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

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(57) **ABSTRACT**

An organometallic compound represented by Formula 1:

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

wherein in Formula 1, M, L_1, L_2, n1, and n2 are the same as described in the specification.

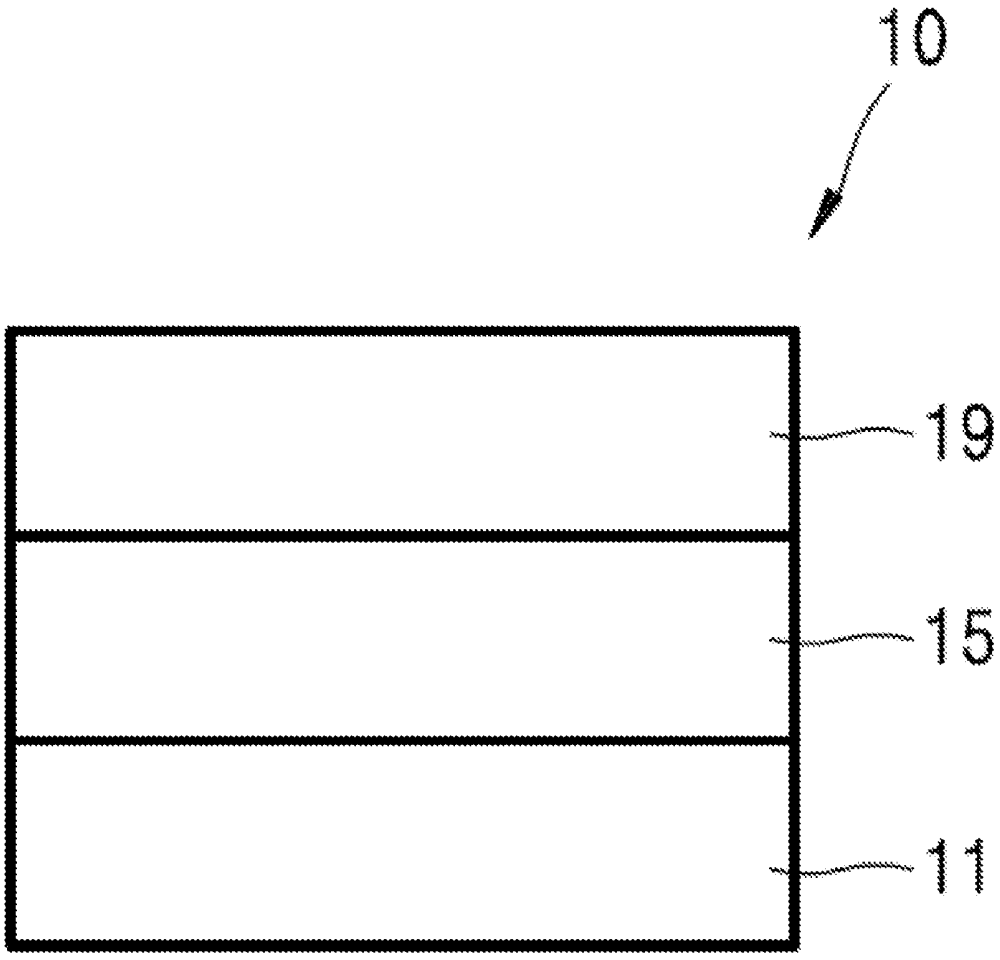
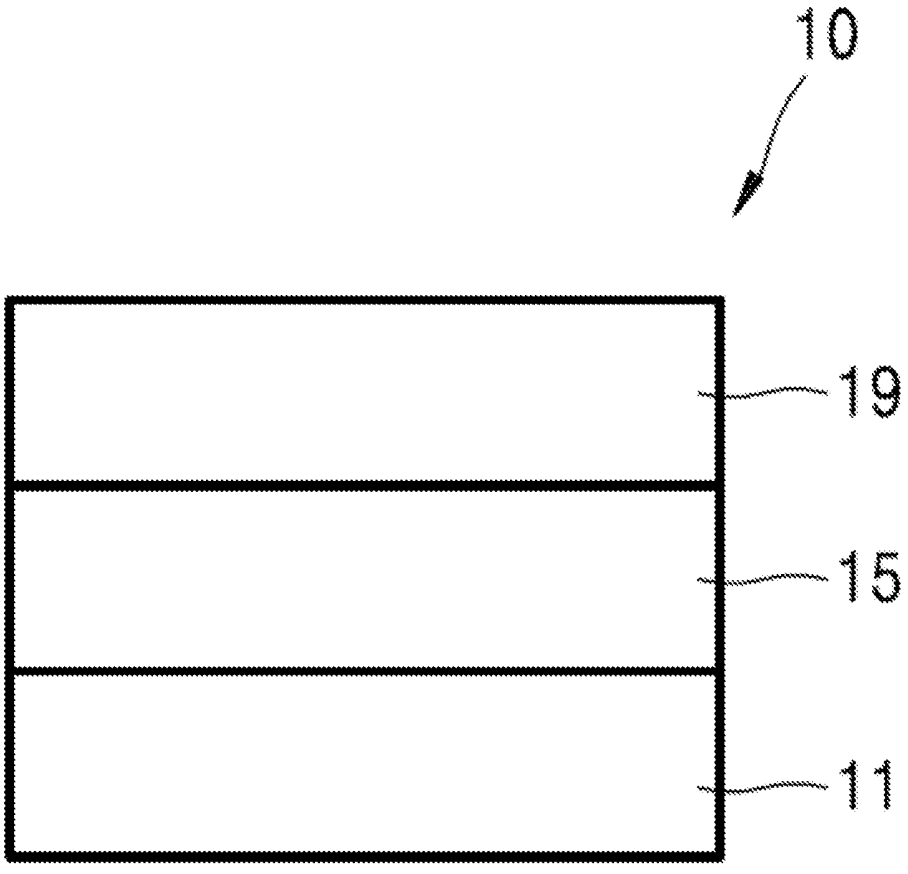


FIG. 1



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 Applications No. 10-2014-0169185, filed on Nov. 28, 2014 and Korean Patent Applications No. 10-2015-0103013, filed on Jul. 21, 2015, in the Korean Intellectual Property Office, the contents of which are incorporated herein in their entirety by reference.

BACKGROUND

[0002] 1. Field

[0003] The present disclosure relates to an organometallic compound and an organic light-emitting device including the same.

[0004] 2. Description of the Related Art

[0005] Organic light-emitting devices (OLEDs) are self-emission devices that have wide viewing angles, high contrast ratios, and short response times. In addition, OLEDs exhibit excellent brightness, driving voltage, and response speed characteristics, and produce full-color images.

[0006] In an example, an organic light-emitting device includes an anode, a cathode, and an organic layer including an emission layer disposed between the anode and the cathode. A hole transport region may be disposed between the anode and the emission layer, and an electron transport region may be disposed between the emission layer and the cathode. Holes provided from the anode may move toward the emission layer through the hole transport region, and electrons provided from the cathode may move toward the emission layer through the electron transport region. The holes and the electrons recombine in the emission layer to produce excitons. These excitons change from an excited state to a ground state, thereby generating light.

[0007] Different types of organic light emitting devices are known. However, there still remains a need in OLEDs having low driving voltage, high efficiency, high brightness, and long lifespan.

SUMMARY

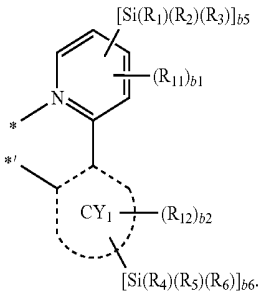
[0008] Provided are a novel organometallic compound and an organic light-emitting device including the same.

[0009] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented exemplary embodiments.

[0010] According to an aspect of an exemplary embodiment, an organometallic compound is represented by Formula 1:

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

Formula 2



[0011] M in Formula 1 is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, Tm, and Rh,

[0012] L_1 in Formula 1 is selected from ligands represented by Formula 2, n1 is 1, 2, or 3, provided that when n1 is 2 or greater, two or more groups L_1 are identical to or different from each other,

[0013] L_2 in Formula 1 is selected from a monovalent organic ligand, a divalent organic ligand, a trivalent organic ligand, and a tetravalent organic ligand, n2 is 0, 1, 2, 3, or 4, provided that when n2 is 2 or greater, two or more groups L_2 are identical to or different from each other,

[0014] L_1 and L_2 in Formula 1 are different from each other,

[0015] CY_1 in Formula 2 is a C_1-C_{18} condensed cyclic ring i) in which two to four unsaturated 6-membered rings are condensed to each other and ii) which optionally has N as a ring forming atom,

[0016] R_1 to R_6, R_{11}, and R_{12} in Formula 2 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF_5, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_8)(Q_9)$,

[0017] b1, b2, b5, and b6 in Formula 2 are each independently an integer selected from 0 to 4, provided that the sum of b5 and b6 is 1 or greater,

[0018] each of * and *' in Formula 2 is a binding site to M in Formula, and

[0019] at least one of substituents of the substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, sub-

stituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is selected from

[0020] 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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;

[0021] 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, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, $—Si(Q_{11})(Q_{12})(Q_{13})$, $—N(Q_{14})(Q_{15})$, $—B(Q_{16})(Q_{17})$, and $—P(=O)(Q_{18})(Q_{19})$;

[0022] 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;

[0023] 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, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, $—Si(Q_{21})(Q_{22})(Q_{23})$, $—N(Q_{24})(Q_{25})$, $—B(Q_{26})(Q_{27})$ and $—P(=O)(Q_{28})(Q_{29})$; and

[0024] $—Si(Q_{31})(Q_{32})(Q_{33})$, $—N(Q_{34})(Q_{35})$, $—B(Q_{36})(Q_{37})$, and $—P(=O)(Q_{38})(Q_{39})$,

[0025] wherein Q_1 to Q_9, Q_{11} to Q_{19}, Q_{21} to Q_{29}, and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0026] According to an aspect of another exemplary embodiment, an organic light-emitting device includes:

[0027] a first electrode;

[0028] a second electrode; and

[0029] an organic layer disposed between the first electrode and the second electrode,

[0030] wherein the organic layer includes an emission layer and at least one organometallic compound represented by Formula 1.

[0031] The emission layer may include the organometallic compound.

[0032] The organometallic compound included in the emission layer may act as a dopant and the emission layer may act as a host.

BRIEF DESCRIPTION OF THE DRAWING

[0033] These and/or other aspects will become apparent and more readily appreciated from the following description of the exemplary embodiments, taken in conjunction with FIG. **1** which is a schematic cross-sectional view of an organic light-emitting device according to an exemplary embodiment.

DETAILED DESCRIPTION

[0034] Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present exemplary embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the exemplary embodiments are merely described below, by referring to the figures, to explain aspects. 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.

[0035] It will be understood that when an element is referred to as being "on" another element, it can be directly in contact with the other element or intervening elements may be present therebetween. In contrast, when an element is referred to as being "directly on" another element, there are no intervening elements present.

[0036] 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 only 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 discussed below could be termed a second element, component, region, layer, or section without departing from the teachings of the present embodiments.

[0037] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0038] The term "or" means "and/or." It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this specification, specify the presence of stated features, regions, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0039] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this general inventive concept belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0040] "About" or "approximately" as used herein is inclusive of the stated value and means within an acceptable range of deviation for the particular value as determined by one of ordinary skill in the art, considering the measurement in question and the error associated with measurement of the particular quantity (i.e., the limitations of the measurement system). For example, "about" can mean within one or more standard deviations, or within ±30%, 20%, 10%, 5% of the stated value.

[0041] Exemplary embodiments are described herein with reference to cross section illustrations that are schematic illustrations of idealized embodiments. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments described herein should not be construed as limited to the particular shapes of regions as illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, a region illustrated or described as flat may, typically, have rough and/or nonlinear features. Moreover, sharp angles that are illustrated may be rounded. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the precise shape of a region and are not intended to limit the scope of the present claims.

[0042] An organometallic compound according to an exemplary embodiment is represented by Formula 1:

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

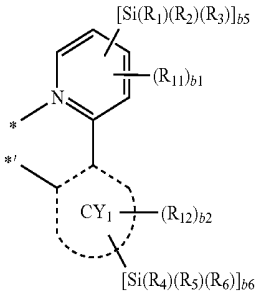
[0043] M in Formula 1 may be selected from iridium (Ir), platinum (Pt), osmium (Os), titanium (Ti), zirconium (Zr), hafnium (Hf), europium (Eu), terbium (Tb), thulium (Tm), and rhodium (Rh).

[0044] For example, M in Formula 1 may be selected from iridium, platinum, osmium, and rhodium.

[0045] In an embodiment, M in Formula 1 may be selected from iridium and platinum, but is not limited thereto.

[0046] L_1 in Formula 1 may be selected from ligands represented by Formula 2, n1 is 1, 2, or 3, provided that when n1 is 2 or greater, two or more groups L_1 may be identical to or different from each other.

Formula 2



[0047] L_2 in Formula 1 may be selected from a monovalent organic ligand, a divalent organic ligand, a trivalent organic ligand, and a tetravalent organic ligand, n2 may be 0, 1, 2, 3, or 4, provided that when n2 is 2 or greater, two or more groups L_2 may be identical to or different from each other.

[0048] L_1 and L_2 in Formula 1 may be different from each other.

[0049] For example, n1 in Formula 1 may be 1 or 2, but is not limited thereto.

[0050] In some embodiments, the organometallic compound represented by Formula 1 may not be a salt consisting of an ion pair, but be neutral.

[0051] In an embodiment, M in Formula 1 may be Ir and the sum of n1 and n2 may be 3; or M is Pt, the sum of n1 and n2 may be 2, and the organometallic compound represented by Formula 1 may be neutral.

[0052] CY_1 in Formula 2 may be a C_1-C_{18} condensed cyclic ring i) in which two to four unsaturated 6-membered rings are condensed to each other and ii) which optionally has nitrogen (N) as a ring forming atom.

[0053] For example, CY_1 in Formula 2 may be selected from a naphthalene, a phenanthrene, an anthracene, a triphenylene, a pyrene, a chrysene, a naphthacene, a tetraphene, a tetracene, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, and a phenazine.

[0054] In an embodiment, CY_1 in Formula 2 may be selected from a naphthalene, a phenanthrene, an anthracene, a triphenylene, a pyrene, a chrysene, a naphthacene, a tetraphene, and a tetracene.

[0055] In some embodiments, CY_1 in Formula 2 may be a triphenylene, but is not limited thereto.

[0056] R_1 to R_6, R_{11}, and R_{12} in Formula 2 may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF_5, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_8)(Q_9)$.

[0057] For example, R_{11} and R_{12} in Formula 2 may be each independently selected from

[0058] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF_5, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0059] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl (adamantyl) group, a norbornanyl (norbornyl) 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;

[0060] 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 benzoimidazolyl 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;

[0061] 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 benzoimidazolyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl 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 benzoimidazolyl 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

[0062] —$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

[0063] wherein Q_6 to Q_9 are each independently selected from

[0064] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0065] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl

group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0066] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

[0067] In some embodiments, R_{11} and R_{12} in Formula 2 may be each independently selected from

[0068] hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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;

[0069] a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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, each substituted with at least one selected from deuterium, —F, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} 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 pyridinyl group, and a pyrimidinyl group; and

[0070] —$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

[0071] wherein Q_6 to Q_9 are each independently selected from

[0072] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0073] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0074] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

[0075] In some embodiments, R_1 to R_6 in Formula 2 may be each independently selected from

[0076] a C_1-C_{10} alkyl group, a phenyl group, and —$Si(Q_1)(Q_2)(Q_3)$; and

[0077] a C_1-C_{10} alkyl group and a phenyl group, each substituted with at least one selected from deuterium and a C_1-C_{10} alkyl group,

[0078] wherein Q_1 to Q_3 are each independently selected from

[0079] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0080] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0081] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

[0082] In Formula 2,

[0083] R_1 to R_3 may all be identical;

[0084] R_1 and R_3 may be identical to each other and R_2 and R_1 may be different from each other; or

[0085] R_1 to R_3 may all be different, and

[0086] R_4 to R_6 may all be identical;

[0087] R_4 and R_6 may be identical to each other and R_5 and R_4 may be different from each other; or

[0088] R_4 to R_6 may all be different from each other.

[0089] In an embodiment, R_{11} and R_{12} in Formula 2 may be each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38,

[0090] R_1 to R_6 in Formula 2 may be each independently selected from

[0091] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0092] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl

group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, a phenyl group, and —Si(Q_1)(Q_2)(Q_3); and

[0093] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, and a phenyl group, each substituted with at least one selected from a deuterium and a C_1-C_{10} alkyl group,

[0094] wherein Q_1 to Q_3 are each independently selected from

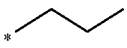
[0095] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0096] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0097] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group:

Formula 9-1

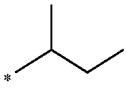
Formula 9-2



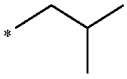
Formula 9-3

Formula 9-4

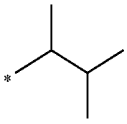
Formula 9-5



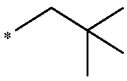
Formula 9-6



Formula 9-7



Formula 9-8



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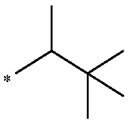
Formula 9-9



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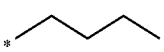
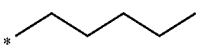
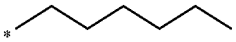


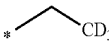
Formula 9-11



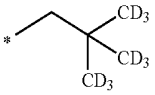
Formula 9-12



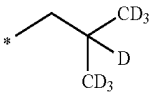
Formula 9-13



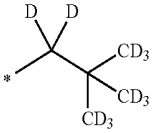
Formula 9-14



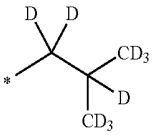
Formula 9-15



Formula 9-16



Formula 9-17



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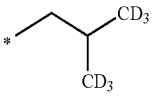
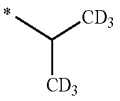
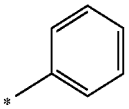


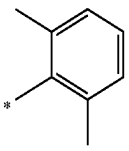
Formula 9-19



Formula 10-1



Formula 10-2



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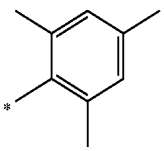

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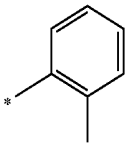
Formula 10-4



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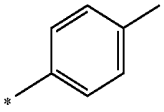
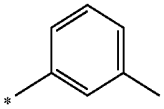


Formula 10-6



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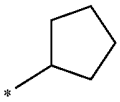
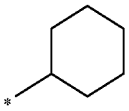
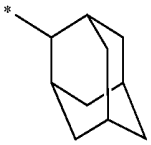


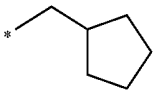
Formula 10-8



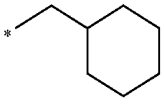
Formula 10-9



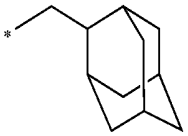
Formula 10-10



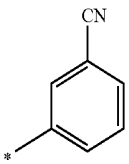
Formula 10-11



Formula 10-12



Formula 10-13



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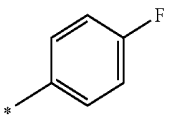

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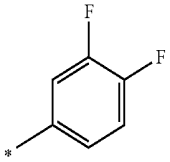

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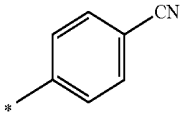

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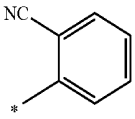

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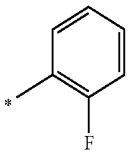

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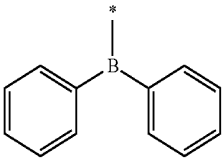

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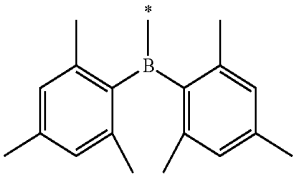
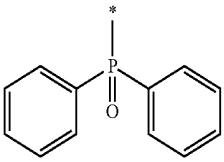
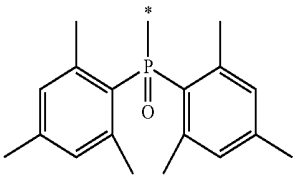


Formula 10-21



Formula 10-22



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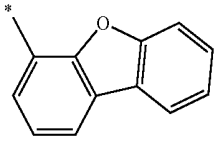

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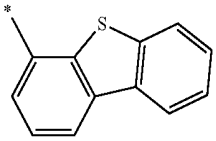

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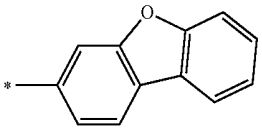

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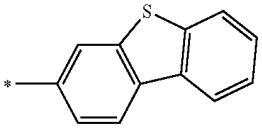

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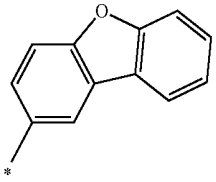

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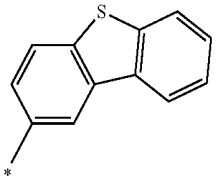

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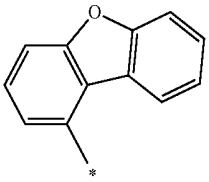
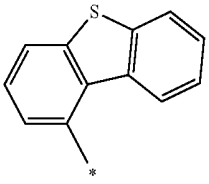


Formula 10-30



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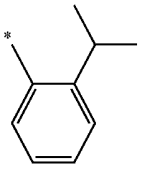
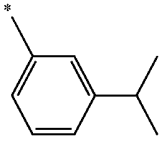


Formula 10-32



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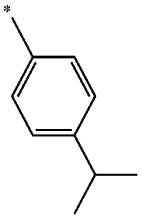
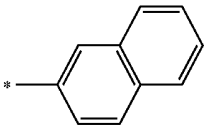


Formula 10-34



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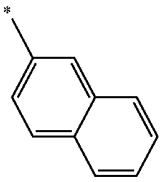
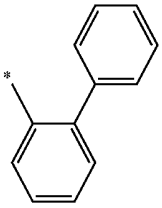
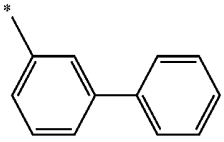


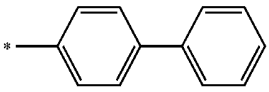
Formula 10-36



Formula 10-37



Formula 10-38



* in Formulae 9-1 to 9-19 and 10-1 to 10-38 is a binding site to a neighboring atom.

[0098] b1 in Formula 2 indicates the number of groups R_{11}, and is an integer selected from 0 to 4. When b1 is 2 or greater, two or more groups R_{11} may be identical to or different from each other.

[0099] b2 in Formula 2 indicates the number of groups R_{12}, and is an integer selected from 0 to 4. When b2 is 2 or greater, two or more groups R_{12} may be identical to or different from each other.

[0100] b5 in Formula 2 indicates the number of groups *—[$Si(R_1)(R_2)(R_3)$], and is an integer selected from 0 to 4. When b5 is 2 or greater, two or more groups *—[$Si(R_1)(R_2)(R_3)$] may be identical to or different from each other. For example, b5 may be 1, 2, or 3, or may be 1.

[0101] b6 in Formula 2 indicates the number of groups *—[$Si(R_4)(R_5)(R_6)$], and is an integer selected from 0 to 4. When b6 is 2 or greater, two or more groups *—[$Si(R_4)(R_5)(R_6)$] may be identical to or different from each other. For example, b6 may be 0, 1, or 2, or may be 0.

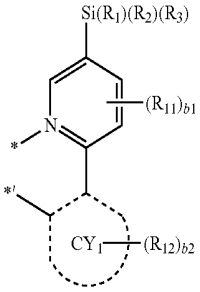
[0102] The sum of b5 and b6 in Formula 2 may be 1 or greater.

[0103] In an embodiment, in Formula 2, b5 may be 1 or 2 and b6 may be 0 or 1, but they are not limited thereto.

[0104] Each of* and *' in Formula 2 indicates a binding site to M in Formula 1.

[0105] In an embodiment, L_1 in Formula 1 may be selected from ligands represented by Formula 2(1):

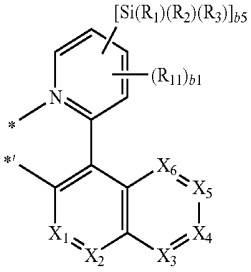
Formula 2(1)



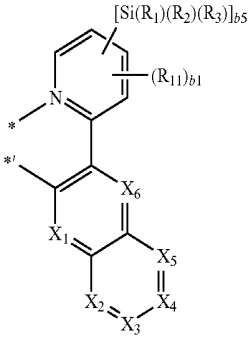
[0106] Descriptions of CY_1, R_1 to R_3, R_{11}, R_{12}, b1, and b2 in Formula 2(1) are the same as presented above, and each of * and *' indicates a binding site to M in Formula 1.

[0107] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formulae 2-1 to 2-47:

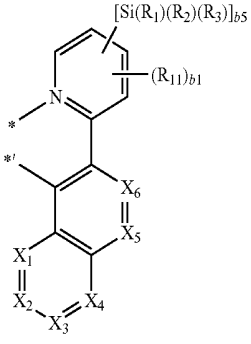
Formula 2-1



Formula 2-2



Formula 2-3



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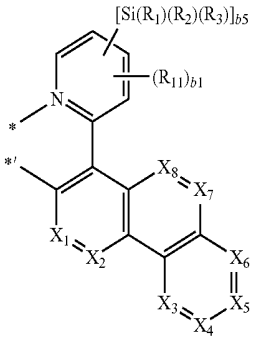
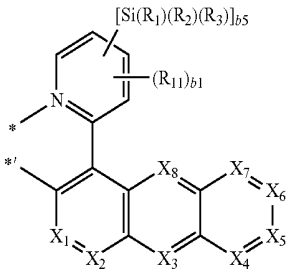
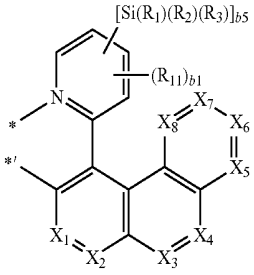
Formula 2-4



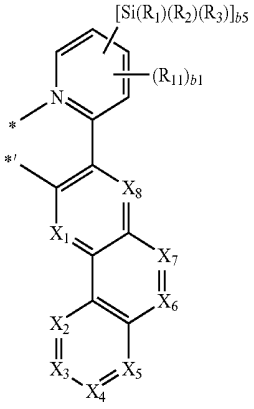
Formula 2-5



Formula 2-6



Formula 2-7



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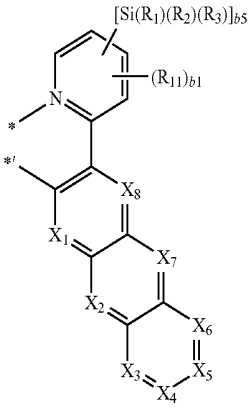
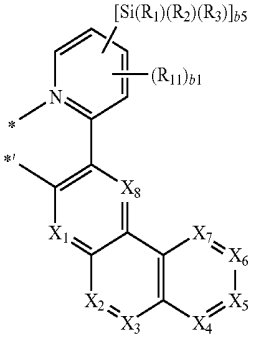
Formula 2-8



Formula 2-9



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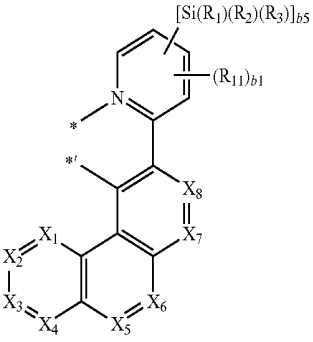
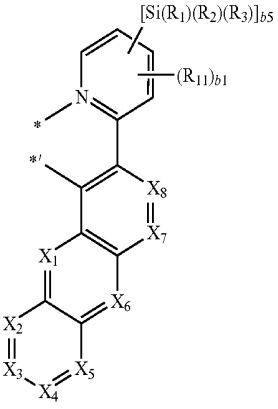


Formula 2-11



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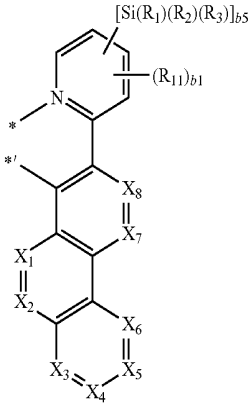
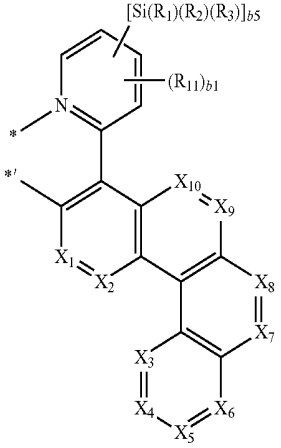
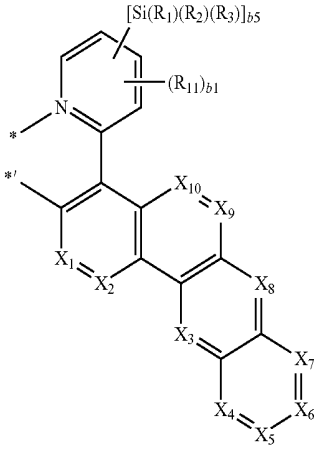
Formula 2-12



Formula 2-13



Formula 2-14



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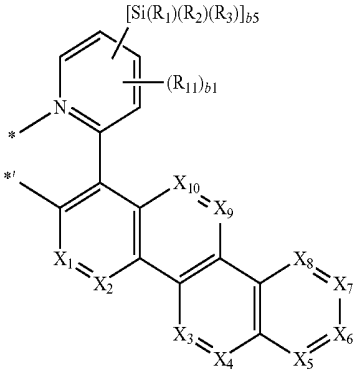
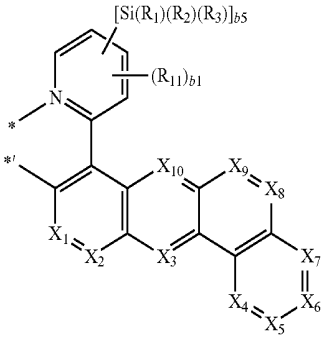


Formula 2-16



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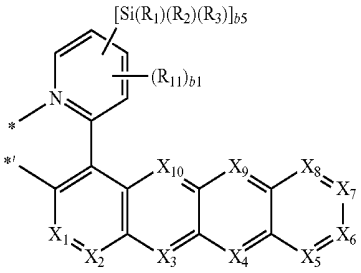

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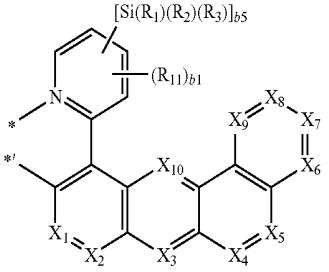
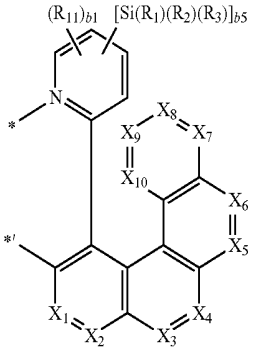


Formula 2-19



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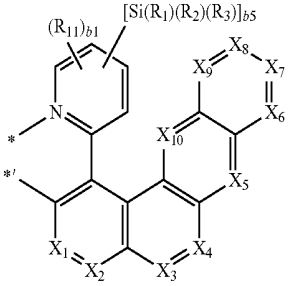

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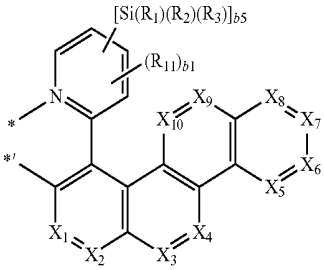

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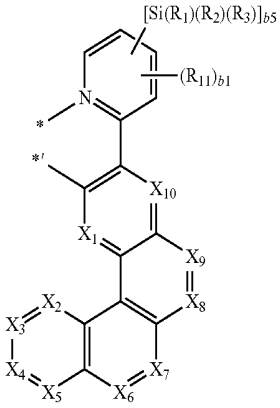
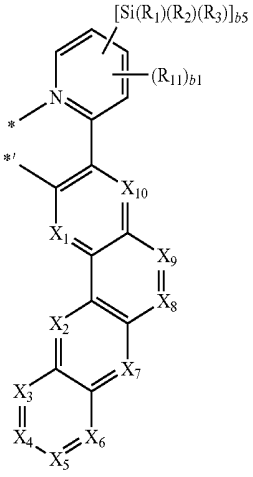


Formula 2-23



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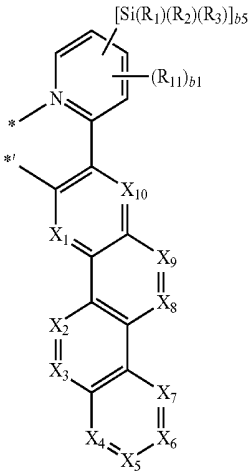

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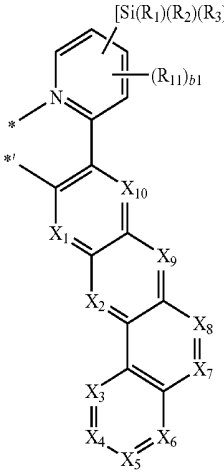

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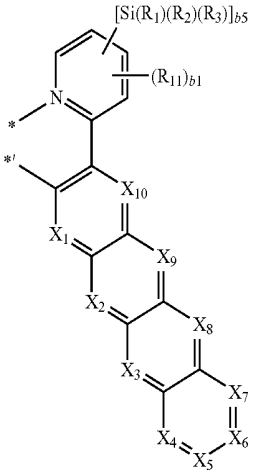

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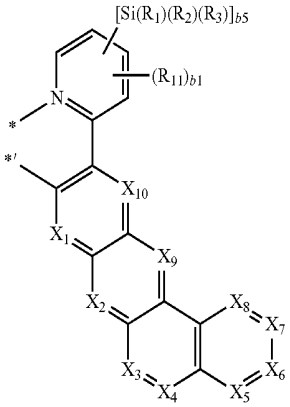

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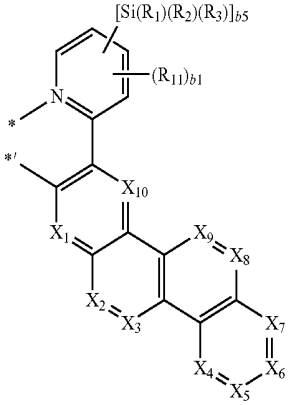

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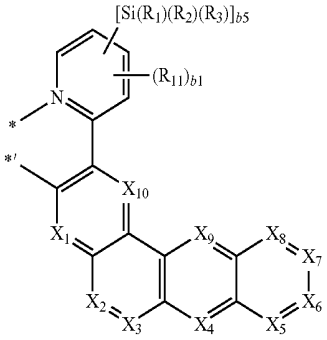

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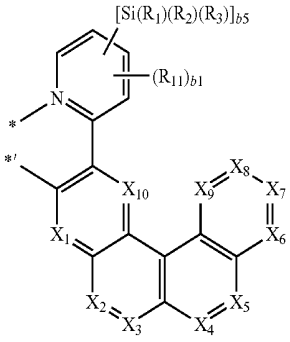

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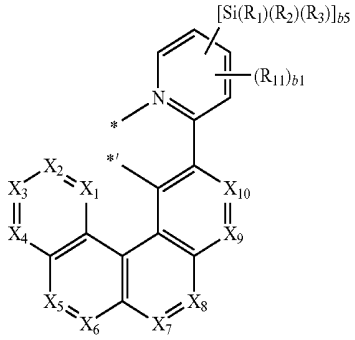

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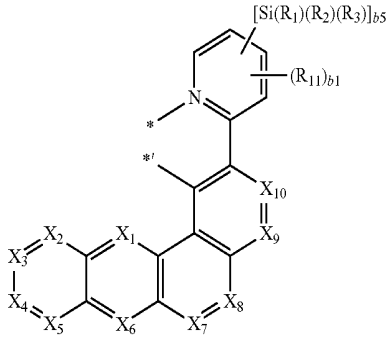

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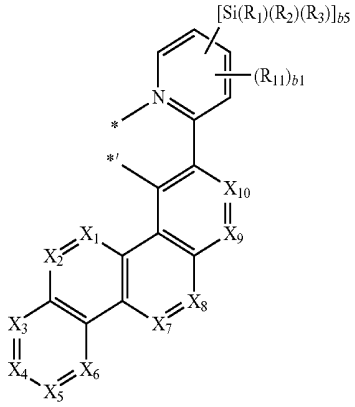

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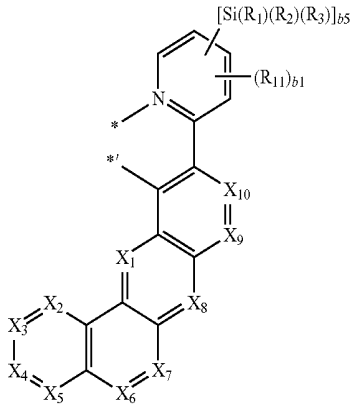

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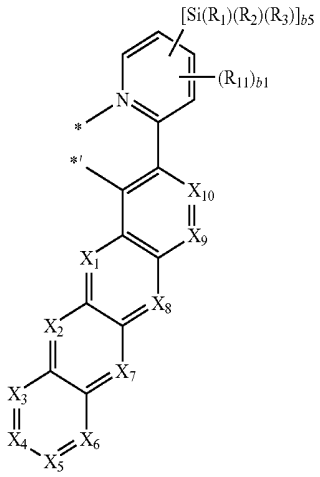

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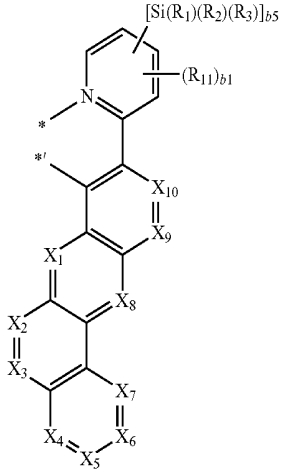
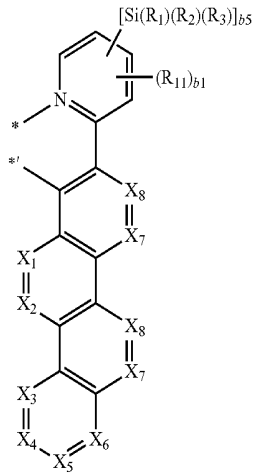


Formula 2-37



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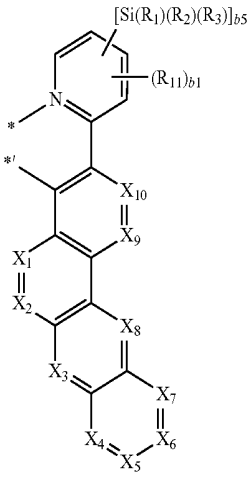

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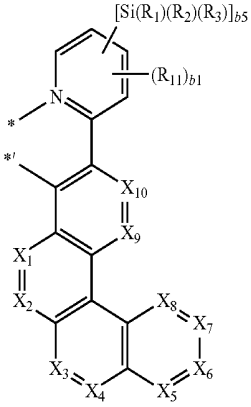

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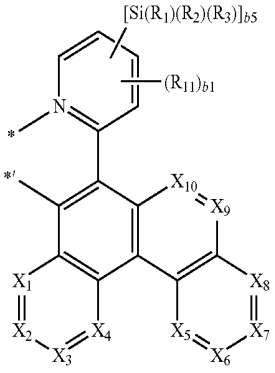
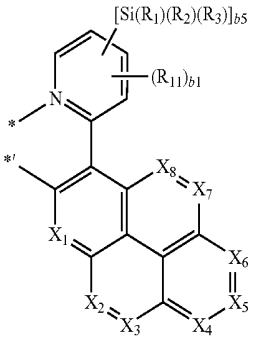


Formula 2-41



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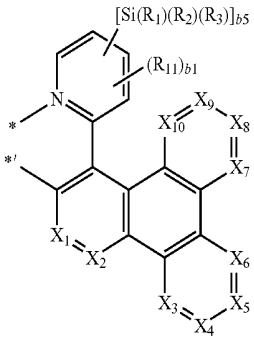
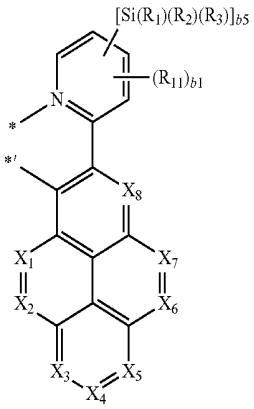


Formula 2-43



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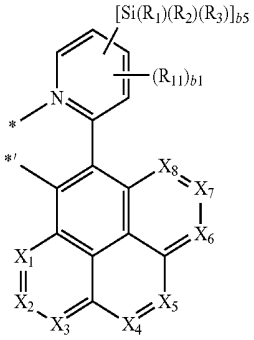
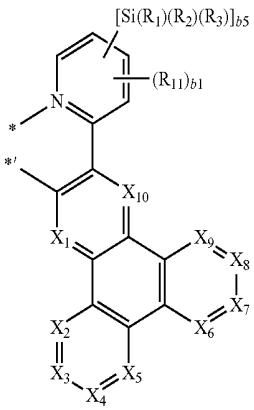


Formula 2-45



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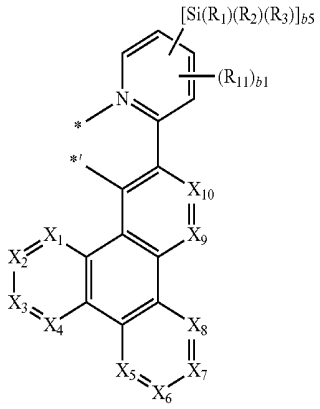
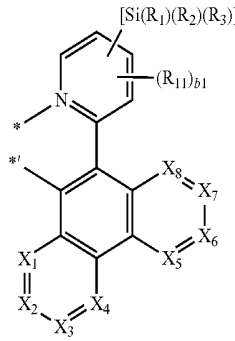
Formula 2-46



Formula 2-47



[0108] In Formulae 2-1 to 2-47,

[0109] descriptions of R_1 to R_3, R_{11}, and b1 are the same as presented above,

[0110] b5 may be 1, 2, or 3,

[0111] X_1 may be N or $C(R_{21})$, X_2 may be N or $C(R_{22})$, X_3 may be N or $C(R_{23})$, X_4 may be N or $C(R_{24})$, X_5 may be N or $C(R_{25})$, X_6 may be N or $C(R_{26})$, X_7 may be N or $C(R_{27})$, X_8 may be N or $C(R_{28})$, X_9 may be N or $C(R_{29})$, X_{10} may be N or $C(R_{30})$,

[0112] descriptions of R_{21} to R_{30} are understood by referring to the descriptions of R_{12}, and

[0113] each of * and *' indicates a binding site to M in Formula 1.

[0114] In an embodiment, in Formulae 2-1 to 2-47, X_1 may be $C(R_{21})$, X_2 may be $C(R_{22})$, X_3 may be $C(R_{23})$, X_4 may be $C(R_{24})$, X_5 may be $C(R_{25})$, X_6 may be $C(R_{26})$, X_7 may be $C(R_{27})$, X_8 may be $C(R_{28})$, X_9 may be $C(R_{29})$, and X_{10} may be $C(R_{30})$.

[0115] For example, in Formulae 2-1 to 2-47,

[0116] R_{21} to R_{30} may be each independently selected from

[0117] a hydrogen, deuterium, —F, a cyano group, a nitro group, $—SF_5$, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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;

[0118] a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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, each substituted with at least one selected from deuterium, —F, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} 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 pyridinyl group, and a pyrimidinyl group; and

[0119] $—B(Q_6)(Q_7)$ and $—P(=O)(Q_5)(Q_9)$,

[0120] wherein Q_6 to Q_9 are each independently selected from

[0121] $—CH_3$, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CH_2CH_3$, $—CH_2CD_3$, $—CH_2CD_2H$, $—CH_2CDH_2$, $—CHDCH_3$, $—CHDCD_2H$, $—CHDCDH_2$, $—CHDCD_3$, $—CD_2CD_3$, $—CD_2CD_2H$, and $—CD_2CDH_2$;

[0122] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl.

[0123] In some embodiments, in Formulae 2-1 to 2-47,

[0124] R_{21} to R_{30} may be each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, $—SF_5$, $—CH_3$, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38, and

[0125] R_1 to R_3 may be each independently selected from

[0126] $—CH_3$, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CH_2CH_3$, $—CH_2CD_3$, $—CH_2CD_2H$, $—CH_2CDH_2$, $—CHDCH_3$,

—$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0127] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, a phenyl group, and —$Si(Q_1)(Q_2)(Q_3)$; and

[0128] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, and a phenyl group, each substituted with at least one selected from deuterium and a C_1-C_{10} alkyl group,

[0129] wherein Q_1 to Q_3 are each independently selected from

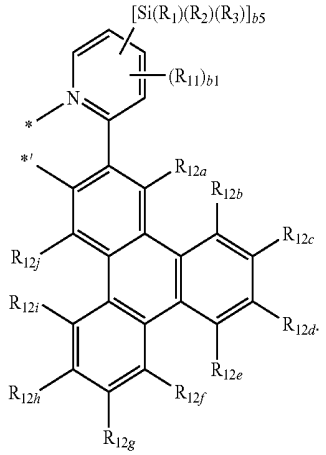
[0130] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0131] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0132] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group, but they are not limited thereto.

[0133] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formula 2BA:

Formula 2BA



[0134] In Formula 2BA,

[0135] descriptions of R_1 to R_3, R_{11}, and b1 are the same as presented above,

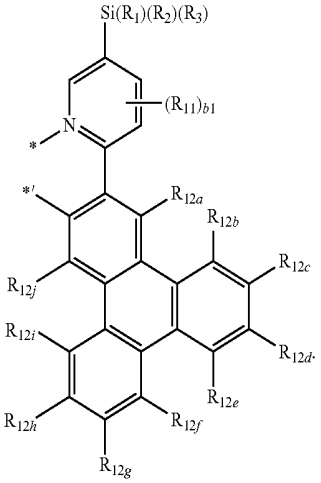
[0136] b5 may be an integer selected from 1 to 4 (for example, b5 is 1 or 2),

[0137] descriptions of R_{12a} to R_{12j} are the same as presented in connection with R_{12}, and

[0138] each of * and *' indicates a binding site to M in Formula 1.

[0139] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formula 2BA(1):

Formula 2BA(1)



[0140] In Formula 2BA(1),

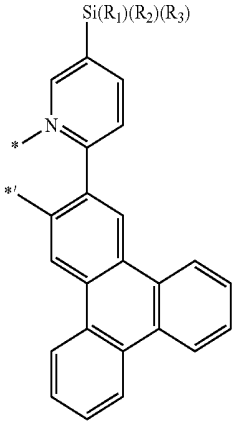
[0141] descriptions of R_1 to R_3, R_{11}, and b1 are the same as described above,

[0142] descriptions of R_{12a} to R_{12j} are the same as presented in connection with R_{12}, and

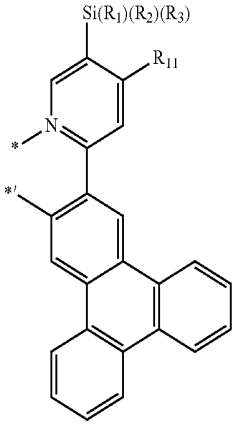
[0143] each of * and *' indicates a binding site to M in Formula 1.

[0144] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formulas 2BA-1 to 2BA-5, but is not limited thereto:

Formula 2BA-1



Formula 2BA-2



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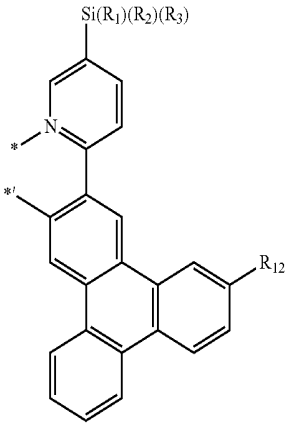
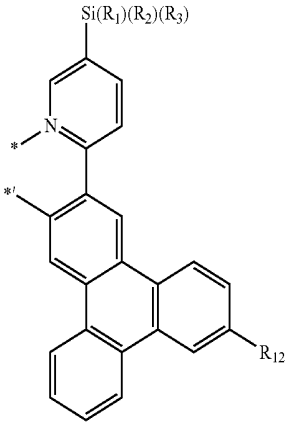
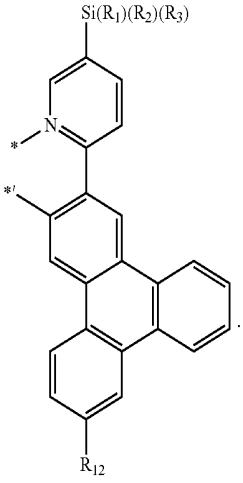
Formula 2BA-3



Formula 2BA-4



Formula 2BA-5



[0145] Descriptions of R_1 to R_3, R_{11}, and R_{12} in Formulae 2BA-1 to 2BA-5 are the same as presented above, provided that each of R_{11} and R_{12} is not hydrogen and each of * and *' indicates a binding site to M in Formula 1.

[0146] For example, in Formulae 2BA-1 to 2BA-5,

[0147] R_{11} and R_{12} are each independently selected from

[0148] deuterium, —F, a cyano group, a nitro group, —SF_5, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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;

[0149] a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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, each substituted with at least one selected from deuterium, —F, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} 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 pyridinyl group, and a pyrimidinyl group; and

[0150] —$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

[0151] Q_6 to Q_9 may be each independently selected from

[0152] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0153] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0154] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group,

[0155] R_1 to R_3 may be each independently selected from

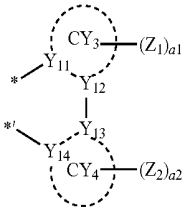
[0156] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0157] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group, and

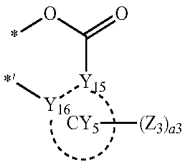
[0158] each of * and *' indicates a binding site to M in Formula 1.

[0159] L_2 in Formula 1 may be selected from ligands represented by Formulae 3A to 3G:

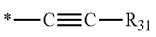
Formula 3A



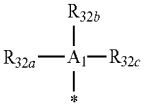
Formula 3B



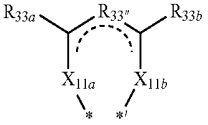
Formula 3C



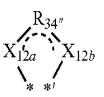
Formula 3D



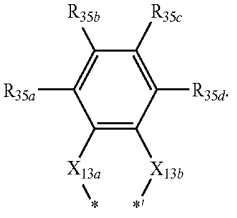
Formula 3E



Formula 3F



Formula 3G



[0160] In Formulae 3A to 3G,

[0161] Y_{11} to Y_{16} may be each independently carbon (C) or nitrogen (N), Y_{11} and Y_{12} may be connected to each other via a single bond or a double bond, Y_{13} and Y_{14} may be connected to each other via a single bond or a double bond, Y_{15} and Y_{16} may be connected to each other via a single bond or a double bond,

[0162] CY_3 to CY_5 may be each independently selected from a C_5-C_{60} carbocyclic group, and a C_2-C_{60} heterocyclic group,

[0163] a1 to a3 may be each independently an integer selected from 1 to 5,

[0164] A_1 is P or As,

[0165] X_{11a}, X_{11b}, X_{12a}, X_{12b}, X_{13a}, and X_{13b} may be each independently selected from N, O, N(R_{34}), P(R_{35})(R_{36}), and As(R_{37})(R_{38}) (provided that X_{12a}, X_{12b}, X_{13a}, and X_{13b} are neither N nor O),

[0166] $R_{33''}$ and $R_{34''}$ may be each independently selected from a single bond, a double bond, a substituted or unsubstituted C_1-C_5 alkylene group, a substituted or unsubstituted C_2-C_5 alkenylene group, and a substituted or unsubstituted C_6-C_{10} arylene group,

[0167] Z_1 to Z_3, R_{31}, R_{32a}, R_{32b}, R_{32c}, R_{33a}, R_{33b}, R_{34} to R_{38}, R_{35a}, R_{35b}, R_{35c}, and R_{35d} may be each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_5)(Q_9)$,

[0168] each of * and *' indicates a binding site to M in Formula 1, and

[0169] at least one of substituents of the substituted C_1-C_5 alkylene group, substituted C_2-C_5 alkenylene group, substituted C_6-C_{10} arylene group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from

[0170] 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 amino group, an amidino group, a hydrazine group, a hydra-

zone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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;

[0171] 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, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{14})(Q_{15})$, —$B(Q_{16})(Q_{17})$, and —$P(=O)(Q_{18})(Q_{19})$;

[0172] 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;

[0173] 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, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{24})(Q_{25})$, —$B(Q_{26})(Q_{27})$, and —$P(=O)(Q_{25})(Q_{29})$; and

[0174] —$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{34})(Q_{35})$, —$B(Q_{36})(Q_{37})$, and —$P(=O)(Q_{38})(Q_{39})$,

[0175] wherein Q_1 to Q_9, Q_{11} to Q_{19}, Q_{21} to Q_{29}, and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0176] CY_3 to CY_5 in Formulae 3A and 3B may be each independently selected from a cyclopentadiene, a benzene, an indene, 1,2,3,4-tetrahydronaphthalene, a naphthalene, an azulene, a heptalene, an indacene, an acenaphthylene, a fluorene, a spiro-bifluorene, a benzofluorene, a dibenzofluorene, a phenalene, a phenanthrene, an anthracene, a fluoranthene, a triphenylene, a pyrene, a chrysene, a naphthacene, a picene, a perylene, a pentacene, a hexacene, a rubicene, a coronene, an ovalene, a pyrrole, an isoindole, an indole, an indazole, a pyrazole, an imidazole, a triazole, an oxazole, an isoxazole, an oxadiazole, a thiazole, an isothiazole, a thiadiazole, a purine, a pyridine, a pyrimidine, a pyrazine, a pyridazine, a triazine, a 5,6,7,8-tetrahydroquinoline, a 5,6,7,8-tetrahydroisoquinoline, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, a phenazine, a benzoimidazole, a benzofuran, a benzothiophene, an isobenzothiazole, a benzoxazole, an isobenzoxazole, a benzocarbazole, a dibenzocarbazole, an imidazopyridine, an imidazopyrimidine, a dibenzofuran, a dibenzothiophene, a dibenzothiophene sulfone, a carbazole, a dibenzosilole, a benzofuropyridine, and a benzothienopyridine.

