

## Tunable Full-Color Electroluminescence from All-Organic Optical Upconversion Devices by Near-Infrared Sensing

Hiroki Tachibana,<sup>†,‡</sup> Naoya Aizawa,<sup>†</sup> Yu Hidaka,<sup>†,‡</sup> and Takuma Yasuda<sup>\*,†,‡</sup>

<sup>†</sup>INAMORI Frontier Research Center (IFRC), Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

<sup>‡</sup>Department of Applied Chemistry, Graduate School of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

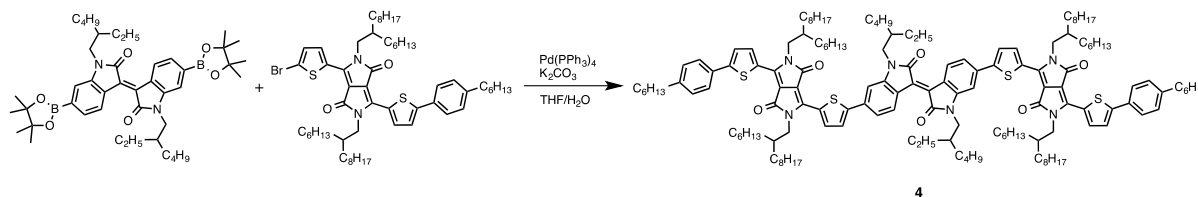
\*Correspondence and requests for materials should be addressed to T.Y. E-mail: yasuda@ifrc.kyushu-u.ac.jp

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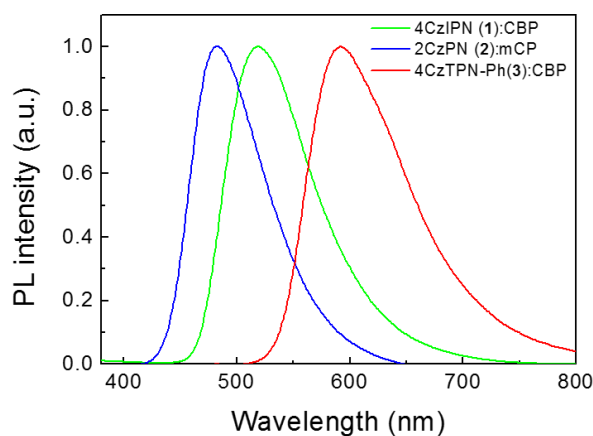
## Synthesis and Characterization

Commercially available reagents and solvents were used without further purification unless otherwise noted. NMR spectra were recorded on an Avance III 500 spectrometer (Bruker). Chemical shifts of  $^1\text{H}$  and  $^{13}\text{C}$  NMR signals were determined relative to the signals of tetramethylsilane ( $\delta = 0.00$ ),  $\text{CDCl}_3$  ( $\delta = 77.0$ ) as internal standards. Matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF) mass spectra were collected on an Autoflex III spectrometer (Bruker Daltonics) using dithranol as a matrix. Elemental analysis was carried out with a MT-5 CHN Corder (Yanaco).

