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

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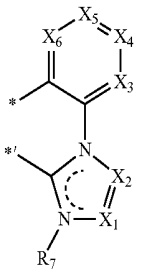
(57) **ABSTRACT**

An organometallic compound and an organic light-emitting device including the same are provided. The organometallic compound may be represented by Formula 1, wherein L_1 is a ligand represented by Formula 2A and L_2 is a ligand represented by Formula 2B. Further details about the compounds are presented in the disclosure.

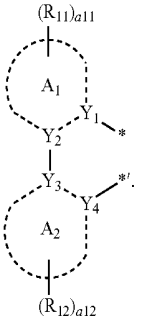
$M(L_1)_{n1}(L_2)_{n2}$, <Formula 1>

wherein M is iridium.

<Formula 2A>



<Formula 2B>



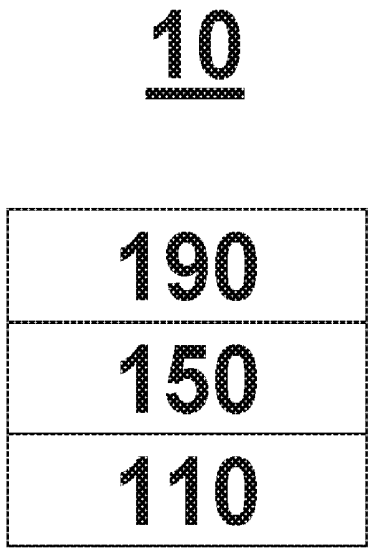
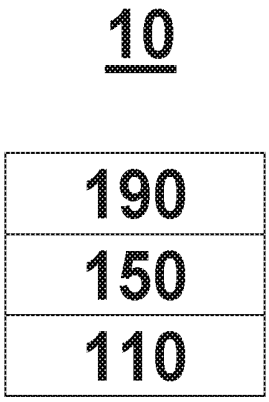


FIG. 1



ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Korean Patent Applications Nos. 10-2016-0124243, filed on Sep. 27, 2016, and 10-2017-0123701, filed on Sep. 25, 2017, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

[0002] One or more embodiments relate to an organometallic 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 have wide viewing angles, high contrast ratios, short response times, and excellent brightness, driving voltage, and response speed characteristics, compared to devices in the art and produce full-color images.

[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 transit from an excited state to a ground state, thereby generating light.

SUMMARY

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

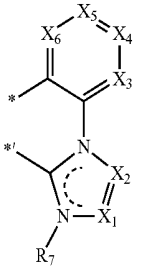
[0006] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

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

<Formula 1>

$$M(L_1)_{n1}(L_2)_{n2}$$

<Formula 2A>



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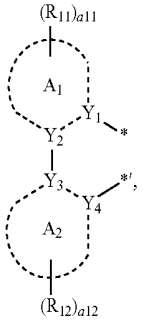
<Formula 2B>



[0008] M in Formula 1 may be iridium (Ir),

[0009] in Formula 1, L_1 may be a ligand represented by Formula 2A and n1 may be 1, 2, or 3, wherein when n1 is two or more, two or more L_1(s) may be identical to or different from each other,

[0010] in Formula 1, L_2 may be a ligand represented by Formula 2B and n2 may be 0, 1, or 2, wherein when n2 is two or more, two or more L_2(s) may be identical to or different from each other,

[0011] the sum of n1 and n2 in Formula 1 may be three,

[0012] * and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1,

[0013] in Formula 2A, X_1 may be N or $C(R_1)$, X_2 may be N or $C(R_2)$, X_3 may be N or $C(R_3)$, X_4 may be N or $C(R_4)$, X_5 may be N or $C(R_5)$, and X_6 may be N or $C(R_6)$,

[0014] in Formula 2B, Y_1 may be C, Y_2 and Y_3 may each independently be C or N, Y_4 may be N, a bond between Y_1 and Y_2 may be a single bond or a double bond, a bond between Y_2 and Y_3 may be a single bond, and a bond between Y_3 and Y_4 may be a single bond or a double bond,

[0015] in Formula 2B, ring A_1 may be a C_4-C_{60} carbocyclic group or a C_1-C_{60} heterocyclic group and ring A_2 may be a C_1-C_{60} heterocyclic group,

[0016] R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B 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 hydrazone 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 —$P(=O)(Q_1)(Q_2)$,

[0017] any two neighboring groups selected from R_1 to R_7 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0018] any two neighboring groups selected from two or more R_{11}(s) in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0019] any two neighboring groups selected from two or more R_{12}(s) in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0020] neighboring R_{11} and R_{12} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

[0021] a11 and a12 in Formula 2B may each independently be 0, 1, 2, 3, 4, or 5,

[0022] i) when n1 in Formula 1 is three, a) X_2 and X_3 in Formula 2A may be N; or b) at least one of X_4 to X_6 may be N, and R_7 may be an electron withdrawing group,

[0023] ii) when n1 in Formula 1 is one or two, a) at least one of X_3, X_5, and X_6 in Formula 2A may be N; and b) X_1 in Formula 2A may be $C(R_1)$, X_4 may be $C(R_4)$, and at least one of R_1 and R_4 may be an electron withdrawing group, and

[0024] at least one substituent of the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, the substituted C_4-C_{60} carbocyclic group, and the substituted C_1-C_{60} heterocyclic group may be selected from:

[0025] deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone 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;

[0026] 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 hydrazone 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 —$P(=O)(Q_{11})(Q_{12})$;

[0027] 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;

[0028] 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 hydrazone 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

[0029] —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$,

[0030] 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 hydrazone 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 C_1-C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C_6-C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

[0031] According to one or more embodiments, an organic light-emitting device includes: a first electrode; a second electrode facing the first 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 organometallic compound.

BRIEF DESCRIPTION OF THE DRAWING

[0032] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with FIG. **1** which is a schematic cross-sectional view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

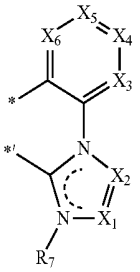
[0033] An organometallic compound according to an embodiment may be represented by Formula 1:

$$M(L_1)_{n1}(L_2)_{n2}, \qquad \text{<Formula 1>}$$

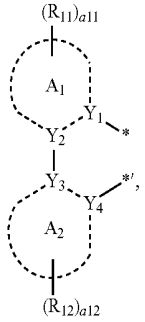
[0034] M in Formula 1 may be iridium (Ir).

[0035] In Formula 1, i) L_1 may be a ligand represented by Formula 2A and n1 may be 1, 2, or 3, wherein when n1 is two or more, two or more L_1(s) may be identical to or different from each other, and ii) L_2 in Formula 1 may be a ligand represented by Formula 2B and n2 may be 0, 1, or 2, wherein when n2 is two or more, two or more L_2(s) may be identical to or different from each other:

<Formula 2A>



<Formula 2B>



[0036] wherein Formulae 2A and 2B are the same as described below. * and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1.

[0037] The sum of n1 and n2 in Formula 1 may be three.

[0038] The organometallic compound represented by Formula 1 does not have a salt form consisting of an anion and a cation and is neutral.

[0039] In Formula 2A, X_1 may be N or $C(R_1)$, X_2 may be N or $C(R_2)$, X_3 may be N or $C(R_3)$, X_4 may be N or $C(R_4)$, X_5 may be N or $C(R_5)$, and X_6 may be N or $C(R_6)$.

[0040] In Formula 2B, Y_1 may be C, Y_2 and Y_3 may each independently be C or N, Y_4 may be N, a bond between Y_1 and Y_2 may be a single bond or a double bond, a bond between Y_2 and Y_3 may be a single bond, and a bond between Y_3 and Y_4 may be a single bond or a double bond.

[0041] For example, in Formula 2B, Y_1 to Y_3 may be C and Y_4 may be N, but embodiments of the present disclosure are not limited thereto.

[0042] In Formula 2B, ring A_1 may be a C_4-C_{60} carbocyclic group or a C_1-C_{60} heterocyclic group and ring A_2 may be a C_1-C_{60} heterocyclic group.

[0043] In one or more embodiments, in Formula 2B,

[0044] ring A_1 may be a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a selenophene group, a pyrrole group, a cyclopentadiene group, a silole group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzoselenophene group, a carbazole group, a fluorene group, a dibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazol group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazol group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group, and

[0045] ring A_2 may be a pyrrole group, an indole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazol group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazol group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

[0046] In one or more embodiments, in Formula 2B,

[0047] ring A_1 may be a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a selenophene group, a pyrrole group, a cyclopentadiene group, a silole group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzoselenophene group, a carbazole group, a fluorene group, or a dibenzosilole group, and

[0048] ring A_2 may be a pyrrole group, an indole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a pyrazole group, an imidazole group, a triazole group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

[0049] In one or more embodiments, in Formula 2B,

[0050] ring A_1 may be a benzene group, a naphthalene group, a 1,2,3,4-tetrahydronaphthalene group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzoselenophene group, a carbazole group, a fluorene group, or a dibenzosilole group, and

[0051] ring A_2 may be a pyrrole group, a pyridine group, a pyrimidine group, a pyrazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a pyrazole group, an imidazole group, a triazole group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

[0052] In one or more embodiments, in Formula 2B, ring A_1 may be a benzene group and ring A_2 may be a pyridine group, but embodiments of the present disclosure are not limited thereto.

[0053] R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B 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 hydrazone 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 —$P(=O)(Q_1)(Q_2)$. Q_1 to Q_3 are the same as described above.

[0054] In one or more embodiments, R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B may each independently be selected from:

[0055] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0056] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl 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 —$P(=O)(Q_{31})(Q_{32})$;

[0057] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0058] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl 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

[0059] —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$,

[0060] wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from:

[0061] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} 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_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0062] a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

[0063] a C_6-C_{20} aryl group substituted with at least one selected from deuterium, —F, and a cyano group; and

[0064] a biphenyl group and a terphenyl group.

[0065] In one or more embodiments, R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B may each independently be selected from:

[0066] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0067] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0068] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

[0069] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

[0070] —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$,

[0071] wherein Q_1 to Q_3 and Q_{31} to Q_{33} are the same as described above.

[0072] 1) any two neighboring groups selected from R_1 to R_7 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group, 2) any two neighboring groups selected from two or more R_{11}(s) in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group, 3) any two neighboring groups selected from two or more R_{12}(s) in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group, and 4) neighboring R_{11} and R_{12} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group. The substituents of the substituted C_4-C_{60} carbocyclic group and the substituted C_1-C_{60} heterocyclic group are the same as described in connection with R_{11}, the C_4-C_{60} carbocyclic group may be a cyclopentane group, a cyclohexane group, an adamantane group, a norbornane group, a benzene group, or a naphthalene group, and the C_1-C_{60} heterocyclic group may be a thiophene group, a furan group, a pyrrole group, a benzothiophene group, a benzofuran group, an indole group, or a pyridine group, but embodiments of the present disclosure are not limited thereto.

[0073] a11 and a12 in Formula 2B may each independently be 0, 1, 2, 3, 4, or 5. a11 indicates the number of R_{11}(s), wherein when a11 is two or more, two or more R_{11}(s) may be identical to or different from each other. a12 indicates the number of R_{12}(s), wherein when a12 is two or more, two or more R_{12}(s) may be identical to or different from each other.

[0074] i) When n1 in Formula 1 is three, a) X_2 and X_3 in Formula 2A may be N; or b) at least one of X_4 to X_6 in Formula 2A may be N, and R_7 may be an electron withdrawing group, and ii) when n1 in Formula 1 is one or two, a) at least one of X_3, X_5, and X_6 in Formula 2A may be N; and b) X_1 in Formula 2A may be $C(R_1)$, X_4 may be $C(R_4)$, and at least one of R_1 and R_4 may be an electron withdrawing group.

[0075] In one or more embodiments, i) when n1 in Formula 1 is three, a) X_2 and X_3 in Formula 2A may be N; or b) one of X_4 to X_6 in Formula 2A may be N, the remaining two of X_4 to X_6 may not be N, R_7 may be an electron

withdrawing group, and ii) when n1 in Formula 1 is one or two, a) one of X_3, X_5, and X_6 in Formula 2A may be N, and the remaining two of X_3, X_5, and X_6 may not be N; and b) X_1 in Formula 2A may be $C(R_1)$, X_4 may be $C(R_4)$, and at least one of R_1 and R_4 may be an electron withdrawing group.

[0076] The electron withdrawing group may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or $—B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, $—CF_3$, $—CF_2H$, $—CFH_2$, a cyano group, a nitro group, and $—B(Q_{31})(Q_{32})$, and

[0077] the first group may be selected from:

[0078] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0079] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, $—CD_3$, $—CD_2H$, $—CDH_2$, a hydroxyl group, an amidino group, a hydrazino group, a hydrazone group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$;

[0080] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0081] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, $—CD_3$, $—CD_2H$, $—CDH_2$, a hydroxyl group, an amidino group, a hydrazino group, a hydrazone group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$,

[0082] wherein Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from:

[0083] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} 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_1o heterocycloalkenyl group, a C_6-C_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0084] a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

[0085] a C_6-C_{20} aryl group substituted with at least one selected from deuterium, —F, and a cyano group; and

[0086] a biphenyl group and a terphenyl group.

[0087] For example, it may be understood from the present disclosure that, 1) when the electron withdrawing group is a first group substituted with at least one —F and the first group is a "methyl group", the electron withdrawing group may be a "methyl group substituted with at least one —F (for example, $—CF_3$, $—CHF_2$, or $—CH_2F$)", and 2) when the electron withdrawing group is a first group substituted with at least one —F, and the first group is a "methyl group substituted with at least one deuterium", the electron withdrawing group is a "methyl group substituted with at least one —F and at least one deuterium (for example, $—CDF_2$ or $—CD_2F$)".

[0088] In one or more embodiments, the electron withdrawing group may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

[0089] the first group may be selected from:

[0090] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0091] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0092] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group; and

[0093] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group,

[0094] wherein Q_1, Q_2, Q_{31}, and Q_{32} may each independently be selected from:

[0095] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

[0096] a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

[0097] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

[0098] a biphenyl group and a terphenyl group.

[0099] In one or more embodiments, the electron withdrawing group may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

[0100] the first group may be selected from:

[0101] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group; and

[0102] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group,

[0103] wherein Q_1, Q_2, Q_{31}, and Q_{32} may each independently be selected from:

[0104] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

[0105] a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

[0106] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

[0107] a biphenyl group and a terphenyl group,

[0108] but embodiments of the present disclosure are not limited thereto.

[0109] n1 in Formula 1 may be three, and three L_1(s) in Formula 1 may be identical to one another. In this case, the organometallic compound represented by Formula 1 may be a homoleptic complex.

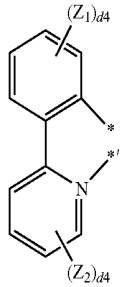
[0110] In one or more embodiments, n1 in Formula 1 may be three, one of X_4 to X_6 in Formula 2A may be N, and R_7 in Formula 2A may be an electron withdrawing group.

[0111] The electron withdrawing group is the same as described above.

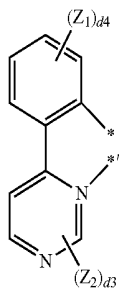
[0112] In one or more embodiments, n1 in Formula 1 may be 1 or 2, one of X_3, X_5, and X_6 in Formula 2A may be N, and at least one of R_1 and R_4 in Formula 2A (for example, R_4 or both R_1 and R_4) may be an electron withdrawing group. The electron withdrawing group is the same as described above.

[0113] L_2 in Formula 1 may be a ligand selected from groups represented by Formulae 2B-1 to 2B-14, but embodiments of the present disclosure are not limited thereto:

Formula 2B-1



Formula 2B-2



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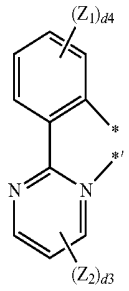
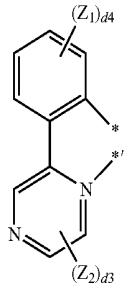
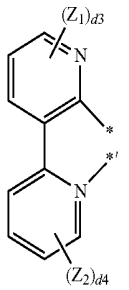
Formula 2B-3



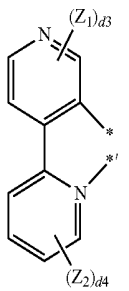
Formula 2B-4



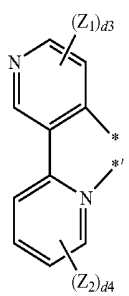
Formula 2B-5



Formula 2B-6



Formula 2B-7



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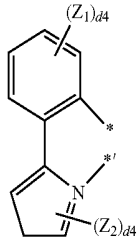
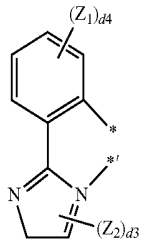
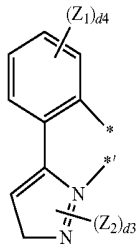
Formula 2B-8



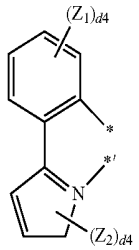
Formula 2B-9



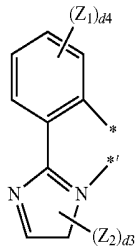
Formula 2B-10



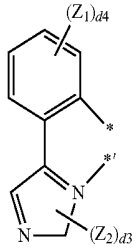
Formula 2B-11



Formula 2B-12

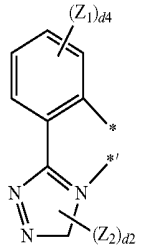


Formula 2B-13



-continued

Formula 2B-14



[0114] wherein, in Formulae 2B-1 to 2B-14,

[0115] Z_1 and Z_2 are the same as described in connection with R_{11} and R_{12},

[0116] d2 may be an integer from 0 to 2,

[0117] d3 may be an integer from 0 to 3,

[0118] d4 may be an integer from 0 to 4, and

[0119] * and *' each indicate a binding site to M in Formula 1.

[0120] For example, Z_1 and Z_2 in Formulae 2B-1 to 2B-14 may each independently be selected from:

[0121] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0122] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0123] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

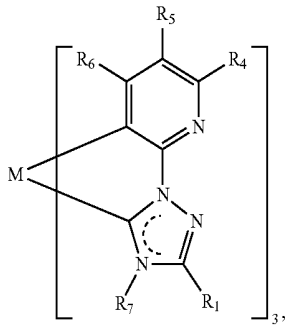
[0124] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrrolyl group, a thiophenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and

[0125] —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$,

[0126] wherein Q_1 to Q_3 and Q_{31} to Q_{33} are the same as described above.

[0127] In one or more embodiments, the organometallic compound may be represented by Formula 1(1):

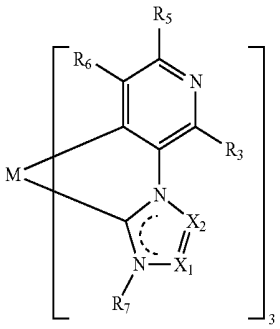
Formula 1(1)



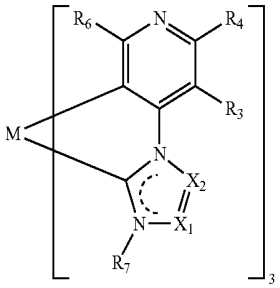
[0128] wherein M, R_1, and R_4 to R_7 are the same as described above.

[0129] In one or more embodiments, the organometallic compound may be represented by one of Formulae 1(2) to 1(4):

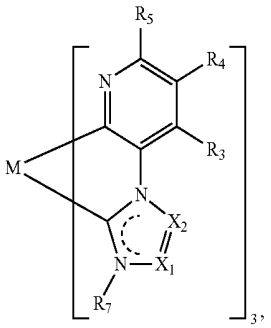
Formula 1(2)



Formula 1(3)



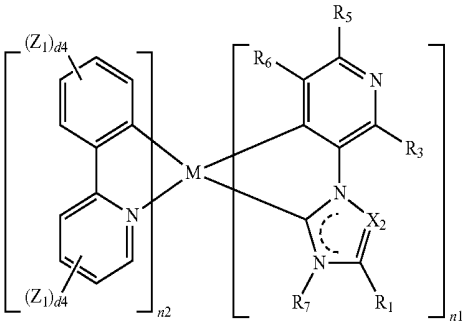
Formula 1(4)



[0130] wherein M, X_1, X_2, and R_3 to R_6 are the same as described above and R_7 is an electron withdrawing group. The electron withdrawing group is the same as described above.

[0131] In one or more embodiments, the organometallic compound may be represented by one of Formulae 2(1) to 2(3):

Formula 2(1)



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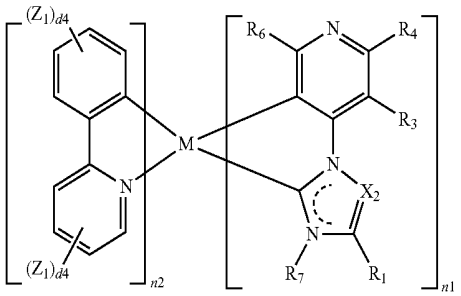
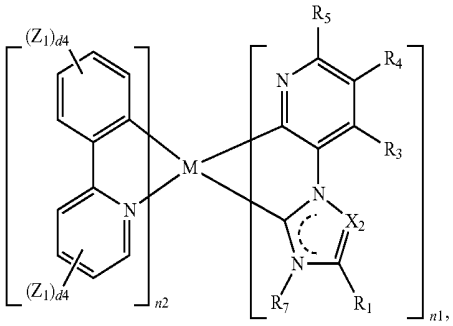
Formula 2(2)



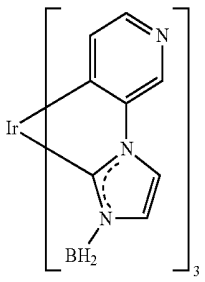
Formula 2(3)



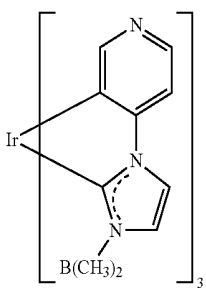
[0132] wherein, in Formulae 2(1) to 2(3), n1 and n2 may each independently be 1 or 2, the sum of n1 and n2 may be three, and M, R_1, X_2, and R_3 to R_7 are the same as described above, Z_1 and Z_2 are the same as described in connection with R_{11} and R_{12}, provided that at least one of R_1 and R_4 may each independently be an electron withdrawing group. The electron withdrawing group is the same as described above.