[0177] In an embodiment, L_2 in Formula 1 may be selected from ligands represented by Formula 3A, 3B, and 3F,

[0178] Y_{11} in Formula 3A may be nitrogen,

[0179] Y_{12} to Y_{14} in Formula 3A may be carbon,

[0180] CY_3 in Formula 3A may be selected from a pyridine, a 5,6,7,8-tetrahydroquinoline, a 5,6,7,8-tetrahydroisoquinoline, a quinoline, and an isoquinoline,

[0181] CY_4 in Formula 3A may be selected from a benzene, 1,2,3,4-tetrahydronaphthalene, a naphthalene, a fluorene, a dibenzofuran, a dibenzothiophene, a benzofuropyridine, and a benzothienopyridine,

[0182] Y_{15} in Formula 3B may be carbon,

[0183] Y_{16} in Formula 3B may be nitrogen,

[0184] CY_5 in Formula 3B may be a pyridine or a pyrimidine,

[0185] Z_1 to Z_3 in Formulae 3A and 3B may be each independently selected from

[0186] a hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF_5, a C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0187] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid

or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl 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;

[0188] 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 benzoimidazolyl 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;

[0189] 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 benzoimidazolyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl 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 benzoimidazolyl 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

[0190] $—Si(Q_1)(Q_2)(Q_3)$, $—N(Q_4)(Q_5)$, $—B(Q_6)(Q_7)$, and $—P(=O)(Q_8)(Q_9)$,

[0191] a1 to a3 may be each independently an integer selected from 0 to 4,

[0192] from among groups Z_1 in the number of a1, groups Z_2 in the number of a2, and groups Z_3 in the number of a3, two or more neighboring substituents may be optionally bonded to form a C_5-C_{30} carbocyclic group or a C_2-C_{30} heterocyclic group, and

[0193] Q_1 to Q_9 may be each independently selected from

[0194] $—CH_3$, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CH_2CH_3$, $—CH_2CD_3$, $—CH_2CD_2H$, $—CH_2CDH_2$, $—CHDCH_3$, $—CHDCD_2H$, $—CHDCDH_2$, $—CHDCD_3$, $—CD_2CD_3$, $—CD_2CD_2H$, and $—CD_2CDH_2$;

[0195] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0196] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from a deuterium and a C_1-C_{10} alkyl group;

[0197] X_{12a} and X_{12b} in Formula 3F may be 0, and

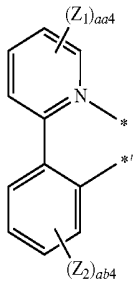
[0198] $R_{34''}$ in Formula 3F may be selected from

[0199] a C_2-C_5 alkenylene group; and

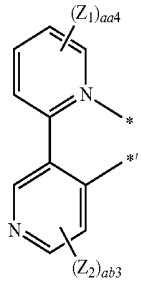
[0200] a C_2-C_5 alkenylene group, substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a phenyl group, but they are not limited thereto.

[0201] In some embodiments, L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1 to 3-111:

Formula 3-1



Formula 3-2



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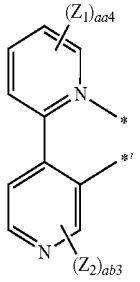

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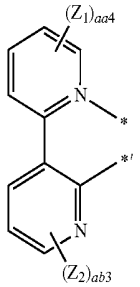

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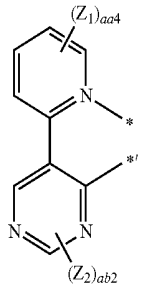

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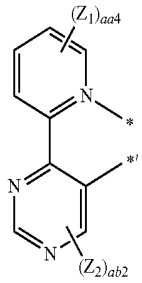

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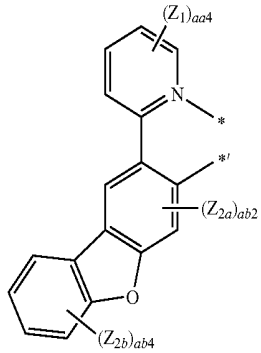

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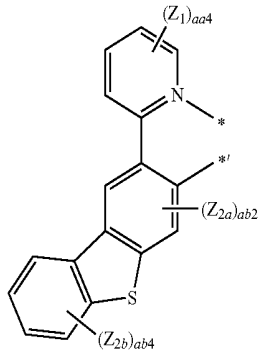

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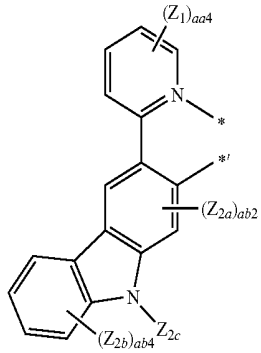

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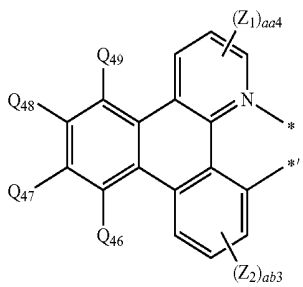

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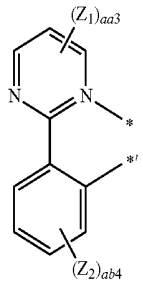

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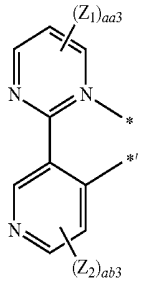

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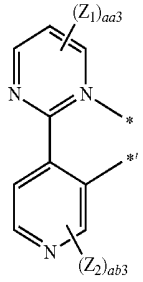

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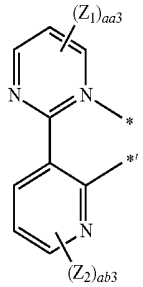

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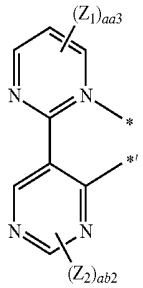

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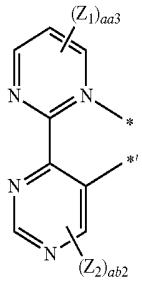

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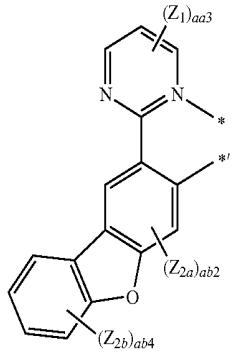

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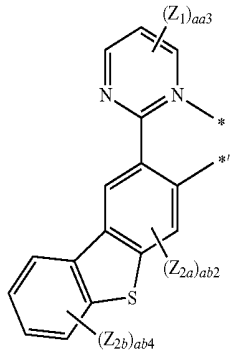

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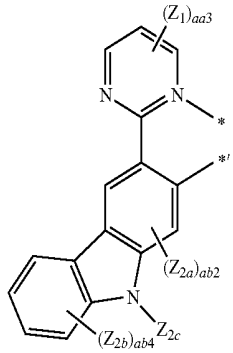

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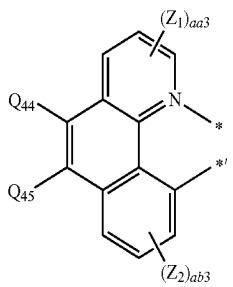

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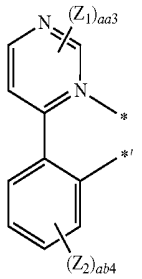

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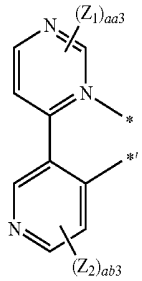

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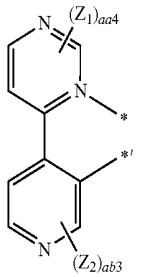

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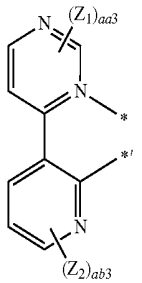

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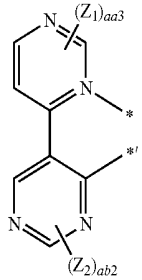

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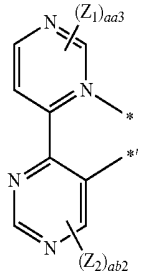

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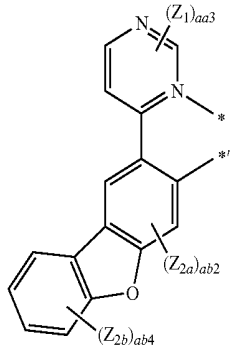

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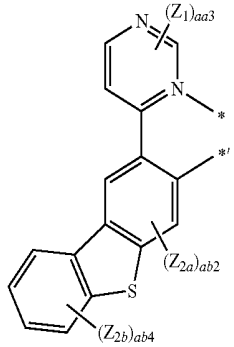

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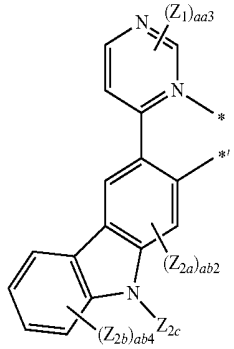

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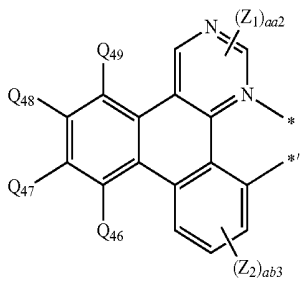

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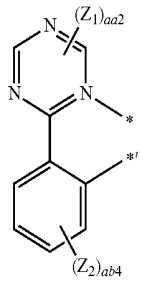

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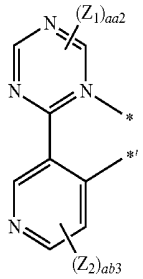

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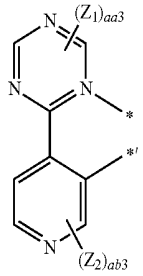

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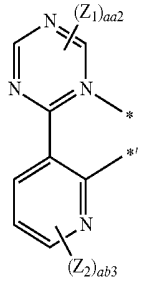

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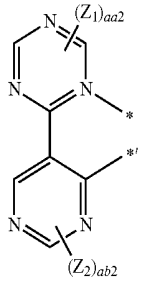

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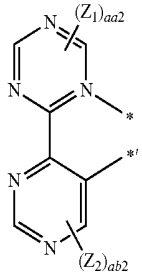

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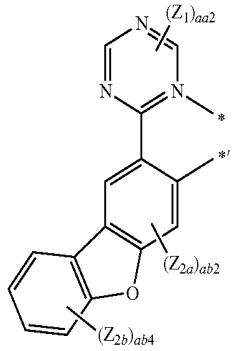

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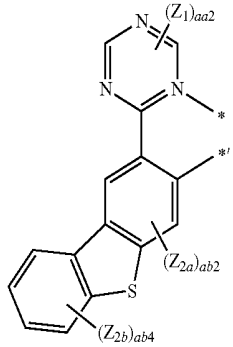

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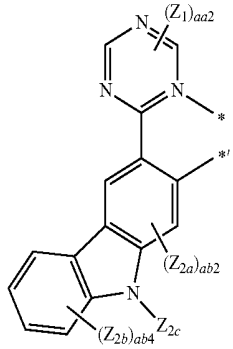

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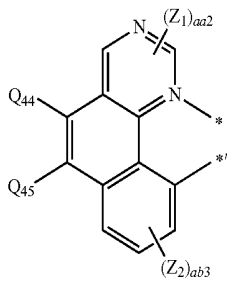

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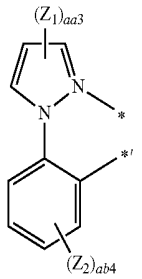

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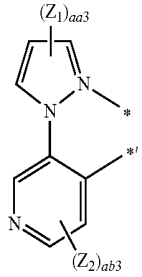

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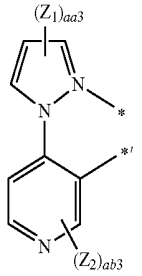

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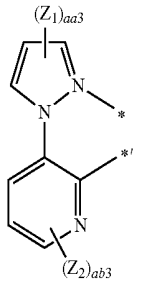

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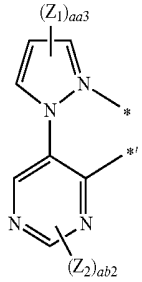

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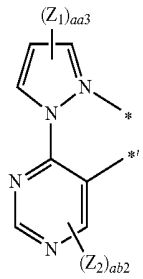

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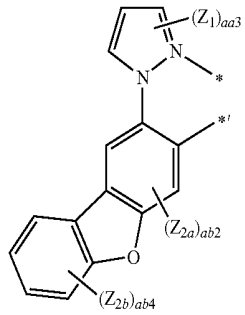

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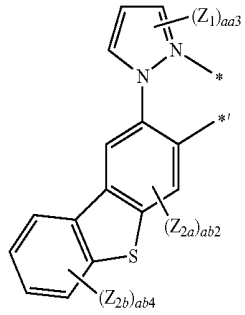

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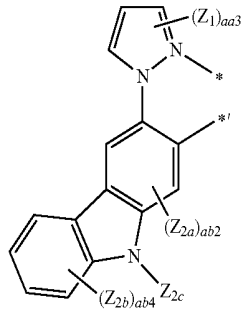

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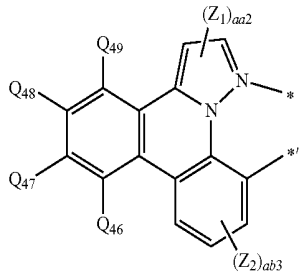

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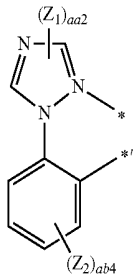

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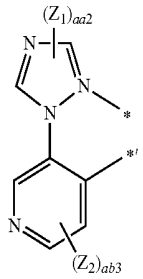

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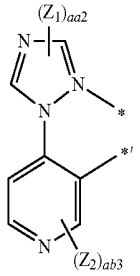

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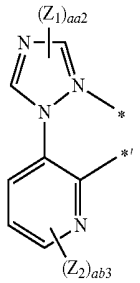
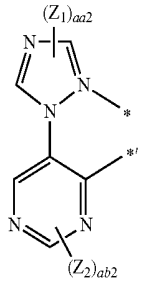


Formula 3-55



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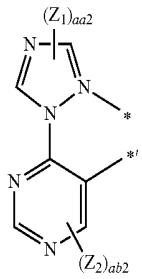

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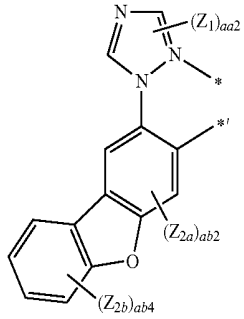

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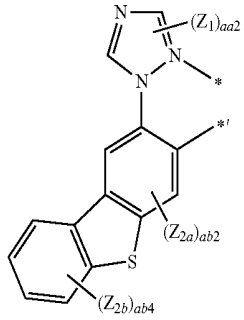

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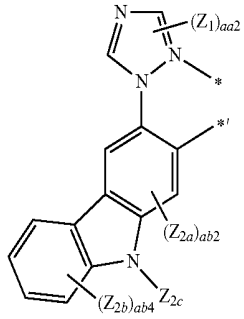

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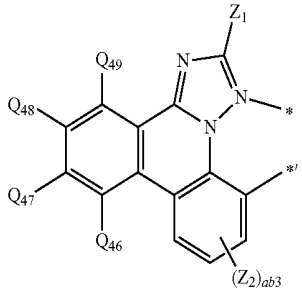

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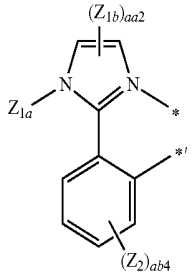

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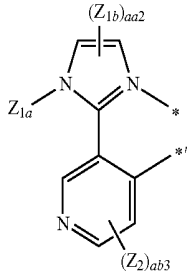

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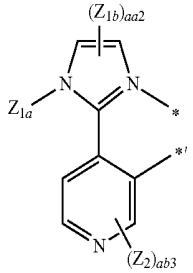

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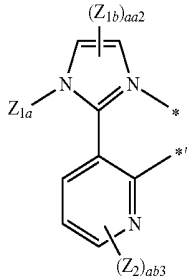

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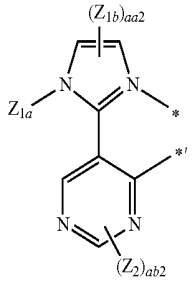

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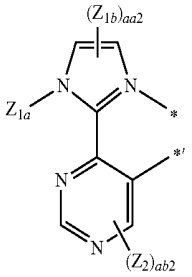

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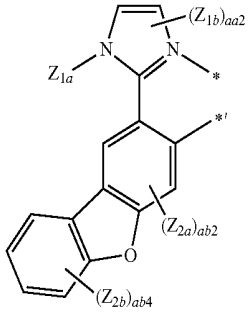

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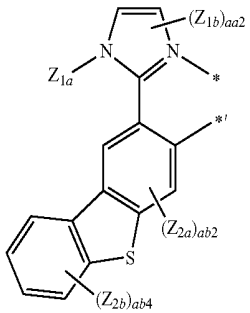

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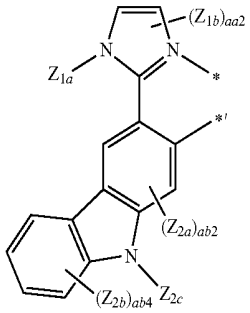

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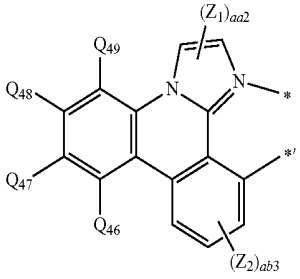

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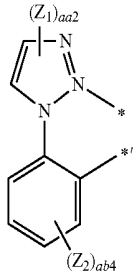

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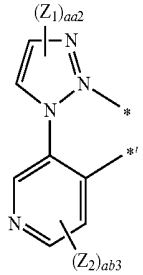

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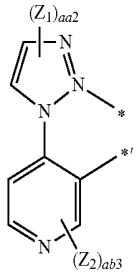

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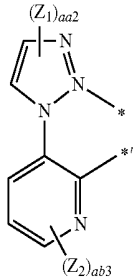

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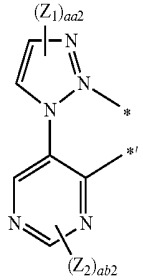

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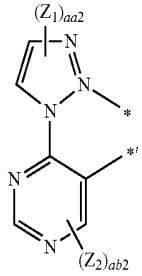

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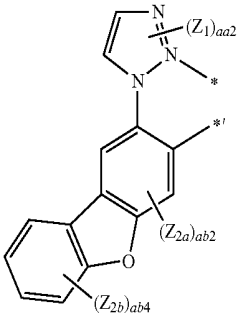

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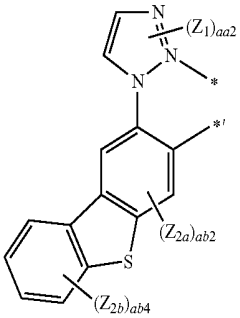

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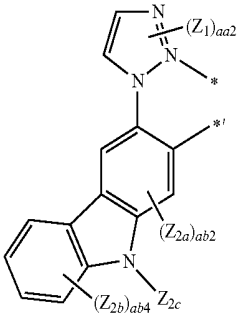

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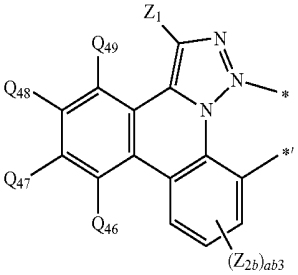

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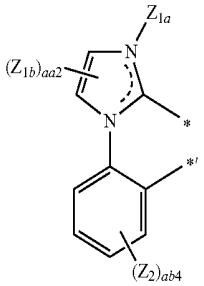

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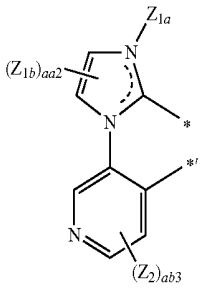

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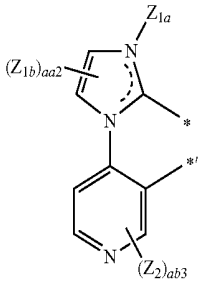

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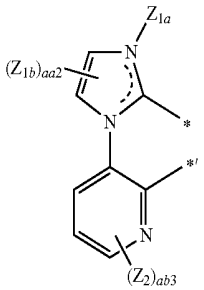

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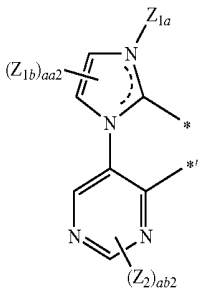

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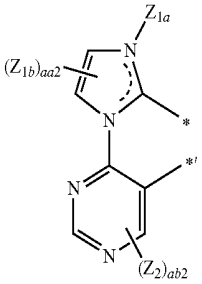

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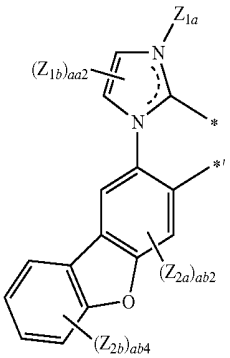

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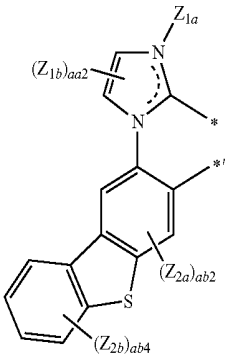

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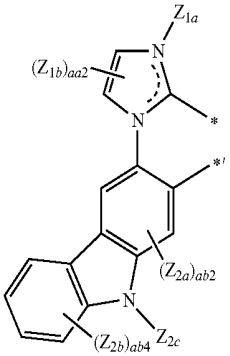

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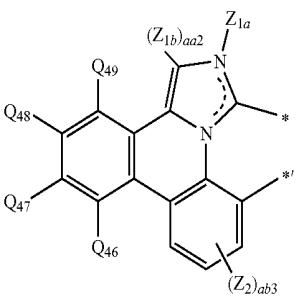

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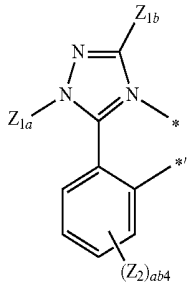

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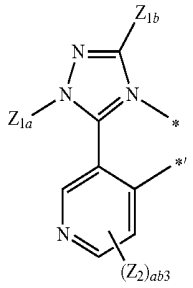

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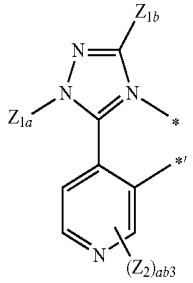

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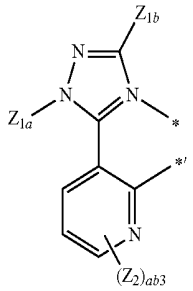

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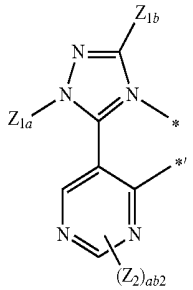

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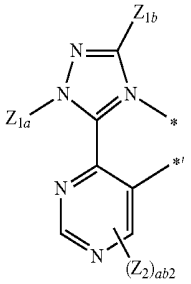

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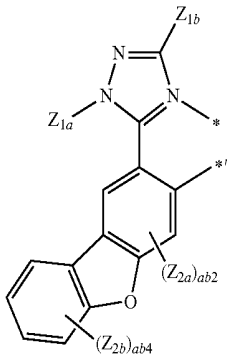

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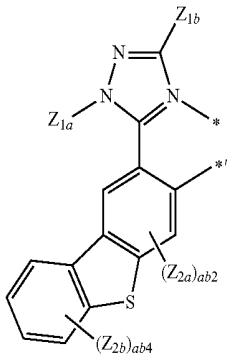

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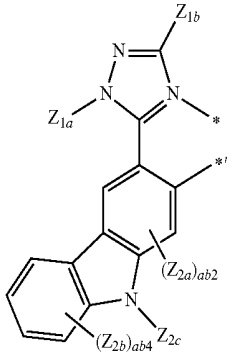

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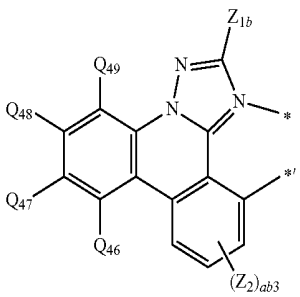

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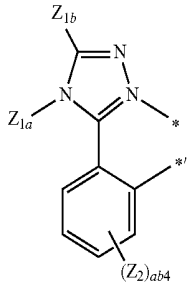

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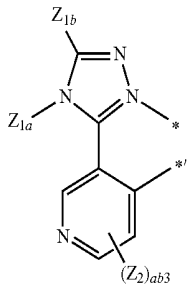

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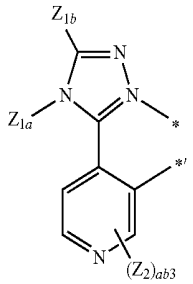

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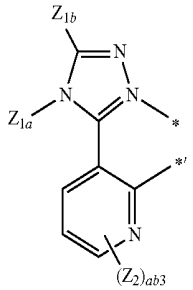

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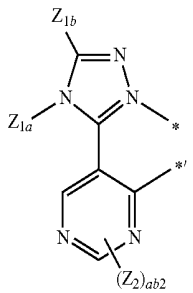

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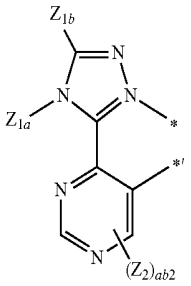
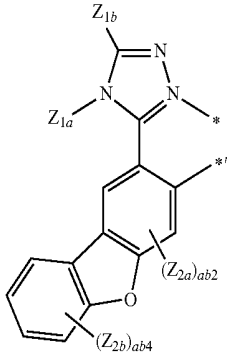
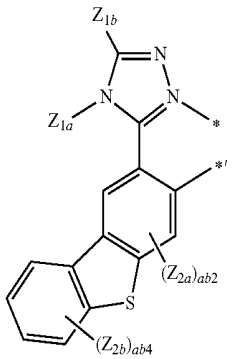


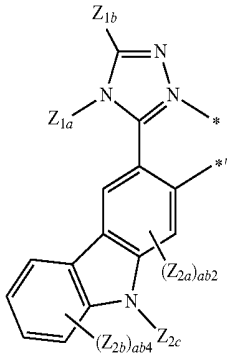
Formula 3-107



Formula 3-108



Formula 3-109



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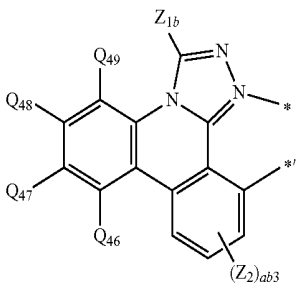

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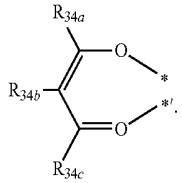
Formula 3-111



[0202] In Formulae 3-1 to 3-111,

[0203] Z_1, Z_2, Z_{1a}, Z_{1b}, Z_{2a}, Z_{2b}, Z_{2c}, R_{34a}, R_{34b}, and R_{34c} may be each independently selected from

[0204] a hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, $—SF_5$, C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

[0205] a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CF_3$, $—CF_2H$, $—CFH_2$, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl 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;

[0206] 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 benzoimidazolyl 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;

[0207] 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 benzoimidazolyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl 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 benzoimidazolyl 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

[0208] $—Si(Q_1)(Q_2)(Q_3)$, $—N(Q_4)(Q_5)$, $—B(Q_6)(Q_7)$, and $—P(=O)(Q_8)(Q_9)$,

[0209] from among Z_1, Z_2, Z_{1a}, Z_{1b}, Z_{2a}, Z_{2b}, Z_{2c}, R_{34a}, R_{34b}, and R_{34c}, two or more neighboring substituents may be optionally bonded to form a C_5-C_{30} carbocyclic group or a C_2-C_{30} heterocyclic group,

[0210] Q_1 to Q_9 may be each independently selected from

[0211] $—CH_3$, $—CD_3$, $—CD_2H$, $—CDH_2$, $—CH_2CH_3$, $—CH_2CD_3$, $—CH_2CD_2H$, $—CH_2CDH_2$, $—CHDCH_3$, $—CHDCD_2H$, $—CHDCDH_2$, $—CHDCD_3$, $—CD_2CD_3$, $—CD_2CD_2H$, and $—CD_2CDH_2$;

[0212] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl

group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0213] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from a deuterium, and a C_1-C_{10} alkyl group;

[0214] aa2 and ab2 may be each independently 1 or 2,

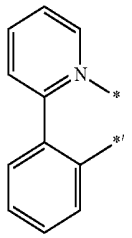
[0215] aa3 and ab3 may be each independently an integer selected from 1 to 3,

[0216] aa4 and ab4 may be each independently an integer selected from 1 to 4, and

[0217] each of * and *' indicates a binding site to M in Formula 1.

[0218] In some embodiments, L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112:

Formula 3-1(1)



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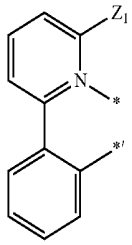

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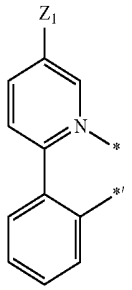

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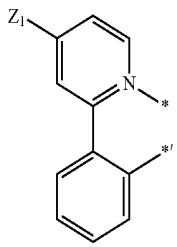

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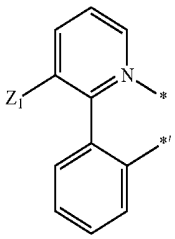

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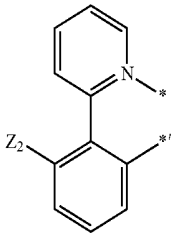

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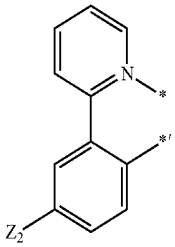

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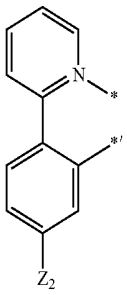

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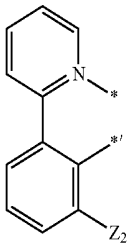

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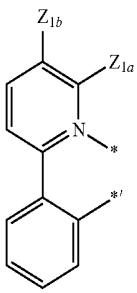

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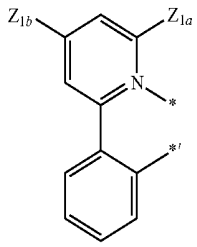

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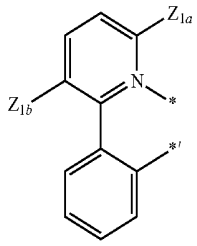

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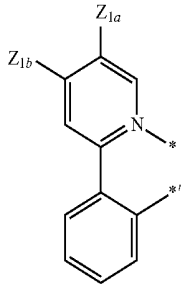

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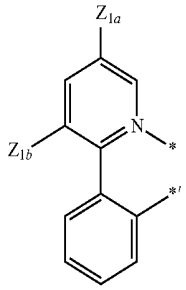

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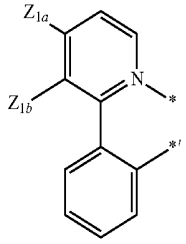

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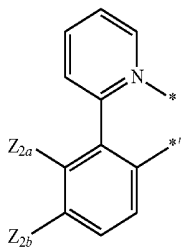

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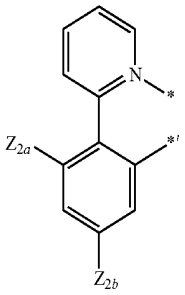

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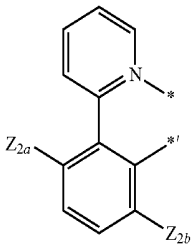

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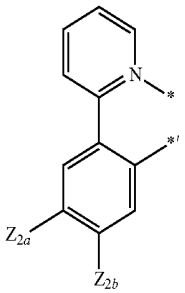

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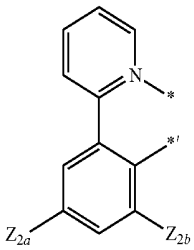

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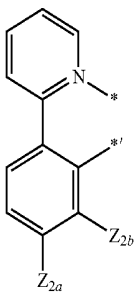

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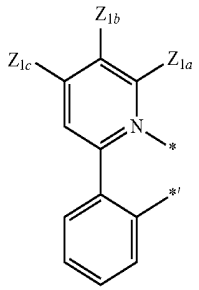

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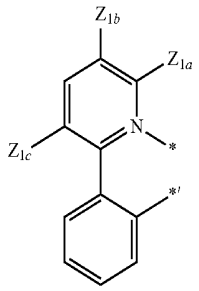

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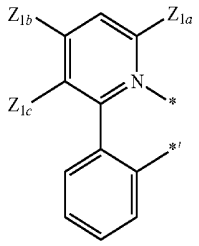

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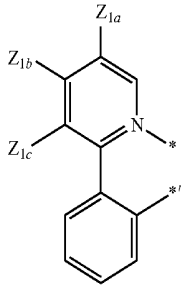

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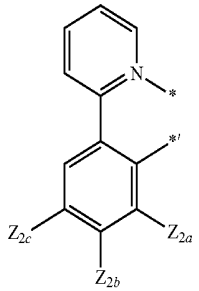

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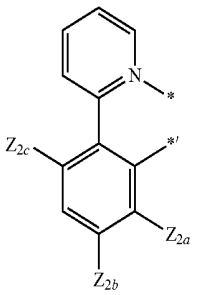

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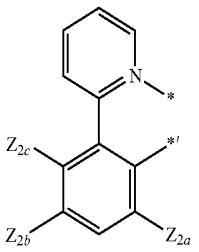

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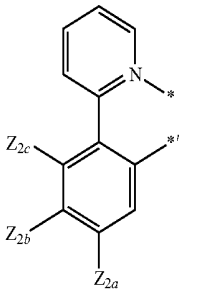

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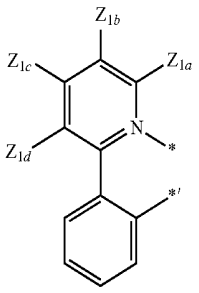

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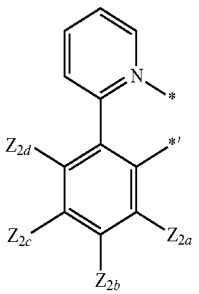

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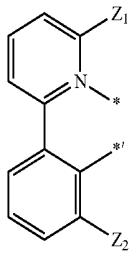

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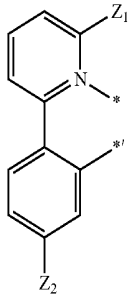

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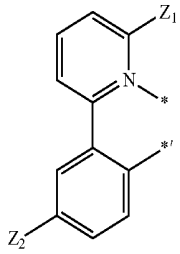

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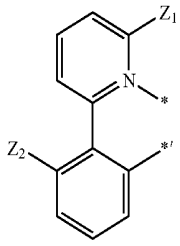

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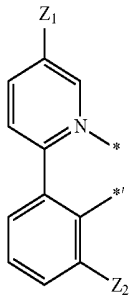

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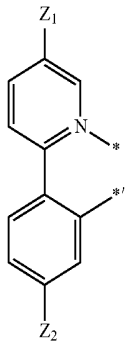

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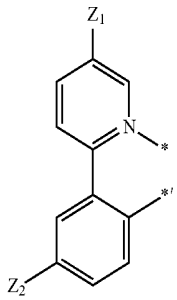

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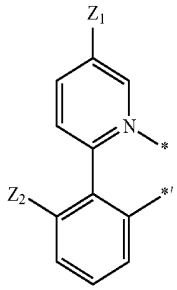

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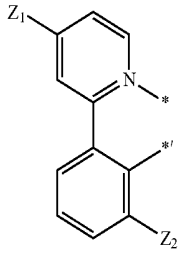

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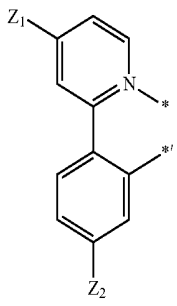

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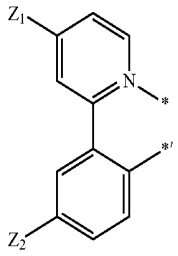

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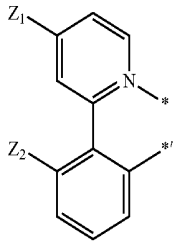

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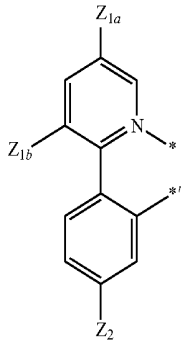

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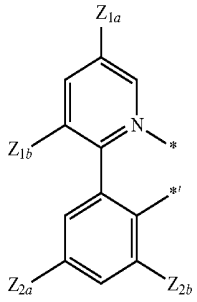

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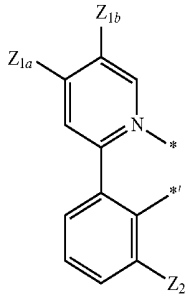

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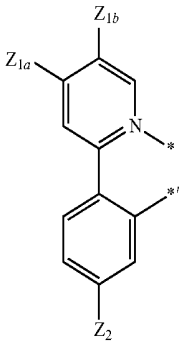

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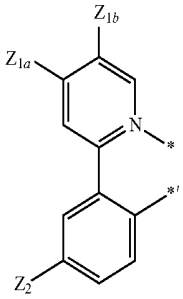

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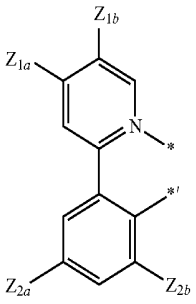

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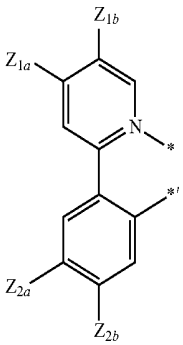

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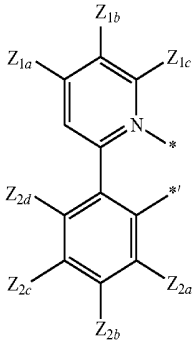

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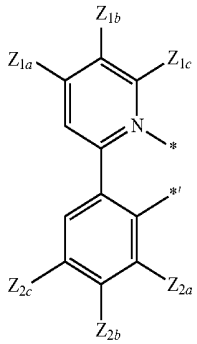

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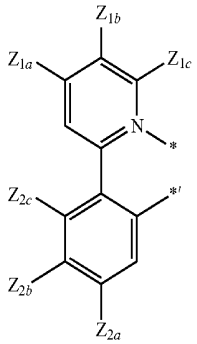

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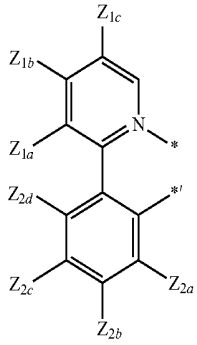

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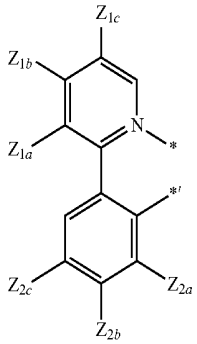

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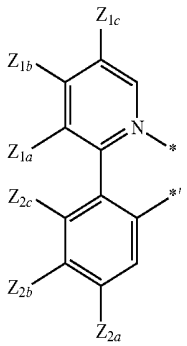

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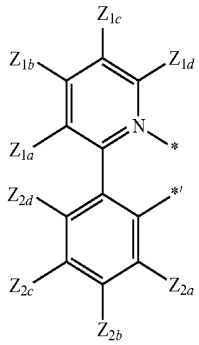

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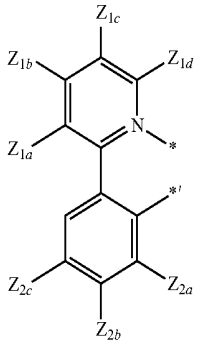

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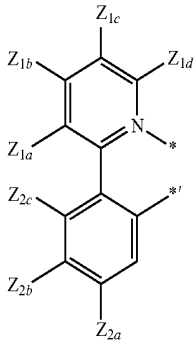

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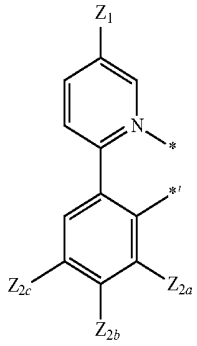

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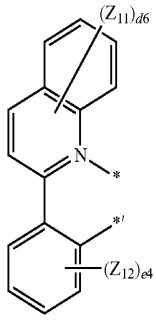

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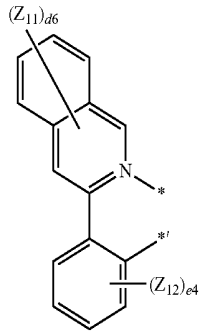

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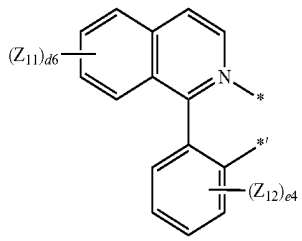

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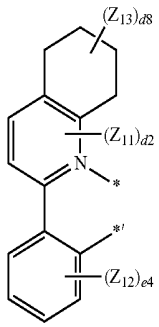

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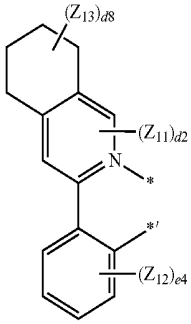

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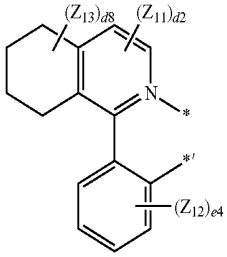

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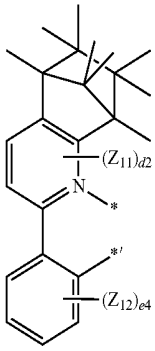

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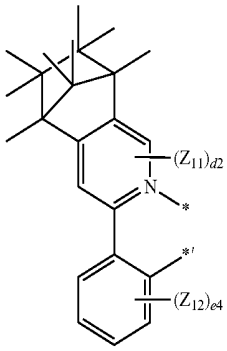

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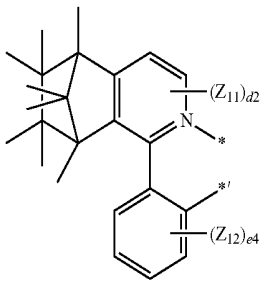

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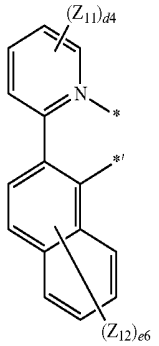

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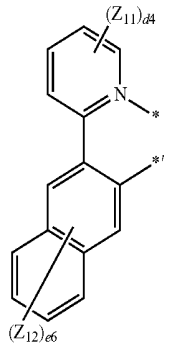

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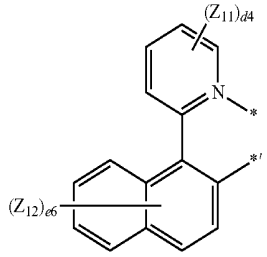

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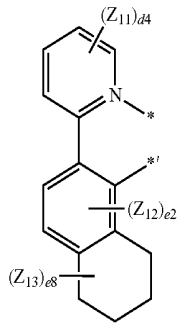

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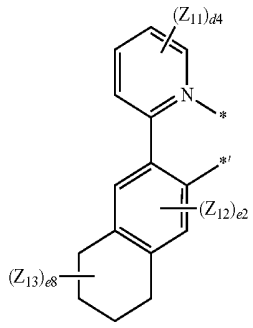

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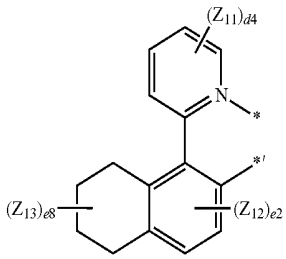

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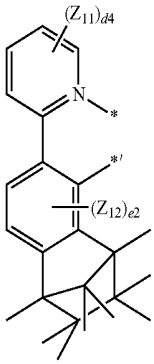

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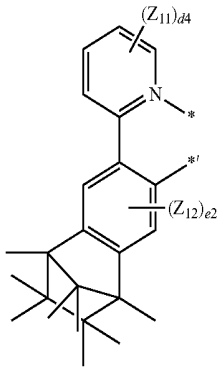

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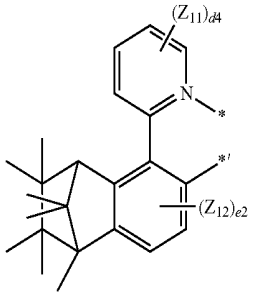

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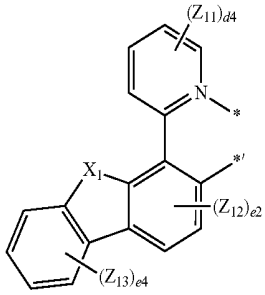

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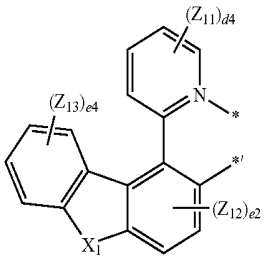

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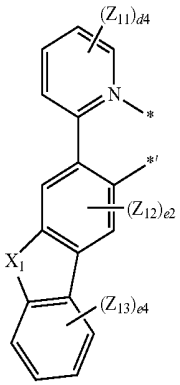

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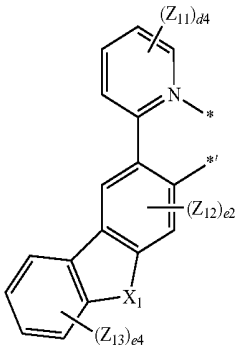

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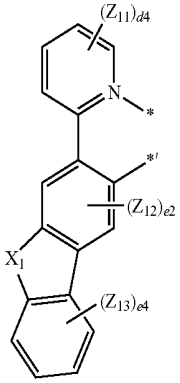

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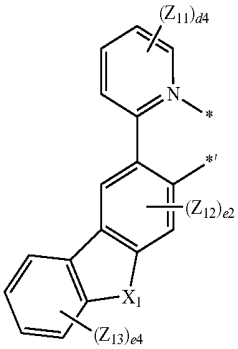

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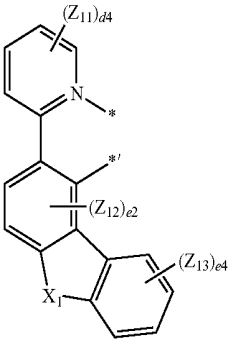

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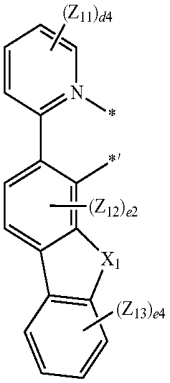

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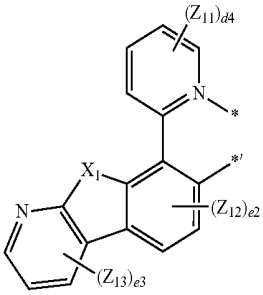

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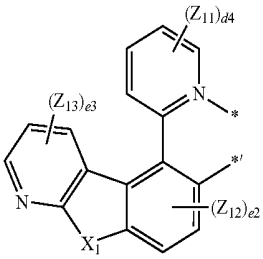

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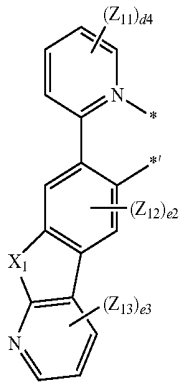

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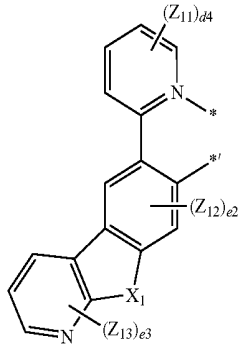

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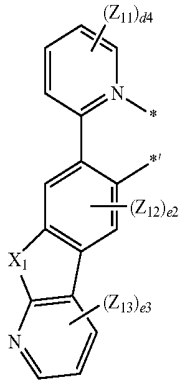

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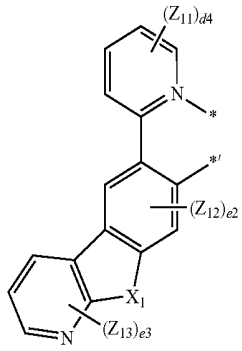

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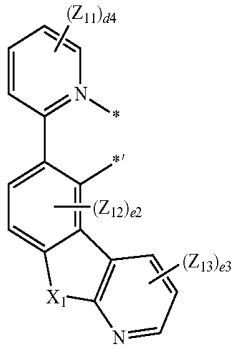

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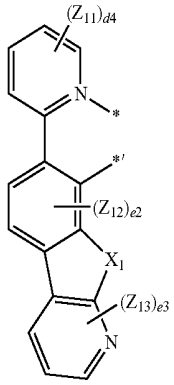

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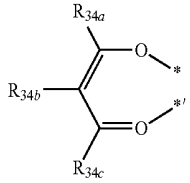
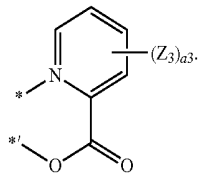


Formula 3-112



[0219] In Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112,

[0220] Z_1, Z_2, Z_{1a}, Z_{1b}, Z_{1c}, Z_{1d}, Z_{2a}, Z_{2b}, Z_{2c}, Z_{2d}, R_{34a}, R_{34b}, and R_{34c} may be each independently selected from deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, —$P(=O)(Q_8)(Q_9)$, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38,

[0221] X_1 may be O, S, $C(Z_{21})(Z_{22})$, or $N(Z_{23})$,

[0222] Z_3, Z_{11} to Z_{13}, and Z_{21} to Z_{23} may be each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, —$P(=O)(Q_8)(Q_9)$, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38,

[0223] Q_1 to Q_9 may be each independently selected from

[0224] —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

[0225] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

[0226] an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from a deuterium and a C_1-C_{10} alkyl group,

[0227] d2 and e2 may be each independently 0 or 2,

[0228] e3 may be an integer selected from 0 to 3,

[0229] d4 and e4 may be each independently an integer selected from 0 to 4,

[0230] d6 and e6 may be each independently an integer selected from 0 to 6,

[0231] d8 and e8 may be each independently an integer selected from 0 to 8, and

[0232] each of * and *' indicates a binding site to M in Formula 1.

[0233] In an embodiment, L_1 in Formula 1 may be selected from ligands represented by Formula 2(1) (for example, a ligand represented by Formula 2BA), and L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112.

[0234] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formulae 2-1 to 2-47, and L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112, but they are not limited thereto.

[0235] In some embodiments, L_1 in Formula 1 may be selected from ligands represented by Formulae 2BA-1 to 2BA-5, and L_2 in Formula 1 may be selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112, but they are not limited thereto.

