Supplementary Information

Increased Crystallinity of Bulk-Heterojunction Morphology Based on Ladder-Type Polymer by Blade-Coating for Enhanced Photovoltaic Performance

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Experimental Section

The solar cells in this study were prepared on ITO glass substrates. Before device fabrication, the substrates were rinsed by sonication in detergent and deionized water, acetone and isopropyl alcohol by sequential. The substrates were further cleaned by oxygen plasma treatment for 1 minute, and then a PEDOT:PSS (Baytron PVP AI 4083, filtered at 0.45 μm) film was spin-coated on the substrates. Afterwards, the substrates were annealed at 150 °C for 10 minutes. PIDT-PhanQ:PC71BM layers were spin- (70-80 nm-thick) and blade-coated (150-160 nm-thick) from 20 wt. % solution in o-dichlorobenzene (filtered at 0.2 μm) and then spin-coated devices were annealed at 110 °C for 10 minutes to fully remove solvent (the blend ratio of PIDT-PhanQ:PC71BM was 3:1 (w/w)). Blade-coating was performed at a speed of 50 mm s⁻¹ with the gap between blade and substrate of 100 μm at room temperature using a Coatmaster 510 (Erichsen). Uniform wet films formed immediately after solution blading were kept at room temperature for 30 min to dry the films. A cathode interfacial layer (C₆₀-bis) was spin-coated and thermal evaporation of silver electrode under a vacuum pressure of 7x10⁻⁷ Torr completed device fabrication with an active area of 3.14 mm².

GIXD spectra were obtained at the Advanced Light Source at the Lawrence Berkeley National Laboratory. An X-ray beam impinged onto the sample at a grazing angle above and below the critical angle of the film (αc=0.16), but below the critical angle of the silicon substrate (αc=0.22). The wavelength of X-rays used was 1.540 Å, and the scattered intensity was detected by using two-dimensional charge-coupled device camera.
Electrical characterization of devices was performed using a Keithley 2400 source meter unit. Photocurrent of the devices was measured under AM 1.5G illumination at intensity of 100 mW cm\(^{-2}\). The EQE spectra were obtained from IPCE setup consisting of a Xenon lamp (Oriel, 450 W) as a light source, monochromator, a chopper with a frequency of 100 Hz, a lock-in amplifier (SR830, Stanford Research Corp), and Si-based diode (J115711-1-Si detector) for calibration. The charge mobilities were determined by fitting the dark current to the model of single carrier space charge limited current, which is described as \( J = (9/8)\varepsilon_0\varepsilon_r\mu_{h,e}(V^2)/(L^3) \), where \( \varepsilon_0 \) is the permittivity of free space, \( \varepsilon_r \) is the relative permittivity of the material (\( \varepsilon_r \) is 3 for PIDT-PhanQ and 3.9 for PC71BM), \( \mu_{h,e} \) is the mobility of each charge carrier and \( L, V \) and \( J \) are the thickness of the active layer, the effective voltage, and the current density respectively.