[0133] The organometallic compound may be selected from Compounds 1-1 to 1-8, 2-1, and 2-2, but embodiments of the present disclosure are not limited thereto:

1-1



1-2



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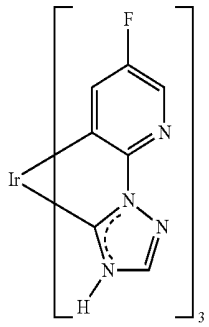
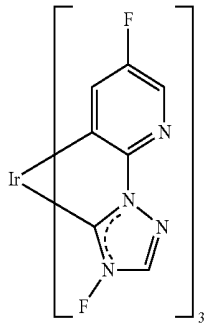
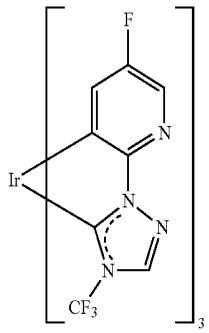
1-3



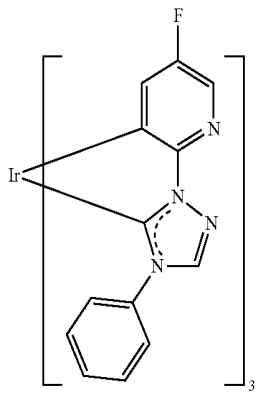
1-4



1-5



1-6



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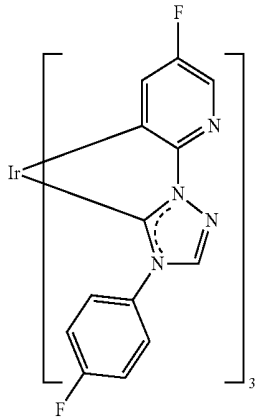
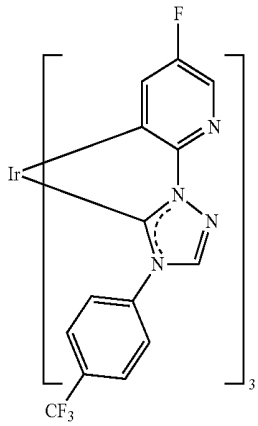
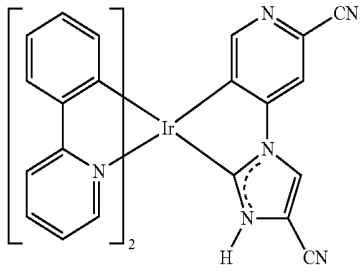
1-7



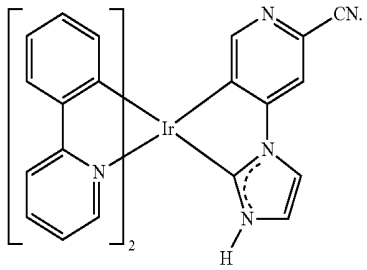
1-8



2-1



2-2



[0134] The organometallic compound may satisfy the following conditions: "i) when n1 in Formula 1 is three, a) X_2 and X_3 in Formula 2A is N; or b) at least one of X_4 to X_6 in Formula 2A is N, and R_7 is an electron withdrawing group, and ii) when n1 in Formula 1 is one or two, a) at least one of X_3, X_5, and X_6 in Formula 2A is N; and b) X_1 in Formula 2A is $C(R_1)$, X_4 is $C(R_4)$, and at least one of R_1 and R_4 is an electron withdrawing group."

[0135] The organometallic compound described above may have a high bond dissociation energy level (eV)

between a relatively large metal (M in Formula 1) and a ligand (L_1 when n2 in Formula 1 is zero, and L_1 and L_2 when n2 in Formula 1 is not zero), and thus, intrinsic degradation of the organometallic compound may be minimized. Accordingly, it is possible to suppress the generation of a decomposition product (for example, ligand species separated from a metal) due to a decomposition of the organometallic compound that may act as a quencher to reduce luminescent efficiency in an electronic device (for example, an organic light-emitting device) including the organometallic compound. Thus, the electronic device (for example, the organic light-emitting device) including the organometallic compound may have a long lifespan.

[0136] In one or more embodiments, a minimum bond disassociation energy level (eV) between the metal and the ligand of the organometallic compound may be higher than a minimum triplet energy level (eV) of the organometallic compound.

[0137] In one or more embodiments, the minimum bond dissociation energy level (eV) between the metal and the ligand of the organometallic compound may be higher than the minimum triplet energy level (eV) of the organometallic compound by 0.002 eV or more, for example, 0.5 eV or more, but embodiments of the present disclosure are not limited thereto.

[0138] The organometallic compound may have a minimum excitation triplet energy level of 2.7 eV to 3.2 eV.

[0139] The organometallic compound may emit blue light. For example, the organometallic compound may emit blue light having a maximum light emission wavelength of about 392 nm to about 460 nm at 77 Kelvin, but embodiments of the present disclosure are not limited thereto.

[0140] Synthesis methods of the organometallic compound represented by Formula 1 may be recognizable by those of ordinary skill in the art by referring to Examples provided below.

[0141] At least one organometallic compound represented by Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the organometallic compound may be included in an emission layer. The organometallic compound included in the emission layer may act as a dopant.

[0142] Accordingly, an organic light-emitting device may include: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode, the organic layer including an emission layer, wherein the organic layer may include at least one organometallic compound represented by Formula 1.

[0143] The expression "(an organic layer) includes at least one organometallic compound" used herein may include a case in which "(an organic layer) includes one organometallic compound represented by Formula 1" and a case in which "(an organic layer) includes two or more different organometallic compounds represented by Formula 1."

[0144] For example, the organic layer may include, as the organometallic compound, only Compound 1-1. In this regard, Compound 1-1 may exist in an emission layer of the organic light-emitting device. In one or more embodiments, the organic layer may include, as the organometallic compound, Compound 1-1 and Compound 1-2. In this regard, Compound 1-1 and Compound 1-2 may exist in an identical layer (for example, Compound 1-1 and Compound 1-2 all may exist in an emission layer), or may exist in different layers (for example, Compound 1-1 may exist in an emission layer and Compound 1-2 may exist in an electron transport region).

[0145] According to one or more embodiments,

[0146] the first electrode of the organic light-emitting device may be an anode,

[0147] the second electrode of the organic light-emitting device may be a cathode,

[0148] the organic layer may further include a hole transport region between the first electrode and the emission layer and an electron transport region between the emission layer and the second electrode,

[0149] the hole transport region may include a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and

[0150] the electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0151] The term "organic layer" used herein refers to a single layer and/or multiple layers 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.

[Description of FIG. **1**]

[0152] 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**.

[0153] 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**.

[First Electrode **110**]

[0154] 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 excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

[0155] 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.

[0156] 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 reflectable 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.

[0157] 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.

[Organic Layer **150**]

[0158] The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** may include an emission layer.

[0159] 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**.

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

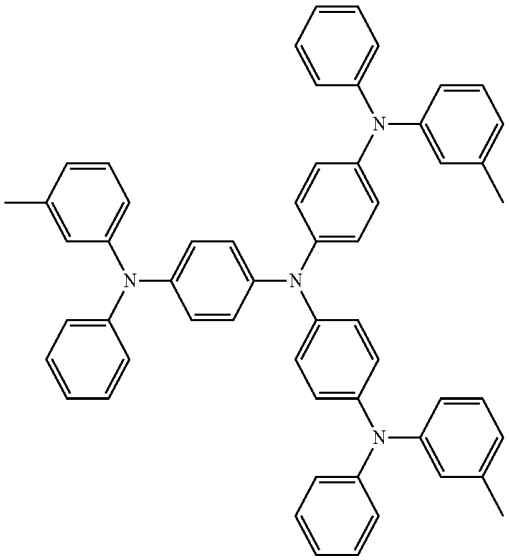
[0160] The hole transport region may have i) a single-layered structure consisting of a single layer consisting of a single material, ii) a single-layered structure consisting of a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0161] 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).

[0162] For example, the hole transport region may have a single-layered structure including a single 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.

[0163] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB (NPD), β-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



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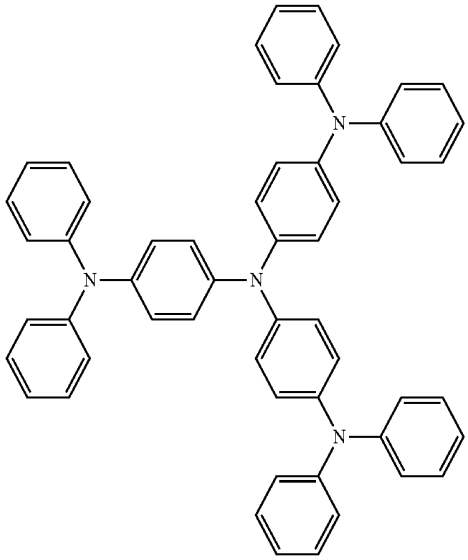
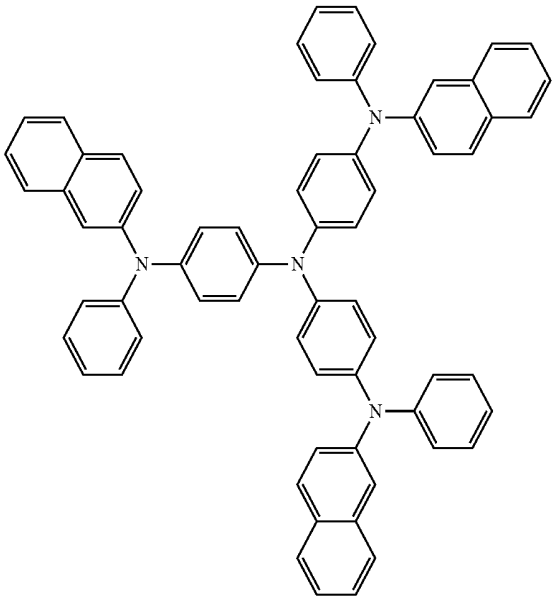
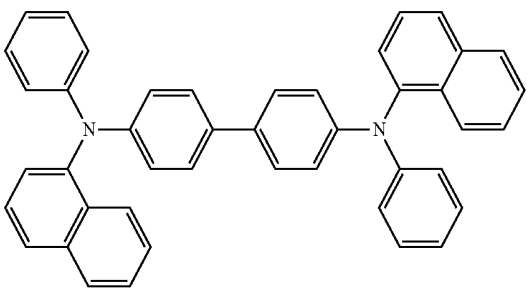
TDATA



2-TNATA



NPB



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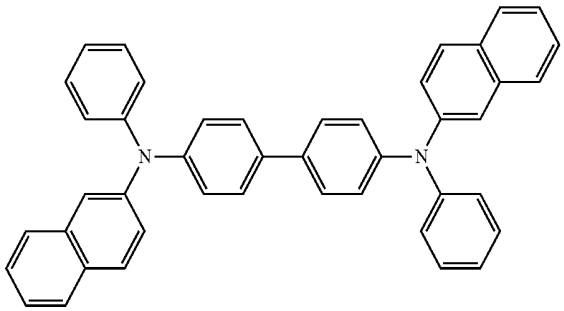
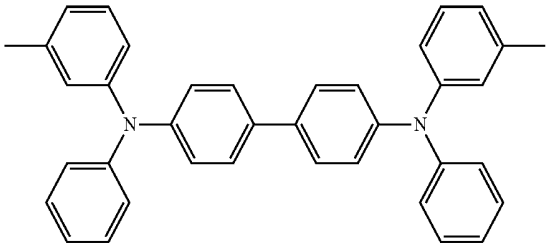
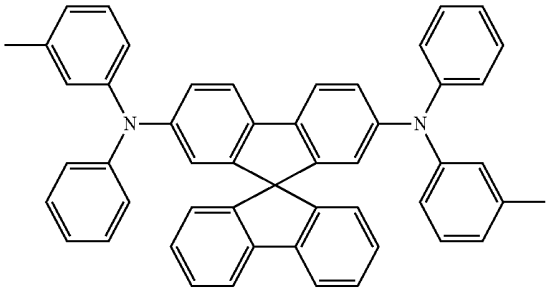
β-NPB



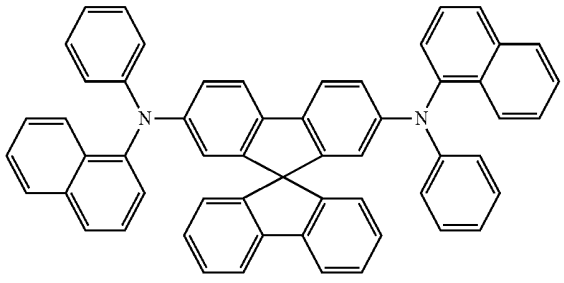
TPD



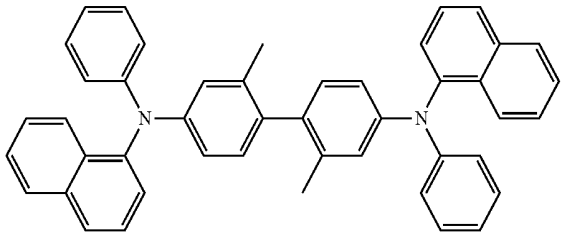
Spiro-TPD



Spiro-NPB



methylated NPB



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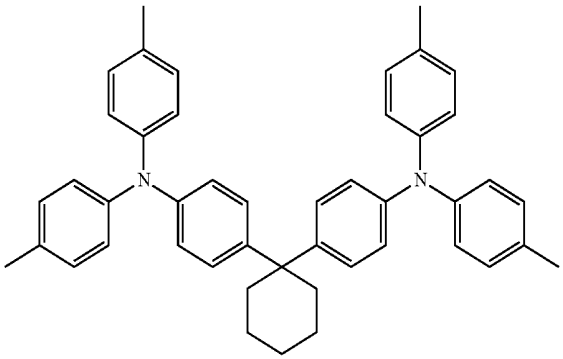
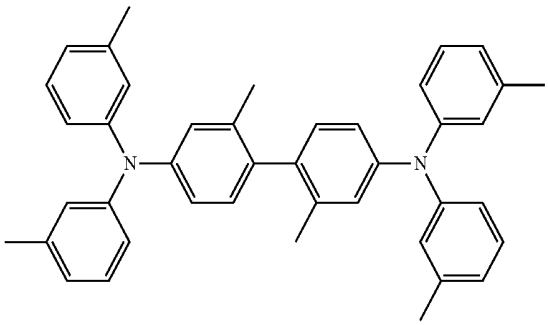
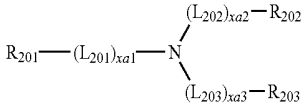
TAPC



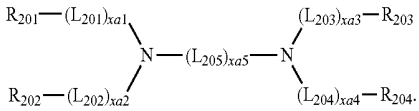
HMTPD



<Formula 201>



<Formula 202>



[0164] In Formulae 201 and 202,

[0165] 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,

[0166] 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,

[0167] xa1 to xa4 may each independently be an integer from 0 to 3,

[0168] xa5 may be an integer from 1 to 10, and

[0169] 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.

[0170] 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.

[0171] In one or more embodiments, in Formulae 201 and 202,

[0172] L_{201} to L_{205} may each independently be selected from:

[0173] 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;

[0174] 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 hydrazone 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

[0175] 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.

[0176] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0177] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0178] 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;

[0179] 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 hydrazone 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

[0180] Q_{31} to Q_{33} may be the same as described above.

[0181] In one or more embodiments, at least one selected from R_{201} to R_{203} in Formula 201 may each independently be selected from:

[0182] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0183] 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 hydrazone 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;

[0184] but embodiments of the present disclosure are not limited thereto.

[0185] 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.

[0186] In one or more embodiments, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from:

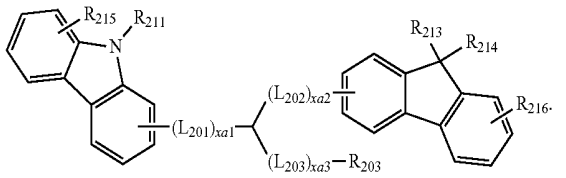
[0187] a carbazolyl group; and

[0188] 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 hydrazone 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;

[0189] but embodiments of the present disclosure are not limited thereto.

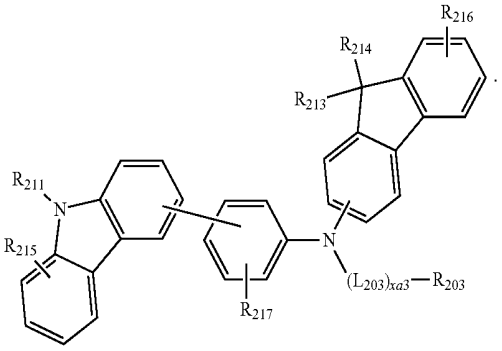
[0190] The compound represented by Formula 201 may be represented by Formula 201A:

<Formula 201A>



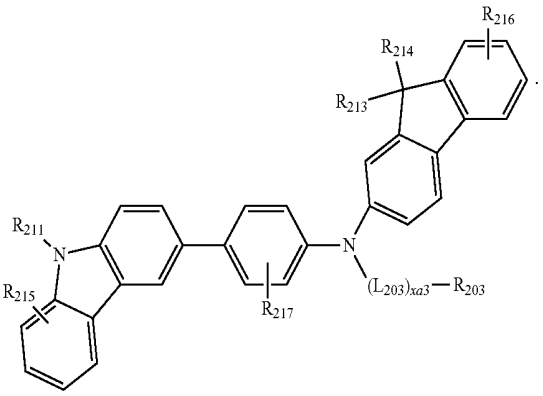
[0191] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:

<Formula 201A(1)>



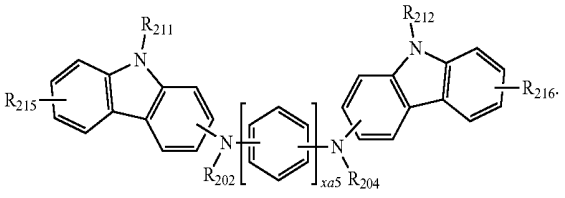
[0192] In one or more embodiments, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:

<Formula 201A-1>



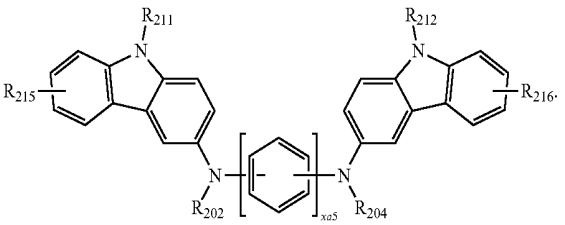
[0193] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A:

<Formula 202A>



[0194] In one or more embodiments, the compound represented by Formula 202 may be represented by Formula 202A-1:

<Formula 202A-1>



[0195] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

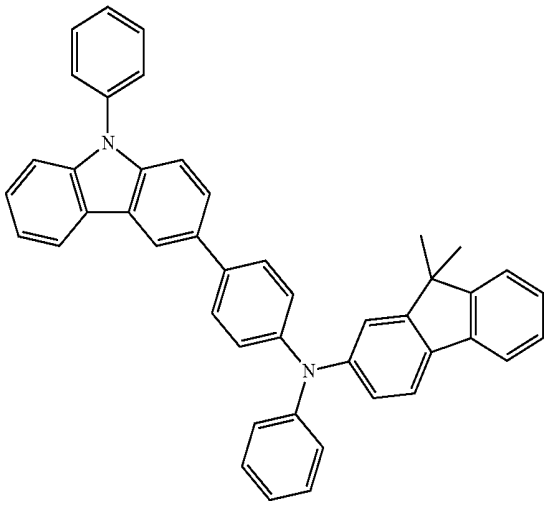
[0196] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} are the same as described above,

[0197] R_{211} and R_{212} may be understood by referring to the description provided herein in connection with R_{203}.

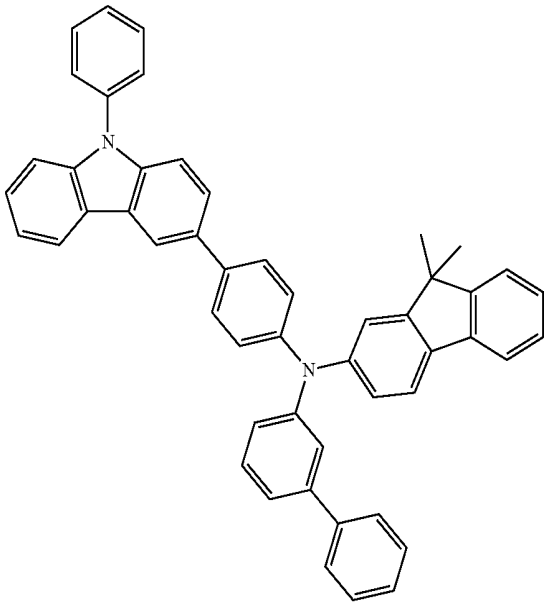
[0198] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, 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.