[0236] The organometallic compound represented by Formula 1 may be selected from Compounds 1 to 288, but is not limited thereto:

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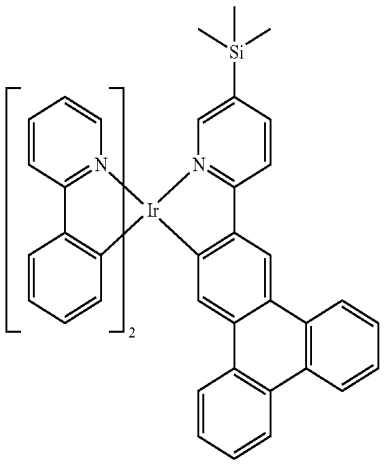

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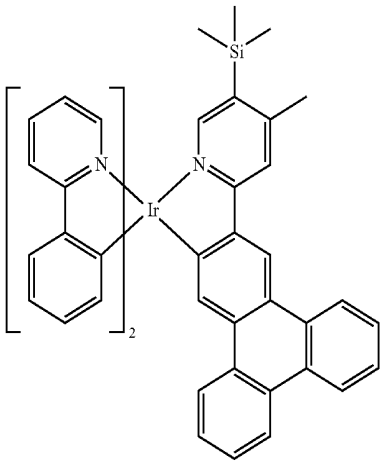

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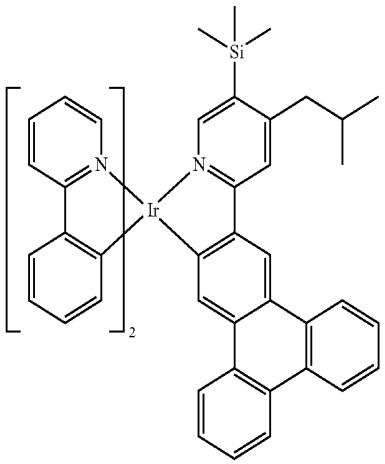

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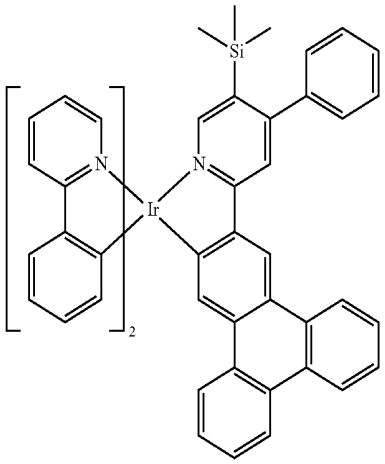

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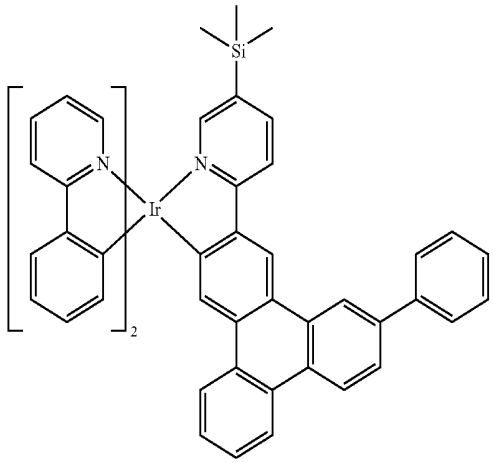

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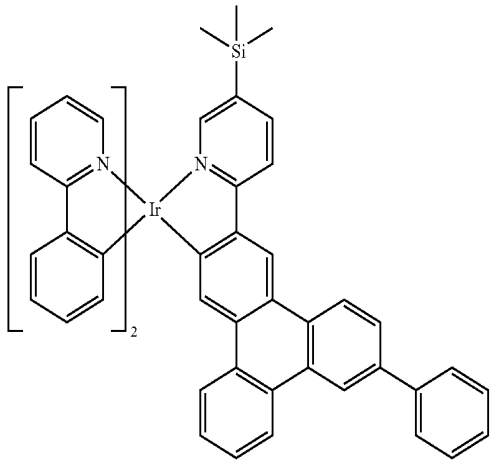

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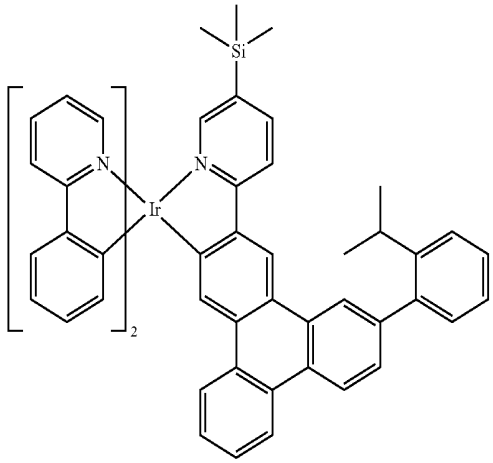

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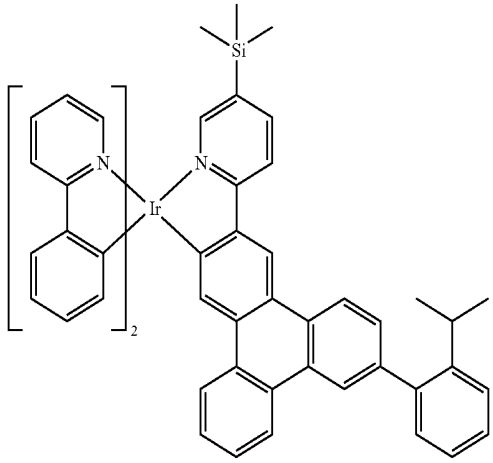

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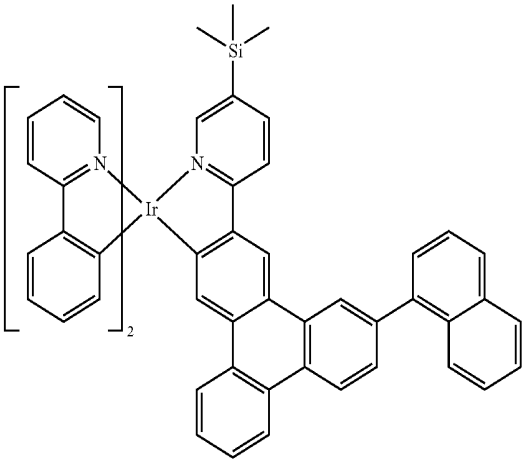

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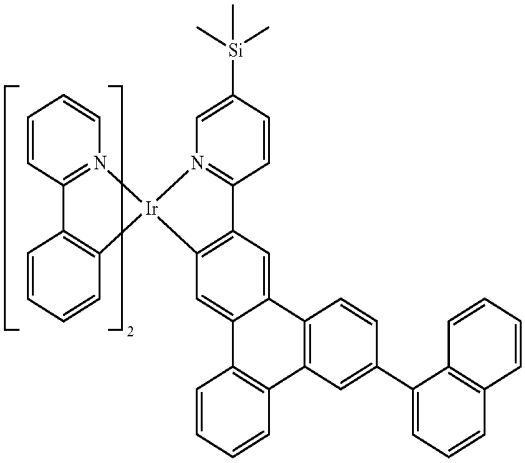

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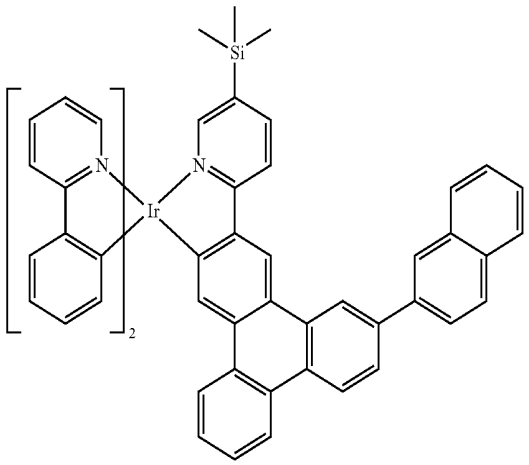

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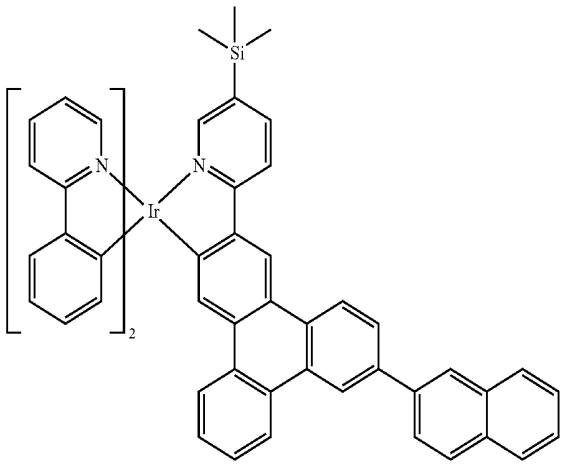

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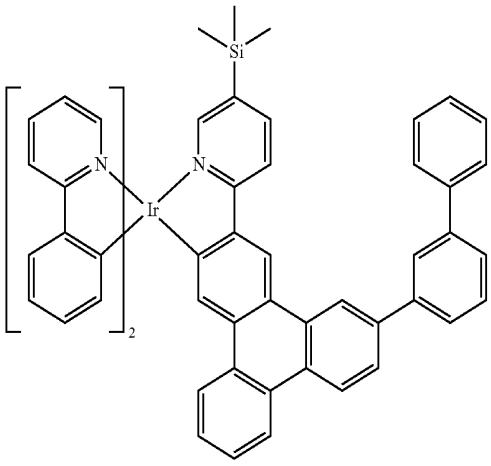

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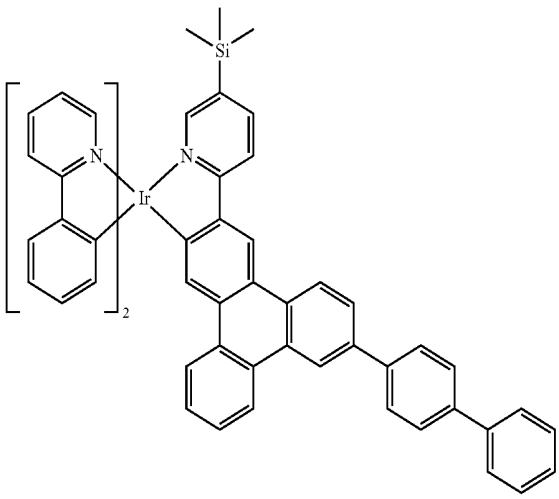

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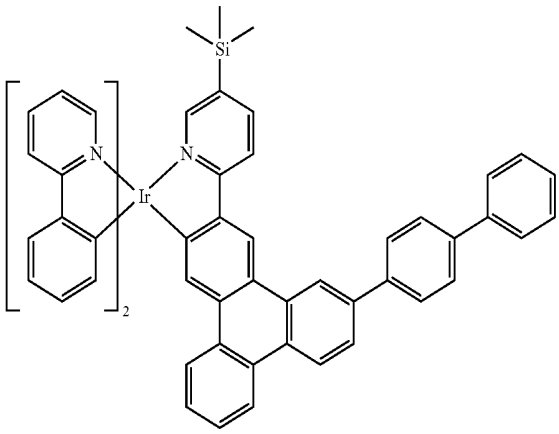

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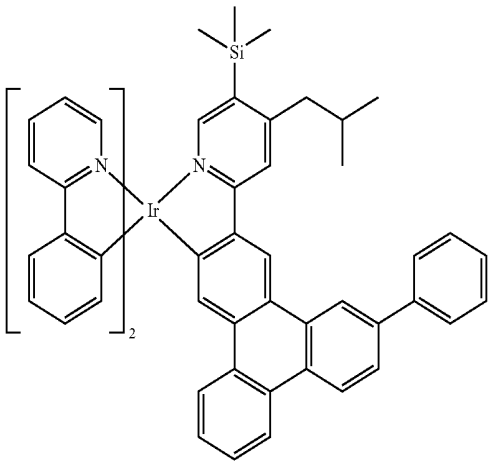

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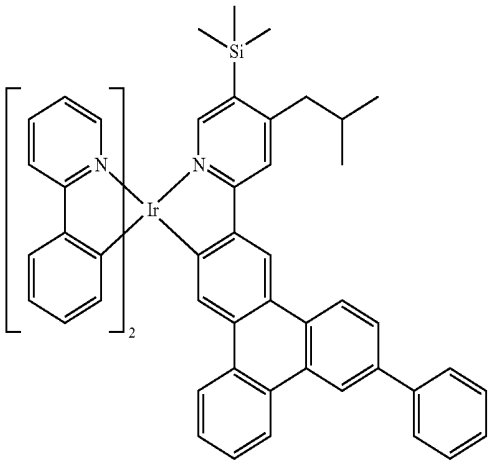

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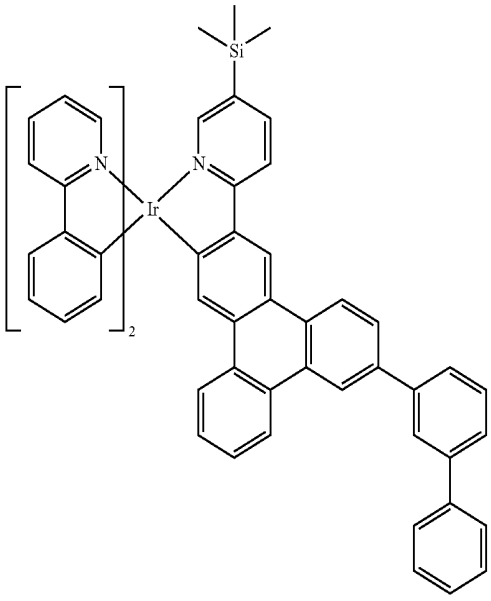

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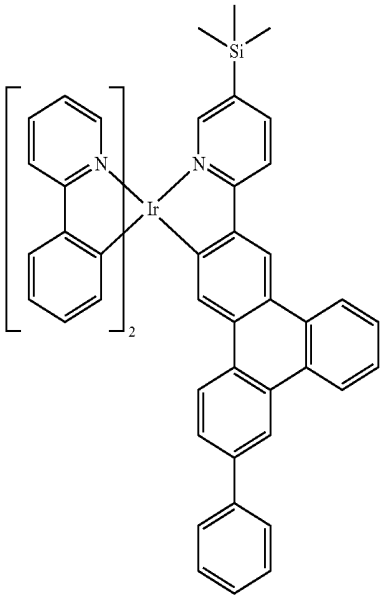

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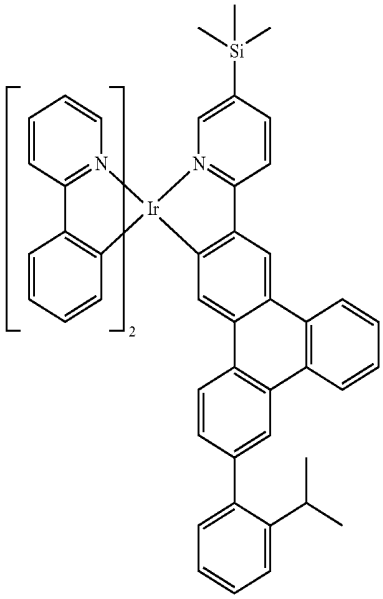

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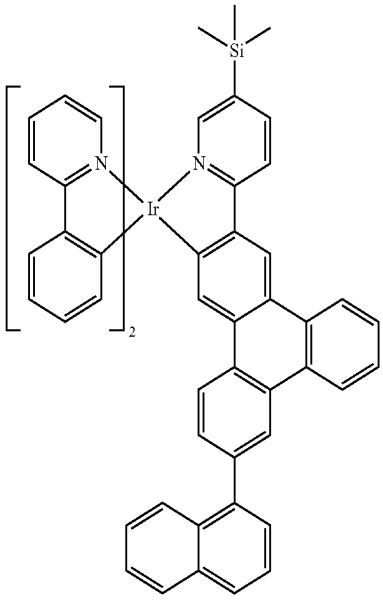

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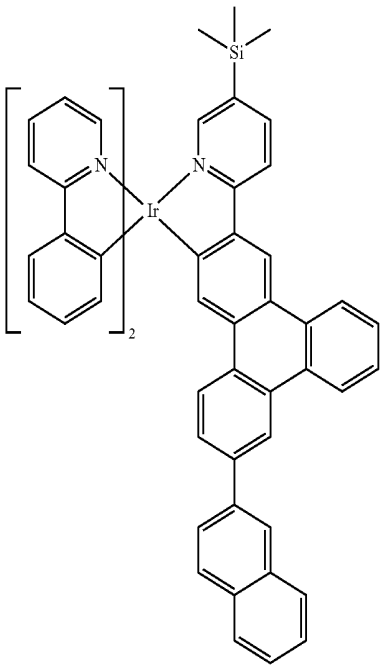

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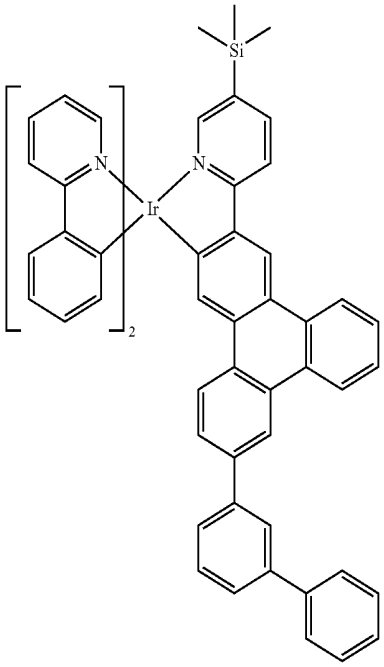

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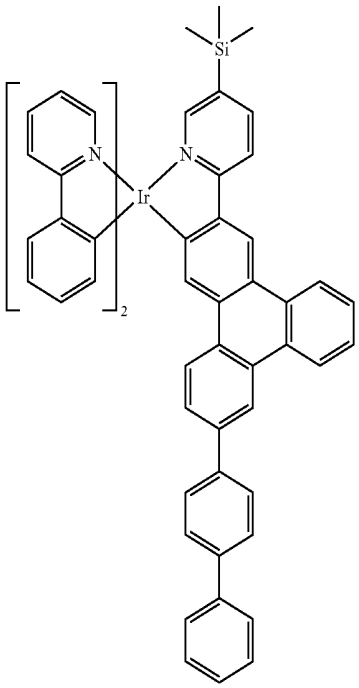

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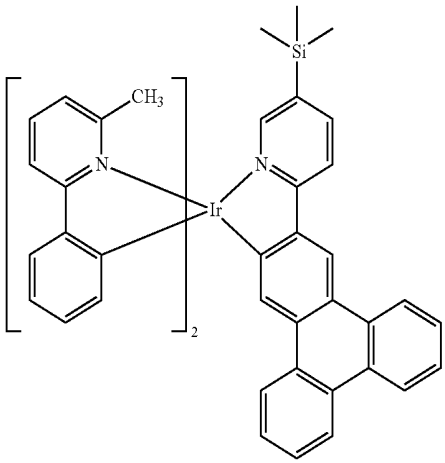

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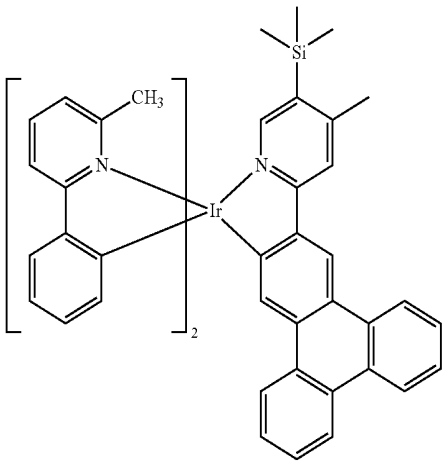

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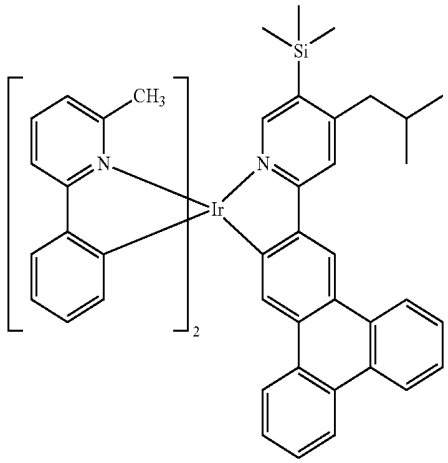

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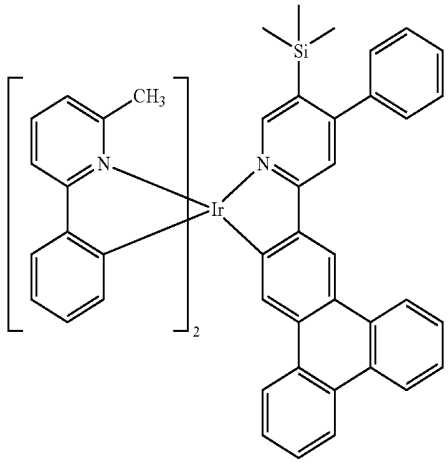

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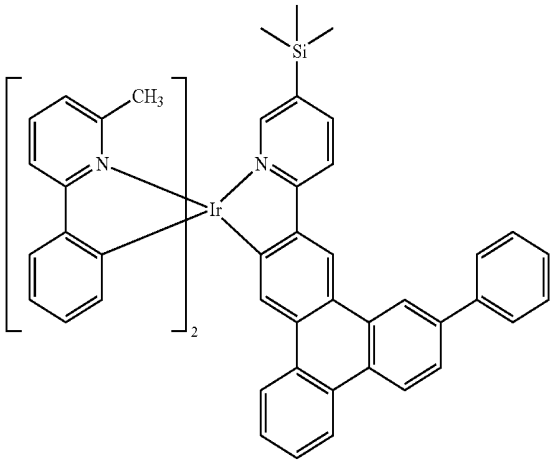

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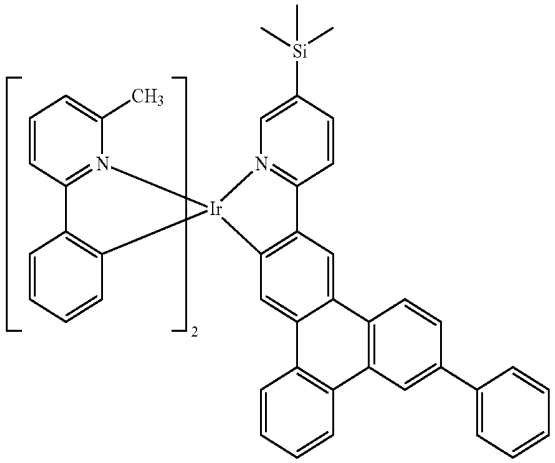

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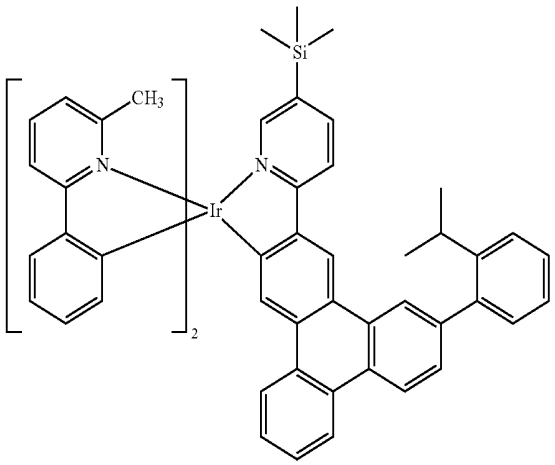

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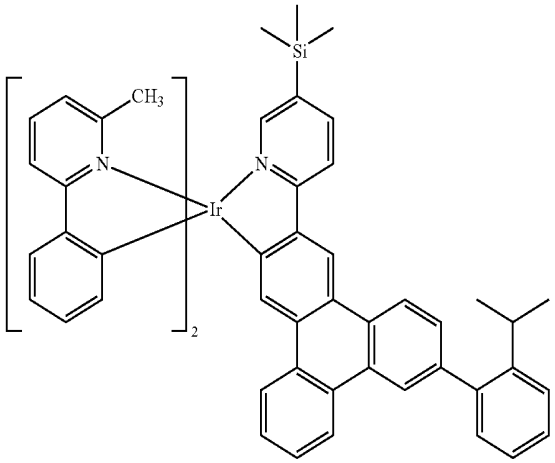

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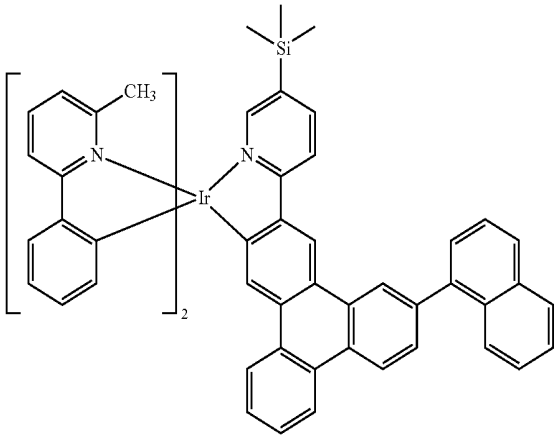

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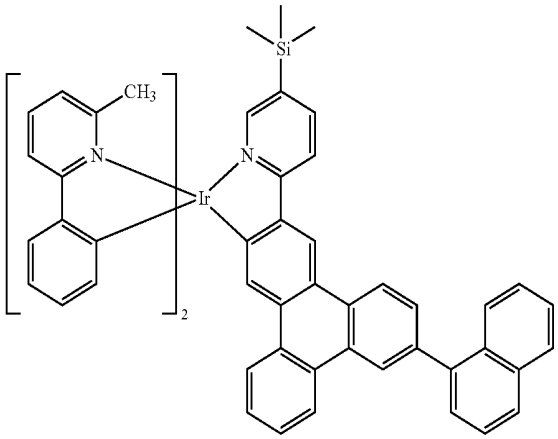

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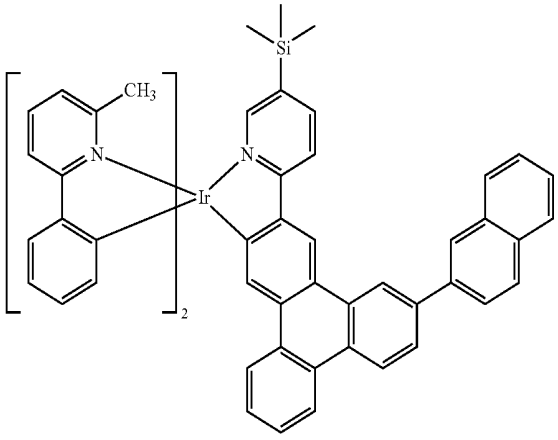

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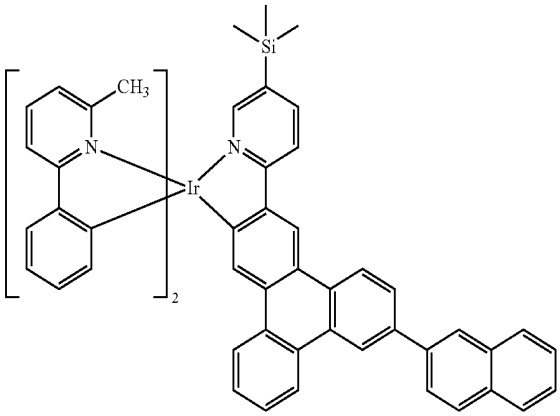

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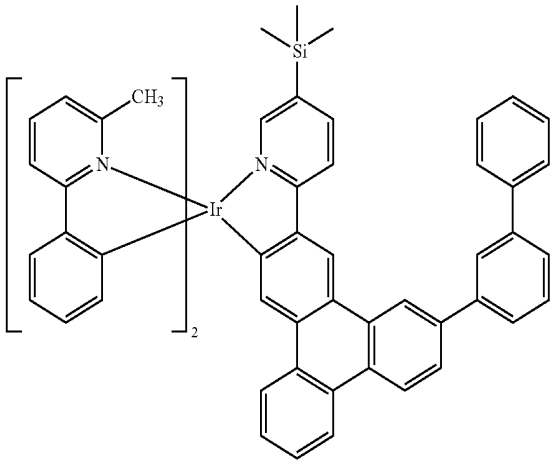

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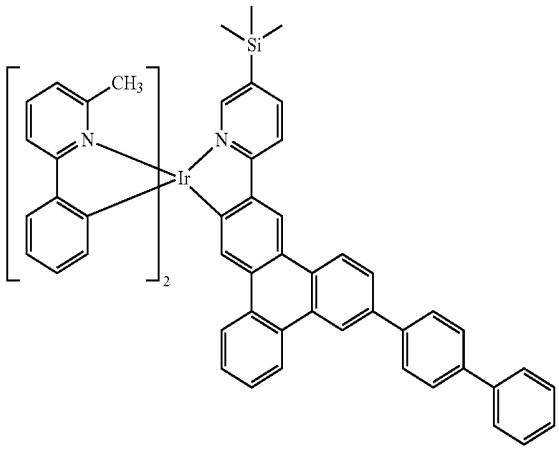

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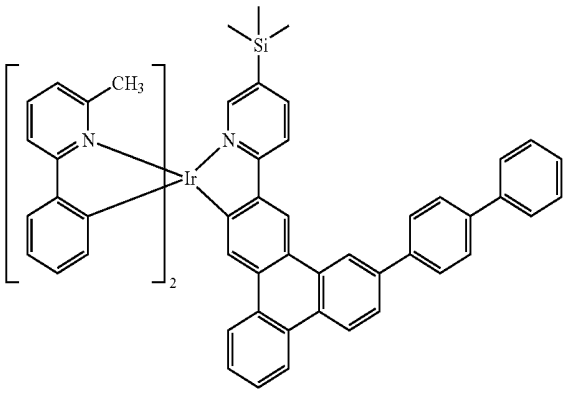

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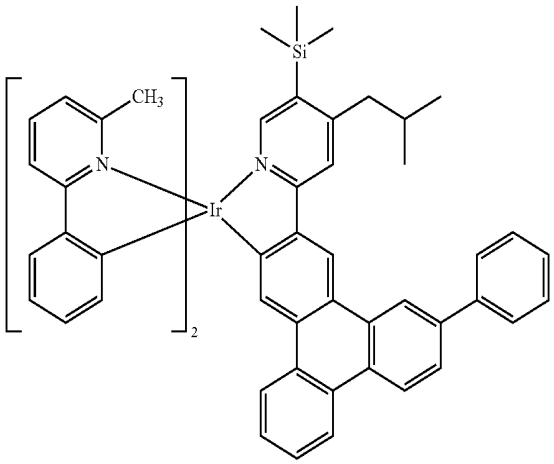

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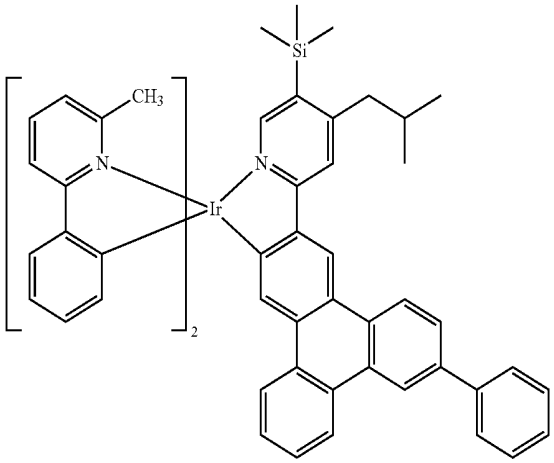

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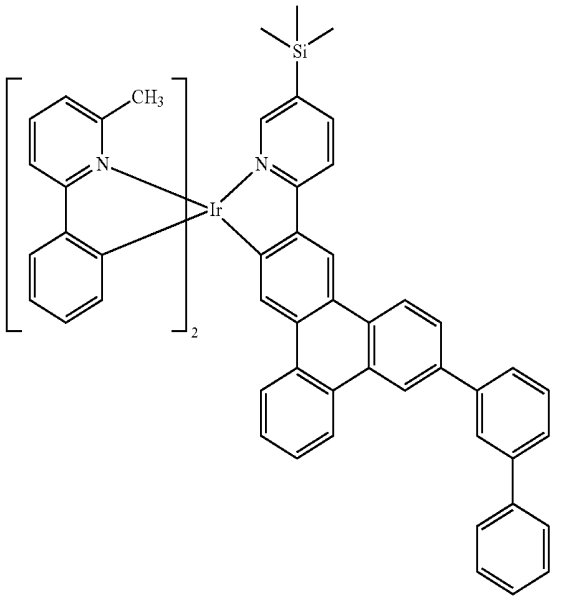

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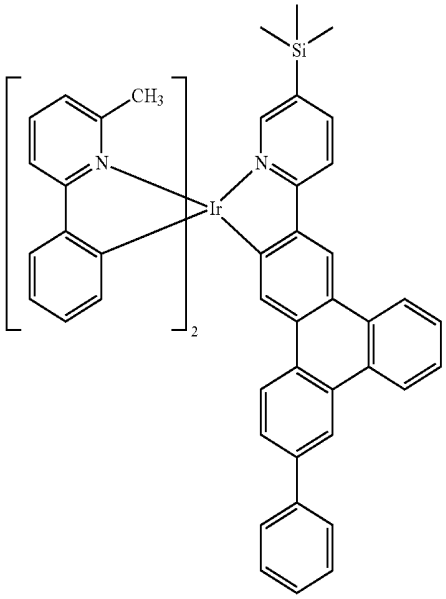

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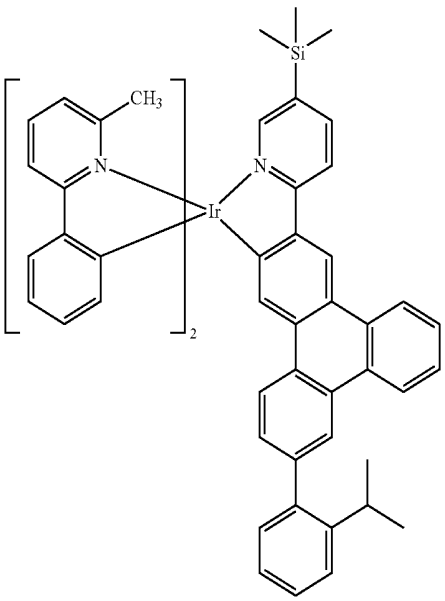

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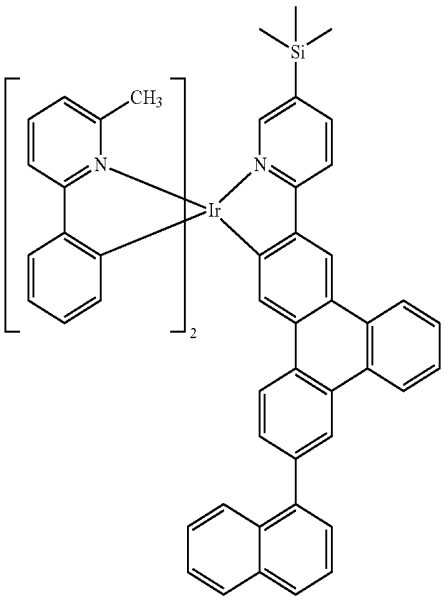

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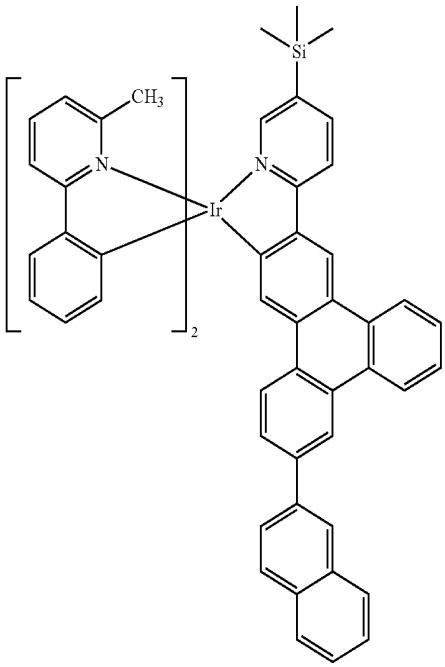

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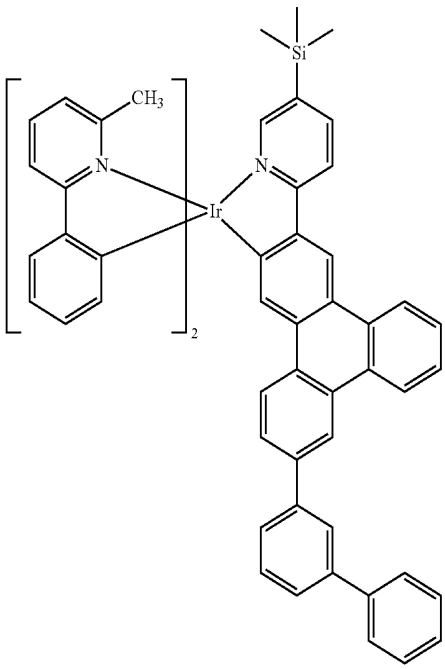

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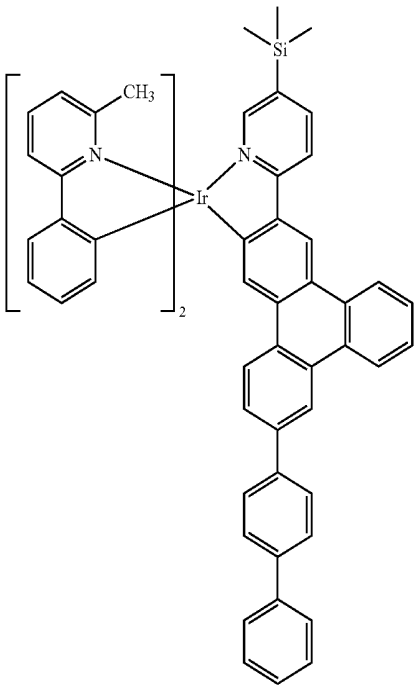

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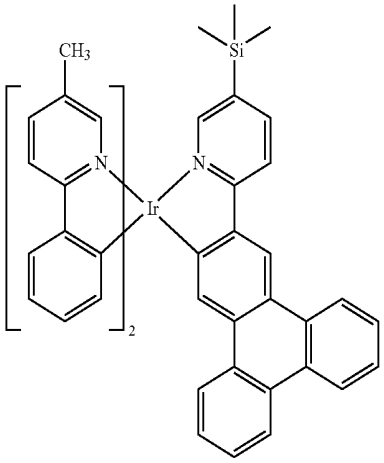

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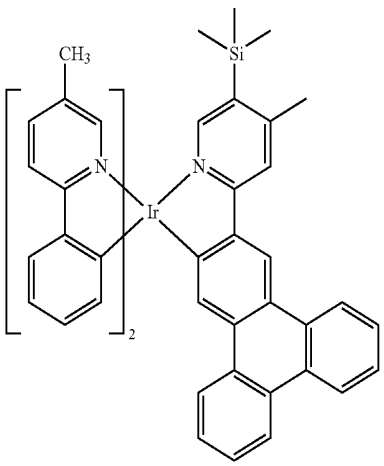

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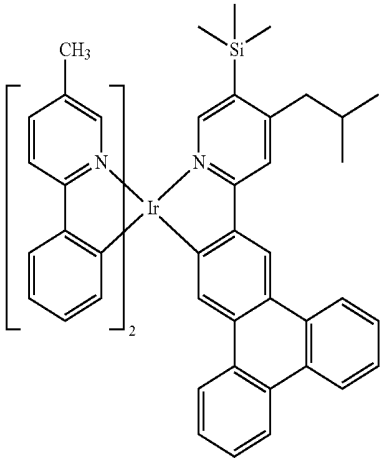

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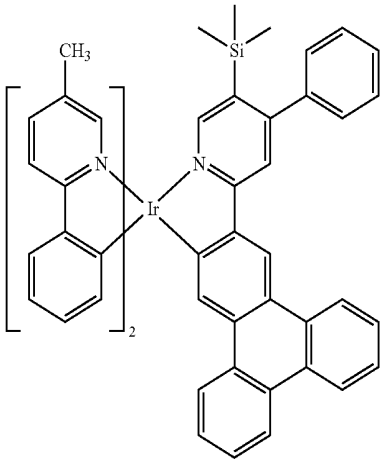

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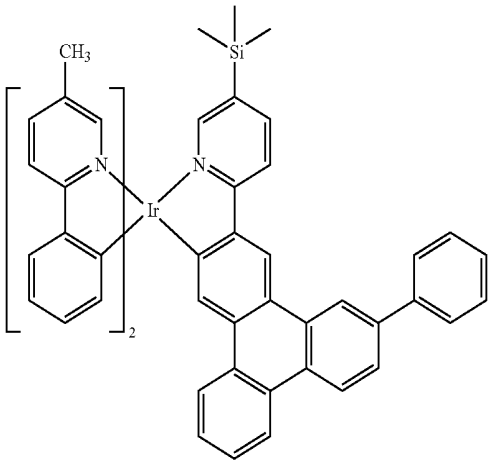

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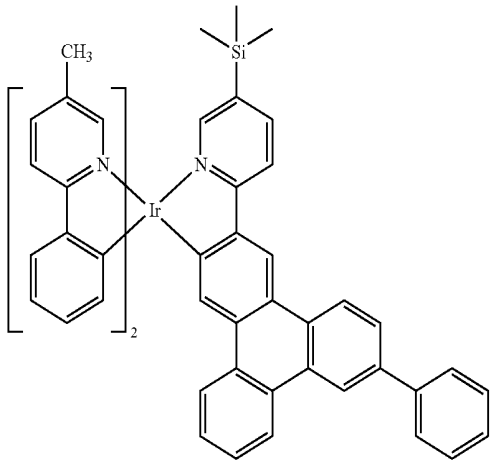

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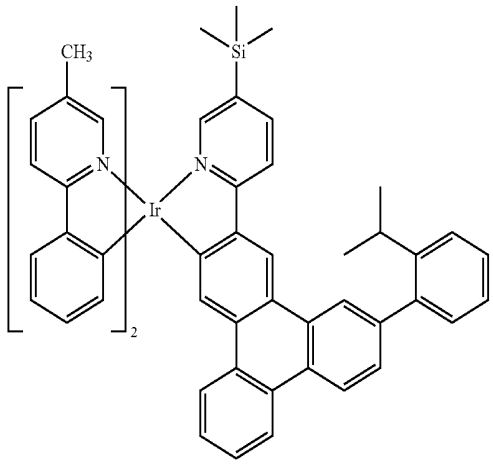

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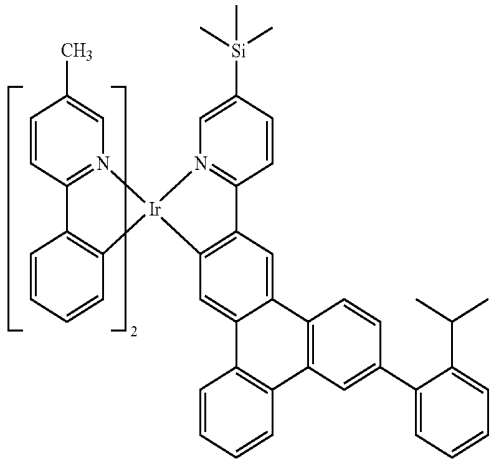

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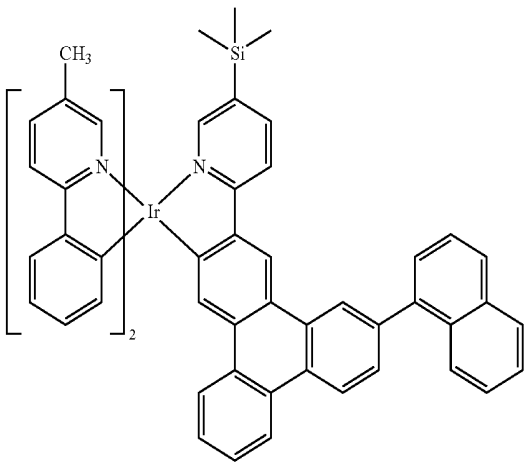

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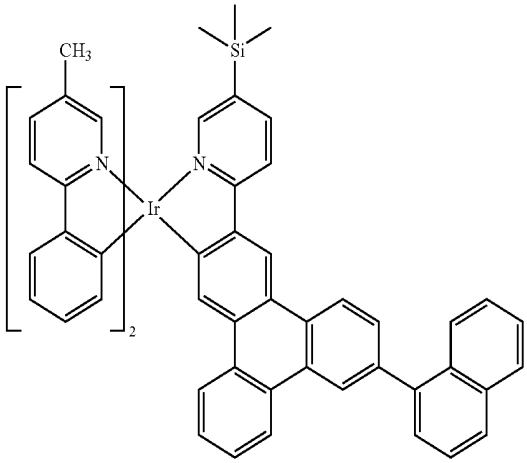

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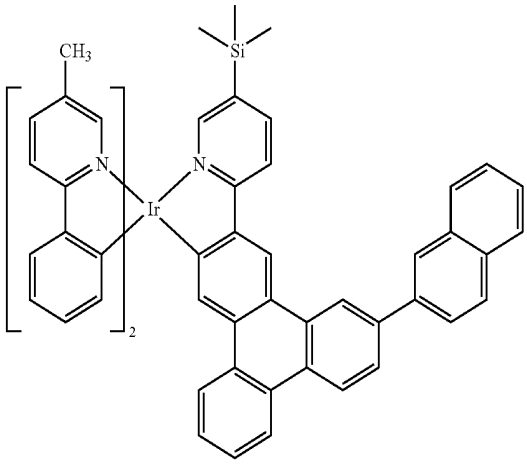

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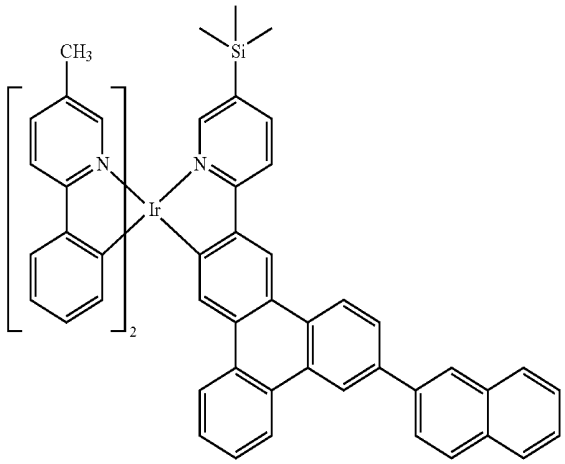

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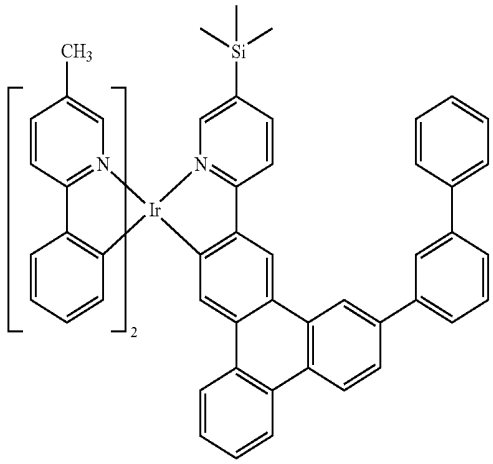

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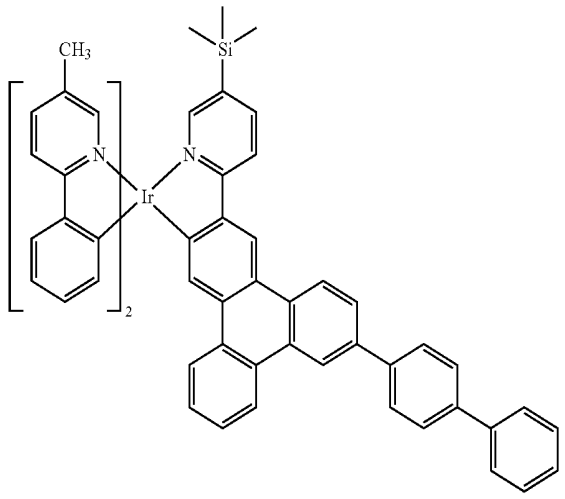

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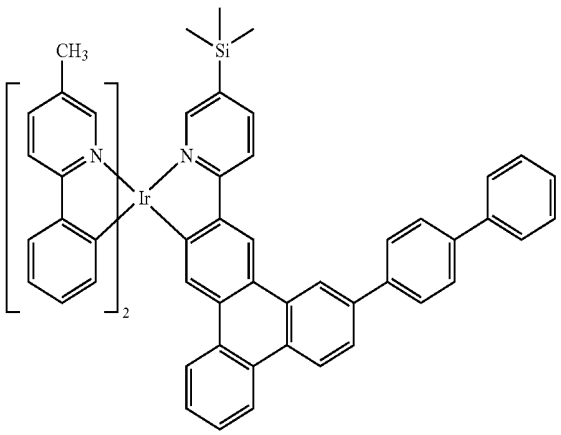

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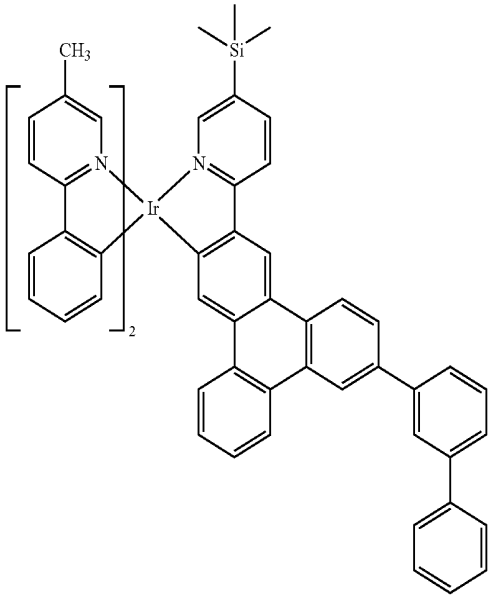

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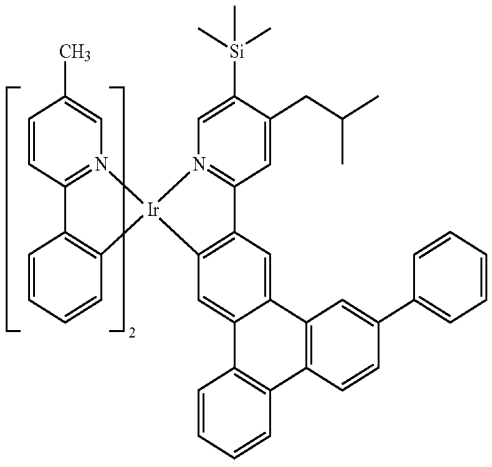

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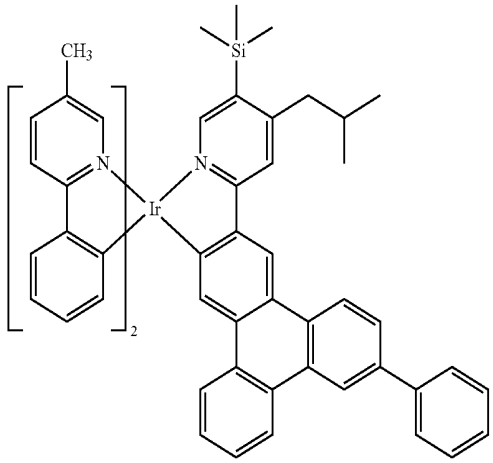

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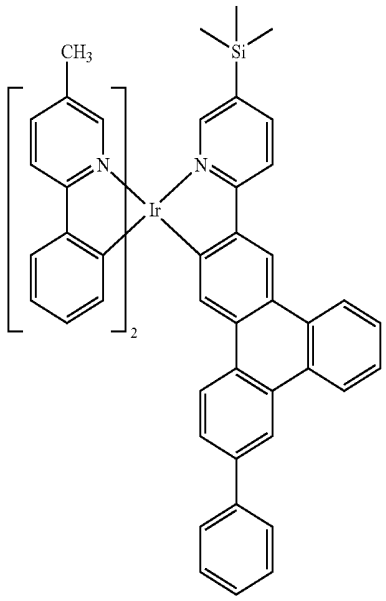

