Solution-Processed Undoped Deep-Blue Organic Light-Emitting Diodes **Based on Starburst Oligofluorenes with a Planar Triphenylamine Core**

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Abstract: A series of starburst oligomers (T1-T3) that contained a fully diarylmethene-bridged triphenylamine core and oligofluorene arms were designed and synthesized through Suzuki cross-coupling reactions. Their thermal, photophysical, and electrochemical properties were also investigated. These materials showed high glass transition, in the range of 123-129°C, and good film-forming abilities. They displayed deep-blue emission both in solution and as thin films. Solution-processed devices based on these oligomers exhibited highly efficient deepelectroluminescence and the blue device performances were significantly

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enhanced with the extension of the oligofluorene arms. The double-layered device that contained T3 as an emitter showed a maximum current efficiency of 3.83 cd A⁻¹ and a maximum external quantum efficiency of 4.19% with CIE coordinates of (0.16, 0.09), which are among the highest values for undoped deep-blue OLEDs that are based on solution-processable starburst oligomers.

Introduction

Since the pioneering work by Tang et al. in 1987.^[1] organic light-emitting diodes (OLEDs) have attracted considerable scientific and industrial attention because of their applications in flat-panel displays and in solid-state lighting.^[2-12] Full-color displays require primary RGB emission of relatively equal stability, efficiency, and color purity. However, the performance of blue-light-emitting devices is often inferior to that of their green and red counterparts for the intrinsic wide band-gap of blue-light-emitting materials, which makes it hard to inject charge into an emitting layer. Thus, the development of blue OLEDs-in particular deep-blue OLEDs-with high electroluminescence (EL) efficiency is a pressing concern to realize commercial full-color displays. The deep-blue color is defined as having blue EL emission with a Commission Internationale de l'Eclairage (CIE) y coordinate value of < 0.15. Such emitters can not only effectively reduce the power consumption of a full-color OLED

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but can also be utilized to generate light of other colors by energy cascade to a lower-energy fluorescent or phosphorescent dopant.[13-15]

Solution-processable OLEDs are critical for realizing lowcost and large-area displays.^[16] However, a few solutionprocessable deep-blue OLEDs have been reported.^[17-24] Recently, monodisperse conjugated star-shaped oligomers that can be deposited by solution processing have been of great interest for use in OLEDs.^[25-35] By combining the advantages of polymers and small molecules, starburst compounds are characterized by a well-defined molecular structure and superior chemical purity as well as good solution processability. Furthermore, their optoelectronic and thermal properties can be independently optimized by the judicious choice of different cores and branches. In OLED applications, oligofluorene is favorably used as the arm because of the associated high quantum yield, good optical stability, and filmforming ability.^[26-35] The core usually plays a major role in the molecular shape, the emission color, and the thermal and morphological properties of the starburst molecules. Different centers, such as benzene,^[34] triazatruxene,^[26-27] pyrene,^[29] porphyrin,^[31] truxene,^[32] 4,4',4"-tris(carbazol-9-vl)triphenylamine (TCTA),^[28] and spirofluorene,^[33] have been used to construct starburst molecules with interesting properties. For example, Lai and co-workers reported a highly efficient deep-blue OLED with $\eta_{c,max} = 2.07 \text{ cd } \text{A}^{-1}$ and CIE coordinates of (0.15, 0.09) by utilizing triazatruxene as a core and six oligofluorene arms as the branches.^[27] Liu and co-workers synthesized a series of deep-blue-emitting starburst oligomers that contained a TCTA core and six oligofluorene arms, and obtained a device with $\eta_{c max} =$ $0.47 \text{ cd } \text{A}^{-1}$ and CIE coordinates of (0.16, 0.07).^[28] By using a pyrene core and four oligofluorene arms, Liu and co-work-

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ers obtained an sky-blue-emitting OLED with $\eta_{c,max} = 1.75 \text{ cd A}^{-1}$ and a maximum luminance of 2716 cd m⁻² with CIE coordinates of (0.20, 0.32).^[29]

