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Advances in Blue Exciplex–Based Organic Light-Emitting Materials and Devices

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Exciplexes possessing thermally activated delayed fluorescence (TADF) characteristics have received much attention in the fields of organic light-emitting materials and devices over the past decade. In general, an exciplex is a physical mixture between a donor (D) with hole transport properties and an acceptor (A) with electron transport characteristics, and the energy difference between the lowest excited singlet state and the lowest excited triplet state is usually fairly small in terms of the long-range charge-transfer process from D to A. In the processes of photoluminescence and electroluminescence, triplet excitons can be converted to singlet excitons through reverse intersystem crossing and then radiate photons to achieve TADF. As a consequence, triplet excitons can be effectively harvested, and the exciton utilization can be significantly enhanced. Up to now, a large number of exciplexes have been developed and applied to organic light-emitting devices. Notably most of them showed green or red emission, while blue exciplexes are relatively few owing to the spectrum characteristics of the large red-shift and broadened emission. In this study, the latest progress of blue exciplex–based organic light-emitting materials and devices is briefly reviewed, and future research is prospected.

Keywords: blue exciplex, organic light-emitting diode, cohost, reverse intersystem crossing, thermally activated delayed florescence

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INTRODUCTION

Since the realization of the first organic light-emitting diode (OLED) possessing a high brightness of >1,000 cd m^{-2} and a low-driving voltage (V_{on}) of <10 V (Tang and VanSlyke, 1987), OLEDs based on small molecules (Tang et al., 1989; Adachi et al., 1990), polymers (Burroughes et al., 1990; Peng et al., 1998), and metal–organic complexes (Baldo et al., 1998; Chang et al., 2013) have attracted tremendous attention in the fields of lighting and displays over the past few decades owing to their fascinating merits such as thinness, fast response, and flexibility (Hong et al., 2021). Among these OLEDs, several different kinds of luminescence mechanisms, including traditional fluorescence (Friend et al., 1999; Huang et al., 2012), phosphorescence (Bernhard et al., 2002; Zhou et al., 2014), triplet–triplet annihilation (TTA) (Fukagawa et al., 2012; Jankus et al., 2013), traditional thermally activated delayed fluorescence (TADF) (Endo et al., 2011; Uoyama et al., 2012; Zhang et al., 2012; Li et al., 2013; Li et al., 2021d), hyperfluorescence (Nakanotani et al., 2014; Chan et al., 2021), singlet–triplet inversion (Ehrmaier et al., 2019; Pollice et al., 2021; Li et al., 2022), exciplex-based TADF (Goushi et al., 2012; Li et al., 2014; Oh et al., 2015; Li et al., 2021c; Gu et al., 2022), aggregation-induced emission (AIE)–based TADF (Peng and Shuai, 2021; Suman et al., 2021), and multiple resonance (MR)–based TADF (Lee et al., 2020; Stavrou et al., 2021; Wu et al., 2021; Zou et al., 2022) have been reported. Thus, the exciplex used to be considered an important reason for poor OLED