[0199] 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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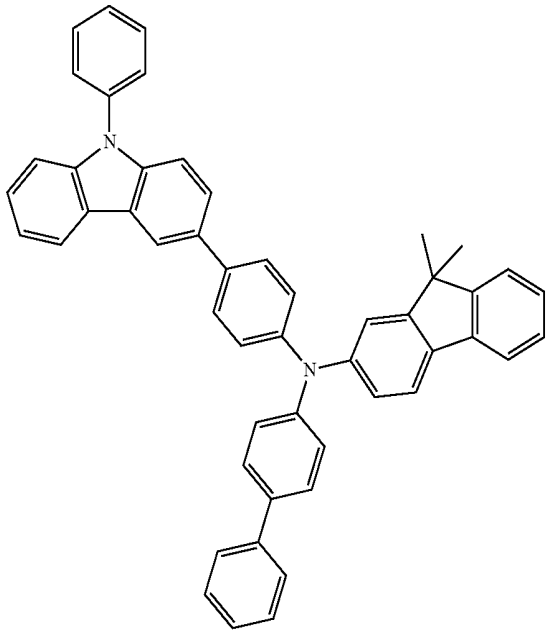
HT3



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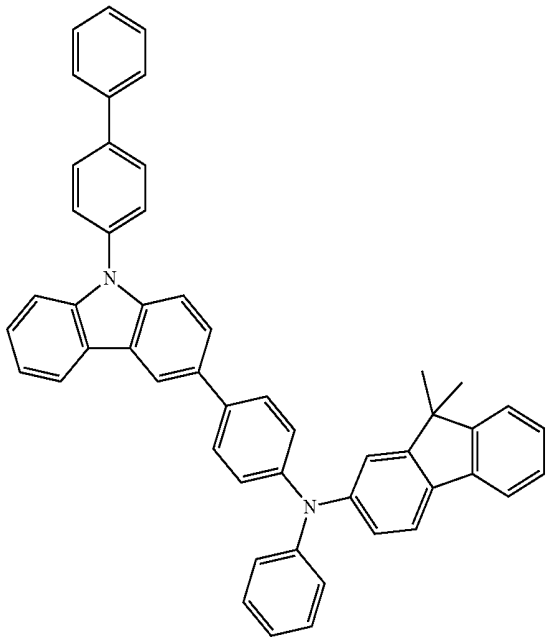

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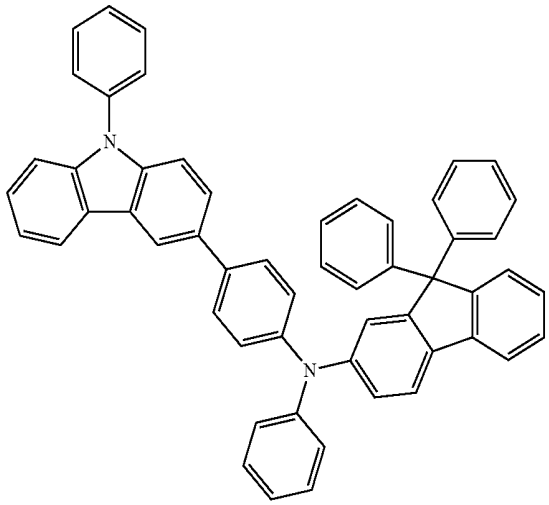

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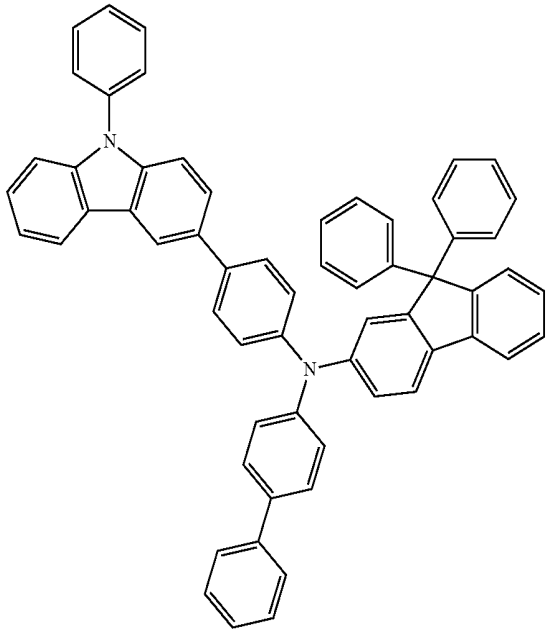

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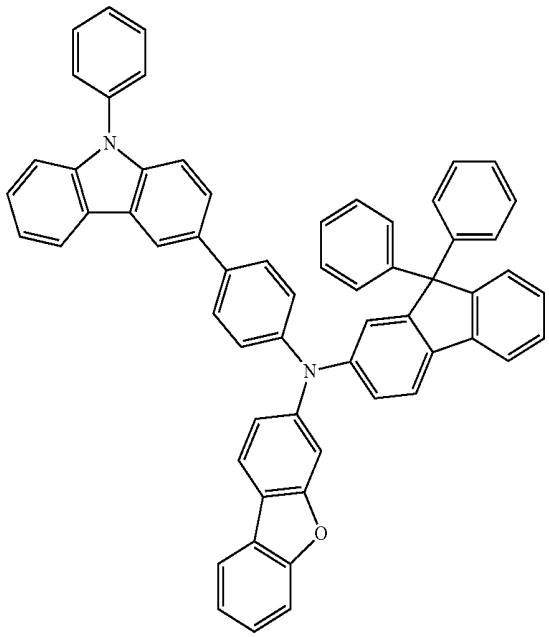

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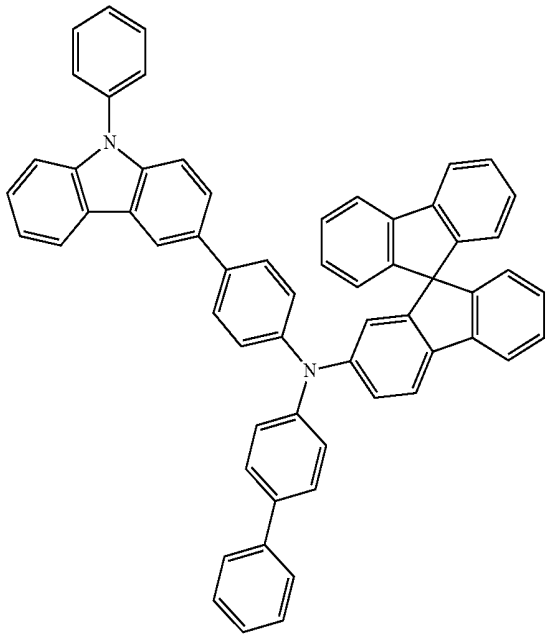

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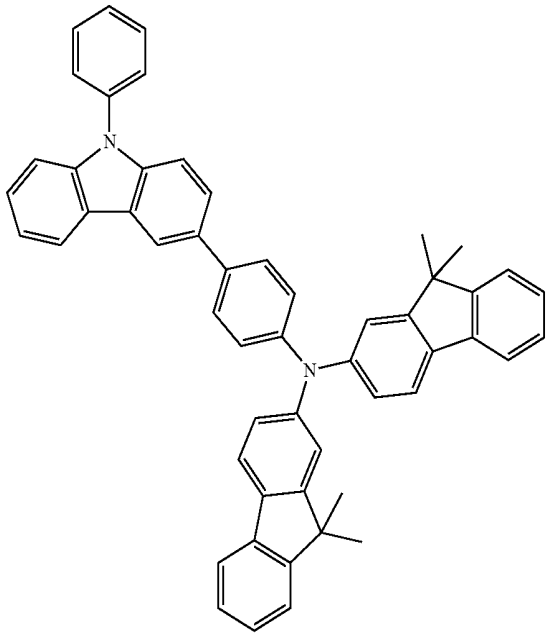

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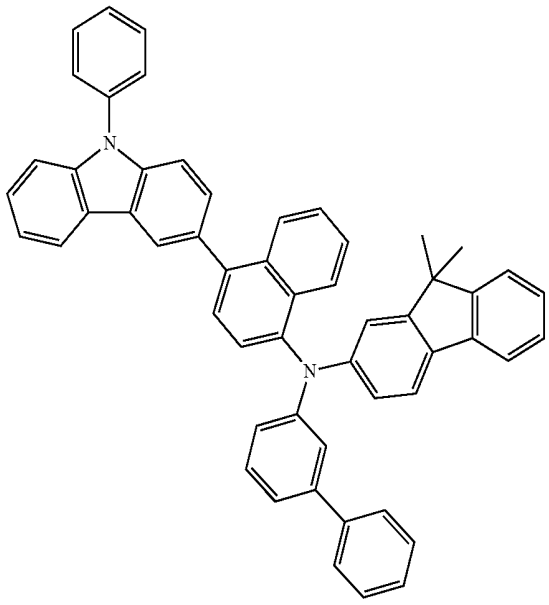

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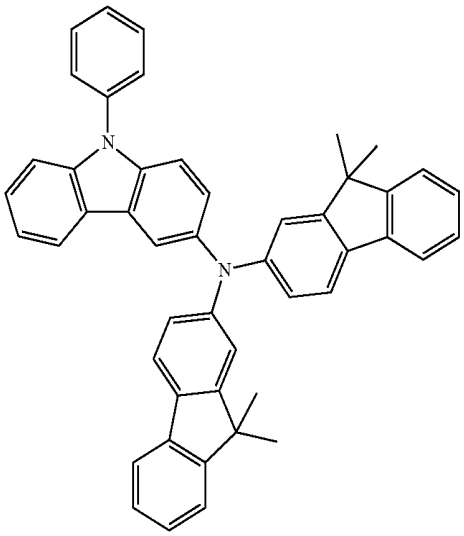

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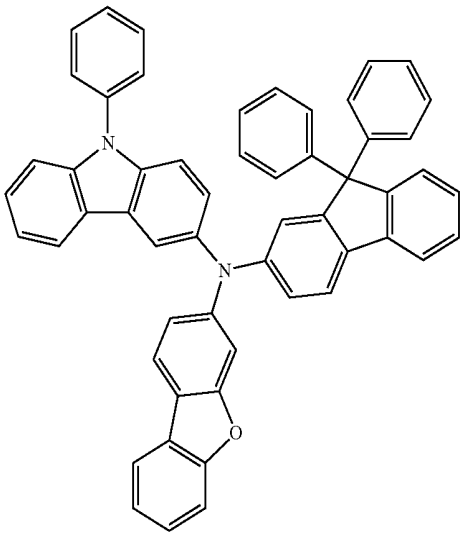

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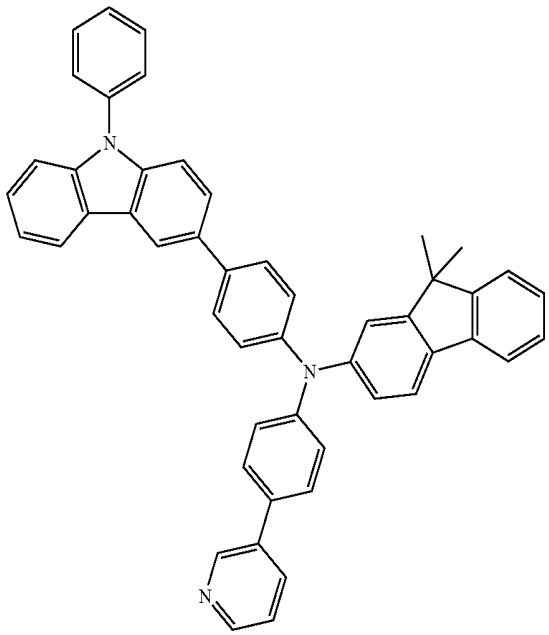

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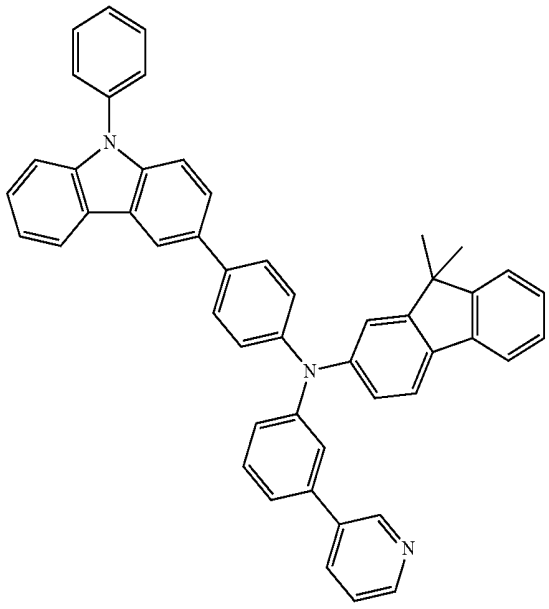

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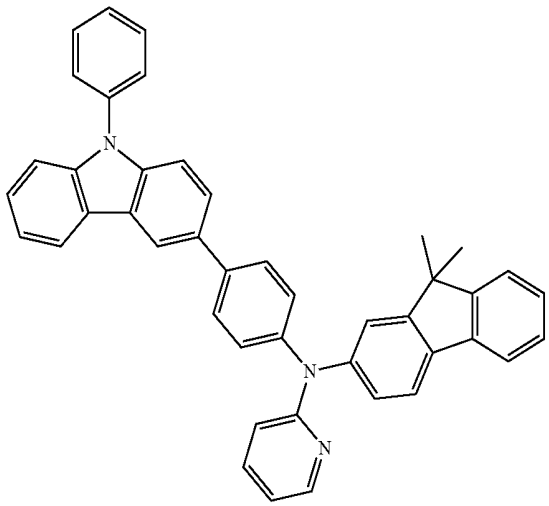

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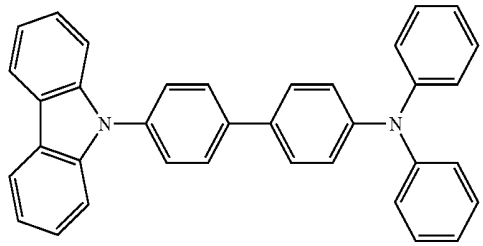

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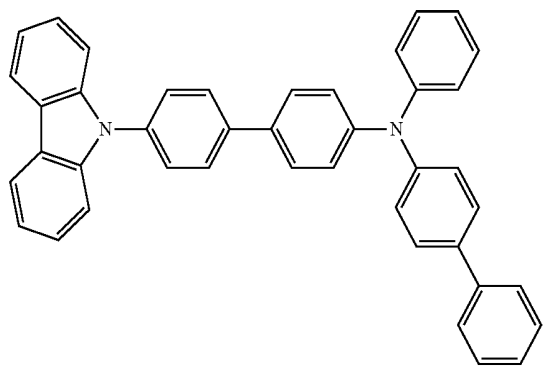

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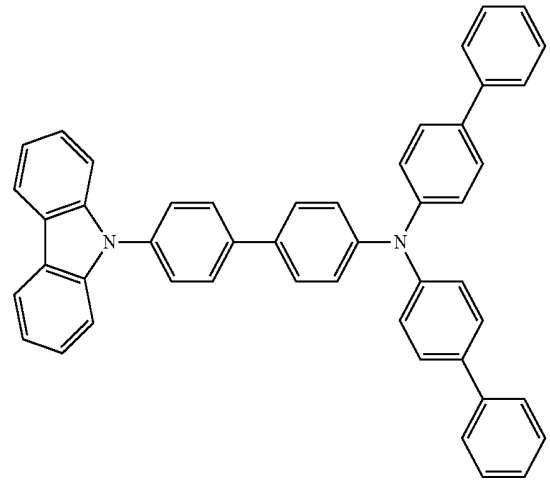

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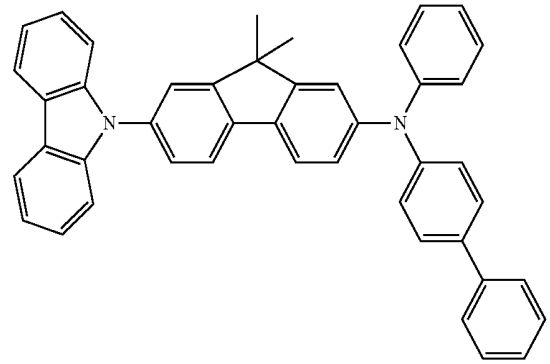

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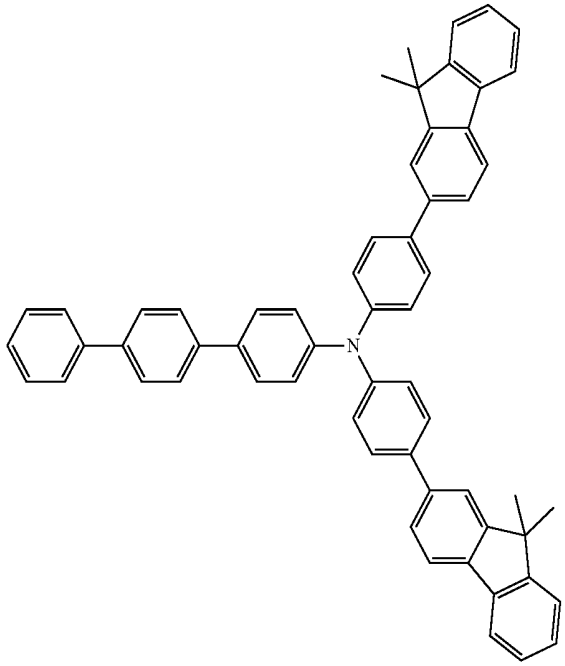

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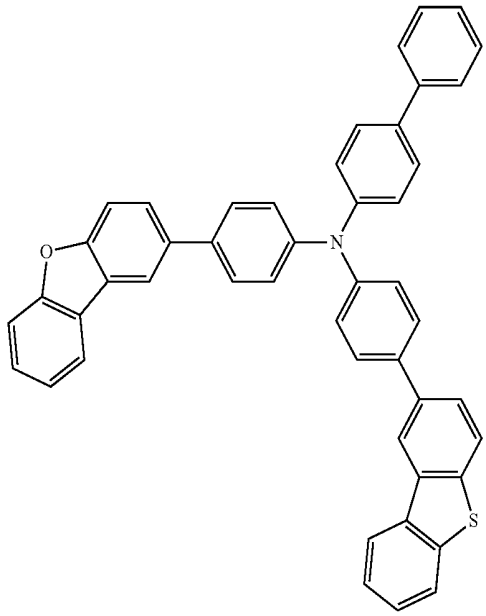

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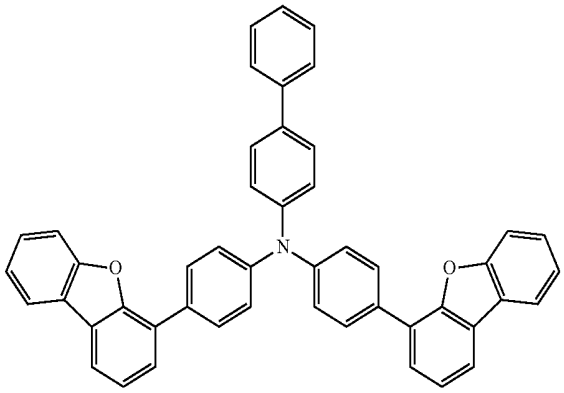

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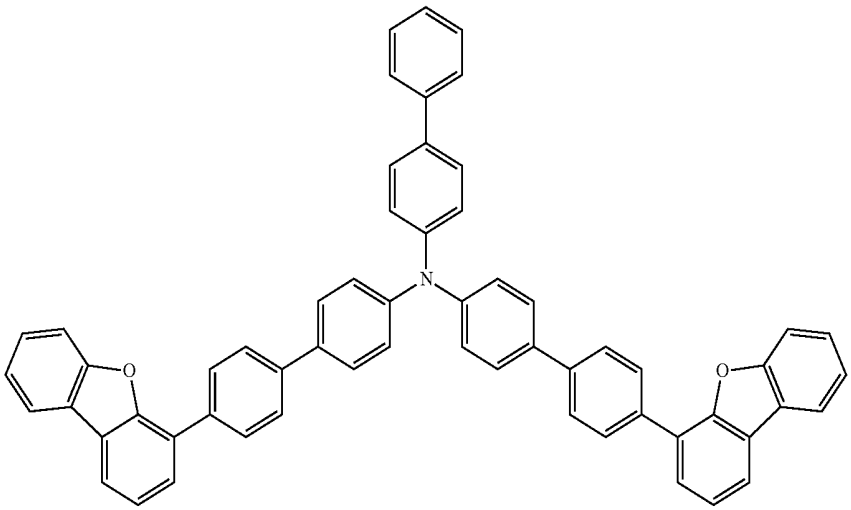

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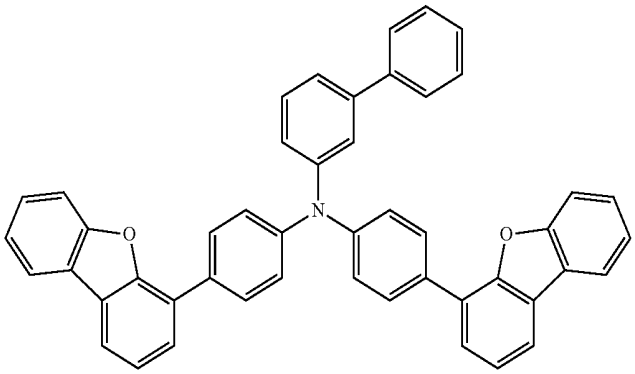

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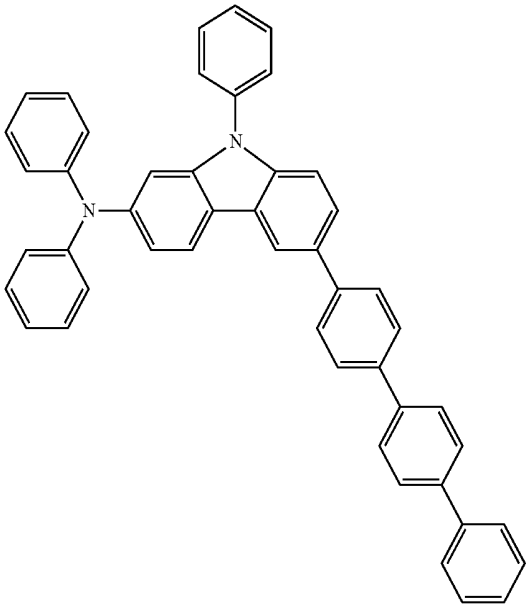

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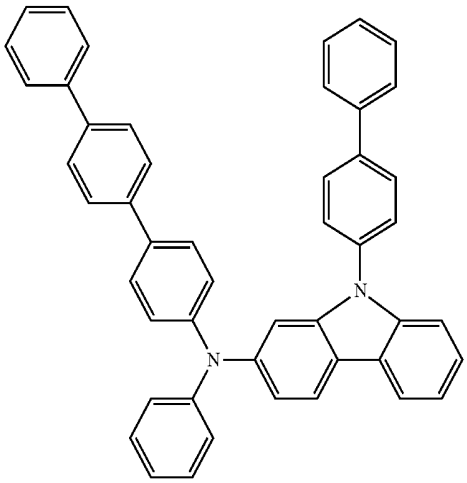

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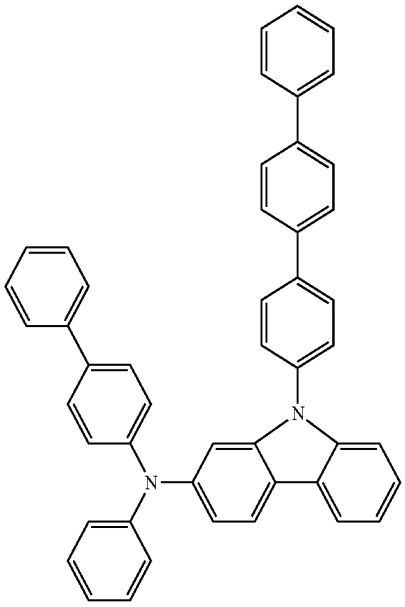

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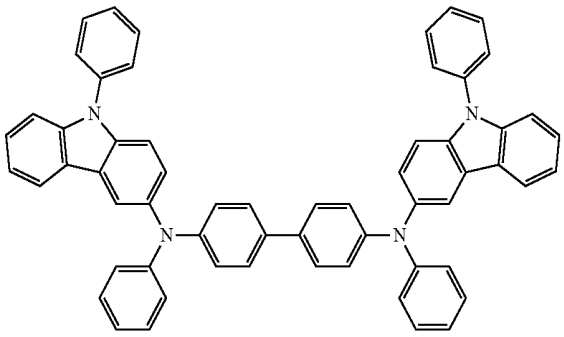

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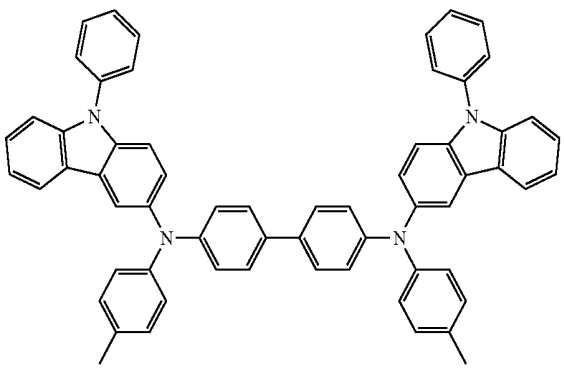

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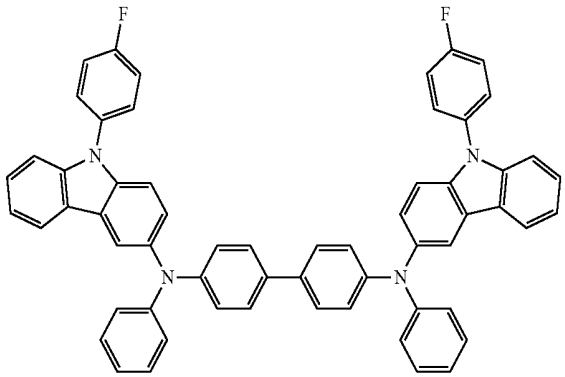

