Supplementary Information

Doped crystalline thin-film deep-blue organic light-emitting diodes

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Contents:

1. Time-of-flight (TOF) mobility

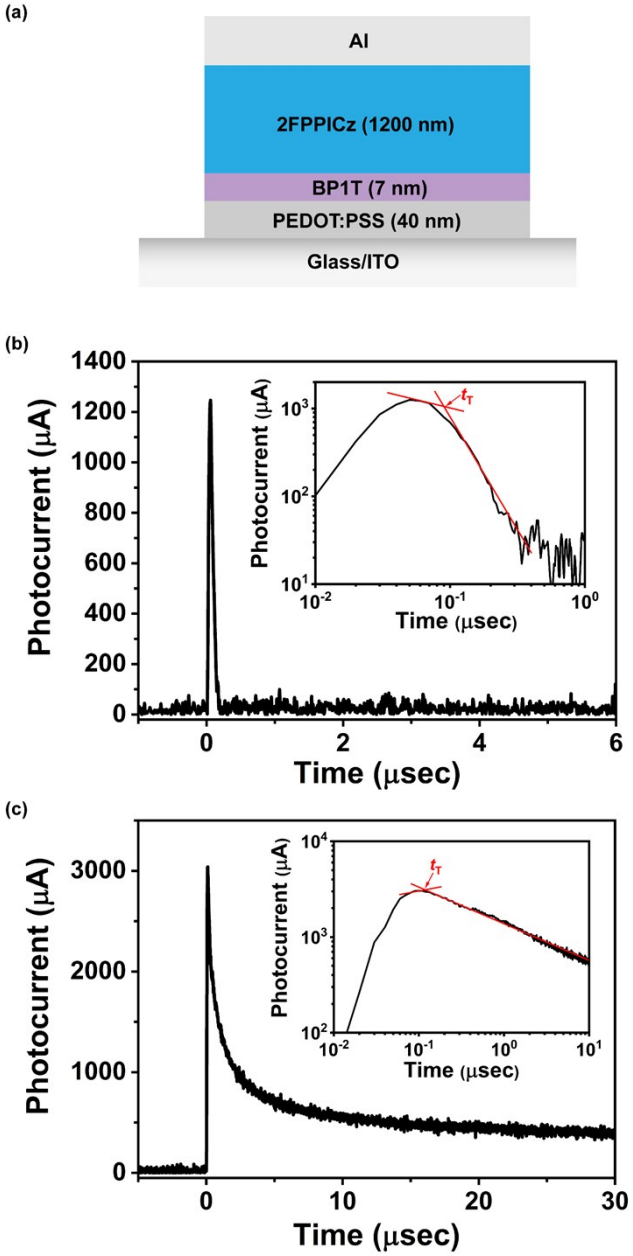


Fig. S1 Typical transient photocurrent signals for 2FPPICz WEG crystalline thin film. (a) Schematic diagram of device structure of TOF mobility measurement. (b-c) Representative TOF transients for hole at $E = 1.0 \times 10^4\, V\, cm^{-1}$ (b) and electron at $E = 9.1 \times 10^4\, V\, cm^{-1}$ (c) at room temperature. The insets are double-logarithmic plots of the data in (b) and (c).

