Supporting Information

Direct C-H arylation-derived low crystallinity guest acceptor for high efficiency organic solar cells

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1. Materials and synthesis

D18, BTP-eC9 and PDINN were purchased from Solarmer Energy Inc. 1-Chloronaphthalene (CN) were purchased from TCI. Super dry reagents were purchased from J&K and other conventional reagents were from SCRC.

The synthetic routes are illustrated in Scheme S1. Diethyl 2,5-dibromoterephthalate and 1-bromo-4hexylbenzene were purchased from BIDE Pharm. Thiophene-2-boronic acid and (2-(5,6-dichloro-3-oxo-2,3-dihydro-1H-inden-1-ylidene)malononitrile were purchased from SunaTech Inc. All other chemicals were used as-received without further purification.



Scheme S1. The synthetic route to S-IDT and D-IDT.

No.	Conditions	Yields
1	Fe(acac) ₃ , TP2, AlMe ₃ , DEO, THF/PhMe	No Reaction
2	Pd(OAc) ₂ , Cu(OAc) ₂ , Na ₂ CO ₃ , PivOH, DMA	70%
3	Pd(OAc) ₂ , Cu(OAc) ₂ , K ₂ CO ₃ , DMF	84%

Table S1. The overview of the reaction results of direct C-H activation reactions under different conditions.

Synthesis of diethyl 2,5-di(thiophen-2-yl)terephthalate (**Compound 2**): Diethyl 2,5-dibromoterephthalate (2281 mg, 6.00 mmol) and thiophene-2-boronic acid (1800 mg, 14.07 mmol) were dissolved in THF (40 mL) under nitrogen. Then NaHCO₃ (2860mg, 34.04 mmol), H₂O (14 mL) and Pd(PPh₃)₄ (60 mg, 0.05 mmol) were added. After reacting 48 h at 80 °C, the mixture was purified by silica gel column chromatography (PE:EA=10:1, v/v) to obtain a white solid **Compound 2** (2040 mg, 88%). ¹H NMR (400 MHz, CDCl₃, ppm) δ : 7.81 (s, 2H, ArH), 7.39 (dd, *J* = 4.8 Hz, 1.6 Hz, 2H, ArH), 7.10-7.06 (m, 4H, ArH), 4.22 (q, *J* = 7.2 Hz, 4H, CH₂), 1.15 (t, *J* = 7.2 Hz, 6H, CH₃).

Synthesis of 4,4,9,9-tetrakis(4-hexylphenyl)-4,9-dihydro-*s*-indaceno[1,2-*b*:5,6-*b*']dithiophene (**IDT**): To the solution of 1-bromo-4-hexylbenzene (6000 mg, 24.88 mmol) in THF (30 mL) under nitrogen at -78°C was added *n*-BuLi (15.6 mL, 1.6 M in hexane), the mixture was kept at -78 °C for 1 h, then the solution of Compound 2 (2000 mg, 5.18 mmol) in THF (20 mL) was added slowly. After the addition, the mixture was stirred at room temperature for 24h and then poured into water and extracted twice with ethyl acetate. The combined organic phase was dried over Na₂SO₄. After removing the solvent, the crude product was charged into three-neck flask. After adding acetic acid (100 mL) and H₂SO₄ (2 mL), the mixture was perified by silica gel column chromatography (PE:EA=10:1, v/v) to obtain a light-yellow solid **IDT** (2830 mg, 60%). ¹H NMR (400 MHz, CDCl₃, ppm) δ : 7.43 (s, 2H, ArH), 7.23(d, *J* = 4.8 Hz, 2H, ArH), 7.15 (d, *J* = 8.4 Hz, 8H, ArH), 7.04 (d, *J* = 8.0 Hz, 8H, ArH), 6.99 (d, *J* = 5.2 Hz, 2H, ArH), 2.55 (t, *J* = 8.0 Hz, 8H, CH₂), 1.61-1.54 (m, 8H, CH₂), 1.34-1.26 (m, 24H, CH₂), 0.89-0.85 (m, 12H, CH₃).

