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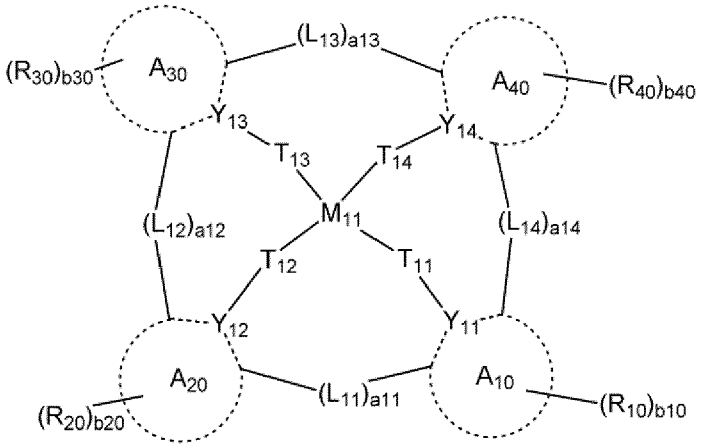
(54) **ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME**

(57) An organometallic compound is represented by Formula 1 below:

Formula 1



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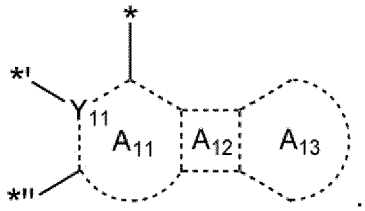
Formula A-10



In Formulae 1 and A-10, M_{11} is selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm). A_{10} is a group represented by Formula A-10.

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, wherein the organic layer includes an emission layer and at least one of the organometallic compound.

10

190
150
110

Description

BACKGROUND

1. Field

[0001] One or more embodiments relate to an organometallic compound and an organic light-emitting device including the same.

2. Description of the Related Art

[0002] Organic light-emitting devices are self-emission devices that produce full-color images, and also have wide viewing angles, high contrast ratios, short response times, and excellent characteristics in terms of brightness, driving voltage, and response speed, compared to related devices in the art.

[0003] 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.

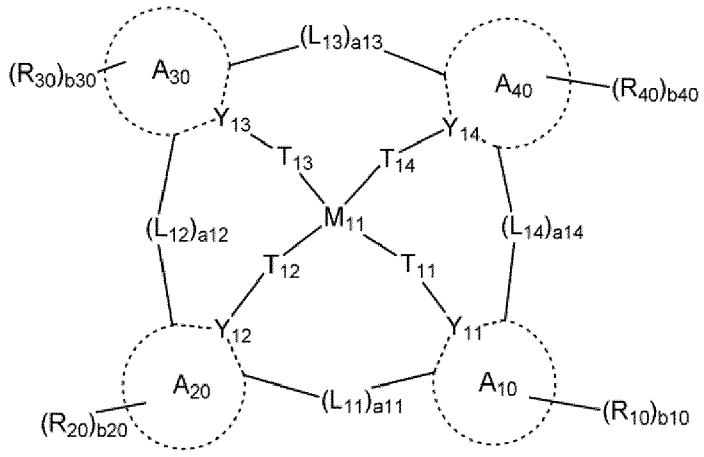
SUMMARY

[0004] Aspects of the present disclosure are directed toward a novel organometallic compound and an organic light-emitting device including the same.

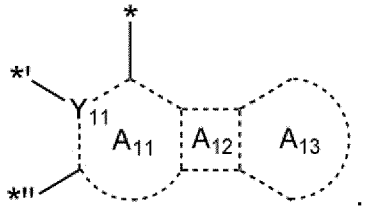
[0005] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0006] According to an embodiment of the present disclosure, an organometallic compound is represented by Formula 1 below:

Formula 1



Formula A-10



In Formulae 1 and A-10,

M_{11} is selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm),

A_{10} is a group represented by Formula A-10,

A_{11}, A_{13}, A_{20}, A_{30}, and A_{40} are each independently selected from a C_5-C_{60} carbocyclic group and a C_1-C_{60} heterocyclic group,

A_{12} is a 5-membered heterocyclic group,

Y_{11} to Y_{14} are each independently N or C,

T_{11} to T_{14} are each independently selected from a single bond, *-O-*', and *-S-*',

L_{11} to L_{14} are each independently selected from a single bond, *-O-*', *-S-*', *-C(R_1)(R_2)-*', *-C(R_1)=*', *=C(R_1)-*', *-C(R_1)=C(R_2)-*', *-C(=O)-*', *-C(=S)-*', *-C≡C-*', *-B(R_1)-*', *-N(R_1)-*', *-P(R_1)-*', *-Si(R_1)(R_2)-*', *-P(=O)(R_1)(R_2)-*', and *-Ge(R_1)(R_2)-*',

a11, a12, and a14 may each independently be selected from 1, 2, and 3,

a13 may be selected from 0, 1, 2, and 3,

when a13 is 0, A_{30} and A_{40} may not be linked to each other,

R_1, R_2, R_{10}, R_{20}, R_{30}, and R_{40} are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C_1-C_{60} hetero aryloxy group, a substituted or unsubstituted C_1-C_{60} hetero arylthio 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),-B(Q_1)(Q_2), -N(Q_1)(Q_2), -P(Q_1)(Q_2), -C(=O)(Q_1), -S(=O)(Q_1), -S(=O)$_2$(Q_1), -P(=O)(Q_1)(Q_2), and -P(=S)(Q_1)(Q_2),

R_1 and R_{10} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

R_1 and R_{20}, R_1 and R_{30}, or R_1 and R_{40} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,

b10, b20, b30, and b40 are each independently selected from 1, 2, 3, 4, 5, 6, 7, and 8,

*, *', and *'' each indicate a binding site to a neighboring atom,

at least one substituent of the substituted C_5-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_2-C_{60} heterocyclic 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 C_1-C_{60} hetero aryloxy group, the substituted C_1-C_{60} hetero arylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

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

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 hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60}

alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{21})(Q_{22})(Q_{23})$,$-N(Q_{21})(Q_{22})$, $-B(Q_{21})(Q_{22})$, $-C(=O)(Q_{21})$, $-S(=O)_2(Q_{21})$, and $-P(=O)(Q_{21})(Q_{22})$; and

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

Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a C_1-C_{60} hetero aryloxy group, a C_1-C_{60} hetero arylthio 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.

[0007] According to another embodiment of the present disclosure, 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, wherein the organic layer includes an emission layer and at least one of the organometallic compound.

[0008] At least some of the above and other features of the invention are set out in the claims.

BRIEF DESCRIPTION OF THE DRAWING

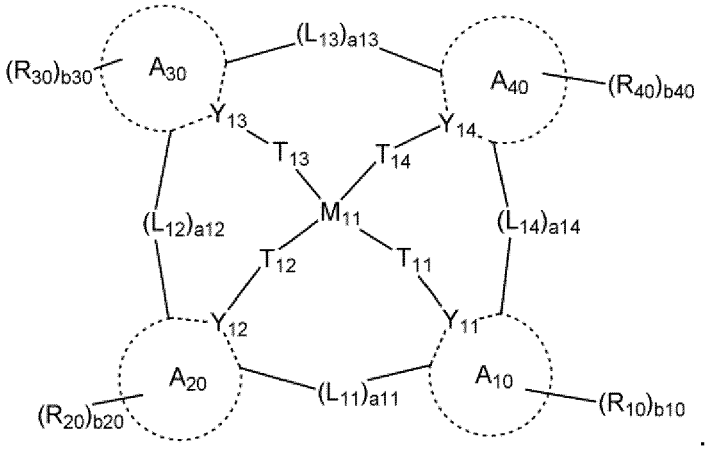
[0009] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the drawing which is a schematic view of an organic light-emitting device according to an embodiment.

DETAILED DESCRIPTION

[0010] Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawing, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the drawing, to explain aspects of the present description. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0011] An organometallic compound according to an embodiment is represented by Formula 1 below:

Formula 1



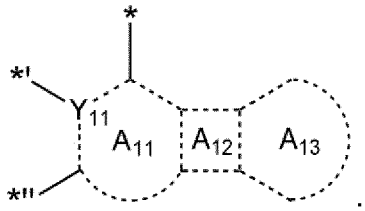
In Formula 1, M_{11} is selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm).

[0012] In one embodiment, M_{11} may be selected from Pt, Pd, Cu, Ag, and Au.

[0013] For example, M_{11} may be Pt, but embodiments of the present disclosure are not limited thereto.

[0014] In Formula 1, A_{10} is a group represented by Formula A-10.

Formula A-10



In Formulae 1 and A-10, A_{11}, A_{13}, A_{20}, A_{30}, and A_{40} are each independently selected from a C_5-C_{60} carbocyclic group and a C_1-C_{60} heterocyclic group,
A_{12} may be a 5-membered heterocyclic group.

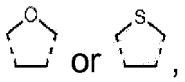
[0015] For example, in Formulae 1 and A-10, A_{11}, A_{13}, A_{20}, A_{30}, and A_{40} may each independently be selected from a C_5-C_{30} carbocyclic group and a C_1-C_{20} heterocyclic group.

[0016] For example, in Formula A-10, A_{11} may be selected from a C_5-C_{20} carbocyclic group and a C_1-C_{15} heterocyclic group. For example, in Formula A-10, A_{11} may be selected from a C_6-C_{10} carbocyclic group and a C_3-C_9 heterocyclic group.

[0017] For example, in Formula A-10, A_{13} may be selected from a C_5-C_{20} carbocyclic group and a C_1-C_{20} heterocyclic group.

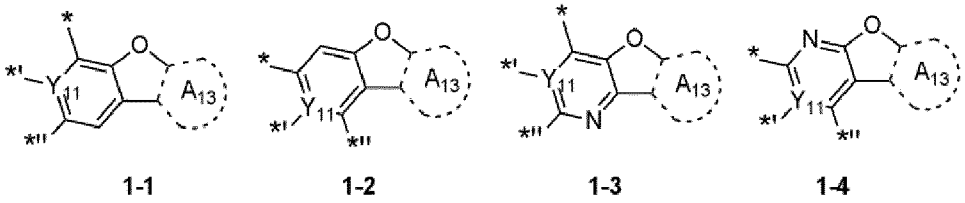
[0018] For example, in Formula 1, A_{20}, A_{30}, and A_{40} may each independently be selected from a C_5-C_{30} carbocyclic group and a C_1-C_{20} heterocyclic group.

[0019] In one embodiment, in Formula A-10, A_{11} may be selected from a benzene group, a naphthalene 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, and a quinazoline group,
A_{12} may be

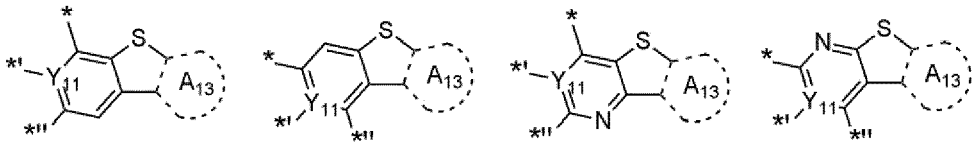


A_{13} may be selected from a cyclohexane group, a cyclohexene group, a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an indeno pyridine group, an indolopyridine group, a benzofuropyridine group, a benzothienopyridine group, a benzosilolopyridine group, an indeno pyrimidine group, an indolopyrimidine group, a benzofuropyrimidine group, a benzothienopyrimidine group, a benzosilolopyrimidine group, a dihydropyridine 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 pyrrole group, a pyrazole group, an imidazole group, a 2,3-dihydroimidazole group, a triazole group, a 2,3-dihydrotriazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a 2,3-dihydrobenzimidazole group, an imidazopyridine group, a 2,3-dihydroimidazopyridine group, an imidazopyrimidine group, a 2,3-dihydroimidazopyrimidine group, an imidazopyrazine group, a 2,3-dihydroimidazopyrazine group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group.

[0020] In one or more embodiments, in Formula 1, A_{10} may be represented by one selected from Formulae 1-1 to 1-8:



1-1 1-2 1-3 1-4

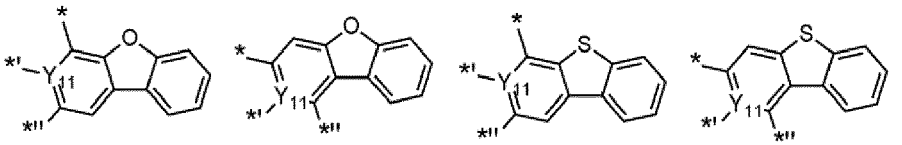


1-5 1-6 1-7 1-8

In Formulae 1-1 to 1-8,

Y_{11} is the same as described below in connection with Formula 1,
A_{13} is selected from a cyclohexane group, a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, a dibenzothiophene group, and a dibenzosilole group, and
*, *', and *'' each indicate a binding site to a neighboring atom.

[0021] For example, in Formula 1, A_{10} may be represented by one selected from Formulae 1-1-1 to 1-1-4:



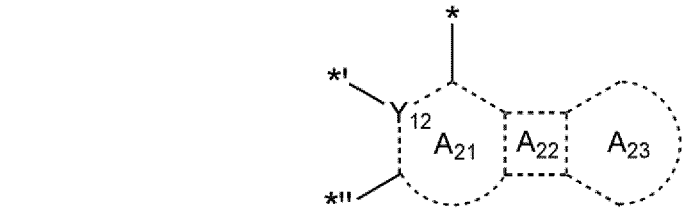
1-1-1 1-1-2 1-1-3 1-1-4

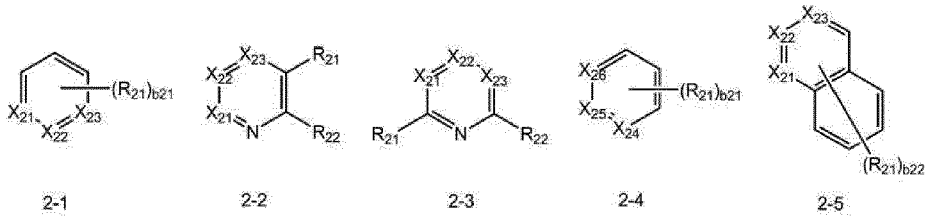
In Formulae 1-1-1 to 1-1-4,

Y_{11} is the same as described below in connection with Formula 1,
*, *', and *'' each indicate a binding site to a neighboring atom.

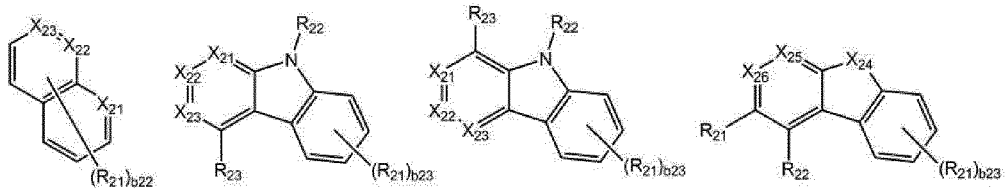
[0022] In one embodiment, in Formula 1, A_{20} may be selected from a group represented by Formula A-20, and a group represented by one of Formulae 2-1 to 2-43, and
A_{30} and A_{40} may each independently be represented by one selected from Formulae 2-1 to 2-43:

Formula A-20

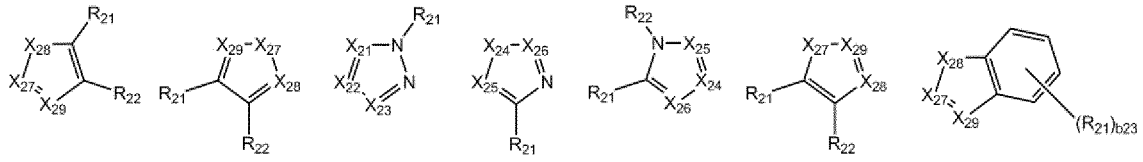




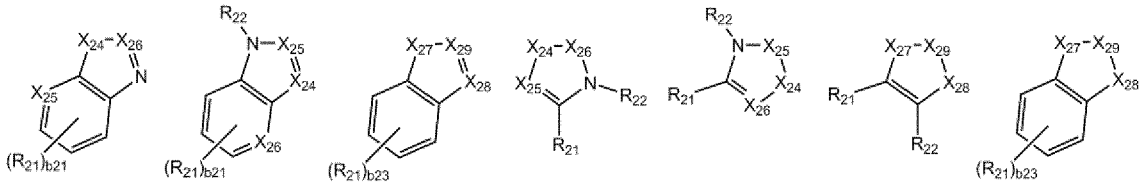
2-1 2-2 2-3 2-4 2-5



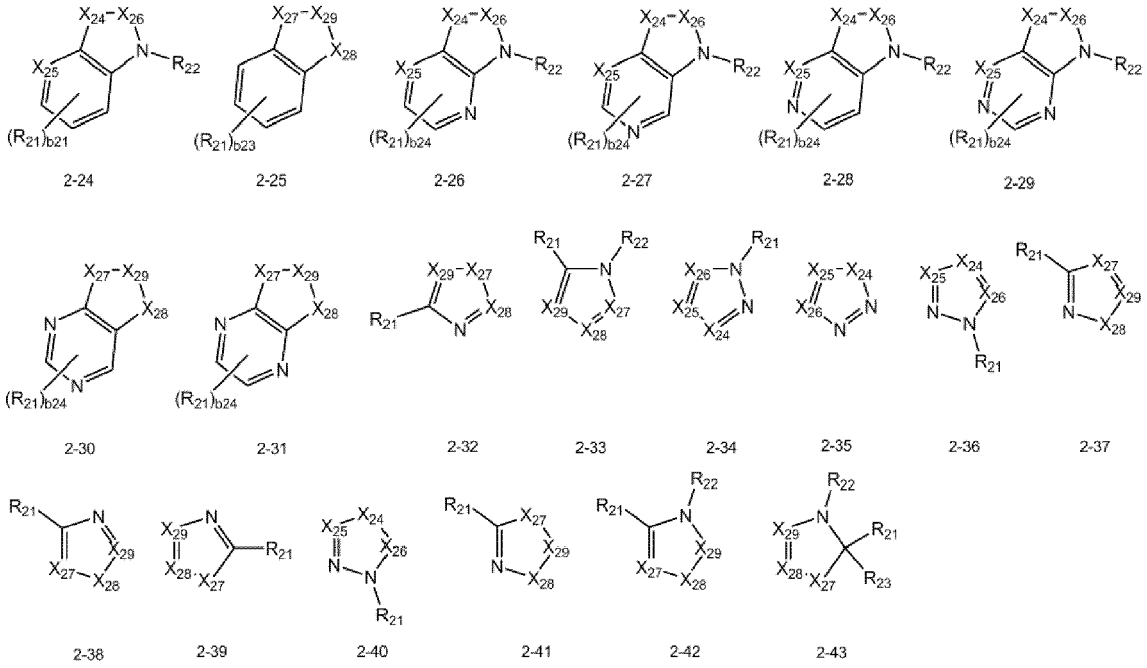
2-6 2-7 2-8 2-9



2-10 2-11 2-12 2-13 2-14 2-15 2-16



2-17 2-18 2-19 2-20 2-21 2-22 2-23



2-24 2-25 2-26 2-27 2-28 2-29

2-30 2-31 2-32 2-33 2-34 2-35 2-36 2-37

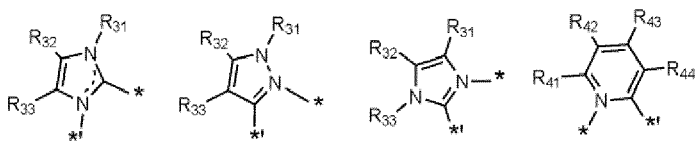
2-38 2-39 2-40 2-41 2-42 2-43

In Formula A-20,

Y_{12} is defined the same as described below in connection with Formula 1,
A_{21} is defined the same as described below in connection with A_{11} in Formula A-10,
A_{22} is defined the same as described below in connection with A_{12} in Formula A-10,
A_{23} is defined the same as described below in connection with A_{13} in Formula A-10,
wherein, in Formulae 2-1 to 2-43,
X_{21} to X_{23} are each independently selected from $C(R_{24})$ and C-*, wherein at least two of X_{21} to X_{23} are each C-*,
X_{24} is N-*, and X_{25} and X_{26} are each independently selected from $C(R_{24})$ and C-*, wherein at least one of X_{25} and X_{26} is C-*,
X_{27} and X_{28} are each independently selected from N, $N(R_{25})$, and N-*, and X_{29} is selected from $C(R_{24})$ and C-*, wherein i) at least one of X_{27} and X_{28} is N-* and X_{29} is C-*, or ii) X_{27} and X_{28} are each N-* and X_{29} is $C(R_{24})$,
R_{21} to R_{24} are each independently defined the same as described below in connection with R_{10} in Formula 1
b21 is selected from 1, 2, and 3,
b22 is selected from 1, 2, 3, 4, and 5,
b23 is selected from 1, 2, 3, and 4,
b24 is selected from 1 and 2, and
* indicates a binding site to a neighboring atom.

[0023] In one or more embodiments, in Formula 1, A_{20} may be a group represented by Formula A-20, a benzene group, or a naphthalene group, and

[0024] A_{30} and A_{40} may each be a group represented by one selected from Formulae 3-1 to 3-4:



3-1 3-2 3-3 3-4

In Formulae 3-1 to 3-4,

R_{31} to R_{33} are defined the same as described below in connection with R_{30} in Formula 1,
R_{41} to R_{44} are defined the same as described below in connection with R_{40} in Formula 1, and

* and *' each indicate a binding site to a neighboring atom.

[0025] For example, in Formula 1, A_{30} may be a group represented by one selected from Formulae 3-1 to 3-3, and A_{40} may be a group represented by Formula 3-4.

[0026] In Formulae 1 and A-10, Y_{11} to Y_{14} are each independently N or C.

[0027] In one embodiment, in Formulae 1 and A-10, Y_{11}, Y_{12}, and Y_{13} may each be C, and Y_{14} may be N;
Y_{11}, Y_{12}, and Y_{14} may each be C, and Y_{13} may be N;
Y_{11}, Y_{13}, and Y_{14} may each be C, and Y_{12} may be N;
Y_{12}, Y_{13}, and Y_{14} may each be C, and Y_{11} may be N;
Y_{11} and Y_{14} may each be C, and Y_{12} and Y_{13} may each be N;
Y_{11} and Y_{14} may each be N, and Y_{12} and Y_{13} may each be C;
Y_{11} and Y_{12} may each be C, and Y_{13} and Y_{14} may each be N;
Y_{11} and Y_{12} may each be N, and Y_{13} and Y_{14} may each be C;
Y_{11} and Y_{13} may each be C, and Y_{12} and Y_{14} may each be N; or
Y_{11} and Y_{13} may each be N, and Y_{12} and Y_{14} may each be C.

[0028] In Formula 1, T_{11} to T_{14} are each independently selected from a single bond, *-O-*', and *-S-*'.

[0029] In one embodiment, in Formula 1, each of T_{11} to T_{14} may be a single bond;
T_{11} may be selected from O and S, and T_{12} to T_{14} may each be a single bond;
T_{12} may be selected from O and S, and T_{11}, T_{13}, and T_{14} may each be a single bond;
T_{13} may be selected from O and S, and T_{11}, T_{12}, and T_{14} may each be a single bond; or
T_{14} may be selected from O and S, and T_{11}, T_{12}, and T_{13} may each be a single bond.

[0030] For example, in Formula 1, each of T_{11} to T_{14} may be a single bond, but embodiments of the present disclosure are not limited thereto.

[0031] In Formula 1, L_{11} to L_{14} are each independently selected from a single bond, *-O-*', *-S-*', *-$C(R_1)(R_2)$-*', *-$C(R_1)$=*', *=$C(R_1)$-*', *-$C(R_1)$=$C(R_2)$-*', *-C(=O)-*', *-C(=S)-*', *-C≡C-*', *-$B(R_1)$-*', *-$N(R_1)$-*', *-$P(R_1)$-*', *-$Si(R_i)(R_2)$-*', *-P(=O)$(R_1)(R_2)$-*', and *-$Ge(R_1)(R_2)$-*',
a11, a12, and a14 may each be selected from 1, 2, and 3,
a13 may be selected from 0, 1, 2, and 3, and
when a13 is 0, A_{30} and A_{40} may not be linked to each other.

[0032] In one or more embodiments, in Formula 1, L_{11} to L_{14} may each independently be selected from a single bond, *-O-*' and *-$N(R_1)$-*'.

[0033] In one embodiment, in Formula 1, L_{11} and L_{14} may each independently be selected from *-O-*', *-S-*', *-$N(R_1)$-*', *-$C(R_1)(R_2)$-*', *-$Si(R_1)(R_2)$-*', and *-$P(R_1)$-*',
L_{12} may be selected from a single bond, *-O-*', *-S-*', *-$N(R_1)$-*', *-$C(R_1)(R_2)$-*', *-$Si(R_1)(R_2)$-*', and *-$P(R_1)$-*'.

[0034] In one or more embodiments, in Formula 1, L_{11} and L_{14} may each independently be selected from *-O-*' and *-$N(R_1)$-*',
L_{12} may be selected from a single bond, *-O-*' and *-$N(R_1)$-*'.

[0035] In one or more embodiments, in Formula 1, L_{11} may be *-$N(R_1)$-*', *-$C(R_1)(R_2)$-*', or *-$Si(R_1)(R_2)$-*', and R_1 and R_{20} may be linked to form a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group,
L_{12} may be *-$N(R_1)$-*', *-$C(R_1)(R_2)$-*', or *-$Si(R_1)(R_2)$-*', and R_1 and R_{20}, or R_1 and R_{30} may be linked to form a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group, or
L_{14} may be *-$N(R_1)$-*', *-$C(R_1)(R_2)$-*', or *-$Si(R_1)(R_2)$-*', and R_1 and R_{40} may be linked to form a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group.

[0036] In one embodiment, a13 in Formula 1 may be 0.

[0037] In Formula 1, R_1, R_2, R_{10}, R_{20}, R_{30}, and R_{40} are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a substituted or unsubstituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a substituted or unsubstituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} (*e.g.* C_6-C_{30}) aryl group, a substituted or unsubstituted C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a substituted or unsubstituted C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero aryloxy group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, -$Si(Q_1)(Q_2)(Q_3)$,-$B(Q_1)(Q_2)$, -$N(Q_1)(Q_2)$, -$P(Q_1)(Q_2)$, -$C(=O)(Q_1)$, -$S(=O)(Q_1)$, -$S(=O)_2(Q_1)$, -P(=O)$(Q_1)(Q_2)$, and -P(=S)$(Q_1)(Q_2)$,
R_1 and R_{10} are optionally linked to form a substituted or unsubstituted C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group or a

substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group,
R_1 and R_{20}; R_1 and R_{30}; or R_1 and R_{40} are optionally linked to form a substituted or unsubstituted C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group or a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group (i.e., when L_{11} is a functional group including R_1, e.g., *-N(R_1)-*', R_1 in L_{11} and R_{20} may optionally be linked to form a substituted or unsubstituted C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group or a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group),
b10, b20, b30, and b40 are each independently selected from 1, 2, 3, 4, 5, 6, 7, and 8, and
Q_1 to Q_3 may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a C_1-C_{60} (*e.g.* 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_{60} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a C_1-C_{60} (*e.g.* C_1-C_{20}) hetero aryloxy group, a C_1-C_{60} (*e.g.* C_1-C_{20}) hetero arylthio group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a biphenyl group, and a terphenyl group.

[0038] In one embodiment, in Formula 1, R_1 and R_2 may each independently be selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;
a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a cyano group, a phenyl group, and a biphenyl group;
a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and
a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl 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, a cyano group, a phenyl group, and a biphenyl group.

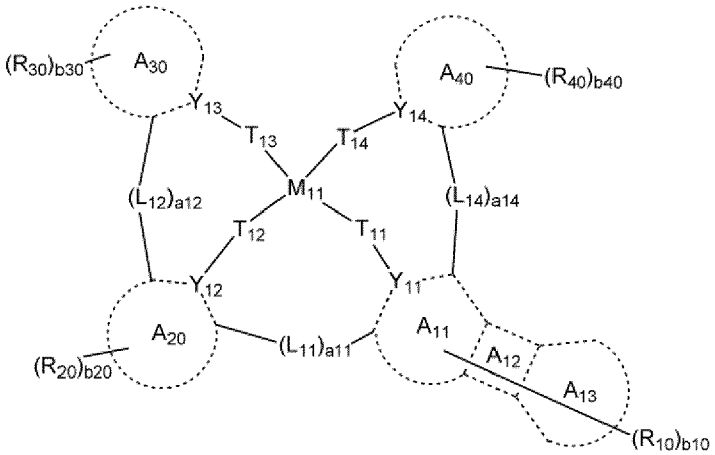
[0039] In one or more embodiments, in Formula 1, R_{10}, R_{20}, R_{30}, and R_{40} may each independently be selected from:

hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group;
a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I and a cyano group; and
a phenyl group, a naphthyl group, and a pyridinyl group.

