Supporting information

Efficient Organic Solar Cells with a Printed p-i-n Stack Enabled by Azeotrope-processed Self-assembled Monolayer

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1. Materials

All the reagents were used as received without any further purification. PM6 and BTP-eC9 were purchased from Solarmer. Isopropanol (IPA), toluene, and chlorobenzene (CB) were purchased from Sigma-Aldrich. PNDIT-F3N was purchased from eFlexPV Limited.

2. Synthesis of SAM



9-(4-bromobutyl)-3,6-diphenyl-9*H***-carbazole:** 3,6-diphenyl-9*H*-carbazole (1.5 g, 4.7 mmol) was dissolved in 1,4- dibromobutane (20 eq, 20.28 g, 11.2 mL, 94 mmol), tetrabuthylammonium bromide (0.15 eq, 227 mg, 0.7 mmol) and 50% KOH aqueous solution (5 eq) were added subsequently. The reaction was stirred at 60°C overnight. After completion of the reaction, extraction was done with dichloromethane. The organic layer was dried over anhydrous Na₂SO₄ and the solvent was distilled off under reduced pressure. The crude product was purified by column chromatography (Hex:DCM 4:1, v:v) to give 2.08 g (97.6 %) of a colorless oil. ¹H NMR (300 MHz, Chloroform-*d*) δ 8.37 (d, *J* = 1.7 Hz, 2H), 7.74 (ddd, *J* = 8.1, 2.9, 1.5 Hz, 6H), 7.49 (t, *J* = 7.7 Hz, 6H), 7.39 – 7.31 (m, 2H), 4.41 (t, *J* = 6.8 Hz, 2H), 3.42 (t, *J* = 6.4 Hz, 2H), 2.12 (dt, *J* = 11.0, 6.5 Hz, 2H), 2.03 – 1.87 (m, 2H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 142.0, 140.3, 132.7, 128.8, 127.3, 126.5, 125.5, 123.6, 119.1, 109.0, 42.5, 33.2, 30.2, 27.8.



Diethyl (4-(3,6-diphenyl-9*H***-carbazol-9-yl)butyl)phosphonate:** 9-(4-bromobutyl)-3,6diphenyl-9*H*-carbazole (2 g, 4.4 mmol) was dissolved in triethyl phosphite (20 eq, 14.6 g, 15 mL, 88 mmol) and the reaction mixture was heated at 145 °C overnight. After reaction completion, the solvent was distilled off under reduced pressure. The crude product was purified by column chromatography (DCM:EA 2:1, v:v) to give 2.1 g (93 %) of colorless oil. ¹H NMR (400 MHz, Chloroform-*d*) δ 8.37 (d, *J* = 1.8 Hz, 2H), 7.74 (dt, *J* = 8.1, 1.3 Hz, 6H), 7.53 – 7.45 (m, 6H), 7.39 – 7.33 (m, 2H), 4.37 (t, *J* = 7.0 Hz, 2H), 4.09 – 3.99 (m, 4H), 2.08 – 2.00 (m, 2H), 1.81 – 1.65 (m, 4H), 1.26 (t, *J* = 7.1 Hz, 6H). ¹³C NMR (100 MHz, Chloroform-*d*) δ 142.0, 140.3, 132.6, 128.8, 127.3, 126.5, 125.5, 123.6, 119.0, 109.0, 61.6, 61.6, 42.8, 29.9, 29.8, 26.2, 24.8, 20.5, 20.5, 16.5, 16.4.



(4-(3,6-diphenyl-9*H*-carbazol-9-yl)butyl)phosphonic acid (JJ36): Diethyl (4-(3,6-diphenyl-9*H*-carbazol-9-yl)butyl)phosphonate (1 g, 1.95 mmol) was dissolved in anhydrous 1,4-dioxane (30 mL) under argon atmosphere and bromotrimethylsilane (10 eq, 3.0 g, 2.6 mL, 19.55 mmol) was added dropwise. The reaction was stirred for 12 h at room temperature under an argon atmosphere. Afterwards solvent was partially distilled off under reduced pressure, and the liquid residue was dissolved in methanol (10 ml). Next, distilled water was added dropwise (30 ml), until the solution became opaque. Product was filtered off and washed with water to give 0.75 g (84 %) of a white solid. ¹H NMR (400 MHz, DMSO-*d*₆) δ 8.64 (d, *J* = 1.8 Hz, 2H), 7.80 (t, *J* = 9.5 Hz, 6H), 7.70 (d, *J* = 8.5 Hz, 2H), 7.49 (t, *J* = 7.6 Hz, 4H), 7.34 (t, *J* = 7.4 Hz, 2H), 4.44 (m, overlapped 14H), 1.89 (t, *J* = 7.3 Hz, 2H), 1.58 (h, *J* = 8.1, 7.4 Hz, 4H). ¹³C NMR (100 MHz, DMSO-*d*₆) δ 141.52, 140.51, 131.67, 129.36, 127.13, 126.95, 125.33, 123.43,