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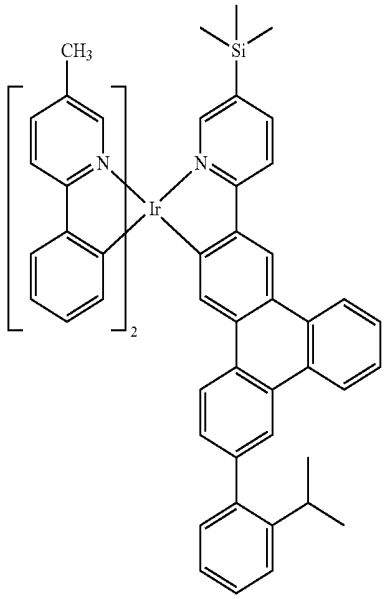

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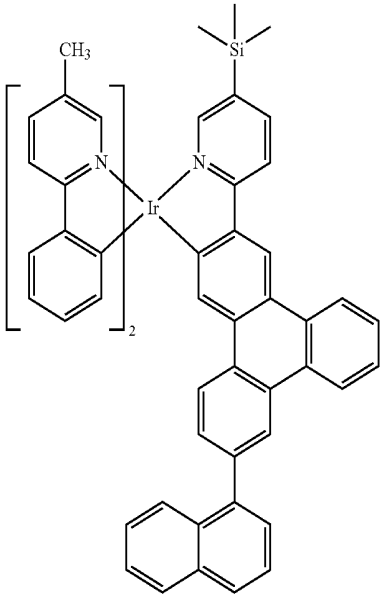

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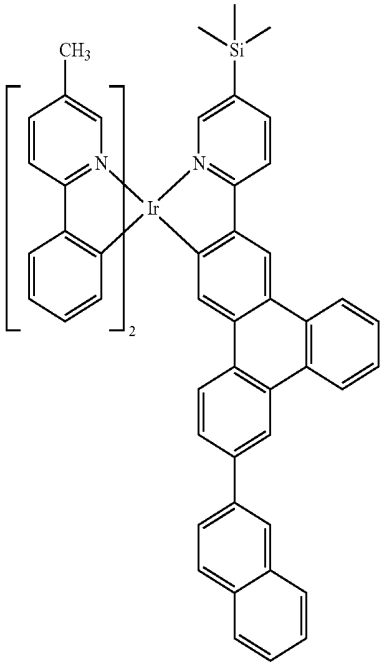

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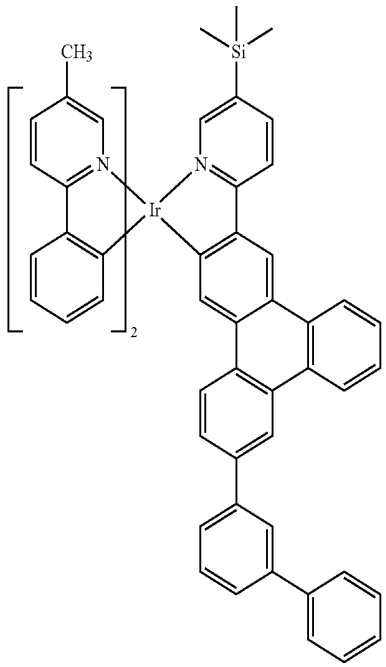

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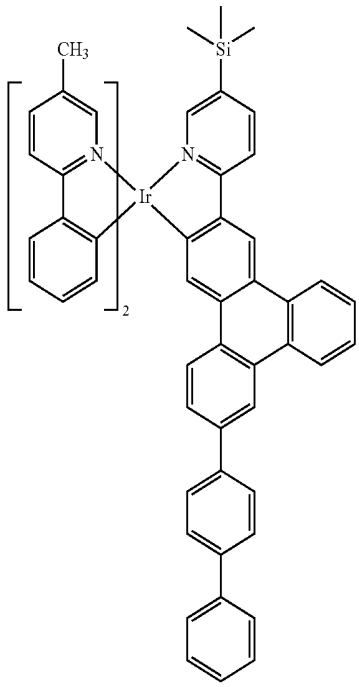

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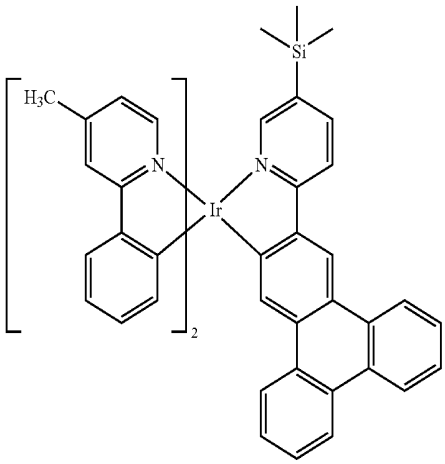

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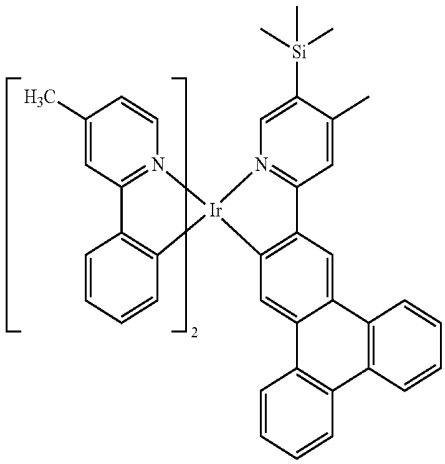

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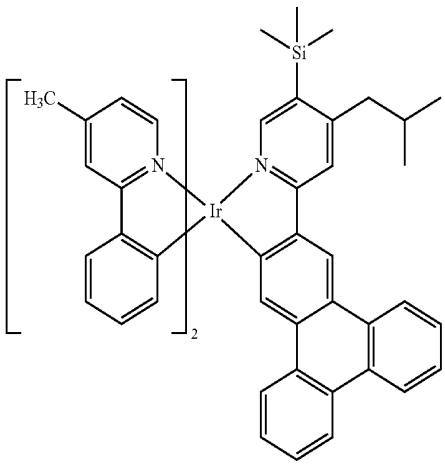

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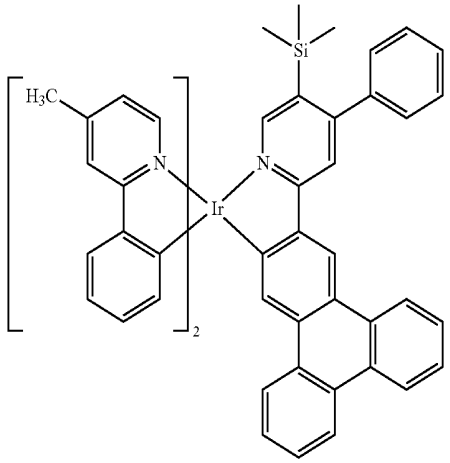

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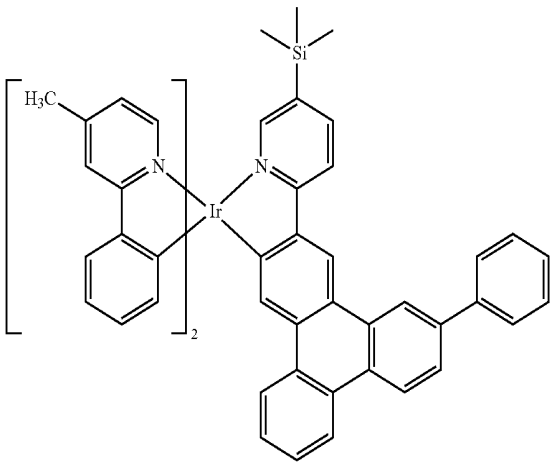

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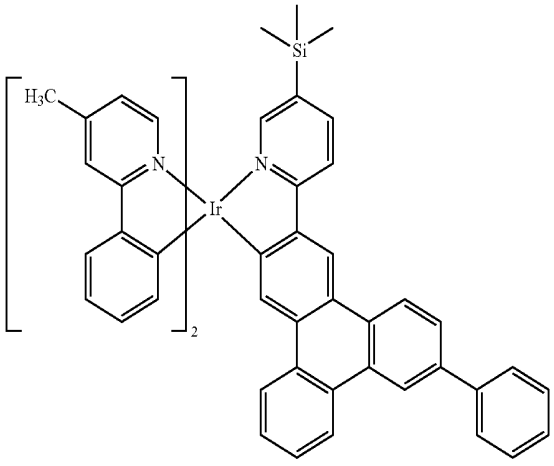

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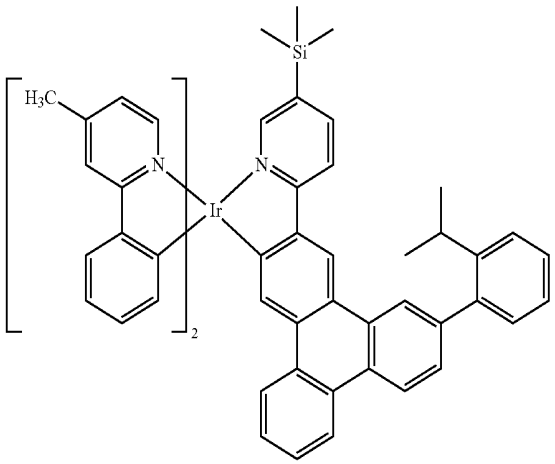

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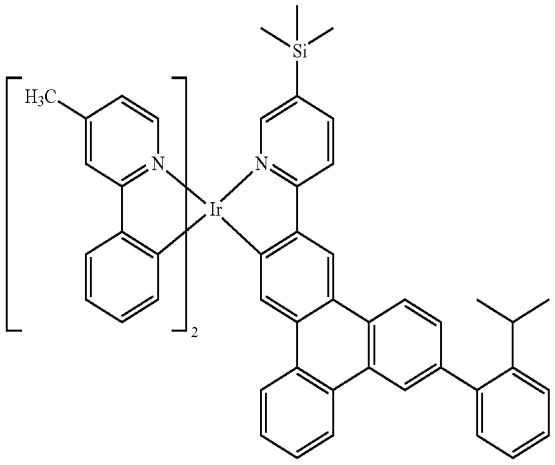

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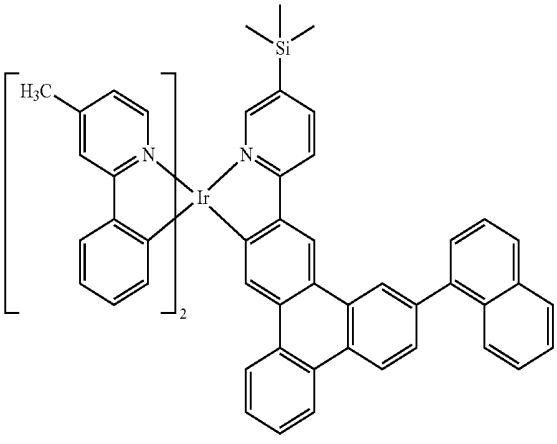

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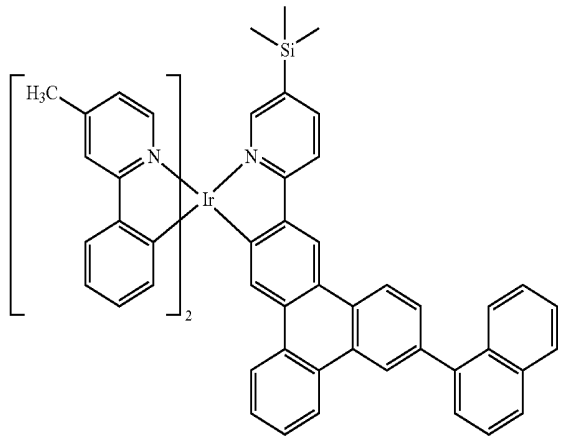

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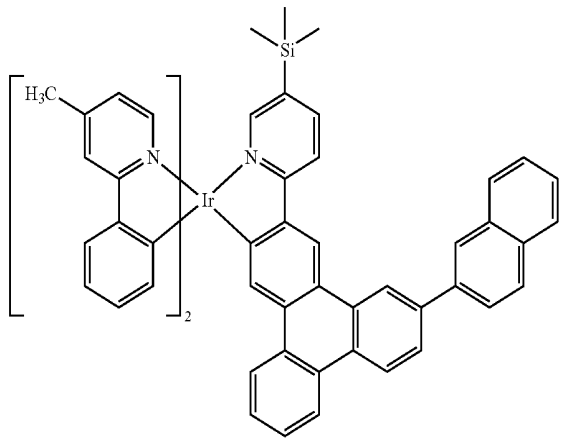

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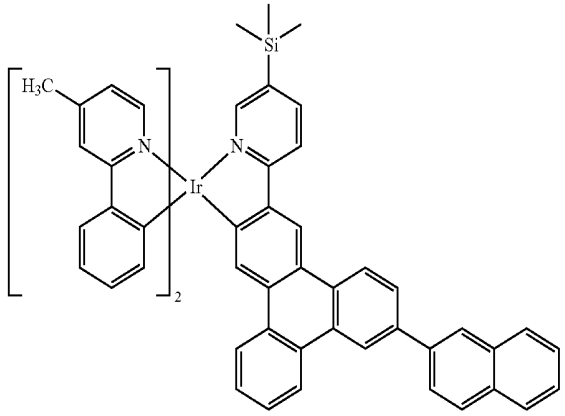

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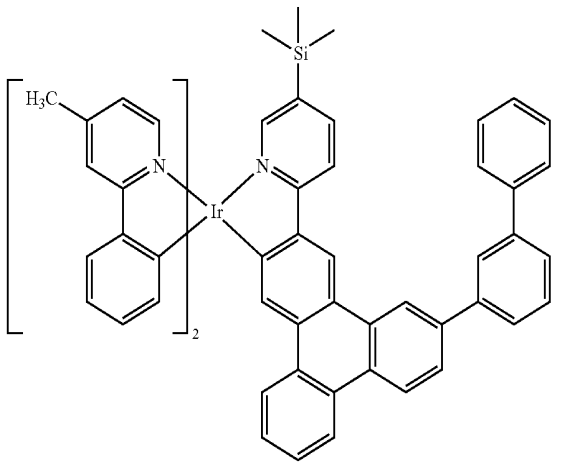

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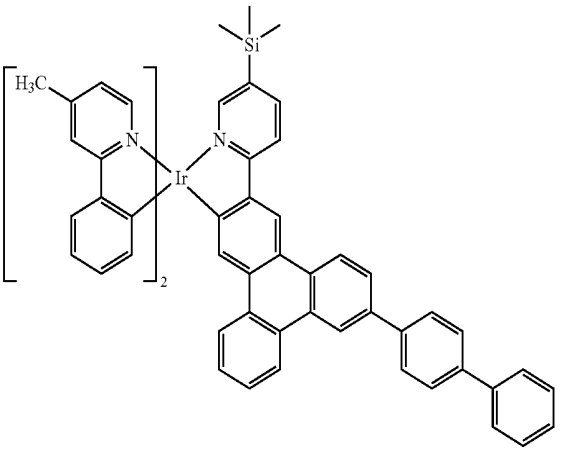

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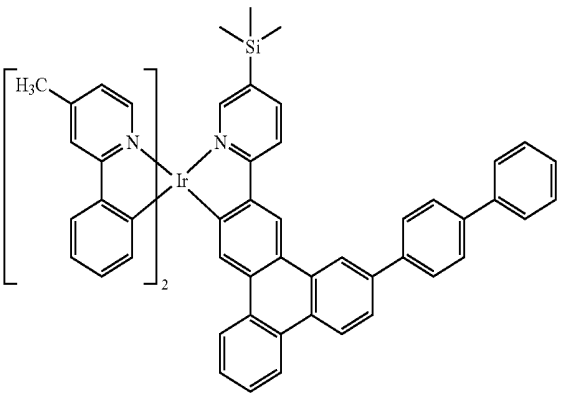

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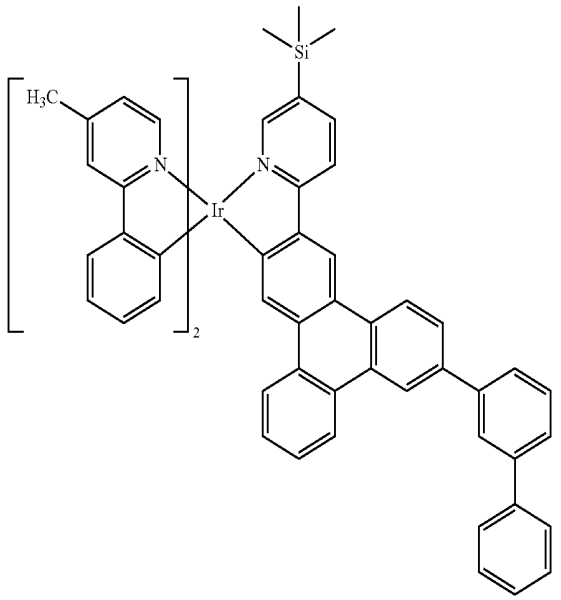

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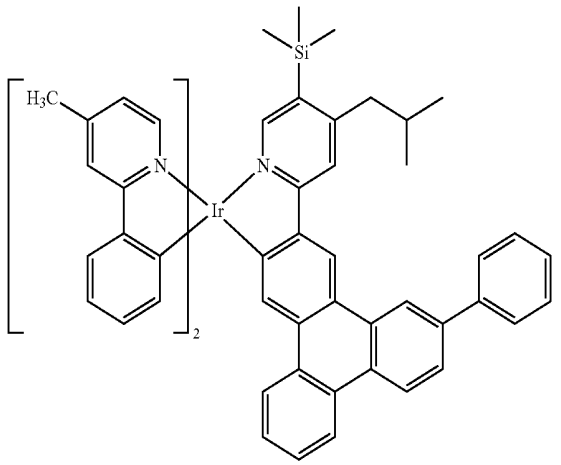

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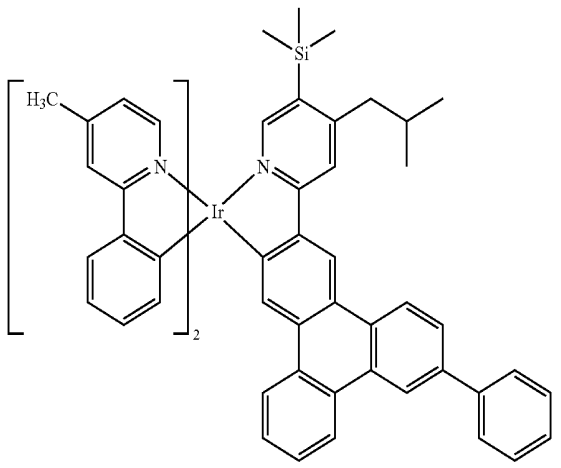

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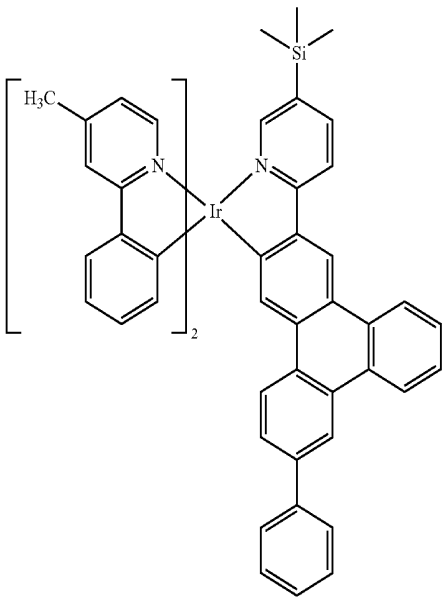

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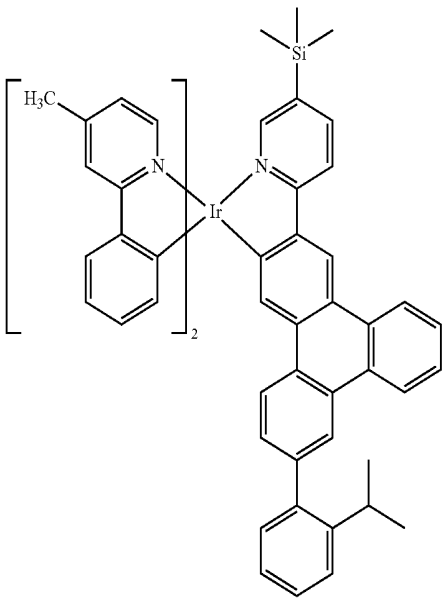

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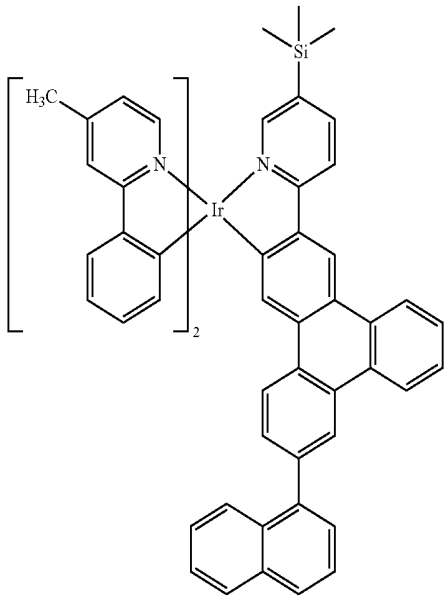

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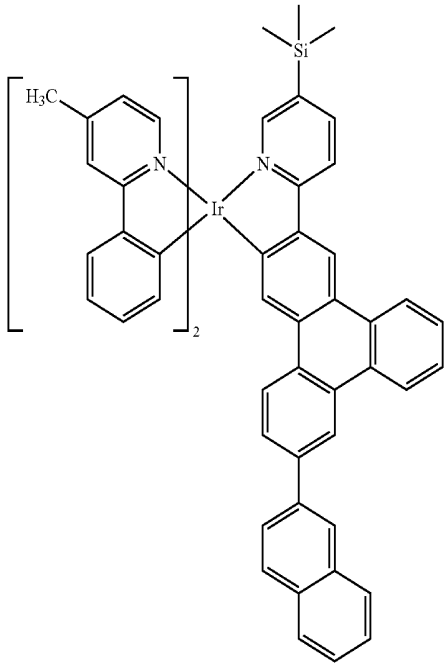

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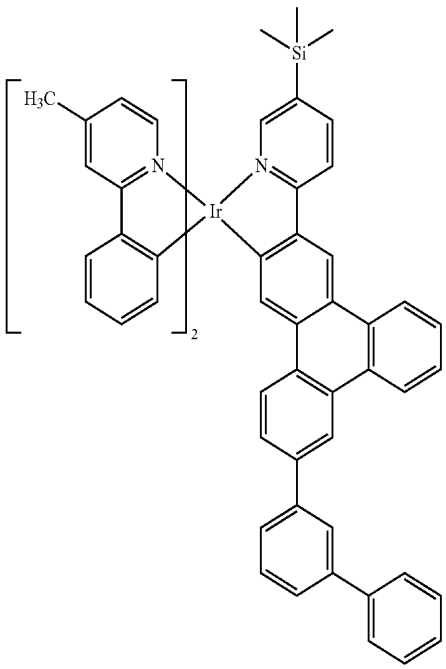

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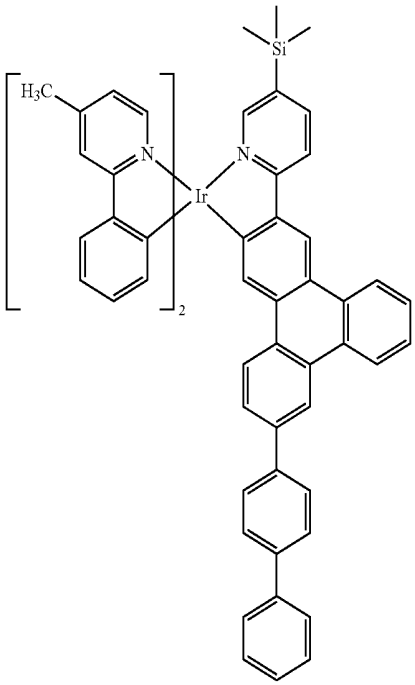

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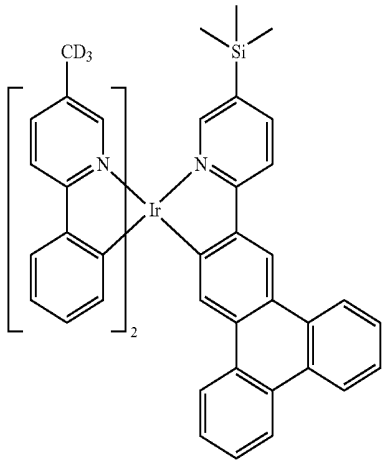

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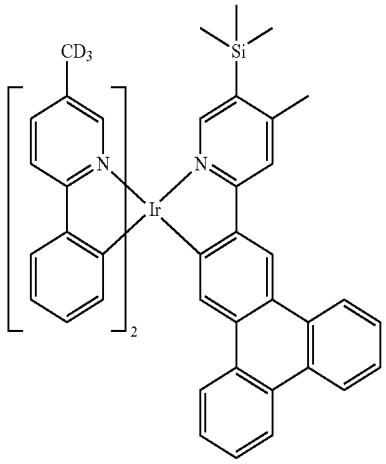

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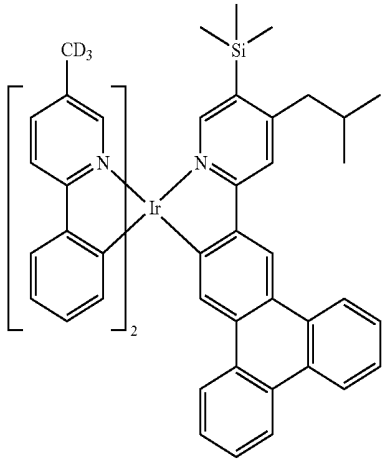

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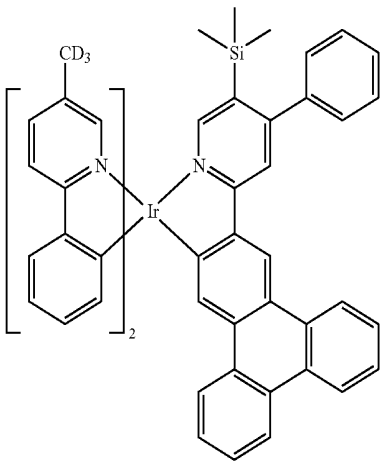

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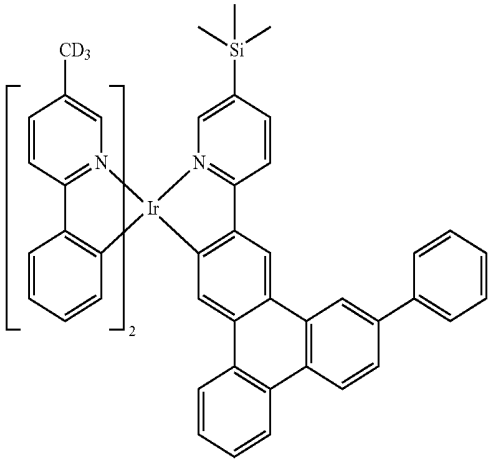

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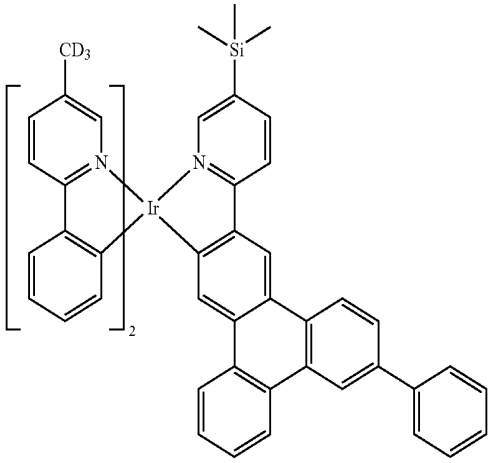

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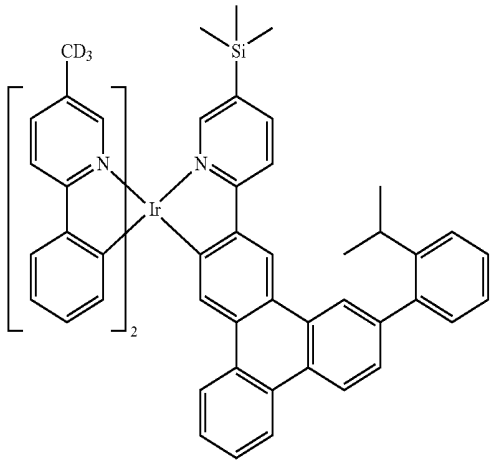

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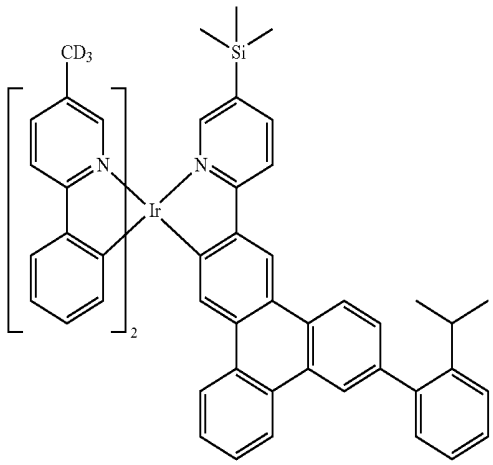

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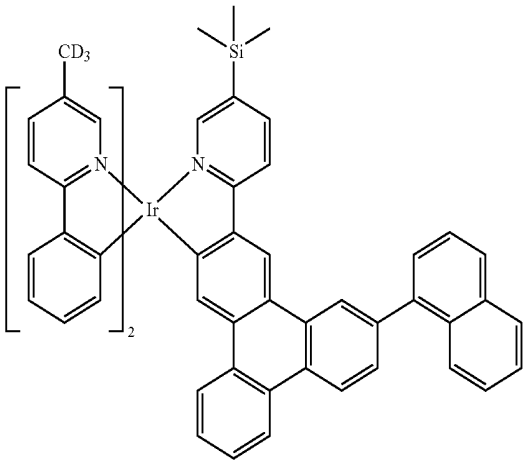

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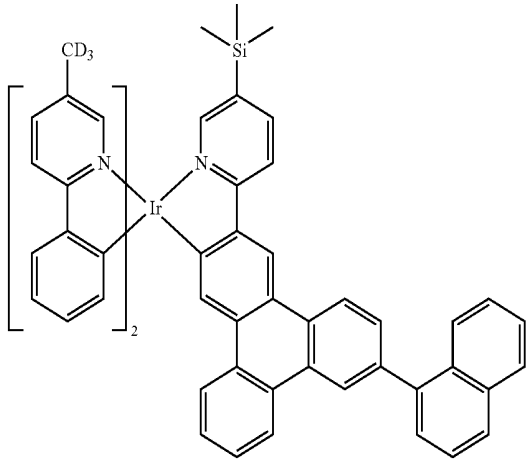

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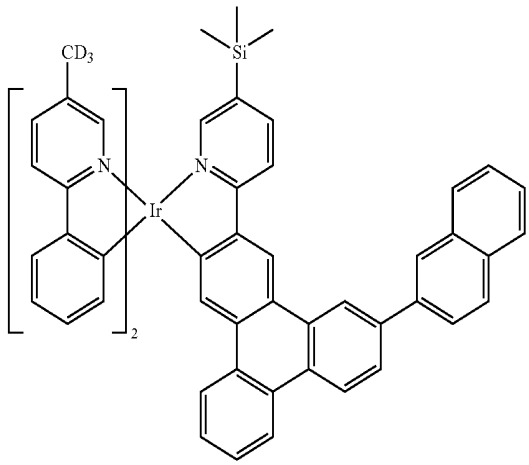

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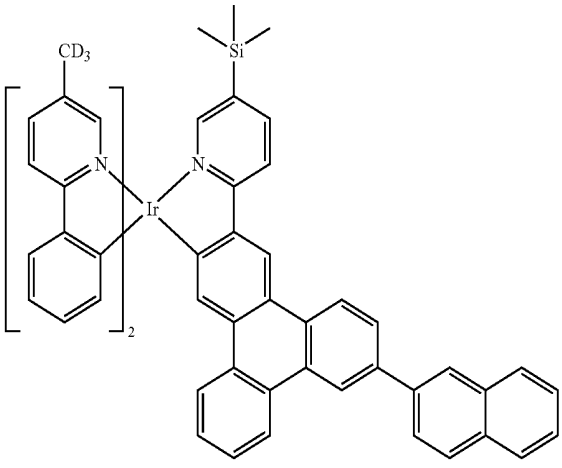

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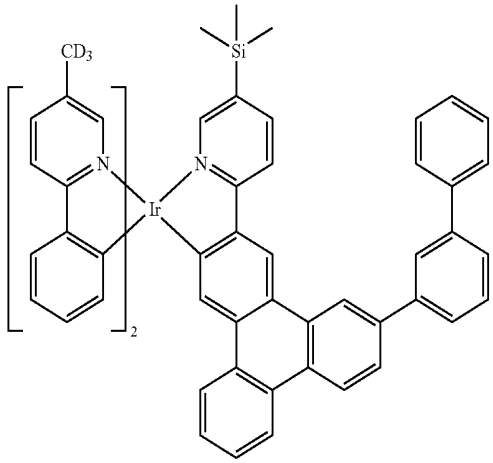

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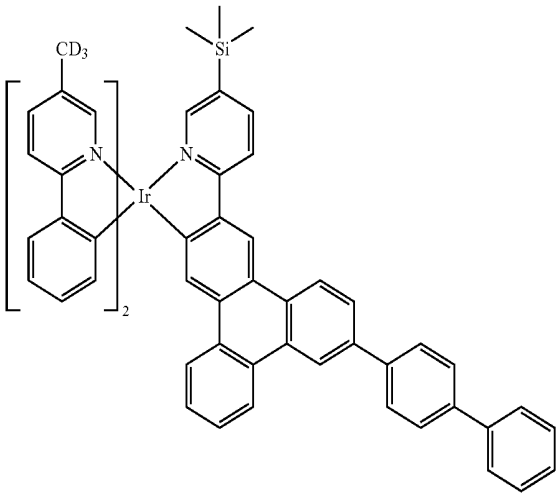

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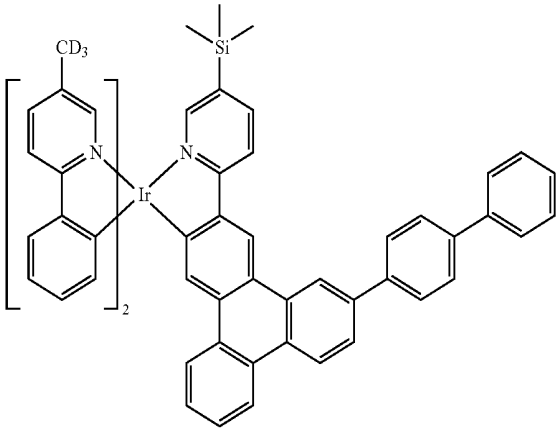

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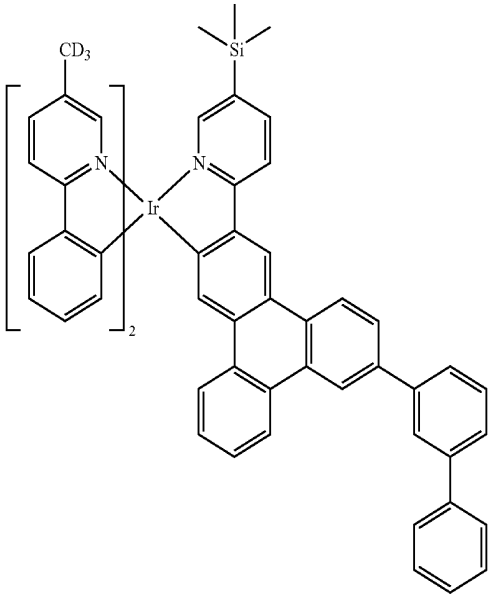

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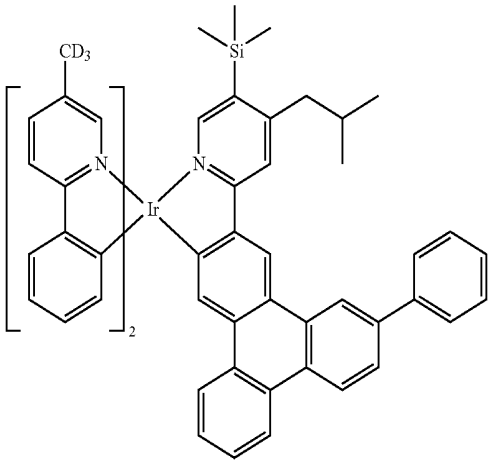

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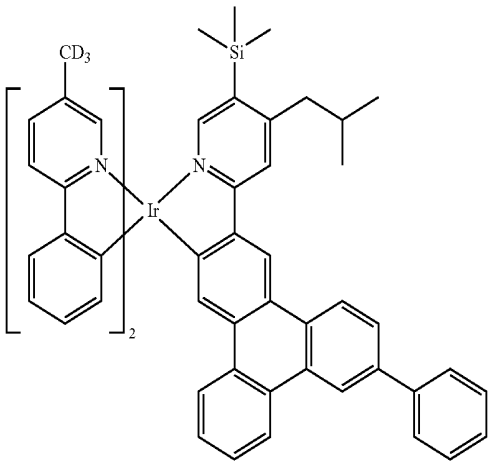

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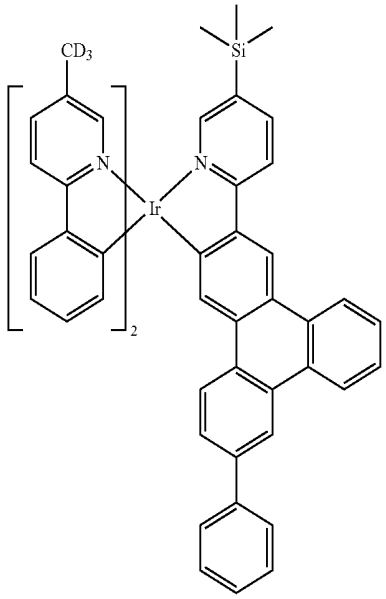

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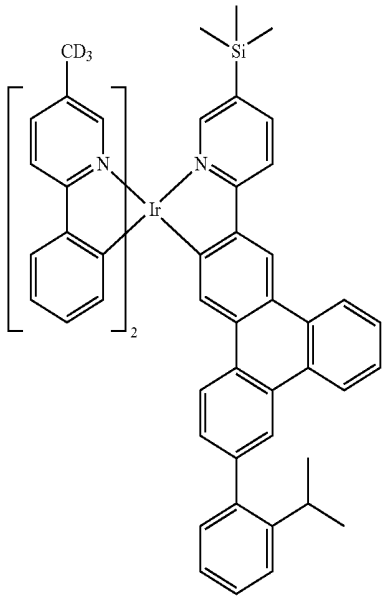

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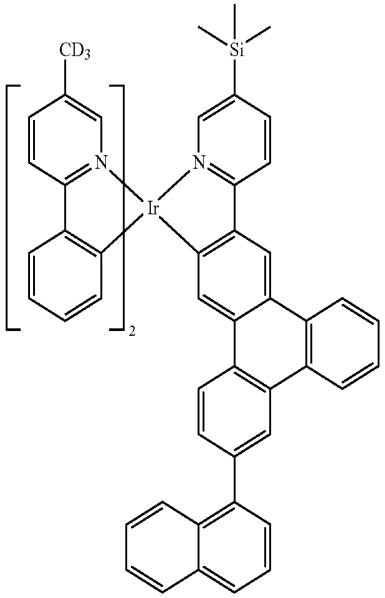

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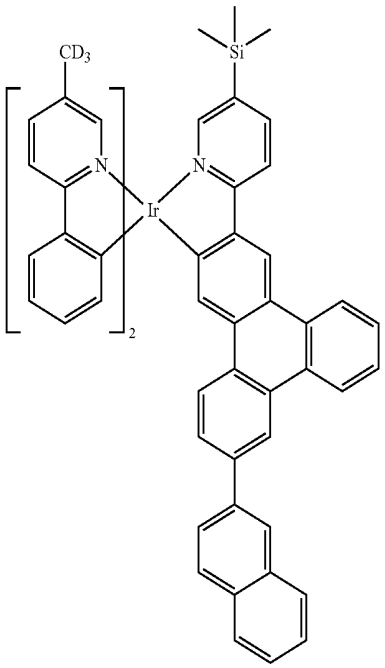

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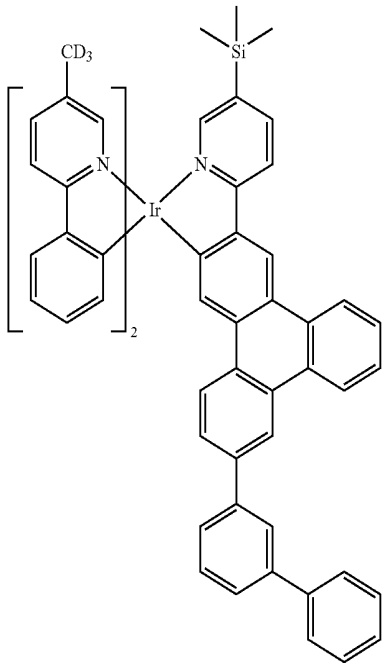

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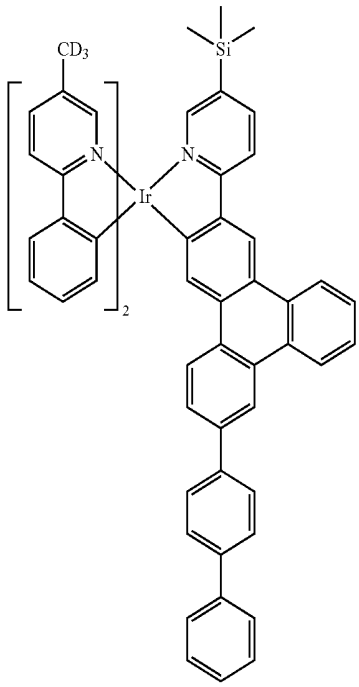

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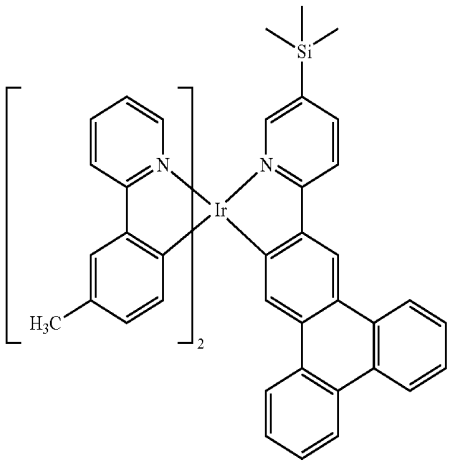

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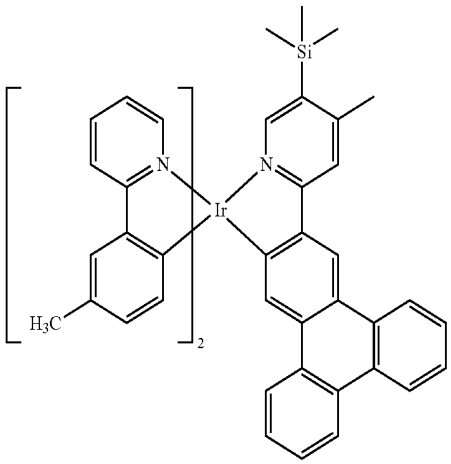

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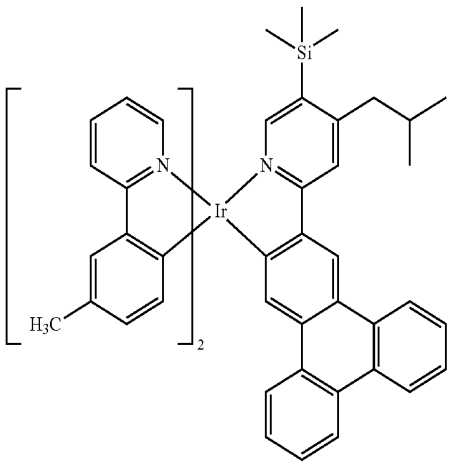

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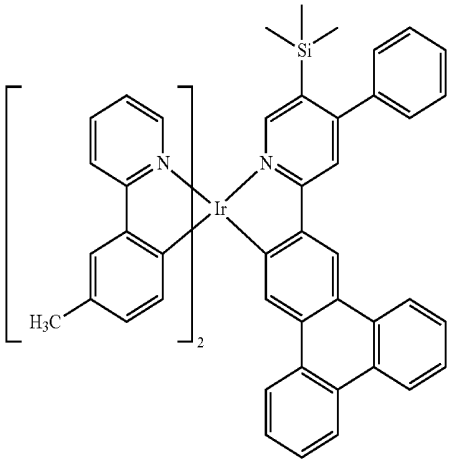

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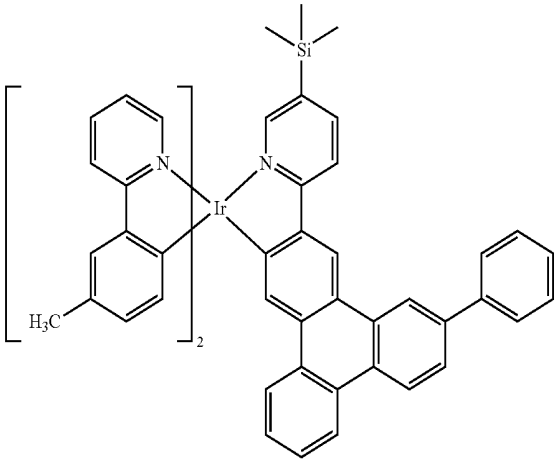

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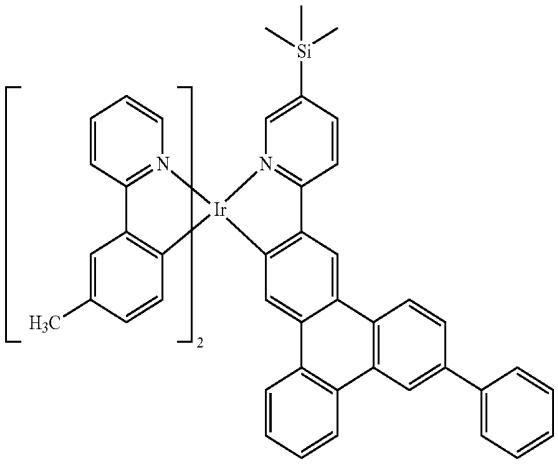

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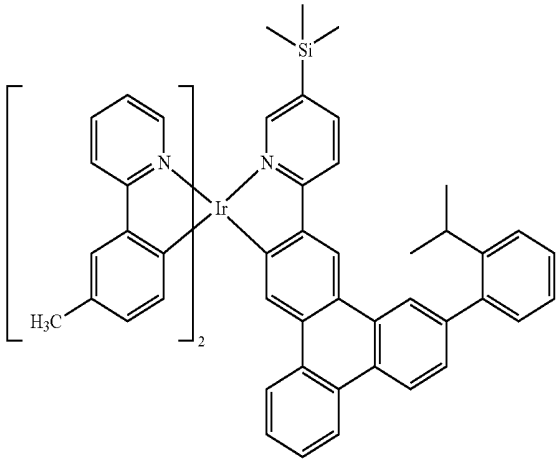

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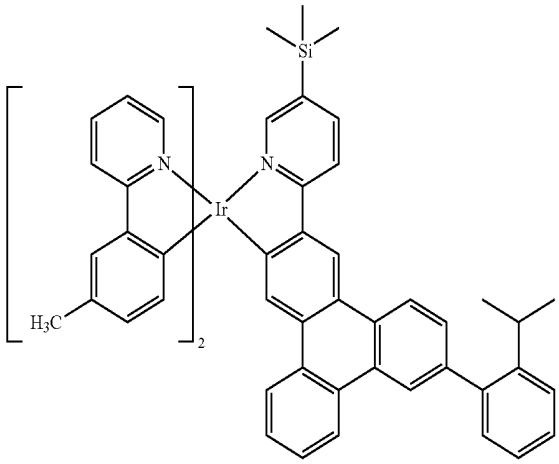

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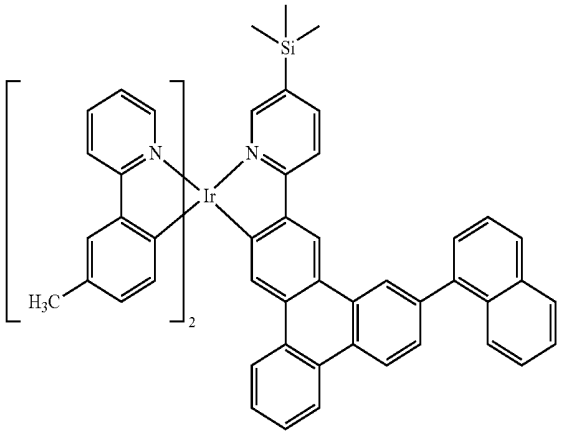

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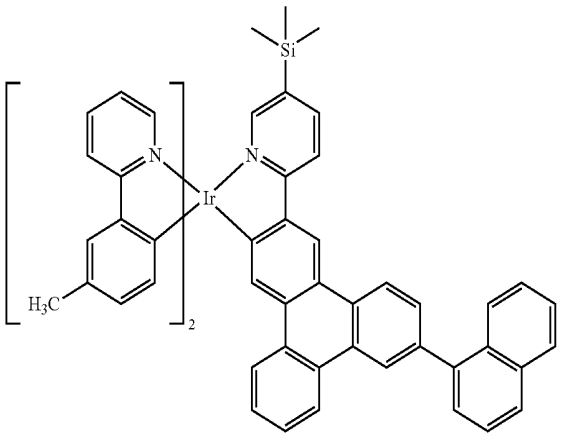

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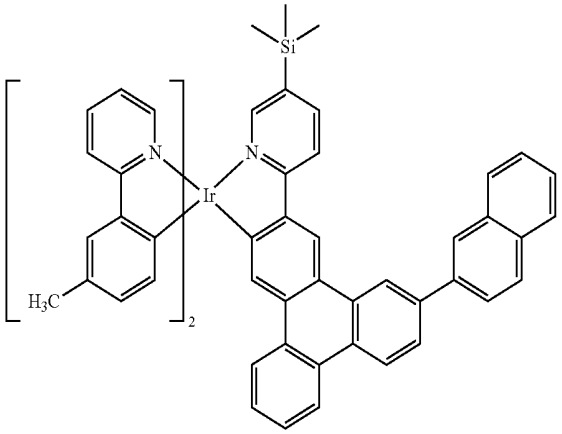

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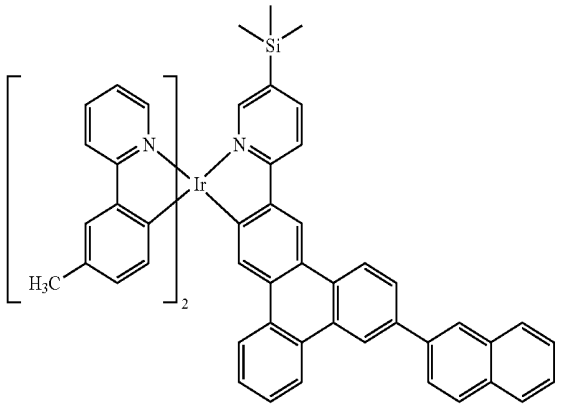

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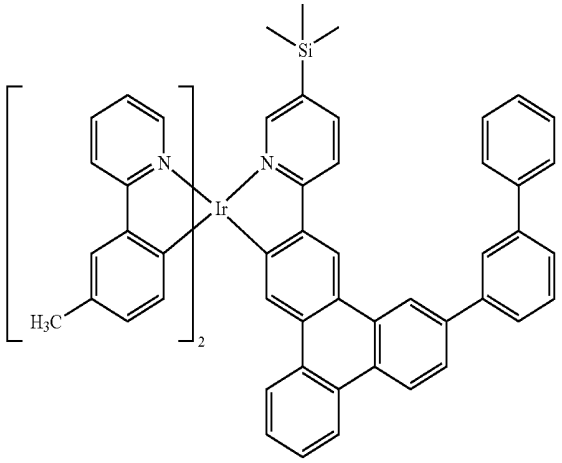