2. EL performance of non-doped C-OLED

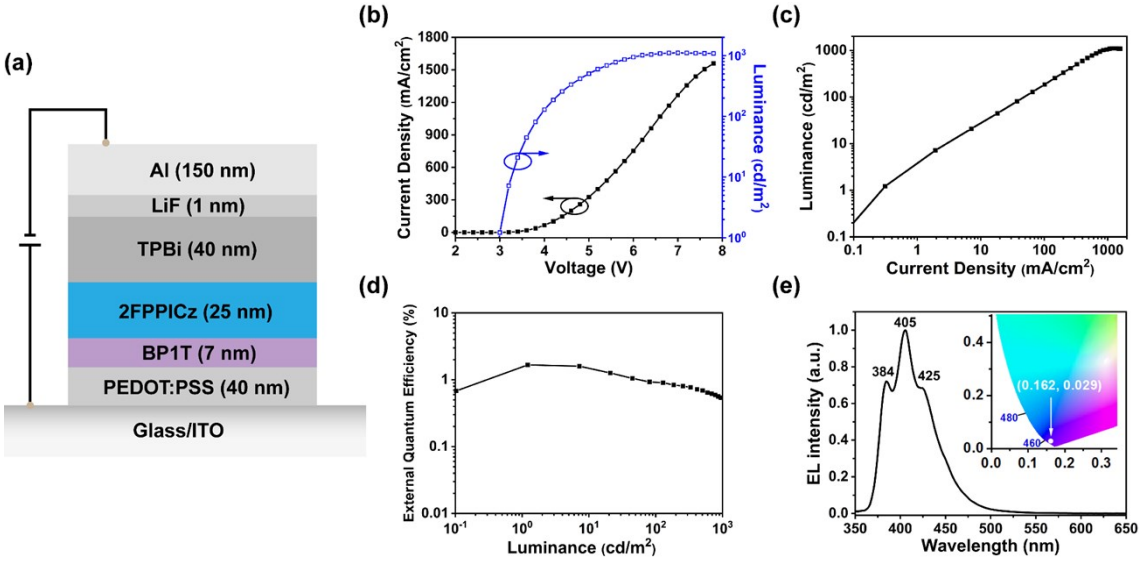


Fig. S2 EL performance of C-OLED. (a) Device structure of C-OLED based on non-doped 2FPPICz WEG crystalline thin film. (b) Voltage dependent of current density and luminance characteristics. (c) Luminance-Current density characteristics. (d) EQE-Luminance- curves. (e) Normalized EL spectra at 5.0 V. The inset is CIE1931 chromaticity diagram including the chromaticity coordinates of EL spectra from the non-doped 2FPPICz C-OLED.

3. Photophysical characterization of 2FPPICz based on different phases

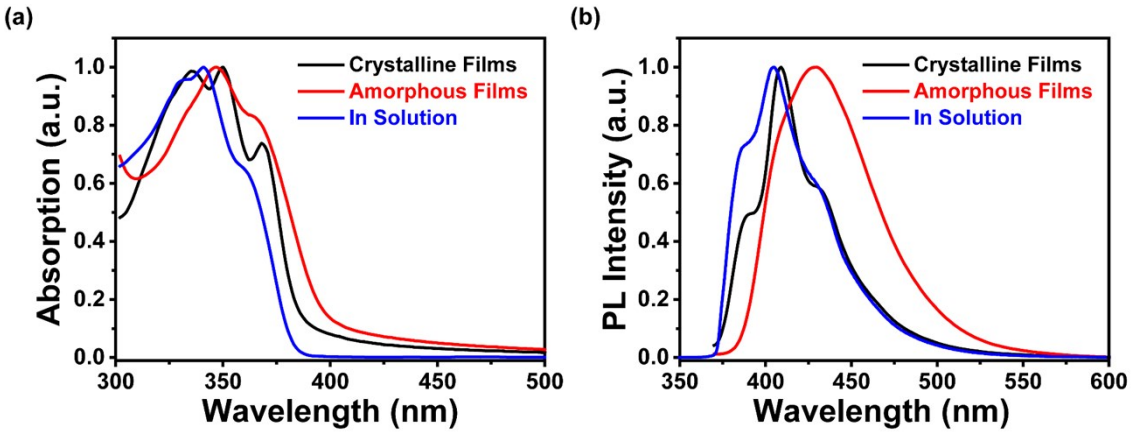
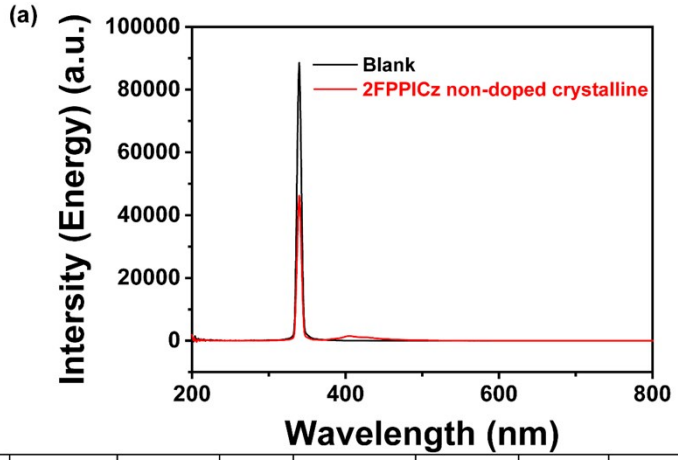
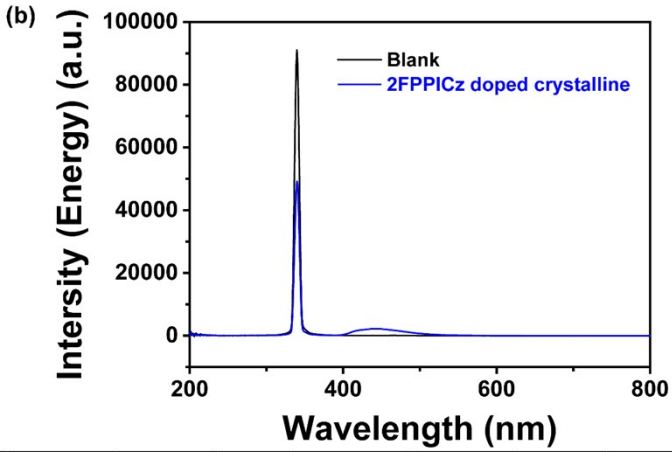


