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(54) **BOROLE COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**

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(57) **ABSTRACT**

A borole compound is represented by Formula 1: X_{11}—$(R_{11})_{b11}$. X_{11}, R_{11}, and b11 are as defined herein. An organic light-emitting device includes the borole compound. The organic light-emitting device includes a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer. The organic layer includes the borole compound.

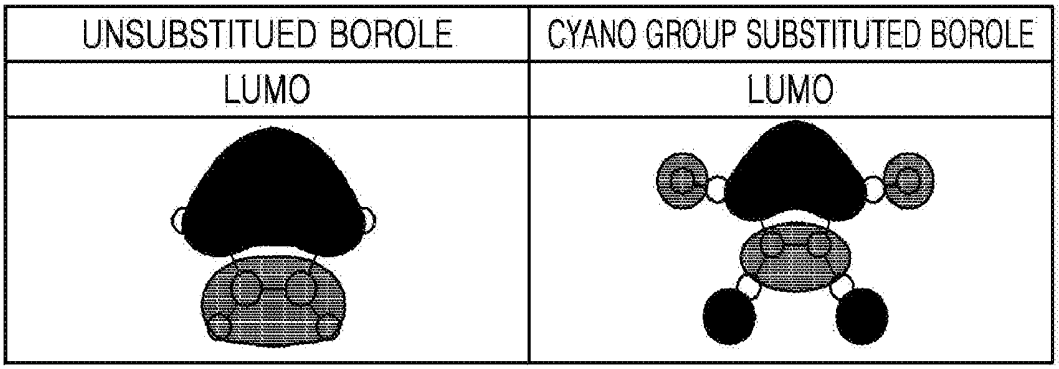


FIG. 1

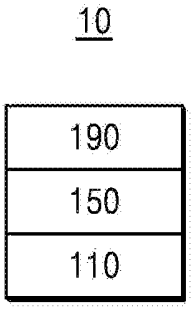


FIG. 2

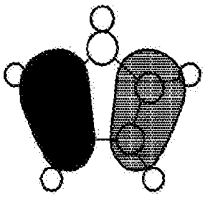
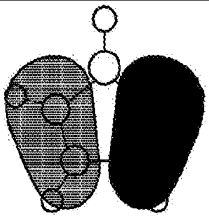
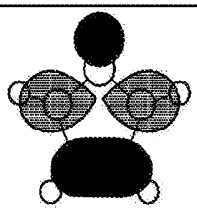
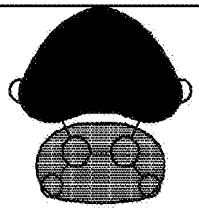
CYCLOPENTADIENE	BOROLE
HOMO	HOMO
	
LUMO	LUMO
	

FIG. 3

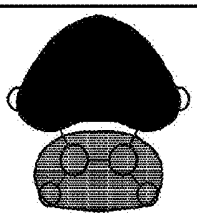
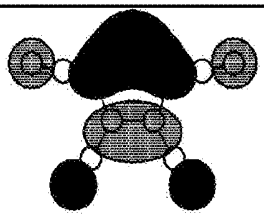
UNSUBSTITUED BOROLE	CYANO GROUP SUBSTITUTED BOROLE
LUMO	LUMO
	

FIG. 4

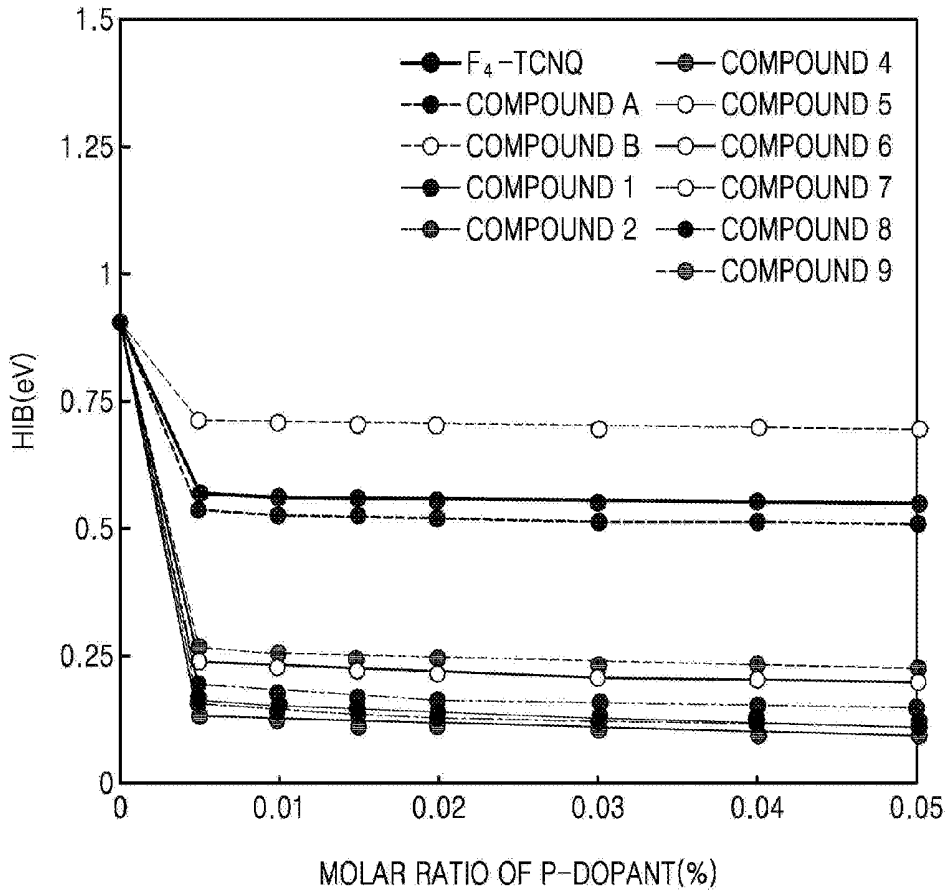

1.5
1.25
1
0.75
0.5
0.25
0
HIB(eV)
0
0.01
0.02
0.03
0.04
0.05
MOLAR RATIO OF P-DOPANT(%)
F4-TCNQ
COMPOUND A
COMPOUND B
COMPOUND 1
COMPOUND 2
COMPOUND 4
COMPOUND 5
COMPOUND 6
COMPOUND 7
COMPOUND 8
COMPOUND 9

FIG. 5

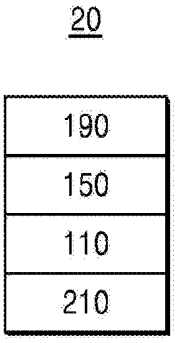


FIG. 6

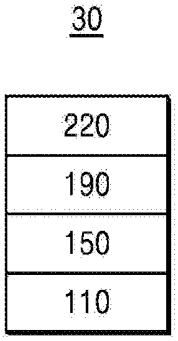
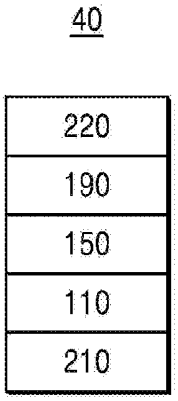


FIG. 7



BOROLE COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2016-0106989, filed on Aug. 23, 2016, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

[0002] One or more embodiments relate to a borole compound and an organic light-emitting device including the same.

2. Description of the Related Art

[0003] Organic light-emitting devices are self-emission devices that produce full-color images, and also have wide viewing angles, high contrast ratios, short response times, as well as excellent characteristics in terms of brightness, driving voltage, and response speed.

[0004] An example of such organic light-emitting devices may include a first electrode disposed on a substrate, and a hole transport region, an emission layer, an electron transport region, and a second electrode, which are sequentially disposed on the first electrode. Holes provided from the first electrode may move toward the emission layer through the hole transport region, and electrons provided from the second electrode may move toward the emission layer through the electron transport region. Carriers, such as holes and electrons, recombine in the emission layer to produce excitons. These excitons transition from an excited state to a ground state, thereby generating light.

SUMMARY

[0005] One or more embodiments include a borole compound and an organic light-emitting device including the same.

[0006] Additional aspects of embodiments will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0007] According to one or more embodiments, a borole compound is represented by Formula 1:

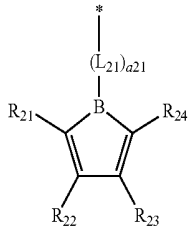
$$X_{11}—(R_{11})_{b11}. \quad \text{Formula 1}$$

[0008] In Formula 1,

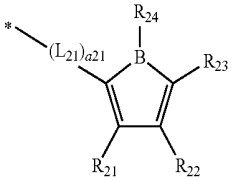
[0009] X_{11} may be selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylene carbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted dibenzoborole, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene, and

[0010] R_{11} may be represented by one of Formulae 2-1 to 2-3:

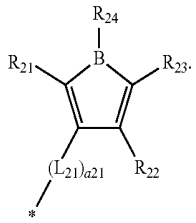
2-1



2-2



2-3



[0011] In Formula 1, b11 may be selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, wherein, when b11 is two or more, a plurality of R_{11}(s) may be identical to or different from each other.

[0012] In Formulae 2-1 to 2-3,

[0013] L_{21} may be selected from a substituted or unsubstituted C_1-C_{10} alkylene group, a substituted or unsubstituted C_2-C_{10} alkenylene group, a C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0014] a21 may be 0 or 1,

[0015] R_{21} to R_{24} may each independently be selected from R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} het-

eroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$, provided that at least one of R_{21} to R_{24} is R_{EW},

[0016] R_{EW} indicates an electron withdrawing group, and

[0017] * indicates a binding site to a neighboring atom.

[0018] According to one or more embodiments, an organic light-emitting device includes: a first electrode; a second electrode; an organic layer between the first electrode and the second electrode, the organic layer including an emission layer,

[0019] wherein the organic layer includes the borole compound described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

[0021] FIG. **1** is a schematic view of an organic light-emitting device according to an embodiment;

[0022] FIG. **2** is a view showing highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) distributions of cyclopentadiene and borole;

[0023] FIG. **3** is a view showing LUMO distributions of unsubstituted borole and borole substituted with a cyano group;

[0024] FIG. **4** is a graph showing a function of a hole injection barrier (HIB) according to Evaluation Example 3; and

[0025] FIGS. **5-7** are schematic views of organic light-emitting devices according to embodiments.

DETAILED DESCRIPTION

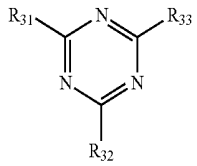
[0026] A borole compound according to an embodiment may be represented by Formula 1:

$$X_{11}—(R_{11})_{b11}. \qquad \text{Formula 1}$$

[0027] X_{11} in Formula 1 may be selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylene carbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted dibenzoborole, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene.

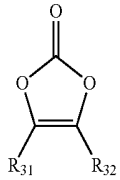
[0028] For example, X_{11} in Formula 1 may be represented by one of Formulae 3-1 to 3-9, but embodiments of the present disclosure are not limited thereto:

3-1

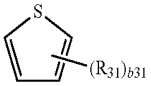


-continued

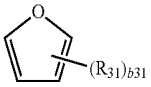
3-2



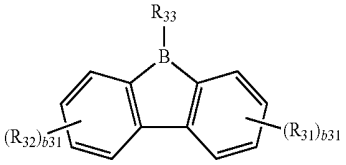
3-3



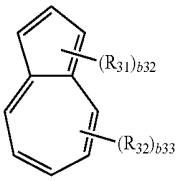
3-4



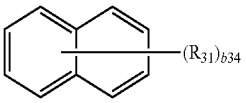
3-5



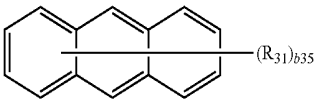
3-6



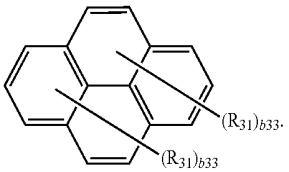
3-7



3-8



3-9



[0029] In Formulae 3-1 to 3-9,

[0030] R_{31} to R_{33} may each independently be selected from:

[0031] a binding site to R_{11}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group;

[0032] a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a

monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0033] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0034] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group,

[0035] at least one selected from R_{31}, the number of which is the same as b11, may be a binding site to R_{11}, at least one selected from R_{31} and R_{32}, the number of which is the same as b11, may be a binding site to R_{11}, or at least one selected from R_{31} to R_{33}, the number of which is the same as b11, may be a binding site to R_{11},

[0036] b31 may be selected from 1, 2, 3, and 4,

[0037] b32 may be selected from 1, 2, and 3,

[0038] b33 may be selected from 1, 2, 3, 4, and 5,

[0039] b34 may be selected from 1, 2, 3, 4, 5, and 6, and

[0040] b35 may be selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.

[0041] In one or more embodiments, R_{31} to R_{33} in Formulae 3-1 to 3-9 may each independently be selected from:

[0042] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

[0043] a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group; and

[0044] a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, but embodiments of the present disclosure are not limited thereto.

[0045] In one or more embodiments, R_{31} to R_{33} in Formulae 3-1 to 3-9 may each independently be selected from:

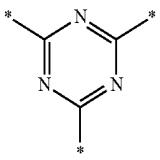
[0046] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0047] a phenyl group and a naphthyl group; and

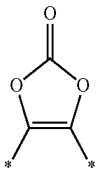
[0048] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0049] In one or more embodiments, X_{11} in Formula 1 may be represented by one of Formulae 4-1 to 4-9, but embodiments of the present disclosure are not limited thereto:

4-1



4-2



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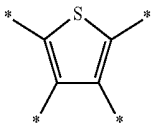
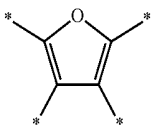


4-4



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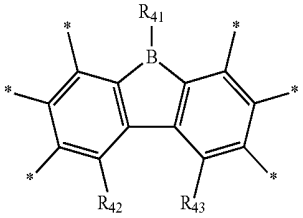

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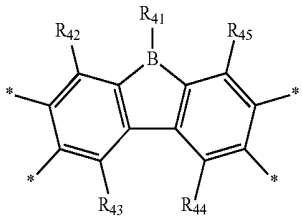
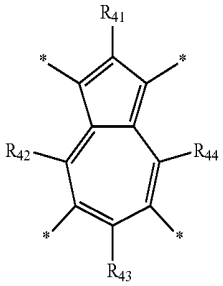
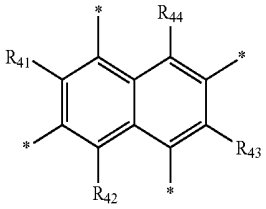
4-6



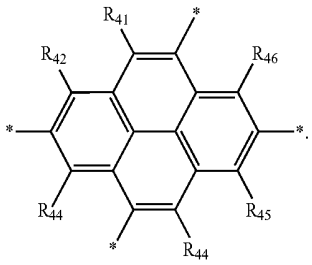
4-7



4-8



4-9



[0050] In Formulae 4-1 to 4-9,

[0051] * indicates a binding site to R_{11}, and

[0052] R_{41} to R_{46} may each independently be selected from:

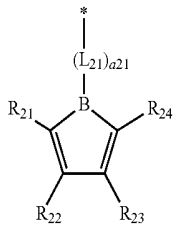
[0053] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0054] a phenyl group and a naphthyl group; and

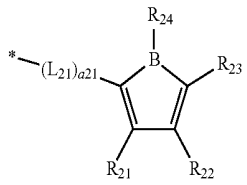
[0055] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

[0056] R_{11} in Formula 1 may be represented by one of Formulae 2-1 to 2-3:

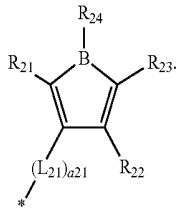
2-1



2-2



2-3



[0057] In Formulae 2-1 to 2-3,

[0058] * indicates a binding site to X_{11}, and

[0059] L_{21}, a21, and R_{21} to R_{24} are the same as described below.

[0060] L_{21} in Formulae 2-1 to 2-3a may be selected from a substituted or unsubstituted C_1-C_{10} alkylene group, a substituted or unsubstituted C_2-C_{10} alkenylene group, a C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group.

[0061] For example, L_{21} in Formulae 2-1 to 2-3 may be selected from:

[0062] a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group; and

[0063] a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0064] In one or more embodiments, L_{21} in Formulae 2-1 to 2-3 may be selected from a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group, but embodiments of the present disclosure are not limited thereto.

[0065] a21 in Formulae 2-1 to 2-3 indicates the repeating number of L_{21}(s) and may be 0 or 1. When a21 is 0, $(L_{21})_{a21}$ may be a single bond.

[0066] For example, a21 in Formulae 2-1 to 2-3 may be 0, but embodiments of the present disclosure are not limited thereto.

[0067] R_{21} to R_{24} in Formulae 2-1 to 2-3 may each independently be selected from R_{EW} (as used herein, "R_{EW}" indicates an electron withdrawing group), hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$,

[0068] wherein Q_1 to Q_3 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0069] For example, R_{21} to R_{24} in Formulae 2-1 to 2-3 may each independently be selected from:

[0070] R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group;

[0071] a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0072] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0073] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, provided that at least one of R_{21} to R_{24} is R_{EW},

[0074] but embodiments of the present disclosure are not limited thereto.

[0075] In one or more embodiments, R_{21} to R_{24} in Formulae 2-1 to 2-3 may each independently be selected from:

[0076] R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

[0077] a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group; and

[0078] a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, provided that at least one of R_{21} to R_{24} is R_{EW},

[0079] but embodiments of the present disclosure are not limited thereto.

[0080] In one or more embodiments, R_{21} to R_{24} in Formulae 2-1 to 2-3 may each independently be selected from:

[0081] R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group,

an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0082] a phenyl group and a naphthyl group; and

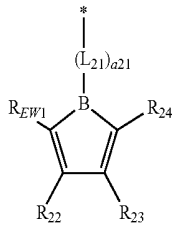
[0083] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group, provided that at least one of R_{21} to R_{24} is R_{EW},

[0084] but embodiments of the present disclosure are not limited thereto.

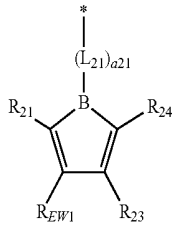
[0085] For example, R_{11} in Formula 1 may be represented by Formula 2-1, but embodiments of the present disclosure are not limited thereto.

[0086] In one or more embodiments, R_{11} in Formula 1 may be represented by one of Formulae 2-11 to 2-19, but embodiments of the present disclosure are not limited thereto:

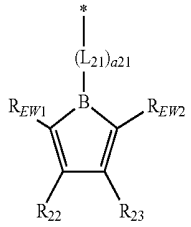
2-11



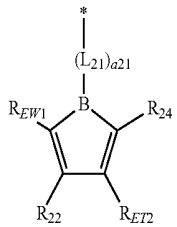
2-12



2-13



2-14



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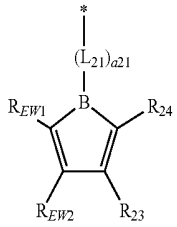
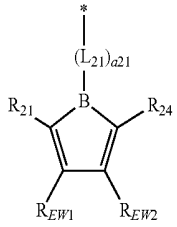
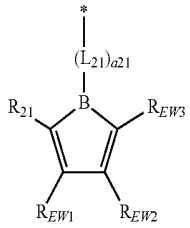
2-15



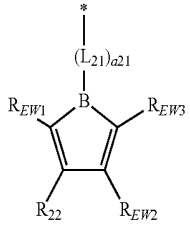
2-16



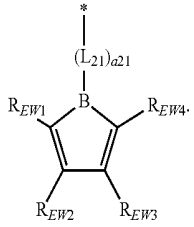
2-17



2-18



2-19



[0087] In Formulae 2-11 to 2-19,

[0088] L_{21} may be selected from a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group,

[0089] a21 may be 0 or 1,

[0090] R_{21} to R_{24} may each independently be selected from:

[0091] R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0092] a phenyl group and a naphthyl group; and

[0093] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl,

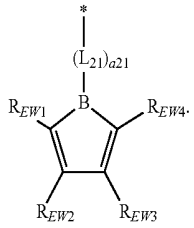
—Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

[0094] R_{EW1} to R_{EW4} may each be an electron withdrawing group, and

[0095] * indicates a binding site to X_{11}.

[0096] In one or more embodiments, R_{11} in Formula 1 may be represented by Formula 2-19, but embodiments of the present disclosure are not limited thereto:

2-19



[0097] In Formula 2-19,

[0098] $(L_{21})_{a21}$ may be a single bond,

[0099] R_{EW1} to R_{EW4} may each independently be selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, $—CF_3$, $—CCl_3$, $—CBr_3$, $—Cl_3$, $—C_2F_3$, $—C_2Cl_3$, $—C_2Br_3$, $—C_2I_3$, $—C_2(CN)_3$, and $—C_2(NO_2)_3$, and

[0100] * indicates a binding site to X_{11}.

[0101] b11 in Formula 1 indicates the number of R_{11}(s) and may be selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. When b11 is two or more, a plurality of R_{11}(s) may be identical to or different from each other.

[0102] R_{EW} in Formula 1 indicates an electron withdrawing group.

[0103] For example, R_{EW} may be selected from:

[0104] —F, —Cl, —Br, —I, a cyano group, and a nitro group; and

[0105] a C_1-C_{10} alkyl group and a C_2-C_{10} alkenyl group, each substituted with at least one selected from —F, —Cl, —Br, —I, a cyano group, and a nitro group, but embodiments of the present disclosure are not limited thereto.

[0106] In one or more embodiments, as used throughout the present application, including the claims, R_{EW} may be selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, $—CF_3$, $—CCl_3$, $—CBr_3$, $—Cl_3$, $—C_2F_3$, $—C_2Cl_3$, $—C_2Br_3$, $—C_2I_3$, $—C_2(CN)_3$, and $—C_2(NO_2)_3$, but embodiments of the present disclosure are not limited thereto.

[0107] In one or more embodiments, in Formula 1, X_{11} may be represented by one of Formulae 4-1 to 4-9, and R_{11} may be represented by one of Formulae 2-11 to 2-19, and

[0108] b11 may be selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, wherein, when b11 is two or more, a plurality of R_{11}(s) may be identical to or different from each other.

[0109] In Formulae 4-1 to 4-9,

[0110] * indicates a binding site to R_{11}, and

[0111] R_{41} to R_{46} may each independently be selected from:

[0112] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0113] a phenyl group and a naphthyl group; and

[0114] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

[0115] In Formulae 2-11 to 2-19,

[0116] $(L_{21})_{a21}$ may be a single bond,

[0117] R_{21} to R_{24} may each independently be selected from:

[0118] R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0119] a phenyl group and a naphthyl group; and

[0120] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group,

[0121] R_{EW1} to R_{EW4} may each independently be selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, $—CF_3$, $—CCl_3$, $—CBr_3$, $—Cl_3$, $—C_2F_3$, $—C_2Cl_3$, $—C_2Br_3$, $—C_2I_3$, $—C_2(CN)_3$, and $—C_2(NO_2)_3$, and

[0122] * indicates a binding site to X_{11}, but embodiments of the present disclosure are not limited thereto.

[0123] In one or more embodiments, in Formula 1, X_{11} may be represented by one of Formulae 4-1 to 4-9, and R_{11} may be represented by Formula 2-19,

[0124] b11 may be selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, wherein, when b11 is two or more, a plurality of R_{11}(s) may be identical to or different from each other.

[0125] In Formulae 4-1 to 4-9,

[0126] * indicates a binding site to R_{11}, and

[0127] R_{41} to R_{46} may each independently be selected from:

[0128] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

[0129] a phenyl group and a naphthyl group; and

[0130] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl,

—Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

[0131] In Formula 2-19,

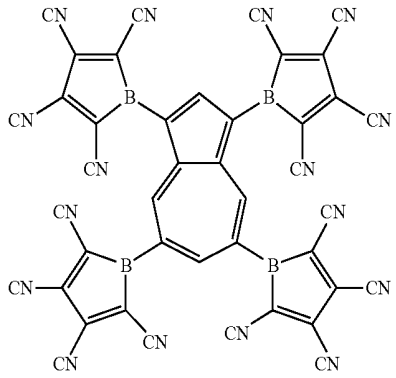
[0132] $(L_{21})_{a21}$ may be a single bond,

[0133] R_{EW1} to R_{EW4} may each independently be selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, $—CF_3$, $—CCl_3$, $—CBr_3$, $—Cl_3$, $—C_2F_3$, $—C_2Cl_3$, $—C_2Br_3$, $—C_2I_3$, $—C_2(CN)_3$, and $—C_2(NO_2)_3$, and

[0134] * indicates a binding site to X_{11}, but embodiments of the present disclosure are not limited thereto.