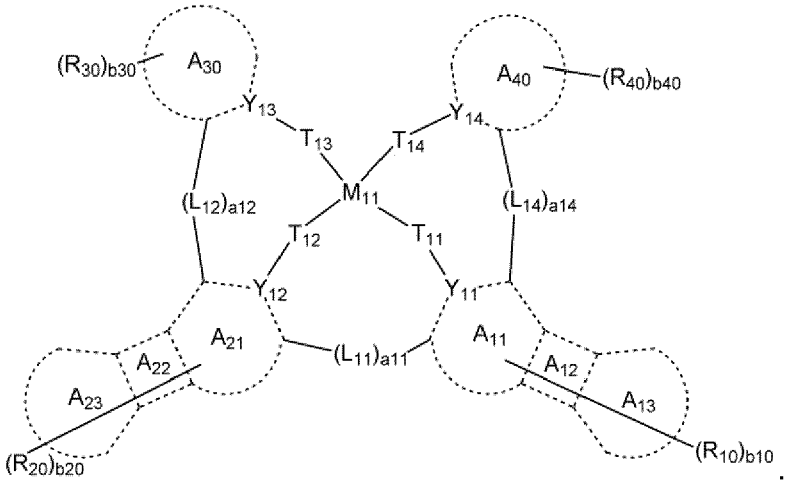
[0040] In Formula A-10, *, *', and *'" each indicate a binding site to a neighboring atom.

[0041] In one embodiment, the organometallic compound represented by Formula 1 may be represented by Formula 10-1 or Formula 10-2:

Formula 10-1



Formula 10-2



In Formulae 10-1 and 10-2,

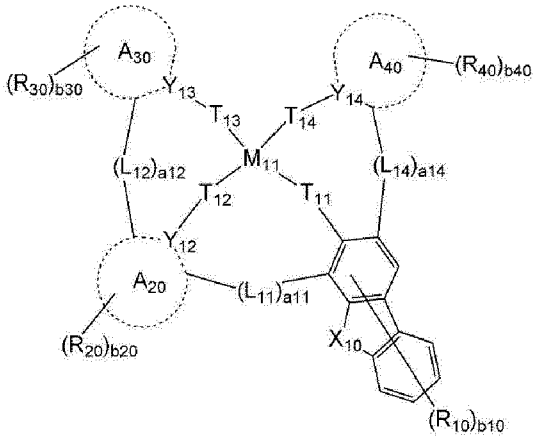
M_{11}, A_{11} to A_{13}, A_{20}, A_{30}, A_{40}, Y_{11} to Y_{14}, T_{11} to T_{14}, L_{11}, L_{12}, L_{14}, a11, a12, a14, R_{10}, R_{20}, R_{30}, R_{40}, b10, b20, b30, and b40 are respectively defined the same as described above in connection with Formulae 1 and A-10,

A_{21} is defined the same as described in connection with A_{11} in Formulae 1 and A-10,

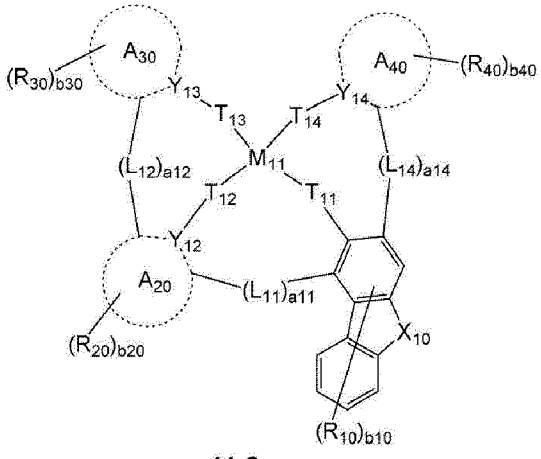
A_{22} is defined the same as described in connection with A_{12} in Formulae 1 and A-10, and

A_{23} is defined the same as described in connection with A_{13} in Formulae 1 and A-10.

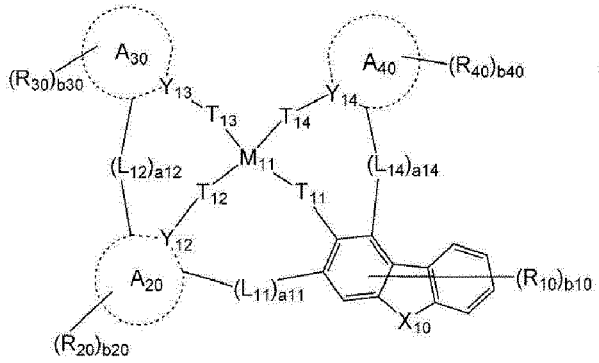
[0042] In one or more embodiments, the organometallic compound represented by Formula 1 may be represented by one selected from Formulae 11-1 to 11-10:



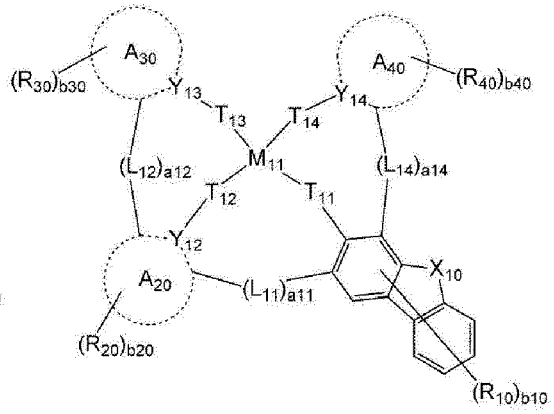
11-1



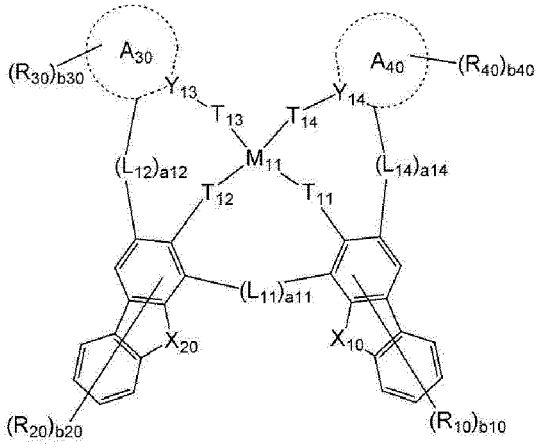
11-2



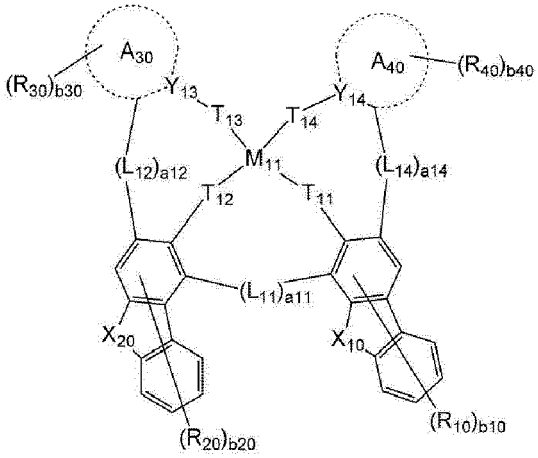
11-3



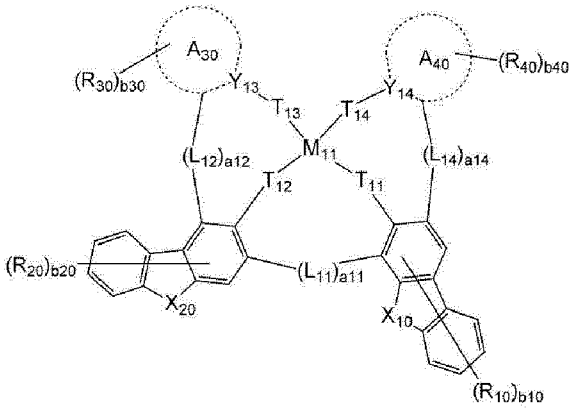
11-4



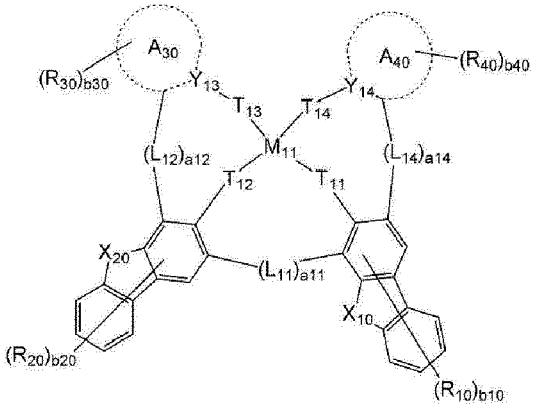
11-5



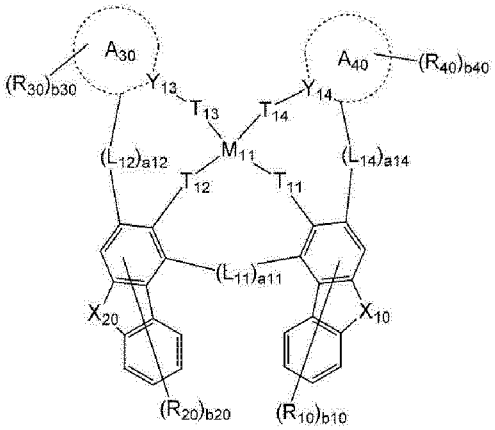
11-6



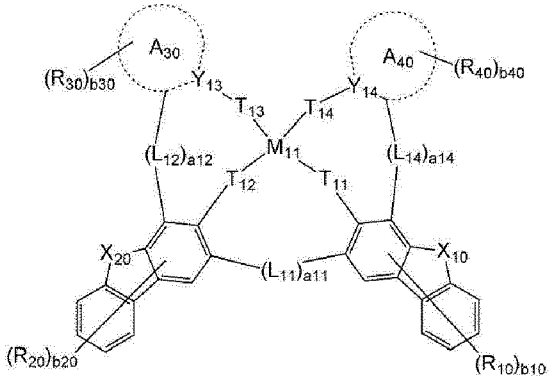
11-7



11-8



11-9



11-10

In Formulae 11-1 to 11-10,

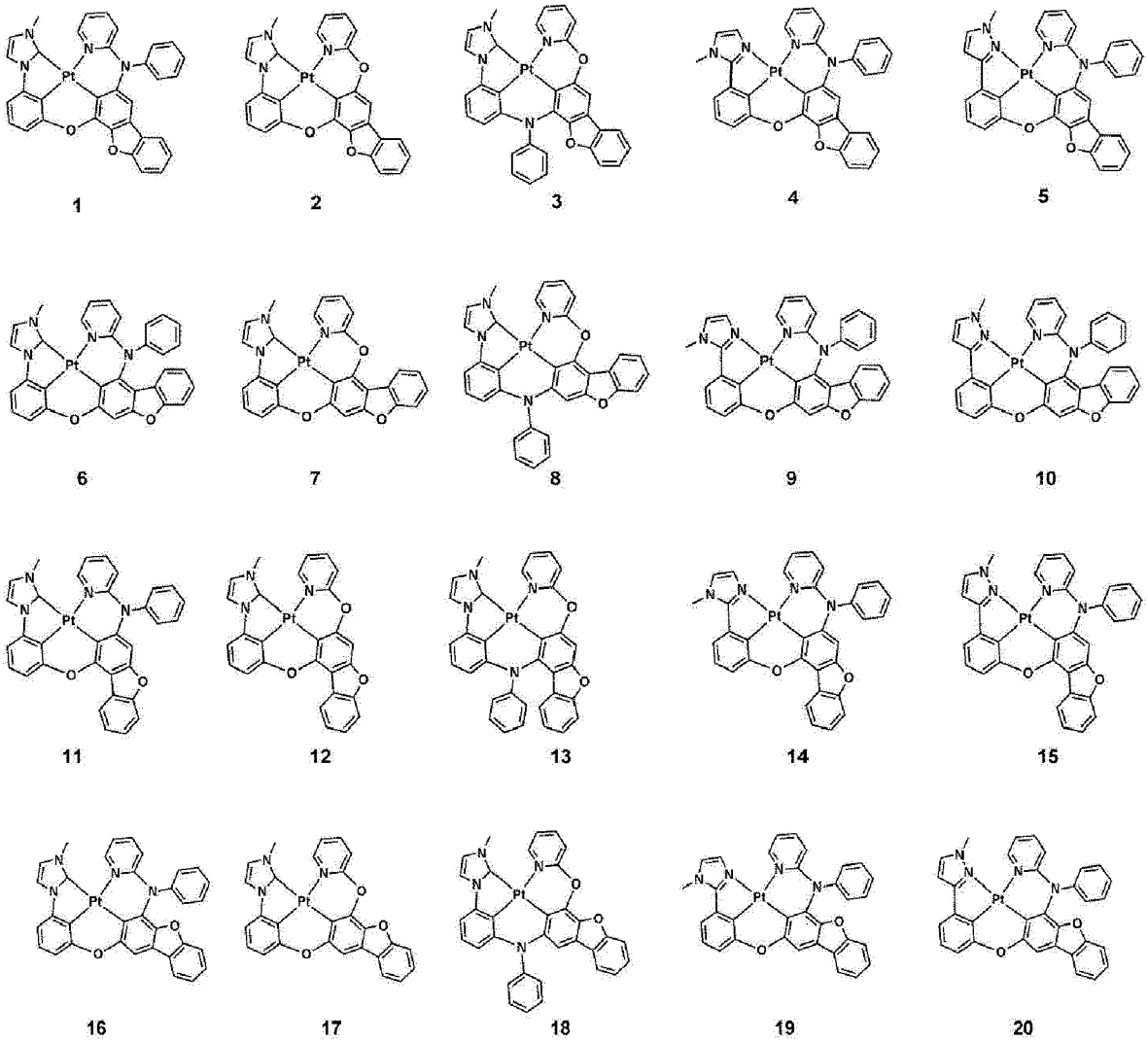
M_{11}, A_{30}, A_{40}, Y_{13}, Y_{14}, T_{11} to T_{14}, L_{11}, L_{12}, L_{14}, a11, a12, a14, R_{10}, R_{20}, R_{30}, R_{40}, b10, b20, b30, and b40 are respectively defined the same as described above in connection with Formulae 1 and A-10, and
X_{10} and X_{20} are each independently O or S.

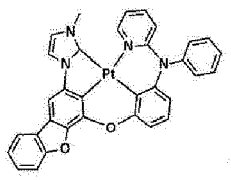
[0043] At least one substituent of the substituted C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) heterocyclic group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, the substituted C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, the substituted C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero aryloxy group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero arylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, and a C_1-C_{60} (*e.g.* C_1-C_{20}) alkoxy group;
a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, and a C_1-C_{60} (*e.g.* C_1-C_{20}) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a C_1-C_{60} (*e.g.* 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_{60} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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 $-P(=O)(Q_{31})(Q_{32})$, and Q_1 to Q_3, Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a C_1-C_{60} (*e.g.* 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_{60} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a C_1-C_{60} (*e.g.* C_1-C_{20}) hetero aryloxy group, a C_1-C_{60} (*e.g.* C_1-C_{20}) hetero arylthio group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group substituted with at least one selected from deuterium, -F, and a cyano group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryl group substituted with at least one selected from deuterium, -F, and a cyano group, a biphenyl group, and a terphenyl group.

[0044] In one embodiment, the organometallic compound may be selected from Compounds 1 to 178, but embodiments of the present disclosure are not limited thereto:





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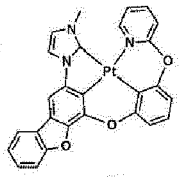

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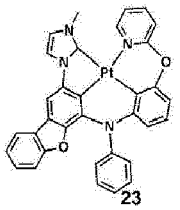

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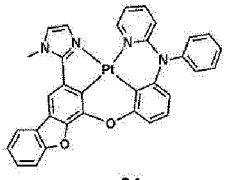

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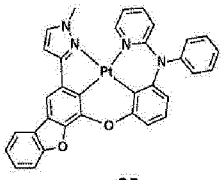

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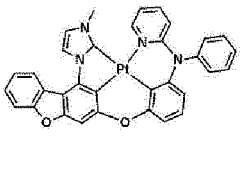

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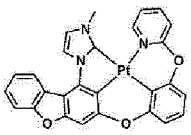

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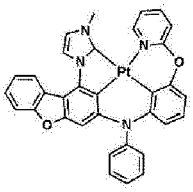

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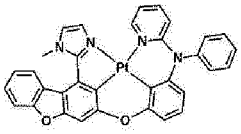

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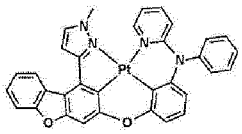

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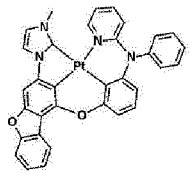

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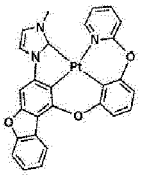

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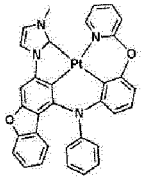

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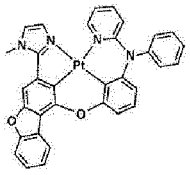

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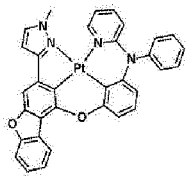

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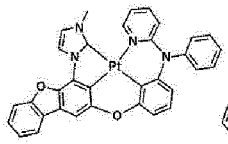

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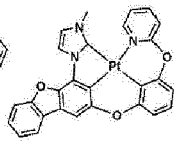

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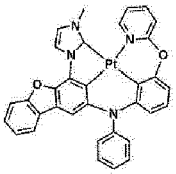

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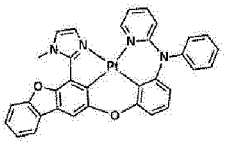

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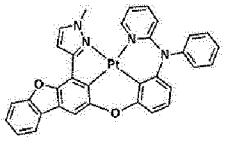

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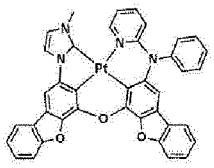

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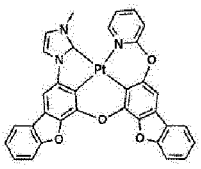

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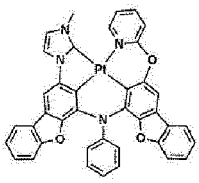

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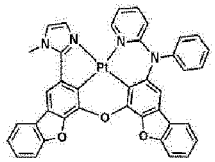

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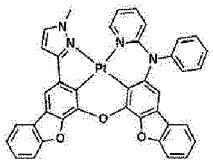

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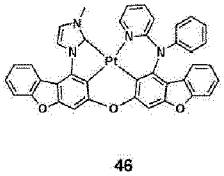

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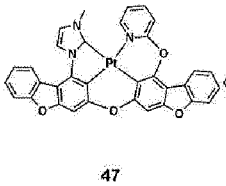

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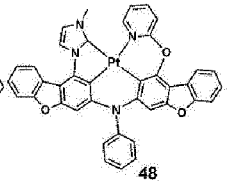

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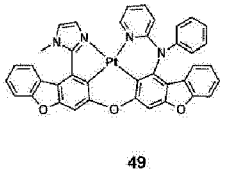

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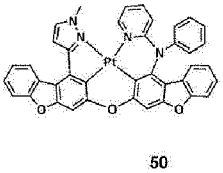

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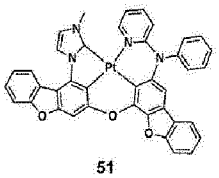

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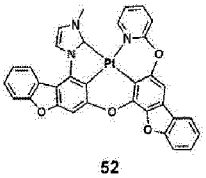

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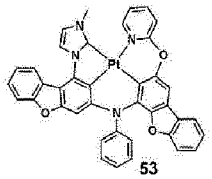

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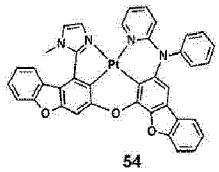

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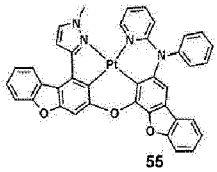

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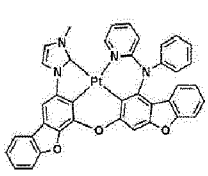
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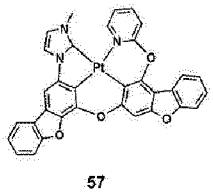
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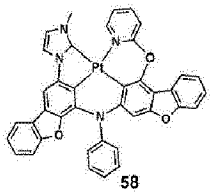
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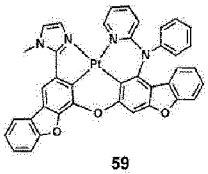
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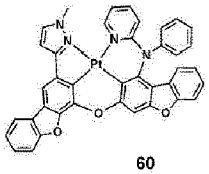
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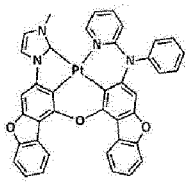
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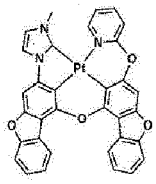
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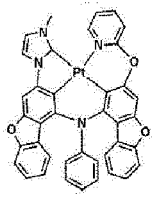
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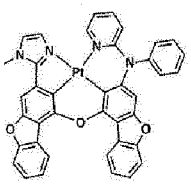
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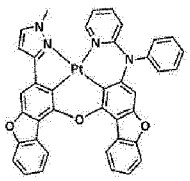
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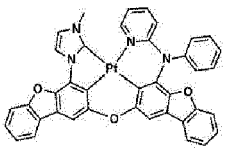
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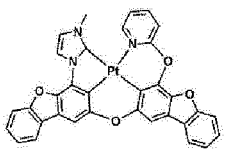
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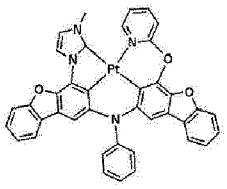
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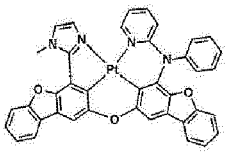
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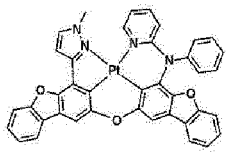
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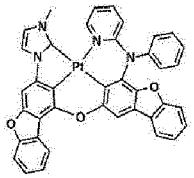
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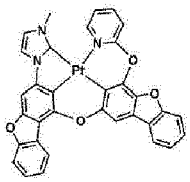
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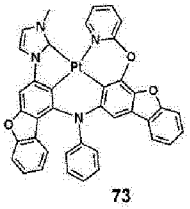
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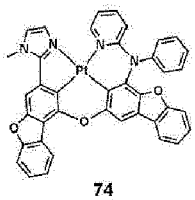
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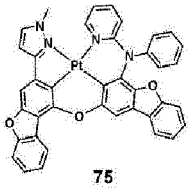
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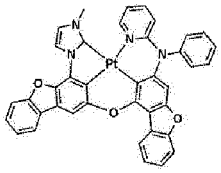
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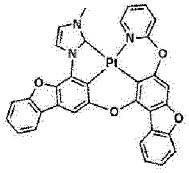
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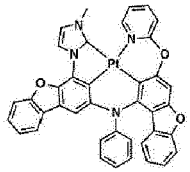
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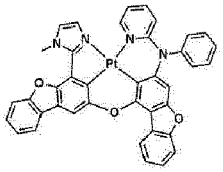
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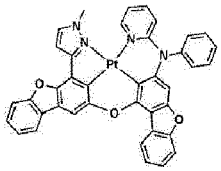
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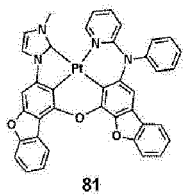
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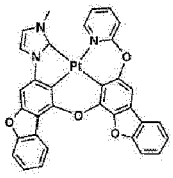
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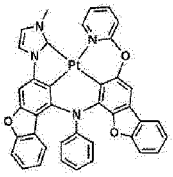
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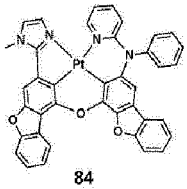
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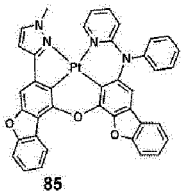
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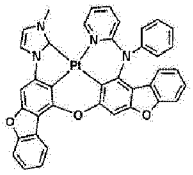
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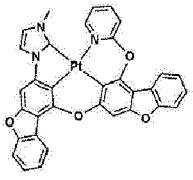
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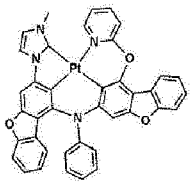
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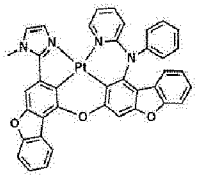
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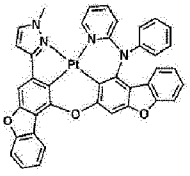
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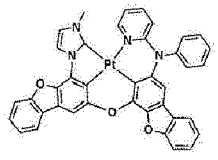

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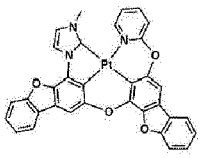

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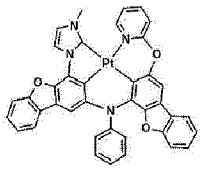

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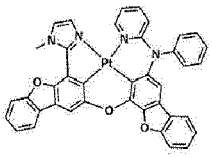

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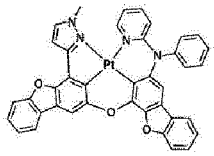

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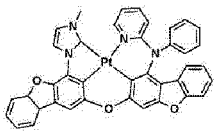

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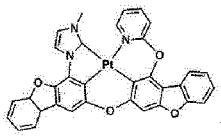

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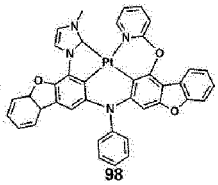

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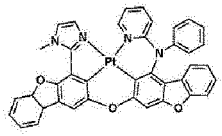

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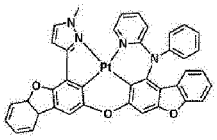

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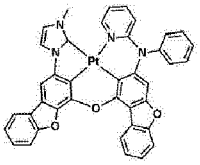

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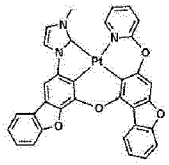

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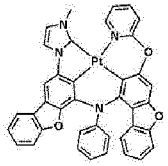

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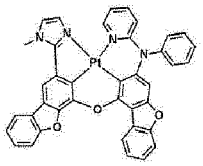

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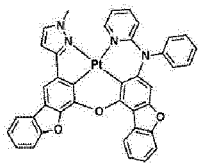

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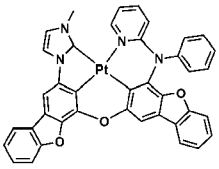

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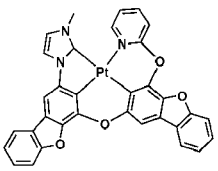

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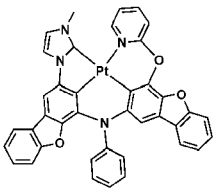

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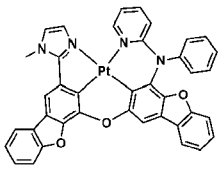

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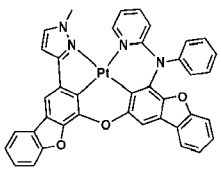

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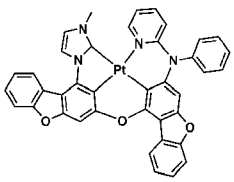

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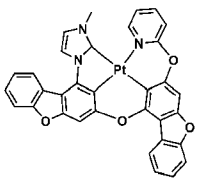

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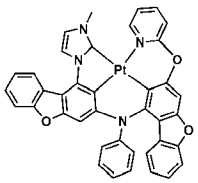

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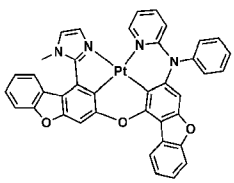

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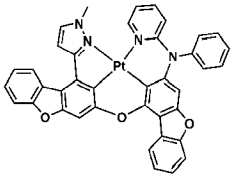

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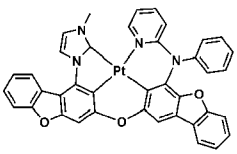