3. Device Fabrication

The ITO substrates were cleaned by ultrasonication sequentially with dilute detergent solution, deionized water, acetone, and isopropanol for 20 min each step before being dried in an oven setting @ 80 °C. The substrates were treated with UV-ozone for 20 min before use. PEDOT: PSS was spin-coated on the ITO substrates (15 mm × 15mm for 0.04-cm² devices and 25 mm × 25mm for 1-cm² devices) and annealed at 150 °C for 10 min in air. The SAM solutions were prepared by dissolving SAM powder in IPA, toluene, or azeotrope of IPA and toluene (with a weight ratio of 0.58:0.42) at 1 mg/ml concentration and stirred for 2 hours before use. All layers printed by slot-die coating platform were performed in ambient conditions with a controlled relative humidity (around 15%). The printing velocity, gap between coating head and substrate, flow rate, and substrate temperature for SAM were adjusted to 25 mm/s, 100 µm, 5 µL/min, and 80 °C. After annealing at 100 °C for 10 min, the substrate was transferred into the glove box for temporary storage. PM6: BTP-eC9 (1:1.2) or PM6:BTP-eC9:L8BO-2F(1:0.96:0.24) blend was dissolved in chlorobenzene with a concentration of 10 mg/ml for slot-die coating and 22 mg/ml for spin coating (without any additive). The solution was stirred at 50 °C for at least 1h. The printing velocity, printing gap, flow rate, and substrate temperature for slot-die coated active layer were adjusted to 50 mm/s, 150 µm, 10 µL/min, and 70 °C. For the spincoated active layer, the rotation speed is 2500 rpm. After coating, the active layer was annealed at 100 °C for 5 min. PNDIT-F3N was dissolved in methanol (with 0.5 vt% acetic acid) with 0.5 mg/ml concentration for spin coating and 3 mg/ml for slot-die coating. The printing velocity, printing gap, flow rate, and substrate temperature for slot-die coated PNDIT-F3N were adjusted to 5 mm/s, 100 µm, 5 µL/min, and room temperature. For devices adopting D18/BTP-eC9 as the active layer, D18 film was spin-coated on the SAM or PEDOT:PSS layer from the chlorobenzene with a rotation velocity of 2600 rpm, then BTP-ec9 dissolved in

chloroform was spin-coated on the D18 layer with a rotation velocity of 2000 rpm. The concentrations of D18 and BTP-eC9 in solvents are 6 mg/ml and 10 mg/ml, respectively. The heating temperature of D18 solution and BTP-eC9 solution are 80 °C and 45 °C, respectively. For spin-coated PNDIT-F3N, the rotation speed is 2000 rpm. Then, samples were transferred to the evaporation chamber for the deposition of Ag (100 nm). The OSCs have an identical active area of 0.04 cm² defined by the overlap area of the anode and the cathode. For *J-V* performance measurement, a test mask with an accurate area of 0.0324 cm² was used. For 1- cm² devices, the width of the coating head of the slot-die coating platform was adjusted to 30 mm, while 12 mm for 0.04-cm² devices. A mask design with a width of 9 mm (this value is larger than the width of a sub-cell in common OPV or perovskite modules, which is usually at 5-7 mm due to the balancing between geometry fill factor and charge carrier transport) and a length of 11.2 mm was employed for 1-cm² devices to explore the feasibility of further scaling-up process.