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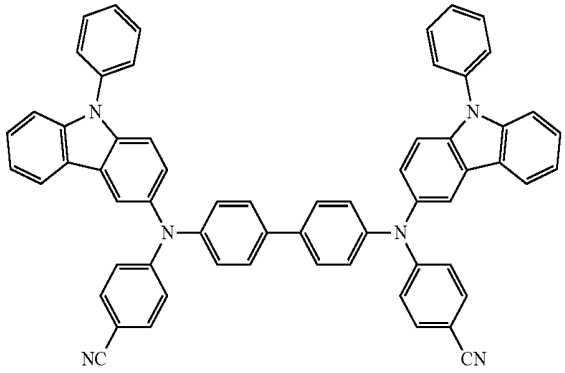

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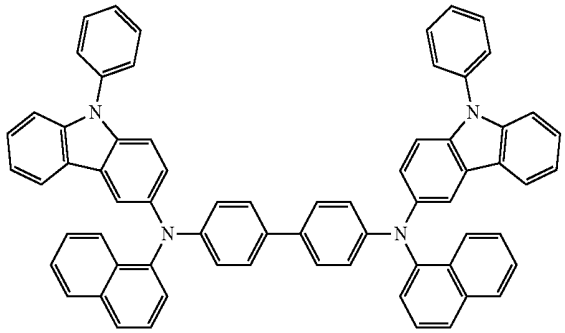

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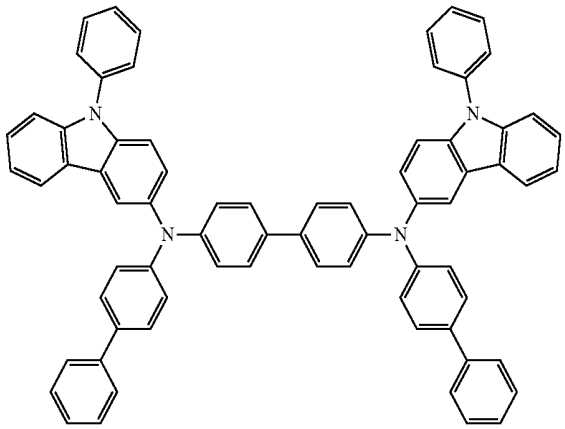

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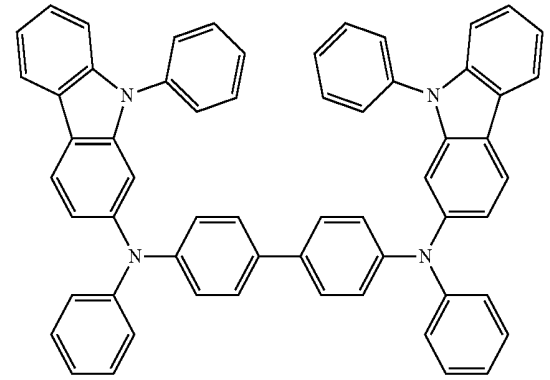

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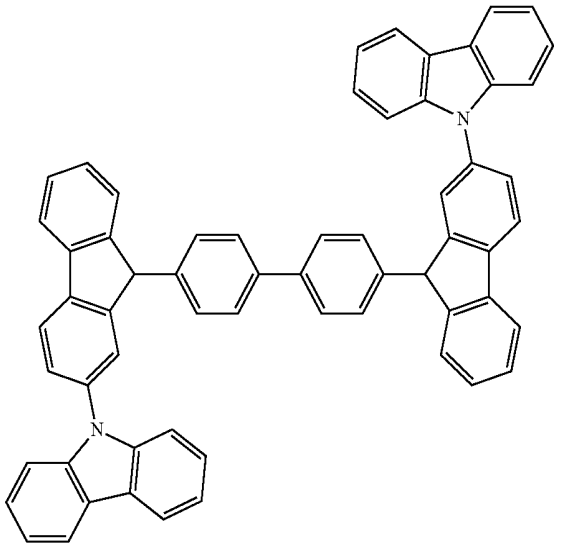

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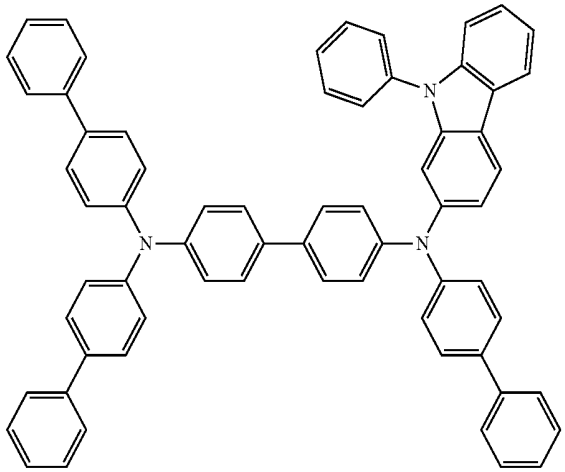

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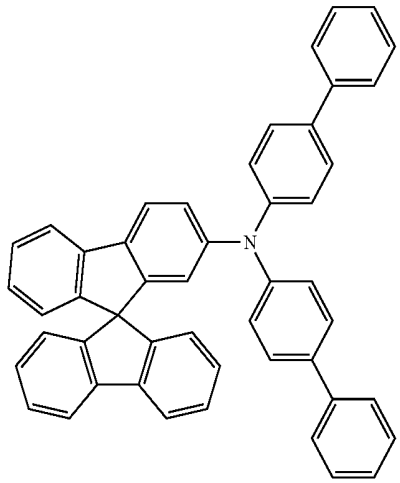
HT37



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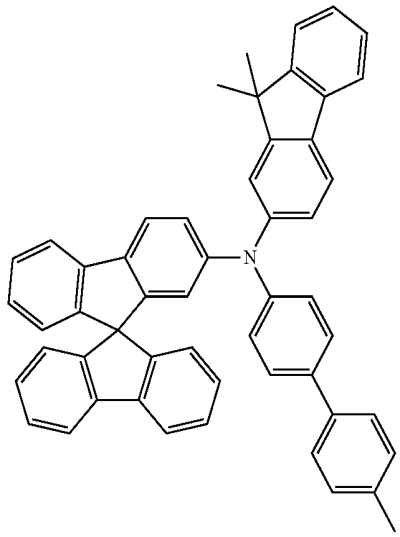

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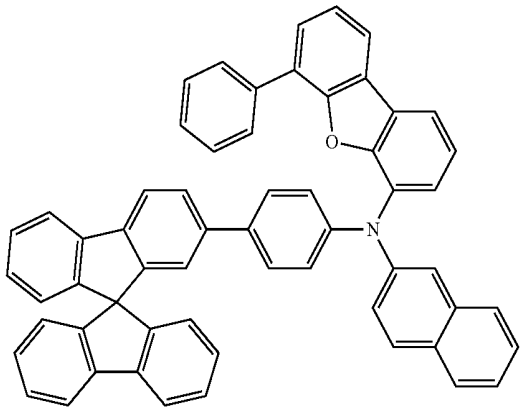


[0200] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å When the hole transport region includes at least one of a hole injection layer and a hole transport layer, a thickness of the hole injection layer may be in a 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 these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0201] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical reso-

nance 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.

[p-Dopant]

[0202] 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.

[0203] The charge-generation material may be, for example, a p-dopant.

[0204] In one or more embodiments, a lowest unoccupied molecular orbital (LUMO) energy level of the p-dopant may be lower than −3.5 eV.

[0205] The p-dopant may include 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.

[0206] For example, the p-dopant may include at least one selected from:

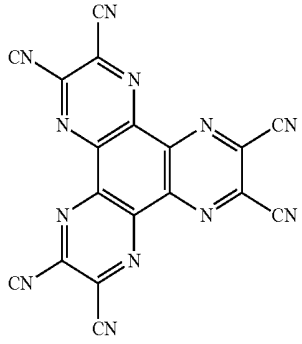
[0207] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0208] a metal oxide, such as tungsten oxide or molybdenum oxide;

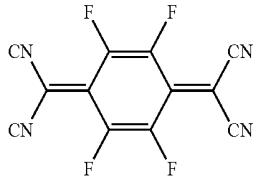
[0209] 1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0210] a compound represented by Formula 221 below:

[0211] but embodiments of the present disclosure are not limited thereto:



<HAT-CN>



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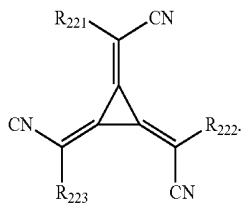


<Formula 221>

[0212] In Formula 221,

[0213] 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, and 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.

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

[0214] 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 emission material, a green-light emission material, and a blue-light emission material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0215] 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.

[0216] An amount of the dopant in the emission layer may be, in general, in a range of about 0.01 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.

[0217] 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 this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

[Host in Emission Layer]

[0218] In one or more embodiments, the host may include a compound represented by Formula 301.

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

[0219] In Formula 301,

[0220] 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,

[0221] xb11 may be 1, 2, or 3,

[0222] L_{301} may 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,

[0223] xb1 may be an integer from 0 to 5,

[0224] 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 hydrazone 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 —$P(=O)(Q_{301})(Q_{302})$,

[0225] xb21 may be an integer from 1 to 5, and

[0226] 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.

[0227] In one or more embodiments, Ar_{301} in Formula 301 may be selected from:

[0228] 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, naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, and a dibenzothiophene group;

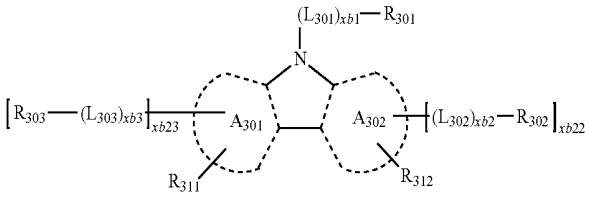
[0229] a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, naphthacene group, a picene group, a perylene 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 hydrazone 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 —$P(=O)(Q_{31})(Q_{32})$; and

[0230] 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.

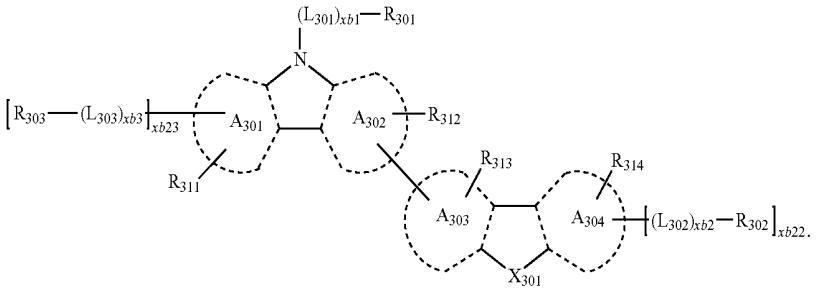
[0231] When xb11 in Formula 301 is two or more, two or more Ar_{301}(s) may be linked via a single bond.

[0232] In one or more embodiments, the organometallic compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

<Formula 301-1>



<Formula 301-2>



[0233] In Formulae 301-1 and 301-2,

[0234] 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, naphtho furan group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0235] X_{301} may be O, S, or N-[$(L_{304})_{xb4}$-R_{304}],

[0236] 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 hydrazone 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 —$P(=O)(Q_{31})(Q_{32})$,

[0237] xb22 and xb23 may each independently be 0, 1, or 2,

[0238] L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may be the same as described above,

[0239] L_{302} to L_{304} may each independently be the same as described in connection with L_{301},

[0240] xb2 to xb4 may each independently be the same as described in connection with xb1, and

[0241] R_{302} to R_{304} may each independently be the same as described in connection with R_{301}.

[0242] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0243] 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

[0244] 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 hydrazone 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

[0245] Q_{31} to Q_{33} may be the same as described above.

[0246] In one or more embodiments, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from:

[0247] 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

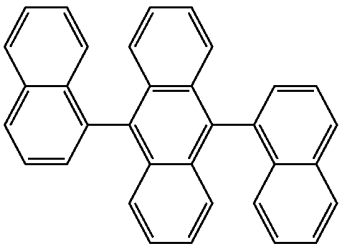
[0248] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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 hydrazone 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

[0249] Q_{31} to Q_{33} may be the same as described above.

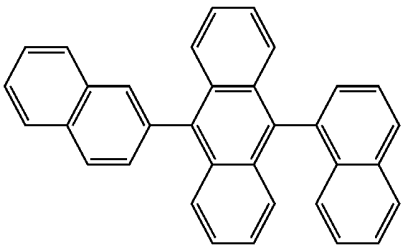
[0250] In one or more embodiments, the host may include an alkaline-earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), an Mg complex, and a Zn complex.

[0251] 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 illustrated below, but embodiments of the present disclosure are not limited thereto:

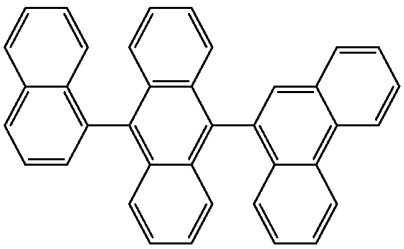
H1



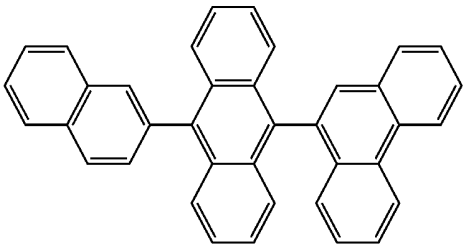
H2



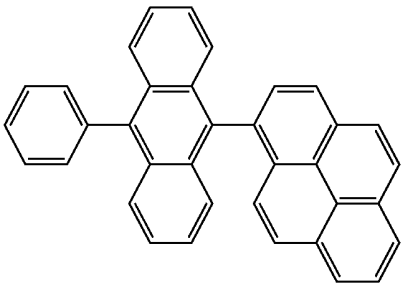
H3



H4



H5



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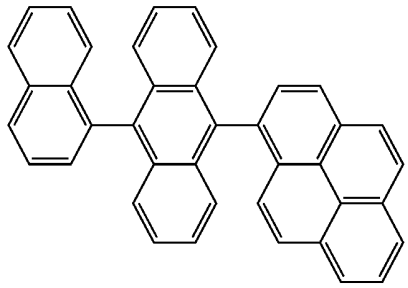
H6



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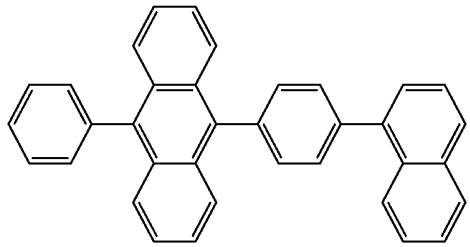
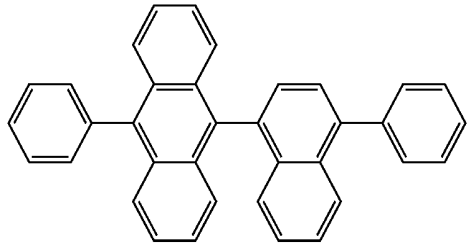
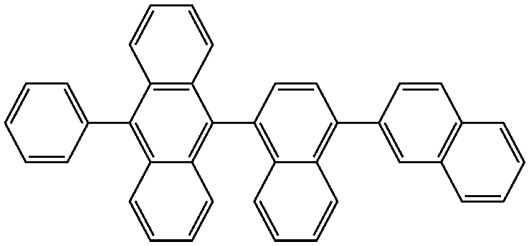


H8



H9



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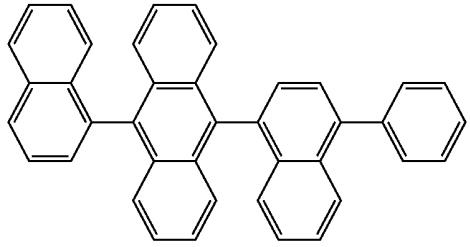
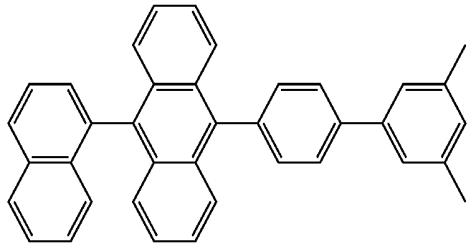


H11



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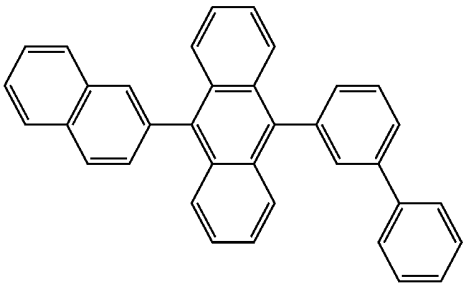
H12



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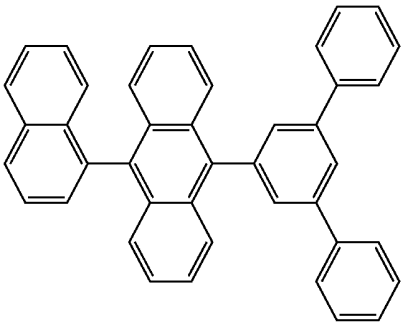
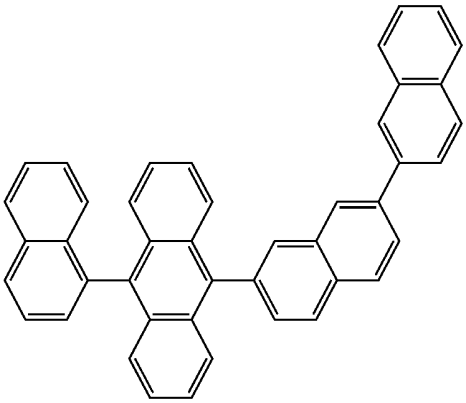
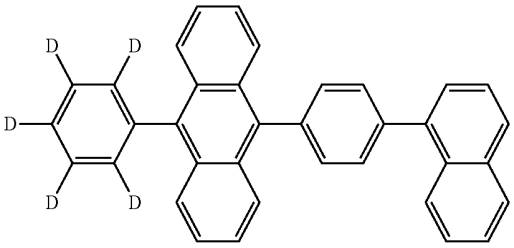


H14



H15



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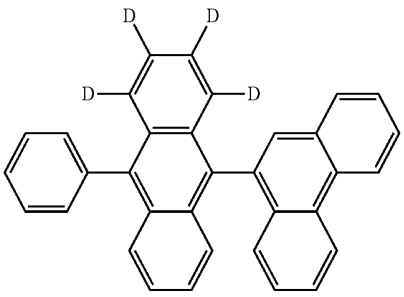

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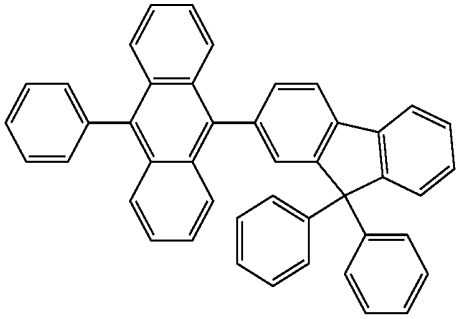
H17



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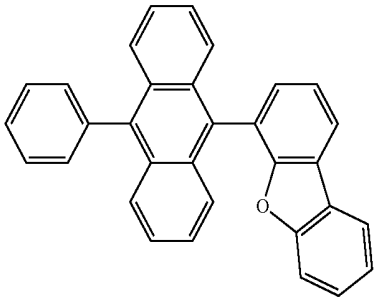
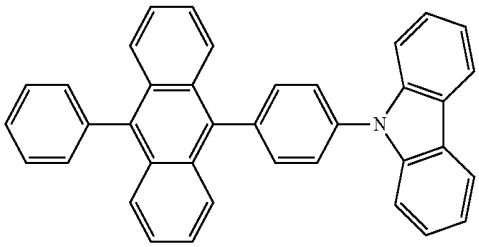
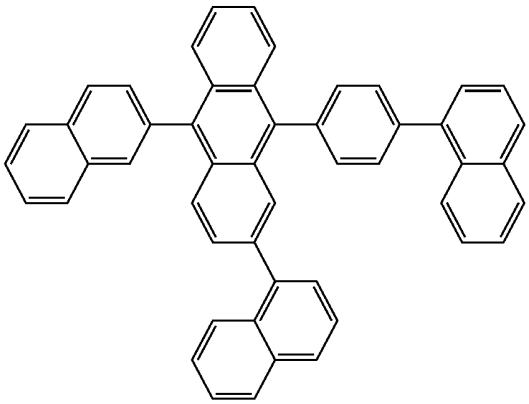


H19



H20



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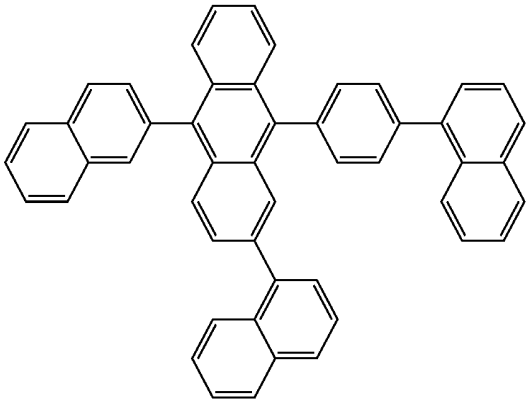
H21



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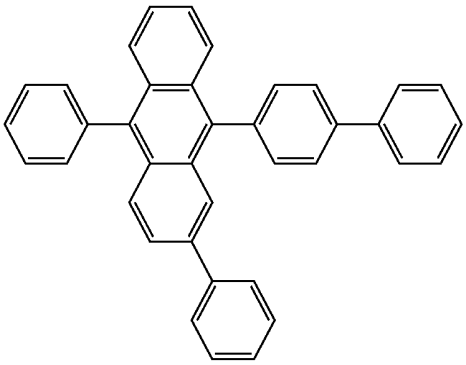

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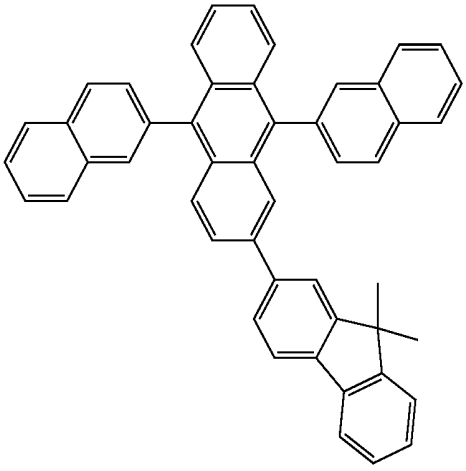

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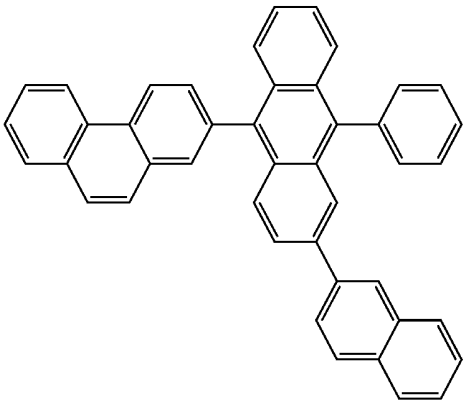