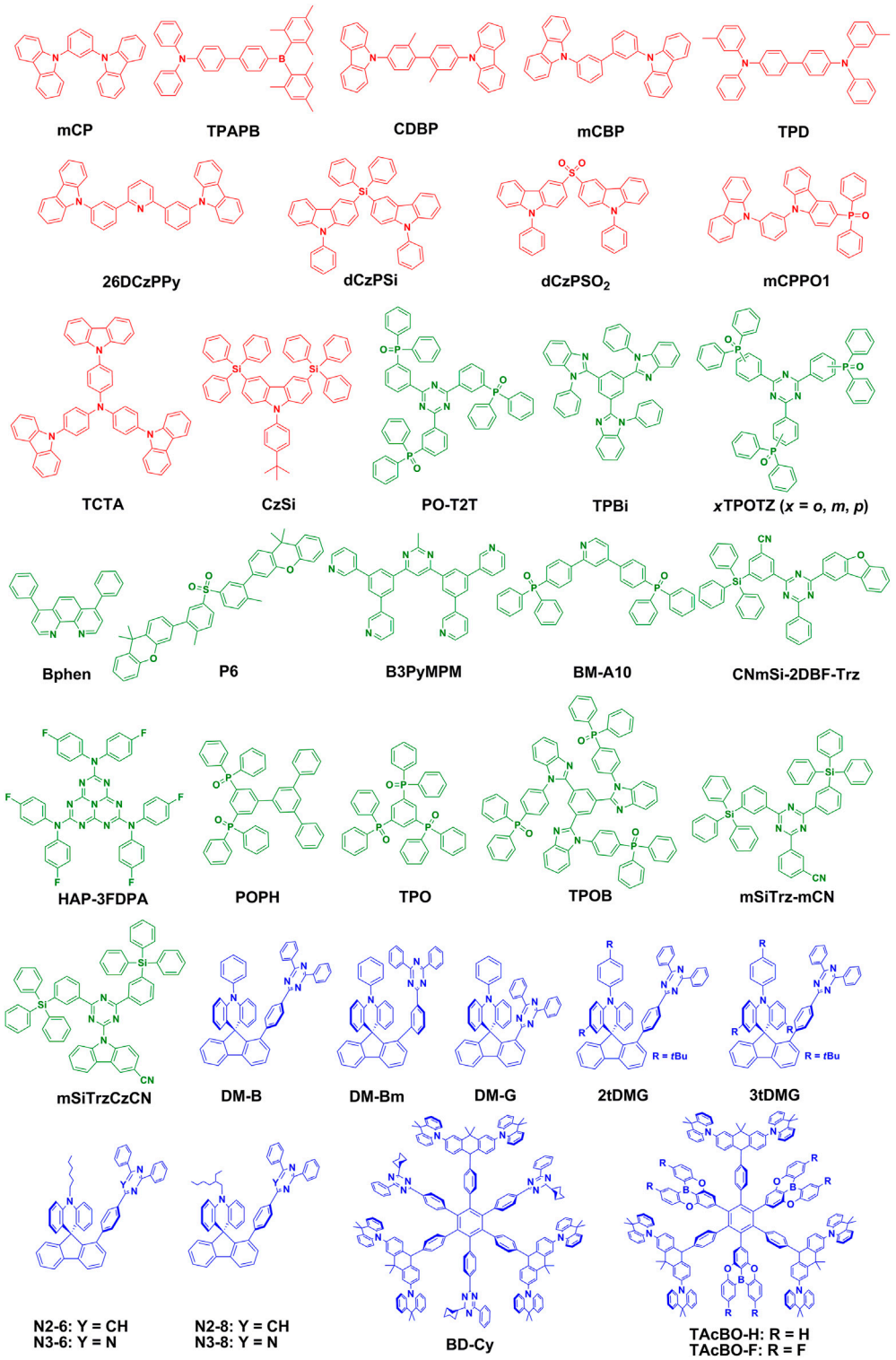

FIGURE 1 | Chemical structures of compounds forming blue exciplexes. The red, green, and blue colors represent donors, acceptors, and intramolecular exciplexes, respectively.

TABLE 1 | Electroluminescence performance of blue exciplex–based organic light-emitting diodes.

