Supplementary Figures

Supplementary Figure 1 | Fluorescence behaviour according to Kasha’s rule and the energetic splitting in H-aggregation and J-aggregation. In H-aggregation, the co-facial dimmers (represented by yellow parallelogram) induce in strong molecular interaction which will cause the appearing of energy splitting and quenching the emission. An efficient way to prevent the quenching is to tune the molecular packing motifs to weaken intermolecular dipole-dipole interactions, e.g., shifting the co-facial H-aggregation to head-to-tail J-aggregation.
Supplementary Figure 2 | Synthetic route to DPA.
Supplementary Figure 3 | XRD pattern of DPA single crystals. The strong and sharp diffraction peaks indicate the high quality of the crystals, and the reflections are indexed to be \( (h00) \) peaks according to the single crystal structure, which suggest the \( (h00) \) crystal plane is parallel to the surface of the substrate.
Supplementary Figure 4 | Molecular structure and packing of DPA in crystal. a, The molecular geometry of DPA. The anthracene core of DPA molecule is flat while the substituted phenyls are slightly out of the conjugated plane with a torsion angle of 20.05°. Molecular packing b, view along the short molecular axis and c, view along the molecular long axis, together with Fig. 2d showing the herringbone motif fashion with J-type aggregates in DPA crystals.
Supplementary Figure 5 | Transition dipole moment of DPA molecule and in crystals. a, Molecular transition dipole moment of DPA was preliminary estimated according to the calculated transition charge density wave of DPA molecule. Calculated transition charge density wave of DPA molecule, indicate that the direction of transition dipole moment (as shown by the arrow in a) is nearly parallel to the long axis of DPA molecule (red and green represents for negative and positive charges, respectively). b, Perspective view of molecular packing model within crystals relative to the substrate, with the light emission parallel to the $bc$ plane, thus leading to the bright edge emission for crystals. c, Measured PL intensity of DPA crystal under polarized laser. Insert: schematic drawing of polarized PL intensity measurement, the unchanged PL intensity in the different angles confirms that the transition dipole moment is perpendicular to the substrate in the crystals.
Supplementary Figure 6 | C-H–π interactions between DPA molecules. Multi- and strong intermolecular C-H-π interactions (with molecular distance only 2.84-2.86 Å) between DPA molecules are observed through the single crystal data analysis.
**Supplementary Figure 7 | Two-dimensional charge transport in DPA crystals.** DPA molecules adopt a herringbone motif with the J-aggregate molecular packing in crystals, which works effectively to minimize the quenching of the fluorescence of DPA in solid state (Supplementary Fig. 4). Meanwhile, multi-/strong intermolecular C-H-π interactions (with molecular distance only 2.84-2.86 Å) and compact molecular packing in DPA crystals are also beneficial for efficient charge carrier transport (Supplementary Fig. 6). Assuming one molecule accepts a charge, it could transfer the accepted charge to its near 2 neighbors, and then to other neighbors quickly, finally forming a two-dimensional network of charge transport (Supplementary Fig. 7) due to the multi-/strong C-H-π interactions and compact molecular packing.
Supplementary Figure 8 | Transport anisotropic features of DPA crystal. Single crystal devices fabricated based on the so-called “organic-ribbon-mask” technique makes it possible to probe the charge transport along different directions. An exemplified device of individual crystal with transfer characteristics along $b$ and $c$ axes are shown, and the mobility-anisotropy ratio is calculated at about 1.46 along $b$ and $c$ axes.
Supplementary Figure 9 | OLEDs performance of DPA devices with 30 and 40 nm DPA layer. a, AFM image of vacuum-deposited DPA films used in OLED device and b, corresponding XRD results, indicating the same molecular packing and orientation in the polycrystalline thin film with that of single crystals. c, Luminance-voltage-current density characteristics of 30 nm DPA devices, the maximum brightness was 3047, the turn on voltage was about 2.5. d, Efficiency of the devices, the performance of 40-nm devices is better than that based on 30-nm DPA film, due to the more balanced charge transport in the thicker films and it could be further optimized by balancing the hole and electron injection and recombination.
Supplementary Figure 10 | A plot of the DPA OLED light output vs time in response to a periodic square wave gate voltage (0 V and -60 V) on the DPA FET at $V_{DS} = -60$ V. The black line is square wave gate voltage applied and the red line is the output luminance. Bottom insert are the corresponding light emission on and off figures from one DPA OLED device driven by DPA FET in response to the periodic square wave gate voltage (0 V and -60 V).
Supplementary Figure 11 | Performances of OFET driving OLED circuits based on the same DPA compound. a, Brightness of the OLED (blue dotted line) and drain current $I_D$ supplied by the OFET to the OLED (dark dotted line) as a function of the OFET gate voltage $V_G$. $I_D$ is normalized by the area $A$ of the OLED. b, Drain current $I_{D,\text{all}}$ supplied by all the 25 OFETs to the OLEDs as a function of the OFET gate voltage $V_G$. c, Electroluminescence spectra of DPA-OLEDs driven by DPA-OFETs.
Supplementary Note 1 | Synthesis procedures of 2,6-diphenylanthracene (DPA)

