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SUPPORTING INFORMATION

Efficient Light Harvesting of a Luminescent Solar Concentrator using Excitation Energy Transfer from an Aggregation-Induced Emitter

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Experimental details

Materials. DPATPAN was synthesized according to published procedures.[1] Crystalline DCJTB (LT-E704, Lot No. E704-130604001) was purchased from Lumtec Corp. and was used as received. PMMA (M_w ~ 350,000 g/mol) was purchased from Sigma-Aldrich. Spectroscopic-grade chloroform was used for film preparation.

Casting solutions. For the 0.1% DCJTB films, 0.2 mg of DCJTB (from a solution of 1.0 mg/cm^3 DCJTB in $CHCl_3$; 10 mg of DCJTB dissolved in 10 cm^3 $CHCl_3$) and 200 mg of PMMA were dissolved in 20 g of $CHCl_3$ to make a 1% casting solution. Different concentrations of DCJTB in PMMA were prepared by just varying the amount of PMMA added. For the 10% blend films, 20 mg of DPATPAN, 0.2 mg of DCJTB (from a solution of 1.0 mg/mL DCJTB in $CHCl_3$), and 200 mg of PMMA were dissolved in 20 g of $CHCl_3$ to make a 1% casting solution. Different concentrations of DPATPAN/DCJTB in PMMA were prepared by varying the amount of PMMA added.

Quantum yield measurements. Thin-film quantum yields were measured using a calibrated integrating sphere accessory (F-3018) attached to a FluroLog-3 (Jobin-Yvon) fluorimeter. Films were prepared by drop casting onto a 1.0 cm × 1.0 cm × 0.1 cm glass substrate and allowing the film to dry slowly in a Petri dish. Quantum yields were determined based on the published procedure.[2] All quantum yield measurements were performed in air.

Glass substrate cleaning. Glass strip substrates with dimensions of 1.2 cm × 7.5 cm × 0.1 cm were cleaned by sonicating the substrates sequentially in 5 M NaOH, distilled water, acetone, isopropanol, and dichloromethane. The substrates were then kept in isopropanol until further use.

LSC film preparation. The glass strips were dried using a strong flow of N_2 and then further treated with UV/Ozone for 15 minutes. Films were cast onto the substrates using the casting solution and were allowed to dry in a Petri dish. For the DCJTB films, the thicknesses of the films were increased by layer-by-layer addition of casting solution after drying of the previous layer. The thickness of the DCJTB/DPATPAN-based LSCs for the absorption coefficient measurements was 16.7 ± 1.1 µm (n = 7). The thicknesses of the 19 and 26 µm DCJTB-based LSCs are 19.0 ± 0.7 µm (n = 7) and 25.5 ± 0.5 µm, (n = 7), respectively. Film thicknesses were measured using a Dektak Stylus 150 Profilometer. The middle, edge, and corners of the LSC were sampled to measure film homogeneity.

IPCE Measurements. The IPCE of the films were measured using an IPCE Measurement Kit (Newport). The films were calibrated using a standard silicon solar cell provide with the kit. The LSC films were excited with a 325 W Hg Arc source. The beam spot size was kept at 0.5 cm for both the measurement and calibration. The LSC and standard silicon solar cell were mounted on a movable stage with a Vernier scale. Distances used in the excitation distance dependence studies were relative from the solar cell. The frame that encapsulates the standard silicon solar cell prevents direct contact between the LSC and the silicon solar cell. Nevertheless, the IPCE decay as a function of excitation distance could be recordede as light intensity decay due to reabsorption from the LSC is detected through the transparent window of the standard solar cell. Note that no other optical accessories (e.g. scatterers, mirrors, etc.) were attached to the LSC and no significant difference in performance was observed when optical coupling fluid between the LSC and silicon solar cell was used (immersion oil, Olympus Corporation, refractive index = 1.518).