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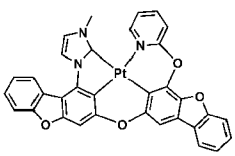

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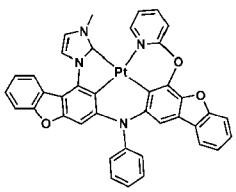

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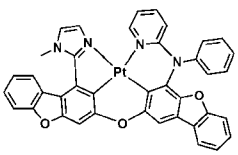

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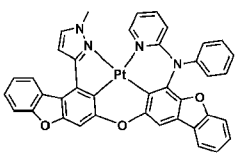

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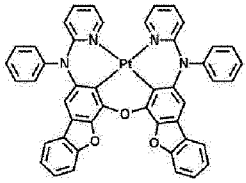

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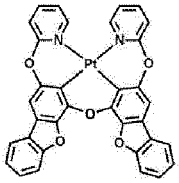

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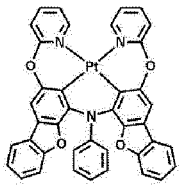

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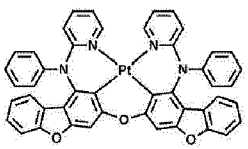

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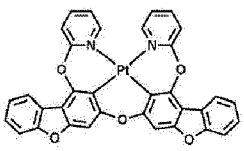

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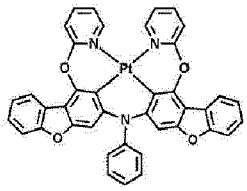

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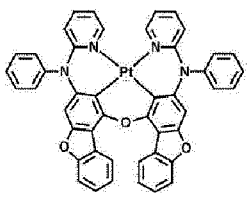

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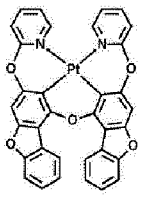

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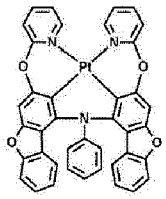

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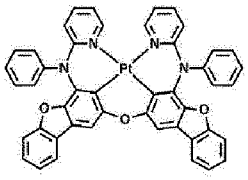

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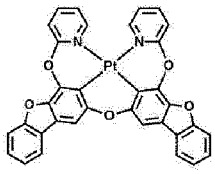

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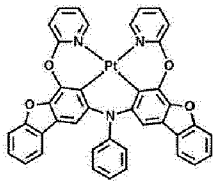

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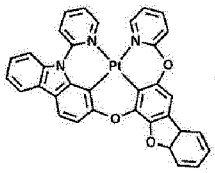

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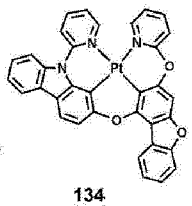

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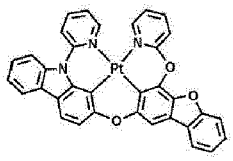

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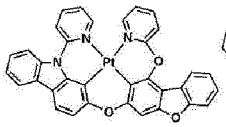

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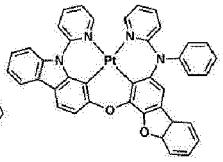

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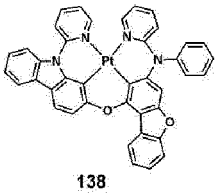

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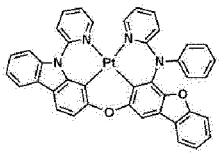

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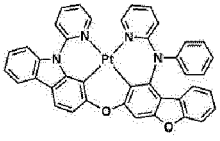

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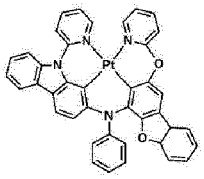

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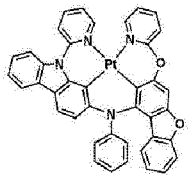

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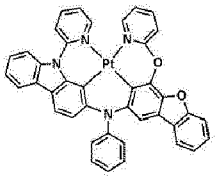

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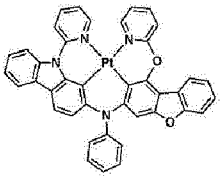

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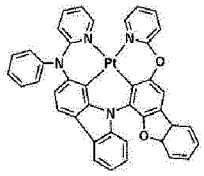

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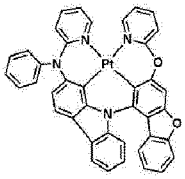

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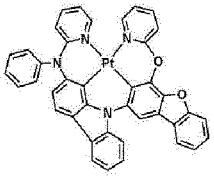

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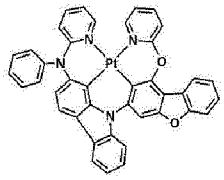

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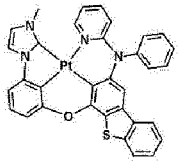

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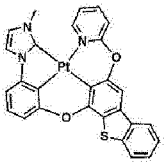

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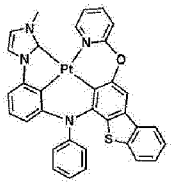

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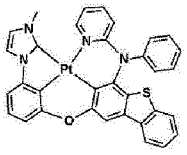

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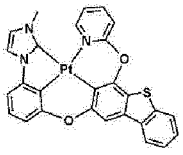

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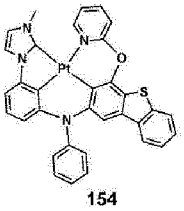

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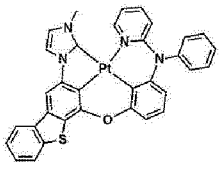

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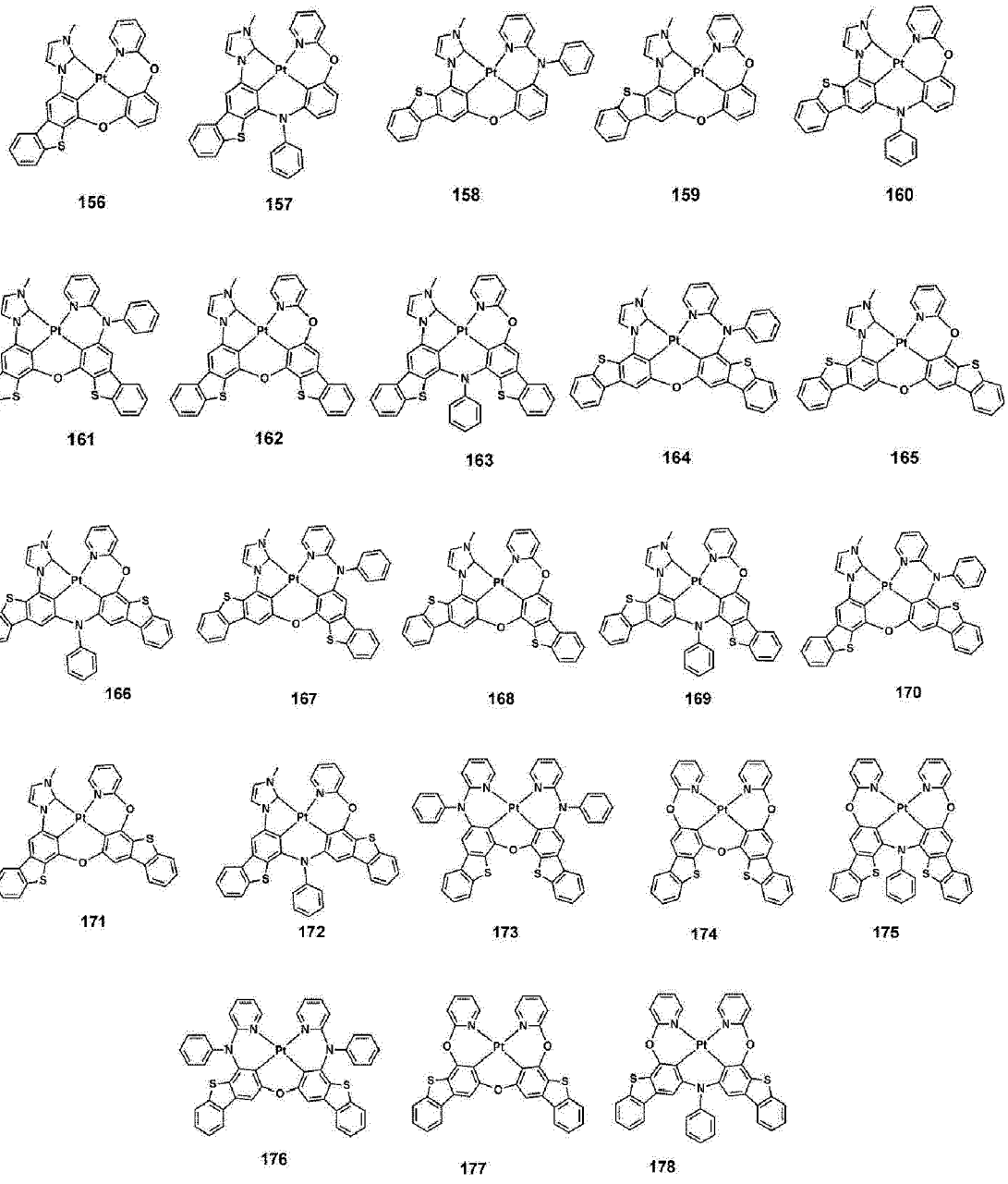


[0045] The organometallic compound represented by Formula 1 includes a moiety represented by Formula A-10 and has a structure in which the moiety represented by Formula A-10 is linked to ring A_{20} via L_{11} and linked to ring A_{40} via L_{14}. Because a 5-membered heterocyclic group (*e.g.* a dibenzofuran or dibenzothiophene structure) that is a rigid condensed structure exists in a ligand, the vibration of molecules may be reduced to thereby reduce an emission full width at half maximum (FWHM). In addition, because Stokes shift is reduced to exhibit a relative blue shift effect, it is an enhancement to blue phosphorescence with high color purity. In addition, the structure of the organometallic compound suppresses a decay of a non-emission path, thereby increasing luminescent efficiency of an organic light-emitting device.

[0046] Because dibenzofuran having donor characteristics is positioned in a condensed form at the second or third phenyl ring at which a highest occupied molecular orbital (HOMO) level exists, it does not greatly affect a lowest unoccupied molecular orbital (LUMO) level and blue light emission is maintained. In addition, because a triplet energy level of dibenzofuran or dibenzothiophene itself is very high, a triplet energy level of a phosphorescent body including the same is high. Therefore, when applying to the organic light-emitting device, energy transfer is facilitated and high luminescent efficiency and high purity may be achieved.

[0047] Because the organometallic compound represented by Formula 1 includes the moiety represented by Formula A-10, the organometallic compound has a rigid structure. Therefore, an organic light-emitting device, to which the organometallic compound is applied, may have high durability and a long lifespan.

[0048] The organometallic compound may emit blue light. For example, the organometallic compound may emit blue light (bottom-emission $CIE_{x,y}$ color coordinates 0.15, 0.05 to 0.15) having a maximum emission wavelength of about 450 nm to about 490 nm, for example, a maximum emission wavelength of about 458 nm to 488 nm, but embodiments of the present disclosure are not limited thereto. Therefore, the organometallic compound represented by Formula 1 may be suitably (e.g., usefully) utilized to manufacture an organic light-emitting device that emits blue light.

[0049] A synthesis method for the organometallic compound represented by Formula 1 would be apparent to those of ordinary skill in the art by referring to the following examples.

[0050] At least one of the organometallic compound of Formula 1 may be utilized 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 may act as a dopant in the emission layer.

[0051] According to an embodiment, 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 represented by Formula 1.

[0052] The expression "(an organic layer) includes at least one organometallic compound" as used herein may include a case in which "(an organic layer) includes the same (i.e., identical) compounds represented by Formula 1" and a case in which "(an organic layer) includes two or more different organometallic compounds represented by Formula 1."

[0053] For example, the organic layer may include, as the organometallic compound, only Compound 1. In this regard, Compound 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 and Compound 2. In this regard, Compound 1 and Compound 2 may exist in an identical layer (for example, Compound 1 and Compound 2 may both exist in an emission layer), or different layers (for example, Compound 1 may exist in an emission layer and Compound 2 may exist in an electron transport region).

[0054] According to one embodiment,

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

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

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,

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

the electron transport region may include a hole blocking layer, an electron transport layer, a buffer layer, an electron control layer, an electron injection layer, or any combination thereof.

[0055] The term "organic layer" as used herein refers to a single layer and/or a plurality of layers disposed between the first electrode and the second electrode of the organic light-emitting device. A material included in the "organic layer" is not limited to an organic material.

[0056] In one or more embodiments, the emission layer may include the organometallic compound represented by Formula 1, and may further include a host, wherein an amount of the host in the emission layer may be greater than that of the organometallic compound in the emission layer.

[0057] In one or more embodiments, the emission layer may further include a host, and the host may include a silyl-containing compound, a phosphine oxide-containing compound, or any combination thereof.

[0058] In one embodiment, the hole transport region may include an electron blocking layer, and the electron blocking layer may include the organometallic compound;

or the electron transport region may include a hole blocking layer, and the hole blocking layer may include the organometallic compound.

[0059] In one embodiment, the hole transport region may have a lowest unoccupied molecular orbital (LUMO) level of -3.5 eV or less.

[0060] In one or more embodiments, the electron transport region may include a hole blocking layer, and the hole blocking layer may be in direct contact with the emission layer, wherein the hole blocking layer may include a phosphine oxide-containing compound or a silyl-containing compound.

Description of the Drawing

[0061] The drawing 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.

[0062] 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 the drawing.

First electrode 110

[0063] In the drawing, 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.

[0064] 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.

[0065] 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), aluminium (Al), aluminium-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.

[0066] 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

[0067] The organic layer 150 is disposed on the first electrode 110. The organic layer 150 may include an emission layer.

[0068] 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.

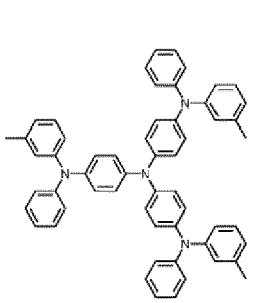
Hole transport region in organic layer 150

[0069] The hole transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including 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.

[0070] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

[0071] 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.

[0072] 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:



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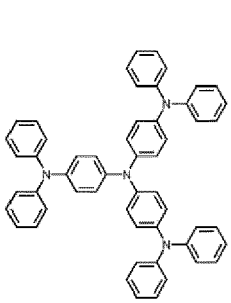

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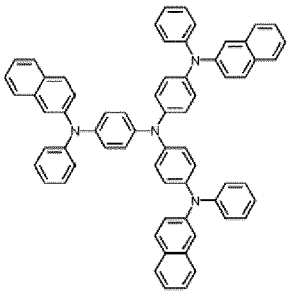

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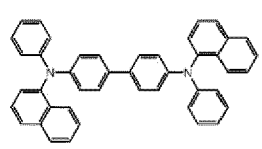
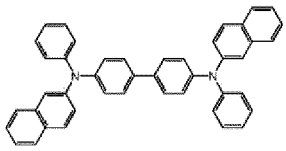
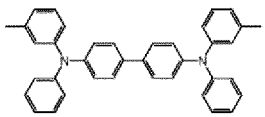
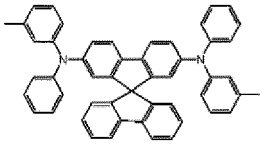
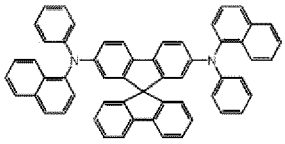
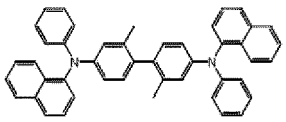

NPB

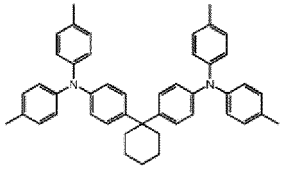

β-NPB

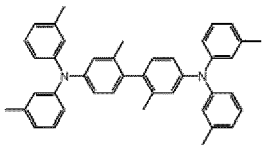

TPD


Spiro-TPD

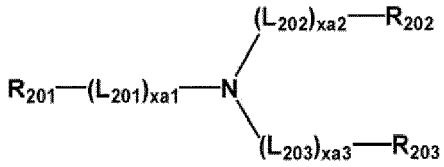

Spiro-NPB


methylated NPB

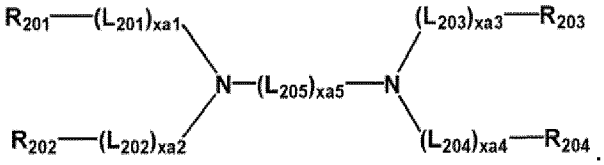

TAPC


HMTPD

Formula 201



Formula 202



In Formulae 201 and 202,

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} (*e.g.* C_6-C_{32}) arylene group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

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} (*e.g.* C_6-C_{32}) arylene group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

xa1 to xa4 may each independently be an integer of 0 to 3,

xa5 may be an integer of 1 to 10, and

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} cycloalke-

nyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} (*e.g.* C_6-C_{32}) aryl group, a substituted or unsubstituted C_6-C_{60} (*e.g.* C_6-C_{32}) aryloxy group, a substituted or unsubstituted C_6-C_{60} *(e.g.* C_6-C_{32}) arylthio group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0073] 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/or R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0074] In one embodiment, in Formulae 201 and 202, L_{201} to L_{205} may each independently be selected from:

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; and

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

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.

[0075] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0076] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0077] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from:

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group; and

a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an

azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, and a pyridinyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with -F, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, a heptalenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenalenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a naphthacenyl group, a picenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a rubicenyl group, a coronenyl group, an ovalenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, and $-N(Q_{31})(Q_{32})$, and
Q_{31} to Q_{33} may respectively be defined the same as described above in connection with L_{201} to L_{205}.

[0078] In one or more embodiments, in Formula 201, at least one selected from R_{201} to R_{203} may each independently be selected from:

a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and
a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with -F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group;
but embodiments of the present disclosure are not limited thereto.

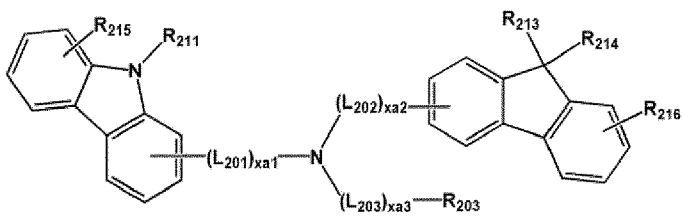
[0079] In one or more embodiments, in Formula 202, i) R_{201} and R_{202} may be linked via a single bond, and/or ii) R_{203} and R_{204} may be linked via a single bond.

[0080] In one or more embodiments, in Formula 202, at least one selected from R_{201} to R_{204} may be selected from:

a carbazolyl group; and
a carbazolyl group substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclopentenyl group, a cyclohexenyl group, a phenyl group, a biphenyl group, a terphenyl group, a phenyl group substituted with a C_1-C_{10} alkyl group, a phenyl group substituted with -F, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group,
but embodiments of the present disclosure are not limited thereto.

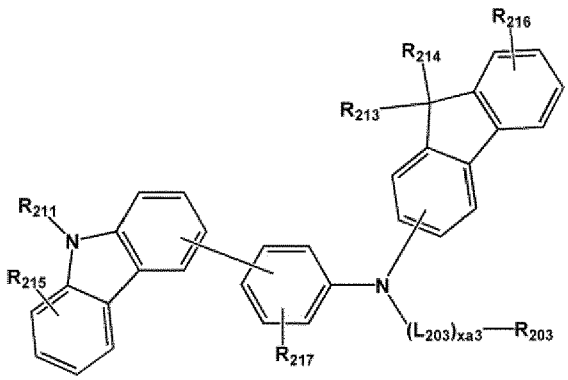
[0081] The compound represented by Formula 201 may be represented by Formula 201A:

Formula 201A



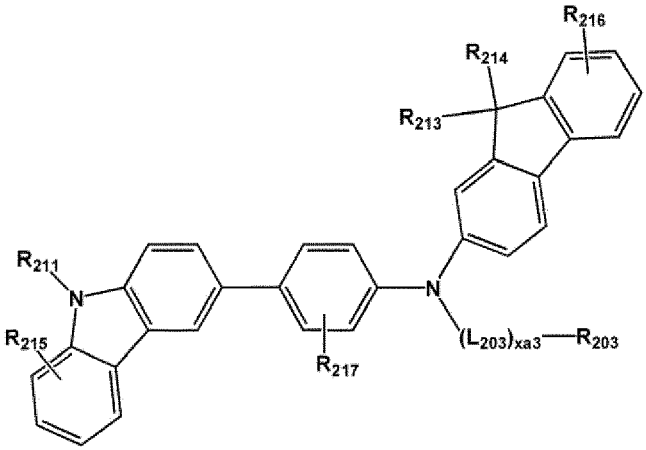
[0082] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:

Formula 201A(1)



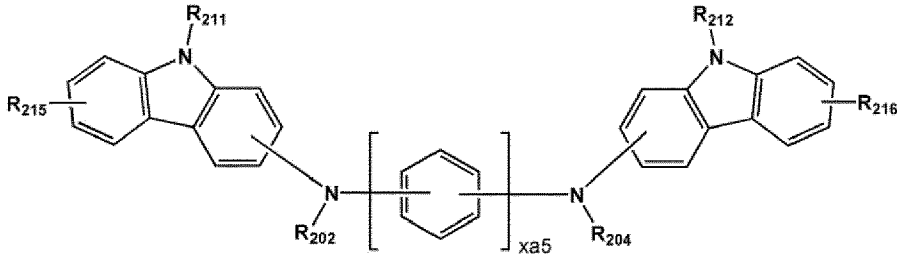
[0083] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:

Formula 201A-1



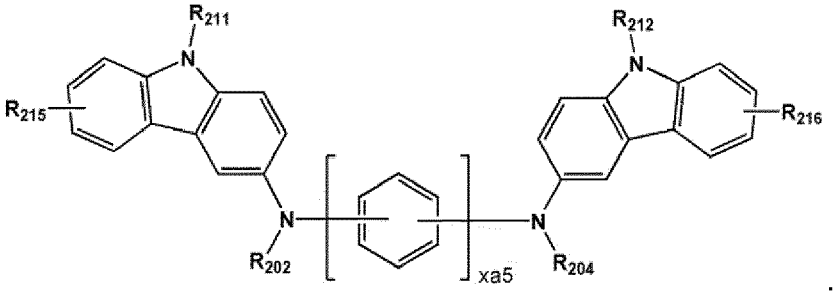
[0084] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A:

Formula 202A



[0085] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:

Formula 202A-1



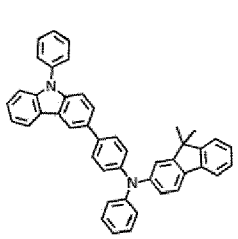
In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

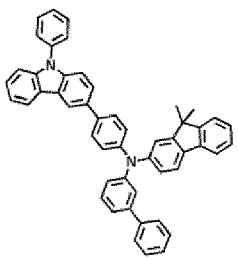
L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R204 may respectively be defined the same as described above in connection with Formulae 201 and 202,

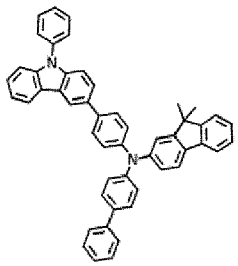
R_{211} and R_{212} may respectively be defined the same as described in connection with R_{203} in Formulae 201 and 202.

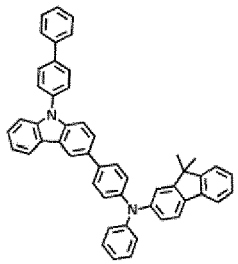
R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl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

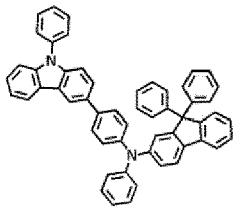
[0086] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

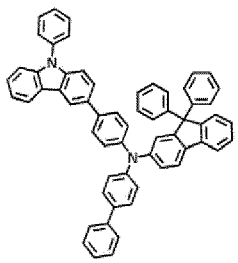

HT1

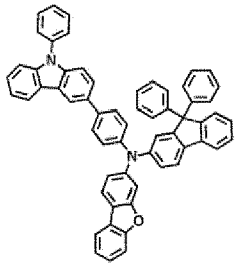

HT2


HT3

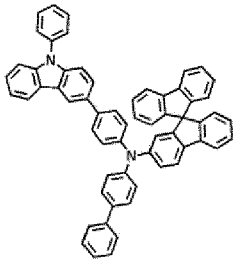

HT4


HT5

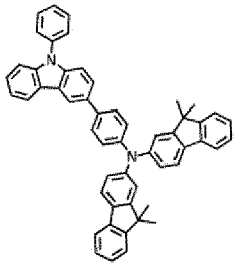

HT6



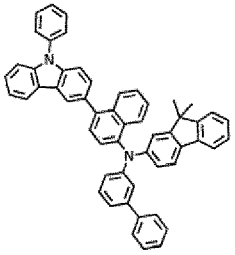
HT7



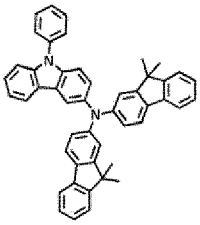
HT8



HT9



HT10



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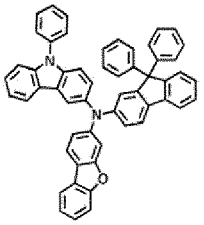

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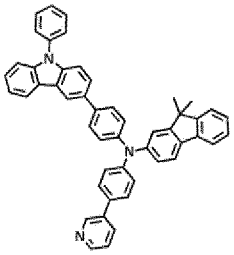

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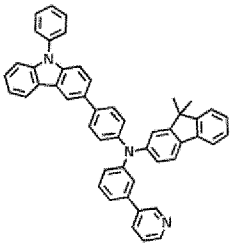

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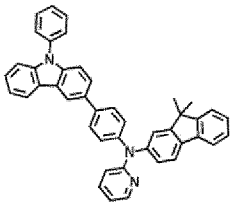

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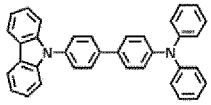

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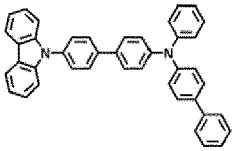

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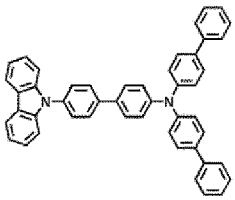

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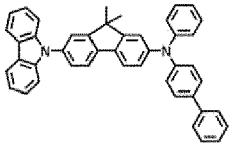

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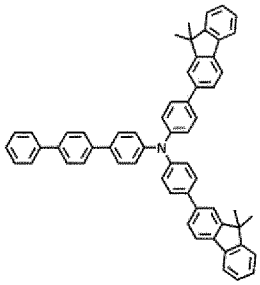

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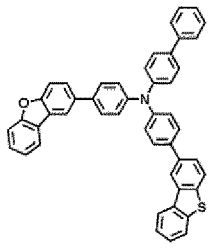

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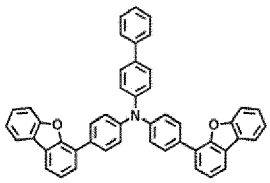

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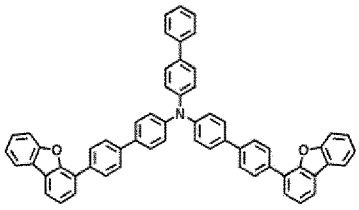

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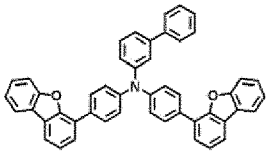

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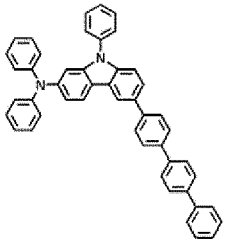

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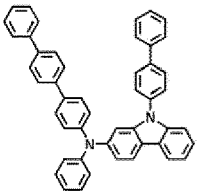

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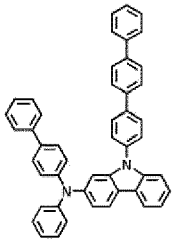

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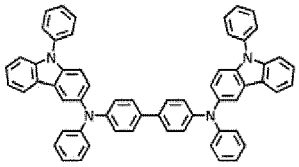

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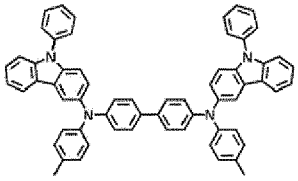

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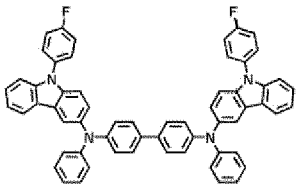

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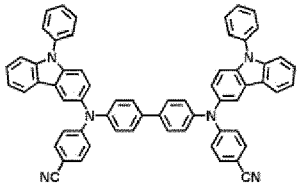

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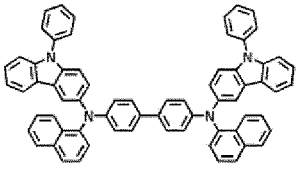

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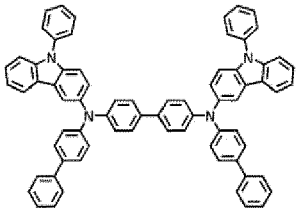

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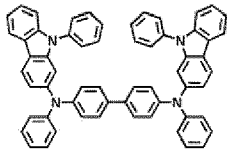

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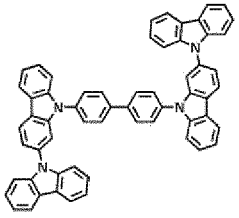

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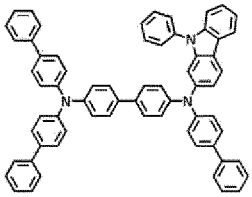

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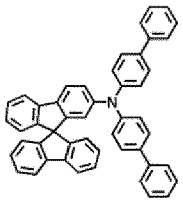

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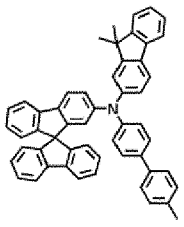

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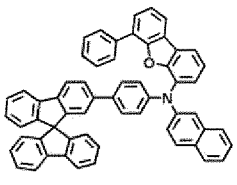


HT39

[0087] 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 7000 Å, about 100 Å to about 5000 Å, about 100 Å to about 3000 Å, or 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 7,000 Å, about 100 Å to about 5,000 Å, about 100 Å to about 3,000 Å, about 100 Å to about 2,000 Å about 100 Å to about 1,000 Å or about 500 Å to about 700 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, about 100 Å to about 1,000 Å, about 100 Å to about 800 Å, about 100 Å to about 500 Å, or about 200 Å to about 400 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.

