Supplementary Information

Absence of delayed fluorescence and triplet-triplet annihilation in organic light emitting diodes with spatially orthogonal bianthracenes

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**Materials.** TAPC, MADN, CBP, and TPBi were purchased from e-Ray. A nitrogen-phosphorus detector was purchased from Chemipro Kasei. PEDOT:PSS was purchased from Clevious. B3PyPB were prepared according to the literature.\(^1\) PPBA was synthesized by general Suzuki coupling methods. \(^1\) 10,10’-Dibromo-9,9′-bianthracene (Luminescence Technology, 0.618 g, 1.21 mmol), phenylboronic acid (Wako, 0.372 g, 3.05 mmol), Pd(PPh\(_3\))\(_4\) (TCI, 50 mg, 0.043 mmol), K\(_2\)CO\(_3\) (0.512 g, 3.70 mmol), water (20 mL) and ethanol (10 mL) were mixed in a flask containing nitrogen-saturated toluene (20.0 mL). The reaction mixture was refluxed for 14 h under nitrogen. After it was cooled to room temperature, the reaction mixture was quenched with brine and extracted with toluene. The combined organic extracts were dried with anhydrous MgSO\(_4\) and evaporated. The crude product was successfully purified by column chromatography using dichloromethane as the eluent, and then further purified by train sublimation to give yellow crystals. Yield: 44% (270 mg). \(^1\) H NMR (400 MHz, CDCl\(_3\), \(\delta\)): 7.72–7.76 (8H), 7.64–7.69 (6H), 7.44 (t, \(J = 7.5\) Hz, 4H, ), 7.27 (t, \(J = 7.5\) Hz, 4H), 7.08 (d, \(J = 8.6\) Hz, 4H) ppm. EI-MS (m/z): calcd for C\(_{40}\)H\(_{26}\), 506.63; found, 507 [M]\(^+\).

**Measurement of optical properties.** UV-vis absorption spectra were recorded on a Shimadzu UV-3150 spectrometer. PL spectra were measured using a Jobin Yvon Fluoromax-4 fluorometer. PL quantum efficiencies were measured on a Hamamatsu C9920-01 integral sphere system in a nitrogen atmosphere. For measurements of PL-decay profiles, a laser-diode (405 nm, Hamamatsu PLP10-040) with a pulse duration of 100 ps and a repetition rate of 100 kHz was used as the excitation light. The PL-decay profiles were obtained using a time-correlated single-photon counting method.

**Device fabrication and characterization.** All the devices were fabricated on glass substrates pre-coated with a 130 nm thick layer of indium tin oxide (ITO) with a sheet resistance of 15 Ω/square. The substrates were cleaned with ultra-purified water and organic solvents and then cleaned for 30 min by exposure to a UV-ozone ambient. The organic compounds were successively deposited onto the ITO substrate under a vacuum (~10-5 Pa). LiF and Al were patterned using a shadow mask with an array of openings (2 mm × 2 mm) without breaking the vacuum (~10-5 Pa). All the devices were encapsulated under a nitrogen atmosphere immediately after preparation using epoxy glue and glass lids. The EL spectra were measured using an optical multichannel analyzer (Hamamatsu Photonics PMA-11). The current density–voltage and luminance–voltage characteristics were measured using a Keithley 2400 source measurement unit and a Minolta CS200 luminance-meter, respectively. The transient EL decay was measured using a function generator (Agilent 33220A), an oscilloscope (Tektronix DPO 3052), and an Si photodetector (Hamamatsu Photonics H7826). After applying a forward-pulse voltage, the \(-2\) V of the reverse-pulse voltage was applied. The magnetic field
dependence of EL was measured with an electromagnet (Tamakawa Co. TM-YSV-043). The magnetic field was applied parallel to the substrate and measured every second using a gaussmeter (Lake Shore, 425). The sample was cooled to 77 K using a cryostat (Oxford Instruments, Optistat DN).
**Table S1.** Photophysical properties of the compounds\(^a\)

<table>
<thead>
<tr>
<th></th>
<th>UV (film) (nm)</th>
<th>PL (neat) (nm)</th>
<th>PLQY (neat) (%)</th>
<th>(\tau_1) (neat) (ns)</th>
<th>PL (doped) (nm)</th>
<th>PLQY (doped) (%)</th>
<th>(\tau_1) (doped) (ns)</th>
<th>(\tau_2) (C(_1)) (doped) (ns)</th>
<th>(R^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADN</td>
<td>405, 384, 365, 345</td>
<td>449</td>
<td>41</td>
<td>1.04</td>
<td>433</td>
<td>62</td>
<td>4.54</td>
<td>_</td>
<td>0.998</td>
</tr>
<tr>
<td>PPBA</td>
<td>407, 384, 364, 344</td>
<td>443</td>
<td>14</td>
<td>0.95</td>
<td>440</td>
<td>80</td>
<td>3.49 (0.338)</td>
<td>9.56 (0.656)</td>
<td>0.999</td>
</tr>
</tbody>
</table>

\(^a\) Doped films were prepared as 1wt% in CBP.  
\(^b\) Obtained by fitting the following equation: \(I = C_1\exp(-t/\tau_1) + C_2\exp(-t/\tau_2)\)

**Table S2.** Performances of the devices.

<table>
<thead>
<tr>
<th>Emitter</th>
<th>(V_{\text{on}}) (^a) (V)</th>
<th>Current efficiency(_{\text{max,100,1000}}) (^b) (cd/A)</th>
<th>Power efficiency(_{\text{max,100,1000}}) (^b) (lm/W)</th>
<th>EQE(_{\text{max,100,1000}}) (^b) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADN</td>
<td>non-doped 2.8</td>
<td>3.7/3.3/2.6</td>
<td>4.1/2.9/1.7</td>
<td>4.7/4.2/3.4</td>
</tr>
<tr>
<td></td>
<td>doped 3.6</td>
<td>2.0/1.5/1.2</td>
<td>1.8/0.95/0.54</td>
<td>3.9/2.9/2.2</td>
</tr>
<tr>
<td>PPBA</td>
<td>non-doped 3.2</td>
<td>3.8/3.5/2.9</td>
<td>3.6/2.7/1.5</td>
<td>2.7/2.6/2.3</td>
</tr>
<tr>
<td></td>
<td>doped 3.8</td>
<td>5.5/1.9/1.5</td>
<td>5.1/1.1/0.66</td>
<td>11/4.0/3.3</td>
</tr>
</tbody>
</table>

\(^a\) At 1 cd m\(^{-2}\); \(^b\) Maximum/at 100cd m\(^{-2}\)/at 1000 cd m\(^{-2}\)

**Fig. S1** UV spectra of the compounds.
**Fig. S2** Transient PL: (a) neat film and (b) 1 wt%-doped in CBP. The black lines are guides to the eye.

**Fig. S3** Current density–voltage and luminance–voltage plots
Fig. S4 Temperature dependence of PL

References