[0135] In one or more embodiments, the borole compound represented by Formula 1 may be selected from Compounds 1 to 9, but embodiments of the present disclosure are not limited thereto:

1



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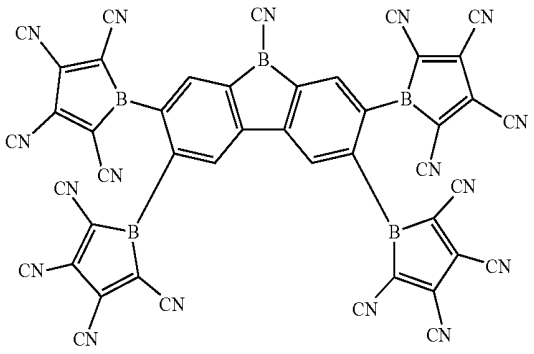

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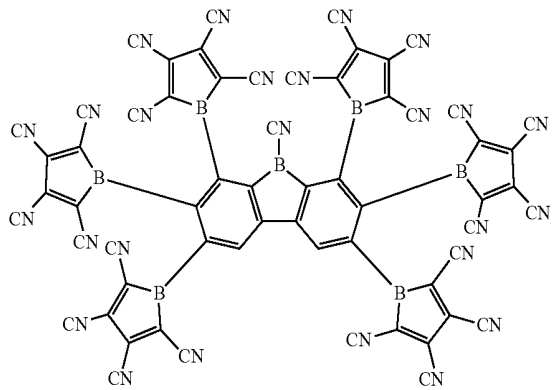

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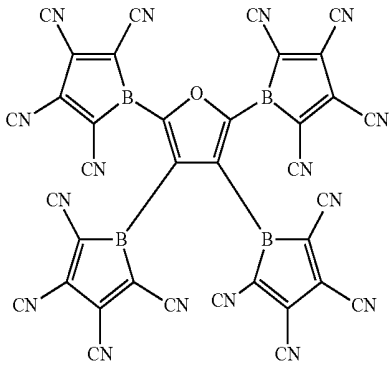

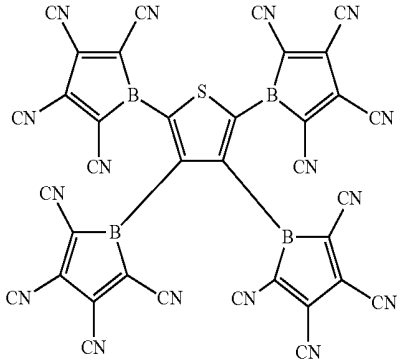

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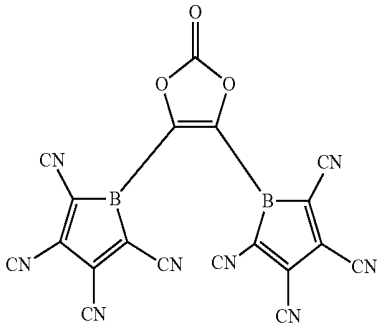

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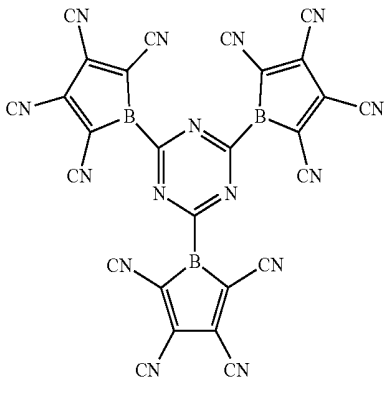

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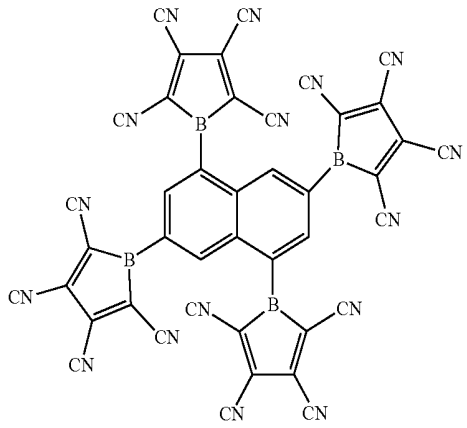
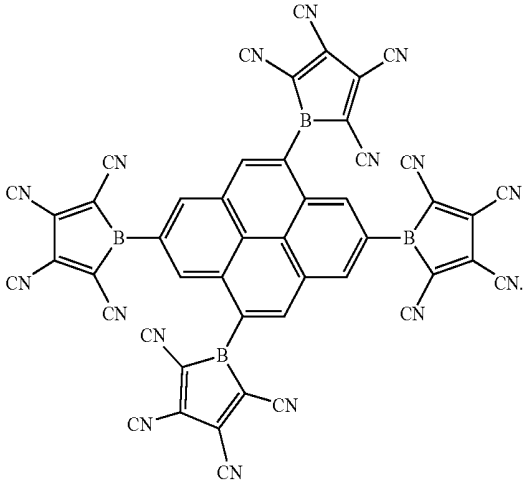
8



9



[0136] The borole compound represented by Formula 1 includes (or essentially includes) a borole structure represented by one of Formulae 2-1 to 2-3.

[0137] Referring to FIG. **2**, in a borole structure, a molecular orbital contributing to a lowest unoccupied molecular orbital (LUMO) is large, as compared with a boron (B)-free cyclopentadiene structure. This means that borole has stronger electron acceptor characteristics than cyclopentadiene. Accordingly, the borole compound represented by Formula 1, which has the borole structure, may have a relatively high electron affinity (for example, the borole compound may have a higher electron affinity than the compound including cyclopentadiene (or pyrrole) by about 2.35 eV).

[0138] Also, referring to FIG. **3**, it can be seen that an electron density of LUMO is further delocalized by introducing the electron withdrawing group, such as a cyano group, into the borole structure. Accordingly, when the electron withdrawing group, such as a cyano group, is introduced into the borole structure, a LUMO energy level of such a compound may be reduced, and the electron affinity of such a component may be increased.

[0139] Also, by introducing the electron withdrawing group into the borole structure, a compound having a high electron affinity may be provided.

[0140] Therefore, the borole compound represented by Formula 1, according to one or more embodiments, may have a high electron affinity because the borole compound has a structure in which R_{11} having a strong electron withdrawing group is substituted with an X_{11} core having strong electron acceptor characteristics.

[0141] An electron affinity of the borole compound represented by Formula 1 may be in a range of about 5.5 eV to about 6.0 eV. When the electron affinity of the borole compound represented by Formula 1 is within this range, a borole compound having a relatively low hole injection barrier may be provided.

[0142] A hole injection barrier of the borole compound represented by Formula 1 may be in a range of about 0.1 eV to about 0.4 eV. When the hole injection barrier of the borole compound represented by Formula 1 is within this range, a hole injection barrier at an interface between the anode and the organic layer may be reduced. Accordingly, an organic light-emitting device including the borole compound may have high efficiency and a low driving voltage.

[0143] The borole compound represented by Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the borole compound may be included in a hole transport region, for example, a hole injection layer and/or a buffer layer. Therefore, an organic light-emitting device includes a first electrode, a second electrode, and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer includes at least one of the borole compound represented by Formula 1.

[0144] For example, the first electrode may be an anode, the second electrode may be a cathode, the organic layer may further include a hole transport region between the first electrode and the emission layer, and the hole transport region may include the borole compound, but embodiments of the present disclosure are not limited thereto.

[0145] In one or more embodiments, the hole transport region may include a hole injection layer including the borole compound, or the hole transport region may include a buffer layer including the borole compound, but embodiments of the present disclosure are not limited thereto.

[0146] In one or more embodiments, the hole transport region may include a hole injection layer including the borole compound and a buffer layer including the borole compound, but embodiments of the present disclosure are not limited thereto.

[0147] In one or more embodiments, the hole injection layer may further include a matrix material, and an amount of the borole compound in the hole injection layer may be in a range of greater than 0 wt % and equal to or smaller than 6 wt % based on a total weight of the hole injection layer, but embodiments of the present disclosure are not limited thereto. For example, the amount of the borole compound in the hole injection layer may be in a range of 1 wt % to 4 wt % based on the total weight of the hole injection layer, but embodiments of the present disclosure are not limited thereto. When the amount of the borole compound is within this range, a hole injection barrier between two neighboring layers may be reduced.

[0148] In one or more embodiments, the buffer layer may further include a matrix material, an amount of the borole compound in the buffer layer may be in a range of greater than 0 wt % and equal to or smaller than 6 wt % based on a total weight of the buffer layer, but embodiments of the present disclosure are not limited thereto. For example, the amount of the borole compound in the buffer layer may be in a range of 1 wt % to 4 wt % based on the total weight of

the buffer layer, but embodiments of the present disclosure are not limited thereto. When the amount of the borole compound is within this range, a hole injection barrier between two neighboring layers may be reduced.

[0149] The matrix material may be selected from the compounds included in the hole transport region to be described below, but embodiments of the present disclosure are not limited thereto.

[0150] The expression "(an organic layer) includes at least one borole compound" used herein may include a case in which "(an organic layer) includes one borole compound represented by Formula 1" and a case in which "(an organic layer) includes two or more different borole compounds represented by Formula 1."

[0151] For example, the organic layer may include, as the borole compound, only Compound 1. In this regard, Compound 1 may be present in a hole injection layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the borole compound, Compound 1 and Compound 2. In one or more embodiments, Compound 1 and Compound 2 may both be present in an identical or same layer (for example, Compound 1 and Compound 2 may both be present in a hole injection layer), or may be present in different layers (for example, Compound 1 may be present in a hole injection layer and Compound 2 may be present in a buffer layer).

[0152] The organic layer includes i) a hole transport region that is disposed between the first electrode (anode) and the emission layer and includes at least one of a hole injection layer, a hole transport layer, a buffer layer, and an electron blocking layer, and ii) an electron transport region that is disposed between the emission layer and the second electrode (cathode) and includes at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer. In one or more embodiment, at least one of the hole injection layer and the buffer layer may include the borole compound represented by Formula 1.

[0153] The term "organic layer" used herein refers to a single (or sole) layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the "organic layer" is not limited to an organic material.

[0154] [Description of FIG. **1**]

[0155] FIG. **1** is a schematic view of an organic light-emitting device **10** according to an embodiment. The organic light-emitting device **10** includes a first electrode **110**, an organic layer **150**, and a second electrode **190**.

[0156] Hereinafter, the structure of the organic light-emitting device **10** according to an embodiment and a method of manufacturing the organic light-emitting device **10** will be described in connection with FIG. **1**.

[0157] [First Electrode **110**]

[0158] In FIG. **1**, a substrate may be additionally disposed under the first electrode **110** or above the second electrode **190**. The substrate may be a glass substrate or a plastic substrate, each having, for example, excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water resistance.

[0159] The first electrode **110** may be formed by depositing or sputtering a material for forming the first electrode **110** on the substrate. When the first electrode **110** is an anode, the material for a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0160] The first electrode **110** may be a reflective electrode, a semi-transmissive electrode, or a transmissive electrode. When the first electrode **110** is a transmissive electrode, a material for forming a first electrode may be selected from indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), zinc oxide (ZnO), and any combinations thereof, but embodiments of the present disclosure are not limited thereto. In one or more embodiments, when the first electrode **110** is a semi-transmissive electrode or a reflective electrode, a material for forming a first electrode may be selected from magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), and any combinations thereof, but embodiments of the present disclosure are not limited thereto. As used herein, the terms "combination thereof" and "combinations thereof" may refer to a chemical combination (e.g., an alloy or chemical compound), a mixture, or a laminated structure of components.

[0161] The first electrode **110** may have a single-layered structure, or a multi-layered structure including two or more layers. For example, the first electrode **110** may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode **110** is not limited thereto.

[0162] [Organic Layer **150**]

[0163] The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** may include an emission layer.

[0164] The organic layer **150** may further include a hole transport region between the first electrode **110** and the emission layer, and an electron transport region between the emission layer and the second electrode **190**.

[0165] [Hole Transport Region in Organic Layer **150**]

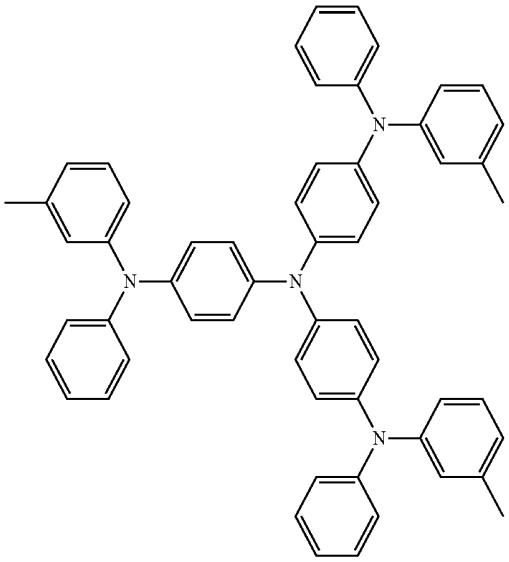
[0166] The hole transport region may have i) a single-layered structure including a single (or sole) layer including a single (or sole) material, ii) a single-layered structure including a single (or sole) layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0167] The hole transport region may include at least one layer selected from a hole injection layer (HIL), a hole transport layer (HTL), an emission auxiliary layer, and an electron blocking layer (EBL).

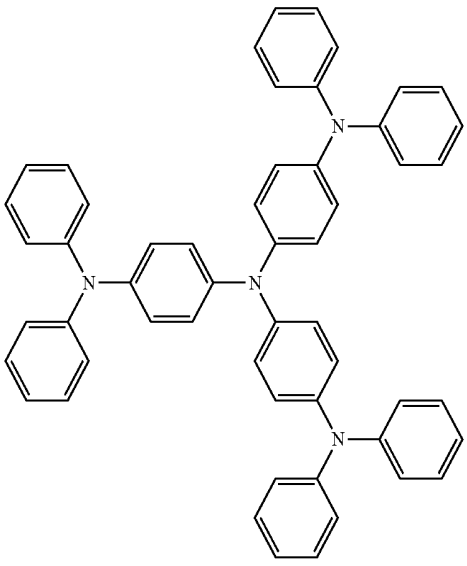
[0168] For example, the hole transport region may have a single-layered structure including a single (or sole) layer including a plurality of different materials, or a multi-layered structure having a hole injection layer/hole transport layer structure, a hole injection layer/hole transport layer/emission auxiliary layer structure, a hole injection layer/emission auxiliary layer structure, a hole transport layer/emission auxiliary layer structure, or a hole injection layer/hole transport layer/electron blocking layer structure, wherein for each

structure, constituting layers are sequentially stacked from the first electrode **110** in this stated order, but the structure of the hole transport region is not limited thereto.

[0169] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), p-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated-NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (PANI/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), polyaniline/poly(4-styrenesulfonate) (PANI/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:



m-MTDATA



TDATA

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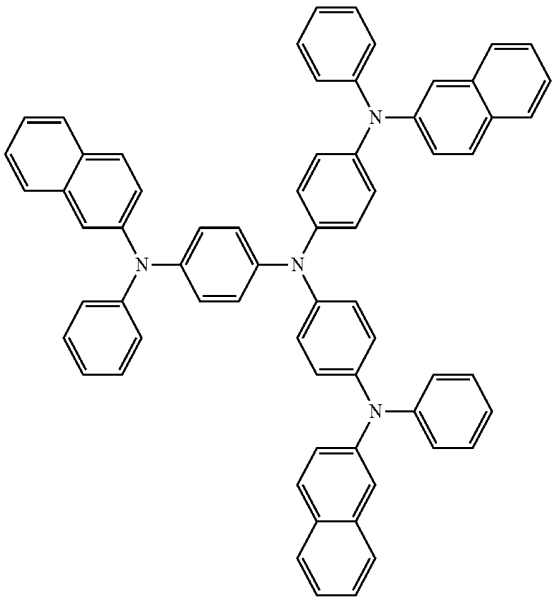
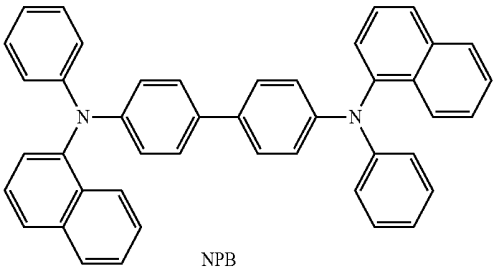
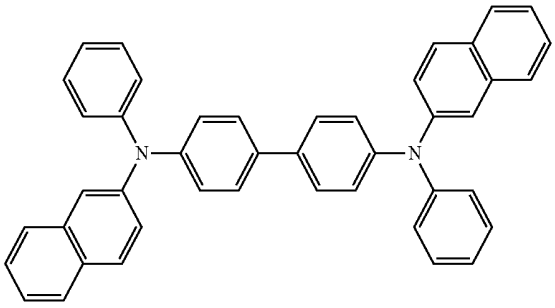


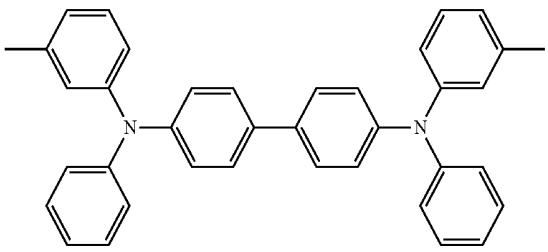
2-TNATA



NPB



β-NPB



TPD

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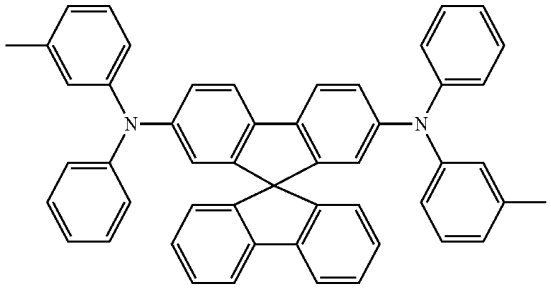
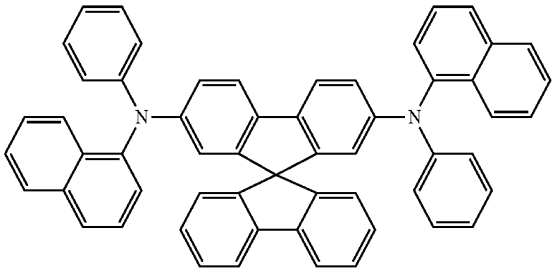
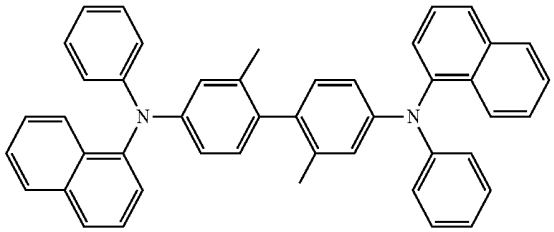


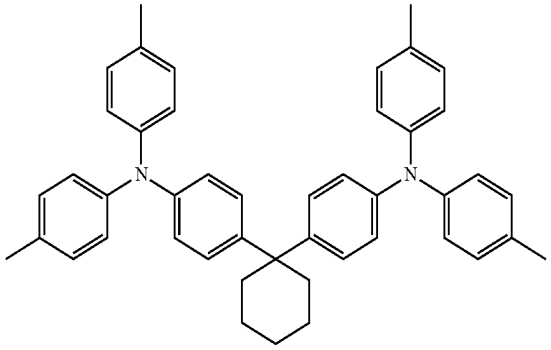
Spiro-TPD



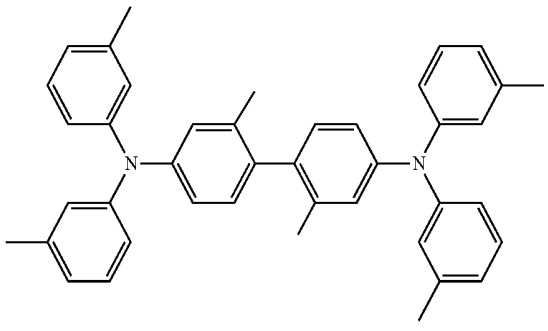
Spiro-NPB



methylated NPB



TAPC



HMTPD

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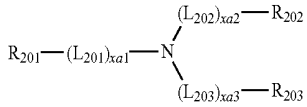
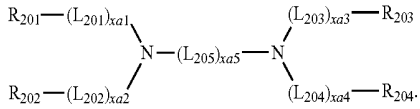
Formula 201



Formula 202



[0170] In Formulae 201 and 202,

[0171] L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group;

[0172] L_{205} may be selected from *—O—*', *—S—*', *—N(Q_{201})-*', a substituted or unsubstituted C_1-C_{20} alkylene group, a substituted or unsubstituted C_2-C_{20} alkenylene group, a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0173] xa1 to xa4 may each independently be an integer from 0 to 3,

[0174] xa5 may be an integer from 1 to 10, and

[0175] R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0176] For example, in Formula 202, R_{201} and R_{202} may optionally be linked via a single bond, a dimethyl-methylene

group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0177] In one or more embodiments, in Formulae 201 and 202,

[0178] L_{201} to L_{205} may each independently be selected from:

[0179] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, and a fluorenylene group,

[0180] a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group; and

[0181] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an indacenylene group, an acenaphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a rubicenylene group, a coronenylene group, an ovalenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, and —$N(Q_{31})(Q_{32})$; and

[0182] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0183] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0184] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0185] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0186] a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a

biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, and —$N(Q_{31})(Q_{32})$; and

[0187] Q_{31} to Q_{33} may be the same as described above.

[0188] In one or more embodiments, at least one selected from R_{201} to R_{203} in Formula 201 may each independently be selected from:

[0189] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0190] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

[0191] In one or more embodiments, in Formula 202, i) R_{201} and R_{202} may be linked via a single bond, and/or ii) R_{203} and R_{204} may be linked via a single bond.

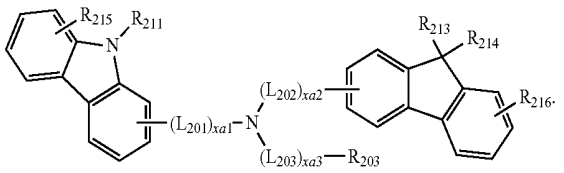
[0192] In one or more embodiments, at least one selected from R_{201} to R_{204} in Formula 202 may be selected from:

[0193] a carbazolyl group; and

[0194] a carbazolyl group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group.

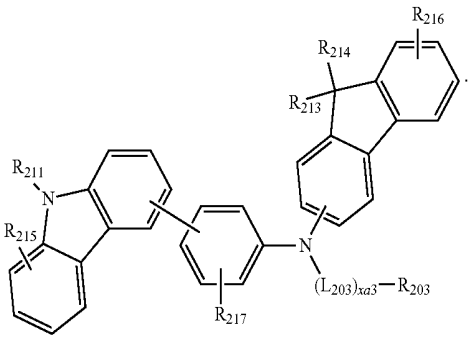
[0195] The compound represented by Formula 201 may be represented by Formula 201A:

Formula 201A



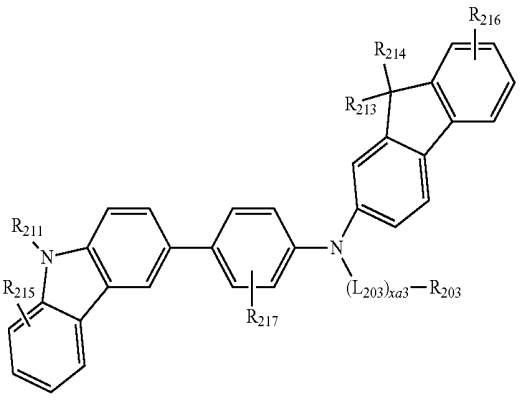
[0196] For example, the compound represented by Formula 201 may be represented by Formula 201A(1), but embodiments of the present disclosure are not limited thereto:

Formula 201A(1)



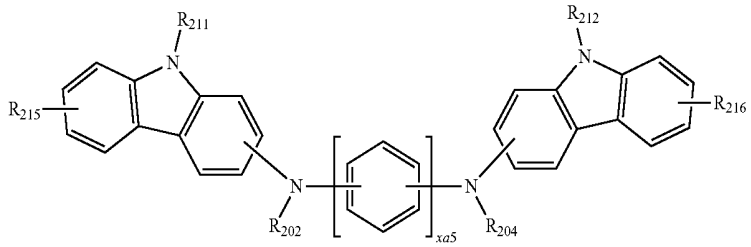
[0197] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1, but embodiments of the present disclosure are not limited thereto:

<Formula 201A-1>



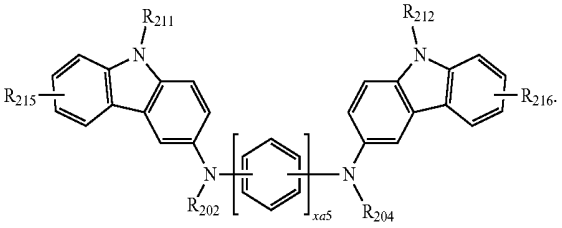
[0198] The compound represented by Formula 202 may be represented by Formula 202A:

Formula 202A



[0199] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:

Formula 202A-1



[0200] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

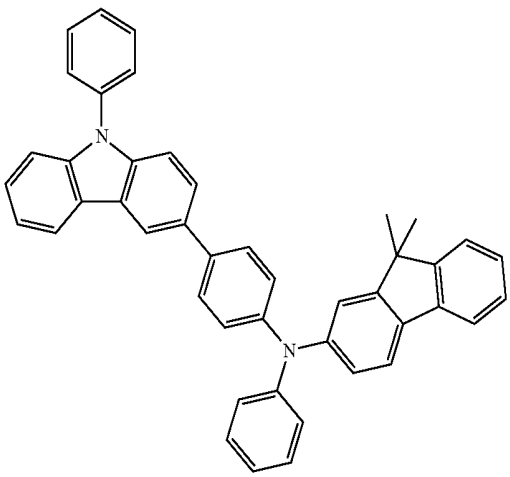
[0201] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} may be the same as described above,

[0202] R_{211} and R_{212} may be the same as described in connection with R_{203},

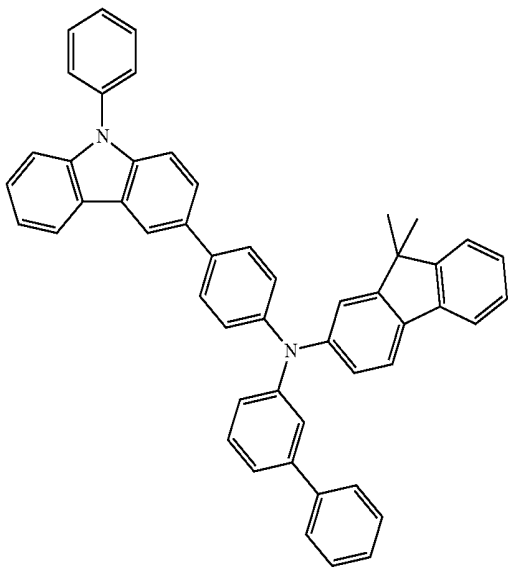
[0203] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with —F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0204] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

HT1



HT2



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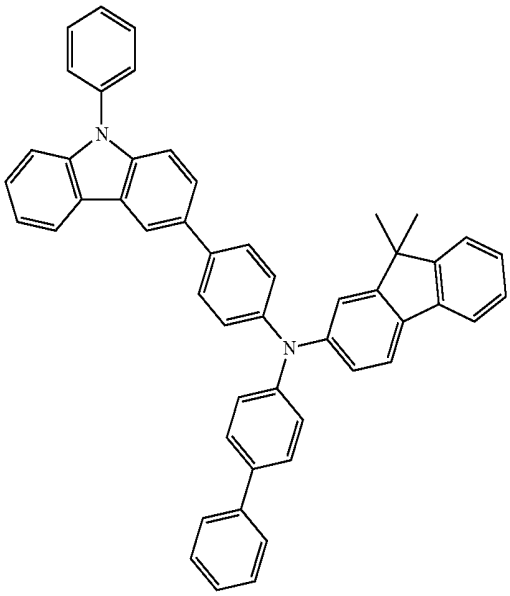
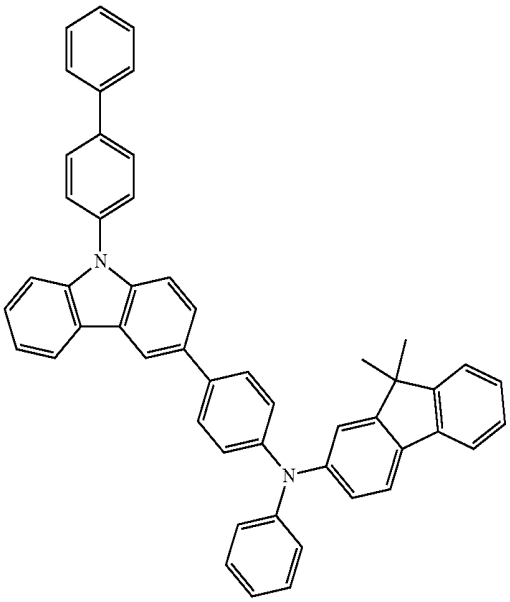
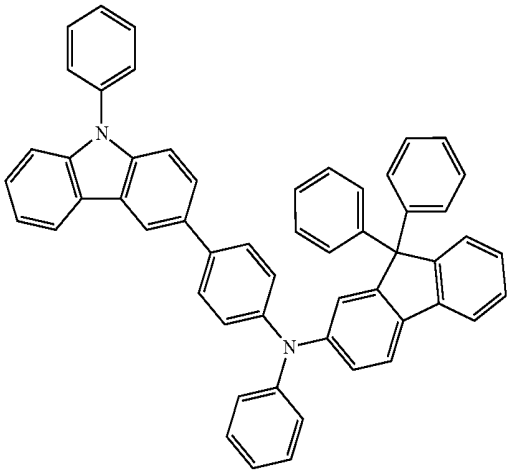
HT3



