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

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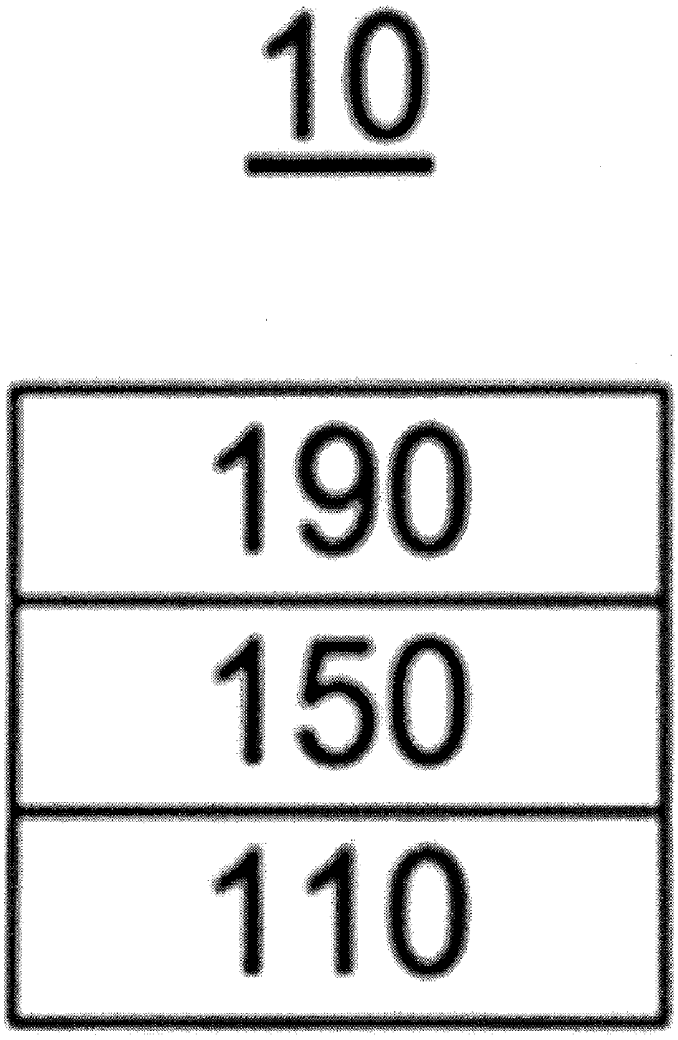
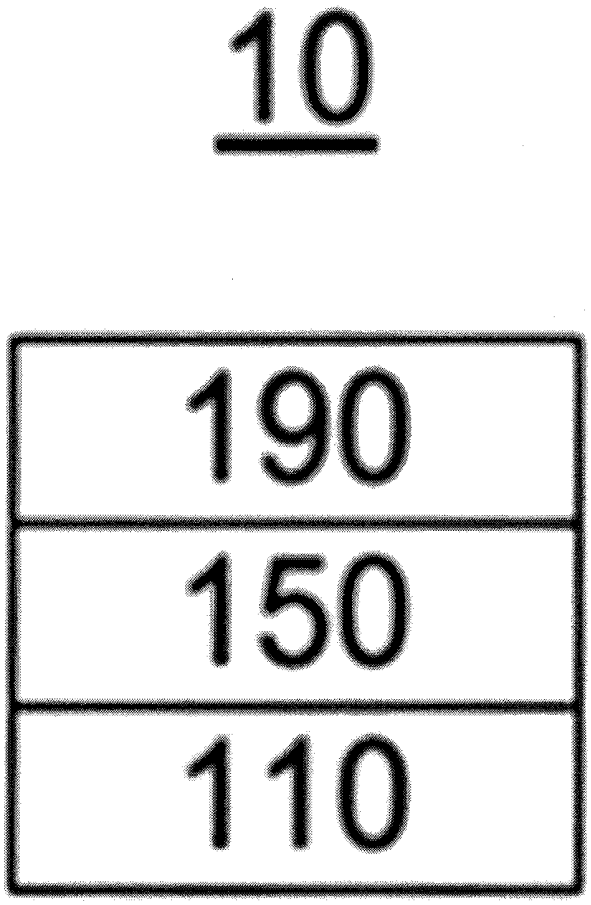
(57) **ABSTRACT**

Provided are an organometallic compound and an organic light-emitting device including the same. The organic light-emitting device may include: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, the organic layer including at least one organometallic compound.

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ORGANOMETALLIC COMPOUND AND ORGANIC LIGHT-EMITTING DEVICE INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0094319, filed on Jul. 25, 2017, in the Korean Intellectual Property Office, the entire content of which is incorporated herein by reference.

BACKGROUND

1. Field

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

2. Description of the Related Art

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

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

SUMMARY

[0005] Aspects of embodiments of the present disclosure provide a novel organometallic compound and an organic light-emitting device including the same.

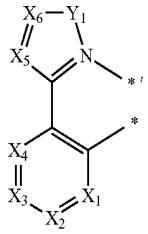
[0006] Additional aspects of embodiments of the disclosure will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0007] An aspect of an embodiment provides an organometallic compound represented by Formula 1 below:

Formula 1

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

Formula 2A



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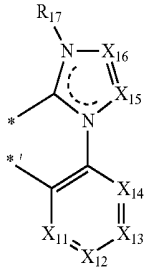
Formula 2B



Formula 7

$$*-(Z_{32})_{b2}-*'.$$

[0008] M in Formula 1 may be a third row transition metal,

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

[0010] in Formula 1, L_2 may be a ligand represented by Formula 2B, and n2 may be 1, 2, or 3, wherein, when n2 is two or more, two or more L_2(s) may be identical to or different from each other,

[0011] the sum of n1 and n2 in Formula 1 may be 2 or 3,

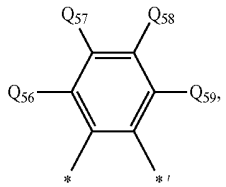
[0012] * and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1,

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

[0014] Y_1 may be selected from $N(R_7)$, O, and S,

[0015] in Formula 2B, X_{11} may be N or $C(R_{11})$, X_{12} may be N or $C(R_{12})$, X_{13} may be N or $C(R_{13})$, X_{14} may be N or $C(R_{14})$, X_{15} may be N or $C(R_{15})$, and X_{16} may be N or $C(R_{16})$,

[0016] Z_{32} in Formula 7 may be *—O—*', *—S—*', *—$N(Q_{51})$-*', *—$B(Q_{51})$-*', *—$C(Q_{52})(Q_{53})$-*', *—$C(Q_{54})$=$C(Q_{55})$-*', or



[0017] b2 may be an integer from 1 to 10, wherein, when b2 is two or more, two or more Z_{32}(s) may be identical to or different from each other,

[0018] R_1 to R_7, R_{11} to R_{17}, and Q_{51} to Q_{59} in Formulae 2A, 2B, and 7 may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a substituted or unsubstituted C_1-C_{60} alkyl group, a substituted or unsubstituted C_2-C_{60} alkenyl group, a substituted or unsubstituted C_2-C_{60} alkynyl group, a substituted or unsubstituted C_1-C_{60} alkoxy group, a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10}

heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, —$P(Q_1)(Q_2)$, and —$P(=O)(Q_1)(Q_2)$,

[0019] two neighboring groups selected from R_1 to R_4 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

[0020] R_5 and R_6 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

[0021] two neighboring groups selected from R_{11} to R_{14} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

[0022] R_{15} and R_{16} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

[0023] R_1 and R_{11} in Formula 2A and 2B may optionally be linked via a single bond or a linking group represented by Formula 7,

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

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

[0026] a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{11})(Q_{12})$, —$B(Q_{11})(Q_{12})$, —$C(=O)(Q_{1i})$, —$S(=O)_2(Q_{11})$, and —$P(=O)(Q_{11})(Q_{12})$;

[0027] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0028] a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_6-C_{60} aryloxy group, a C_6-C_{60} arylthio group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a 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

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

[0030] Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C_1-C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C_6-C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

[0031] Another aspect of an embodiment provides an organic light-emitting device including: a first electrode; a second electrode facing the first electrode; and an organic layer between the first electrode and the second electrode and including an emission layer, wherein the organic layer includes at least one organometallic compound.

BRIEF DESCRIPTION OF THE DRAWING

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

DETAILED DESCRIPTION

[0033] Reference will now be made in more detail to embodiments of the present disclosure, 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 accompanying drawing, to explain aspects of embodiments 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.

[0034] An organometallic compound according to an embodiment is represented by Formula 1 below:

$$M(L_1)_{n1}(L_2)_{n2}. \quad \text{Formula 1}$$

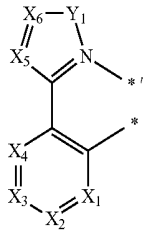
[0035] M in Formula 1 may be a third row transition metal.

[0036] For example, M in Formula 1 may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), thulium (Tm), rhenium (Re), and rhodium (Rh).

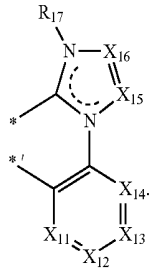
[0037] In one embodiment, M in Formula 1 may be iridium or platinum, but embodiments of the present disclosure are not limited thereto.

[0038] In Formula 1, L_1 may be a ligand represented by Formula 2A, n1 may be 1, 2, or 3, wherein, when n1 is two or more, two or more L_1(s) may be identical to or different from each other, L_2 may be a ligand represented by Formula 2B, and n2 may be 1, 2, or 3, wherein, when n2 is two or more, two or more L_2(s) may be identical to or different from each other:

Formula 2A



Formula 2B



[0039] In Formula 1, the sum of n1 and n2 may be 2 or 3.

[0040] The organometallic compound represented by Formula 1 does not have a salt form consisting of an anode and a cation and is neutral.

[0041] In one embodiment, in Formula 1, M may be iridium and the sum of n1 and n2 may be 3; or, in Formula 1, M may be platinum, n1 may be 1, and n2 may be 1, but embodiments of the present disclosure are not limited thereto. For example, in Formula 1, M may be iridium (Ir), n1 may be 2, and n2 may be 1; or, in Formula 1, M may be platinum (Pt), n1 may be 1, and n2 may be 1, but embodiments of the present disclosure are not limited thereto.

[0042] * and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1.

[0043] In Formula 2A, X_1 may be $C(R_1)$, X_2 may be $C(R_2)$, X_3 may be $C(R_3)$, and X_4 may be $C(R_4)$.

[0044] In one embodiment, Y_1 in Formula 2A may be $N(R_7)$ or O.

[0045] In one or more embodiments, in Formula 2A, X_5 may be $C(R_5)$, and X_6 may be $C(R_6)$.

[0046] In one or more embodiments, at least one of R_5 and R_6 may not be hydrogen, but embodiments of the present disclosure are not limited thereto. For example, R_6 may not be hydrogen, but embodiments of the present disclosure are not limited thereto.

[0047] In one embodiment, in Formula 2B, i) X_{11} may be $C(R_{11})$, X_{12} may be $C(R_{12})$, X_{13} may be $C(R_{13})$, and X_{14} may be $C(R_{14})$; ii) X_{11} may be $C(R_{11})$, X_{12} may be $C(R_{12})$, X_{13} may be N, and X_{14} may be $C(R_{14})$; or iii) X_{11} may be N, X_{12} may be $C(R_{12})$, X_{13} may be N, and X_{14} may be $C(R_{14})$.

[0048] In one or more embodiments, in Formula 2B, i) X_{15} may be $C(R_{15})$, and X_{16} may be $C(R_{16})$; or ii) X_{15} may be N, and X_{16} may be $C(R_{16})$.

[0049] In one or more embodiments, in Formula 1, M may be platinum, and R_1 and R_{11} may be linked via a linking group represented by Formula 7.

$$*-(Z_{32})_{b2}-*' \quad \text{Formula 7}$$

[0050] In one embodiment, Z_{32} in Formula 7 may be *—O—*', *—$N(Q_{51})$-*', or *—$B(Q_{51})$-*'. In this case, Q_{51} may be a phenyl group, or a phenyl group substituted with at least one C_1-C_{20} alkyl group. For example, R_1 to R_7, R_{11} to R_{17}, and Q_{51} to Q_{59} in Formulae 2A, 2B, and 7 may each independently be selected from:

[0051] 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_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0052] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$;

[0053] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an

indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

[0054] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $P(=O)(Q_{31})(Q_{32})$; and

[0055] $—Si(Q_1)(Q_2)(Q_3)$, $—N(Q_1)(Q_2)$, $—B(Q_1)(Q_2)$, $—C(=O)(Q_1)$, $—S(=O)_2(Q_1)$, $—P(Q_1)(Q_2)$, and $—P(=O)(Q_1)(Q_2)$, and

[0056] Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from:

[0057] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0058] a C_1-C_{20} alkyl group, substituted with at least one selected from deuterium, —F, and a cyano group;

[0059] a C_6-C_{20} aryl group, substituted with at least one selected from deuterium, —F, and a cyano group; and

[0060] a biphenyl group and a terphenyl group.

[0061] In one or more embodiments, R_1 to R_7, R_{11} to R_{17}, and Q_{51} to Q_{59} in Formulae 2A, 2B, and 7 may each independently be selected from:

[0062] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a nitro group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0063] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a cyano group, a nitro group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0064] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, and a dibenzocarbazolyl group;

[0065] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl

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

[0066] —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, —$P(Q_1)(Q_2)$, and —$P(=O)(Q_1)(Q_2)$, and

[0067] Q_1 to Q_3 and Q_{31} to Q_{33} are the same as described herein.

[0068] 1) Two neighboring groups selected from R_1 to R_4 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group, 2) R_5 and R_6 in Formula 2A may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group, 3) two neighboring groups selected from R_{11} to R_{14} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group, and 4) R_{15} and R_{16} in Formula 2B may optionally be linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group. The substituents of the substituted C_4-C_{60} carbocyclic group and the substituted C_2-C_{60} heterocyclic group are the same as described in connection with R_1 to R_7 and R_{11} to R_{17}, the C_4-C_{60} carbocyclic group may be, for example, a cyclopentane group, a cyclohexane group, an adamantane group, a norbornane group, a benzene group, or a naphthalene group, and the C_2-C_{60} heterocyclic group may be, for example, a thiophene group, a furan group, a pyrrole group, a benzothiophene group, a benzofuran group, an indole group, a pyridine group, or diazine group, but embodiments of the present disclosure are not limited thereto.

[0069] In one embodiment, in Formula 2A, i) when X_1 is $C(R_1)$, X_2 is $C(R_2)$, X_3 is $C(R_3)$, X_4 is $C(R_4)$, and Y_1 is $N(R_7)$, ia) R_1 to R_5 may each be hydrogen, and R_6 and R_7 may each independently be a methyl group or a phenyl group, ib) R_1 to R_4 may each be hydrogen, R_5 may be selected from a phenyl group, a carbazolyl group, an acridinyl group substituted with at least one methyl group, —$Si(Q_1)(Q_2)(Q_3)$, —$B(Q_1)(Q_2)$, —$P(Q_1)(Q_2)$, and —$P(=O)(Q_1)(Q_2)$, and R_6 and R_7 may each be a phenyl group, or ic) and R_{11} may be linked via a linking group represented by Formula 7, R_1 to R_4 may each be hydrogen, R_5 may be a phenyl group substituted with at least one methyl group, and R_6 and R_7 may each be a phenyl group, and

[0070] Q_1 to Q_3 may each independently be a methyl group or a phenyl group.

[0071] In one or more embodiments, in Formula 2B, i) when X_{11} is $C(R_{11})$, X_{12} is $C(R_{12})$, X_{13} is $C(R_{13})$, and X_{14} is $C(R_{14})$, ia) R_{11} to R_{14} may each be hydrogen, or ib) R_{11}, R_{13}, and R_{14} may each be hydrogen, and R_{12} may be an electron withdrawing group;

[0072] ii) when X_{11} is $C(R_{11})$, X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$, iia) R_{11}, R_{12}, and R_{14} may each be hydrogen, iib) R_{11} may be hydrogen, and R_{12} and R_{14} may each be an electron withdrawing group, or ic) R_{11} and R_{14} may each be hydrogen, and R_{12} may be an electron withdrawing group; or

[0073] iii) when X_{11} is N, X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$, R_{12} and R_{14} may each be hydrogen. The electron withdrawing groups is the same as described herein.

[0074] The "electron withdrawing group" may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or —$B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, and —$B(Q_{31})(Q_{32})$,

[0075] provided that the group is selected from:

[0076] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0077] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —CD_3, —CD_2H, —CDH_2, a hydroxyl group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$;

[0078] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxali-

nyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group; and

[0079] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, $—CD_3$, $—CD_2H$, $—CDH_2$, a hydroxyl group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$, and

[0080] Q_1 to Q_3 and Q_{31} to Q_{33} may each independently be selected from:

[0081] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

[0082] a C_1-C_{20} alkyl group, substituted with at least one selected from deuterium, —F, and a cyano group;

[0083] a C_6-C_{20} aryl group, substituted with at least one selected from deuterium, —F, and a cyano group; and

[0084] a biphenyl group and a terphenyl group.

[0085] For example, it is understood from the present disclosure that, 1) when the electron withdrawing group is a first group substituted with at least one —F and the first group is "a methyl group", the electron withdrawing group may be "a methyl group substituted with at least one —F (for example, $—CF_3$, $—CHF_2$, or $—CH_2F$)", 2) when the electron withdrawing group is a first group substituted with at least one —F and the first group is "a methyl group substituted with at least one deuterium", the electron withdrawing group may be "a methyl group substituted with at least one —F and at least one deuterium (for example, $—CDF_2$ or $—CD_2F$)".

[0086] In one or more embodiments, the electron withdrawing group may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or $—B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, $—CF_3$, $—CF_2H$, $—CFH_2$, a cyano group, a nitro group, and $—B(Q_{31})(Q_{32})$,

[0087] provided that the first group is selected from:

[0088] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

[0089] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, $—CD_3$, $—CD_2H$, $—CDH_2$, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group;

[0090] a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, and a fluorenyl group; and

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

[0092] Q_1, Q_2, Q_{31}, and Q_{32} may each independently be selected from:

[0093] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

[0094] a C_1-C_{20} alkyl group, substituted with at least one selected from deuterium, —F, and a cyano group;

[0095] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

[0096] a biphenyl group and a terphenyl group.

[0097] In one or more embodiments, the electron withdrawing group may be —F, —Cl, —Br, —I, a cyano group, a nitro group, or $—B(Q_1)(Q_2)$, or may be a first group substituted with at least one selected from —F, —Cl, —Br, —I, $—CF_3$, $—CF_2H$, $—CFH_2$, a cyano group, a nitro group, and $—B(Q_{31})(Q_{32})$,

[0098] provided that the first group is selected from:

[0099] a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group; and

[0100] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, $—CD_3$, $—CD_2H$, $—CDH_2$, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, and a pyrimidinyl group, and

[0101] Q_1, Q_2, Q_{31}, and Q_{32} may each independently be selected from:

[0102] hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, and a naphthyl group;

[0103] a C_1-C_{20} alkyl group, substituted with at least one selected from deuterium, —F, and a cyano group;

[0104] a phenyl group and a naphthyl group, each substituted with at least one selected from deuterium, —F, and a cyano group; and

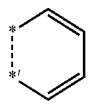
[0105] a biphenyl group and a terphenyl group,

[0106] but embodiments of the present disclosure are not limited thereto.

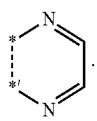
[0107] In one embodiment, in Formula 2B, i) when X_{15} is $C(R_{15})$ and X_{16} is $C(R_{16})$, ia) R_{15} and R_{16} may each be hydrogen, and R_{17} may be a methyl group or a phenyl group, or ib) R_{15} and R_{16} may be linked to form a group represented by Formula 2B-A or 2B-B, and R_{17} may be a methyl group or a phenyl group; or

[0108] ii) when X_{15} is N and X_{16} is $C(R_{16})$, R_{16} may be hydrogen and R_{17} may be a methyl group or a phenyl group:

Formula 2B-A



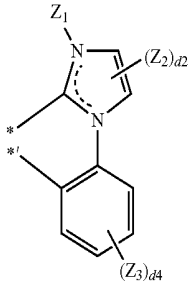
Formula 2B-B



[0109] * and *' in Formula 2B-A or 2B-B each indicate a binding site to X_{15} and X_{16} in Formula 2B.

[0110] L_2 may be a ligand selected from groups represented by Formulae 2B-1 to 2B-88:

2B-1



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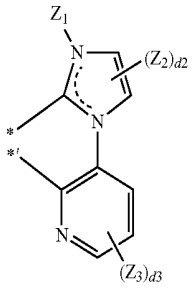

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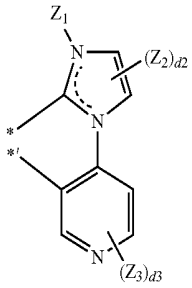

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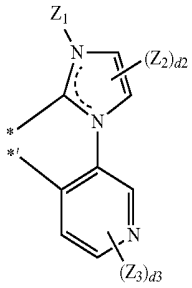

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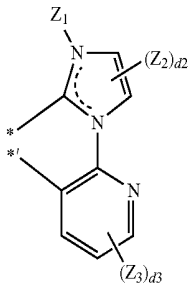

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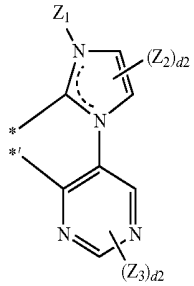

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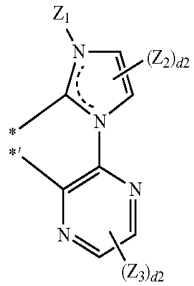

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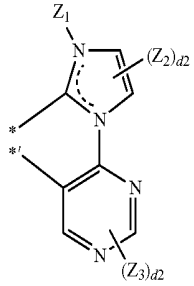

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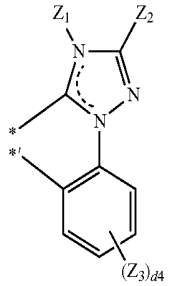

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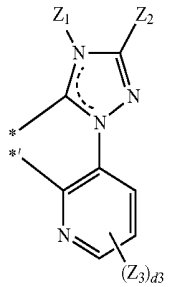

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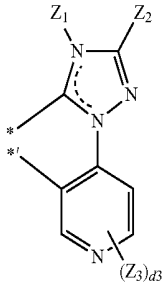

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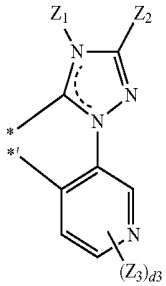

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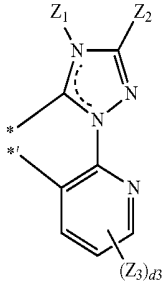

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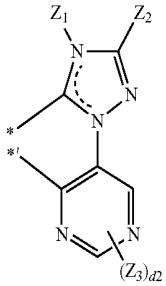

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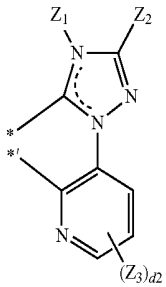

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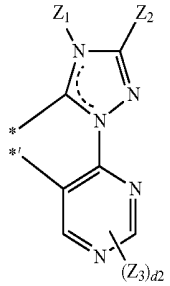

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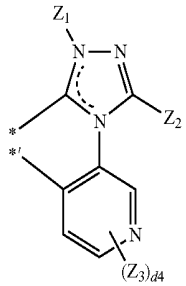

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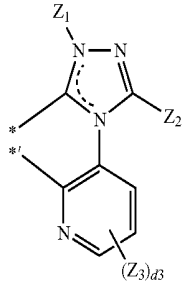

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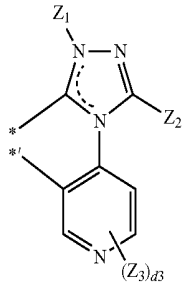

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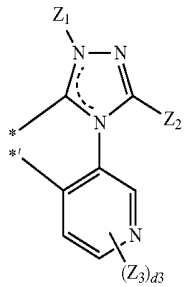

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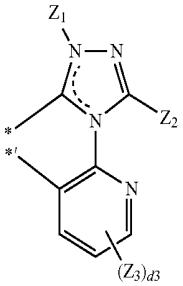

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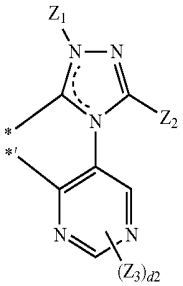

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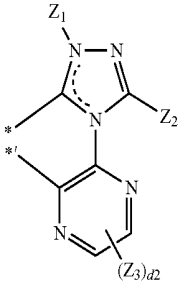

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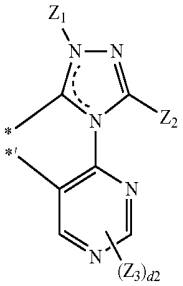

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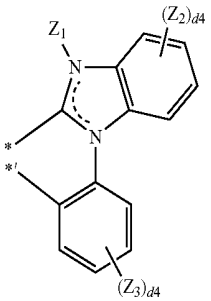

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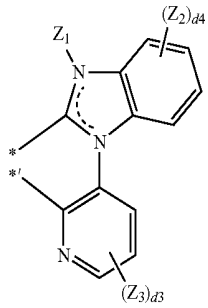

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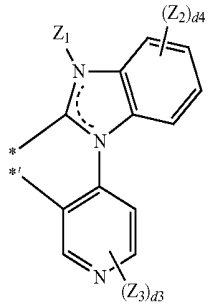

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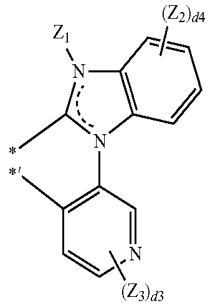

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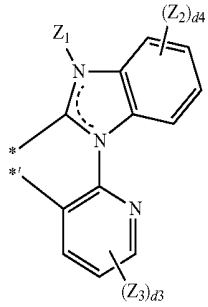

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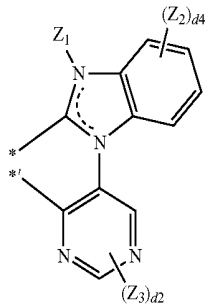

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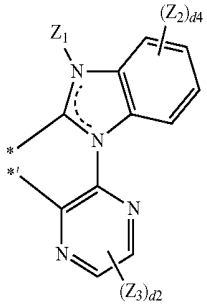

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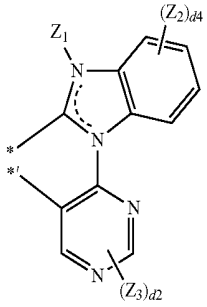

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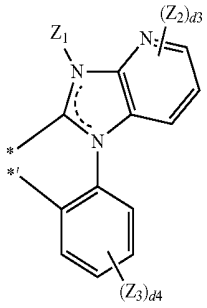

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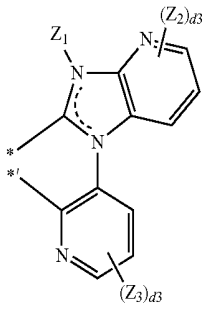

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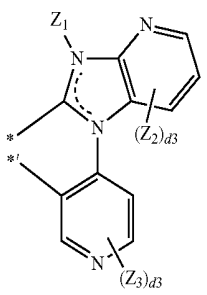

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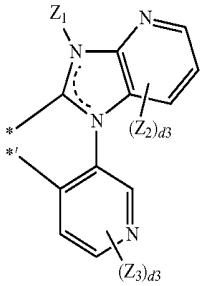

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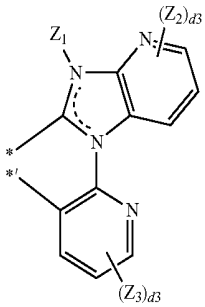

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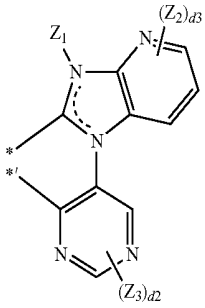

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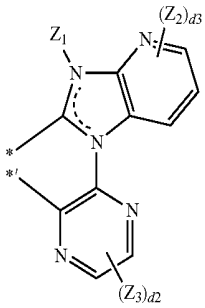

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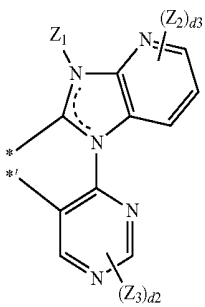

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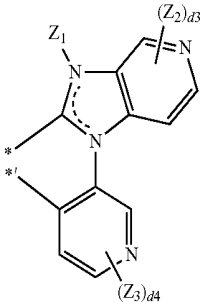

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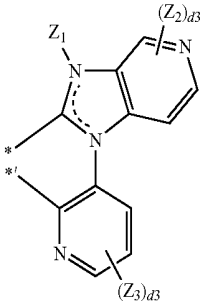

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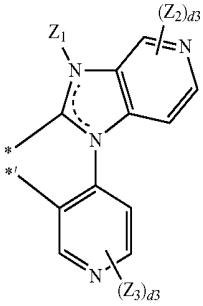

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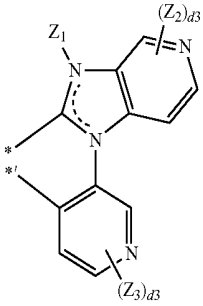

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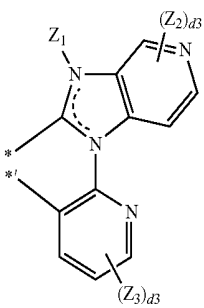

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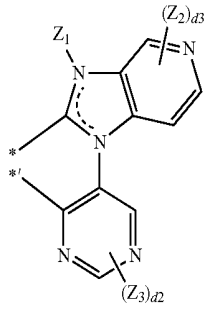
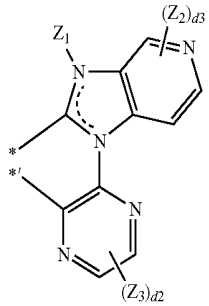
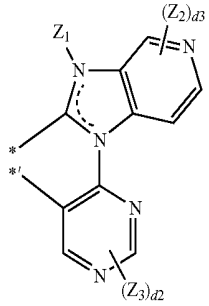


2B-47



2B-48



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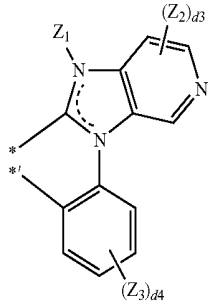
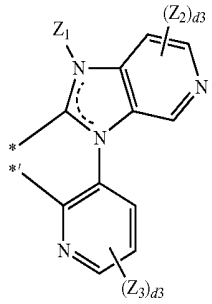


2B-50



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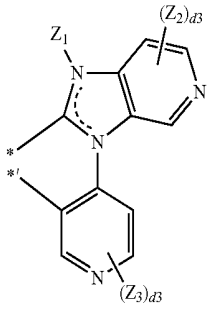
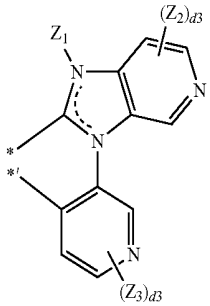
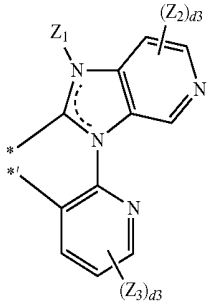


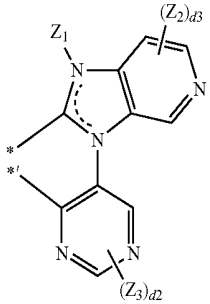
2B-52



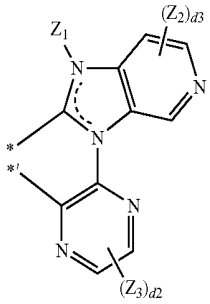
2B-53



2B-54



2B-55



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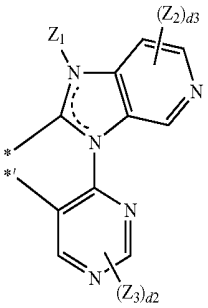
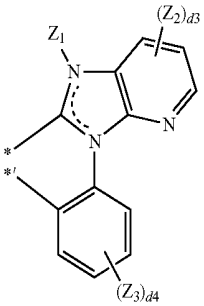
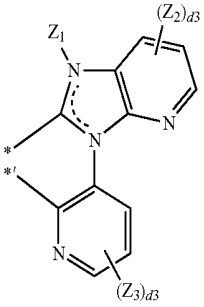
2B-56



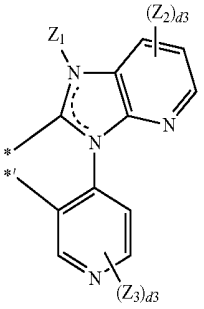
2B-57



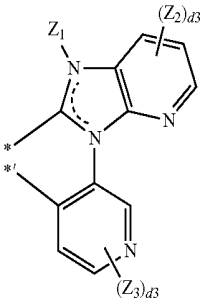
2B-58



2B-59



2B-60



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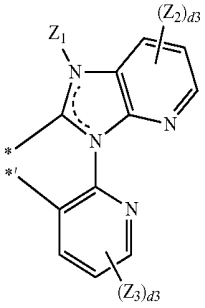
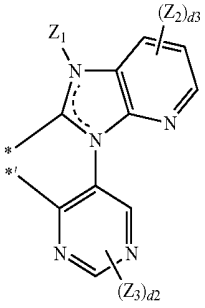
2B-61



2B-62



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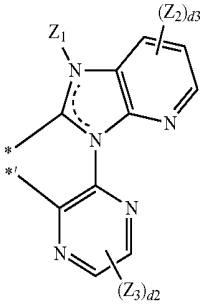
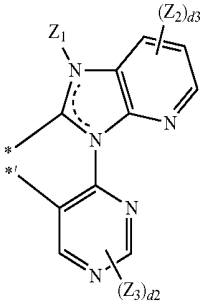


2B-64



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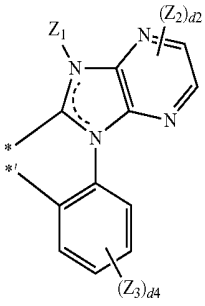

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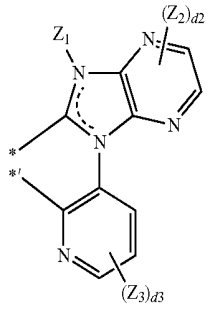
2B-66



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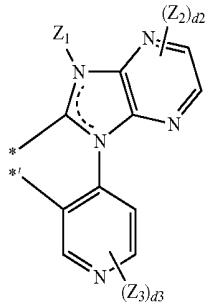

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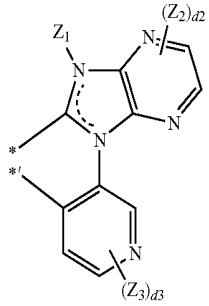

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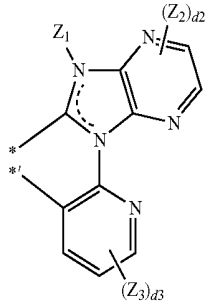
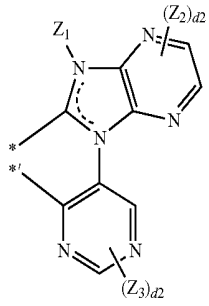


2B-70



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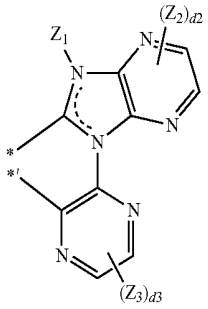
2B-71



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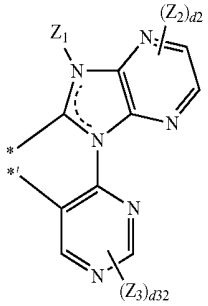

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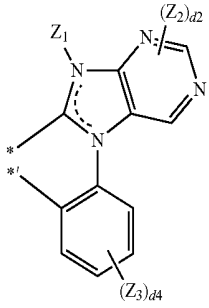
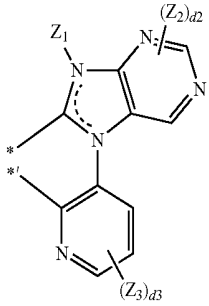
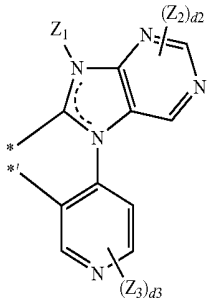


2B-74



2B-75



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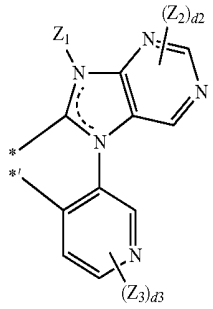
2B-76



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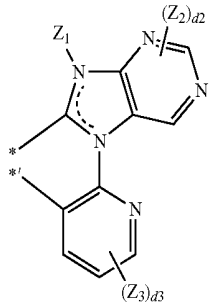

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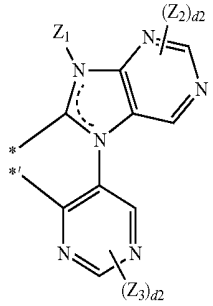
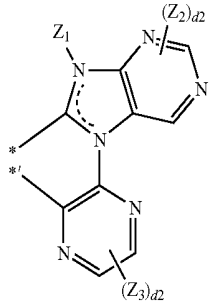
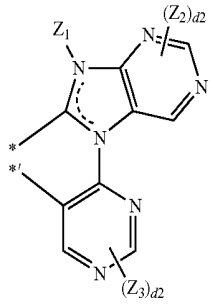


2B-79



2B-80



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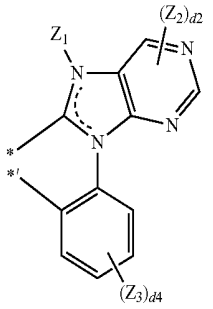
2B-81



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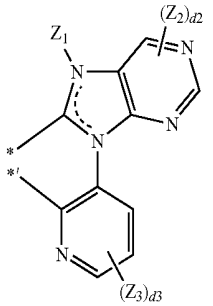
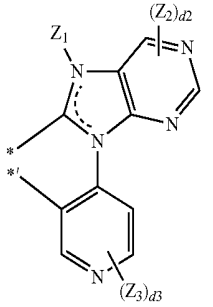
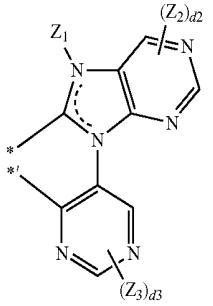


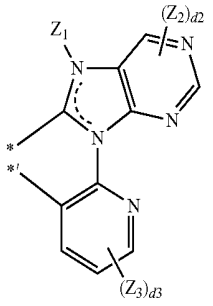
2B-83



2B-84



2B-85



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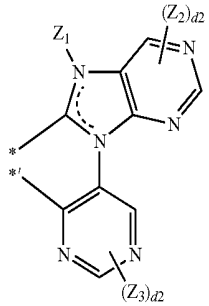
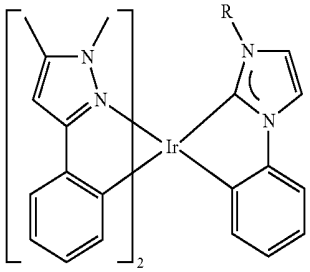
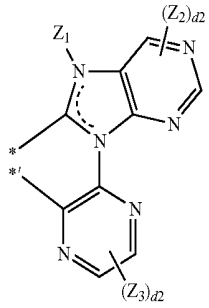
2B-86

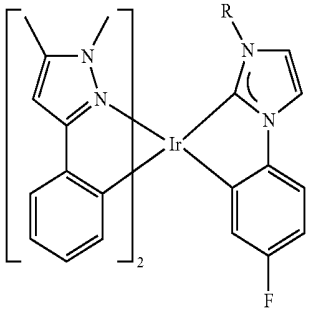




1 (R = Me)
2 (R = Ph)

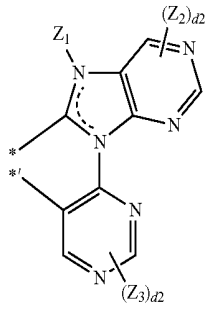
2B-87

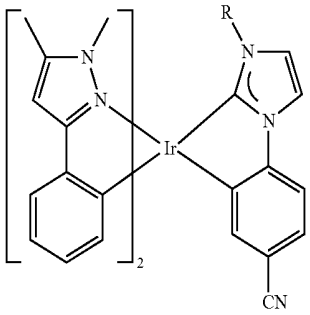




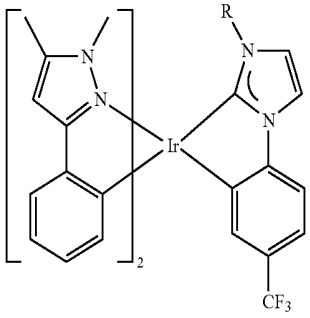
3 (R = Me)
4 (R = Ph)

2B-88





5 (R = Me)
6 (R = Ph)



7 (R = Me)
8 (R = Ph)

[0111] In Formulae 2B-1 to 2B-88,

[0112] Z_1 to Z_3 are each independently the same as described in connection with R_{11} to R_{17},

[0113] d2 may be an integer from 0 to 2,

[0114] d3 may be an integer from 0 to 3,

[0115] d4 may be an integer from 0 to 4, and

[0116] * and *' each indicate a binding site to M in Formula 1.

[0117] For example, L_2 may be a ligand selected from groups represented by Formulae 2B-1, 2B-4, 2B-6, 2B-9, 2B-12, 2B-14, 2B-25, 2B-28, 2B-30, 2B-65, 2B-68, and 2B-70, but embodiments of the present disclosure are not limited thereto.

[0118] In one or more embodiments, the organometallic compound may be selected from Compounds 1 to 454, but embodiments of the present disclosure are not limited thereto:

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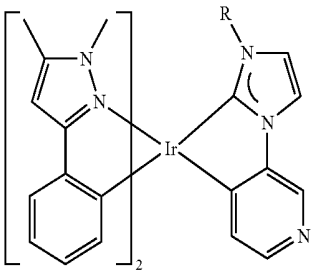

9 (R = Me)
10 (R = Ph)

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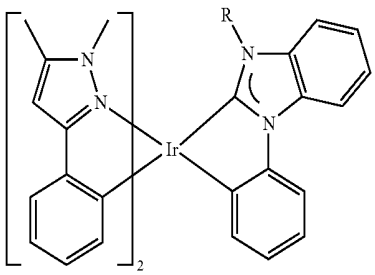
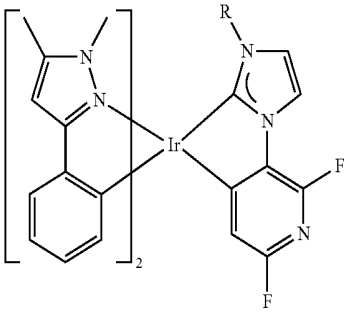
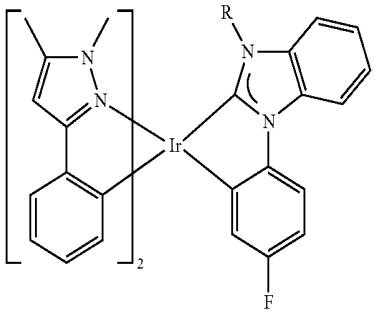


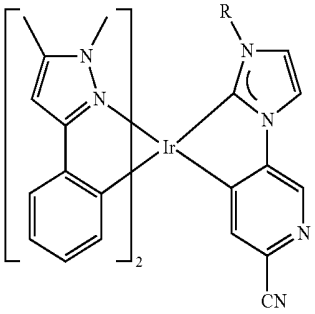
17 (R = Me)
18 (R = Ph)



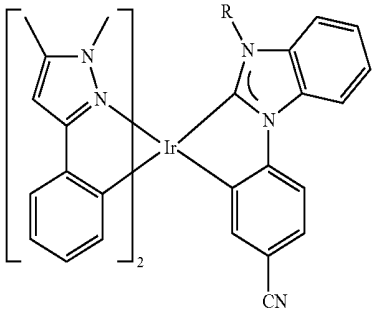
11 (R = Me)
12 (R = Ph)



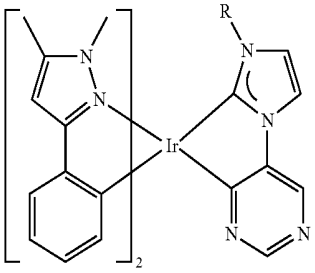
19 (R = Me)
20 (R = Ph)



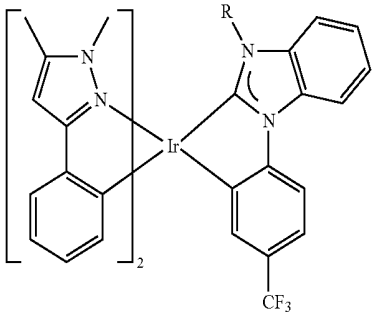
13 (R = Me)
14 (R = Ph)



21 (R = Me)
22 (R = Ph)



15 (R = Me)
16 (R = Ph)



23 (R = Me)
24 (R = Ph)

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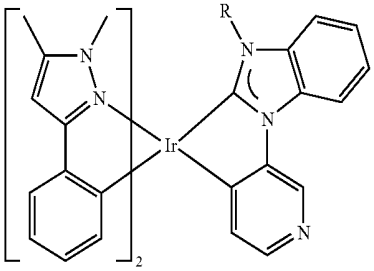
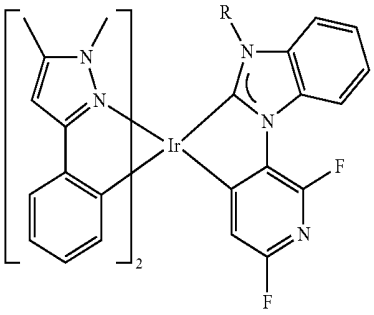
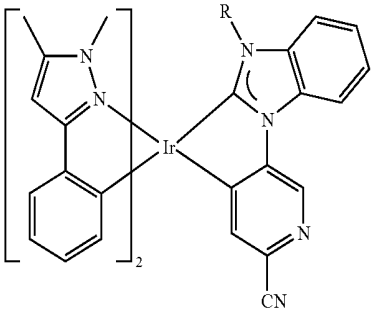


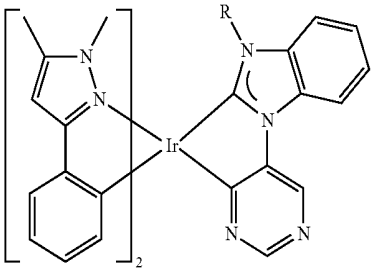
25 (R = Me)
26 (R = Ph)



27 (R = Me)
28 (R = Ph)



29 (R = Me)
30 (R = Ph)



31 (R = Me)
32 (R = Ph)

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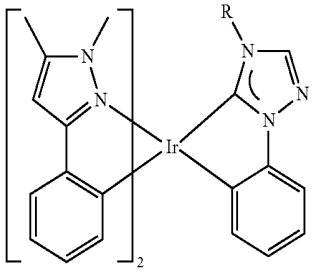
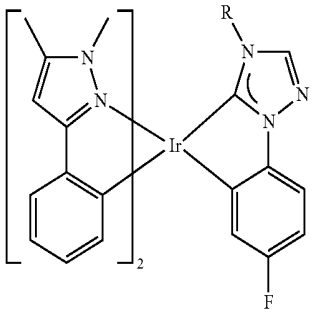
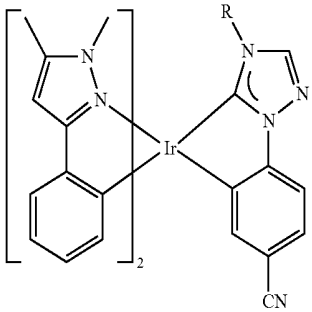


33 (R = Me)
34 (R = Ph)



35 (R = Me)
36 (R = Ph)



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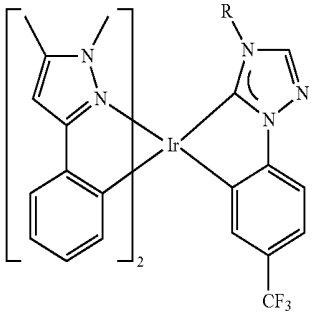
38 (R = Ph)



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40 (R = Ph)

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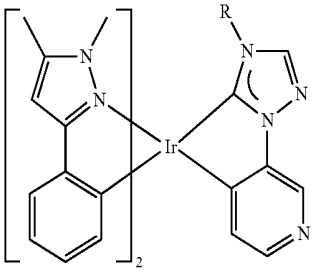

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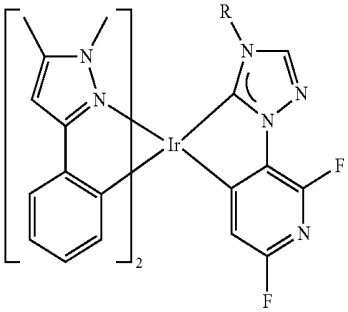

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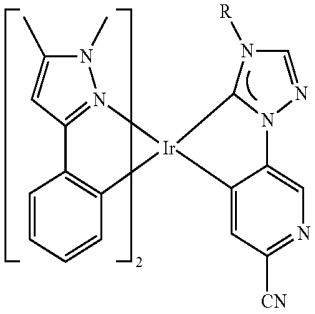

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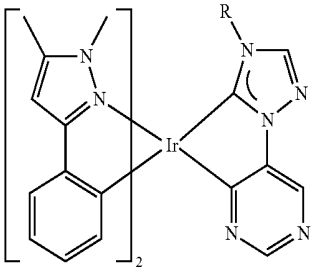

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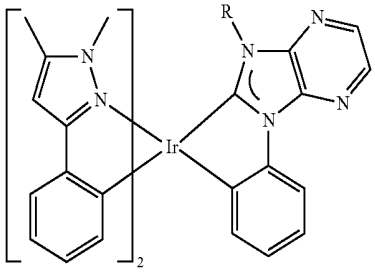

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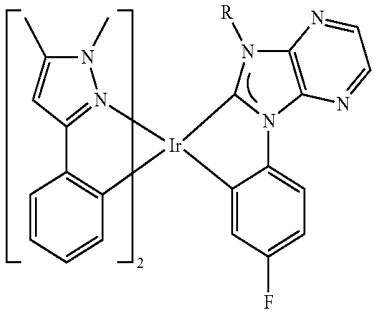

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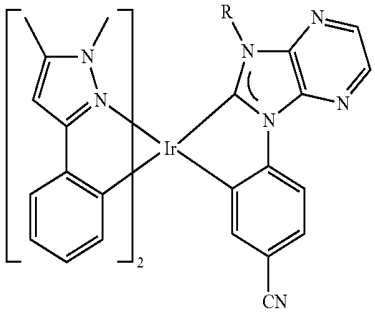

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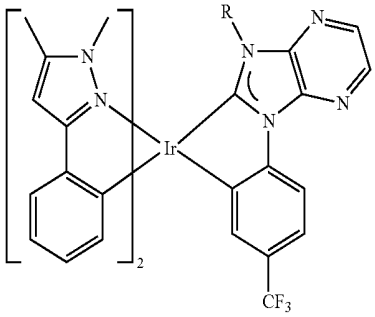

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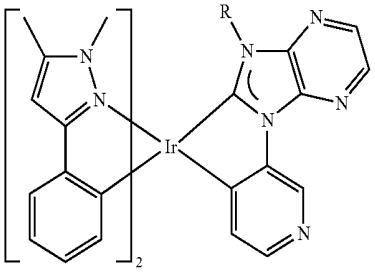

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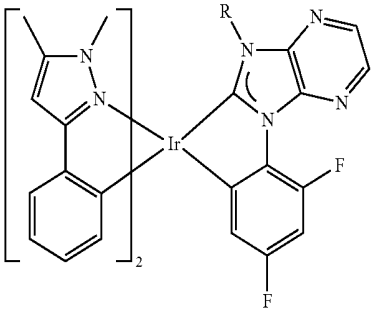

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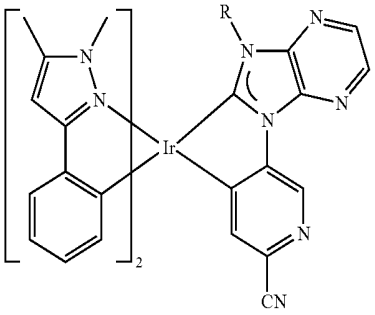

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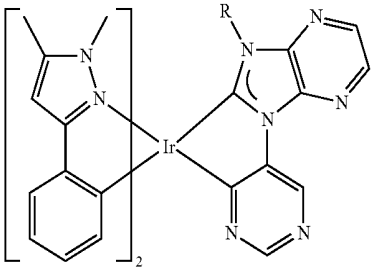

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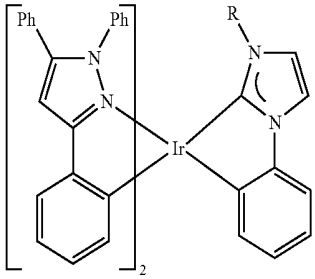

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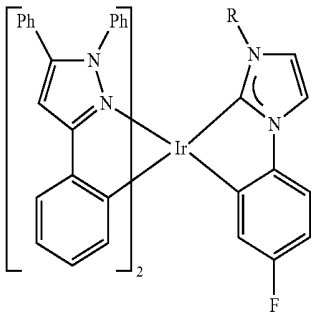

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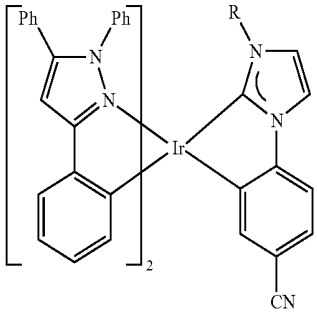
68 (R = Ph)



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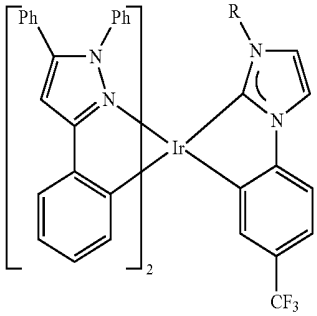

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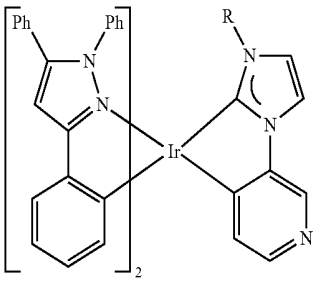

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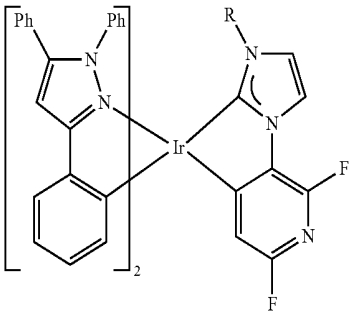

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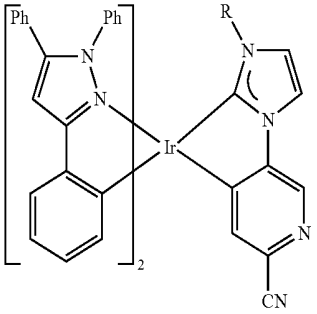

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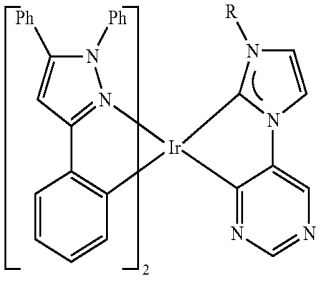

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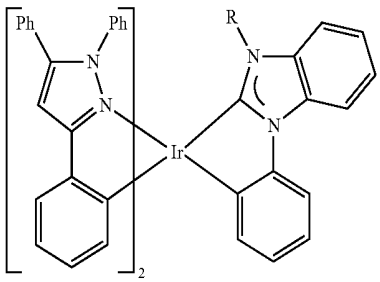

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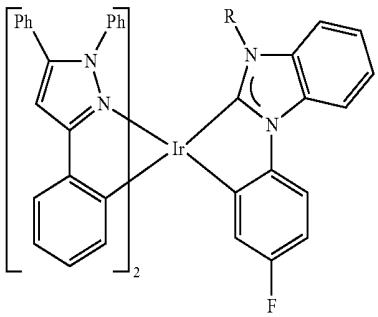

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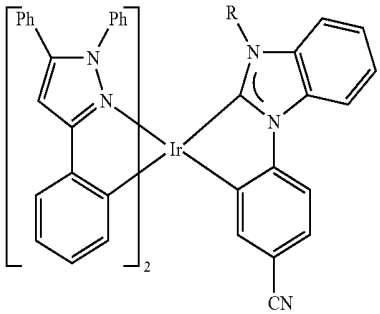

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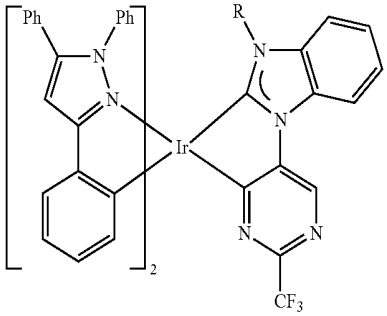