4. Instruments and Characterizations

Dynamic light scattering (DLS) experiments were conducted by a dynamic light scattering particle size Analyzer (Malven Zeta sizer Nano ZS) at 25 °C with a monochromatic coherent He–Ne laser (640 nm) as the light source. An avalanche photodiode detector that detected the scattered light at an angle of 173°. DLS measurements were carried out in SAM solutions in IPA, toluene, or other mixed solvents to determine the size of the particles. Contact angle was measured with a DataPhysics contact angle tester and the water drop volume was set as 3 μ L. The cyclic voltammetry experiments were performed at room temperature in a nitrogen atmosphere with a three-electrode system using a bare ITO or SAM-modified ITO as the working electrode, Pt wire as the counter electrode, and an Ag/AgCl (saturated KCl) as the reference electrode. Tetrabutylammonium phosphorus hexafluoride (Bu₄NPF₆, 0.1M) in *o*-DCB solution was used as the supporting electrolyte, and a series of scan rates was applied.

For calibration, the redox potential of ferrocene/ferrocenium (Fc/Fc+) was measured under the same condition. The detailed calculation for the surface density of SAM molecules on ITO can be found in literature.¹

AFM and KPFM images were probed by a Dimension Icon AFM (Bruker) with the tapping mode at ambient conditions. UV-vis absorption spectra were characterized by a Hitachi UH4150 UV-VIS-NIR Spectrophotometer.

The devices used for maximum power point (MPP) tracking were constructed using the same methods outlined in the "Device Fabrication" section. This involved using printed azeotrope-SAM and spin-coated PEDOT:PSS as the hole-selective layers (HSL), respectively, and printed PM6:BTP-eC9 for the active layer, with silver electrodes evaporated using the same mask. For the stability assessments, these devices were placed in an MPP tracking box situated within a nitrogen glove box, and they were tested without encapsulation. The LED light source was calibrated to provide one sun illumination during the MPP tracking, and the ambient temperature within the testing box was maintained at approximately 45-50 °C, according to the temperature sensor readings.

The thermal cycling test was conducted in a nitrogen glove box with temperature variations ranging from 30 °C to 85 °C. Device structure for the thermal cycling test is glass/ITO/SAM or PEDOT:PSS/PM6:BTP-eC9/PNDIT-F3N/Ag. The heating of the substrate and subsequent cooling at ambient temperatures facilitated this process.

For the mechanical bending tests on flexible devices (PET/ITO/SAM or PEDOT:PSS/PM6:BTP-eC9/PNDIT-F3N/Ag), these were performed under a constant bending radius of 6 mm, verified using an optical rod of the same diameter.

The UPS and XPS characterizations were performed by a VG ESCALAB 220i-XL surface analysis system equipped with a He discharge lamp (hv = 21.22 eV) and a monochromatic Al–K α X-ray gun (hv = 1486.6 eV). The SAM solutions were deposited on ITO in the same process

as device fabrication. Typically, the characterized peak of hydrocarbon C1s from adventitious carbon at 284.8 eV was used for binding energy calibration.

The J-V characteristics of the OSC devices were measured under a solar simulator (Enlitech, SS-F5, Taiwan) using a Keithley 2400 source meter in a nitrogen glove box at room temperature. The light intensity is calibrated using KG2 NREL-calibrated silicon solar cells, giving a value of 100 mW cm⁻². EQE spectra are measured by EnLi Technology (Taiwan) EQE measurement system equipped with a standard silicon diode, where the monochromatic light was generated from a Newport 300 W lamp.

5. Supporting Figures and Tables



Figure S1 Calculated size of Cbz-2Ph molecule in vacuum. (X-direction: 1.732 nm, Y-direction: 1.671 nm, Z-direction: 0.661 nm)



Figure S2 a) Turbid suspension of Cbz-2Ph in toluene. b) Clear solution in IPA: toluene azeotrope.



Figure S3 Scattering under a laser beam of Cbz-2Ph SAM in toluene (a) and IPA: toluene azeotrope (b).



Figure S4 Cbz-2Ph in IPA: toluene azeotrope (left) and IPA (right) after 45 days of storage. (Apparent crystallization could be observed as the red rectangle shows.)



Figure S5 Optical image of slot-die coating platform. (The effective width of the coating head is 10 mm)



Figure S6 Transmission spectra of ITO/IPA-SAM and ITO/azeotrope-SAM, and the reference line is bare ITO.



Figure S7 Schematic illustration of observation in reflection mode to expose the pinholes in PM6: BTP-eC9 layer.



