Supporting information

Low-Cost Silicon Phthalocyanine as a Non-Fullerene Acceptor for Flexible large area Organic Photovoltaics

*Chithiravel Sundaresan,[1,2] Mário C. Vebber[1], Jaclyn L. Brusso[3], Ye Tao[2], Salima Alem[2] *, and Benoît H. Lessard[1,4*]*

[1]Department of Chemical & Biological Engineering, University of Ottawa, 161 Louis Pasteur, Ottawa, ON, Canada, K1N 6N5

[2]Advanced Electronics and Photonics Research Centre, National Research Council of Canada, Ottawa, ON, K1A 0R6, Canada

[3]Department of Chemistry and Biomolecular Science, University of Ottawa, 150 Louis-Pasteur Pvt, Ottawa, ON, Canada, K1N 6N5

[4]School of Electrical Engineering and Computer Science, University of Ottawa, 800 King Edward Ave. Ottawa, ON, Canada, K1N 6N5

*Corresponding authors: benoit.lessard@uottawa.ca (B.H.L) and salima.alem@nrc-cnrc.gc.ca (S.A.)

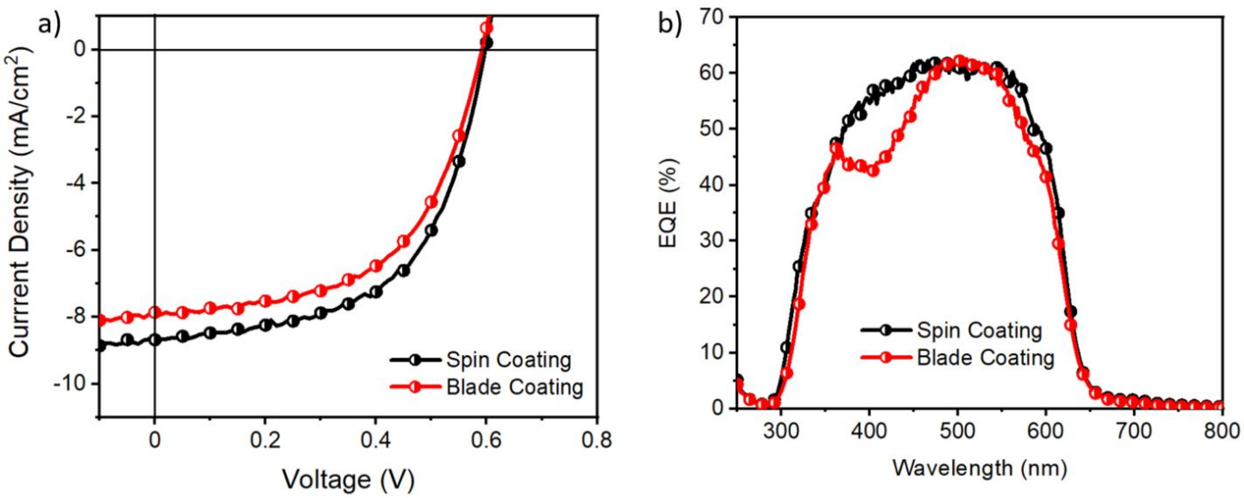

Figure S1. (a) *J-V* curves of P3HT: $PC_{61}BM$ BHJ photovoltaics fabricated on glass/ITO and PET/ITO flexible substrates by spin and blade coating respectively, (b) corresponding EQE curves.

Table S1: Photovoltaic performance parameters of baseline P3HT: $PC_{61}BM$ OPVs fabricated using o-DCB by spin and blade coating methods.