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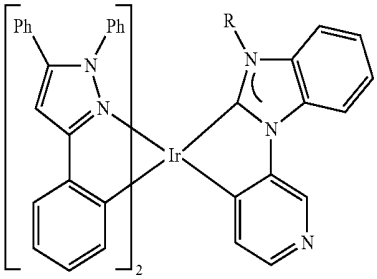

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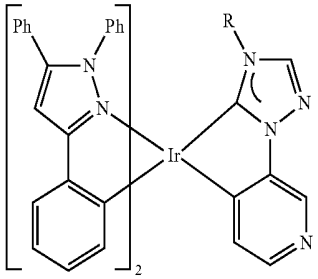

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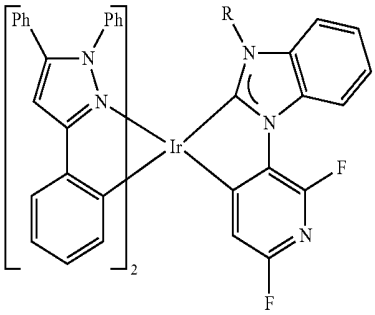
98 (R = Ph)



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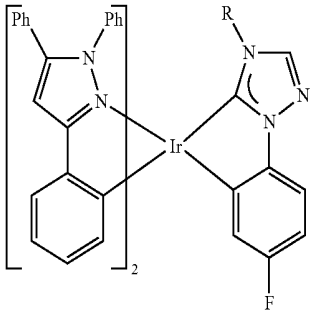

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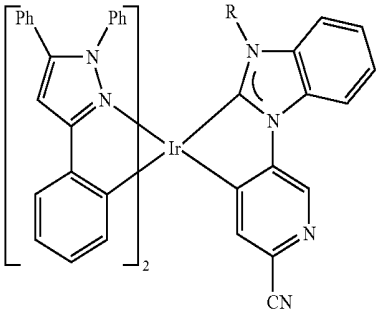

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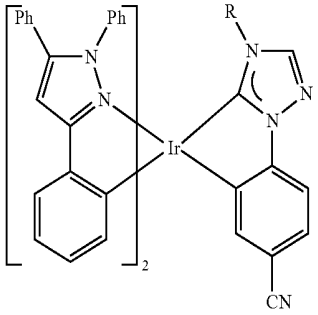

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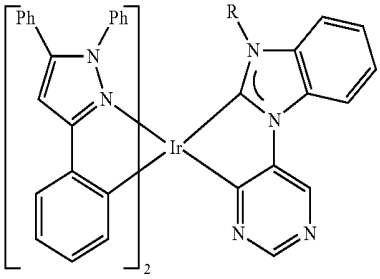

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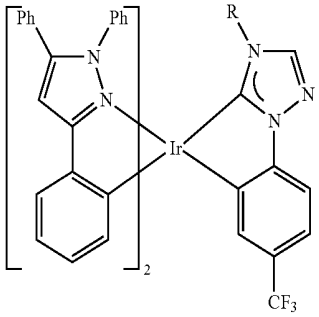
96 (R = Ph)



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104 (R = Ph)

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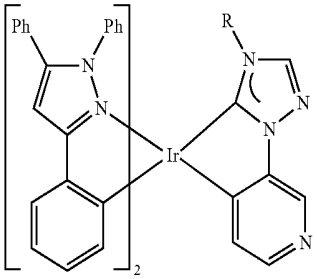

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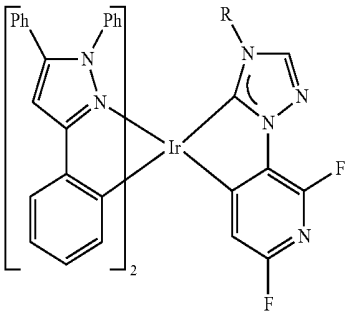

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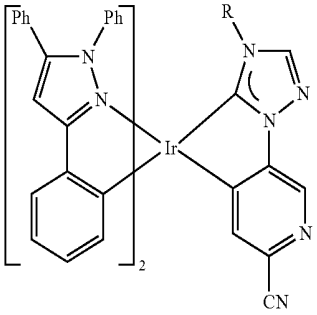

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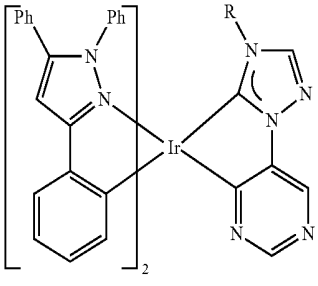

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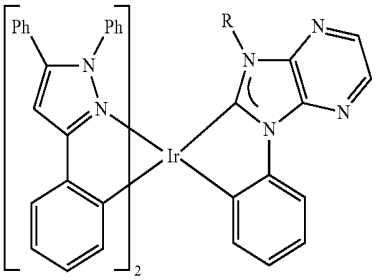

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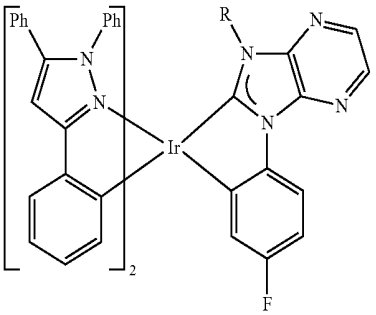

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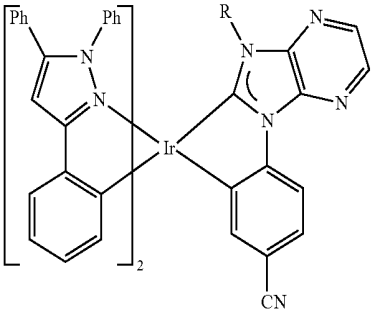

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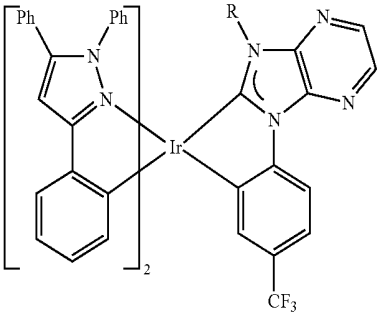

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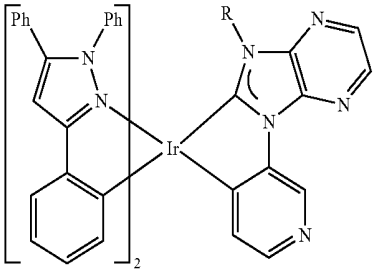

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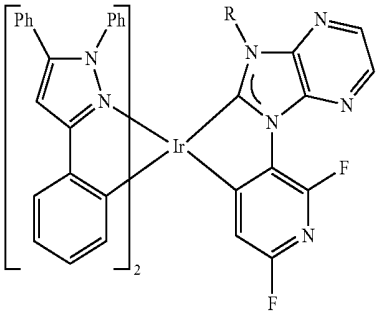

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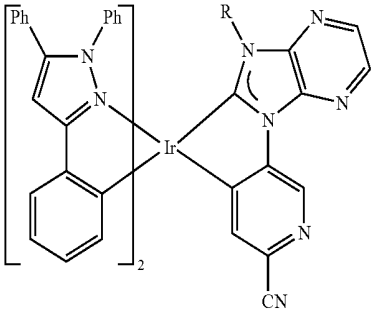

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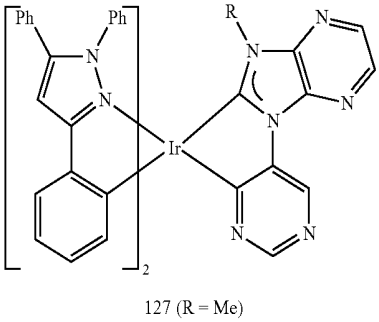

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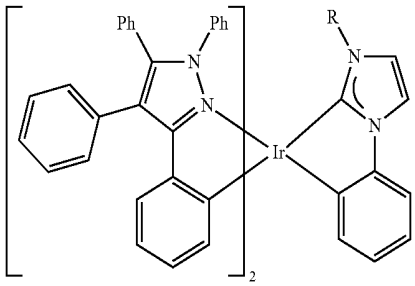

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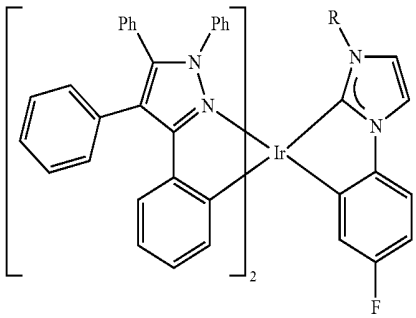

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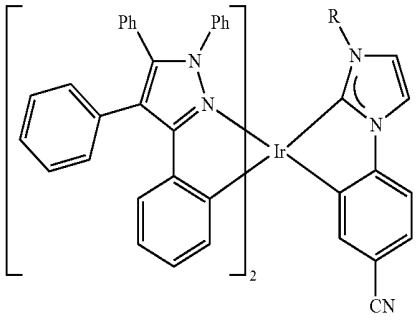

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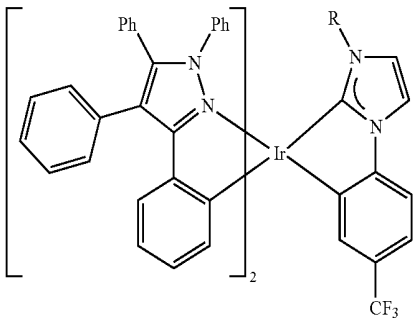

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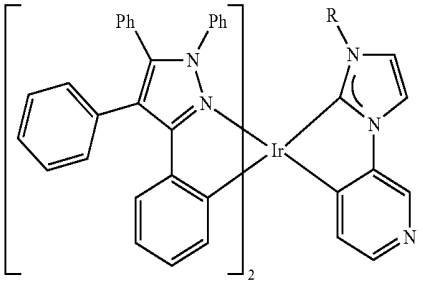

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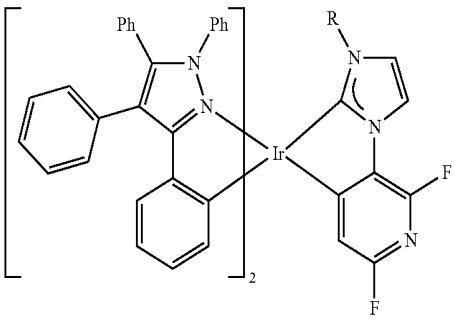

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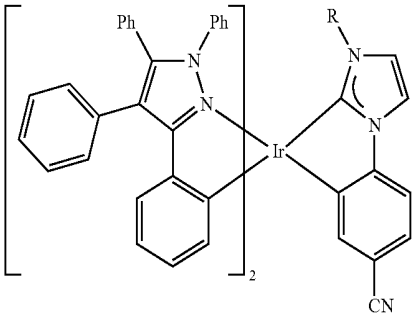

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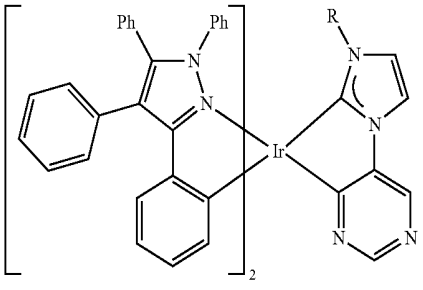

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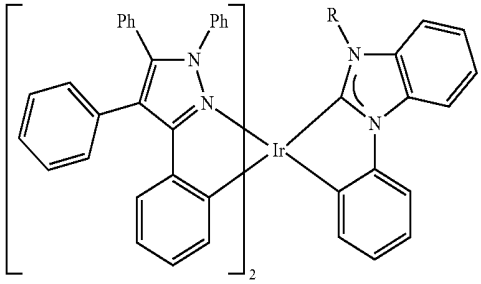

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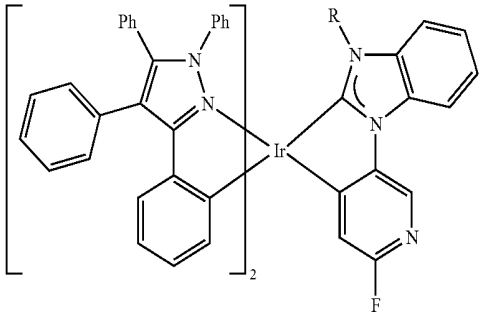
146 (R = Ph)



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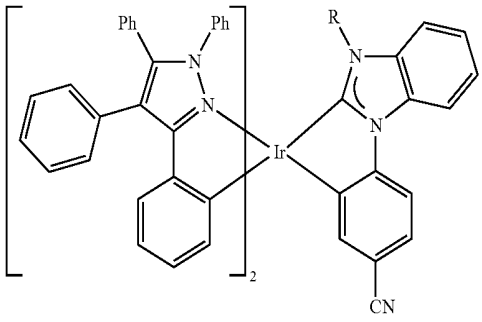

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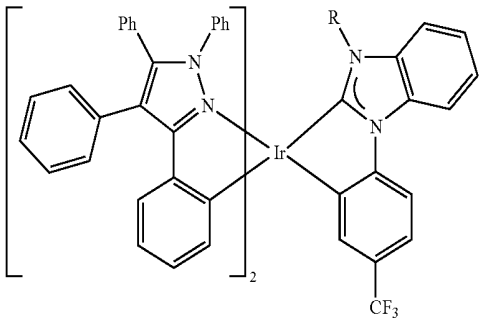

151 (R = Me)
152 (R = Ph)

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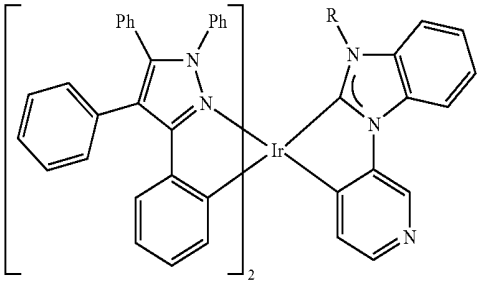

153 (R = Me)
154 (R = Ph)

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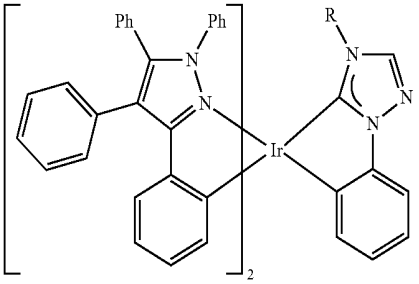

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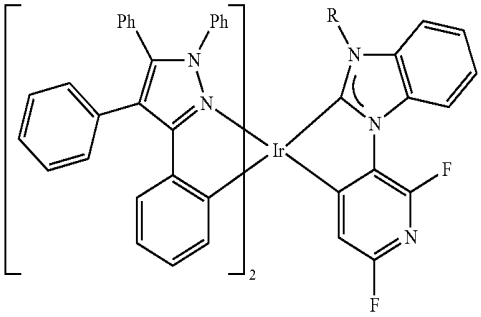

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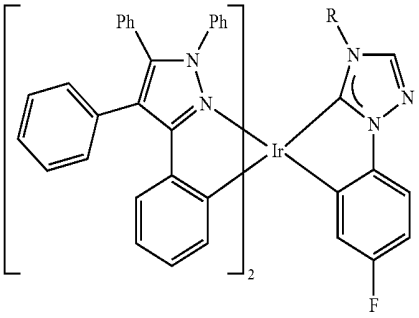

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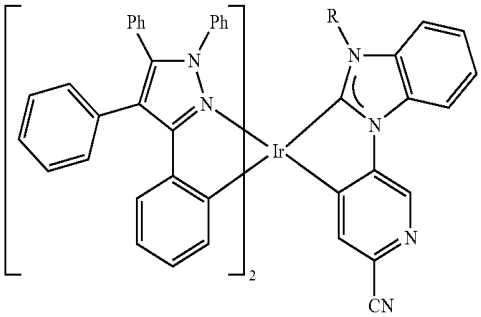

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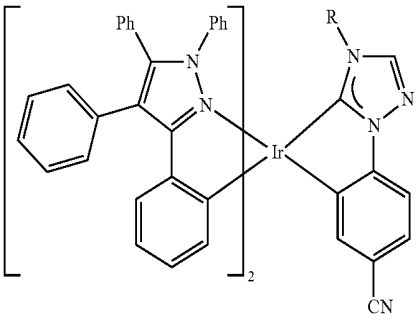

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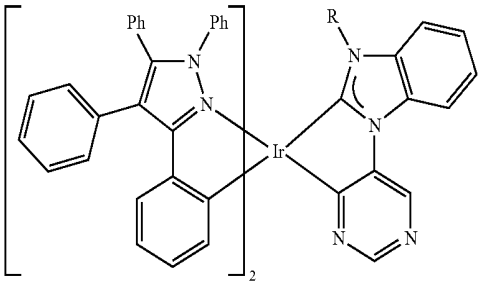

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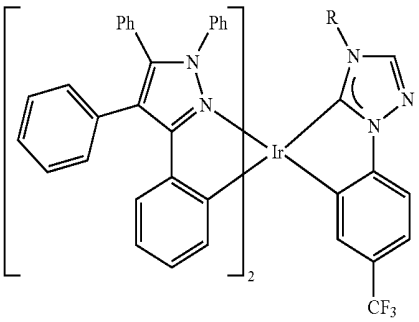

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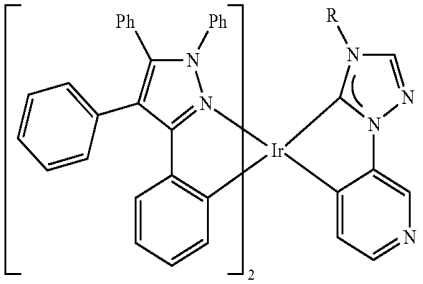

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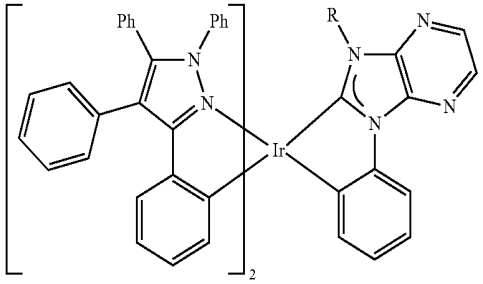

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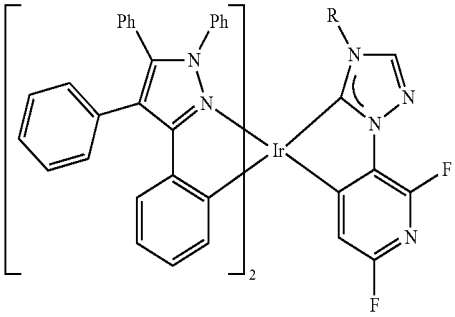

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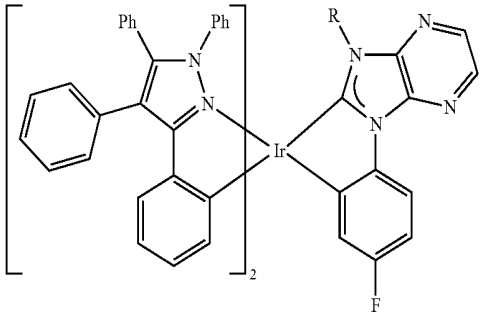

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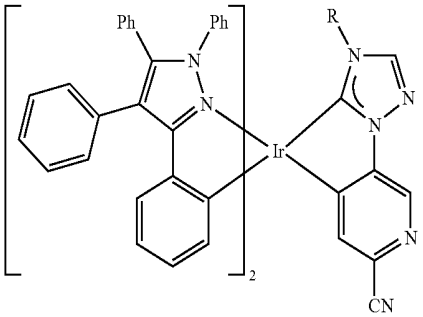

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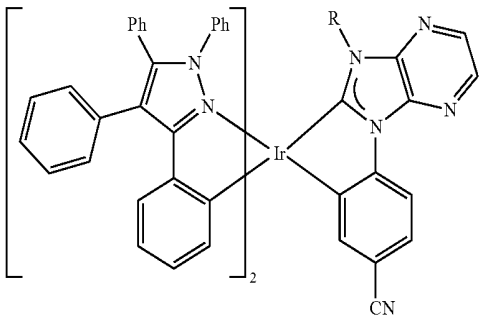

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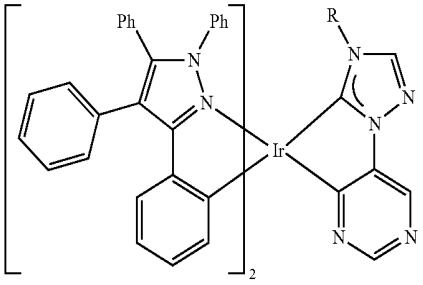

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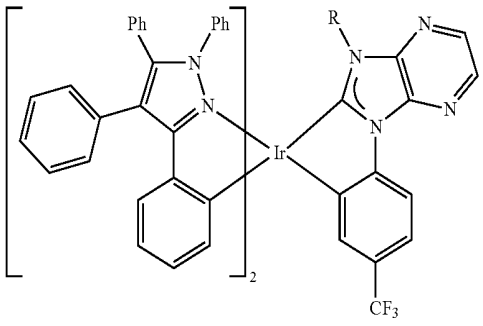

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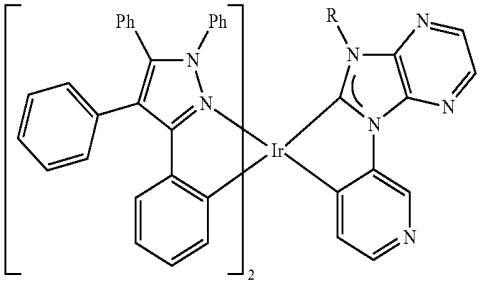

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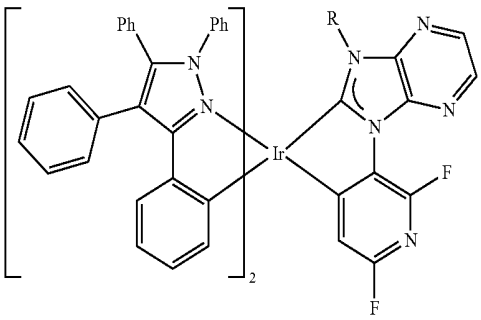

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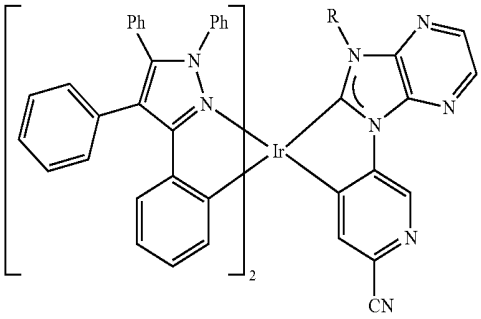

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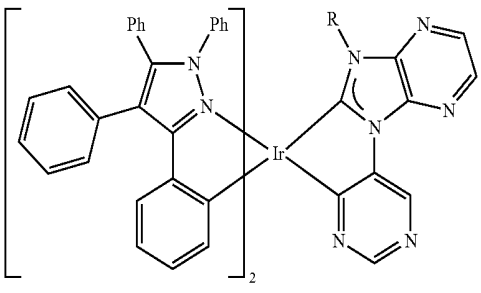

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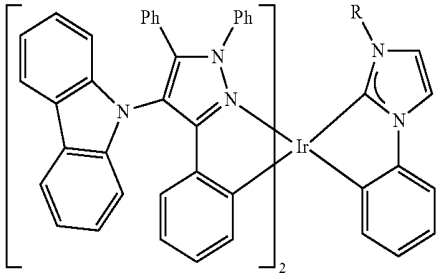

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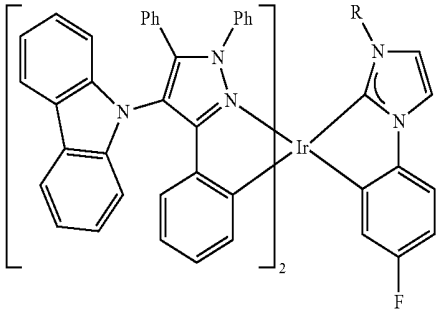

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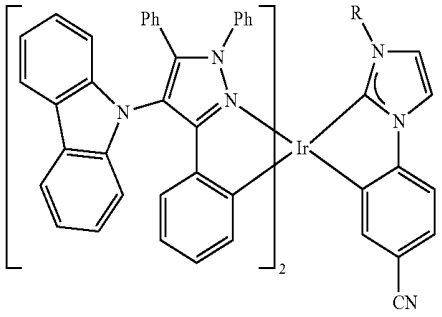

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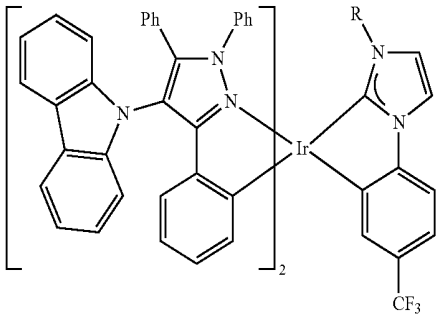

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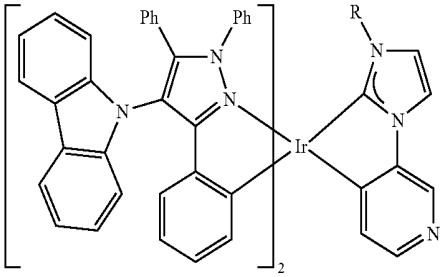

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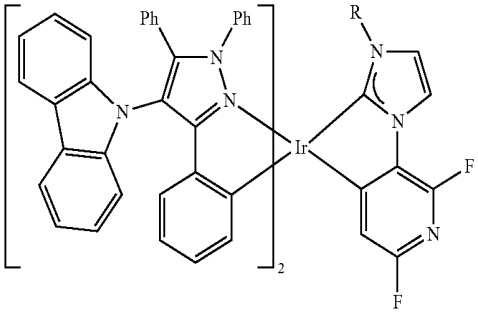

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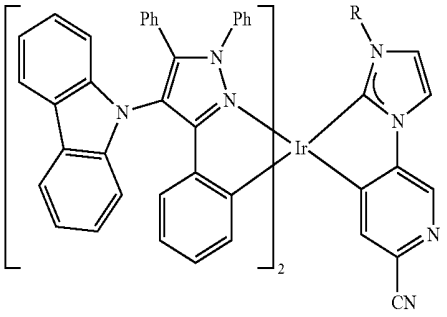

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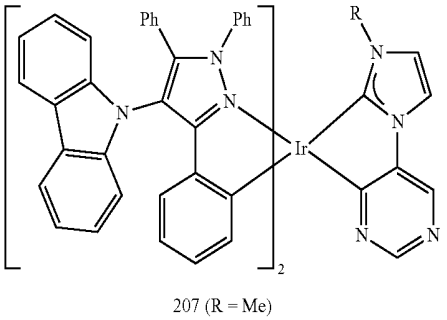

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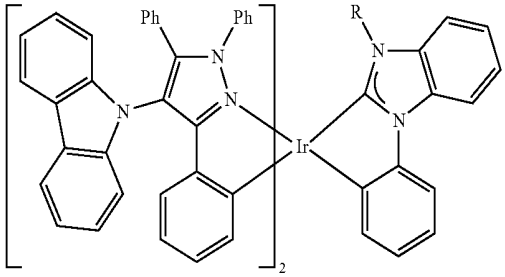

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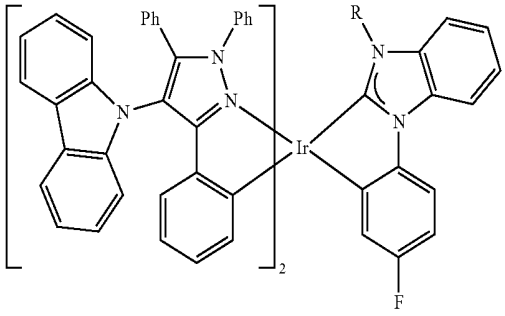

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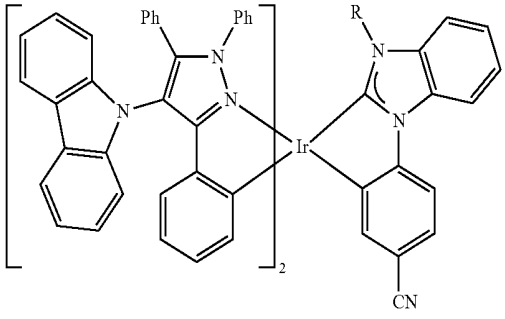

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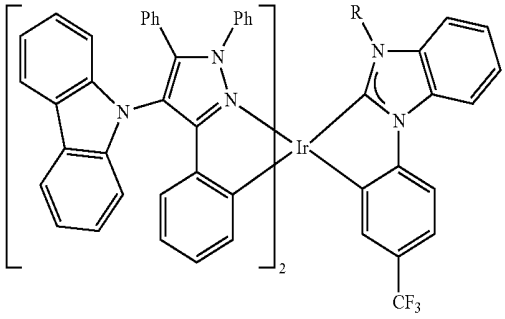

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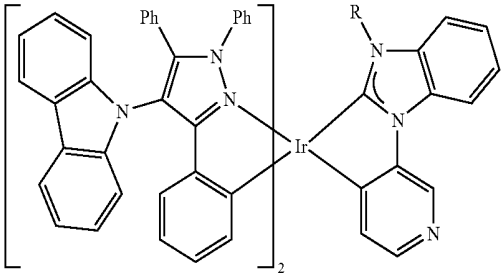

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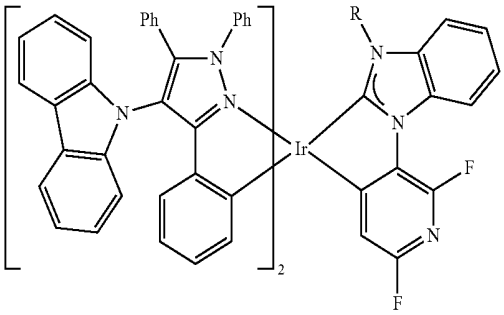

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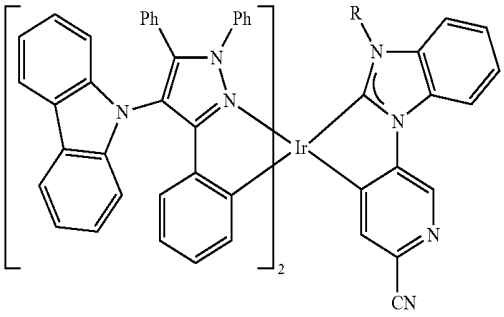

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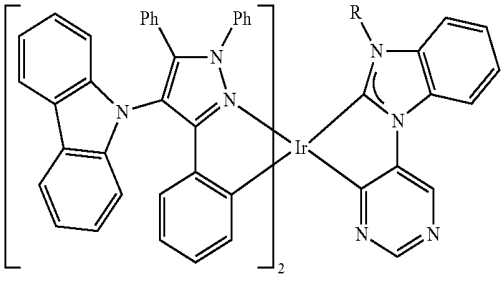

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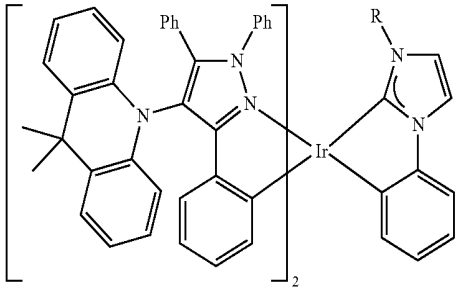

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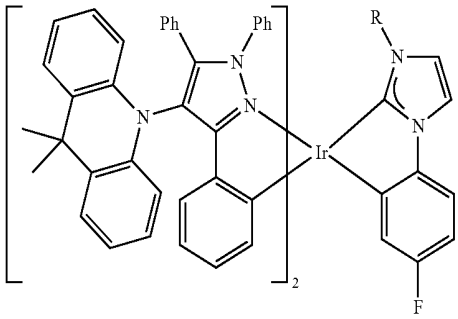

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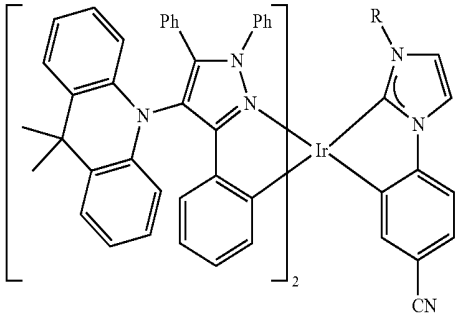

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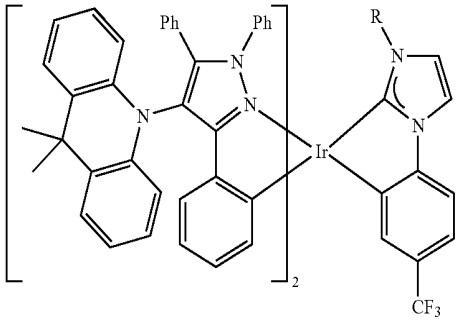

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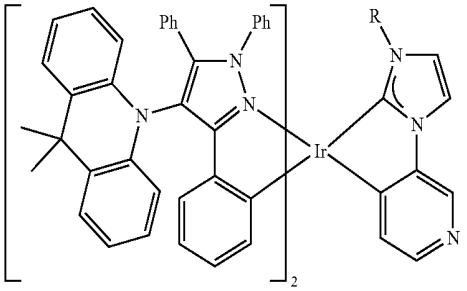

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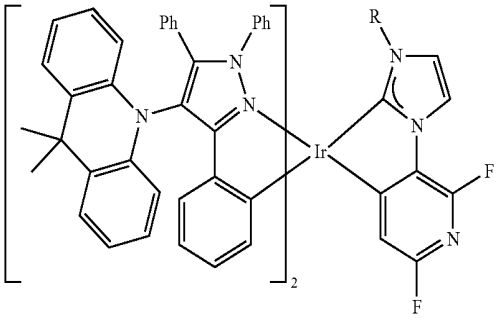

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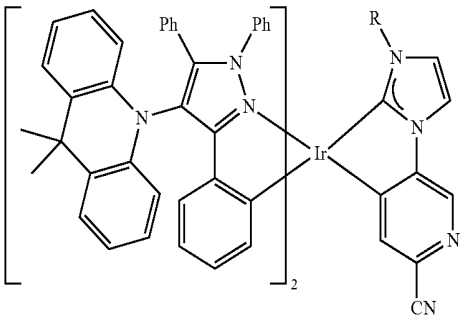

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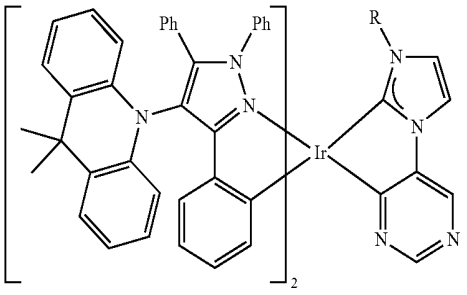

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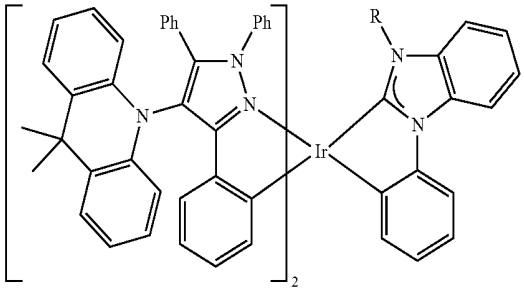

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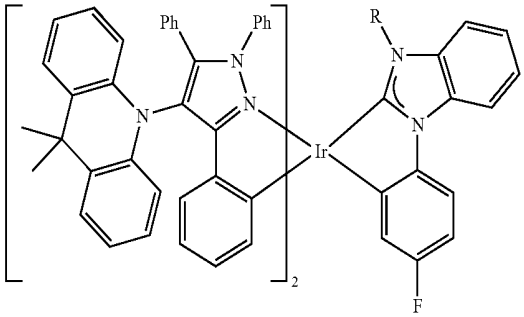

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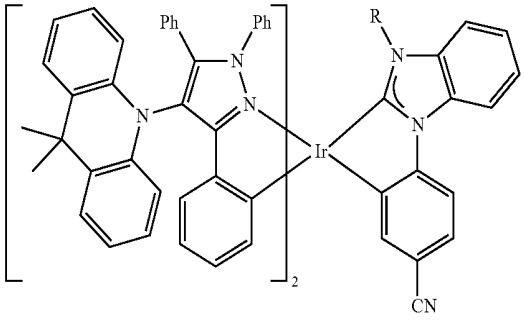

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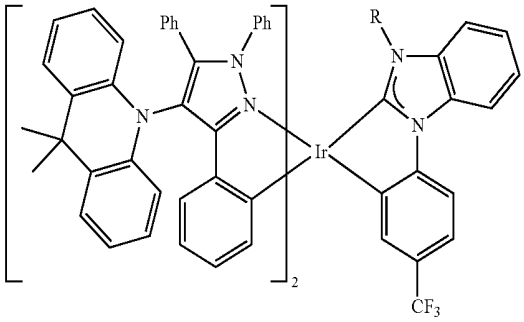

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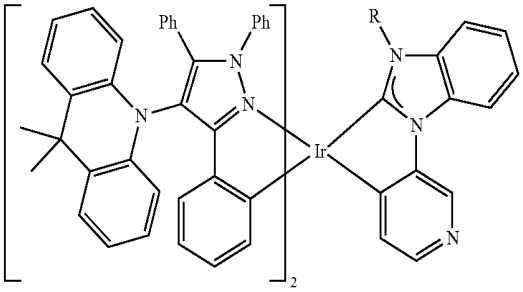

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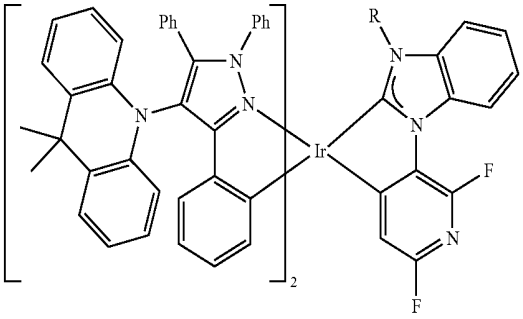

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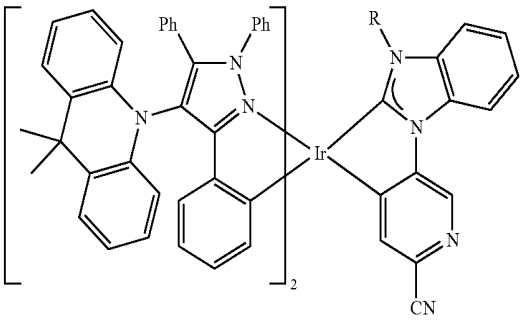
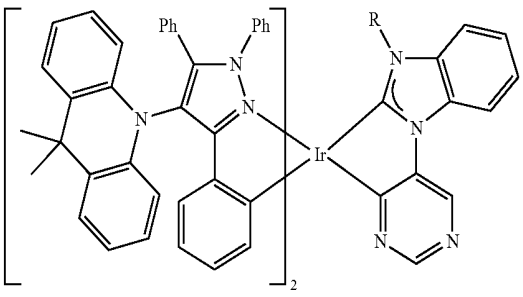


253 (R = Me)
254 (R = Ph)



255 (R = Me)
256 (R = Ph)

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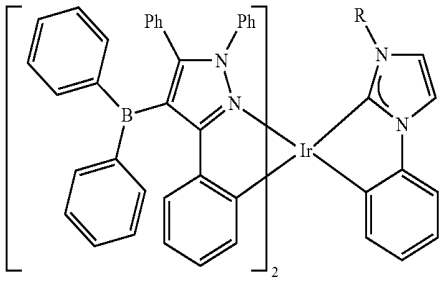
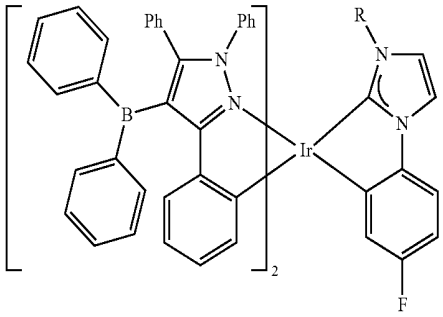
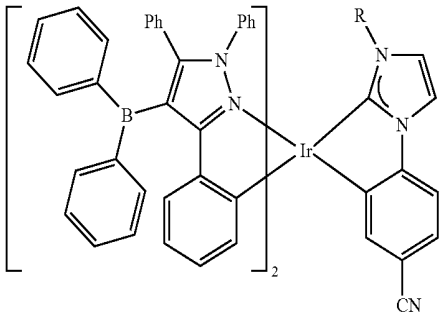


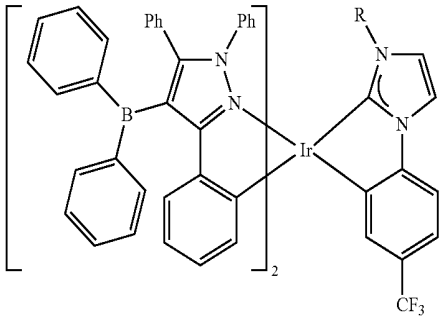
257 (R = Me)
258 (R = Ph)



259 (R = Me)
260 (R = Ph)



261 (R = Me)
262 (R = Ph)



263 (R = Me)
264 (R = Ph)

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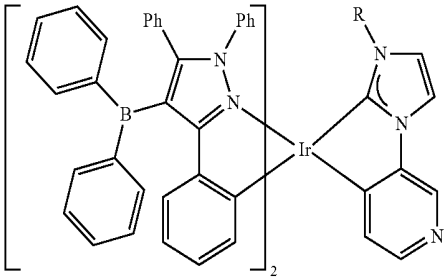
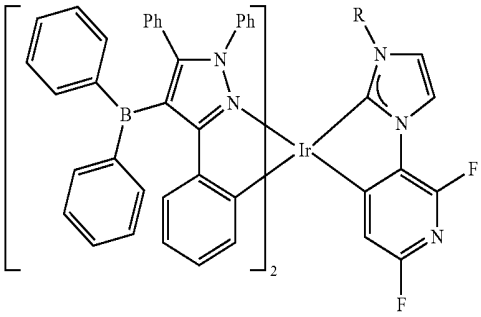
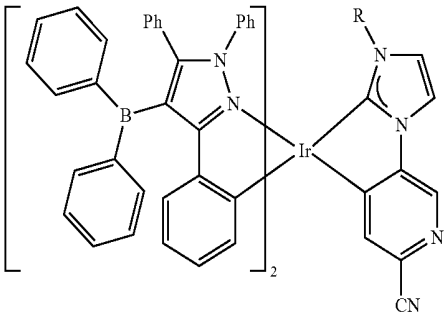


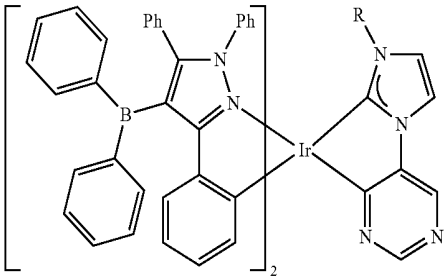
265 (R = Me)
266 (R = Ph)



267 (R = Me)
268 (R = Ph)



269 (R = Me)
270 (R = Ph)



271 (R = Me)
272 (R = Ph)

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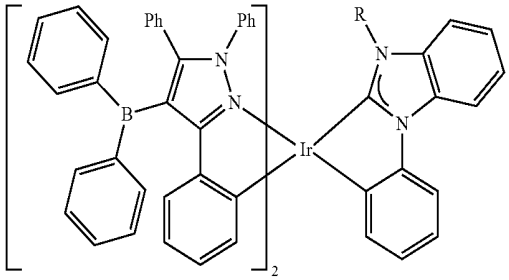
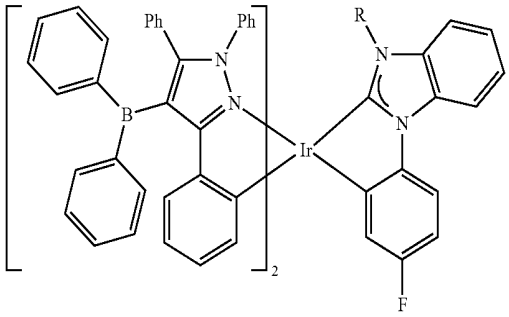
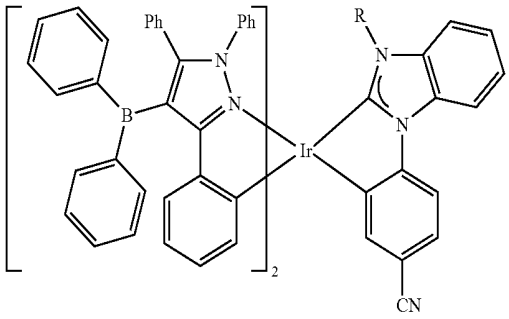


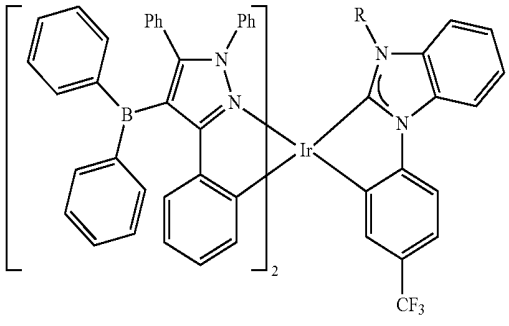
273 (R = Me)
274 (R = Ph)



275 (R = Me)
276 (R = Ph)



277 (R = Me)
278 (R = Ph)



279 (R = Me)
280 (R = Ph)

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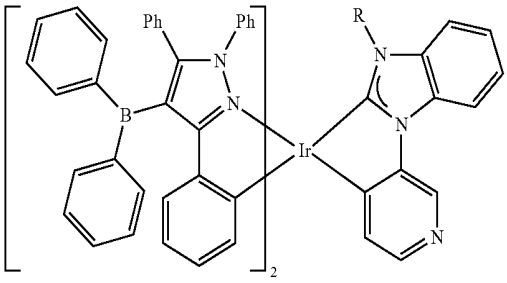

281 (R = Me)
282 (R = Ph)

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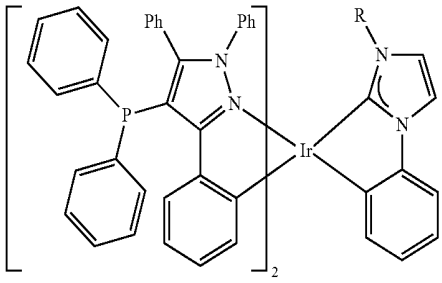
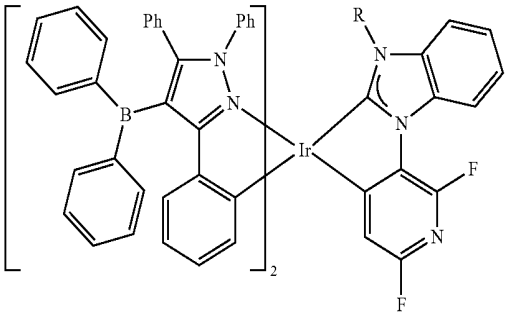
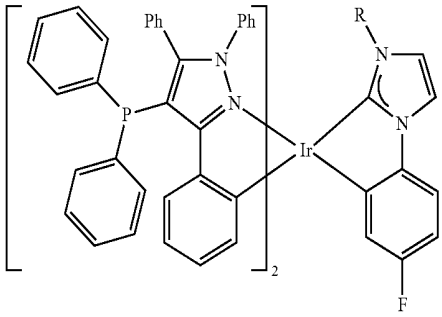


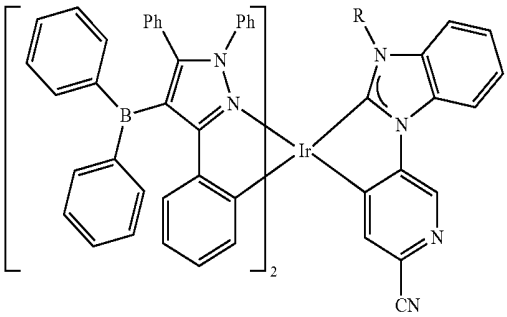
289 (R = Me)
290 (R = Ph)



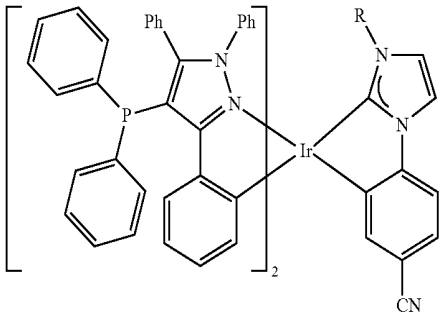
283 (R = Me)
284 (R = Ph)



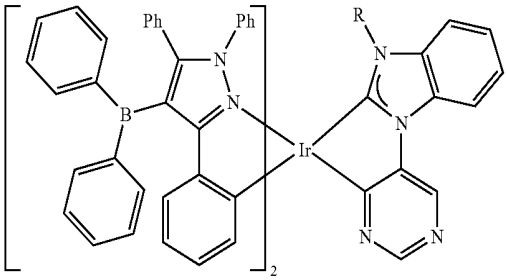
291 (R = Me)
292 (R = Ph)



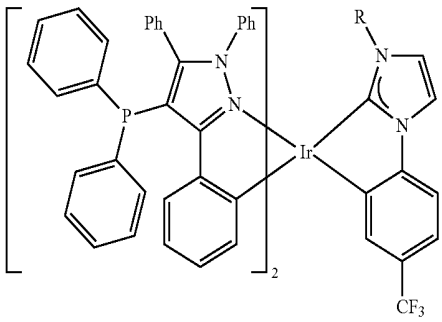
285 (R = Me)
286 (R = Ph)



293 (R = Me)
294 (R = Ph)



287 (R = Me)
288 (R = Ph)



295 (R = Me)
296 (R = Ph)

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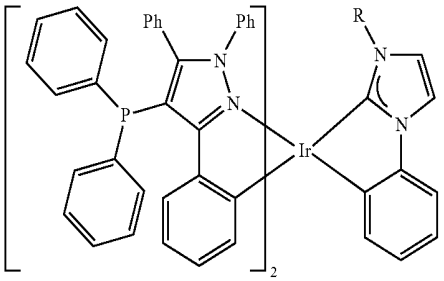

297 (R = Me)
298 (R = Ph)

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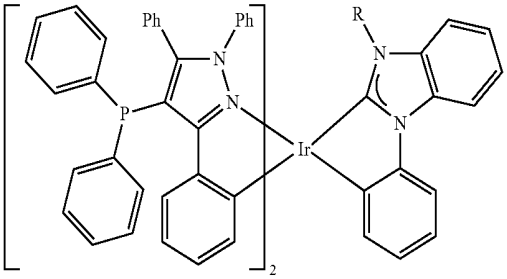
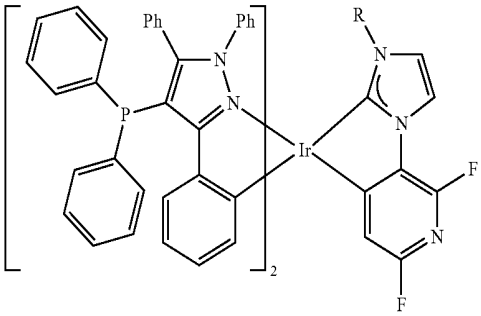
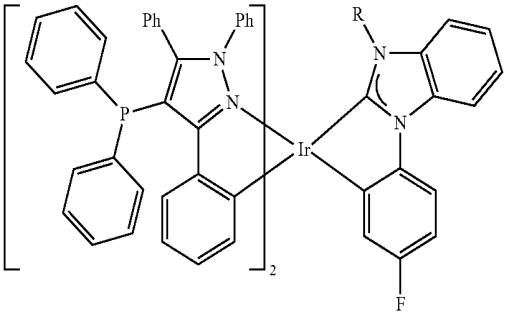


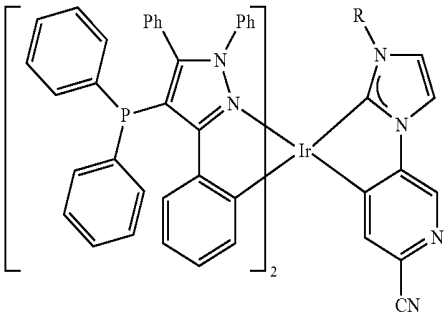
305 (R = Me)
306 (R = Ph)



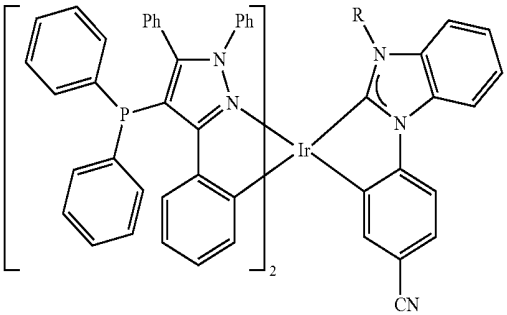
299 (R = Me)
300 (R = Ph)



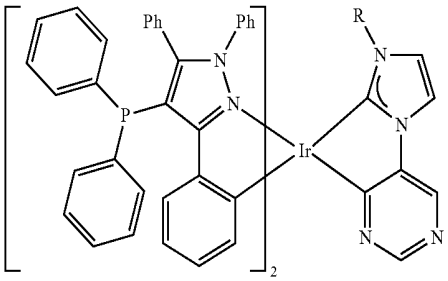
307 (R = Me)
308 (R = Ph)



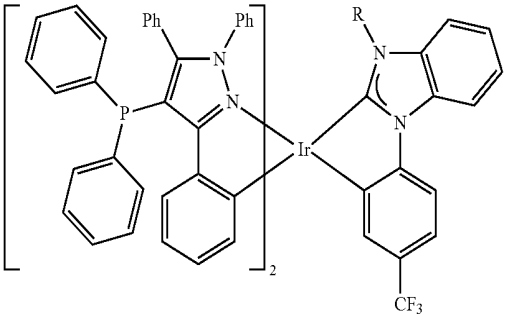
301 (R = Me)
302 (R = Ph)



301 (R = Me)
302 (R = Ph)



303 (R = Me)
304 (R = Ph)



311 (R = Me)
312 (R = Ph)

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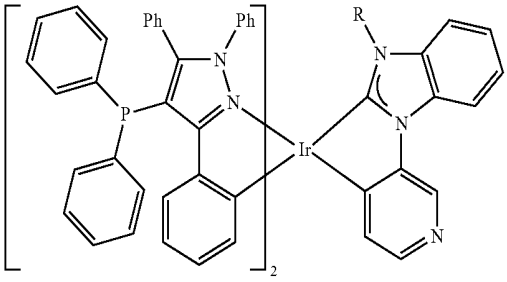
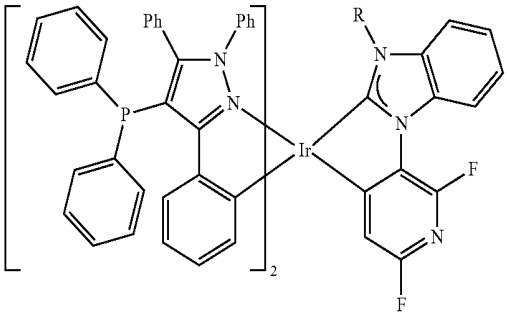
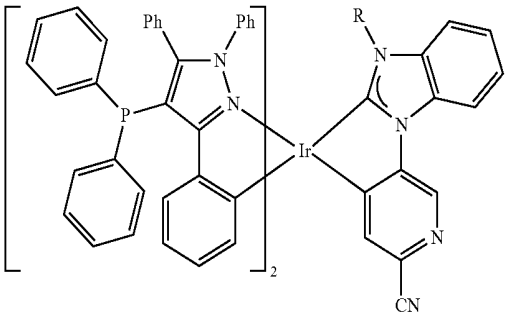


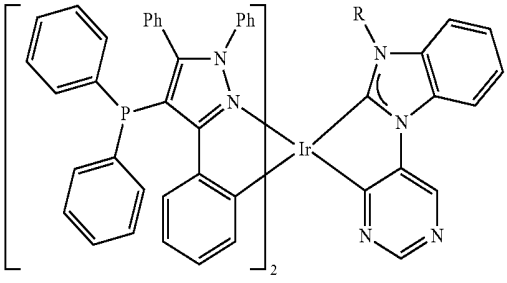
313 (R = Me)
314 (R = Ph)



315 (R = Me)
316 (R = Ph)



317 (R = Me)
318 (R = Ph)



319 (R = Me)
320 (R = Ph)