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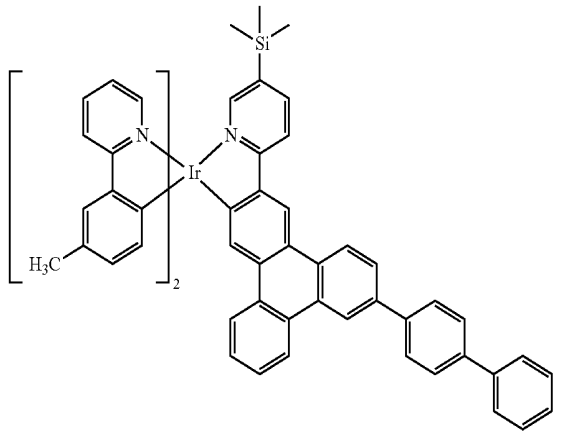

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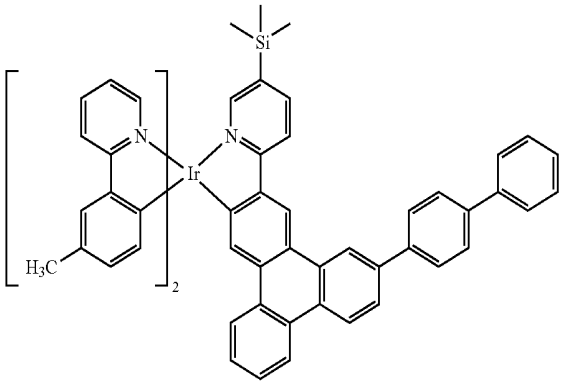

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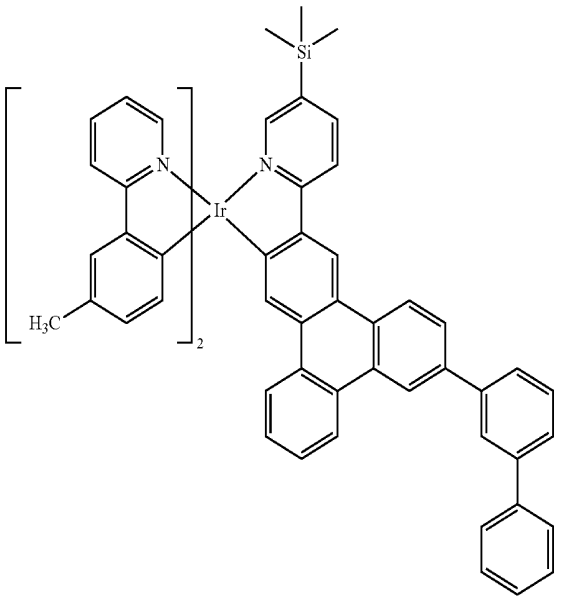

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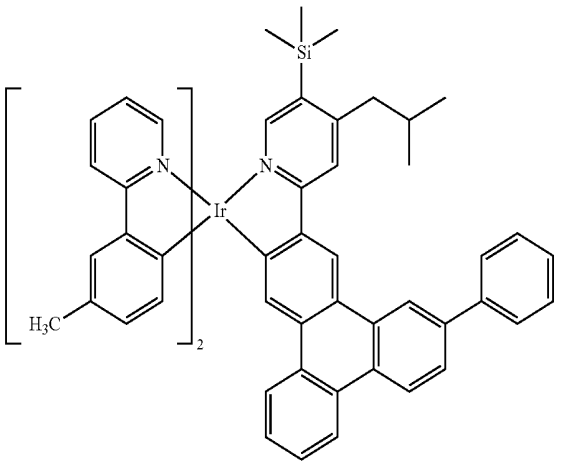

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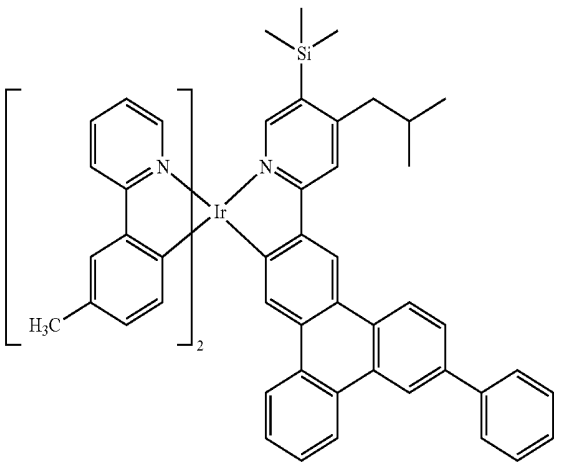

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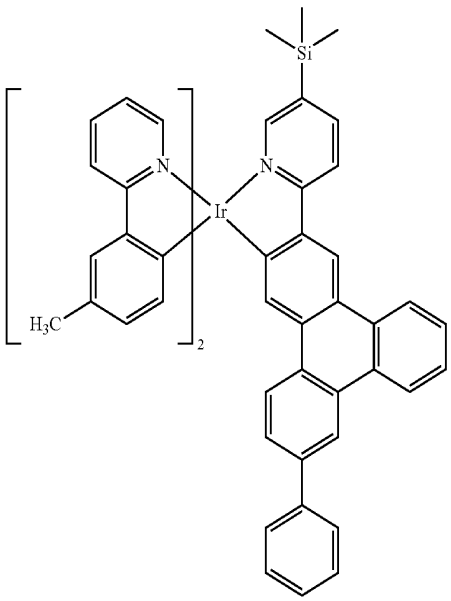

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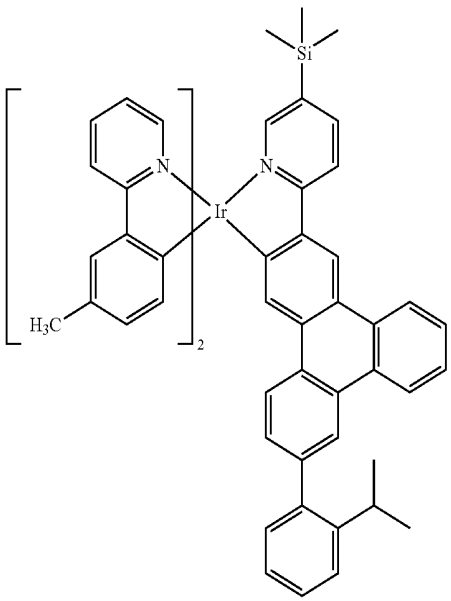

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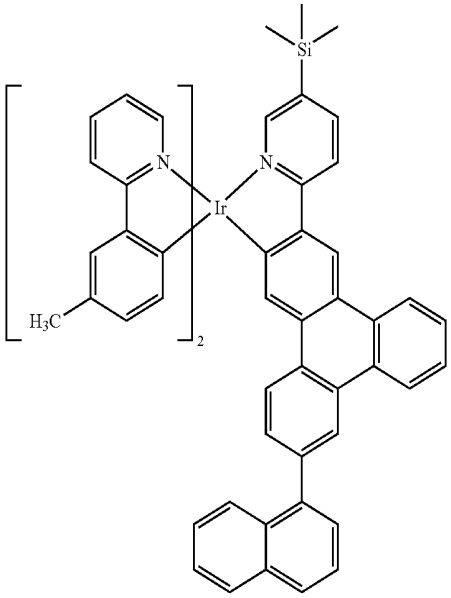

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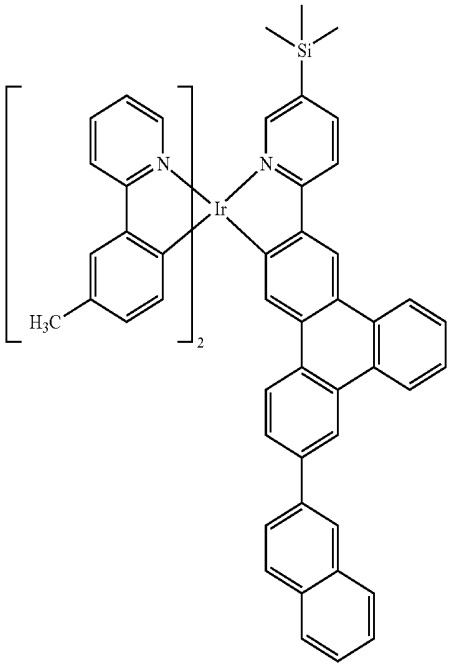

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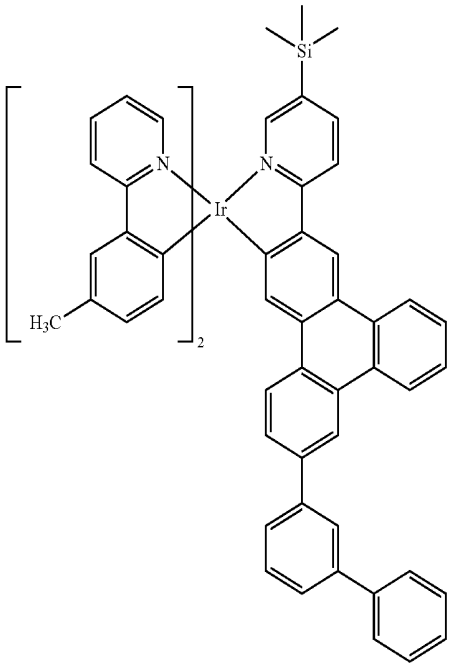

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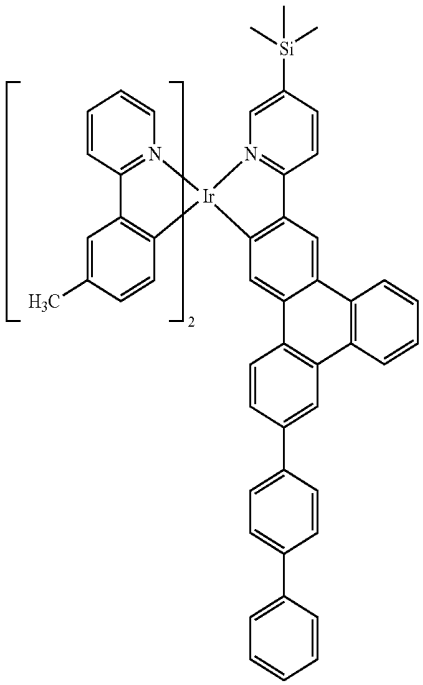

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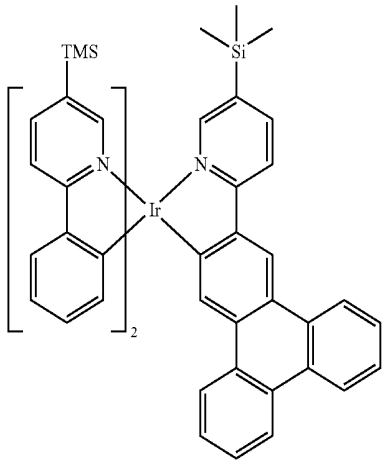

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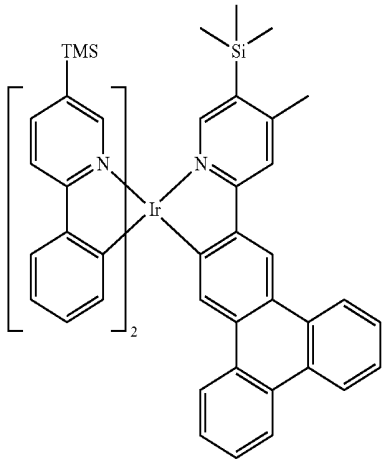

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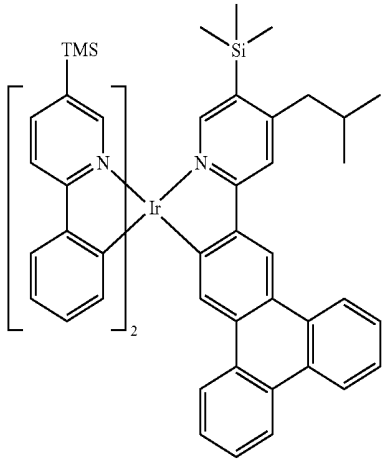

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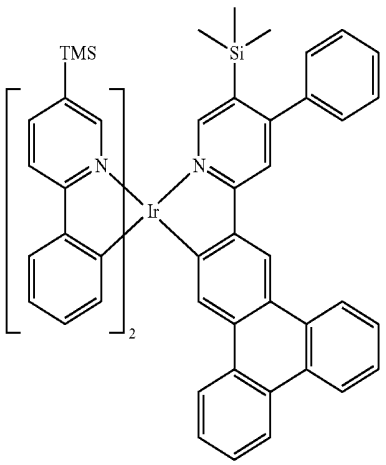

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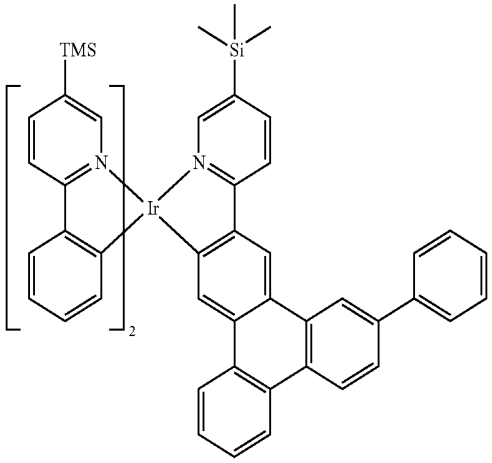

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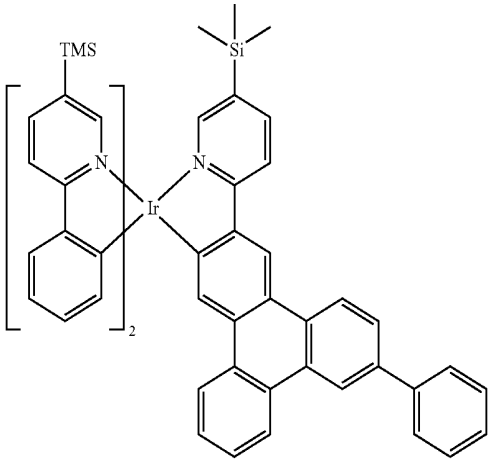

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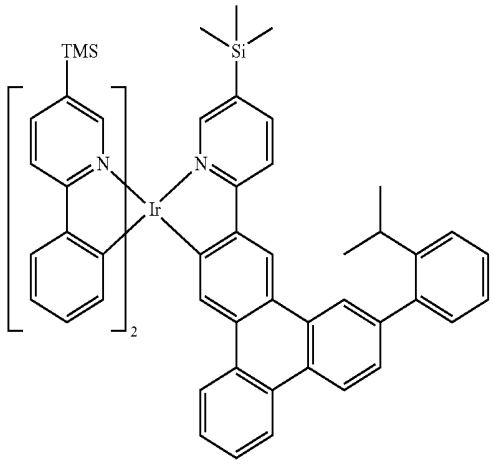

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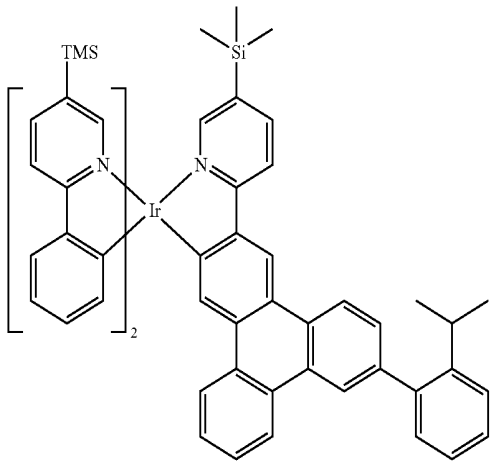

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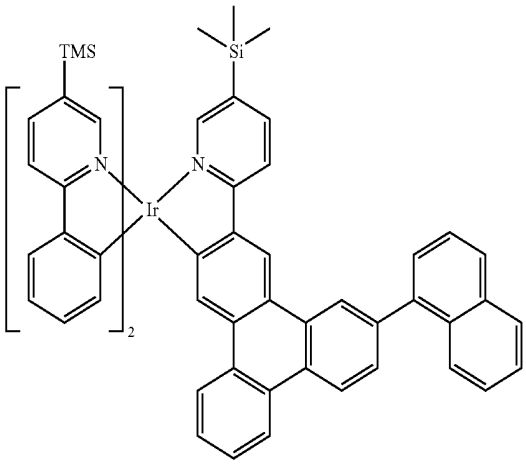

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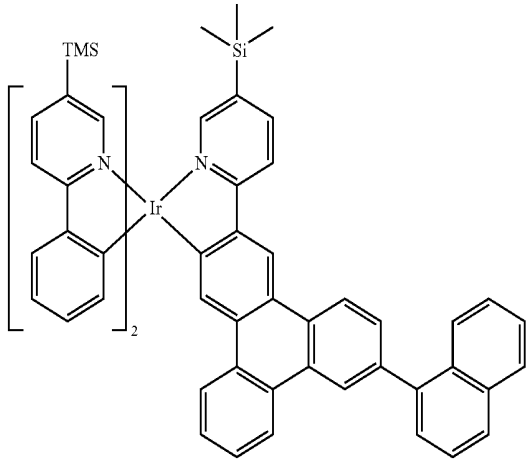

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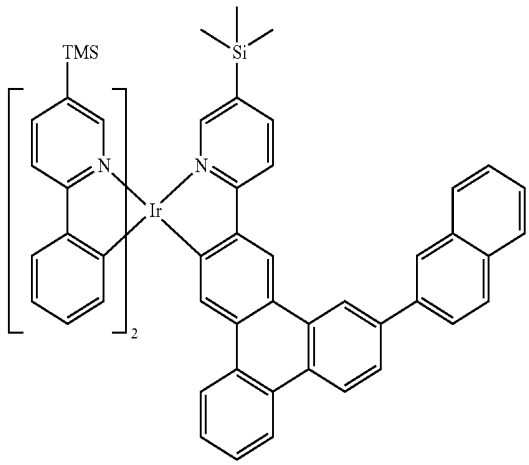

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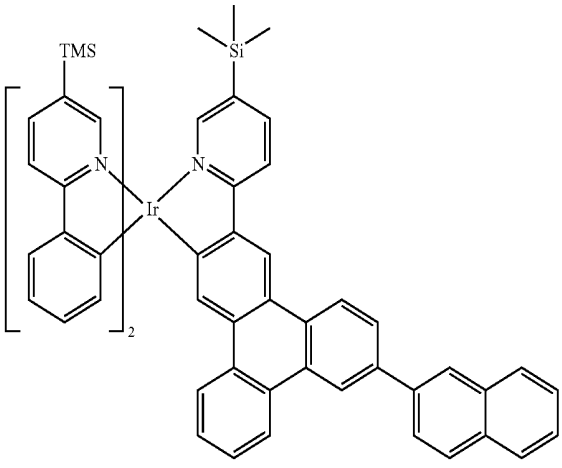

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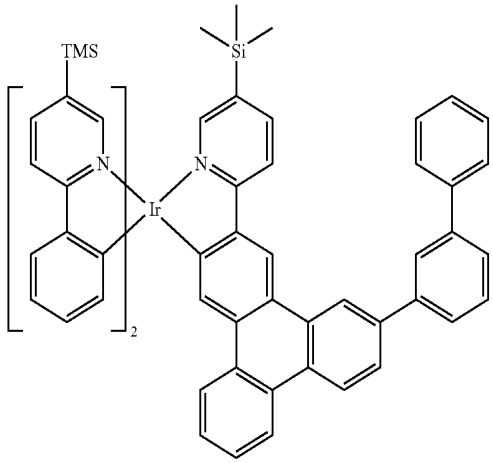

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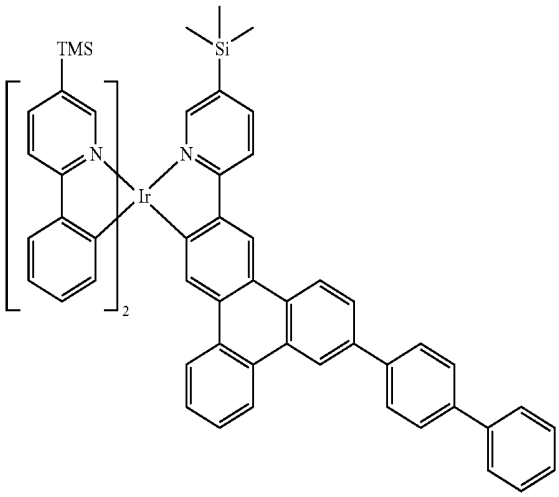

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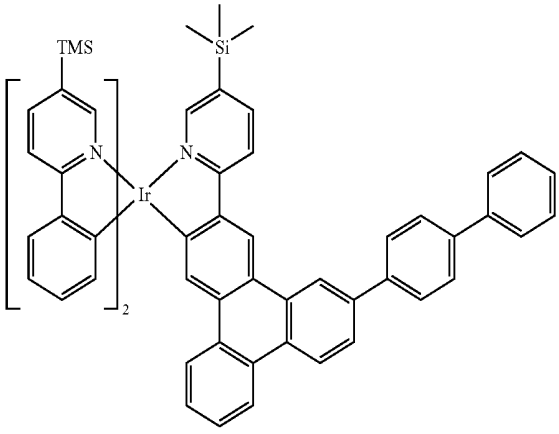

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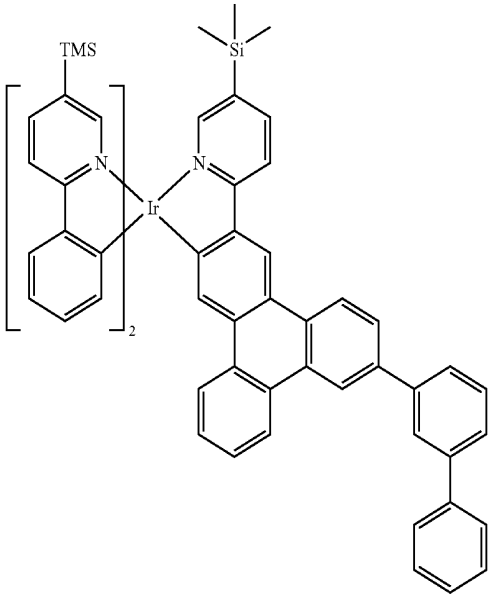

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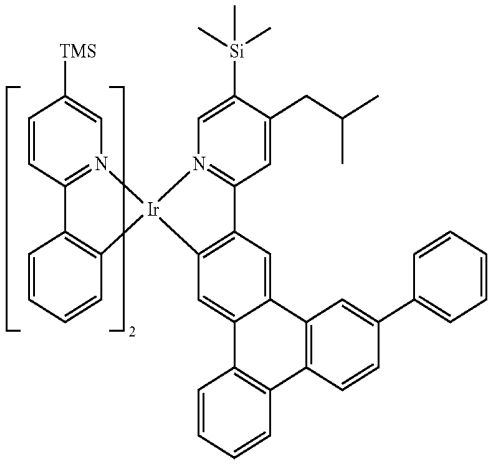

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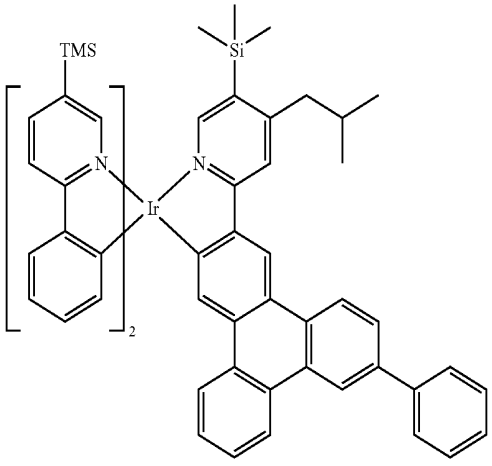

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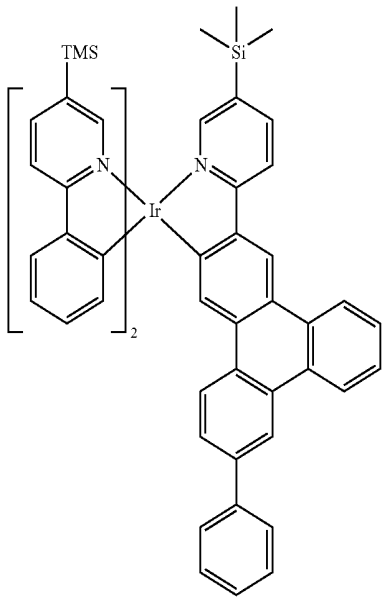

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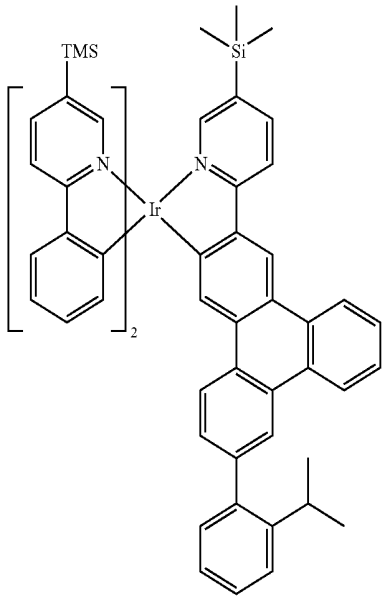

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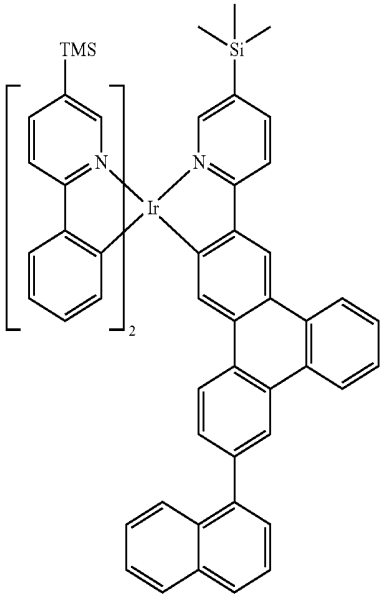

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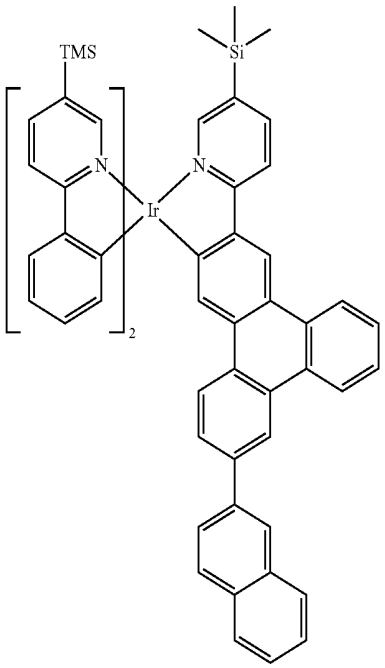

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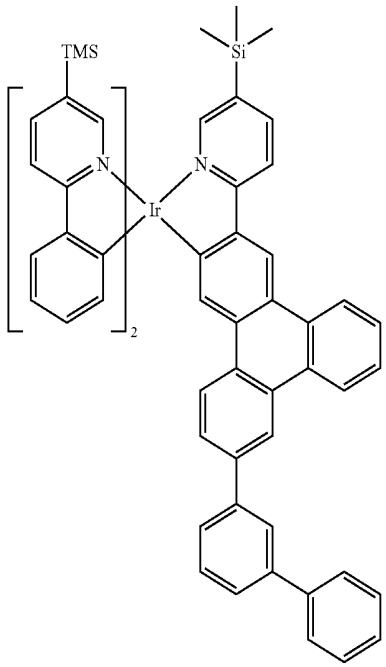

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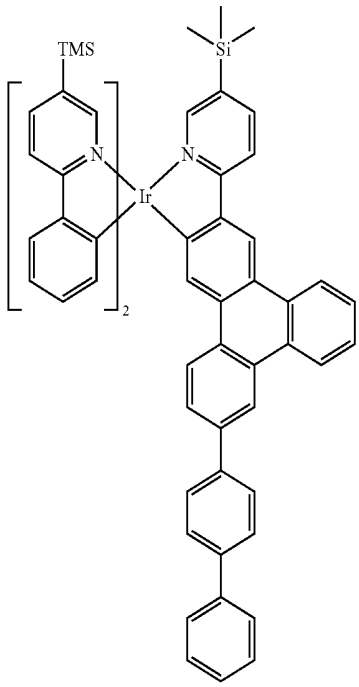

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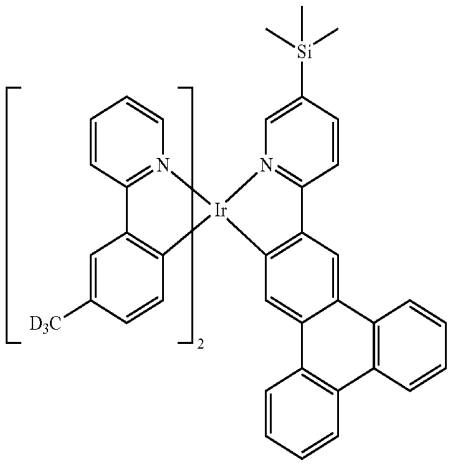

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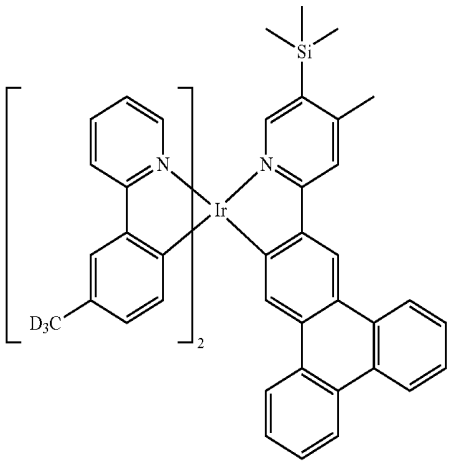

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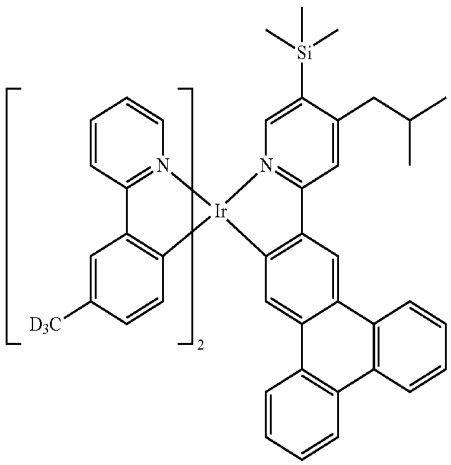

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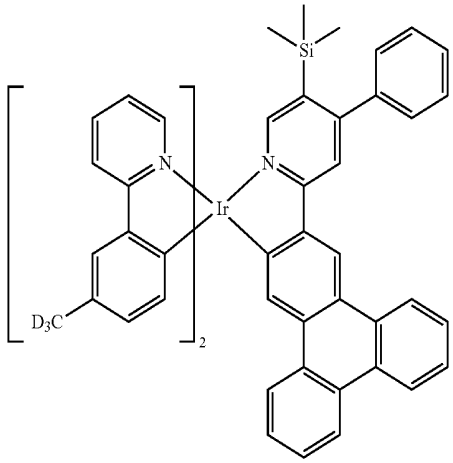

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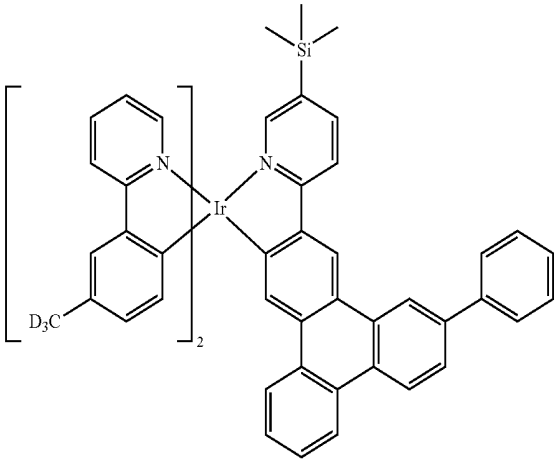

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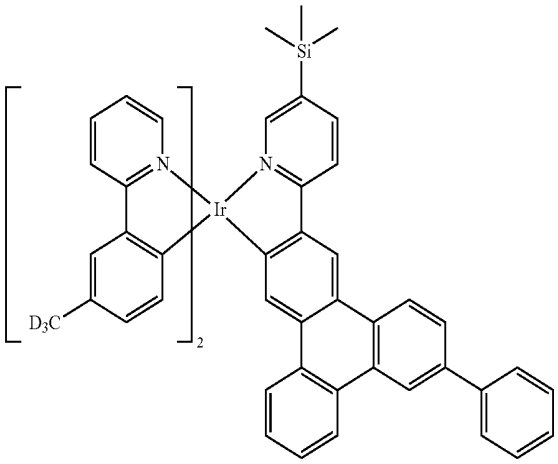

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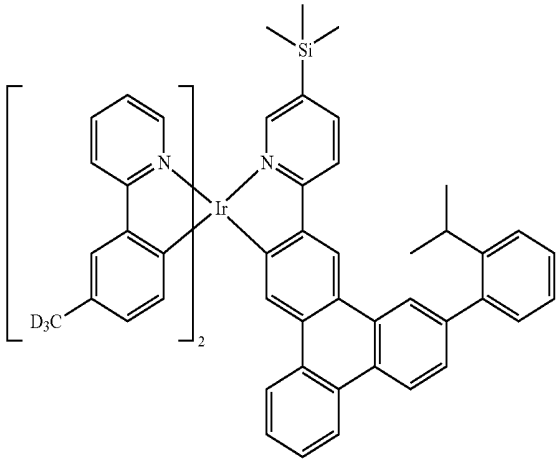

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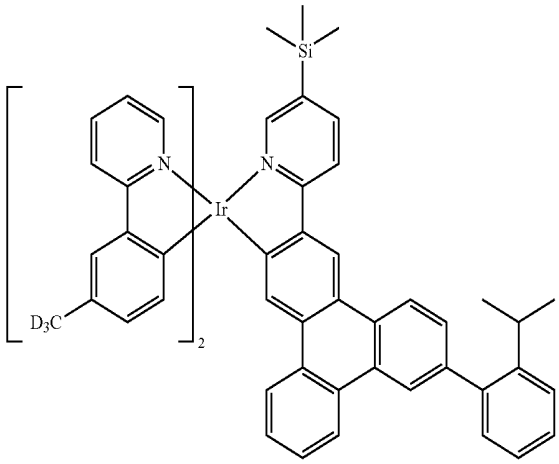

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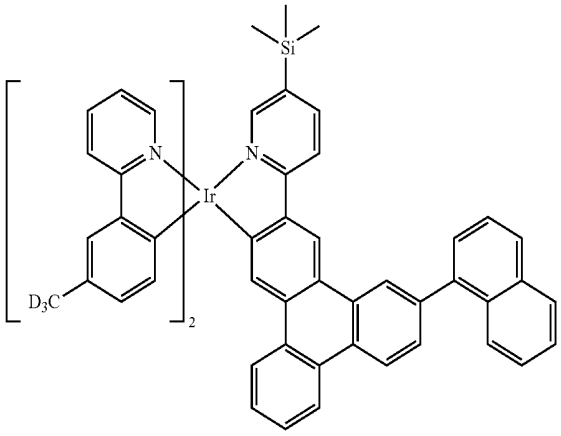

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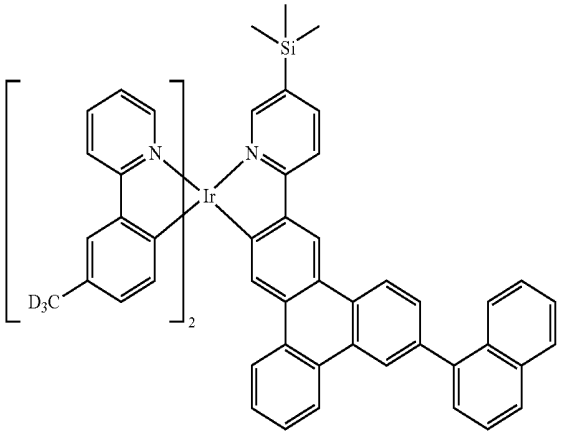

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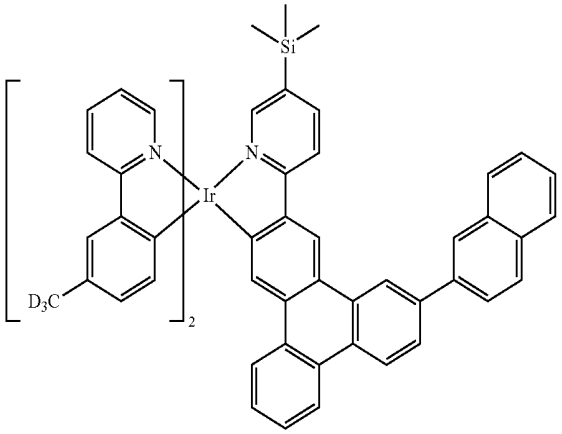

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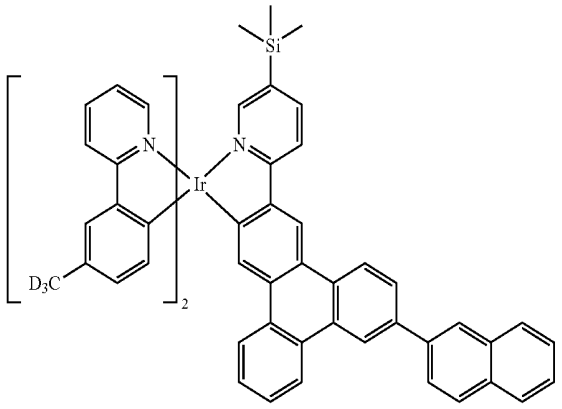

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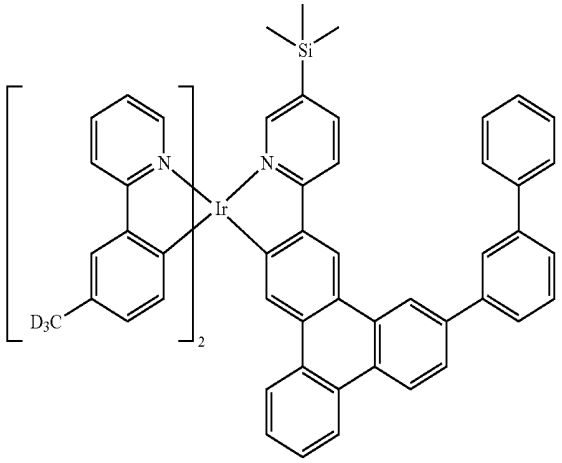

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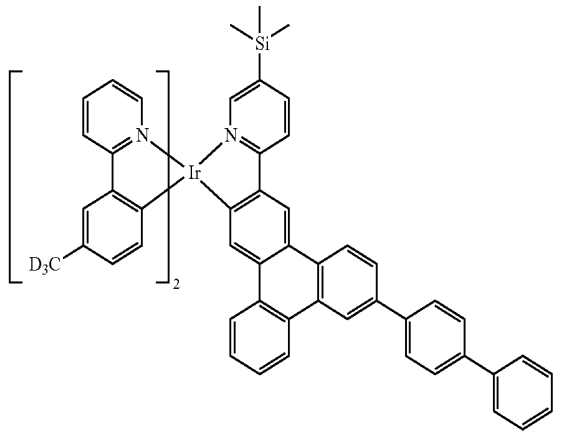

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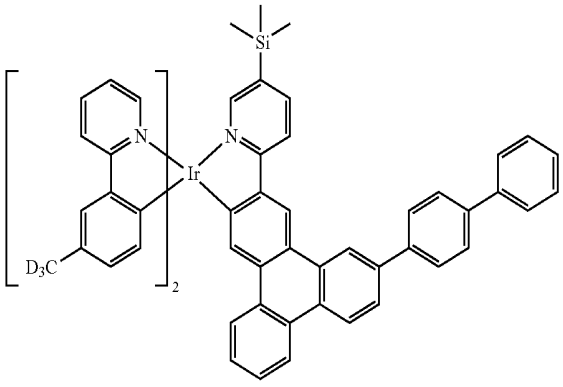

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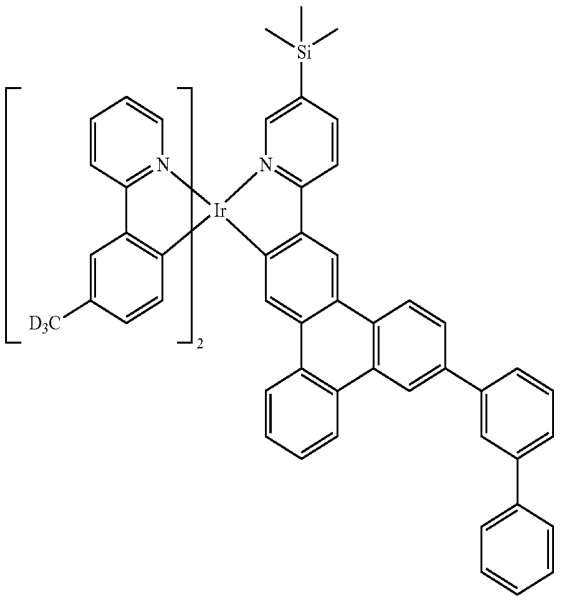

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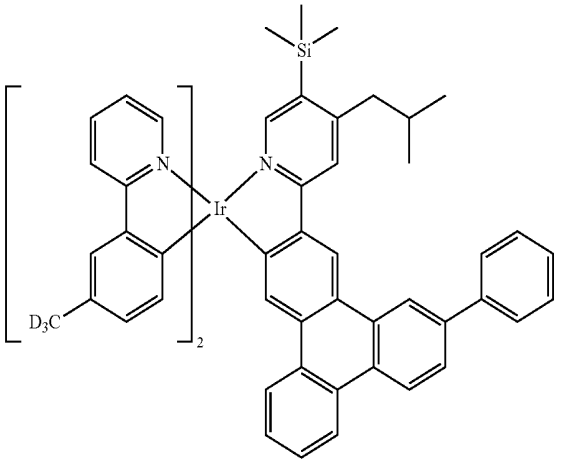

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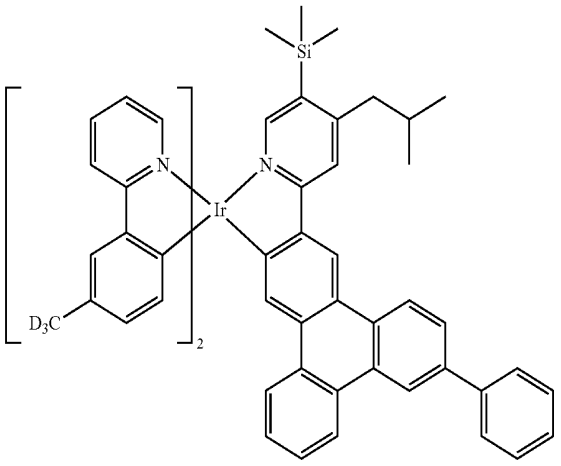

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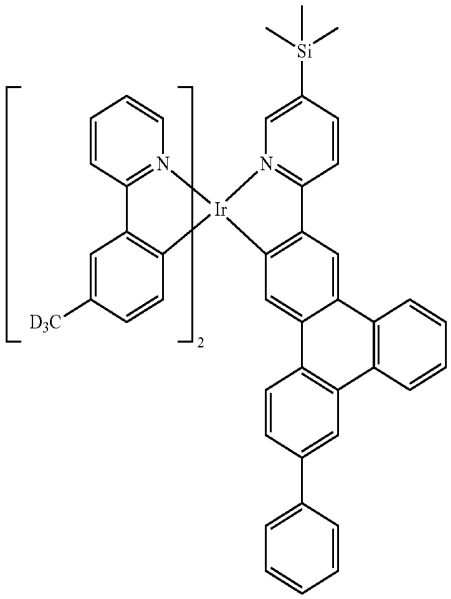

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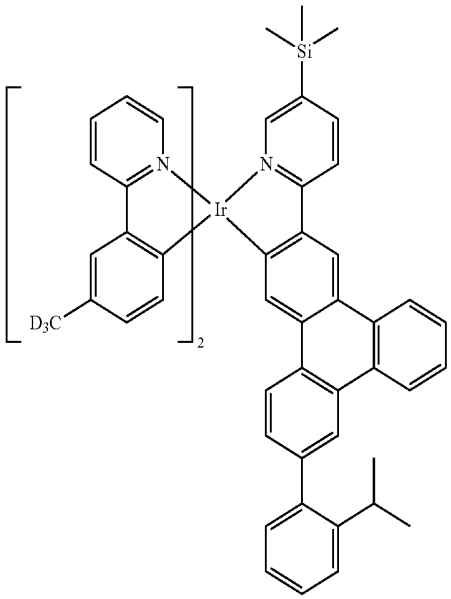

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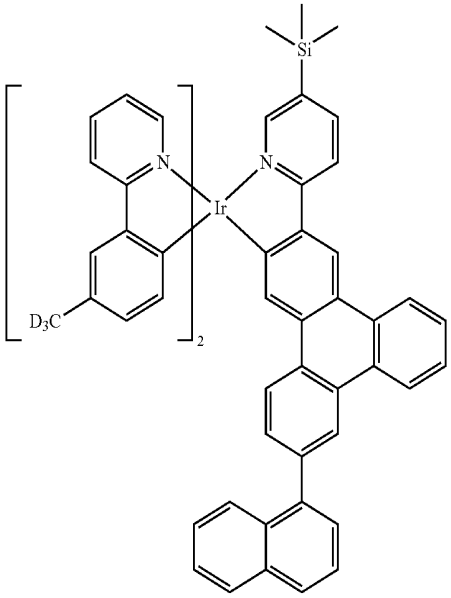

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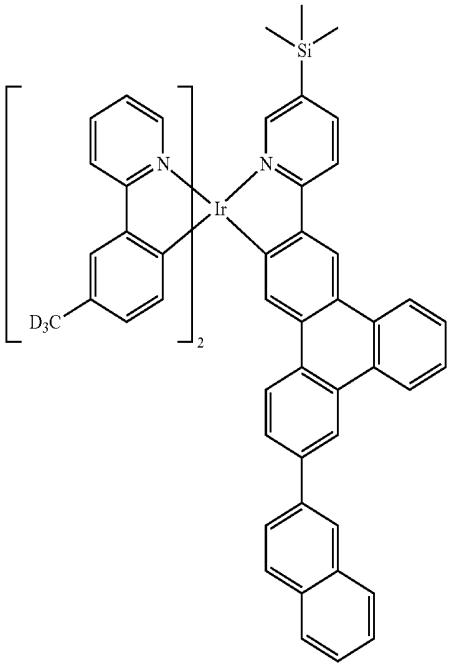

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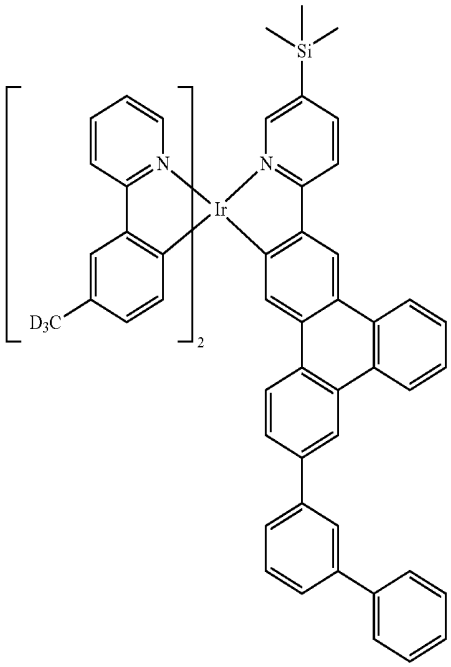

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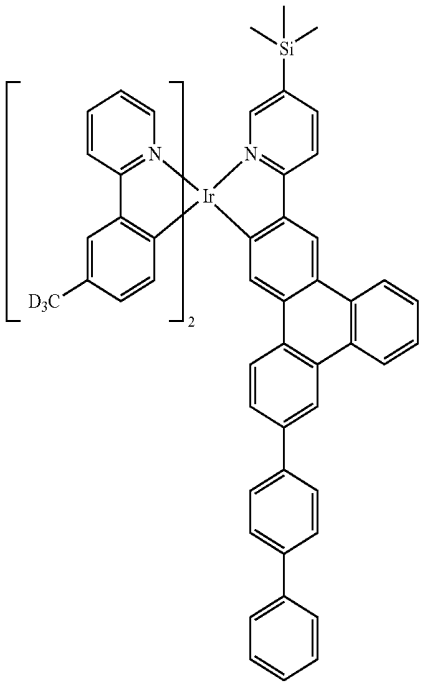

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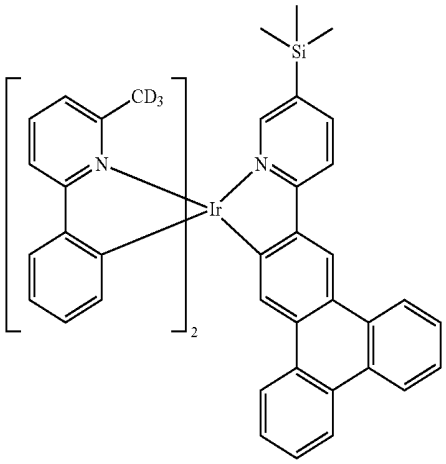

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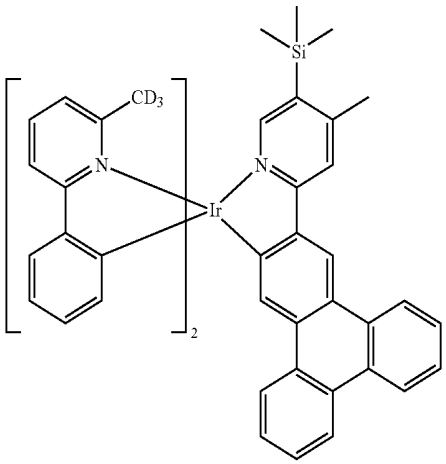

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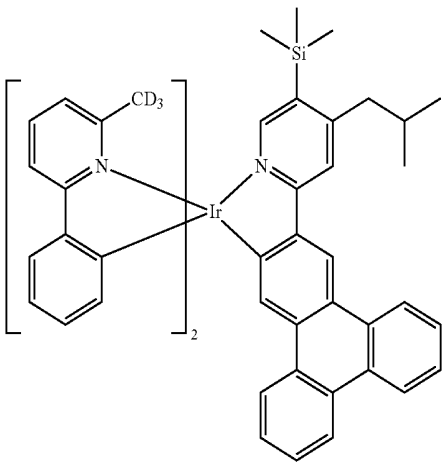

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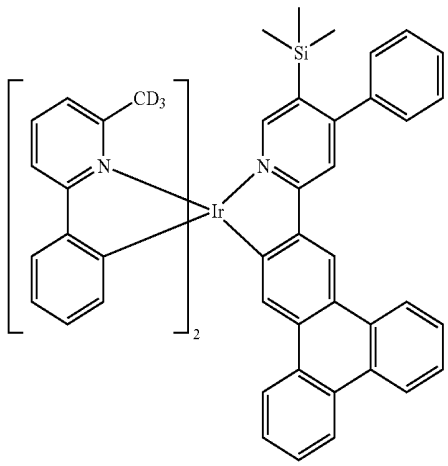

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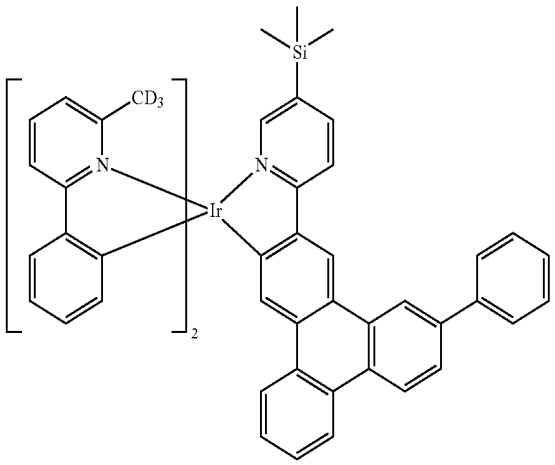

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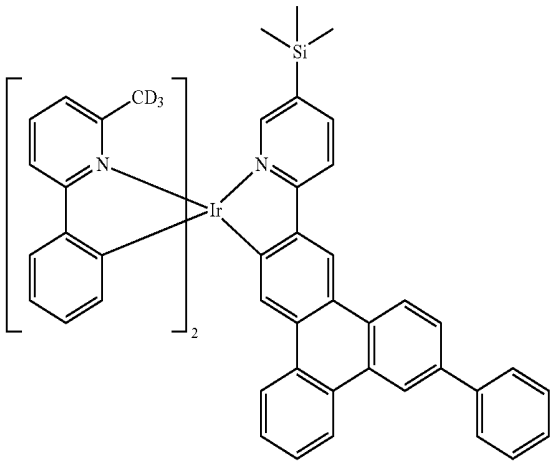