Exciplex	λ_{EL} [nm]	V_{on}[a)] [V]	EQE_{max}[b)] [%]	CE_{max}[c)] [cd A^{-1}]	PE_{max}[d)] [lm W^{-1}]	CIE (x,y)	References
mCP:PO-T2T	471	2.0	8.0	15.5	18.4	(0.17, 0.23)	Hung et al. (2014)
TCTA:Bphen	464	2.6	2.65	3.66	3.82	-	Zhao et al. (2015)
TPAPB:TPBi	468	3.2	7.0 ± 0.4	9.1 ± 0.7	7.2 ± 0.5	(0.14, 0.18)	Chen et al. (2015)
CDBP:PO-T2T	480	2.5	13.0	26.6	27.8	(0.17,0.29)	Liu et al. (2015a)
mCBP:PO-T2T	~470	-	7.66	15.08	17.78	(0.17, 0.23)	Zhang et al. (2015)
26DCzPPy:PO-T2T	488	3.1	7.8	18.0	17.7	(0.23, 0.36)	Liu et al. (2016)
mCP:*o*TPOTZ	480	3.6	0.4	1.4	1.0	(0.20, 0.30)	Duan et al. (2018)
mCP:*m*TPOTZ	478	2.7	4.34	10.1	11.5	(0.16, 0.29)	Duan et al. (2018)
mCP:*p*TPOTZ	481	2.5	11.1	26.2	32.4	(0.19, 0.36)	Duan et al. (2018)
dCzPSi:PO-T2T	~480	2.4	8.6	14.7	11.5	(0.15, 0.21)	Hung et al. (2018)
$dCzPSO_2$:PO-T2T	~480	2.4	1.8	4.2	4.8	(0.15, 0.21)	Hung et al. (2018)
CzSi:PO-T2T	465	3.0	6.1	8.9	7	(0.16, 0.21)	Chapran et al. (2019)
mCP:PO-T2T	480	3.0	16.0	27	26.4	(0.16, 0.28)	Chapran et al. (2019)
mCPPO1:PO-T2T	480	3.0	6.5	9.4	8	(0.18, 0.29)	Chapran et al. (2019)
TPD:Bphen	480	3.0	0.46	1.0	0.95	(0.20, 0.31)	Guo et al. (2020)
TCTA:P6	433	6.2	9.1	-	-	-	Tan et al. (2020)
mCP:HAP-3FDPA	437	4.0	10.2	-	-	(0.16, 0.12)	Li et al. (2021b)
DM-B	~500	2.8	27.4	-	68.1	(0.20, 0.44)	Tang et al. (2020)
DM-Bm	~500	2.6	21.7	-	62.7	(0.22, 0.48)	Tang et al. (2020)
DM-G	500	3.0	18.5	-	47.5	(0.24, 0.50)	Tang et al. (2020)
2tDMG	504	-	30.8	88.5	71.8	(0.24, 0.53)	Peng et al. (2020)
3tDMG	501	-	20.8	58.0	45.0	(0.24, 0.52)	Peng et al. (2020)
N2-6	480	-	14.1	28.2	14.8	-	Wang et al. (2021a)
N2-8	479	-	17.6	34.4	27.0	-	Wang et al. (2021a)
N3-6	490	-	14.7	33.4	17.5	-	Wang et al. (2021a)
N3-8	488	-	18.9	43.1	27.1	-	Wang et al. (2021a)
BD-Cy	477	2.9	18.2	36.8	36.1	(0.18, 0.28)	Wang et al. (2021b)
TAcBO-H	460	3.1	15.8	23.1	-	(0.16, 0.16)	Du et al. (2021)
TAcBO-F	493	3.0	19.5	52.0	-	(0.20, 0.43)	Du et al. (2021)

[a]*Turn-on voltage at 1 cd m^{-2}.*
[b]*Maximum external quantum efficiency.*
[c]*Maximum current efficiency.*
[d]*Maximum power efficiency.*

performance, and it thus should be avoided and eliminated (Adachi et al., 1990; Jenekhe, 1995; Morteani et al., 2003). Nevertheless, the studies on enhanced exciplex emission over the past decade suggested the possibility of exciplexes as unique light-emitting materials (Goushi and Adachi, 2012; Sarma and Wong, 2018; Zhang et al., 2021) or highly efficient cohost materials for OLEDs with high efficiencies, low V_{on}, and low roll-offs (Liu et al., 2015b; Wu et al., 2017; Xiao et al., 2018; Wang et al., 2019; Zhao et al., 2019; Jung and Lee, 2020).

