Ternary blend hostes for solution processed green phosphorescent organic light-emitting diodes

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Abstract

In this paper a series of solution processed green phosphorescent organic light-emitting diodes (PhOLEDs) based on blend hosts-guest configuration have been fabricated and the effect of various hole transport materials, e.g. 1,3-Di-9-carbazolylbenzene (mCP), poly(9-vinylcarbazole) (PVK) and 4,4',4"-tris(N-carbazolyl)-triphenylamine (TCTA) and their combination as the hosts on the performance of PhOLEDs have investigated. The superior electroluminescence (EL) performance for ternary blend host-based green PhOLEDs was attributed to the efficient energy transfer from the host to dopant, the appropriate highest occupied molecular orbital (HOMO) level and the enhanced charge carrier transport balance.

INTRODUCTION

As a common component of PhOLED, the host material plays an important role in inhibiting the self-aggregation quenching and triplet-triplet annihilation of EML. In order to achieve high performance EL devices, the ideal host material should meet the following requirements. In this paper, we manufactured solution-processed blend hosts-based green PhOLEDs with enhanced performance, using MCP, PVK and TCTA as the first, second and third host, respectively. The introduction of the second host PVK leads to a redshift of PL spectrum of the blend hosts relative to that of the first host, which realizes a more efficient energy transfer between the host and dopant. The balance of charge carriers is improved by introducing the third host TCTA. Devices were fabricated with a configuration of ITO/PEDOT:PSS (30nm)/host:Ir(mppy)$_3$ (9:1 w/w) (25nm)/TPBI (30nm)/ LiF (1nm)/Al (100nm), as shown in Figure 1.

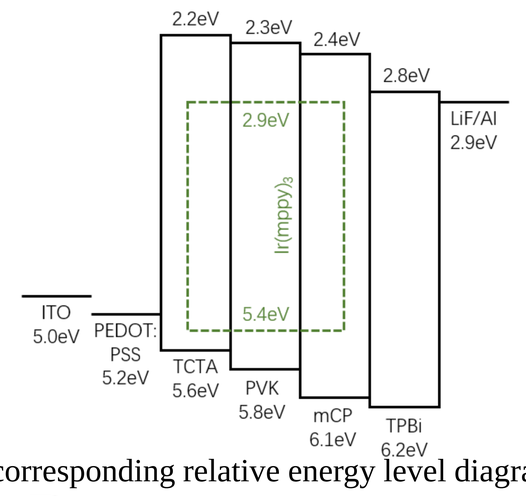

Figure 1. The corresponding relative energy level diagram in the devices

RESULTS AND DISCUSSION

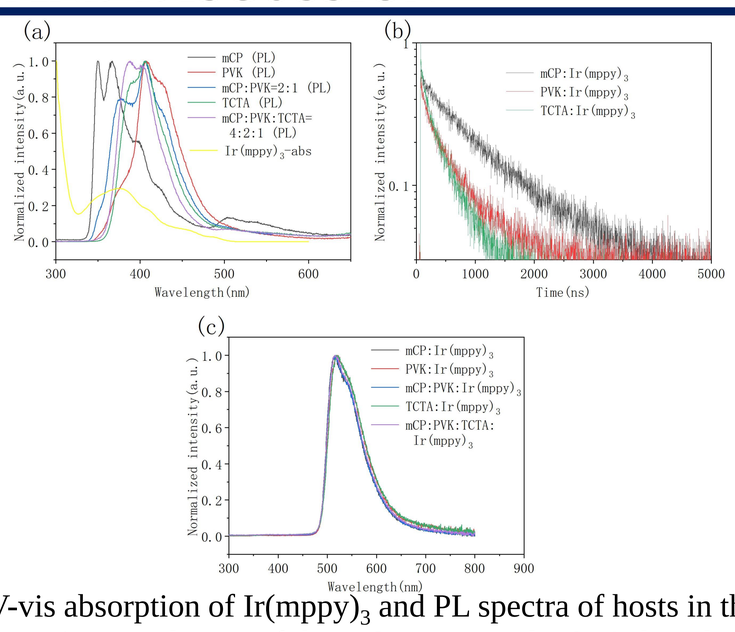

Figure 2. (a)UV-vis absorption of Ir(mppy)$_3$ and PL spectra of hosts in thin solid film at temperature. (b) Transient PL decays of the mCP, PVK and TCTA doped with Ir(mppy)$_3$. (c) PL spectra of the hosts doped with Ir(mppy)$_3$.

The PL spectra of mCP, PVK and TCTA partially overlapped with the absorption of Ir(mppy)$_3$, implying that the energy of these hosts can efficiently transfer to Ir(mppy)$_3$ dopant. The decay curves of three films are long exponential decay, especially for the mCP host, which shows an obviously delayed decay with long exciton lifetime, demonstrating the less aggregation of Ir(mppy)$_3$. Therefore, we chose mCP as the primary host, while PVK and TCTA as the second and third hosts, respectively. The disappearance of the hosts emission indicates the perfect Föster energy transfer from the host to guest.