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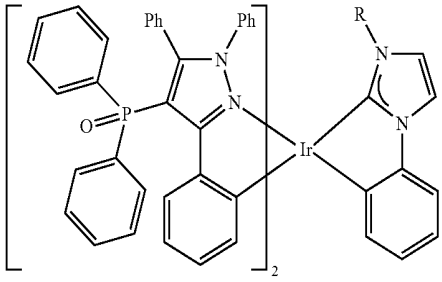
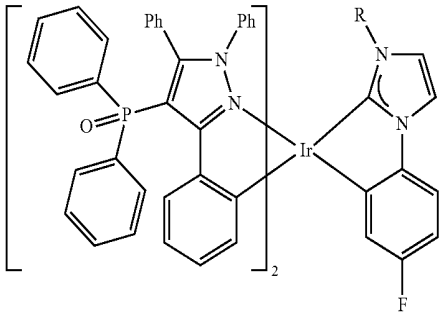
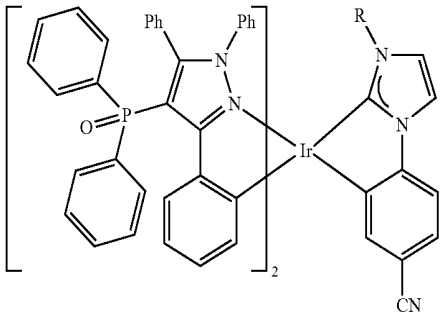


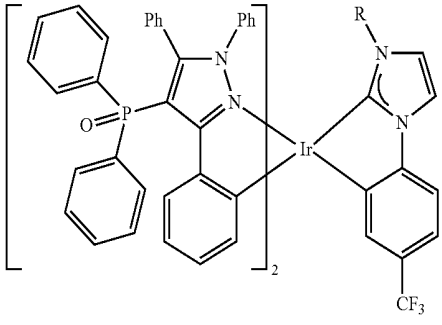
321 (R = Me)
322 (R = Ph)



323 (R = Me)
324 (R = Ph)



325 (R = Me)
326 (R = Ph)



327 (R = Me)
328 (R = Ph)

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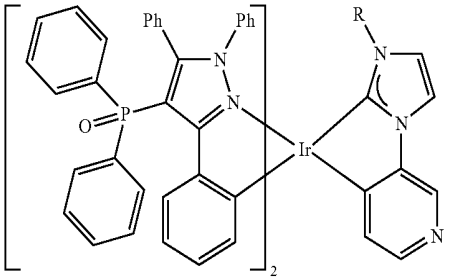

329 (R = Me)
330 (R = Ph)

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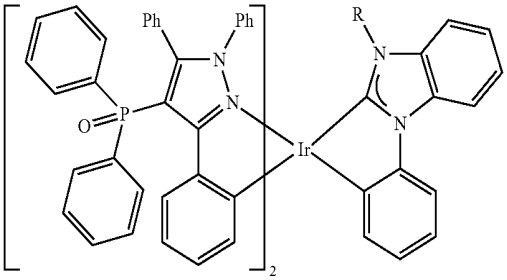
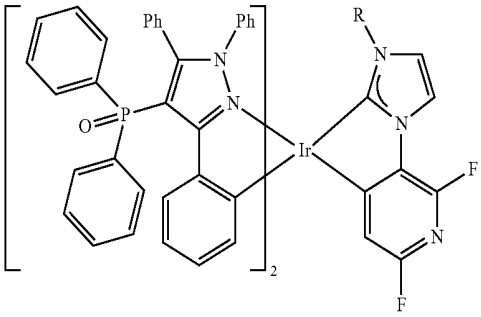
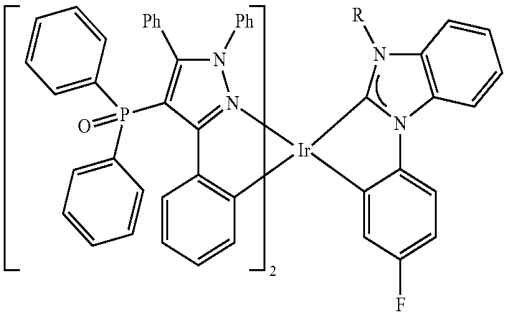


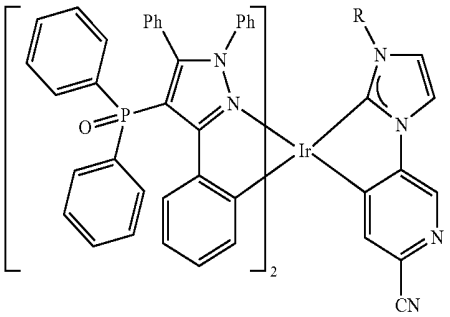
337 (R = Me)
338 (R = Ph)



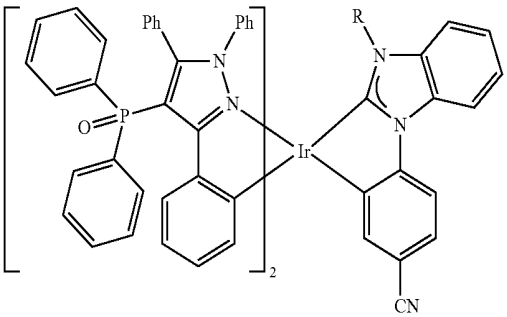
331 (R = Me)
332 (R = Ph)



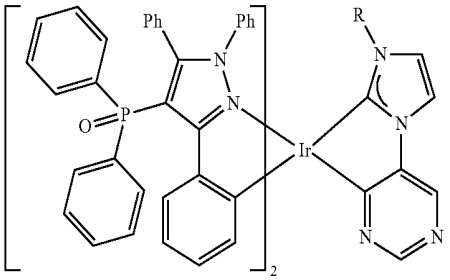
339 (R = Me)
340 (R = Ph)



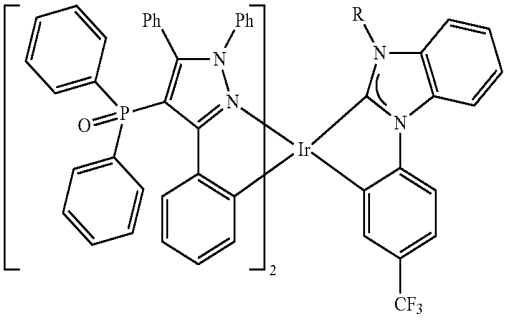
333 (R = Me)
334 (R = Ph)



341 (R = Me)
342 (R = Ph)



335 (R = Me)
336 (R = Ph)



343 (R = Me)
344 (R = Ph)

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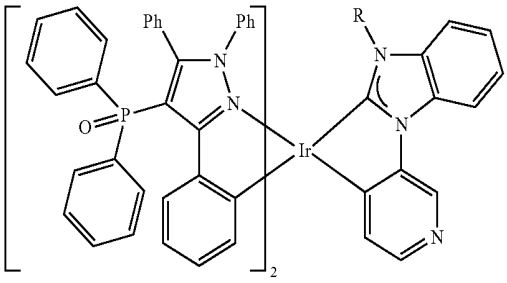

345 (R = Me)
346 (R = Ph)

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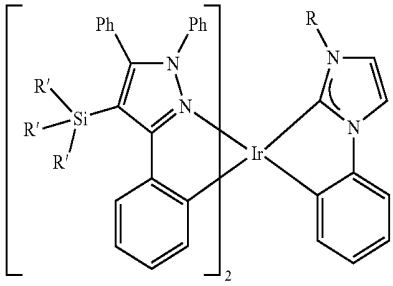
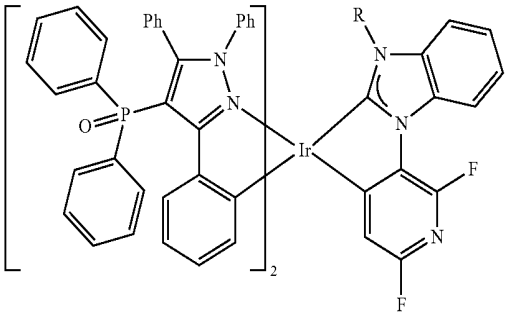
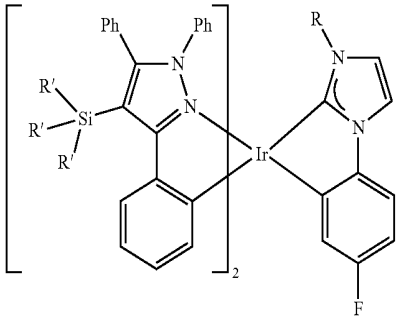


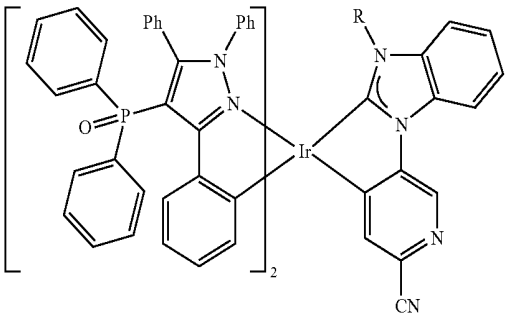
353 (R = Me, R′ = Me)
354 (R = Ph, R′ = Ph)



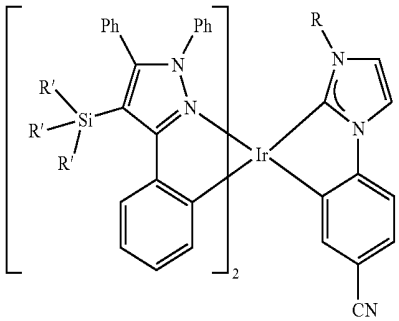
347 (R = Me)
348 (R = Ph)



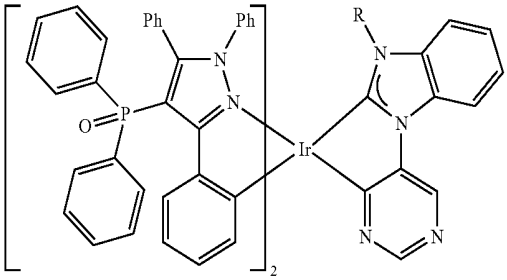
355 (R = Me, R′ = Me)
356 (R = Ph, R′ = Ph)



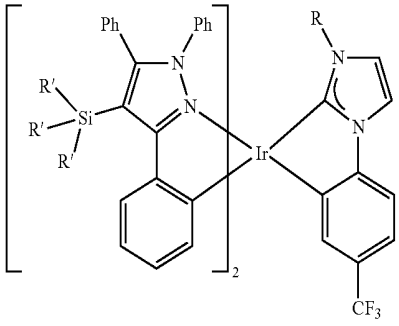
349 (R = Me)
350 (R = Ph)



357 (R = Me, R′ = Me)
358 (R = Ph, R′ = Ph)



351 (R = Me)
352 (R = Ph)



359 (R = Me, R′ = Me)
360 (R = Ph, R′ = Ph)

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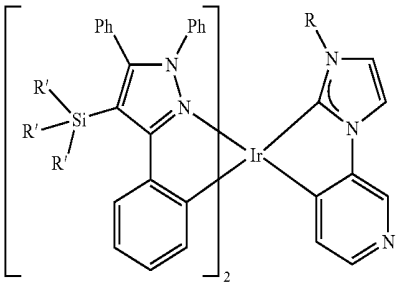
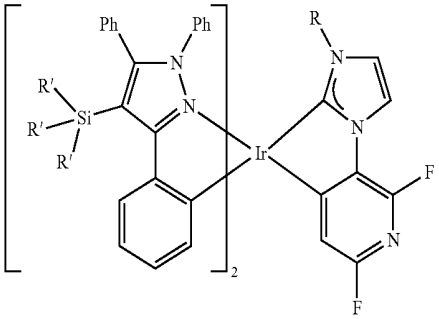
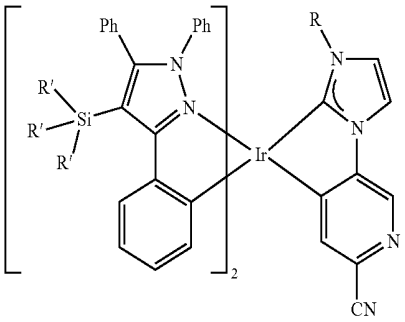


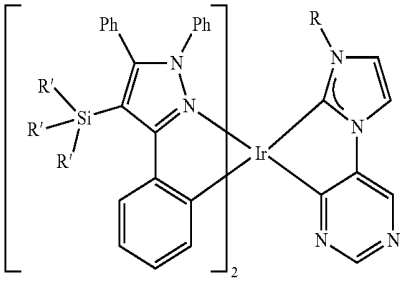
361 (R = Me, R′ = Me)
362 (R = Ph, R′ = Ph)



363 (R = Me, R′ = Me)
364 (R = Ph, R′ = Ph)



365 (R = Me, R′ = Me)
366 (R = Ph, R′ = Ph)



367 (R = Me, R′ = Me)
368 (R = Ph, R′ = Ph)

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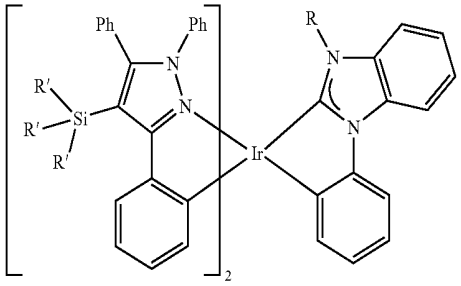
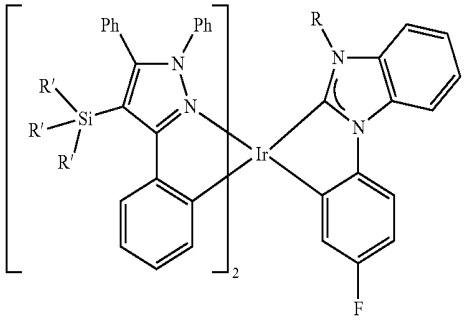
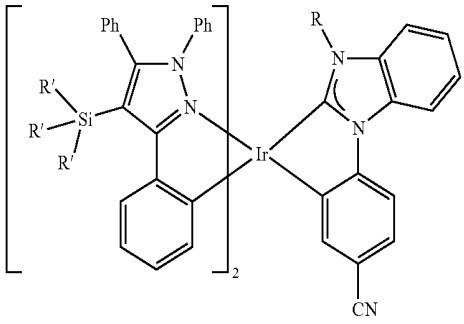


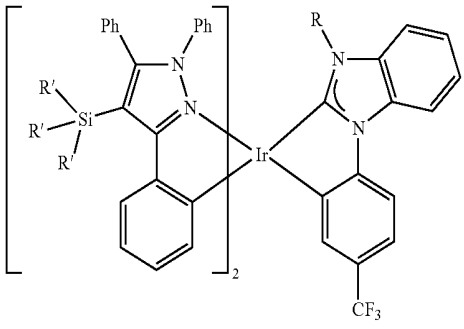
369 (R = Me, R′ = Me)
370 (R = Ph, R′ = Ph)



371 (R = Me, R′ = Me)
372 (R = Ph, R′ = Ph)



373 (R = Me, R′ = Me)
374 (R = Ph, R′ = Ph)



375 (R = Me, R′ = Me)
376 (R = Ph, R′ = Ph)

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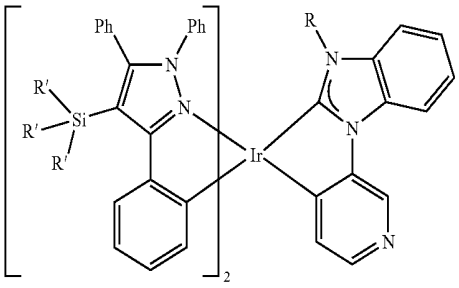

377 (R = Me, R′ = Me)
378 (R = Ph, R′ = Ph)

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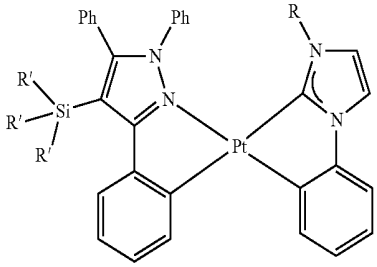

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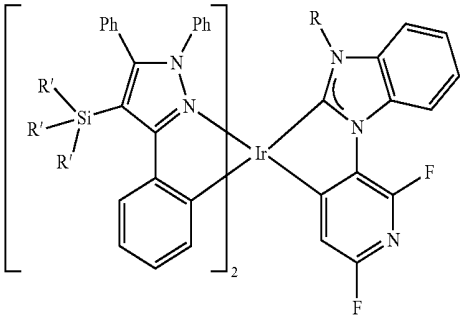
386 (R = Ph, R′ = Ph)



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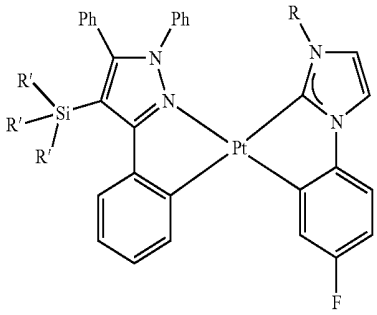
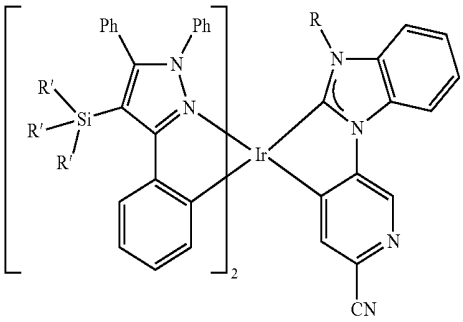
380 (R = Ph, R′ = Ph)



387 (R = Me, R′ = Me)
388 (R = Ph, R′ = Ph)



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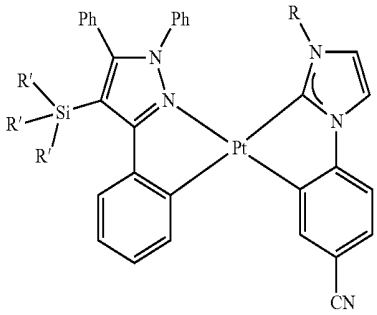
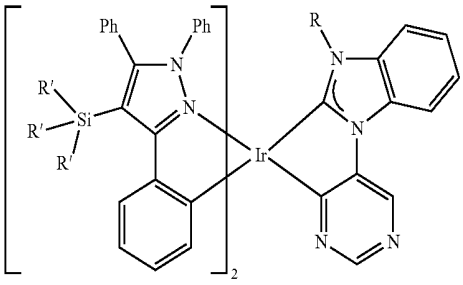
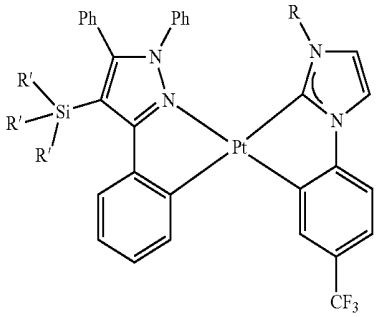
382 (R = Ph, R′ = Ph)



389 (R = Me, R′ = Me)
390 (R = Ph, R′ = Ph)



383 (R = Me, R′ = Me)
384 (R = Ph, R′ = Ph)



391 (R = Me, R′ = Me)
392 (R = Ph, R′ = Ph)

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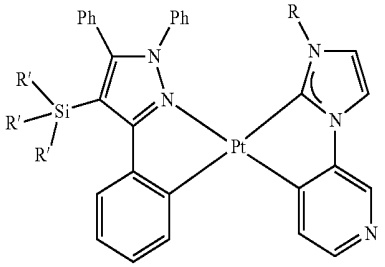
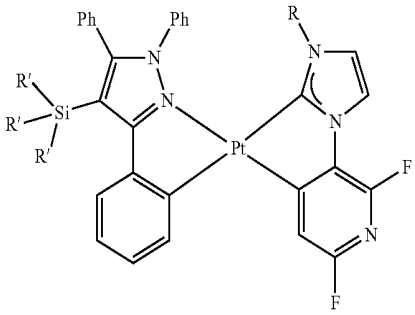
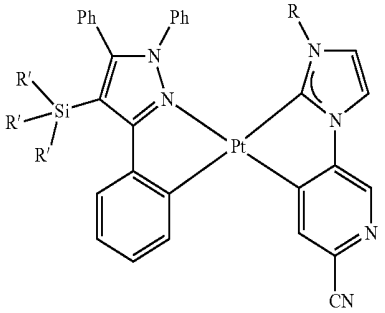


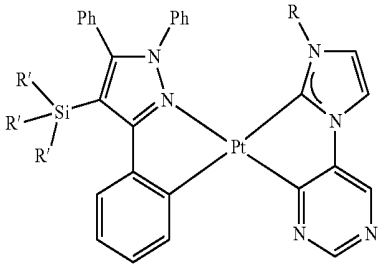
393 (R = Me, R′ = Me)
394 (R = Ph, R′ = Ph)



395 (R = Me, R′ = Me)
396 (R = Ph, R′ = Ph)



397 (R = Me, R′ = Me)
398 (R = Ph, R′ = Ph)



399 (R = Me, R′ = Me)
400 (R = Ph, R′ = Ph)

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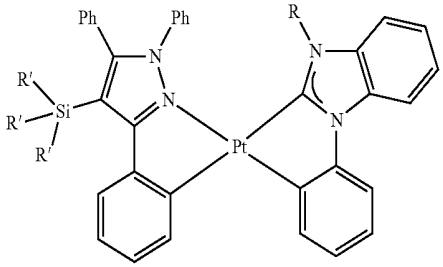
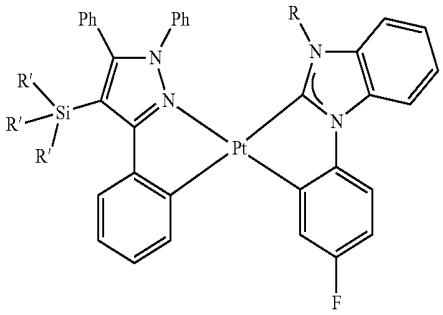
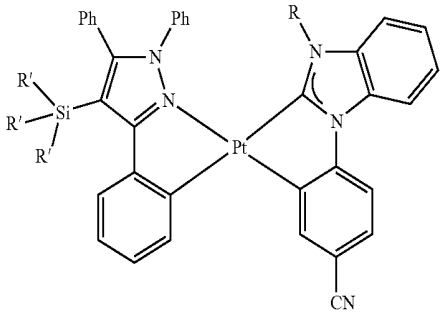


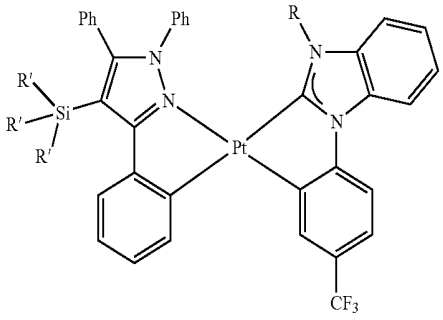
401 (R = Me, R′ = Me)
402 (R = Ph, R′ = Ph)



403 (R = Me, R′ = Me)
404 (R = Ph, R′ = Ph)



405 (R = Me, R′ = Me)
406 (R = Ph, R′ = Ph)



407 (R = Me, R′ = Me)
408 (R = Ph, R′ = Ph)

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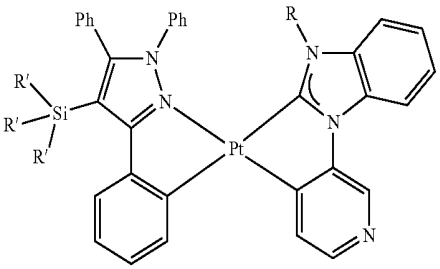
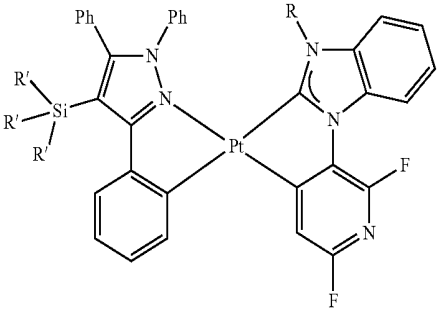
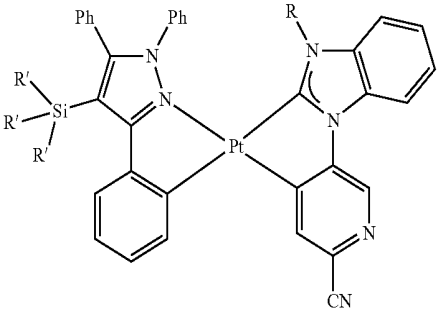


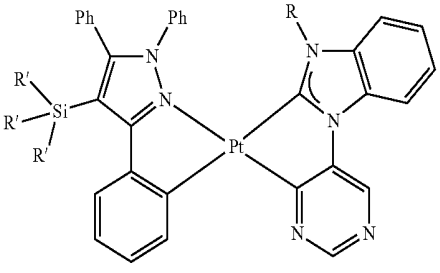
409 (R = Me, R′ = Me)
410 (R = Ph, R′ = Ph)



411 (R = Me, R′ = Me)
412 (R = Ph, R′ = Ph)



413 (R = Me, R′ = Me)
414 (R = Ph, R′ = Ph)



415 (R = Me, R′ = Me)
416 (R = Ph, R′ = Ph)

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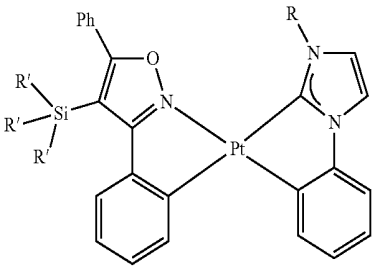
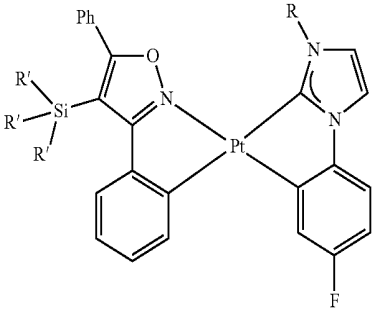
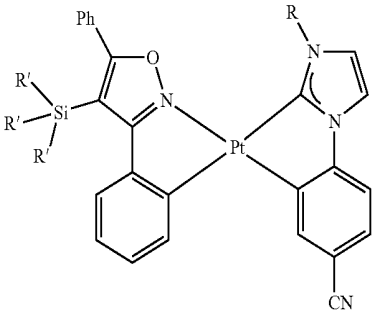


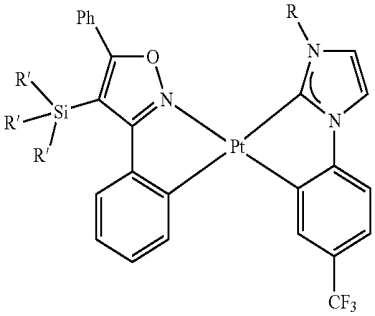
417 (R = Me, R′ = Me)
418 (R = Ph, R′ = Ph)



419 (R = Me, R′ = Me)
420 (R = Ph, R′ = Ph)



421 (R = Me, R′ = Me)
422 (R = Ph, R′ = Ph)



423 (R = Me, R′ = Me)
424 (R = Ph, R′ = Ph)

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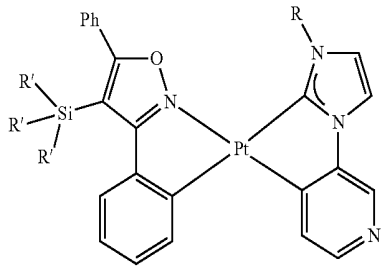
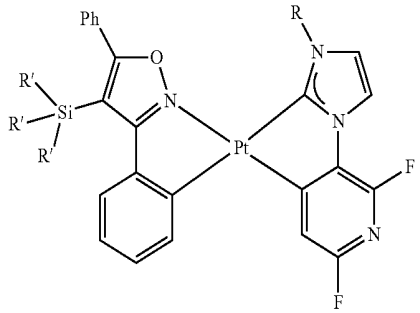
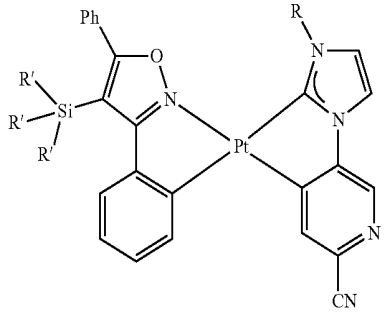


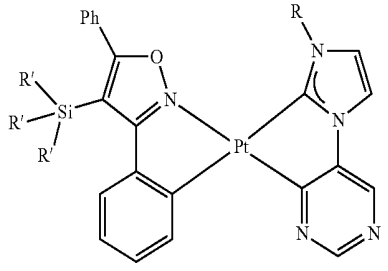
425 (R = Me, R′ = Me)
426 (R = Ph, R′ = Ph)



427 (R = Me, R′ = Me)
428 (R = Ph, R′ = Ph)



429 (R = Me, R′ = Me)
430 (R = Ph, R′ = Ph)



431 (R = Me, R′ = Me)
432 (R = Ph, R′ = Ph)

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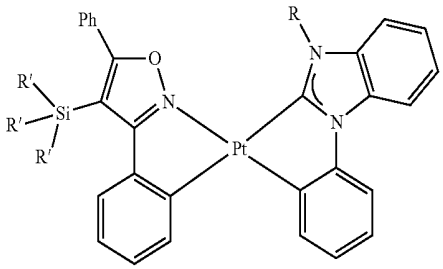
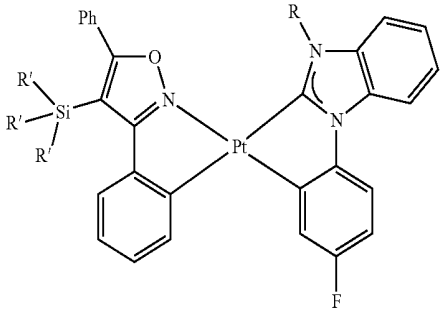
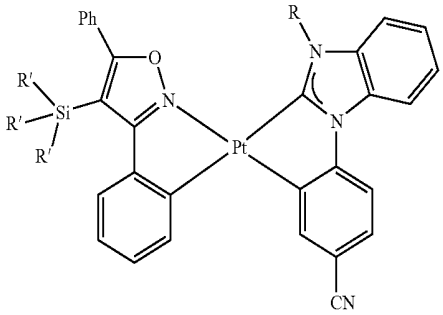


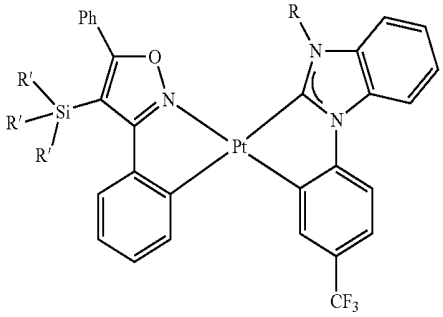
433 (R = Me, R′ = Me)
434 (R = Ph, R′ = Ph)



435 (R = Me, R′ = Me)
436 (R = Ph, R′ = Ph)



437 (R = Me, R′ = Me)
438 (R = Ph, R′ = Ph)



439 (R = Me, R′ = Me)
440 (R = Ph, R′ = Ph)

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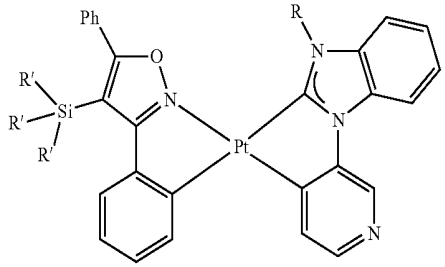
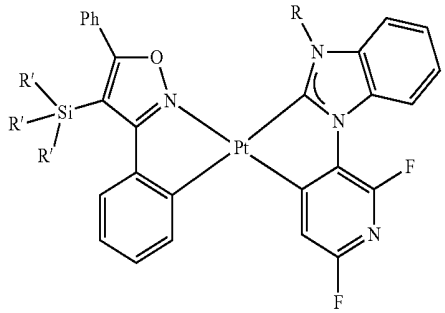
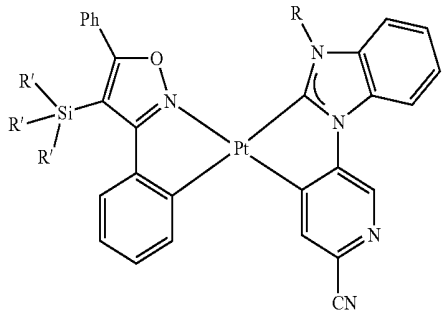


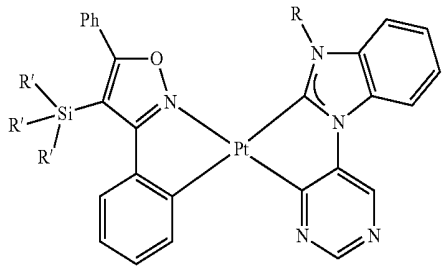
441 (R = Me, R′ = Me)
442 (R = Ph, R′ = Ph)



443 (R = Me, R′ = Me)
444 (R = Ph, R′ = Ph)



445 (R = Me, R′ = Me)
446 (R = Ph, R′ = Ph)



447 (R = Me, R′ = Me)
448 (R = Ph, R′ = Ph)

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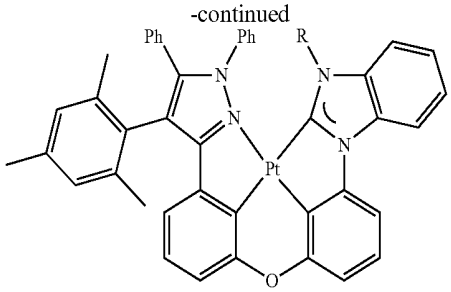
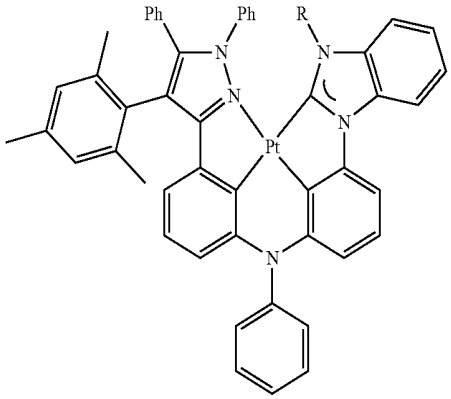
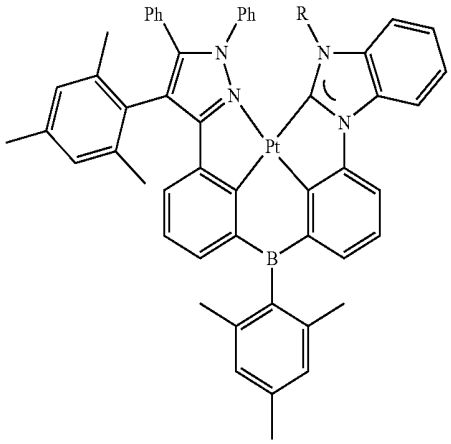


449 (R = Me)
450 (R = Ph)



451 (R = Me)
452 (R = Ph)



453 (R = Me)
454 (R = Ph)

[0119] In Compounds 1 to 454, Me indicates a methyl group, and Ph indicates a phenyl group.

[0120] The organometallic compound represented by Formula 1 essentially includes at least one ligand represented by Formulae 2A and 2B. Since the ligand represented by Formula 2A includes a non-carbene moiety such as a pyrazole, isoxazole, or isothiazole ring, ligand-ligand energy transfer may be adjusted to improve luminescent efficiency, emission wavelength, and full width at half maximum (FWHM). Also, since a 5-membered ring and a 6-membered

ring in Formula 2A are linked via a carbon-carbon bond, a bond energy therebetween increases to improve material stability.

[0121] Also, since the organometallic compound represented by Formula 1 includes both the ligand represented by Formula 2A, which includes a non-carbene moiety, and the ligand represented by Formula 2B, which includes a carbene moiety, a d-orbital of a metal may be split. Thus, the effect of increasing luminescent efficiency may be exhibited based on a mechanism capable of suppressing d-d* transition.

[0122] In a case where the organometallic compound includes three ligands, the organometallic compound includes one ligand including the carbene moiety and two ligands each including the non-carbene moiety. Thus, upon synthesis, the yield may be more easily improved, and relatively high luminescent efficiency may be induced.

[0123] The organometallic compound may emit blue light. For example, the organometallic compound may emit blue light having an upper (e.g., a maximum) emission wavelength of equal to or greater than about 450 nm and less than about 485 nm, for example, equal to or greater than about 450 nm and less than about 475 nm, but embodiments of the present disclosure are not limited thereto. Therefore, the organometallic compound represented by Formula 1 may be suitably used for manufacturing an organic light-emitting device that emits deep blue light.

[0124] 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.

[0125] At least one of the organometallic compound of Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the organometallic compound may be included in an emission layer. The organometallic compound may act as a dopant in the emission layer.

[0126] Accordingly, provided is an organic light-emitting device including: 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 cyclic compound represented by Formula 1.

[0127] The expression "(an organic layer) includes at least one of organometallic compounds," as used herein, may include a case in which "(an organic layer) includes identical organometallic compounds represented by Formula 1" and a case in which "(an organic layer) includes two or more different organometallic compounds represented by Formula 1."

[0128] 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 all 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).

[0129] According to one embodiment,

[0130] the first electrode of the organic light-emitting device may be an anode,

[0131] the second electrode of the organic light-emitting device may be a cathode,

[0132] 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,

[0133] 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

[0134] the electron transport region may include a hole blocking layer, an electron transport layer, an electron injection layer, or any combination thereof.

[0135] The term "organic layer," as used herein, refers to a single layer and/or a plurality of layers between the first electrode and the second electrode of an organic light-emitting device. A material included in the "organic layer" is not limited to an organic material.

[0136] In one or more embodiments, the emission layer may include the organometallic compound of 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 of Formula 1 in the emission layer.

[0137] For example, the host may include at least one of a silicon-containing compound and a phosphine oxide-containing compound.

[0138] In one embodiment, the hole transport region may include a p-dopant having a lowest unoccupied molecular orbital energy level of about −3.5 eV or less.

[0139] The accompanying 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**.

[0140] 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 accompanying drawing.

First Electrode **110**

[0141] In the accompanying 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.

[0142] 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 forming a first electrode may be selected from materials with a high work function to facilitate hole injection.

[0143] 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. When the first electrode **110** is a semi-transmissive electrode or a reflective electrode, as a material for forming the first electrode **110**, magnesium (Mg), silver (Ag), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), or any combination thereof may be used. However, the material for forming the first electrode **110** is not limited thereto.

[0144] 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**

[0145] The organic layer **150** is disposed on the first electrode **110**. The organic layer **150** may include an emission layer.

[0146] 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**.

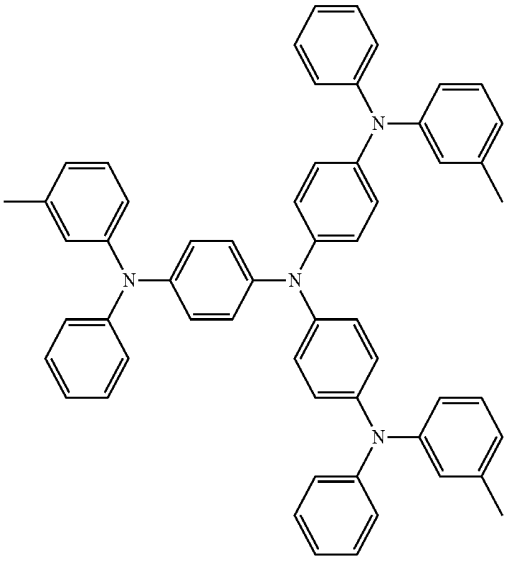
Hole Transport Region in Organic Layer **150**

[0147] 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.

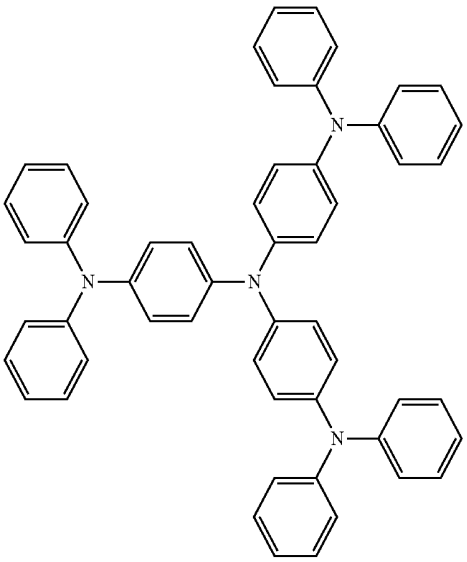
[0148] The hole transport region may include at least one layer selected from a hole injection layer, a hole transport layer, an emission auxiliary layer, and an electron blocking layer.

[0149] 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.

[0150] 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), PEDOT/PSS (poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate)), polyaniline/camphor sulfonic acid (PANT/CSA), polyaniline/poly(4-styrenesulfonate) (PANT/PSS), a compound represented by Formula 201, and a compound represented by Formula 202:

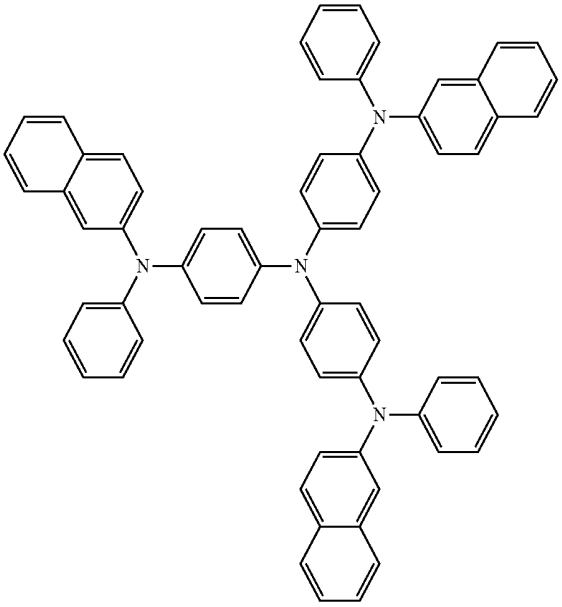


m-MTDATA



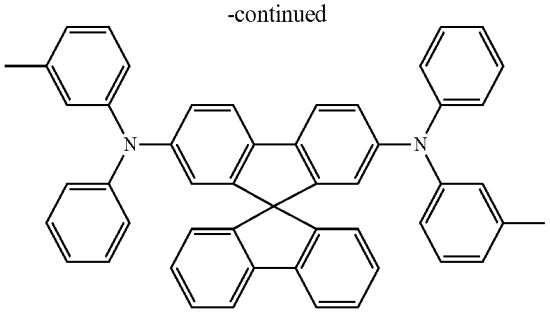
TDATA

-continued

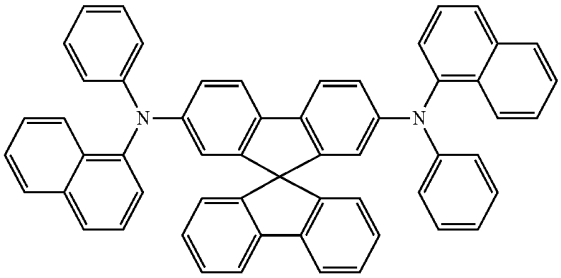


2-TNATA

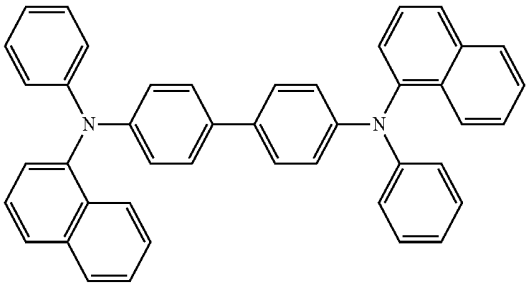
-continued



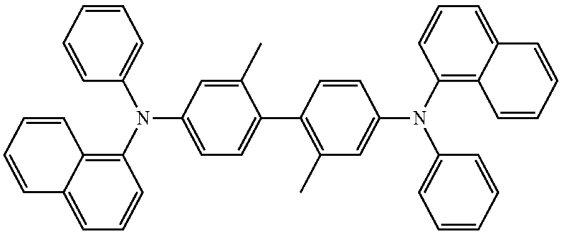
Spiro-TPD



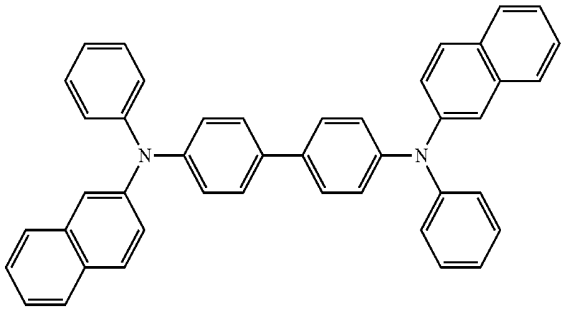
Spiro-NPB



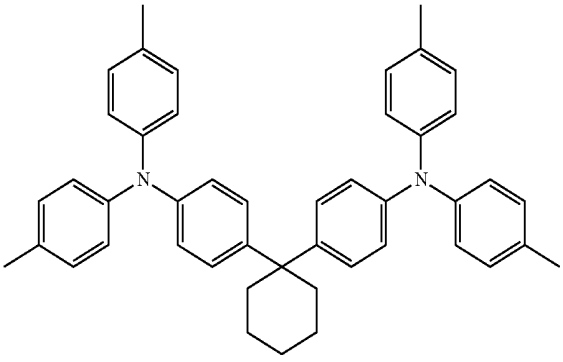
NPB



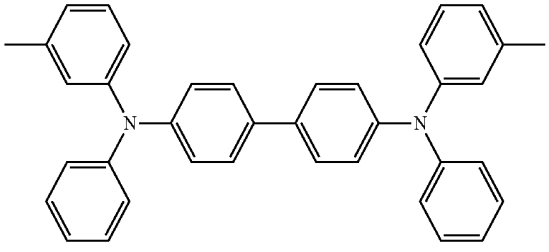
methylated NPB



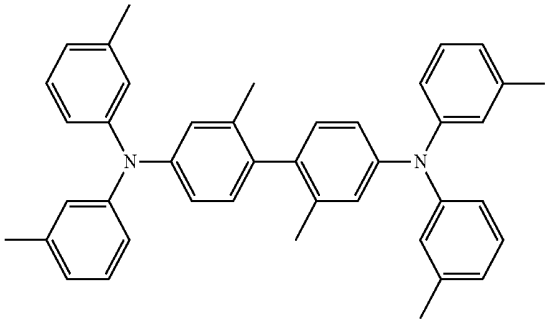
β-NPB



TAPC



TPD



HMTPD

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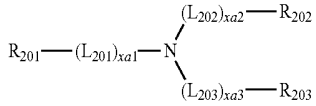
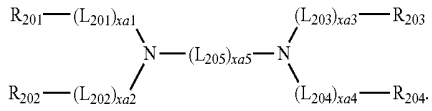
Formula 201



Formula 202



In Formulae 201 and 202,

[0151] L_{201} to L_{204} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0152] L_{205} may be selected from *—O—*', *—S—*', *—N(Q_{201})-*', a substituted or unsubstituted C_1-C_{20} alkylene group, a substituted or unsubstituted C_2-C_{20} alkenylene group, a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0153] xa1 to xa4 may each independently be an integer from 0 to 3,

[0154] xa5 may be an integer from 1 to 10, and

[0155] R_{201} to R_{204} and Q_{201} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_6-C_{60} aryloxy group, a substituted or unsubstituted C_6-C_{60} arylthio group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0156] For example, R_{201} and R_{202} in Formula 202 may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group, and R_{203} and R_{204} may optionally be linked via a single bond, a dimethyl-methylene group, or a diphenyl-methylene group.

[0157] In one embodiment, in Formulae 201 and 202,

[0158] L_{201} to L_{205} may each independently be selected from:

[0159] 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

[0160] 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

[0161] 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.

[0162] In one or more embodiments, xa1 to xa4 may each independently be 0, 1, or 2.

[0163] In one or more embodiments, xa5 may be 1, 2, 3, or 4.

[0164] In one or more embodiments, R_{201} to R_{204} and Q_{201} may each independently be selected from:

[0165] 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

[0166] 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

[0167] Q_{31} to Q_{33} are the same as described herein.

[0168] In one or more embodiments, at least one of R_{201} to R_{203} in Formula 201 may be selected from:

[0169] a fluorenyl group, a spiro-bifluorenyl group, a carbazolyl group, a dibenzofuranyl group, and a dibenzothiophenyl group; and

[0170] 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,

[0171] but embodiments of the present disclosure are not limited thereto.

[0172] 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.

[0173] In one or more embodiments, at least one of R_{201} to R_{204} in Formula 202 may be selected from:

[0174] a carbazolyl group; and

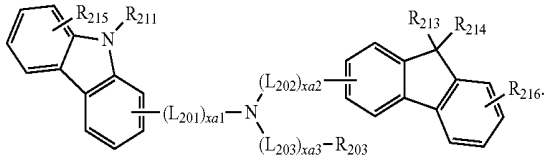
[0175] a carbazolyl group, substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl 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,

[0176] but embodiments of the present disclosure are not limited thereto.

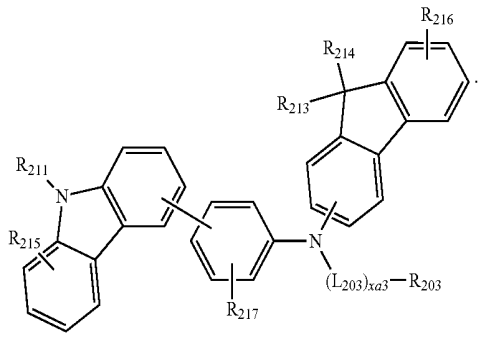
[0177] The compound represented by Formula 201 may be represented by Formula 201A:

Formula 201A



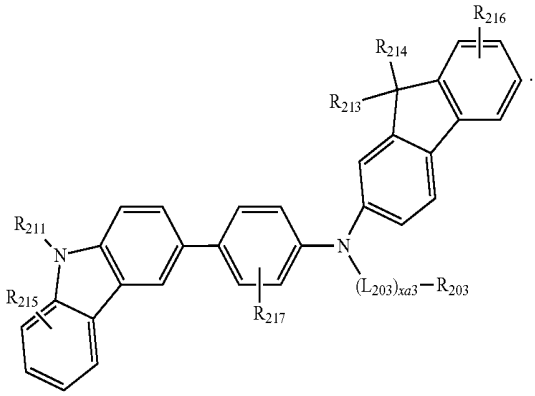
[0178] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A(1) below, but embodiments of the present disclosure are not limited thereto:

Formula 201A(1)



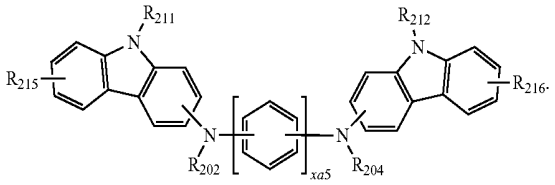
[0179] In one embodiment, the compound represented by Formula 201 may be represented by Formula 201A-1 below, but embodiments of the present disclosure are not limited thereto:

Formula 201A-1



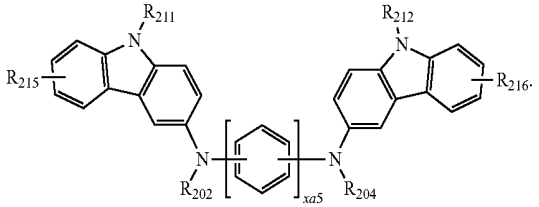
[0180] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A:

Formula 202A



[0181] In one embodiment, the compound represented by Formula 202 may be represented by Formula 202A-1:

Formula 202A-1



[0182] In Formulae 201A, 201A(1), 201A-1, 202A, and 202A-1,

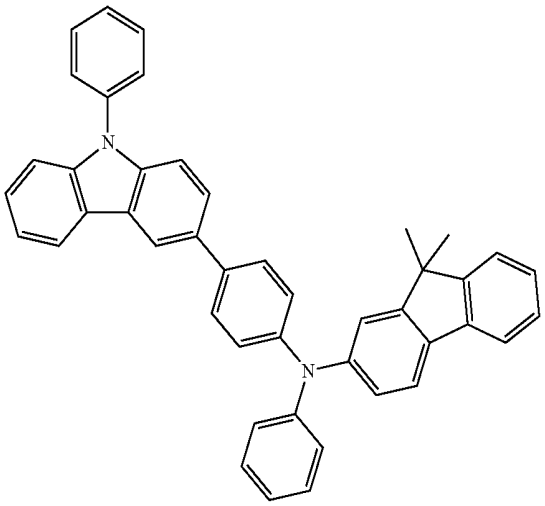
[0183] L_{201} to L_{203}, xa1 to xa3, xa5, and R_{202} to R_{204} are the same as described above,

[0184] R_{211} and R_{212} may be understood by referring to the description provided herein in connection with R_{203}, and

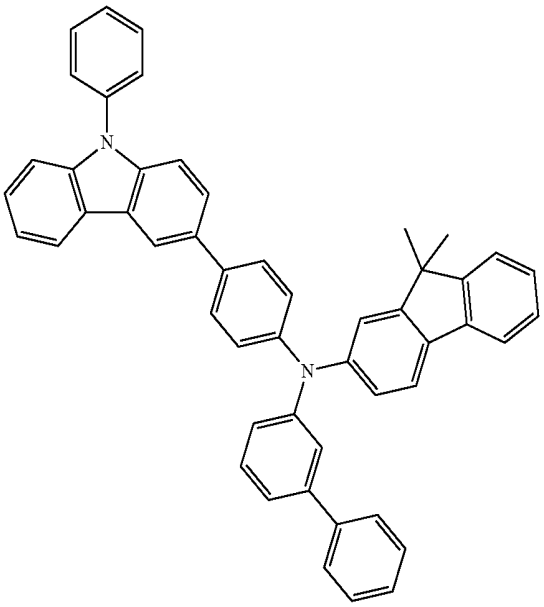
[0185] R_{213} to R_{217} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, 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.