We have recently reported a fully diarylmethene-bridged triphenylamine (FATPA), which had an almost planar triphenylamine (TPA) skeleton and exhibited excellent thermal and morphological stability.^[36-37] Herein, we designed and synthesized a series of starburst oligofluorenes that were based on the FATPA core. Their thermal, photophysical, and electrochemical properties, as well as the characteristics of devices that used these starbursts as a blue emitter were investigated. All of the compounds showed deep-blue emission with almost unit fluorescence quantum yields in solution. Solution-processed devices based on these oligomers exhibited efficient deep-blue electroluminescence. Furthermore, the device performances were significantly enhanced with the extension of the oligofluorene arms. The doublelayered device with T3 as the emitter showed a maximum current efficiency of $3.83 \text{ cd } A^{-1}$ and a maximum external quantum efficiency of 4.19% with CIE coordinates of (0.16, 0.09). To the best of our knowledge, this device performance is among the highest for deep-blue fluorescent OLEDs that are based on solution-processable conjugated starbursts.

Results and Discussion

Synthesis and characterization: Oligofluorene boronic acids of different chain lengths (F1–F3) were prepared according to a literature procedure.^[32–33] FATPA-Br was synthesized according to our previous procedure.^[36–37] Starburst oligofluorenes T1–T3 were prepared through Suzuki cross-coupling reactions of FATPA-Br and the oligofluorene boronic acids (Scheme 1). All of the new compounds were character-

ized by ¹H and ¹³C NMR spectroscopy, MS (MALDI-TOF), and elemental analysis.

Thermal properties: The good thermal stability of these compounds was indicated by their high decomposition temperatures (T_d , which corresponded to 5% weight loss), which were in the range of 409–435°C, as determined by TGA (Figure 1). Their glass-transition temperatures (T_e),



Figure 1. TGA thermograms of oligomers T1–T3 at a heating rate of 10 °C min⁻¹; inset: DSC traces of oligomers T1–T3 at a heating rate of 10 °C min⁻¹.

which were determined by DSC, increased with increasing arm length (T1: 123 °C to T3: 129 °C; Figure 1, inset). These values were significantly higher than those for corresponding star-shaped oligofluorenes that were based on a benzene core^[34] and poly(9,9-dihexylfluorene) ($T_g = 103$ °C).^[38] This result demonstrated that the construction of a bulky star-shaped architecture with a rigid FATPA core could effectively suppress the crystallizing tendency and improve the morphological stability.



Scheme 1. Synthesis of oligomers T1–T3; reagents and conditions: a) [Pd(PPh_3)_4], 2 M Na₂CO₃, THF, 85 °C, 48 h.



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Figure 2. AFM topographic images of solid thin films of oligofluorenes T1-T3 (thickness: 50 nm, size: 5 µm × 5 µm).

We also recorded atomic force microscopy (AFM) images to investigate the morphological stability of these materials. Figure 2 shows the AFM images of oligomers T1-T3 on an ITO substrate. The thin film was prepared by spin-coating and annealing under a N₂ atmosphere at 100°C for 10 min. The annealed films had a fairly smooth surface morphology with root-mean-square (rms) roughness of 0.361, 0.365, and 0.417 nm for oligomers T1, T2, and T3, respectively. The excellent thermal and morphological stability of these oligomers enabled the preparation of homogeneous and stable amorphous thin films through solution processing.