Device Structure	**Process**	**J_{SC} (mA/cm^2) [(a)]**	**V_{OC} (V)**	**FF**	**PCE (%)**
Inverted	Spin Coating	8.60 (±0.20)	0.59 (±0.01)	0.55 (±0.01)	2.8 (±0.17)
	Blade Coating	7.3 (±0.16)	0.59 (±0.01)	0.52 (±0.02)	2.2 (±0.24)

All values are average with five devices, and the values in parentheses are the standard deviation. [a] Current density (J_{SC}) calculated from the EQE curve

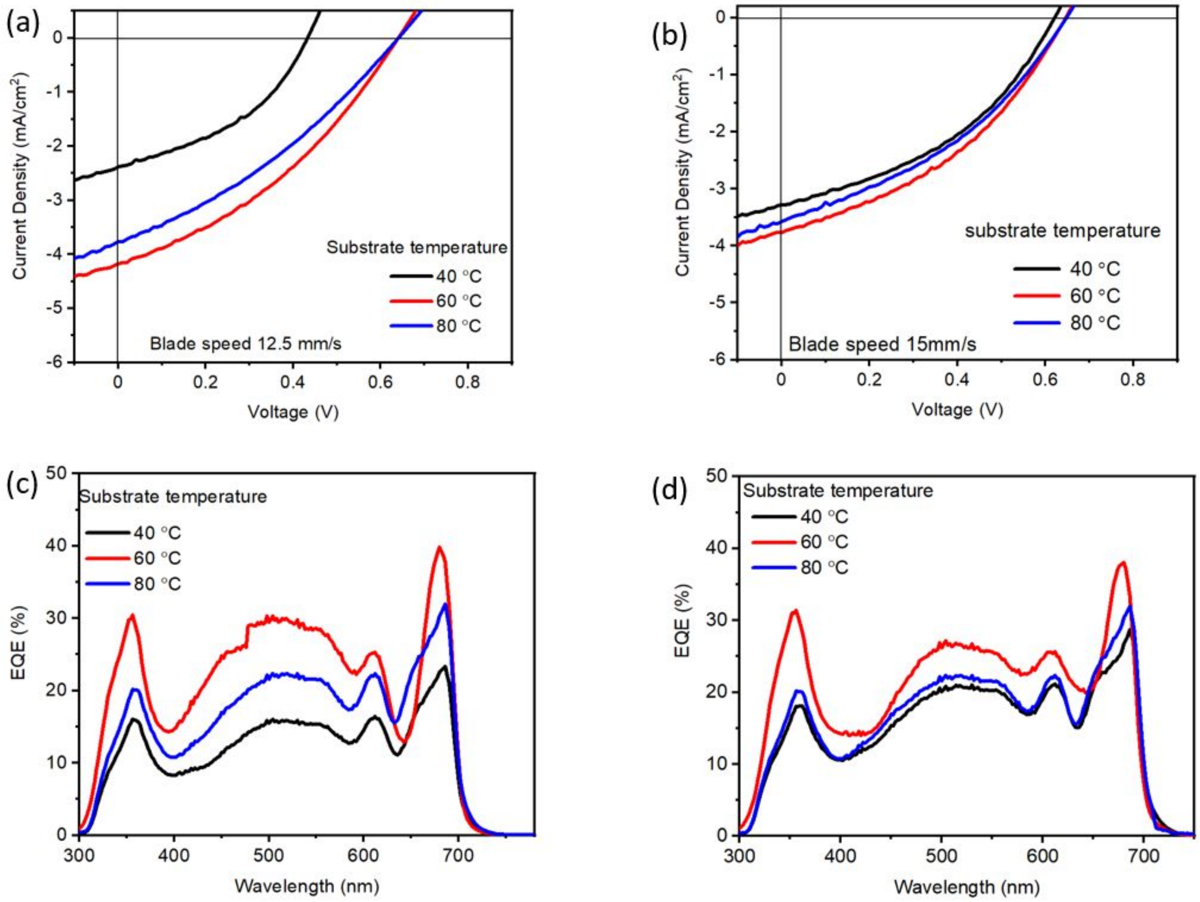

Figure S2. J-V and corresponding EQE curves of P3HT: $(3BS)_2$-SiPc BHJ OPVs fabricated using o-Xylene and thickness optimization under different substrate temperatures and blade speeds. (a, c) P3HT: $(3BS)_2$-SiPc (1:1) weight ratio and (b,d) P3HT: $(3BS)_2$-SiPc (1:0.6) weight ratio.