Fig. S3 Photophysical characteriazation. (a-b) Normalized ultraviolet-visible (UV-vis) absorption (a) and photoluminescence (PL) spectrum (b) of 2FPPICz based on different forms. Note: The samples for the photophysical characterization of 2FPPICz crystalline and amorphous thin films were prepared by vacuum deposition based on quartz substrates. The photophysical of dispersed 2FPPICz form was characterized in toluene dilute solution (10^{-5} M). The excitation wavelength of PL spectrum is 340 nm.

4. Photoluminescence quantum yields (PLQYs) results



NO:	Cursor1-2: 329.09 350.21 (nm)	Cursor3-4: 374.34 728.21 (nm)	Quantum Yield	Abs	Peak Wavelength	Peak Count	Peak FWHM	Peak Wavelength	Peak Count	Peak FWHM
Blank	211279938	——	——	——	339.65	88559.64	6.66	375.10	254.82	84.61
2FPPICz Non-doped crystalline	112372944	28404116	0.287	0.468	339.65	46592.64	6.72	405.24	1272.71	49.63



NO:	Cursor1-2: 329.09 350.21 (nm)	Cursor3-4: 394.69 550.24 (nm)	Quantum Yield	Abs	Peak Wavelength	Peak Count	Peak FWHM	Peak Wavelength	Peak Count	Peak FWHM
Blank	231520708	——	——	——	339.65	91064.89	7.17	397.71	147.56	115.80
2FPPICz Doped crystalline	127964033	70431997	0.680	0.447	339.65	49240.14	7.34	442.88	2247.36	74.33

Fig. S4 Photoluminescence quantum yields (PLQYs) results. (a) PLQY of 2FPPICz non-doped crystalline thin films. (b) PLQY of 2FPPICz doped crystalline thin film.