Figure S8 a) and b) Optical images (187 μ m × 140 μ m) of azeotrope-SAM/PM6:BTP-eC9/Ag and IPA-SAM/PM6:BTP-eC9/Ag structure, respectively. c) and d) Binarization images (187 μ m × 140 μ m) of azeotrope-SAM/PM6:BTP-eC9/Ag and IPA-SAM/PM6:BTP-eC9/Ag structure, respectively. e) Statistical counts of defects from 9 binarization images (187 μ m × 140 μ m) of IPA-SAM group and azeotrope-SAM groups, respectively.



Figure S9 AFM height image of bare ITO (Root mean square (RMS) roughness = 2.69 nm).



Figure S10 KPFM potential image (a) and potential distribution (b) of bare ITO.



Figure S11 UPS spectra (using He I lamp with a photon energy of 21.22 eV) of ITO/azeotrope-SAM (a) and ITO/IPA-SAM (b).



Figure S12 Cyclic voltammograms of a) Bare ITO, b) ITO/azeotrope-SAM, c) ITO/IPA-SAM in o-DCB solution under different scan rates. (d, e) Corresponding peak current vs. scan rate chart of ITO/azeotrope-SAM and ITO/IPA-SAM, respectively.



Figure S13 XPS spectra of ITO/azeotrope-SAM (a) and ITO/IPA-SAM (b).



Figure S14 Parameter distribution of 20 devices in one batch a) open-circuit voltage (V_{OC}), b) short-circuit current density (J_{SC}), c) fill factor (FF).



Figure S15 Absorption of PM6: BTP-ec9 layer with a thickness of about 100 nm on IPA-SAM and azeotrope-SAM, respectively.



Figure S16 a) Transient photocurrent and b) photovoltage of OSCs with IPA-SAM and azeotrope-SAM, respectively.



Figure S17 *J-V* curves of the organic solar cells adopting D18:BTP-eC9 as the active layer on IPA-SAM and azeotrope-SAM, respectively.



Figure S18 AFM height images of BHJ (PM6:BTP-eC9) on ITO/azeotrope-SAM by spin coating (a) and slot-die coating (c). AFM height images of ESL (PNDIT-F3N) on ITO/azeotrope-SAM/BHJ by spin coating (b) and slot-die coating (d).



Figure S19 *J-V* curves of 1.0-cm² device (with a structure of ITO/azeotrope-SAM/PM6:BTP-eC9(slot-die coated)/PNDIT-F3N(slot-die coated)/Ag) and 0.04-cm² device (with a structure of ITO/azeotrope-SAM/PM6:BTP-eC9:L8BO-2F(spin-coated)/PNDIT-F3N(spin coated)/Ag).



Figure S20 a) Schematic illustration of peel-off test. b) A scene of the peel-off test.



Figure S21 a) Temperature variation of thermal cycling test. b) PCE evolution of PEDOT:PSS and SAM devices after thermal cycling. c) PCE evolution of PEDOT:PSS and SAM based flexible devices (PET/ITO/SAM or PEDOT:PSS/PM6:BTP-eC9/PNDIT-F3N/Ag) in bending tests (with a bending radius of 6 mm).

	Surface tension (mN/m)		
Toluene	28.54		
IPA	21.32		
DMF	37.15		

Table S1 Surface tension of different solvents @ 20 °C.

	Saturated vapor pressure (kPa)		
Toluene	2.911		
IPA	4.418		
DMF	0.360		

Table S2 Saturated vapor pressure of different solvents @ 20 °C.

	V _{OC} (V)	$J_{ m SC}$ (mA cm ⁻²)	FF (%)	PCE (%)
IPA:Tol=1:1	0.853	27.84	76.24	18.11
IPA:Tol=1:5	0.825	29.54	73.85	18.00
IPA:O-XY=1:1	0.856	27.60	75.79	17.91
IPA:DMF=1:1	0.845	25.38	72.20	15.48

Table S3 Device parameters with Cbz-2Ph SAM printed using different solvents. (device area: 0.04 cm²) ("Tol", "O-XY", and "DMF" are the abbreviation of toluene, O-xylene, and N,N-Dimethylformamide.)