[0186] The hole transport region may include at least one compound selected from Compounds HT1 to HT39, but embodiments of the present disclosure are not limited thereto:

HT1



HT2



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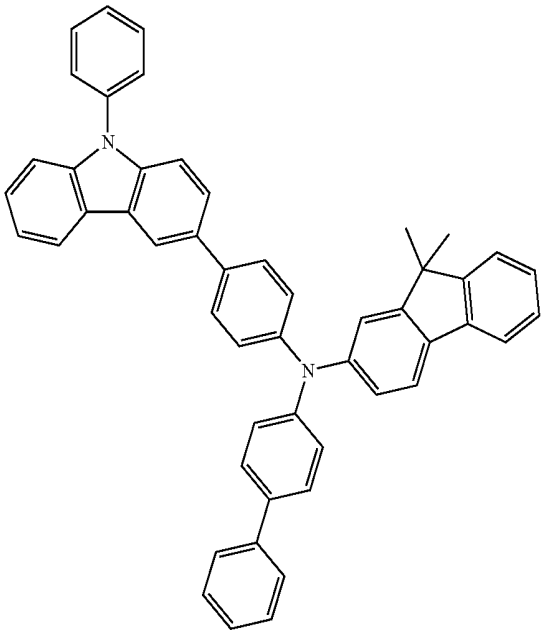

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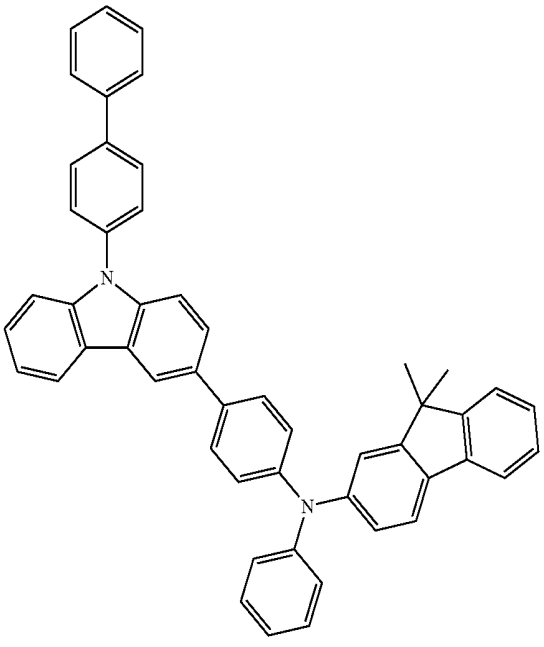

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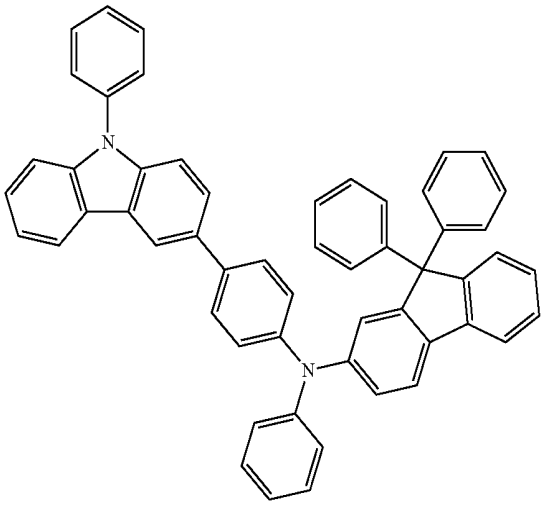

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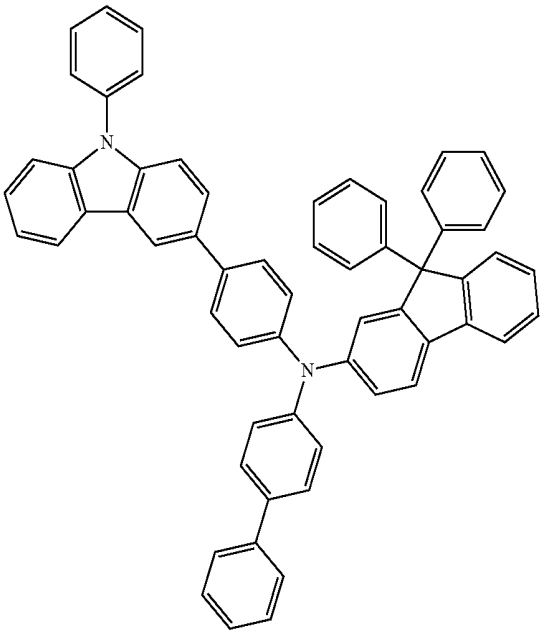

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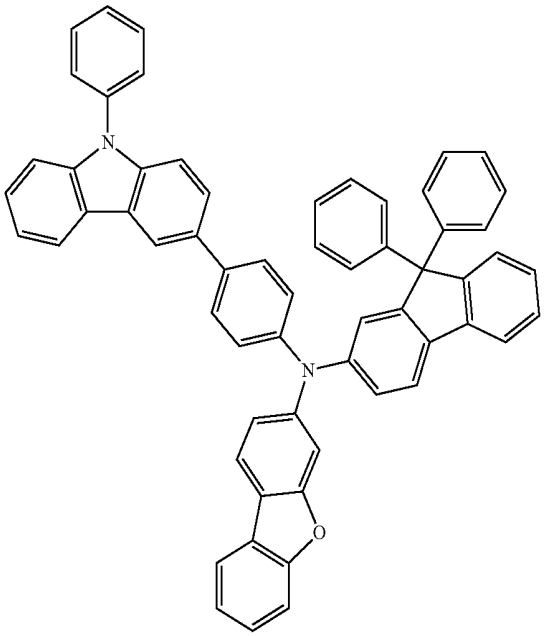

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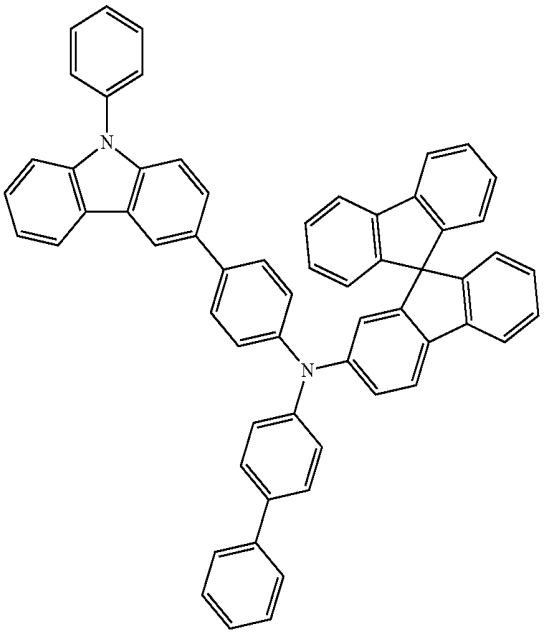

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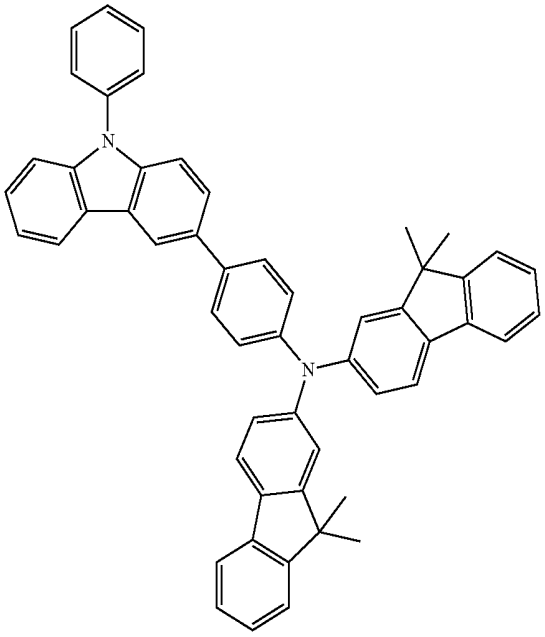

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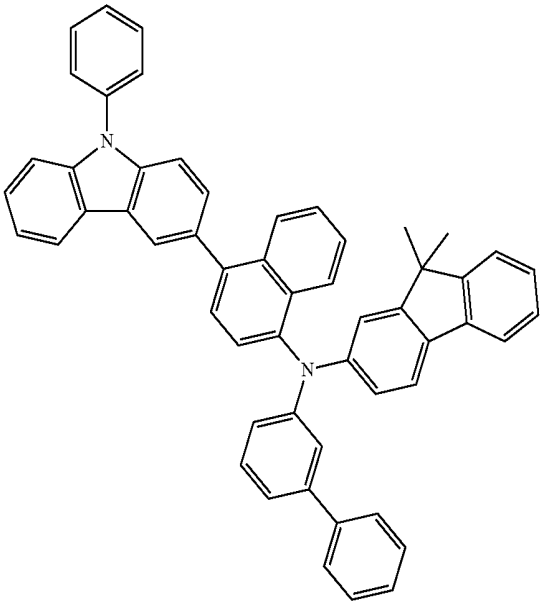

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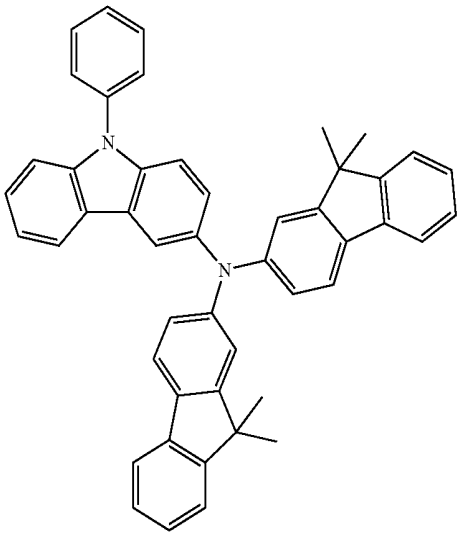

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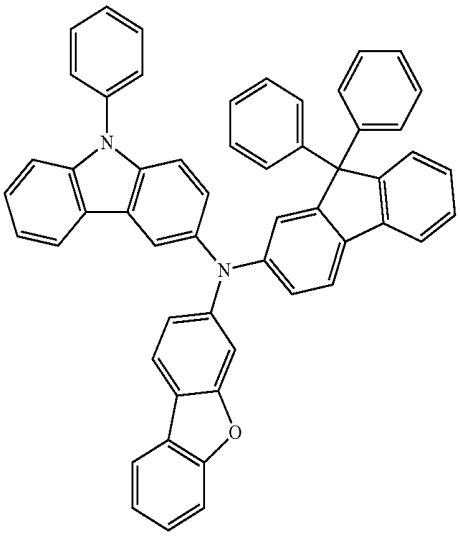

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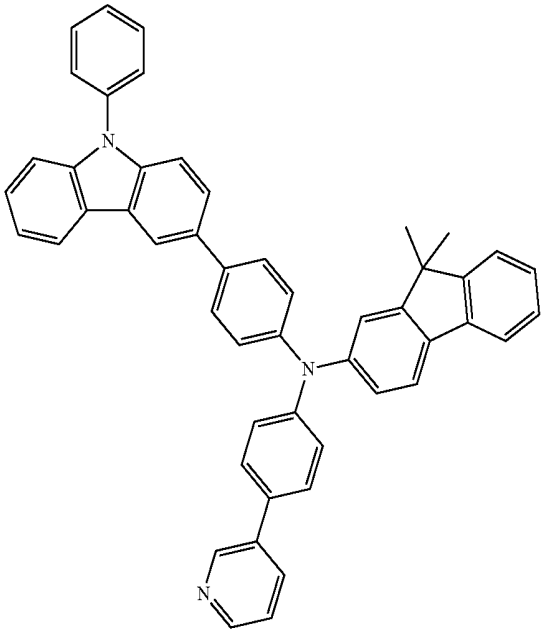

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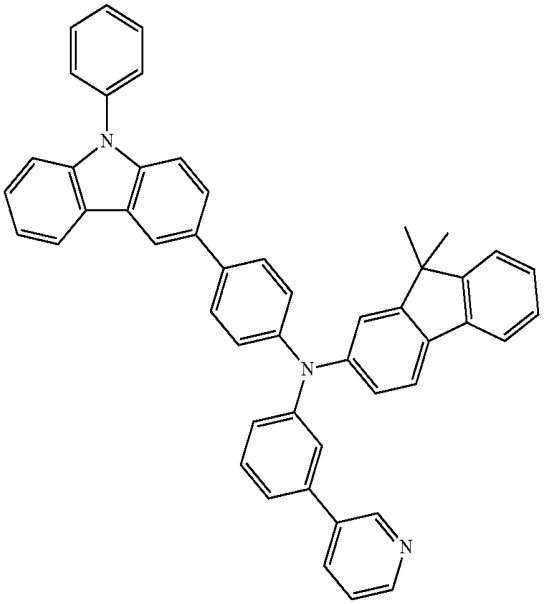

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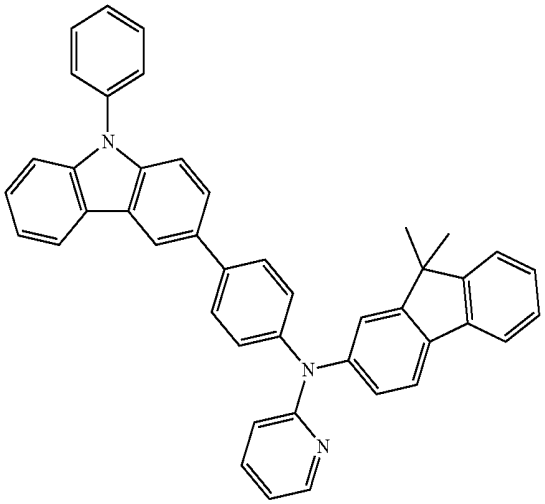

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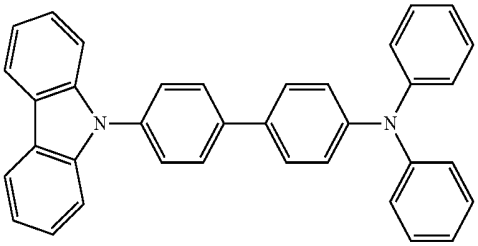

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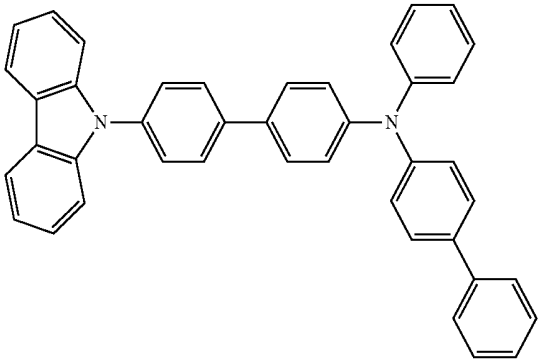

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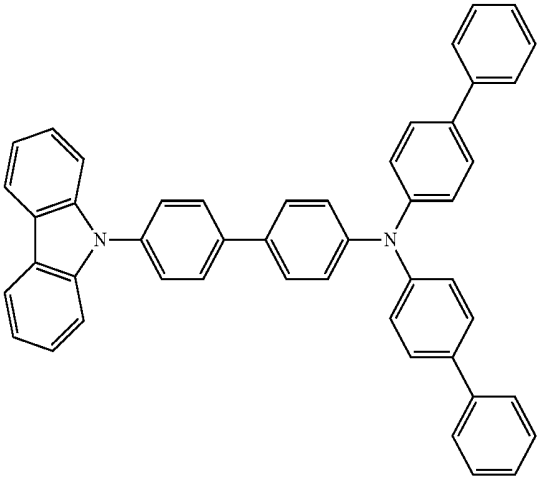

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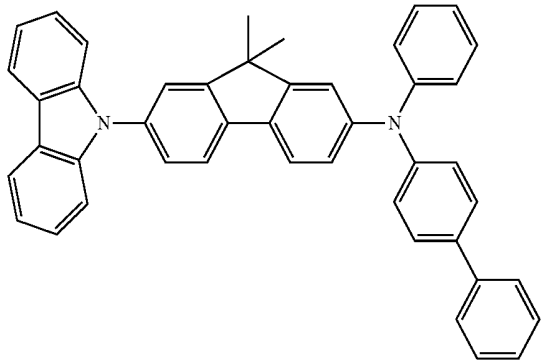

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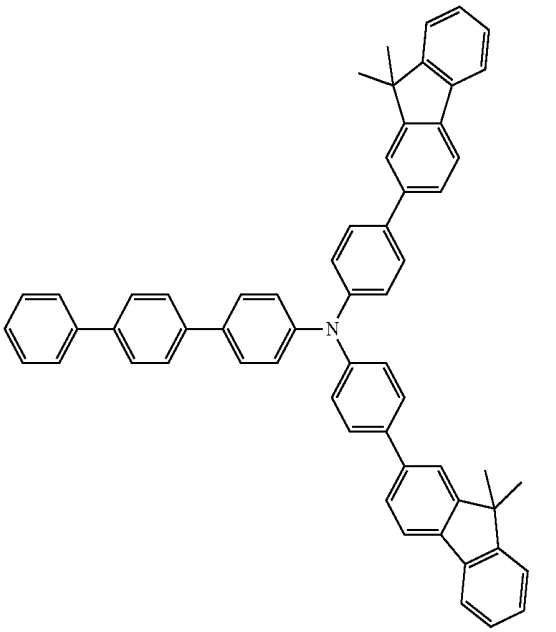

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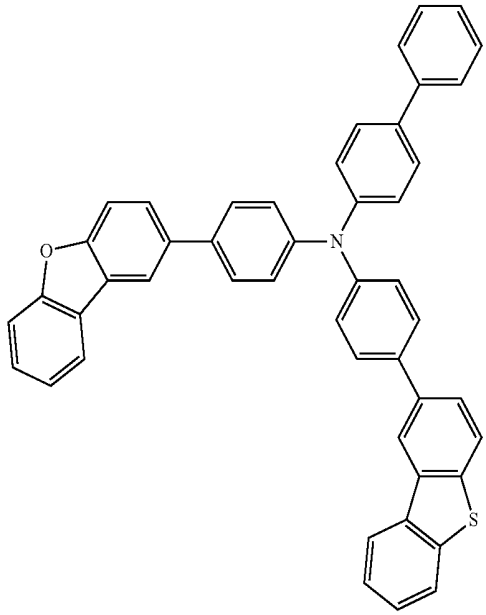

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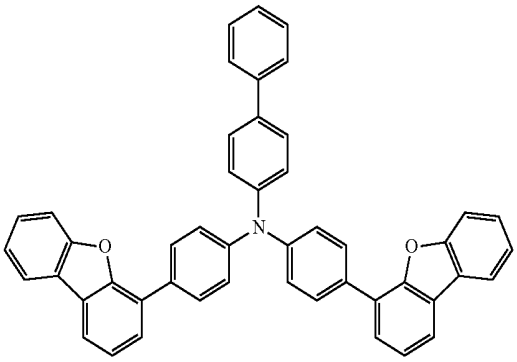

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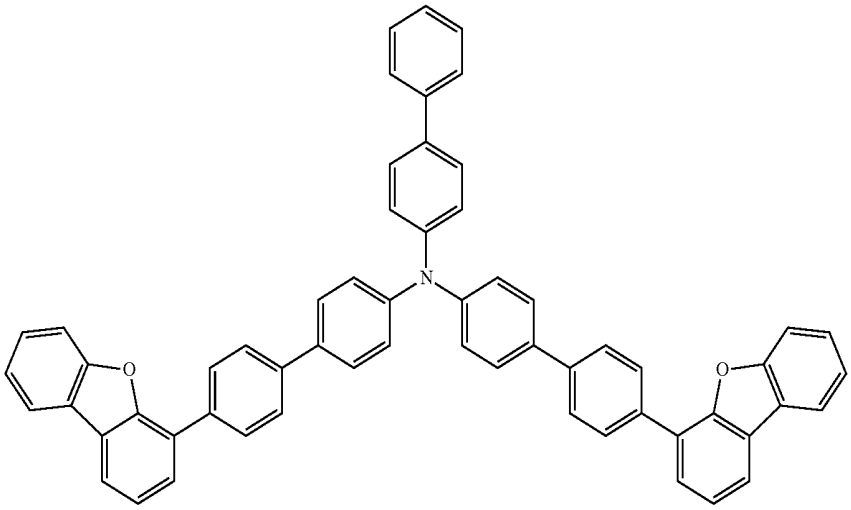

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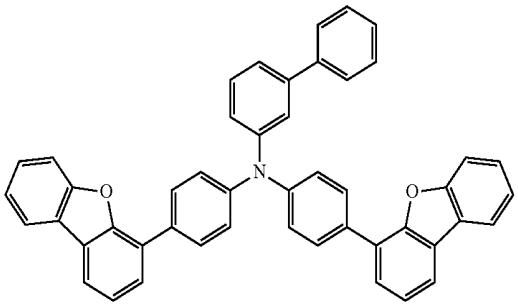

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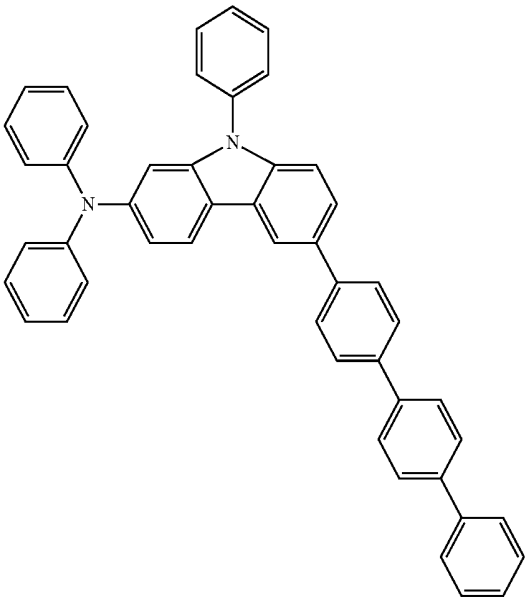

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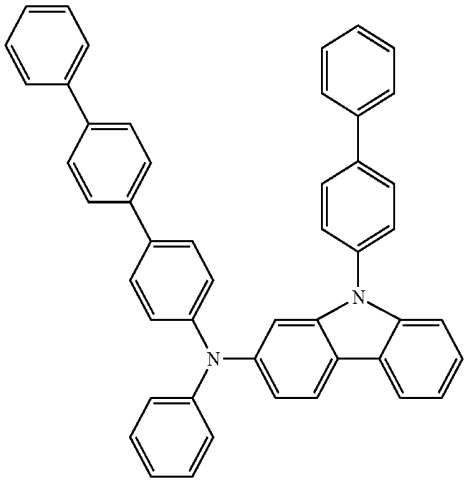

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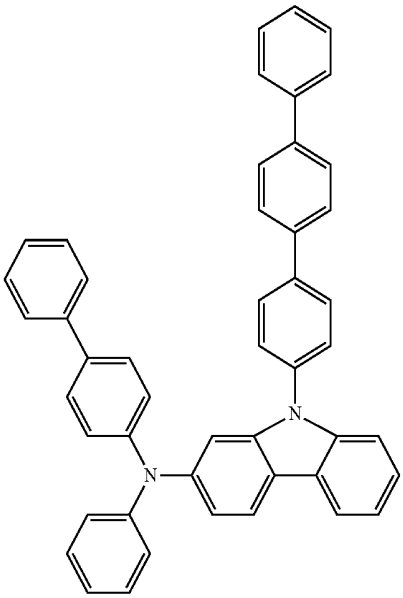

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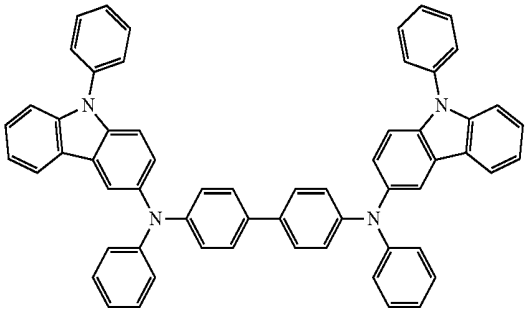

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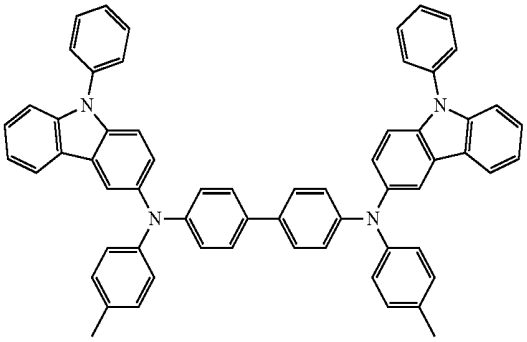

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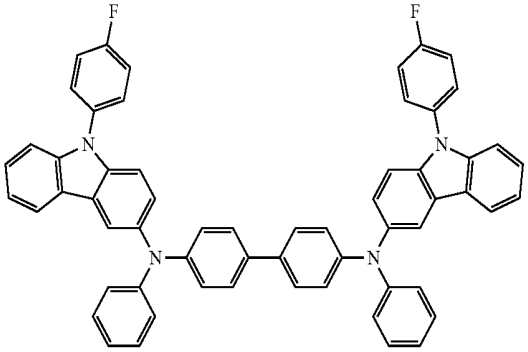

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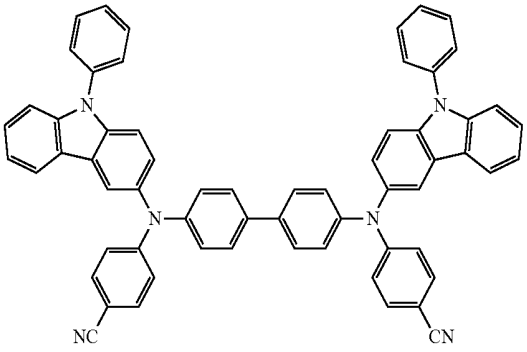

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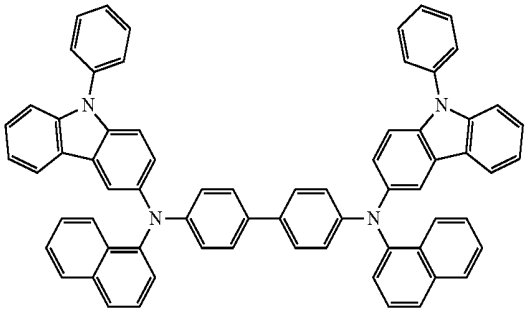
HT32



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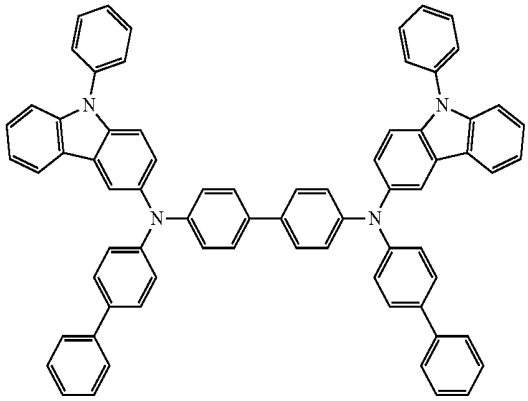

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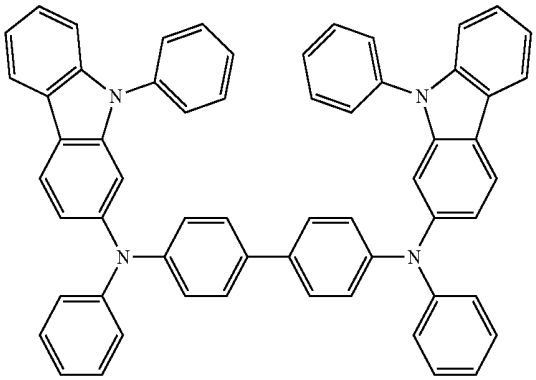
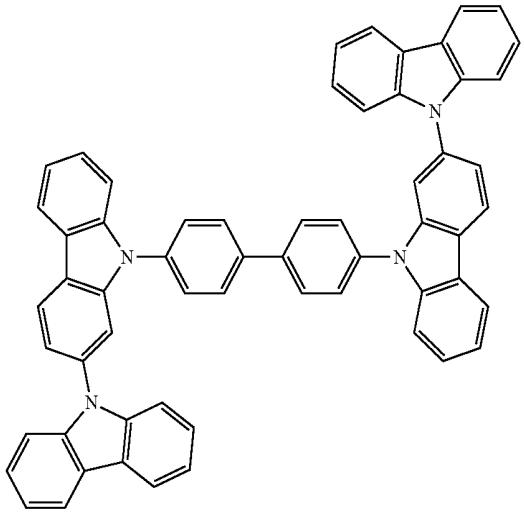


HT35



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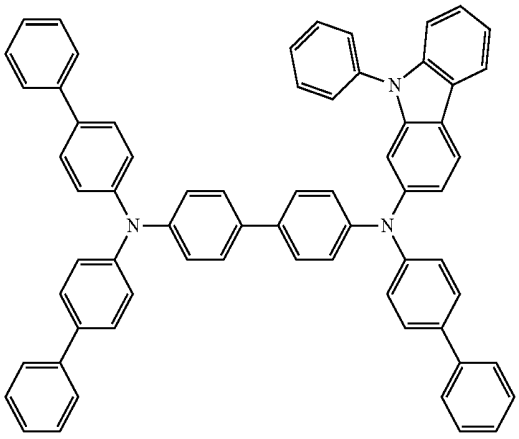

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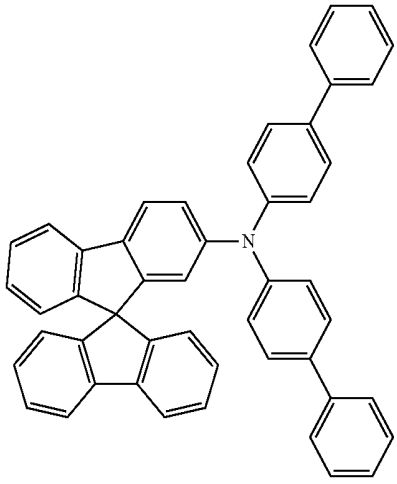

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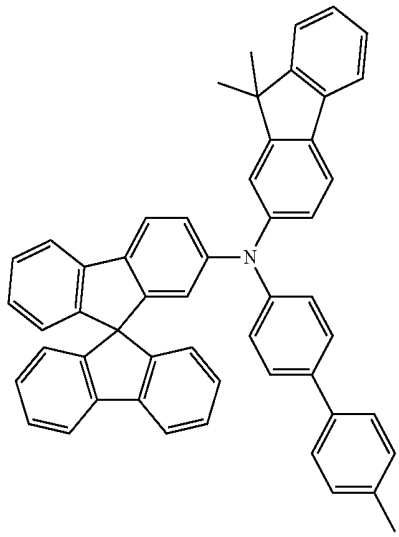
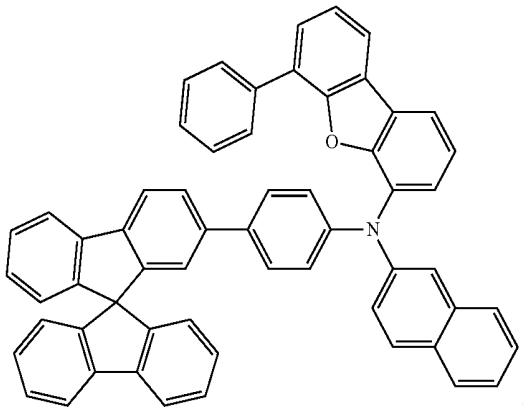
HT38



HT39



[0187] A thickness of the hole transport region may be in a range of about 100 Å to about 10,000 Å, for example, about 100 Å to about 1,000 Å. When the hole transport region includes at least one of a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 9,000 Å, and for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, for example, about 100 Å to about 1,500 Å. When the thicknesses of the hole transport region, the hole injection layer, and the hole transport layer are within these ranges, satisfactory hole transporting characteristics may be obtained without a substantial increase in driving voltage.

[0188] 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

[0189] 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.

[0190] The charge-generation material may be, for example, a p-dopant.

[0191] In one embodiment, the p-dopant may have a lowest unoccupied molecular orbital (LUMO) energy level of −3.5 eV or less.

[0192] 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.

[0193] For example, the p-dopant may include at least one selected from:

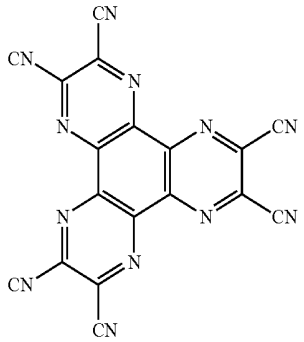
[0194] a quinone derivative, such as tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ);

[0195] a metal oxide, such as a tungsten oxide and a molybdenum oxide;

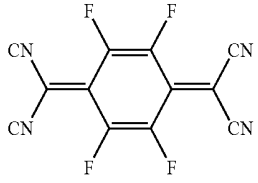
[0196] 1,4,5,8,9,12-hexaazatriphenylene-hexacarbonitrile (HAT-CN); and

[0197] a compound represented by Formula 221,

[0198] but embodiments of the present disclosure are not limited thereto:



HAT-CN



F4-TCNQ

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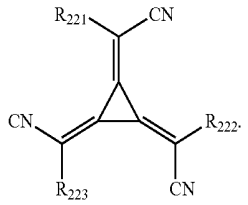
Formula 221



[0199] In Formula 221,

[0200] R_{221} to R_{223} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkyl group, a substituted or unsubstituted C_3-C_{10} cycloalkenyl group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenyl group, a substituted or unsubstituted C_6-C_{60} aryl group, a substituted or unsubstituted C_1-C_{60} heteroaryl group, a substituted or unsubstituted monovalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, provided that at least one selected from R_{221} to R_{223} has 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**

[0201] When the organic light-emitting device **10** is a full-color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, or a blue emission layer, according to a sub-pixel. In one or more embodiments, the emission layer may have a stacked structure of two or more layers selected from a red emission layer, a green emission layer, and a blue emission layer, in which the two or more layers contact each other or are separated from each other. In one or more embodiments, the emission layer may include two or more materials selected from a red light-emitting material, a green light-emitting material, and a blue light-emitting material, in which the two or more materials are mixed with each other in a single layer to emit white light.

[0202] 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.

[0203] An amount of the dopant in the emission layer may be 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.

[0204] A thickness of the emission layer may be in a range of about 100 Å to about 1,000 Å, for example, about 200 Å to about 600 Å. When the thickness of the emission layer is within this range, excellent light-emission characteristics may be obtained without a substantial increase in driving voltage.

Host in Emission Layer

[0205] In one or more embodiments, the host may include a compound represented by Formula 301 below.

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

[0206] In Formula 301,

[0207] 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,

[0208] xb11 may be 1, 2, or 3,

[0209] 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 heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0210] xb1 may be an integer from 0 to 5,

[0211] 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 —$P(=O)(Q_{301})(Q_{302})$,

[0212] xb21 may be an integer from 1 to 5, and

[0213] 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.

[0214] In one embodiment, Ar_{301} in Formula 301 may be selected from:

[0215] a naphthalene group, a fluorene group, a spirobifluorene 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

[0216] a naphthalene group, a fluorene group, a spirobifluorene 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

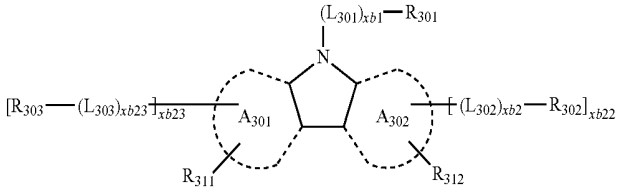
terphenyl group, a naphthyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$, and

[0217] 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.

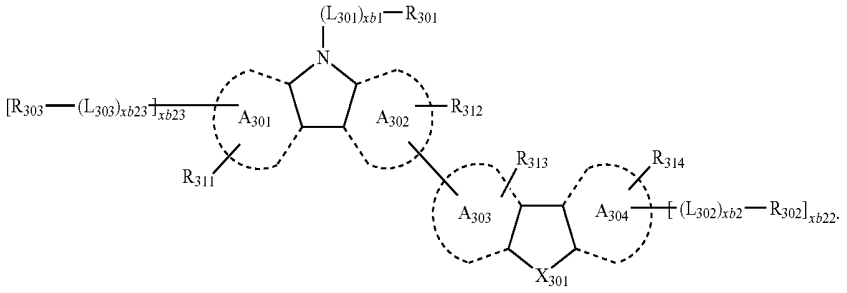
[0218] When xb11 in Formula 301 is two or more, two or more Ar301(s) may be linked via a single bond.

[0219] In one or more embodiments, the compound represented by Formula 301 may be represented by Formula 301-1 or 301-2:

Formula 301-1



Formula 301-2



[0220] In Formulae 301-1 and 301-2,

[0221] A_{301} to A_{304} may each independently be selected from a benzene group, a naphthalene group, a phenanthrene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a pyridine group, a pyrimidine group, an indene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, an indole group, a carbazole group, a benzocarbazole group, a dibenzocarbazole group, a furan group, a benzofuran group, a dibenzofuran group, a naphthofuran group, a benzonaphthofuran group, a dinaphthofuran group, a thiophene group, a benzothiophene group, a dibenzothiophene group, a naphthothiophene group, a benzonaphthothiophene group, and a dinaphthothiophene group,

[0222] X_{301} may be O, S, or N-[$(L_{304})_{xb4}$-R_{304}],

[0223] 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 —$P(=O)(Q_{31})(Q_{32})$,

[0224] xb22 and xb23 may each independently be 0, 1, or 2,

[0225] L_{301}, xb1, R_{301} and Q_{31} to Q_{33} are the same as described above,

[0226] L_{302} to L_{304} may each independently be the same as described in connection with L_{301},

[0227] xb2 to xb4 may each independently be the same as described in connection with xb1, and

[0228] R_{302} to R_{304} may each independently be the same as described in connection with R_{301}.

[0229] For example, in Formulae 301, 301-1, and 301-2, L_{301} to L_{304} may each independently be selected from:

[0230] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an z, 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

[0231] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene

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

[0232] Q_{31} to Q_{33} are the same as described above.

[0233] In one embodiment, in Formulae 301, 301-1, and 301-2, R_{301} to R_{304} may each independently be selected from:

[0234] 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

[0235] 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 ben-

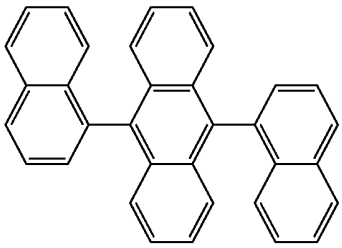
zimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, an azacarbazolyl group, —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{31})(Q_{32})$, —$B(Q_{31})(Q_{32})$, —$C(=O)(Q_{31})$, —$S(=O)_2(Q_{31})$, and —$P(=O)(Q_{31})(Q_{32})$, and

[0236] Q_{31} and Q_{33} may be the same as described above.

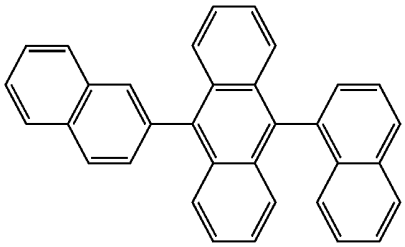
[0237] In one or more embodiments, the host may include an alkaline earth metal complex. For example, the host may be selected from a Be complex (for example, Compound H55), a Mg complex, and a Zn complex.

[0238] The host may include at least one selected from 9,10-di(2-naphthyl)anthracene (ADN), 2-methyl-9,10-bis(naphthalen-2-yl)anthracene (MADN), 9,10-di-(2-naphthyl)-2-t-butyl-anthracene (TBADN), 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP), 1,3-di-9-carbazolylbenzene (mCP), 1,3,5-tri(carbazol-9-yl)benzene (TCP), and Compounds H1 to H55, but embodiments of the present disclosure are not limited thereto:

H1



H2



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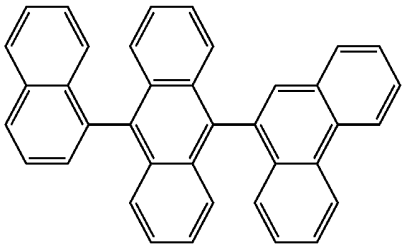

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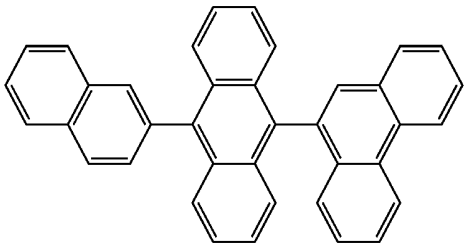

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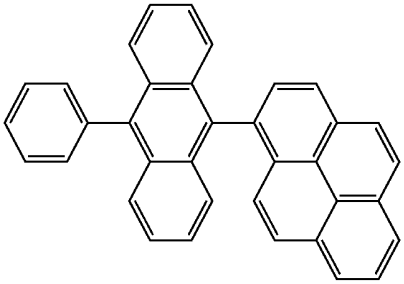

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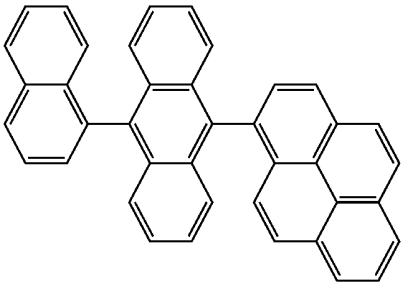

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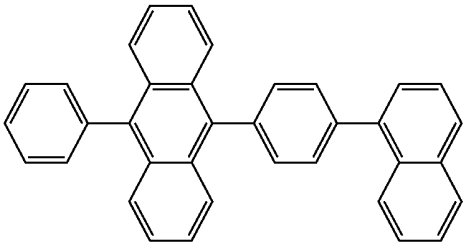

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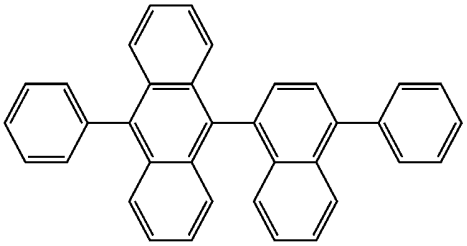

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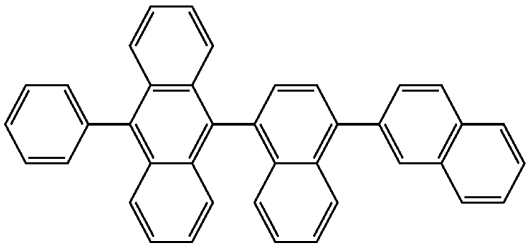

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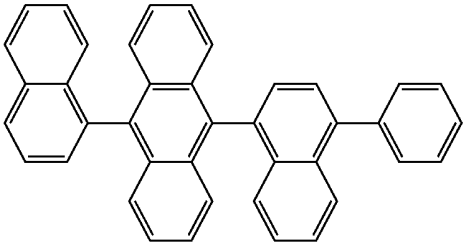

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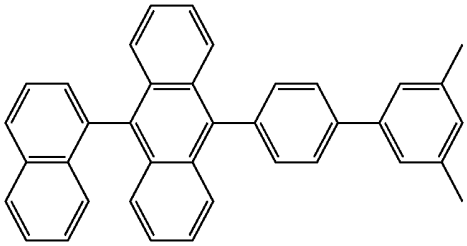
H11



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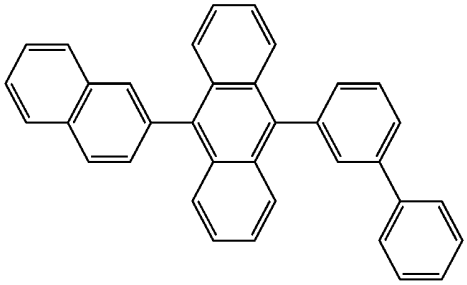

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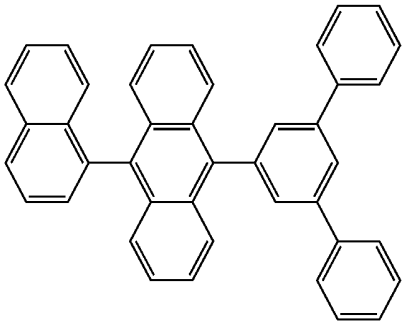

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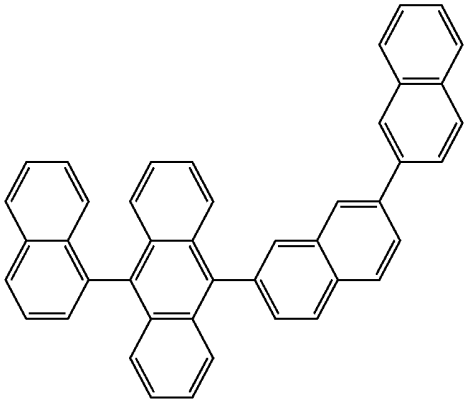

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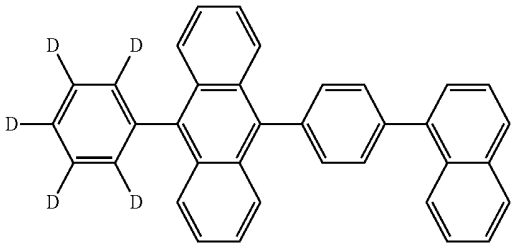

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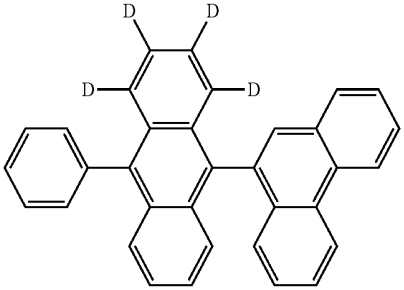
H16



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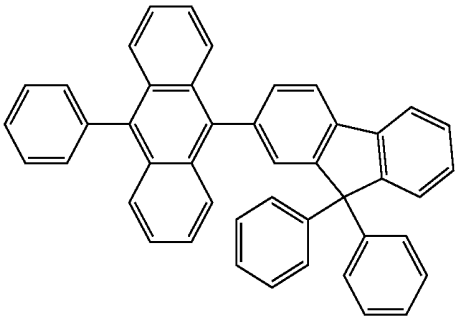

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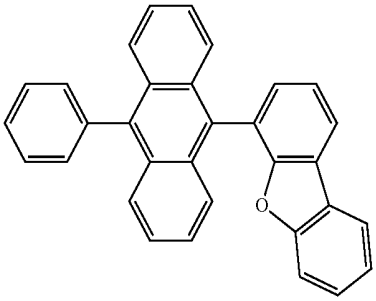
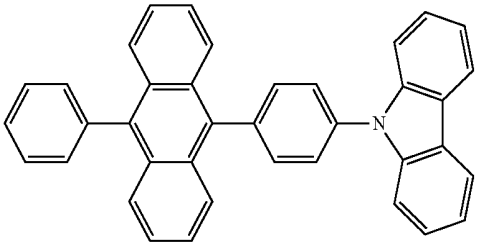
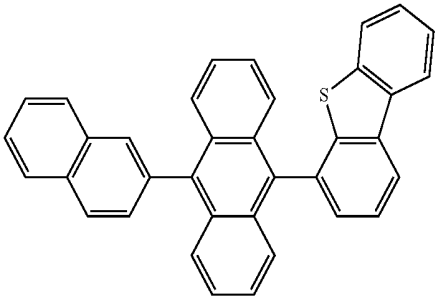


H19



H20



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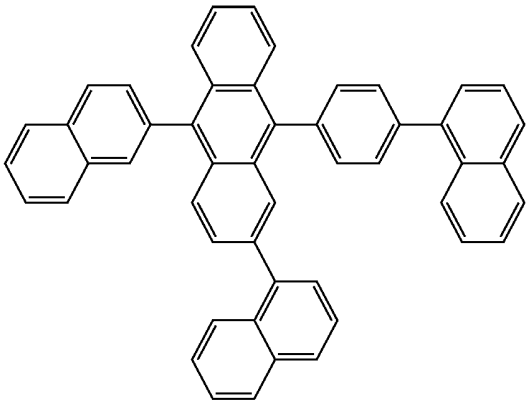

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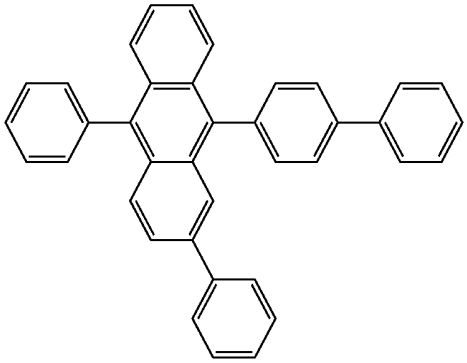

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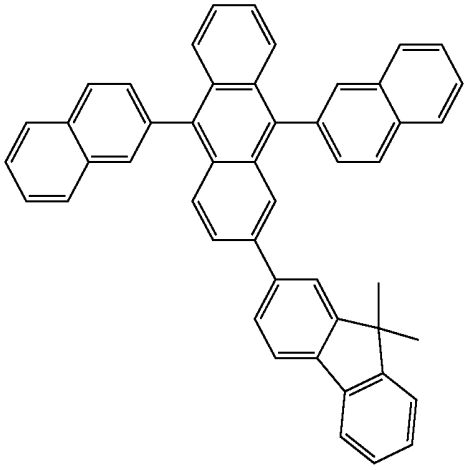

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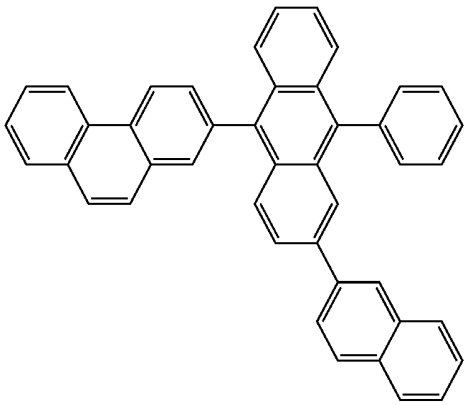

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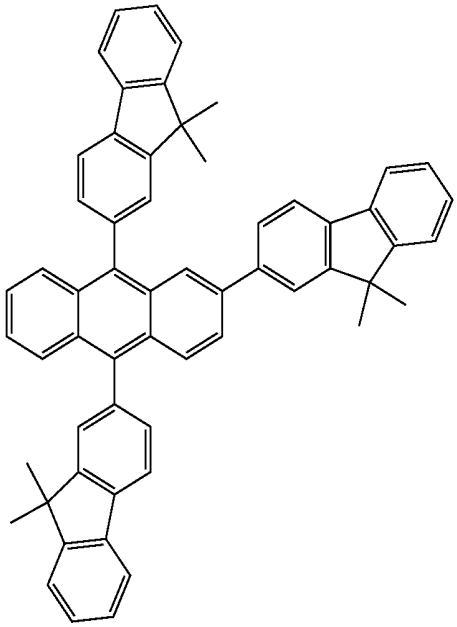

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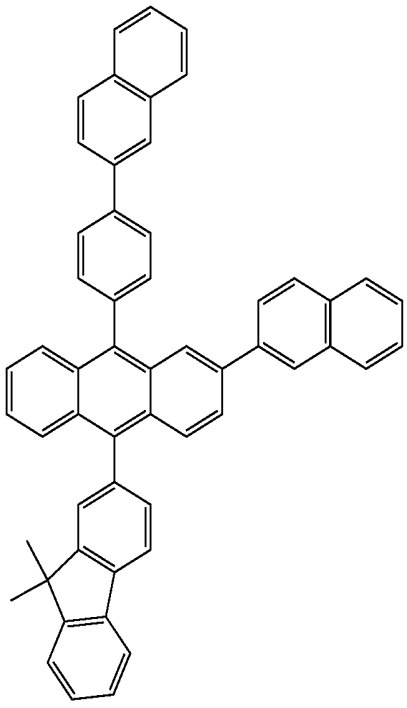

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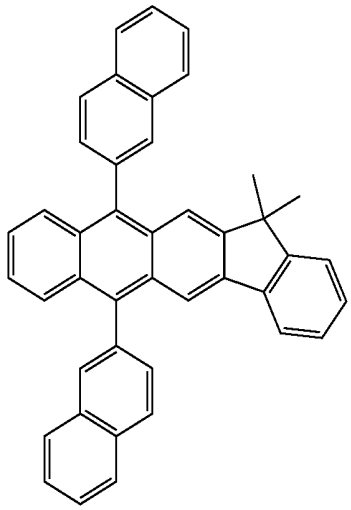

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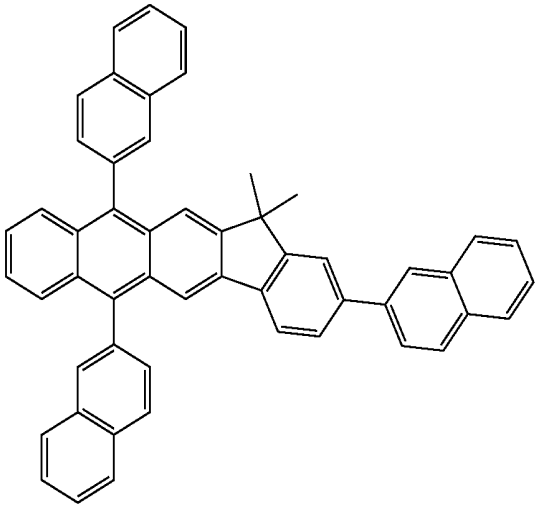

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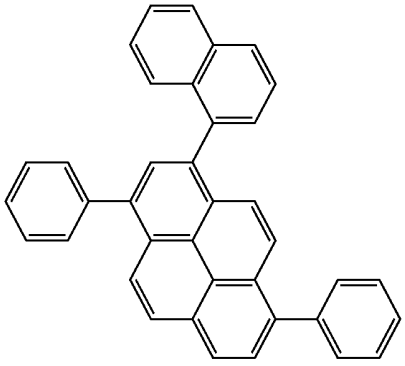

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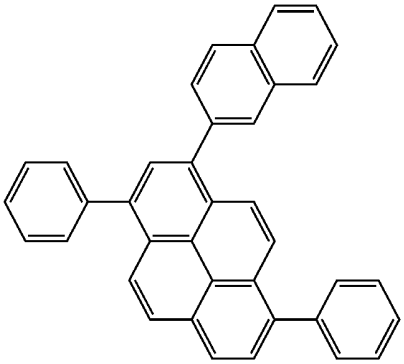

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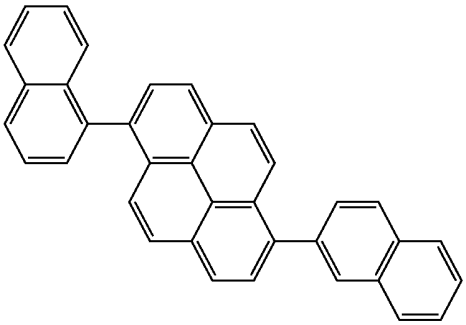

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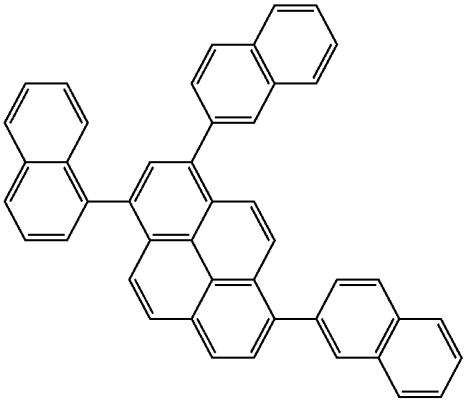

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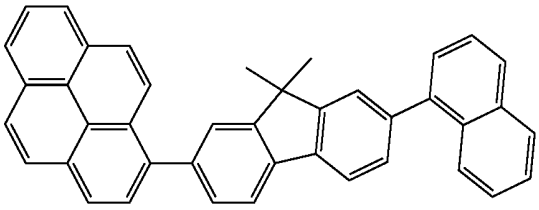

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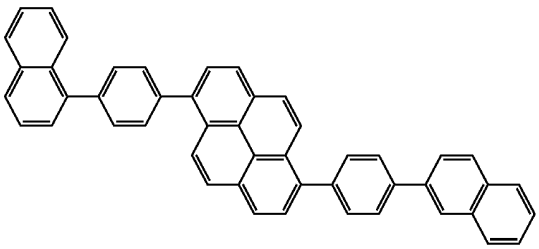

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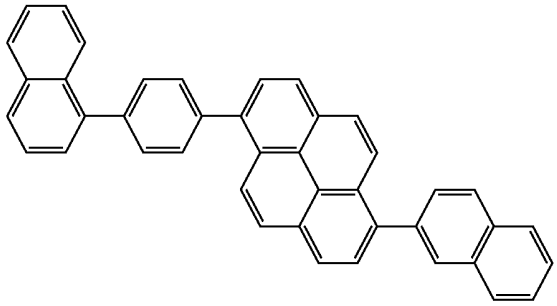

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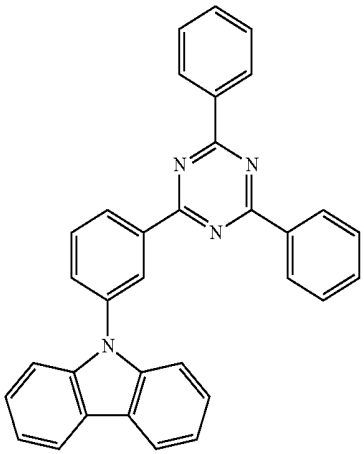

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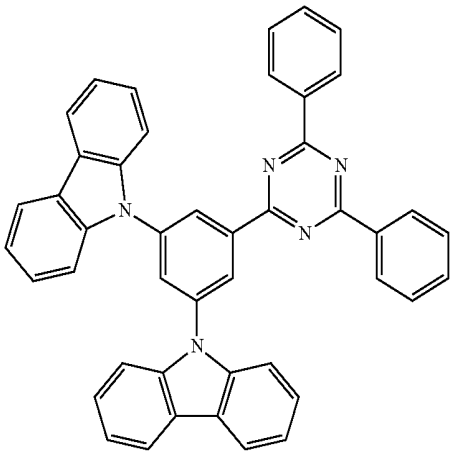

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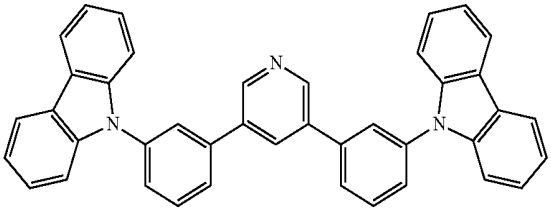

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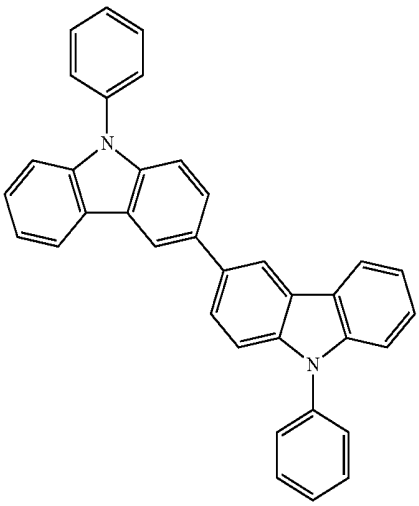

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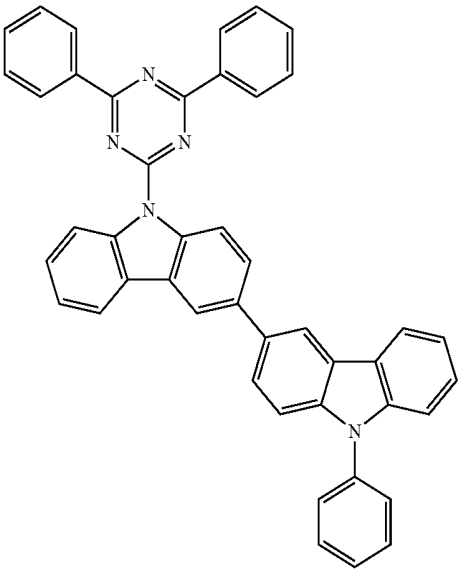

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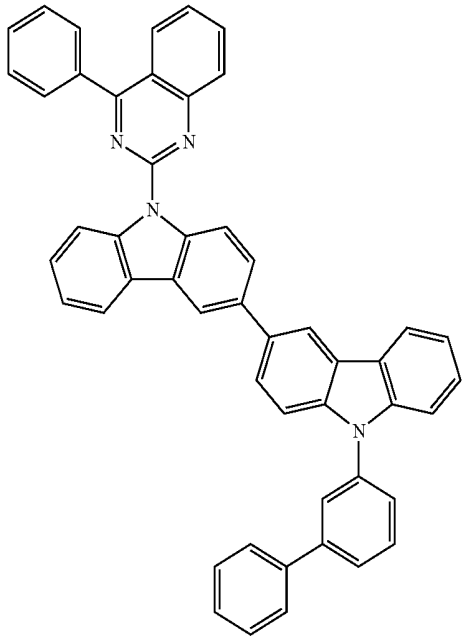

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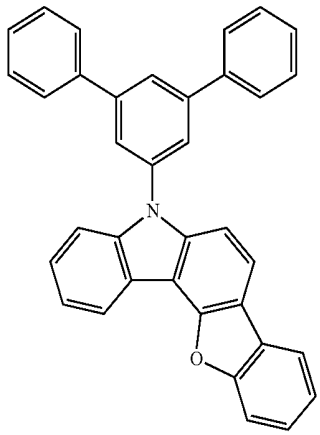

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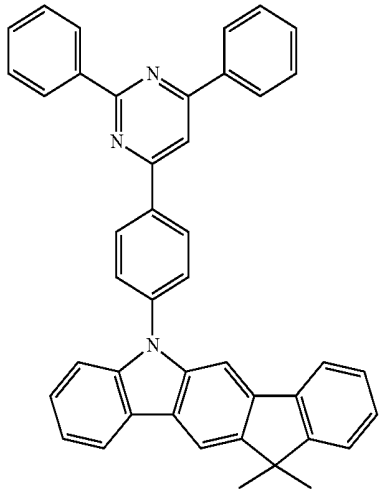

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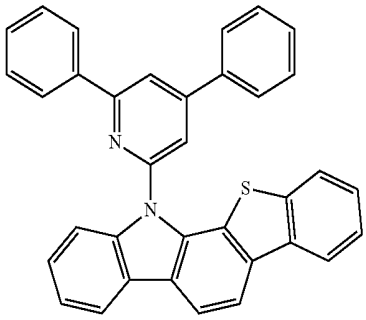

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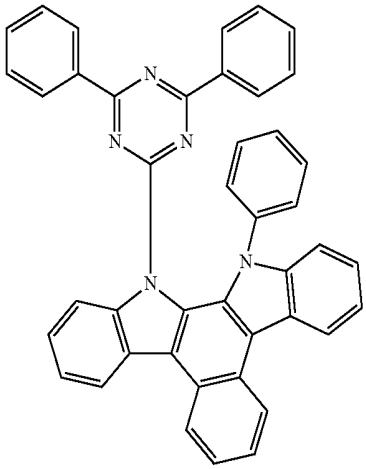

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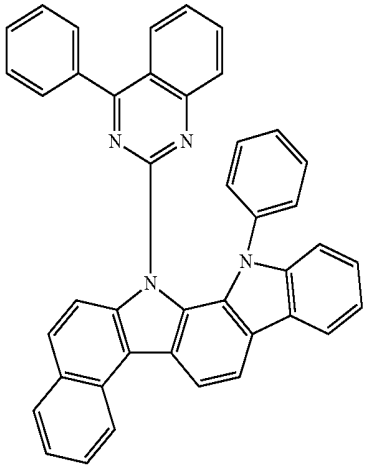

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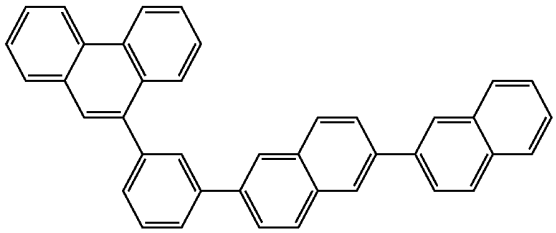

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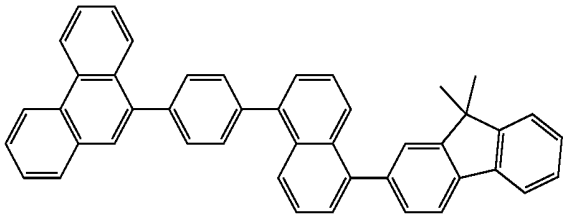

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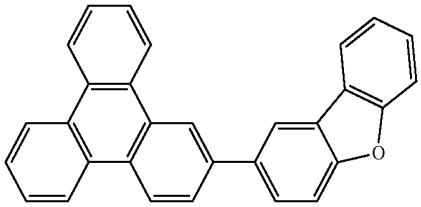

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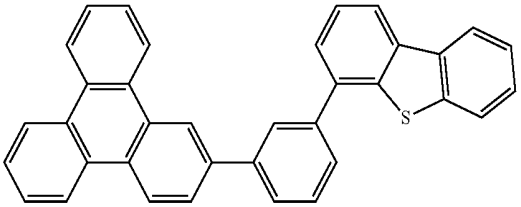

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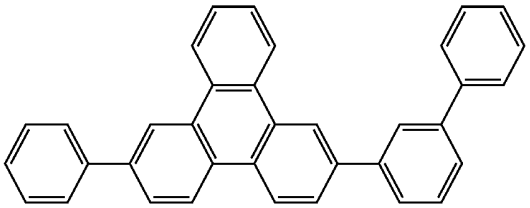

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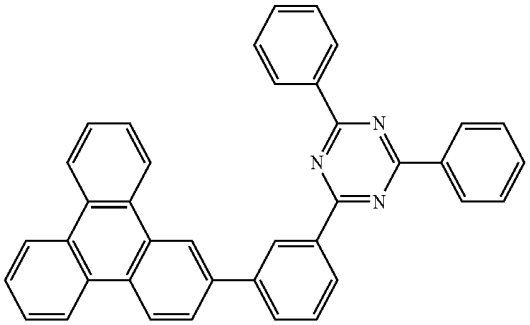

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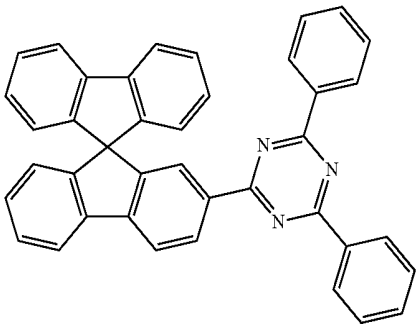

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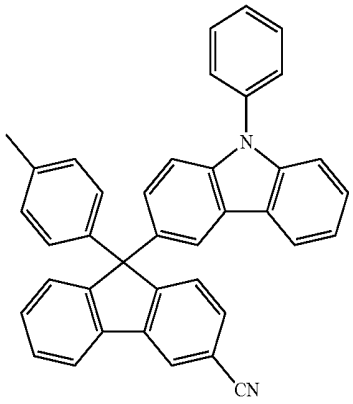

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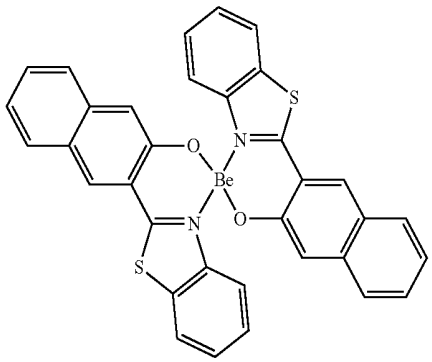


[0239] In one embodiment, the host may include at least one selected from a silicon-containing compound (for example, bis(4-(9H-carbazol-9-yl)phenyl)diphenylsilane (BCPDS) used in the following examples or the like) and a phosphine oxide-containing compound (for example, (4-(1-(4-(diphenylamino)phenyl)cyclohexyl)phenyl)diphenylphosphine oxide (POPCPA) used in the following examples or the like).