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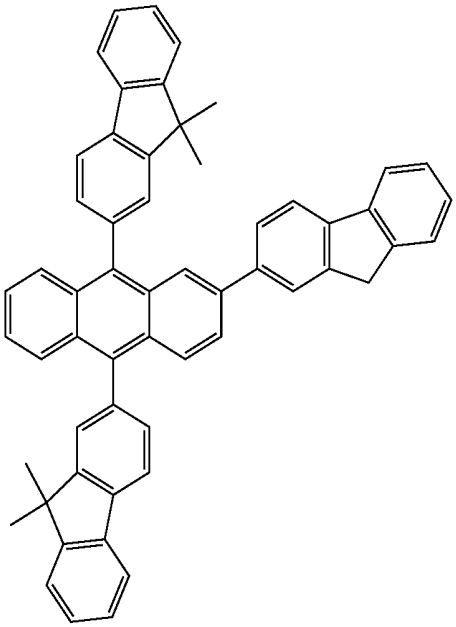
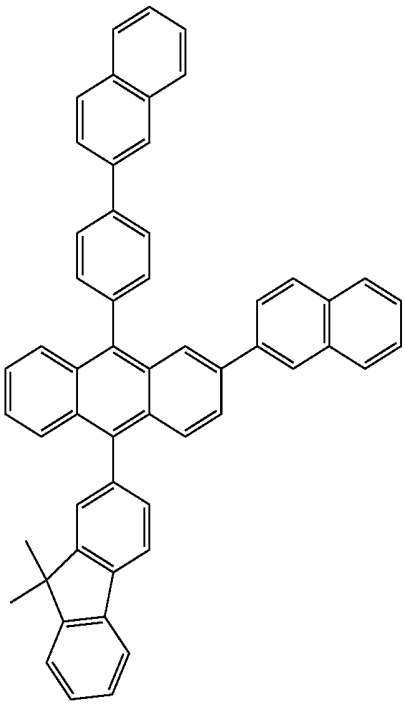
H25



H26



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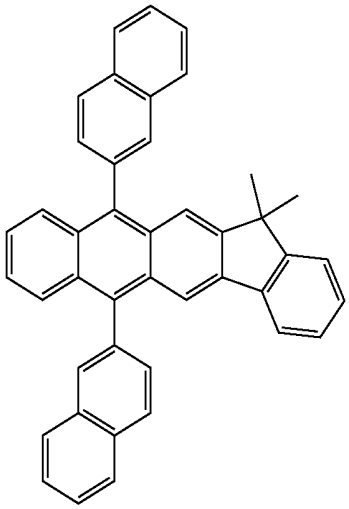
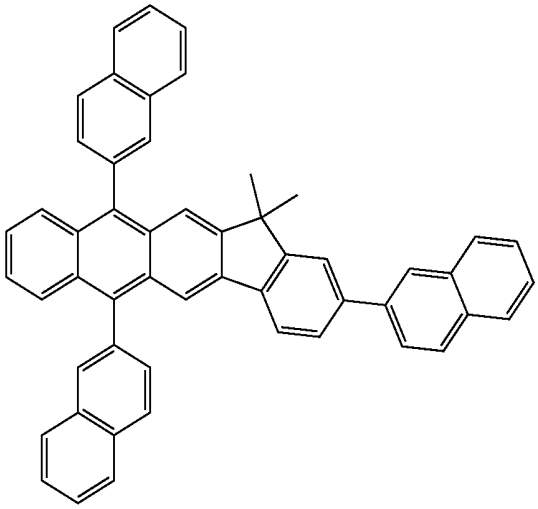
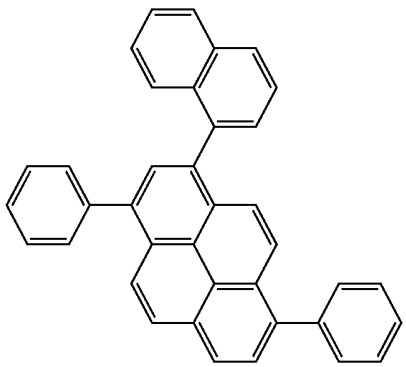
H27



H28



H29



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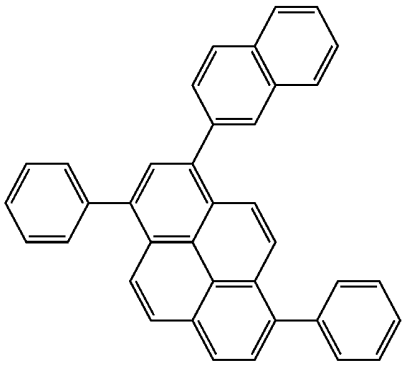

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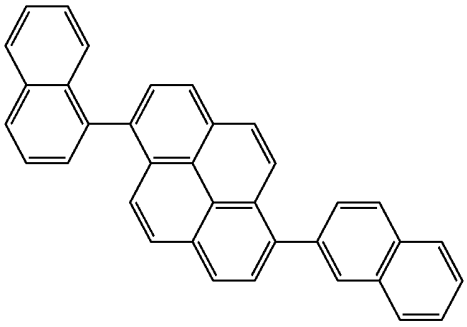

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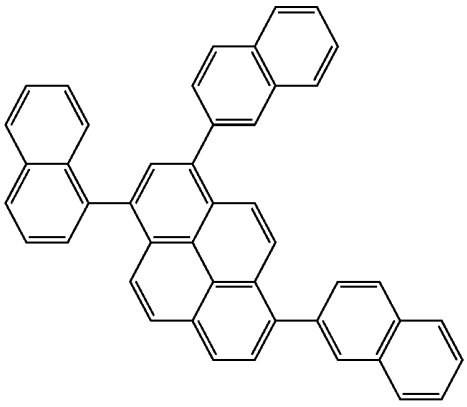

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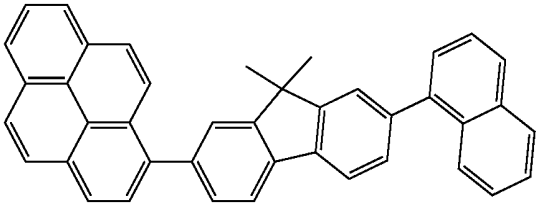

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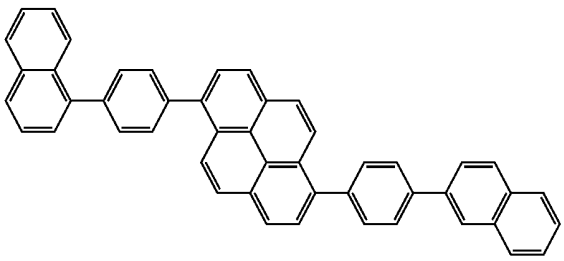

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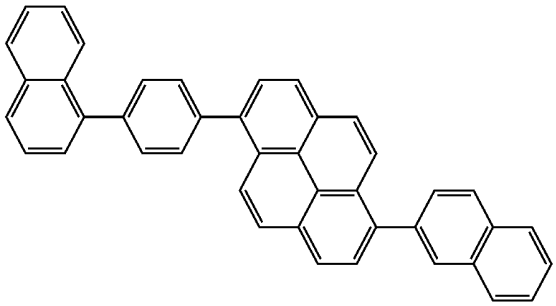

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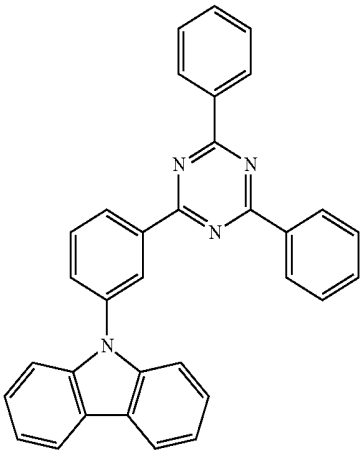

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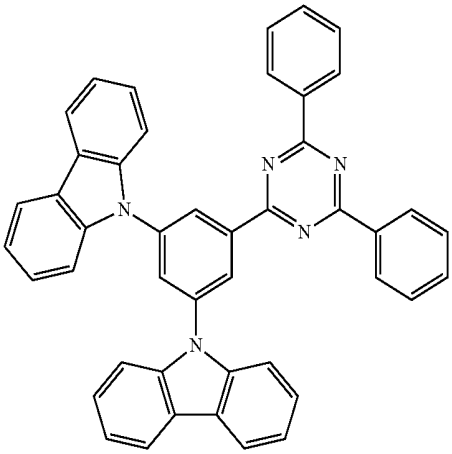

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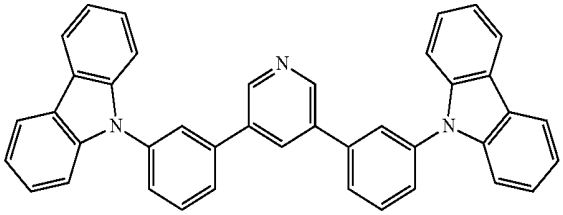

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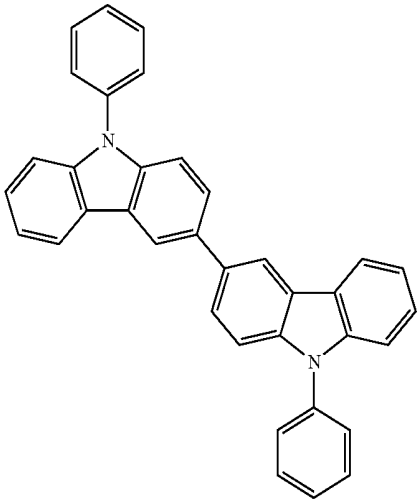

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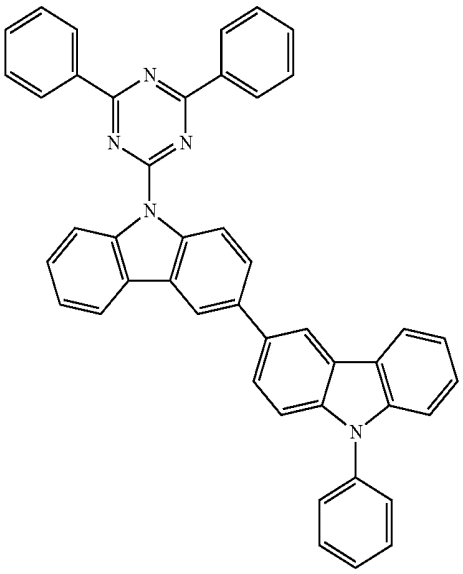

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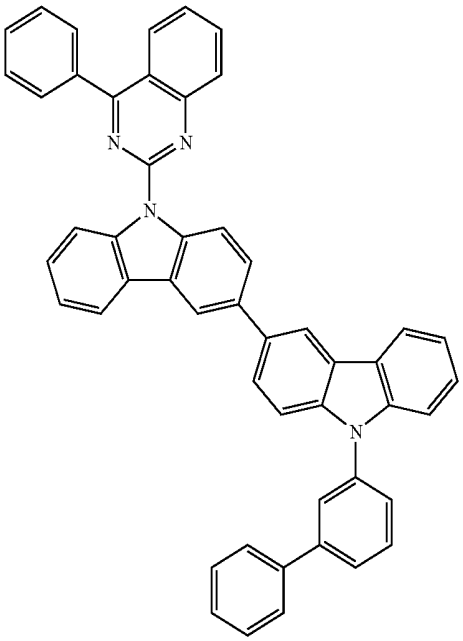

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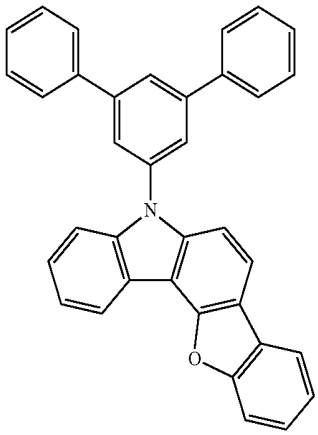

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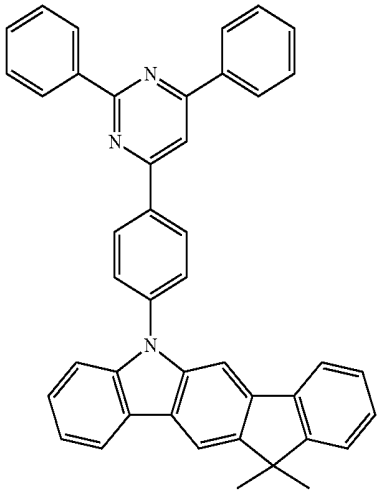

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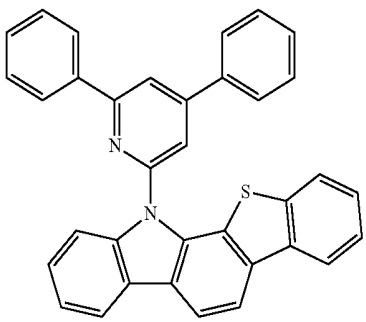

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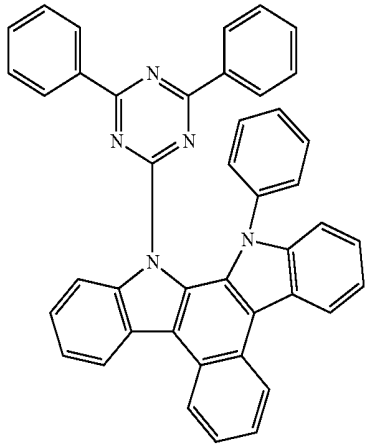

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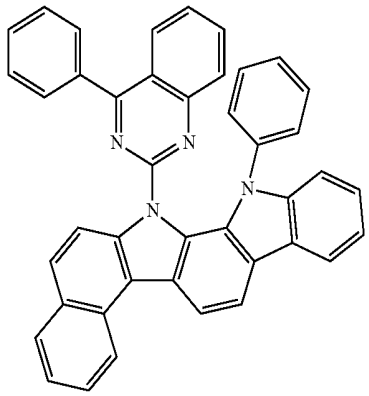

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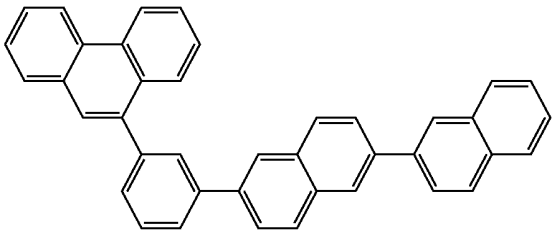

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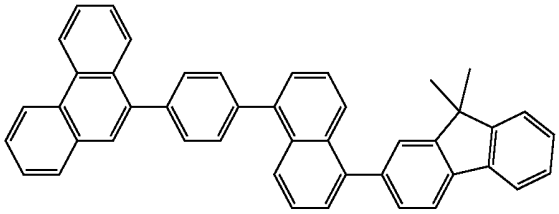

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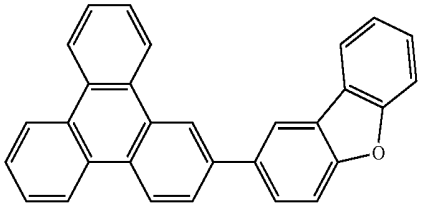

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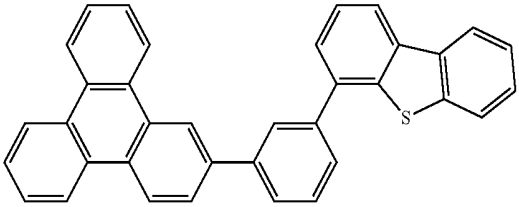

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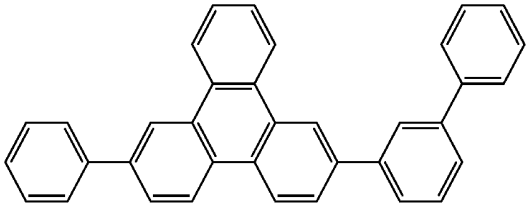

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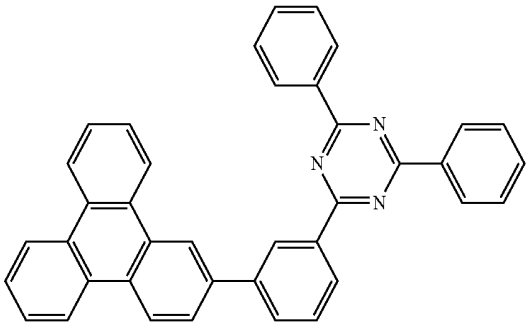

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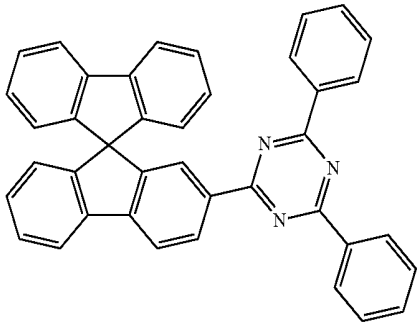

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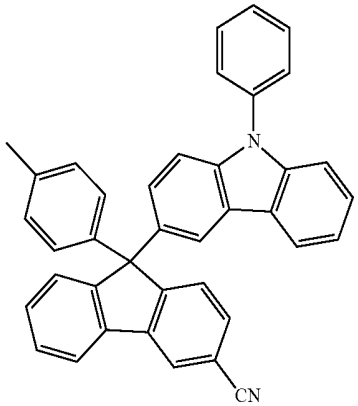

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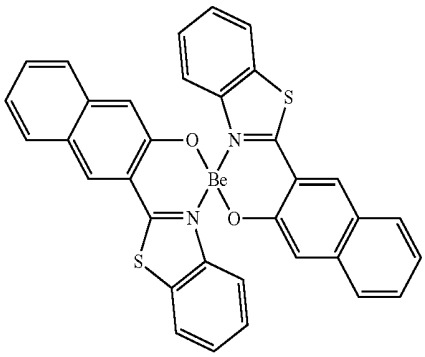


[Phosphorescent Dopant Included in Emission Layer in Organic Layer **150**]

[0252] The phosphorescent dopant may include the organometallic compound represented by Formula 1 herein:

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

[0253] The electron transport region may have i) a single-layered structure consisting of a single layer consisting of a single material, ii) a single-layered structure consisting of a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0254] 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.

[0255] 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.

[0256] 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.

[0257] The "π electron-depleted nitrogen-containing ring" indicates a C_1-C_{60} heterocyclic group having at least one *—N=*' moiety as a ring-forming moiety.

[0258] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered hetero monocyclic group having at least one *—N=*' moiety, ii) a heteropoly cyclic group in which two or more 5-membered to 7-membered hetero monocyclic groups each having at least one *—N=*' moiety are condensed with each other, or iii) a heteropoly cyclic group in which at least one of 5-membered to 7-membered hetero monocyclic groups, each having at least one *—N=*' moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

[0259] 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.

[0260] For example, the electron transport region may include a compound represented by Formula 601:

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

[0261] In Formula 601,

[0262] 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,

[0263] xe11 may be 1, 2, or 3,

[0264] L_{601} may 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;

[0265] xe1 may be an integer from 0 to 5,

[0266] 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 —$P(=O)(Q_{601})(Q_{602})$,

[0267] 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

[0268] xe21 may be an integer from 1 to 5.

[0269] In one or more embodiments, at least one selected from Ar_{601}(s) in the number of xe11 and at least one of R_{601}(s) in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

[0270] In one or more embodiments, ring Ar_{601} in Formula 601 may be selected from:

[0271] 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, 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, 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 iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and

[0272] 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, 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, 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 iso-benzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazol group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole 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 hydrazone 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

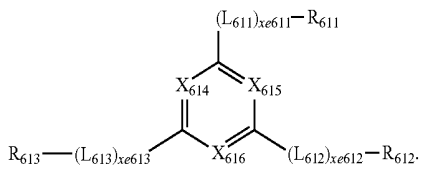
[0273] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0274] When xe11 in Formula 601 is two or more, two or more Ar_{601}(s) may be linked to each other via a single bond.

[0275] In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

[0276] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

<Formula 601-1>



[0277] In Formula 601-1,

[0278] 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,

[0279] L_{611} to L_{613} may each independently be the same as described in connection with L_{601},

[0280] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0281] R_{611} to R_{613} may each independently be the same as described in connection with R_{601},

[0282] 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 hydrazone 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.

[0283] 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:

[0284] 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

[0285] 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 hydrazone 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, and an imidazopyrimidinyl group, and an azacarbazolyl group;

[0286] but embodiments of the present disclosure are not limited thereto.

[0287] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0288] 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:

[0289] 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;

[0290] 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 hydrazone 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; and

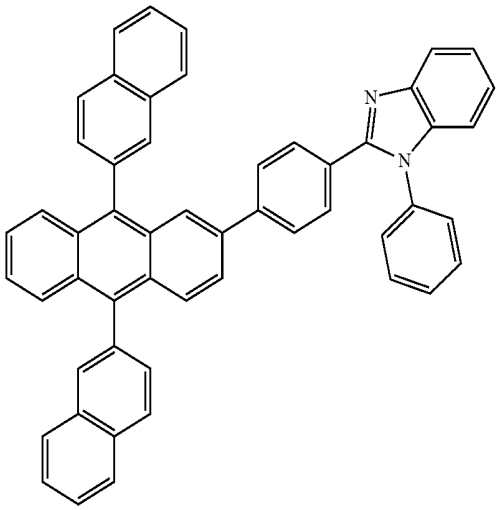
[0291] $—S(=O)_2(Q_{601})$ and $—P(=O)(Q_{601})(Q_{602})$; and

[0292] Q_{601} and Q_{602} may be the same as described above.