Photophysical properties: Figure 3 shows the absorption and fluorescence spectra of oligomers T1-T3 both as a solution in toluene and as solid-state films. The photophysical data of the compounds are summarized in Table 1. The absorption band from 378–390 nm was due to the π - π * transition of the FATPA core, whilst the absorption peaks at around 296, 335, and 353 nm were attributed to the π - π * transition of the oligofluorenes. The absorption bands showed a red-shift on increasing the length of the oligofluorene arms, owing to the extended conjugation. The emission maxima of these compounds were in the range of 427-441 nm in solution and 431-450 nm in the solid-state films. The absorption and emission spectra of the films were similar to those in solution and only exhibited a small red-shift in the emission maxima, thereby indicating the absence of intermolecular interactions in the thin films. This result could be attributed to the bulky star-shaped structures that effectively restrained intermolecular aggregation. The emission bands showed a significant red-shift from oligomers T2 to T1, but only a slight red-shift from oligomers T3 to T2, thus suggesting that the emission was rapidly saturated with the extended arms. The fluorescence quantum yields of the starbursts were measured in a dilute solution in toluene by using 9,10diphenyl-anthracene (DPA; $\Phi = 0.90$) as a reference. These



Figure 3. UV/Vis absorption and PL spectra of oligomers T1-T3 as a) a solution in toluene $(5 \times 10^{-6} \text{ M})$ and b) a thin film.

deep-blue emitters showed almost unit quantum efficiencies, of 0.97, 0.98, and 1.00, respectively.

Electrochemical properties: The electrochemical behavior of compounds T1-T3 was investigated by CV (Figure 4). All of these compounds showed two well-defined stepwise-oxidation waves: The first reversible oxidation process at around 0.4 V (versus Fc⁺/Fc) could be attributed to the oxidation of the bridged triphenylamine core whilst the second wave could be attributed to the oxidation of the oligofluorene arms. As shown in Figure 4, an increase in the conjugat-

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Table 1. Photophysical and thermal data of oligomers T1-T3.

Compound	$T_{g}^{[a]}$ [°C]	$T_{d}^{[b]}$ [°C]	$\lambda_{abs}^{[c]}$ [nm]	$\lambda_{em,max}^{[c]}$ [nm]	$\lambda_{abs}^{[d]}$ [nm]	$\lambda_{\mathrm{em,max}}^{[d]}$ [nm]	HOMO ^[e] / LUMO ^[f] [eV]	${\pmb \Phi}_{ ext{PL}}{}^{[ext{g}]}$
T1	123	409	296,	427	296, 284	431	5.15/2.22	0.97
T2	125	435	378 335,	439	384 339,	445	5.14/2.29	(0.31) 0.98
Т3	129	432	389 353.	442	397 359.	450	5.15/2.32	(0.28)
			389		394			(0.46)

[a] Obtained from DSC measurements; [b] obtained from TGA measurements; [c] measured in toluene; [d] measured in a thin film; [e] determined from the onset of the oxidation potentials; [f] deduced from the HOMO and E_g values; [g] fluorescence quantum yields in toluene were measured with 9,10-diphenyl-anthracence (Φ =0.90) as a standard, and the fluorescence quantum yields in solid-state films were measured on a quartz plate with an integrating sphere (in parenthesis).



Figure 4. CVs of oligomers T1-T3 in CH₂Cl₂.

ed length from T1 to T3 led to a shift in the peaks of the second wave from 1.02 to 0.86 V (versus Fc⁺/Fc). Moreover, the ratio of the current value of the second wave to the first wave was significantly enhanced owing to the increase in number of fluorene units from oligomers T1 to T3. The HOMO energy levels, estimated from the $E_{1/2}$ (half-wave potential) values of the oxidation, were around 5.15 eV with regard to the energy level of ferrocene (4.8 eV below vacuum), which matched well with that of poly(3,4-ethylenedioxythiopene):poly(styrenesulfonate) (PEDOT:PSS) (5.1 eV) and should result in an efficient hole-injection from PEDOT:PSS to the emissive layer. The band gaps (E_{g}) of oligomers T1-T3, on the basis of the red edge of the longest absorption wavelength for the solid-film sample, were estimated to be 2.93-2.83 eV, and decreased with increasing the length of the oligofluorene arms. The LUMOs were in the range of 2.22-2.32, which were deduced from the HOMO and $E_{\rm g}$ values (Table 1).