In general, an exciplex originates from the intermolecular charge-transfer (CT)–excited state between the highest occupied molecular orbital of an electron donor (D) and the lowest unoccupied molecular orbital of an electron acceptor (A), leading to a fairly small energy difference (ΔE_{ST}) between the lowest excited singlet state (S_1) and the lowest excited triplet state (T_1) by means of the long-range CT process from D to A (Sarma and Wong, 2018; Shao et al., 2022). In the processes of photoluminescence (PL) and electroluminescence (EL), nonradiative triplet excitons can be converted to be radiative singlet excitons through efficient reverse intersystem crossing (RISC). Thus, triplet excitons can be effectively harvested and the luminescence efficiencies can be significantly enhanced, thus ensuring that exciplexes are an important class of emitters in OLEDs (Hung et al., 2014; Kim and Kim, 2019; Guo et al., 2021).

Up to now, a large number of exciplex-based molecular systems have been developed and applied to OLEDs. In particular, most of them are green or red exciplexes, while blue exciplexes are relatively few (Zhang et al., 2021). This is mainly because the realization of blue exciplexes is a herculean task on account of a large red-shifted and broadened exciplex emission spectrum as compared to those of the corresponding D and A compounds (Guo et al., 2021). In this study, the latest progress of blue exciplex–based organic light-emitting materials and devices is briefly reviewed, and future research is prospected. The chemical structures of compounds forming blue exciplexes involved in the following descriptions are depicted in **Figure 1**, and the EL performance of blue exciplex–based OLEDs is summarized in **Table 1**.

BLUE EXCIPLEX–BASED ORGANIC LIGHT-EMITTING MATERIALS AND DEVICES

Although exciplex emission has been studied for decades, exciplex-based organic light-emitting materials have not received extensive attention for a long time, mainly because of their relatively low luminous efficiency and poor color purity

(Gould et al., 1992; Osaheni and Jenekhe, 1994; Gebler et al., 1997; Chao and Chen, 1998; Wang et al., 1998; Cocchi et al., 2002; Kulkarni and Jenekhe, 2008; Zhao et al., 2008; Zhu et al., 2009; Yang et al., 2010). Exciplex-based OLEDs have triggered much attention since Goushi and coworkers demonstrated a pronounced EL enhancement using the RISC process in the 4,4′,4″-tris [3-ethylphenyl (phenyl)amino]triphenylamine (*m*-MTDATA):tris-[3-(3-pyridyl)mesityl]borane (3TPYMB) exciplex system, which showed a relatively high maximum external quantum efficiency (EQE_{max}) of 5.4% in view of a rather low photoluminescence quantum efficiency (PLQE) of 26%, exceeding the corresponding limit of fluorescence-based OLEDs (Goushi et al., 2012). Afterward, a much higher EQE_{max} of 10.0% and a maximum power efficiency (PE_{max}) of 47.0 lm W^{-1} were achieved by changing the exciplex system from *m*-MTDATA:3TPYMB to *m*-MTDATA:2,8-bis(diphenylphosphoryl)dibenzo [*b*,*d*]thiophene (PPT) (Goushi and Adachi, 2012).