Table S1. PLQYs of 2FPPICz doped and non-doped WEG crystalline thin films		
emitter	**PLQYs (%)**	**ref**
Non-doped 2FPPICz WEG crystalline thin films	29	this work
Doped 2FPPICz WEG crystalline thin films	68	this work
2FPPICz amorphous thin films	53	27
2FPPIPCz amorphous thin films	79	27

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5. EL performance of doped C-OLEDs with different concentrations

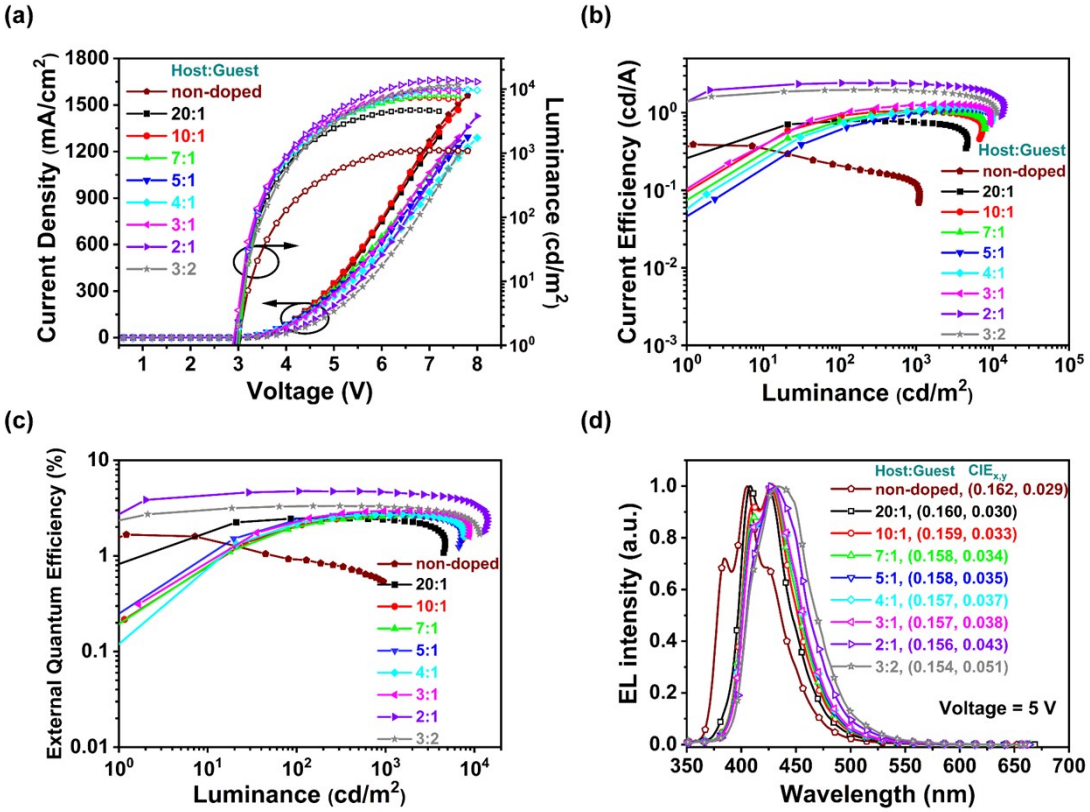

Fig. S5 EL performance of doped C-OLEDs with different concentrations. (a) Voltage-dependent current density and luminance characteristics. (b) Current Efficiency-Luminance characteristics. (c) EQE-Luminance curves. (d) Normalized EL spectra at 5.0 V of doped C-OLEDs based on various doping concentrations.

6. Summary of the non-doped and doped C-OLEDs based on 2FPPICz, and other high-efficiency deep-blue OLEDs with $CIE_y \leq 0.05$

Table S2. Summary of the non-doped and doped C-OLEDs based on 2FPPICz, and other high-efficiency deep-blue OLEDs with $CIE_y \leq 0.05$ (Ref.[1-29])