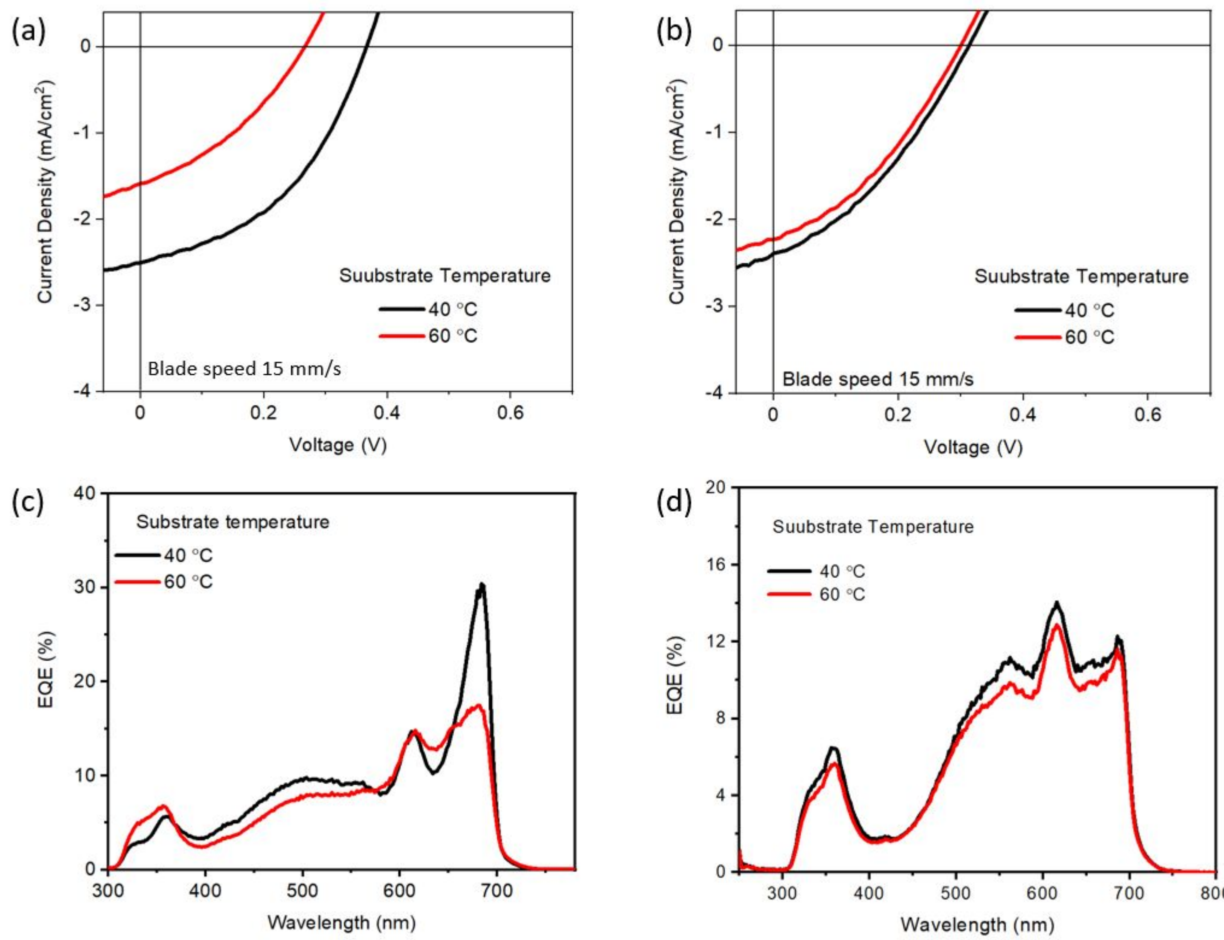

Figure S3. J-V and corresponding EQE curves of P3HT: $(3BS)_2$-SiPc BHJ OPVs fabricated using o-Xylene and thickness optimisation under different substrate temperatures. (a, c) P3HT: $(3BS)_2$-SiPc (1:0.4) weight ratio and (b,d) P3HT: $(3BS)_2$-SiPc (0.6:1) weight ratio.