[0088] The emission auxiliary layer may increase light-emission efficiency by compensating for an optical resonance distance according to the wavelength of light emitted by an emission layer, and the electron blocking layer may block the flow of electrons from an electron transport region. The emission auxiliary layer and the electron blocking layer may include the materials as described above.

p-dopant

[0089] 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.

[0090] The charge-generation material may be, for example, a p-dopant.

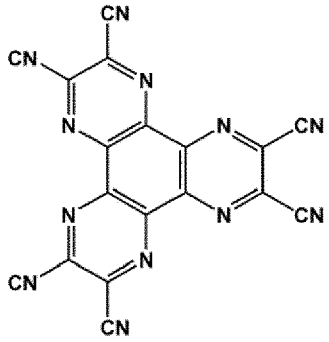
[0091] In one embodiment, the LUMO energy level of the p-dopant may be about - 3.5 eV or less.

[0092] 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.

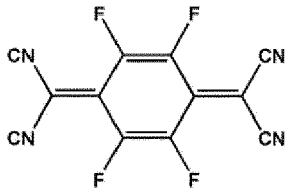
[0093] For example, the p-dopant may include at least one selected from:

a quinone derivative, such as tetracyanoquinodimethane (TCNQ) or 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);
a metal oxide, such as tungsten oxide or molybdenum oxide;
1,4,5,8,9,11-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and
a compound represented by Formula 221,
but embodiments of the present disclosure are not limited thereto:

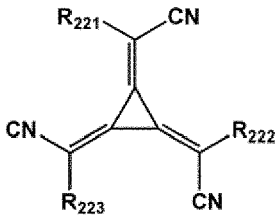
HAT-CN



F4-TCNQ



Formula 221



In Formula 221,
R_{221} to R_{223} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a sub-

stituted 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} (*e.g.* C_6-C_{32}) aryl group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, wherein at least one selected from R_{221} to R_{223} may include 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]

[0094] 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 are in contact with each other or are separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0095] 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. In addition, the phosphorescent dopant may include an organometallic compound represented by Formula 1.

[0096] In the emission layer, an amount of the dopant may be generally in a range of about 0.01 parts by weight 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.

[0097] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 100 Å to about 800 Å, about 150 Å to about 800 Å, about 150 Å to about 700 Å, about 150 Å to about 650 Å, about 200 Å to about 600 Å or about 200 Å to about 400 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]

[0098] In one or more embodiments, the host may include a compound represented by Formula 301:

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

In Formula 301,

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,

xb11 may be 1, 2, or 3,

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,

xb1 may be an integer from 0 to 5,

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

xb21 may be an integer from 1 to 5, and

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.

[0099] For example, Ar_{301} may be a substituted or unsubstituted C_6-C_{32} carbocyclic group or a substituted or unsubstituted C_1-C_{12} heterocyclic group, but embodiments are not limited thereto.

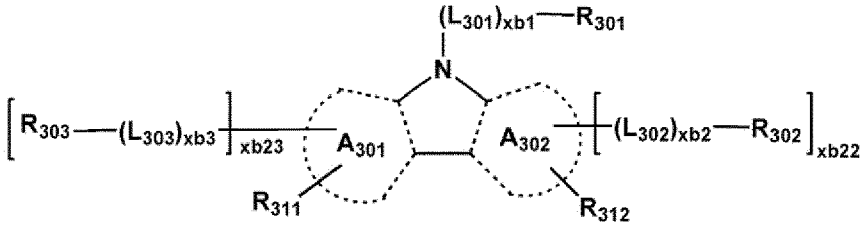
[0100] In one embodiment, Ar_{301} in Formula 301 may be selected from:

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

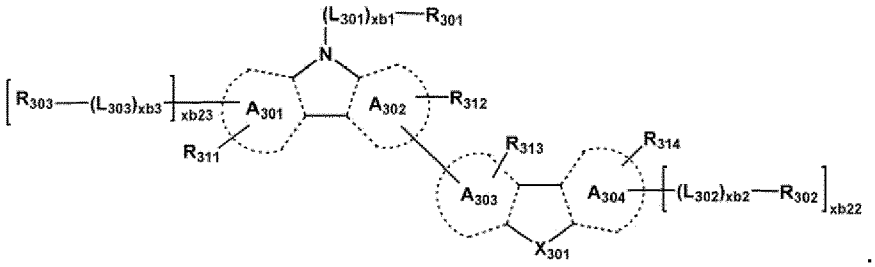
[0101] When xb11 in Formula 301 is two or more, two or more Ar_{301}(s) may be linked via a single bond.

[0102] In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or Formula 301-2:

Formula 301-1



Formula 301-2



In Formulae 301-1 and 301-2,

A_{301} to A_{304} may each independently be selected from a benzene, a naphthalene, a phenanthrene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a pyridine, a pyrimidine, an indene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, an indole, a carbazole, benzocarbazole, dibenzocarbazole, a furan, a benzofuran, a dibenzofuran, a naphthofuran, a benzonaphthofuran, dinaphthofuran, a thiophene, a benzothiophene, a dibenzothiophene, a naphthothiophene, a benzonaphthothiophene, and a dinaphthothiophene,
X_{301} may be O, S, or N-[$(L_{304})_{xb4}$-R_{304}],
R_{311} to R_{314} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group -$Si(Q_{31})(Q_{32})(Q_{33})$, -$N(Q_{31})(Q_{32})$,

$-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$,
xb22 and xb23 may each independently be 0, 1, or 2,
L_{301}, xb1, R_{301}, and Q_{31} to Q_{33} may respectively be defined the same as described above in connection with Formula 301,
L_{302} to L_{304} may respectively be defined the same as described in connection with L_{301} in Formula 301,
xb2 to xb4 may respectively be defined the same as described in connection with xb1 in Formula 301, and
R_{302} to R_{304} may respectively be defined the same as described in connection with R_{301} in Formula 301.

[0103] For example, L_{301} to L_{304} in Formulae 301, 301-1, and 301-2 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_{30} arylene group, a substituted or unsubstituted C_1-C_{20} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, but embodiments are not limited thereto.

[0104] For example, in Formulae 301, 301-1, and 301-2, L_{301} to L_{304} may each independently be selected from:

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

$-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$, and
Q_{31} to Q_{33} may respectively be defined the same as described above in connection with Formula 301.

[0105] As another example, R_{301} to R_{304} in Formulae 301, 301-1, and 301-2 may each independently be selected from: deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{10}) alkyl group, a substituted or unsubstituted C_2-C_{60} (*e.g.* C_2-C_{10}) alkenyl group, a substituted or unsubstituted C_2-C_{60} (*e.g.* C_2-C_{10}) alkynyl group, a substituted or unsubstituted C_1-C_{60} (*e.g.* C_1-C_{10}) 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_{30} aryl group, a substituted or unsubstituted C_6-C_{30} aryloxy group, a substituted or unsubstituted C_6-C_{30} arylthio group, a substituted or unsubstituted C_1-C_{20} 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 $-P(=O)(Q_{301})(Q_{302})$, but embodiments are not limited thereto.

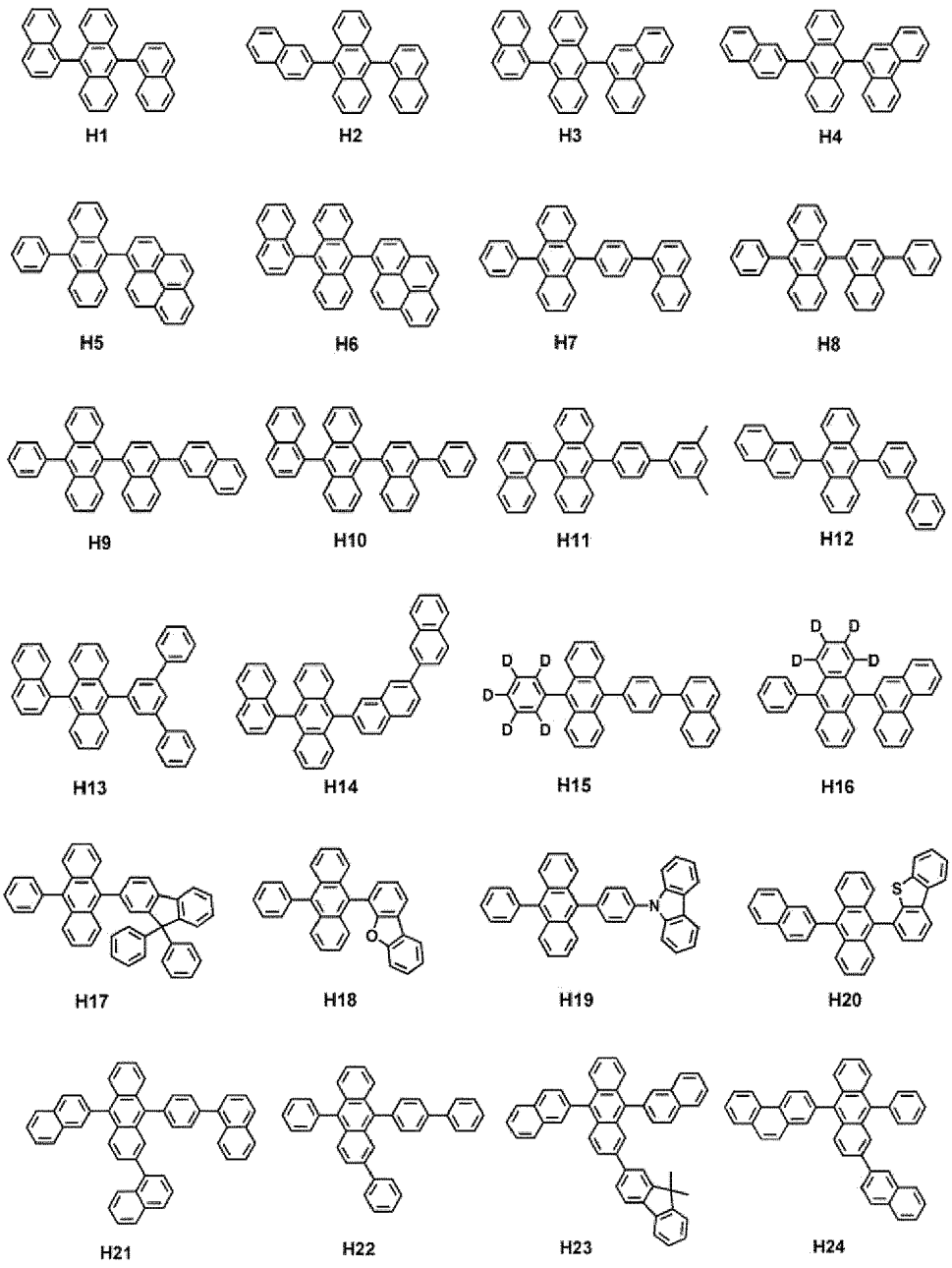
[0106] In one embodiment, in Formulae 301, 301-1, and 301-2, R_{301} to R_{304} may each independently be selected from:

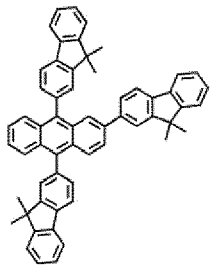
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl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

a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an 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
Q_{31} to Q_{33} may respectively be defined the same as described above in connection with Formula 301.

[0107] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may include a complex selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0108] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:





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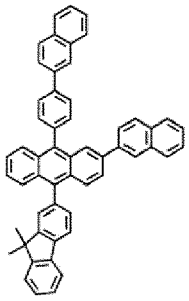

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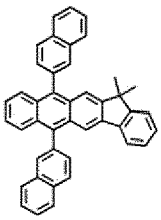

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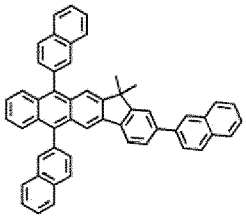

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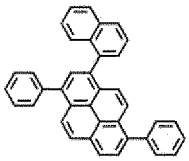

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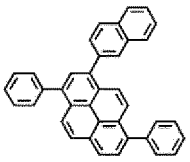

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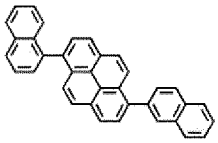

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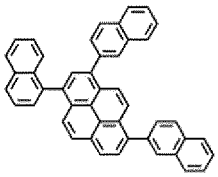

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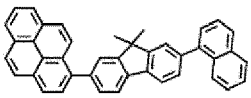

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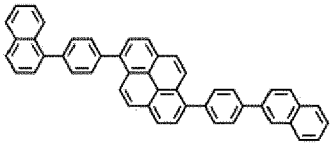

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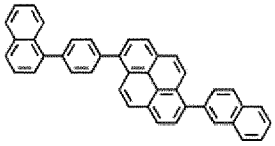

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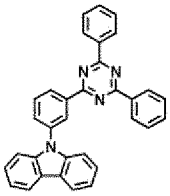

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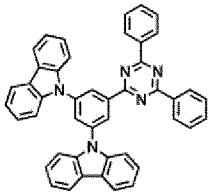

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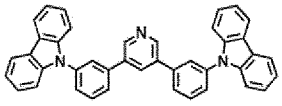

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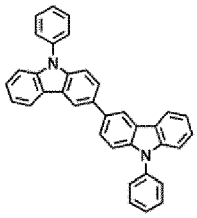

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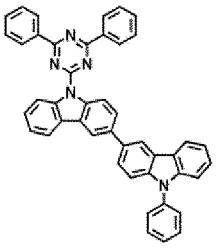

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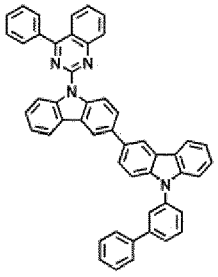

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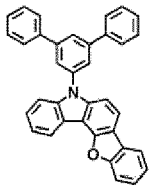

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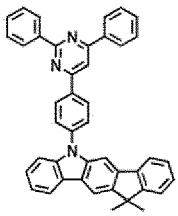

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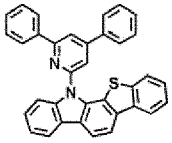

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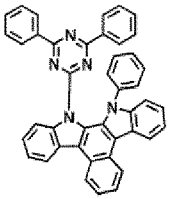

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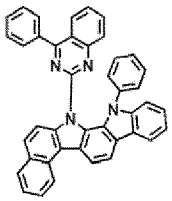

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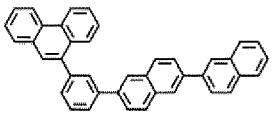

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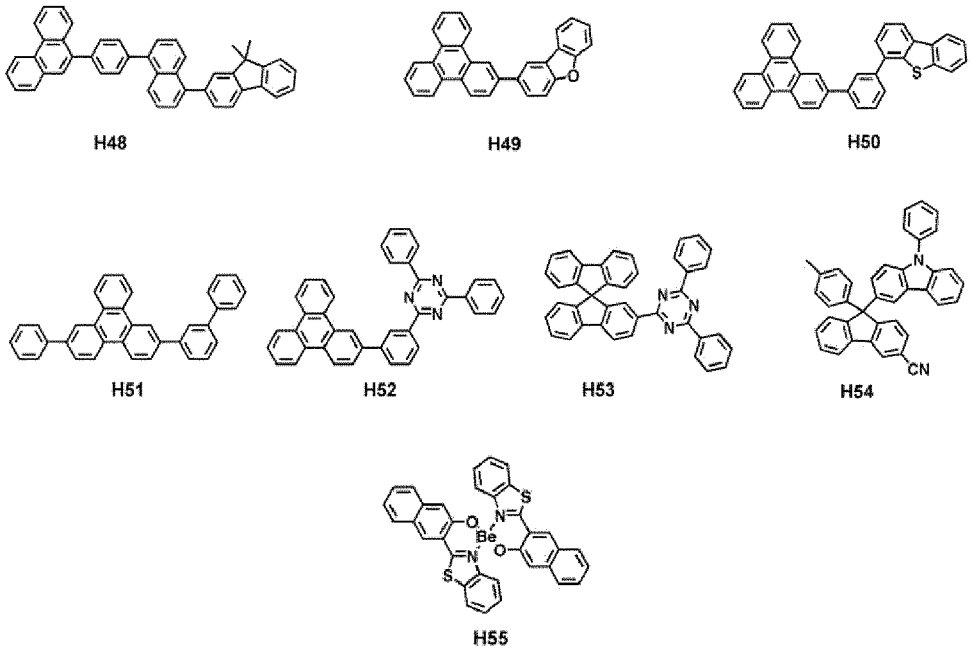


[0109] In one embodiment, the host may include at least one selected from a silicon-containing compound (for example, BCPDS utilized in the following examples or the like) and a phosphine oxide-containing compound (for example, POPCPA utilized in the following examples or the like).

[0110] However, embodiments of the present disclosure are not limited thereto. In one embodiment, the host may include only one compound, or two or more different compounds (for example, a host utilized in the following examples includes BCPDS and POPCPA).

Phosphorescent dopant included in emission layer in organic layer 150

[0111] The phosphorescent dopant may include an organometallic compound represented by Formula 1 described above.

Electron transport region in organic layer 150

[0112] The electron transport region may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including 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.

[0113] 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.

[0114] 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.

[0115] 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.

[0116] The term "π electron-depleted nitrogen-containing ring" as used herein refers to a C_1-C_{60} (*e.g.* C_1-C_{30}) heterocyclic group having at least one *-N=*' moiety as a ring-forming moiety.

[0117] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one *-N=*' moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *-N=*' moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *-N=*' moiety, is condensed with at least one C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group.

[0118] 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, thiadiazole, an imidazopyridine, an imidazopyrimidine, and an azacarbazole, but embodiments of the present disclosure are not limited thereto.

[0119] For example, the electron transport region may include a compound represented by Formula 601:

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

In Formula 601,

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,
xe11 may be 1, 2, or 3,
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,
xe1 may be an integer from 0 to 5,
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 $-P(=O)(Q_{601})(Q_{602})$,
Q_{601} to Q_{603} 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 or a naphthyl group, and
xe21 may be an integer from 1 to 5.

[0120] In one embodiment, at least one of Ar_{601}(s) in the number of xe11 and R_{601}(s) in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

[0121] For example, Ar_{601} may be a substituted or unsubstituted C_5-C_{30} carbocyclic group or a substituted or unsubstituted C_1-C_{20} heterocyclic group, but embodiments are not limited thereto.

[0122] In one embodiment, in Formula 601, ring Ar_{601} may be selected from:

a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole group, an imidazopyridine group, an imidazopyrimidine group, and an azacarbazole group; and
a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a phenanthridine group, an acridine group, a phenanthroline group, a phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, a thiadiazole 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 hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, $-Si(Q_{31})(Q_{32})(Q_{33})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$, and

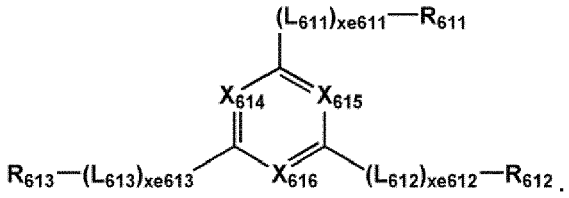
Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0123] When xe11 in Formula 601 is two or more, two or more Ar601 (s) may be linked via a single bond.

[0124] In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

[0125] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



In Formula 601-1,

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,

L_{611} to L_{613} may respectively be defined the same as described in connection with L_{601} in Formula 601,

xe611 to xe613 may respectively be defined the same as described in connection with xe1 in Formula 601,

R_{611} to R_{613} may respectively be defined the same as described in connection with R_{601} in Formula 601, and

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

[0126] For example, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 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_{30} arylene group, a substituted or unsubstituted C_1-C_{20} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group, but embodiments are not limited thereto.

[0127] In one embodiment, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

a phenylene group, a naphthylene group, a fluorenylene group, a spirobifluorenylene 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

a phenylene group, a naphthylene group, a fluorenylene group, a spirobifluorenylene 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 dibenzo-

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

[0128] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0129] For example, R_{601} and R_{611} to R_{613} in Formulae 601 and 601-1 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_{30} aryl group, a substituted or unsubstituted C_6-C_{30} aryloxy group, a substituted or unsubstituted C_6-C_{30} arylthio group, a substituted or unsubstituted C_1-C_{20} 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 $-P(=O)(Q_{601})(Q_{602})$.

[0130] In one or more embodiments, in Formulae 601 and 601-1, R_{601} and R_{611} to R_{613} may each independently be selected from:

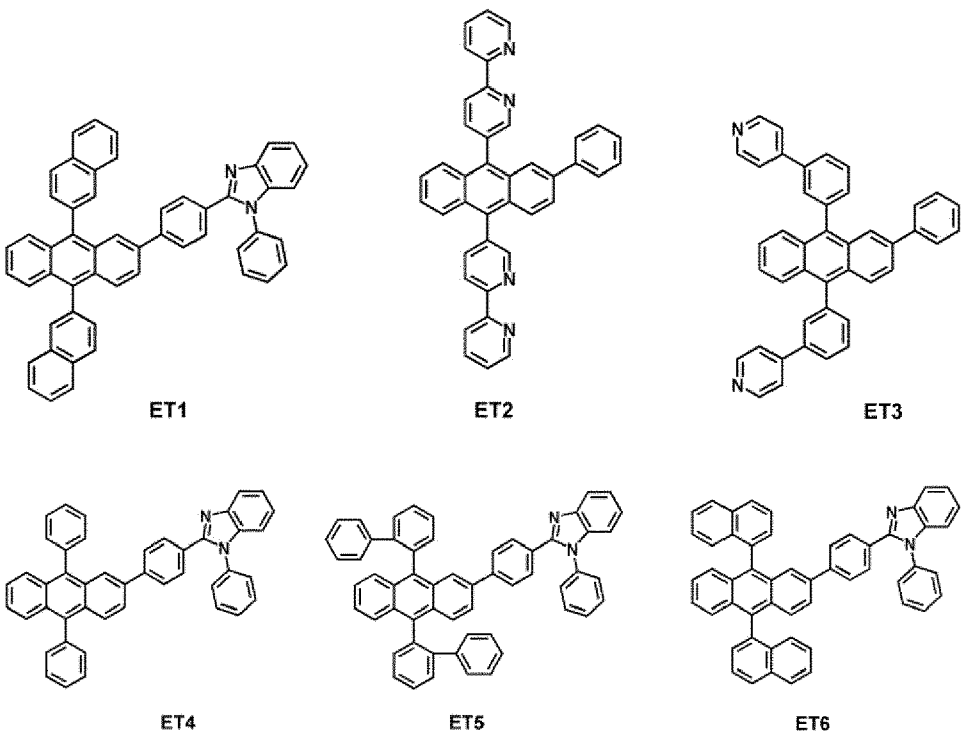
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl 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;
a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group,

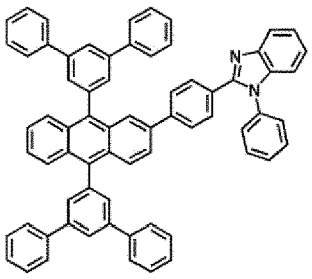
an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group,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

$-S(=O)_2(Q_{601})$ and $-P(=O)(Q_{601})(Q_{602})$, and

Q_{601} and Q_{602} may respectively be defined the same as described above in connection with Formula 601.