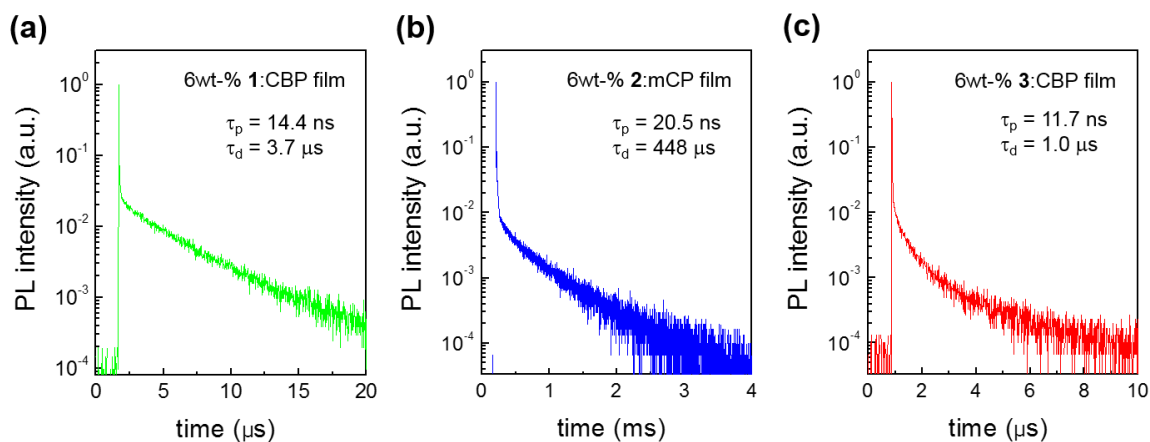


**Scheme 1.** Synthesis of **4**.

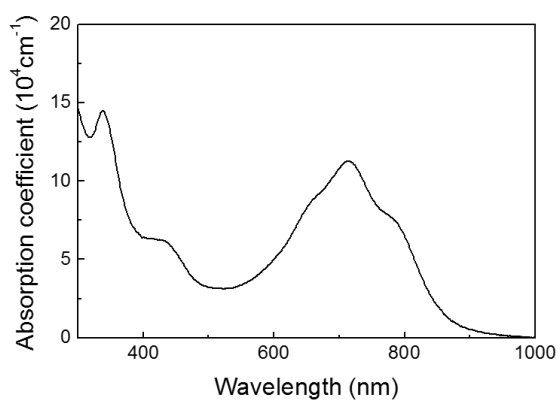
**Synthesis of 4.** To a mixture of 6,6'-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-*N,N'*-(2-ethylhexyl)isoindigo (0.505 g, 0.684 mmol) and 3-(5-bromothiophen-2-yl)-6-[5-(4-hexylphenyl)thiophen-2-yl]-2,5-bis(2-hexyldecyl)pyrrolo[3,4-*c*]pyrrole-1,4-dione (1.55 g, 1.57 mmol) in THF (20 mL) were added  $\text{Pd}(\text{PPh}_3)_4$  (0.032 g, 0.027 mmol) and aqueous  $\text{K}_2\text{CO}_3$  (2.0 M, 10 mL). The mixture was stirred for 48 h at 60 °C under  $\text{N}_2$ . After cooling to room temperature, the reaction mixture was poured into water and then extracted with chloroform. The combined organic layers were washed with water and dried over anhydrous  $\text{MgSO}_4$ . After filtration and evaporation, the product was purified by silica gel column chromatography (eluent: chloroform), recrystallized from chloroform/methanol, and dried under vacuum to afford **4** as a dark blue solid (yield = 0.905 g, 57%). This compound was further purified by recycling preparative gel permeation chromatography (eluent: chloroform) prior to use.  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ ):  $\delta$  9.17 (d,  $J = 8.5$  Hz, 2 H), 9.02 (d,  $J = 4.0$  Hz, 2 H), 9.01 (d,  $J = 4.0$  Hz, 2 H), 7.55 (d,  $J = 8.0$  Hz, 4 H), 7.47 (d,  $J = 3.0$  Hz, 2 H), 7.39 (d,  $J = 4.0$  Hz, 2 H), 7.24 (d,  $J = 8.0$  Hz, 2 H), 7.18 (d,  $J = 8.0$  Hz, 4 H), 6.96 (s, 2 H), 4.09 (d,  $J = 7.0$  Hz, 4 H), 4.01 (d,  $J = 7.0$  Hz, 4 H), 3.82-3.74 (m, 4 H), 2.60 (t,  $J = 7.5$  Hz, 4 H), 2.02-1.95 (m, 4 H), 1.92-1.87 (m, 2 H), 1.63-1.57 (m, 4 H), 1.48-1.22 (m, 124 H), 1.02 (t,  $J = 7.3$  Hz, 6 H), 0.94 (t,  $J = 7.0$  Hz, 6 H), 0.89 (t,  $J = 6.8$  Hz, 6 H), 0.86-0.82 (m, 24 H).  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ):  $\delta$  168.33, 161.50, 161.37, 150.11, 148.44, 145.62, 144.04, 140.03, 138.76, 137.42, 136.91, 135.91, 131.49, 130.67, 130.45, 129.85, 129.01, 128.22, 125.76, 124.87, 123.70, 122.01, 118.94, 108.58, 107.95, 104.42, 46.41, 46.29, 44.08, 38.06, 37.99, 35.75, 31.91, 31.88, 31.70, 31.40, 31.16, 31.03, 30.17, 31.14, 29.86, 29.79, 29.63, 29.60, 29.35, 29.34, 29.03, 28.90, 26.46, 26.40, 26.25, 24.33, 23.12, 22.69, 22.67, 22.64, 22.62. MS (MALDI-TOF):  $m/z$   $[M]^+$  calcd, 2300.55; found, 2301.27. Anal. Calcd (%) for  $\text{C}_{148}\text{H}_{214}\text{N}_6\text{O}_6\text{S}_4$ : C, 77.23; H, 9.37; N, 3.65; found: C, 77.16; H, 9.30; N, 3.69.