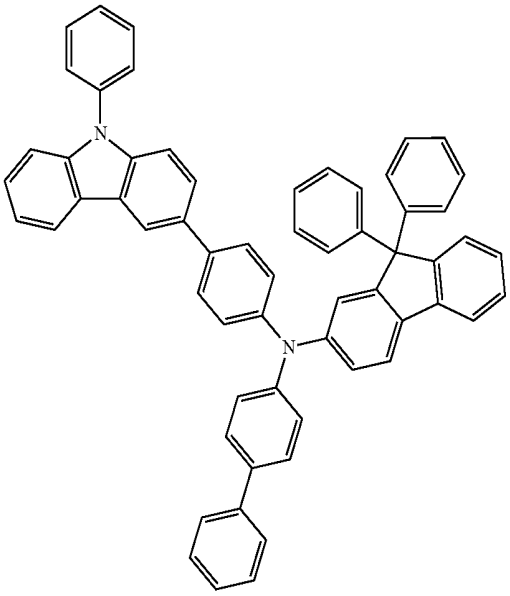
HT4



HT5



HT6



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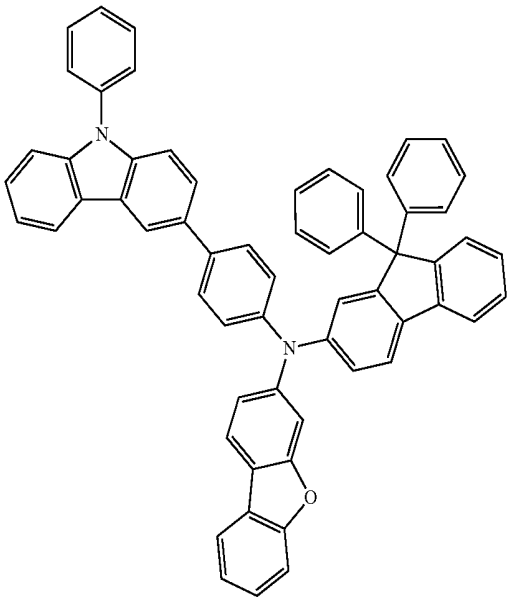
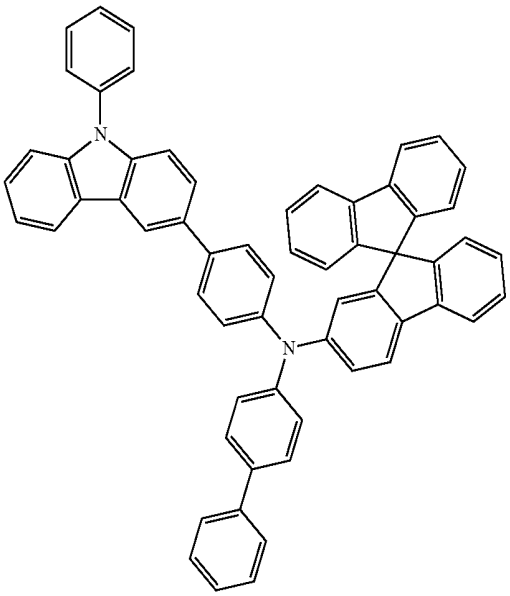
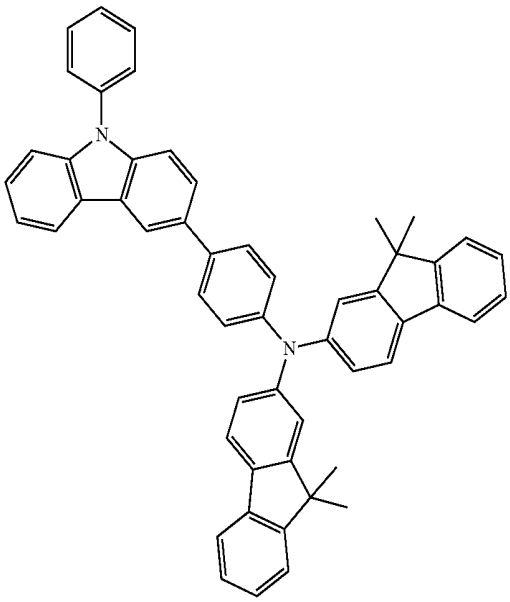
HT7



HT8



HT9



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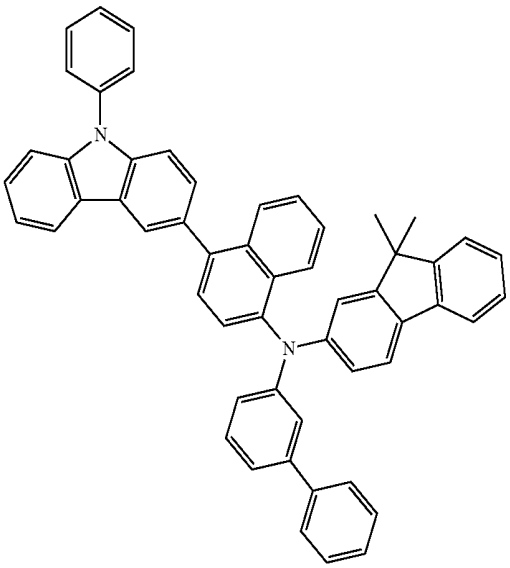

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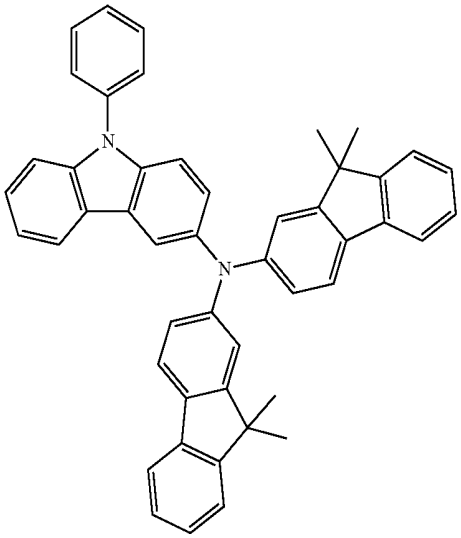
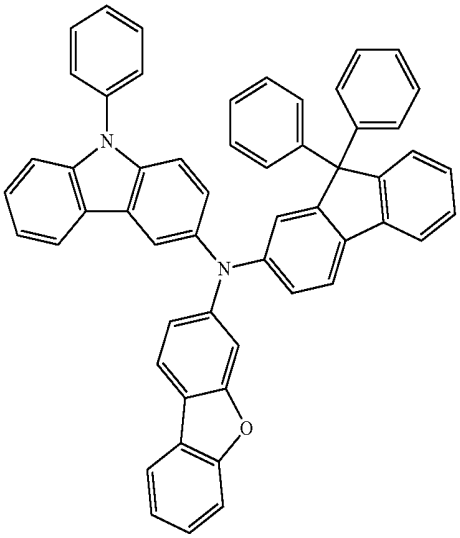
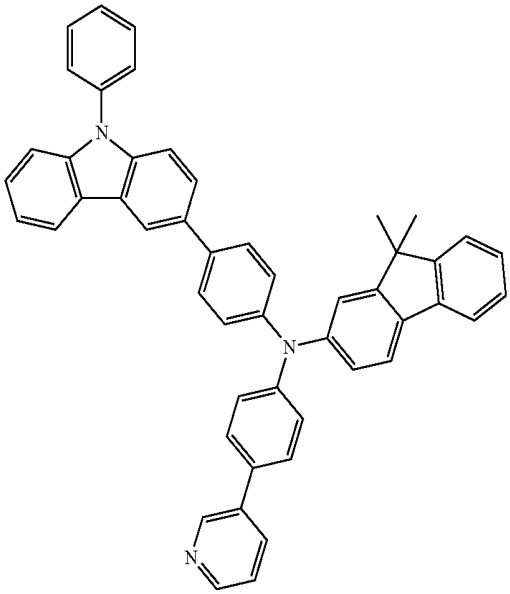
HT11



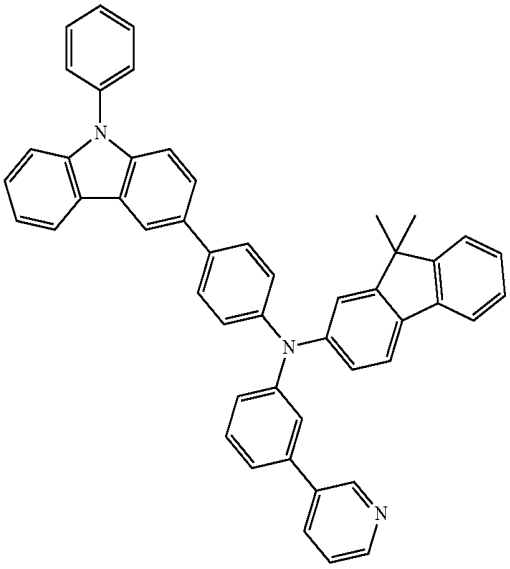
HT12



HT13



HT14



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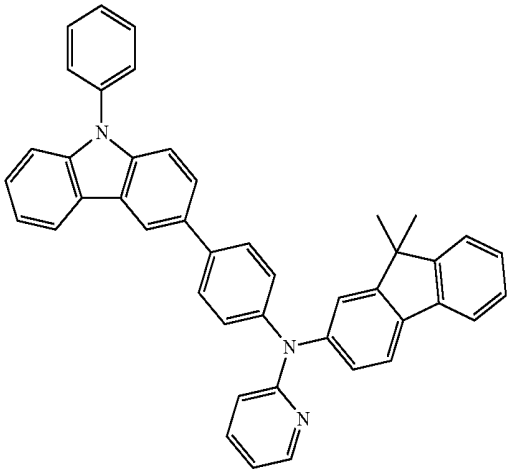
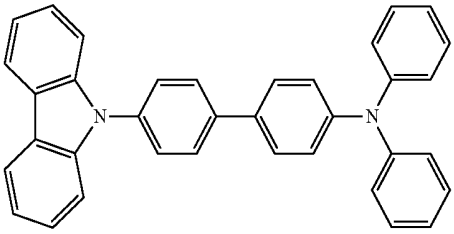


HT16



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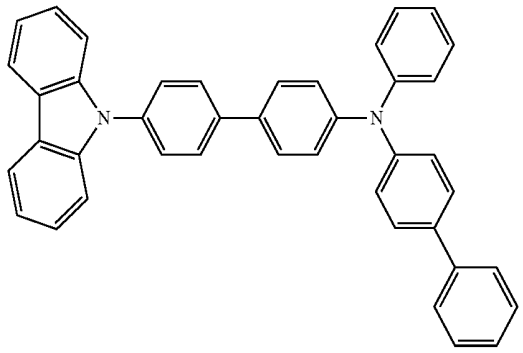
HT17



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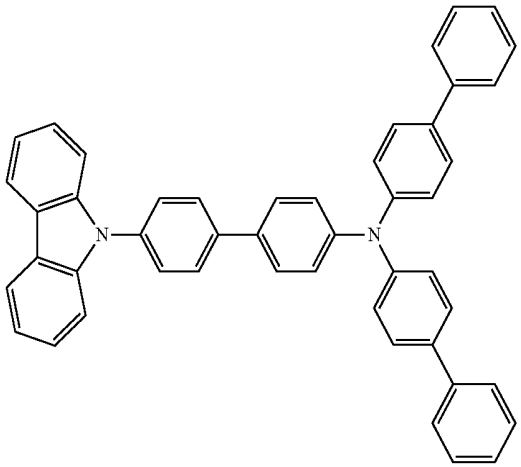

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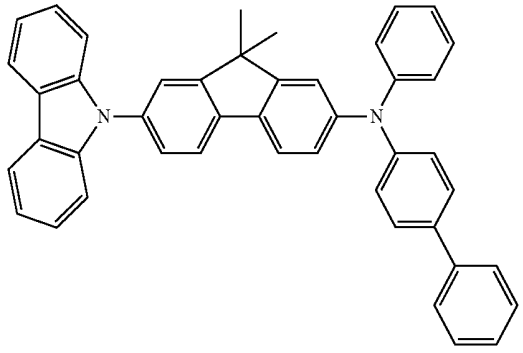

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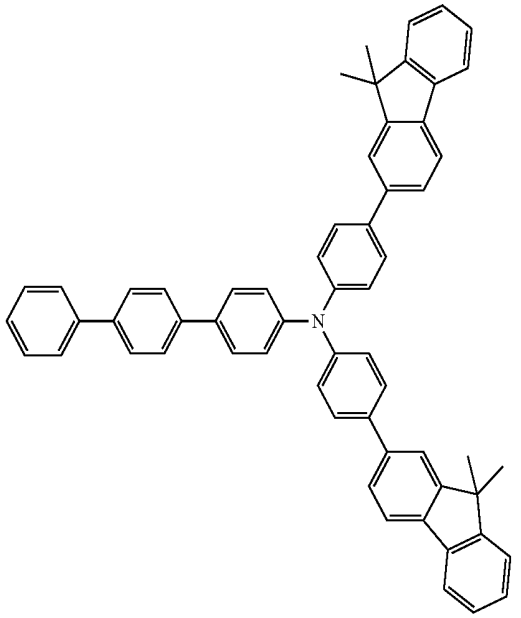

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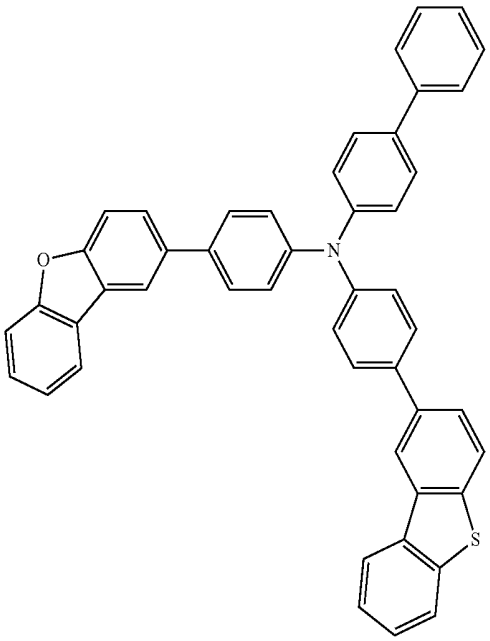
HT21



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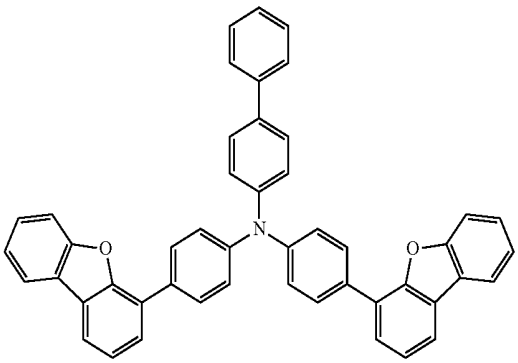

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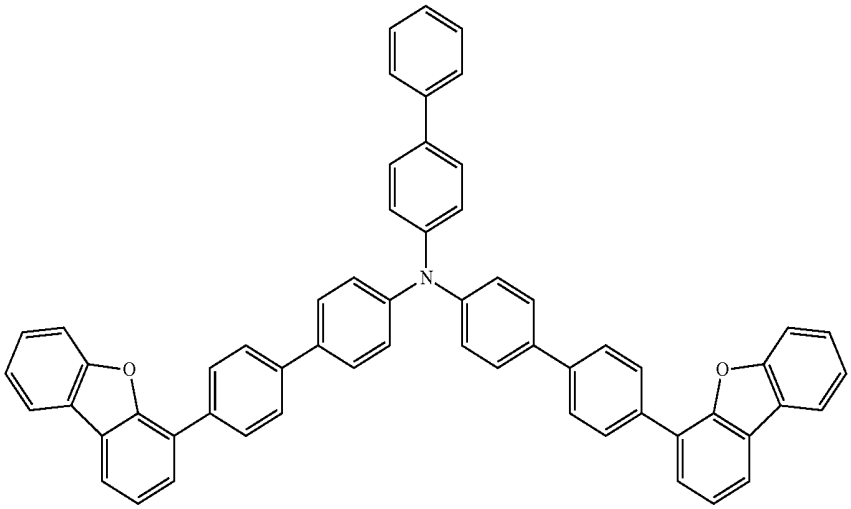

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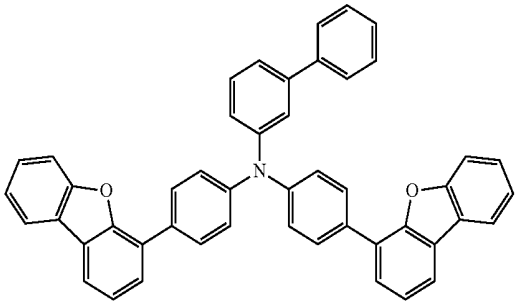
HT24



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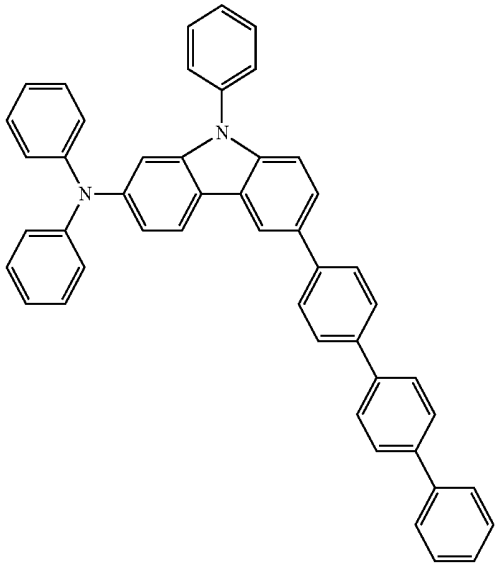

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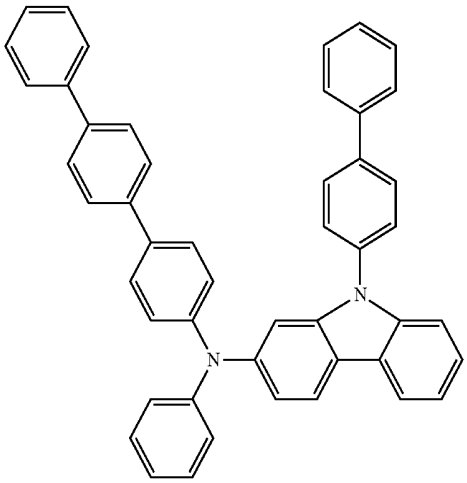
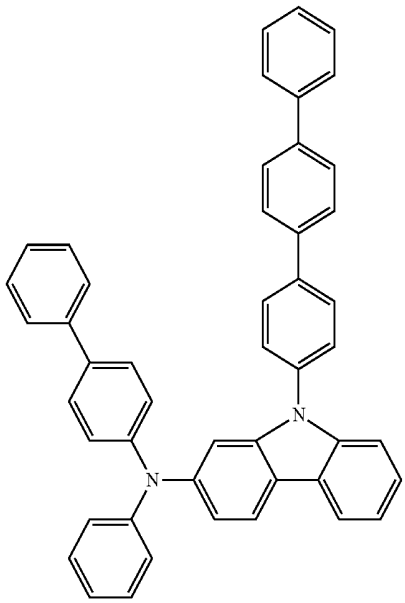
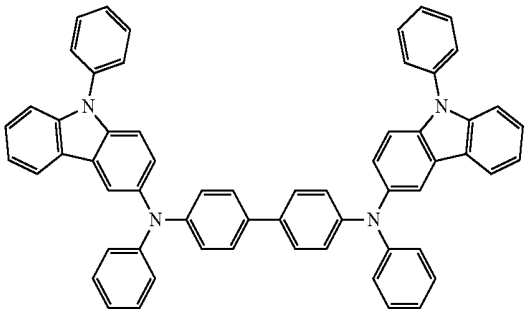


HT27



HT28



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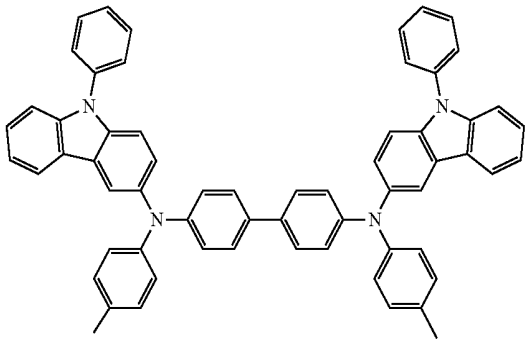

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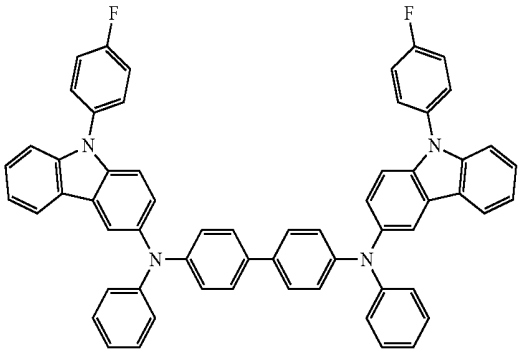
HT30



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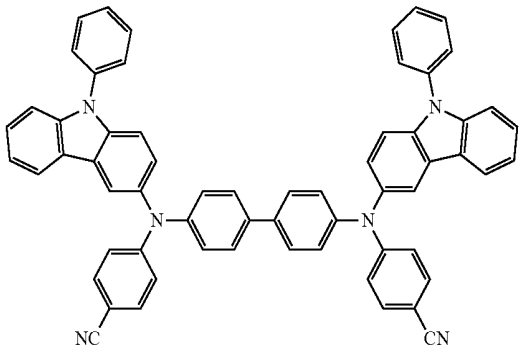

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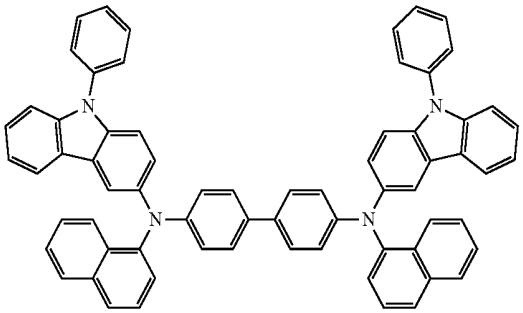

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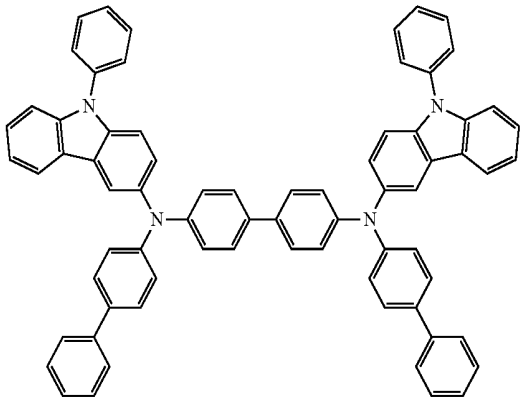

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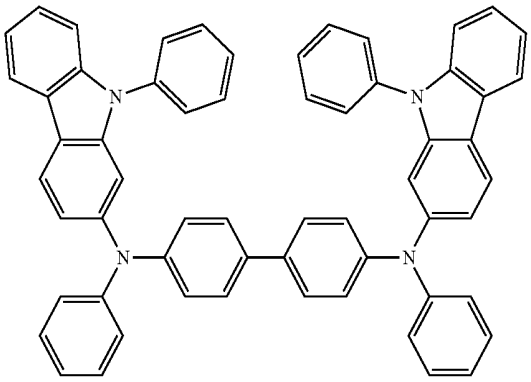

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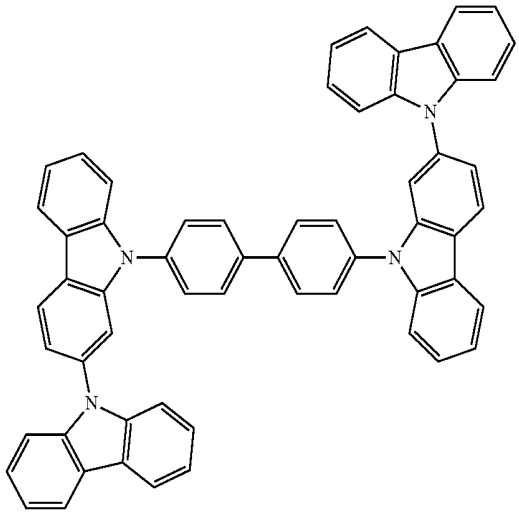

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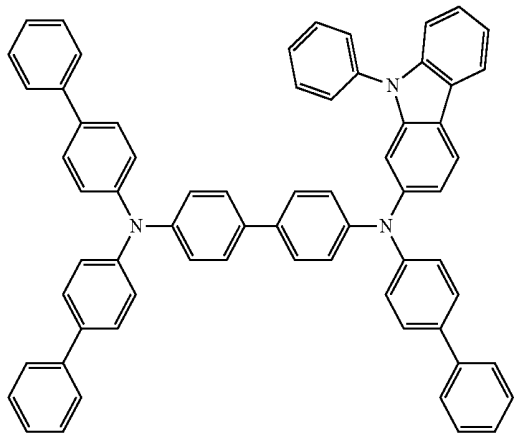

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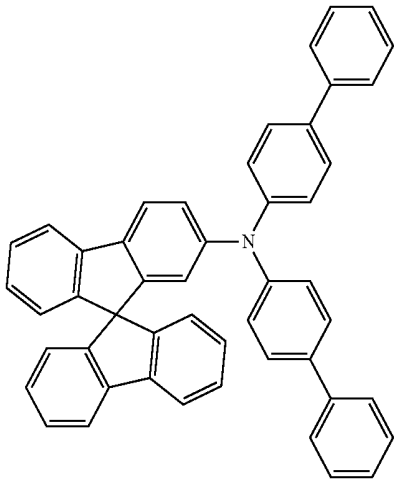

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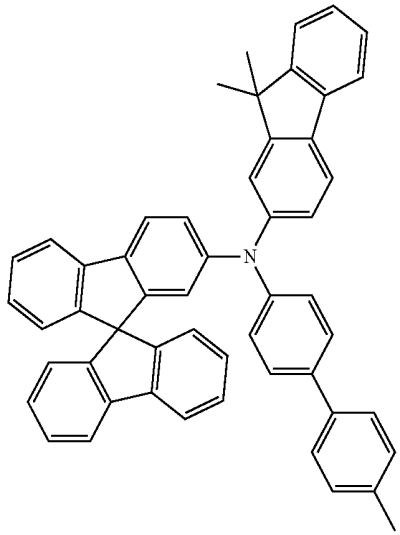

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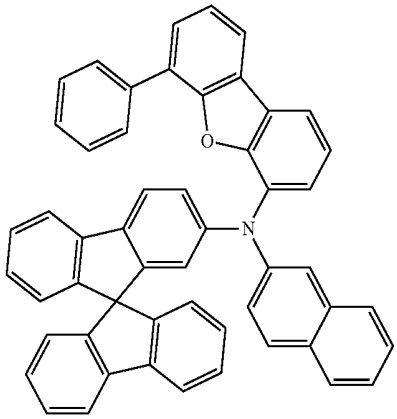


[0205] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, for example, about 100 Å to about 1,000 Å, and a thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer and the hole transport layer are within any of the foregoing ranges, suitable or satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0206] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

[0207] [p-Dopant]

[0208] The hole transport region may further include, in addition to these materials, a charge-generation material for the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0209] The charge-generation material may be, for example, a p-dopant.