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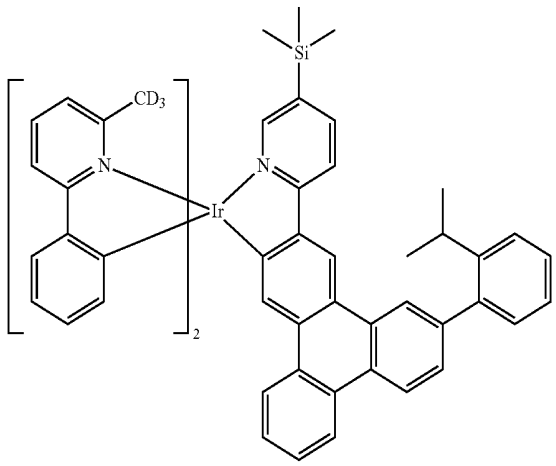

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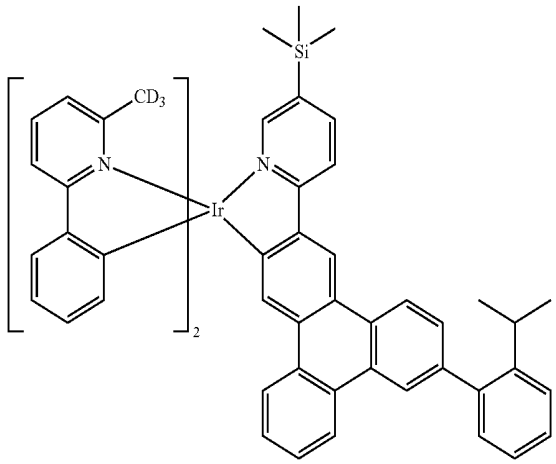

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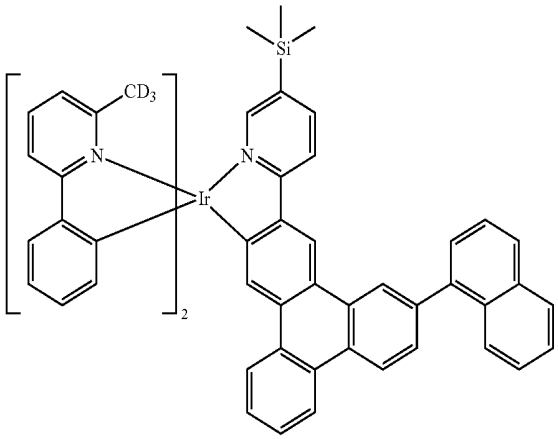

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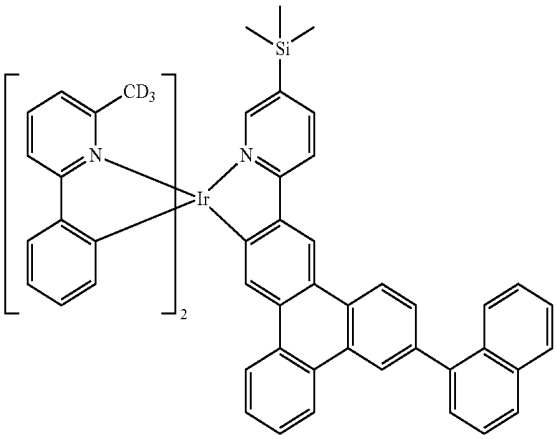

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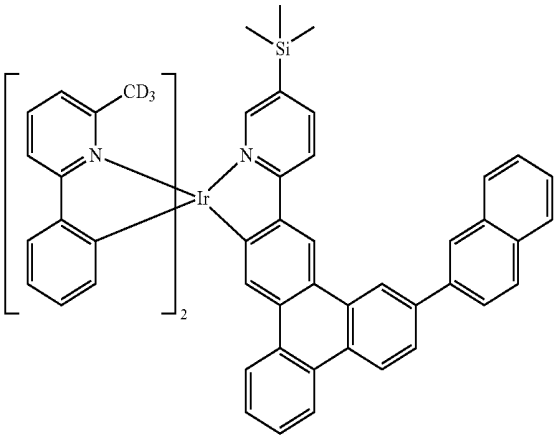

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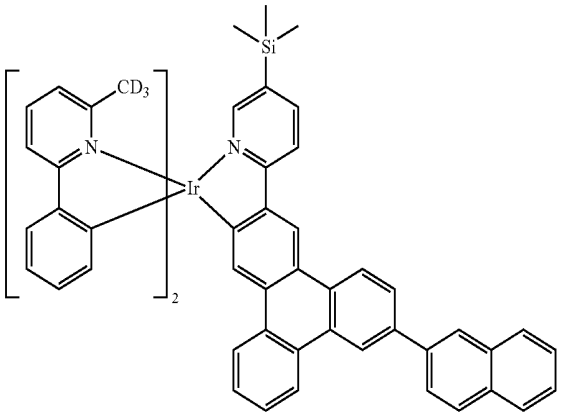

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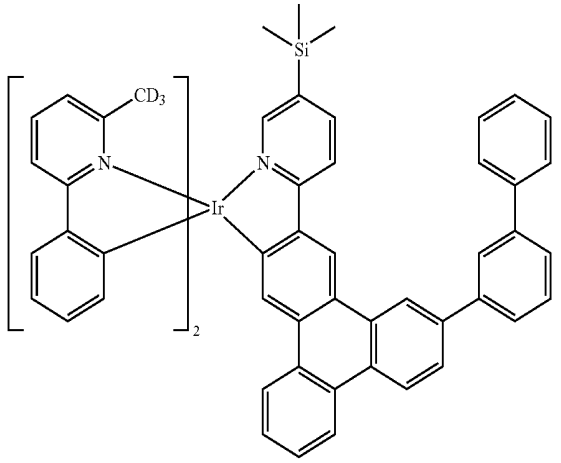

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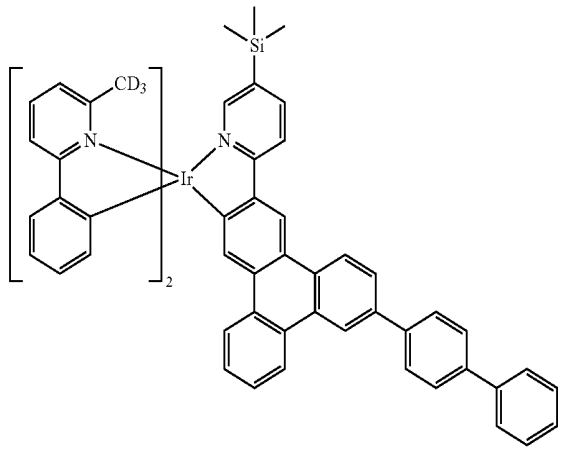

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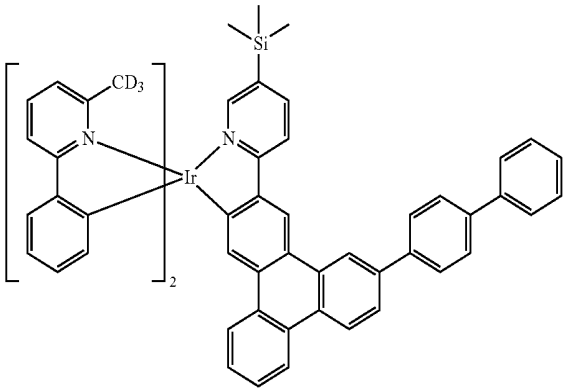

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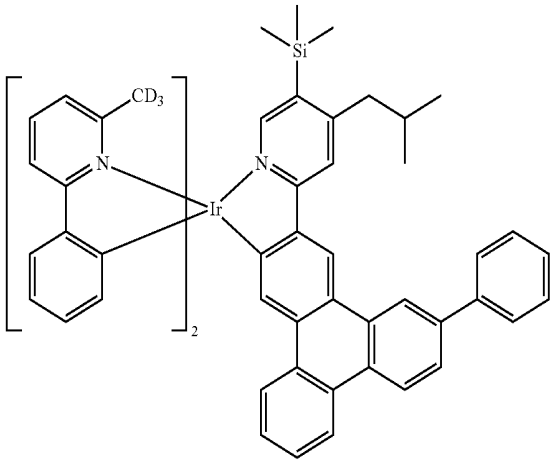

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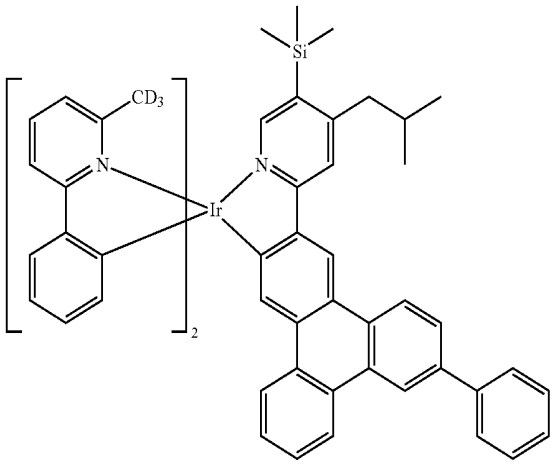

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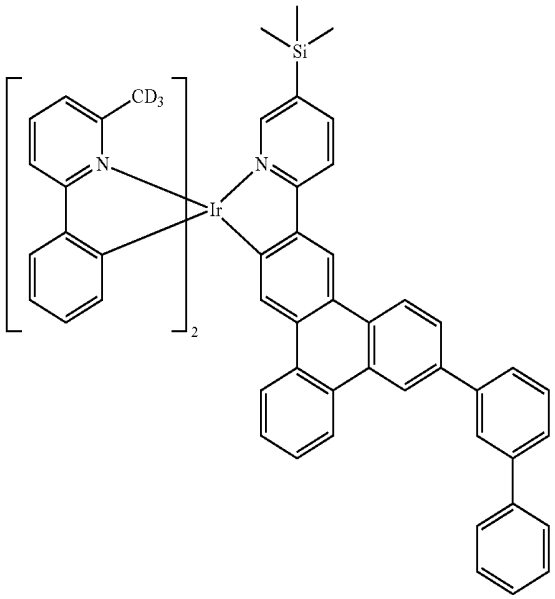

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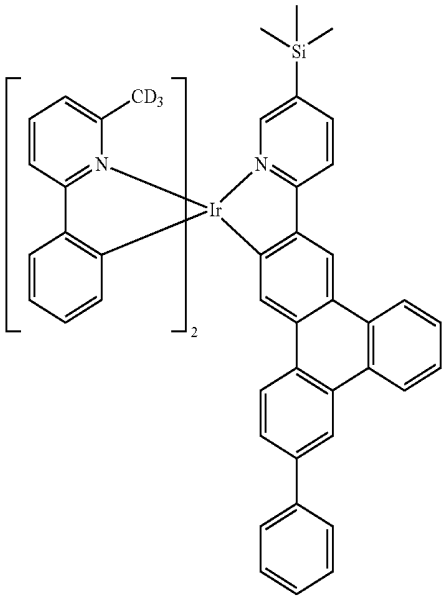

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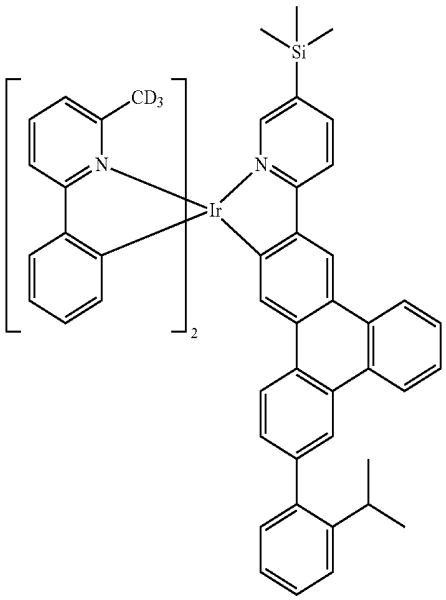

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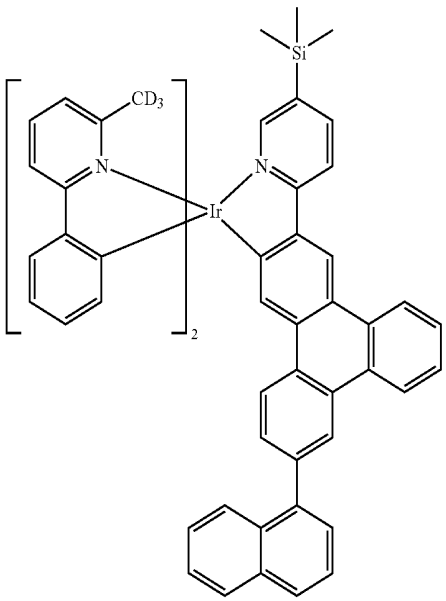

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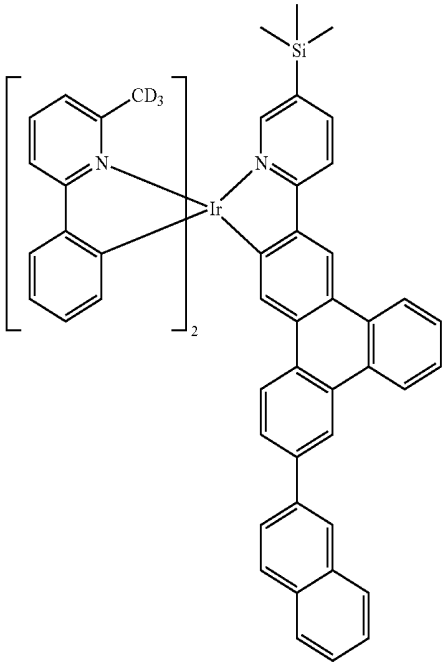

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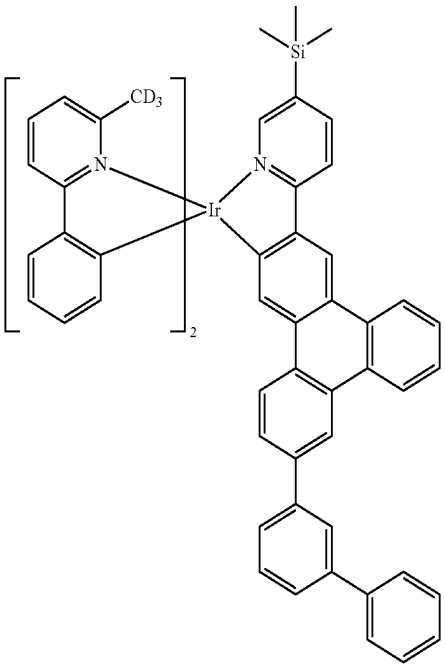

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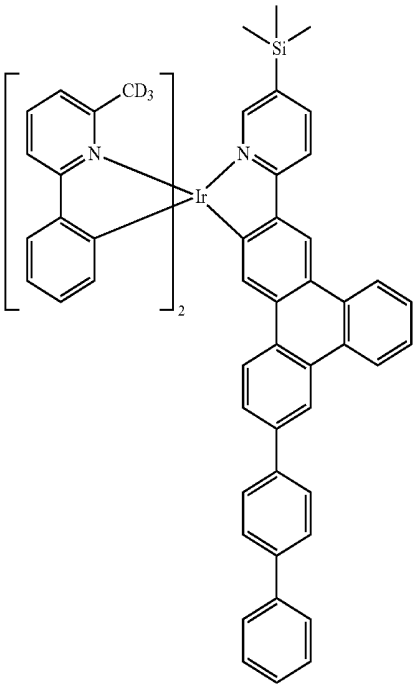

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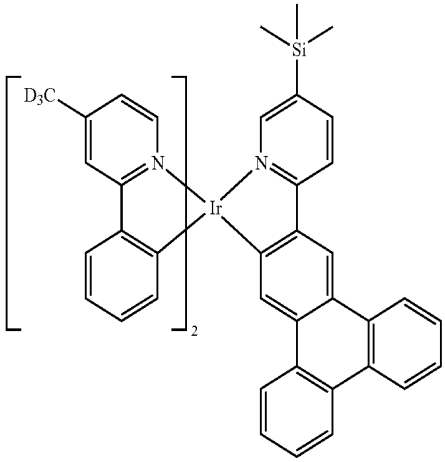

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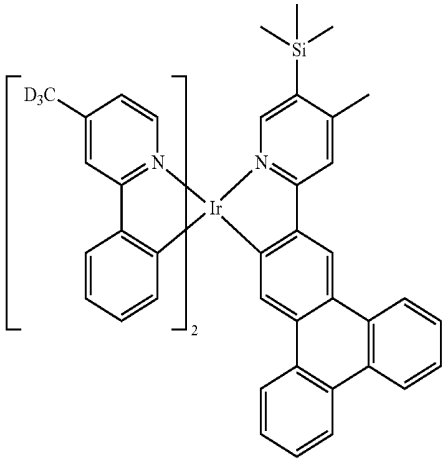

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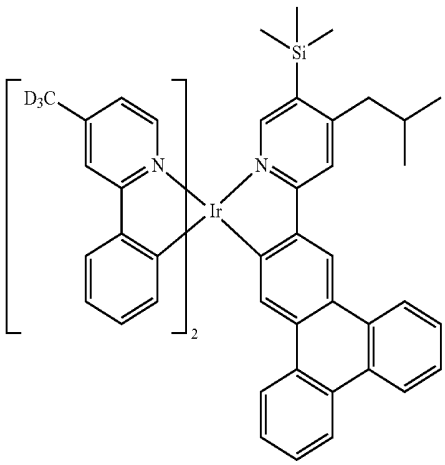

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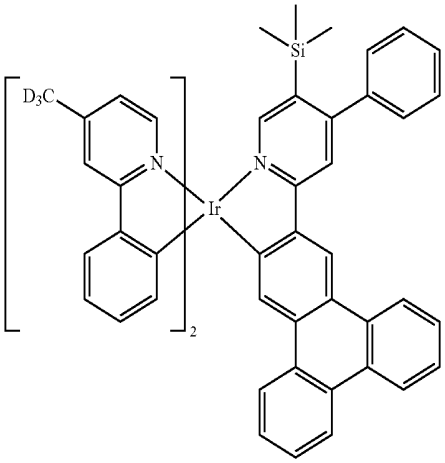

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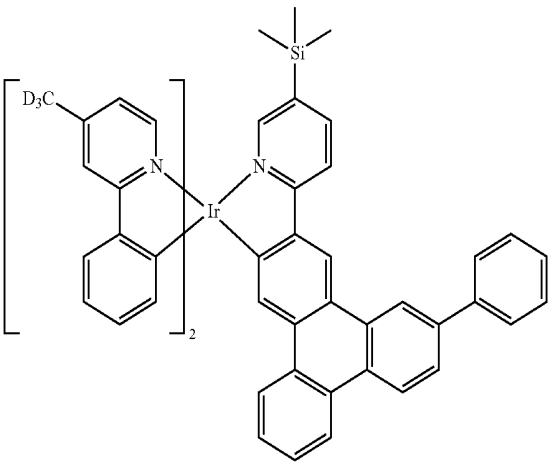

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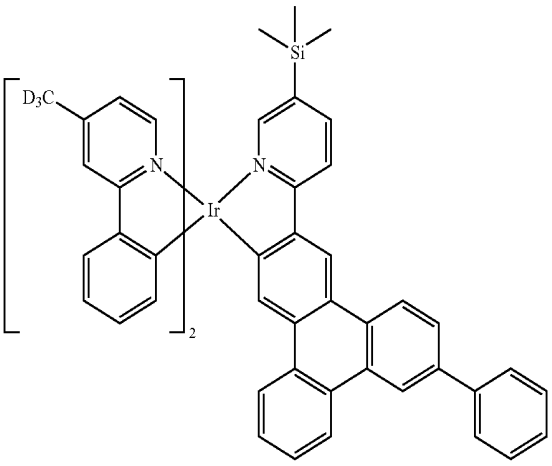

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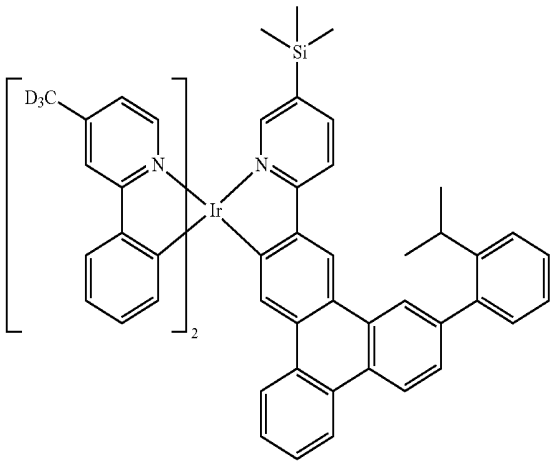

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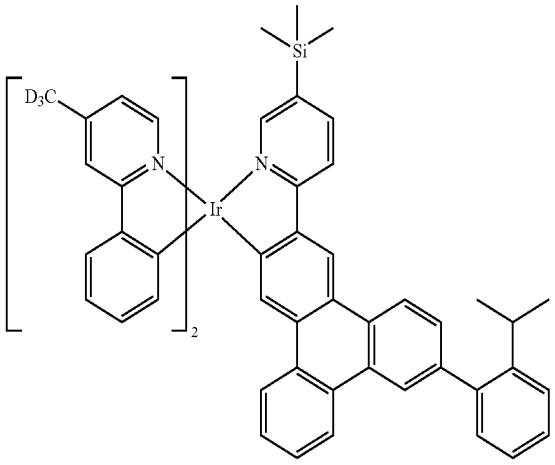

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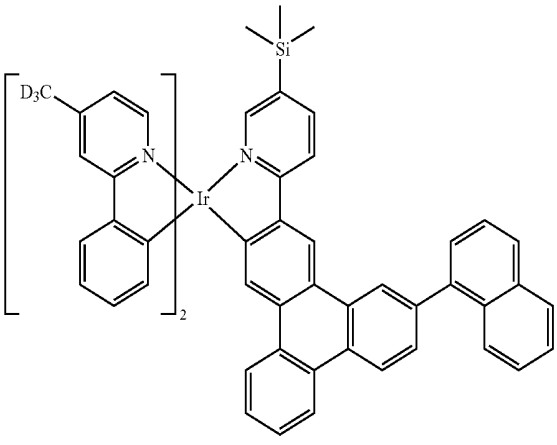

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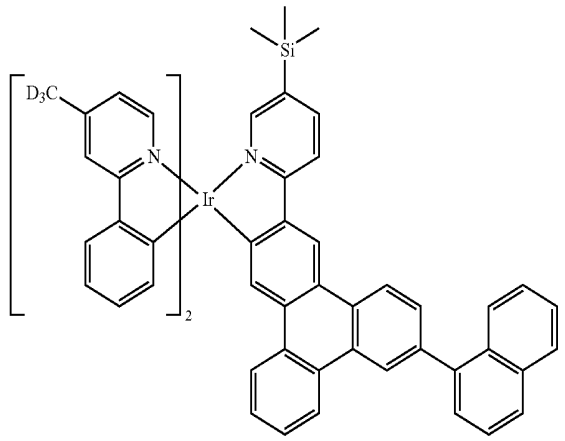

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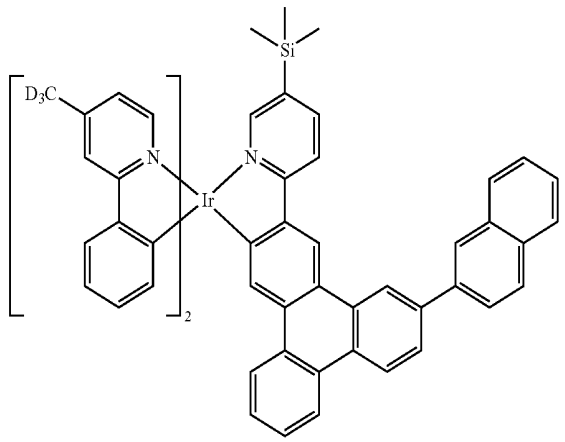

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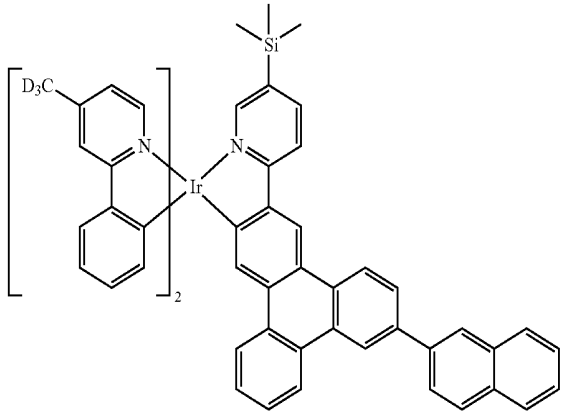

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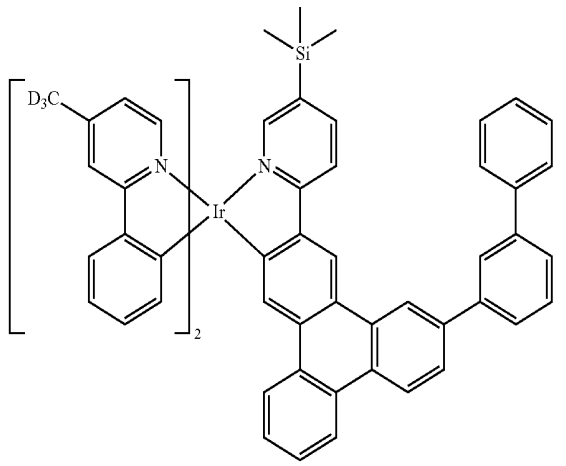

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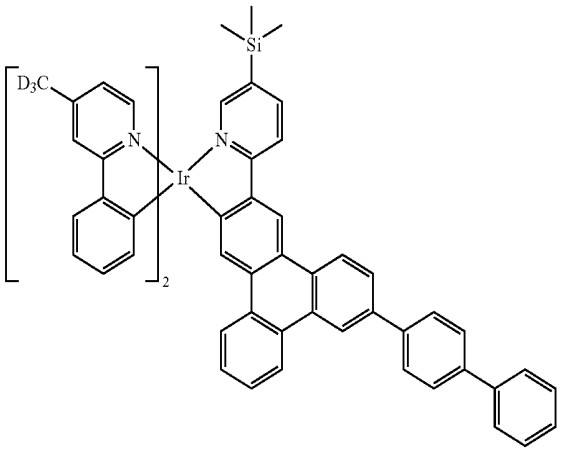

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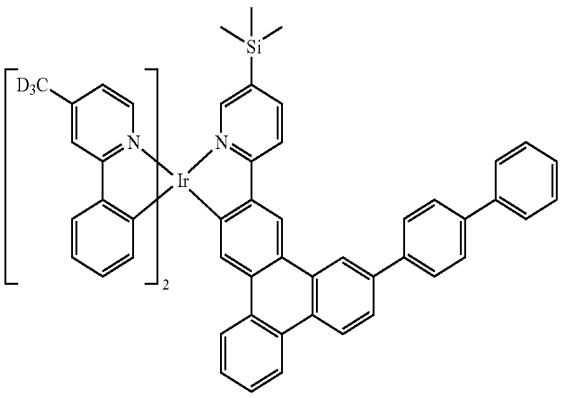

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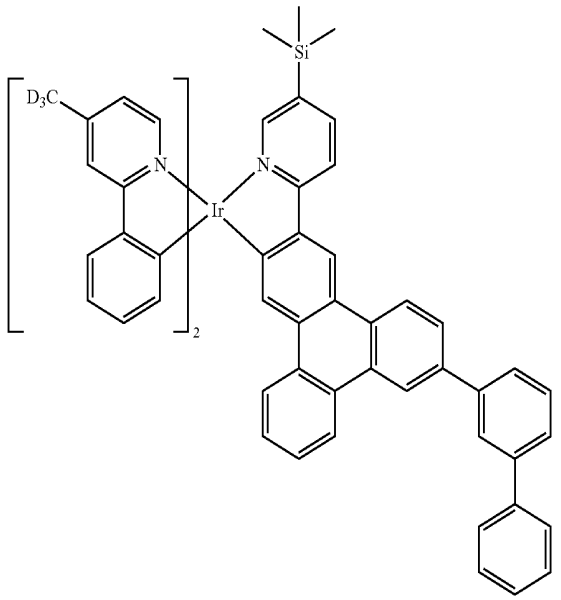

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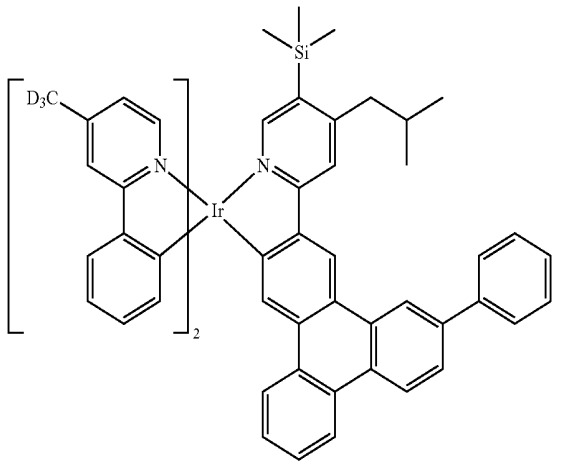

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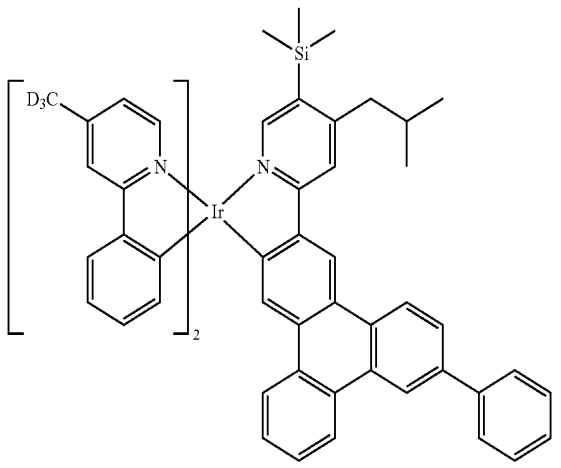

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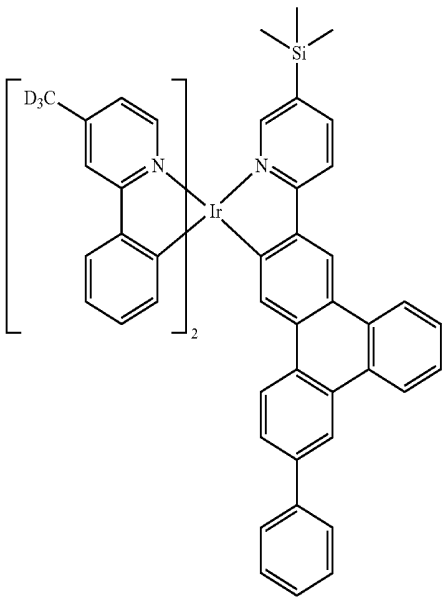

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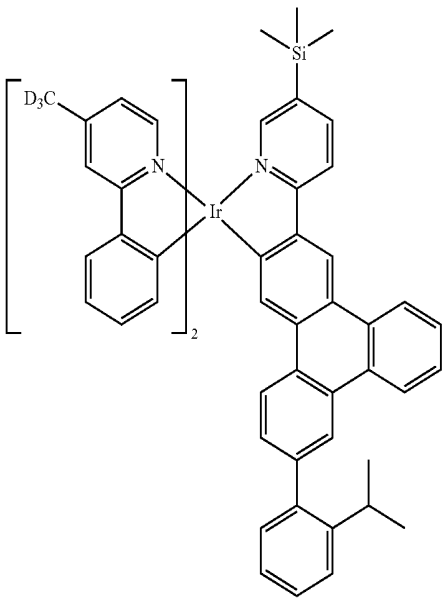

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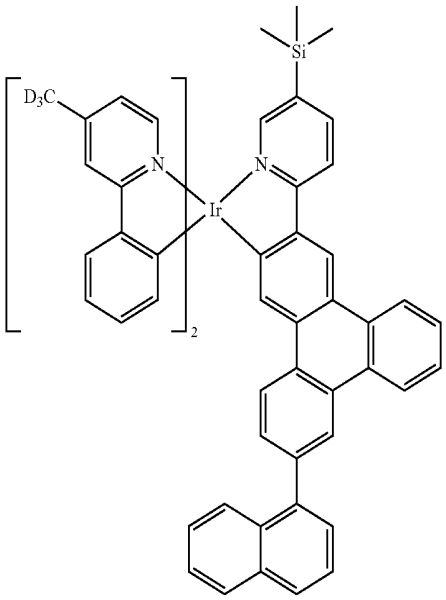

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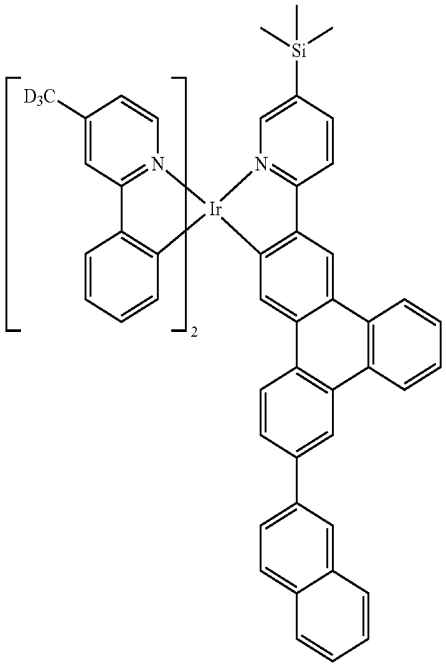

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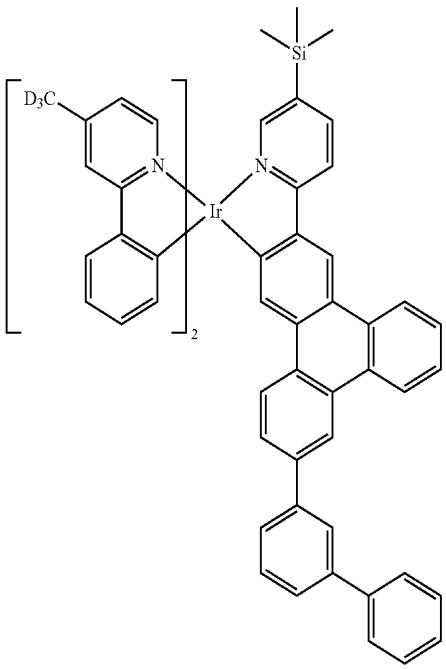

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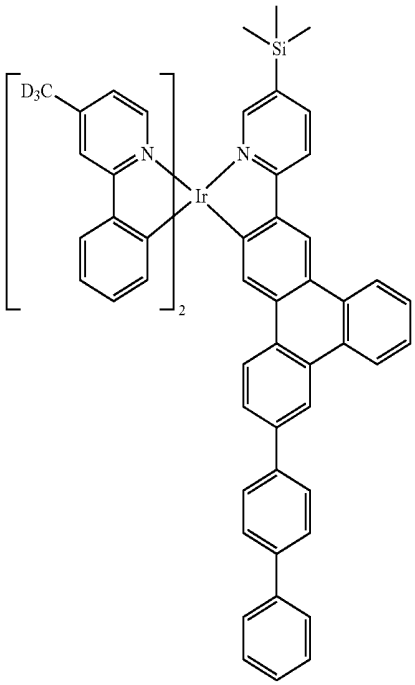

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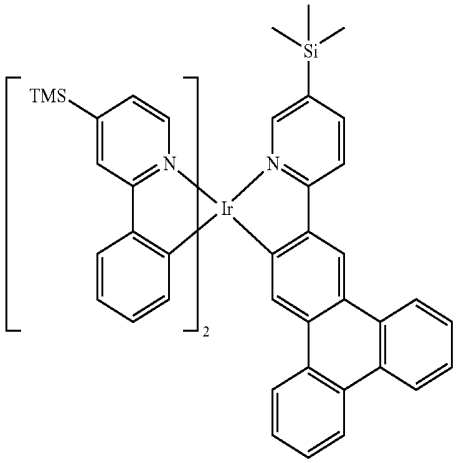

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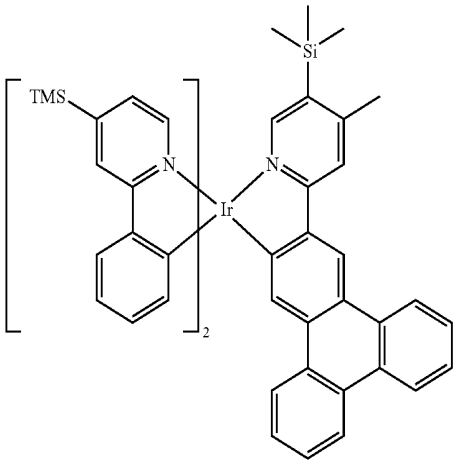

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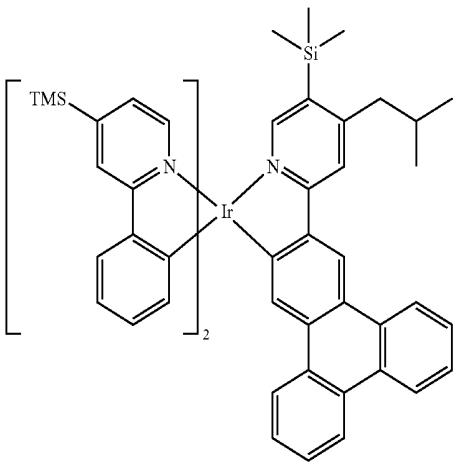

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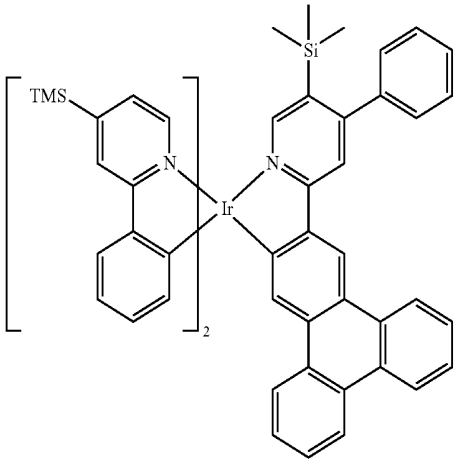

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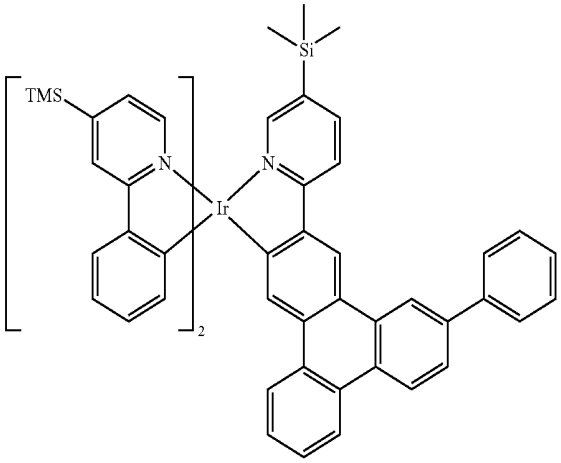

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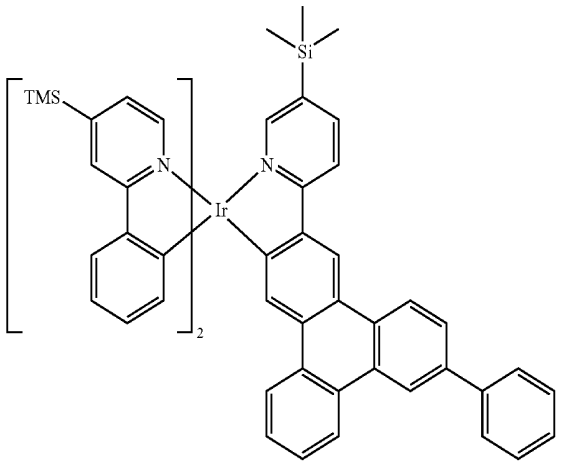

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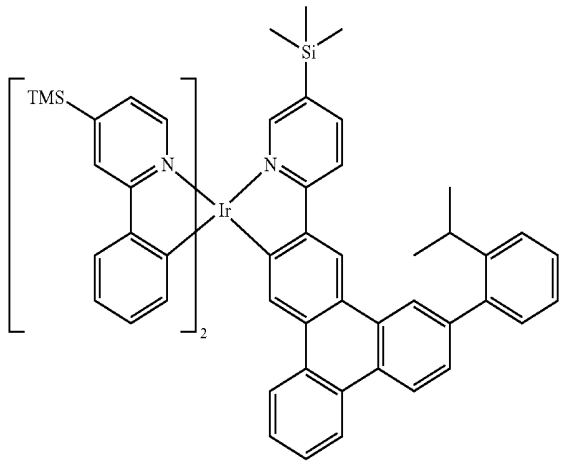

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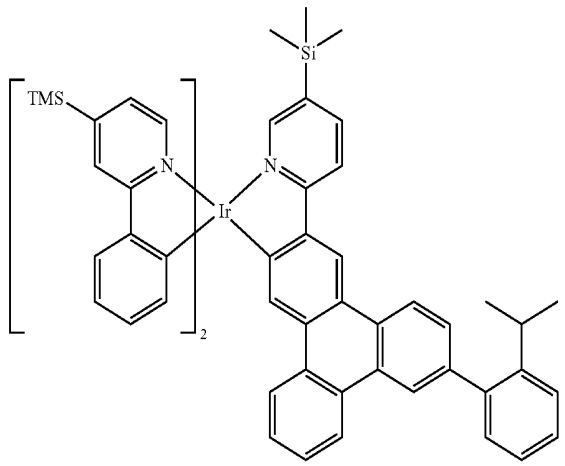

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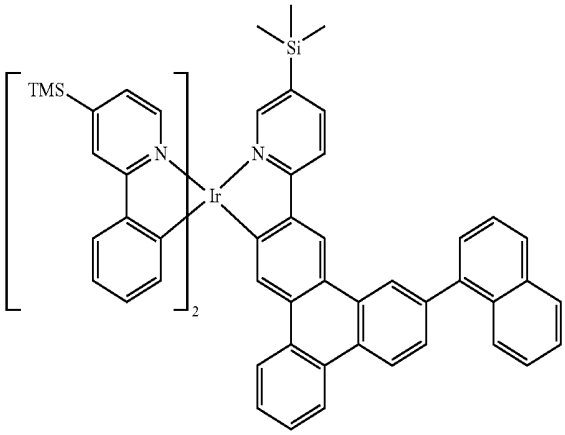

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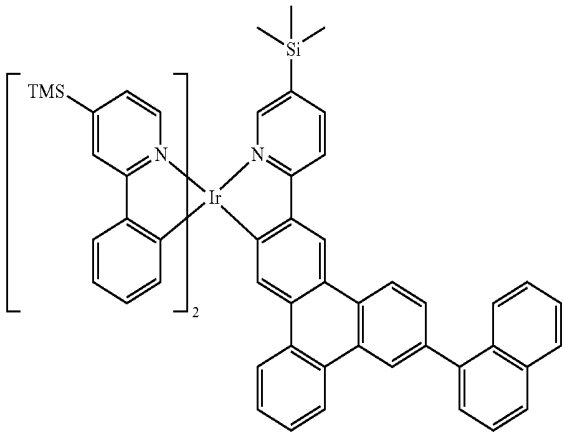

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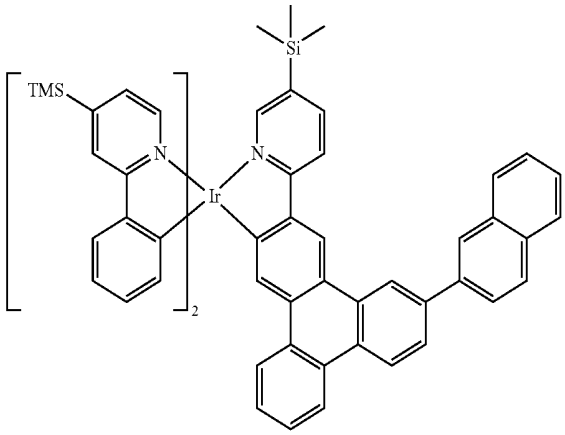

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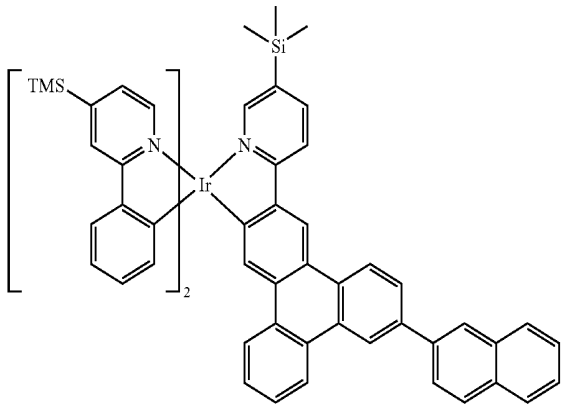

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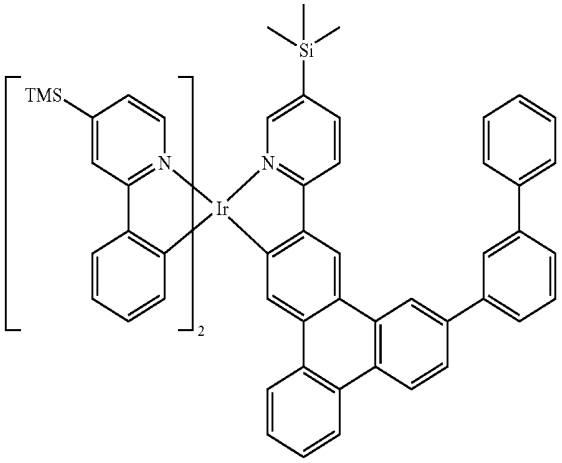

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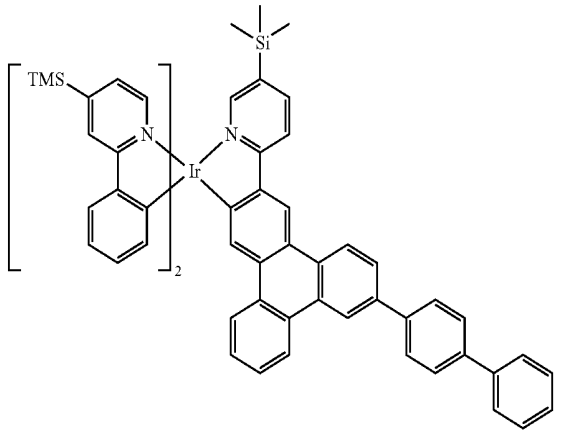

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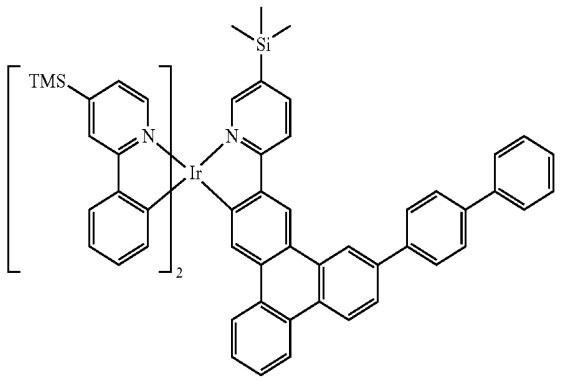

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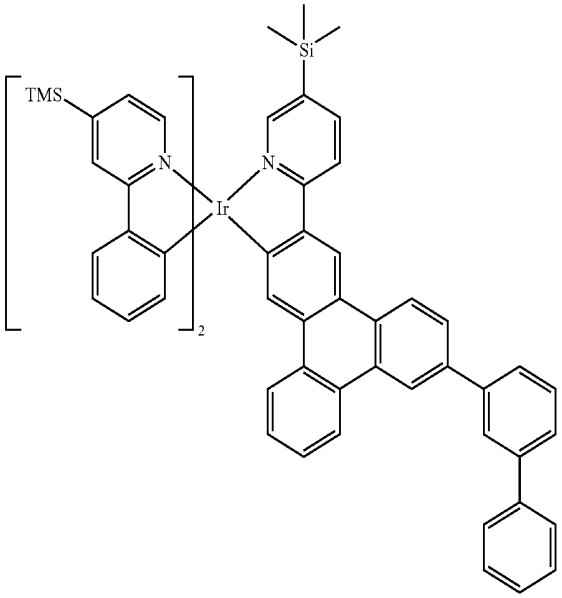

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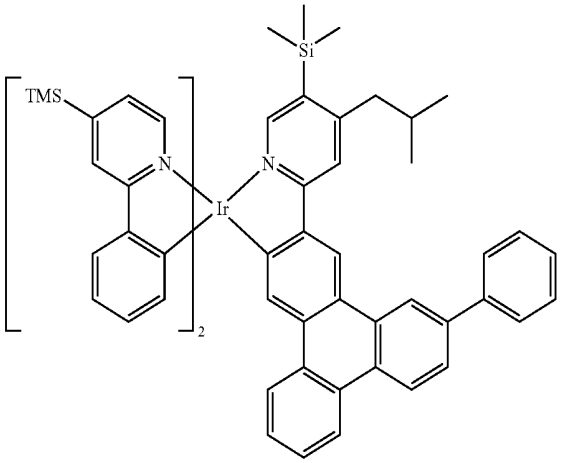

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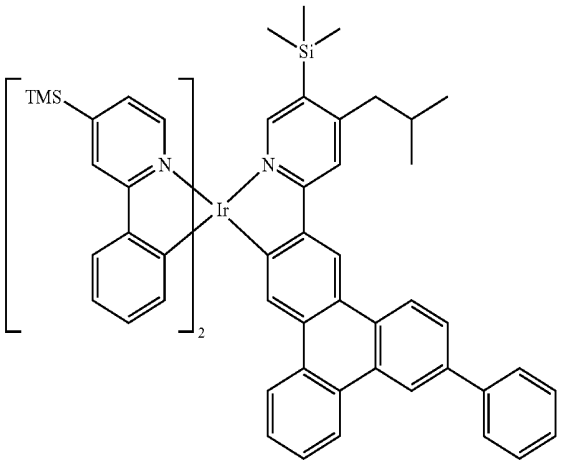

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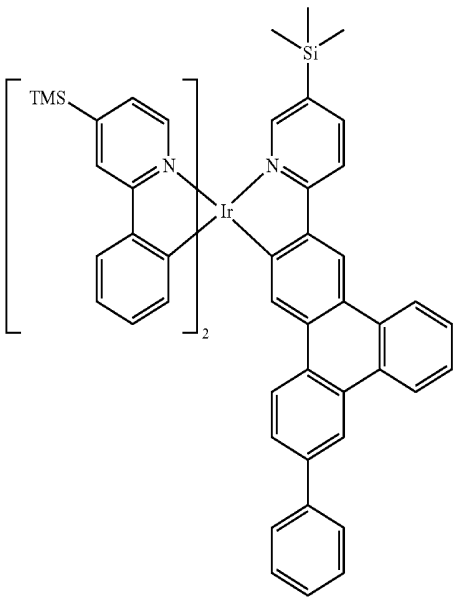

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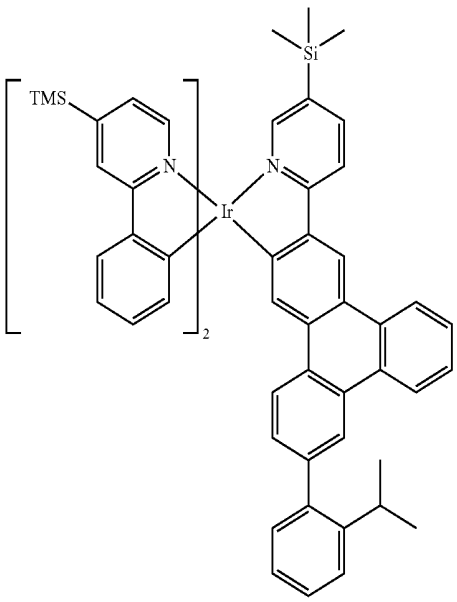