DPA is synthesized through three facile steps with yields over 85% (Supplementary Fig. 2). 2,6-dihydroxyanthracene-9,10-dione was purchased from Sigma Aldrich and was used as received. Triethylamine and dichloromethane (dried by molecular sieve) were used for the esterification reaction. Tetrakis(triphenylphosphine)palladium(0) and trifluoromethanesulfonic anhydride was purchased from Strem Chemicals and were used as received. NMR spectra were recorded using a Bruker ADVANCE 400 NMR Spectrometer and \(^1\)H NMR spectra were referenced to CDCl\(_3\) (7.26 ppm). Elemental analysis was carried out on Flash EA 1112 Elemental Analyzer. AEI-MS50-MS spectrometer was used for molecular weight determination.

2,6-Diol-anthracene: Sodium borohydride (2.4 g, 62.5 mmol) and 1M sodium carbonate solution (60 mL) were added into a flask with magnetic bar. 2,6-Dihydroxyanthracene-9,10-dione (1.2 g, 5 mmol) was added. After gas evolution stopped, the flask was heated up to 80 °C for 30 min, and then transferred to a 500 mL baker fitted with magnetic bar and slowly acidified with 3M HCl (60 mL) and then filtrated and dried. The filtrate was washed on a filter with acetone and the solution was evaporated under reduced pressure to afford brown solid 0.72 g (68% yield). \(^1\)H-NMR (400 MHz, CDCl\(_3\)): \(\delta\) [ppm] 9.69 (s, 2H), 8.19 (s, 2H), 7.87 (d, 2H), 7.18 (d, 2H), 7.12 (dd, 2H). MS (EI): m/z 210 (M\(^+\)).

2,6-Diyl bis(trifluoromethanesulfonate)-anthracene: Crude product 1 (420 mg, 2 mmol), dry dichloromethane (8 mL) and triethylamine (1.4 mL) were added into a 50 mL flask charged with magnetic bar, then protected under argon. After cooling to -20 °C, triflic anhydride (0.82 mL, 5 mmol) was added dropwise via syringe. The mixture was stirred for 2 h and then warmed up to room temperature. Dichloromethane (10 mL) was added and the mixture was washed with water (10 mL × 3) and brine (10 mL × 3). The organic layer was separated, dried over Na\(_2\)SO\(_4\) and evaporated under reduced
pressure, the crude product was purified by column chromatography (silica, petroleum/dichloromethane) to afford white yellowish solid (550 mg, 58% yield). $^1$H-NMR (400 MHz, CDCl$_3$): $\delta$ [ppm] 8.41 (s, 2H), 8.03 (d, 2H), 7.89 (d, 2H), 7.40 (dd, 2H). MS (EI): m/z 474 (M$^+$).

2,6-Diphenylanthracene (DPA): 474 mg (1 mmol) 2,6-Diyl bis(trifluoromethanesulfonate)-anthracene, 268 mg (2.2 mmol) phenylo boric acid and Pd(PPh$_3$)$_4$ 63 mg (0.05 mmol) were added into a 100 mL flask under argon. Then 2 mL ethanol, 8 mL toluene and 2 mL 2 M K$_2$CO$_3$ aqueous solution were added, and heated to 90 °C and kept overnight. Then the system was filtered, washed with triethylamine, dichloromethane, water and ethanol successively. DPA is obtained as a yellow solid in a yield of 85% (280 mg). $^1$H-NMR (400 MHz, CDCl$_3$): $\delta$ [ppm] 8.50 (s, 2H), 8.21 (s, 2H), 8.10 (d, 2H), 7.78 (m, 6H), 7.52 (t, 4H), 7.40 (m, 2H). MS (EI): m/z 330 (M$^+$). Elemental analysis calculated for C$_{26}$H$_{18}$: C 94.51, H 5.49. Found: C 94.48, H 5.45.