[0240] 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 used in the following examples includes BCPDS and POPCPA).

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

[0241] The phosphorescent dopant may include an organometallic compound represented by Formula 1 below:

Electron Transport Region in Organic Layer **150**

[0242] 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.

[0243] 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.

[0244] 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.

[0245] 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.

[0246] The term "π electron-depleted nitrogen-containing ring," as used herein, refers to a C_1-C_{60} heterocyclic group having at least one *—N=*' moiety as a ring-forming moiety.

[0247] For example, the "π electron-depleted nitrogen-containing ring" may be i) a 5-membered to 7-membered heteromonocyclic group having at least one *—N=*' moiety, ii) a heteropolycyclic group in which two or more 5-membered to 7-membered heteromonocyclic groups each having at least one *—N=*' moiety are condensed with each other, or iii) a heteropolycyclic group in which at least one of 5-membered to 7-membered heteromonocyclic groups, each having at least one *—N=" moiety, is condensed with at least one C_5-C_{60} carbocyclic group.

[0248] Examples of the π electron-depleted nitrogen-containing ring are 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 iso-benzothiazole 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, but embodiments of the present disclosure are not limited thereto.

[0249] For example, the electron transport region may include a compound represented by Formula 601:

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

[0250] In Formula 601,

[0251] 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,

[0252] xe11 may be 1, 2, or 3,

[0253] L_{601} may each independently be selected from a substituted or unsubstituted C_3-C_{10} cycloalkylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkylene group, a substituted or unsubstituted C_3-C_{10} cycloalkenylene group, a substituted or unsubstituted C_1-C_{10} heterocycloalkenylene group, a substituted or unsubstituted C_6-C_{60} arylene group, a substituted or unsubstituted C_1-C_{60} heteroarylene group, a substituted or unsubstituted divalent non-aromatic condensed polycyclic group, and a substituted or unsubstituted divalent non-aromatic condensed heteropolycyclic group,

[0254] xe1 may be an integer from 0 to 5,

[0255] 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 —$P(=O)(Q_{601})(Q_{602})$,

[0256] Q_{601} to Q_{603} may each independently be a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, or a naphthyl group, and

[0257] xe21 may be an integer from 1 to 5.

[0258] In one embodiment, at least one of Ar_{60i}(s) in the number of xe11 and/or at least one of R_{601}(s) in the number of xe21 may include the π electron-depleted nitrogen-containing ring.

[0259] In one embodiment, ring Ar_{601} in Formula 601 may be selected from:

[0260] 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

[0261] a benzene group, a naphthalene group, a fluorene group, a spiro-bifluorene group, a benzofluorene group, a dibenzofluorene group, a phenalene group, a phenanthrene group, an anthracene group, a fluoranthene group, a triphenylene group, a pyrene group, a chrysene group, a naphthacene group, a picene group, a perylene group, a pentaphene group, an indenoanthracene group, a dibenzofuran group, a dibenzothiophene group, a carbazole group, an imidazole group, a pyrazole group, a thiazole group, an isothiazole group, an oxazole group, an isoxazole group, a pyridine group, a pyrazine group, a pyrimidine group, a pyridazine group, an indazole group, a purine group, a quinoline group, an isoquinoline group, a benzoquinoline group, a phthalazine group, a naphthyridine group, a quinoxaline group, a quinazoline group, a cinnoline group, a

phenanthridine group, an acridine group, phenanthroline group, phenazine group, a benzimidazole group, an isobenzothiazole group, a benzoxazole group, an isobenzoxazole group, a triazole group, a tetrazole group, an oxadiazole group, a triazine group, 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

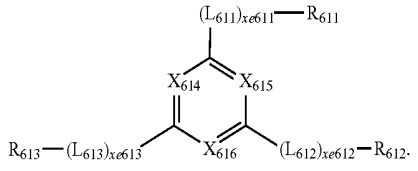
[0262] Q_{31} to Q_{33} may each independently be selected from a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, and a naphthyl group.

[0263] When xe11 in Formula 601 is two or more, two or more Ar_{601}(s) may be linked via a single bond.

[0264] In one or more embodiments, Ar_{601} in Formula 601 may be an anthracene group.

[0265] In one or more embodiments, a compound represented by Formula 601 may be represented by Formula 601-1:

Formula 601-1



[0266] In Formula 601-1,

[0267] 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,

[0268] L_{611} to L_{613} may each independently be the same as described in connection with L_{601},

[0269] xe611 to xe613 may each independently be the same as described in connection with xe1,

[0270] R_{611} to R_{613} may each independently be the same as described in connection with R_{601}, and

[0271] 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.

[0272] In one embodiment, L_{601} and L_{611} to L_{613} in Formulae 601 and 601-1 may each independently be selected from:

[0273] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group; and

[0274] a phenylene group, a naphthylene group, a fluorenylene group, a spiro-bifluorenylene group, a benzofluorenylene group, a dibenzofluorenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylene group, a perylenylene group, a pentaphenylene group, a hexacenylene group, a pentacenylene group, a thiophenylene group, a furanylene group, a carbazolylene group, an indolylene group, an isoindolylene group, a benzofuranylene group, a benzothiophenylene group, a dibenzofuranylene group, a dibenzothiophenylene group, a benzocarbazolylene group, a dibenzocarbazolylene group, a dibenzosilolylene group, a pyridinylene group, an imidazolylene group, a pyrazolylene group, a thiazolylene group, an isothiazolylene group, an oxazolylene group, an isoxazolylene group, a thiadiazolylene group, an oxadiazolylene group, a pyrazinylene group, a pyrimidinylene group, a pyridazinylene group, a triazinylene group, a quinolinylene group, an isoquinolinylene group, a benzoquinolinylene group, a phthalazinylene group, a naphthyridinylene group, a quinoxalinylene group, a quinazolinylene group, a cinnolinylene group, a phenanthridinylene group, an acridinylene group, a phenanthrolinylene group, a phenazinylene group, a benzimidazolylene group, an isobenzothiazolylene group, a benzoxazolylene group, an isobenzoxazolylene group, a triazolylene group, a tetrazolylene group, an imidazopyridinylene group, an imidazopyrimidinylene group, and an azacarbazolylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a perylenyl group, a pentaphenyl group, a hexacenyl group, a pentacenyl group, a thiophenyl group, a furanyl group, a carbazolyl group, an indolyl group, an isoindolyl group, a benzofuranyl group, a benzothiophenyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, a dibenzosilolyl group, a pyridinyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a thiadiazolyl group, an oxadiazolyl group, a pyrazinyl

group, a pyrimidinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a phthalazinyl group, a naphthyridinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a phenanthridinyl group, an acridinyl group, a phenanthrolinyl group, a phenazinyl group, a benzimidazolyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, and an azacarbazolyl group, but are not limited thereto,

[0275] but embodiments of the present disclosure are not limited thereto.

[0276] In one or more embodiments, xe1 and xe611 to xe613 in Formulae 601 and 601-1 may each independently be 0, 1, or 2.

[0277] In one or more embodiments, R_{601} and R_{611} to R_{613} in Formula 601 and 601-1 may each independently be selected from:

[0278] 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;

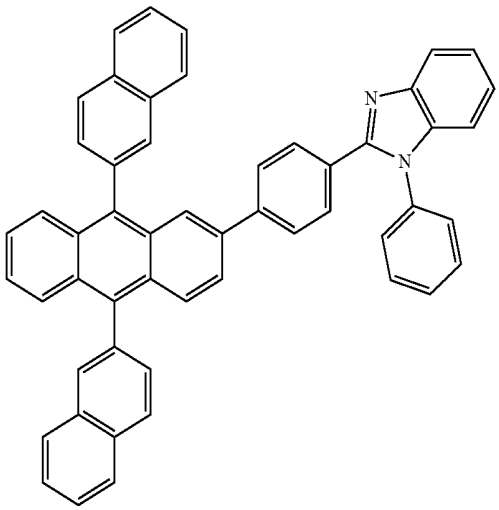
[0279] a phenyl group, a biphenyl group, a terphenyl group, a naphthyl group, a fluorenyl group, a spiro-bifluorenyl group, a benzofluorenyl group, a dibenzofluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, 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

[0280] —$S(=O)_2(Q_{601})$ and —$P(=O)(Q_{601})(Q_{602})$, and

[0281] Q_{601} and Q_{602} may be the same as described herein.

[0282] 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:

ET1



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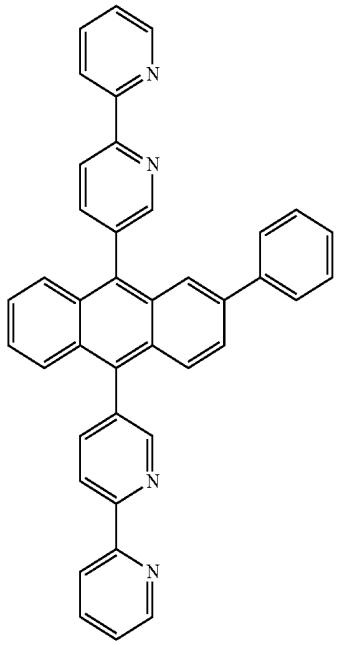
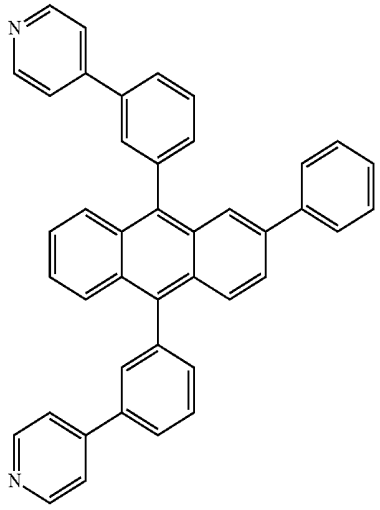
ET2



ET3



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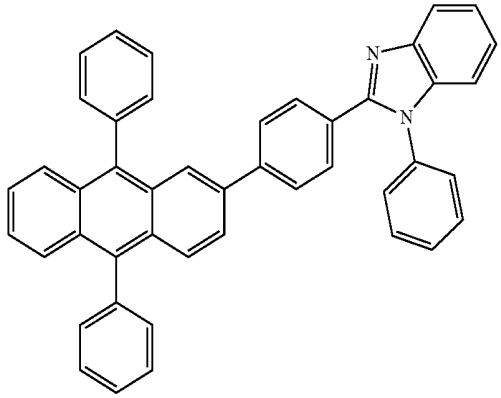

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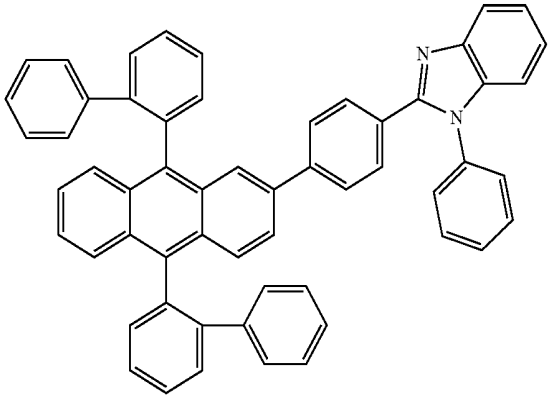
ET5



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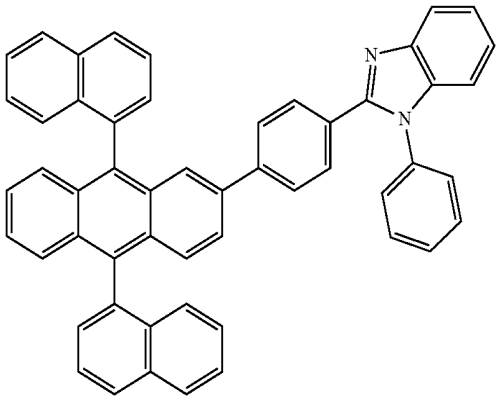

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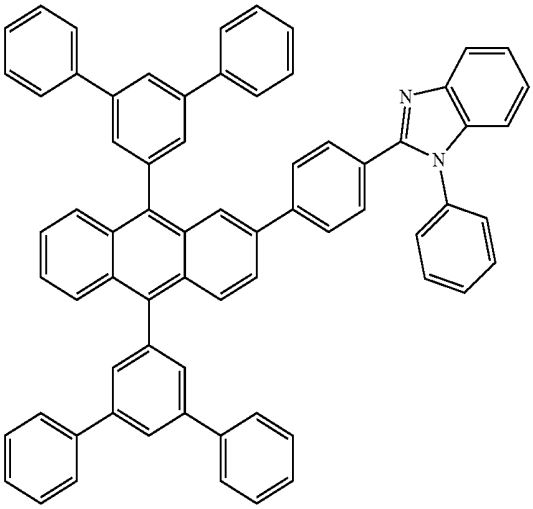

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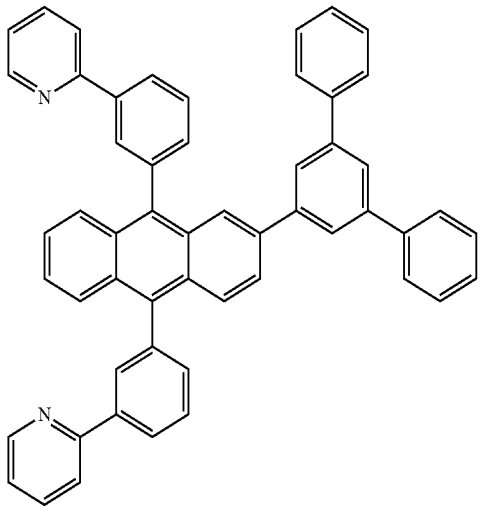
ET8



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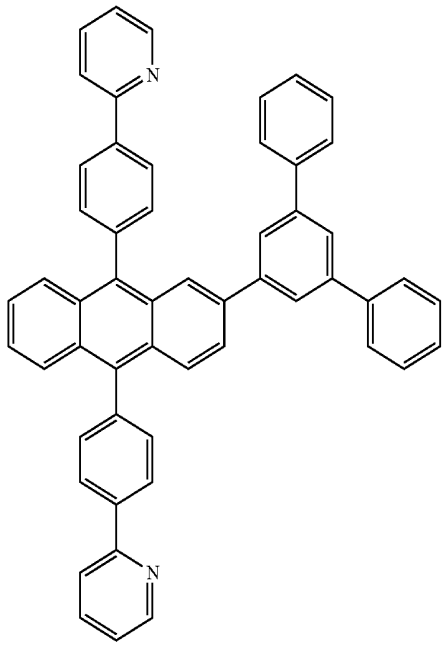

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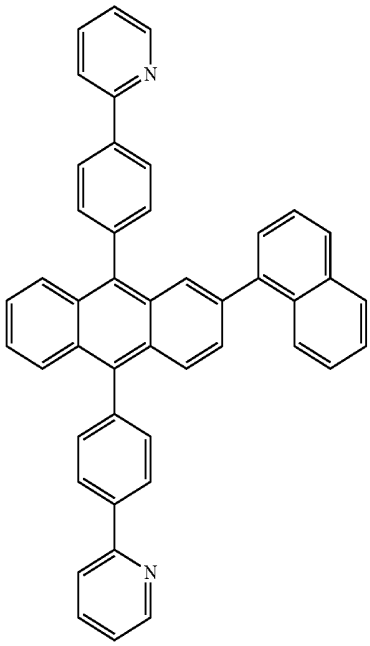

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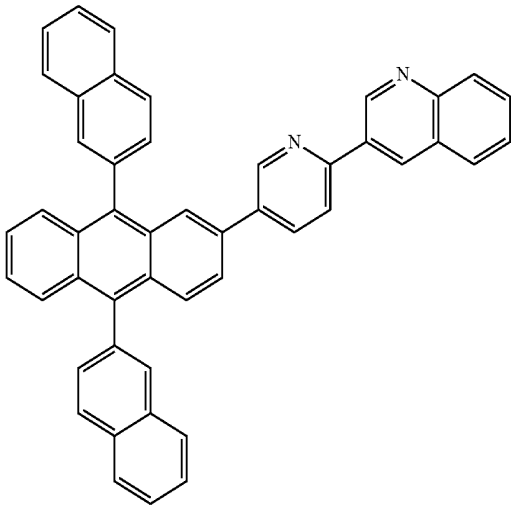

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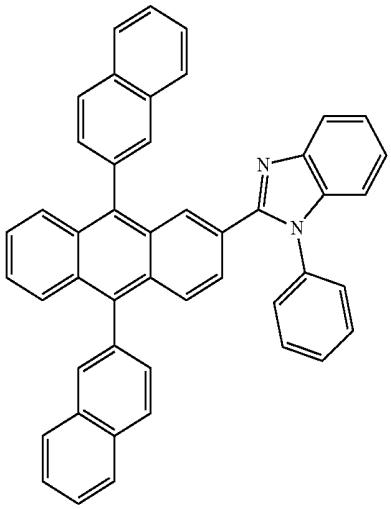

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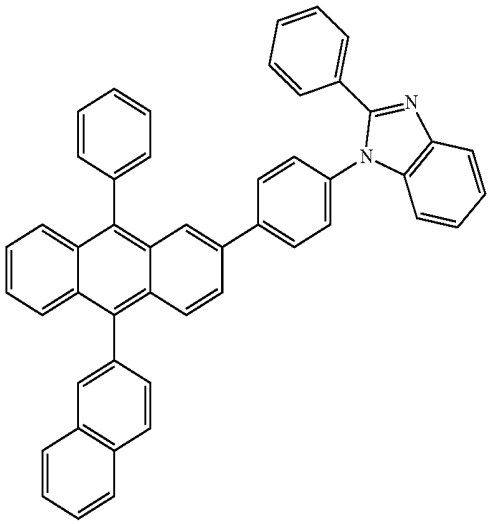

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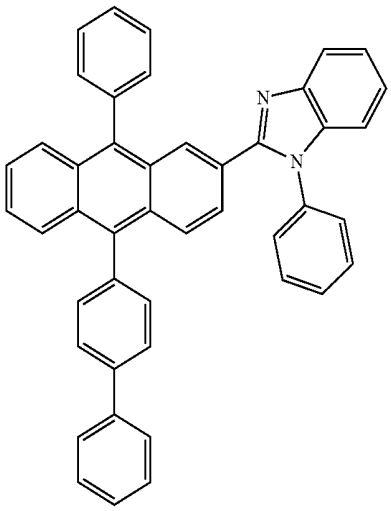

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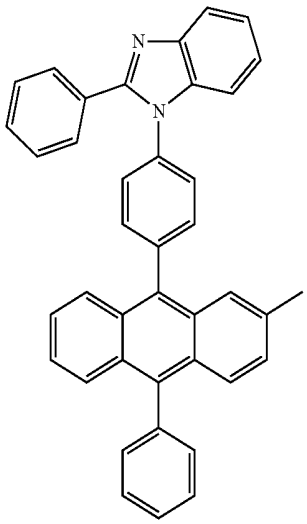

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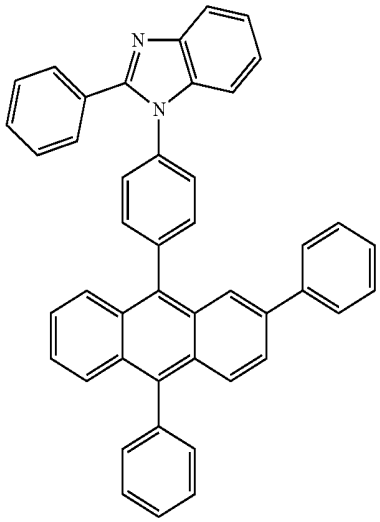
ET16



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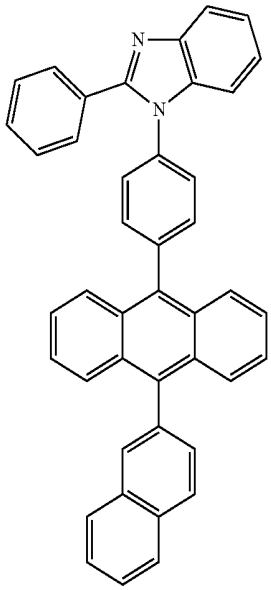

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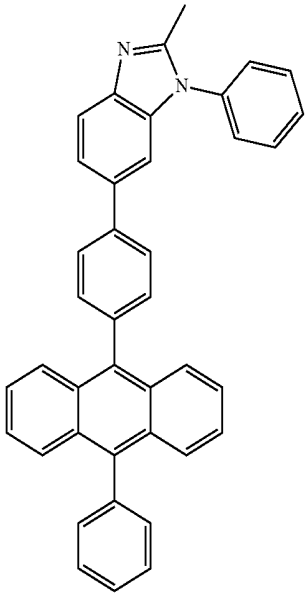

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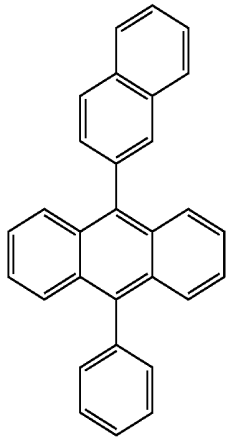

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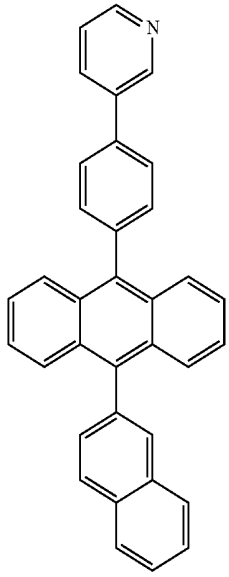

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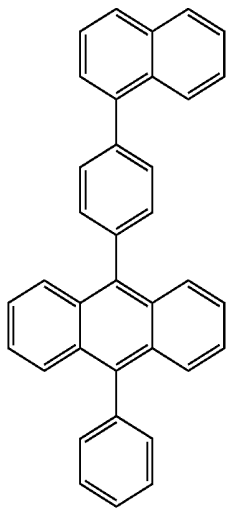

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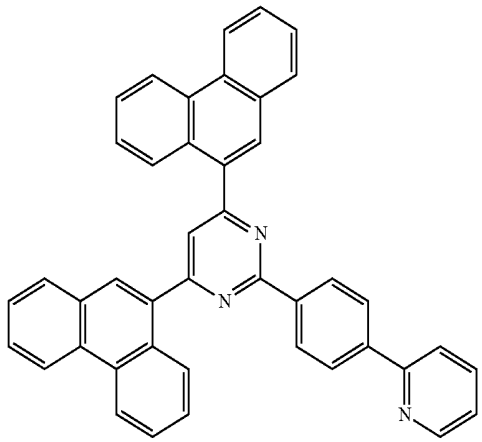

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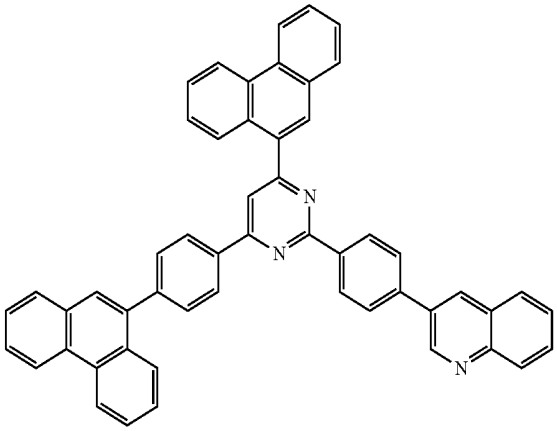

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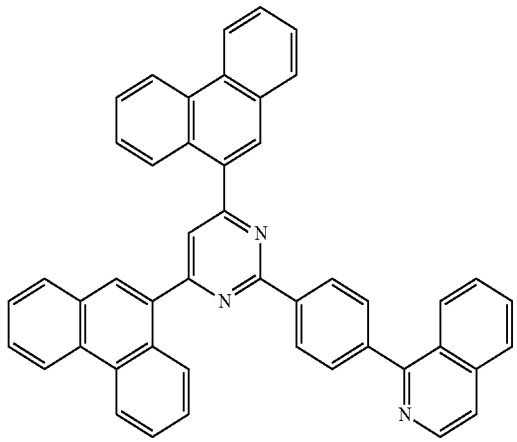

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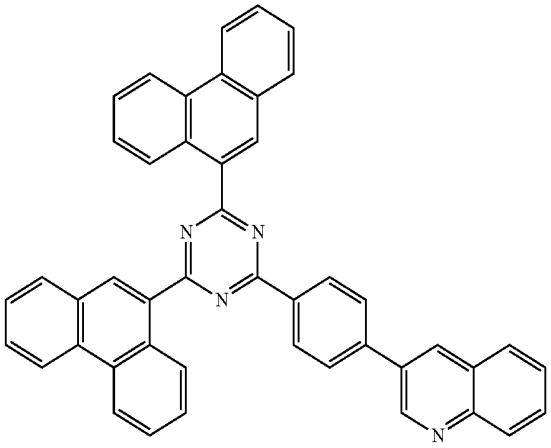
ET25



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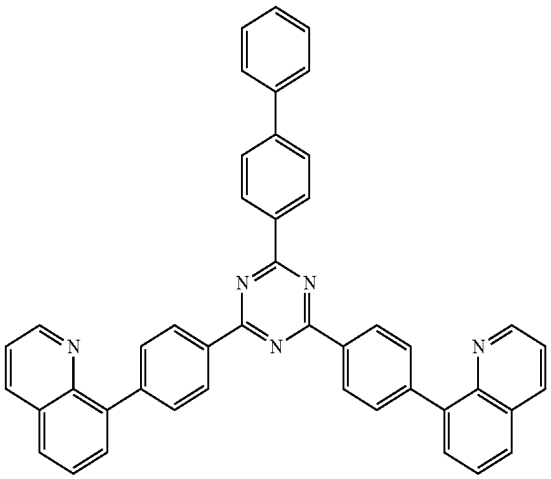

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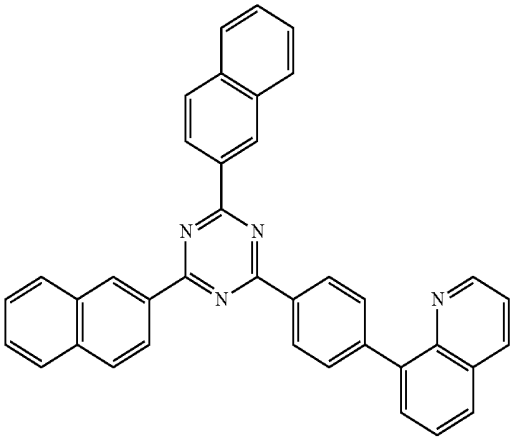

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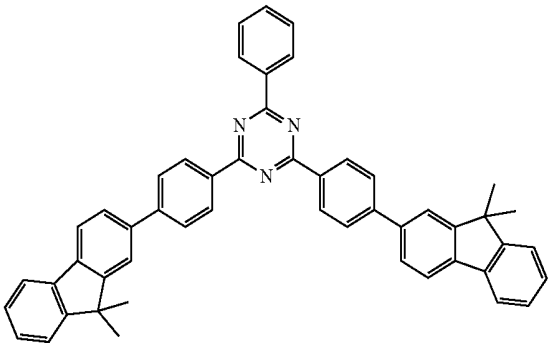
EET28



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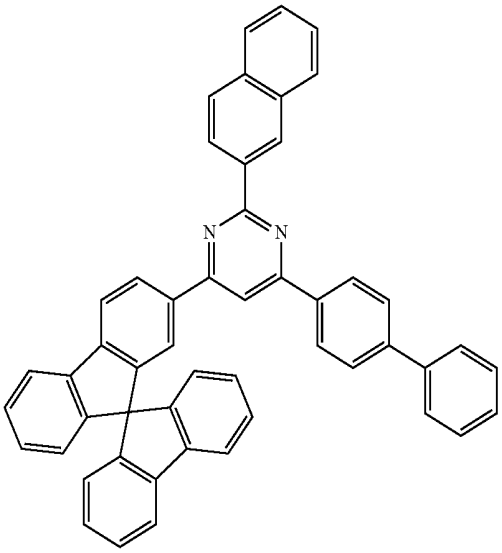

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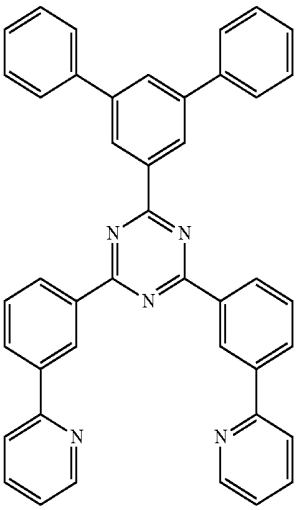

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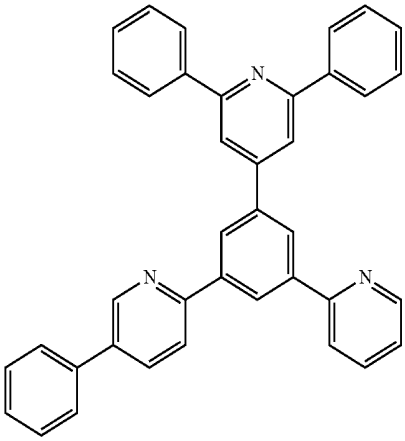

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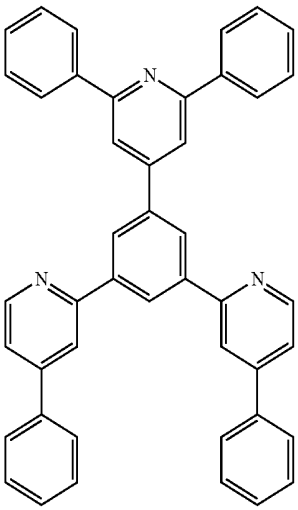

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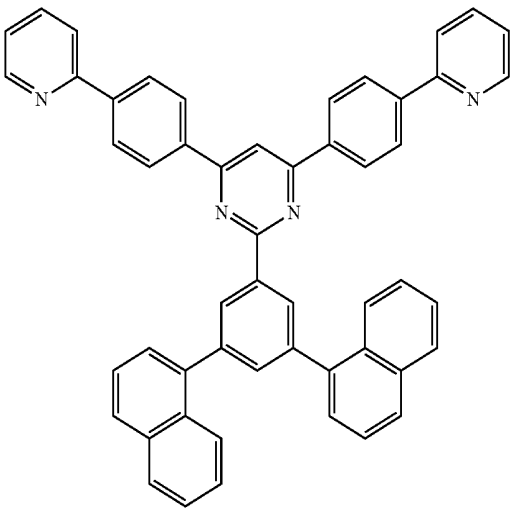

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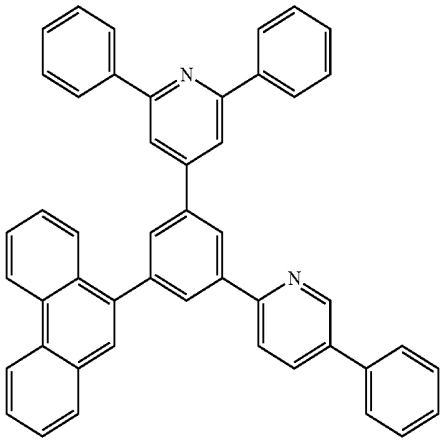

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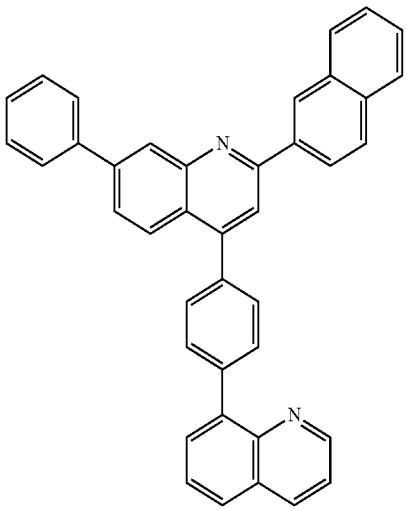
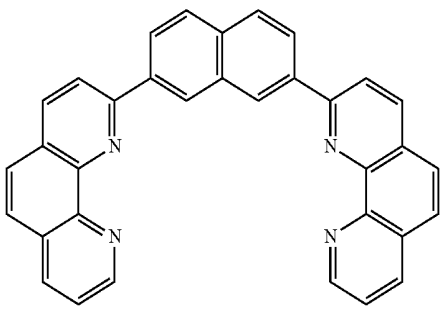
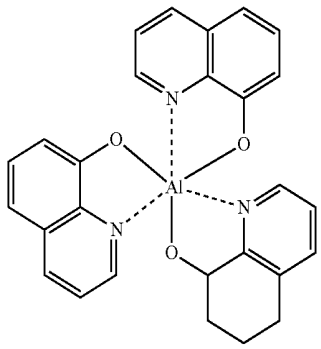


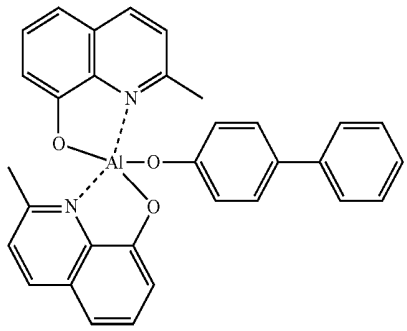
ET36



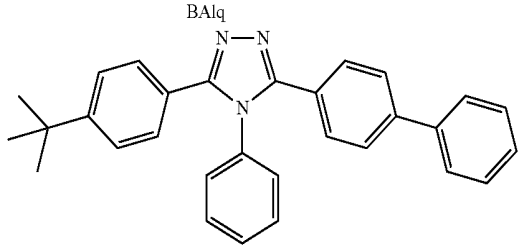
[0283] In one or more embodiments, the electron transport region may include at least one selected from 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP), 4,7-dphenyl-1,10-phenanthroline (Bphen), Alq_3, BAlq, 3-(biphenyl-4-yl)-5-(4-tert-butylphenyl)-4-phenyl-4H-1,2,4-triazole (TAZ), and NTAZ:



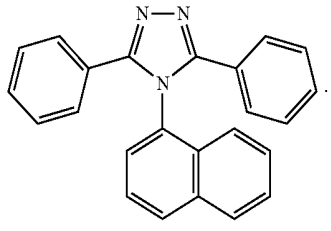
Alq_3



BAlq



TAZ



NTAZ

[0284] In one embodiment, the electron transport region may include a phosphine oxide-containing compound (for example, TSPO1 used 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 used in a hole blocking layer in the electron transport region, but embodiments of the present disclosure are not limited thereto.

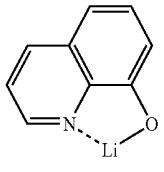
[0285] A thickness of the buffer layer, the hole blocking layer, or the electron controlling layer may each independently be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. When the thicknesses of the buffer layer, the hole blocking layer, and the electron control layer are within these ranges, the electron blocking layer may have excellent electron blocking characteristics or electron control characteristics without a substantial increase in driving voltage.

[0286] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. When the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

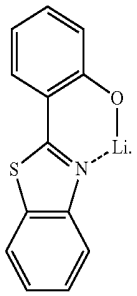
[0287] The electron transport region (for example, the electron transport layer in the electron transport region) may further include, in addition to the materials described above, a metal-containing material.

[0288] 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 diphenylthiadiazol, a hydroxy phenylpyridine, a hydroxy phenylbenzimidazole, a hydroxy phenylbenzothiazole, a bipyridine, a phenanthroline, and a cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0289] 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

[0290] The electron transport region may include an electron injection layer that facilitates injection of electrons from the second electrode **190**. The electron injection layer may directly contact the second electrode **190**.

[0291] 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.

[0292] 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.

[0293] The alkali metal may be selected from Li, a Na, K, Rb, and Cs. In one embodiment, the alkali metal may be Li, a 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.

[0294] The alkaline earth metal may be selected from Mg, Ca, Sr, and Ba.

[0295] The rare earth metal may be selected from Sc, Y, Ce, Tb, Yb, and Gd.

[0296] 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.

[0297] 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.

[0298] 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.

[0299] The rare earth metal compound may be selected from YbF_3, ScF_3, ScO_3, Y_2O_3, Ce_2O_3, GdF_3, and TbF_3. In one 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.

[0300] 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 phenyl oxazole, hydroxy phenylthiazole, hydroxy diphenyl oxadiazole, hydroxy diphenylthiadiazol, hydroxy phenylpyridine, hydroxy phenylbenzimidazole, hydroxy phenylbenzothiazole, bipyridine, phenanthroline, and cyclopentadiene, but embodiments of the present disclosure are not limited thereto.

[0301] The electron injection layer may consist of an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof, as described above. In one or more embodiments, the electron injection layer may further include an organic material. When the electron injection layer further includes an organic material, an alkali metal, an alkaline earth metal, a rare earth metal, an alkali metal compound, an alkaline earth-metal compound, a rare earth metal compound, an alkali metal complex, an alkaline earth-metal complex, a rare earth metal complex, or any combinations thereof may be homogeneously or non-homogeneously dispersed in a matrix including the organic material.

[0302] A thickness of the electron injection layer may be in a range of about 1 Å to about 100 Å, for example, about 3 Å to about 90 Å. When the thickness of the electron injection layer is within the range described above, the electron injection layer may have satisfactory electron injection characteristics without a substantial increase in driving voltage.

Second Electrode **190**

[0303] The second electrode **190** may be disposed on the organic layer **150** having such a structure. The second electrode **190** may be a cathode that is an electron injection electrode, and in this regard, a material for forming the second electrode **190** may be a material having a low work function, and such a material may be metal, alloy, an electrically conductive compound, or a combination thereof.

[0304] The second electrode **190** may include at least one selected from lithium (Li), silver (Si), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), magnesium-silver (Mg—Ag), ITO, and IZO, but embodiments of the present disclosure are not limited thereto. The second electrode **190** may be a transmissive electrode, a semi-transmissive electrode, or a reflective electrode.

[0305] The second electrode **190** may have a single-layered structure, or a multi-layered structure including two or more layers.

[0306] Layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region may be formed in a certain region by using one or more suitable methods selected from vacuum deposition, spin coating, casting, Langmuir-Blodgett (LB) deposition, ink-jet printing, laser-printing, and laser-induced thermal imaging.

[0307] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by vacuum deposition, the vacuum deposition may be performed at a deposition temperature of about 100° C. to about 500° C., at a vacuum degree of about 10^{-8} torr to about 10^{-3} torr, and at a deposition 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.

[0308] When layers constituting the hole transport region, an emission layer, and layers constituting the electron transport region are formed by spin coating, the spin coating may be performed at a coating speed of about 2,000 rpm to about 5,000 rpm and at a heat treatment temperature of about 80° C. to about 200° C., depending on a material to be included in a layer and the structure of each layer to be formed.

General Definition of Some of the Substituents

[0309] The term "C_1-C_{60} alkyl group," as used herein, refers to a linear or branched saturated aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms, and non-limiting examples thereof include a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an iso-amyl group, and a hexyl group. The term "C_1-C_{60} alkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{60} alkyl group, except that the C_1-C_{60} alkylene group is divalent instead of monovalent.

[0310] The term "C_2-C_{60} alkenyl group," as used herein, refers to a hydrocarbon group formed by substituting at least one carbon-carbon double bond at a main chain (e.g., in the middle) or at a terminus of the C_2-C_{60} alkyl group, and non-limiting examples thereof include an ethenyl group, a propenyl group, and a butenyl group.

[0311] The term "C_2-C_{60} alkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_2-C_{60} alkenyl group, except that the C_2-C_{60} alkenylene group is divalent instead of monovalent.

[0312] The term "C_2-C_{60} alkynyl group," as used herein, refers to a hydrocarbon group formed by substituting at least one carbon-carbon triple bond at a main chain (e.g., in the middle) or at a terminus of the C_2-C_{60} alkyl group, and non-limiting examples thereof include an ethynyl group, and a propynyl group. The term "C_2-C_{60} alkynylene group," as used herein, refers to a divalent group having substantially the same structure as the C_2-C_{60} alkynyl group, except that the C_2-C_{60} alkynylene group is divalent instead of monovalent.

[0313] The term "C_1-C_{60} alkoxy group," as used herein, refers to a monovalent group represented by —OA_{101} (wherein A_{101} is the C_1-C_{60} alkyl group), and non-limiting examples thereof include a methoxy group, an ethoxy group, and an isopropyloxy group.

[0314] 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 non-limiting examples thereof include a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. The term "C_3-C_{10} cycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkyl group, except that the C_3-C_{10} cycloalkylene group is divalent instead of monovalent.

[0315] The term "C_1-C_{10} heterocycloalkyl group," as used herein, refers to a monovalent saturated monocyclic group having at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom and 1 to 10 carbon atoms, and non-limiting examples thereof include a 1,2,3,4-oxatriazolidinyl group, a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. The term "C_1-C_{10} heterocycloalkylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkyl group, except that the C_1-C_{10} heterocycloalkylene group is divalent instead of monovalent.

[0316] 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 a ring thereof and no aromaticity (e.g., the ring is not aromatic), and non-limiting examples thereof include a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl group. The term "C_3-C_{10} cycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_3-C_{10} cycloalkenyl group, except that the C_3-C_{10} cycloalkenylene group is divalent instead of monovalent.

[0317] The term "C_1-C_{10} heterocycloalkenyl group," as used herein, refers to a monovalent monocyclic group that has at least one heteroatom selected from N, O, Si, P, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one carbon-carbon double bond in its ring. Non-limiting examples of the C_1-C_{10} heterocycloalkenyl group include a 4,5-dihydro-1,2,3,4-oxatriazolyl group, a 2,3-dihydrofuranyl group, and a 2,3-dihydrothiophenyl group. The term "C_1-C_{10} heterocycloalkenylene group," as used herein, refers to a divalent group having substantially the same structure as the C_1-C_{10} heterocycloalkenyl group, except that the C_1-C_{10} heterocycloalkenylene group is divalent instead of monovalent.

[0318] 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 (e.g., combined together).

[0319] The term "C_1-C_{60} heteroaryl group," as used herein, refers to a monovalent group having a heterocyclic 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 heterocyclic 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 fused to each other (e.g., combined together).

[0320] The term "C_6-C_{60} aryloxy group," as used herein, refers to —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and the term "C_6-C_{60} arylthio group," as used herein, refers to —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0321] 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 (e.g., entire molecule is not aromatic). A non-limiting example of the monovalent non-aromatic condensed polycyclic group includes a fluorenyl group. The term "divalent non-aromatic condensed polycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed polycyclic group, except that the divalent non-aromatic condensed polycyclic group is divalent instead of monovalent.

[0322] 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 (e.g., combined together), 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 (e.g., the entire molecule is not aromatic). An example of the monovalent non-aromatic condensed heteropolycyclic group includes a carbazolyl group. The term "divalent non-aromatic condensed heteropolycyclic group," as used herein, refers to a divalent group having substantially the same structure as the monovalent non-aromatic condensed

heteropolycyclic group, except that the divalent non-aromatic condensed heteropolycyclic group is divalent instead of monovalent.

[0323] The term "C_4-C_{60} carbocyclic group," as used herein, refers to a monocyclic or polycyclic group having 4 to 60 carbon atoms in which a ring-forming atom is a carbon atom only. The C_4-C_{60} carbocyclic group may be an aromatic carbocyclic group or a non-aromatic carbocyclic group. The C_4-C_{60} carbocyclic group may be a ring, such as 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_4-C_{60} carbocyclic group, the C_4-C_{60} carbocyclic group may be a trivalent group or a quadrivalent group.

[0324] The term "C_2-C_{60} heterocyclic group," as used herein, refers to a group having substantially the same structure as the C_2-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).

[0325] At least one substituent of the substituted C_4-C_{60} carbocyclic group, the substituted C_2-C_{60} heterocyclic group, the substituted C_3-C_{10} cycloalkylene group, the substituted C_1-C_{10} heterocycloalkylene group, the substituted C_3-C_{10} cycloalkenylene group, the substituted C_1-C_{10} heterocycloalkenylene group, the substituted C_6-C_{60} arylene group, the substituted C_1-C_{60} heteroarylene group, the substituted divalent non-aromatic condensed polycyclic group, the substituted divalent non-aromatic condensed heteropolycyclic group, the substituted C_1-C_{60} alkyl group, the substituted C_2-C_{60} alkenyl group, the substituted C_2-C_{60} alkynyl group, the substituted C_1-C_{60} alkoxy group, the substituted C_3-C_{10} cycloalkyl group, the substituted C_1-C_{10} heterocycloalkyl group, the substituted C_3-C_{10} cycloalkenyl group, the substituted C_1-C_{10} heterocycloalkenyl group, the substituted C_6-C_{60} aryl group, the substituted C_6-C_{60} aryloxy group, the substituted C_6-C_{60} arylthio group, the substituted C_1-C_{60} heteroaryl group, the substituted monovalent non-aromatic condensed polycyclic group, and the substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from:

[0326] 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;

[0327] 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, $—Si(Q_{11})(Q_{12})(Q_{13})$, $—N(Q_{11})(Q_{12})$, $—B(Q_{11})(Q_{12})$, $—C(=O)(Q_{11})$, $—S(=O)_2(Q_{1i})$, and $—P(=O)(Q_{ii})(Q_{12})$;

[0328] 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;

[0329] 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

[0330] Q_{11} to Q_{13}, Q_{21} to Q_{23}, and Q_{31} to Q_{33} may each independently be selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_1-C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{60} aryl group, a C_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a 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.

[0331] The term "Ph," as used herein, refers to a phenyl group, the term "Me," as used herein, refers to a methyl group, the term "Et," as used herein, refers to an ethyl group, the terms "ter-Bu" or "But," as used herein, refers to a tert-butyl group, and the term "OMe," as used herein, refers to a methoxy group.

[0332] The term "terphenyl group," as used herein, refers to "a phenyl group substituted with a biphenyl group." In other words, an example of the "terphenyl group" includes a phenyl group having, as a substituent, a C_6-C_{60} aryl group substituted with a C_6-C_{60} aryl group.

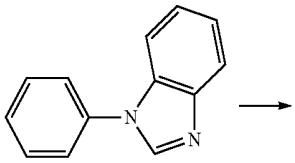
[0333] * *', and as used herein, unless defined otherwise, each refer to a binding site to a neighboring atom in a corresponding formula.

[0334] Hereinafter, a compound according to embodiments and an organic light-emitting device according to embodiments will be described in detail with reference to Synthesis Examples and Examples. The wording "B was used instead of A" used in describing Synthesis Examples refers to that an identical molar equivalent of B was used in place of A.

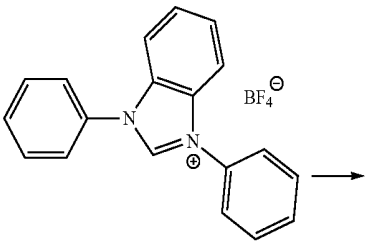
EXAMPLES

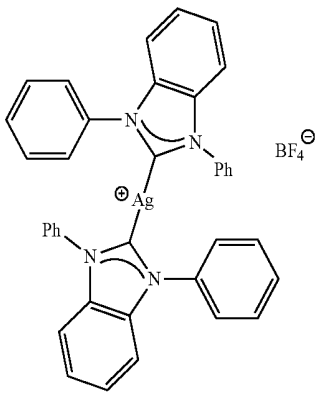
Synthesis Example 1: Synthesis of Compound 18

[0335]

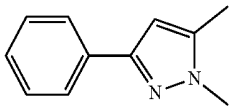


1-phenyl-1H-benzo[d]imidazole

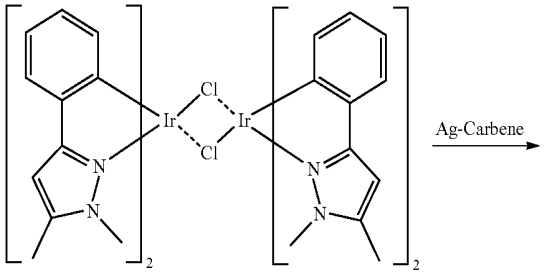




Ag-Carbene



1,5-dimethly-3-phenyl-1H-pyrazole



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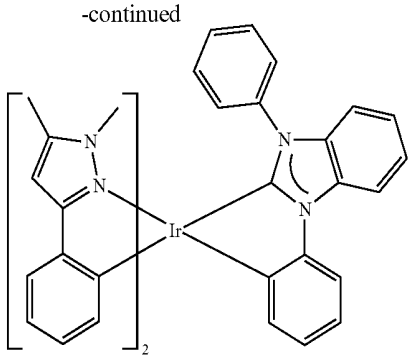
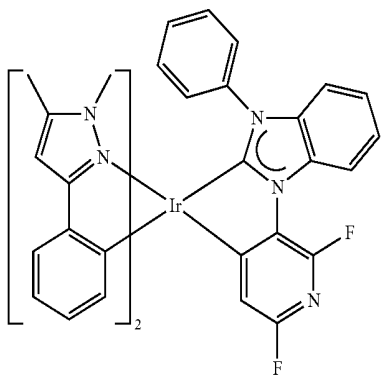


[0336] 2.00 g (10.31 mmol) of 1-phenyl-1H-benzo[d]imidazole, 5.69 g (15.47 mmol) of diphenyliodinium tetrafluoroborate, and 0.28 g (1.55 mmol) of $Cu(OAc)_2$ were dissolved in 50 mL of dimethylformamide (DMF) and stirred at a temperature of 100° C. for 24 hours. The reaction mixture was cooled to room temperature, and a solvent was removed therefrom. The resultant product was filtered therefrom under a diethyl ether condition to obtain a solid. The obtained benzo[d]imidazolium salt and 2.84 g (12.37 mmol) of silver(I) oxide were stirred at room temperature for 6 hours under a dichloromethane (50 mL) solvent. The solid produced after the reaction was filtered, and a solvent was removed from a filtrate to obtain silver (Ag)-carbene Intermediate. Then, Ag-carbene Intermediate was dissolved in 50 mL of tetrahydrofuran (THF) together with 5.89 g (5.16 mmol) of iridium dimmer obtained through reaction between 1,5-dimethyl-3-phenyl-1H-pyrazole and iridium (III) chloride hydrate at a temperature of 120° C. for 6 hours under a 2-ethoxyethanol solvent and stirred at a temperature of 70° C. for 24 hours. The reaction mixture was cooled to room temperature, and an organic layer was extracted therefrom three times by using dichloromethane and water. The extracted organic layer was dried by using magnesium sulfate and filtered by using celite. Then, column chromatography was performed thereon to synthesize 2.16 g (2.68 mmol, yield=26%) of Compound 18.