Since then, exciplex-based emitters have aroused widespread attention by virtue of their fascinating optoelectronic properties, and a number of efficient blue exciplex–based OLEDs have been realized (Shao et al., 2022). In 2014, Hung and coworkers attained a record-high blue exciplex OLED (λ_{EL} = 471 nm) with an EQE_{max} of 8.0% based on 1,3-bis(*N*-carbazolyl)benzene (mCP): 2,4,6-tris[3-(1*H*-pyrazol-1-yl)phenyl]-1,3,5-triazine (PO-T2T) (Hung et al., 2014). In 2015, Zhao et al. (2015) achieved a blue exciplex–based OLED based on 4,4′,4″-tri (*N*-carbazolyl) triphenylamine (TCTA):4,7-di-phenyl-1,10-phenanthroline (Bphen), which displayed a low EQE_{max} of 2.65%. Chen et al. (2015) developed a highly efficient blue exciplex system using a novel electron donor molecule (4-dimesitylboryl) phenyltriphenylamine (TPAPB) and a conventional electron acceptor 1,3,5-tris(1-phenyl-1*H*-benzimidazol-2-yl)benzene (TPBi), while a blue-emitting device containing TPAPB:TPBi exhibited a low V_{on} of 3.2 V, a high EQE_{max} of 7.0 ± 0.4%, and CIE coordinates of (0.14, 0.18). Liu and coworkers reported an efficient blue exciplex emitter consisting of 4,4′-bis(9-carbazolyl)-2,2′-dimethylbiphenyl (CDBP):PO-T2T, which showed obvious TADF emission and intrinsically high T_1, making itself an excellent candidate as a blue emitter or a host for green and red phosphors (Liu et al., 2015a). Meanwhile, the CDBP:PO-T2T exciplex–based blue device delivered a record-high EQE of 13.0% with an EL emission peak at 480 nm and CIE coordinates of (0.17, 0.29). Zhang et al. (2015) demonstrated that the energy could transfer from blue exciplexes to both fluorescent and phosphorescent orange dopants using an efficient blue exciplex system of 9,9′-biphenyl-3,3′-diylbis-9*H*-carbazole (mCBP) and PO-T2T as the electron donor and acceptor, respectively, and a high EQE_{max} of 7.66% with CIE coordinates of (0.17, 0.23) were realized. Liu et al. (2016) investigated the EL property of a blue exciplex of 2,6-bis[3-(9H-carbazol-9-yl)phenyl]pyridine (26DCzPPy):POT2T and an OLED incorporating this exciplex as an emitting layer turned on at 3.1 V, and realized a high EQE_{max} of 7.8% with blue emission peaked at 488 nm. Based on the acceptors *x*TPOTZ (*x* = *o*, *m*, or *p*), which are triphenyltrazine derivatives substituted with diphenylphosphine oxide groups at *ortho*-, *meta*-, and *para*-positions, respectively (Jia et al., 2015), Duan et al. (2018) constructed a series of exciplexes mCP:*x*TPOTZ (*x* = *o*, *m*, or *p*). Thus, in virtue of the strongest electron-withdrawing effect and appropriate steric hindrance, an efficient sky-blue OLED based on mCP:*p*TPOTZ realized an ultralow V_{on} of 2.5 eV, a high CE_{max} up to 26.2 cd A^{-1}, a high PE_{max} of 32.4 lm W^{-1}, and an EQE_{max} of 11.1%. Hung et al. (2018) designed two new nonconjugated linked dicarbazole materials, diphenylbis(9-phenyl-9*H*-carbazol-3-yl)silane (dCzPSi) and 3,3′-sulfonylbis(9-phenyl-9*H*-carbazole) ($dCzPSO_2$). The electron-transporting acceptor, PO-T2T, was introduced to give two exciplex-forming systems, dCzPSi:PO-T2T and $dCzPSO_2$:PO-T2T. The dCzPSi:PO-T2T–based device revealed a V_{on} as low as 2.4 V and a high EQE_{max} of 8.6% with the CIE coordinates of (0.15, 0.21), significantly higher than that of the device based on $dCzPSO_2$:PO-T2T (EQE_{max} = 1.8%), which is due to the fact that $dCzPSO_2$:PO-T2T possessing a large ΔE_{ST} is unfavorable in forming a CT complex.