[0131] 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:





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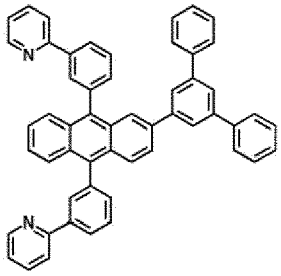

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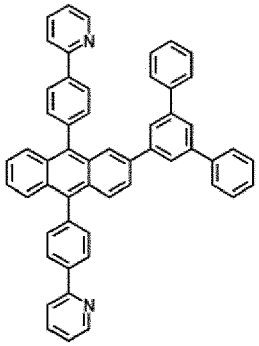

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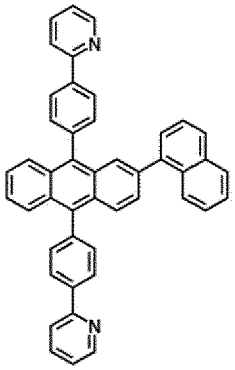

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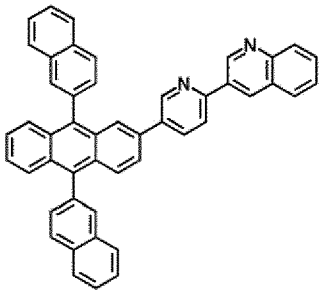

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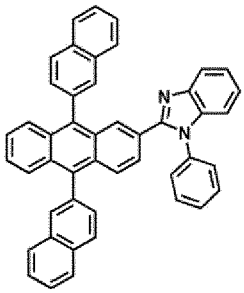

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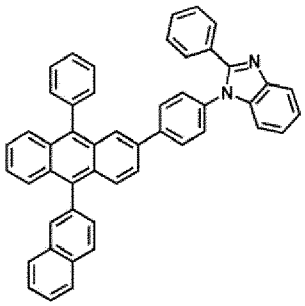

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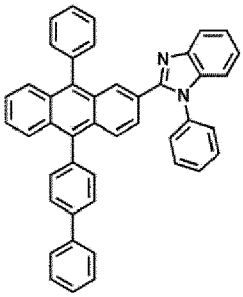

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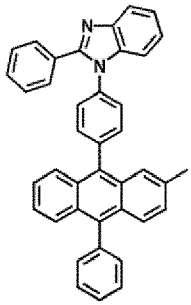

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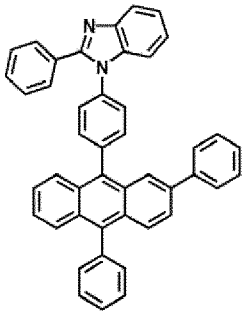
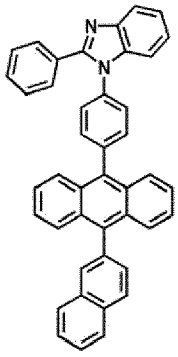


ET16



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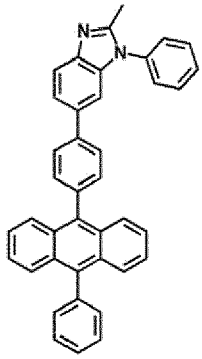

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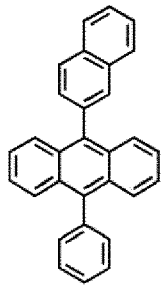

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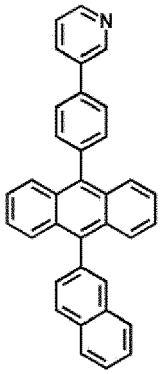

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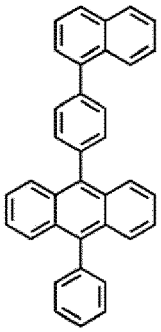

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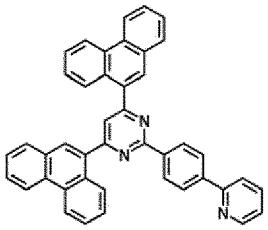

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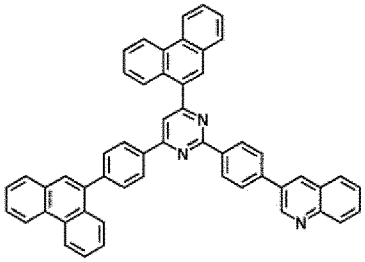

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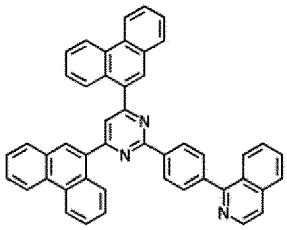

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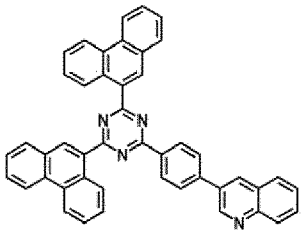

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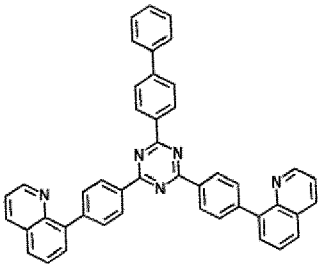

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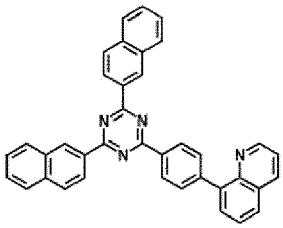

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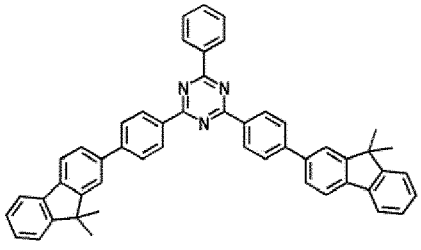

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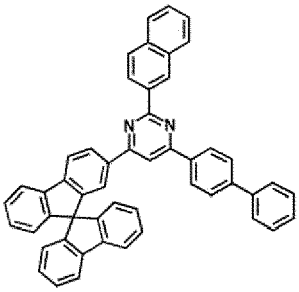

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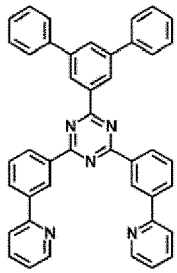

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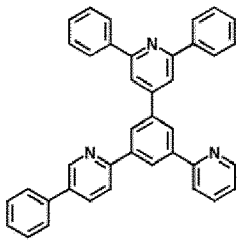

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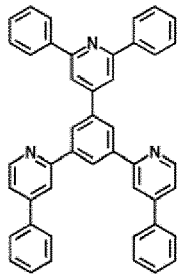

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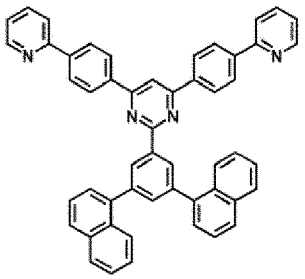

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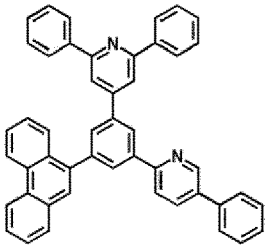

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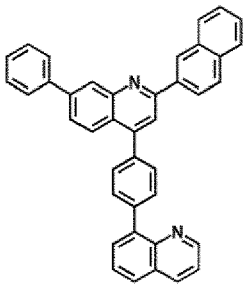

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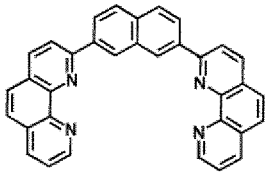
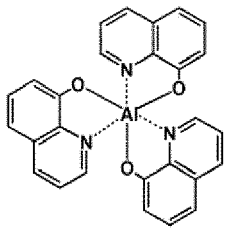
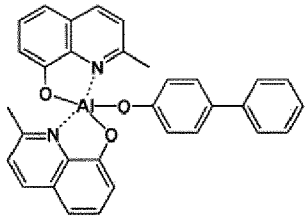


ET36

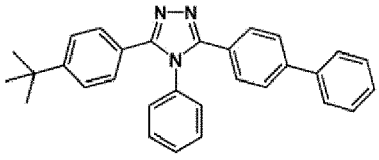
[0132] In one or more embodiments, the electron transport region may include at least one compound selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-diphenyl-1,10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-*tert*-butylphenyl)-4-phenyl-4*H*-1,2,4-triazole (TAZ), and NTAZ.



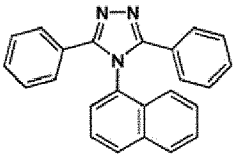
Alq_3



BAlq



TAZ



NTAZ

[0133] In one embodiment, the electron transport region may include a phosphine oxide-containing compound (for example, TSPO1 utilized in the following examples or the like), but embodiments of the present disclosure are not limited thereto. In one embodiment, the phosphine oxide-containing compound may be utilized in a hole blocking layer in the electron transport region, but embodiments of the present disclosure are not limited thereto.

[0134] 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 20 Å to about 700 Å, about 20 Å to about 500 Å, about 20 Å to about 400 Å, about 30 Å to about 400 Å or 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.

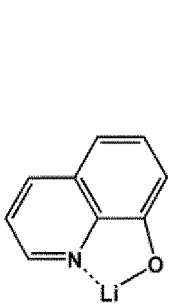
[0135] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 100 Å to about 700 Å, about 100 Å to about 600 Å, about 150 Å to about 600 Å, about 150 Å to about 500 Å or about 250 Å to about 350 Å. When the thickness of the electron transport layer is within the range described above, the

electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

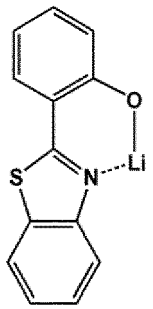
[0136] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0137] The metal-containing material may include at least one selected from alkali metal complex and alkaline earth-metal complex. The alkali metal complex may include a metal ion selected from a Li ion, a Na ion, a K ion, a Rb ion, and a Cs ion, and the alkaline earth-metal complex may include a metal ion selected from a Be ion, a Mg ion, a Ca ion, a Sr ion, and a Ba ion. A ligand coordinated with the metal ion of the alkali metal complex or the alkaline earth-metal complex may be selected from a hydroxy quinoline, a hydroxy isoquinoline, a hydroxy benzoquinoline, a hydroxy acridine, a hydroxy phenanthridine, a hydroxy phenyloxazole, a hydroxy phenylthiazole, a hydroxy diphenyloxadiazole, a hydroxy diphenylthiadiazole, 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.

[0138] For example, the metal-containing material may include a Li complex. The Li complex may include, for example, Compound ET-D1 (lithium quinolate, LiQ) or ET-D2.



ET-D1



ET-D2

[0139] 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 be in direct contact with the second electrode 190.

[0140] The electron injection layer may have i) a single-layered structure including a single layer including a single material, ii) a single-layered structure including 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.

[0141] The electron injection layer may include an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof.

[0142] The alkali metal may be selected from Li, Na, K, Rb, and Cs. In one embodiment, 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.

[0143] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0144] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0145] The alkali metal compound, the alkaline earth-metal compound, and the rare earth metal compound may be selected from oxides and halides (for example, fluorides, chlorides, bromides, or iodides) of the alkali metal, the alkaline earth-metal, and the rare earth metal.

[0146] 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 embodiment, 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.

[0147] 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 embodiment, the alkaline earth-metal compound may be selected from BaO, SrO, and CaO, but embodiments of the present disclosure are not limited thereto.

[0148] The rare earth metal compound may be selected from YbF_3, ScF_3, Sc_2O_3, Y_2O_3, Ce_2O_3, GdF_3, and TbF_3. In one embodiment, 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.

[0149] The alkali metal complex, the alkaline earth-metal complex, and the rare earth metal complex may include an ion of alkali metal, alkaline earth-metal, and rare earth metal as described above, and a ligand coordinated with a metal ion of the alkali metal complex, the alkaline earth-metal complex, or the rare earth metal complex may be selected from hydroxy quinoline, hydroxy isoquinoline, hydroxy benzoquinoline, hydroxy acridine, hydroxy phenanthridine, hydroxy phenyloxazole, hydroxy phenylthiazole, hydroxy diphenyloxadiazole, hydroxy diphenylthiadiazole, hydroxy phenylpyri-

dine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0150] The electron injection layer may include (e.g., consist of) an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0151] 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 or about 3 Å to about 20 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

[0152] 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.

[0153] The second electrode 190 may include at least one selected from lithium (Li), silver (Ag), magnesium (Mg), aluminium (Al), aluminium-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.

[0154] The second electrode 190 may have a single-layered structure, or a multi-layered structure including two or more layers.

[0155] Layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region may be formed in a certain region utilizing 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.

[0156] When layers constituting the hole transport region, the emission layer, and layers constituting the electron transport region are formed by vacuum deposition, the deposition may be performed at a deposition temperature of about 100 °C to about 500 °C, a vacuum degree of about 10^{-8} torr to about 10^{-3} torr, and a deposition speed of about 0.01 Å/sec to about 100 Å/sec by taking into account a material to be included in a layer to be formed, and the structure of a layer to be formed.

[0157] 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 2000 rpm to about 5000 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

[0158] The term "C_1-C_{60} alkyl group" as used herein refers to a linear or branched aliphatic saturated hydrocarbon monovalent group having 1 to 60 carbon atoms, and examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an isoamyl group, and a hexyl group. The term "C_1-C_{60} alkylene group" as used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkyl/alkylene group.

[0159] The term "C_2-C_{60} alkenyl group" as used herein refers to a hydrocarbon group having at least one carbon-carbon double bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and examples thereof include an ethenyl group, a propenyl group, and a butenyl group. The term "C_2-C_{60} alkenylene group" as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkenyl/alkenylene group.

[0160] The term "C_2-C_{60} alkynyl group" as used herein refers to a hydrocarbon group having at least one carbon-carbon triple bond in the middle or at the terminus of the C_2-C_{60} alkyl group, and examples thereof include an ethynyl group, and a propynyl group. The term "C_2-C_{60} alkynylene group" as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkynyl/alkynylene group.

[0161] The term "C_1-C_{60} alkoxy group" as used herein refers to a monovalent group represented by $-OA_{101}$ (wherein

A_{101} represents the C_1-C_{60} alkyl group), and examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group. Corresponding definitions apply to other ranges given for the number of carbon atoms in an alkoxy group.

[0162] 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.

[0163] The term "C_1-C_{10} heterocycloalkyl group" as used herein refers to a monovalent monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom in addition to 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.

[0164] The term "C_3-C_{10} cycloalkenyl group" as used herein refers to a monovalent monocyclic group that has 3 to 10 carbon atoms and at least one carbon-carbon double bond in the ring thereof and no aromaticity, and examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group" as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

[0165] 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 in addition to 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.

[0166] 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 the term "C_6-C_{60} arylene group" as 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. Corresponding definitions apply to other ranges given for the number of carbon atoms in an aryl/arylene group.

[0167] 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 60 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. Corresponding definitions apply to other ranges given for the number of carbon atoms in an heteroaryl/heteroarylene group.

[0168] The term "C_6-C_{60} aryloxy group" as used herein refers to $-OA_{102}$ (wherein A_{102} represents the C_6-C_{60} aryl group), and the term "C_6-C_{60} arylthio group" as used herein refers to $-SA_{103}$ (wherein A_{103} represents the C_6-C_{60} aryl group). Corresponding definitions apply to other ranges given for the number of carbon atoms in an aryloxy group and an arylthio group.

[0169] The term "monovalent non-aromatic condensed polycyclic group" as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) having two or more rings condensed with each other, only carbon atoms as ring-forming atoms, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0170] The term "monovalent non-aromatic condensed heteropolycyclic group" as used herein refers to a monovalent group (for example, having 1 to 60 carbon atoms) having two or more rings condensed to each other, at least one heteroatom selected from N, O, Si, P, and S, other than carbon atoms, as a ring-forming atom, and no aromaticity in its entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group" as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0171] The term "C_5-C_{60} carbocyclic group" as used herein refers to a monocyclic or polycyclic group having 5 to 60 carbon atoms in which the ring-forming atom is only carbon atoms. The C_5-C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_5-C_{60} carbocyclic group may be a ring (e.g., a neutral ring), such as benzene, a monovalent group, such as a phenyl group, or a divalent group, such as a phenylene group. In one or more embodiments, depending on the number of substituents connected to the C_5-C_{60} carbocyclic group, the C_5-C_{60} carbocyclic group may be a trivalent group or a quadrivalent group.

[0172] The term "C_1-C_{60} heterocyclic group" as used herein refers to a group having the same structure as the C_5-C_{60} carbocyclic group, except that as a ring-forming atom, at least one heteroatom selected from N, O, Si, P, and S is used in addition to carbon (the number of carbon atoms may be in a range of 1 to 60). Corresponding definitions apply to other ranges given for the number of carbon atoms in a heterocyclic group.

[0173] At least one substituent of the substituted C_5-C_{60} (*e.g.* C_5-C_{30}) carbocyclic group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) heterocyclic group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) 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} heterocycloalkenylene group, the substituted C_6-C_{60} (*e.g.* C_6-C_{30}) arylene group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, the substituted C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, the substituted C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, the substituted C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero aryloxy group, the substituted C_1-C_{60} (*e.g.* C_1-C_{20}) hetero arylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, and a C_1-C_{60} (*e.g.* C_1-C_{20}) alkoxy group;

a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, and a C_1-C_{60} (*e.g.* C_1-C_{20}) alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a C_1-C_{60} (*e.g.* 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_{60} (*e.g.* C_6-C_{30}) aryl group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryloxy group, a C_6-C_{60} (*e.g.* C_6-C_{30}) arylthio group, a C_1-C_{60} (*e.g.* C_1-C_{20}) 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 $-P(=O)(Q_{31})(Q_{32})$, and

Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkenyl group, a C_2-C_{60} (*e.g.* C_2-C_{20}) alkynyl group, a C_1-C_{60} (*e.g.* 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_{60} (*e.g.* C_6-C_{30}) aryl group, a C_1-C_{60} (*e.g.* C_1-C_{20}) heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C_1-C_{60} (*e.g.* C_1-C_{20}) alkyl group substituted with at least one selected from deuterium, -F, and a cyano group, a C_6-C_{60} (*e.g.* C_6-C_{30}) aryl group substituted with at least one selected from deuterium, -F, and a cyano group, a biphenyl group, and a terphenyl group.

[0174] The term "Ph" as used herein represents a phenyl group, the term "Me" as used herein represents a methyl group, the term "Et" as used herein represents an ethyl group, the term "ter-Bu" or "Bu^t," as used herein represents a tert-butyl group, and the term "OMe" as used herein represents a methoxy group.

[0175] The term "biphenyl group" as used herein refers to a "phenyl group substituted with a phenyl group." The term "biphenyl group" as used herein may be "a substituted phenyl group" having "a C_6-C_{60} aryl group" as a substituent.

[0176] The term "terphenyl group" used herein refers to a "phenyl group substituted with a biphenyl group." The "terphenyl group" is a "phenyl group" having, as a substituent, a "C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group."

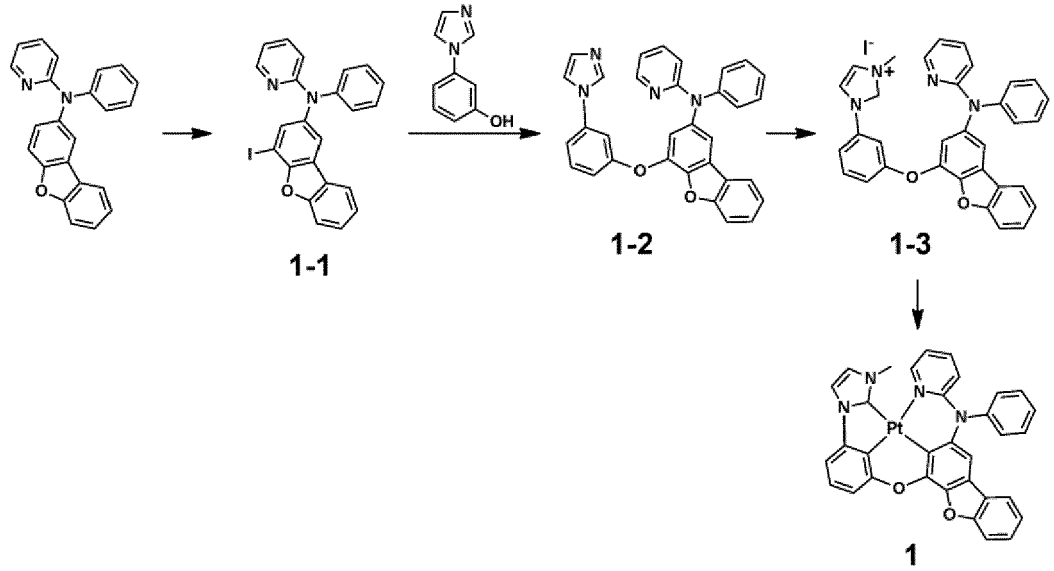
[0177] * and *' as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0178] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in more detail with reference to Synthesis Examples and Examples. The expression "B was utilized instead of A" utilized in describing Synthesis Examples means that an identical number of molar equivalents of B was utilized in place of molar equivalents of A.

Synthesis Example

Synthesis Example 1: Synthesis of Compound 1

[0179]



(1) Synthesis of Intermediate 1-1

[0180] N-(dibenzo[b,d]furan-2-yl)-N-phenylpyridin-2-amine (1.0 eq) acting as a starting material was dissolved in tetrahydrofuran (THF), and n-butyllithium (2.5 M in hexane) (1.1 eq) was added thereto at a temperature of -78 °C. The reaction mixture was stirred at room temperature for 2 hours and cooled again to a temperature of -78 °C, and I_2 (1.5 eq) was dissolved in THF and added thereto. The reaction mixture was stirred at room temperature for 5 hours, water was added thereto, and a diethylether layer was washed three times utilizing diethylether (100 mL). The washed diethylether layer was dried utilizing $MgSO_4$ and dried under reduced pressure to obtain a product. Then, the product was separated and purified by silica gel column chromatography to obtain Intermediate 1-1.

(2) Synthesis of Intermediate 1-2

[0181] Intermediate 1-1 (1.0 eq), 3-(1H-imidazol-1-yl)phenol (1.2 eq), CuI (0.02 eq), K_2CO_3 (2.0 eq), and L-Proline (0.04 eq) were dissolved in dimethylsulfonate (0.1M) and stirred at a temperature of 160 °C for 48 hours. The reaction mixture was cooled to room temperature, and an organic layer was extracted therefrom three times utilizing dichloromethane and water. The extracted organic layer was dried utilizing magnesium sulfate and concentrated, and column chromatography was utilized to obtain Intermediate 1-2 (yield: 44 %).

(3) Synthesis of Intermediate 1-3

[0182] Intermediate 1-2 (1.0 eq) and iodomethane (1.5 eq) were dissolved in THF (0.1 M) and stirred at a temperature

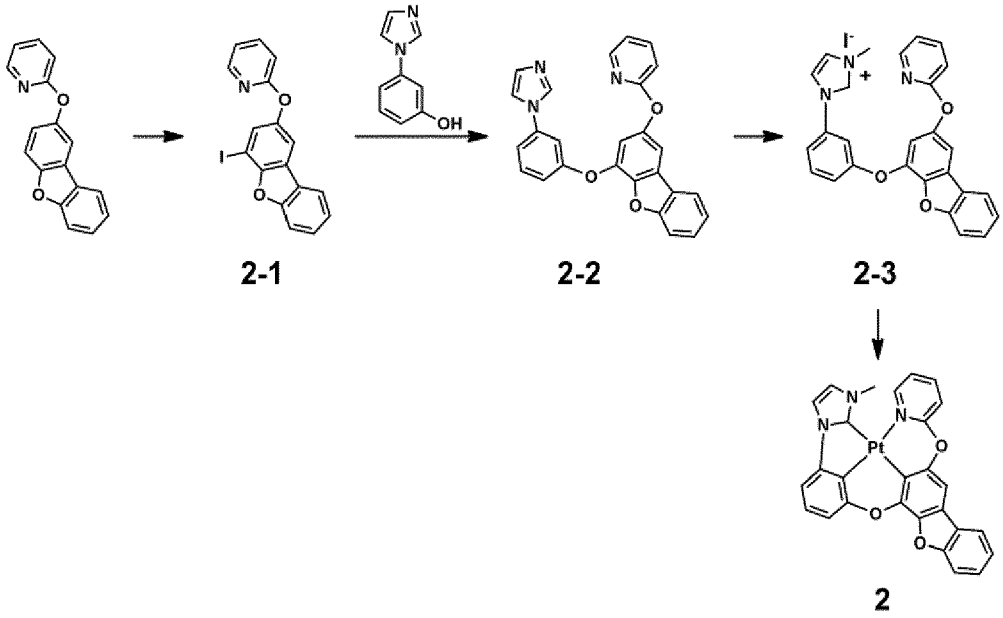
of 70 °C for 12 hours. The reaction mixture was cooled to room temperature, and a solvent was removed therefrom. The product obtained therefrom was filtered utilizing diethyl ether and washed to obtain Intermediate 1-3 (yield: 85 %).

(4) Synthesis of Compound 1

[0183] Intermediate 1-3 (1.0 eq), dichloro(1,5-cyclooctadienyl) platinum (II) (1.05 eq), and sodium acetate (3.0 eq) were dissolved in THF (0.1 M) and stirred at a temperature of 120 °C in a nitrogen atmosphere for 72 hours. The reaction mixture was cooled to room temperature and a solvent was removed therefrom under reduced pressure. The concentrated reaction mixture was dissolved in dichloromethane, and the remaining precipitate was filtered. The filtrate obtained therefrom was purified by column chromatography to obtain Compound 1 (yield: 35 %).

Synthesis Example 2: Synthesis of Compound 2

[0184]



2-1 2-2 2-3 2

(1) Synthesis of Intermediate 2-1

[0185] Intermediate 2-1 (yield: 65 %) was obtained in the same manner as in Synthesis of Intermediate 1-1, except that 2-(dibenzo[b,d]furan-2-yloxy)pyridine was utilized instead of N-(dibenzo[b,d]furan-2-yl)-N-phenylpyridin-2-amine.

(2) Synthesis of Intermediate 2-2

[0186] Intermediate 2-2 (yield: 40 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that Intermediate 2-1 was utilized instead of Intermediate 1-1.

(3) Synthesis of Intermediate 2-3

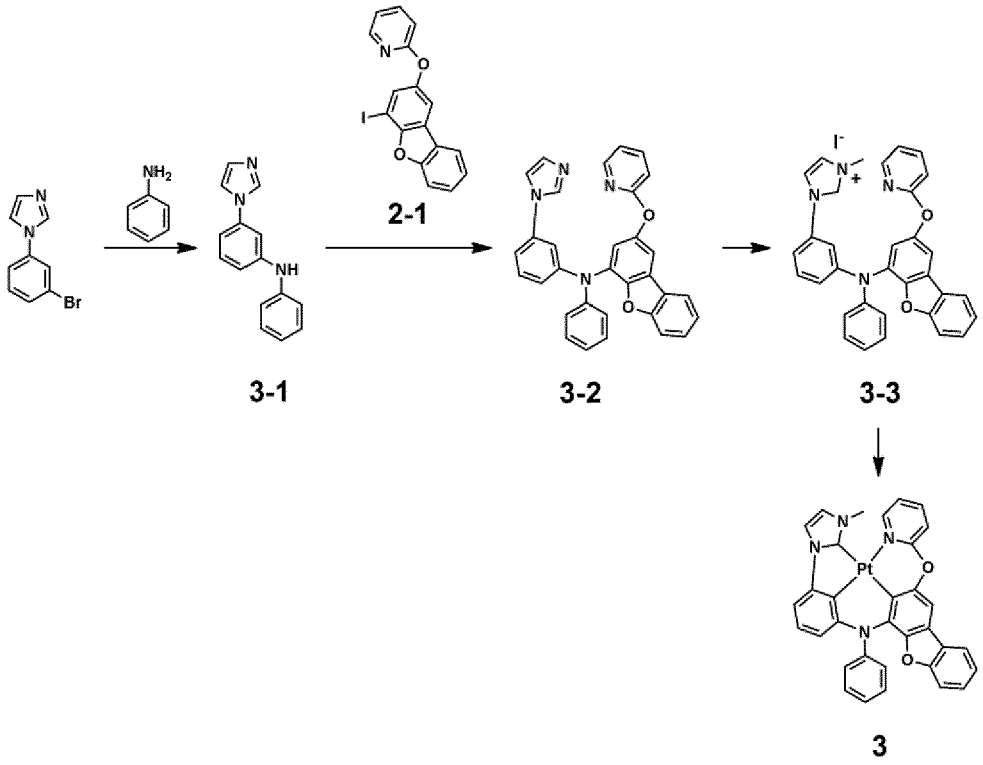
[0187] Intermediate 2-3 (yield: 80 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 2-2 was utilized instead of Intermediate 1-2.

(4) Synthesis of Compound 2

[0188] Compound 2 (yield: 30 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 2-3 was utilized instead of Intermediate 1-3.

Synthesis Example 3: Synthesis of Compound 3

[0189]



(1) Synthesis of Intermediate 3-1

[0190] 1-(3-bromophenyl)-1H-imidazole (1.0 eq), aniline (1.0 eq), tris(dibenzylideneacetone)dipalladium (0) (0.1 eq), tri-tert-butylphosphine (0.1 eq), and sodium tert-butoxide (3.0 eq) were dissolved in toluene and stirred at a temperature of 100 °C for 2 hours. The reaction mixture was cooled and washed three times utilizing ethyl acetate and water to obtain an organic layer. The organic layer was dried utilizing $MgSO_4$ and dried under reduced pressure. Column chromatography was utilized to obtain Intermediate 3-1 (yield: 65 %).

(2) Synthesis of Intermediate 3-2

[0191] Intermediate 3-2 (yield: 64 %) was obtained in the same manner as in Synthesis of Intermediate 3-1, except that Intermediate 2-1 was utilized instead of 1-(3-bromophenyl)-1H-imidazole, and Intermediate 3-1 was utilized instead of aniline.

(3) Synthesis of Intermediate 3-3

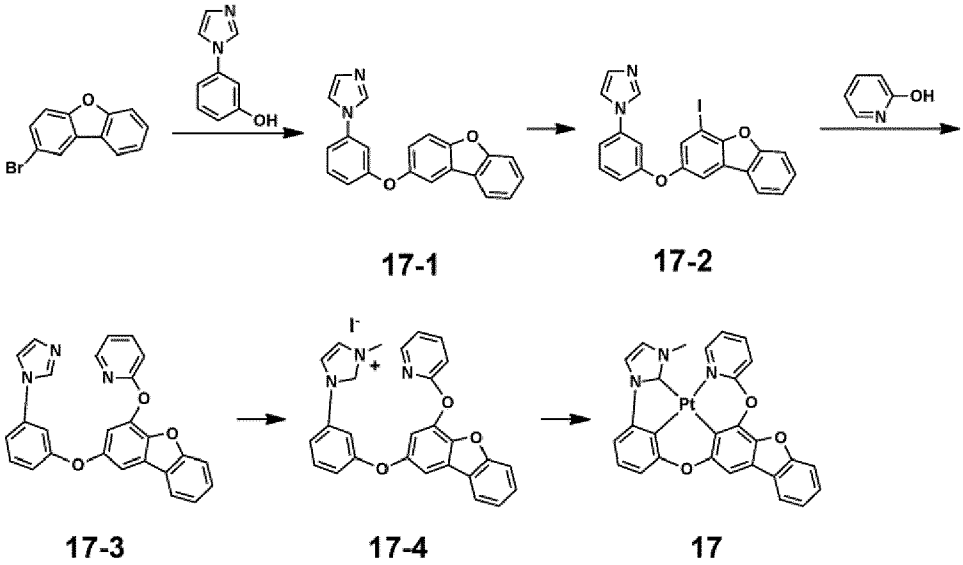
[0192] Intermediate 3-3 (yield: 84 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 3-2 was utilized instead of Intermediate 1-2.