Table S2. Photovoltaic performance parameters of P3HT:$(3BS)_2$-SiPc BHJ OPVs processed in o-Xylene. Active layers optimization with donor-acceptor ratios, substrate temperature, and active layer thickness

S.No	D:A blend ratio	Substrate temperature (°C)	Blade Speed (mm/s)	Thickness ~(nm)	J_{SC} $(mA/cm^2)^a$	V_{OC} (V)	FF	PCE (%)
1	1:1	40	12.5	190 (±4)	2.60 (±0.2)	0.44 (±0.01)	0.39 (±0.05)	0.45 (±0.1)
2	1:1	60	12.5	120 (±5)	4.20 (±0.2)	0.61 (±0.01)	0.38 (±0.05)	0.92 (±0.1)
3	1:1	80	12.5	110 (±3)	3.82 (±0.2)	0.60 (±0.01)	0.36 (±0.05)	0.79 (±0.1)
4	1:0.6	40	15	180 (±6)	3.32 (±0.2)	0.60 (±0.01)	0.39 (±0.03)	0.77 (±0.2)
5	1:0.6	60	15	120 (±5)	4.11 (±0.2)	0.63 (±0.01)	0.44 (±0.05)	1.13 (±0.1)
6	1:0.6	60	25	182 (±4)	1.48 (±0.3)	0.45 (±0.01)	0.31 (±0.02)	0.21 (±0.1)
7	1:0.6	80	15	90 (±8)	3.70 (±0.2)	0.64 (±0.01)	0.43 (±0.03)	1.02 (±0.1)
8	1:0.4	40	15	155 (±5)	2.68 (±0.4)	0.36 (±0.02)	0.42 (±0.07)	0.39 (±0.1)
9	1:0.4	60	15	110 (±5)	1.88 (±0.4)	0.25 (±0.02)	0.34 (±0.07)	0.28 (±0.1)
10	0.6:1	40	15	110 (±5)	2.69 (±0.3)	0.26 (±0.02)	0.34 (±0.04)	0.23 (±0.1)
11	0.6:1	60	15	104 (±5)	2.32 (±0.3)	0.25 (±0.02)	0.32 (±0.04)	0.18 (±0.1)

[a] current density (J_{SC}) calculated from the EQE curve

At least five devices were taken into consideration for average value calculations

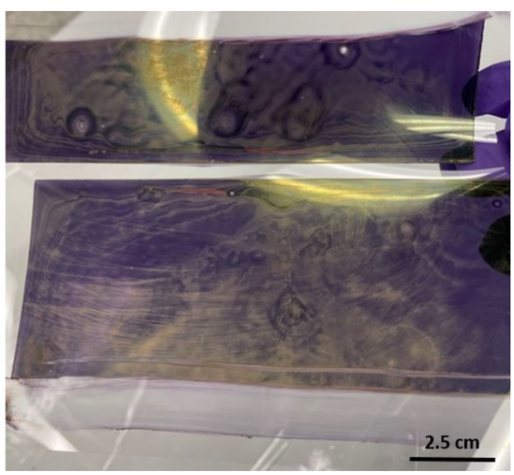

Figure S4: BHJ film of P3HT: $(3BS)_2$-SiPc (o-Xylene, 1:0.6 ratio) blade coated on PET sheets at a blade speed of 25mm/s.