In 2019, Chapran and coworkers investigated the exciplex properties by selecting PO-T2T as an electron acceptor with different electron donors, and the emissions of these exciplexes spanned from blue to orange-red regions (Chapran et al., 2019). The blue-emitting exciplexes CzSi:PO-T2T–, mCP:PO-T2T–, and mCPPO1:PO-T2T–based OLEDs exhibited high EQE_{max} of 6.1%, 16.0%, and 6.5%, respectively. Guo et al. (2020) reported a blue exciplex–based OLED based on *N*,*N*′-bis(3-methylphenyl)-*N*,*N*′-diphenylbenzidine (TPD):Bphen, which exhibited a relatively low EQE_{max} of 0.46%, possibly resulting from the low PLQE of the exciplex. Tan et al. (2020) designed and investigated a series of donor–acceptor–donor materials based on sulfone substituents as acceptors and found that one of these materials (P6) could form blue exciplexes with TCTA. The TCTA:P6-exciplex–based OLED showed a high EQE_{max} of 9.1% and deep-blue emission with λ_{EL} = 433 nm. Li et al. (2021b) designed and synthesized a heptazine-based electron acceptor, 2,5,8-tris[di (4-fluorophenyl)amine]-1,3,4,6,7,9,9b-heptaazaphenalene (HAP-3FDPA), and the exciplex system of 8 wt% mCP:HAP-3FDPA exhibited a high PLQE of 53.2%. More importantly, an OLED containing this exciplex system as an emitting layer showed deep-blue emission with CIE coordinates of (0.16, 0.12), and a rather high EQE_{max} of 10.2% along with a low roll-off.

Of late, intramolecular exciplexes based on through-space charge transfer (TSCT) are an attractive class of emitters with spatial D/A architecture and TADF characteristics (Shao and Wang, 2020; Li B. et al., 2021; Xue and Xie, 2021). For intramolecular exciplexes, the D and A segments are spatially proximate to each other but are physically separated by a nonconjugated structure (Shao and Wang, 2020; Yang et al., 2020). Tang and coworkers presented an intramolecular design strategy for exciplex-based emitters via a space-confined CT to enhance the light emission (Tang et al., 2020). By connecting the donor and acceptor units *via* a rigid linker, the electronic coupling between the donor and acceptor units is sufficient to allow for efficient direct absorption by the CT state. In contrast to more flexible or less strongly coupled samples, the three rigid sky-blue exciplex emitters, 1′-[4-(4,6-diphenyl-1,3,5-triazin-2-yl)

phenyl]-10-phenyl-10*H*-spiro[acridine-9,9′-fluorene] (DM-B), 1′-[3-(4,6-diphenyl-1,3,5-triazin-2-yl)phenyl]-10-phenyl-10*H*-spiro[acridine-9,9′-fluorene] (DM-Bm) and 1′-(4,6-diphenyl-1,3,5-triazin-2-yl)-10-phenyl-10*H*-spiro[acridine-9,9′-fluorene] (DM-G) possess very high PLQEs of >90% when incorporated in a solid matrix. The sky-blue OLEDs based on DM-B achieved a fairly high EQE_{max} of 27.4% along with a small efficiency roll-off. Peng et al. (2020) developed two greenish-blue TADF emitters with a tilted face-to-face alignment of D/A units presenting intramolecular noncovalent interactions, 2-(tert-butyl)-10-[4-(tert-butyl)phenyl]-1′-[4-(4,6-diphenyl-1,3,5-triazin-2-yl)phenyl]-10*H*-spiro[acridine-9,9′-fluorene] (2tDMG) and 2,7-di-tert-butyl-10-[4-(tert-butyl)phenyl]-1′-[4-(4,6-diphenyl-1,3,5-triazin-2-yl)phenyl]-10*H*-spiro[acridine-9,9′-fluorene] (3tDMG). 2tDMG and 3tDMG achieved extremely high EQE_{max} of 30.8% (evaporation-process) and 20.2% (solution-process), respectively. These excellent results opened new avenues for the study of spatial electronic interactions in organic light-emitting materials. Wang T. T. et al. (2021) designed and synthesized four small blue-emitting molecules containing a spiro-scaffold based on fluorene, namely, N2-6, N2-8, N3-6, and N3-8, while the rather short D–A distance led to large steric hindrance as well as a π-stacking manner, favoring CT from D to A. The blue OLED based on N3-8 achieved a high EQE_{max} of 18.9%. Wang and coworkers reported the design of π-stacked dendrimers consisting of cofacially aligned D and A for highly efficient OLEDs, and the dendritic structure and orthogonal configuration led to the TSCT emission (Wang X. et al., 2021). Thus, the blue device based on the dendrimer BD-Cy showed promising performance with CE_{max} = 36.8 cd A^{-1}, EQE_{max} of 18.2%, and PE_{max} = 36.1 lm W^{-1}. Du et al. (2021) reported two blue TSCT dendrimers consisting of dendritic triacridan donors and oxygen-bridged triarylboron acceptors, TAcBO-H and TAcBO-F. More importantly, the solution-processed OLEDs based on these two dendrimers exhibited blue EL emission and a high EQE_{max} of >15%.