Synthesis of 4,4,9,9-tetrakis(4-hexylphenyl)-4,9-dihydro-*s*-indaceno[1,2-*b*:5,6-*b*']dithiophene-2,7dicarbaldehyde (**IDT-2CHO**) and 4,4,9,9-tetrakis(4-hexylphenyl)-4,9-dihydro-*s*-indaceno[1,2-*b*:5,6*b*']dithiophene-2-carbaldehyde (**IDT-CHO**). IDT (1510 mg, 1.66 mmol) was dissolved in anhydrous DMF (40 mL) at 0 °C. Then POCl₃ (290 mg, 1.89 mmol) was added. The solution was gradually warmed to room temperature, heated to 50 °C, and allowed to stir for 8 h. Then, saturated NaOAc (60 mL) was added and the solution was stirred for a further 30 min. The mixture was extracted with dichloromethane and saturated NaCl solution. The solvent was removed under reduced pressure. Then the organic phase was purified by silica gel column chromatography (PE:DCM=1:1, v/v) to obtain yellow solid **IDT-2CHO** (465 mg, 29%) and **IDT-CHO** (1050 mg, 67%). **IDT-2CHO**: ¹H NMR (400 MHz, CDCl₃, ppm) δ : 9.83 (s, 2H, ArH), 7.65 (s, 2H, ArH), 7.59 (s, 2H, ArH), 7.11 (m, 16H, ArH), 2.57 (t, *J* = 8.0 Hz, 8H, CH₂), 1.62-1.54 (m, 8H, CH₂), 1.35-1.27 (m, 24H, CH₂), 0.89-0.85 (m, 12H, CH₃). **IDT-CHO**: ¹H NMR (400 MHz, CDCl₃, ppm) δ : 9.80 (s, 1H, ArH), 7.64 (s, 1H, ArH), 7.56 (s, 1H, ArH), 7.46 (s, 1H, ArH), 7.31 (d, *J* = 5.2 Hz, 1H, ArH), 7.16-7.14 (m, 8H, ArH), 7.09-7.06 (m, 8H, ArH), 7.02 (d, *J* = 4.8 Hz, 1H, ArH), 2.59-2.54 (m, 8H, CH₂), 1.62-1.57 (m, 8H, CH₂), 1.37-1.25 (m, 24H, CH₂), 0.89-0.86 (m, 12H, CH₃).

Synthesis of 2,2'-((2Z,2'Z)-((4,4,9,9-tetrakis(4-hexylphenyl)-4,9-dihydro-*s*-indaceno[1,2-*b*:5,6*b*']dithiophene-2,7-diyl)bis(methaneylylidene))bis(5,6-dichloro-3-oxo-2,3-dihydro-1*H*-indene-2,1diylidene))dimalononitrile (**S-IDT**): IDT-2CHO (200 mg, 0.21 mmol) and (2-(5,6-dichloro-3-oxo-2,3dihydro-1H-inden-1-ylidene)malononitrile (158 mg, 0.60 mmol) were dissolved in toluene. Then Ac₂O (0.4 mL) and BF₃OEt₂ (0.6 mL) were added. After reacting 1h at room temperature, the mixture was purified by silica gel column chromatography (PE:DCM=1:1, v/v) to obtain a dark brown solid **S-IDT** (272 mg, 90%). ¹H NMR (400 MHz, CDCl₃, ppm) δ : 8.91 (s, 2H, ArH), 8.78 (s, 2H, ArH), 7.93 (s, 2H, ArH), 7.74 (d, *J* = 4.8 Hz, 4H, ArH), 7.15-7.10 (m, 16H, ArH), 2.58 (t, *J* = 8.0 Hz, 8H, CH₂), 1.63-1.56 (m, 8H, CH₂), 1.34-1.29 (m, 24H, CH₂), 0.89-0.85 (m, 12H, CH₃). ¹³C NMR (101 MHz, CDCl₃) δ : 186.2, 160.1, 158.7, 158.2, 156.9, 142. 7, 141.8, 140.2, 140.1, 139.7, 139.4, 138.8, 137.4, 136.2, 129.0, 127. 8, 127.2, 125.4, 121.9, 120.4, 114.3, 77.5, 76.8, 70.3, 63.2, 35.7, 31.9, 31.4, 29.2, 22.7, 14.2. HR-TOF-MS (APCI) *m/z*: [M+H]⁺ calcd. for C₉₀H₇₉Cl₄N₄O₂S₂, 1453.4369; found: 1453.4177.