Supplementary Figure –Absorption coefficient of donor/acceptor in PMMA

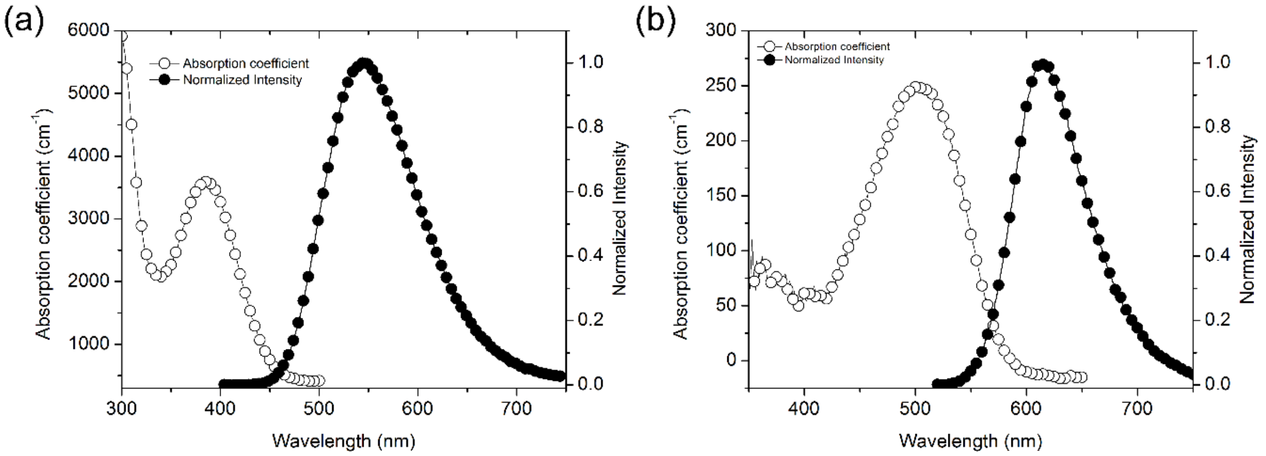

Figure S1. Absorption coefficient and emission spectra of 10% DPATPAN in PMMA (a) and 0.1% DCJTB in PMMA (b).

Supplementary Discussion – Optimization of PMMA films

The Φ_F of the DPATPAN, DCJTB, and blends in PMMA films at different concentrations measured in the integrating sphere are shown Figure S3. The fluorescence quantum yield of DPATPAN is not sensitive to concentration compared to DCJTB, which is consistent with the AIE behavior observed previously.[1] The quantum yield of the blend films decreases with concentration which is possibly due to the increased concentration of DCJTB in the blend relative to PMMA. DPATPAN is not a good host for DCJTB (see Supplementary Discussion – Pure thin-films, Figure S4). Based on the concentration experiments, the optimized blend concentration for LSC is 10% w/w of the dyes in PMMA with the dye ratio at DPATPAN:DCJTB 99:1 w/w. The quantum yield of spin-casted films (absorbance of 0.07 ± 0.01, n = 3 at 400 nm compared to 1.21 ± 0.01, n = 3 at 400 nm for drop-casted films) of 10% (99:1)DPATPAN/DCJTB is 85.1 ± 9.2%. The photoluminescence and excitation spectra indicate an efficient energy transfer from donor to acceptor in the blend films.

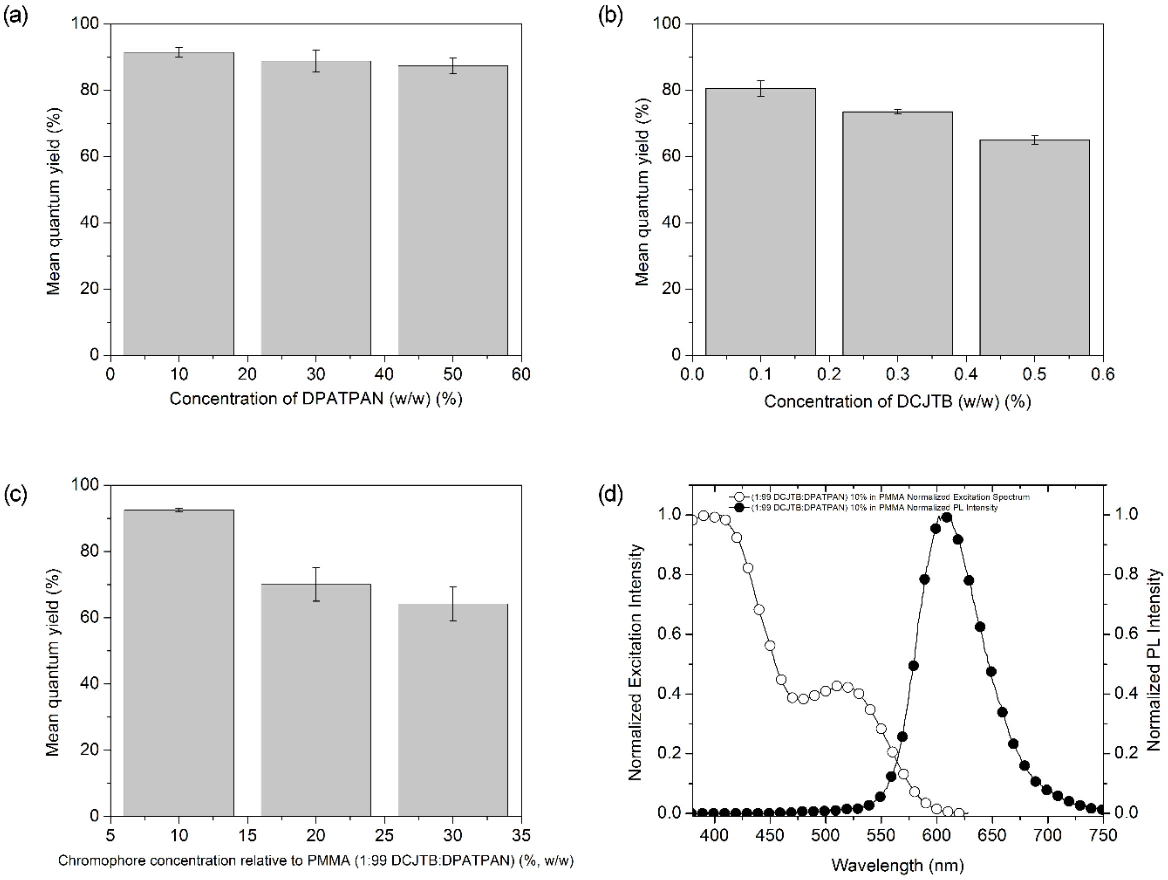

Figure S2. Concentration dependence of the fluorescence quantum yield of (a) DPATPAN, (b) DCJTB, (c) (1:99 DCJTB:DPATPAN) blend. (d) Corrected excitation and emission spectrum of (1:99 DCJTB:DPATPAN) 10% in PMMA. The excitation spectrum was measured by monitoring the emission at 650 nm and scanning from 380 to 630 nm.