	С	0	Ν	Р	In	P/In
Azeotrope-SAM	46.93	33.02	2.25	2.39	15.4	0.16
IPA-SAM	43.02	35.66	2.24	2.08	17	0.12

Table S4 Atomic concentration determined by XPS for azeotrope-SAM and IPA-SAM.

	V _{OC} (V)	$J_{ m SC}$ (mA cm ⁻²)	FF (%)	PCE (%)	J_{Cal_EQE} (mA cm ⁻²)
PEDOT:PS	0.829	27.71	77.76	17.86	26.30
S	(0.829±0.001)	(27.68±0.08)	(77.42±0.39)	(17.76±0.07)	

Table S5 Parameters for PEDOT:PSS-based devices (0.04 cm^2). (Notes: Statistics were calculated from 10 independent devices.)

	$V_{\rm OC}({ m V})$	$J_{\rm SC}({\rm mA~cm^{-2}})$	FF (%)	PCE (%) ^a
IDA CAM	0.866	28.02	74.28	18.04
IPA-SAM	(0.859 ± 0.007)	(27.74±0.56)	(74.88±1.15)	(17.83±0.29)
Azeotrope-	0.873	28.29	77.30	19.10
SAM	(0.869±0.007)	(28.24±0.49)	(76.22±0.88)	(18.70±0.31)

Table S6 Photovoltaics parameters of D18:BTP-eC9-based organic solar cells.

a: The parameters in brackets were averaged from 5 devices.

Year	Device structure	Device area (cm2)	PCE (%)	Ref
2019	glass/ITO/ZnO/PBDB-T-SF:IT-4F(SD)/MoO3/A1	0.10	12.90	2
2019	glass/ITO/ZnO/PBDB-T:i-IEICO-4F(SD)/MoO3/A1	0.04	12.50	3
2020	glass/ITO/ZnO/PM7:IT4F(SD)/MoO3/A1	/	13.20	4
2020	glass/ITO/ZnO/PM6:Y6(SD)/MoO3/A1	/	15.60	5
2021	glass/ITO/ZnO/D18:BTR-C1:Y6(SD)/MoO3/A1	0.04	17.20	6
2022	glass/ITO/PEDOT:PSS/PM6:Y6(SD)/PFN-Br/Ag	/	16.22	7
2022	glass/ITO/ZnO/D18:Y6(SD)/MoO3/Al	0.04	17.38	8
2022	glass/ITO/PEDOT:PSS/PM6(SD)/L8BO(SD)/PDINO/Al	0.04	17.07	9
2023	glass/ITO/ZnO/PM6:BTR-Cl:CH1007(SD)/MoO3/Al	0.04	16.30	10
2023	glass/ITO/ZnO/PM6:Qx-1(SD)/MoOx/Ag	0.03	13.70	11
2024	glass/ITO/Cbz-2Ph(<mark>SD</mark>)/PM6:BTP-eC9(SD)/PNDIT- F3N/Ag	0.04	18.65	this work
2024	glass/ITO/ Cbz-2Ph(SD)/PM6:BTP-eC9(SD)/PNDIT- F3N(SD)/Ag	0.04	18.28	this work

Table S7 PCE record from literature (over 12%) of slot-die coated OSCs (area $\leq 0.1 \text{ cm}^2$)

Table S8 Parameters for 1.0-cm² device (with a structure of ITO/azeotrope-SAM/PM6:BTP-eC9(slot-die coated)/PNDIT-F3N(slot-die coated) and 0.04-cm² device (with a structure of ITO/azeotrope-SAM/PM6:BTP-eC9:L8BO-2F(spin-coated)/PNDIT-F3N(spin coated)/Ag).

Device area	Active layer	V _{OC} (V)	$J_{ m SC}$ (mA cm ⁻²)	FF (%)	PCE (%)
1.0 cm^2	PM6:BTP-eC9	0.837	28.53	66.82	15.96
0.04 cm^2	PM6:BTP-eC9:L8BO-2F	0.858	28.57	76.54	18.77

Table S9 PCE record (over 10%) for 1-cm² devices by large-area technologies from literature. ("BC" and "SD" indicate the corresponding layer was processed by blade coating and slot-die coating, respectively; "Other method" indicates other large-area technologies except for blade coating and slot-die coating).