Synthesis of 4,4,4',4',9,9,9',9'-octakis(4-hexylphenyl)-4,4',9,9'-tetrahydro-[2,2'-bis-indaceno[1,2-b:5,6-b']dithiophene]-7,7'-dicarbaldehyde (**2IDT-CHO**): IDT-CHO (374 mg, 0.40 mmol), Pd(OAc)₂ (7 mg, 0.03 mmol), Cu(OAc)₂ (50 mg, 0.28 mmol), and K₂CO₃ (52 mg, 0.38 mmol) were dissolved in DMF (6 mL) under nitrogen. After reacting 12 h at 100 °C, the mixture was purified by silica gel column chromatography (PE:DCM=1:1, v/v) to obtain a dark red solid **2IDT-CHO** (312 mg, 84%). ¹H NMR (400 MHz, CDCl₃, ppm) δ : 9.80 (s, 2H, ArH), 7.63 (s, 2H, ArH), 7.52 (s, 2H, ArH), 7.39 (s, 2H, ArH), 7.15-7.12 (m, 16H, ArH), 7.08-

7.07 (m, 18H, ArH), 2.58-2.54 (t, *J* = 6.8 Hz, 16H, CH₂), 1.61-1.58 (m, 16H, CH₂), 1.34-1.26 (m, 48H, CH₂), 0.88-0.86 (m, 24H, CH₃).

Synthesis of 2,2'-((2Z,2'Z)-((4,4,4',4',9,9,9',9'-octakis(4-hexylphenyl)-4,4',9,9'-tetrahydro-[2,2'-bisindaceno[1,2-*b*:5,6-*b*']dithiophene]-7,7'-diyl)bis(methaneylylidene))bis(5,6-dichloro-3-oxo-2,3-dihydro-1*H*-indene-2,1-diylidene))dimalononitrile (**D-IDT**): 2IDT-CHO (200 mg, 0.11 mmol) and (2-(5,6-dichloro-3-oxo-2,3-dihydro-1H-inden-1-ylidene)malononitrile (80 mg, 0.30 mmol) were dissolved in toluene. Then Ac₂O (0.5 mL) and BF₃OEt₂ (0.6 mL) were added. After reacting 2h at room temperature, the mixture was purified by silica gel column chromatography (PE:DCM=1:1, v/v) to obtain a dark brown solid **D-IDT** (225 mg, 89%). ¹H NMR (400 MHz, CDCl₃, ppm) δ : 8.88 (s, 2H, ArH), 8.76 (s, 2H, ArH), 7.90 (s, 2H, ArH), 7.70 (s, 2H, ArH), 7.66 (s, 2H, ArH), 7.41 (s, 2H, ArH), 7.16-7.13 (m, 16H, ArH), 7.11-7.08 (m, 18H, ArH), 2.57 (t, *J* = 8.0 Hz, 16H, CH₂), 1.63-1.56 (m, 16H, CH₂), 1.34-1.27 (m, 48H, CH₂), 0.89-0.86 (m, 24H, CH₃). ¹³C NMR (101 MHz, CDCl₃): δ : 186.3, 162.7, 159.1, 158.5, 157.8, 156.9, 154.5, 142.9, 142.4, 142.2, 141.0, 140.7, 140.6, 140.5, 140.0, 139.7, 139.6, 139.3, 138.8, 136.2, 133.6, 128.8, 128.8, 127.9, 127.1, 125.2, 120.4, 120.2, 119.9, 117.6, 114.6, 77.5, 76.8, 69.0, 63.3, 63.0, 35.7, 35.7, 31.9, 31.4, 29.3, 22.7, 14.2. HR-TOF-MS (APCI) *m/z*: [M+H]⁺ calcd. for C₁₅₄H₁₅₁Cl₄N₄O₂S₄: 2358.9478; found: 2358.9034.



Figure S1. ¹H NMR spectrum of Compound 2 in CDCl₃.



Figure S2. ¹H NMR spectrum of IDT in CDCl₃.







Figure S4. ¹H NMR spectrum of IDT-CHO in CDCl₃.











Figure S7. HR-TOF-MS spectrum of S-IDT.



Figure S8. ¹H NMR spectrum of 2IDT-CHO in CDCl₃.











Figure S11. HR-TOF-MS spectrum of D-IDT.