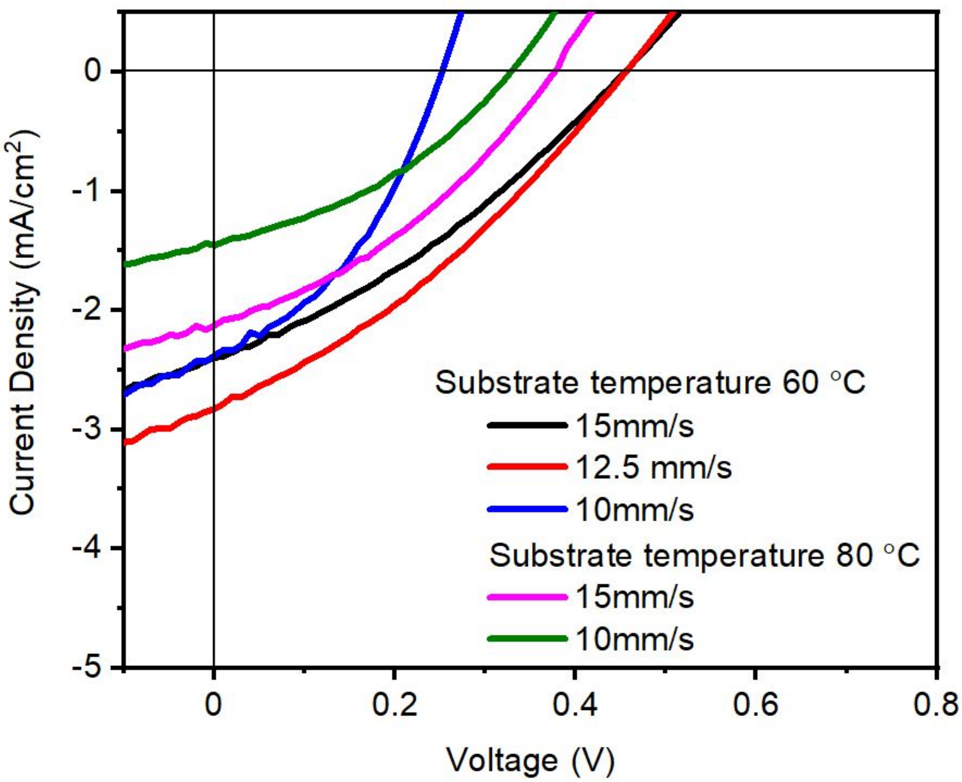

Figure S5. J-V curves of P3HT :$(3BS)_2$-SiPc (1:1) BHJ OPVs fabricated using o-Xylene with different thicknesses of active layer annealed at 110 °C for 30 min.

Table S3. Photovoltaic performance parameters of P3HT :$(3BS)_2$-SiPc (1:1) BHJ devices processed in o-Xylene and the devices were annealed at 110 °C for 30 min.

S.No	**Blade speed (mm/s)**	**Substrate temperature (°C)**	**Thickness ~(nm)**	**J_{SC} (mA/cm²)[a]**	**V_{OC} (V)**	**FF**	**PCE (%)**
1	15	60	180 (±5)	2.41 (±0.3)	0.42 (±0.02)	0.34 (±0.04)	0.34 (±0.2)
2	12.5	60	120 (±5)	2.81 (±0.2)	0.42 (±0.01)	0.32 (±0.03)	0.37 (±0.2)
3	10	60	110 (±4)	2.40 (±0.2)	0.23 (±0.03)	0.39 (±0.05)	0.21 (±0.3)
4	15	80	155 (±5)	2.23 (±0.3)	0.35 (±0.02)	0.34 (±0.03)	0.27(±0.2)
5	12.5	80	110 (±5)	1.60 (±0.2)	0.30 (±0.01)	0.36 (±0.02)	0.17 (±0.2)

[a] current density (J_{SC}) calculated from the EQE curve

At least four devices were taken into consideration for average value calculations