Supplementary Discussion – Pure thin-films

Attempts to use pure organic thin-films of DPATPAN:DCJTB as the light absorbing layer prepared using drop casting led to low emission quantum yields possibly be due to the phase separation of DCJTB and DPATPAN into large aggregates during the solvent evaporation process. DCJTB is known to suffer from fluorescence concentration quenching.[3] The fluorescence quantum yield of the blend, even at low DCJTB doping, was far too low for constructing efficient LSC devices (Figure S4).

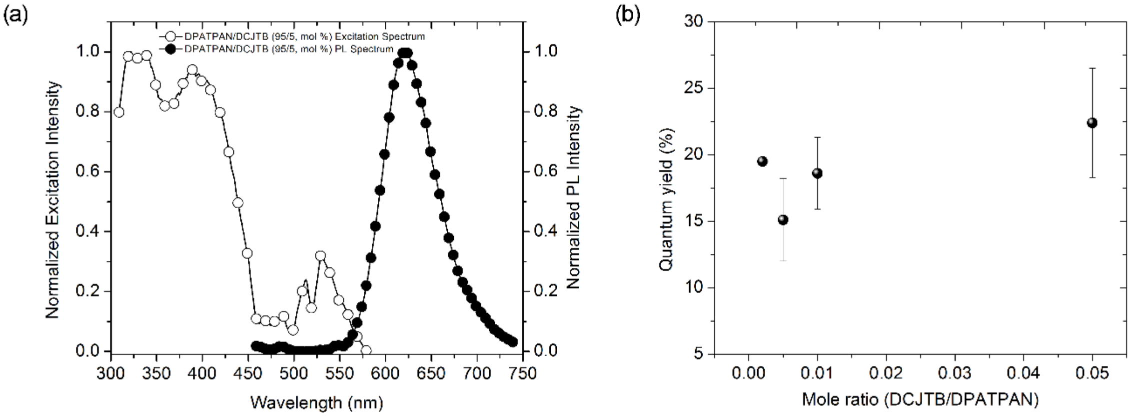

Figure S3. (a) Corrected excitation and emission spectrum of DCJTB:DPATPAN (5:95 mol/mol) pure thin-film on quartz, (b) Quantum yield dependence on the mole ratio of acceptor:donor as pure thin films. Quantum yields of the pure organic thin-film on a 1 cm × 1 cm × 0.1 cm quartz substrate were measured using an integrating sphere. Films were excited at 400 nm.

Supplementary Figure – LSC Absorbance Spectra

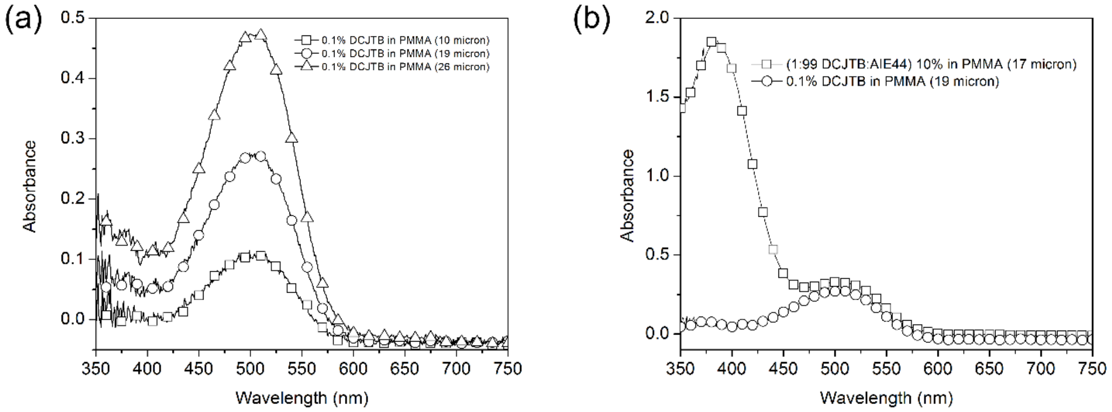

Figure S4. (a) Absorbance spectrum of different thicknesses of 0.1% DCJTB in PMMA on glass. (b) Comparison of absorbance spectrum of DCJTB/PMMA and DCJTB/DPATPAN-based LSCs.

References

1. Gong, Y.; Tan, Y.; Liu, J.; Lu, P.; Feng, C.; Yuan, W. Z.; Lu, Y.; Sun, J. Z.; He, G.; Zhang, Y., Chem. Commun. 2013, 49, 4009-4011.
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