2. Device fabrication

The OSCs were fabricated with the traditional sandwich structure: ITO/BrBACz/Active layer/PDINN/Ag. After being cleaned with deionized water, acetone and isopropanol, the ITO glass was treated with the UV-Ozone for 25 minutes. Firstly, BrBACz in ethanol solution was spin-coated on the treated-ITO glass at 3000 r.p.m for 30 s and then thermal annealing at 100 °C for 20 minutes. Then, the active layer was spin-coated from 13 mg mL⁻¹ solution dissolved in chloroform (D18: Acceptors = 1:1.2-1.3, D18: BTP-eC9: Acceptor = 1:1.1:0.2, 0.45% v/v CN) at varied spinning speed for 30 s to form an active layer. After solution deposition, the active layer was annealed at 100 °C for 10 minutes. Subsequently, PDINN was dissolved in methyl alcohol solution (1 mg mL⁻¹) and spin-coated at 2000 r.p.m for 30 s. Finally, Ag was deposited ca. 150 nm under the pressure of 3×10^{-5} Pa.



Scheme S2. The chemical structures of the used materials in devices.

3. Characterization

¹H NMR and ¹³C NMR spectra were recorded on Bruker (AVANCE III 400MH). High resolution time of flight mass spectrometer (HR-TOF-MS) was obtained from AB Sciex (TripleTOF 4600). Absorption spectra of both solution and thin-film samples of the compounds were recorded using a Perkin Elmer (Lamdba 1050) UV-Vis scanning spectrophotometer. Grazing Incidence Wide Angle X-Ray Scattering (GIWAXS) were performed on a XEUSS SAXS/WAXS system (XENOCS, France) at the National Center for Nanoscience and Technology. Grazing Incidence Small Angle X-Ray Scattering (GISAXS) were performed on a XEUSS SAXS/WAXS system (XENOCS, France) at the Ningbo Institute of Materials Technology and Engineering. Morphologies of the active layers were analyzed through atomic force microscopy (AFM) in tapping mode under ambient conditions using Bruker (Dimension ICON) instrument. Contact angles of pure films by applying deionized water (H₂O) and diiodomethane (DIM) liquid drops tested by a contact angle meter (OCA25). The J-V measurement was performed via the solar simulator (Newport-Oriel® Sol3A 450W). The intensity of the AM 1.5G spectra was calibrated by a certified standard silicon solar cell. The area of the tested solar cells was determined by an optical microscope. The effective areas of the cells were 0.04 cm². Keithley 2440 source meter with a solar simulator (Newport-Oriel® Sol3A 450W) were used to do the electrical conductivity test (under dark). A solar cell QE tester (QE-R, Enli Technology Co., Ltd) calibrated with a 75W xenon lamp source standard probe was be utilized to obtain the external quantum efficiency

(EQE) spectrums.

4. Cyclic voltammetry measurement

The Cyclic Voltammetry (CV) measurement was carried out with the film made by dropping 8 mg mL⁻¹ solution onto the working electrode (Bu_4NCIO_4 , as supporting electrolyte) under an argon atmosphere at a scan rate of 0.1 V s⁻¹ using a PC controlled electrochemical workstation (Shanghai Chenghua CHI604E). The CV system was constructed using a Pt disk as the working electrode, a Pt wire as the counter electrode, and an Ag/AgNO₃ (0.1 mol L⁻¹ in acetonitrile) electrode as the reference electrode. Ferrocene was used as an internal standard. The electrochemical potential was internally calibrated against the standard ferrocene/ ferrocenium redox couple (Fc/Fc⁺), which has a known reduction potential of -4.80 eV relative to vacuum level. The HOMO and LUMO of the objective compounds are calculated according to the following equations:

HOMO =
$$-[\frac{E^{onest}}{ox} + 4.8]$$

LUMO = $-[\frac{E^{onest}}{red} + 4.8]$

Where E_{ox}^{onset} and E_{red}^{onest} are the onset of oxidation potential and reduction potential vs. Fc/Fc⁺, respectively.

5. SCLC measurement

The charge mobilities were measured by SCLC method. The hole-only device was fabricated via a structure of ITO/PEDOT:PSS/Active layer/MoO₃/Ag, and the electron-only device was constructed via a structure of ITO/ZnO/Active layer/PDINN/Ag. By fitting the curves of $J^{1/2}$ -V, the mobility value can be obtained according to the equation:

$$J_{SCLC} = \frac{9}{8} \varepsilon_0 \varepsilon_r \mu \frac{V^2}{L^3}$$

Where J_{SCLC} is current density; ε_0 is the permittivity of vacuum; ε_r is the relative permittivity; μ is mobility value; *L* is the thickness of the active layer; and *V* is the effective voltage.