[0210] In one or more embodiments, a lowest unoccupied molecular orbital (LUMO) of the p-dopant may be −3.5 eV or less.

[0211] The p-dopant may include, in addition to the borole compound represented by Formula 1, at least one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments of the present disclosure are not limited thereto.

[0212] For example, the p-dopant may include, in addition to the borole compound represented by Formula 1,

[0213] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

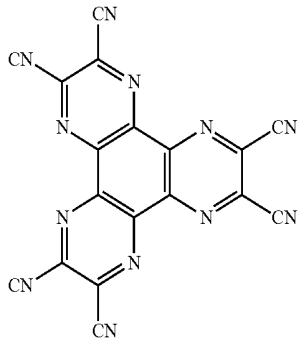
[0214] a metal oxide, such as tungsten oxide or molybdenum oxide;

[0215] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

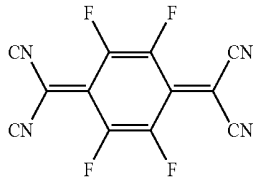
[0216] a compound represented by Formula 221 below:

[0217] but embodiments of the present disclosure are not limited thereto:

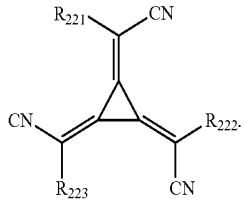
HAT-CN



F4-TCNQ



Formula 221



[0218] In Formula 221,

[0219] R_{221} to R_{223} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, wherein at least one selected from R_{221} to R_{223} may have at least one substituent selected from a cyano group, —F, —Cl, —Br, —I, a C_1-C_{20} alkyl group substituted with —F, a C_1-C_{20} alkyl group substituted with —Cl, a C_1-C_{20} alkyl group substituted with —Br, and a C_1-C_{20} alkyl group substituted with —I.

[0220] [Emission Layer in Organic Layer **150**]

[0221] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single (or sole) layer to emit white light.

[0222] The emission layer may include a host and a dopant. The dopant may include at least one selected from a phosphorescent dopant and a fluorescent dopant.

[0223] An amount of the dopant in the emission layer may be, in general, in a range of about 0.01 parts to about 15 parts by weight based on 100 parts by weight of the host, but embodiments of the present disclosure are not limited thereto.

[0224] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within any of the foregoing ranges, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[0225] [Host in Emission Layer]

[0226] In one or more embodiments, the host may include a compound represented by Formula 301 below.

$$[Ar_{301}]_{xb11}\text{-}[(L_{301})_{xb1}\text{-}R_{301}]_{xb21}. \qquad \text{<Formula 301>}$$

[0227] In Formula 301,

[0228] Ar_{301} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0229] xb11 may be 1, 2, or 3,

[0230] L_{301} is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0231] xb1 may be an integer from 0 to 5,

[0232] R_{301} may be selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{301})(Q_{302})(Q_{303})$, —$N(Q_{301})(Q_{302})$, —$B(Q_{301})(Q_{302})$, —$C(=O)(Q_{301})$, —$S(=O)_2(Q_{301})$, and —$P(=O)(Q_{301})(Q_{302})$,

[0233] xb21 may be an integer from 1 to 5, and

[0234] Q_{301} to Q_{303} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl

group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0235] In one or more embodiments, Ar_{301} in Formula 301 may be selected from:

[0236] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, a dibenzofuran group, and a dibenzothiophene group; and

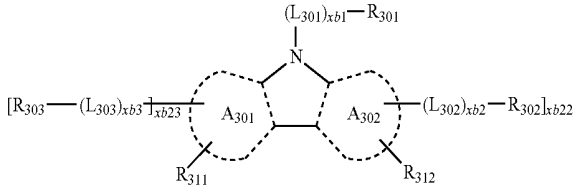
[0237] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$,

[0238] wherein Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

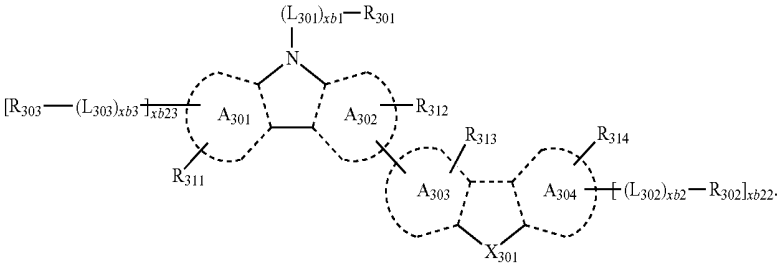
[0239] When xb11 in Formula 301 is two or more, two or more Ar301(s) may be linked via a single bond.

[0240] In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

Formula 301-1



Formula 301-2



[0241] In Formulae 301-1 and 301-2,

[0242] A_{301} to A_{304} may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphtho thiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0243] X_{301} may be O, S, or N-$[(L_{304})_{xb4}$-$R_{304}]$,

[0244] R_{311} to R_{314} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$,

[0245] xb22 and xb23 may each independently be 0, 1, or 2,

[0246] L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may be the same as described above,

[0247] L_{302} to L_{304} may each independently be the same as described in connection with L_{301},

[0248] xb2 to xb4 may each independently be the same as described in connection with xb1, and

[0249] R_{302} to R_{304} may each independently be the same as described in connection with R_{301}.

[0250] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0251] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imida-

zolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group;

[0252] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$; and

[0253] Q_{31} to Q_{33} may be the same as described above.

[0254] In one or more embodiments, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0255] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group; and

[0256] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br,

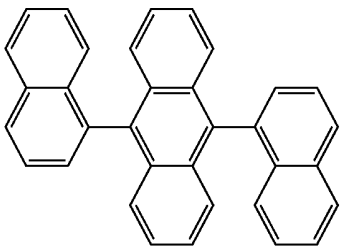
—I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an aza carbazolyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

[0257] Q_{31} and Q_{33} may be the same as described above.

[0258] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0259] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1, 1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:

H1



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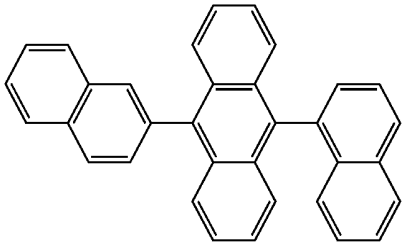

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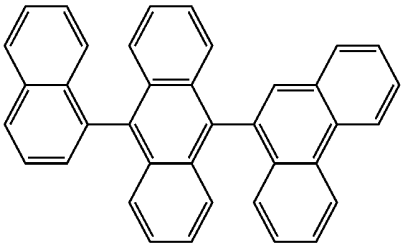

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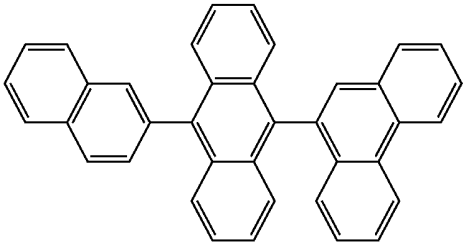

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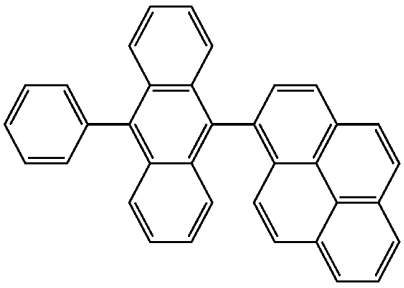

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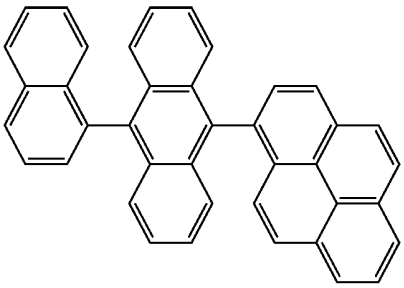

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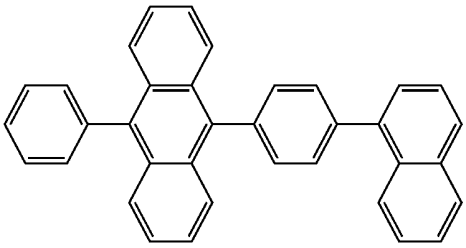

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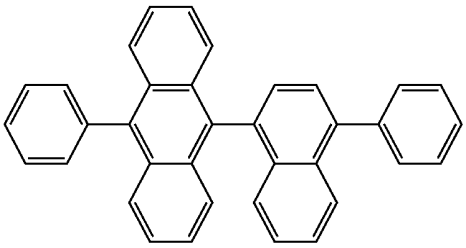

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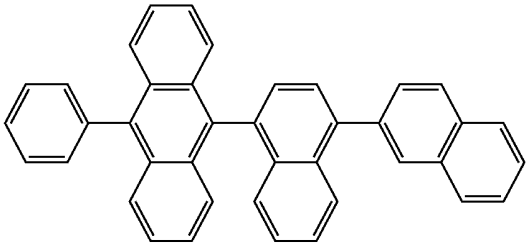

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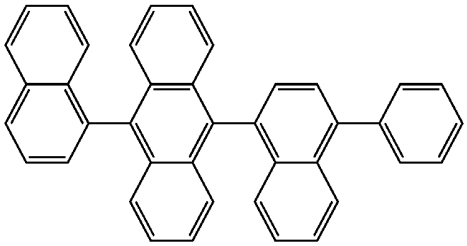

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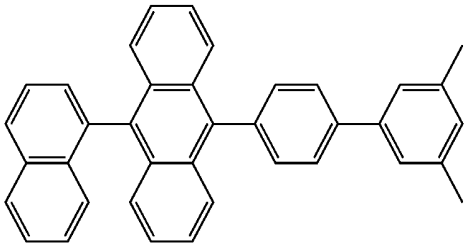

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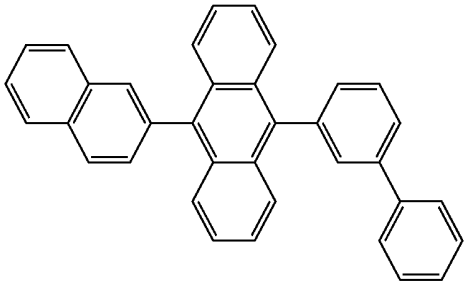

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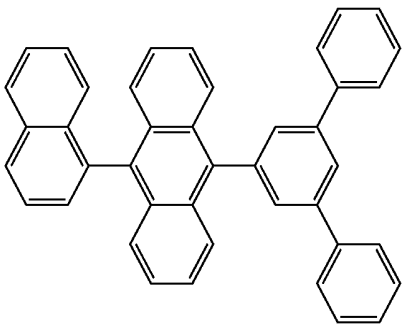

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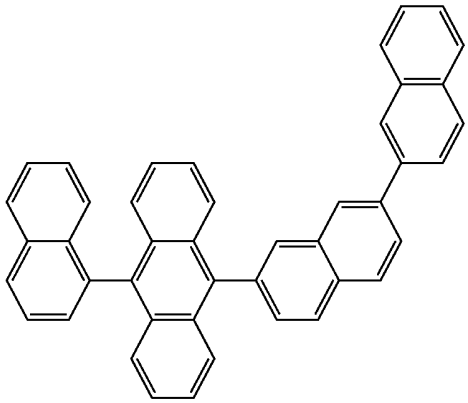

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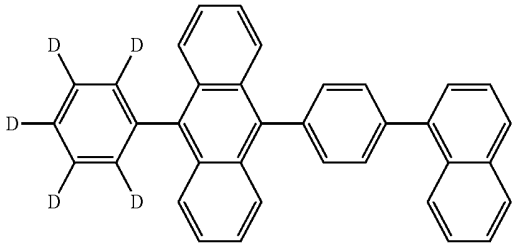

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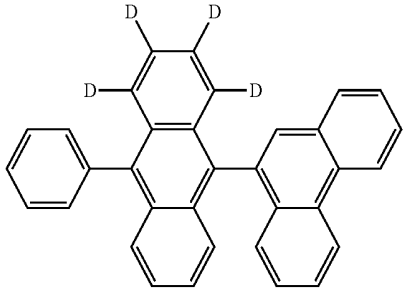

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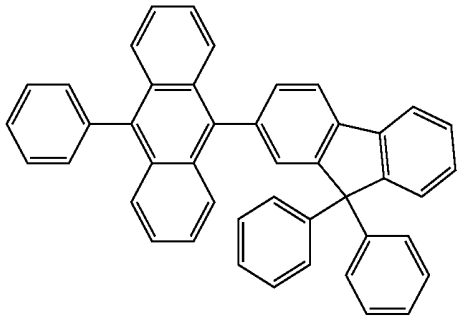

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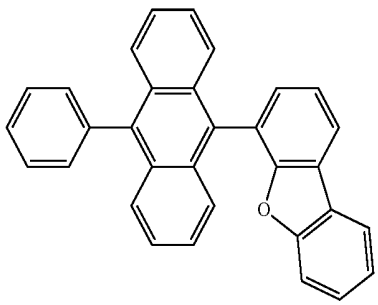

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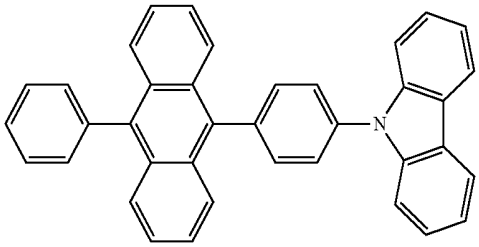

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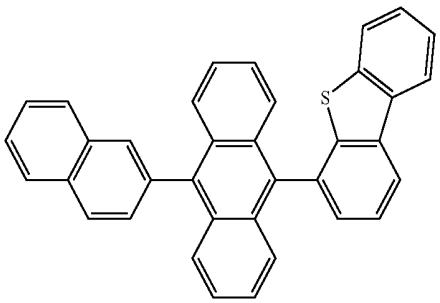

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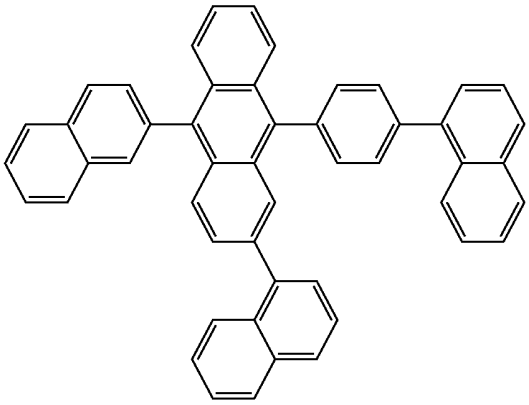

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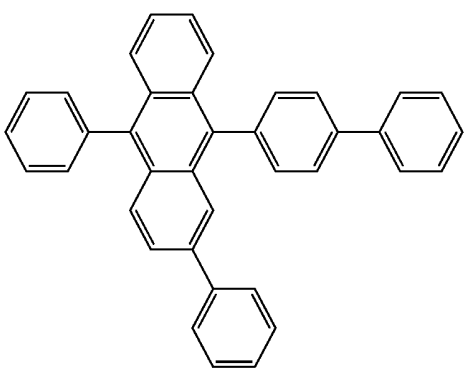

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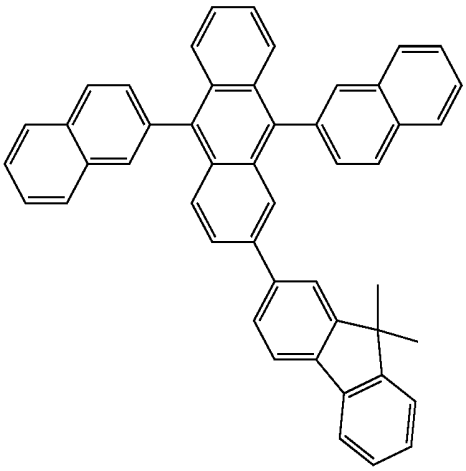

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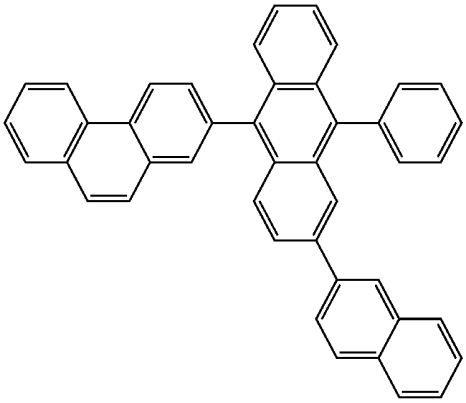

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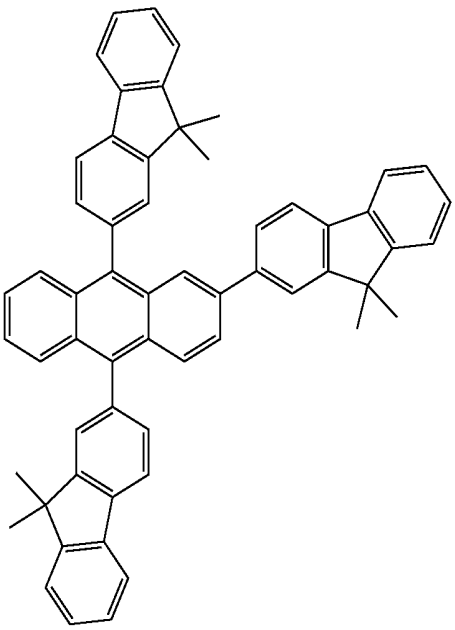

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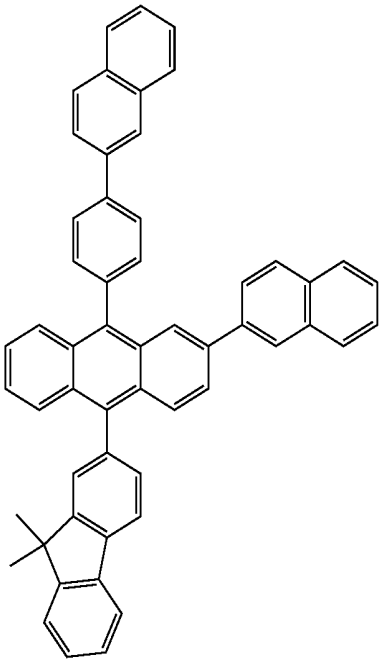

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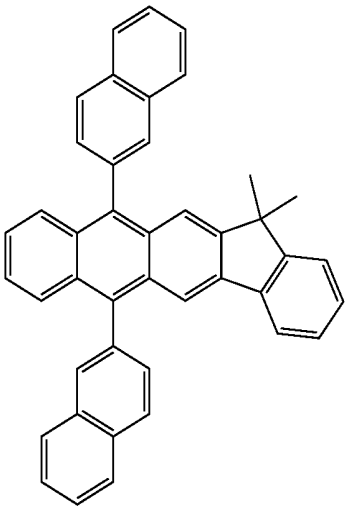

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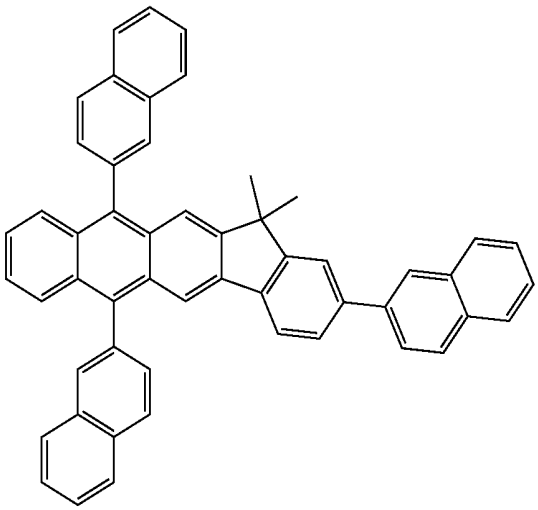

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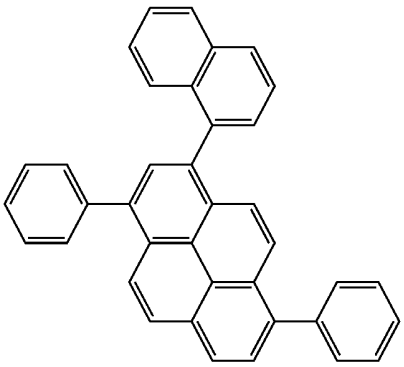

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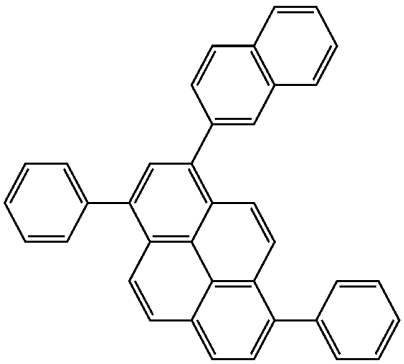

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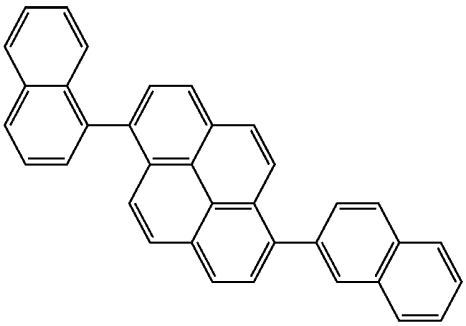

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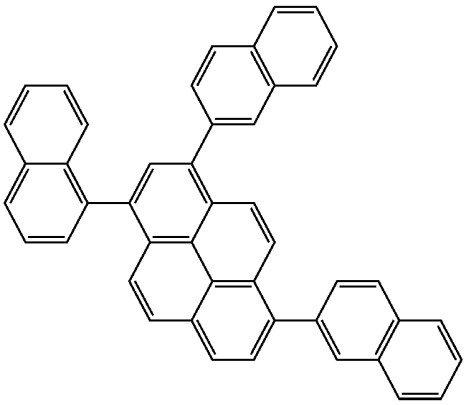

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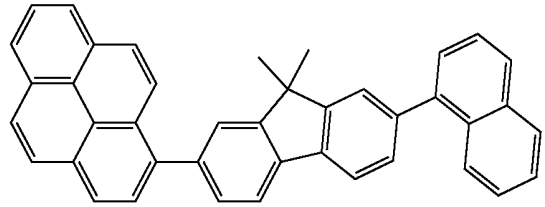

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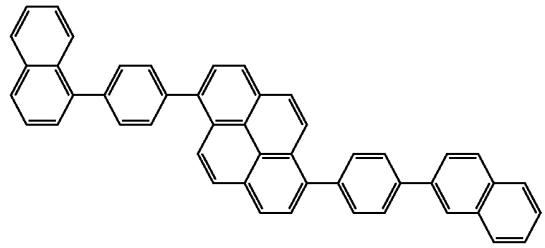

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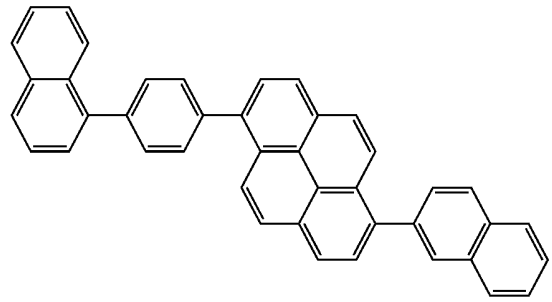

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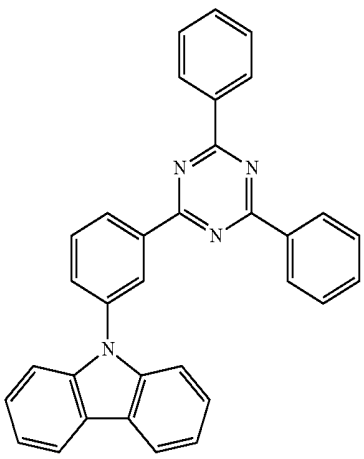

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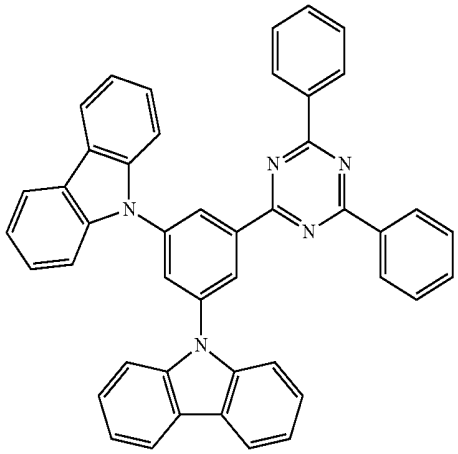

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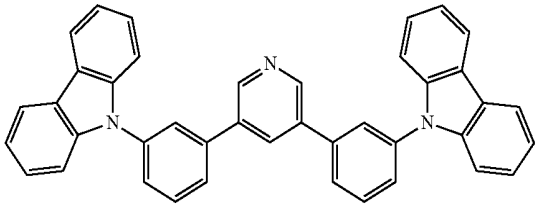