BLUE EXCIPLEXES AS COHOST MATERIALS IN BLUE PHOSPHORESCENT ORGANIC LIGHT-EMITTING DIODES

Balanced carrier transporting for electron and hole in the emitting layer is significant for the OLED performance in the EL process. To achieve good electron and hole balance, various host materials possessing bipolar characteristics have been developed. There are two approaches to realize bipolar hosts. One is to design single molecules consisting of both hole and electron-transporting units (Su et al., 2008; Lee et al., 2009; Chou and Cheng, 2010). The other is to use exciplex-based cohosts inherently containing hole and electron-transporting molecules (Park et al., 2013a; Park et al., 2013b; Lee et al., 2013). In particular, the latter approach commonly does not require a new molecular synthesis, and the hole and electron mobilities of the exciplex can be tuned by adjusting the ratio of hole and electron-transporting molecules. Thus, exciplex-based cohost materials are conductive to the achievement of OLEDs with low V_{on} and high efficiencies (Park et al., 2013b; Lee et al., 2013). To realize high-performance blue phosphorescent OLEDs (PhOLEDs) utilizing exciplex-based cohost materials, the T_1 level of the exciplex should be lower than those of the consisting molecules in order to confine the excitation energy in the exciplex state, not to transfer to the D and A molecules. Meanwhile, the T_1 level of the exciplex should also be higher than that of a phosphorescent dopant to guarantee the energy transfer from the exciplex to a blue dopant. Hence, it seems to be a challenging issue to attain an ideal exciplex system meeting these requirements (Jung and Lee, 2020; Tan et al., 2020).