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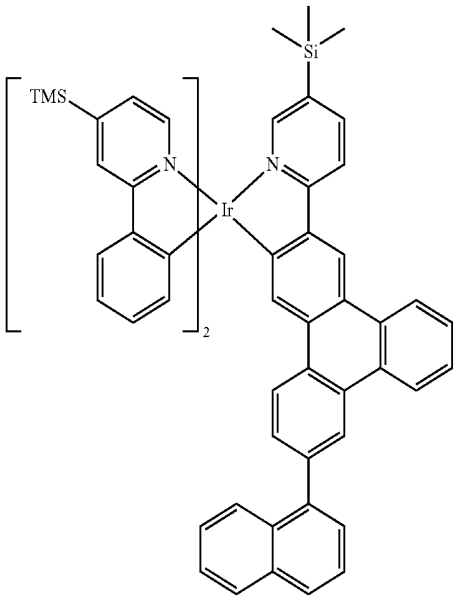

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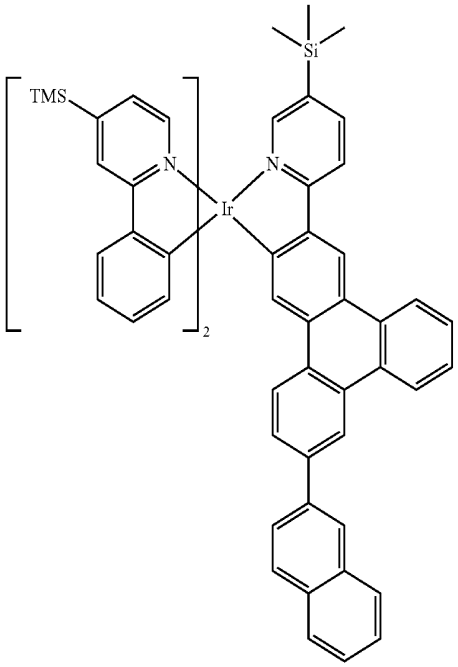

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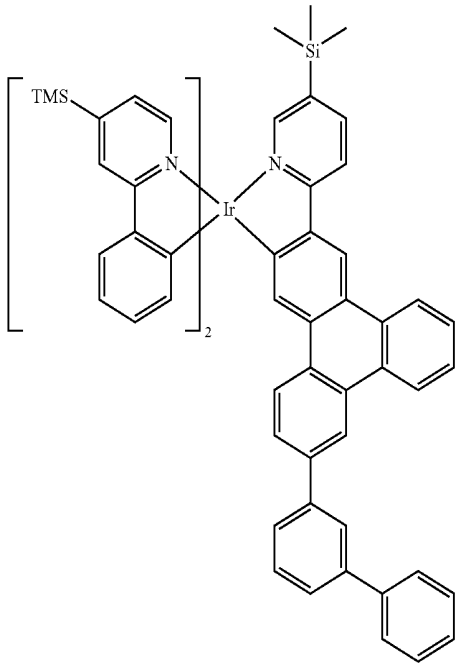

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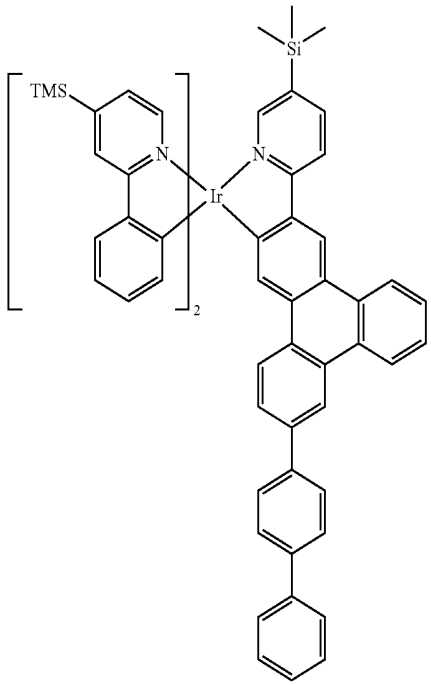

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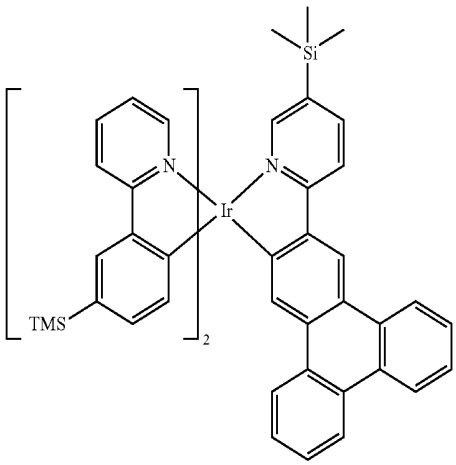

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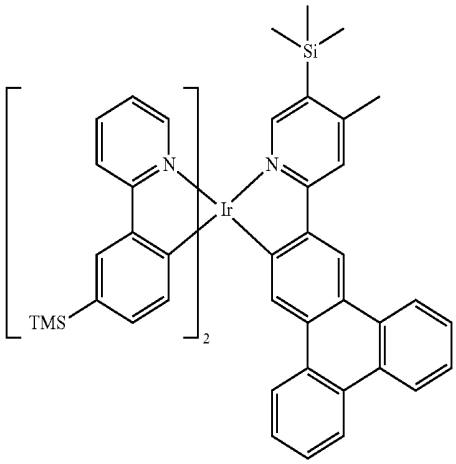

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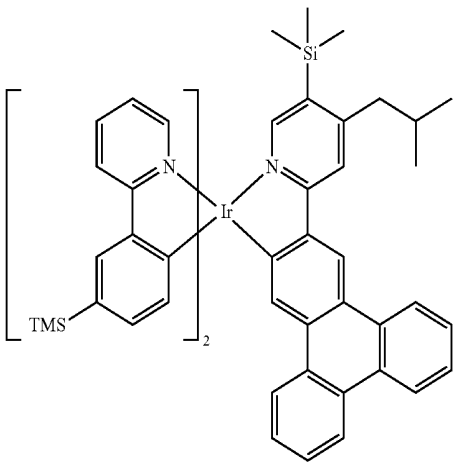

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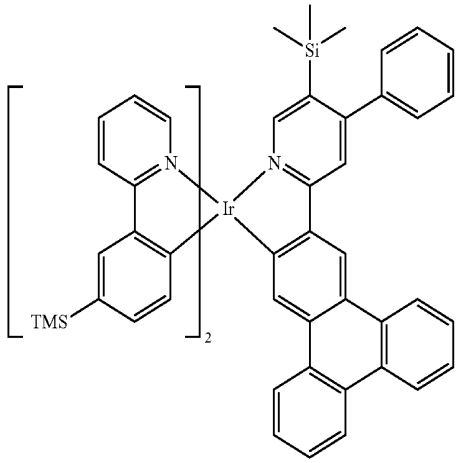

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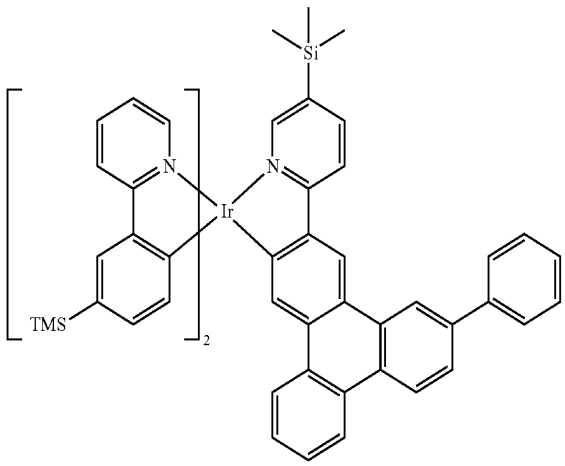

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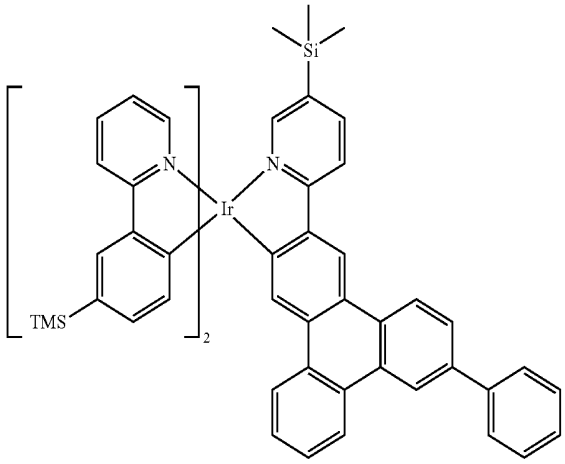

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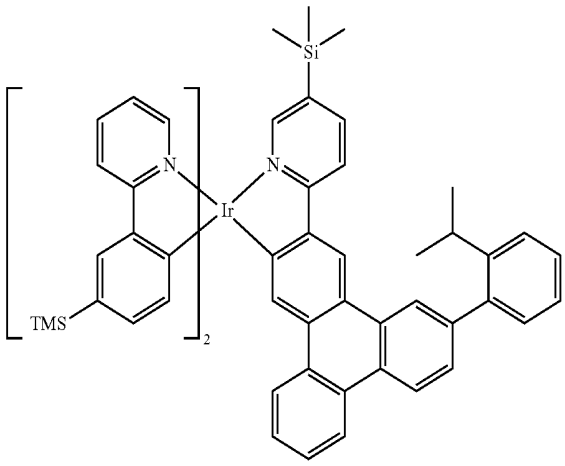

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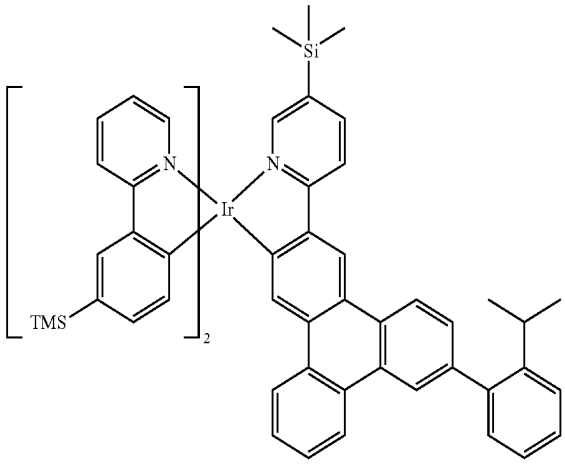

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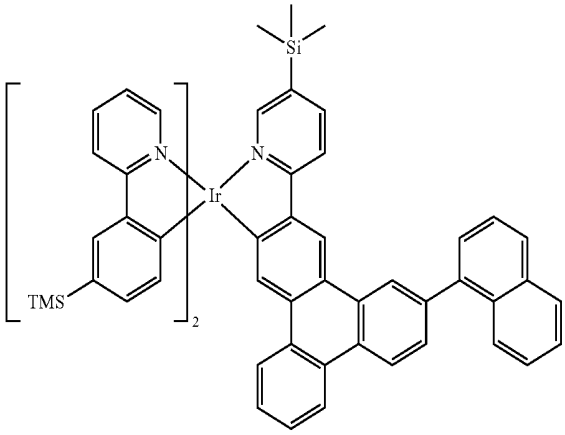

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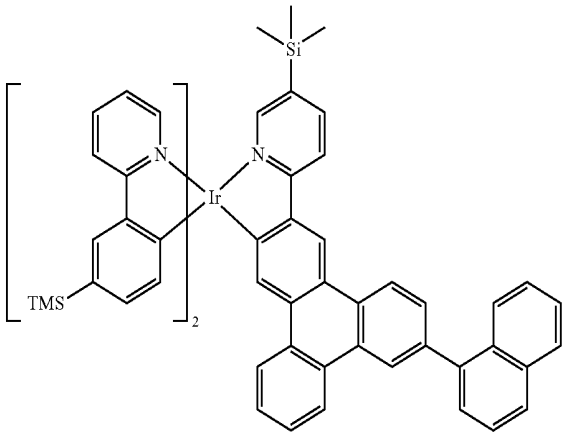

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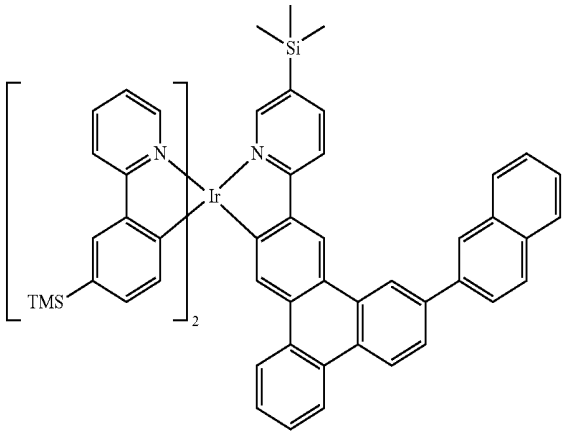

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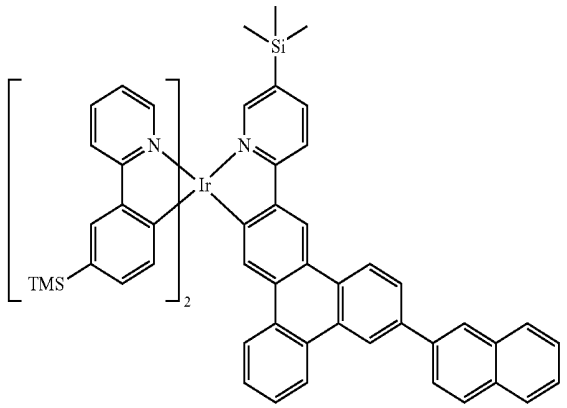

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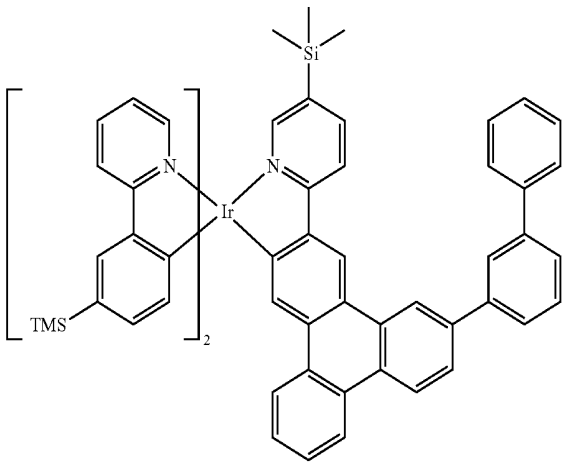

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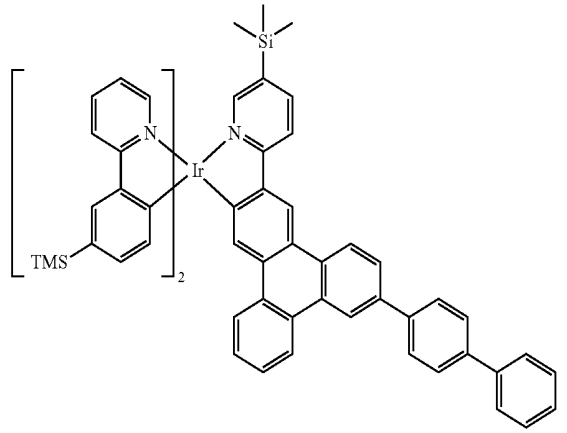

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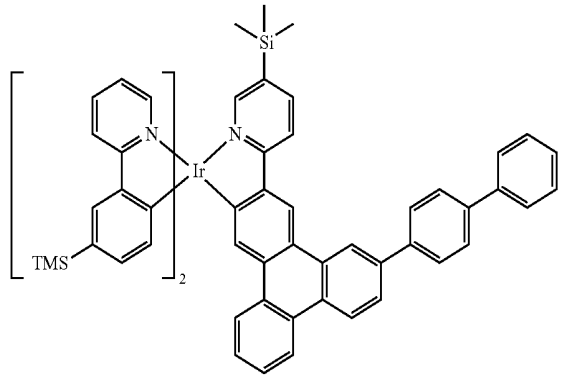

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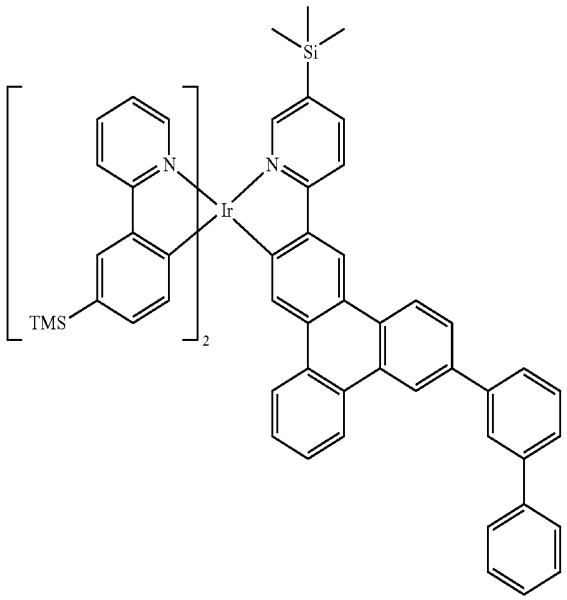

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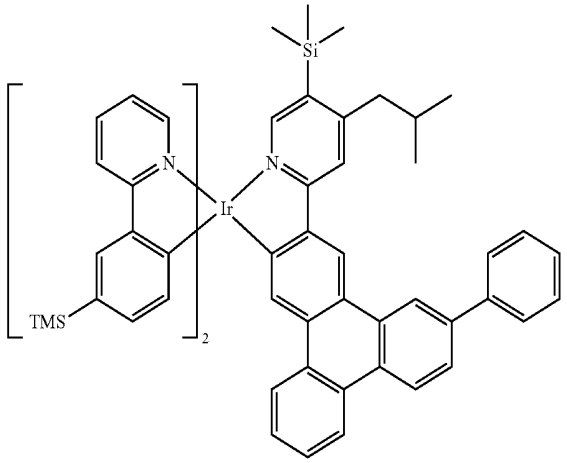

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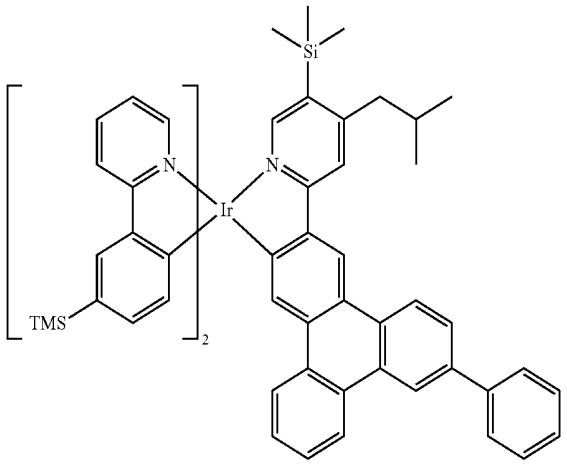

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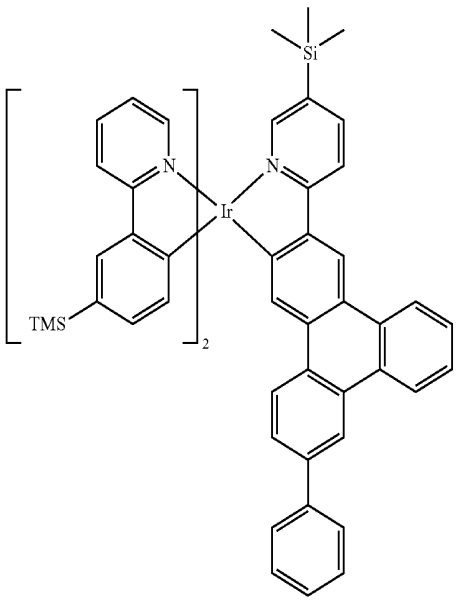

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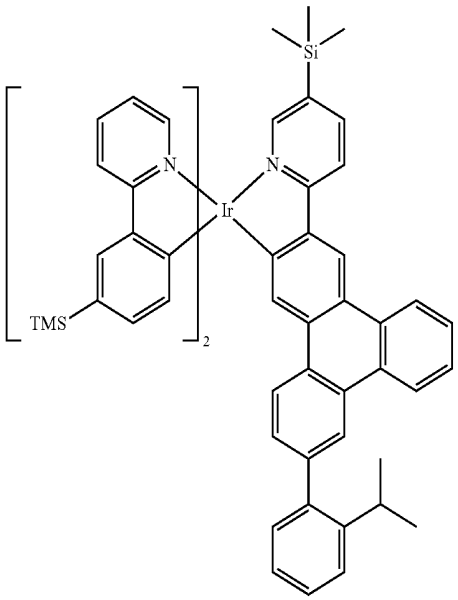

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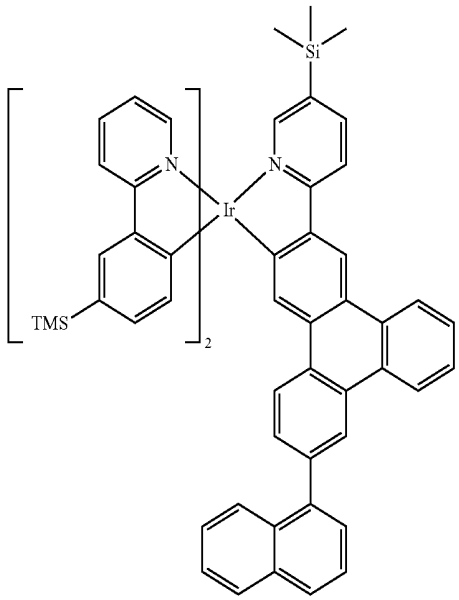

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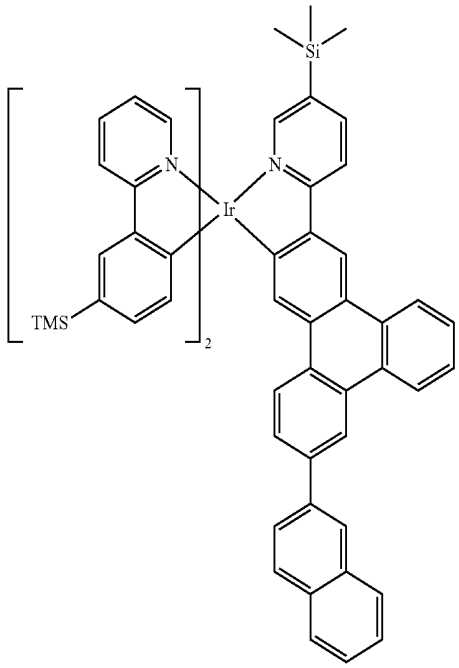

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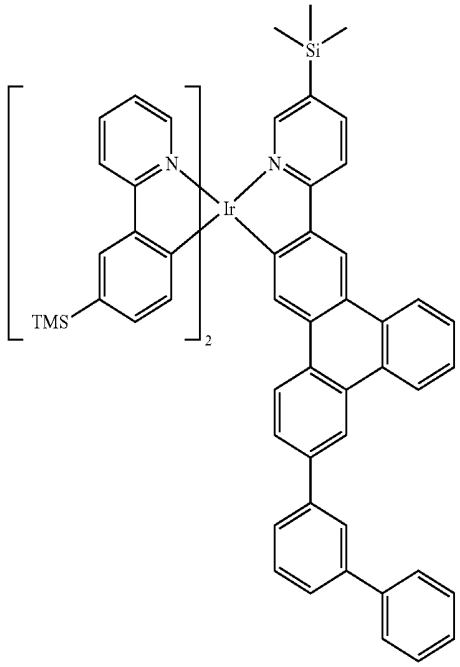

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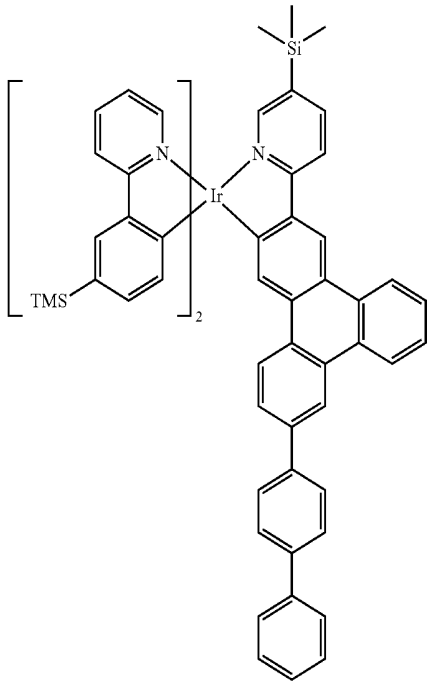


[0237] Regarding the organometallic compound represented by Formula 1, L_1 is represented by Formula 2, and CY_1 in Formula 2 is a C_1-C_{18} condensed cyclic ring i) in which two to four unsaturated 6-membered rings are condensed to each other and ii) which optionally has nitrogen (N) as a ring forming atom. Due to this structure, the charge mobility of the organometallic compound represented by Formula 1 may be improved, and accordingly, an electric device, such as an organic light-emitting device, including the organometallic compound, may have long lifespan characteristics.

[0238] In addition, since the sum of b5 and b6 in Formula 2 is 1 or greater, a ligand represented by Formula 2 has at least

one silyl group. In some embodiments, b5 may be 1, 2, or 3. Accordingly, a pyridine ring in the ligand represented by Formula 2 may have at least one silyl group. Due to this structure, a device, such as an organic light-emitting device, including the organometallic compound, may have high efficiency and a long lifespan.

[0239] For example, the highest occupied molecular orbital (HOMO), lowest unoccupied molecular orbital (LUMO), and triplet (T_1) energy levels of some of these organometallic compounds are evaluated by using a DFT (Density Function Theory) method of a Gaussian program (structurally optimized at a level of B3LYP, 6-31G (d,p)). Evaluation results are shown in Table 1.

TABLE 1

Compound No.	HOMO (eV)	LUMO (eV)	T_1 energy level (eV)
1	−4.834	−1.438	2.450
2	−4.809	−1.431	2.446
3	−4.805	−1.391	2.475
4	−4.818	−1.490	2.421
28	−4.827	−1.494	2.437
52	−4.764	−1.459	2.407
76	−4.747	−1.442	2.406
97	−4.782	−1.398	2.445
124	−4.777	−1.473	2.410
145	−4.792	−1.413	2.445
147	−4.766	−1.373	2.467
149	−4.791	−1.432	2.439
150	−4.762	−1.434	2.422
151	−4.789	−1.426	2.441
152	−4.771	−1.429	2.429
153	−4.794	−1.432	2.445
154	−4.771	−1.438	2.428
155	−4.800	−1.445	2.438
160	−4.764	−1.435	2.423
163	−4.786	−1.462	2.402
164	−4.787	−1.444	2.420
165	−4.796	−1.468	2.409
166	−4.792	−1.490	2.381

[0240] Referring to Table 1, the organometallic compound represented by Formula 1 has such electric characteristics that are suitable for use as a material for an electric device, for example, as a material for an organic light-emitting device (for example, a dopant).

[0241] Methods of synthesizing the organometallic compound represented by Formula 1 may be easily recognizable by one of ordinary skill in the art by referring to the following Synthesis Examples.

[0242] Since the organometallic compound represented by Formula 1 is suitable for an organic layer of an organic light-emitting device, for example, a dopant of an emission layer of the organic layer, another aspect provides an organic light-emitting device including:

[0243] a first electrode;

[0244] a second electrode; and

[0245] an organic layer that is disposed between the first electrode and the second electrode,

[0246] wherein the organic layer includes an emission layer and at least one organometallic compound represented by Formula 1.

[0247] Due to the inclusion of the organic layer including the organometallic compound represented by Formula 1, the organic light-emitting device may have a low driving voltage, high efficiency, and a long lifespan.

[0248] The organometallic compound represented by Formula 1 may be used between a pair of electrodes of an organic light-emitting device. For example, the organometallic compound represented by Formula 1 may be included in the emission layer. In this regard, the organometallic compound may act as a dopant and the emission layer may further include a host (that is, the amount of the organometallic compound represented by Formula 1 is smaller than that of the host).

[0249] The expression that "(an organic layer) includes at least one of the organometallic compounds" as used herein may include an embodiment in which "(an organic layer) includes identical organometallic compounds represented by Formula 1 and an embodiment in which (an organic layer) includes two or more different organometallic compounds represented by Formula 1.

[0250] For example, the organic layer may include, as the organometallic compound, only Compound 1. In this regard, Compound 1 may be included in an emission layer of the organic light-emitting device. In some embodiments, the organic layer may include, as the organometallic compound, Compound 1 and Compound 2. In this regard, Compound 1 and Compound 2 may be included in the same layer (for example, Compound 1 and Compound 2 both may be included in an emission layer).

[0251] The first electrode may be an anode, which is a hole injection electrode, and the second electrode may be a cathode, which is an electron injection electrode; or the first electrode may be a cathode, which is an electron injection electrode, and the second electrode may be an anode, which is a hole injection electrode.

[0252] For example, the first electrode may be an anode, the second electrode may be a cathode, and the organic layer may include a hole transport region disposed between the first electrode and the emission layer and an electron transport region disposed between the emission layer and the second electrode, wherein the hole transport region includes at least one selected from a hole injection layer, a hole transport layer, and an electron blocking layer, and wherein the electron transport region includes at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0253] 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 the organic light-emitting device. The "organic layer" may include, in addition to an organic compound, an organometallic complex including metal.

[0254] FIG. **1** is a schematic view of an organic light-emitting device **10** according to an embodiment. Hereinafter, the structure of an organic light-emitting device according to an embodiment and a method of manufacturing an organic light-emitting device, according to an embodiment, will be described in connection with FIG. **1**. The organic light-emit-

ting device **10** includes a first electrode **11**, an organic layer **15**, and a second electrode **19**, which are sequentially stacked on each other in this order.

[0255] A substrate may be additionally disposed under the first electrode **11** or above the second electrode **19**. As the substrate, any substrate that is used in general organic light-emitting devices may be used, and the substrate may be a glass substrate or transparent plastic substrate, each with excellent mechanical strength, thermal stability, transparency, surface smoothness, ease of handling, and water-resistance.

[0256] The first electrode **11** may be formed by depositing or sputtering a material for forming the first electrode **11** on the substrate. The first electrode **11** may be an anode. The material for the first electrode **11** may be selected from materials with a high work function to allow holes be easily provided. The first electrode **11** may be a reflective electrode or a transmissive electrode. The material for the first electrode **11** may be, for example, indium tin oxide (ITO), indium zinc oxide (IZO), tin oxide (SnO_2), and zinc oxide (ZnO). In some embodiments, magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be used as the material for the first electrode **11**.

[0257] The first electrode **11** may have a single-layer structure or a multi-layer structure including two or more layers. For example, the first electrode **11** may have a three-layered structure of ITO/Ag/ITO, but the structure of the first electrode **110** is not limited thereto.

[0258] The organic layer **15** is disposed on the first electrode **11**.

[0259] The organic layer **15** may include a hole transport region, an emission layer, and an electron transport region.

[0260] The hole transport region may be disposed between the first electrode **11** and the emission layer.

[0261] The hole transport region may include at least one selected from a hole injection layer, a hole transport layer, an electron blocking layer, and a buffer layer.

[0262] The hole transport region may include only either a hole injection layer or a hole transport layer. In some embodiments, the hole transport region may have a structure of hole injection layer/hole transport layer or hole injection layer/hole transport layer/electron blocking layer, which are sequentially stacked in this stated order from the first electrode **11**.

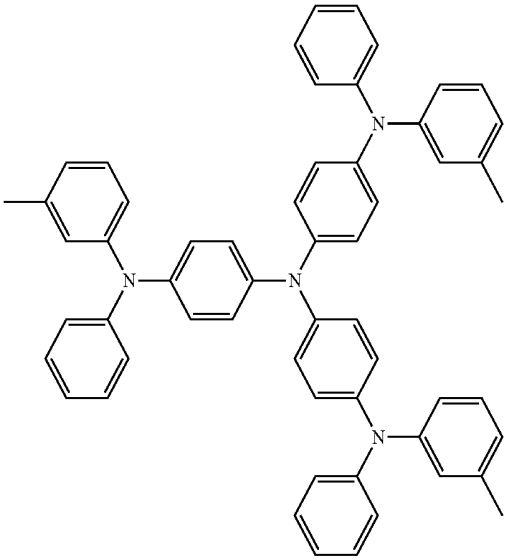
[0263] A hole injection layer may be formed on the first electrode **11** by using one or more methods, such as vacuum deposition, spin coating, casting, or Langmuir-Blodgett (LB).

[0264] When a hole injection layer is formed by vacuum deposition, the deposition conditions may vary according to a material that is used to form the hole injection layer, and the structure and thermal characteristics of the hole injection layer. For example, the deposition conditions may include a deposition temperature of about 100 to about 500° C., a vacuum pressure of about 10^{-8} to about 10^{-3} torr, and a deposition rate of about 0.01 to about 100 Angstroms per second (A /sec). However, the deposition conditions are not limited thereto.

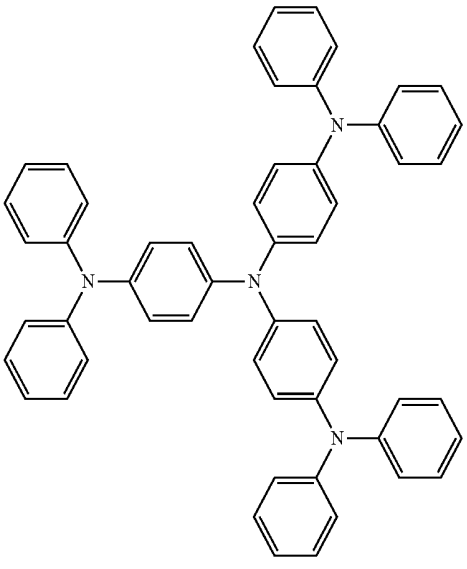
[0265] When the hole injection layer is formed using spin coating, coating conditions may vary according to the material used to form the hole injection layer, and the structure and thermal properties of the hole injection layer. For example, a coating speed may be from about 2,000 revolutions per minute (rpm) to about 5,000 rpm, and a temperature at which a heat treatment is performed to remove a solvent after coating may be from about 80° C. to about 200° C. However, the coating conditions are not limited thereto.

[0266] Conditions for a hole transport layer and an electron blocking layer may be understood by referring to conditions for forming the hole injection layer.

[0267] The hole transport region may include at least one selected from m-MTDATA, TDATA, 2-TNATA, NPB, β-NPB, TPD, Spiro-TPD, Spiro-NPB, methylated NPB, TAPC, HMTPD, 4,4',4"-tris(N-carbazolyl)triphenylamine (TCTA), polyaniline/dodecylbenzenesulfonic acid (Pani/DBSA), poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate) (PEDOT/PSS), polyaniline/camphor sulfonic acid (PANI/CSA), (polyaniline)/poly(4-styrenesulfonate) (Pani/PSS), a compound represented by Formula 201 below, and a compound represented by Formula 202 below:



m-MTDATA



TDATA

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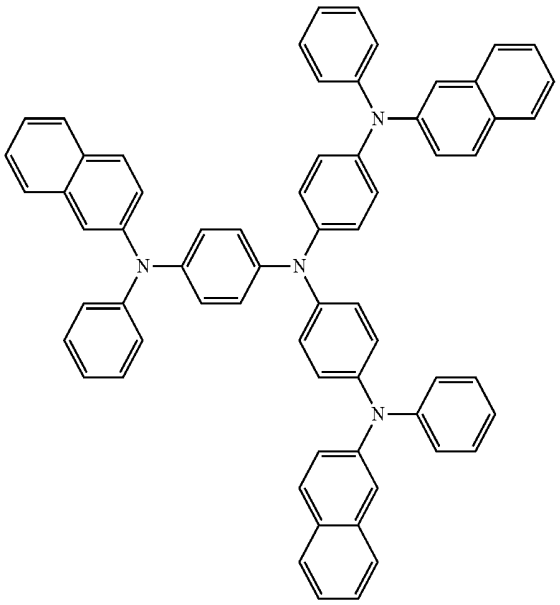
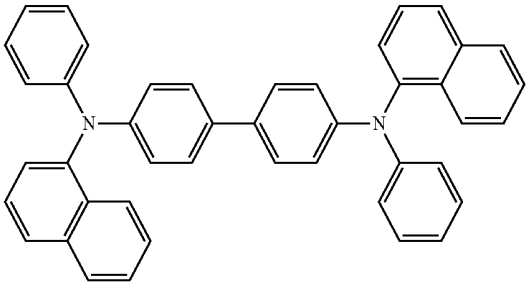
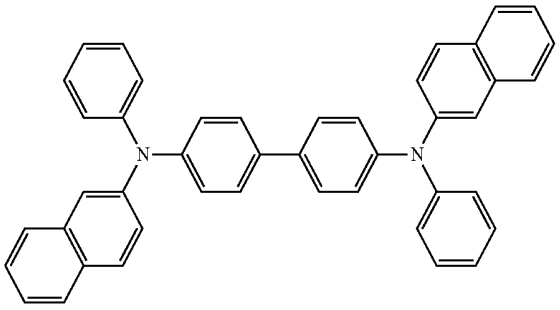


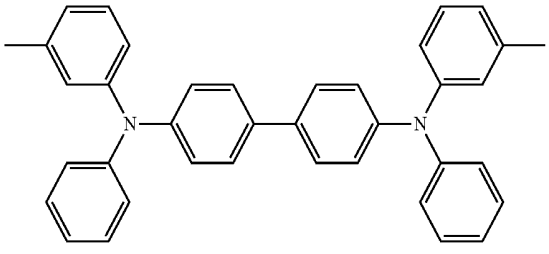
2-TNATA



NPB



β-NPB



TPD

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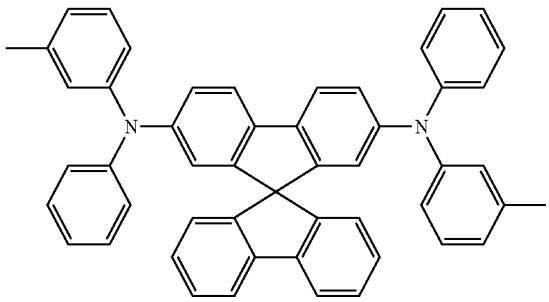
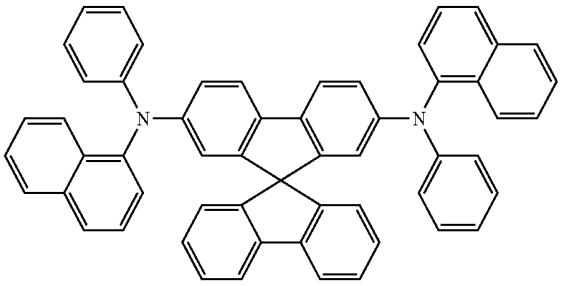


Spiro-TPD



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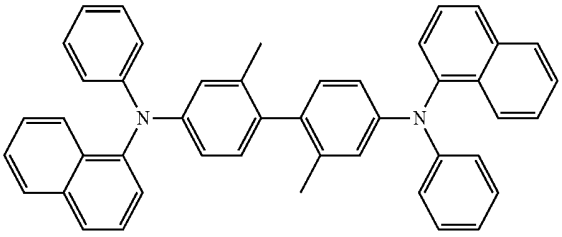
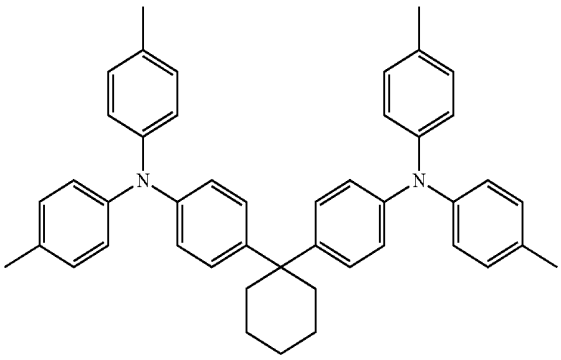
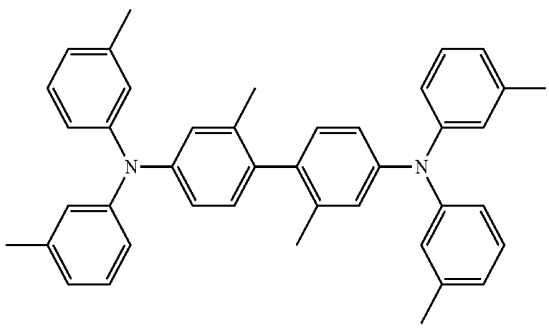


methylated NPB



TAPC



HMTPD

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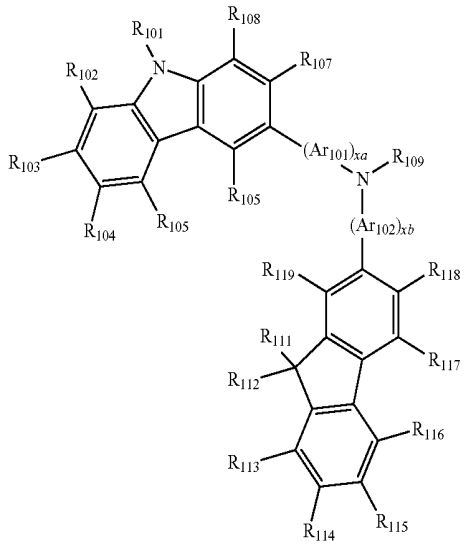
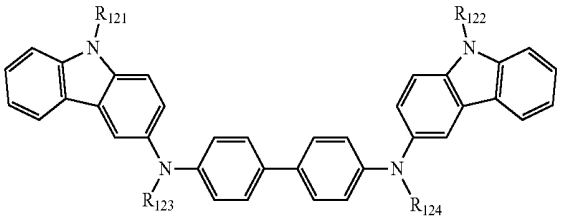
Formula 201



Formula 202



[0268] Ar_{101} and Ar_{102} in Formula 201 may be each independently selected from

[0269] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group; and

[0270] a phenylene group, a pentalenylene group, an indenylene group, a naphthylene group, an azulenylene group, a heptalenylene group, an acenaphthylene group, a fluorenylene group, a phenalenylene group, a phenanthrenylene group, an anthracenylene group, a fluoranthenylene group, a triphenylenylene group, a pyrenylene group, a chrysenylenylene group, a naphthacenylene group, a picenylene group, a perylenylene group, and a pentacenylene group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, a C_r C_{60} alkoxy group, a C_3-C_{10} cycloalkyl group, a C_3-C_{10} cycloalkenyl group, a C_1-C_{10} heterocycloalkyl 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.

[0271] In Formula 201, xa and xb may be each independently an integer of 0 to 5, or 0, 1, or 2. For example, xa is 1 and xb is 0, but xa and xb are not limited thereto.

[0272] R_{101} to R_{108}, R_{111} to R_{119}, and R_{121} to R_{124} in Formulae 201 and 202 may be each independently selected from

[0273] hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group (for example, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, and so on), and a C_1-C_{10} alkoxy group (for example, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, and so on);

[0274] a C_1-C_{10} alkyl group or a C_1-C_{10} alkoxy group, each substituted with at least one selected from a deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, and a phosphoric acid group or a salt thereof;

[0275] a phenyl group, a naphthyl group, an anthracenyl group, a fluorenyl group, and a pyrenyl group; and

[0276] a phenyl group, a naphthyl group, a fluorenyl group, and a pyrenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, a C_1-C_{10} alkyl group, or a C_1-C_{10} alkoxy group.

[0277] However, they are not limited thereto.

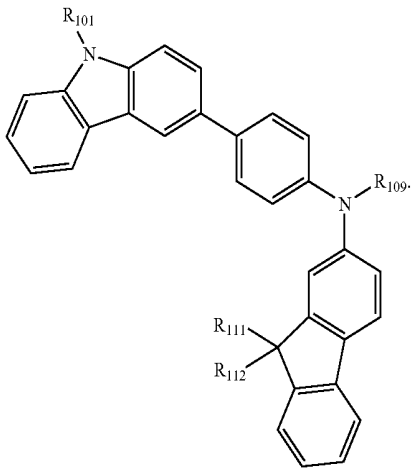
[0278] R_{109} in Formula 201 may be selected from

[0279] a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group; and

[0280] a phenyl group, a naphthyl group, an anthracenyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl group, a C_1-C_{20} alkoxy group, a phenyl group, a naphthyl group, an anthracenyl group, and a pyridinyl group.

[0281] According to an embodiment, the compound represented by Formula 201 may be represented by Formula 201A, but is not limited thereto:

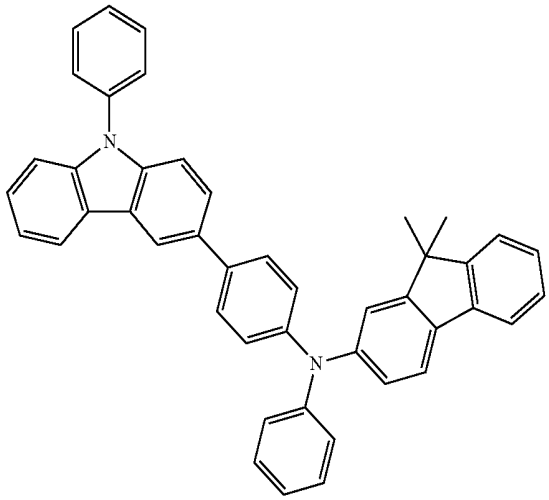
Formula 201A



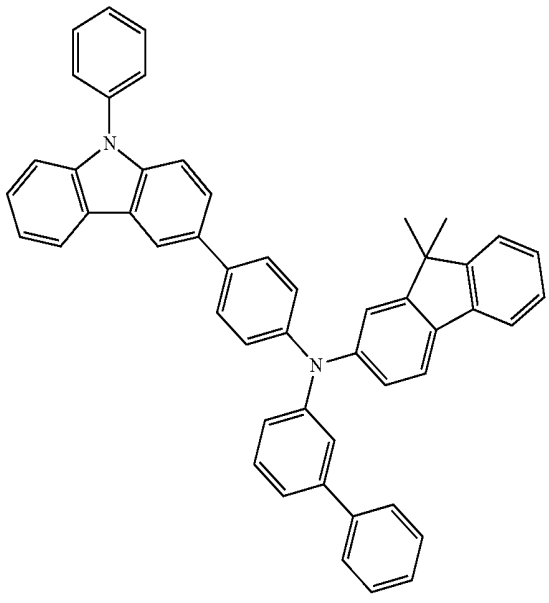
[0282] R_{101}, R_{111}, R_{112}, and R_{109} in Formula 201A may be understood by referring to the description provided herein.

[0283] For example, the compound represented by Formula 201 and the compound represented by Formula 202 may include compounds HT1 to HT20 illustrated below, but are not limited thereto.