Synthesis Example 2: Synthesis of Compound 28

[0337]

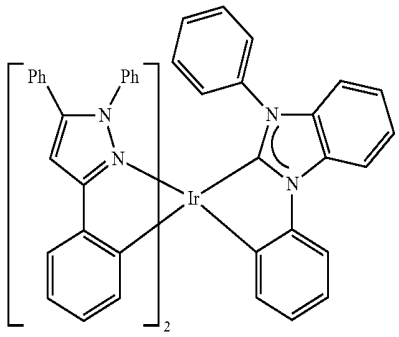


[0338] 1.73 g (2.06 mmol, yield=20%) of Compound 28 was synthesized in substantially the same manner as in

Synthesis Example 1, except that 1-(2,6-difluoropyridin-3-yl)-1H-benzo[d]imidazole was used instead of 1-phenyl-1H-benzo[d]imidazole.

Synthesis Example 3: Synthesis of Compound 82

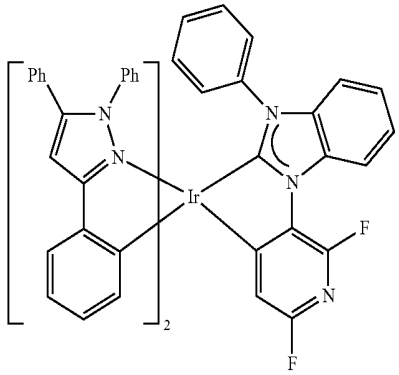
[0339]



[0340] 2.82 g (2.68 mmol, yield=26%) of Compound 82 was synthesized in substantially the same manner as in Synthesis Example 1, except that 1,3,5-triphenyl-1H-pyrazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 4: Synthesis of Compound 92

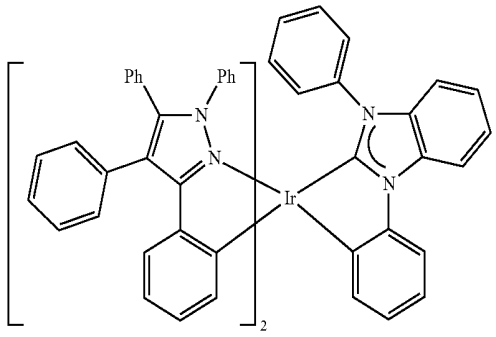
[0341]



[0342] 2.02 g (1.86 mmol, yield=18%) of Compound 92 was synthesized in substantially the same manner as in Synthesis Example 2, except that 1,3,5-triphenyl-1H-pyrazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 5: Synthesis of Compound 146

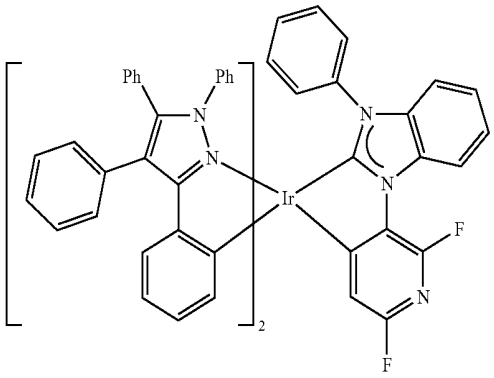
[0343]



[0344] 2.73 g (2.27 mmol, yield=22%) of Compound 146 was synthesized in substantially the same manner as in Synthesis Example 1, except that 1,3,4,5-tetraphenyl-1H-pyrazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 6: Synthesis of Compound 156

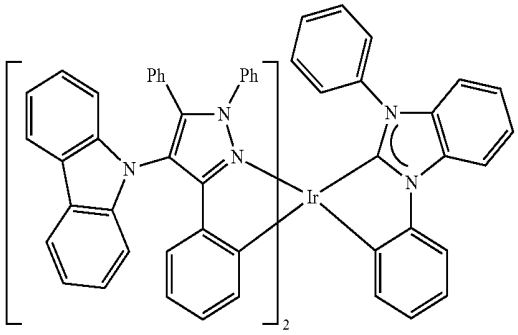
[0345]



[0346] 2.05 g (1.65 mmol, yield=16%) of Compound 156 was synthesized in substantially the same manner as in Synthesis Example 2, except that 1,3,4,5-tetraphenyl-1H-pyrazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 7: Synthesis of Compound 210

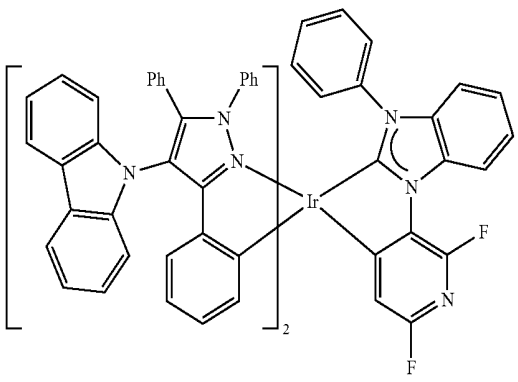
[0347]



[0348] 2.14 g (1.55 mmol, yield=15%) of Compound 210 was synthesized in substantially the same manner as in Synthesis Example 1, except that 9-(1,3,5-triphenyl-1H-pyrazol-4-yl)-9H-carbazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 8: Synthesis of Compound 220

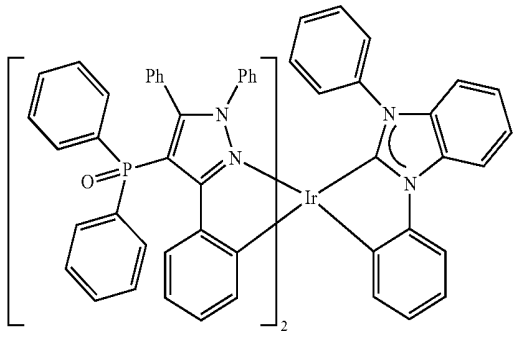
[0349]



[0350] 1.90 g (1.34 mmol, yield=13%) of Compound 220 was synthesized in substantially the same manner as in Synthesis Example 2, except that 9-(1,3,5-triphenyl-1H-pyrazol-4-yl)-9H-carbazole was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 9: Synthesis of Compound 338

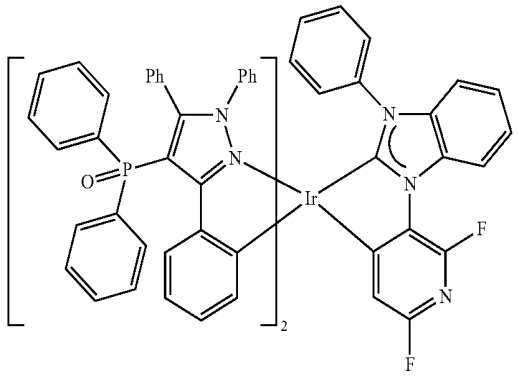
[0351]



[0352] 3.29 g (1.34 mmol, yield=22%) of Compound 338 was synthesized in substantially the same manner as in Synthesis Example 1, except that diphenyl(1,3,5-triphenyl-1H-pyrazol-4-yl)phosphine oxide was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 10: Synthesis of Compound 348

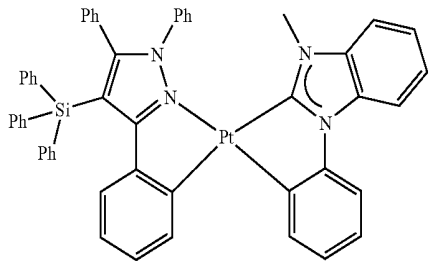
[0353]



[0354] 3.69 g (2.47 mmol, yield=24%) of Compound 348 was synthesized in substantially the same manner as in Synthesis Example 2, except that diphenyl(1,3,5-triphenyl-1H-pyrazol-4-yl)phosphine oxide was used instead of 1,5-dimethyl-3-phenyl-1H-pyrazole.

Synthesis Example 11: Synthesis of Compound 401

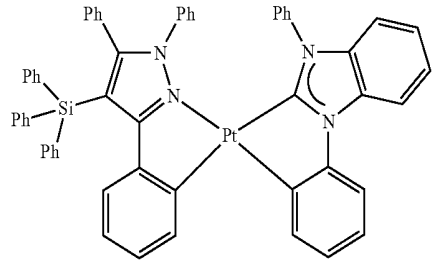
[0355]



[0356] 3.66 g (12.37 mmol) of 3-methyl-1-phenyl-1H-benzo[d]imidazol-3-ium tetrafluoroborate salt and 2.84 g (12.37 mmol) of silver(I) oxide were stirred at room temperature for 6 hours under a dichloromethane (50 mL) solvent. A solid produced after reaction was filtered, and a solvent was removed from a filtrate to obtain silver (Ag)-carbene Intermediate. Then, Ag-carbene Intermediate was dissolved in 50 mL of THF together with 0.5 equiv. of $[(CH_3)_2PtS(CH_3)]_2$ dimer and 1 equiv. of 1,3,5-triphenyl-4-(triphenylsilyl)-1H-pyrazole and stirred at a temperature of 70° C. for 24 hours. The reaction mixture was cooled to room temperature, and an organic layer was extracted therefrom three times by using dichloromethane and water. The extracted organic layer was dried by using magnesium sulfate and filtered by using celite. Then, column chromatography was performed thereon to synthesize 5.32 g (5.57 mmol, yield=45%) of Compound 401.

Synthesis Example 12: Synthesis of Compound 402

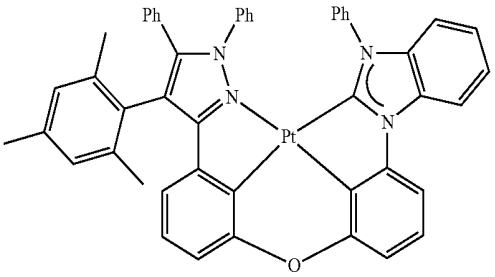
[0357]



[0358] 6.04 g (5.94 mmol, yield=48%) of Compound 402 was synthesized in substantially the same manner as in Synthesis Example 11, except that 1,3-diphenyl-1H-benzo[d]imidazol-3-ium tetrafluoroborate was used instead of 3-methyl-1-phenyl-1H-benzo[d]imidazol-3-ium tetrafluoroborate.

Synthesis Example 13: Synthesis of Compound 450

[0359]



[0360] 7.00 g (10.00 mmol) of 3-(3-(3-(4-mesityl-1,5-diphenyl-1H-pyrazol-3-yl)phenoxy)phenyl)-1-phenyl-1H-3l4-benzo[d]imidazole, 3.74 g (10.00 mmol) of dichloro(1,5-cyclooctadiene)platinum(II), and 2.46 g (30 mmol) of NaOAc were dissolved in 50 mL of THF and stirred at a temperature of 70° C. for 60 hours. The reaction mixture was cooled to room temperature, and an organic layer was extracted therefrom three times by using dichloromethane and water. The extracted organic layer was dried by using

magnesium sulfate and filtered by using celite. Then, column chromatography was performed thereon to synthesize 5.61 g (6.30 mmol, yield=63%) of Compound 450.

[0361] ^{1}H NMR and FAB-MS of Compounds synthesized according to Synthesis Examples 1 to 13 are shown in Table 1.

[0362] Methods of synthesizing compounds other than Compounds shown in Table 1 will be readily apparent to those of ordinary skill in the art by referring to the synthesis mechanisms and source materials described above.

TABLE 1

Compound	^{1}H NMR ($CDCl_3$, 500 MHz)	FAB-MS [M$^+$] found	FAB-MS [M$^+$] calc.
18	δ = 8.74 (d, 1H), 7.98-7.93 (m, 3H), 7.49-7.20 (m, 12H), 7.18 (d, 2H), 6.46 (s, 1H), 6.44 (s, 1H), 6-22 6.20 (m, 1H), 5.98-5.94 (m, 2H), 3.63 (s, 3H), 3.61 (3H), 2.41 (s, 3H), 2.39 (s, 3H).	804.31	804.26
28	δ = 8.77 (d, 1H), 7.97-7.92 (m, 2H), 7.52-7.21 (m, 10H), 7.09 (d, 2H), 6.43 (s, 1H), 6.44 (s, 1H), 6-22 6.20 (m, 1H), 5.96-5.93 (m, 2H), 3.62 (s, 3H), 3.60 (3H), 2.40 (s, 3H), 2.37 (s, 3H).	841.29	841.23
82	δ = 8.30 (d, 1H), 8.28 (d, 1H), 7.60-7.28 (m, 22H), 7.14-6.8 (m, 17H), 7.02 (s, 1H), 7.00 (S1H).	1052.36	1052.32
92	δ = 8.60 (d, 2H), 8.05 (d, 1H), 8.03 (d, 1H), 7.70-7.42 (m, 19H), 7.30-7.26 (d, 2H), 7.24 (s, 1H), 7.20-7.00 (m, 14H).	1089.36	1089.30
146	δ = 8.56 (d, 2H), 7.88-7.84 (m, 6H), 7.60-7.44 (m, 40 H), 7.33 (d, 1H), 7.28 (dd, 2H).	1204.44	1204.38
154	δ = 8.58 (d, 2H), 7.90-7.82 (m, 6H), 7.62-7.42 (m, 37 H), 7.30 (dd, 2H), 7.22 (s, 1H).	1241.48	1241.36
210	δ = 8.58 (d, 2H), 8.55 (d, 2H), 8.19 (d, 2H), 7.86-7.60 (m, 23H), 7.60-7.35 (m, 24H), 7.20-7.18 (m, 4H).	1382.47	1382.43
220	δ = 8.60 (d, 2H), 8.54 (d, 2H), 8.18 (d, 2H), 7.80-7.58 (m, 20H), 7.58-7.30 (m, 24H), 7.19-7.08 (m, 4H).	1419.46	1419.41
338	δ = 8.55 (d, 2H), 7.84-7.77 (m, 16H), 7.60-7.52 (m, 32H), 7.48-7.33 (m, 11H).	1452.42	1452.40
348	δ = 8.62 (d, 2H), 7.84-7.77 (m, 16H), 7.60-7.52 (m, 32H), 7.50-7.28 (m, 8H).	1489.43	1489.37
401	δ = 8.56 (d, 1H), 7.84 (d, 2H), 7.64-7.28 (m, 33H), 7.10 (d, 1H), 3.74 (s, 3H).	955.35	955.27
402	δ = 8.58 (d, 2H), 7.84 (d, 2H), 7.64-7.10 (m, 35H), 7.28 (m, 2H), 7.13 (d, 1H).	1017.33	1017.28
450	δ = 8.56 (d, 2H), 7.86 (d, 2H), 7.64-7.10 (m, 19H), 7.11 (d, 1H), 7.05 (s, 2H), 7.00 (d, 1H), 2.93 (s, 6H), 2.35 (s, 3H).	891.29	891.25

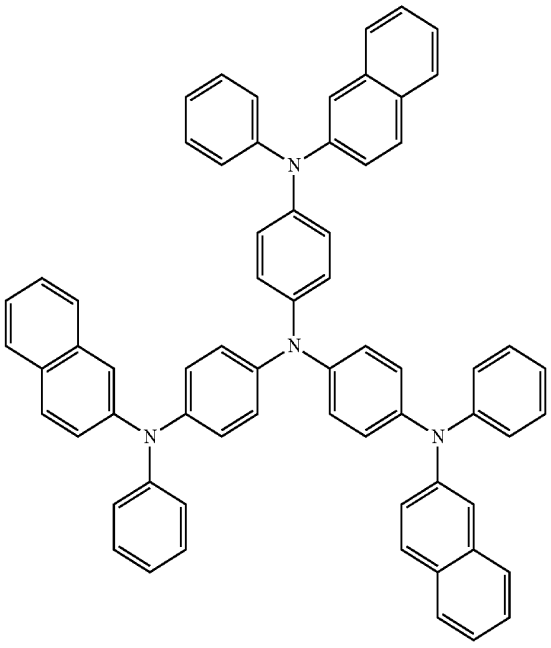
Example 1

[0363] As a substrate and an anode, a Corning 15 Ω/cm^2 (1,200 Å) ITO glass substrate was cut to a size of 50 mm×50 mm×0.7 mm, sonicated with isopropyl alcohol and substantially pure water each for 5 minutes, and then cleaned by exposure to ultraviolet rays and ozone for 30 minutes. Then, the resultant ITO glass substrate was provided to a vacuum deposition apparatus.

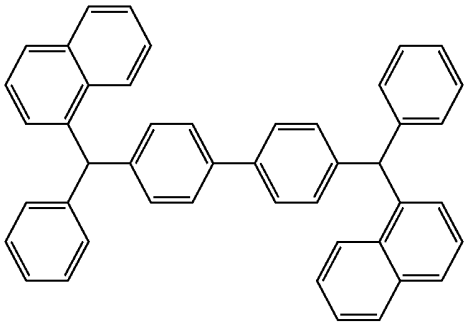
[0364] 2-TNATA, which is a generally available compound, was vacuum-deposited on the ITO glass substrate to form a hole injection layer having a thickness of 600 Å, and 4,4'-bis[N-(1-naphthyl)-N-phenylamino]biphenyl (NPB), which is a generally available hole transport compound, was vacuum-deposited on the hole injection layer to form a hole transport layer having a thickness of 300 Å.

[0365] Next, (bis(4-(9H-carbazol-9-yl)phenyl)diphenylsilane) (BCPDS) and (4-(1-(4-(diphenylamino)phenyl)cyclohexyl)phenyl)diphenyl-phosphine oxide (POPCPA) (weight ratio=1:1), which are a co-host, and Compound 18, which is a dopant, were co-deposited on the hole transport layer at a weight ratio of 90:10 to form a blue fluorescent emission layer having a thickness of 300 Å.

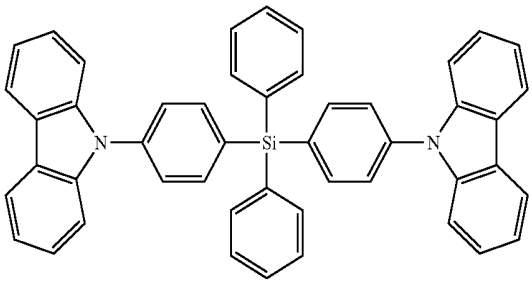
[0366] Then, (diphenyl(4-(triphenylsilyl)phenyl)-phosphine oxide) (TSPO1) was vacuum-deposited on the emission layer to form a hole blocking layer having a thickness of 50 Å. Then, Alq_3 was deposited on the emission layer to form an electron transport layer having a thickness of 300 Å, LiF, which is an alkali metal halide, was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å, and Al was vacuum-deposited on the electron injection layer to form an cathode electrode having a thickness of 3,000 Å, thereby forming a LiF/Al electrode. In this manner, an organic light-emitting device was manufactured.



2-TNATA



NPB



BCPDS

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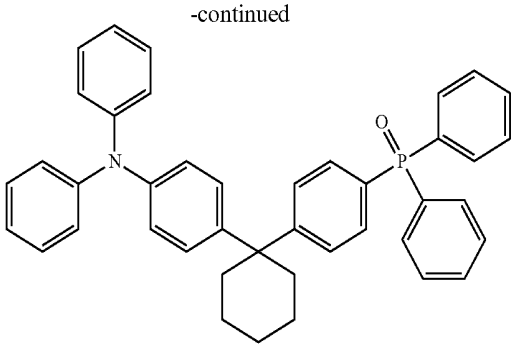
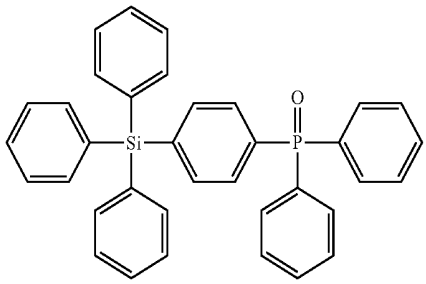


POPCPA



TSPO1

Examples 2 to 13 and Comparative Examples 1 to 6

[0367] Organic light-emitting devices were manufactured in substantially the same manner as in Example 1, except that Compounds shown in Table 2 were each used instead of Compound 18 as a dopant in forming an emission layer.

Evaluation Example 1

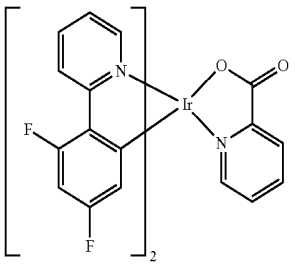
[0368] The driving voltage, current density, luminance, luminescent efficiency, and upper (e.g., maximum) emission wavelength of the organic light-emitting devices manufactured according to Examples 1 to 13 and Comparative Examples 1 to 6 were measured by using Keithley SMU 236 and a luminance meter PR650, and results thereof are shown in Table 2 below.

TABLE 2

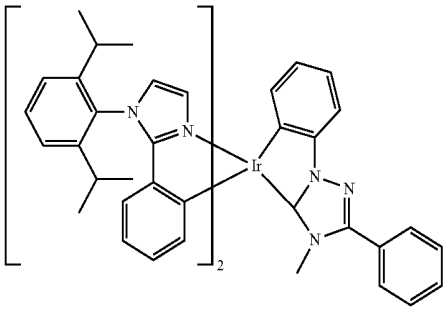
	Dopant compound	Driving voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Luminescent efficiency (cd/A)	Emission color	Maximum emission wavelength (nm)
Example 1	18	3.90	50	4382	19.45	Blue	453
Example 2	28	3.92	50	4324	19.05	Blue	455
Example 3	82	3.98	50	4404	19.60	Blue	454
Example 4	92	3.96	50	4678	19.65	Blue	458
Example 5	146	3.92	50	4837	20.05	Blue	452
Example 6	154	3.90	50	4953	20.65	Blue	458
Example 7	210	3.98	50	4835	19.74	Blue	460

TABLE 2-continued

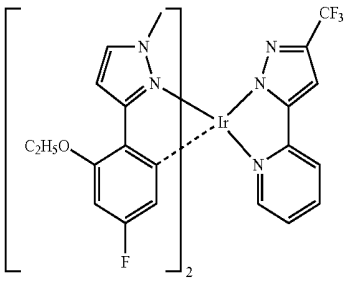
	Dopant compound	Driving voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Luminescent efficiency (cd/A)	Emission color	Maximum emission wavelength (nm)
Example 8	220	3.98	50	4811	19.73	Blue	468
Example 9	338	3.98	50	4764	18.74	Blue	468
Example 10	348	3.97	50	4896	19.74	Blue	470
Example 11	401	3.62	50	4631	16.85	Blue	468
Example 12	402	4.06	50	4645	17.36	Blue	469
Example 13	450	3.90	50	4831	19.85	Blue	466
Comparative Example 1	FIrpic	3.92	50	3870	11.65	Blue	475
Comparative Example 2	A	3.80	50	4230	13.20	Blue	460
Comparative Example 3	B	3.85	50	4353	10.35	Blue	472
Comparative Example 4	C	3.56	50	2530	9.62	Blue	465
Comparative Example 5	D	3.98	50	890	7.25	Blue	445
Comparative Example 6	E	4.05	50	1954	8.22	Blue	478



FIrpic



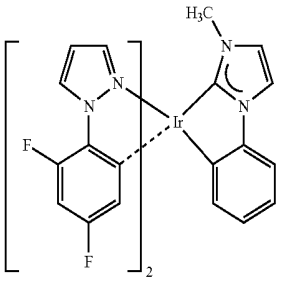
Compound A



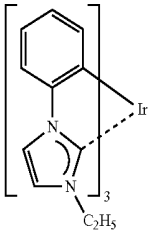
Compound B

TABLE 2-continued

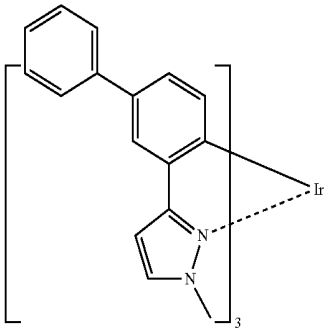
Dopant compound	Driving voltage (V)	Current density (mA/cm^2)	Luminance (cd/m^2)	Luminescent efficiency (cd/A)	Emission color	Maximum emission wavelength (nm)



Compound C



Compound D



Compound E

[0369] Referring to Table 2, it is confirmed that the organic light-emitting devices of Examples 1 to 13 have a lower driving voltage, higher luminance, and higher luminescent efficiency and are suitable for emission of deep blue light, as compared with the organic light-emitting devices of Comparative Examples 1 to 6.

[0370] An organic light-emitting device including the organometallic compound of the present disclosure may have a low driving voltage, high luminescent efficiency, high luminance, and a long lifespan.

[0371] It will be understood that, although the terms "first," "second," "third," etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section described below could be termed a second element, component, region, layer or section, without departing from the spirit and scope of the present disclosure.

[0372] Spatially relative terms, such as "beneath," "below," "lower," "under," "above," "upper," and the like, may be used herein for ease of explanation to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the FIGURES. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or in operation, in addition to the orientation depicted in the FIGURES. For example, if the device in the FIGURES is turned over, elements described as "below" or "beneath" or "under" other elements or features would then be oriented "above" the other elements or features. Thus, the example terms "below" and "under" can encompass both an orientation of above and below. The device may be otherwise oriented (e.g., rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein should be interpreted accordingly.

[0373] It will be understood that when an element or layer is referred to as being "on," "connected to," or "coupled to" another element or layer, it can be directly on, connected to,

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

[0374] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a" and "an" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and "including," when used in this specification, specify the presence of the stated features, integers, acts, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, acts, operations, elements, components, and/or groups thereof.

[0375] As used herein, the terms "substantially," "about," and similar terms are used as terms of approximation and not as terms of degree, and are intended to account for the inherent deviations in measured or calculated values that would be recognized by those of ordinary skill in the art. Further, the use of "may" when describing embodiments of the present disclosure refers to "one or more embodiments of the present disclosure." As used herein, the terms "use," "using," and "used" may be considered synonymous with the terms "utilize," "utilizing," and "utilized," respectively.

[0376] Also, any numerical range recited herein is intended to include all subranges of the same numerical precision subsumed within the recited range. For example, a range of "1.0 to 10.0" is intended to include all subranges between (and including) the recited minimum value of 1.0 and the recited maximum value of 10.0, that is, having a minimum value equal to or greater than 1.0 and a maximum value equal to or less than 10.0, such as, for example, 2.4 to 7.6. Any maximum numerical limitation recited herein is intended to include all lower numerical limitations subsumed therein, and any minimum numerical limitation recited in this specification is intended to include all higher numerical limitations subsumed therein. Accordingly, Applicant reserves the right to amend this specification, including the claims, to expressly recite any sub-range subsumed within the ranges expressly recited herein.

[0377] 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.

[0378] While one or more embodiments have been described with reference to the accompanying drawing, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

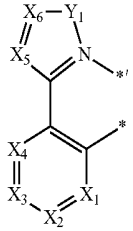
What is claimed is:

1. An organometallic compound represented by Formula 1:

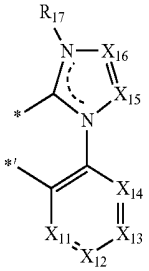
Formula 1

$M(L1)_{n1}(L_2)_{n2}$

Formula 2A



Formula 2B



Formula 7

$*\text{-}(Z_{32})_{b2}\text{-}*'$,

wherein M in Formula 1 is a third row transition metal,

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

in Formula 1, L_2 is a ligand represented by Formula 2B, and n2 is 1, 2, or 3, wherein, when n2 is two or more, two or more L_2(s) are identical to or different from each other,

the sum of n1 and n2 in Formula 1 is 2 or 3,

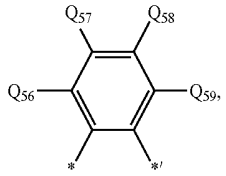
* and *' in Formulae 2A and 2B each indicate a binding site to M in Formula 1,

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

Y_1 is selected from $N(R_7)$, O, and S,

in Formula 2B, X_{11} is N or $C(R_{11})$, X_{12} is N or $C(R_{12})$, X_{13} is N or $C(R_{13})$, X_{14} is N or $C(R_{14})$, X_{15} is N or $C(R_{15})$, and X_{16} is N or $C(R_{16})$,

Z_{32} in Formula 7 is *—O—*', *—S—*', *—$N(Q_{51})$-*', *—$B(Q_{51})$-*', *—$C(Q_{52})(Q_{53})$-*', *—$C(Q_{54})$=$C(Q_{55})$ *', or



b2 is an integer from 1 to 10, wherein, when b2 is 2 or more, two or more Z_{32}(s) are identical to or different from each other,

R_1 to R_7, R_{11} to R_{17}, and Q_{51} to Q_{59} in Formulae 2A, 2B, and 7 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 monovalent non-aromatic condensed polycyclic group, a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_1)(Q_2)$, —$B(Q_1)(Q_2)$, —$C(=O)(Q_1)$, —$S(=O)_2(Q_1)$, —$P(Q_1)(Q_2)$, and —$P(=O)(Q_1)(Q_2)$,

two neighboring groups selected from R_1 to R_4 in Formula 2A are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

R_5 and R_6 in Formula 2A are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

two neighboring groups selected from R_{11} to R_{14} in Formula 2B are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

R_{15} and R_{16} in Formula 2B are optionally linked to form a substituted or unsubstituted C_4-C_{60} carbocyclic group or a substituted or unsubstituted C_2-C_{60} heterocyclic group,

R_1 and R_{11} in Formulae 2A and 2B are optionally linked via a single bond or a linking group represented by Formula 7,

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

deuterium (-D), —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a 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_r 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_{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_1-C_{60} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, a C_1-C_{60} alkyl group substituted with at least one selected from deuterium, —F, and a cyano group, a C_6-C_{60} aryl group substituted with at least one selected from deuterium, —F, and a cyano group, a biphenyl group, and a terphenyl group.

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

in Formula 1, M is iridium (Ir), n1 is 2, and n2 is 1, or M is platinum (Pt), n1 is 1, and n2 is 1.

3. The organometallic compound of claim 1, wherein, in Formula 2A, X_1 is $C(R_1)$, X_2 is $C(R_2)$, X_3 is $C(R_3)$, and X_4 is $C(R_4)$.

4. The organometallic compound of claim 1, wherein, Y_1 in Formula 2A is $N(R_7)$ or O.

5. The organometallic compound of claim 1, wherein, in Formula 2A, X_5 is $C(R_5)$, and X_6 is $C(R_6)$.

6. The organometallic compound of claim 5, wherein, at least one of R_5 and R_6 is not hydrogen.

7. The organometallic compound of claim 1, wherein, in Formula 2B, i) X_{11} is $C(R_{11})$, X_{12} is $C(R_{12})$, X_{13} is $C(R_{13})$, and X_{14} is $C(R_{14})$;

ii) X_{11} is X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$; or

iii) X_{11} is N, X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$.

8. The organometallic compound of claim 1, wherein, in Formula 2B, i) X_{15} is $C(R_{15})$, and X_{16} is $C(R_{16})$; or

ii) X_{15} is N, and X_{16} is $C(R_{16})$.

9. The organometallic compound of claim 1, wherein, R_1 to R_7, R_{11} to R_{17}, and Q_{51} to Q_{59} in Formulae 2A, 2B, and 7 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_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a pyridinyl group, a pyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amidino group, a hydrazino group, a hydrazono group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, an acridinyl group, a phenanthrolinyl group, a benzimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, an imidazopyrimidinyl group, $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{31})(Q_{32})$, $—B(Q_{31})(Q_{32})$, $—C(=O)(Q_{31})$, $—S(=O)_2(Q_{31})$, and $—P(=O)(Q_{31})(Q_{32})$; and

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

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

hydrogen, deuterium, —F, —Cl, —Br, —I, a cyano group, a C_1-C_{20} alkyl group, a C_2-C_{20} alkenyl group, a C_2-C_{20} alkynyl group, a C_1-C_{20} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_1-C_{10} heterocycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkenyl group, a C_6-C_{20} aryl group, a C_1-C_{20} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, and a monovalent non-aromatic condensed heteropolycyclic group;

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

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

a biphenyl group and a terphenyl group.

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

in Formula 2A, when X_1 is $C(R_1)$, X_2 is $C(R_2)$, X_3 is $C(R_3)$, X_4 is $C(R_4)$, and Y_1 is $N(R_7)$, i) R_1 to R_5 are each hydrogen, and R_6 and R_7 are each independently a methyl group or a phenyl group, ii) R_1 to R_4 are each hydrogen, R_5 is selected from a phenyl group, a carbazolyl group, an acridinyl group substituted with at least one methyl group, —$Si(Q_1)(Q_2)(Q_3)$, —$B(Q_1)(Q_2)$, —$P(Q_1)(Q_2)$, and —$P(=O)(Q_1)(Q_2)$, and R_6 and R_7 are each a phenyl group, or iii) R_1 and R_{11} are linked via a linking group represented by Formula 7, R_1 to R_4 are each hydrogen, R_5 is a phenyl group substituted with at least one methyl group, and R_6 and R_7 are each a phenyl group, and

Q_1 to Q_3 are each independently a methyl group or a phenyl group.

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

in Formula 2B, i) when X_{11} is $C(R_{11})$, X_{12} is $C(R_{12})$, X_{13} is $C(R_{13})$, and X_{14} is $C(R_{14})$, ia) R_{11} to R_{14} are each hydrogen, or ib) R_{11}, R_{13}, and R_{14} are each hydrogen, and R_{12} is an electron withdrawing group;

ii) when X_{11} is $C(R_{11})$, X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$, iia) R_{11}, R_{12}, and R_{14} are each hydrogen, or iib) R_{11} is hydrogen, and R_{12} and R_{14} are each an electron withdrawing group, or ic) R_{11} and R_{14} are each hydrogen, and R_{12} is an electron withdrawing group; or

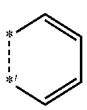
iii) when X_{11} is N, X_{12} is $C(R_{12})$, X_{13} is N, and X_{14} is $C(R_{14})$, R_{12} and R_{14} are each hydrogen.

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

in Formula 2B, i) when X_{15} is $C(R_{15})$ and X_{16} is $C(R_{16})$, ia) R_{15} and R_{16} are each hydrogen, and R_{17} is a methyl group or a phenyl group, or ib) R_{15} and R_{16} are linked to form a group represented by Formula 2B-A or 2B-B, and R_{17} is a methyl group or a phenyl group; or

ii) when X_{15} is N and X_{16} is $C(R_{16})$, R_{16} is hydrogen, and R_{17} is a methyl group or a phenyl group:

Formula 2B-A



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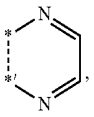
Formula 2B-B

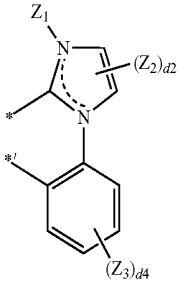


wherein * and *' in Formula 2B-A and 2B-B each indicate a binding site to X_{15} and X_{16} in Formula 2B.

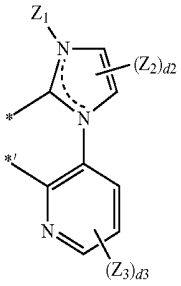
13. The organometallic compound of claim **1**, wherein,

L_2 is a ligand selected from groups represented by Formulae 2B-1 to 2B-88:

2B-1



2B-2



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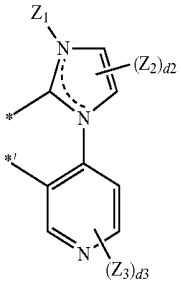

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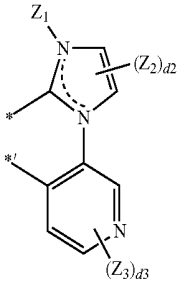

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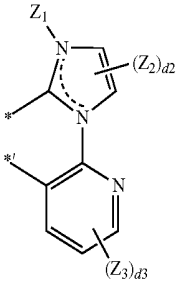

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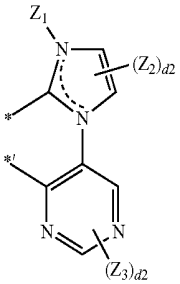
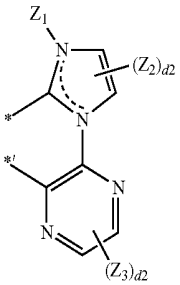
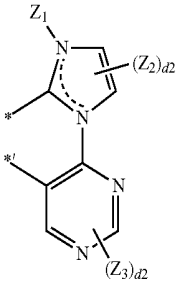


2B-7



2B-8



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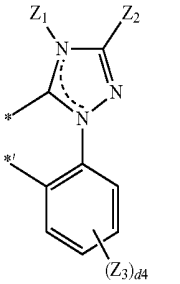

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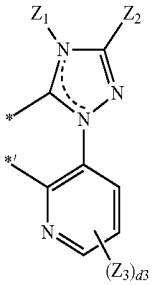
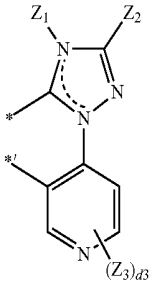
2B-10



2B-11



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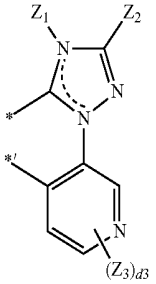

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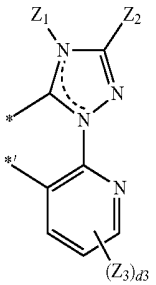

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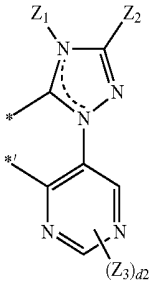

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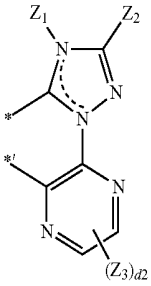
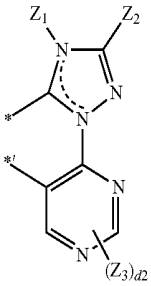
2B-15



2B-16



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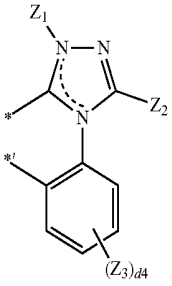

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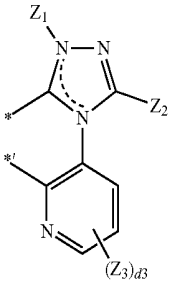

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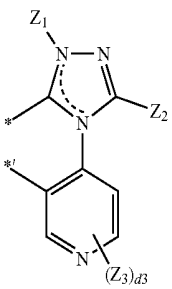

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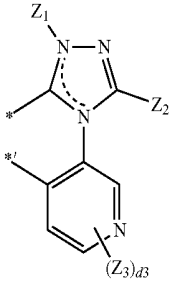

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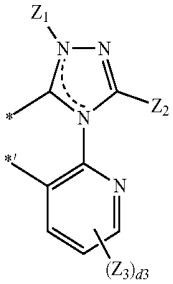

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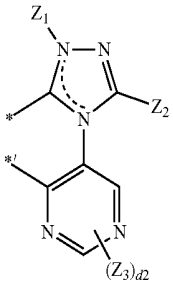
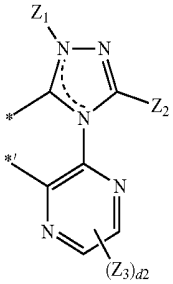


2B-23



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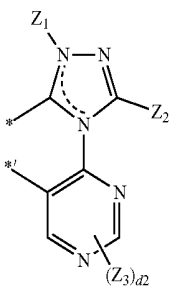

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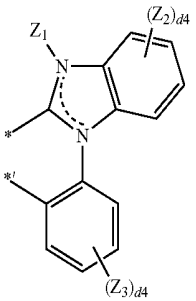

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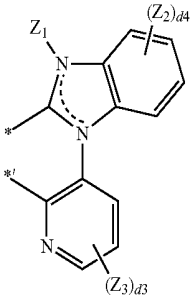
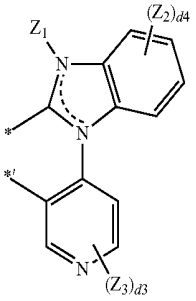
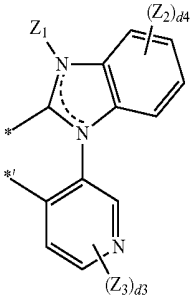


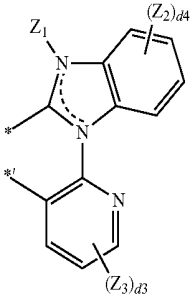
2B-27



2B-28



2B-29



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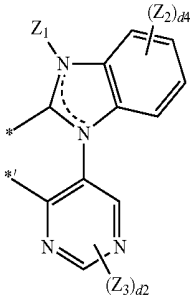

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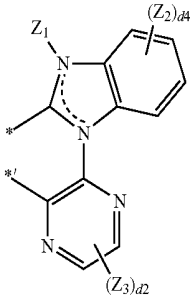
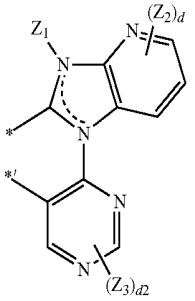
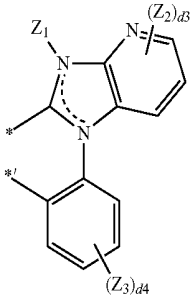


2B-32



2B-33



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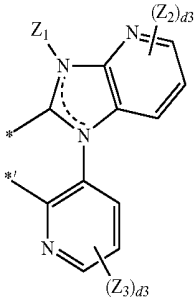

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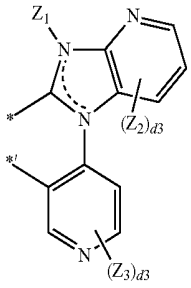
2B-35



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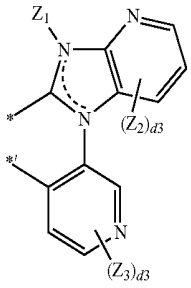
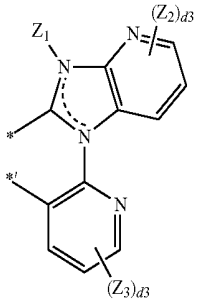
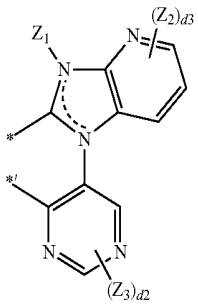


2B-37



2B-38



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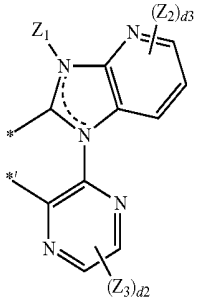

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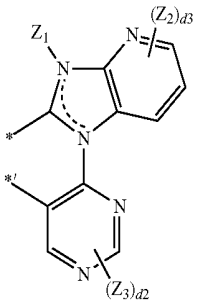

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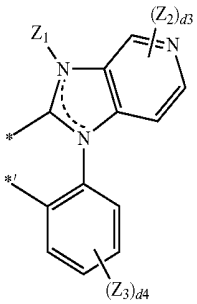

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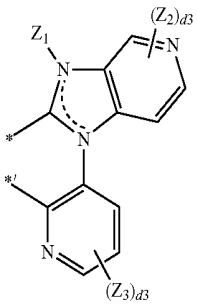
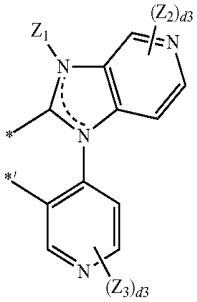


2B-43



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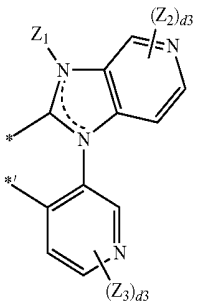

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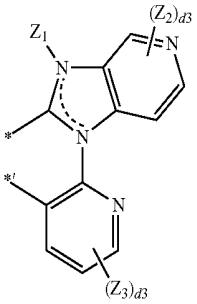

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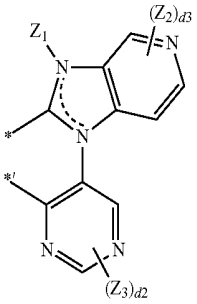
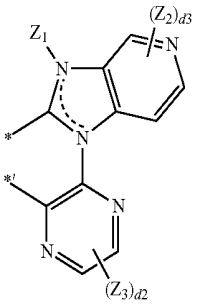
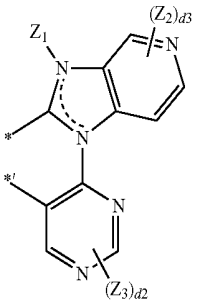


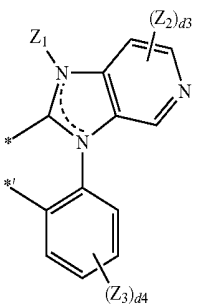
2B-47



2B-48



2B-49



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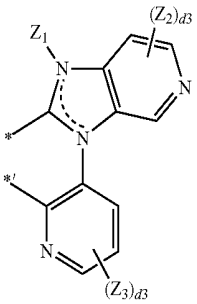

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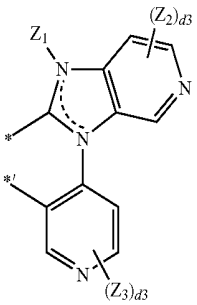

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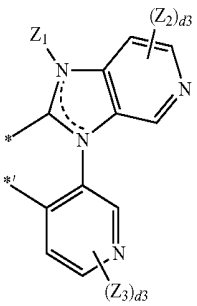

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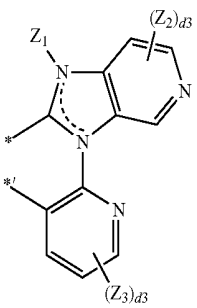
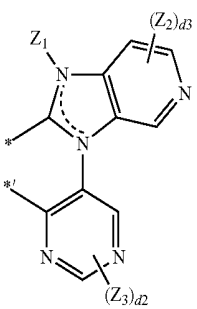


2B-54



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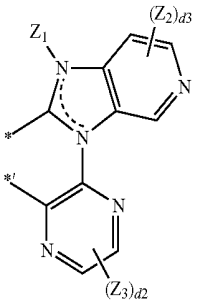
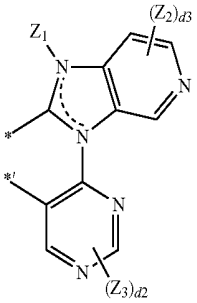
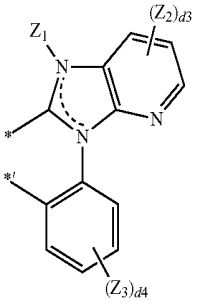
2B-55



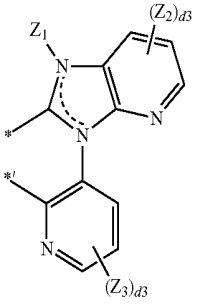
2B-56



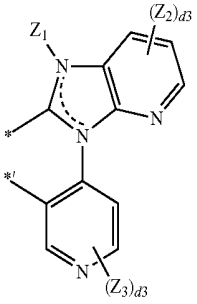
2B-57



2B-58



2B-59



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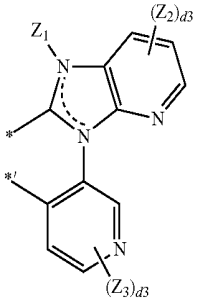
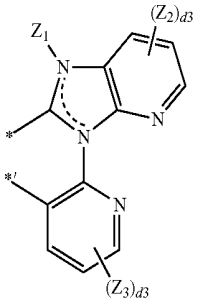
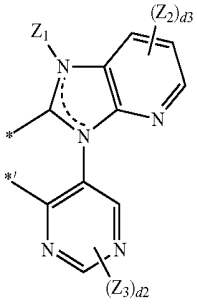
2B-60



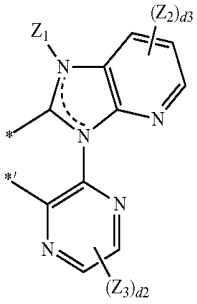
2B-61



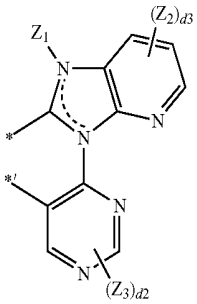
2B-62



2B-63



2B-64



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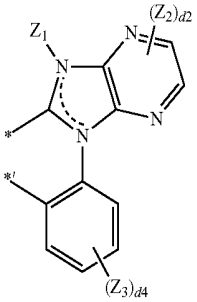
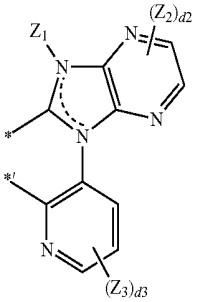
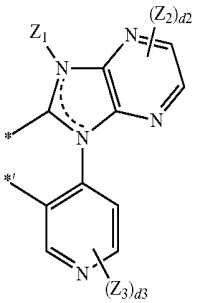
2B-65



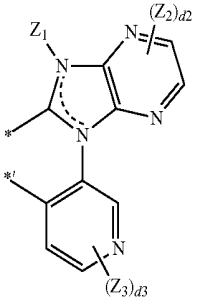
2B-66



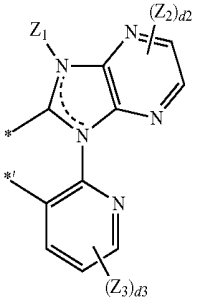
2B-67



2B-68



2B-69



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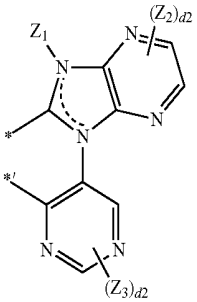
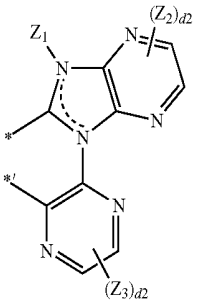
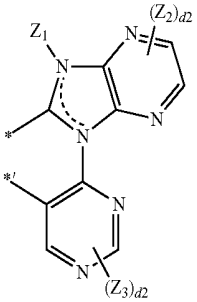
2B-70



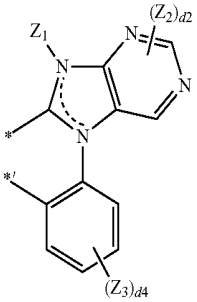
2B-71



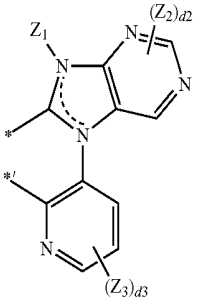
2B-72



2B-73



2B-74



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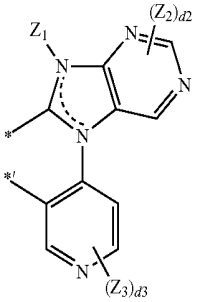
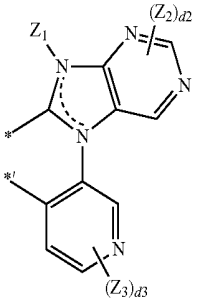
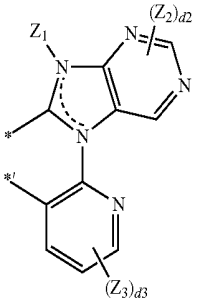
2B-75



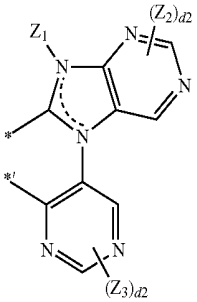
2B-76



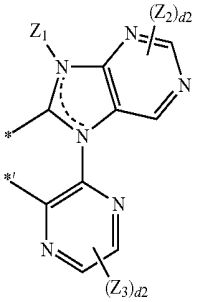
2B-77



2B-78



2B-79



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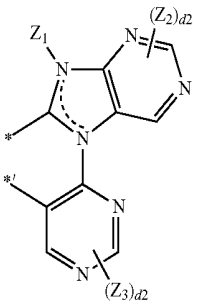
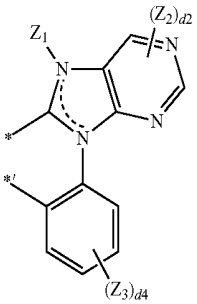
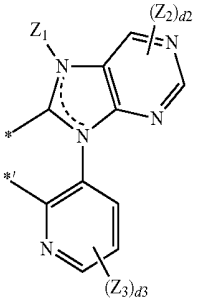
2B-80



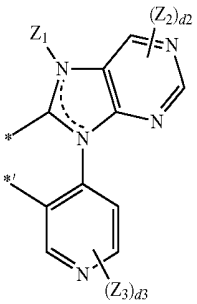
2B-81



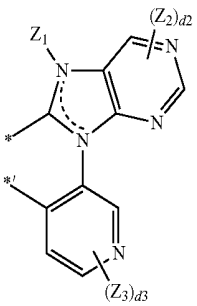
2B-82



2B-83



2B-84



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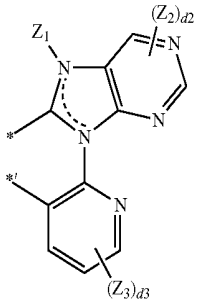
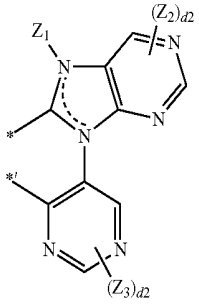
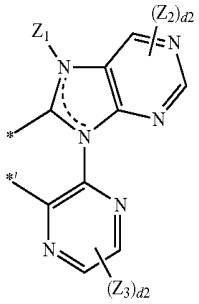
2B-85



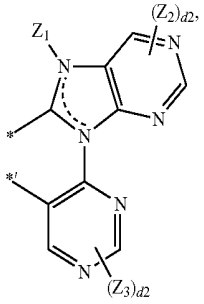
2B-86



2B-87



2B-88



wherein, in Formulae 2B-1 to 2B-88,

Z_1 to Z_3 are each independently the same as described in connection with R_{11} to R_{17} in claim **1**,

d2 is an integer from 0 to 2,

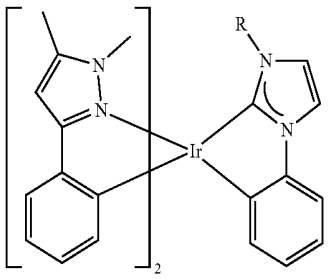
d3 is an integer from 0 to 3,

d4 is an integer from 0 to 4, and

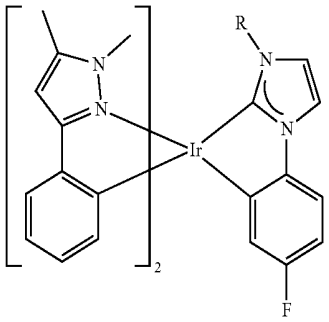
and *' each indicate a binding site to M in Formula 1.