(4) Synthesis of Compound 3

[0193] Compound 3 (yield: 25 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 3-3 was utilized instead of Intermediate 1-3.

Synthesis Example 4: Synthesis of Compound 17

[0194]



17-1 17-2

17-3 17-4 17

(1) Synthesis of Intermediate 17-1

[0195] Intermediate 17-1 (yield: 77 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that 2-bromodibenzofuran was utilized instead of Intermediate 1-1.

(2) Synthesis of Intermediate 17-2

[0196] Intermediate 17-2 (yield: 55 %) was obtained in the same manner as in Synthesis of Intermediate 1-1, except that Intermediate 17-1 was utilized instead of N-(dibenzo[b,d]furan-2-yl)-N-phenylpyridin-2-amine.

(3) Synthesis of Intermediate 17-3

[0197] Intermediate 17-3 (yield: 60 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that Intermediate 17-2 was utilized instead of Intermediate 1-1, and pyridin-2-ol was utilized instead of 3-(1H-imidazol-1-yl)phenol.

(4) Synthesis of Intermediate 17-4

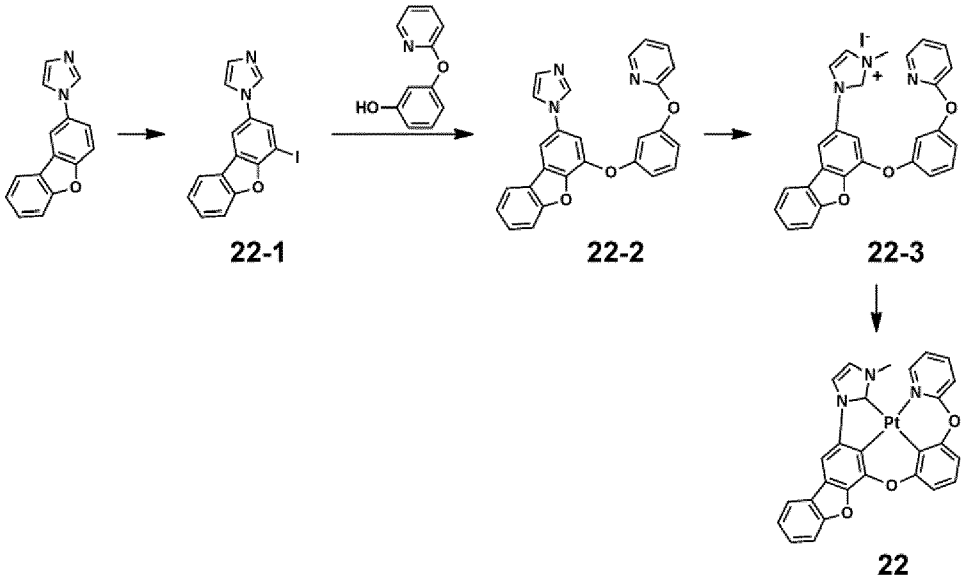
[0198] Intermediate 17-4 (yield: 84 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 17-3 was utilized instead of Intermediate 1-2.

(5) Synthesis of Compound 17

[0199] Compound 17 (yield: 28 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 17-4 was utilized instead of Intermediate 1-3.

Synthesis Example 5: Synthesis of Compound 22

[0200]



(1) Synthesis of Intermediate 22-1

[0201] Intermediate 22-1 (yield: 66 %) was obtained in the same manner as in Synthesis of Intermediate 1-1, except that 1-(dibenzo[b,d]furan-2-yl)-1H-imidazole was utilized instead of N-(dibenzo[b,d]furan-2-yl)-N-phenylpyridin-2-amine.

(2) Synthesis of Intermediate 22-2

[0202] Intermediate 22-2 (yield: 43 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that Intermediate 22-1 was utilized instead of Intermediate 1-1, and 3-(pyridin-2-yloxy)phenol was utilized instead of 3-(1H-imidazol-1-yl)phenol.

(3) Synthesis of Intermediate 22-3

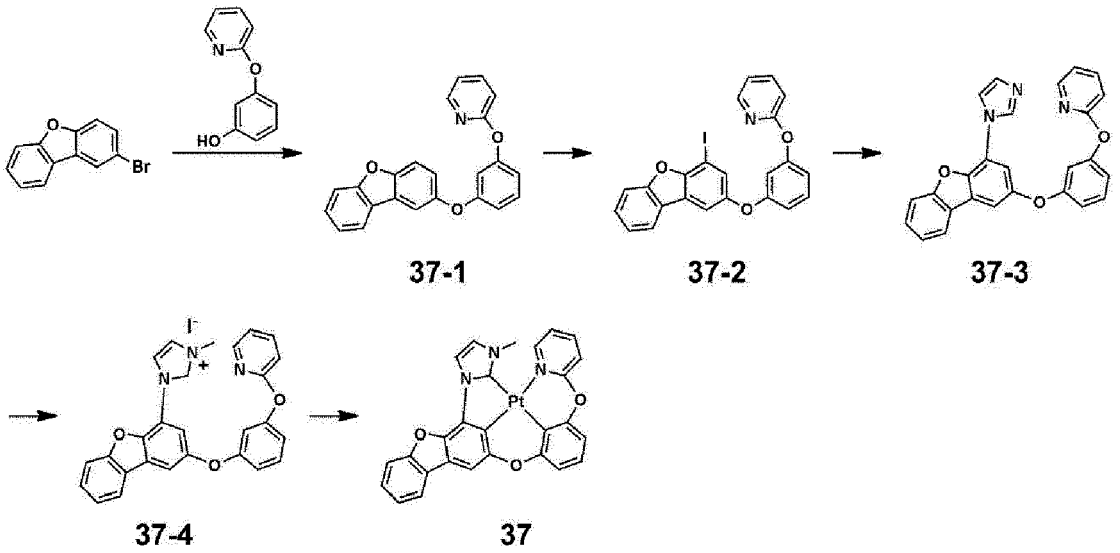
[0203] Intermediate 22-3 (yield: 80 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 22-2 was utilized instead of Intermediate 1-2.

(4) Synthesis of Compound 22

[0204] Compound 22 (yield: 25 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 22-3 was utilized instead of Intermediate 1-3.

Synthesis Example 6: Synthesis of Compound 37

[0205]



(1) Synthesis of Intermediate 37-1

[0206] Intermediate 37-1 (yield: 53 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that 2-bromodibenzofuran was utilized instead of Intermediate 1-1, and 3-(pyridin-2-yloxy)phenol was utilized instead of 3-(1H-imidazol-1-yl)phenol.

(2) Synthesis of Intermediate 37-2

[0207] Intermediate 37-2 (yield: 50 %) was obtained in the same manner as in Synthesis of Intermediate 1-1, except that Intermediate 37-1 was utilized instead of N-(dibenzo[b,d]furan-2-yl)-N-phenylpyridin-2-amine.

(3) Synthesis of Intermediate 37-3

[0208] Intermediate 37-3 (yield: 63 %) was obtained in the same manner as in Synthesis of Intermediate 1-2, except that Intermediate 37-2 was utilized instead of Intermediate 1-1, and imidazole was utilized instead of 3-(1H-imidazol-1-yl)phenol.

(4) Synthesis of Intermediate 37-4

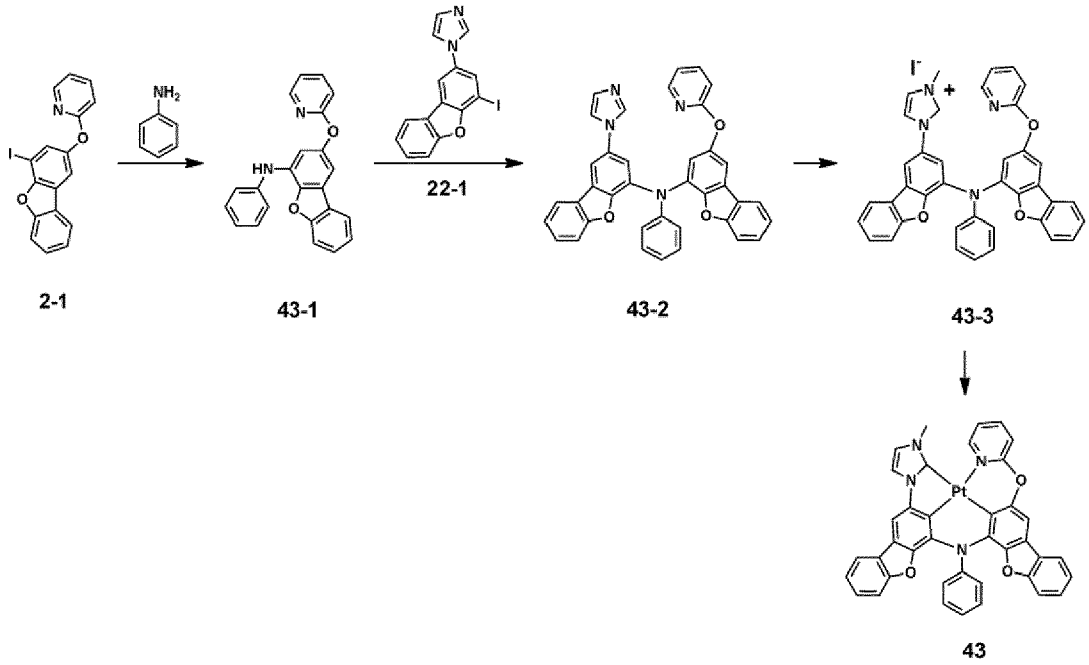
[0209] Intermediate 37-4 (yield: 70 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 37-3 was utilized instead of Intermediate 1-2.

(5) Synthesis of Compound 37

[0210] Compound 37 (yield: 35 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 37-4 was utilized instead of Intermediate 1-3.

Synthesis Example 7: Synthesis of Compound 43

[0211]



(1) Synthesis of Intermediate 43-1

[0212] Intermediate 43-1 (yield: 58 %) was obtained in the same manner as in Synthesis of Intermediate 3-1, except that Intermediate 2-1 was utilized instead of 1-(3-bromophenyl)-1H-imidazole.

(2) Synthesis of Intermediate 43-2

[0213] Intermediate 43-2 (yield: 67 %) was obtained in the same manner as in Synthesis of Intermediate 3-1, except that Intermediate 43-1 was utilized instead of 1-(3-bromophenyl)-1H-imidazole, and Intermediate 22-1 was utilized instead of aniline.

(3) Synthesis of Intermediate 43-3

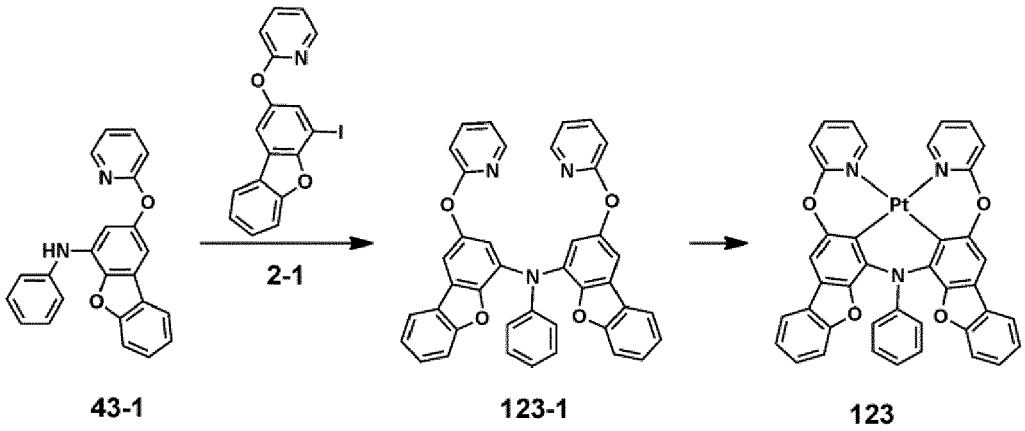
[0214] Intermediate 43-3 (yield: 76 %) was obtained in the same manner as in Synthesis of Intermediate 1-3, except that Intermediate 43-2 was utilized instead of Intermediate 1-2.

(4) Synthesis of Compound 43

[0215] Compound 43 (yield: 31 %) was obtained in the same manner as in Synthesis of Compound 1, except that Intermediate 43-3 was utilized instead of Intermediate 1-3.

Synthesis Example 8: Synthesis of Compound 123

[0216]



(1) Synthesis of Intermediate 123-1

[0217] Intermediate 123-1 (yield: 45 %) was obtained in the same manner as in Synthesis of Intermediate 3-1, except that Intermediate 2-1 was utilized instead of 1-(3-bromophenyl)-1H-imidazole, and Intermediate 43-1 was utilized instead of aniline.

(2) Synthesis of Compound 123

[0218] Compound 123-1 (1.0 eq), potassium tetrachloroplatinate (K_2PtCl_4) (1.1 eq), and tetrabutylammonium bromide (0.1 eq) were dissolved in acetic acid (0.1M) and stirred at a temperature of 120 °C for 72 hours. The reaction mixture was cooled to room temperature, and an organic layer was extracted therefrom three times utilizing dichloromethane and water. The extracted organic layer was dried utilizing magnesium sulfate and concentrated, and column chromatography was utilized to obtain Compound 123 (yield: 31 %).

[0219] ^{1}H-NMR and MS/FAB analysis results of Compounds synthesized in Synthesis Examples are shown in Table 1. Synthesis methods of compounds other than Compounds shown in Table 1 may also be easily recognized by those of ordinary skill in the art by referring to the synthesis mechanisms and source materials described above.

Table 1

Compound	^{1}H NMR ($CDCl_3$, 400 MHz)	MS/FAB	
		found	calc.
1	8.10-8.15 (1H, m), 7.86-7.89 (1H, m), 7.65-7.69 (1H, m) 7.54-7.58 (1H, m), 7.31-7.39 (3H, m), 7.18-7.21 (3H, m) 6.80-6.82 (1H, m), 6.62-6.70 (4H, m), 6.46-6.47 (1H, m) 6.30-6.32 (1H, m), 5.06-5.21 (2H, m), 3.03-3.12 (3H, m)	702.64	702.66
2	7.86-7.93 (1H, m), 7.65-7.69 (3H, m), 7.31-7.39 (2H, m) 7.18-7.21 (2H, m), 6.30-6.55 (4H, m), 5.06-5.21 (2H, m) 3.01-3.13 (3H, m)	627.53	627.54
3	7.87-7.89 (1H, m), 7.65-7.69 (3H, m), 7.31-7.39 (2H, m) 7.18-7.21 (2H, m), 6.86-6.98 (3H, m), 6.54-6.63 (3H, m) 5.95-5.96 (2H, m), 5.06-5.21 (2H, m), 3.01-3.04 (3H, m)	702.64	702.66
17	7.80-7.85 (1H, m), 7.65-7.69 (3H, m), 7.17-7.41 (4H, m) 6.30-6.55 (4H, m), 5.06-5.20 (2H, m), 3.05-3.09 (3H, m)	627.52	627.54
22	7.85-7.88 (1H, m), 7.65-7.69 (3H, m), 7.23-7.39 (4H, m) 6.40-6.70 (4H, m), 5.06-5.20 (2H, m), 3.00-3.04 (3H, m)	627.52	627.54
37	7.78-7.84 (1H, m), 7.65-7.69 (3H, m), 7.23-7.39 (3H, m) 7.00-7.03 (1H, m), 6.67-6.70 (2H, m), 6.40-6.54 (2H, m) 5.06-5.20 (2H, m), 3.01-3.06 (3H, m)	627.53	627.54
43	7.82-7.89 (2H, m), 7.63-7.70 (4H, m), 7.20-7.39 (6H, m) 6.81-6.98 (3H, m), 6.40-6.63 (4H, m), 5.06-5.20 (2H, m) 3.04-3.14 (3H, m)	792.72	792.74
123	7.84-7.92 (2H, m), 7.63-7.70 (6H, m), 7.31-7.39 (4H, m) 6.81-6.90 (3H, m), 6.39-6.63 (6H, m)	804.72	804.73

Examples

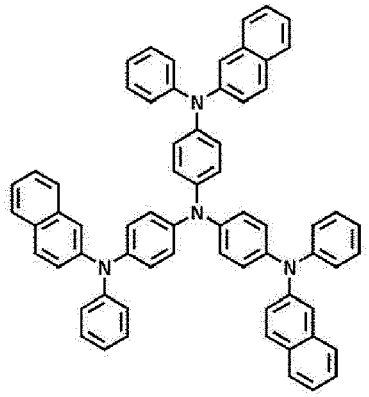
Example 1

[0220] As a substrate and an ITO anode, a Corning 15 Ω/cm^2 (1,200 Å) ITO glass substrate was cut to a size of 50 mm x 50 mm x 0.7 mm, sonicated with isopropyl alcohol and pure water each for 5 minutes, and then cleaned by exposure to ultraviolet rays and ozone for 30 minutes. The ITO glass substrate was provided to a vacuum deposition apparatus.

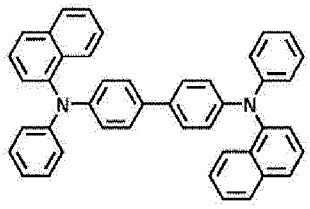
[0221] 2-TNATA was vacuum-deposited on the ITO anode formed on the ITO glass substrate to form a hole injection layer having a thickness of 600 Å, and NPB was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å.

[0222] BCPDS and POPCPA (co-host) (a weight ratio of BCPDS to POPCPA was 1:1) and Compound 1 (dopant) were co-deposited on the hole transport layer at a co-host to dopant weight ratio of 90:10 to form an emission layer having a thickness of 300 Å.

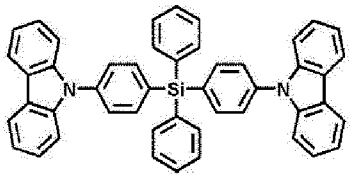
[0223] TSPO1 was deposited on the emission layer to form a hole blocking layer having a thickness of 50 Å, Alq_3 was deposited on the hole blocking layer to form an electron transport layer having a thickness of 300 Å, LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was co-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.



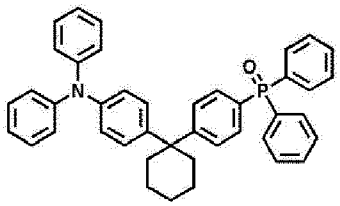
2-TNATA



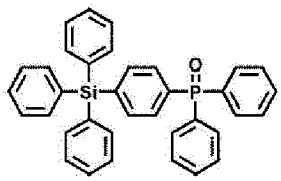
NPB



BCPDS



POPCPA



TSPO1

Examples 2 to 8 and Comparative Examples 1 to 5

[0224] Organic light-emitting devices were manufactured in the same manner as in Example 1, except that Compounds shown in Table 1 were each utilized instead of Compound 1 as a dopant in forming an emission layer.

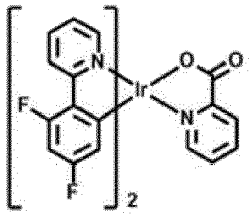
Evaluation Example 1

[0225] The driving voltage, current density, luminance, luminescent efficiency, emission color, and maximum emission wavelength of the organic light-emitting devices manufactured according to Examples 1 to 8 and Comparative Examples 1 to 5 were measured utilizing Keithley SMU 236 and a luminance meter PR650, and results thereof are shown in Table 2.

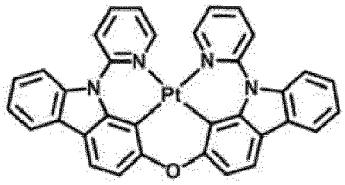
Table 2

	Dopant compound	Driving voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Luminescent efficiency (cd/A)	Emission color	Maximum emission wavelength (nm)
Example 1	Compound 1	5.22	50	4123	8.246	Blue	458
Example 2	Compound 2	5.32	50	4057	8.114	Blue	461
Example 3	Compound 3	5.38	50	4033	8.066	Blue	463
Example 4	Compound 17	5.36	50	4024	8.048	Blue	458
Example 5	Compound 22	5.32	50	4055	8.11	Blue	459
Example 6	Compound 37	5.40	50	4102	8.204	Blue	460
Example 7	Compound 43	5.44	50	4022	8.044	Blue	461
Example 8	Compound 123	5.46	50	4010	8.02	Blue	458
Comparative Example 1	Compound A	6.56	50	3870	7.74	Blue	478
Comparative Example 2	Compound B	5.49	50	3670	7.34	Blue	488
Comparative Example 3	Compound C	5.9	50	29250	58.5	Green	545
Comparative Example 4	Compound D	6.1	50	25550	51.1	Green	533
Comparative Example 5	Compound E	5.8	50	24250	48.5	Green	543

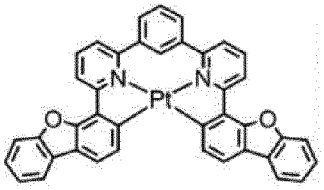
Compound A



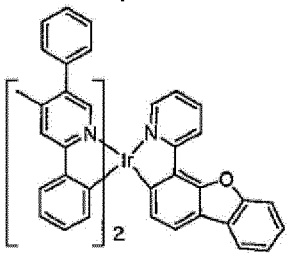
Compound B



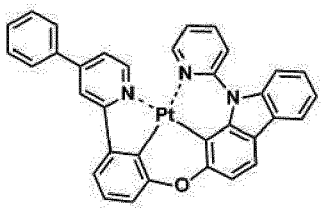
Compound C



Compound D



Compound E



[0226] Referring to Table 2, it is confirmed that the organic light-emitting devices of Examples 1 to 8 have a low driving voltage as compared with the organic light-emitting devices of Comparative Examples 1 to 5, have high luminance and high luminescent efficiency as compared with the organic light-emitting devices of Comparative Examples 1 and 2, and are suitable for blue light emission as compared with the organic light-emitting devices of Comparative Examples 3 to 5.

[0227] The organic light-emitting device including the organometallic compound may have a low driving voltage, high luminance, and high efficiency.

[0228] 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.

[0229] Any numerical range recited herein is intended to include all sub-ranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein.

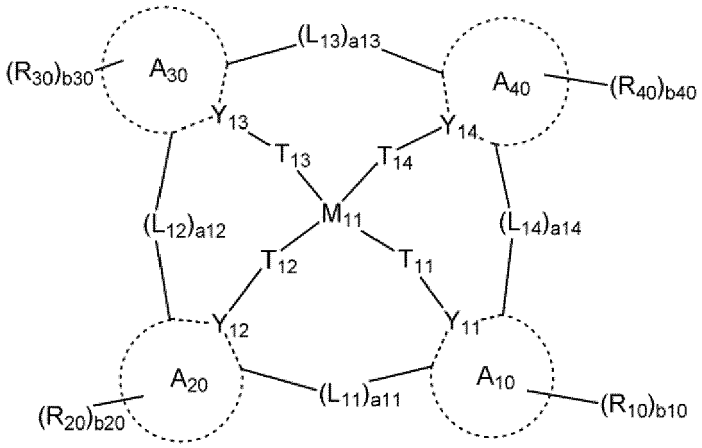
[0230] While one or more embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the scope as defined by the following claims, and equivalents thereof.

Claims

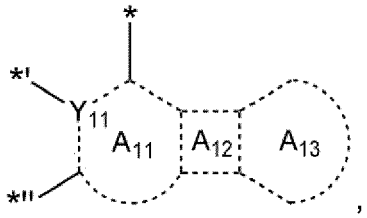
1. An organic light-emitting device comprising:

a first electrode;
a second electrode; and
an organic layer between the first electrode and the second electrode,
wherein the organic layer comprises an emission layer and an organometallic compound represented by Formula 1:

Formula 1



Formula A-10



,

wherein, in Formulae 1 and A-10,

M_{11} is selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm),

A_{10} is a group represented by Formula A-10,

A_{11}, A_{13}, A_{20}, A_{30}, and A_{40} are each independently selected from a C_5-C_{60} carbocyclic group and a C_1-C_{60} heterocyclic group,

A_{12} is a 5-membered heterocyclic group,

Y_{11} to Y_{14} are each independently N or C,

T_{11} to T_{14} are each independently selected from a single bond, *-O-*', and *-S-*',

L_{11} to L_{14} are each independently selected from a single bond, *-O-*', *-S-*', *-C(R_1)(R_2)-*', *-C(R_1)=*', *=C(R_1)-*', *-C(R_1)=C(R_2)-*', *-C(=O)-*', *-C(=S)-*', *-C≡C-*', *-B(R_1)-*', *-N(R_1)-*', *-P(R_1)-*', *-Si(R_1)(R_2)-*', *-P(=O)(R_1)(R_2)-*', and *-Ge(R_1)(R_2)-*',

a11, a12, and a14 are each independently selected from 1, 2, and 3,

a13 is selected from 0, 1, 2, and 3,

when a13 is 0, A_{30} and A_{40} are not linked to each other,

R_1, R_2, R_{10}, R_{20}, R_{30}, and R_{40} are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C_1-C_{60} hetero aryloxy group, a substituted or unsubstituted C_1-C_{60} hetero arylthio 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), - B(Q_1)(Q_2), -N(Q_1)(Q_2), -P(Q_1)(Q_2), -C(=O)(Q_1), -S(=O)(Q_1), -S(=O)$_2$(Q_1), -P(=O)(Q_1)(Q_2), and -P(=S)(Q_1)(Q_2),

R_1 and R_{10} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a

substituted or unsubstituted C_1-C_{60} heterocyclic group,
R_1 and R_{20}, R_1 and R_{30}, or R_1 and R_{40} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,
b10, b20, b30, and b40 are each independently selected from 1, 2, 3, 4, 5, 6, 7, and 8,
*, *', and *'' each indicate a binding site to a neighboring atom,
at least one substituent of the substituted C_5-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_2-C_{60} heterocyclic 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 C_1-C_{60} hetero aryloxy group, the substituted C_1-C_{60} hetero arylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:
deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, 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 hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{11})(Q_{12})(Q_{13})$, $-N(Q_{11})(Q_{12})$, $-B(Q_{11})(Q_{12})$, $-C(=O)(Q_{11})$, $-S(=O)_2(Q_{11})$, and $-P(=O)(Q_{11})(Q_{12})$;
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 hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{21})(Q_{22})(Q_{23})$, $-N(Q_{21})(Q_{22})$, $-B(Q_{21})(Q_{22})$, $-C(=O)(Q_{21})$, $-S(=O)_2(Q_{21})$, and $-P(=O)(Q_{21})(Q_{22})$; and
$-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and $-P(=O)(Q_{31})(Q_{32})$, and
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 hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a C_1-C_{60} hetero aryloxy group, a C_1-C_{60} hetero arylthio 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. An organic light-emitting device according to claim 1, 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 at least one selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer, and

the electron transport region comprises at least one selected from a hole blocking layer, a buffer layer, an electron transport layer, and an electron injection layer.

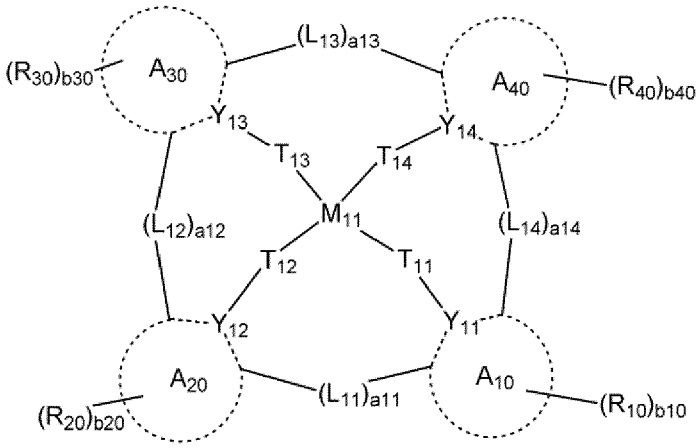
3. An organic light-emitting device according to claim 2, wherein
the emission layer comprises the organometallic compound.

4. An organic light-emitting device according to claim 3, wherein
the emission layer further comprises a host, and
the host comprises a silyl-containing compound, a phosphine oxide-containing compound, or a combination thereof.

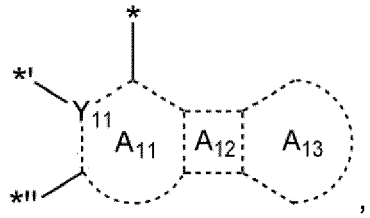
5. An organic light-emitting device according to any one of claims 2 to 4, wherein
the electron transport region comprises a hole blocking layer,
the hole blocking layer is in direct contact with the emission layer, and
the hole blocking layer comprises a phosphine oxide-containing compound or a silyl-containing compound.