Deep-blue electroluminescence: The good solubility, deepblue emission, and good film-forming ability enabled the starburst oligofluorenes to be used as the solution-processable deep-blue emitters in electroluminescent devices. Initially, single-layer devices were fabricated with the structure of indium tin oxide (ITO)/PEDOT:PSS (40 nm)/T1–T3 (50 nm)/CsF (1.5 nm)/Al (120 nm). PEDOT:PSS and CsF acted as hole- and electron-injecting layers, respectively. The maximum external quantum efficiency increased from

0.27% for the T1-based device to 0.82% for the T3-based device (see the Supporting Information, Figure S1 and Table S1). To optimize the device structure, double-layer devices were fabricated with the configuration of ITO/PEDOT:PSS (40 nm)/T1-(50 nm)/1,3,5-tris(N-phenylbenzimidazol-2-yl)-T3 benzene (TPBI) (40 nm)/CsF (1.5 nm)/Al (120 nm) (emitter: T1, device A; T2, device B; T3, device C), in which TPBI was inserted between the EML and CsF layers as an electron-transporting layer. As a result, the EL performances of the bilayer devices showed significant improvement (Table 2). This result could be attributed to the lower LUMO energy (2.7 eV) and the much-lower HOMO energy level (6.2 eV) of TPBI than those of oligomers T1-T3, which could facilitate electron transport and efficiently block the holes and excitons.

Table 2. Electroluminescence characteristics of the devices.^[a]

Device	$V_{ m on}$ [V]	$L_{\max} [\operatorname{cd} \operatorname{m}^{-2}], V [V]$	$\eta_{ m c,max} \ [m cdA^{-1}]$	$\eta_{ m p,max} \ [m lm \ W^{-1}]$	$\eta_{ m max}$ [%]	CIE $[x, y]^{[b]}$
A	4.4	365, 9.0	1.63	0.98	1.82	0.19, 0.11
В	3.8	602, 7.8	1.96	1.23	2.30	0.16, 0.11
С	3.4	732, 6.6	3.83	3.16	4.19	0.16, 0.09

[a] Abbreviations: V_{on} : turn-on voltage; L_{max} : maximum luminance; $\eta_{\text{c,max}}$: maximum current efficiency; $\eta_{\text{p,max}}$: maximum power efficiency; $\eta_{\text{ext,max}}$: maximum external quantum efficiency; CIE [x, y]: Commission International de l'Eclairage coordinates. [b] Measured at 10 mA m⁻².

Oligomers T1–T3 showed deep-blue emission in their EL spectra with CIE coordinates of (0.19, 0.11) for device A, (0.16, 0.11) for device B, and (0.16, 0.09) for device C (Figure 5). The EL spectra of T2- and T3-based devices are similar to their PL spectrum, thus indicating the efficient suppression of the excimer or exciplex during the EL process. However, the EL spectrum of the T1-based device shows a residue residual emission band at 520–620 nm, which may have been due to the formation of an exciplex at the interface between TPBI and the emitting layer.



Figure 5. Normalized EL spectra of devices A-C. Inset: CIE coordinates.

Figure 6 shows the current-density-voltage-brightness (J-V-L) characteristics and plots of efficiency versus current

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Figure 6. a) Current-density–voltage–brightness (J–V–L) characteristics for devices A–C; b) current efficiency c) EQE and power efficiency versus current density curves for devices A–C.

density for the three devices. All of the devices had a low turn-on voltage (below 5 V), which should be attributed to the high-lying HOMO levels of these oligomers, which matched well with the HOMO level of the adjacent PE-DOT:PSS and thus facilitated the hole injection of the device.