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

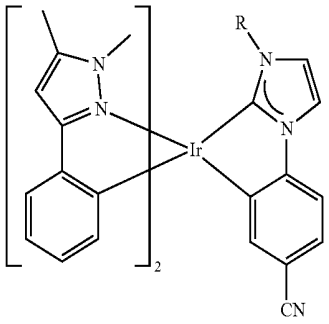
the organometallic compound is selected from Compounds 1 to 454:



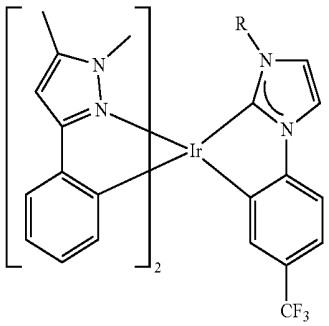
1 (R = Me)
2 (R = Ph)



3 (R = Me)
4 (R = Ph)



5 (R = Me)
6 (R = Ph)



7 (R = Me)
8 (R = Ph)

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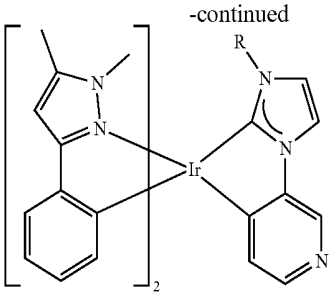
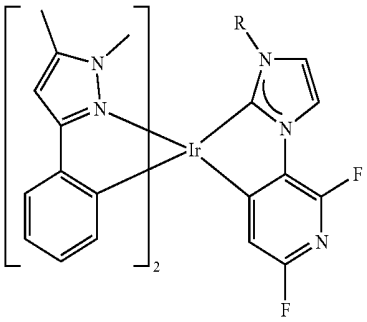
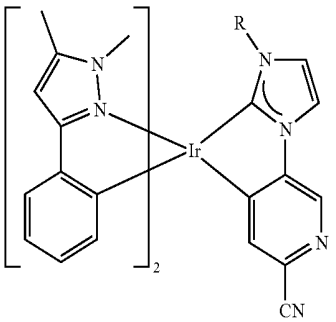


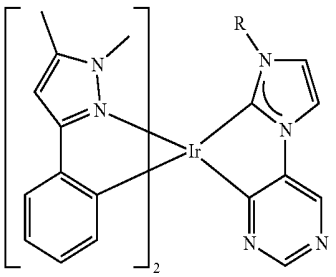
9 (R = Me)
10 (R = Ph)



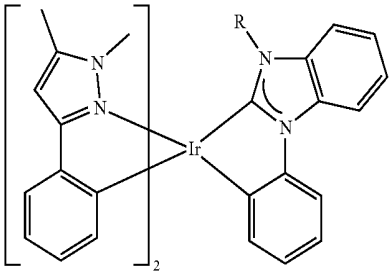
11 (R = Me)
12 (R = Ph)



13 (R = Me)
14 (R = Ph)



15 (R = Me)
16 (R = Ph)



17 (R = Me)
18 (R = Ph)

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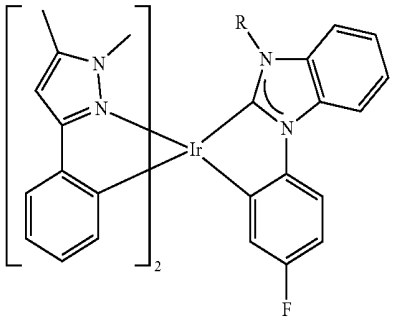
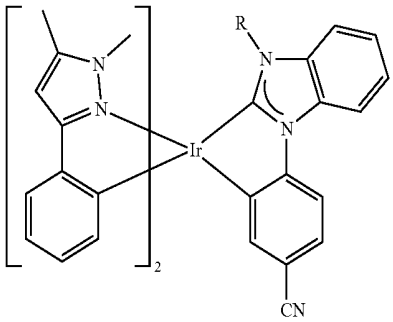
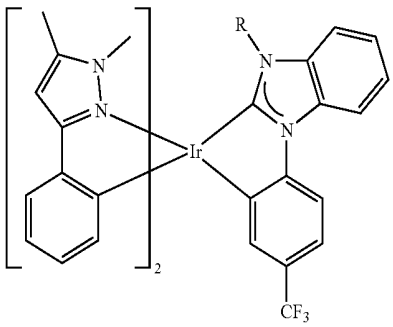


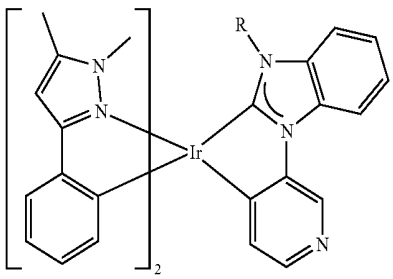
19 (R = Me)
20 (R = Ph)



21 (R = Me)
22 (R = Ph)



23 (R = Me)
24 (R = Ph)



25 (R = Me)
26 (R = Ph)

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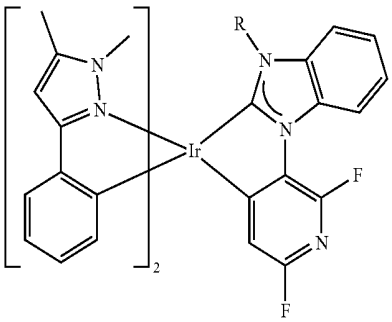
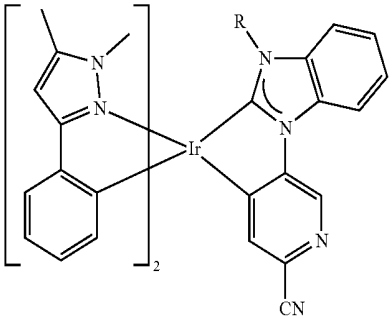
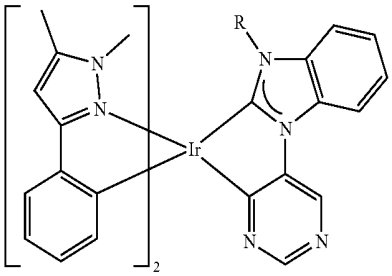


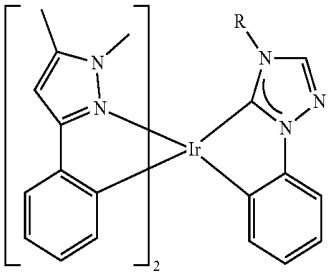
27 (R = Me)
28 (R = Ph)



29 (R = Me)
30 (R = Ph)



31 (R = Me)
32 (R = Ph)



33 (R = Me)
34 (R = Ph)

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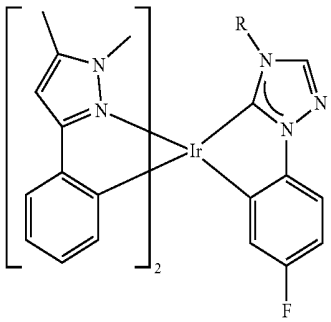
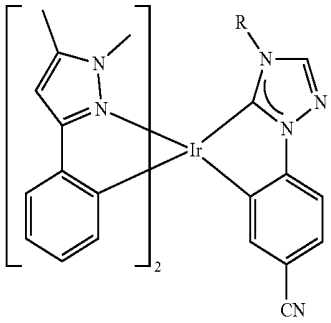
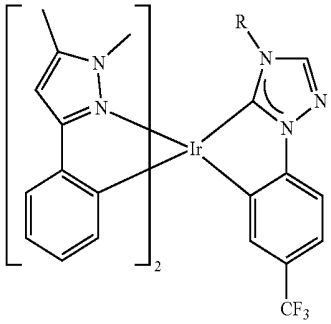


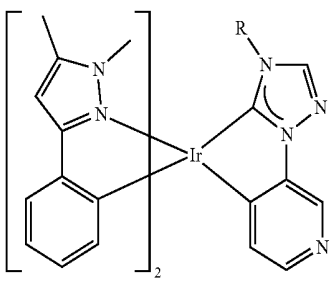
35 (R = Me)
36 (R = Ph)



37 (R = Me)
38 (R = Ph)



39 (R = Me)
40 (R = Ph)



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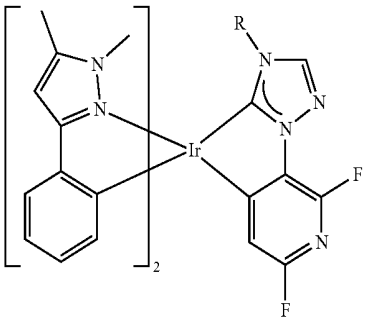

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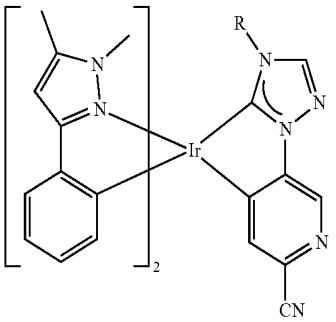

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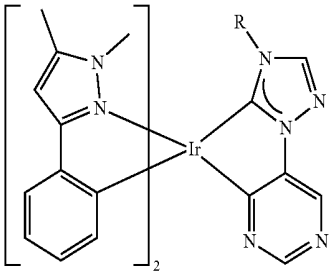

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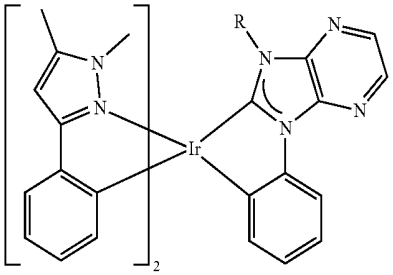

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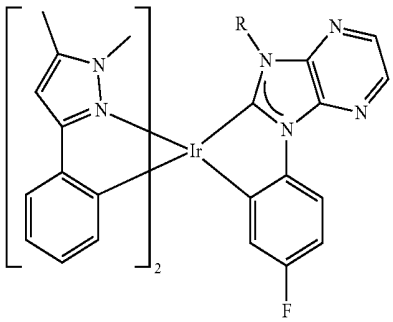

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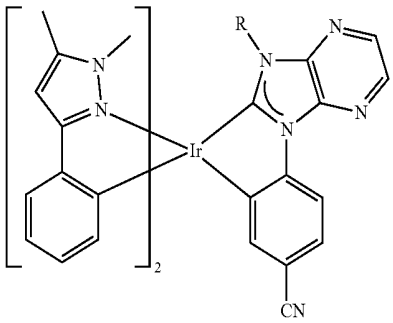

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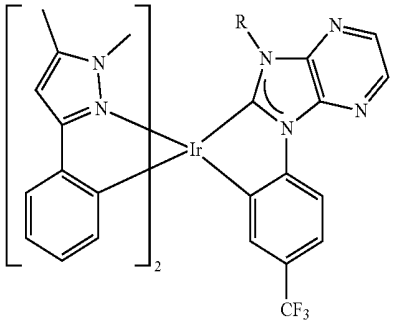

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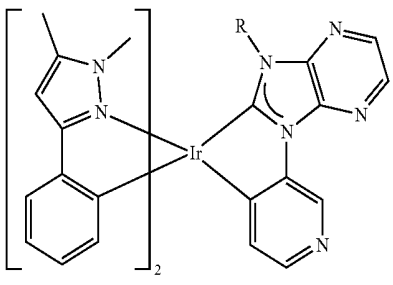

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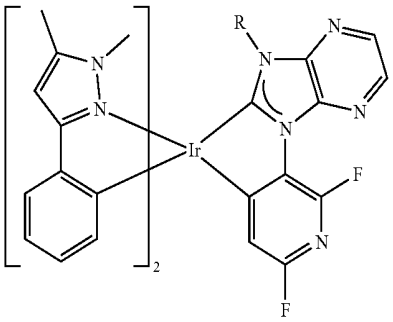

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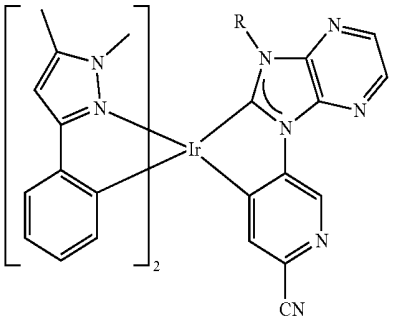

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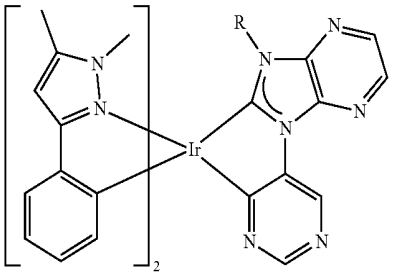

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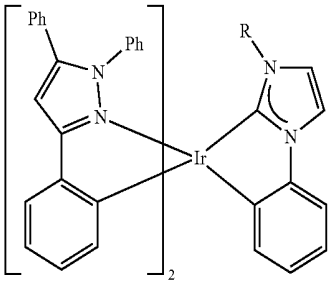

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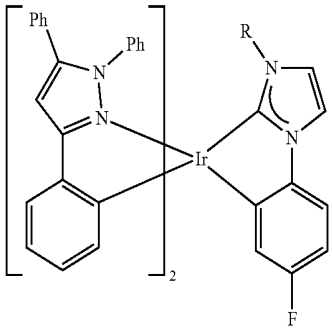

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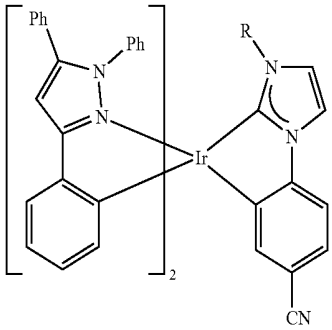

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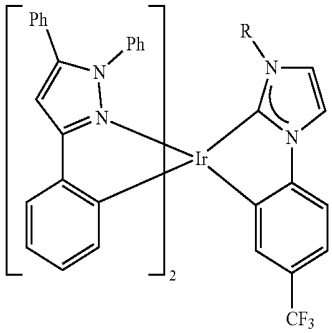

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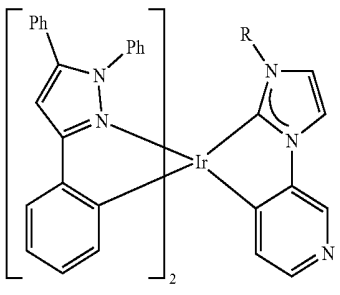

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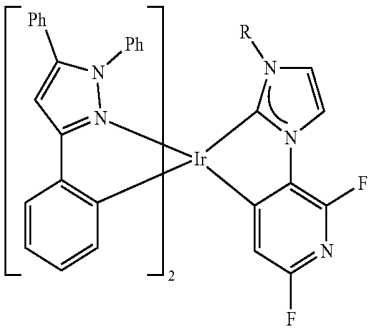

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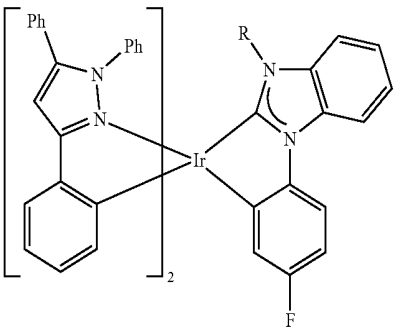

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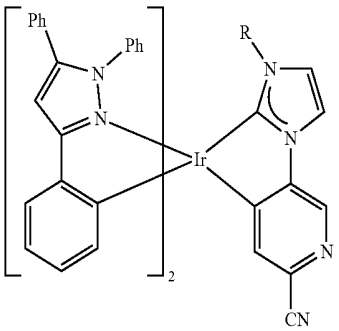

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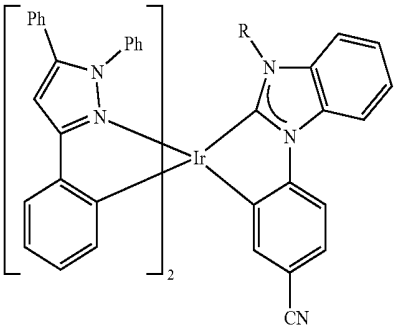

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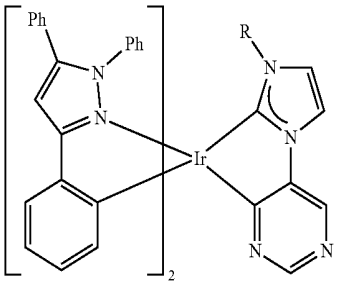

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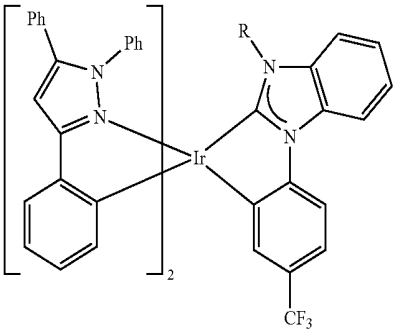

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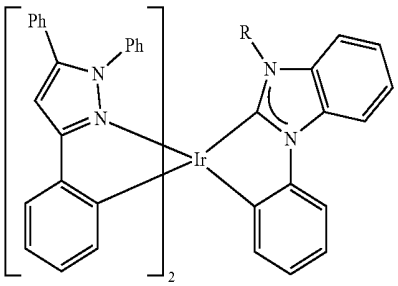

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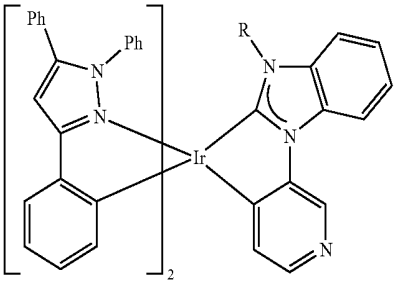

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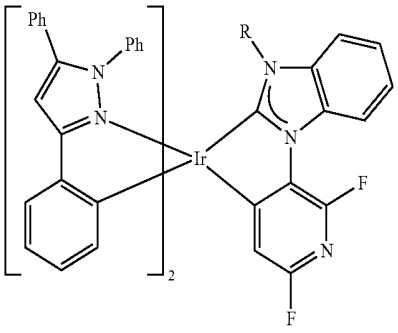

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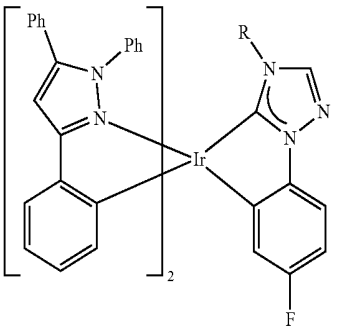

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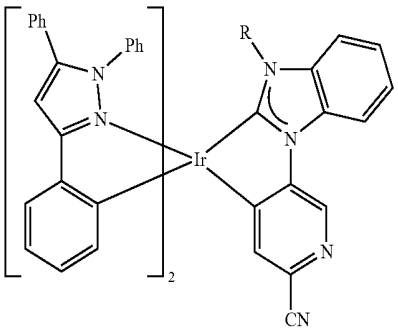

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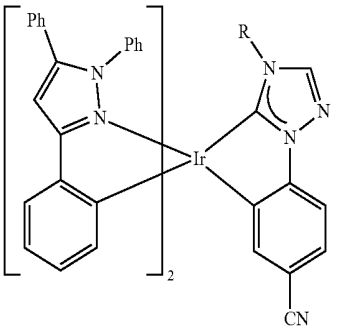

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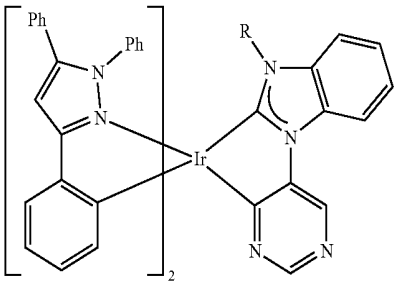

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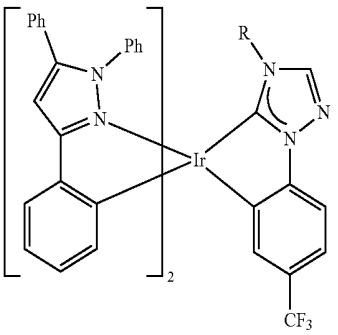

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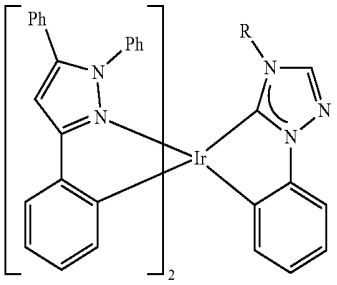

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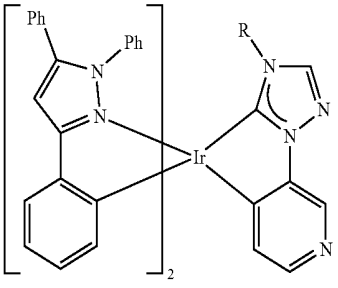

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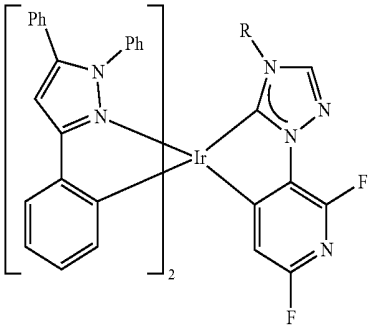

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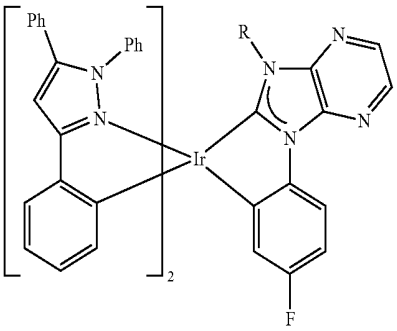

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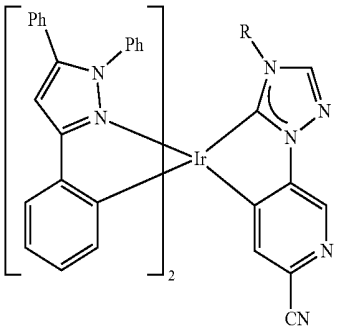

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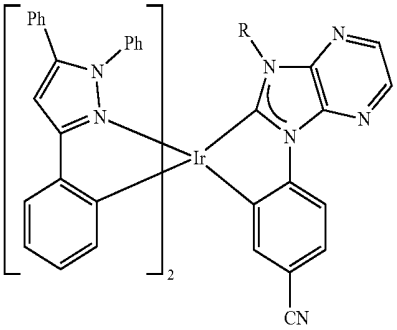

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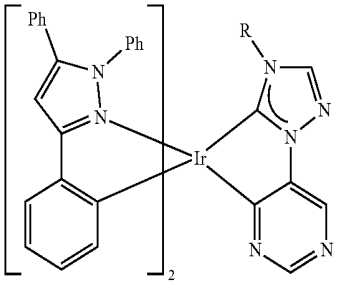

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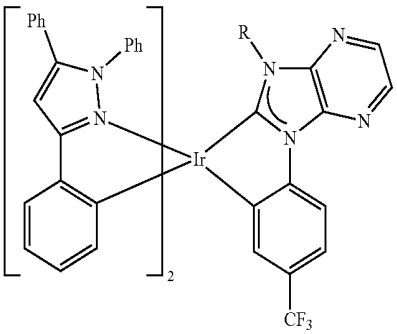

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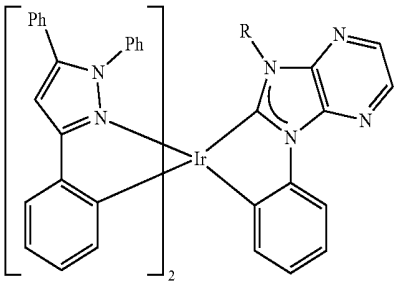

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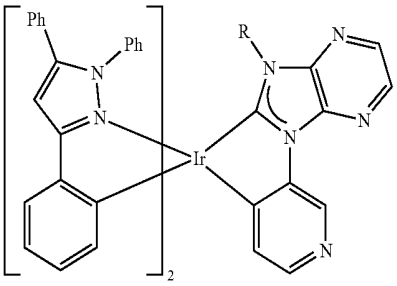

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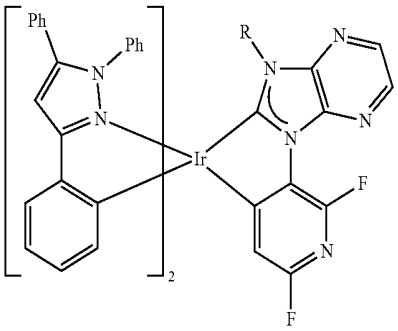

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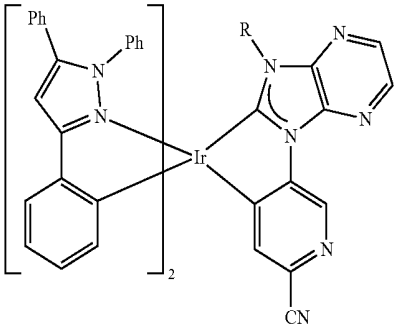

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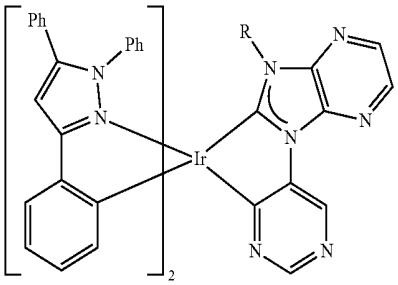

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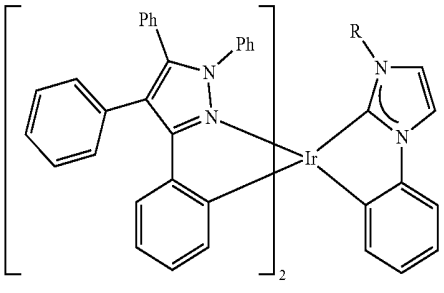

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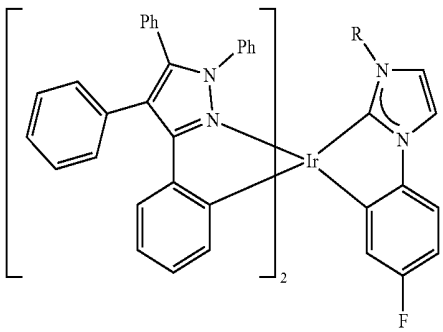

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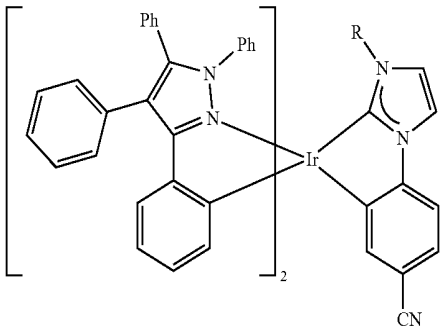

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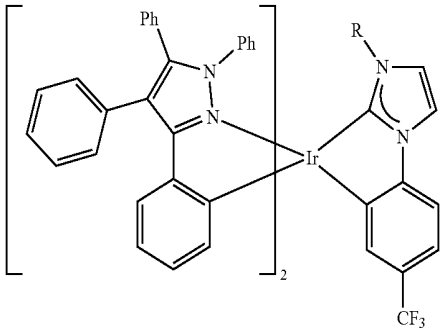

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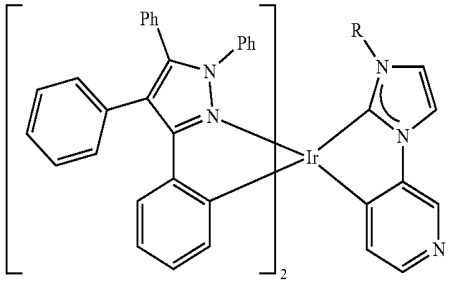

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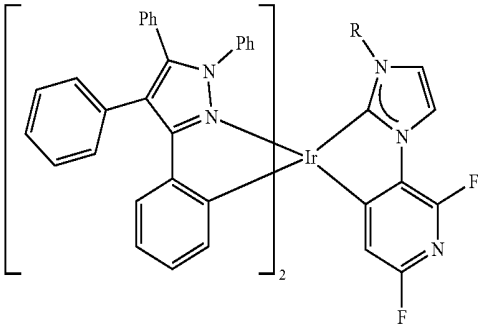

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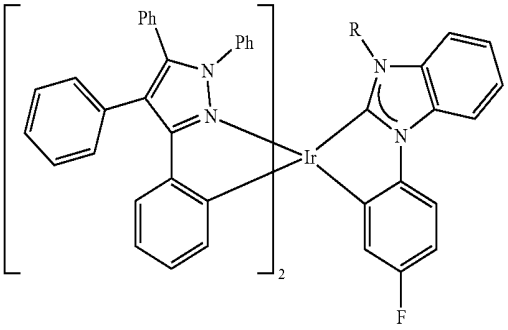

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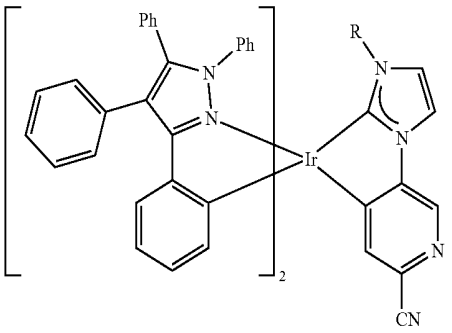

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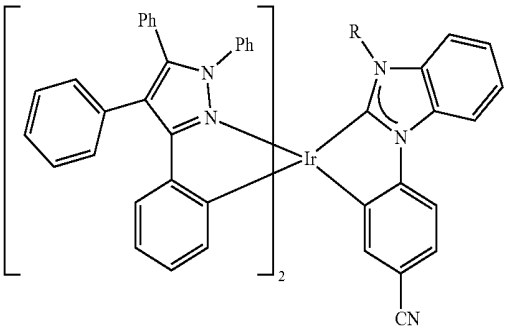

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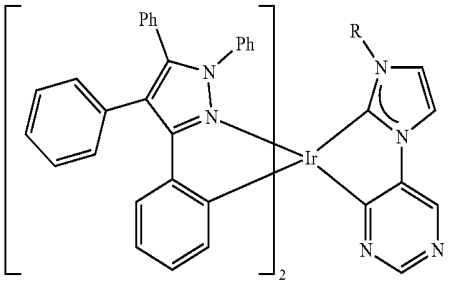

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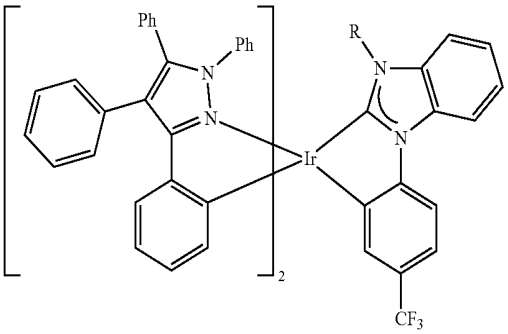

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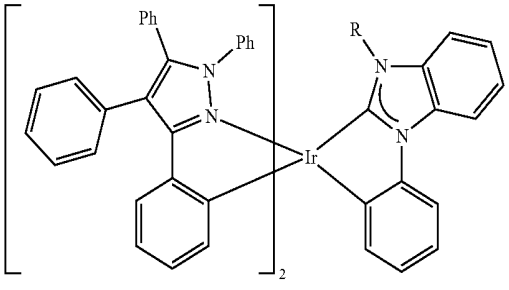

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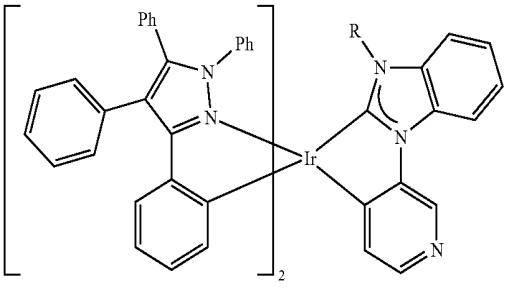

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154 (R = Ph)

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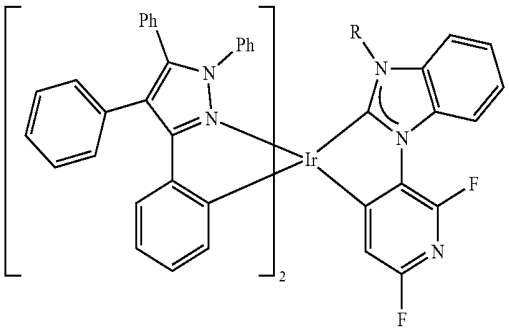

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156 (R = Ph)

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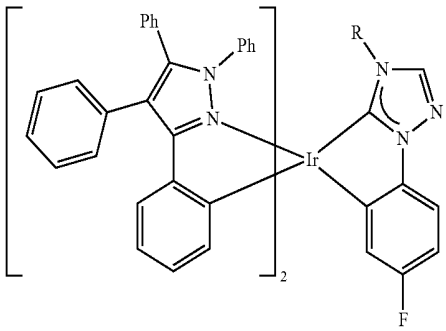

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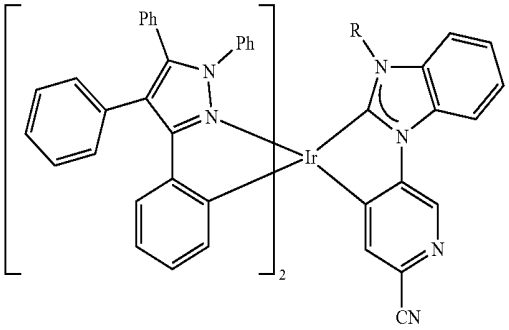

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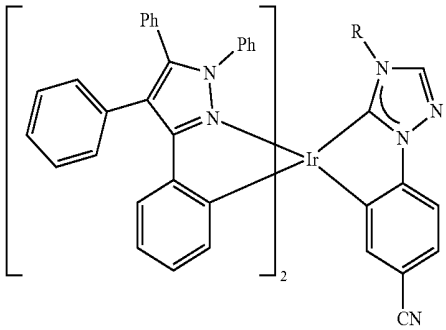

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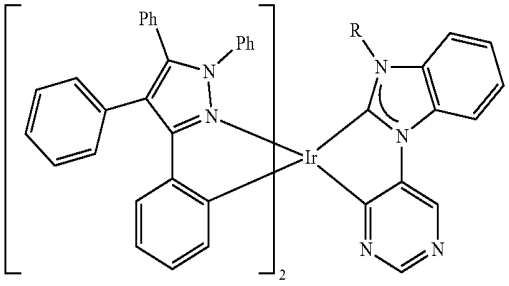

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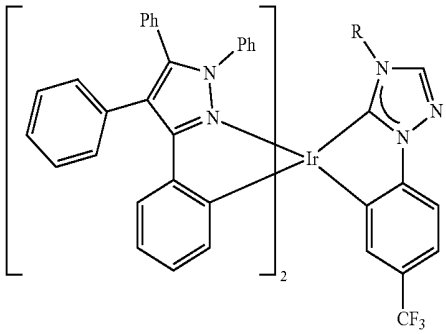

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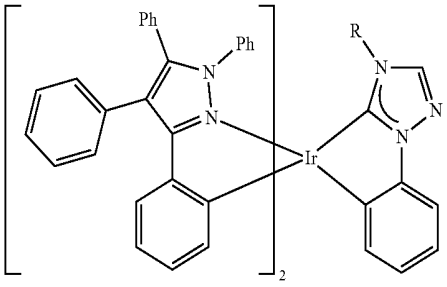

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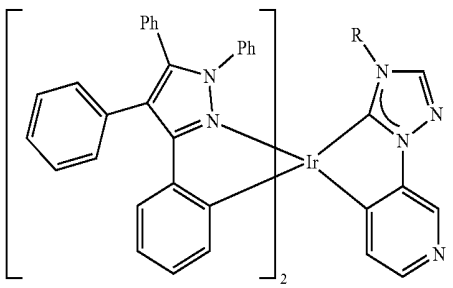

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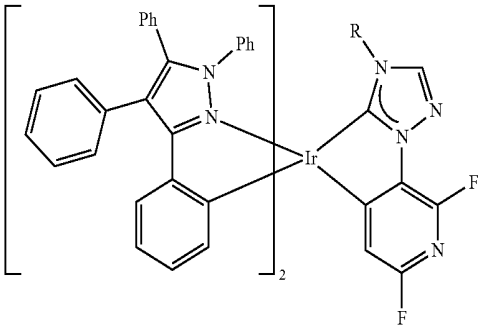

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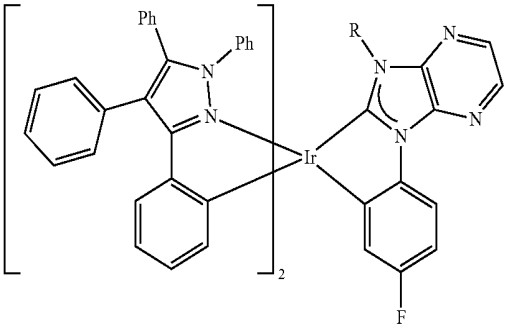

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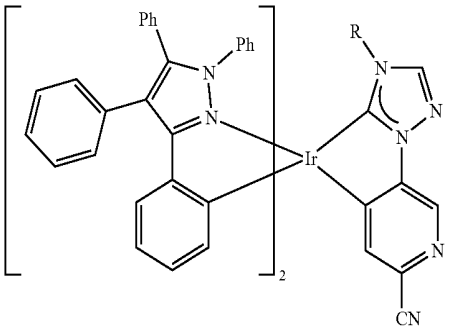

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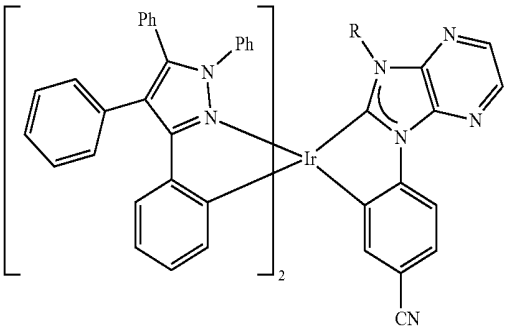

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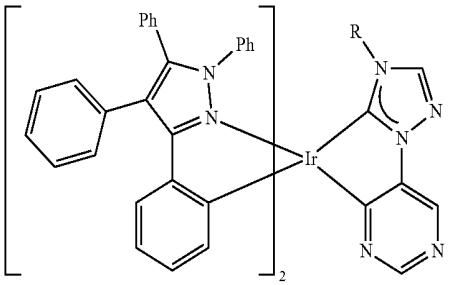

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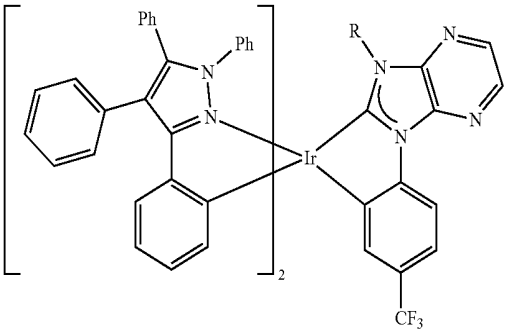

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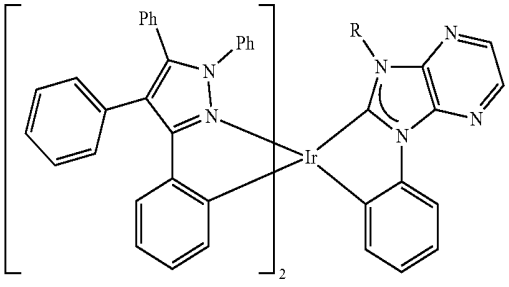

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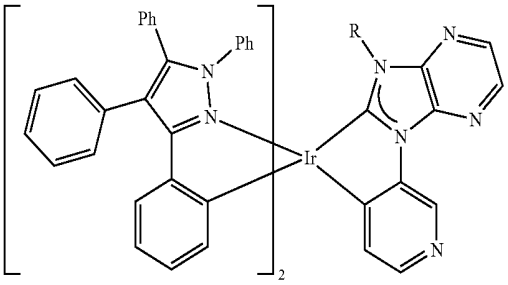

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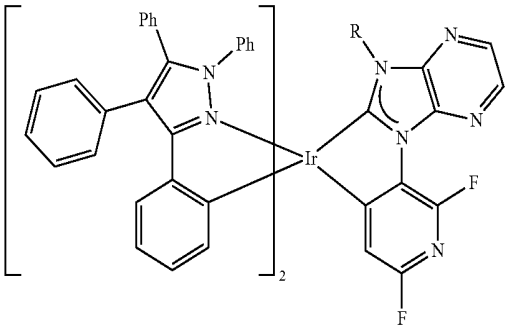

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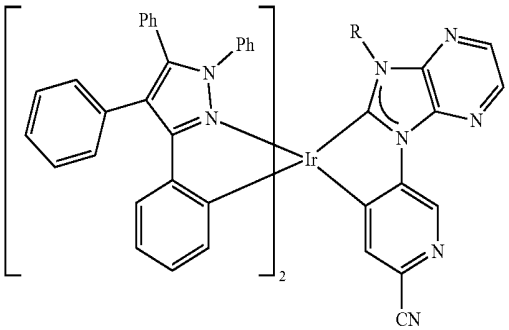

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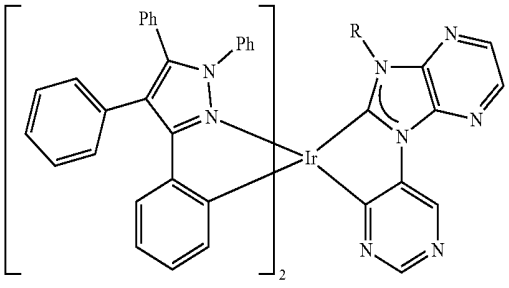

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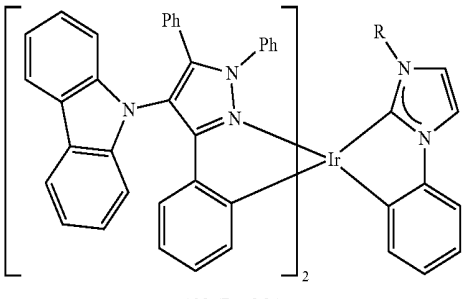

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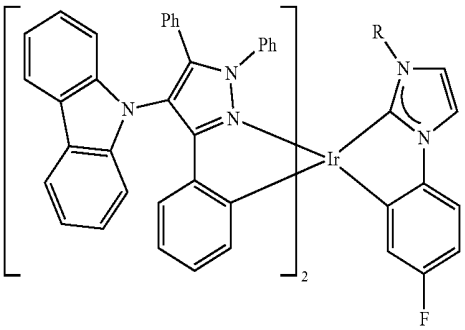

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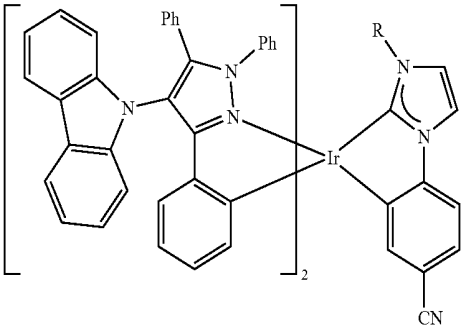

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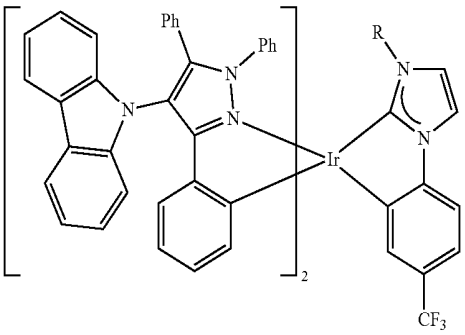

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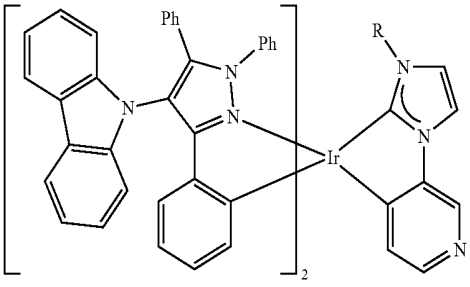

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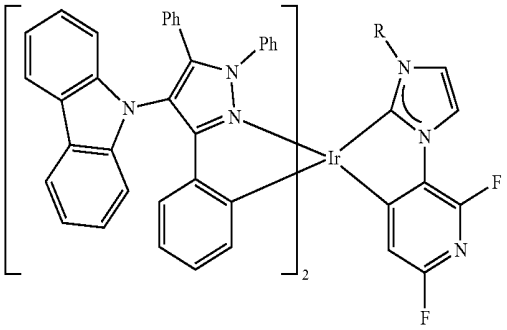

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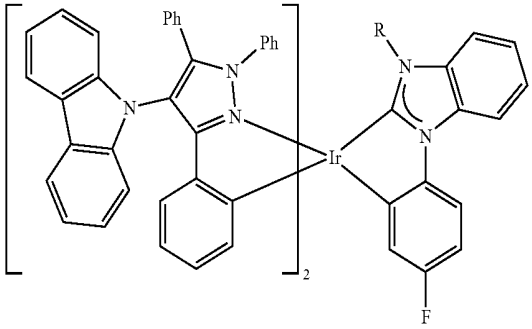

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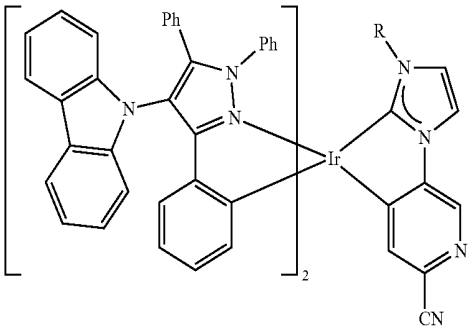

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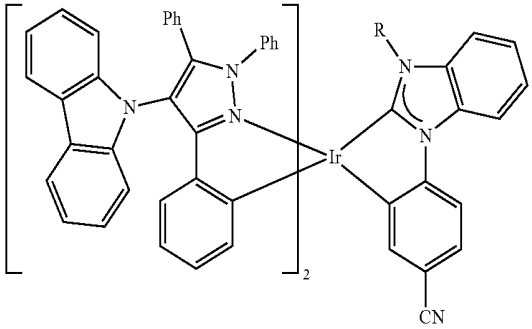

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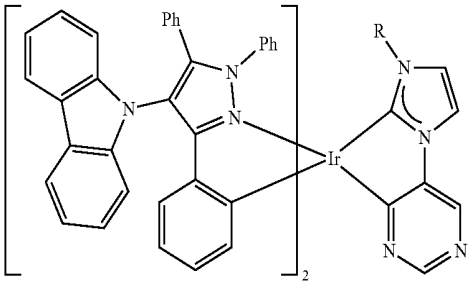

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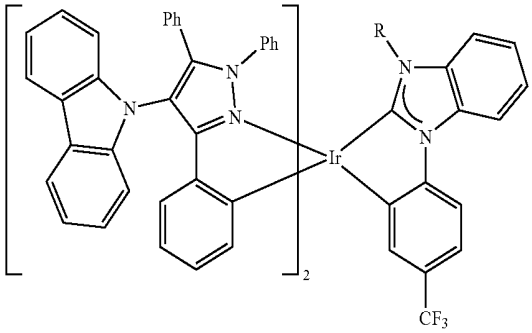

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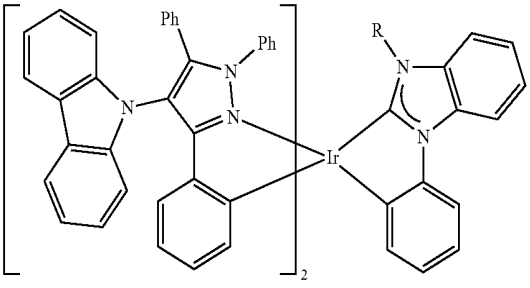

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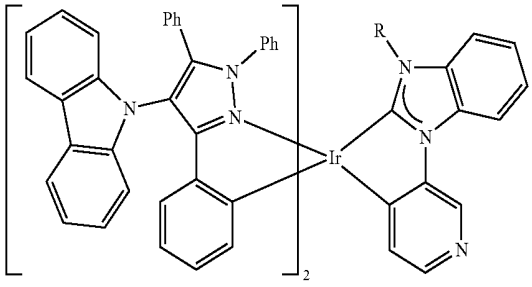

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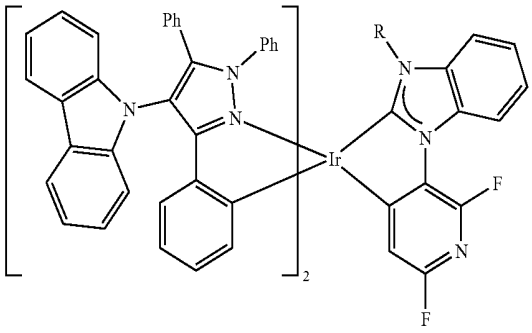

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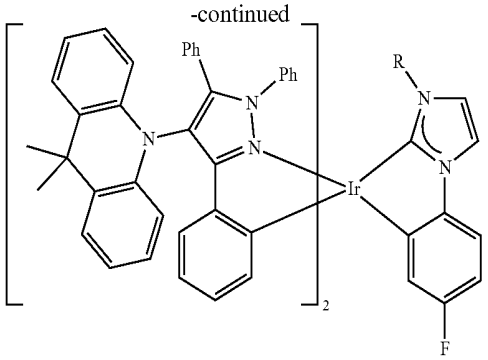

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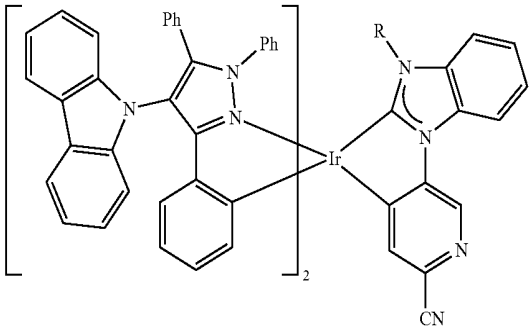

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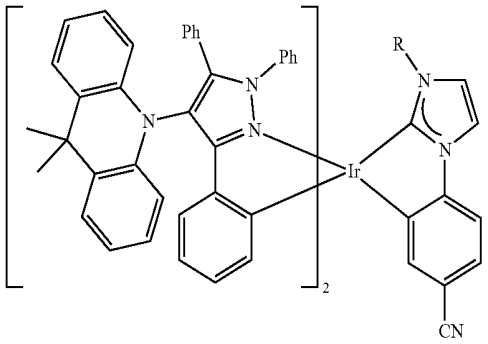

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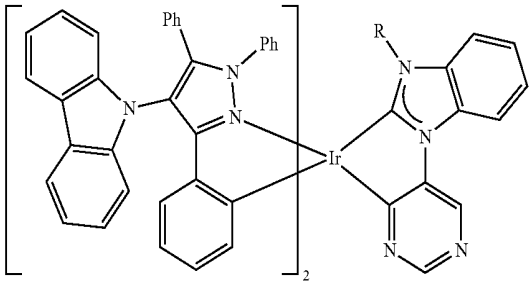

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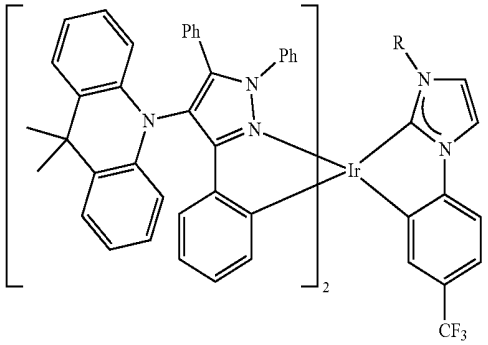

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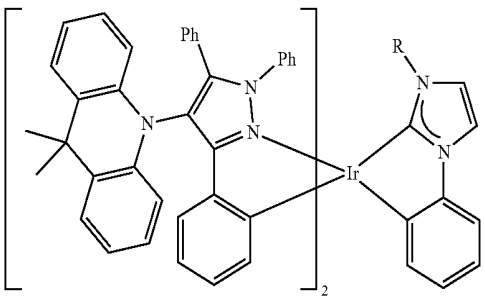

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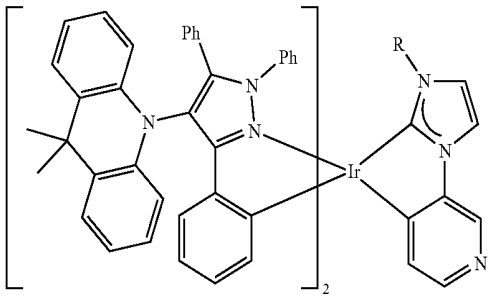

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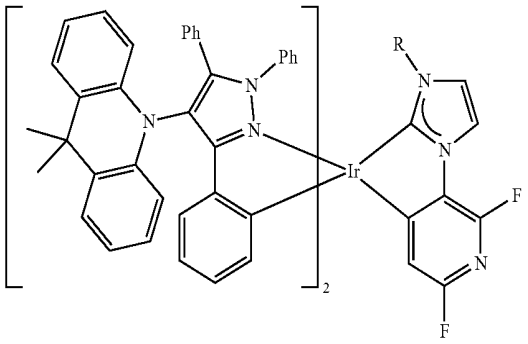

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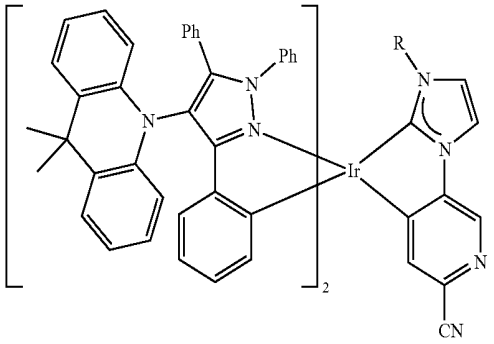

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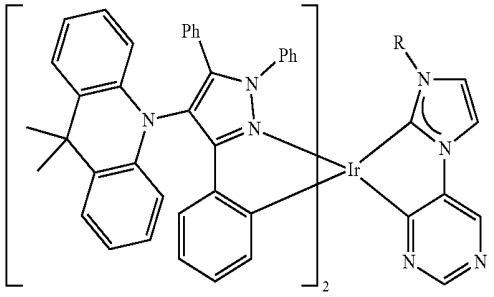

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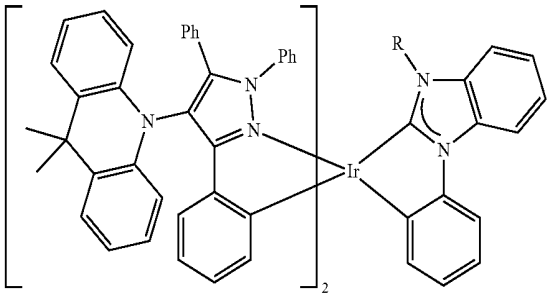

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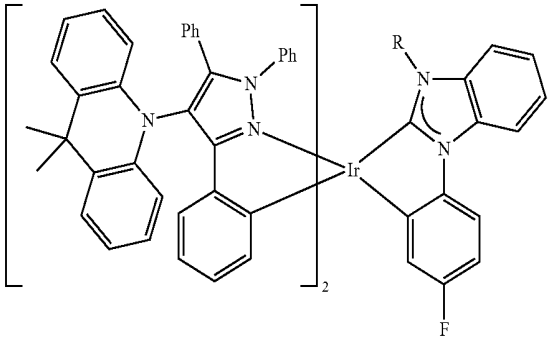

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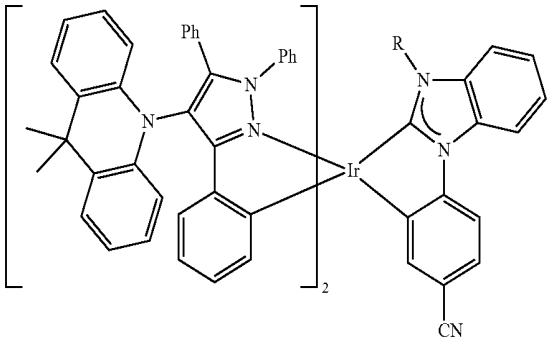

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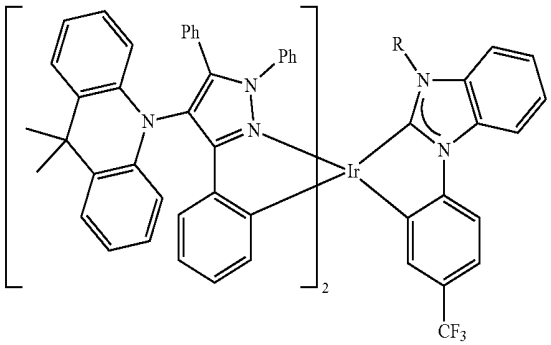

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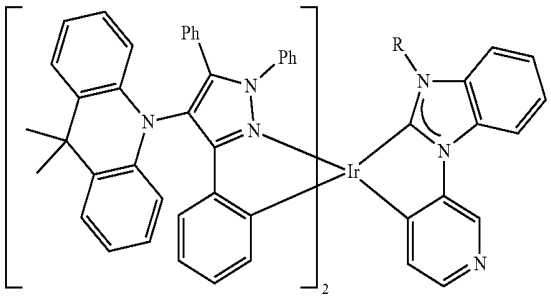

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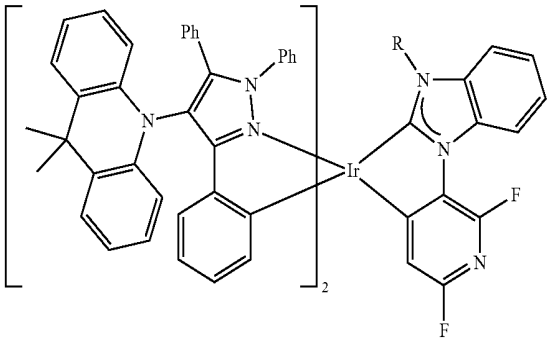

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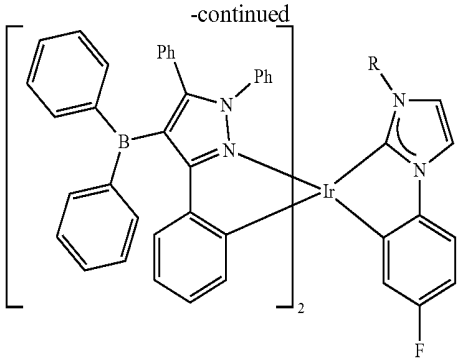