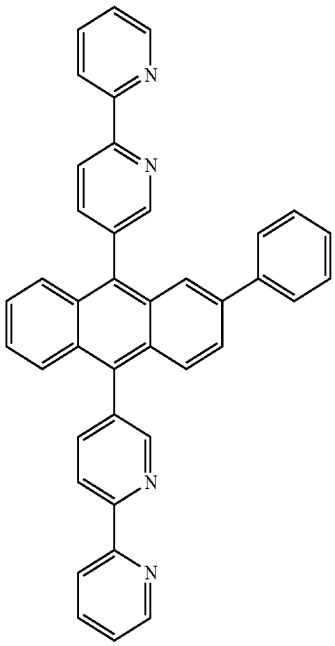
[0293] The electron transport region may include at least one compound selected from Compounds ET1 to ET36, but embodiments of the present disclosure are not limited thereto:

-continued

ET1



ET2



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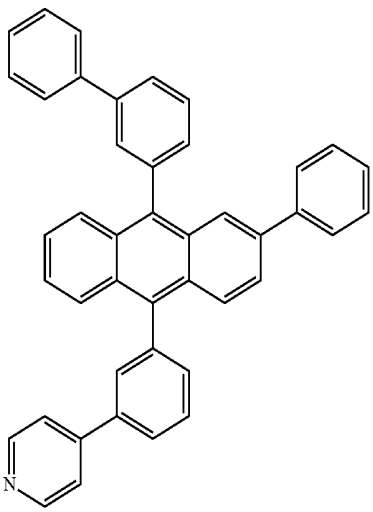
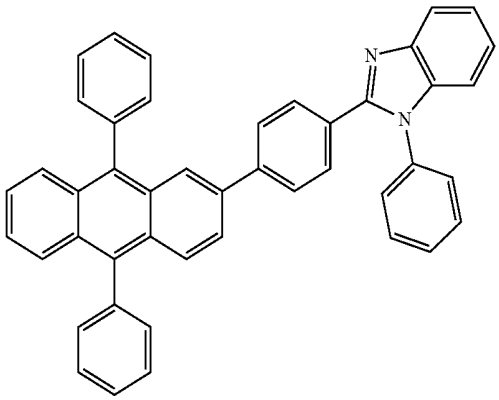
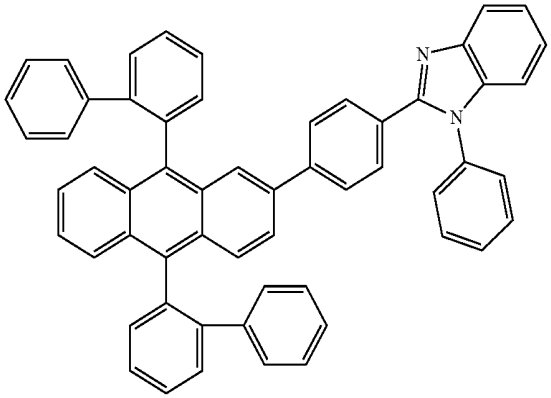


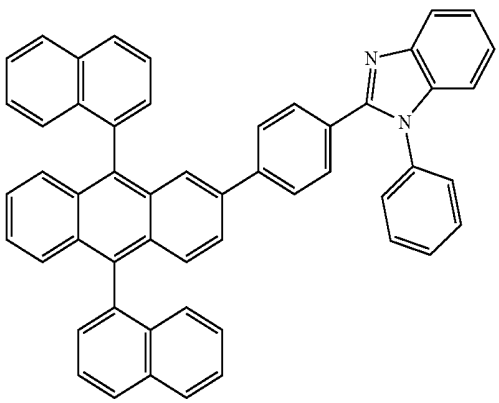
ET4



ET5



ET6



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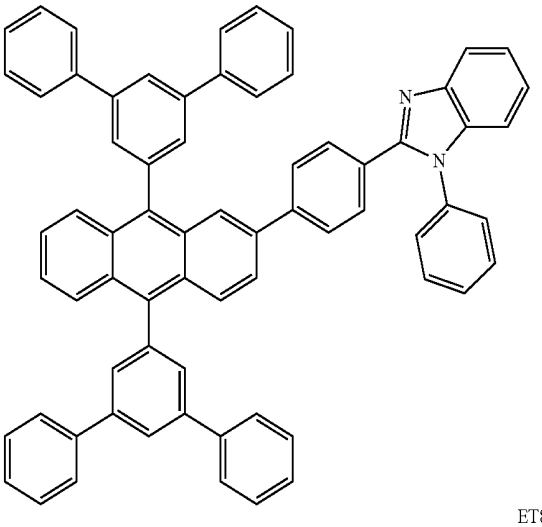
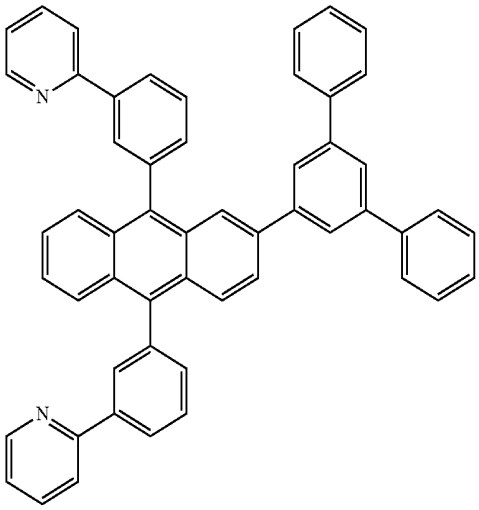
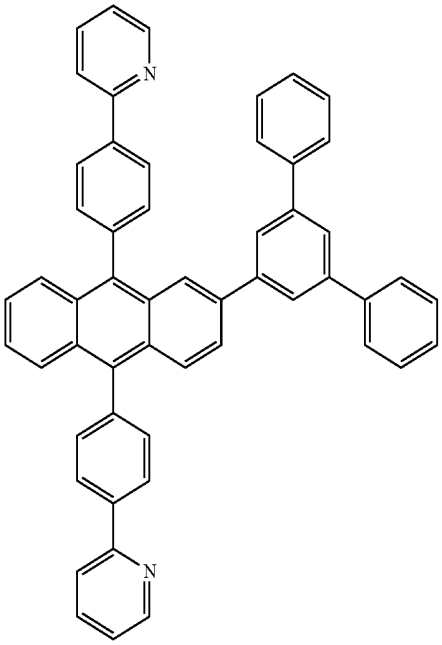
ET7



ET8



ET9



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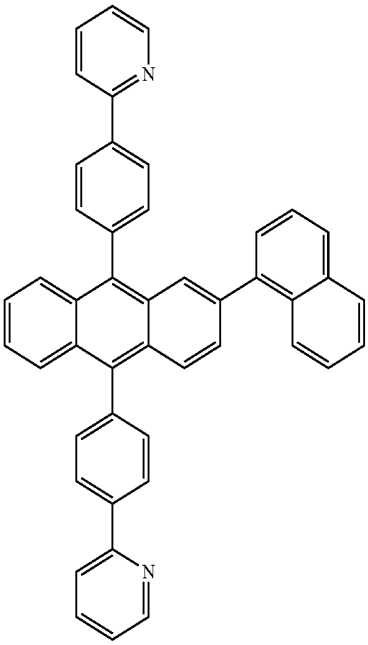
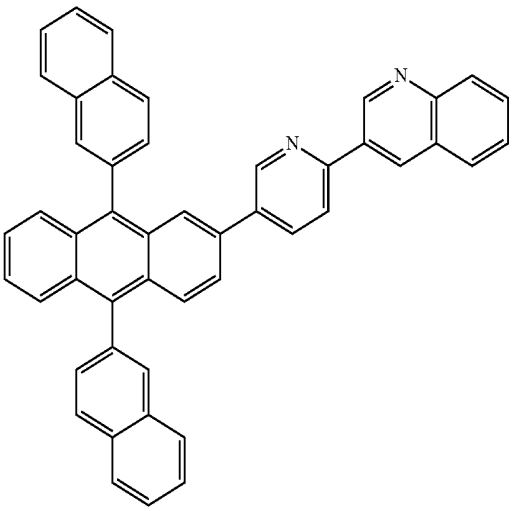
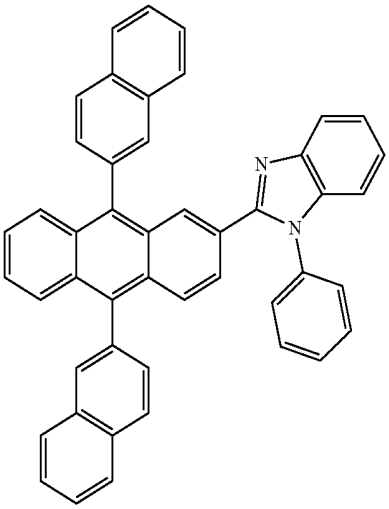
ET10



ET11



ET12



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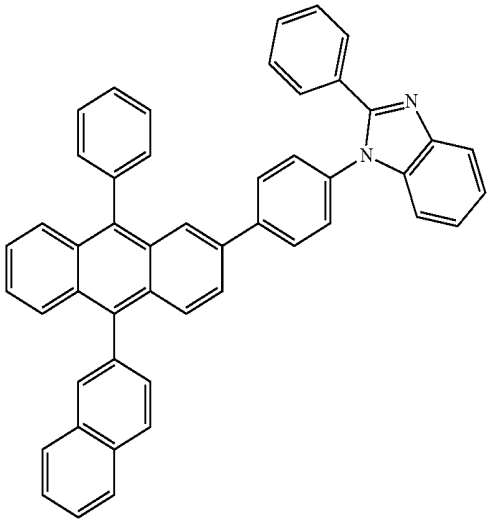
ET13



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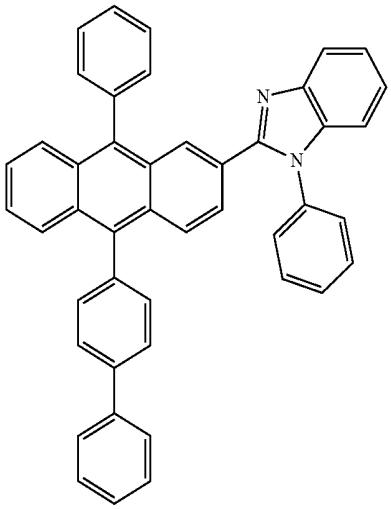
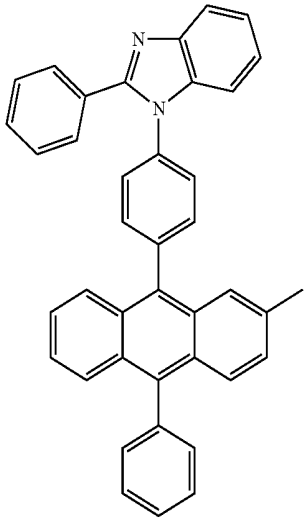


ET15



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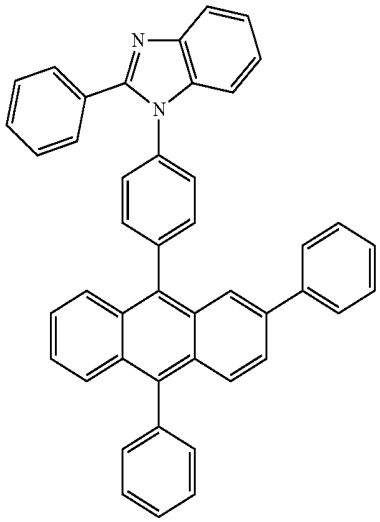
ET16



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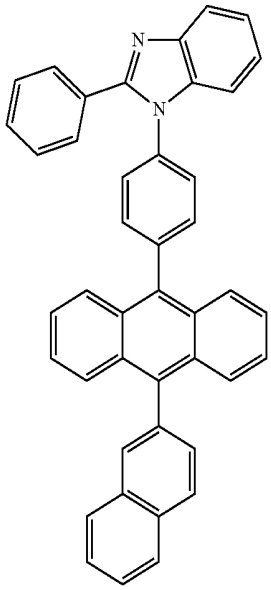
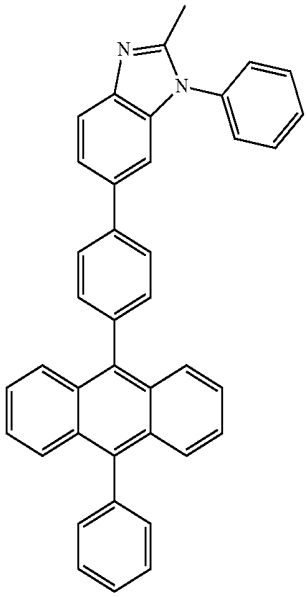


ET18



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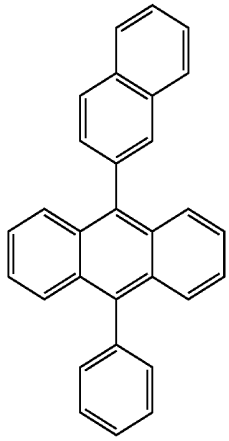
ET19



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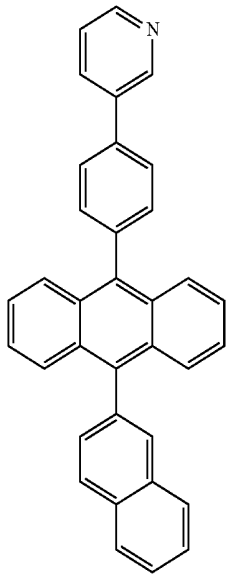

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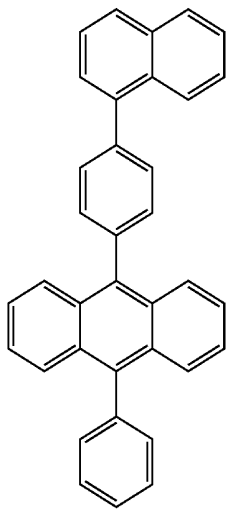

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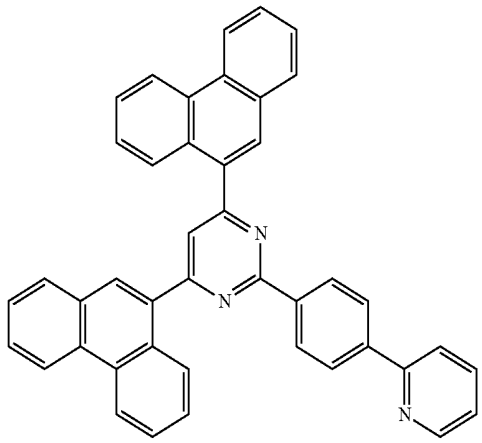
ET22



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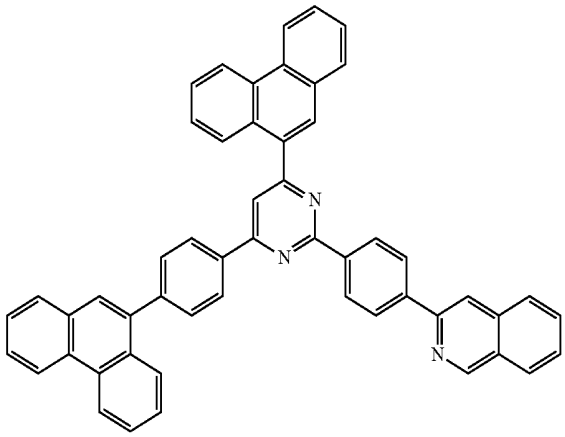

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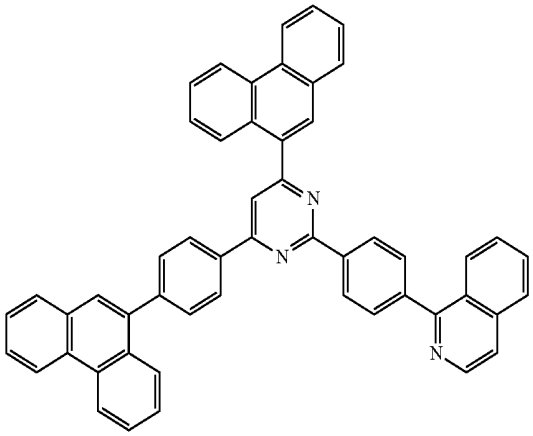

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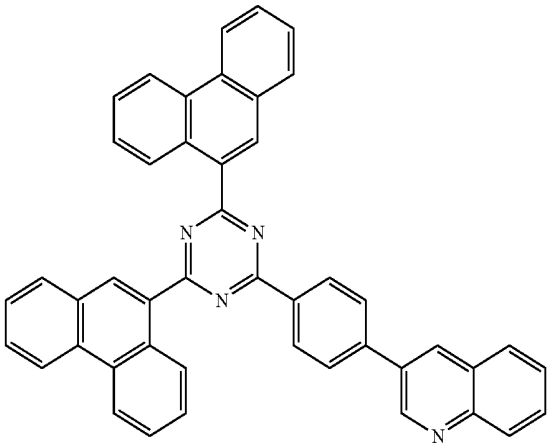
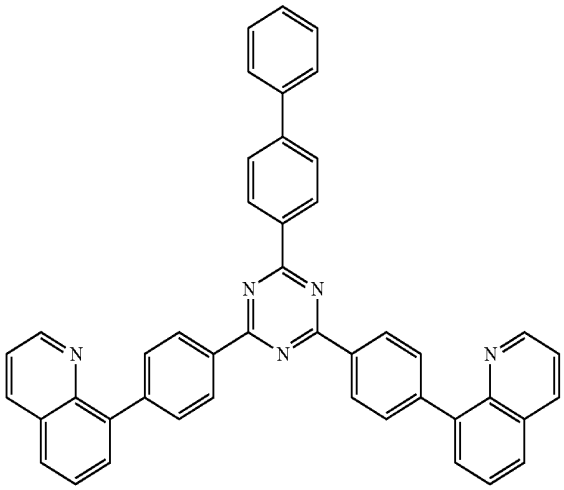
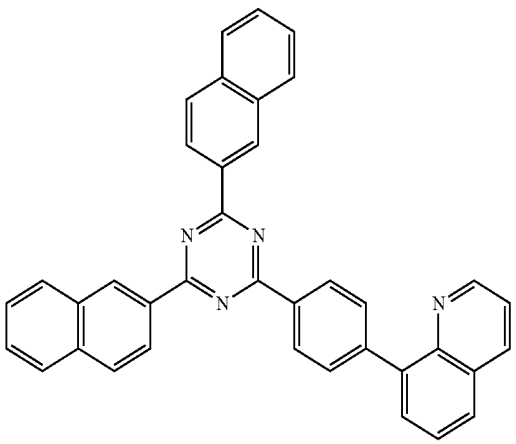
ET25



ET26



ET27



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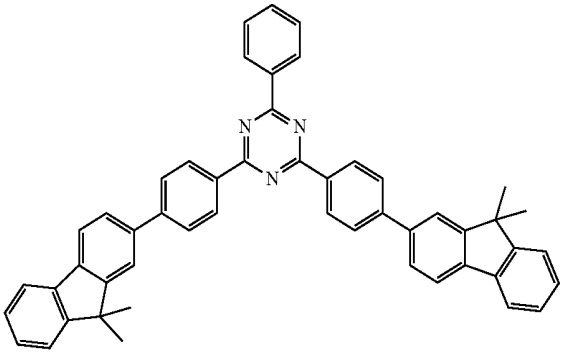
ET28



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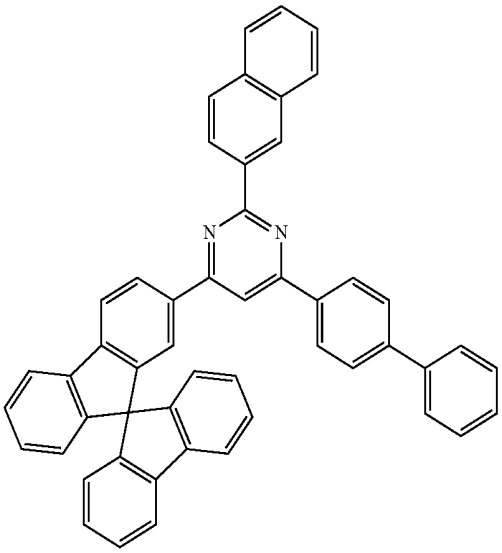

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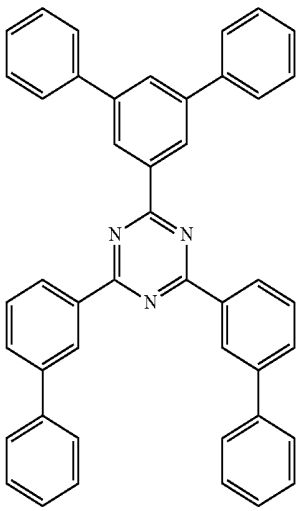

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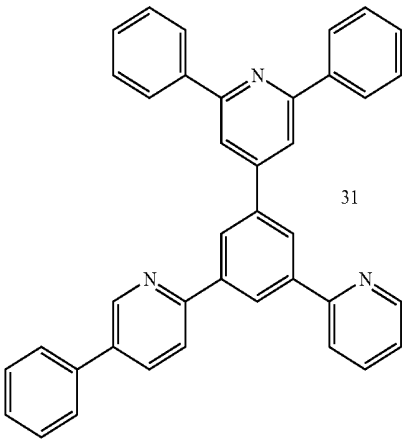
ET31



31

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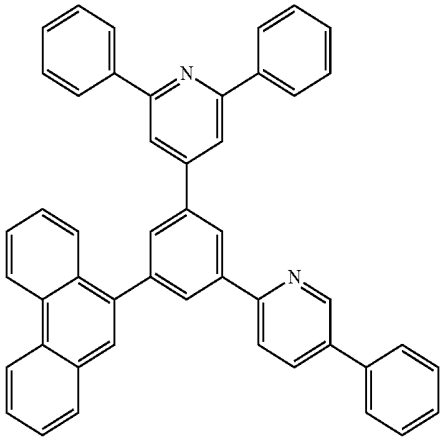
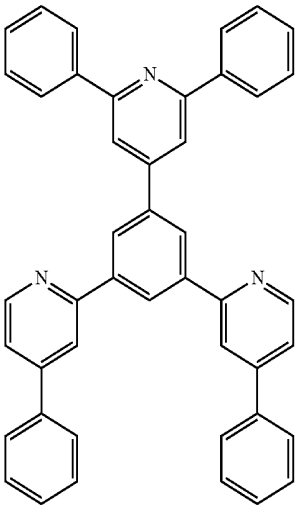
ET34



ET32



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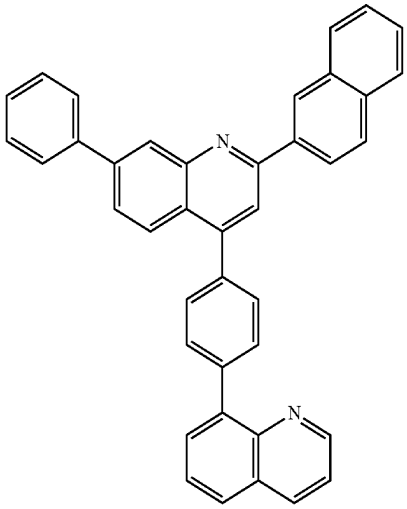

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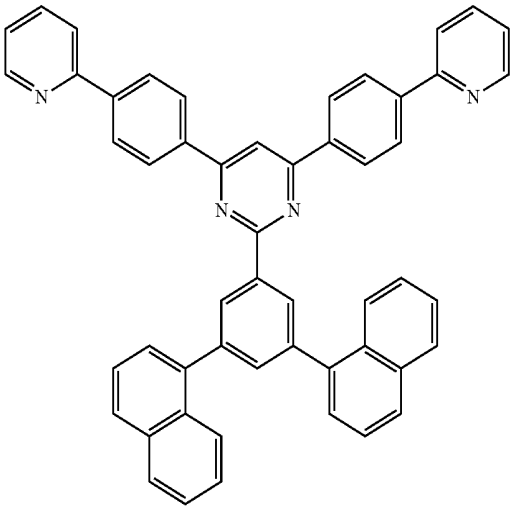

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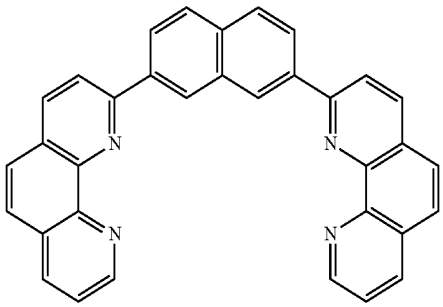
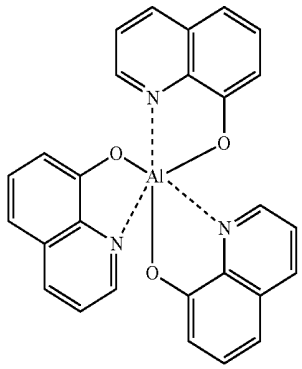
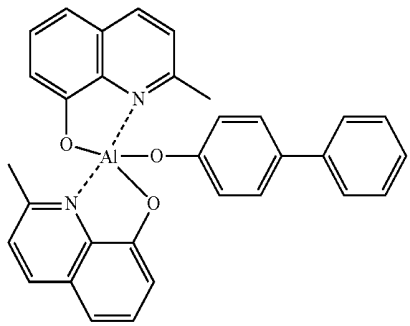


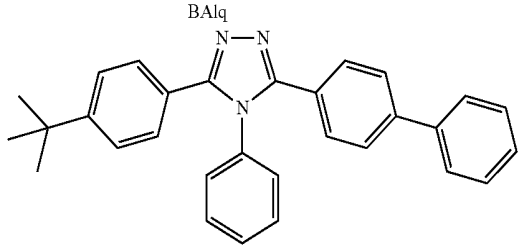
[0294] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1, 10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ.