6. An organometallic compound represented by Formula 1:

Formula 1



Formula A-10



,

wherein, in Formulae 1 and A-10,

M_{11} is selected from platinum (Pt), palladium (Pd), copper (Cu), silver (Ag), gold (Au), rhodium (Rh), iridium (Ir), ruthenium (Ru), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), and thulium (Tm),
A_{10} is a group represented by Formula A-10,
A_{11}, A_{13}, A_{20}, A_{30}, and A_{40} are each independently selected from a C_5-C_{60} carbocyclic group and a C_1-C_{60} heterocyclic group,
A_{12} is a 5-membered heterocyclic group,
Y_{11} to Y_{14} are each independently N or C,
T_{11} to T_{14} are each independently selected from a single bond, *-O-*', and *-S-*',
L_{11} to L_{14} are each independently selected from a single bond, *-O-*', *-S-*', *-C(R_1)(R_2)-*', *-C(R_1)=*', *=C(R_1)-*', *-C(R_1)=C(R_2)-*', *-C(=O)-*', *-C(=S)-*', *-C=C-*', *-B(R_1)-*', *-N(R_1)-*', *-P(R_1)-*', *-Si(R_1)(R_2)-*', *-P(=O)(R_1)(R_2)-*', and *-Ge(R_1)(R_2)-*',

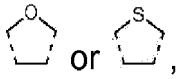
a11, a12, and a14 are each independently selected from 1, 2, and 3,
a13 is selected from 0, 1, 2, and 3,
when a13 is 0, A_{30} and A_{40} are not linked to each other,
R_1, R_2, R_{10}, R_{20}, R_{30}, and R_{40} are each independently selected from hydrogen, deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a 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 C_1-C_{60} hetero aryloxy group, a substituted or unsubstituted C_1-C_{60} hetero arylthio group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_1)(Q_2)(Q_3)$,$-B(Q_1)(Q_2)$, $-N(Q_1)(Q_2)$, $-P(Q_1)(Q_2)$, $-C(=O)(Q_1)$, $-S(=O)(Q_1)$, $-S(=O)_2(Q_1)$, $-P(=O)(Q_1)(Q_2)$, and $-P(=S)(Q_1)(Q_2)$,
R_1 and R_{10} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,
R_1 and R_{20}, R_1 and R_{30}, or R_1 and R_{40} are optionally linked to form a substituted or unsubstituted C_5-C_{60} carbocyclic group or a substituted or unsubstituted C_1-C_{60} heterocyclic group,
b10, b20, b30, and b40 are each independently selected from 1, 2, 3, 4, 5, 6, 7, and 8,
*, *', and *'' each indicate a binding site to a neighboring atom,
at least one substituent of the substituted C_5-C_{60} carbocyclic group, the substituted C_1-C_{60} heterocyclic group, the substituted C_2-C_{60} heterocyclic 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 C_1-C_{60} hetero aryloxy group, the substituted C_1-C_{60} hetero arylthio group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group is selected from:

deuterium, -F, -Cl, -Br, -I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, 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 hydrazono group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{11})(Q_{12})(Q_{13})$, $-N(Q_{11})(Q_{12})$, $-B(Q_{11})(Q_{12})$, $-C(=O)(Q_{11})$,$-S(=O)_2(Q_{11})$, and $-P(=O)(Q_{11})(Q_{12})$;
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 hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, $-Si(Q_{21})(Q_{22})(Q_{23})$,$-N(Q_{21})(Q_{22})$, $-B(Q_{21})(Q_{22})$, $-C(=O)(Q_{21})$, $-S(=O)_2(Q_{21})$, and $-P(=O)(Q_{21})(Q_{22})$; and
$-Si(Q_{31})(Q_{32})(Q_{33})$, $-N(Q_{31})(Q_{32})$, $-B(Q_{31})(Q_{32})$, $-C(=O)(Q_{31})$, $-S(=O)_2(Q_{31})$, and$-P(=O)(Q_{31})(Q_{32})$, and
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 hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a C_1-C_{60} hetero aryloxy group, a C_1-C_{60} hetero arylthio 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.

7. An organometallic compound according to claim 6, wherein
M_{11} is selected from Pt, Pd, Cu, Ag, and Au.

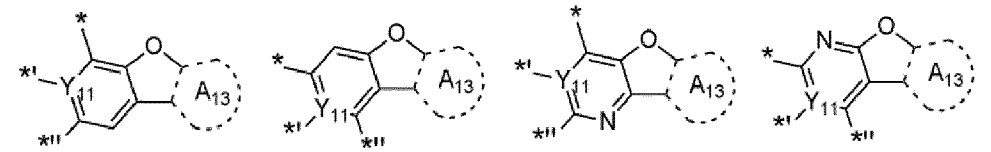
8. An organometallic compound according to claim 6 or claim 7, wherein
A_{11} is selected from a benzene group, a naphthalene group, a pyridine group, a pyrimidine group, a pyrazine group, a pyridazine group, a triazine group, a quinoline group, an isoquinoline group, a quinoxaline group, and a quinazoline group,
A_{12} is

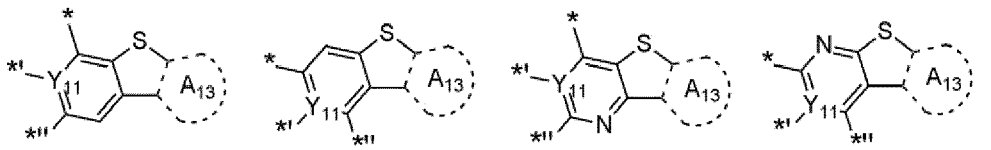


,

A_{13} is selected from a cyclohexane group, a cyclohexene group, a benzene group, a naphthalene group, an anthracene group, a phenanthrene group, a triphenylene group, a pyrene group, a chrysene group, a cyclopentadiene group, a 1,2,3,4-tetrahydronaphthalene group, a furan group, a thiophene group, a silole group, an indene group, a fluorene group, an indole group, a carbazole group, a benzofuran group, a dibenzofuran group, a benzothiophene group, a dibenzothiophene group, a benzosilole group, a dibenzosilole group, an indeno pyridine group, an indolopyridine group, a benzofuropyridine group, a benzothienopyridine group, a benzosilolopyridine group, an indeno pyrimidine group, an indolopyrimidine group, a benzofuropyrimidine group, a benzothienopyrimidine group, a benzosilolopyrimidine group, a dihydropyridine 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 pyrrole group, a pyrazole group, an imidazole group, a 2,3-dihydroimidazole group, a triazole group, a 2,3-dihydrotriazole group, an oxazole group, an isoxazole group, a thiazole group, an isothiazole group, an oxadiazole group, a thiadiazole group, a benzopyrazole group, a benzimidazole group, a 2,3-dihydrobenzimidazole group, an imidazopyridine group, a 2,3-dihydroimidazopyridine group, an imidazopyrimidine group, a 2,3-dihydroimidazopyrimidine group, an imidazopyrazine group, a 2,3-dihydroimidazopyrazine group, a benzoxazole group, a benzothiazole group, a benzoxadiazole group, a benzothiadiazole group, a 5,6,7,8-tetrahydroisoquinoline group, and a 5,6,7,8-tetrahydroquinoline group.

9. An organometallic compound according to any one of claims 6 to 8, wherein
A_{10} is represented by one of Formulae 1-1 to 1-8:





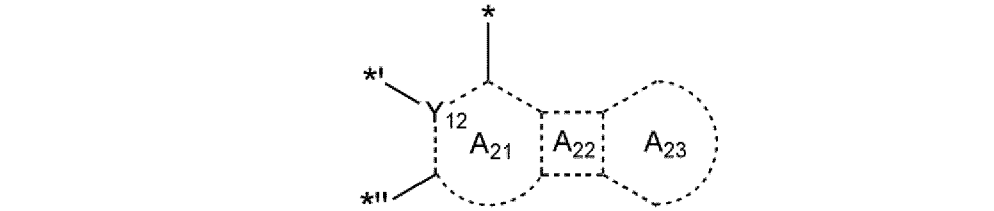
,

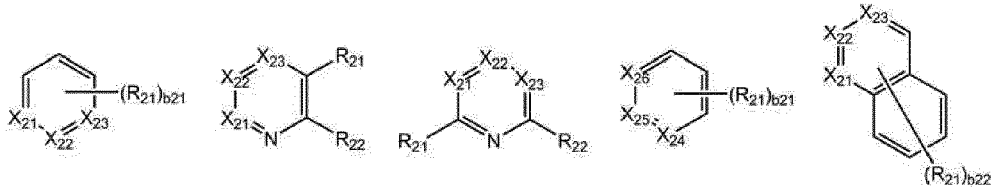
wherein, in Formulae 1-1 to 1-8,

Y_{11} is as defined in connection with in Formulae 1 and A-10,
A_{13} is selected from a cyclohexane group, a benzene group, a naphthalene group, a fluorene group, a carbazole group, a dibenzofuran group, a dibenzothiophene group, and a dibenzosilole group, and
*, *' and *'' each indicate a binding site to a neighboring atom.

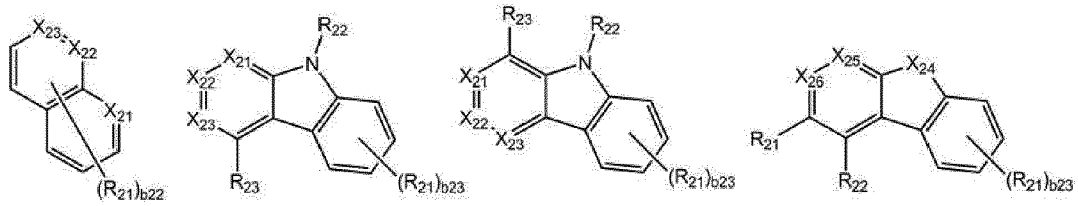
10. An organometallic compound according to any one of claims 6 to 9, wherein
A_{20} is selected from a group represented by Formula A-20 and a group represented by one of Formulae 2-1 to 2-43,
A_{30} and A_{40} are each independently represented by one of Formulae 2-1 to 2-43:

Formula A-20

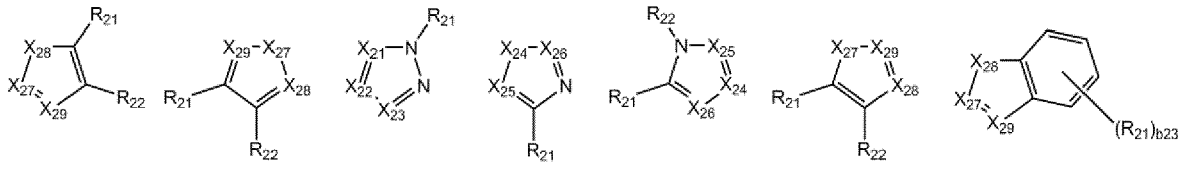




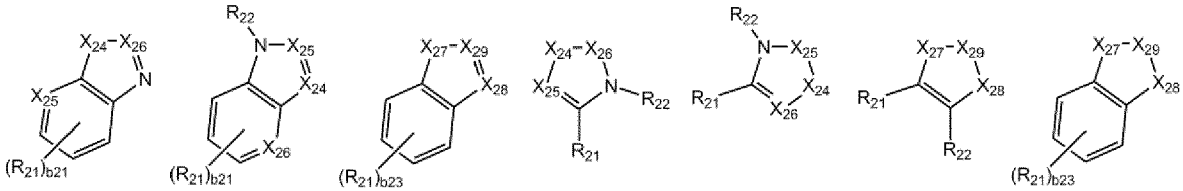
2-1 2-2 2-3 2-4 2-5



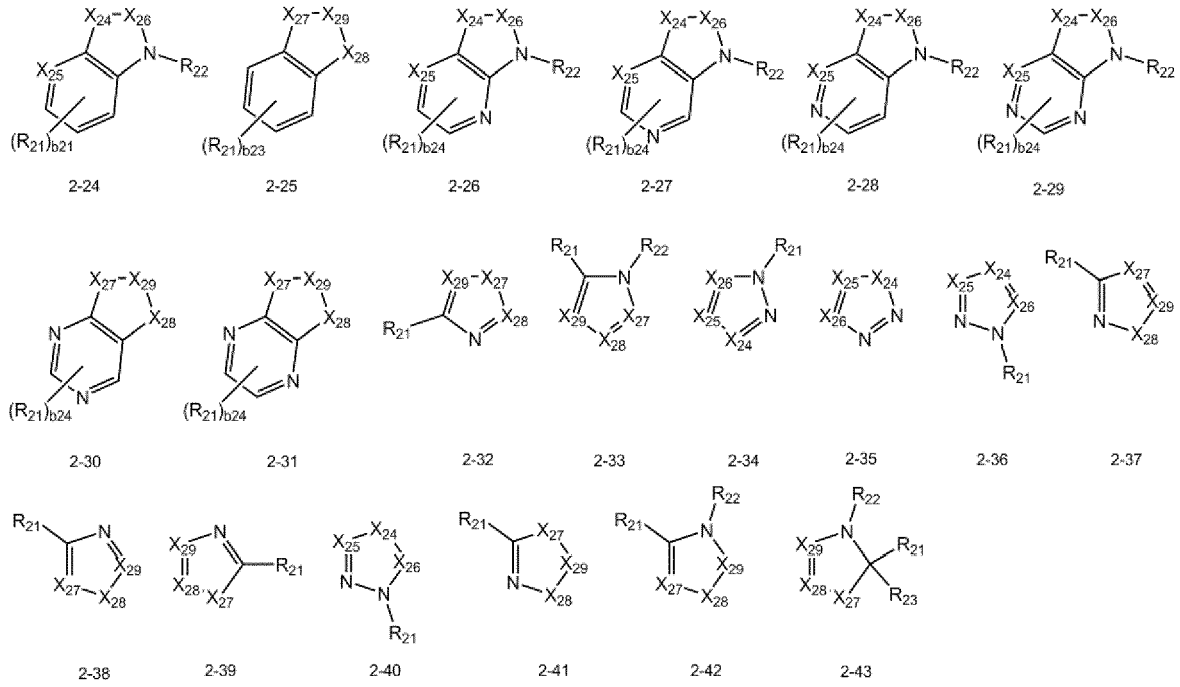
2-6 2-7 2-8 2-9



2-10 2-11 2-12 2-13 2-14 2-15 2-16



2-17 2-18 2-19 2-20 2-21 2-22 2-23



,

wherein, in Formula A-20,

Y_{12} is as defined in Formula 1 ,
A_{21} is defined the same as A_{11} in Formulae 1 and A-10,
A_{22} is defined the same as A_{12} in Formulae 1 and A-10, and
A_{23} is defined the same as A_{13} in Formulae 1 and A-10,
wherein, in Formulae 2-1 to 2-43,
X_{21} to X_{23} are each independently selected from $C(R_{24})$ and C-*, wherein at least two of X_{21} to X_{23} are each C-*,
X_{24} is N-*, and X_{25} and X_{26} are each independently selected from $C(R_{24})$ and C-*, wherein at least one of X_{25} and X_{26} is C-*,
X_{27} and X_{28} are each independently selected from N, $N(R_{25})$, and N-*, and X_{29} is selected from $C(R_{24})$ and C-*, wherein i) at least one of X_{27} and X_{28} is N-* and X_{29} is C-*, or ii) X_{27} and X_{28} are each N-* and X_{29} is $C(R_{24})$,
R_{21} to R_{24} are each independently defined the same as R_{10} in Formula 1 ,
b21 is selected from 1, 2, and 3,
b22 is selected from 1, 2, 3, 4, and 5,
b23 is selected from 1, 2, 3, and 4,
b24 is selected from 1 and 2, and
*, *' and *'' each indicate a binding site to a neighboring atom.

11. An organometallic compound according to any one of claims 6 to 10, wherein
Y_{11}, Y_{12}, and Y_{13} are each C, and Y_{14} is N;
Y_{11}, Y_{12}, and Y_{14} are each C, and Y_{13} is N;
Y_{11}, Y_{13}, and Y_{14} are each C, and Y_{12} is N;
Y_{12}, Y_{13}, and Y_{14} are each C, and Y_{11} is N;
Y_{11} and Y_{14} are each C, and Y_{12} and Y_{13} are each N;
Y_{11} and Y_{14} are each N, and Y_{12} and Y_{13} are each C;
Y_{11} and Y_{12} are each C, and Y_{13} and Y_{14} are each N;
Y_{11} and Y_{12} are each N, and Y_{13} and Y_{14} are each C;
Y_{11} and Y_{13} are each C, and Y_{12} and Y_{14} are each N; or
Y_{11} and Y_{13} are each N, and Y_{12} and Y_{14} are each C.

12. An organometallic compound according to any one of claims 6 to 11, wherein
each of T_{11} to T_{14} is a single bond,
T_{11} is selected from O and S, and T_{12} to T_{14} are each a single bond,

T_{12} is selected from O and S, and T_{11}, T_{13}, and T_{14} are each a single bond;
T_{13} is selected from O and S, and T_{11}, T_{12}, and T_{14} are each a single bond; or
T_{14} is selected from O and S, and T_{11}, T_{12}, and T_{13} are each a single bond.

13. An organometallic compound according to any one of claims 6 to 12, wherein
L_{11} and L_{14} are each independently selected from *-O-*', *-S-*', *-N(R_1)-*', *-C(R_1)(R_2)-*', *-Si(R_1)(R_2)-*', and *-P(R_1)-*', and
L_{12} is selected from a single bond, *-O-*', *-S-*', *-N(R_1)-*', *-C(R_1)(R_2)-*', *-Si(R_1)(R_2)-*', and *-P(R_1)-*'.

14. An organometallic compound according to any one of claims 6 to 13, wherein
L_{11} is *-N(R_1)-*', *-C(R_1)(R_2)-*', or *-Si(R_1)(R_2)-*', and R_1 and R_{20} are linked to form a substituted or unsubstituted C_1-C_{60} heterocyclic group,
L_{12} is *-N(R_1)-*', *-C(R_1)(R_2)-*', or *-Si(R_1)(R_2)-*', and R_1 and R_{20}, or R_1 and R_{30} are linked to form a substituted or unsubstituted C_1-C_{60} heterocyclic group, or
L_{14} is *-N(R_1)-*', *-C(R_1)(R_2)-*', or *-Si(R_1)(R_2)-*', and R_1 and R_{40} are linked to form a substituted or unsubstituted C_1-C_{60} heterocyclic group.

15. An organometallic compound according to any one of claims 6 to 14, wherein
a13 is 0.

16. An organometallic compound according to any one of claims 6 to 15, wherein
R_1 and R_2 are each independently selected from:

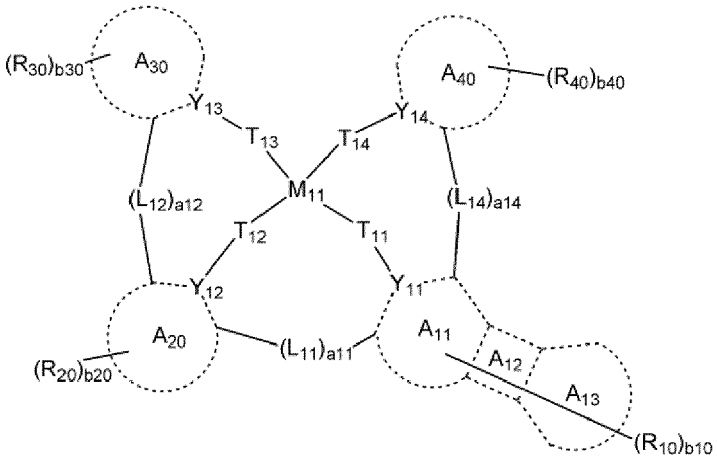
hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;
a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, a cyano group, a phenyl group, and a biphenyl group;
a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group; and
a phenyl group, a biphenyl group, a terphenyl group, a pentalenyl group, an indenyl group, a naphthyl group, an azulenyl group, an indacenyl group, an acenaphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a carbazolyl 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, a cyano group, a phenyl group, and a biphenyl group.

17. An organometallic compound according to any one of claims 6 to 16, wherein
R_{10}, R_{20}, R_{30}, and R_{40} are each independently selected from:

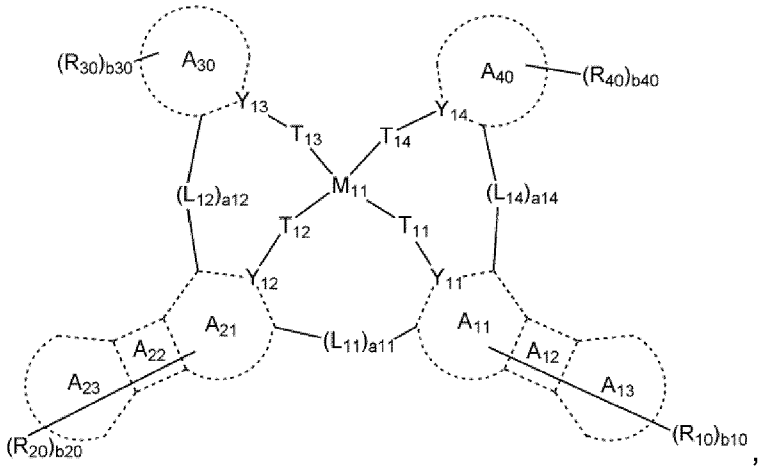
hydrogen, deuterium, -F, -Cl, -Br, -I, a cyano group, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group;
a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, and a tert-butyl group, each substituted with at least one selected from deuterium, -F, -Cl, -Br, -I, and a cyano group; and
a phenyl group, a naphthyl group, and a pyridinyl group.

18. An organometallic compound according to any one of claims 6 to 17, wherein
the organometallic compound is represented by Formula 10-1 or 10-2:

Formula 10-1



Formula 10-2

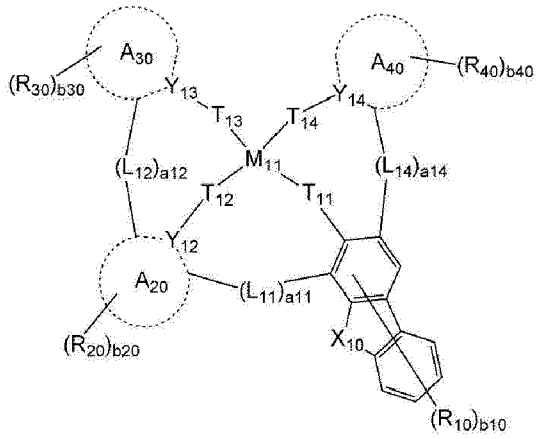


,

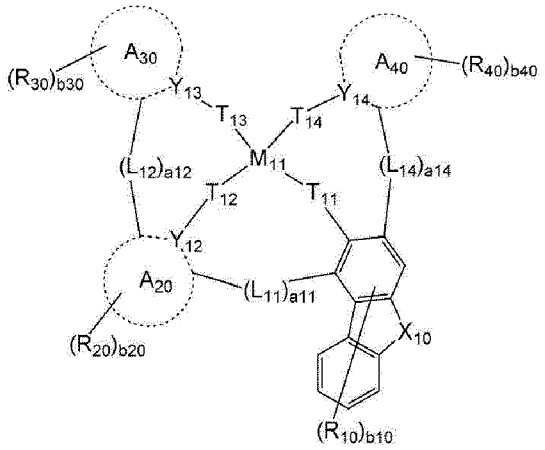
wherein, in Formulae 10-1 and 10-2,

M_{11}, A_{11} to A_{13}, A_{20}, A_{30}, A_{40}, Y_{11} to Y_{14}, T_{11} to T_{14}, L_{11}, L_{12}, L_{14}, a11, a12, a14, R_{10}, R_{20}, R_{30}, R_{40}, b10, b20, b30, and b40 are each as defined in Formulae 1 and A-10,
A_{21} is defined the same as A_{11} in Formulae 1 and A-10,
A_{22} is defined the same as A_{12} in Formulae 1 and A-10, and
A_{23} is defined the same as A_{13} in Formulae 1 and A-10.

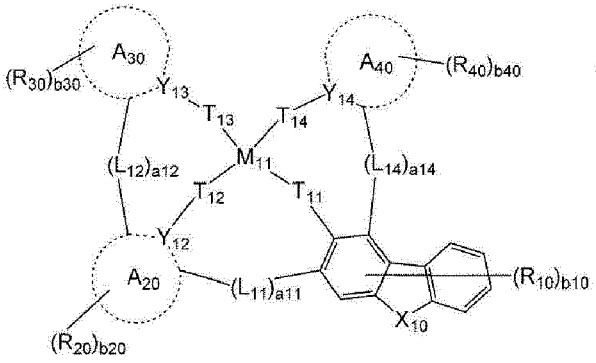
19. An organometallic compound of according to any one claims 6 to 18, wherein the organometallic compound is represented by one of Formulae 11-1 to 11-10:



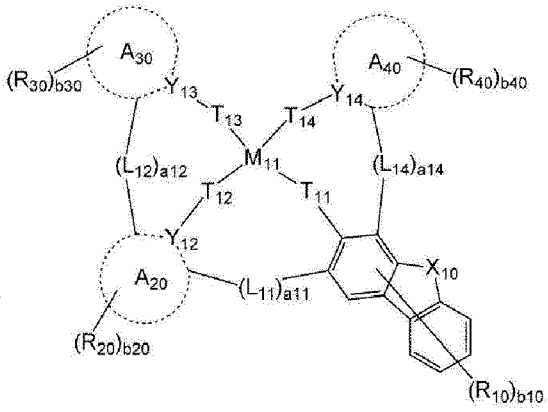
11-1



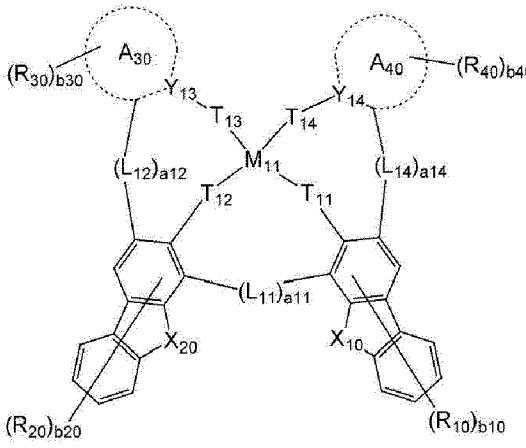
11-2



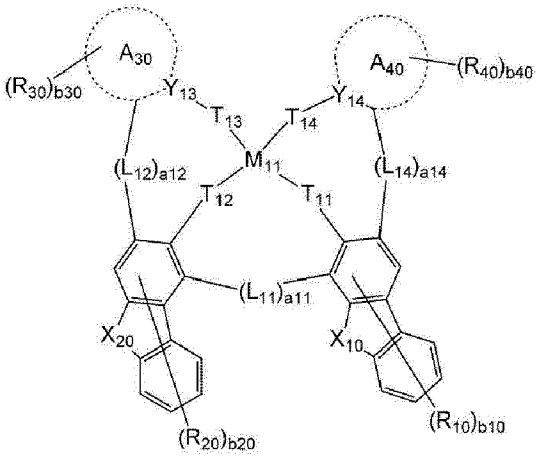
11-3



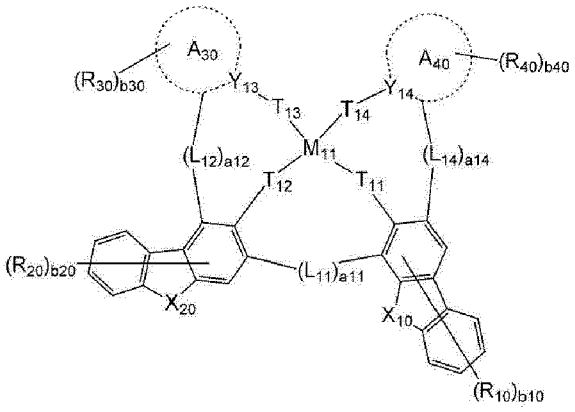
11-4



11-5



11-6



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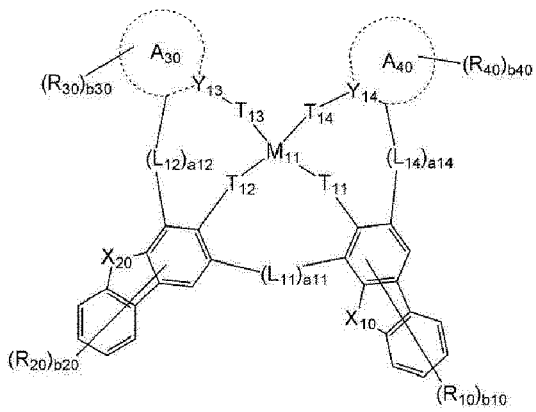

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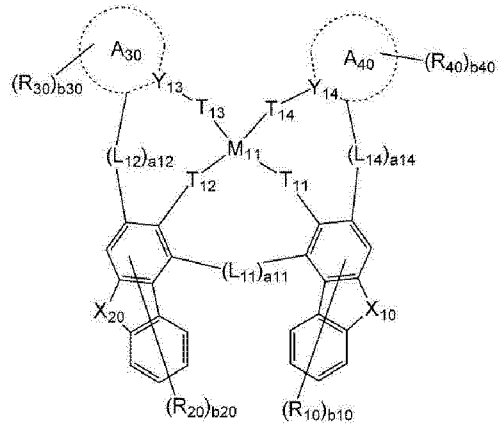

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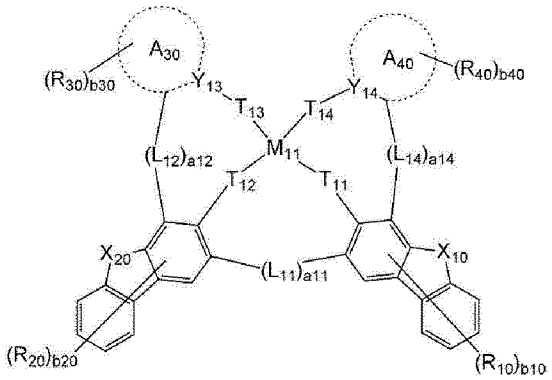
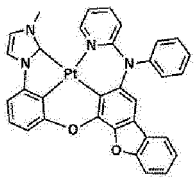


11-10 ,

wherein, in Formulae 11-1 to 11-10,

M_{11}, A_{30}, A_{40}, Y_{13}, Y_{14}, T_{11} to T_{14}, L_{11}, L_{12}, L_{14}, a11, a12, a14, R_{10}, R_{20}, R_{30}, R_{40}, b10, b20, b30, and b40 are each as defined in Formulae 1 and A-10, and
X_{10} and X_{20} are each independently O or S.