6. Femtosecond transient absorption (fs-TA) spectroscopy measurement

Femtosecond transient absorption spectra (fs-TAs) were recorded utilizing a Yb:KGW laser (Pharos, Light Conversion) with a fundamental output wavelength of approximately 1030 nm. A custom-designed noncollinear optical parametric amplifier was employed to generate pump pulses centered at 800 nm. A supercontinuum probe beam spanning 500-950 nm was produced by focusing a small portion of the 1030 nm fundamental beam onto a 5 mm thick sapphire plate. Subsequently, the supercontinuum light was divided into two balanced detection beams using a double-line Si camera (S14417, Hamamatsu). Pulse-to-pulse spectral analysis was performed at a 50 kHz repetition rate with the assistance of a homemade field-programmable gate array (FPGA) control board. The pump fluence was maintained at 2 μ J cm⁻² unless otherwise noted. Samples were maintained under a nitrogen atmosphere throughout the measurement process to mitigate photo-degradation. The data were processed by using the software Surface Xplorer.

7. In-situ ultraviolet-visible (UV-vis) absorption measurements

In-situ UV-vis absorption measurements were performed by the Filmetrics F20-EXR spectrometer using the transmission mode with a time resolution of 25 ms. The spectrometer consists of a light source and detector. The light source and detector are fixed above and below the substrate, respectively, and on the same vertical line. The solution was spined onto the substrate, and the film was formed on the glass substrate. The detector collects the transmission spectra ranging from 400 to 1050 nm during coating. The UV-vis absorption spectra are calculated from the transmission spectra according to the equation $\Delta \lambda = -\log 10(T)$, where $\Delta \lambda$ is the absorbance at a certain wavelength (λ), and T is the calculated transmittance. The light source and detector were turned on before coating the film, so time zero is the point when the first solution transmission spectrum was collected by the detector. Before time zero, there is only noise in the transmission spectra.

8. Theoretical calculation.

All the calculations of the model compounds studied in this work were performed using the Gaussian 09 software package. Ground state geometry optimizations of 5-IDT and 6-IDT in this paper are calculated by DFT at the B3LYP/6-31G (d, p) (empirical dispersion = gd3bj) level. The alkyl side-chains are replaced with methyl groups for saving computation time without affecting the description of electronic properties. The visualization of the molecular orbitals was performed using GaussView 6.0.16.



Figure S12. The cyclic voltammograms of S-IDT and D-IDT.



Figure S13. Theoretical electron distribution calculated by the DFT for S-IDT and D-IDT.



Figure S14. The normalized absorption spectra of D18, BTP-eC9, S-IDT and D-IDT in chloroform solution.

Acceptors	$\lambda_{\max}^{sol.}$ (nm)	$\lambda_{\max}^{\text{film}}$ (nm)	$\Delta\lambda$ (nm)
S-IDT	689	754	65
D-IDT	723	748	25



Figure S15. Simulated molecular geometries obtained via DFT calculations for simplified chemical structures of S-IDT and D-IDT.



Figure S16. J–V characteristics of the devices based on (a) PM6:BTP-eC9 and (b) D18:L8-BO.

Table S3. Detailed GIWAXS peak information of the blend films in OOP and IP.

Blend films		Location (Å ⁻¹)	d-spacing (Å)	FWHM (Å ⁻¹)	CCL (Å)
S-IDT	OOP(010)	1.731	3.63	0.255	22.18
D-IDT	00P (010)	1.401	4.47	0.704	8.03
S-IDT	ID (100)	0.400	15.71	0.118	47.92
D-IDT	IP (100)	0.373	16.85	0.157	36.02



Figure S17. The dependence of J_{SC} on light intensity (P_{light}) of relevant devices.



Figure S18. The electron mobilities (a) hole mobilities (b) of the devices.