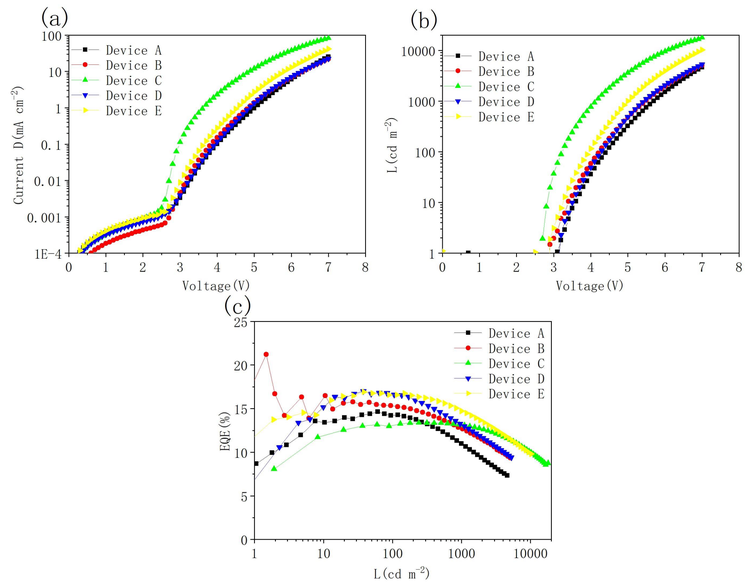

Figure 3. Comparison of (a) J-V, (b) L-V and (c) EQE-L

Based on the general structure of ITO/PEDOT:PSS (30nm)/host:Ir(mppy)$_3$ (9:1 w/w) (25nm)/TPBi (30nm)/LiF (1nm)/Al (100nm), a series of solution-processed PhOLEDs (Devices A-E) were fabricated with their device parameters, as shown in Table 1. The Voltage (V)-current density (J) , Voltage (V)-luminance (L), L-external quantum efficiency (EQE), and the corresponding electroluminescent (EL) spectra of Devices A-E are shown in Figure 3. The EL peaks of all devices were all around 514nm, with ±2nm deviation. As summarized in Table 1, in comparation with the EQE 14.62% of the single host Device A and 15.77% of the single host Device B, the binary host Device D exhibited the highest EQE of 16.99%. The PL spectra of binary host mCP:PVK (2:1 w/w) has an excellent overlap with the absorption spectra of the dopant Ir(mppy)$_3$, which realized the most efficient Förster resonance energy transfer between the host and dopant. The lower turn-on voltage of 2.9 V in the ternary host Device E than those of Device A and D, can be ascribed to the more efficient hole injection due to addition of the third host TCTA. As can be seen from the energy level diagram in Figure 1, the highest occupied molecular orbital (HOMO) level of TCTA is 5.6 eV, which is 0.2 and 0.5 eV lower than HOMO level of PVK and mCP, respectively, resulting in enhanced hole injection from PEDOT:PSS to EML. The Device E had corresponding efficiency roll-off of 12.95% at the brightness values of 1000 cd m^{-2} and the maximum luminance of 10213 cd/m^2 at the voltage of 7V, which were the best among those of Device A-E. The hole mobilities of mCP, PVK and TCTA are known to be 1.2 × 10^{-4}, 2.5 × 10^{-6} and 3.0 × 10^{-4} cm^2 V^{-1} s^{-1}, respectively. The introduction of the third host TCTA to Device E improve the hole transport of the ternary blend host, thus achieving a better carrier balance.

CONCLUSION

In summary, a superior performance of solution processed green PhOLED based on a ternary blend host-dopant system was achieved and the mixture of the tri-HTL materials advantageously improved the energy transfer from the host to the guest, the carrier injection and transfer balance of the PhOLEDs. It has been proved that the mixing of multiple functional materials is an effective way to improve the device performance of OLEDs.

ACKNOWLEDGMENT

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Table 1. Summary Of OLED Characteristics Based On Various Host Materials

Device[a]	Host structure	Ratio[b]	V_{on}[c] [V]	L_{7V}[d] [cd m^{-2}]	EQE[e][%] Max/100/1000	Color coordinate	EL[f] [nm]
A	mCP	-	3.1	4600	14.62/14.20/10.98	(0.32,0.61)	512
B	PVK	-	2.9	5116	15.77/15.33/12.65	(0.33,0.61)	516
C	TCTA	-	2.7	17933	13.36/12.98/13.15	(0.33,0.61)	516
D	mCP:PVK	2:1	3.1	5275	16.99/16.58/13.24	(0.32,0.61)	514
E	mCP:PVK:TCTA	4:2:1	2.9	10213	16.91/16.57/14.72	(0.31,0.61)	512

[a]Device configuration: Glass/ITO/PEDOT:PSS (30nm)/EML (25nm)/TPBi (30nm)/ LiF (1nm)/Al (100nm). [b]The blend ratio of host materials in EML. [c]The operating voltage at a brightness of 1 cd m^{-2}. [d]The luminance at the voltage of 7V. [e]EQE at the maximum value/at 100 cd m^{-2}/at 1000 cd m^{-2}. [f]The EL emission peak wavelength at the voltage of 7V.