Emitters[a]	Voltage (V)[b]	EQE (%)[c]	CE (cd/A)[c]	PE (lm/W)[c]	λ_{max} (nm)[d]	L_{max} (cd/m^2)[e]	CIE	ref
2FPPICz (N)	3.0/6.2/3.2	1.6/0.5	0.38/0.12	0.41/0.06	405	1100 (6.8)	(0.162, 0.029)[f]	this work
2FPPICz (20:1) (D)	3.0/4.3/1.3	2.5/2.4	0.78/0.75	0.71/0.53	407	4700 (6.8)	(0.160, 0.030)[f]	this work
2FPPICz (7:1) (D)	3.0/4.1/1.1	2.7/2.6	1.03/1.02	0.82/0.78	427	8007 (7.2)	(0.158, 0.034)[f]	this work
2FPPICz (2:1) (D)	3.0/4.1/1.1	4.7/4.5	2.42/2.35	2.30/1.78	431	13900 (7.2)	(0.156, 0.043)[f]	this work
TDAF1 (N)	2.5/8.8*/6.3*	5.3/-[g]	1.53/-	-/-	408*	13700* (11.6)	(0.158, 0.041)	1
TDAF2 (N)	2.5/8.5*/6.0*	4.1/-	1.1/-	-/-	408*	7700* (10.8)	(0.160, 0.044)	1
TCPC-6 (N)	-/-/-	3.72/-	1.35/-	-/-	-	398 (-)	(0.16, 0.05)	2
CPhBzIm (N)	2.5/8.1/5.6	3/2.4	1.6/-	1.07/0.5*	435*	4600 (12.0)	(0.16, 0.05)	3
TPAXAN (N)	3.4/-/-	4.62/-	-/-	-/-	428	900* (10.0)	(0.155, 0.049)	4
CzS2 (N)	2.8/7.0*/4.2*	2.7/2.2	0.82/0.73	0.84/0.33	417	2000* (9.7)	(0.157, 0.044)	5
TTP-TPI (N)	3.1/5.7*/2.6*	5.02/3.98	2.1/1.47	1.88/0.81	424	2000* (7.0)	(0.16, 0.05)	6
XBTPI (N)	3.1/7.7/4.6	4.93/4.05	2.06/1.68	1.60/0.67	428	1100* (8.0)	(0.16, 0.05)	7
SiPIM (N)	4.2/10*/5.8*	6.29/2.8*	1.94/1.5*	-/-	420	1950 (12.0)	(0.163, 0.040)	8
TPA-PIM (N)	-/-/-	3.28/3.11	1.14/1.08	0.79/-	420	4510 (-)	(0.161, 0.046)	9
DPA-PIM (D)	3.2/6.3*/3.1*	5.1/3.6	2.5/1.7	-/-	436	9505 (10.0)	(0.15,0.05)	10
TPA-S (N)	3.0/7.8/4.8	1.76/-	0.47/0.42	-/0.17	407*	3000* (10.5)	(0.158, 0.039)	11
mTPA-PPI (N)	3.2/-/-	3.33/2.8*	0.84/0.7*	0.48/0.28*	404	4065 (-)	(0.161, 0.049)	12
^{t}Cbz-SO_2-SPIRO-^{t}Cbz (D)	4.2/9.8*/5.6*	4.7/2.1*	1.8/0.8*	1.2/0.22*	420*	1000* (9.8)	(0.16, 0.04)	13
TPA-TAZ (N)	3.1/6.5*/3.4*	6.8/5.3	2.2*/1.8*	-/-	432*	7323 (9.0)	(0.158, 0.043)	14
TPIBNCz (D)	3.2/5.6*/2.4*	5.99/5.47	2.34/-	2.14/-	428	1900* (6.5)	(0.157,0.048)	15
DIP (N)	3.2/7.2*/4.0*	3.27/2.6*	1.11/-	0.89/-	424	2100* (9.0)	(0.158, 0.040)	16
Tmtp (N)	3.3/7.5*/4.2*	3.0/2.9*	1.24/1.1*	1.14/-	436	4580 (9.4)	(0.15, 0.04)	17
TAZ-4Cz (N)	3.9/9.9*/6.0*	2.48/1.1*	0.68/0.41*	0.58/0.15*	412	1478 (11.0)	(0.16, 0.04)	18
PhImEn (N)	3.3/7.0*/3.7*	2.5/2.4*	2.30/2.2*	1.32/1.0*	414	11696 (14.0)	(0.15, 0.05)	19
TN4T-PCZ (D)	4.2/7.6*/3.4*	20.4/19*	5.01/4.74	2.3*/1.9*	410*	5377 (11.0)	(0.16, 0.03)	20
TPATZ (N)	3.1/8.0*/4.9*	5.92/-	2.41/1.9*	2.20/0.78*	430	4970 (10.4)	(0.155, 0.047)	21
BBPA (D)	3.5/9.5*/6.0*	6.02/2.41	-/1.25	-/0.41*	412	2300* (12.5)	(0.15, 0.03)	22
1 (N)	3.4/9.8*/6.4*	1.79/1.65*	0.36/0.31*	0.27/0.12*	410	1326 (11.2)	(0.16, 0.04)	23
PImPI (N)	3.2/7.5*/4.3*	6.83/4.25	2.21/-	2.28/-	416	3362 (9.5)	(0.16, 0.05)	24
DFPBI (D)	3.0/-/-	4.96/-	1.62/-	-/-	425	270 (6.8)	(0.157, 0.039)	25
DFPBI (N)	3.0/6.0*/3.0*	4.18/2.9*	1.48/1.0*	1.43/0.5*	435	2690 (7.6)	(0.154, 0.042)	25
F-2CzB (N)	3.2/5.8*/2.6*	4.43/3.5*	-/-	-/-	404	2775 (9.5)	(0.162, 0.028)	26
2FPPICz (N)	3.0/5.2/2.2	4.3/2.5	1.8/1.1	1.7/0.7	425	3835 (8.2)	(0.160, 0.045)	27
TPBPPI-PY (N)	4.1/7.8*/3.7*	5.7/4.1*	1.8/1.4*	1.38/-	420	2300* (9.0)	(0.16, 0.049)	28
NPBI-PPI-TPA (N)	3.0/5.7*/2.7*	5.59/4.18	2.6/1.92	2.72/1.02	429	3366 (8.2)	(0.15, 0.05)	29