Year	Device structure	PCE (%)	Ref
2017	glass/ITO/ZnO/PBTA-TF:IT-M(BC)/MoO3/Al	10.6	12
2018	glass/ITO/PEDOT:PSS(BC)/PM6(BC)/IT- 4F(BC)/PNDIT-F3N(BC)/Ag	11.4	13
2019	(glass/ITO/PEDOT:PSS(BC)/PBDB-T-2F:IT- 4F(BC)/NDI-N(BC)/Al	13.2	14
2019	glass/ITO/ZnO/PBDB-TF:PTO2:IT-4(BC)/MoO3/Ag	13.1	15
2019	glass/ITO/PEDOT:PSS/PBDB-TF:BTP-4F- 12(BC)/PFN-Br/Al	14.4	16
2019	glass/ITO/PEDOT:PSS/PM6:Y6:N2200(BC)/PNDIT- F3N/Ag	15.1	17
2020	glass/ITO/PEDOT:PSS(BC)/PM6(BC)/Y6(BC)/PNDIT- F3N-Br(BC)/Ag	15.23	18
2020	glass/ITO/PEDOT:PSS/PBDB-T-2F:IT- 4F:ICBA/(BC)/PDINO/A1	13.7	19
2021	glass/ITO/PEDOT:PSS/PM6:PYF-T-o(BC)/PNDIT- F3N/Ag	13	20
2021	glass/ITO/PEDOT:PSS/PM6:Y6(BC)/PFN-Br/Al	13.87	21
2021	glass/ITO/PEDOT:PSS/PTQ10:Y6-BO(other method)/PDINO/Ag	13.05	22
2021	glass/ITO/PEDOT:PSS/PTQ10:Y6(other method)/PDINO/Ag	13.62	23
2021	glass/ITO/PEDOT:PSS/PM6:IT-4F(BC)/PDINO/A1	13.94	24
2021	glass/ITO/ZnO/D18:BTR-C1:Y6(SD)/MoO3/A1	16.3	6
2022	glass/ITO/ZnO/PM6:AITC:BTP-eC9(BC)/MoO3/Ag	16.7	25
2022	glass/ITO/PEDOT:PSS/PM6:BTP-eC9(BC)/PDINO/Ag	14.82	26
2022	glass/ITO/PEDOT:PSS/PTQ10:Y6-BO(other method)/PDINO/Ag	13.48	27

2022	glass/ITO/PEDOT:PSS/PBDB-T:PYSe-TCl20:PTClo-	13.81	28
2022	Y(BC)/PDINO/Al	15.01	
2022	PET/Em-Ag/AgNWs(BC)/AZO/PM6:BTP-	15.82	29
2022	eC9:PC71BM(BC)/MoO3/A1	10102	
2022	glass/ITO/ZnO/PBDB-T-2F:N3:P(NDI2OD-	14.12	30
	T2)(BC)/MoO3/Al		
2022	glass/ITO/ZnO/PM6:BTR-Cl:Y6(SD)/MoO3/Al	13.7	10
2022	glass/ITO/ZnO/PM6:BTR-Cl:CH1007(SD)/MoO3/A1	14.2	10
2022	glass/ITO/PEDOT:PSS/PM6:5BDDBDT-F:BTP-	17 11	31
2023	eC9(BC)/PFN-Br/Ag	1/.11	51
2023	glass/ITO/PEDOT:PSS/PM6:5BDDBDT-Cl:BTP-	17.06	31
2023	eC9(BC)/PFN-Br/Ag	17.00	
	PET silver-		
2023	grid/PH1000(SD)/ZnO(SD)/PM6:L8BO(SD)/	12.17	32
	MoOx/Ag		
2024	glass/ITO/PEDOT:PSS/PM6(BC)/BTP-	17.52	33
	eC9:PYIT(BC)/PFN-Br/Ag		
2024	glass/ITO/ZnO/PM6:L8-BO:PC61BM(BC)/MoO3/Ag	17.55	34
2024	glass/ITO/Cbz-2Ph(SD)/PM6:BTP-eC9:L8BO-	17 75	this
2024	2F(SD)/PNDIT-F3N(SD)/Ag	17.75	work

	Maximum force per unit area (N m^{-2})	Total energy per unit area $(J m^{-2})$
PEDOT:PSS	897.78	2.06
Azeotrope-SAM	10617.78	25.09

Table S10 Maximum force and total energy information from the peel-off measurements.

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