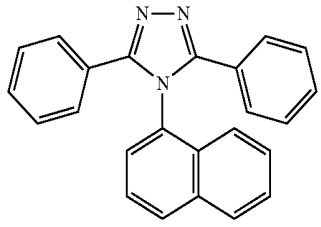
Alq_3



BAlq



TAZ



NTAZ

[0295] 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 these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

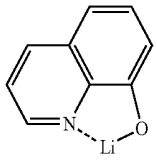
[0296] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

[0297] 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.

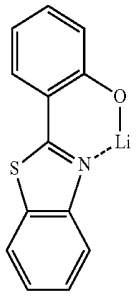
[0298] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from an Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, an 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.

[0299] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (8-hydroxyquniolinolato lithium, LiQ) or ET-D2.

ET-D1



ET-D2



[0300] 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**.

[0301] The electron injection layer may have i) a single-layered structure consisting of a single layer consisting of a single material, ii) a single-layered structure consisting of a single layer including a plurality of different materials, or iii) a multi-layered structure having a plurality of layers including a plurality of different materials.

[0302] The electron injection layer may include alkali metal, alkaline earth metal, rare-earth metal, alkali metal compound, alkaline earth-metal compound, rare-earth metal compound, alkali metal complex, alkaline earth-metal complex, rare-earth metal complex or any combinations thereof.

[0303] 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.

[0304] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0305] The rare-earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0306] 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 rare-earth metal.

[0307] 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.

[0308] The alkaline earth-metal compound may be selected from alkaline earth-metal oxides, such as BaO, SrO, CaO, $Ba_xSr_{1-x}O$ ($0<x<1$), or $Ba_xCa_{1-x}O$ ($0<x<1$). 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.

[0309] 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.

[0310] 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, and the rare-earth metal complex may each independently be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenyl 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.

[0311] The electron injection layer may consist of alkali metal, alkaline earth metal, 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.

[0312] When the electron injection layer further includes an organic material, alkali metal, alkaline earth metal, rare-earth metal, alkali metal compound, alkaline earth-metal compound, rare-earth metal compound, alkali metal complex, alkaline earth-metal complex, rare-earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0313] 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 the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

[Second Electrode **190**]

[0314] 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.

[0315] 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.

[0316] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0317] 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.

[0318] 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 to about 500° C. at a vacuum degree of about 10^{-8} to about 10^{-3} torr, and at a deposition rate of about 0.01 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.

[0319] 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 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.

General Definition of Substituents

[0320] 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 non-limiting 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" used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

[0321] The term "C_2-C_{60} alkenyl group" as used herein refers to a hydrocarbon group formed by substituting at least one double bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and non-limiting 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 the same structure as the C_2-C_{60} alkenyl group.

[0322] The term "C_2-C_{60} alkynyl group" as used herein refers to a hydrocarbon group having at least one 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 the same structure as the C_2-C_{60} alkynyl group.

[0323] 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 non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0324] 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 the same structure as the C_3-C_{10} cycloalkyl group.

[0325] The term C_1-C_{10} heterocycloalkyl group 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 the same structure as the C_1-C_{10} heterocycloalkyl group.

[0326] The term C_3-C_{10} cycloalkenyl group 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 does not have 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 the same structure as the C_3-C_{10} cycloalkenyl group.

[0327] 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 the same structure as the C_1-C_{10} heterocycloalkenyl group.

[0328] 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. Non-limiting examples of the C_6-C_{60} aryl group include 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.

[0329] 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 6 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. Non-limiting examples of the C_1-C_{60} heteroaryl group include 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 condensed with each other.

[0330] The term "C_6-C_{60} aryloxy group" as used herein refers to —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group used herein indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0331] The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) that has two or more rings condensed with each other, only carbon atoms as a ring-forming atom, and non-aromaticity in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0332] The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) that has two or more rings condensed to each other, has at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and has non-aromaticity in the 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," used herein, refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0333] The term "C_4-C_{60} carbocyclic group" as used herein refers to a monocyclic or polycyclic group having 4 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C_4-C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_4-C_{60} carbocyclic group may be a ring, such as a benzene group, 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_4-C_{60} carbocyclic group, the C_4-C_{60} carbocyclic group may be a trivalent group or a quadrivalent group.

[0334] The term "C_1-C_{60} heterocyclic group" as used herein refers to a group having the same structure as the C_4-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).

[0335] At least one substituent of the substituted C_4-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} het-

erocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0336] deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone 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;

[0337] 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 hydrazone 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 $—P(=O)(Q_{11})(Q_{12})$;

[0338] 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;

[0339] 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 hydrazone 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 $—P(=O)(Q_{21})(Q_{22})$;

[0340] $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

[0341] 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 hydrazone 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 C_1-C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C_6-C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

[0342] The term "Ph" used herein refers to a phenyl group, the term "Me" used herein refers to a methyl group, the term "Et" used herein refers to an ethyl group, the term "ter-Bu" or "Bu^t" used herein refers to a tert-butyl, and the term "OMe" used herein refers to a methoxy group.

[0343] The term "biphenyl group" as used therein refers to "a phenyl group substituted with a phenyl group." In other words, a "biphenyl group" is a substituted phenyl group having a C_6-C_{60} aryl group as a substituent.

[0344] 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 substituted phenyl group having, as a substituent, a C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group.

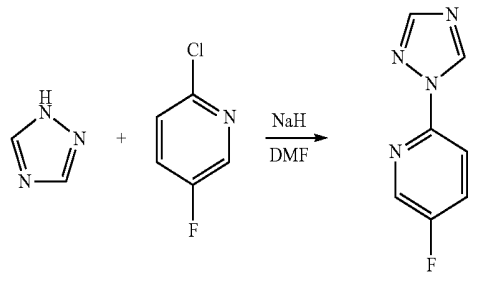
[0345] * and *' used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0346] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in 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 molar equivalent of B was used in place of A.

EXAMPLE

Synthesis Example 1: Synthesis of Compound 1-6

[0347] Synthesis of Intermediate 1-6(1)

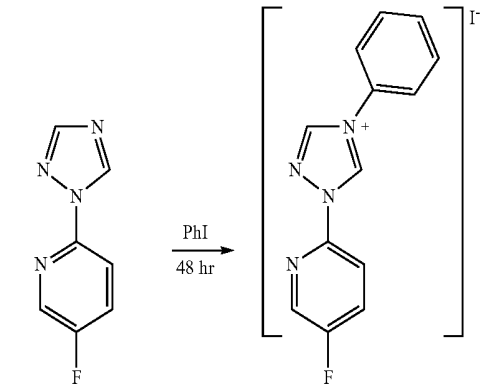


Intermediate 1-6(1)

[0348] 72.7 g (0.6 mol) of 2-chloro-5-fluoropyridine, 61.2 g (0.9 mol) of 1,2,4-triazole, and 21.6 g (0.9 mol) of NaH

were mixed with 1,500 ml of N,N-dimethyl formamide (DMF) in a nitrogen blanket apparatus, and the resultant mixture were heated to a temperature of 100° C. for 4 hours. Then, the resultant mixture was additionally stirred for 4 hours at the same temperature and stirred at room temperature all night to obtain a reaction mixture. An extraction process was performed on the reaction mixture three times by using dichloromethane and water. An organic layer obtained therefrom was dried by using magnesium sulfate, filtered by using celite, and then purified by column chromatography, thereby completing the preparation of 93 g (yield=93%) of Intermediate 1-6(1).

[0349] Synthesis of Intermediate 1-6(2)

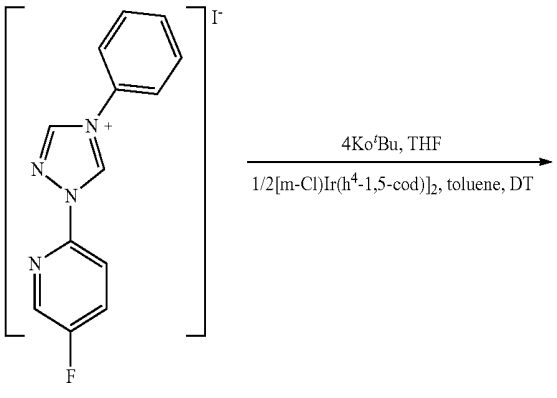


Intermediate 1-6(1) Intermediate 1-6(2)

[0350] 56 g (0.33 mol) of Intermediate 1-6(1) was dissolved in 560 ml of a tetrahydrofuran (THF) solution, and 234.2 g (1.65 mol) of phenyl iodide was added thereto. Then, the resultant mixture was heated and stirred at a temperature of 100° C. A reaction mixture obtained therefrom was cooled to room temperature to obtain a solid. Then, the obtained solid was filtered and dried, thereby completing the preparation of 81.54 g (yield=79.7%) of Intermediate 1-6(2).

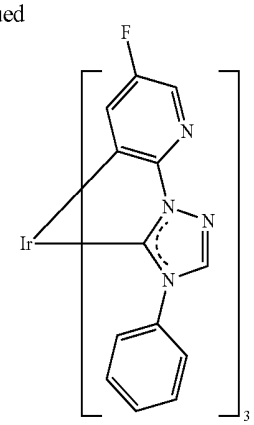
Synthesis of Compound 1-6

[0351]



Intermediate 1-6(2)

-continued



Compound 1-6

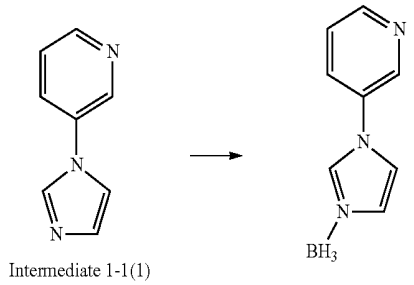
[0352] 64.3 ml of potassium tert-butoxide (KO^{t}Bu) was added to 10 g (32 mmol) of synthesized Intermediate 1-6(2) (iodide salt in toluene), a reaction was performed thereon at room temperature for 30 minutes, and then, the resultant mixture was additionally stirred for 30 minutes to obtain a reactant. 2.16 g (3.2 mmol) of bis(1,5-cyclooctadiene)di-iridium(I) dichloride [m-Cl)Ir(h^4-1,5,-cod)]$_2$ (in toluene) was added to the obtained reactant. The resultant mixture was stirred at room temperature for 1 hour, additionally stirred at a temperature of 70° C. for 2 hours, and then refluxed all night. A resultant obtained therefrom was cooled to room temperature. An extraction process was performed on the resultant three times by using dichloromethane and water. An organic layer obtained therefrom was dried by using magnesium sulfate, filtered by using celite, and then purified by column chromatography, thereby completing the preparation of 1.15 g (yield=24%) of Compound 1-6. The prepared Compound 1-6 was identified by ^{1}H NMR ($CDCl_3$, 500 MHz) and FAB-MS.

[0353] ^{1}H NMR: δ=6.57 (6H), 6.74 (6H), δ=7.12 (6H), δ=7.34 (3H), δ=7.94 (3H), δ=8.04 (3H)

[0354] FAB-MS [M+] found: 859.2, calc.: 859.

Synthesis Example 2: Synthesis of Compound 1-1

[0355]



Intermediate 1-1(1) Intermediate 1-1(2)

[0356] Synthesis of Intermediate 1-1(1)

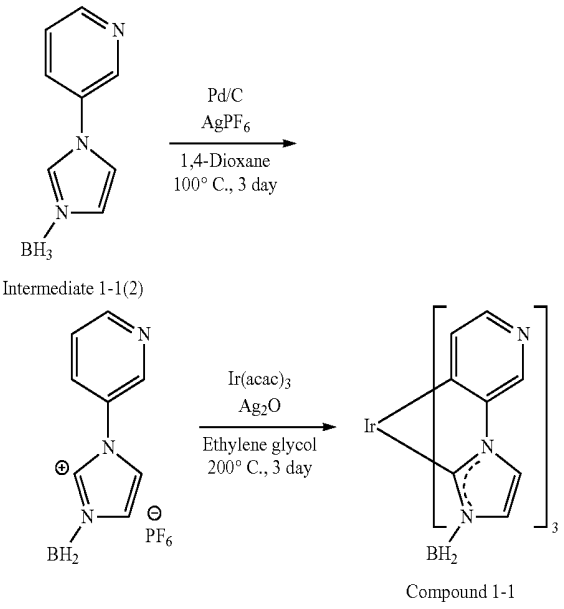
[0357] 72.7 g (0.6 mol) of 2-chloro-5-fluoropyridine, 61.2 g (0.9 mol) of imidazole, and 21.6 g (0.9 mol) of NaH were mixed with 1,500 ml of DMF in a nitrogen blanket apparatus, and the resultant mixture was heated to a temperature of 100° C. for 4 hours. Then, the resultant mixture was

additionally stirred for 4 hours at the same temperature, and stirred at room temperature all night to obtain a reaction mixture. An extraction process was performed on the reaction mixture three times by using dichloromethane and water. An organic layer obtained therefrom was dried by using magnesium sulfate, filtered by using Celite, and then purified by column chromatography, thereby completing the preparation of 86 g (yield=86%) of Intermediate 1-1(1).

[0358] Synthesis of 1-1(2)

[0359] 56 g (0.33 mol) of Intermediate 1-1(1) was dissolved in 560 ml of a THF solution, and 234.2 g (1.65 mol) of iodobrane was added thereto. Then, the resultant mixture was heated and stirred at a temperature of 120° C. A reaction mixture obtained therefrom was cooled to room temperature to obtain a solid. Then, the obtained solid was filtered and dried, thereby completing the preparation of 72.13 g of Intermediate 1-1(2) (yield=45.34%).

[0360] Synthesis of Compound 1-1



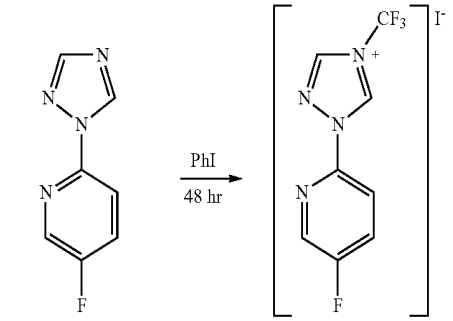
[0361] 10 g (32 mmol) of Intermediate 1-1(2) was stirred with 3 equivalents of $AgPF_6$ by using a Pd/C catalyst (20 wt %) at a temperature of 100° C. for 3 days, and refluxed all night. 0.33 equivalents of $Ir(acac)_3$ were added thereto, and as a base, 1.2 equivalents of Ag_2O were also added thereto. Then, the resultant mixture was stirred in ethylene glycol for 3 days, and refluxed all night. A reaction mixture obtained therefrom was cooled to room temperature, and an extraction process was performed thereon three times by using dichloromethane and water. An organic layer obtained therefrom was dried by using magnesium sulfate, filtered by using celite, and then, purified by column chromatography, thereby completing the preparation of 1.15 g (yield=20%) of Compound 1-1. The prepared Compound 1-1 was identified by ^1H NMR ($CDCl_3$, 500 MHz) and FAB-MS.

[0362] ^1H NMR: δ=7.23 (6H), 6.77 (3H), δ=6.67 (3H), δ=5.21 (3H), δ=5.06 (3H),

[0363] FAB-MS [M+] found: 661.2, calc.: 661.

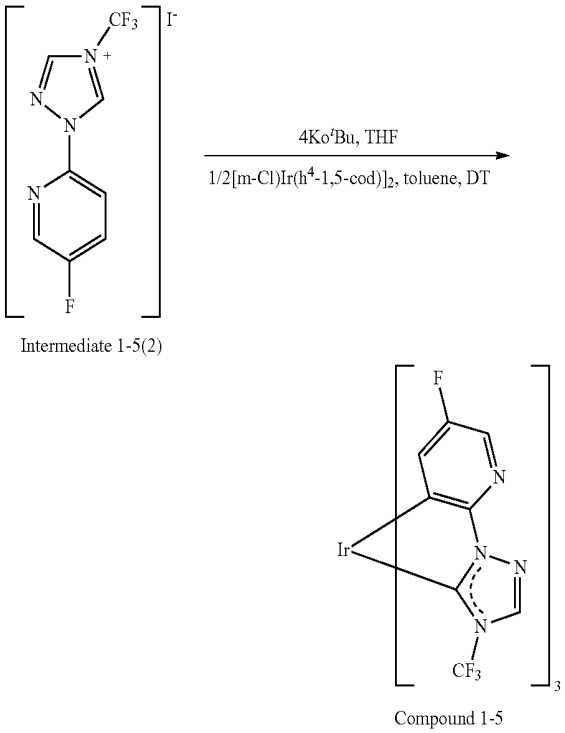
Synthesis Example 3: Synthesis of Compound 1-5

[0364] Synthesis of Intermediate 1-5(2)



[0365] 85 g (yield=85%) of Intermediate 1-5(2) was synthesized in the same manner as in Synthesis of Intermediate 1-6(2) of Synthesis Example 1, except that trifluoroiodomethane was used instead of phenyl iodide.

[0366] Synthesis of Compound 1-5



[0367] 1.02 g (yield=19%) of Compound 1-5 was synthesized in the same manner as in Synthesis of Compound 1-6 of Synthesis Example 1, except that Intermediate 1-5(2) was used instead of Intermediate 1-6(2). The obtained Compound 1-5 was identified by ^1H NMR ($CDCl_3$, 500 MHz) and FAB-MS.

[0368] ^1H NMR: δ=3.8 (3H), 7.32 (3H), δ=7.50 (3H), δ=7.63 (6H), δ=8.35 (3H)

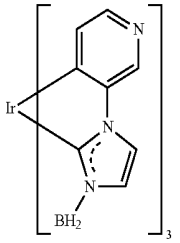
[0369] FAB-MS [M+] found: 832.1, calc.: 832.

Evaluation Example 1

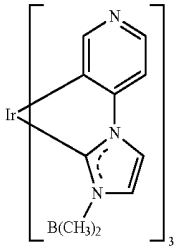
[0370] A minimum bond dissociation level energy (BDE) between a metal and a ligand and a minimum excitation triplet (Ti) energy level with respect to Compounds 1-1 to 1-8, 1-A to 1-C, 2-1, 2-2, and 2-A to 2-C were evaluated by a density functional theory (DFT) method of a Gaussian program (the structure was optimized at B3LYP, LANL2DZ: 6-31+G* level). Results thereof are shown in Table 1.

TABLE 1

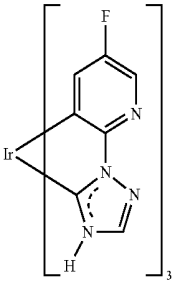
Compound No.	Simulation Data: Minimum BDE (eV)	Simulation Data: T_1 energy level (eV)	Simulation Data: Minimum BDE − T_1 energy level (eV)
1-1	3.674	2.718	0.956
1-2	2.894	2.892	0.002
1-3	3.729	3.156	0.573
1-4	3.709	3.149	0.56
1-5	3.288	3.063	0.225
1-6	3.557	3.175	0.382
1-7	3.556	3.184	0.327
1-8	3.225	3.162	0.057
1-A	3.182	3.234	−0.052
1-B	3.166	3.287	−0.121
1-C	3.27	3.280	−0.01
2-1	2.910	2.864	0.046
2-2	3.551	2.816	0.735
2-A	0.94	3.096	−2.102
2-B	2.57	2.67	−0.1
2-C	2.58	2.99	−0.38



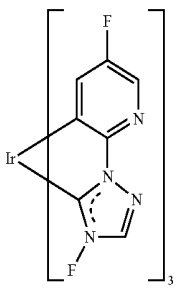
1-1



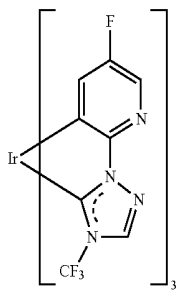
1-2



1-3



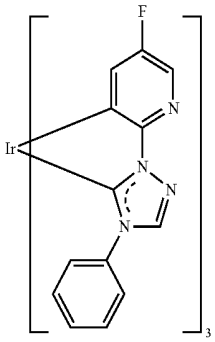
1-4



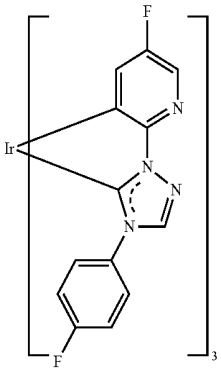
1-5

TABLE 1-continued

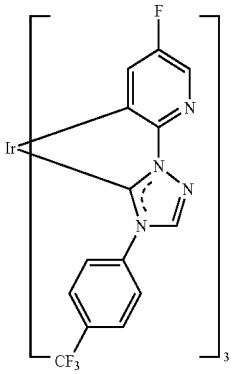
Compound No.	Simulation Data: Minimum BDE (eV)	Simulation Data: T_1 energy level (eV)	Simulation Data: Minimum BDE − T_1 energy level (eV)



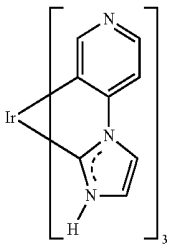
1-6



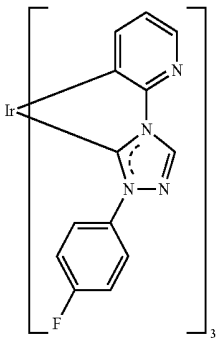
1-7



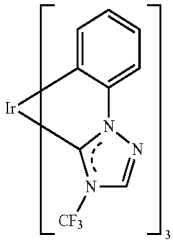
1-8



1-A



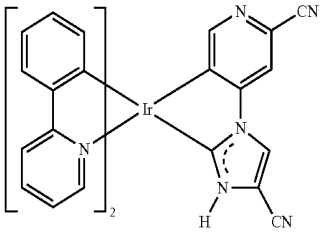
1-B



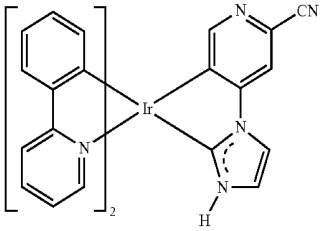
1-C

TABLE 1-continued

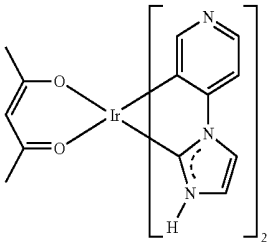
Compound No.	Simulation Data: Minimum BDE (eV)	T_1 energy level (eV)	Minimum BDE – T_1 energy level (eV)



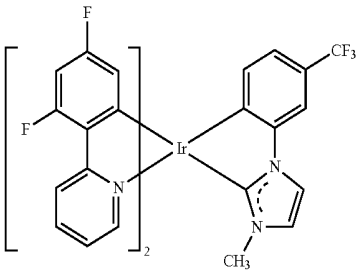
2-1



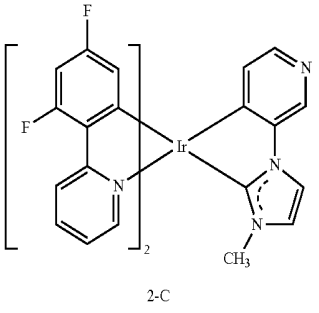
2-2



2-A



2-B



2-C

Example 1

[0371] An anode was prepared by cutting an ITO glass substrate (manufactured by Corning), on which an ITO layer was deposited to a thickness of 15 Ω/cm^2 (1,200 Å), to a size of 50 mm×50 mm×0.7 mm, ultrasonically cleaning the ITO glass substrate by using isopropyl alcohol and pure water each for 5 minutes, and then, exposing the ITO glass substrate to UV irradiation and ozone for 30 minutes to clean the ITO glass substrate. Then, the ITO glass substrate was loaded into a vacuum deposition apparatus.