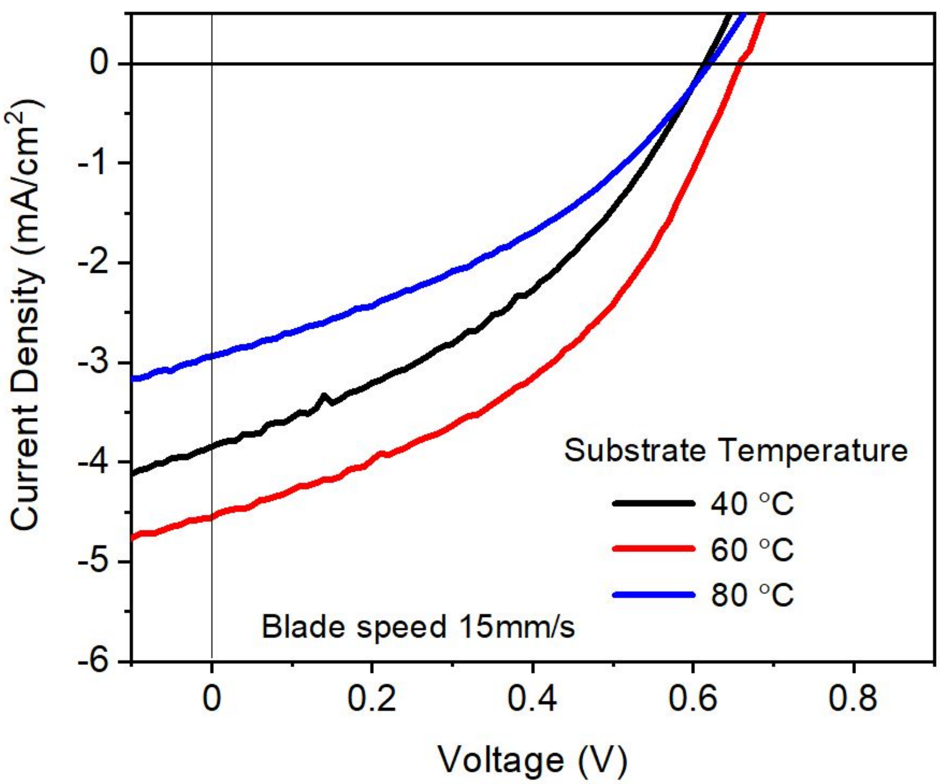

Figure S6. J-V curves of P3HT :$(3BS)_2$-SiPc (1:0.6) BHJ OPVs fabricated using TMB solvent with optimized active layer thickness processed under different substrate temperature

Table S4. Photovoltaic performance parameters of P3HT :$(3BS)_2$-SiPc (1:0.6) BHJ devices processed in TMB solvent and the active layer coated with blade speed at 15mm/s.

S.No	Substrate temperature (°C)	Thickness ~(nm)	J_{SC} (mA/cm^2)[a]	V_{OC} (V)	FF	PCE (%)
1	40	170 (±5)	-3.8 (±0.3)	0.61 (±0.02)	0.37 (±0.04)	0.80 (±0.2)
2	60	130 (±5)	-4.6 (±0.3)	0.65 (±0.01)	0.44 (±0.03)	1.31 (±0.1)
3	80	110 (±5)	3.1 (±0.2)	0.62 (±0.03)	0.40 (±0.05)	0.71 (±0.3)

[a] current density (J_{SC}) calculated from the EQE curve

At least four devices were taken into consideration for average value calculations

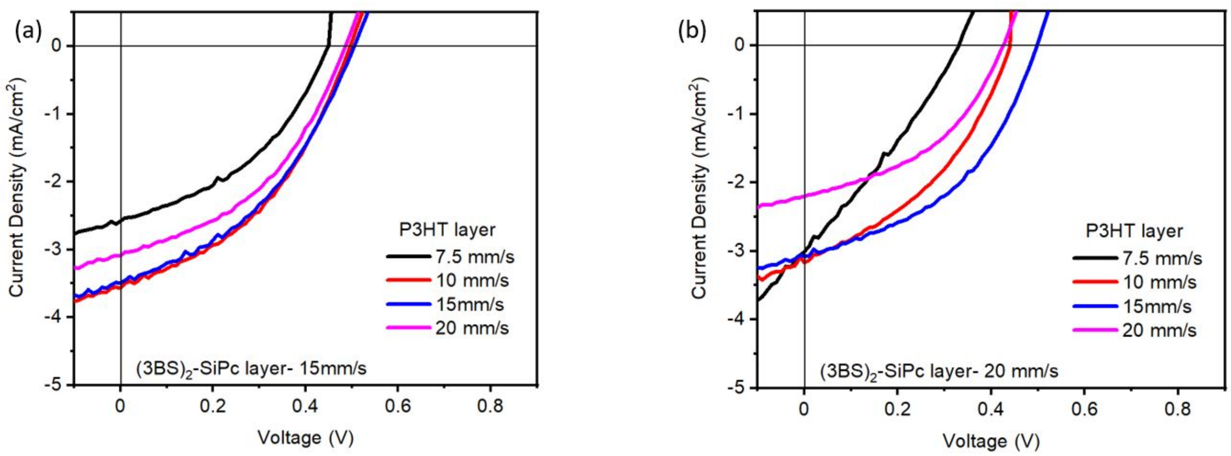

Figure S7: J-V curves of $(3BS)_2$-SiPc / P3HT (1:0.6) sequential bilayer (Sq) OPVs fabricated using O-xylene/TMB solvent with optimized active layer thickness processed under different blade speed