Acive layer	<i>V_{oc}</i> [V]	<i>Eg</i> [eV]	E _{loss} [eV]	<i>V_{oc}^s</i> [V]	Voc ^{rad} [V]	⊿ <i>E</i> 1 [eV]ª	<i>∆E</i> ₂ [eV] ^b	<i>∆E</i> 3 [eV] ^c
D18:BTP-eC9	0.851	1.403	0.552	1.141	1.060	0.262	0.081	0.196
D18:BTP-eC9: S-IDT	0.848	1.411	0.563	1.149	1.079	0.263	0.070	0.205
D18:BTP-eC9: D-IDT	0.875	1.409	0.534	1.147	1.081	0.262	0.066	0.193

Table S4. Detailed V_{loss} parameters of the devices.

 $^{a} \varDelta E_{I} = E_{g} - q V_{OC}$

 ${}^{\mathrm{b}}\!\varDelta E_2 = q V_{OC} {}^{S\!\mathcal{Q}} \text{ - } q V_{OC} {}^{rad}$

 $^{c}\Delta E_{3} = -ktlnEQE_{EL}$



Figure S19. Details of optical E_g determination. (E_g plots determined from the intersection of the absorption and the PL emission.)



Figure S20. The transient absorption spectra of D18:BTP-eC9 (a), D18:BTP-eC9:S-IDT (b) and D18:BTP-eC9:D-IDT (c) films extracted from different time.



Figure S21. Comparison of the hole-transfer kinetics probed at 586 nm for the corresponding blends.



Figure S22. Film-depth-dependent exciton generation contours and the dependence of the simulated exciton generation rate (G) on the film depths of D18:BTP-eC9, D18:BTP-eC9:S-IDT and D18:BTP-eC9:D-IDT.



Figure S23. Contact angles of D18, BTP-eC9, S-IDT, and D-IDT thin films by applying deionized water (H₂O) and diiodomethane (DIM) liquid drops.

Materials	θ_{Water} [°]	θ_{DIM} [°]	$\gamma^d \ [mN \ m^{-1}]$	$\gamma^{p} [mN m^{-1}]$	γ [mN m ⁻¹]	χ D18/A ^a	χbtp-eC9/A ^b
D18	104.036	60.038	29.120	0.111	29.231	-	-
BTP-eC9	96.562	45.046	37.348	0.269	37.615	0.528 K	-
S-IDT	95.428	36.465	42.263	0.133	42.396	1.220 K	0.143 K
D-IDT	94.853	50.452	33.360	0.791	34.151	0.191 K	0.084 K

Table S5. Summarized contact angels and surface energies of D18, BTP-eC9, S-IDT, and D-IDT.

a. The Flory-Huggins interaction parameter between the donor and accepter is calculated through equation of $\chi_{D18/A} = \kappa (\sqrt{\gamma_A} - \sqrt{\gamma_{D18}})^2$.

b. The Flory-Huggins interaction parameter between the two accepter (BTP-eC9 and A) is calculated through equation of $\chi_{BTP - eC9/A} = \kappa (\sqrt{\gamma_{BTP - eC9}} - \sqrt{\gamma_A})^2$.



Figure S24. Line profiles across the AFM phase images of D18:BTP-eC9, D18:BTP-eC9:S-IDT and D18:BTP-eC9:D-IDT.



Figure S25. The line-cut-of profiles along the in-plane (IP) and out-of-plane directions (OOP) of blend films corresponding to the 2D G-IWAXS patterns.

Blend films		Location (Å ⁻¹)	d-spacing (Å)	FWHM (Å ⁻¹)	CCL (Å)
D18:BTP-eC9		1.720	3.65	0.286	19.77
D18:BTP-eC9:S-IDT	OOP (010)	1.727	3.64	0.277	20.42
D18:BTP-eC9:D-IDT		1.725	3.64	0.294	19.23
D18:BTP-eC9		0.313	20.07	0.073	77.46
D18:BTP-eC9:S-IDT	IP (100)	0.314	20.01	0.074	76.42
D18:BTP-eC9:D-IDT		0.312	20.14	0.078	72.50

Table S6. Detailed GIWAXS peak information of the blend films in OOP and IP.



Figure S26. GISAXS plots of the in-plane line-cut plots and fitting lines.



Figure S27. (a) Photo-stability OSCs of the encapsulated devices under continuous 1-sun illumination. (b) Thermal stability of the unencapsulated devices in an N_2 atmosphere. (Device structure: ITO/SnO₂/Active layer/MoO₃/Ag.)