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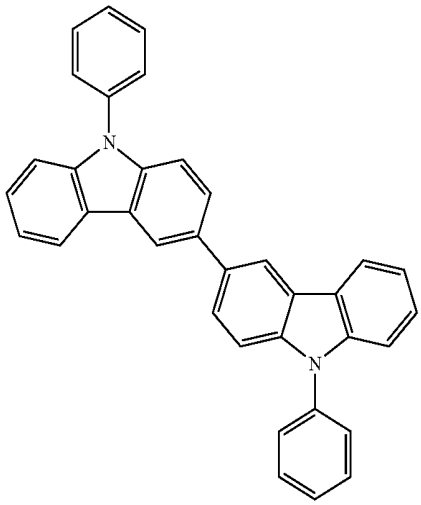

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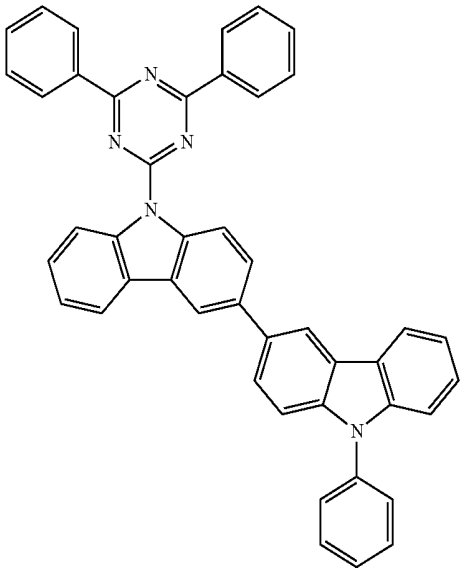

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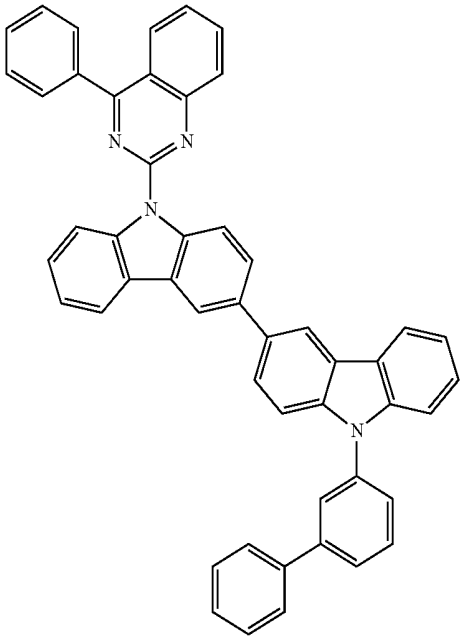

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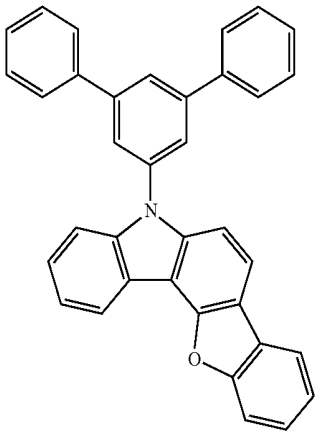

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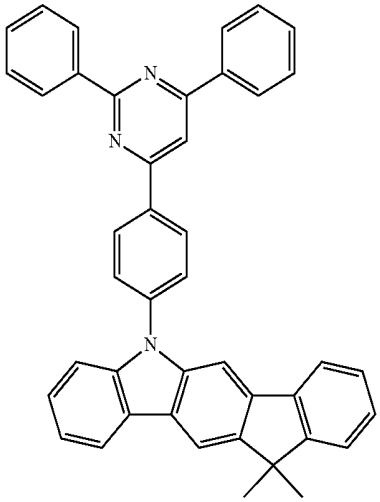

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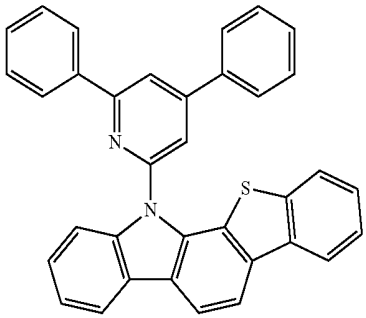

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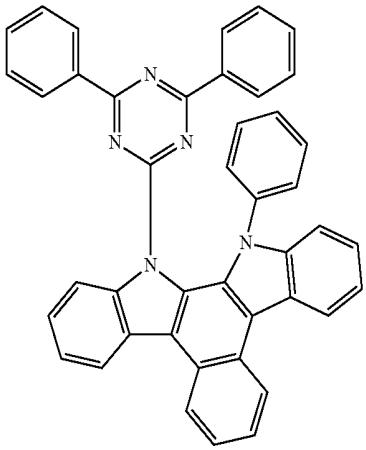

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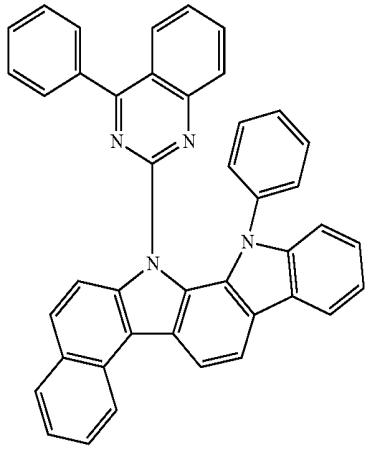

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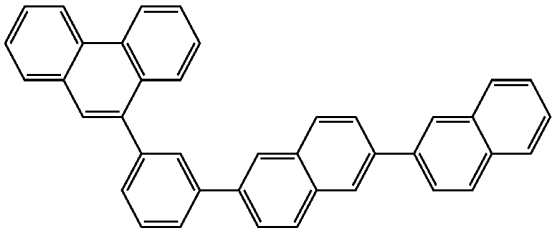

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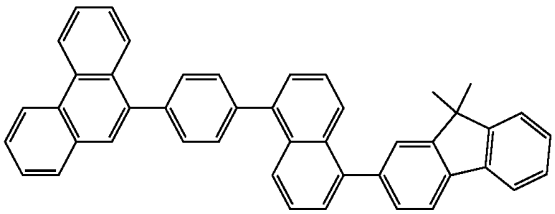

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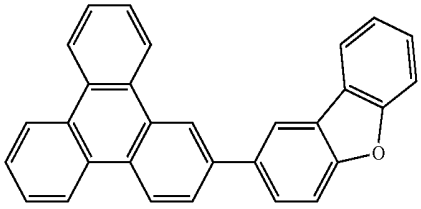

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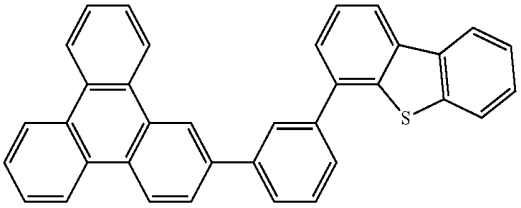

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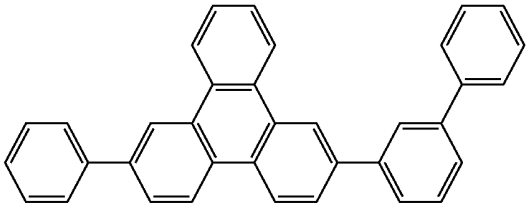

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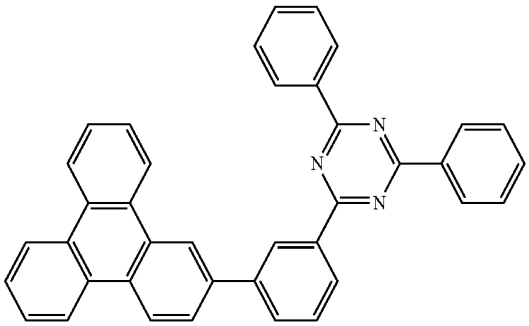

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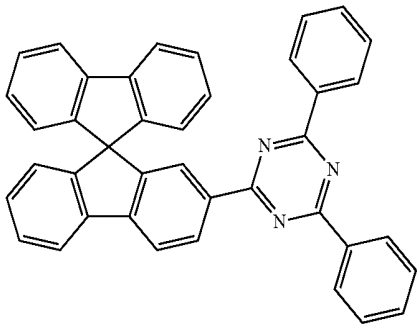

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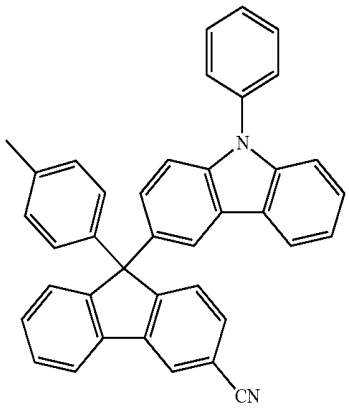

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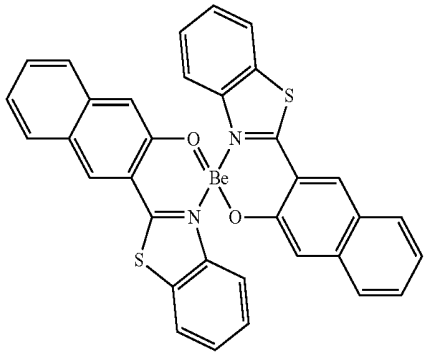


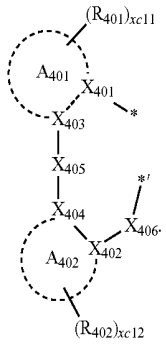
[0260] [Phosphorescent Dopant Included in Emission Layer in Organic Layer **150**]

[0261] The phosphorescent dopant may include an organometallic complex represented by Formula 401 below:

Formula 401

$$M(L_{401})_{xc1}(L_{402})_{xc2}$$

Formula 402



[0262] In Formulae 401 and 402,

[0263] M may be selected from iridium (Ir), platinum (Pt), palladium (Pd), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), rhodium (Rh), and thulium (Tm),

[0264] L_{401} may be selected from ligands represented by Formula 402, and xc1 may be 1, 2, or 3, wherein, when xc1 is two or more, two or more L_{401}(s) may be identical to or different from each other,

[0265] L_{402} may be an organic ligand, and xc2 may be an integer from 0 to 4, wherein, when xc2 is two or more, two or more L_{402}(s) may be identical to or different from each other,

[0266] X_{401} to X_{404} may each independently be nitrogen or carbon,

[0267] X_{401} and X_{403} may be linked via a single bond or a double bond, and X_{402} and X_{404} may be linked via a single bond or a double bond,

[0268] A_{401} and A_{402} may each independently be a C_5-C_{60} cyclic group or a C_1-C_{60} heterocyclic group,

[0269] X_{405} may be a single bond, *—O—*', *—S—*', *—C(=O)—*', *—N(Q_{411})-*', *—C(Q_{411})(Q_{412})-*', *—C(Q_{411})=C(Q_{412})-*', *—C(Q_{411})=*', or *=C(Q_{411})=*', wherein Q_{411} and Q_{412} may be hydrogen, deuterium, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group,

[0270] X_{406} may be a single bond, O, or S,

[0271] R_{401} and R_{402} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{20} alkyl group, a substituted or unsubstituted C_1-C_{20} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —Si(Q_{401})(Q_{402})(Q_{403}), —N(Q_{401})(Q_{402}), —B(Q_{401})(Q_{402}), —C(=O)(Q_{401}), —S(=O)$_2$(Q_{401}), and —P(=O)(Q_{401})(Q_{402}), wherein Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a C_6-C_{20} aryl group, and a C_1-C_{20} heteroaryl group, and

[0272] xc11 and xc12 may each independently be an integer from 0 to 10,

[0273] * and *' in Formula 402 each indicate a binding site to M in Formula 401.

[0274] In one or more embodiments, A_{401} and A_{402} in Formula 402 may each independently be selected from a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, an indene group, a pyrrole group, a thiophene group, a furan group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a quinoxaline group, a quinazoline group, a carbazole group, a benzimidazole group, a benzofuran group, a benzothiophene group, an isobenzothiophene group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a dibenzofuran group, and a dibenzothiophene group.

[0275] In one or more embodiments, in Formula 402, i) X_{401} may be nitrogen, and X_{402} may be carbon, or ii) X_{401} and X_{402} may each be nitrogen.

[0276] In one or more embodiments, R_{401} and R_{402} in Formula 402 may each independently be selected from:

[0277] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0278] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a phenyl group, a naphthyl group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, and a norbornenyl group;

[0279] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;

[0280] a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl

group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0281] —$Si(Q_{401})(Q_{402})(Q_{403})$, —$N(Q_{401})(Q_{402})$, —$B(Q_{401})(Q_{402})$, —$C(=O)(Q_{401})$, —$S(=O)_2(Q_{401})$, and —$P(=O)(Q_{401})(Q_{402})$; and

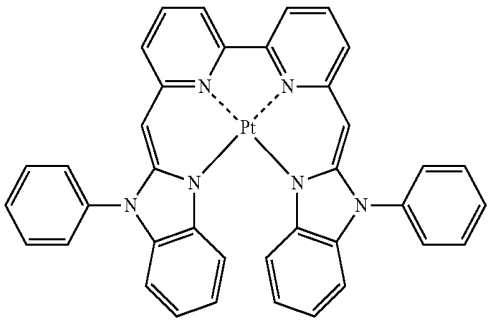
[0282] Q_{401} to Q_{403} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, and a naphthyl group, but embodiments of the present disclosure are not limited thereto.

[0283] In one or more embodiments, when xc1 in Formula 401 is two or more, two A_{401}(s) in 2 or more L_{401}(s) may optionally be linked via X_{407}, which is a linking group, or two A_{402}(s) in 2 or more L_{401}(s) may optionally be linked via X_{408}, which is a linking group (see Compounds PD1 to PD4 and PD7). X_{407} and X_{408} may each independently be a single bond, *—O—*', *—S—*', *—C(=O)—*', *—N(Q_{413})-*', *—C(Q_{413})(Q_{414})-*', or *—C(Q_{413})=C(Q_{414})-*' (wherein Q_{413} and Q_{414} may each independently be hydrogen, deuterium, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group), but embodiments of the present disclosure are not limited thereto.

[0284] L_{402} in Formula 401 may be a monovalent, divalent, or trivalent organic ligand. For example, L_{402} may be selected from halogen, diketone (for example, acetylacetonate), a carboxylic acid (for example, picolinate), —C(=O), isonitrile, —CN, and phosphorus (for example, phosphine or phosphite), but embodiments of the present disclosure are not limited thereto.

[0285] In one or more embodiments, the phosphorescent dopant may be, for example, selected from Compounds PD1 to PD25, but embodiments of the present disclosure are not limited thereto:

PD1



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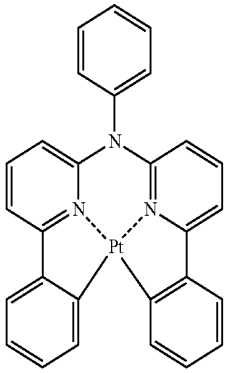
PD2



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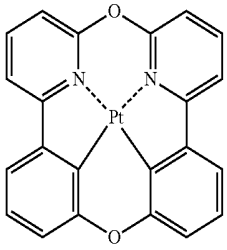

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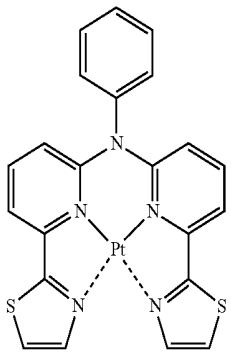

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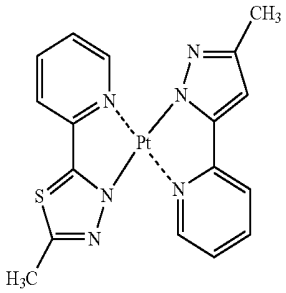

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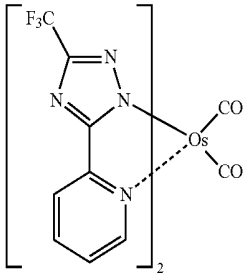

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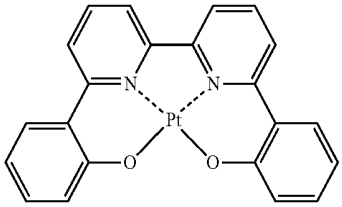

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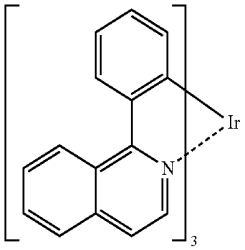

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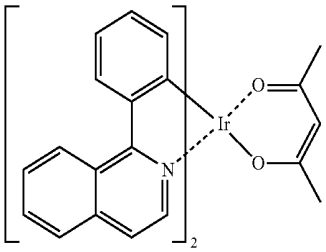

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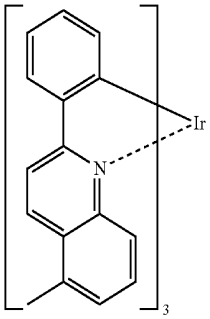

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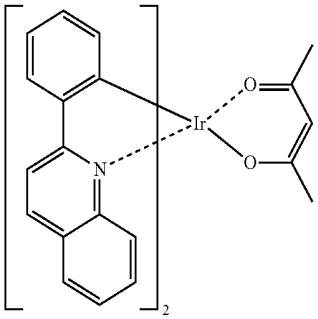

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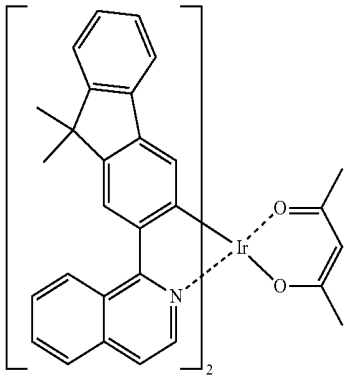

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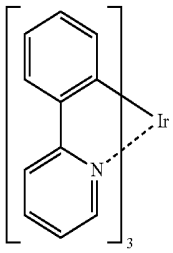

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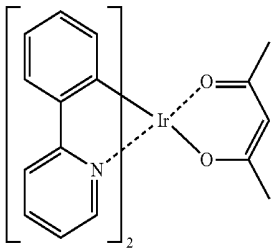

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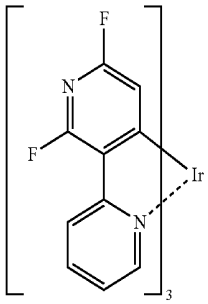

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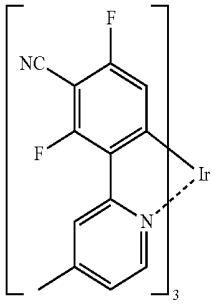

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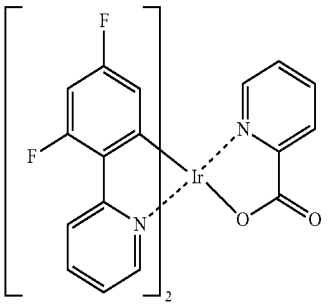

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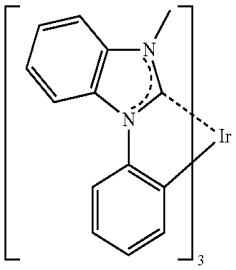

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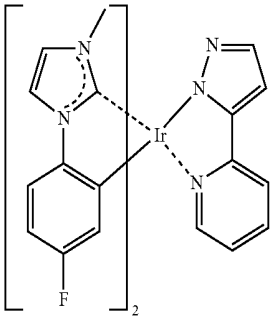

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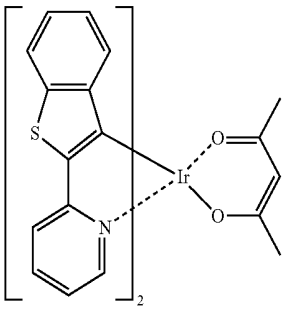

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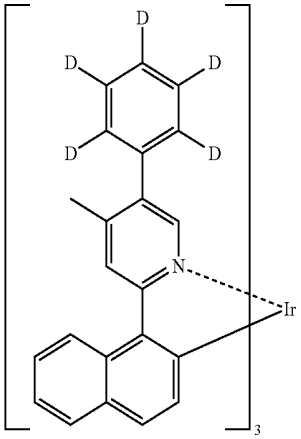

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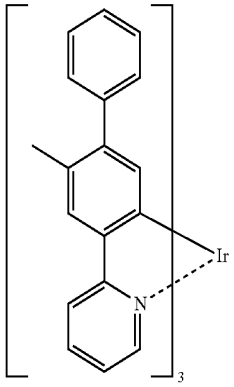

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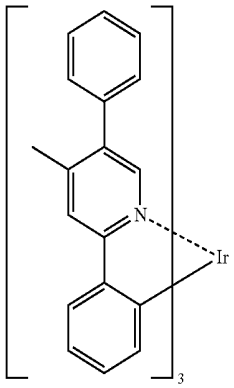

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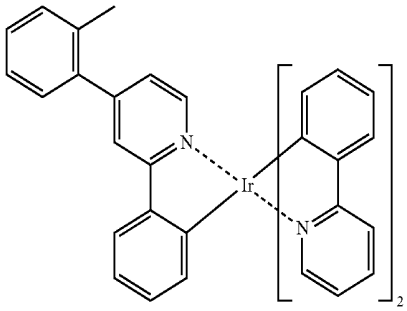

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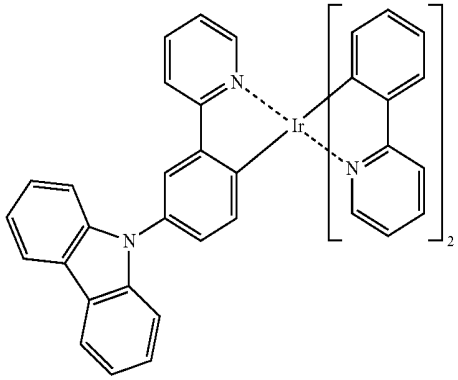
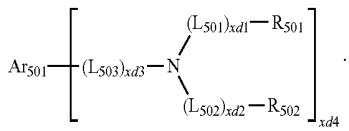


[0286] [Fluorescent Dopant in Emission Layer]

[0287] The fluorescent dopant may include an arylamine compound or a styrylamine compound.

[0288] The fluorescent dopant may include a compound represented by Formula 501:

Formula 501



[0289] In Formula 501,

[0290] Ar_{501} may be a substituted or unsubstituted C_5-C_{60}carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0291] L_{501} to L_{503} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0292] xd1 to xd3 may each independently be an integer from 0 to 3,

[0293] R_{501} and R_{502} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, and

[0294] xd4 may be an integer from 1 to 6.

[0295] In one or more embodiments, Ar_{501} in Formula 501 may be selected from:

[0296] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group; and

[0297] a naphthalene group, a heptalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, and an indenophenanthrene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0298] In one or more embodiments, L_{501} to L_{503} in Formula 501 may each independently be selected from:

[0299] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group; and

[0300] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, and a pyridinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group.

[0301] In one or more embodiments, R_{501} and R_{502} in Formula 501 may each independently be selected from:

[0302] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

[0303] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a

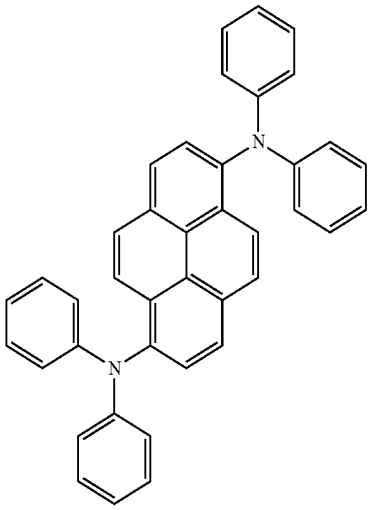
dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, and —$Si(Q_{31})(Q_{32})(Q_{33})$; and

[0304] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

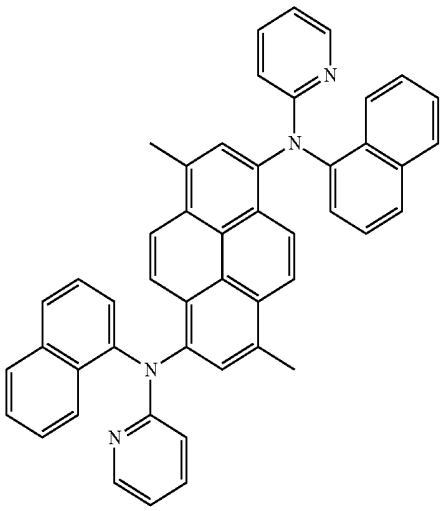
[0305] In one or more embodiments, xd4 in Formula 501 may be 2, but embodiments of the present disclosure are not limited thereto.