Table S5. Photovoltaic performance parameters of $(3BS)_2$-SiPc/P3HT (Sq) layer by layer processed with o-Xylene solvent and different blade coating speeds.

S.No	Blade speed (mm/s)		Thickness ~(nm)	J_{SC} (mA/cm^2)[a]	V_{OC} (V)	FF	PCE (%)
	$(3BS)_2$-SiPc	P3HT					
1	15	7.5	120 (±6)	2.57 (±0.2)	0.40 (±0.01)	0.41 (±0.05)	0.42 (±0.1)
2	15	10	130 (±6)	3.71 (±0.2)	0.49 (±0.01)	0.41 (±0.05)	0.73 (±0.1)
3	15	15	140 (±4)	3.62 (±0.1)	0.51 (±0.01)	0.44 (±0.04)	0.80 (±0.05)
4	15	20	140 (±5)	3.20 (±0.2)	0.48 (±0.01)	0.40 (±0.03)	0.62 (±0.1)
5	20	7.5	125 (±5)	3.24 (±0.4)	0.33 (±0.02)	0.28 (±0.05)	0.28 (±0.1)
6	20	10	140 (±6)	3.30 (±0.4)	0.45 (±0.02)	0.40 (±0.05)	0.55 (±0.1)
7	20	15	150 (±6)	3.20 (±0.3)	0.51 (±0.02)	0.43 (±0.04)	0.66 (±0.1)
8	20	20	160 (±8)	2.20 (±0.3)	0.42 (±0.02)	0.43 (±0.04)	0.40 (±0.1)

[a] Current density (J_{SC}) calculated from the EQE curve,

At least five devices were taken into consideration for average value calculations

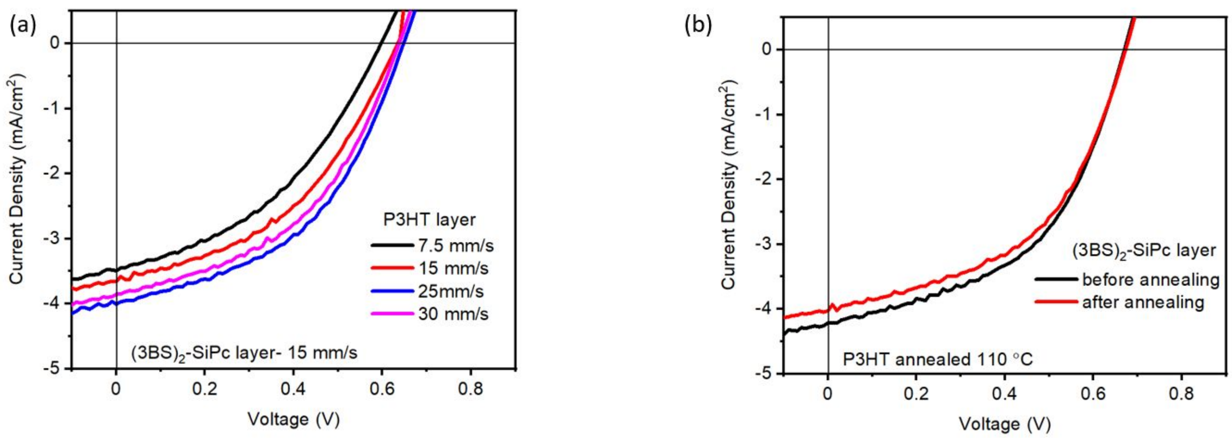

Figure S8: J-V curves of P3HT/ 3BS)$_2$-SiPc Alternate sequential bilayer (Alt-Sq) OPVs fabricated using O-xylene/TMB solvent with optimized active layer thickness processed under different blade speed and annealing conditions.