The T1-based device showed a turn-on voltage of 4.4 V, a maximum current efficiency ($\eta_{c,max}$) of 1.63 cd A⁻¹, a maximum power efficiency ($\eta_{p,max}$) of 0.98 lm W⁻¹, and a maximum external quantum efficiency ($\eta_{ext,max}$) of 1.82%. The performance of the T2-based device was significantly improved, with a turn-on voltage of 3.8 V, $\eta_{c,max} = 1.96$ cd A⁻¹, $\eta_{p,max} = 1.23$ lm W⁻¹, and $\eta_{ext,max} = 2.30$ %. The best performance was achieved by T3, with a low turn-on voltage of 3.4 V, $\eta_{c,max} = 3.83$ cd A⁻¹, $\eta_{p,max} = 3.16$ lm W⁻¹, and $\eta_{ext,max} =$ 4.19%. The device performances are summarized in Table 2. To the best of our knowledge, the performance of the T3based device is comparable with the other solution-processed deep-blue fluorescent OLEDs,^[20-24] and among the highest reported for undoped deep-blue OLEDs that are based on solution-processable starburst oligofluorenes.^[26-30] The EL performance was enhanced with the lengthening of the oligofluorene arms from T1 to T3: the turn-on voltages decreased from 4.4 to 3.4 V, whilst the maximum efficiencies (current efficiency, power efficiency, and external quantum efficiency) increased from 1.63 to 3.83 cd A^{-1} , from 0.98 to 3.16 lm W^{-1} , and from 1.82 to 4.19%, respectively. This improvement could be elucidated from the following observations: 1) The carrier-transport ability of the emitters would be gradually enhanced from T1 to T3 because of the extended conjugation. 2) As shown in Figure 7, the LUMO



Figure 7. Energy level diagrams for devices A-C.

level of T3 (2.32 eV) was 0.03 eV lower than that of T2, and 0.10 eV lower than T1. Thus, the electron injection barriers between TPBI (LUMO: 2.7 eV) and the EML decreased from T1 to T3; therefore, more-balanced charge flux could be anticipated in T3. 3) T3 showed the highest photoluminescence quantum yield in the solid-state film among the three compounds.

Conclusion

We have developed a series of starburst oligofluorenes (T1– T3) that were based on a rigid planar triphenylamine core. All of the starbursts showed excellent thermal stability, pronounced PL efficiency, and good solution-processability. Double-layer devices that used the oligofluorenes as the emission layer were fabricated by using a spin-coating method. All three devices showed high EL performance and the T3-based device achieved a maximum current efficiency of 3.83 cd A⁻¹ and maximum external quantum efficiency of 4.19% with CIE coordinates of (0.16, 0.09). This strategy will be valuable for the rational design and development of efficient blue EL oligomers and other related materials.

Experimental Section

General information: ¹H and ¹³C NMR spectra were measured on a MECUYR-VX300 spectrometer. Elemental analysis was performed on a Vario EL III microanalyzer. MS was measured on a ZAB 3F-HF mass spectrophotometer. MALDI-TOF (matrix-assisted laser-desorption/ionization time-of-flight) MS was performed on Bruker BIFLEX III TOF mass spectrometer. UV/Vis absorption spectra were recorded on a Shi-



madzu UV-2500 recording spectrophotometer. Photoluminescence spectra were recorded on a Hitachi F-4500 fluorescence spectrophotometer. The PL quantum yields of the solid-state films were measured according to an absolute method by using an Edinburgh Instruments (FLS920) integrating sphere that was excited with a Xe lamp. Differential scanning calorimetry (DSC) was performed on a NETZSCH DSC 200 PC unit from RT to 300 °C at a heating rate of 10 °C min⁻¹ under an argon atmosphere. The glass-transition temperature was determined from the second heating scan. Thermogravimetric analysis (TGA) was performed on a NETZSCH STA 449C instrument. The thermal stability of the samples under a nitrogen atmosphere was determined by measuring their weight loss whilst heating from 25-800 °C at a rate of 15 °C min⁻¹. Cyclic voltammetry was carried out in nitrogen-purged THF (reduction scan) and CH22Cl2 (oxidation scan), with a CHI voltammetric analyzer. Tetrabutylammonium hexafluorophosphate (TBAPF₆, 0.1 M) was used as the supporting electrolyte. The conventional three-electrode configuration consisted of a platinum working electrode, a platinum wire auxiliary electrode, and a Ag wire pseudo-reference electrode with ferrocenium/ferrocene (Fc+/Fc) as the internal standard. CVs were obtained at a scan rate of 100 mV s^{-1} . Formal potentials are calculated as the average of the cyclic voltammetric anodic and cathodic peaks. The onset potential was determined from the half-wave oxidation potential.