[0306] For example, the fluorescent dopant may be selected from Compounds FD1 to FD22:

FD1



FD2



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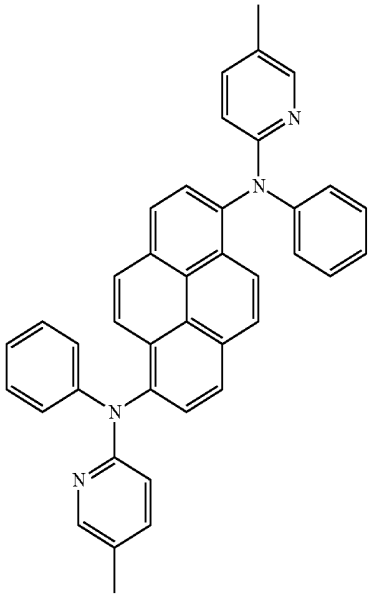
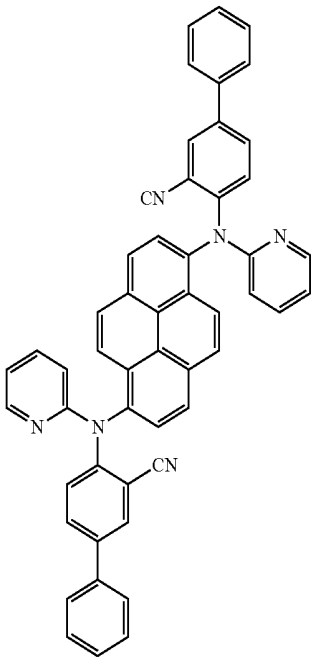
FD3



FD4



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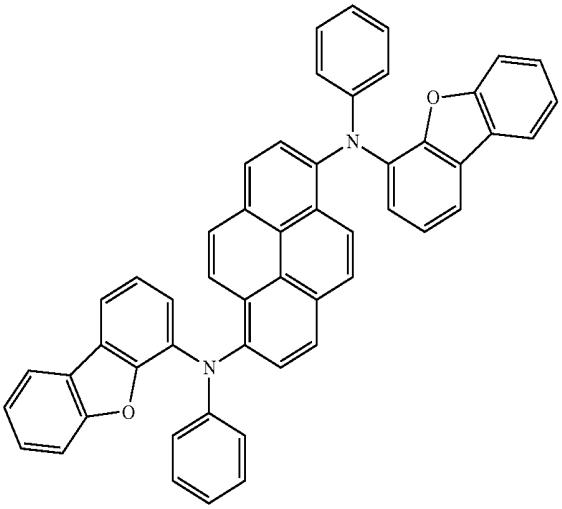
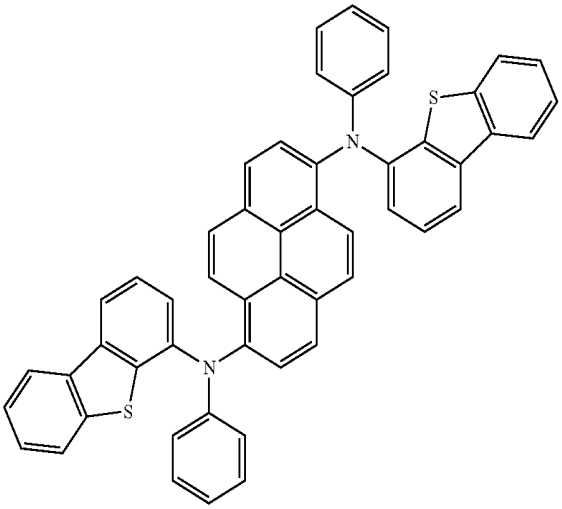
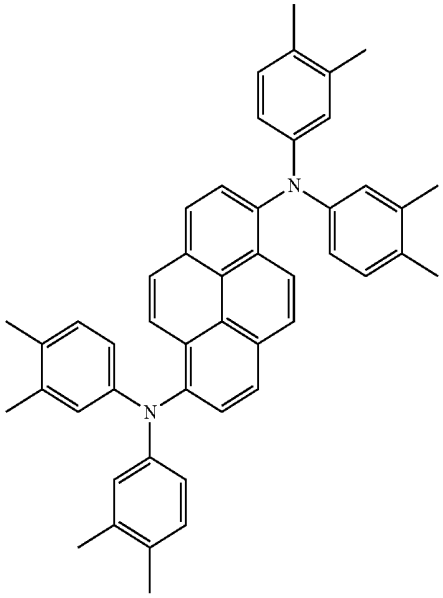
FD5



FD6



FD7



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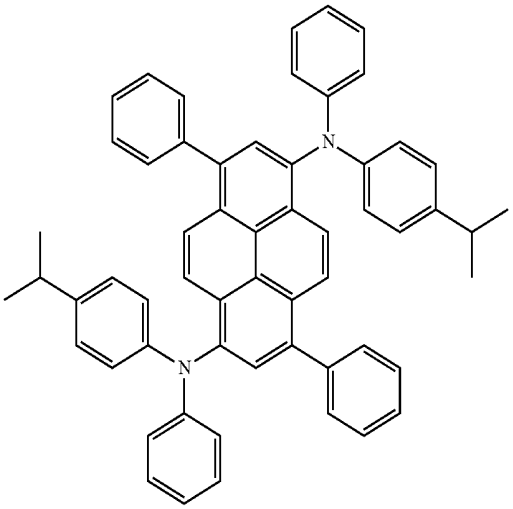
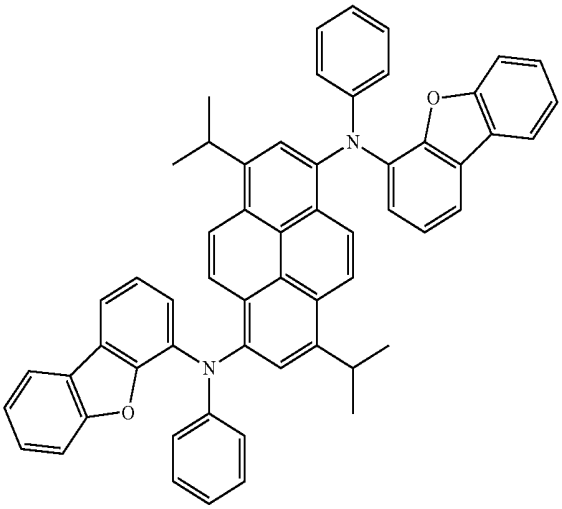
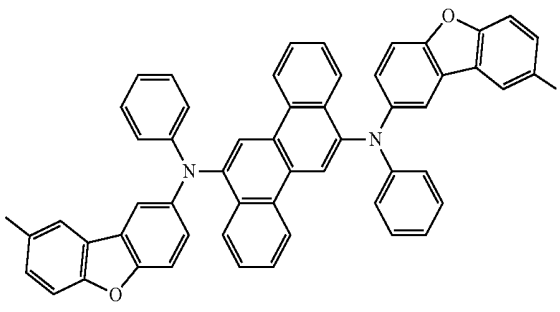
FD8



FD9



FD10



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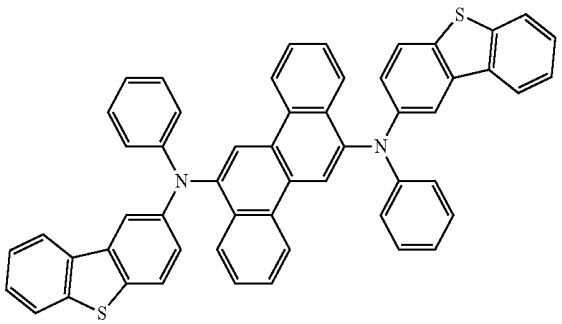
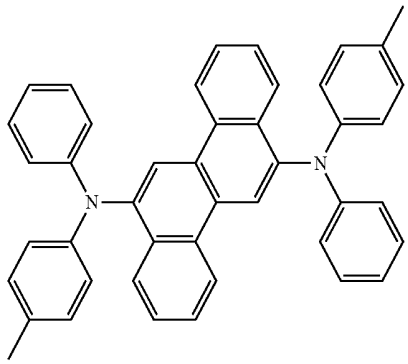
FD11



FD12



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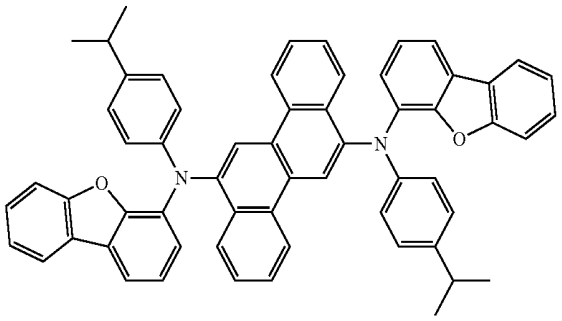

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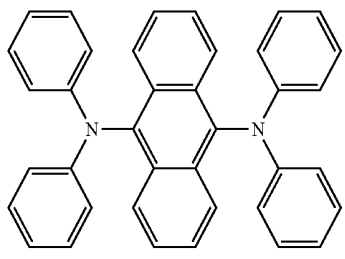

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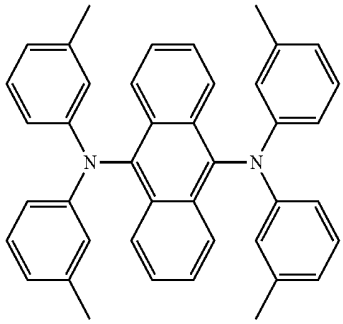
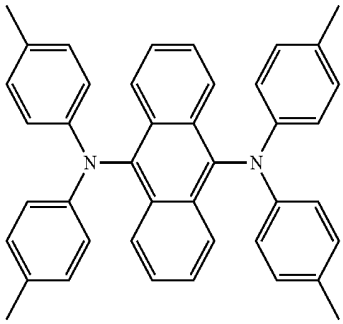
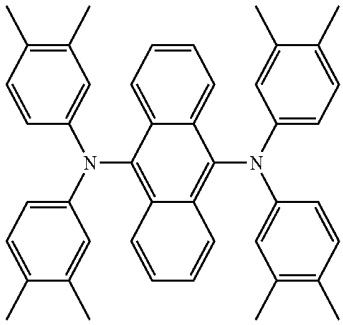
FD15



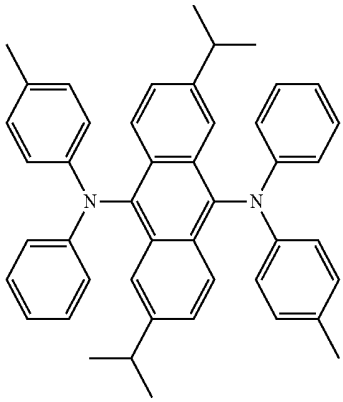
FD16



FD17



FD18



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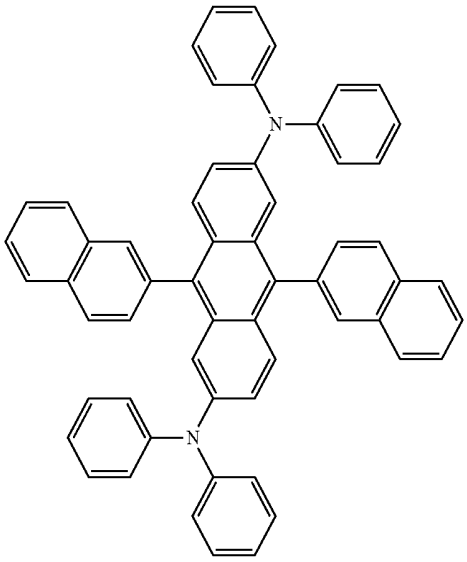
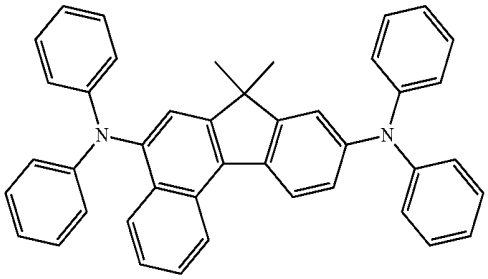
FD19



FD20



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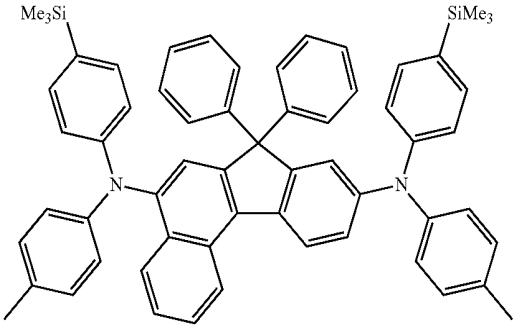
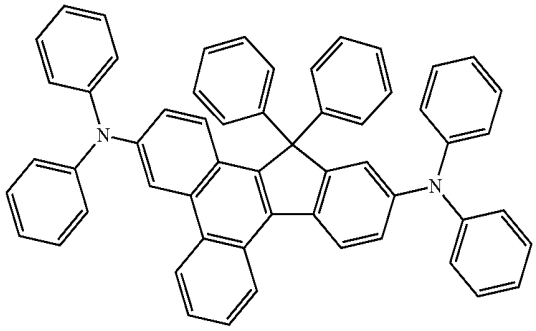
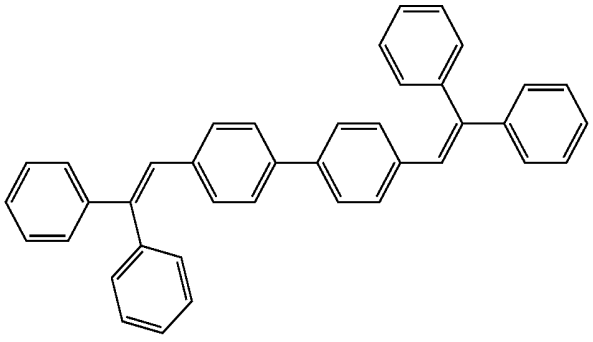
FD21



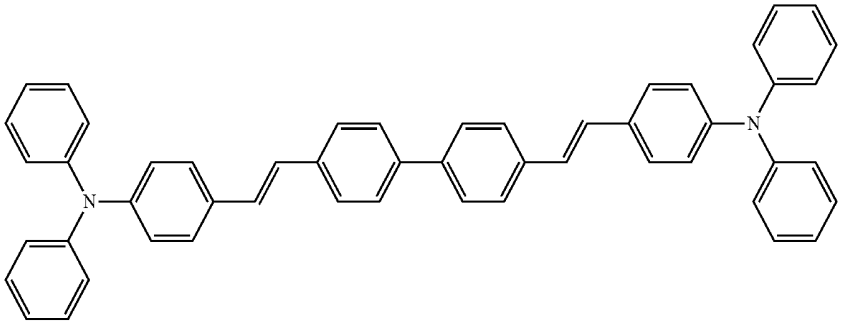
FD22



[0307] In one or more embodiments, the fluorescent dopant may be selected from the following compounds, but embodiments of the present disclosure are not limited thereto.



DPVBi



DPAVBi

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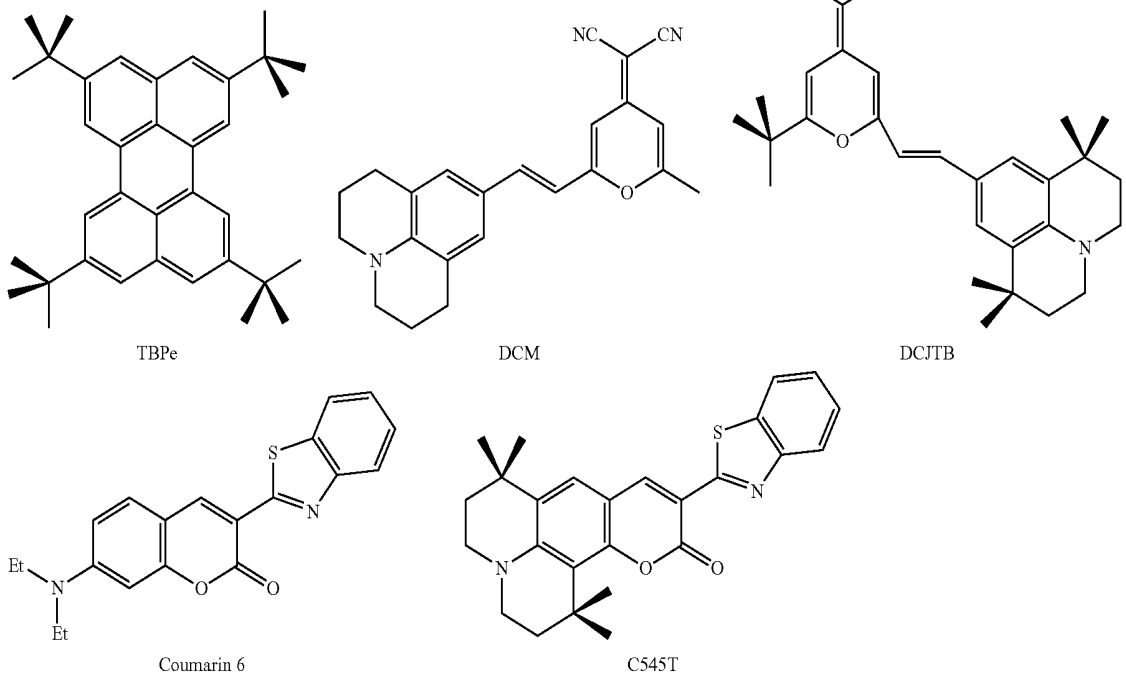


TBPe DCM DCJTB

Coumarin 6 C545T

[0308] [Electron Transport Region in Organic Layer **150**]

[0309] The electron transport region may have i) a single-layered structure including a single (or sole) layer including a single (or sole) material, ii) a single-layered structure including a single (or sole) layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0310] The electron transport region may include at least one selected from a buffer layer, a hole blocking layer, an electron control layer, an electron transport layer, and an electron injection layer, but embodiments of the present disclosure are not limited thereto.

[0311] For example, the electron transport region may have an electron transport layer/electron injection layer structure, a hole blocking layer/electron transport layer/electron injection layer structure, an electron control layer/electron transport layer/electron injection layer structure, or a buffer layer/electron transport layer/electron injection layer structure, wherein for each structure, constituting layers are sequentially stacked from an emission layer. However, embodiments of the structure of the electron transport region are not limited thereto.

[0312] The electron transport region (for example, a buffer layer, a hole blocking layer, an electron control layer, or an electron transport layer in the electron transport region) may include a metal-free compound containing at least one π electron-depleted nitrogen-containing ring.

[0313] As used herein, the expression "π electron-depleted nitrogen-containing ring" refers to a C_1-C_{60} heterocyclic group having at least one *—N=*' moiety as a ring-forming moiety.

[0314] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one *—N=*' moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *—N=*' moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *—N=*' moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

[0315] Examples of the π electron-depleted nitrogen-containing ring include an imidazole, a pyrazole, a thiazole, an isothiazole, an oxazole, an isoxazole, a pyridine, a pyrazine, a pyrimidine, a pyridazine, an indazole, a purine, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzimidazole, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a triazole, a tetrazole, an oxadiazole, a triazine, thiadiazol, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but are not limited thereto.

[0316] For example, the electron transport region may include a compound represented by Formula 601:

$$[Ar_{601}]_{xe11}\text{-}[(L_{601})_{xe1}\text{-}R_{601}]_{xe21}. \qquad \text{<Formula 601>}$$

[0317] In Formula 601,

[0318] Ar_{601} may be a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0319] xe11 may be 1, 2, or 3,

[0320] L_{601} is selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0321] xe1 may be an integer from 0 to 5,

[0322] R_{601} may be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{601})(Q_{602})(Q_{603})$, —$C(=O)(Q_{601})$, —$S(=O)_2(Q_{601})$, and —$P(=O)(Q_{601})(Q_{602})$,

[0323] Q_{601} to Q_{603} may each independently be a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0324] xe21 may be an integer from 1 to 5.

[0325] In one or more embodiments, at least one of Ar_{601}(S) in the number of xe11 and R_{601}(S) in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

[0326] In one or more embodiments, ring Ar_{601} in Formula 601 may be selected from:

[0327] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0328] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, phenanthroline group, phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an aza carbazole group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$; and

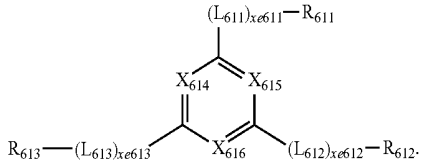
[0329] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0330] When xe11 in Formula 601 is two or more, two or more Ar_{601}(s) may be linked via a single bond.

[0331] In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

[0332] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0333] In Formula 601-1,

[0334] X_{614} may be N or $C(R_{614})$, X_{615} may be N or $C(R_{615})$, X_{616} may be N or $C(R_{616})$, and at least one selected from X_{614} to X_{616} may be N,

[0335] L_{611} to L_{613} may each independently be the same as described in connection with L_{601},

[0336] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0337] R_{611} to R_{613} may each independently be the same as described in connection with R_{601}, and

[0338] R_{614} to R_{616} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0339] In one or more embodiments, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

[0340] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group,

an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and

[0341] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, but embodiments of the present disclosure are not limited thereto.

[0342] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0343] In one or more embodiments, R_{601} and R_{611} to R_{613} in Formulae 601 and 601-1 may each independently be selected from:

[0344] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

[0345] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br,

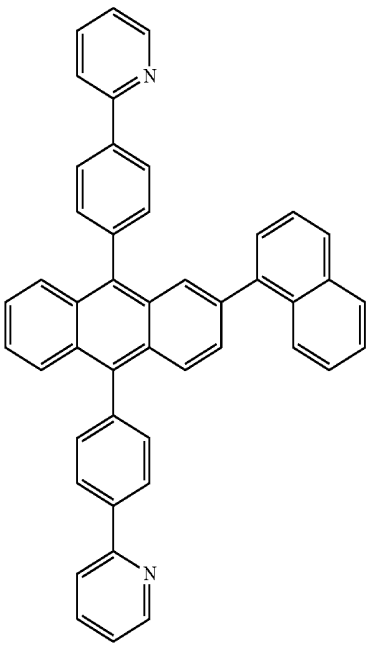
—I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group;

[0346] —$S(=O)_2(Q_{601})$ and —$P(=O)(Q_{601})(Q_{602})$; and

[0347] Q_{601} and Q_{602} may be the same as described above.

[0348] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

ET10



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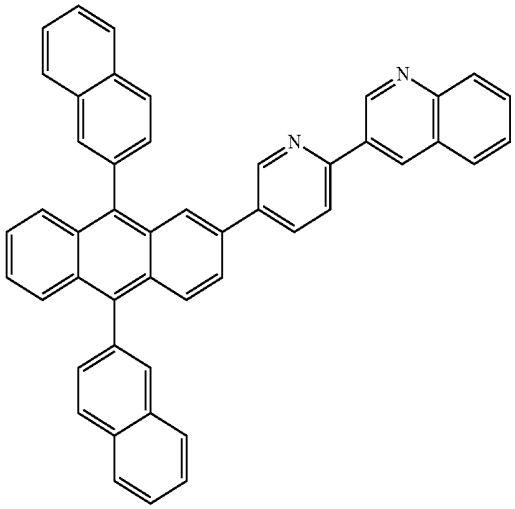

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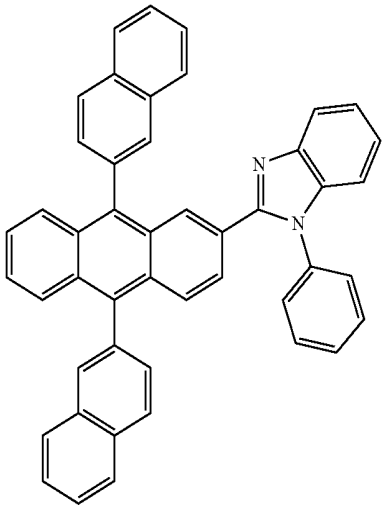

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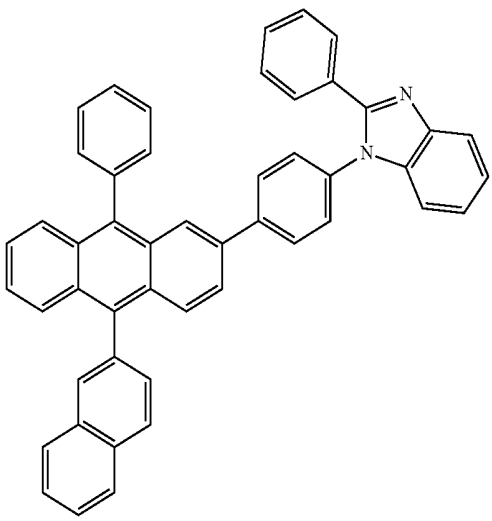

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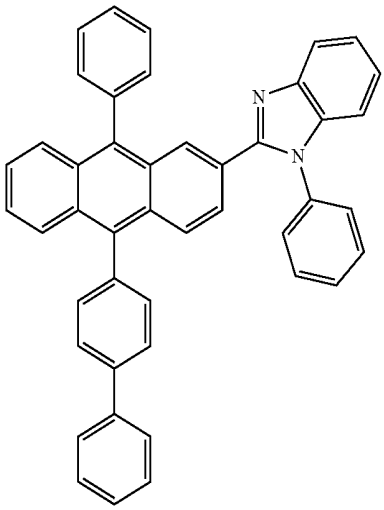

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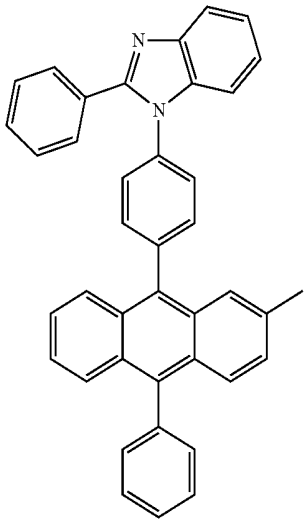

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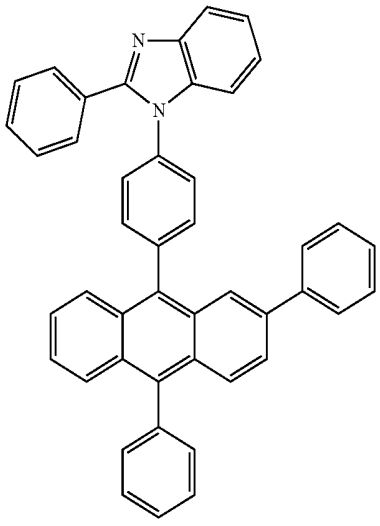

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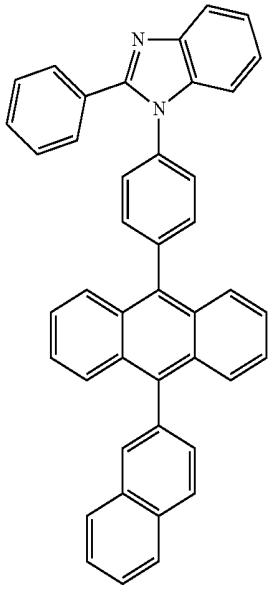

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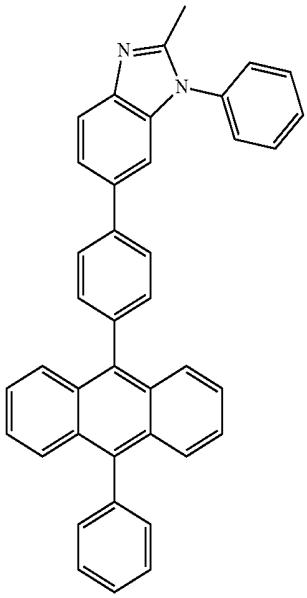

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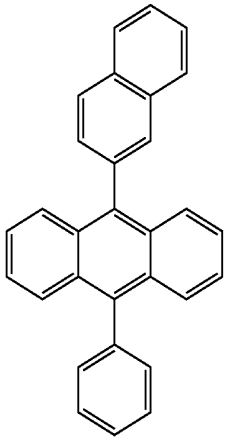

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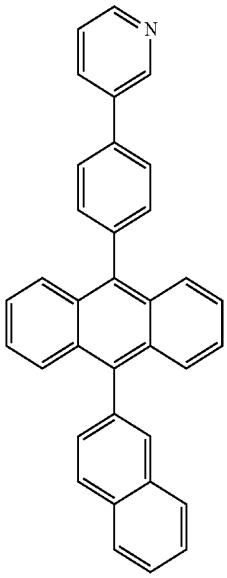

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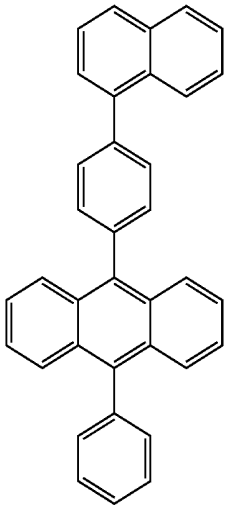