[0372] 2-TNATA was vacuum-deposited on the anode formed on the ITO glass substrate to form a hole injection layer having a thickness of 600 Å, and NPB was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å.

[0373] CBP (host) and Compound 1-5 (dopant) were co-deposited on the hole transport layer at a weight ratio of 98:2 to form an emission layer having a thickness of 300 Å.

[0374] BCP was co-deposited on the emission layer to form a hole blocking layer having a thickness of 200 Å, Alq_3 was deposited on the hole blocking layer to form an electron transport layer having a thickness of 300 Å LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å and then, Al was vacuum-deposited on the electron injection layer to form a cathode having a thickness of 3,000 Å, thereby completing the manufacture of an organic light-emitting device.

Comparative Example A

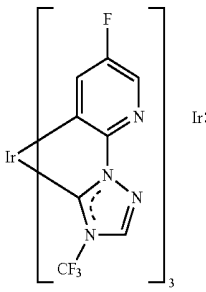
[0375] An organic light-emitting device was manufactured in the same manner as in Example 1, except that Compound 1-A was used instead of Compound 1-5 as a dopant used in forming an emission layer.

Evaluation Example 2

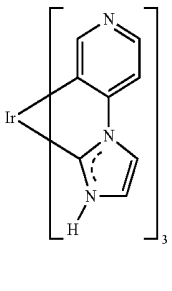
[0376] The current density, emission efficiency, maximum emission wavelength, and lifespan of the organic light-emitting devices manufactured according to Example 1 and Comparative Example A were measured by using a Keithley SMU 236 and a luminance meter PR650. Results thereof are shown in Table 2. The term "lifespan (T_{97})" refers to time spent in which brightness (@ 1,000 nit) was reduced to 97% relative to the initial brightness (100%) after driving the organic light-emitting devices.

TABLE 2

	Dopant compound No.	Current density (mA/cm^2)	Emission efficiency (cd/A)	Maximum emission wavelength (nm)	Lifespan (T_{97}) (hr @ 1000 nit)
Example 1	1-5	4.2	15	461	0.7
Comparative Example A	1-A	4.1	13	454	0.2



1-5



1-A

[0377] Referring to Table 2, it was confirmed that the organic light-emitting device of Example 1 showed current

density, emission efficiency, and lifespan at an equivalent as or a higher level than those of the organic light-emitting device of Comparative Example A.

[0378] According to one or more embodiments, an organic light-emitting device including the organometallic compound may have a low driving voltage, high efficiency, high luminance, and a long lifespan.

[0379] 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.

[0380] 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.

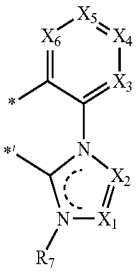
What is claimed is:

1. An organometallic compound represented by Formula 1:

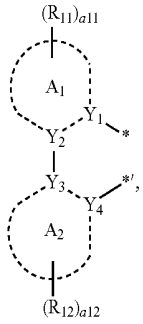
<Formula 1>

$M(L_1)_{n1}(L_2)_{n2}$

<Formula 2A>



<Formula 2B>



wherein M in Formula 1 is iridium (Ir),

in Formula 1, L_1 is a ligand represented by Formula 2A and n1 is 1, 2, or 3, wherein when n1 is two or more, two or more L_1(s) are identical to or different from each other,

in Formula 1, L_2 is a ligand represented by Formula 2B and n2 is 0, 1, or 2, wherein when n2 is two or more, two or more L_2(s) are identical to or different from each other,

the sum of n1 and n2 in Formula 1 is three,

* and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1,

in Formula 2A, X_1 is N or $C(R_1)$, X_2 is N or $C(R_2)$, X_3 is N or $C(R_3)$, X_4 is N or $C(R_4)$, X_5 is N or $C(R_5)$, and X_6 is N or $C(R_6)$,

in Formula 2B, Y_1 is C, Y_2 and Y_3 is each independently C or N, Y_4 is N, a bond between Y_1 and Y_2 is a single bond or a double bond, a bond between Y_2 and Y_3 is a single bond, and a bond between Y_3 and Y_4 is a single bond or a double bond,

in Formula 2B, ring A_1 is a C_4-C_{60} carbocyclic group or a C_1-C_{60} heterocyclic group and ring A_2 is a C_1-C_{60} heterocyclic group,

R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B 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 hydrazone 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 $—P(=O)(Q_1)(Q_2)$,

any two neighboring groups selected from R_1 to R_7 in Formula 2A are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

any two neighboring groups selected from two or more R_{11}(s) in Formula 2B are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

any two neighboring groups selected from two or more R_{12}(s) in Formula 2B are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

neighboring R_{11} and R_{12} in Formula 2B are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

a11 and a12 in Formula 2B are each independently 0, 1, 2, 3, 4, or 5,

i) when n1 in Formula 1 is three, a) X_2 and X_3 in Formula 2A are N; or b) at least one of X_4 to X_6 in Formula 2A is N, and R_7 is an electron withdrawing group,

ii) when n1 in Formula 1 is one or two, a) at least one of X_3, X_5, and X_6 in Formula 2A is N; and b) X_1 in Formula 2A is $C(R_1)$, X_4 is $C(R_4)$, and at least one of R_1 and R_4 is an electron withdrawing group, and

at least one substituent of the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted

C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, the substituted monovalent non-aromatic condensed heteropolycyclic group, the substituted C_4-C_{60} carbocyclic group, and the substituted C_1-C_{60} heterocyclic group is selected from:

deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone 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;

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 hydrazone 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 —$P(=O)(Q_{11})(Q_{12})$;

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;

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 hydrazone 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

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

wherein Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} 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 hydrazone 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 C_1-C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C_6-C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

2. The organometallic compound of claim **1**, wherein,

in Formula 2B,

ring A_1 is a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a selenophene group, a pyrrole group, a cyclopentadiene group, a silole group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzoselenophene group, a carbazole group, a fluorene group, a dibenzosilole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazol group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazol group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group, and

ring A_2 is a pyrrole group, an indole group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group, a phenanthroline group, a pyrazole group, an imidazole group, a triazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazol group, a benzopyrazole group, a benzimidazole group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazol group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

3. The organometallic compound of claim **1**, wherein,

in Formula 2B,

ring A_1 is a benzene group, a naphthalene group, a 1,2,3,4-tetrahydronaphthalene group, a benzofuran group, a benzothiophene group, a benzoselenophene group, an indole group, an indene group, a benzosilole group, a dibenzofuran group, a dibenzothiophene group, a dibenzoselenophene group, a carbazole group, a fluorene group, or a dibenzosilole group, and

ring A_2 is a pyrrole group, a pyridine group, a pyrimidine group, a pyrazine group, a quinoline group, an isoquinoline group, a quinoxaline group, a quinazoline group,

a pyrazole group, an imidazole group, a triazole group, a 5,6,7,8-tetrahydroisoquinoline group, or a 5,6,7,8-tetrahydroquinoline group.

4. The organometallic compound of claim **1**, wherein

R_1 to R_7, R_{11}, and R_{12} in Formulae 2A and 2B 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 hydrazone group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazone group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl 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 —$P(=O)(Q_{31})(Q_{32})$;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl 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

—$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, and —$P(=O)(Q_1)(Q_2)$,

wherein Q_1 to Q_3 and Q_{31} to Q_{33} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} 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_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

a C_6-C_{20} aryl group substituted with at least one selected from deuterium, —F, and a cyano group; and

a biphenyl group and a terphenyl group.

5. The organometallic compound of claim **1**, wherein

i) the electron withdrawing group is —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or ii) the electron withdrawing group is a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

the first group is selected from:

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a hydroxyl group, an amidino group, a hydrazino group, a hydrazone group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a hydroxyl group, an amidino group, a hydrazino group, a hydrazone group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl 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, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$,

wherein Q_1, Q_2 and Q_{31} to Q_{33} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} 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_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

a C_6-C_{20} aryl group substituted with at least one selected from deuterium, —F, and a cyano group; and

a biphenyl group and a terphenyl group.

6. The organometallic compound of claim **1**, wherein

i) the electron withdrawing group is —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or ii) the electron withdrawing group is a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

the first group is selected from:

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3,—CD_2H, —CDH_2, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group; and

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group,

wherein Q_1, Q_2, Q_{31}, and Q_{32} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

a biphenyl group and a terphenyl group.

7. The organometallic compound of claim **1**, wherein

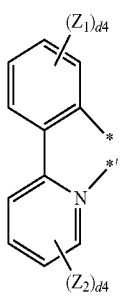
n1 in Formula 1 is three, and

three L_1(s) in Formula 1 are identical to one another.

8. The organometallic compound of claim **1**, wherein

L_2 is selected from groups represented by Formulae 2B-1 to 2B-14:

Formula 2B-1



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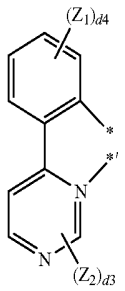
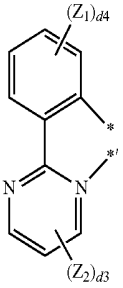
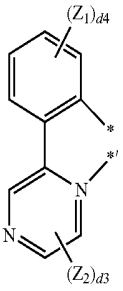
Formula 2B-2



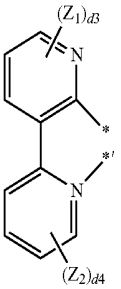
Formula 2B-3



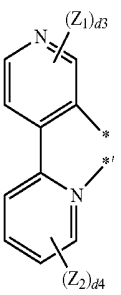
Formula 2B-4



Formula 2B-5

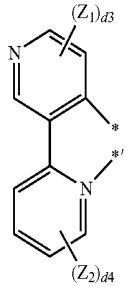


Formula 2B-6

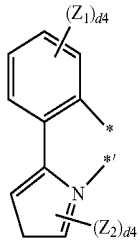


-continued

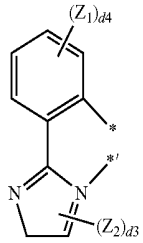
Formula 2B-7



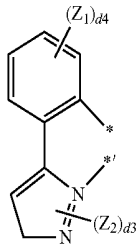
Formula 2B-8



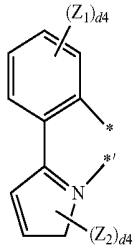
Formula 2B-9



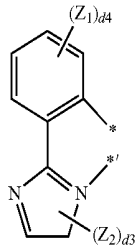
Formula 2B-10



Formula 2B-11



Formula 2B-12



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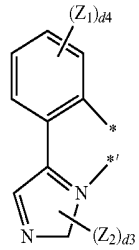
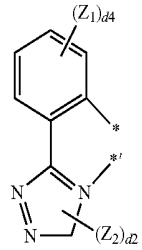
Formula 2B-13



Formula 2B-14



wherein, in Formulae 2B-1 to 2B-14,

Z_1 and Z_2 are the same as described in connection with R_{11} and R_{12} in claim **1**,

d2 is an integer from 0 to 2,

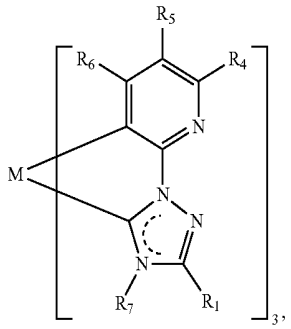
d3 is an integer from 0 to 3,

d4 is an integer from 0 to 4, and

* and *' each indicate a binding site to M in Formula 1.

9. The organometallic compound of claim **1**, wherein the organometallic compound is represented by Formula 1(1):

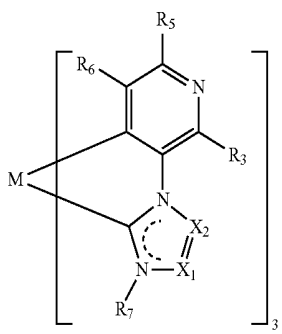
Formula 1(1)



wherein M, R_1, and R_4 to R_7 in Formula 1(1) are the same as described in claim **1**.

10. The organometallic compound of claim **1**, wherein the organometallic compound is represented by one of Formulae 1(2) to 1(4):

Formula 1(2)



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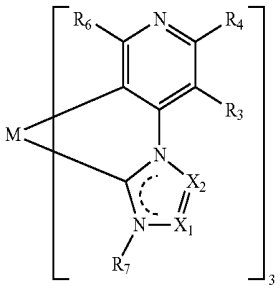
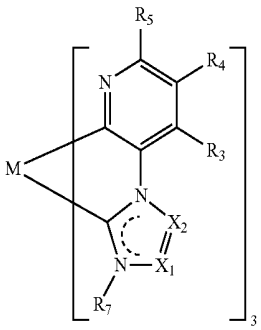
Formula 1(3)



Formula 1(4)



wherein, in Formulae 1(2) to 1(4),

M, X_1, X_2, and R_3 to R_6 are the same as described in claim **1**,

i) R_7 is —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or ii) R_7 is a first group substituted by at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

the first group is selected from:

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group; and

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group,

wherein Q_1, Q_2, Q_{31}, and Q_{32} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

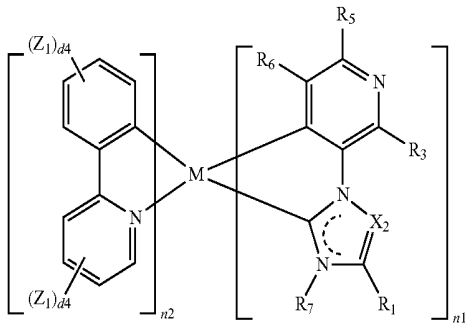
a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

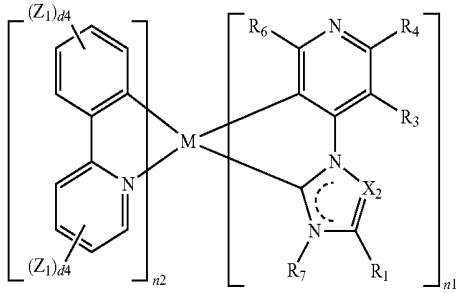
a biphenyl group and a terphenyl group.

11. The organometallic compound of claim **1**, wherein the organometallic compound is represented by one of Formulae 2(1) to 2(3):

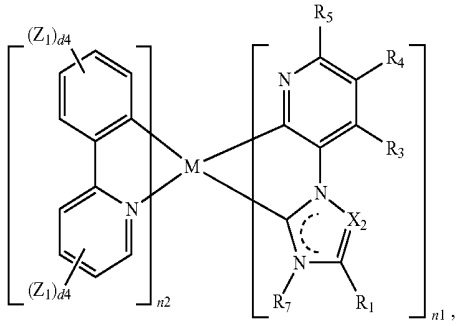
Formula 2(1)



Formula 2(2)



Formula 2(3)



wherein, in Formulae 2(1) to 2(3),

n1 and n2 are each independently 1 or 2,

Z_1 and Z_2 are the same as described in connection with R_{11} and R_{12} in claim **1**, M, R_1, X_2, and R_3 to R_7 are the same as described in claim **1**, i) at least one of R_1 and R_4 is each independently —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or ii) at least one of R_1 and R_4 is a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$, and

the first group is selected from:

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group; and

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohex-

enyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group,

wherein Q_1, Q_2, Q_{31}, and Q_{32} are each independently selected from:

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

a C_1-C_{20} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group;

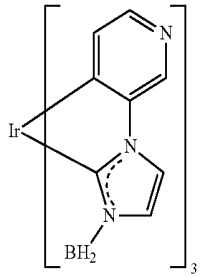
a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

a biphenyl group and a terphenyl group.

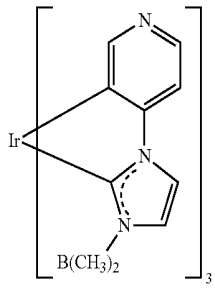
12. The organometallic compound of claim **1**, wherein

the organometallic compound is selected from Compounds 1-1 to 1-8, 2-1 and 2-2:

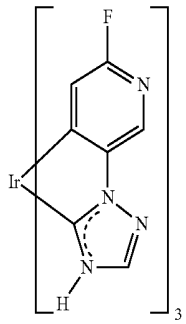
1-1



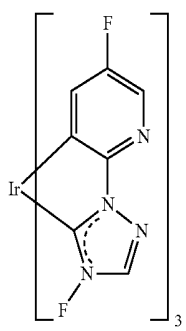
1-2



1-3



1-4



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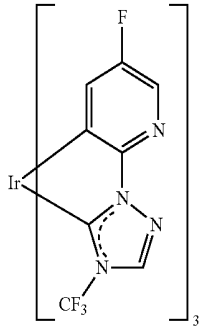
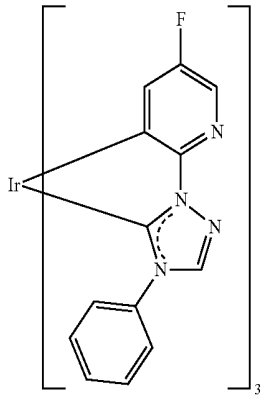
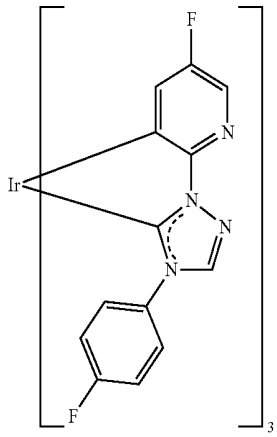
1-5



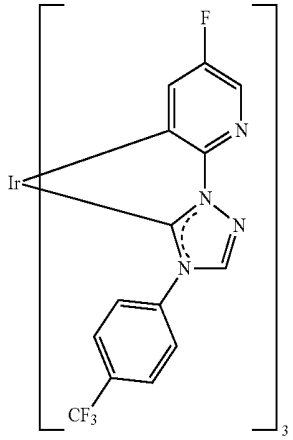
1-6



1-7



1-8



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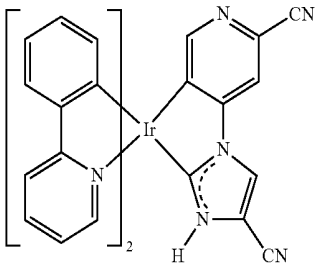
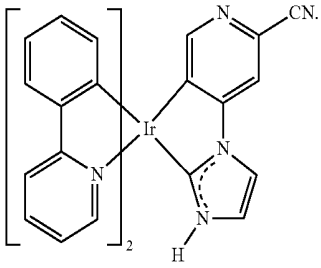
2-1



2-2



13. The organometallic compound of claim **1**, wherein

a minimum bond dissociation energy level (eV) between a metal and a ligand of the organometallic compound is higher than a minimum excitation triplet energy level (eV) of the organometallic compound.

14. The organometallic compound of claim **1**, wherein

the organometallic compound has a minimum excitation triplet energy level of about 2.7 eV to about 3.3 eV.

15. The organometallic compound of claim **1**, wherein

the organometallic compound emits blue light having a maximum light emission wavelength of about 392 nm to 460 nm at 77 Kelvin.

16. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first 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 at least one organometallic compound of claim **1**.

17. The organic light-emitting device of claim **16**, 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 an electron transport region between the emission layer and the second electrode,

the hole transport region comprises a hole injection layer, a hole transport layer, an emission auxiliary layer, an electron blocking layer, or any combination thereof, and

the electron transport region comprises a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

18. The organic light-emitting device of claim **16**, wherein

the emission layer comprises the organometallic compound, the emission layer further comprises a host, and an amount of the host in the emission layer is larger than an amount of the organometallic compound in the emission layer.

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

an absolute value of a lowest unoccupied molecular orbital (LUMO) energy level of the organometallic compound is smaller than an absolute value of a LUMO energy level of the host.

20. The organic light-emitting device of claim **17**, wherein

the hole transport region comprises a dopant having a LUMO energy level lower than about −3.5 eV.

* * * * *

专利名称(译)	有机金属化合物和包括其的有机发光器件		
公开(公告)号	US20180090692A1	公开(公告)日	2018-03-29
申请号	US15/716263	申请日	2017-09-26
[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DISPLAY CO.，LTD.		
[标]发明人	KANG SUNWOO JEON SANGHO CHO YOUNGMI KO SOOBYUNG KIM TAEKYUNG		
发明人	KANG, SUNWOO JEON, SANGHO CHO, YOUNGMI KO, SOOBYUNG KIM, TAEKYUNG		
IPC分类号	H01L51/00 H01L51/50 C07F15/00 C09K11/06		
CPC分类号	H01L51/0085 H01L51/5004 H01L51/506 C07F15/0033 C09K11/06 H01L2251/552 H01L51/5016 C09K2211/185 C09K2211/1029 C09K2211/1059 C09K2211/1044		
优先权	1020160124243 2016-09-27 KR 1020170123701 2017-09-25 KR		
外部链接	Espacenet USPTO		

摘要(译)

提供有机金属化合物和包含其的有机发光装置。有机金属化合物可由式1表示，其中L 1 是由式2A表示的配体，L 2 是由式2B表示的配体。关于化合物的进一步细节在本公开中给出。 M（L 1 ）n1 （L 2 ）n2 ，& #x3c;公式1> 其中M是铱。