Supporting Information

A Detailed Evaluation of Charge Recombination Dynamics in Dye Solar Cells

Based on Starburst Triphenylamine Dyes

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Figure S1. Structure of TPAA1 and TPAA2.



Figure S2. Differential scanning calorimetry analysis (a) TPAA4 and (b) TPAA5.



Figure S3. Negative solvatochromism exhibited by the dyes (a) TPAA4 and (b) TPAA5.



Figure S4. Absorption spectra at different concentrations in chloroform by the dyes (a) TPAA4 and (b) TPAA5.



Figure S5. Solid state absorption spectra of the dyes with and without CDCA for (a) TPAA4 and (b) TPAA5.



Figure S6. Solid state fluorescence spectra of the dyes with and without CDCA for (a) TPAA4 and (b) TPAA5.



Figure S7. Differential pulse voltammograms for (a) TPAA4 and (b) TPAA5 in acetonitrile solvent with $(n-Bu)_4NPF_6$ as supporting electrolyte and Ag/AgCl as the reference electrode.



Figure S8. Different modes of binding of carboxylic acids on TiO₂ surface.



HOMO - 1



LUMO + 1



HOMO - 2

LUMO + 2

Figure S9. Electron distributions in various orbitals of TPAA4 calculated by Density Functional Theory with the Gaussian 09W program package at the B3LYP/6-31G*(d) level.

TPAA4



НОМО - 2

LUMO + 2

Figure S10. Electron distributions in various orbitals of TPAA5 calculated by Density Functional Theory with the Gaussian 09W program package at the B3LYP/6-31G*(d) level.



Figure S11. Dark *J-V* plot of TPAA4 and TPAA5.



Figure S12. Nyquist spectra of TPAA4 at direct applied potentials ranging from 0.65 V to 0.85 V.



Figure S13. Bode phase spectra of TPAA4 at direct applied potentials ranging from 0.65 V to 0.85 V.



Figure S14. Nyquist spectra of TPAA5 at direct applied potentials ranging from 0.65 V to 0.85 V.



Figure S15. Bode phase spectra of TPAA5 at direct applied potentials ranging from 0.65 V to 0.85 V.



Figure S16. Complete equivalent circuit used for fitting impedance spectrums at various applied bias.



Figure S17. Efficiency variation of DSCs based on TPAA4 and TPAA5 up to 500 h.

Dye	CDCA	$J_{\rm SC}$ (mAcm ⁻²)	$V_{\rm OC}({ m V})$	FF	η (%)
TPAA1	No	9.96	0.69	0.73	5.05
TPAA2	No	8.36	0.69	0.72	4.14

Table S1. Photovoltaic data for TPAA1 and TPAA2.¹

Reference

(1) M. V. Vinayak, T. M. Lakshmykanth, M. Yoosuf, S. Soman, K. R. Gopidas, *Solar Energy* 2016, **124**, 227-241.