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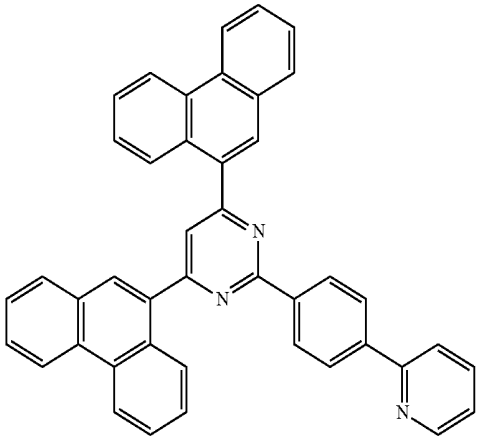

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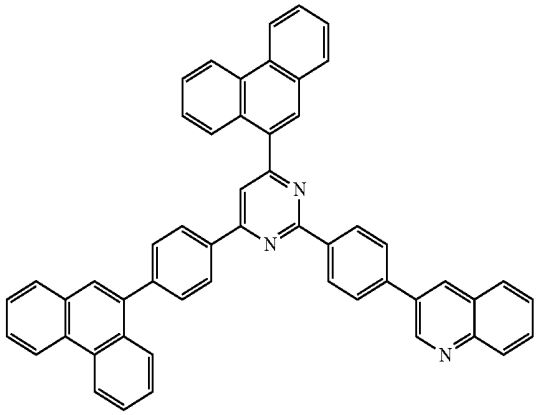

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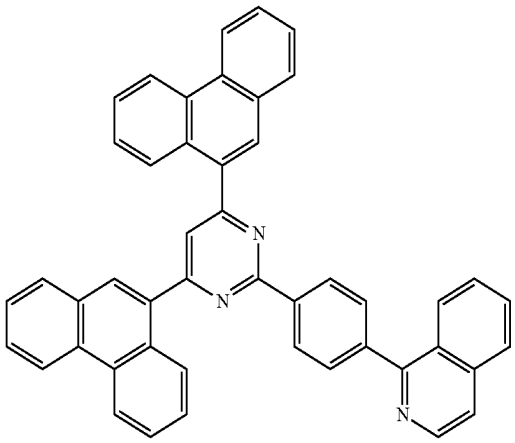

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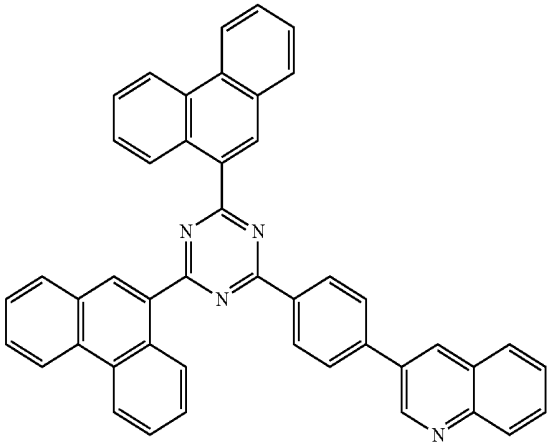

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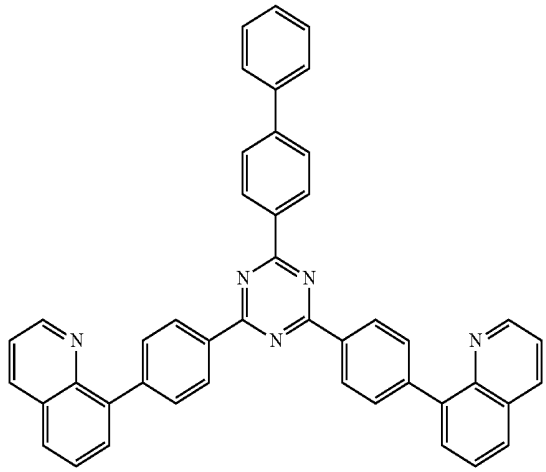

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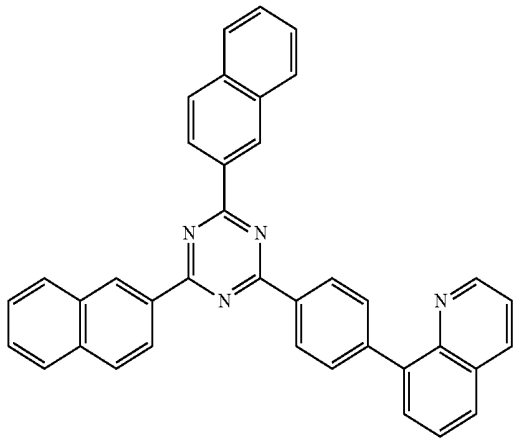

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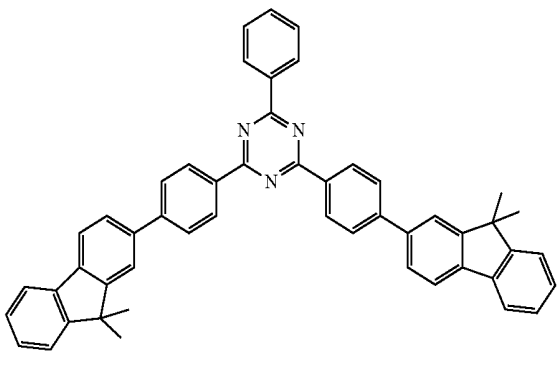

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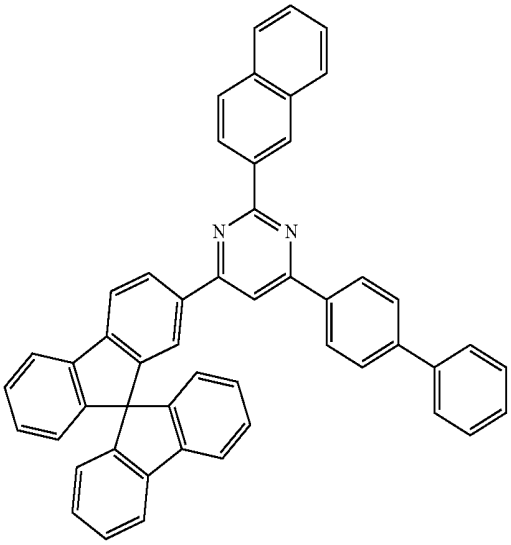

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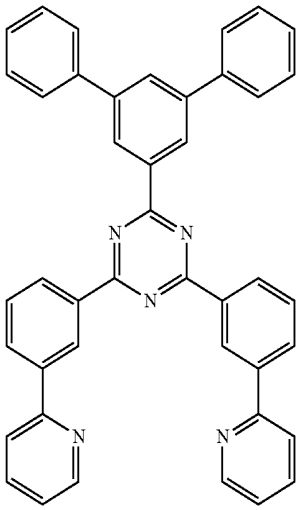

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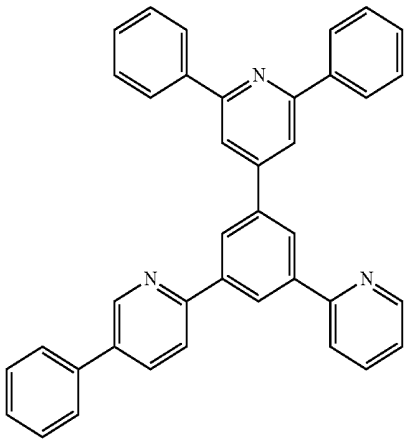

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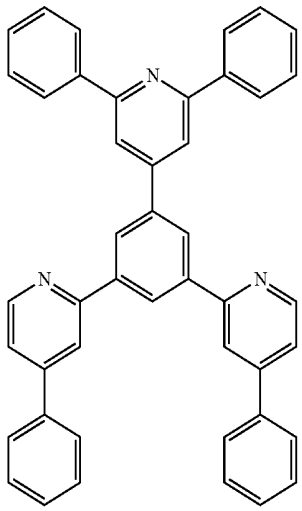

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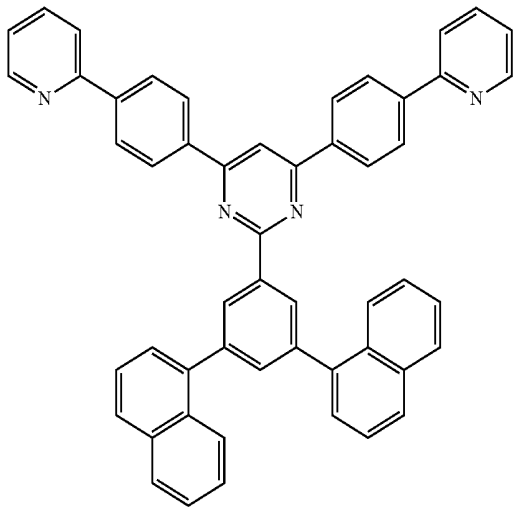

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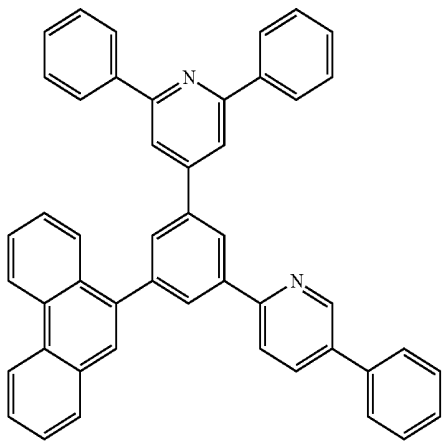

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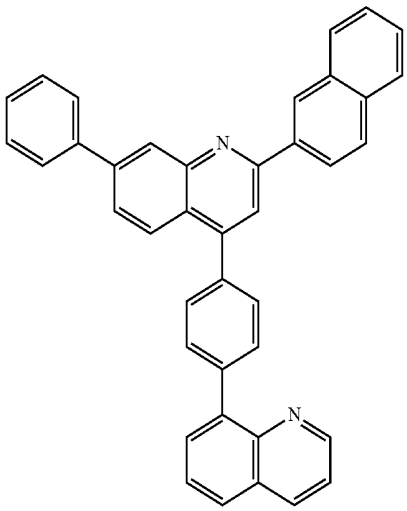
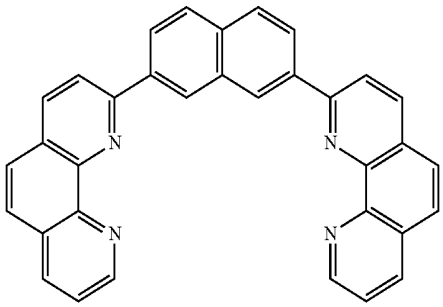
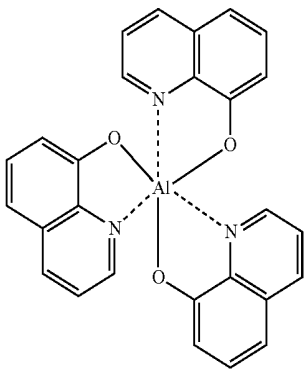
ET35



ET36



[0349] In one or more embodiments, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-dphenyl-1,10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ.



Alq_3

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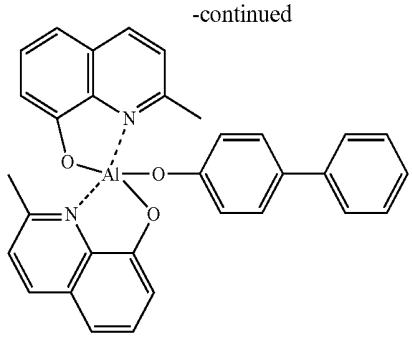
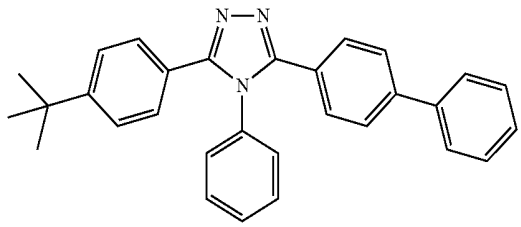
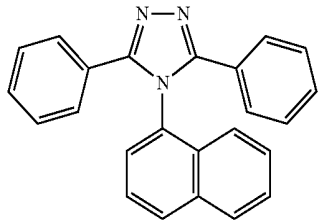


BAlq



TAZ



NTAZ

[0350] A thickness of the buffer layer, the hole blocking layer, or the electron control layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within any of the foregoing ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

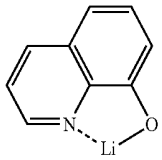
[0351] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within any of the foregoing ranges, the electron transport layer may have suitable or satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0352] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

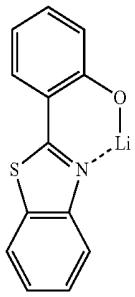
[0353] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenylan oxazole, a hydroxy phenylthiazole, a hydroxy diphenylan oxadiazole, a hydroxy diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0354] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.

ET-D1



ET-D2



[0355] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0356] The electron injection layer may have i) a single-layered structure including a single (or sole) layer including a single (or sole) material, ii) a single-layered structure including a single (or sole) layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0357] The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth metal complex, a rare earth metal complex, or any combinations thereof.

[0358] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one or more embodiments, the alkali metal may be Li, Na, or Cs. In one or more embodiments, the alkali metal may be Li or Cs, but embodiments of the present disclosure are not limited thereto.

[0359] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0360] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0361] The alkali metal compound, the alkaline earth metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0362] The alkali metal compound may be selected from alkali metal oxides, such as Li_2O, Cs_2O, or K_2O, and alkali metal halides, such as LiF, NaF, CsF, KF, LiI, NaI, CsI, or

KI. In one or more embodiments, the alkali metal compound may be selected from LiF, Li_2O, NaF, LiI, NaI, CsI, and KI, but embodiments of the present disclosure are not limited thereto.

[0363] The alkaline earth metal compound may be selected from alkaline earth metal oxides, such as BaO, SrO, CaO, $Ba_xSr_{1-x}O$ ($0<x<1$), $Ba_xCa_{1-x}O$ ($0<x<1$). In one or more embodiments, the alkaline earth metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0364] The rare earth metal compound may be selected from YbF_3, ScF_3, ScO_3, Y_2O_3, Ce_2O_3, GdF_3, and TbF_3. In one or more embodiments, the rare earth metal compound may be selected from YbF_3, ScF_3, TbF_3, YbI_3, ScI_3, and TbI_3, but embodiments of the present disclosure are not limited thereto.

[0365] The alkali metal complex, the alkaline earth metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenylan oxazole, hydroxy phenylthiazole, hydroxy diphenylan oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0366] The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0367] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within any of the foregoing ranges, the electron injection layer may have suitable or satisfactory electron injection characteristics without a substantial increase in driving voltage.

[0368] [Second Electrode **190**]

[0369] The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode which is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function.

[0370] The second electrode **190** may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0371] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0372] [Description of FIGS. **5** to **7**]

[0373] An organic light-emitting device **20** of FIG. **5** includes a first capping layer **210**, a first electrode **110**, an organic layer **150**, and a second electrode **190** which are sequentially stacked in this stated order, an organic light-emitting device **30** of FIG. **6** includes a first electrode **110**, an organic layer **150**, a second electrode **190**, and a second capping layer **220** which are sequentially stacked in this stated order, and an organic light-emitting device **40** of FIG. **7** includes a first capping layer **210**, a first electrode **110**, an organic layer **150**, a second electrode **190**, and a second capping layer **220**.

[0374] Regarding FIGS. **5** to **7**, the first electrode **110**, the organic layer **150**, and the second electrode **190** may be understood by referring to the description presented in connection with FIG. **1**.

[0375] In the organic layer **150** of each of the organic light-emitting devices **20** and **40**, light generated in an emission layer may pass through the first electrode **110**, which is a semi-transmissive electrode or a transmissive electrode, and the first capping layer **210** toward the outside, and in the organic layer **150** of each of the organic light-emitting devices **30** and **40**, light generated in an emission layer may pass through the second electrode **190**, which is a semi-transmissive electrode or a transmissive electrode, and the second capping layer **220** toward the outside.

[0376] The first capping layer **210** and the second capping layer **220** may increase external luminescent efficiency according to the principle of constructive interference.

[0377] The first capping layer **210** and the second capping layer **220** may each independently be an organic capping layer including an organic material, an inorganic capping layer including an inorganic material, or a composite capping layer including an organic material and an inorganic material.

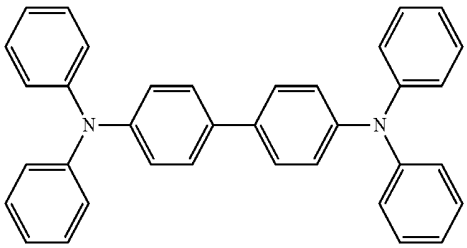
[0378] At least one selected from the first capping layer **210** and the second capping layer **220** may each independently include at least one material selected from carbocyclic compounds, heterocyclic compounds, amine-based compounds, porphyrine derivatives, phthalocyanine derivatives, naphthalocyanine derivatives, alkali metal complexes, and alkaline earth-based complexes. The carbocyclic compound, the heterocyclic compound, and the amine-based compound may be optionally substituted with a substituent containing at least one element selected from O, N, S, Se, Si, F, Cl, Br, and I. In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include an amine-based compound.

[0379] In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include the compound represented by Formula 201 or the compound represented by Formula 202.

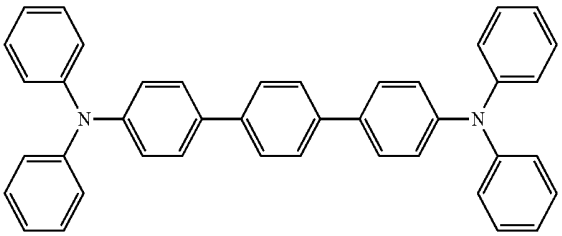
[0380] In one or more embodiments, at least one selected from the first capping layer **210** and the second capping layer **220** may each independently include a compound selected

from Compounds HT28 to HT33 and Compounds CP1 to CP5, but embodiments of the present disclosure are not limited thereto.

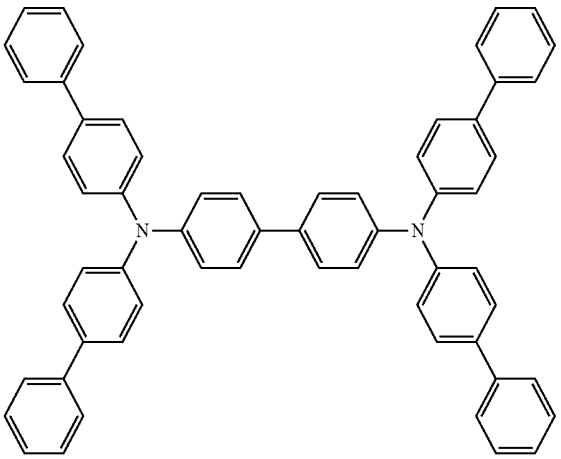
CP1



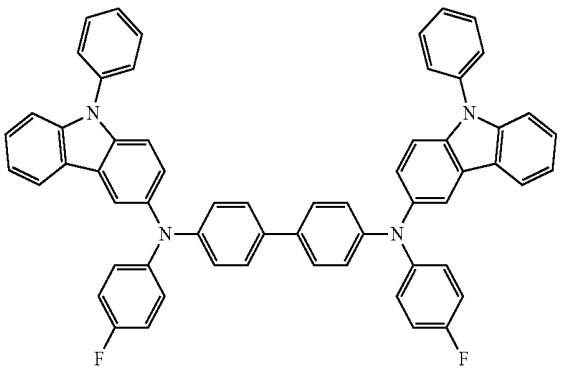
CP2



CP3



CP4



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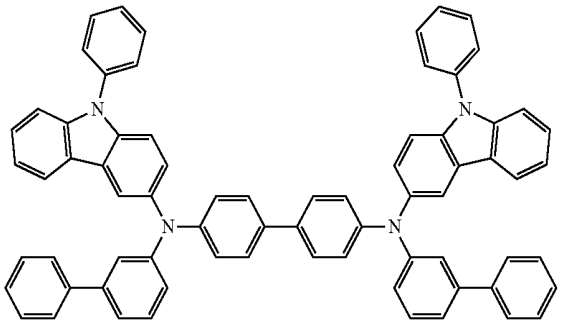
CP5



[0381] Hereinbefore, the organic light-emitting device according to an embodiment has been described in connection with FIGS. **1** and **5-7**. However, embodiments of the present disclosure are not limited thereto.

[0382] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0383] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, for example, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10^{-8} torr to about 10^{-3} torr, and at a deposition rate of about 0.01 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0384] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to about 200° C. by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0385] [General Definition of Substituents]

[0386] The term "C_1-C_{60} alkyl group," as used herein, refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term "C_1-C_{60} alkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{60} alkyl group.

[0387] The term "C_2-C_{60} alkenyl group," as used herein, refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term "C_2-C_{60} alkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_2-C_{60} alkenyl group.

[0388] The term "C_2-C_{60} alkynyl group," as used herein, refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the

C_2-C_{60} alkyl group, and examples thereof include an ethynyl group and a propynyl group. The term "C_2-C_{60} alkynylene group," as used herein, refers to a divalent group having substantially the same structure as the C_2-C_{60} alkynyl group.

[0389] The term "C_1-C_{60} alkoxy group," as used herein, refers to a monovalent group represented by —OA_{101} (wherein A_{101} is the C_1-C_{60} alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0390] The term "C_3-C_{10} cycloalkyl group," as used herein, refers to a monovalent saturated hydrocarbon monocyclic group having 3 to 10 carbon atoms, and examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "C_3-C_{10} cycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkyl group.

[0391] The term "C_1-C_{10} heterocycloalkyl group," as used herein, refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term "C_1-C_{10} heterocycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkyl group.

[0392] The term "C_3-C_{10} cycloalkenyl group," as used herein, refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkenyl group.

[0393] The term "C_1-C_{10} heterocycloalkenyl group," as used herein, refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C_1-C_{10} heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term "C_1-C_{10} heterocycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkenyl group.

[0394] The term "C_6-C_{60} aryl group," as used herein, refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C_6-C_{60} arylene group used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Examples of the C_6-C_{60} aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be fused to each other.

[0395] The term "C_1-C_{60} heteroaryl group," as used herein, refers to a monovalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 1 carbon atoms. The term "C_1-C_{60} heteroarylene group," as used herein, refers to a divalent group having a carbocyclic aromatic system that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, in addition to 1 to 60 carbon atoms. Examples of the C_1-C_{60} heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

[0396] The term "C_6-C_{60} aryloxy group," as used herein, indicates —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0397] The term "monovalent non-aromatic condensed polycyclic group," as used herein, refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. A more detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group.

[0398] The term "monovalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0399] The term "C_5-C_{60} carbocyclic group," as used herein, refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C_5-C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_5-C_{60} carbocyclic group may be a ring, such as benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C_5-C_{60} carbocyclic group, the C_5-C_{60} carbocyclic group may be a trivalent group or a tetravalent group.

[0400] The term "C_1-C_{60} heterocyclic group," as used herein, refers to a group having substantially the same structure as the C_5-C_{60} carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60).

[0401] At least one substituent of the substituted C_5-C_{60} carbocyclic group, substituted C_1-C_{60} heterocyclic group, substituted C_3-C_{10} cycloalkylene group, substituted C_1-C_{10} heterocycloalkylene group, substituted C_3-C_{10} cycloalkenylene group, substituted C_1-C_{10} heterocycloalkenylene group, substituted C_6-C_{60} arylene group, substituted C_1-C_{60} heteroarylene group, substituted divalent non-aromatic condensed polycyclic group, substituted divalent non-aromatic condensed heteropolycyclic group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocy-

cloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0402] deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

[0403] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{11})$, —$S(=O)_2(Q_{11})$, and —$P(=O)(Q_{11})(Q_{12})$;

[0404] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0405] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{21})(Q_{22})$, —$B(Q_{21})(Q_{22})$, —$C(=O)(Q_{21})$, —$S(=O)_2(Q_{21})$, and —$P(=O)(Q_{21})(Q_{22})$; and

[0406] —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$;

[0407] wherein Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0408] The term "Ph," as used herein, refers to a phenyl group, the term "Me," as used herein, refers to a methyl group, the term "Et," as used herein, refers to an ethyl group, the term "ter-Bu" or "But," as used herein, refers to a tert-butyl group, and the term "OMe," as used herein, refers to a methoxy group.

[0409] The term "biphenyl group," as used herein, refers to "a phenyl group substituted with a phenyl group." In other words, the "biphenyl group" is a substituted phenyl group having a C_6-C_{60} aryl group as a substituent.

[0410] The term "terphenyl group," as used herein, refers to "a phenyl group substituted with a biphenyl group." In other words, the "terphenyl group" is a phenyl group having, as a substituent, a C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group.

[0411] * and *', as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0412] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in more detail with reference to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples refers to that an identical or substantially identical molar equivalent of B was used in place of A.

EXAMPLE

Evaluation Example 1

[0413] Ionization energy (IP) and electron affinity (EA) of Compounds 1, 2, and 4 to 9, F_4-TCNQ, and Compounds A and B were calculated through simulation by using Vienna Ab-initio Simulation Package (VASP). Results thereof are shown in Table 1 below. The calculations were performed using density functional theory with the Perdew-Burke-Enzerhof (PBE) functional and the plane augmented wave (PAW) basis set. Further, the ionization energy (IP) and electron affinity were calculated according to the following equations:

$$IP = E_{cat} - E_{neutral}$$

$$EA = E_{neutral} - E_{anion}$$

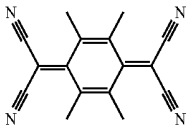
[0414] Also, for reference, ionization energy and electron affinity of Compound HT3 are also shown.

TABLE 1

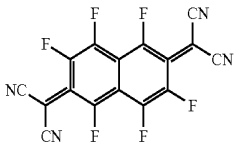
Compound No.	Electron affinity (eV)	Ionization energy (eV)
Compound 1	5.565	9.481
Compound 2	5.552	9.486
Compound 4	5.640	8.588
Compound 5	5.590	9.521
Compound 6	5.358	8.927
Compound 7	5.594	9.705
Compound 8	5.500	9.789
Compound 9	5.272	9.667
F_4-TCNQ	4.010	9.340

TABLE 1-continued

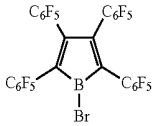
Compound No.	Electron affinity (eV)	Ionization energy (eV)
Compound A	4.190	8.760
Compound B	3.110	7.850
HT3	0.940	5.710



F_4-TCNQ



Compound A



Compound B .

[0415] Referring to Table 1, it can be seen that Compounds 1, 2, and 4 to 9 have a high electron affinity, as compared with F_4-TCNQ and Compounds A and B.