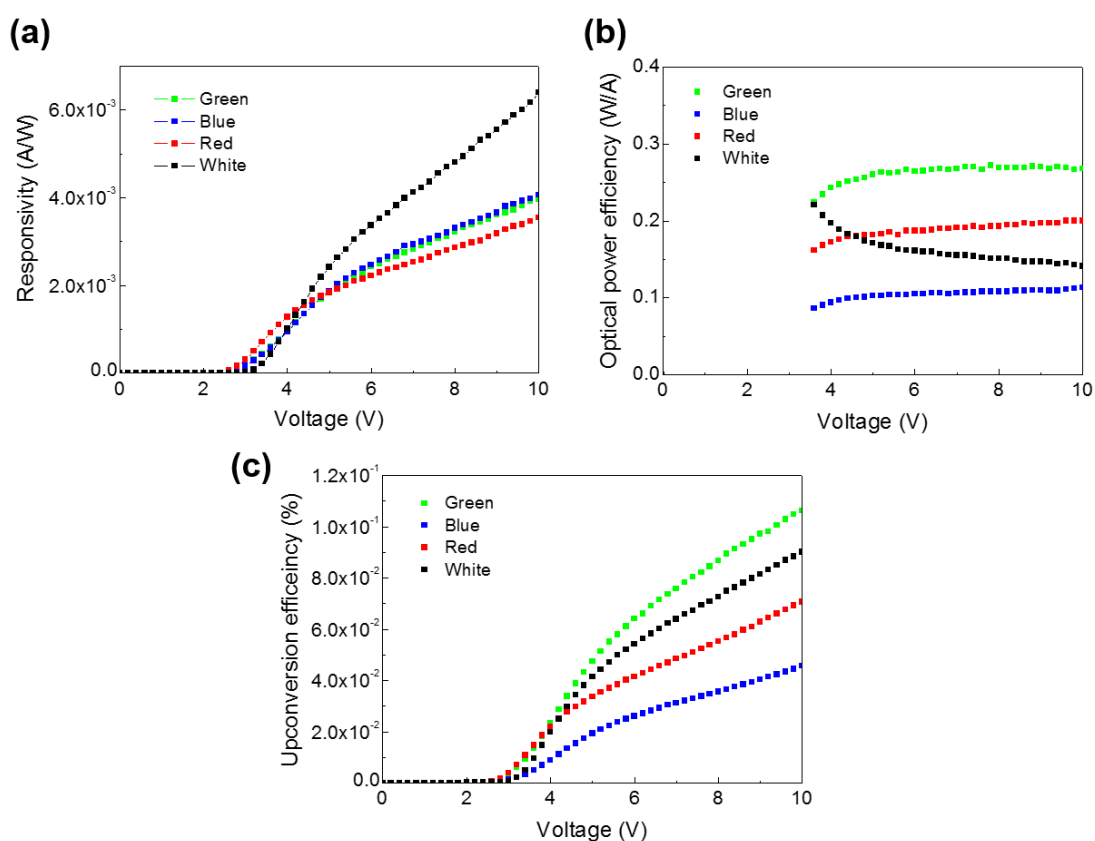
**Figure S1.** Photoluminescence spectra of 6-wt% doped thin films of **1** in CBP (green), **2** in mCP (blue), and **3** in CBP (red).



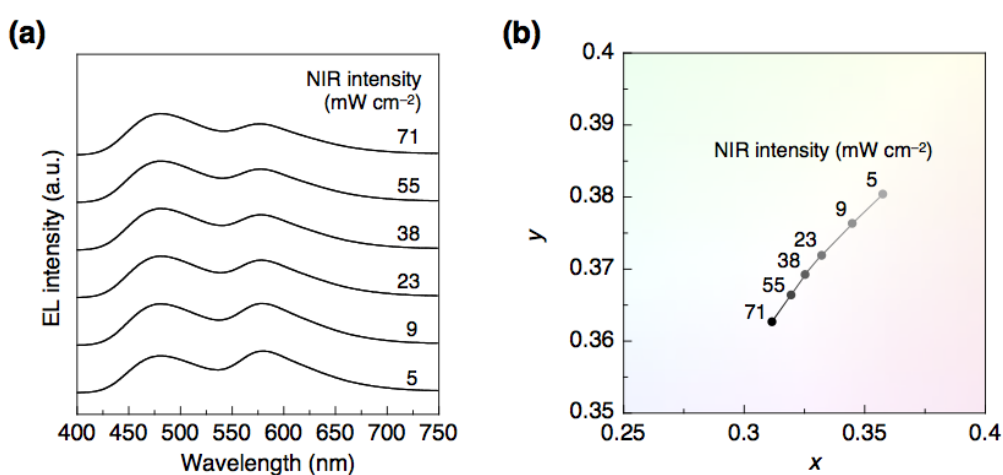
**Figure S2.** Transient PL decay curves of 6-wt% doped thin films of (a) **1** in CBP, (b) **2** in mCP, and (c) **3** in CBP measured at room temperature under N<sub>2</sub>.



**Figure S3.** UV-vis-NIR absorption spectrum of a BHJ blend film of **4**:PC61BM (1:1, w/w).



**Figure S4.** (a) Responsivities, (b) optical power efficiencies, and (c) upconversion efficiencies of organic optical upconversion devices based on TADF emitters **1** (green), **2** (blue), **3** (red), and **2/3** (white).



**Figure S5.** (a) EL spectra and (b) CIE color coordinates as a function of NIR intensity for the white upconversion device.