In 2014, Shin et al. (2014) reported a high efficiency blue-emitting PhOLED approaching the theoretical efficiency limit (EQE_{max} = 29.5%) using a blue exciplex cohost of mCP:bis-4,6-(3,5-di-3-pyridylphenyl)-2-methylpyrimi-dine (B3PYMPM) and a phosphorescent emitter of iridium (III)bis[(4,6-difluorophenyl)-pyridinato-N,C2′]picolinate (FIrpic), and meanwhile, the OLED exhibited a low V_{on} of 3 V and low-efficiency roll-off. In 2015, Ban and coworkers designed and synthesized a novel electron-transporting molecule (5-terphenyl-1,3-phenylene)bis(diphenylphosphine oxide) (POPH), and the solution-processed blue PhOLED incorporating a blue exciplex–based cohost TCTA:POPH displayed an extremely low V_{on} of 2.7 V, a high PE_{max} of 22.5 lm W^{-1}, and a very low-efficiency roll-off even the luminance was up to 10,000 cd m^{-1} (Ban et al., 2015). Lee et al. (2015) reported an efficient exciplex–based cohost system of mCP:PO-T2T, and a high-performance blue PhOLED using the exciplex cohost doped with FIrpic possessing a remarkably high EQE_{max} of 30.3%, PE_{max} of 66 lm W^{-1}, and a low V_{on} of 2.4 V was realized. Based on the time resolved PL measurement, these results should be ascribed to the suitable T_1 level of the exciplex (2.64 eV) ,which is lower than the T_1 levels of the consisting molecules of mCP (2.94 eV) and PO-T2T (2.99 eV), and higher than that of FIrpic (2.63 eV), so that the exciplex system well confines the excitons in the exciplex state, followed by energy transfer to a blue dopant of FIrpic. In 2016, Ban et al. realized a highly efficient blue PhOLED based on a blue exciplex cohost system of TCTA:1,3,5-tris(diphenylphosphoryl)benzene (TPO) with the CE_{max} of 23.8 cd A^{-1} and PE_{max} of 15.8 lm W^{-1} (Ban X. X. et al., 2016). Afterward, they designed and synthesized a novel electron acceptor 1,3,5-tris(1-[4-(diphenylphosphoryl)phenyl]-1*H*-benzo [d]imidazol-2-yl)benzene (TPOB) to form an exciplex-type cohost with TCTA, and the solution-processed blue PhOLED achieved an extremely low V_{on} of 2.8 V and a high PE_{max} of 22 lm W^{-1} along with a low-efficiency roll-off (Ban X. et al., 2016). Lim et al. (2017) developed an exciplex-forming cohost composed of mCP as the donor and 2,4-bis[4-(diphenylphosphoryl)phenyl]pyridine (BM-A10) as the acceptor for deep-blue PhOLEDs achieving a V_{on} of 2.9 eV, a rather high EQE_{max} of 24% with CIE coordinates of (0.15, 0.21). Yun and coworkers designed n-type molecules with isomeric molecular structure, while the corresponding exciplex cohosts formed by mCBP:3-(4,6-bis[3-(triphenylsilyl)phenyl]-1,3,5-triazin-2-yl)benzonitrile (mSiTrz-mCN) showed blue emission (Yun et al., 2021a). The deep-blue PhOLED employing this

exciplex as a cohost showed a low V_{on} of 2.8 V and a high EQE_{max} of 21.0% with a color coordinate of (0.14, 0.18). Afterward, Yun et al. developed a bipolar n-type host material, 9-(4,6-bis[3-(triphenylsilyl)phenyl]-1,3,5-triazin-2-yl)-9*H*-carbazole-3-carbonitrile (mSiTrzCzCN), and the blue-emitting mCBP:mSiTrzCzCN exciplex system showed a high T_1 energy close to 3.0 eV (Yun et al., 2021b). The mCBP:mSiTrzCzCN exciplex–based deep-blue PhOLED realized a high EQE_{max} of 21.8% and a lifetime elongation of more than double relative to the conventional n-type host-based device. Kim et al. developed three n-type hosts to form blue exciplex with mCBP (Kim et al., 2022). Among them, the exciplex developed by mCBP:CNmSi-2DBF-Trz showed a high T_1 of 2.95 eV and the fabricated blue PhOLED showed a rather high EQE_{max} over 23%.

CONCLUSION AND OUTLOOK

In summary, this study provided an overview of blue exciplex–based organic light-emitting materials and devices. The research background and luminescence mechanism were briefly introduced. Benefiting from the intriguing merits of exciplex-based OLEDs including low-driving voltages and low-efficiency roll-offs, simultaneously, as well as simple device structures, exciplexes have drawn significant attention on account of the potentials for efficient electroluminescence or for the use as high-performance cohost materials. Manipulating blue exciplex emissions by adjusting molecular structures gives an ideal strategy to fully utilize all exciton energies for high-performance OLEDs. We believe that our work will be conductive to the future development of blue exciplex–based OLEDs with high efficiencies and simplified device structures. Meanwhile, we expect that further systematic investigations of the excited-state dynamics and the structure-property relationships will be of benefit for the development of more efficient exciplex–based emitters and cohost materials oriented for WOLEDs and solution-processed OLEDs.

AUTHOR CONTRIBUTIONS

JL and QG conceived the idea and supervised the whole work. ZL, HL, HG, and JZ collected the articles and revised the manuscript. All authors contributed to the manuscript revision and approved the submitted version.

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