20. An organometallic compound according to claim 6, wherein
the organometallic compound represented by Formula 1 is selected from Compounds 1 to 178:



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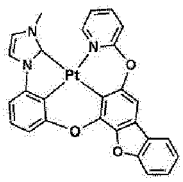

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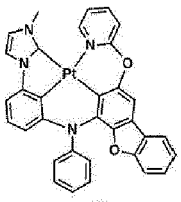

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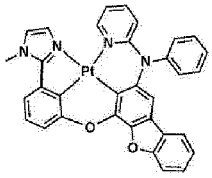

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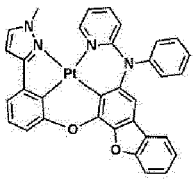

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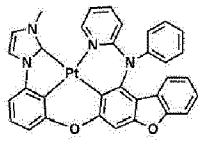

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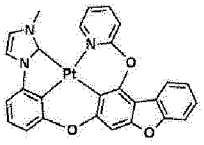

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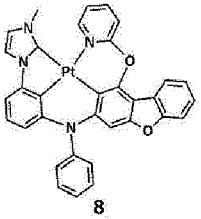

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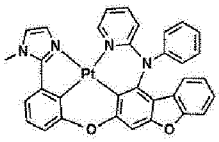

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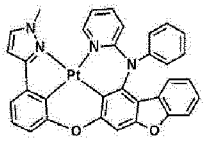

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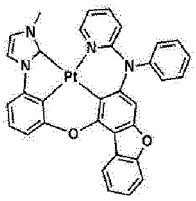

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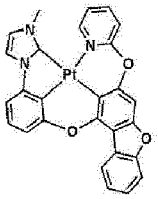

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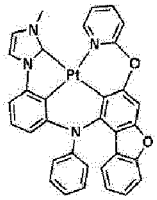

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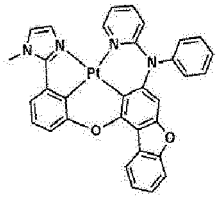

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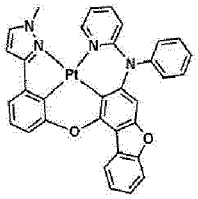

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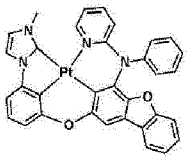

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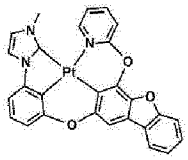

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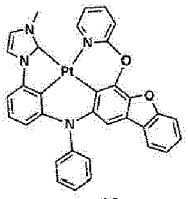

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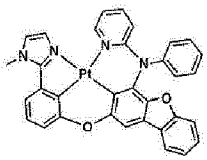

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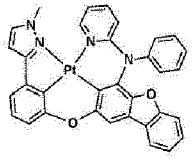

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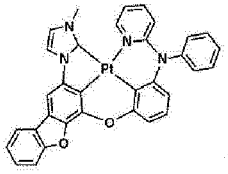

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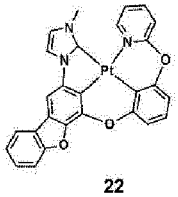

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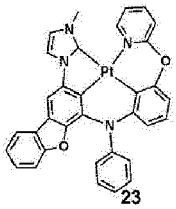

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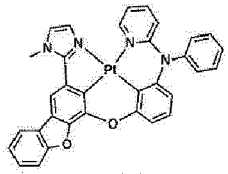

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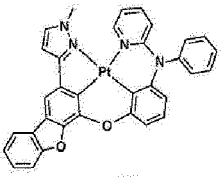

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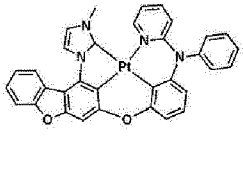

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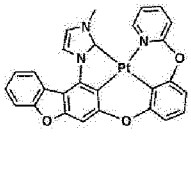

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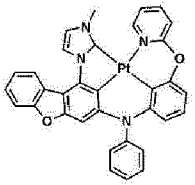

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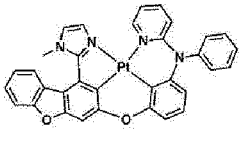

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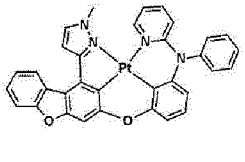

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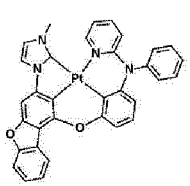

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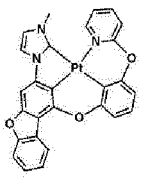

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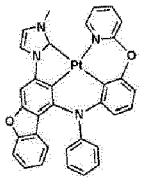

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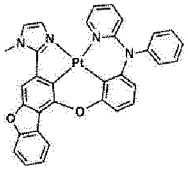

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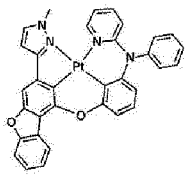

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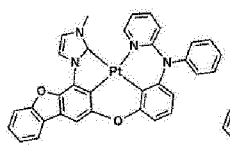

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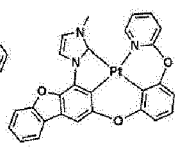

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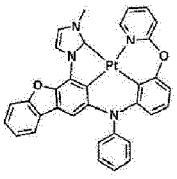

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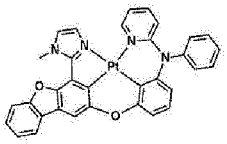

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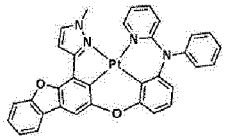

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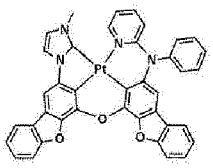

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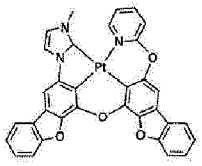

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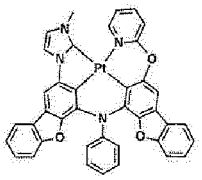

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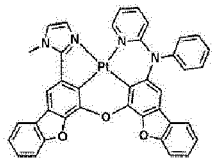

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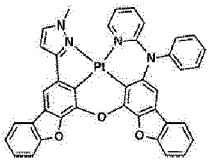

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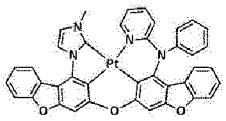

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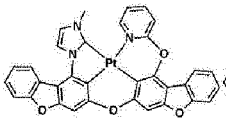

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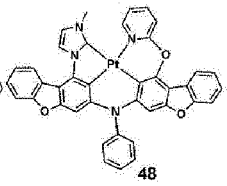

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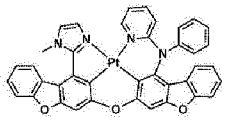

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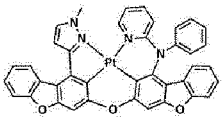

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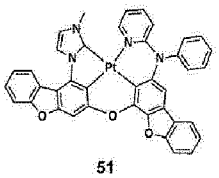

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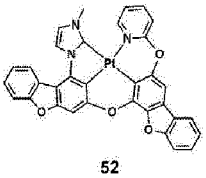

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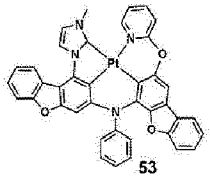

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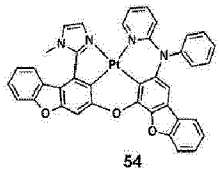

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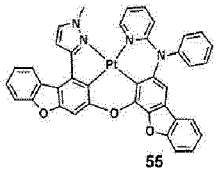

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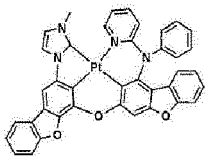

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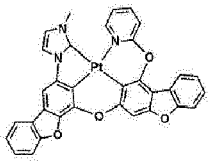

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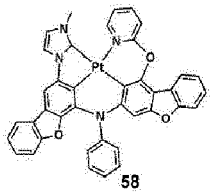

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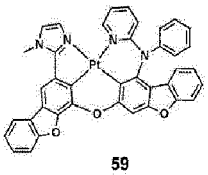

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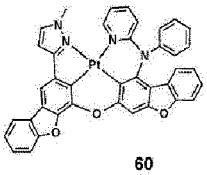

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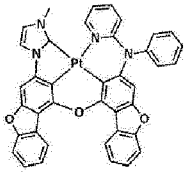

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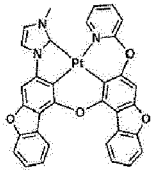

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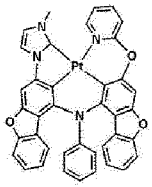

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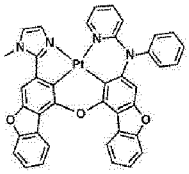

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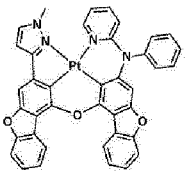

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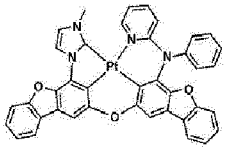

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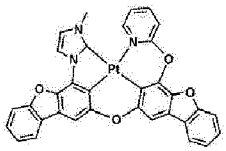

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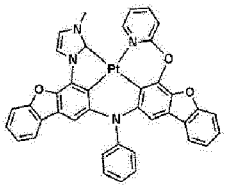

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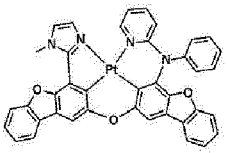

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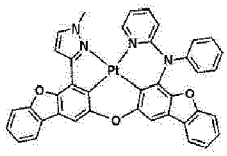

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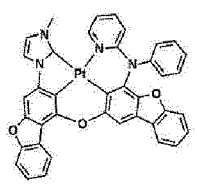
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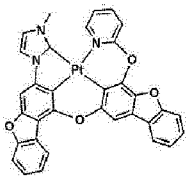
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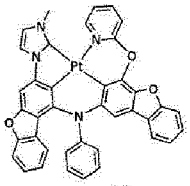
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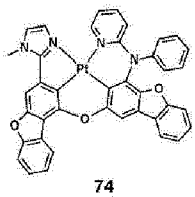
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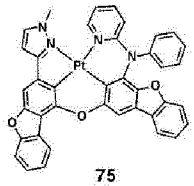
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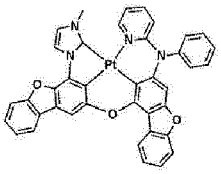
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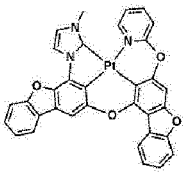
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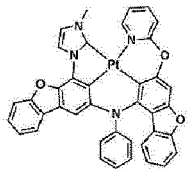
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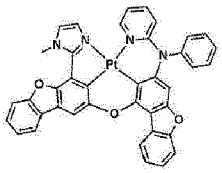
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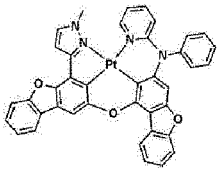
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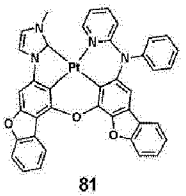
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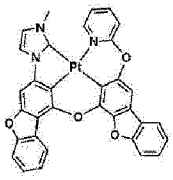
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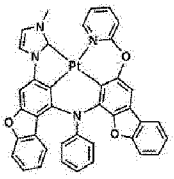
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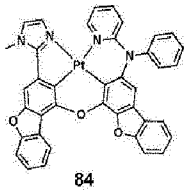
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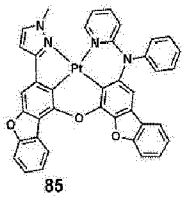
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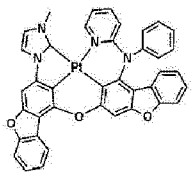
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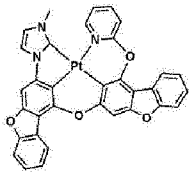
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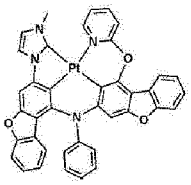
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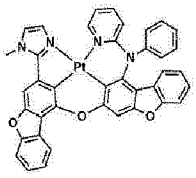
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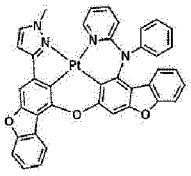
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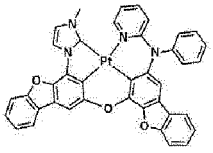
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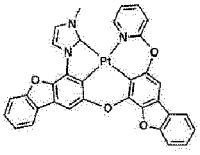
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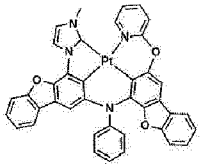
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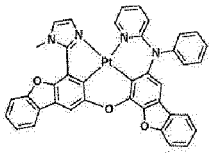
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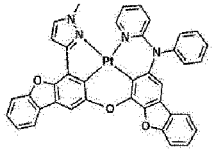
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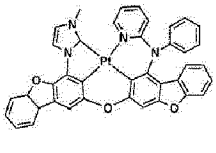
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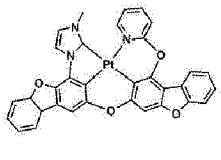
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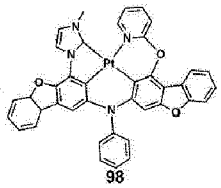
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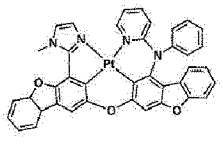
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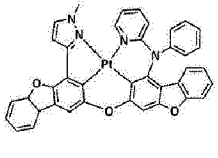
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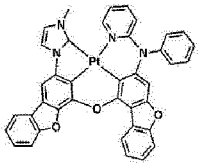
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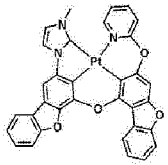
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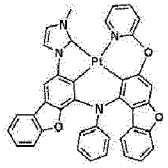
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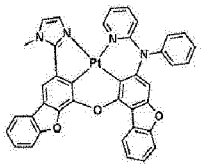
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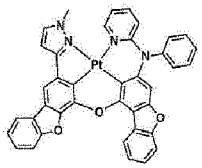
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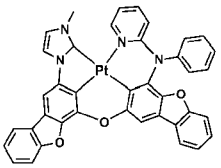

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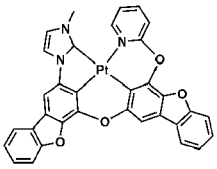

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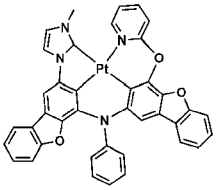

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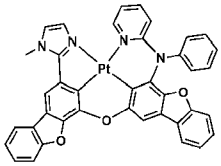

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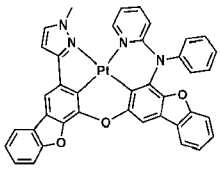

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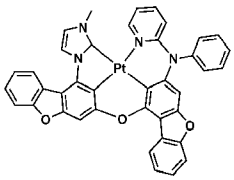

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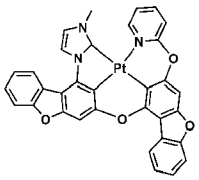

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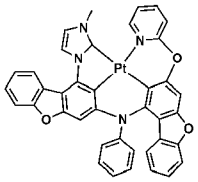

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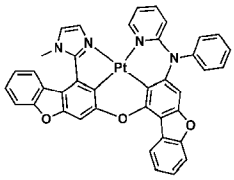

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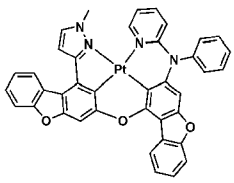

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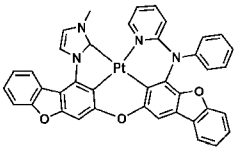

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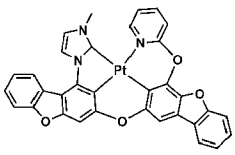

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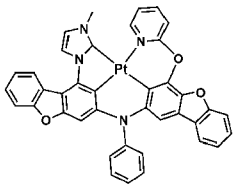

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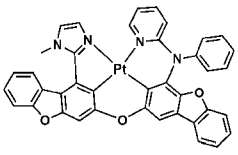

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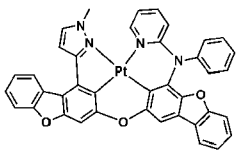

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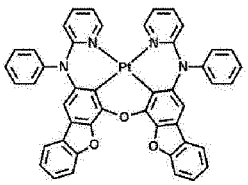

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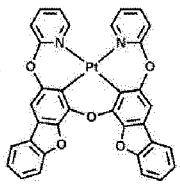

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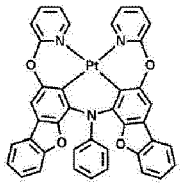

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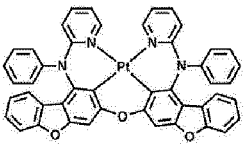

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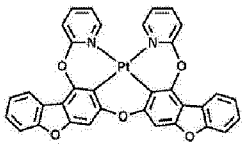

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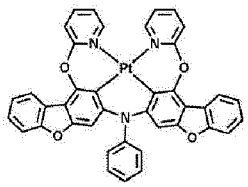

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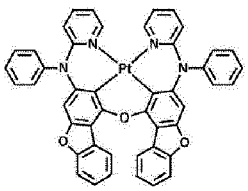

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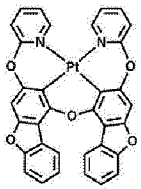

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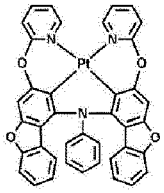

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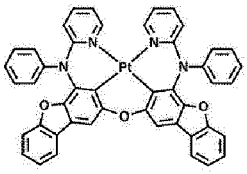

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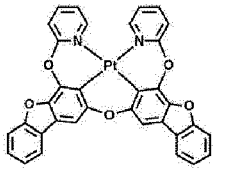

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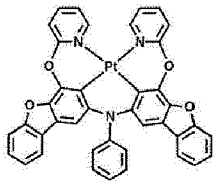

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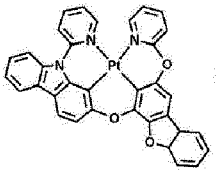

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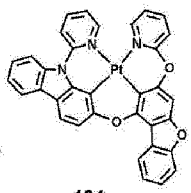

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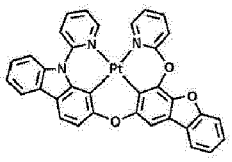

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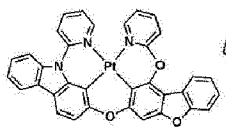

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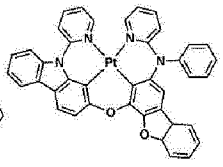

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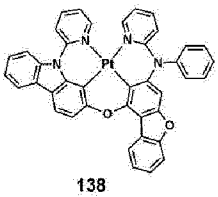

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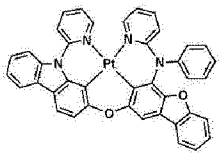

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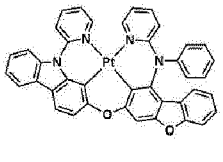

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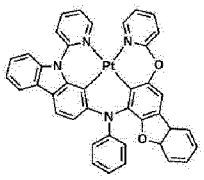
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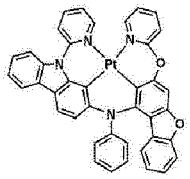
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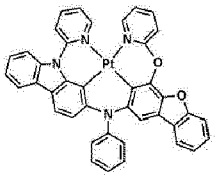
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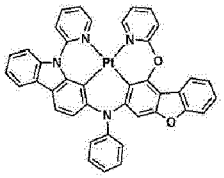
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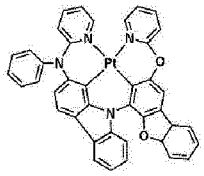
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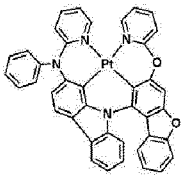
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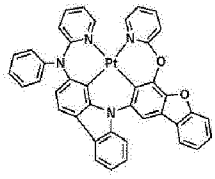
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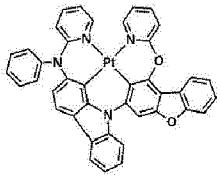
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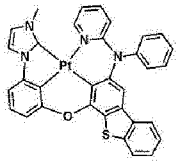
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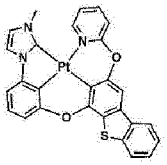
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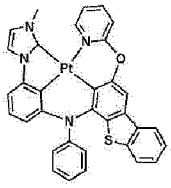
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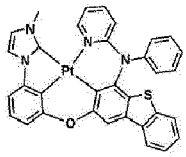
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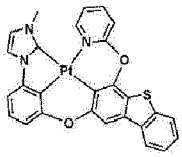
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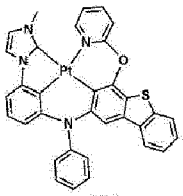
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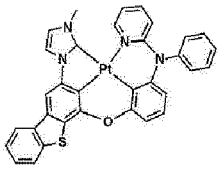
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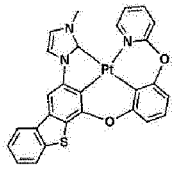
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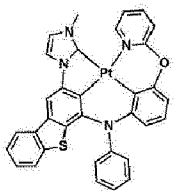
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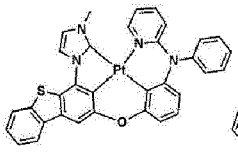
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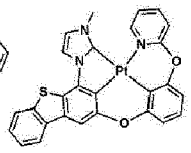
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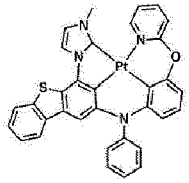
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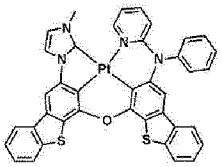
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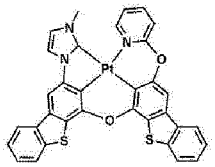
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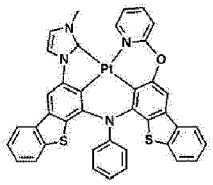
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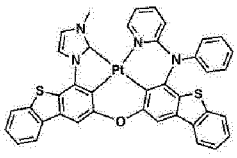
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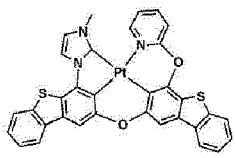
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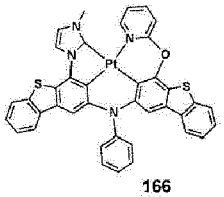
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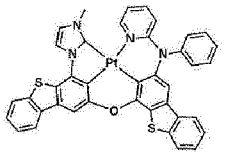
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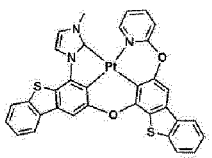
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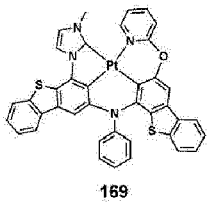
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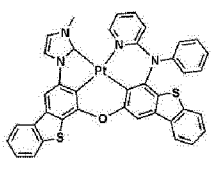
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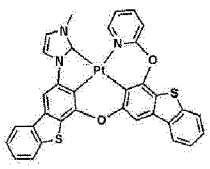

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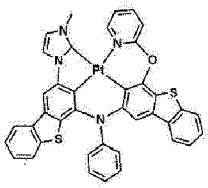

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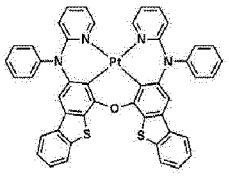

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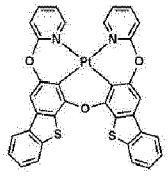

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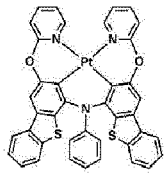

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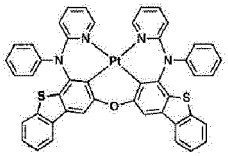

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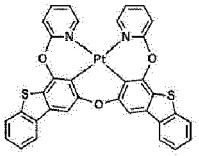

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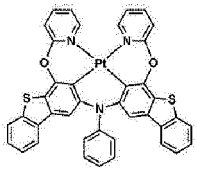

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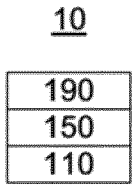
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EUROPEAN SEARCH REPORT

Application Number
EP 19 16 1751

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 266 790 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 10 January 2018 (2018-01-10) * Organometallic Pt-complexes with a ligand of type Cyc1-Cyc2-Cy3-Cyc4, where "Cyc" stands for a cyclic carbo/heterocyclic group, and wherein either Cyc2 or Cyc3 or both represents a dibenzofuran-unit: compounds such as 2.2 to 2-29, 3-5 to 3-25, 3-56 to 3-73, 3-119 etc.; page 133 - page 164; claim 12 * * OLED devices with such compounds: claims 13-14 * -----	1-20	INV. C07F15/00 C09K11/06 H01L51/50 H05B33/14
X	US 2018/062088 A1 (CHO YONGSUK [KR] ET AL) 1 March 2018 (2018-03-01) * compound 1, page 38; compound 2, page 39 * * Use of such compounds in OLEDs: 16-19 * -----	1-20	
X	EP 3 205 659 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 16 August 2017 (2017-08-16) * Claim 9, Markush formulae 1(5) and 1(7) * * compound 24, claim 10 * * OLED devices with such compounds: claims 11-13 * -----	1-20	TECHNICAL FIELDS SEARCHED (IPC) C07F H05B C09K H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	17 July 2019	Lange, Tim

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 16 1751

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17-07-2019

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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	KR1020190108223A	公开(公告)日	2019-09-24
申请号	KR1020180029287	申请日	2018-03-13
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星显示器有限公司		
[标]发明人	심문기 박준하 이효영 고수병 김성범 김영국 한정훈 황석환		
发明人	심문기 박준하 이효영 고수병 김성범 김영국 전미나 한정훈 황석환		
IPC分类号	C09K11/06 C07F15/00		
CPC分类号	C09K11/06 C07F15/0086 C09K2211/185 H01L51/0087 H01L51/5012 C09K2211/1007 C09K2211/1014 C09K2211/1029 C09K2211/1044 C09K2211/1088 C09K2211/1092 H01L51/5016 C09K2211/1033 H01L51/5096		
外部链接	Espacenet		

摘要(译)

本发明涉及在有机发光器件中能够具有低驱动电压，高亮度和高效率的有机金属化合物，以及包括该有机金属化合物的有机发光器件。 本发明的有机金属化合物包括：第一电极；和第二电极。 第二电极； 有机层包括介于第一电极和第二电极之间的发光层。