Table S6. Photovoltaic performance parameters of P3HT / 3(BS)2-SiPc (Alt-Sq) layer by layer processed with o-Xylene solvent and different blade coating speeds.

S.No	**Blade speed (mm/s)**		**Thickness ~(nm)**	**J_{SC} (mA/cm^2)^a**	**V_{OC} (V)**	**FF**	**PCE (%)**
	P3HT	(3BS)2-SiPc					
1	7.5	15	80 (±6)	3.42 (±0.2)	0.49 (±0.01)	0.38 (±0.03)	0.63 (±0.1)
2	12.5	15	110 (±6)	3.66 (±0.2)	0.58 (±0.01)	0.42 (±0.02)	0.90 (±0.1)
3	15^b	15	120 (±5)	4.35 (±0.1)	0.67 (±0.01)	0.50 (±0.02)	1.42 (±0.1)
4	15^b	15^c	120 (±4)	4.01 (±0.2)	0.67 (±0.01)	0.43 (±0.03)	1.30 (±0.1)
5	25	15	140 (±5)	4.25 (±0.1)	0.65 (±0.02)	0.43 (±0.02)	1.17 (±0.1)
6	25	15^b	140 (±4)	3.83 (±0.2)	0.63 (±0.02)	0.45 (±0.03)	1.06 (±0.1)
7	30	15	160 (+4)	3.82 (±0.2)	0.63 (±0.02)	0.43 (±0.02)	1.06 (±0.1)
8	30	15^b	160 (+4)	3.54 (±0.2)	0.65 (±0.02)	0.47 (±0.03)	1.20 (±0.1)
9	30	30	180 (±6)	2.42 (±0.1)	0.35 (±0.02)	0.32 (±0.03)	0.23 (±0.1)
10	30	30^b	180 (±6)	2.20 (±0.1)	0.31 (±0.02)	0.38 (±0.02)	0.30 (±0.1)

^{a} Current density (J_{SC}) calculated from the EQE curve, ^{b} P3HT layer annealed at 100 ºC, ^{c} the active layer was annealed at 110 ºC after (BS)$_2$-SiPc deposition in o-Xylene. At least 6 devices were taken into consideration for average value calculations

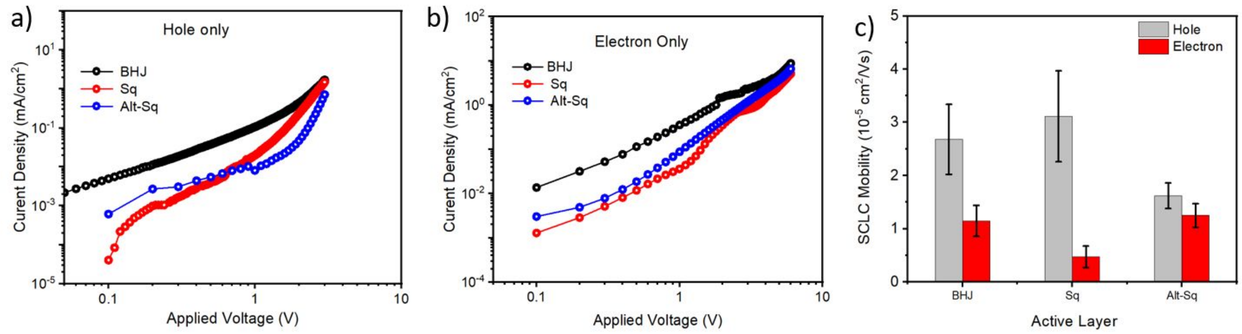

Figure S9**.** Log-log plot of J-V characteristics of (a) Hole-only devices with a structure of ITO/PEDOT:PSS/active layer/MoO_x/Ag. (b) Electron-only devices with a structure of ITO/ZnO/active layer/Al with BHJ, Sq and Alt-Sq blade coated active layers (c) Bar chart representation of charge carrier mobility values, standard deviation calculated for four device measurements.