Device fabrication and measurement: Patterned ITO-coated glass with a sheet resistance of 15–20 Ω square⁻¹ were cleaned by a surfactant scrub followed by a wet-cleaning process inside an ultrasonic bath, beginning with deionized water, and followed by acetone and isopropanol. After oxygen plasma cleaning for 4 min, 40 nm of PEDOT:PSS (Bayer Baytron P 4083), which was used as a hole-injection layer at the anode interface, was spin-coated on the ITO substrate and then dried in a vacuum oven at 80°C overnight. The emissive layer (EML) was coated onto the anode by spin-coating from a solution of chlorobenzene, and then annealed at 100°C for 10 min to remove the solvent residue. The thickness of the EML was about 50 nm. Finally, an electron-transporting layer of TPBI $(30 \ nm)$ and a cathode that was composed of CsF $(1.5 \ nm)$ and an Al (120 nm) layer were evaporated with a shadow mask at a base pressure of 3×10^{-4} Pa. The thickness of the evaporated cathode was monitored by a quartz crystal thickness/ratio monitor (Model: STM-100/MF, Sycon). The overlapping area between the cathode and the anode defined a pixel size of 19 mm². Except for the deposition of the PEDOT layers, all of the fabrication processes were carried out inside a controlled atmosphere of a nitrogen dry-box (Vacuum Atmosphere Co.) that contained less than 10 ppm oxygen and moisture. The current-density-luminance-voltage characteristic was measured by using a Keithley 236 source measurement unit and a calibrated silicon photodiode. The forward-viewing luminance was calibrated by a spectrophotometer (SpectraScan PR-705, Photo Research) and the forward-viewing LE was calculated accordingly. Herein, the luminance and LE values were for the forward-viewing direction only. The external quantum efficiency of EL was collected by measuring the total light output in all directions in an integrating sphere (IS-080, Labsphere). The EL spectra were collected on a PR-705 photometer.

Materials and synthesis: Oligofluorene boronic acids of different chain lengths (F1–F3) were prepared according to a literature procedure.^[32–33] FATPA-Br was synthesized according to our previous procedure.^[36–37] The Suzuki coupling reaction was conducted under a nitrogen atmosphere and by avoiding exposure to light.

Synthesis of T1: To a mixture of FATPA-Br (0.265 g, 0.25 mmol), 9, 9-dihexyl-9*H*-fluoren-2-ylboronic acid (0.416 g, 1.10 mmol), [Pd(PPh₃)₄] (0.026 g, 0.02 mmol), were added degassed THF (6 mL) and 2 M Na₂CO₃ in distilled water (2 mL, 4.00 mmol). The mixture was heated to reflux for 48 h under an argon atmosphere. After cooling to RT, the solution was extracted with CH₂Cl₂ and the organic layer was washed with brine and water and then dried over anhydrous Na₂SO₄. After the solvent had been removed under reduced pressure, the residue was purified by column chromatography on silica gel (petroleum ether/EtOAc, 50:1) to give the product as a yellow powder. Yield: 77%; ¹H NMR (300 MHz, CDCl₃): δ =7.75-7.43 (m, 21 H), 7.33-7.25 (m, 6H), 6.91 (d, *J*=7.2 Hz 12 H), 6.81 (d, *J*=8.1 Hz, 12 H), 2.33 (s, 18 H), 1.95-1.70 (m, 12 H), 1.15-0.95 (m, 48 H), 0.75 ppm (t, *J*=7.2 18 H); ¹³C NMR (75 MHz, CDCl₃):