Evaluation Example 2

[0416] Hole injection barriers (HIBs) at interfaces between an anode (indium tin oxide (ITO)) and hole injection layers (HIL) (matrix:HT3, p-dopant: Compounds 1, 2, and 4 to 9, F_4-TCNQ, and Compounds A and B) were calculated by using Electronegativity Equalization model (EEM) based anode/p-dopant doped HTL (PHIL) interface barrier simulation technology, based on Equation (1) (Equation (1) is an equation derived from an electronegative equalization principle that neighboring atoms or molecules have substantially the same electron affinity (χ)). Results thereof are shown in Table 2 below:

$$HIB = \eta^{Org} + \frac{(\chi^{Org} - \chi^{M})}{(1 + \eta^{M}/\eta^{Org})}. \quad \text{Equation (1)}$$

[0417] In Equation (1), χ represents electronegativity, η represents chemical hardness, and superscripts M and Org represent a metal (for example, an anode material) and an organic material (for example, an HIL material), respectively. and χ and n may be calculated from the ionization energy (IP) and the electron affinity (EA) by using Equation (2) below:

$$\chi = \frac{IP + EA}{2}, \eta = \frac{IP - EA}{2} \quad \text{Equation (2)}$$

[0418] Based on Equation (2), χ^{M} is 5.85 eV, and η^{M} is 1.7 eV.

TABLE 2

Compound No.	Hole injection barrier (eV)
Compound 1	0.13
Compound 2	0.13
Compound 4	0.1
Compound 5	0.15
Compound 6	0.24
Compound 7	0.12
Compound 8	0.21
Compound 9	0.12
F_4-TCNQ	0.55
Compound A	0.58
Compound B	0.68
HT3	0.9

Evaluation Example 3

[0419] χ and η of the PHIL (a case where a molar ratio of the p-dopant is taken into account) may be calculated from EA and IP values of the HIL material and the p-dopant. An equation for calculating χ and η of the PHIL is as follows:

$$N^{H}\exp\left[-\frac{\chi^{PHIL} - IP^{H}}{kT}\right] = (N^{H} - N^{D})\exp\left[-\frac{EA^{H} - IP^{H}}{2\,kT}\right] + N^{D}\exp\left[-\frac{EA^{D} - IP^{H}}{2\,kT}\right] \quad \text{Equation (3)}$$

$$\chi^{PHIL} = IP^{H} - kT\log\left\{\exp\left[-\frac{EA^{H} - IP^{H}}{2\,kT}\right] - \frac{N^{D}}{N^{H}}\left(\exp\left[-\frac{EA^{H} - IP^{H}}{2\,kT}\right] - \exp\left[-\frac{EA^{D} - IP^{H}}{2\,kT}\right]\right)\right\} \quad \text{Equation (4)}$$

$$\eta^{PHIL} = IP^{H} - \chi^{PHIL}. \quad \text{Equation (5)}$$

[0420] In Equations (3) to (5), N, k, and T represent a molar ratio, a Boltzmann constant, and temperature (room temperature), respectively, a superscript H represents the HIL material, and D represents the p-dopant.

[0421] In Equations (3) and (4), EA^{H}=0.94 eV, and IP^{H}=5.71 eV.

[0422] If χ^{PHIL} and η^{PHIL} calculated from Equations (4) and (5) are substituted into χ^{Org} and η^{Org} in Equation (1), anode/PHIL HIB based on the molar ratio of the p-dopant may be calculated. Results thereof are shown in FIG. **4** below.

[0423] Referring to FIG. **4**, it can be seen that an organic light-emitting device including Compounds 1, 2, and 4 to 9 has a low hole injection barrier (HIB), as compared with an organic light-emitting device including F_4-TCNQ, and Compounds A and B.

[0424] According to one or more embodiments, an organic light-emitting device including the borole compound may have high efficiency and a low driving voltage.

[0425] It will be understood that, although the terms "first," "second," "third," etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section described below could be termed a

second element, component, region, layer or section, without departing from the spirit and scope of the present disclosure. In the drawings, the relative sizes of elements, layers, and regions may be exaggerated for clarity.

[0426] Spatially relative terms, such as "beneath," "below," "lower," "under," "above," "upper," and the like, may be used herein for ease of explanation to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or in operation, in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" or "under" other elements or features would then be oriented "above" the other elements or features. Thus, the example terms "below" and "under" can encompass both an orientation of above and below. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein should be interpreted accordingly.

[0427] It will be understood that when an element or layer is referred to as being "on" another element or layer, it can be directly on the other element or layer, or one or more intervening elements or layers may be present. In addition, it will also be understood that when an element or layer is referred to as being "between" two elements or layers, it can be the only element or layer between the two elements or layers, or one or more intervening elements or layers may also be present.

[0428] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a" and "an" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and "including," when used in this specification, specify the presence of the stated features, integers, acts, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, acts, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0429] As used herein, the terms "substantially," "about," and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art. Further, the use of "may" when describing embodiments of the present disclosure refers to "one or more embodiments of the present disclosure." As used herein, the terms "use," "using," and "used" may be considered synonymous with the terms "utilize," "utilizing," and "utilized," respectively. Also, the term "exemplary" is intended to refer to an example or illustration.

[0430] Also, any numerical range recited herein is intended to include all subranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein, and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0431] It should be understood that embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

[0432] While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims, and equivalents thereof.

What is claimed is:

1. A borole compound represented by Formula 1:

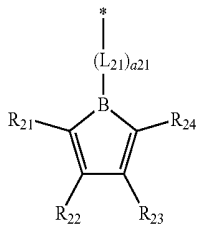
$$X_{11}—(R_{11})_{b11},$$ Formula 1

wherein, in Formula 1,

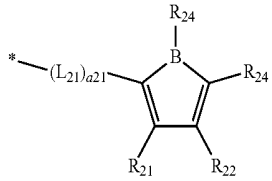
X_{11} is selected from a substituted or unsubstituted triazine, a substituted or unsubstituted vinylene carbonate, a substituted or unsubstituted thiophene, a substituted or unsubstituted furan, a substituted or unsubstituted dibenzoborole, a substituted or unsubstituted azulene, a substituted or unsubstituted naphthalene, a substituted or unsubstituted anthracene, and a substituted or unsubstituted pyrene, and

R_{11} is represented by one of Formulae 2-1 to 2-3:

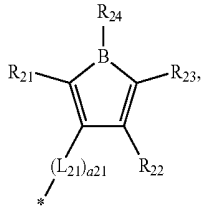
2-1



2-2



2-3



wherein b11 is selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, wherein, when b11 is two or more, a plurality of R_{11}(s) are identical to or different from each other,

in Formulae 2-1 to 2-3,

L_{21} is selected from a substituted or unsubstituted C_1-C_{10} alkylene group, a substituted or unsubstituted C_2-C_{10} alkenylene group, a C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

a21 is 0 or 1,

R_{21} to R_{24} are each independently selected from R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$, provided that at least one of R_{21} to R_{24} is R_{EW},

R_{EW} is an electron withdrawing group,

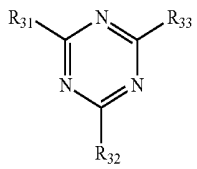
Q_1 to Q_3 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group, and

* indicates a binding site to a neighboring atom.

2. The borole compound of claim **1**, wherein:

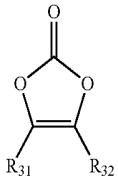
X_{11} is represented by one of Formulae 3-1 to 3-9:

3-1

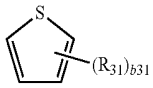


-continued

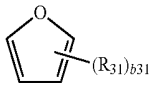
3-2



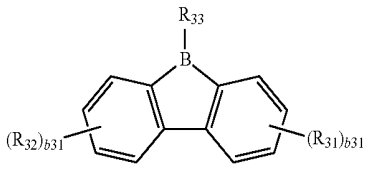
3-3



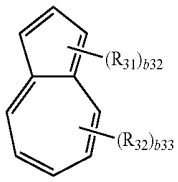
3-4



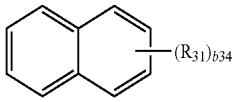
3-5



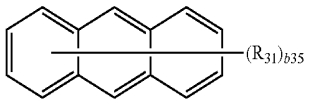
3-6



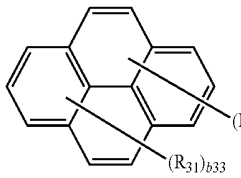
3-7



3-8



3-9



wherein, in Formulae 3-1 to 3-9,

R_{31} to R_{33} are each independently selected from:

a binding site to R_{11}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group;

a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a

C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group,

at least one selected from R_{31}, the number of which is the same as b11, is a binding site to R_{11}, at least one selected from R_{31} and R_{32}, the number of which is the same as b11, is a binding site to R_{11}, or at least one selected from R_{31} to R_{33}, the number of which is the same as b11, is a binding site to R_{11},

b31 is selected from 1, 2, 3, and 4,

b32 is selected from 1, 2, and 3,

b33 is selected from 1, 2, 3, 4, and 5,

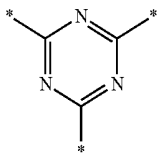
b34 is selected from 1, 2, 3, 4, 5, and 6, and

b35 is selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.

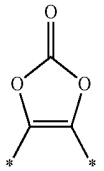
3. The borole compound of claim **1**, wherein:

X_{11} is represented by one of Formulae 4-1 to 4-9:

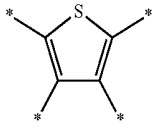
4-1



4-2

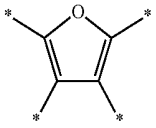


4-3

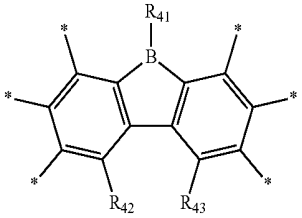


-continued

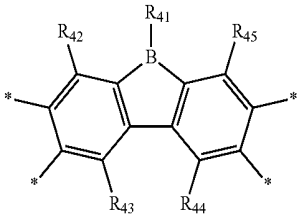
4-4



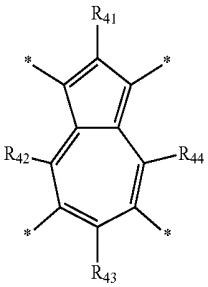
4-5



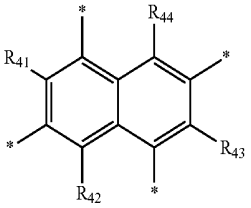
4-6



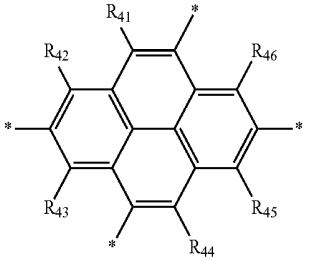
4-7



4-8



4-9



,

wherein, in Formula 4-1 to 4-9,

* indicates a binding site to R_{11}, and

R_{41} to R_{46} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

4. The borole compound of claim **1**, wherein:

R_{11} is represented by Formula 2-1.

5. The borole compound of claim **1**, wherein:

L_{21} is selected from:

a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group; and

a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group.

6. The borole compound of claim **1**, wherein:

a21 is 0.

7. The borole compound of claim **1**, wherein:

R_{21} to R_{24} are each independently selected from:

R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group;

a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, and a C_1-C_{10} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group; and

a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{10} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a C_2-C_{10} alkynyl group, a C_1-C_{10} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{10} aryl group, a C_6-C_{10} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{10} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, provided that at least one of R_{21} to R_{24} is R_{EW}.

8. The borole compound of claim **1**, wherein:

R_{21} to R_{24} are each independently selected from:

R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a C_1-C_{10} alkyl group, and a C_1-C_{10} alkoxy group;

a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group; and

a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{10} alkyl group, a C_2-C_{10} alkenyl group, a phenyl group, a naphthyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a quinolinyl group, and an isoquinolinyl group, provided that at least one of R_{21} to R_{24} is R_{EW}.

9. The borole compound of claim **1**, wherein:

R_{21} to R_{24} are each independently selected from:

R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

a phenyl group and a naphthyl group; and

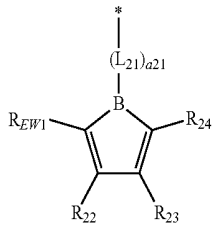
a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a

phenyl group, and a naphthyl group, provided that at least one of R_{21} to R_{24} is R_{EW}.

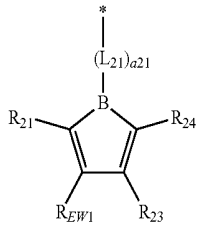
10. The borole compound of claim **1**, wherein:

R_{11} is represented by one of Formulae 2-11 to 2-19:

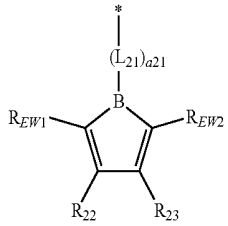
2-11



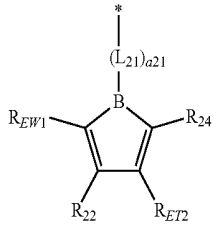
2-12



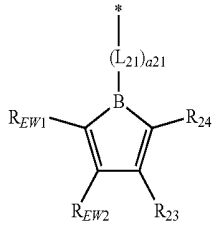
2-13



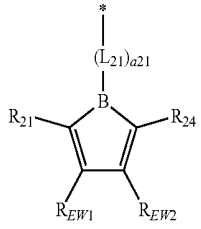
2-14



2-15



2-16



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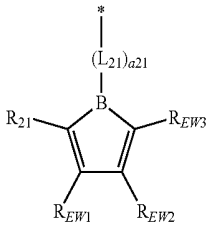
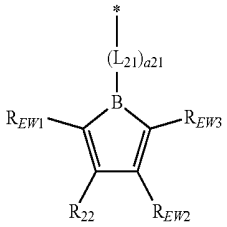
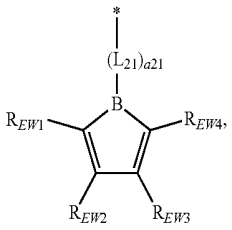
2-17



2-18



2-19



wherein, in Formulae 2-11 to 2-19,

L_{21} is selected from a phenylene group, a naphthylene group, a pyridinylene group, a pyrimidinylene group, a pyrazinylene group, and a triazinylene group, a21 is 0 or 1,

R_{21} to R_{24} are each independently selected from:

R_{EW}, hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group,

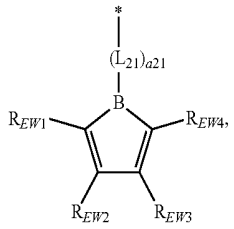
R_{EW1} to R_{EW4} are each an electron withdrawing group, and

* indicates a binding site to a neighboring atom.

11. The borole compound of claim **1**, wherein:

R_{11} is represented by Formula 2-19:

2-19



wherein, in Formula 2-19,

$(L_{21})_{a21}$ is a single bond,

R_{EW1} to R_{EW4} are each independently selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, —CF_3, —CCl_3, —CBr_3, —Cl_3, —C_2F_3, —C_2Cl_3, —C_2Br_3, —C_2I_3, —$C_2(CN)_3$, and —$C_2(NO_2)_3$, and

* indicates a binding site to X_{11}.

12. The borole compound of claim **1**, wherein:

R_{EW} is selected from:

—F, —Cl, —Br, —I, a cyano group, and a nitro group; and

a C_1-C_{10} alkyl group and a C_2-C_{10} alkenyl group, each substituted with at least one selected from —F, —Cl, —Br, —I, a cyano group, and a nitro group.

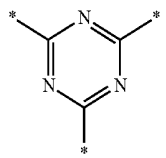
13. The borole compound of claim **1**, wherein:

X_{11} is represented by one of Formulae 4-1 to 4-9,

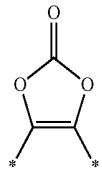
R_{11} is represented by Formula 2-19, and

b11 is selected from 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10, wherein, when b11 is two or more, a plurality of R_{11}(s) are identical to or different from each other:

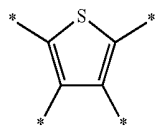
4-1



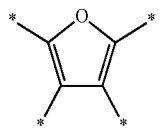
4-2



4-3



4-4



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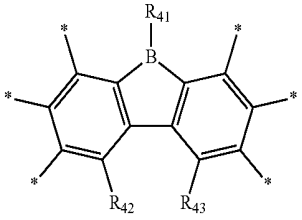
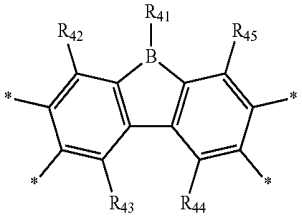
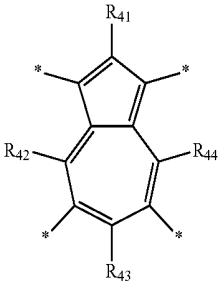
4-5



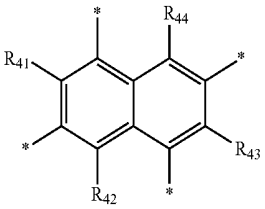
4-6



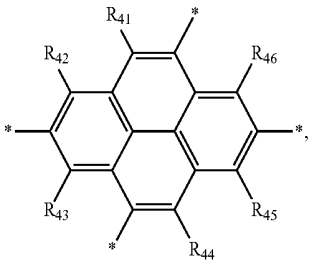
4-7



4-8



4-9



wherein, in Formulae 4-1 to 4-9,

* indicates a binding site to R_{11},

R_{41} to R_{46} are each independently selected from:

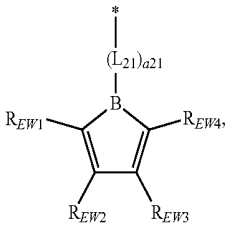
hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, and a tert-butoxy group;

a phenyl group and a naphthyl group; and

a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro

group, a methyl group, an ethyl group, an n-propyl group, an iso-propyl group, an n-butyl group, a sec-butyl group, an iso-butyl group, a tert-butyl group, a methoxy group, an ethoxy group, an n-propoxy group, an iso-propoxy group, an n-butoxy group, a sec-butoxy group, an iso-butoxy group, a tert-butoxy group, a phenyl group, and a naphthyl group,

2-19



wherein, in Formula 2-19,

$(L_{21})_{a21}$ is a single bond,

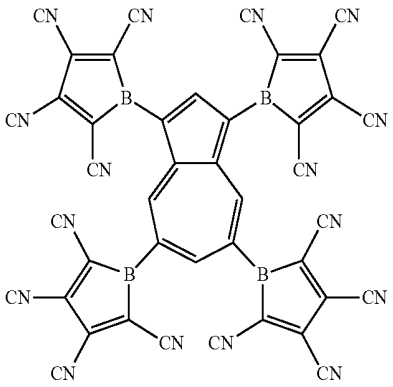
R_{EW1} to R_{EW4} are each independently selected from —F, —Cl, —Br, —I, a cyano group, a nitro group, —CF_3, —CCl_3, —CBr_3, —Cl_3, —C_2F_3, —C_2Cl_3, —C_2Br_3, —C_2I_3, —$C_2(CN)_3$, and —$C_2(NO_2)_3$, and

* indicates a binding site to X_{11}.

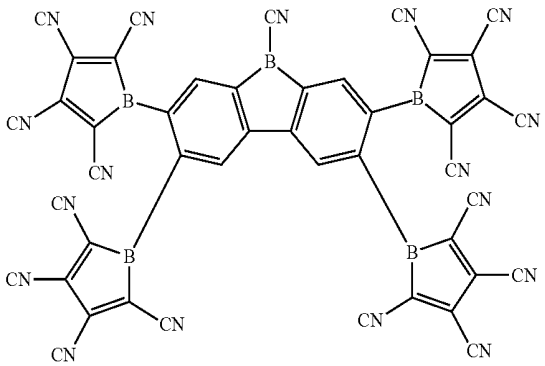
14. The borole compound of claim **1**, wherein:

the borole compound is selected from Compounds 1 to 9:

1



2



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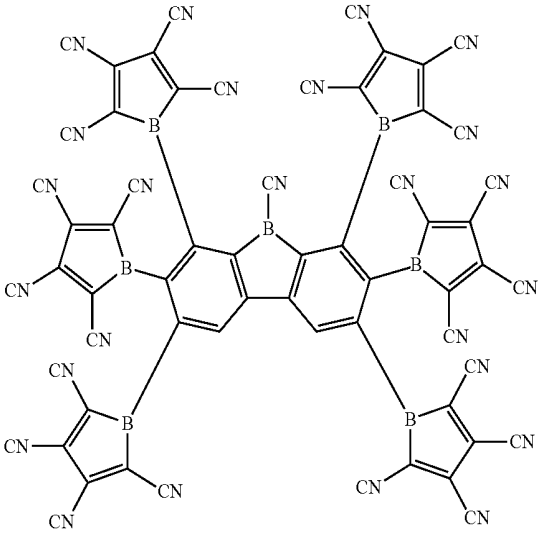
3



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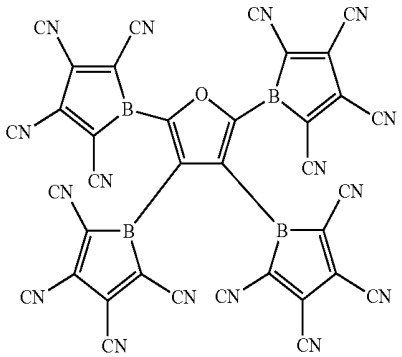

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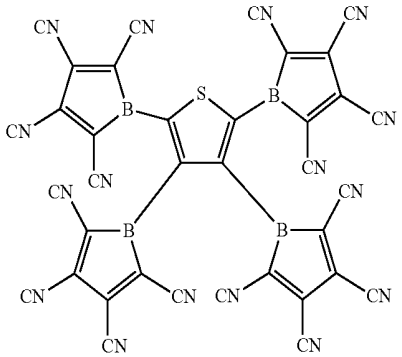

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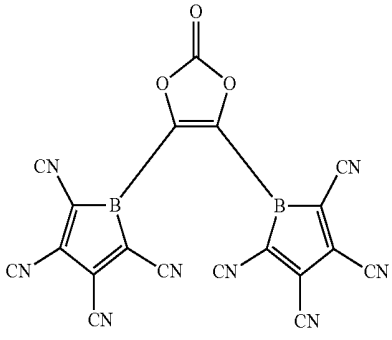

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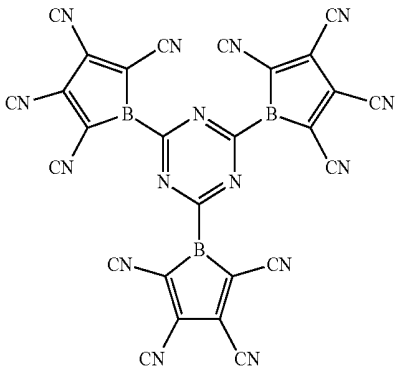
7



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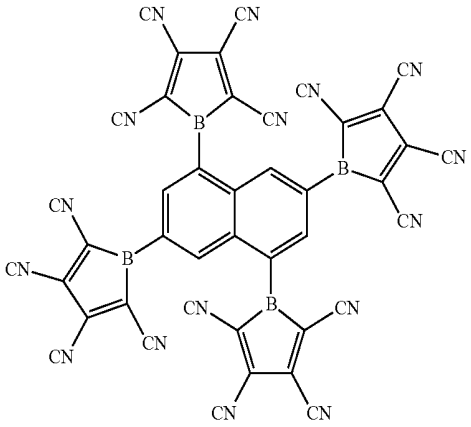

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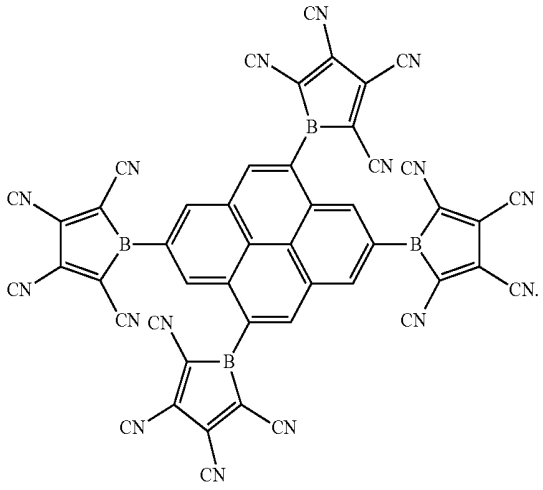

15. The borole compound of claim 1, wherein:

an electron affinity of the borole compound is in a range of about 5.5 eV to about 6.0 eV.

16. The borole compound of claim 1, wherein:

a hole injection barrier of the borole compound is in a range of about 0.1 eV to about 0.4 eV.

17. An organic light-emitting device comprising:

a first electrode;

a second electrode; and

an organic layer between the first electrode and the second electrode, the organic layer comprising an emission layer,

wherein the organic layer comprises the borole compound of claim 1.

18. The organic light-emitting device of claim 17, wherein:

the first electrode is an anode,

the second electrode is a cathode,

the organic layer further comprises a hole transport region between the first electrode and the emission layer, and

the hole transport region comprises the borole compound.

19. The organic light-emitting device of claim 18, wherein:

the hole transport region comprises a hole injection layer comprising the borole compound, or

the hole transport region comprises a buffer layer comprising the borole compound.

20. The organic light-emitting device of claim 19, wherein:

the hole injection layer comprising the borole compound further comprises a matrix material, and an amount of the borole compound in the hole injection layer is in a range of greater than 0 wt % and equal to or smaller than 6 wt % based on a total weight of the hole injection layer; or

the buffer layer comprising the borole compound further comprises a matrix material, and an amount of the borole compound in the buffer layer is in a range of greater than 0 wt % and equal to or smaller than 6 wt % based on the total weight of the buffer layer.

* * * * *

专利名称(译)	硼化合物和包括其的有机发光器件		
公开(公告)号	US20180057737A1	公开(公告)日	2018-03-01
申请号	US15/584826	申请日	2017-05-02
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星显示设备		
[标]发明人	KANG SUNWOO JEON SANGHO CHO YOUNGMI		
发明人	KANG, SUNWOO JEON, SANGHO CHO, YOUNGMI		
IPC分类号	C09K11/63 C07F5/02 C07D333/10 C07D317/10 C07D251/14 C09K11/06 C09K11/56 C07D333/50 C07D333/32		
CPC分类号	C09K11/63 C07F5/02 C07D333/10 C07D317/10 C07D251/14 C07C2603/72 C09K11/56 C09K11/632 C07D333/50 C07D333/32 C09K11/06 C07F5/027		
优先权	1020160106989 2016-08-23 KR		
其他公开文献	US10259996		
外部链接	Espacenet USPTO		

摘要(译)

硼化合物由式1表示：X 11 -（R 11 ）b11 。 X 11 ，R 11 ，和b11如本文所定义。有机发光装置包括硼化合物。有机发光装置包括第一电极，第二电极和在第一电极和第二电极之间的有机层，有机层包括发光层。有机层包括硼化合物。