[a] N: Non-doped devices; D: Doped devices. [b] Operating voltage at the brightness of 1 cd/m^2 and 1000 cd/m^2. [c] External quantum efficiency (EQE), current efficiency (CE) and power efficiency (PE): maximum value (left) and value at the luminance of 1000 cd/m^2, respectively.[d] Maximum emission wavelength. [e] Maximum luminance and the corresponding voltage value. [f] Measured at the voltage of 5.0 V. [g] No valid information. * Estimated values based on figures in the corresponding literatures.

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7. Summary of areal energy loss from Joule heat of series resistance[30, 31]

Table S3. Summary of areal energy loss from Joule heat of series resistance of the 7:1 doped C-OLED and other typical deep-blue OLEDs with $CIE_y \leq 0.05$ at about 1000 cd/m²

Voltage (V)	Current density (mA/cm²)	Input power (mW/cm²)	Differential conductance (mS/cm²)	Differential resistance (kΩ cm²)	Energy loss from Joule heat of series resistance (mW/cm²)	Energy loss from Joule heat of series resistance ratio (%)	CIE	ref
4.1	96.2	394.42	177.5	0.00563	52.14	13.2	(0.158, 0.034)	This work
5.5	45.9	252.45	44.9	0.0223	46.92	18.6	(0.157, 0.048)	15
6.8	55.5	377.40	52.3	0.0191	58.90	15.6	(0.158, 0.043)	14
7.5	73.1	548.25	61.6	0.0162	86.75	15.8	(0.16, 0.05)	24
6.5	61.4	399.10	58.3	0.0172	64.66	16.2	(0.15, 0.05)	10
7.8	53.0	413.40	38.4	0.0260	73.15	17.7	(0.155, 0.047)	21

Note: The series resistance is derived from the differential conductance in Fig. 4b in this manuscript.

8. References

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