$$\begin{split} &\delta\!=\!151.63,\ 151.28,\ 143.29,\ 141.12,\ 140.21,\ 139.55,\ 135.67,\ 135.36,\ 134.96,\\ &130.64,\ 129.74,\ 128.52,\ 127.11,\ 126.47,\ 125.28,\ 123.18,\ 121.14,\ 119.98,\ 56.07,\\ &55.21,\ 40.67,\ 31.79,\ 30.09,\ 24.05,\ 22.94,\ 21.34,\ 14.36\ ppm;\ MS\ (MALDI-TOF):\ m/z:\ 1819.7;\ elemental\ analysis\ calcd\ (\%)\ for\ C_{138}H_{147}N:\ C\ 90.97,\\ H\ 8.55,\ N\ 0.99;\ found:\ C\ 91.09,\ H\ 8.14,\ N\ 0.77. \end{split}$$

Synthesis of T2: Oligomer T2 was synthesized according to a similar procedure as T1. Yield: 71 %; ¹H NMR (300 MHz, CDCl₃): δ = 7.79–7.59 (m, 33 H), 7.37–7.25 (m, 12 H), 6.94 (d, *J* = 6.3 Hz 12 H), 6.84 (d, *J* = 7.2 Hz, 12 H), 2.35 (s, 18 H), 2.15–1.80 (m, 24 H), 1.18–0.96 (m, 72 H), 0.85–0.65 ppm (m, 60 H); ¹³C NMR (75 MHz, CDCl₃): δ = 151.62, 151.32, 150.87, 140.69, 140.20, 135.23, 130.22, 128.08, 126.71, 125.92, 122.78, 121.32, 119.76, 55.03, 54.92, 40.27, 31.33, 29.60, 23.67, 22.46, 20.90, 13.91 ppm; MS (MALDI-TOF): *m*/*z*: 2816.6; elemental analysis calcd (%) for C₂₁₃H₂₄₃N: C 90.89, H 8.72, N 0.44; found: C 90.81, H 8.69, N 0.50.

Synthesis of T3: Oligomer T3 was synthesized according to a similar procedure as T1. Yield: 73 %; ¹H NMR (300 MHz, CDCl₃): δ =7.83–7.60 (m, 33 H), 7.40–7.17 (m, 30 H), 6.94 (d, *J*=8.1 Hz 12 H), 6.85 (d, *J*=8.1 Hz, 12 H), 2.36 (s, 18 H), 2.15–1.82 (m, 36 H), 1.18–1.02 (m, 108 H), 0.85–0.67 ppm (m, 90 H); ¹³C NMR (75 MHz, CDCl₃): δ =151.70, 142.86, 140.46, 139.93, 135.29, 130.26, 129.38, 128.14, 126.94, 126.07, 122.84, 121.42, 119.86, 55.09, 40.32, 31.37, 29.61, 23.73, 22.49, 20.93, 13.94 ppm; MS (MALDI-TOF): *m/z*: 3814.5; elemental analysis calcd (%) for C₂₈₈H₃₃₉N: C 90.57, H 9.08, N 0.19; found: C 90.68, H 8.96, N 0.37.

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OLEDs -

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Solution-Processed Undoped Deep-Blue Organic Light-Emitting Diodes Based on Starburst Oligofluorenes with a Planar Triphenylamine Core



She's a star: Three starburst oligomers that have a rigid planar triphenylamine core and oligofluorene arms were synthesized (see figure). The undoped deep-blue OLED with T3 as the emitter showed a maximum current efficiency of 3.83 cd A^{-1} and a maximum external quantum efficiency of 4.19 % with CIE coordinates of (0.16, 0.09), which is among the highest values for undoped deep-blue OLEDs that are based on solution-processable conjugated starbursts.