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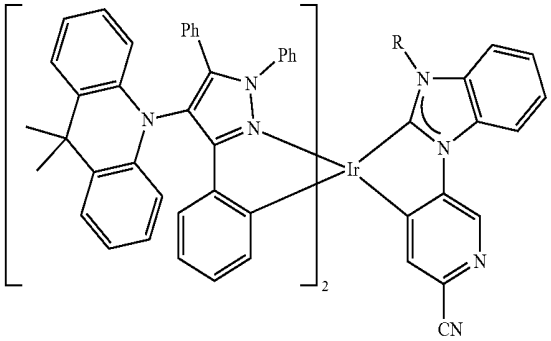
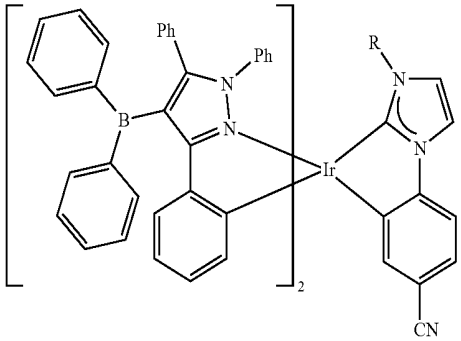
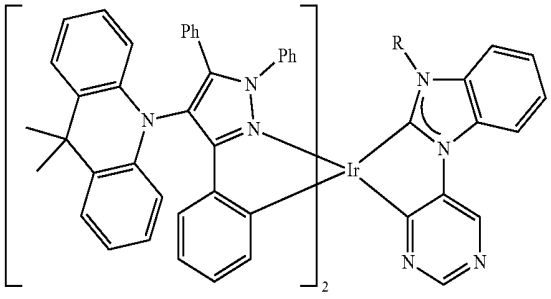


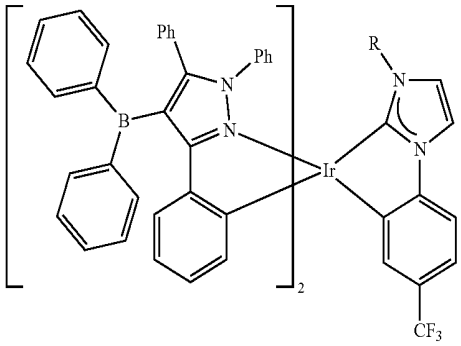
253 (R = Me)
254 (R = Ph)



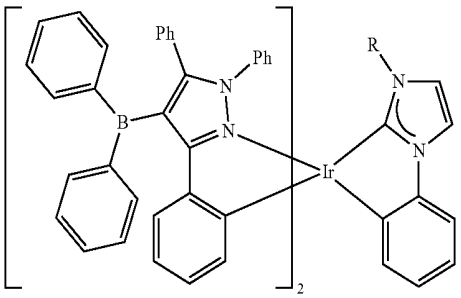
261 (R = Me)
262 (R = Ph)



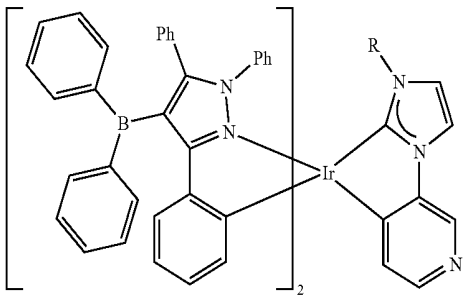
255 (R = Me)
256 (R = Ph)



263 (R = Me)
264 (R = Ph)



257 (R = Me)
258 (R = Ph)



265 (R = Me)
266 (R = Ph)

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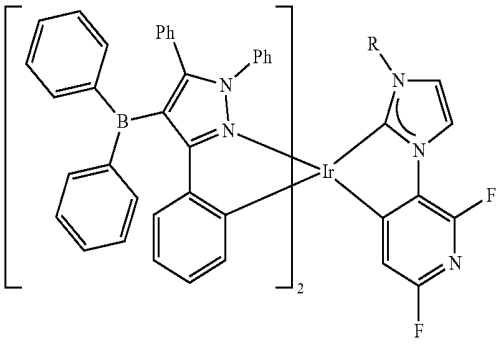

267 (R = Me)
268 (R = Ph)

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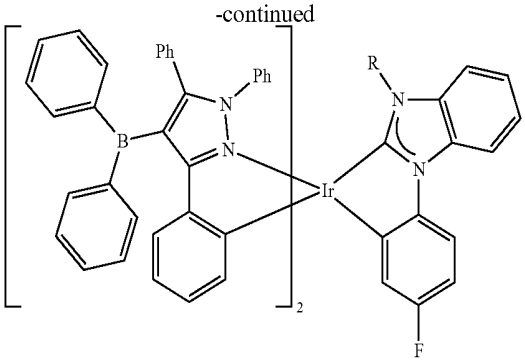
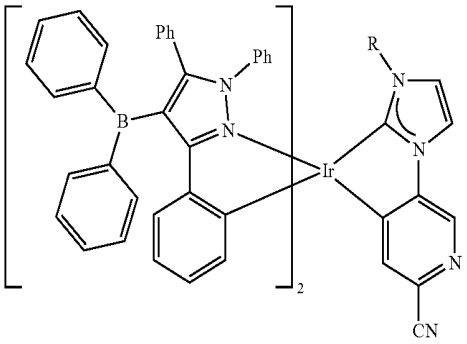
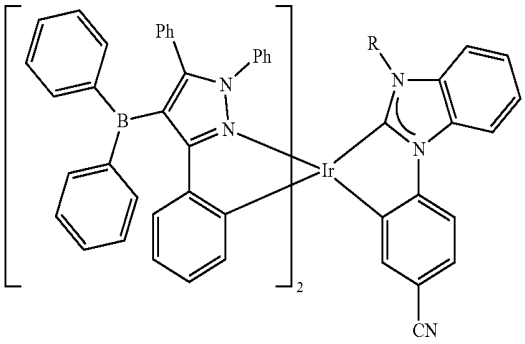


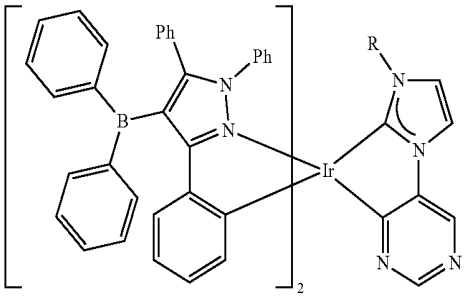
275 (R = Me)
276 (R = Ph)



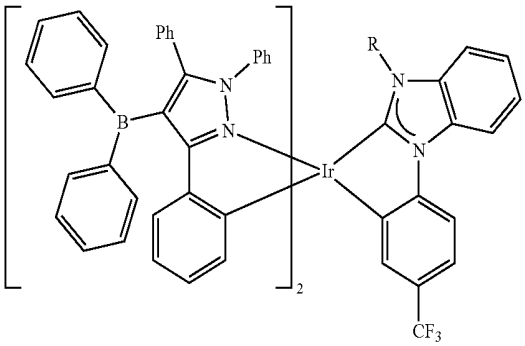
269 (R = Me)
270 (R = Ph)



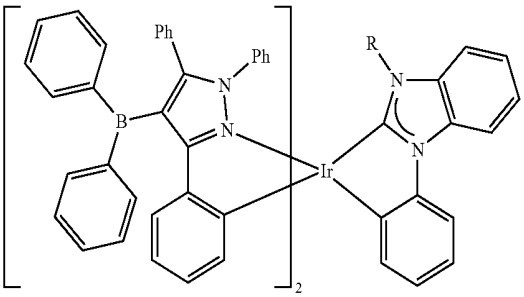
277 (R = Me)
278 (R = Ph)



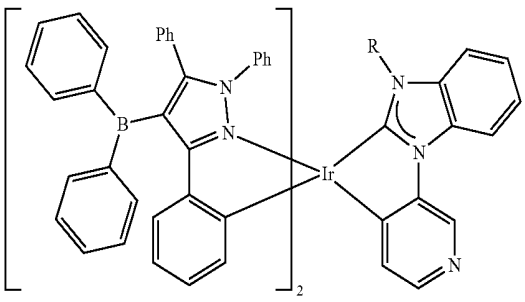
271 (R = Me)
272 (R = Ph)



279 (R = Me)
280 (R = Ph)



273 (R = Me)
274 (R = Ph)



281 (R = Me)
282 (R = Ph)

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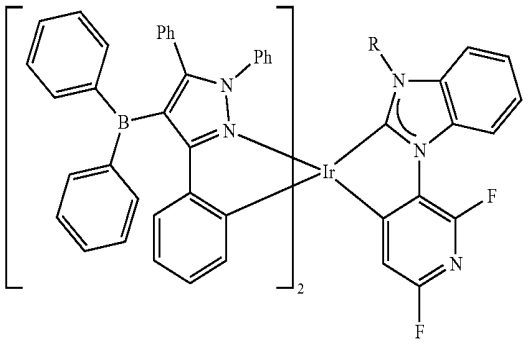
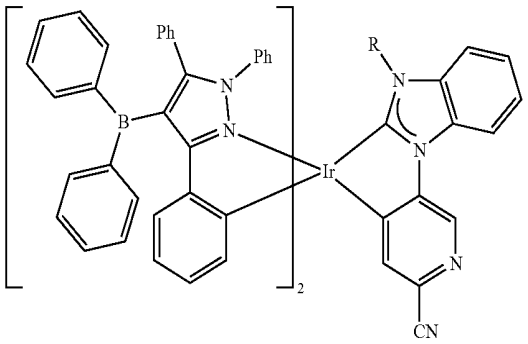
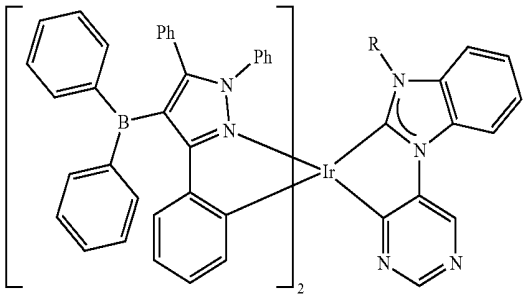


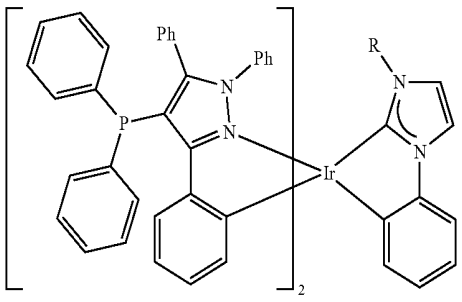
283 (R = Me)
284 (R = Ph)



285 (R = Me)
286 (R = Ph)



287 (R = Me)
288 (R = Ph)



289 (R = Me)
290 (R = Ph)

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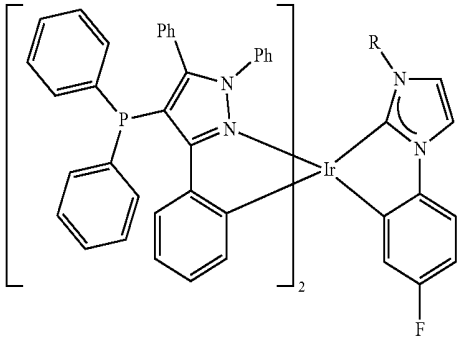
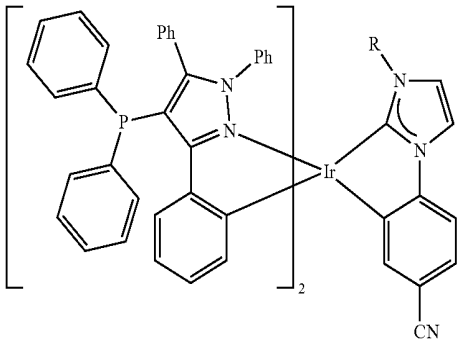
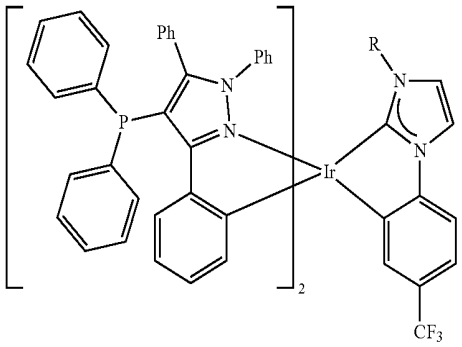


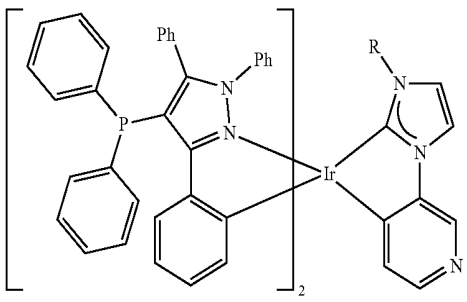
291 (R = Me)
292 (R = Ph)



293 (R = Me)
294 (R = Ph)



295 (R = Me)
296 (R = Ph)



297 (R = Me)
298 (R = Ph)

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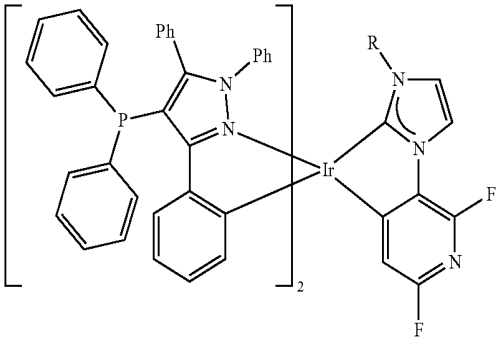
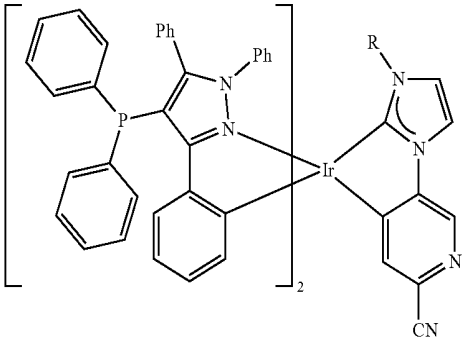
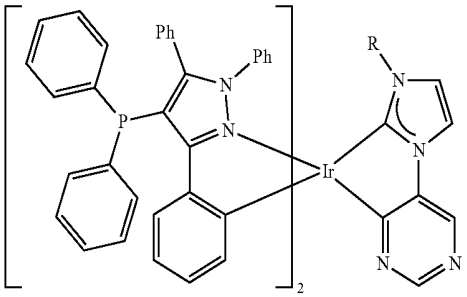


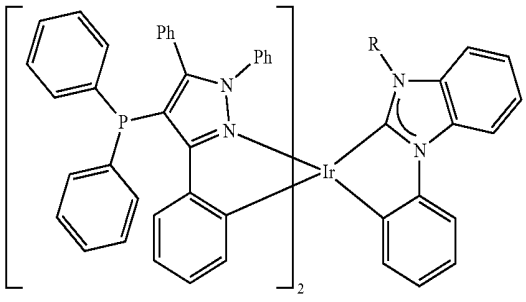
299 (R = Me)
300 (R = Ph)



301 (R = Me)
302 (R = Ph)



303 (R = Me)
304 (R = Ph)



305 (R = Me)
306 (R = Ph)

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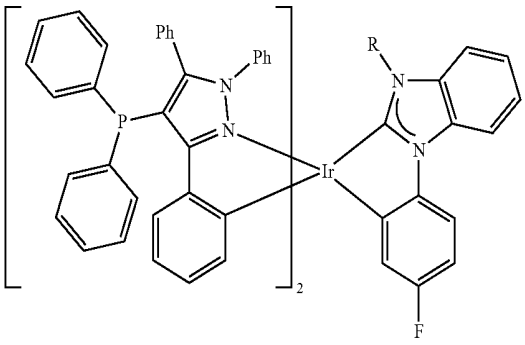
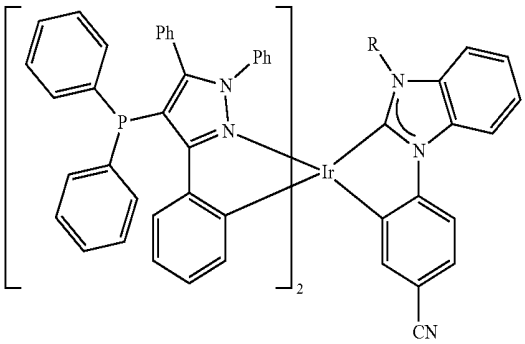
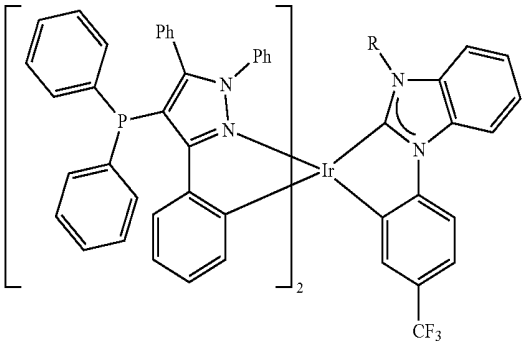


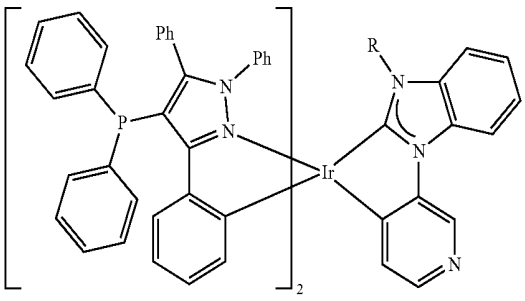
307 (R = Me)
308 (R = Ph)



309 (R = Me)
310 (R = Ph)



311 (R = Me)
312 (R = Ph)



313 (R = Me)
314 (R = Ph)

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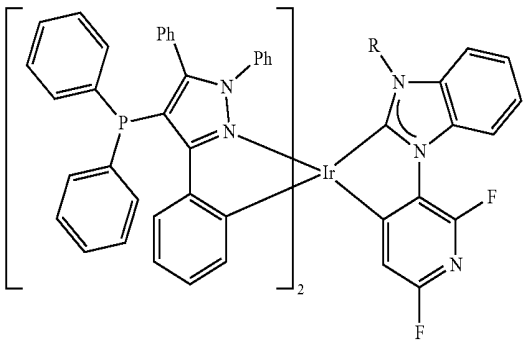

315 (R = Me)
316 (R = Ph)

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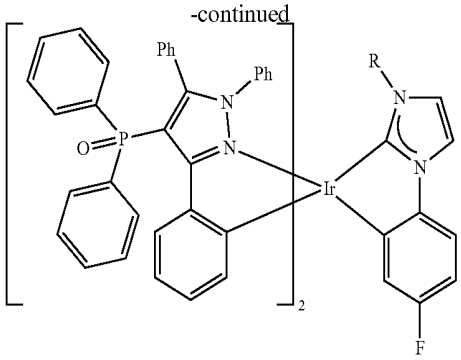
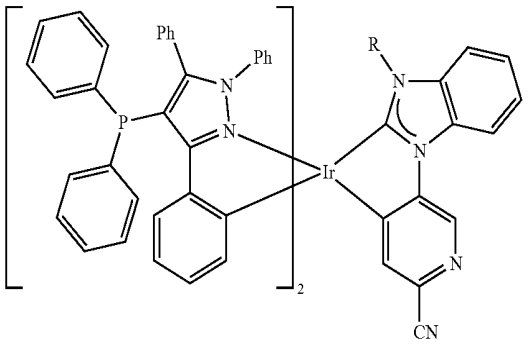
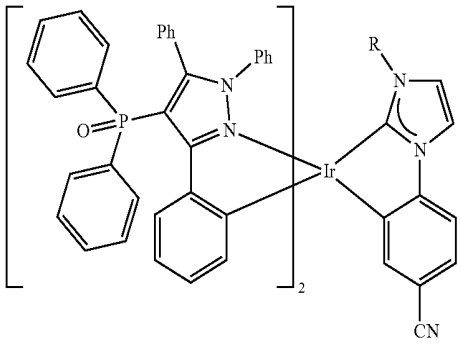


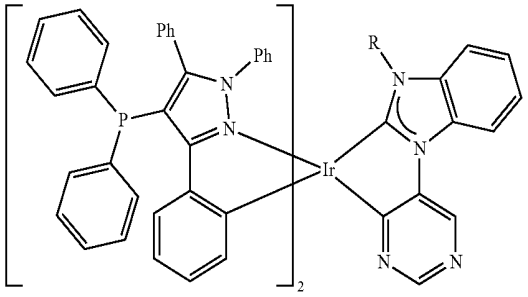
323 (R = Me)
324 (R = Ph)



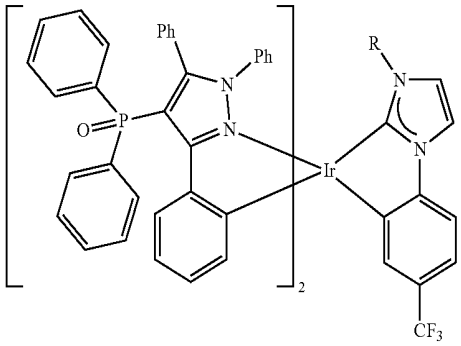
317 (R = Me)
318 (R = Ph)



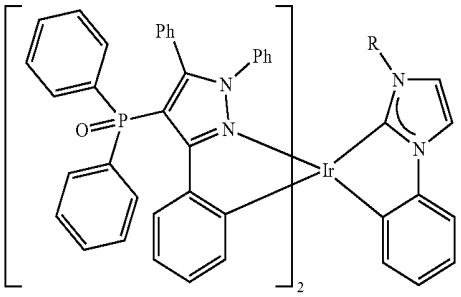
325 (R = Me)
326 (R = Ph)



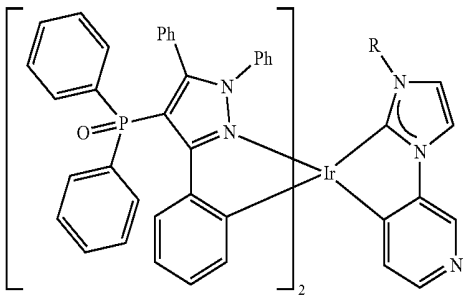
319 (R = Me)
320 (R = Ph)



327 (R = Me)
328 (R = Ph)



321 (R = Me)
322 (R = Ph)



329 (R = Me)
330 (R = Ph)

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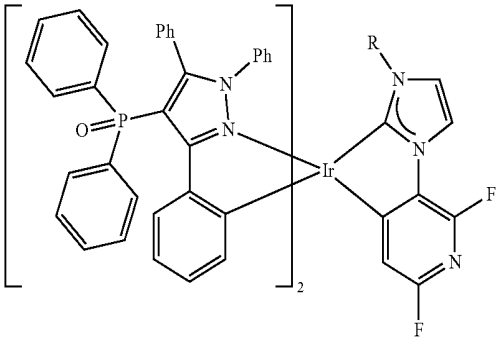
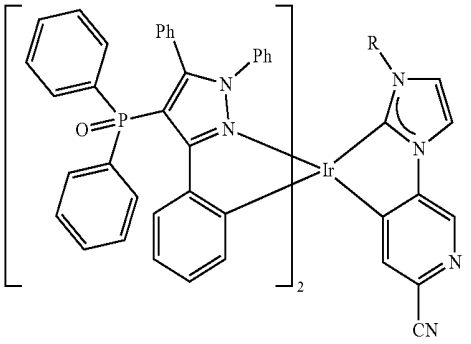
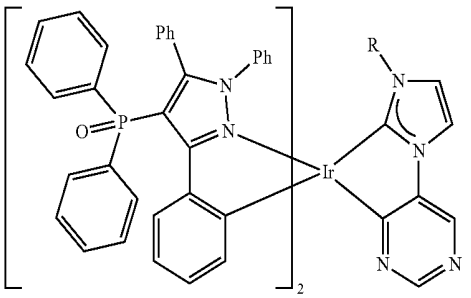


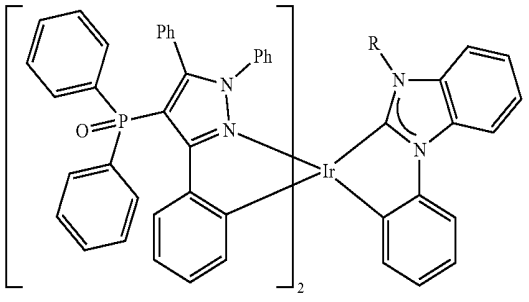
331 (R = Me)
332 (R = Ph)



333 (R = Me)
334 (R = Ph)



335 (R = Me)
336 (R = Ph)



337 (R = Me)
338 (R = Ph)

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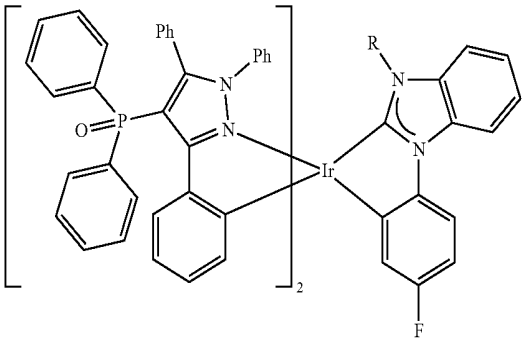
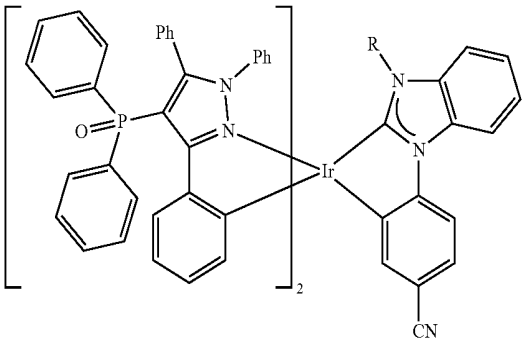
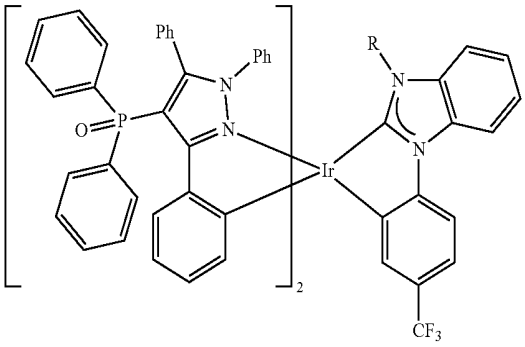


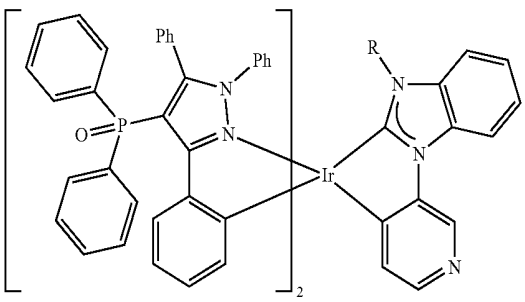
339 (R = Me)
340 (R = Ph)



341 (R = Me)
342 (R = Ph)



343 (R = Me)
344 (R = Ph)



345 (R = Me)
346 (R = Ph)

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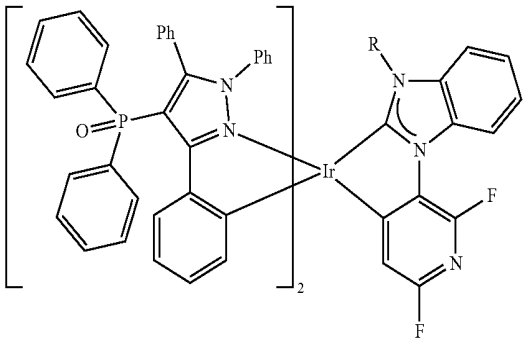

347 (R = Me)
348 (R = Ph)

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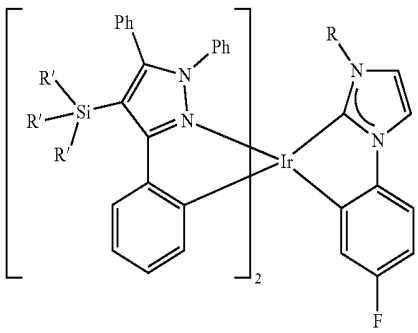
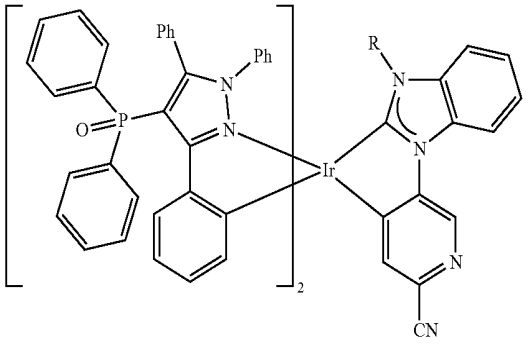
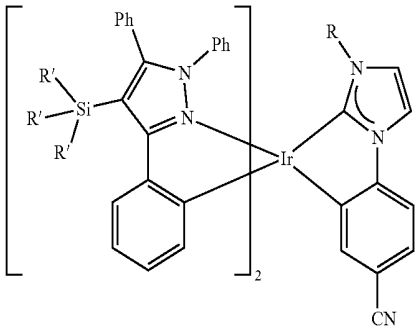


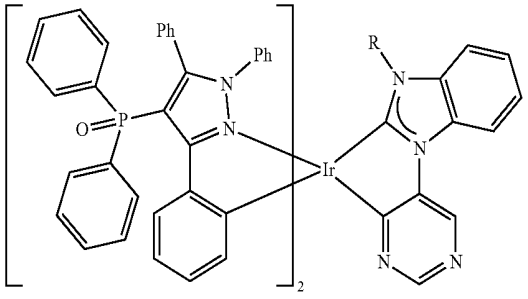
355 (R = Me, R′ = Me)
356 (R = Ph, R′ = Ph)



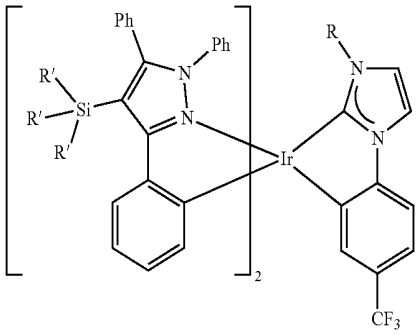
349 (R = Me)
350 (R = Ph)



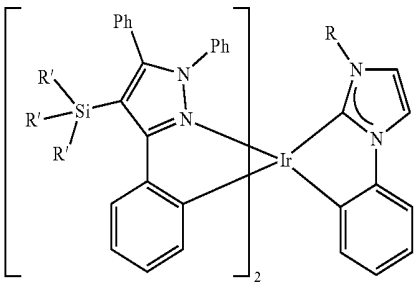
357 (R = Me, R′ = Me)
358 (R = Ph, R′ = Ph)



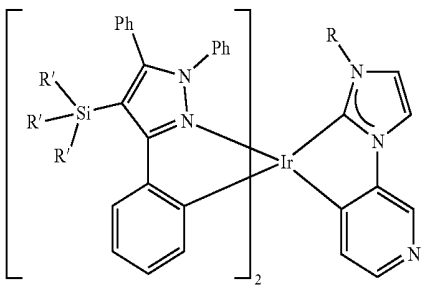
351 (R = Me)
352 (R = Ph)



359 (R = Me, R′ = Me)
360 (R = Ph, R′ = Ph)



353 (R = Me, R′ = Me)
354 (R = Ph, R′ = Ph)



361 (R = Me, R′ = Me)
362 (R = Ph, R′ = Ph)

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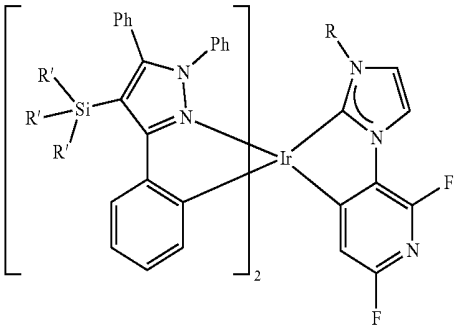
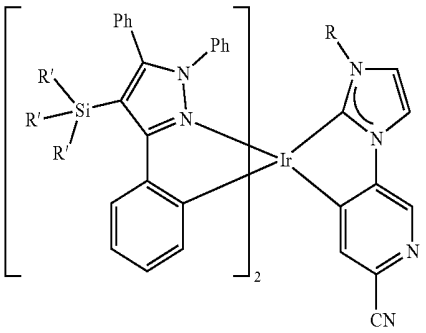
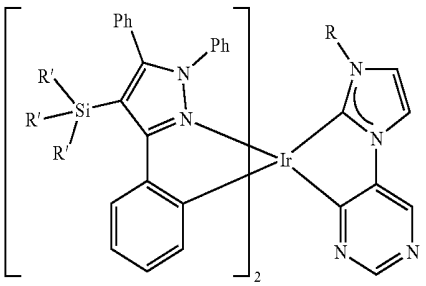


363 (R = Me, R′ = Me)
364 (R = Ph, R′ = Ph)



365 (R = Me, R′ = Me)
366 (R = Ph, R′ = Ph)



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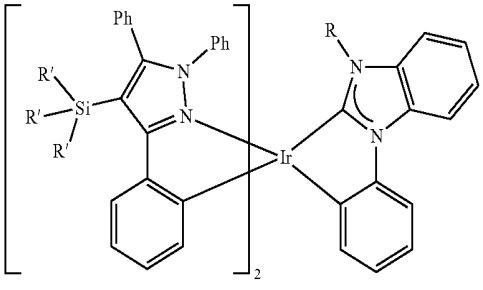

369 (R = Me, R′ = Me)
370 (R = Ph, R′ = Ph)

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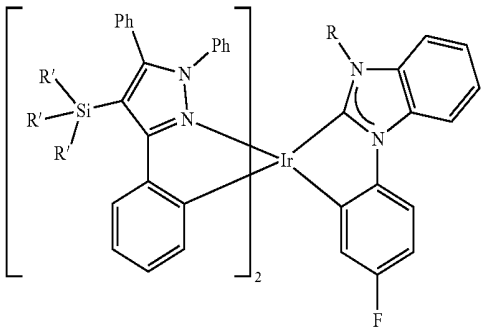

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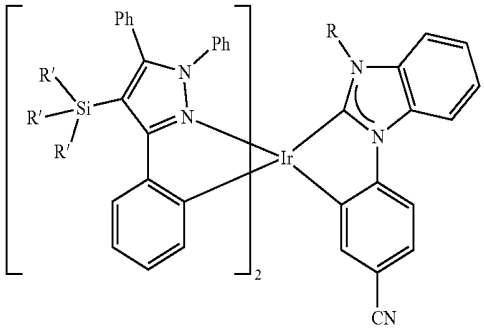
372 (R = Ph, R′ = Ph)



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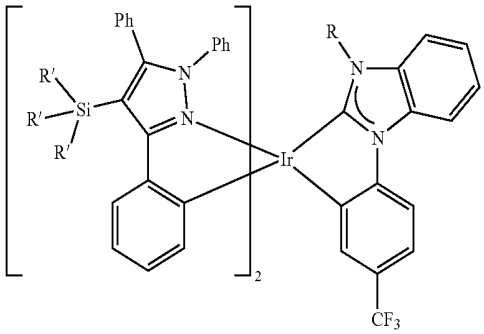

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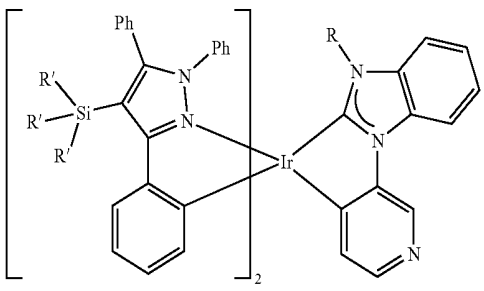
376 (R = Ph, R′ = Ph)



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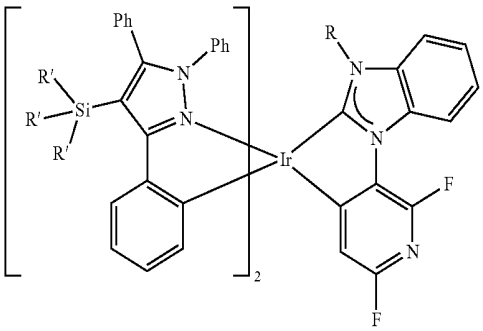

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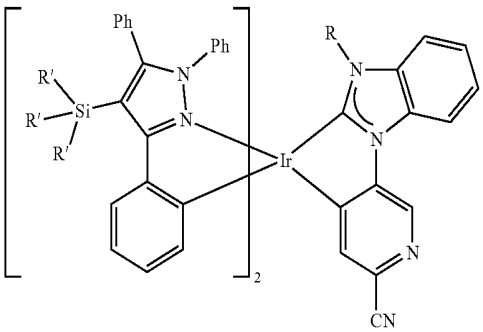

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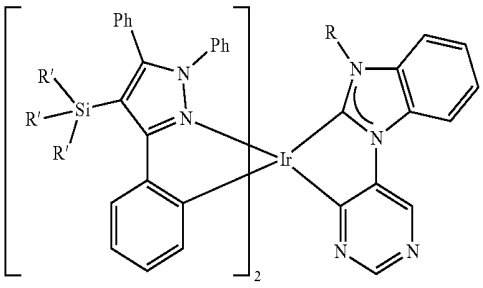
382 (R = Ph, R′ = Ph)



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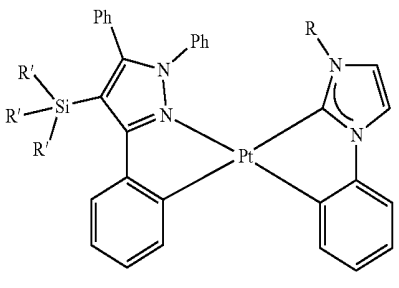
384 (R = Ph, R′ = Ph)



385 (R = Me, R′ = Me)
386 (R = Ph, R′ = Ph)

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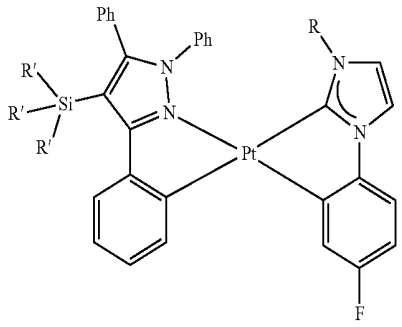

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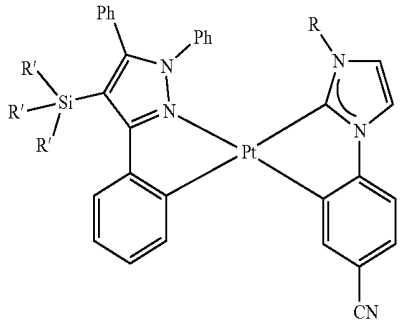
388 (R = Ph, R′ = Ph)



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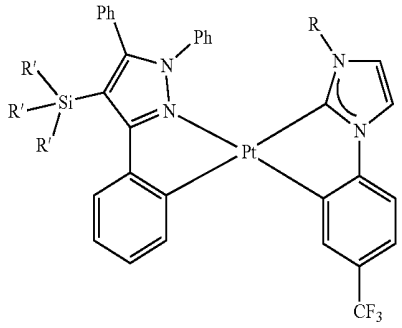
390 (R = Ph, R′ = Ph)



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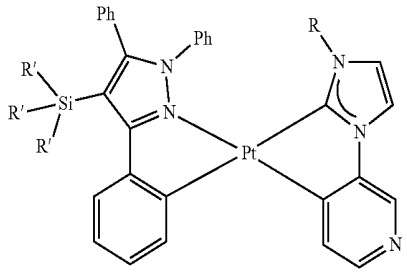
392 (R = Ph, R′ = Ph)



393 (R = Me, R′ = Me)
394 (R = Ph, R′ = Ph)

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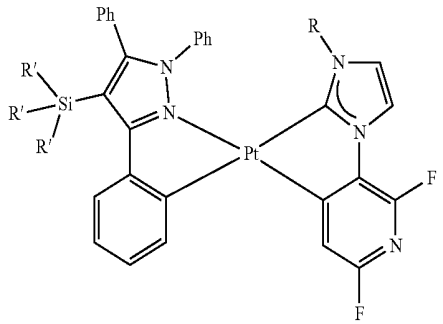
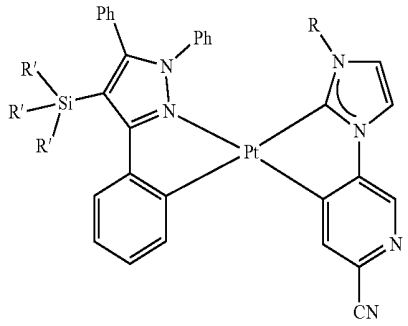
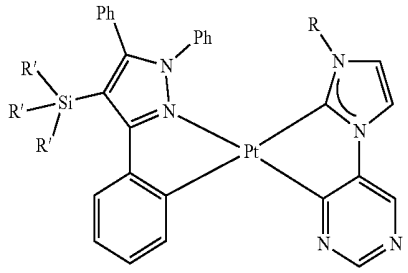


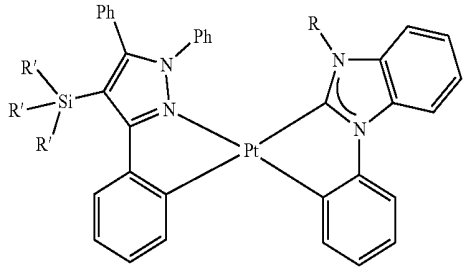
395 (R = Me, R′ = Me)
396 (R = Ph, R′ = Ph)



397 (R = Me, R′ = Me)
398 (R = Ph, R′ = Ph)



399 (R = Me, R′ = Me)
400 (R = Ph, R′ = Ph)



401 (R = Me, R′ = Me)
402 (R = Ph, R′ = Ph)

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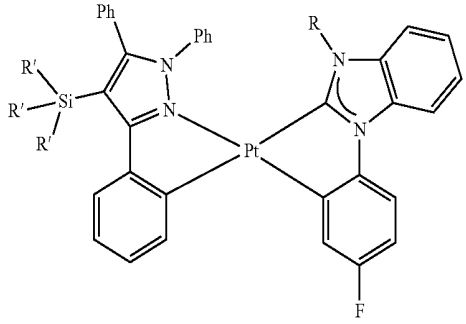
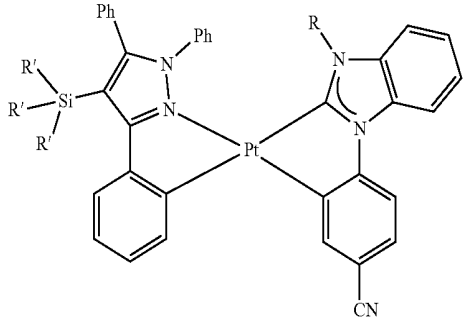


403 (R = Me, R′ = Me)
404 (R = Ph, R′ = Ph)



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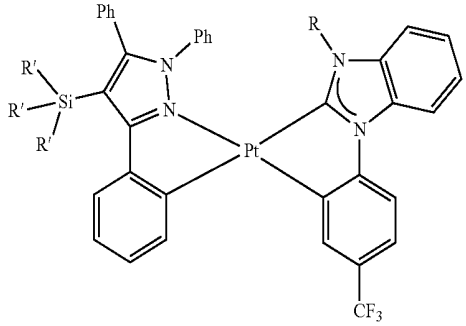
406 (R = Ph, R′ = Ph)



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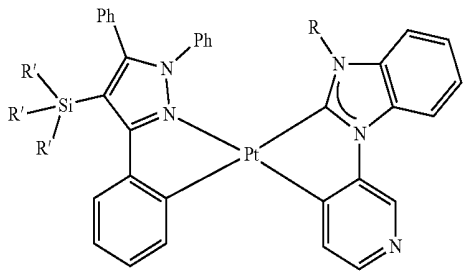
408 (R = Ph, R′ = Ph)



409 (R = Me, R′ = Me)
410 (R = Ph, R′ = Ph)

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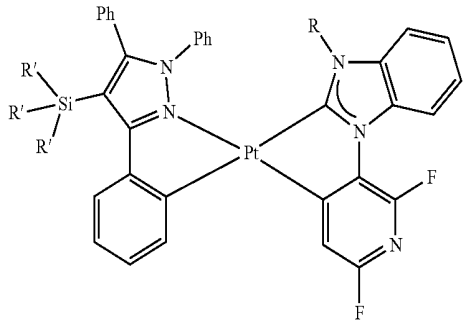
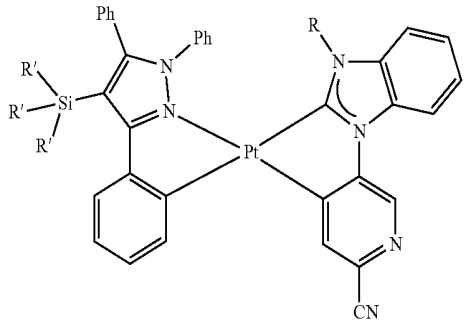
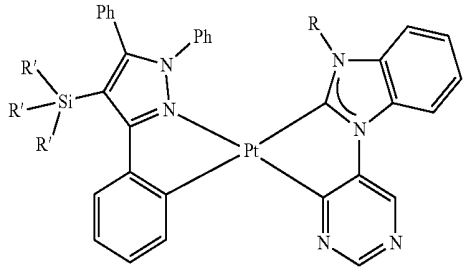


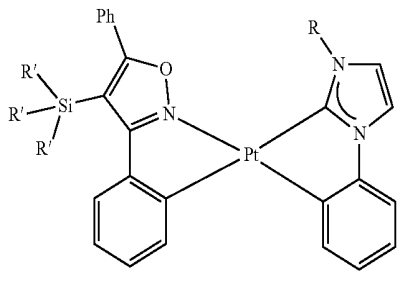
411 (R = Me, R′ = Me)
412 (R = Ph, R′ = Ph)



413 (R = Me, R′ = Me)
414 (R = Ph, R′ = Ph)



415 (R = Me, R′ = Me)
416 (R = Ph, R′ = Ph)



417 (R = Me, R′ = Me)
418 (R = Ph, R′ = Ph)

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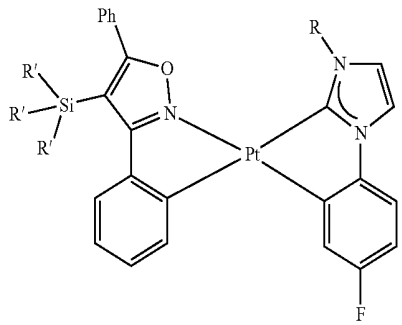

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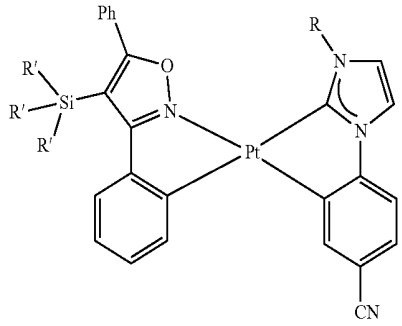
420 (R = Ph, R′ = Ph)



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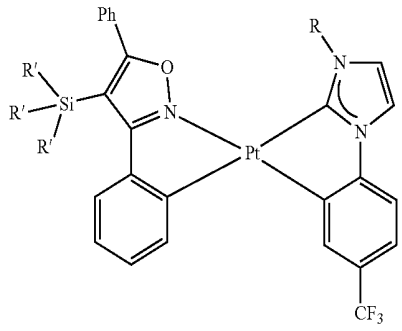

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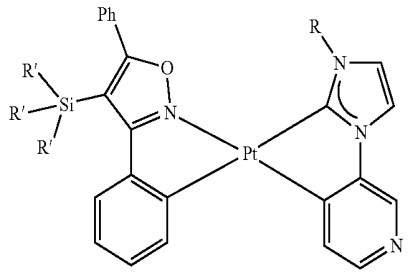
424 (R = Ph, R′ = Ph)



425 (R = Me, R′ = Me)
426 (R = Ph, R′ = Ph)

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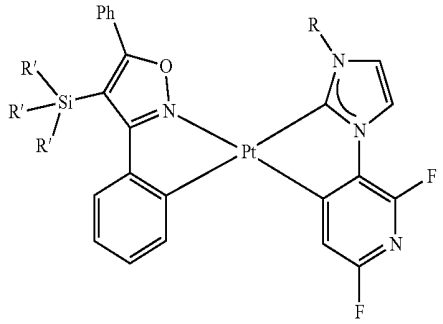

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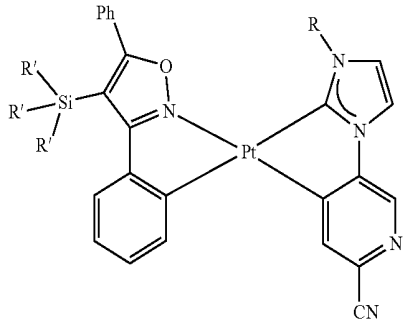
428 (R = Ph, R′ = Ph)



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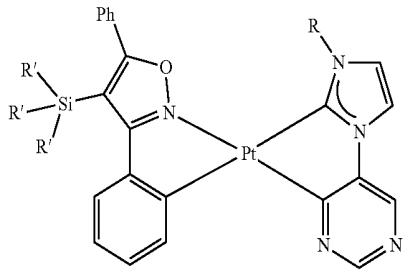

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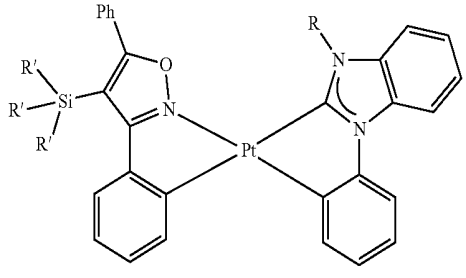

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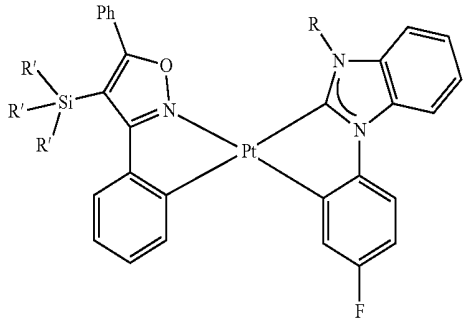

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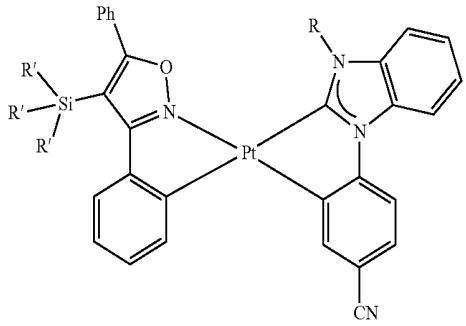

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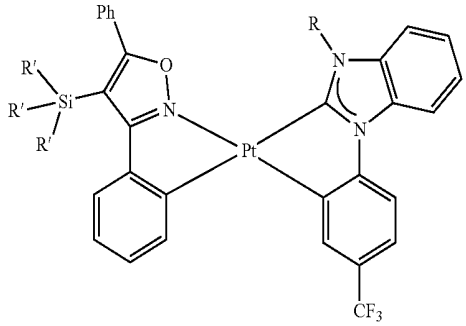

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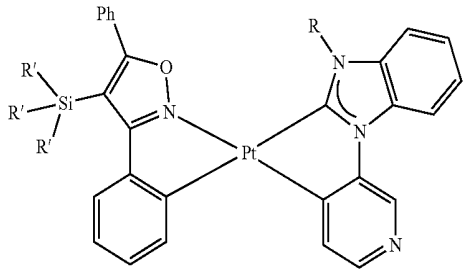

441 (R = Me, R′ = Me)
442 (R = Ph, R′ = Ph)

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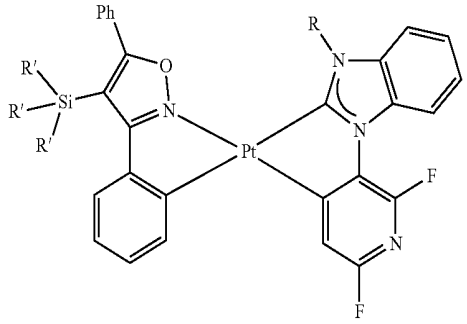

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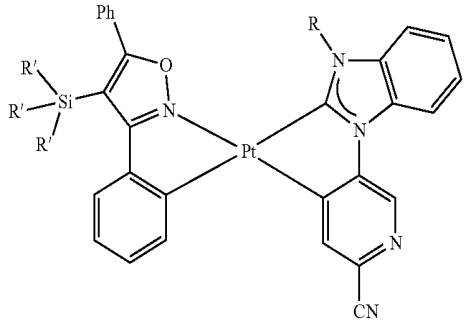

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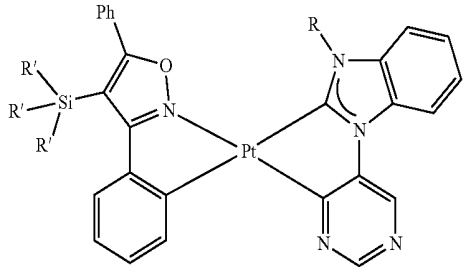
446 (R = Ph, R′ = Ph)



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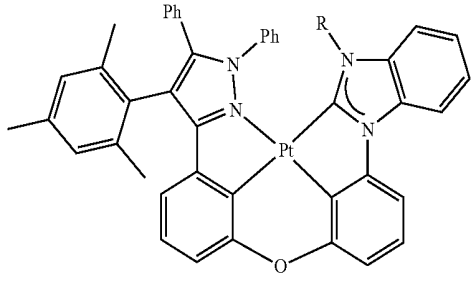

449 (R = Me)
450 (R = Ph)

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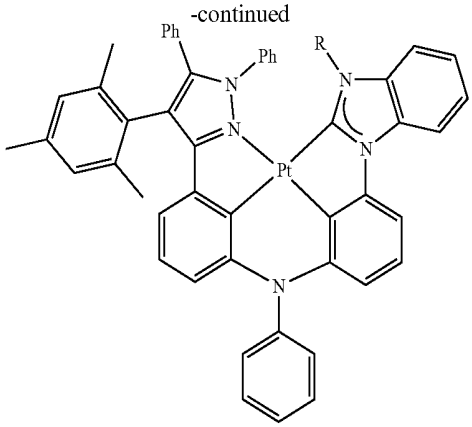
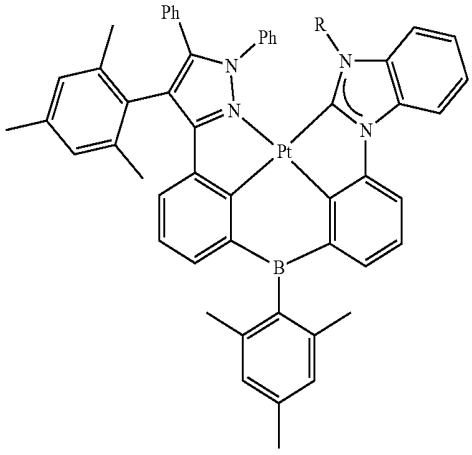


451 (R = Me)
452 (R = Ph)



453 (R = Me)
454 (R = Ph)

wherein, in Compounds 1 to 454, Me indicates a methyl group, and Ph indicates a phenyl group.

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

the organometallic compound emits blue light having an upper emission wavelength of equal to or greater than about 450 nm to less than about 485 nm.

16. An organic light-emitting device comprising:

a first electrode;

a second electrode facing the first electrode; and

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

wherein the organic layer comprises an emission layer and at least one of the organometallic compound of claim **1**.

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

the first electrode is an anode,

the second electrode is a cathode,

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

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

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

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

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

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

the host comprises at least one of a silicon-containing compound and a phosphine oxide-containing compound.

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

the hole transport region comprises a p-dopant having a lowest unoccupied molecular orbital (LUMO) energy level of about −3.5 eV or less.

* * * * *

专利名称(译)	有机化合物和有机发光装置，包括相同的装置		
公开(公告)号	US20190036038A1	公开(公告)日	2019-01-31
申请号	US15/866395	申请日	2018-01-09
[标]申请(专利权)人(译)	三星显示有限公司		
申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
当前申请(专利权)人(译)	三星DISPLAY CO.，LTD.		
[标]发明人	KO SOOBYUNG KIM SUNGBUM JEON MINA AHN HEECHOON JUN MIEUN KIM YOUNGKOOK HWANG SEOKHWAN		
发明人	KO, SOOBYUNG KIM, SUNGBUM JEON, MINA AHN, HEECHOON JUN, MIEUN KIM, YOUNGKOOK HWANG, SEOKHWAN		
IPC分类号	H01L51/00 C07F15/00 C09K11/06 C09K11/02		
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优先权	1020170094319 2017-07-25 KR		
外部链接	Espacenet USPTO		

摘要(译)

本发明提供有机金属化合物和包含该有机金属化合物的有机发光装置。有机发光装置可包括：第一电极;面向第一电极的第二电极;在第一电极和第二电极之间并包括发光层的有机层，该有机层包括至少一种有机金属化合物。