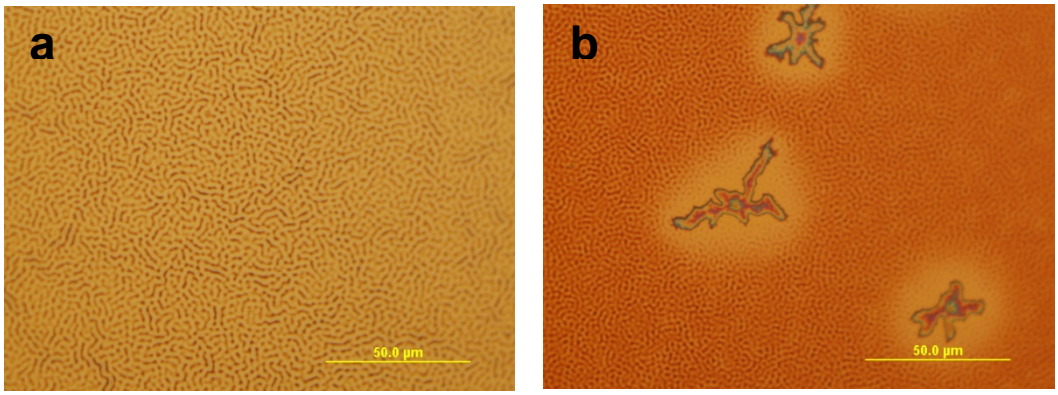


Figure S10. OM images for thin film of P3HT-32k:PCPDTBT:PC_{61}BM (3/1/4) (a) and P3HT-32k:PC_{61}BM (1/1) (b) spin-coated by CB and post-annealed for 2 hours. The worm-like structures on the surface are the wrinkles existing in the post-annealed samples.

Table S1. Device performance as a function of annealing time for thin films of P3HT-32k : $PC_{61}BM$ (1/1), P3HT-32k:PCPDTBT:$PC_{61}BM$ (3/1/4) and PCPDTBT:$PC_{61}BM$ (1/1) spin-coated by CB and post-annealed.

		V_{oc} (V)	J_{sc} (mA/cm^2)	Fill Factor (%)	Efficiency (%)
P3HT-32k: $PC_{61}BM$ (1:1)	as-spun	0.64±0.01	0.71±0.07	30±1	0.14±0.01
	post-30 s	0.58±0.001	6.25±0.08	55±2	1.99±0.04
	post-3 min	0.58±0.002	6.02±0.27	63±1	2.18±0.11
	post-10 min	0.58±0.005	6.47±0.11	63±2	2.35±0.05
	post-30 min	0.58±0.005	6.80±0.05	63±1	2.50±0.04
	post-2 h	0.58±0.002	6.48±0.11	62±1	2.30±0.02
P3HT-32k: PCPDTBT: $PC_{61}BM$ (3:1:4)	as-spun	0.54±0.01	1.54±0.10	35±1	0.29±0.02
	post-30 s	0.63±0.001	5.29±0.16	51±1	1.72±0.06
	post-3 min	0.61±0.001	7.06±0.27	48±1	2.06±0.10
	post-10 min	0.60±0.01	7.35±0.38	49±1	2.16±0.13
	post-30 min	0.60±0.004	7.48±0.31	47±1	2.13±0.06
	post-2 h	0.60±0.001	7.86±0.31	50±1	2.38±0.09
PCPDTBT: $PC_{61}BM$ (1:1)	as-spun	0.49±0.01	5.03±0.09	38±1	0.92±0.03
	post-30 s	0.58±0.02	5.11±0.14	35±1	1.04±0.04
	post-3 min	0.66±0.001	5.16±0.19	36±1	1.24±0.07
	post-10 min	0.66±0.005	5.37±0.18	36±1	1.28±0.05
	post-30 min	0.65±0.005	5.28±0.28	36±1	1.23±0.09
	post-2 h	0.64±0.005	5.35±0.19	36±1	1.24±0.05

Table S2. Device performance for the ternary blend solar cells using P3HT-28k or P3HT-19k and their binary references spin-coated by CB and post-annealed for 10 minutes.

batch of P3HT	blending ratio of P3HT:PCPDTBT:$PC_{61}BM$	V_{oc} (V)	J_{sc} (mA/cm^2)	Fill Factor (%)	Efficiency (%)
P3HT-28k	1:0:1	0.55±0.004	6.84±0.16	64±2	2.39±0.02
	3:1:4	0.59±0.007	9.51±0.22	54±1	3.04±0.02
P3HT-19k	1:0:1	0.61±0.005	6.73±0.28	57±2	2.34±0.05
	3:1:4	0.65±0.008	2.95±0.42	45±2	0.86±0.16

Table S3. Device performance for the ternary blend solar cells using P3HT-32k with different blending ratios and binary references spin-coated by CB and post-annealed for 10 minutes.

	V_{oc} (V)	J_{sc} (mA/cm^2)	Fill Factor (%)	Efficiency (%)
PCPDTBT:$PC_{61}BM$ (1:1)	0.66±0.005	5.37±0.18	36±1	1.28±0.05
P3HT-32k: PCPDTBT:$PC_{61}BM$ (1:3:4)	0.64±0.005	4.68±0.20	37±1	1.10±0.05
P3HT-32k: PCPDTBT:$PC_{61}BM$ (2:2:4)	0.64±0.01	4.36±0.19	37±1	1.04±0.06
P3HT-32k: PCPDTBT:$PC_{61}BM$ (3:1:4)	0.60±0.01	7.35±0.38	49±1	2.16±0.13
P3HT-32k:$PC_{61}BM$ (1:1)	0.58±0.005	6.47±0.11	63±2	2.35±0.05