HT1



HT2



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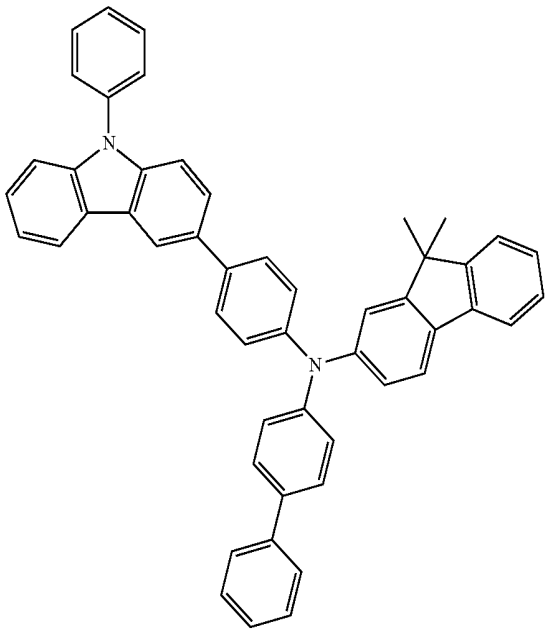
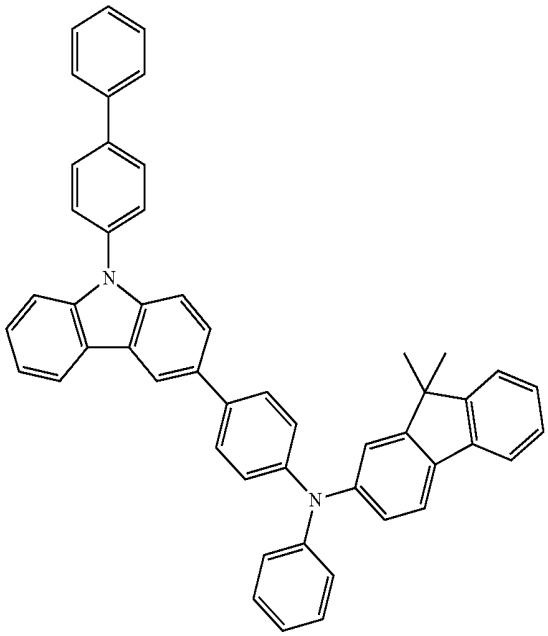
HT3



HT4



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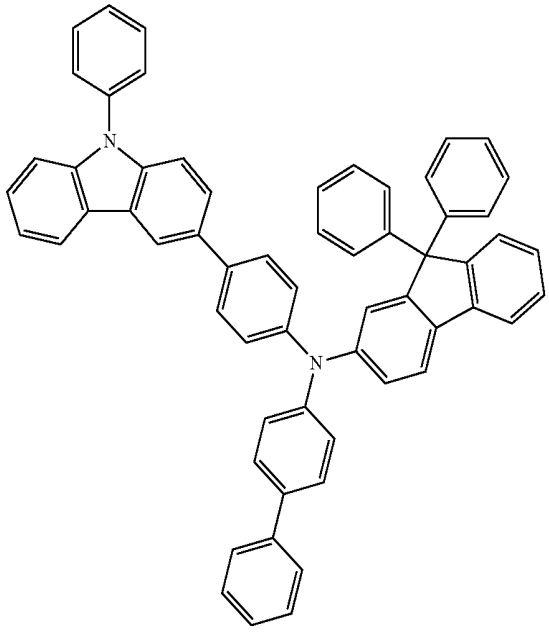
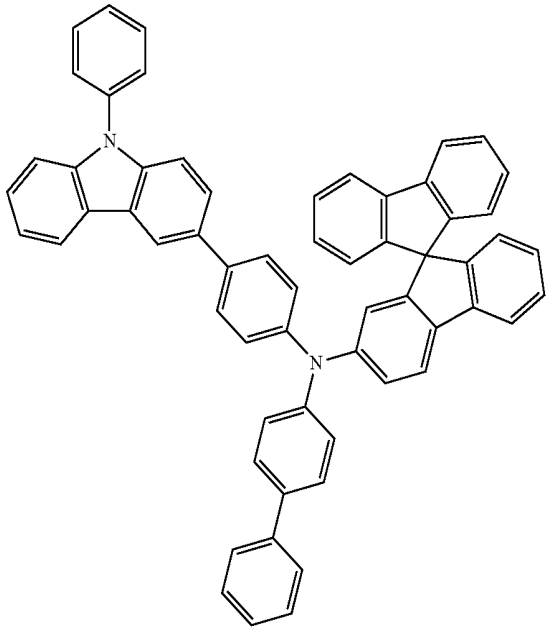
HT5



HT6



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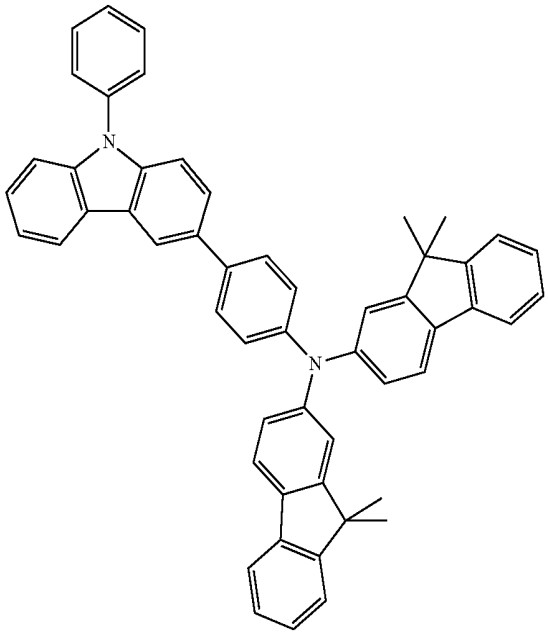
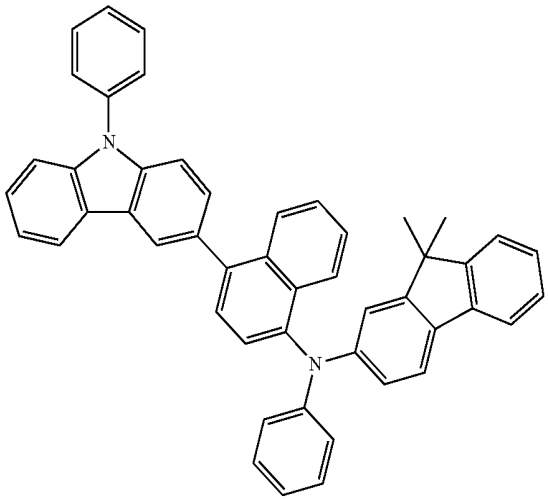
HT7



HT8



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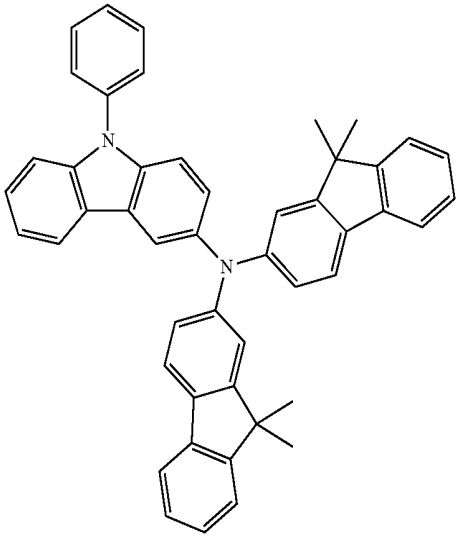
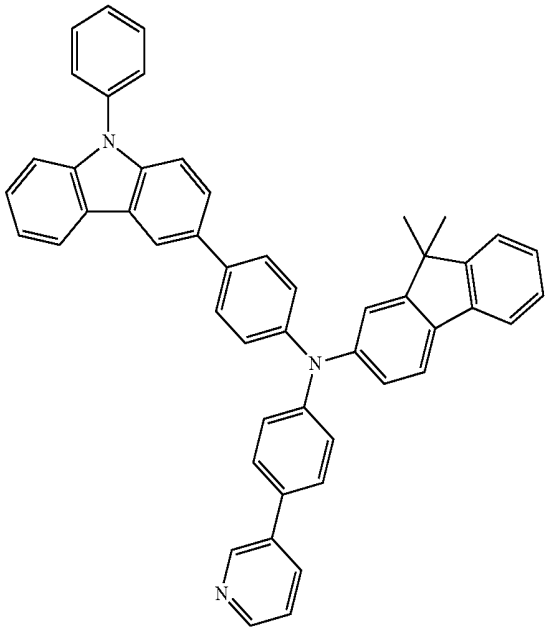
HT9



HT10



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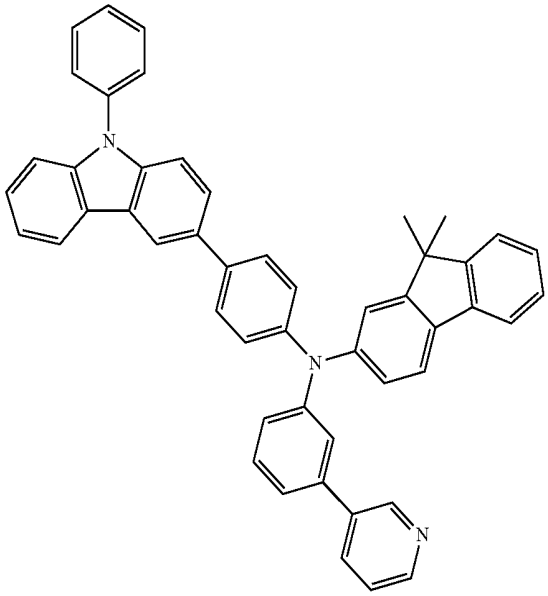
HT11



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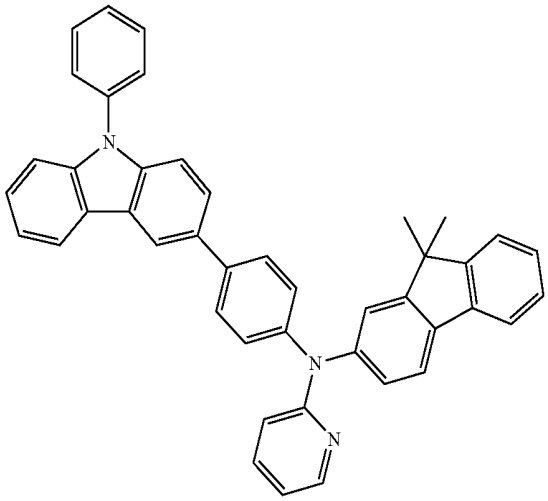

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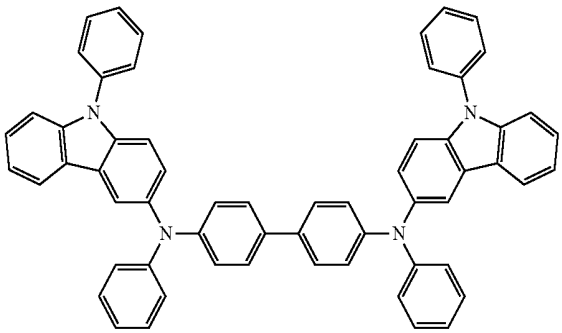

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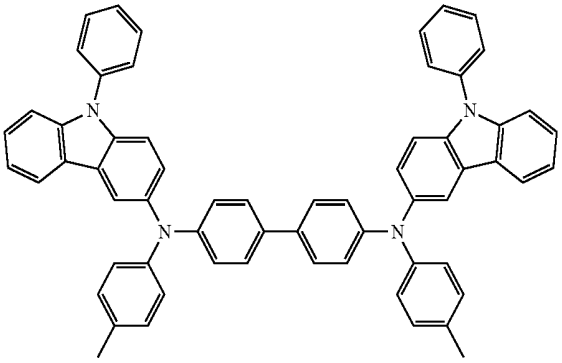

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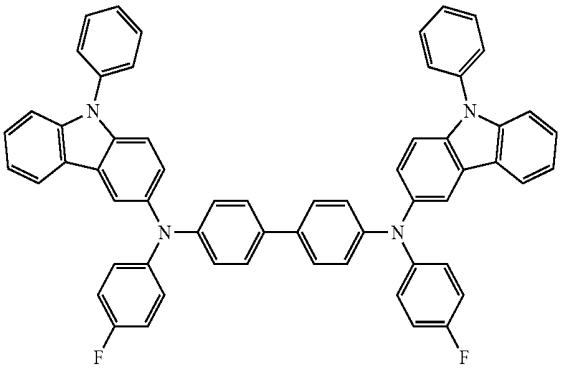

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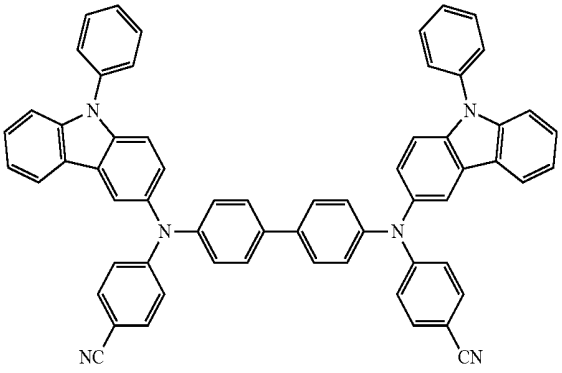

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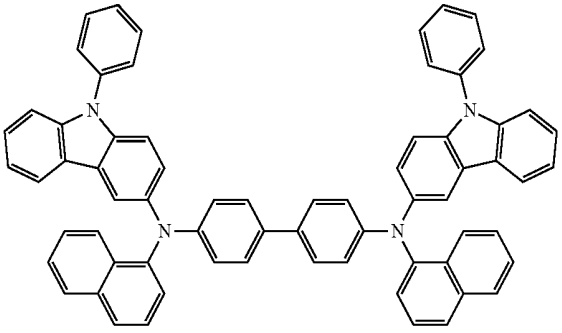

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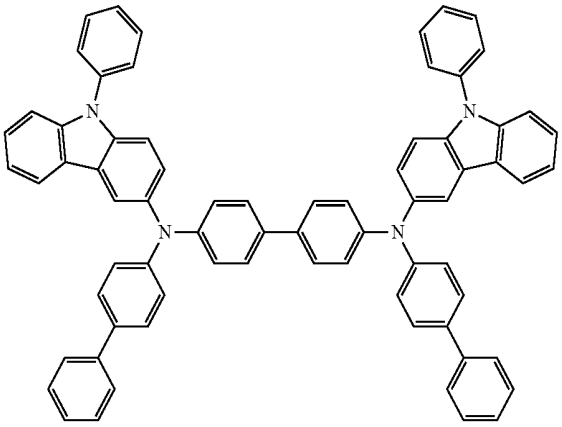

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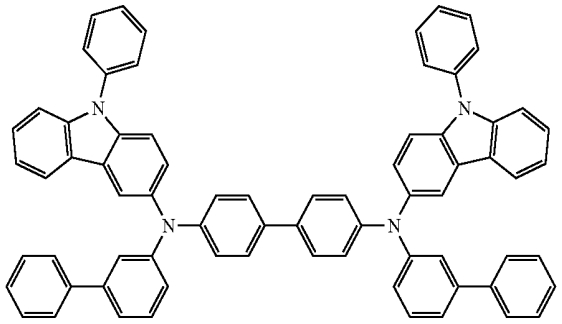

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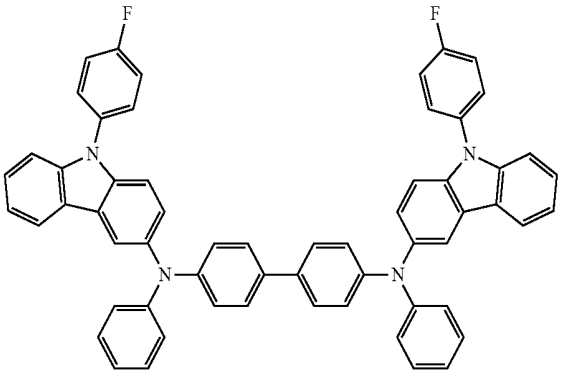


[0284] A thickness of the hole transport region may be in a range of about 100 Angstroms (Å) to about 10,000 Å, for example, about 100 Å to about 1,000 Å.

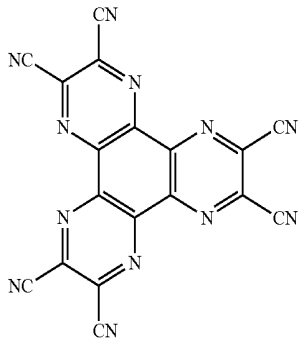
[0285] While not wishing to be bound by a theory, it is understood that when the hole transport region includes a hole injection layer and a hole transport layer, the thickness of the hole injection layer may be in a range of about 100 Å to about 10,000 Å, and for example, about 100 Å to about 1,000 Å, and the thickness of the hole transport layer may be in a range of about 50 Å to about 2,000 Å, and for example, about 100 Å to about 1,500 Å. While not wishing to be bound by a theory, it is understood that 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.

[0286] The hole transport region may further include, in addition to these materials, a charge-generation material for

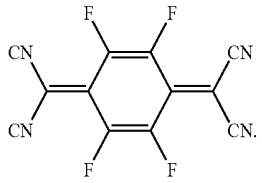
the improvement of conductive properties. The charge-generation material may be homogeneously or non-homogeneously dispersed in the hole transport region.

[0287] The charge-generation material may be, for example, a p-dopant. The p-dopant may be one selected from a quinone derivative, a metal oxide, and a cyano group-containing compound, but embodiments are not limited thereto. Non-limiting examples of the p-dopant are a quinone derivative, such as tetracyanoquinonedimethane (TCNQ) or 2,3,5,6-tetrafluoro-tetracyano-1,4-benzoquinonedimethane (F4-TCNQ); a metal oxide, such as a tungsten oxide or a molybdenium oxide; and a cyano group-containing compound, such as Compound HT-D1 below, but are not limited thereto.

Compound HT-D1



F4-TCNQ



[0288] The hole transport region may include a buffer layer.

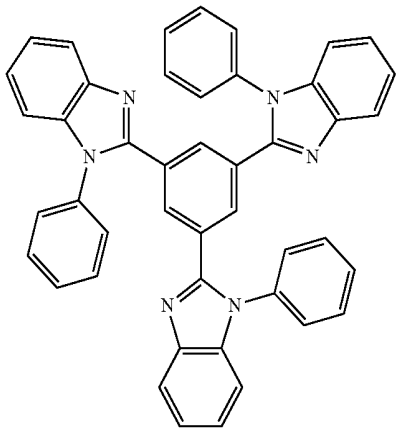
[0289] Also, the buffer layer may compensate for an optical resonance distance according to a wavelength of light emitted from the emission layer, and thus, the efficiency of a formed organic light-emitting device may be improved.

[0290] Then, an emission layer may be formed on the hole transport region by vacuum deposition, spin coating, casting, LB deposition, or the like. When the emission layer is formed by vacuum deposition or spin coating, the deposition or coating conditions may be similar to those applied to form the hole injection layer although the deposition or coating conditions may vary according to the material that is used to form the emission layer.

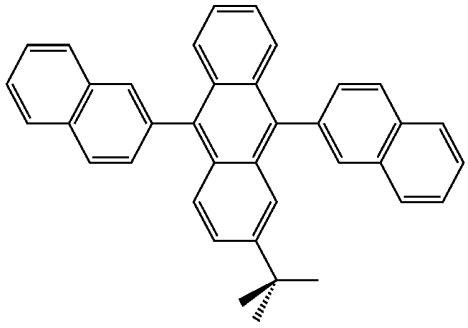
[0291] Meanwhile, when the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be selected from materials for the hole transport region described above and materials for a host to be explained later. However, the material for the electron blocking layer is not limited thereto. For example, when the hole transport region includes an electron blocking layer, a material for the electron blocking layer may be mCP, which will be explained below.

[0292] The emission layer may include a host and a dopant, and the dopant may include the organometallic compound represented by Formula 1.

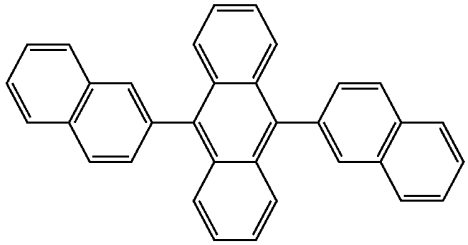
[0293] The host may include at least one selected from TPBi, TBADN, ADN (also referred to as "DNA"), CBP, CDBP, TCP, mCP, Compound HSO, and Compound H51:



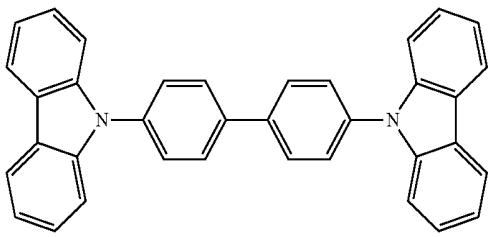
TPBi



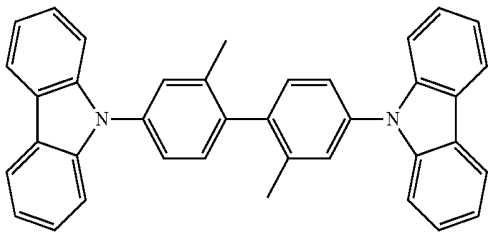
TBADN



ADN



CBP



CDBP

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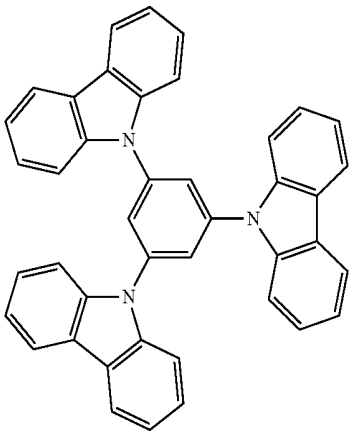
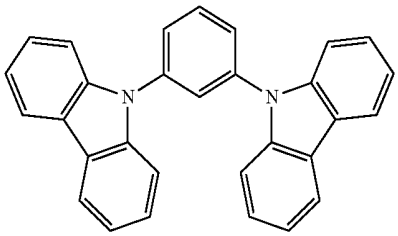
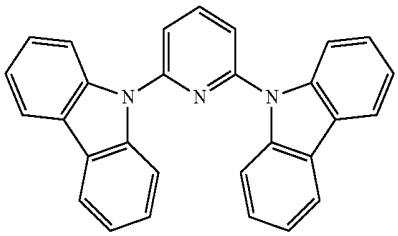


TCP

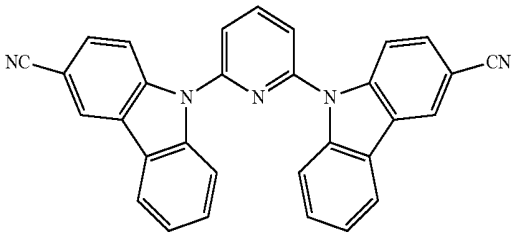


<mCP>

<Compound H50>

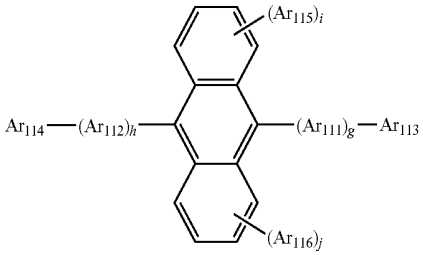


<Compound H51>



[0294] In some embodiments, the host may further include a compound represented by Formula 301 below.

Formula 301



[0295] Ar_{111} and Ar_{112} in Formula 301 may be each independently selected from

[0296] a phenylene group, a naphthylene group, a phenanthrenylene group, and a pyrenylene group; and

[0297] a phenylene group, a naphthylene group, a phenanthrenylene group, and a pyrenylene group, each substituted with at least one selected from a phenyl group, a naphthyl group, and an anthracenyl group.

[0298] Ar_{113} to Ar_{116} in Formula 301 may be each independently selected from

[0299] a C_1-C_{10} alkyl group, a phenyl group, a naphthyl group, a phenanthrenyl group, and a pyrenyl group; and

[0300] a phenyl group, a naphthyl group, a phenanthrenyl group, and a pyrenyl group, each substituted with at least one selected from a phenyl group, a naphthyl group, and an anthracenyl group.

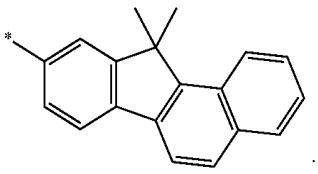
[0301] g, h, l, and j in Formula 301 may be each independently an integer of 0 to 4, for example, an integer of 0, 1, or 2.

[0302] Ar_{113} to Ar_{116} in Formula 301 may be each independently selected from

[0303] a C_1-C_{10} alkyl group, substituted with at least one selected from a phenyl group, a naphthyl group, and an anthracenyl group;

[0304] a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl, a phenanthrenyl group, and a fluorenyl group;

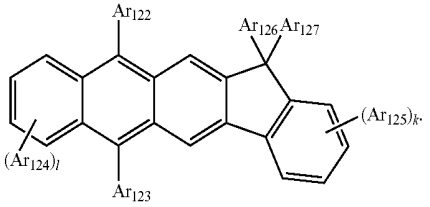
[0305] a phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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 phenyl group, a naphthyl group, an anthracenyl group, a pyrenyl group, a phenanthrenyl group, and a fluorenyl group; and



[0306] However, they are not limited thereto.

[0307] In some embodiments, the host may include a compound represented by Formula 302 below:

Formula 302



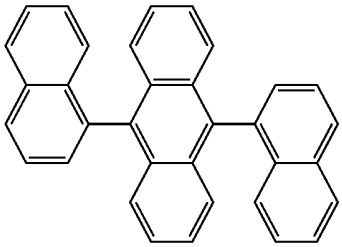
[0308] Ar_{122} to Ar_{125} in Formula 302 are the same as described in detail in connection with Ar_{113} in Formula 301.

[0309] Ar_{126} and Ar_{127} in Formula 302 may be each independently a C_1-C_{10} alkyl group (for example, a methyl group, an ethyl group, or a propyl group).

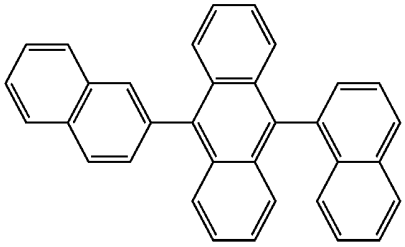
[0310] k and l in Formula 302 may be each independently an integer of 0 to 4. For example, k and l may be 0, 1, or 2.

[0311] The compound represented by Formula 301 and the compound represented by Formula 302 may include Compounds H1 to H42 illustrated below, but are not limited thereto.

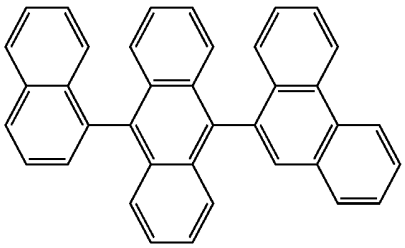
H1



H2



H3



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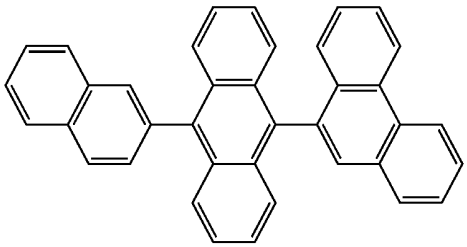

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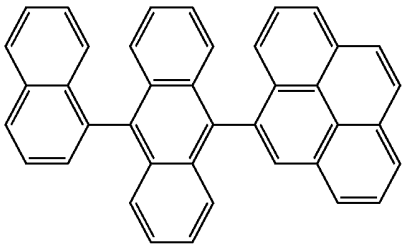

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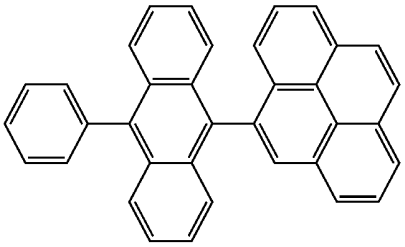
H6



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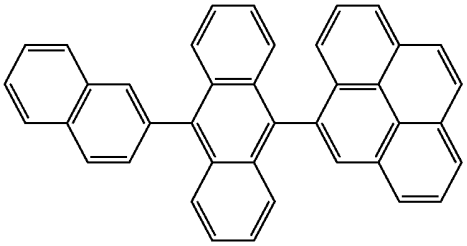

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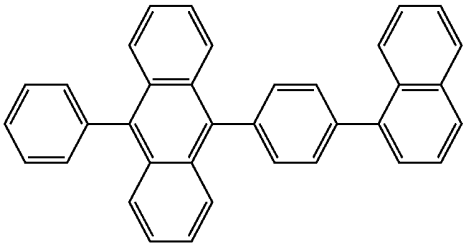

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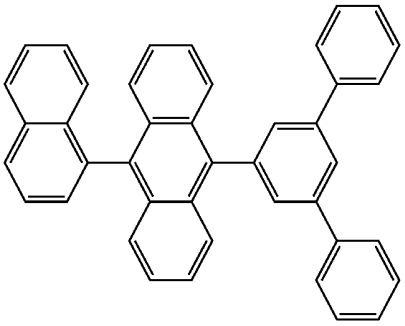

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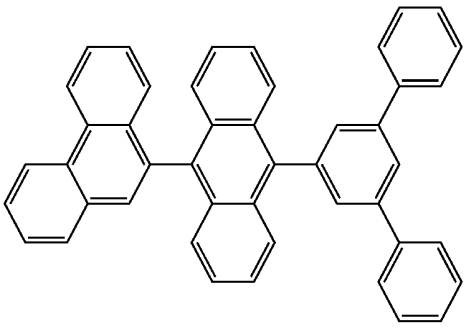

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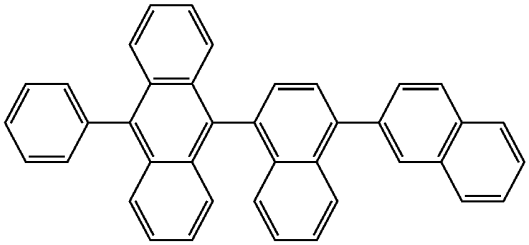

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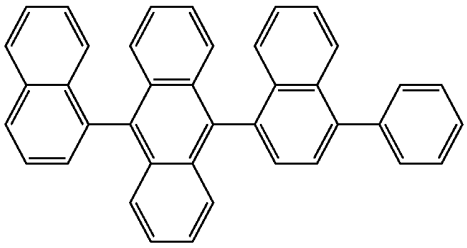

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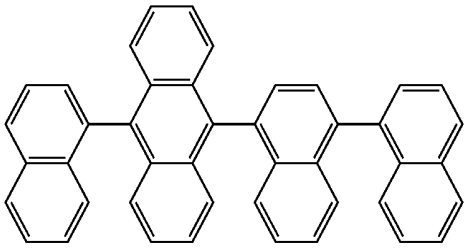

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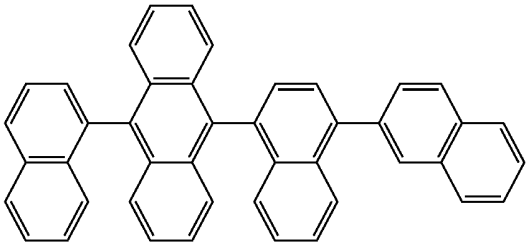

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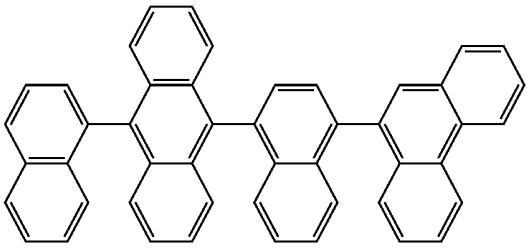

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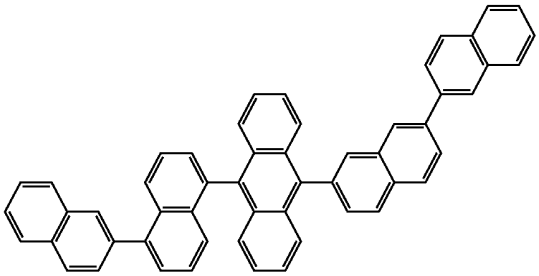

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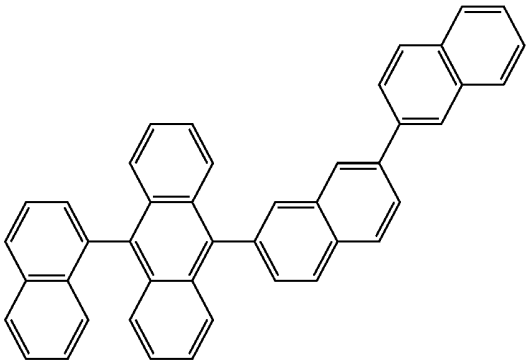

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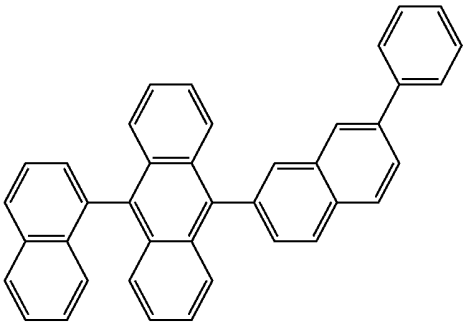

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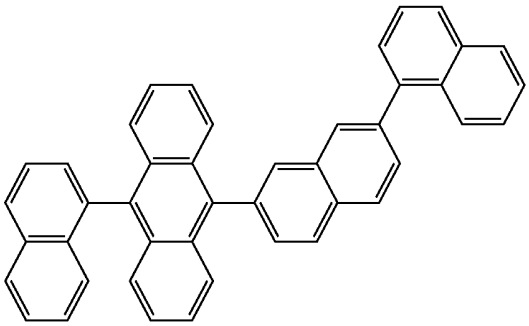

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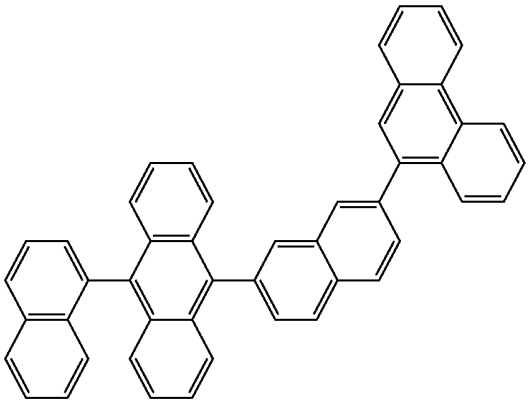

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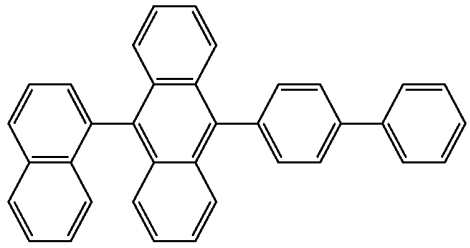
H21



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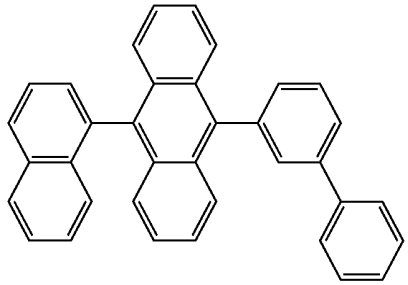

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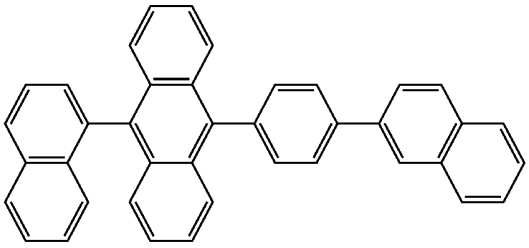

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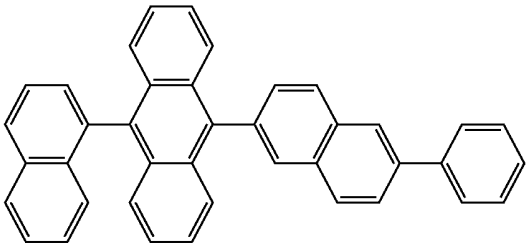
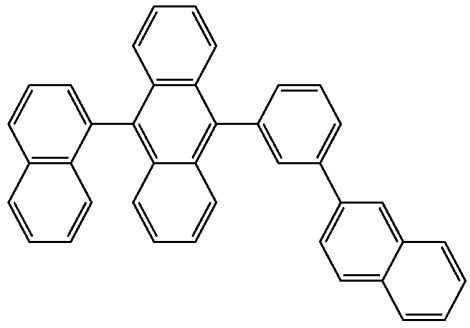


H25



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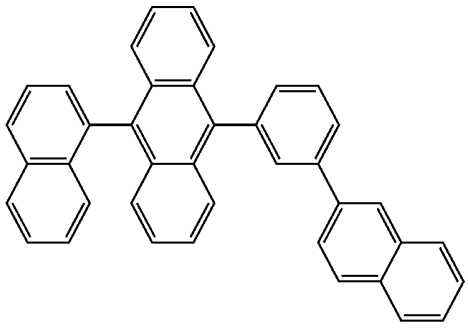

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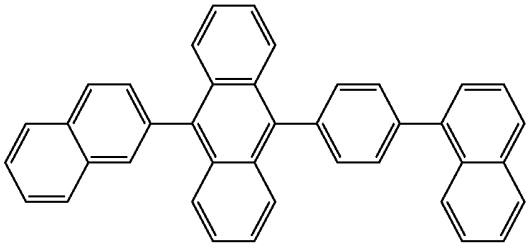

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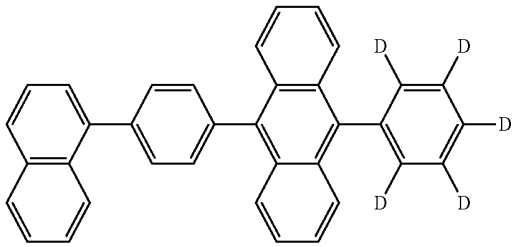

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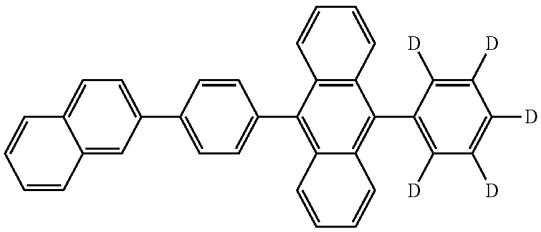

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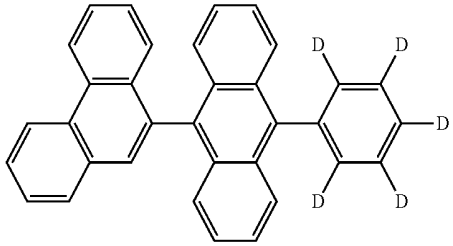

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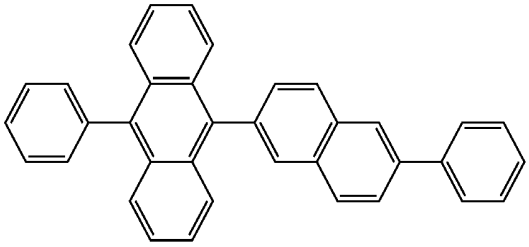

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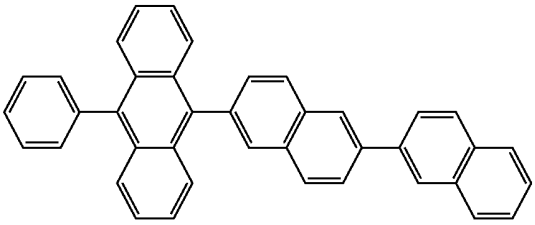

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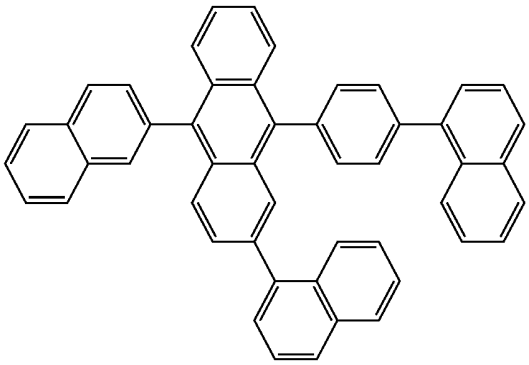

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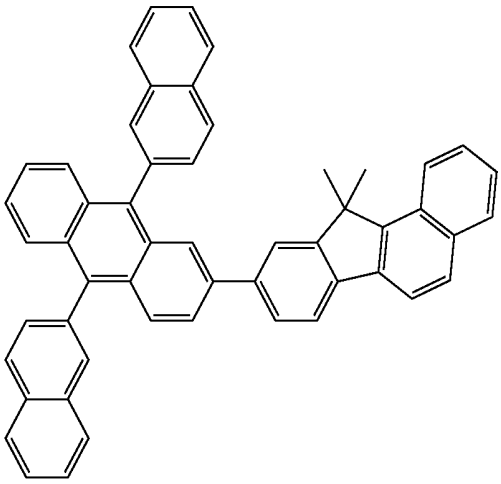

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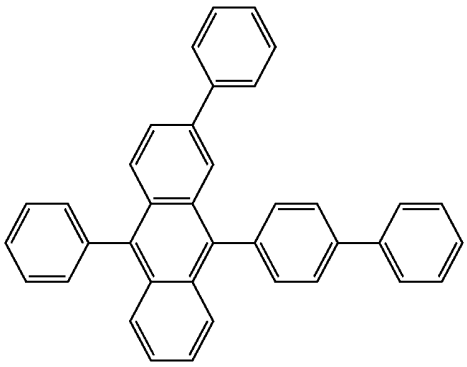

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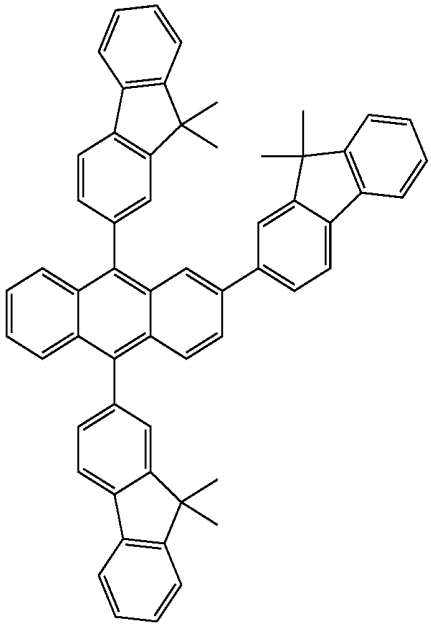

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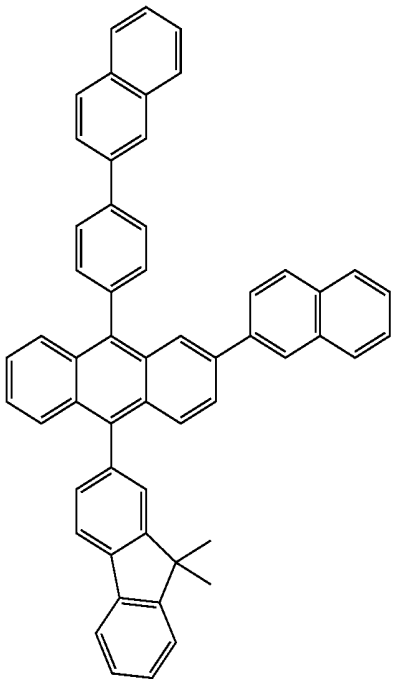

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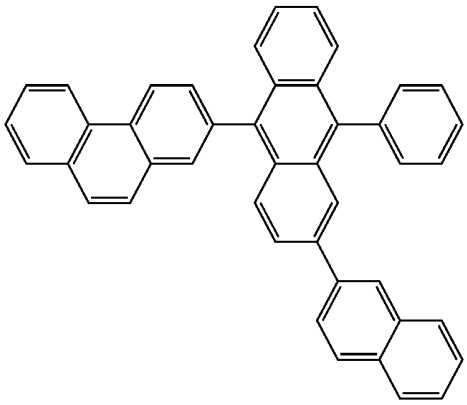

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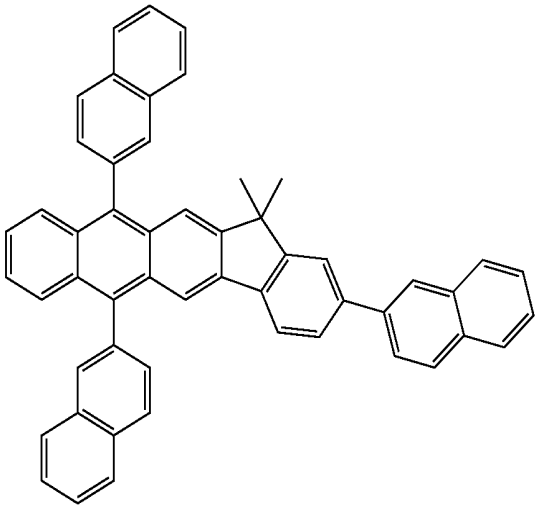

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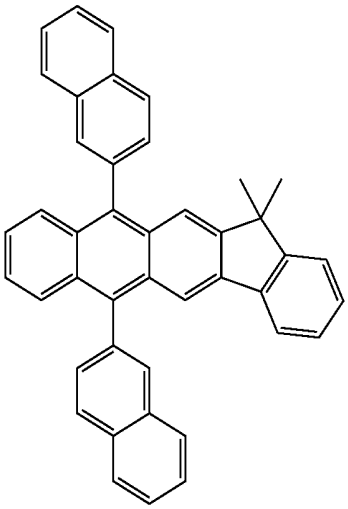

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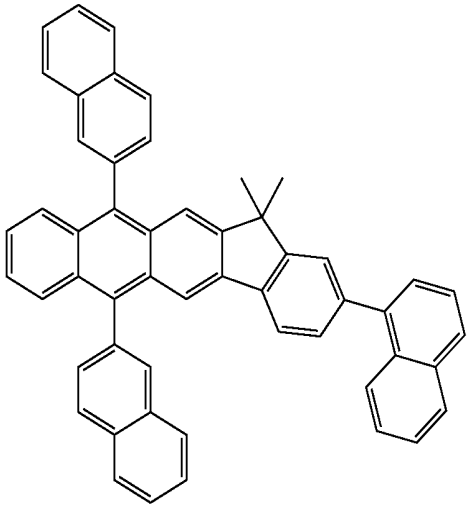
H41



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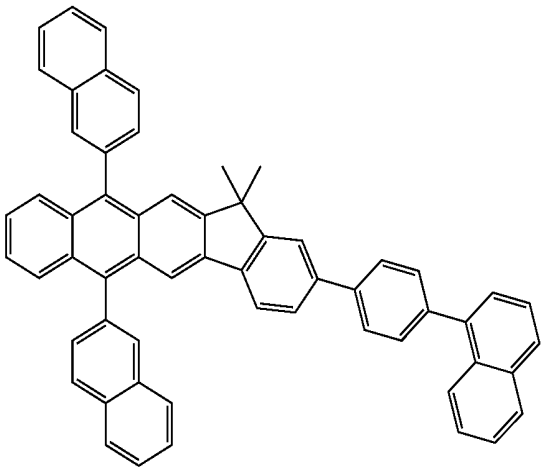


[0312] When the organic light-emitting device is a full color organic light-emitting device, the emission layer may be patterned into a red emission layer, a green emission layer, and a blue emission layer. In some embodiments, due to a stack structure including a red emission layer, a green emission layer, and/or a blue emission layer, the emission layer may emit white light.

[0313] When the emission layer includes a host and a dopant, the amount of the dopant may be in a range of about 0.01 to about 15 parts by weight based on 100 parts by weight of the host, but is not limited thereto.

[0314] 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. While not wishing to be bound by a theory, it is understood that 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.

[0315] Then, an electron transport region may be disposed on the emission layer.

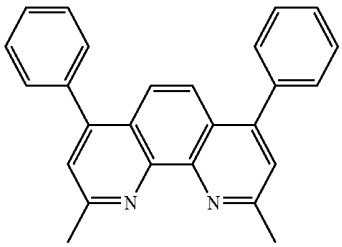
[0316] The electron transport region may include at least one selected from a hole blocking layer, an electron transport layer, and an electron injection layer.

[0317] For example, the electron transport region may have a structure of hole blocking layer/electron transport layer/

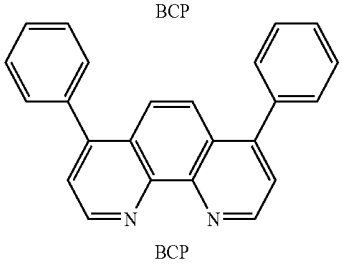
electron injection layer or a structure of electron transport layer/electron injection layer, but the structure of the electron transport region is not limited thereto. The electron transport layer may have a single-layered structure or a multi-layer structure including two or more different materials.

[0318] Conditions for forming the hole blocking layer, the electron transport layer, and the electron injection layer which constitute the electron transport region may be understood by referring to the conditions for forming the hole injection layer.

[0319] When the electron transport layer includes a hole blocking layer, the hole blocking layer may include, for example, at least one of BCP, Bphen, and Balq. However, materials included in the hole blocking layer are limited thereto.



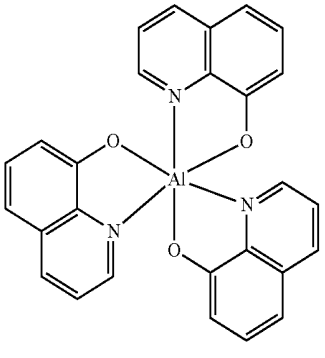
BCP



BCP

[0320] A thickness of the hole blocking layer may be in a range of about 20 Å to about 1,000 Å, for example, about 30 Å to about 300 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the hole blocking layer is within these ranges, the hole blocking layer may have improved hole blocking ability without a substantial increase in driving voltage.

[0321] The electron transport layer may further include at least one selected from BCP, Bphen, Alq_3, Balq, TAZ, and NTAZ.



Alq_3

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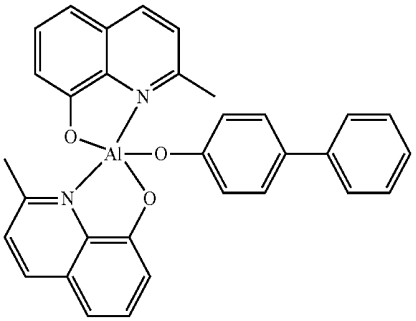
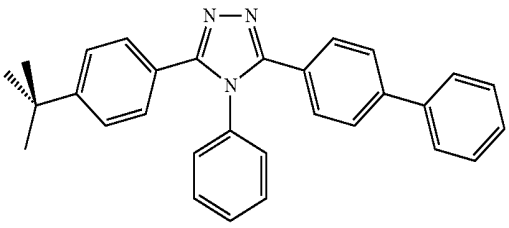
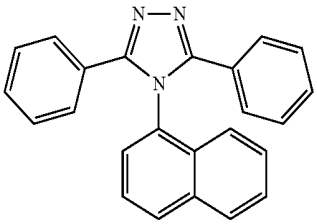


BAlq



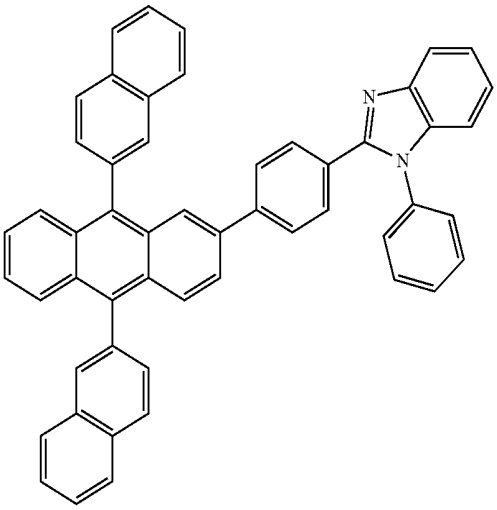
TAZ



NTAZ

[0322] In some embodiments, the electron transport layer may include at least one of ET1 and ET2, but are not limited thereto:

ET1



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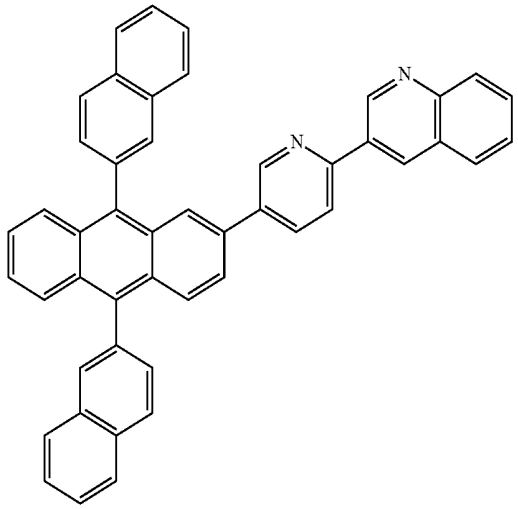
ET2

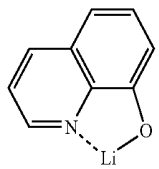


[0323] A thickness of the electron transport layer may be in a range of about 100 Å to about 1,000 Å, for example, about 150 Å to about 500 Å. While not wishing to be bound by a theory, it is understood that when the thickness of the electron transport layer is within the range described above, the electron transport layer may have satisfactory electron transport characteristics without a substantial increase in driving voltage.

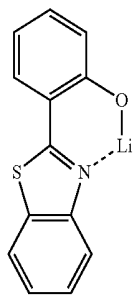
[0324] Also, the electron transport layer may further include, in addition to the materials described above, a metal-containing material.

[0325] 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



[0326] The electron transport layer may include an electron injection layer (EIL) that promotes flow of electrons from the second electrode **19** thereinto.

[0327] The electron injection layer may include at least one selected from, LiF, NaCl, CsF, Li_2O, BaO, and LiQ.

[0328] 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. While not wishing to be bound by a theory, it is understood that 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.

[0329] The second electrode **19** is disposed on the organic layer **15**. The second electrode **19** may be a cathode. A material for forming the second electrode **19** may be selected from metal, an alloy, an electrically conductive compound, and a combination thereof, which have a relatively low work function. For example, lithium (Li), magnesium (Mg), aluminum (Al), aluminum-lithium (Al—Li), calcium (Ca), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) may be formed as a material for forming the second electrode **19**. In some embodiments, to manufacture a top emission type light-emitting device, a transmissive electrode formed using ITO or IZO may be used as the second electrode **19**.

[0330] Hereinbefore, the organic light-emitting device has been described with reference to FIG. **1**, but is not limited thereto.

[0331] A C_1-C_{60} alkyl group as used herein refers to a linear or branched aliphatic hydrocarbon monovalent group having 1 to 60 carbon atoms. Detailed examples thereof are a methyl group, an ethyl group, a propyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, a pentyl group, an isoamyl group, and a hexyl group. A C_1-C_{60} alkylene group as used herein refers to a divalent group having the same structure as the C_1-C_{60} alkyl group.

[0332] A 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). Detailed examples thereof are a methoxy group, an ethoxy group, and an isopropyloxy group.

[0333] A C_2-C_{60} alkenyl group as used herein refers to a hydrocarbon group formed by placing at least one carbon double bond in the middle or at the terminal of the C_2-C_{60} alkyl group. Detailed examples thereof are an ethenyl group, a propenyl group, and a butenyl group. A C_2-C_{60} alkenylene group as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkenyl group.

[0334] A C_2-C_{60} alkynyl group as used herein refers to a hydrocarbon group formed by placing at least one carbon triple bond in the middle or at the terminal of the C_2-C_{60} alkyl group. Detailed examples thereof are an ethynyl group, and a propynyl group. A C_2-C_{60} alkynylene group as used herein refers to a divalent group having the same structure as the C_2-C_{60} alkynyl group.

[0335] A C_3-C_{10} cycloalkyl group as used herein refers to a monovalent hydrocarbon monocyclic group having 3 to 10 carbon atoms. Detailed examples thereof are a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, and a cycloheptyl group. A C_3-C_{10} cycloalkylene group as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkyl group.

[0336] A C_1-C_{10} heterocycloalkyl group as used herein refers to a monovalent monocyclic group having at least one hetero atom selected from N, O, P, Si, and S as a ring-forming atom and 1 to 10 carbon atoms. Detailed examples thereof are a tetrahydrofuranyl group, and a tetrahydrothiophenyl group. A C_1-C_{10} heterocycloalkylene group as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkyl group.

[0337] A 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 double bond in the ring thereof, and which is not aromatic. Detailed examples thereof are a cyclopentenyl group, a cyclohexenyl group, and a cycloheptenyl

group. A C_3-C_{10} cycloalkenylene group as used herein refers to a divalent group having the same structure as the C_3-C_{10} cycloalkenyl group.

[0338] A C_1-C_{10} heterocycloalkenyl group as used herein refers to a monovalent monocyclic group that has at least one hetero atom selected from N, O, P, Si, and S as a ring-forming atom, 1 to 10 carbon atoms, and at least one double bond in its ring. Examples of the C_1-C_{10} heterocycloalkenyl group are a 2,3-dihydrofuranyl group and a 2,3-dihydrothiophenyl group. A C_1-C_{10} heterocycloalkenylene group as used herein refers to a divalent group having the same structure as the C_1-C_{10} heterocycloalkenyl group.

[0339] A C_6-C_{60} aryl group as used herein refers to a monovalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms, and a C_6-C_{60} arylene group as used herein refers to a divalent group having a carbocyclic aromatic system having 6 to 60 carbon atoms. Detailed examples of the C_6-C_{60} aryl group are a phenyl group, a naphthyl group, an anthracenyl group, a phenanthrenyl group, a pyrenyl group, and a chrysenyl group. When the C_6-C_{60} aryl group and the C_6-C_{60} arylene group each include two or more rings, the rings may be fused to each other.

[0340] A C_1-C_{60} heteroaryl group as used herein refers to a monovalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, Si, and S as a ring-forming atom, and 1 to 60 carbon atoms. A C_1-C_{60} heteroarylene group as used herein refers to a divalent group having a carbocyclic aromatic system that has at least one hetero atom selected from N, O, P, Si, and S as a ring-forming atom, and 1 to 60 carbon atoms. Examples of the C_1-C_{60} heteroaryl group are a pyridinyl group, a pyrimidinyl group, a pyrazinyl group, a pyridazinyl group, a triazinyl group, a quinolinyl group, and an isoquinolinyl group. When the C_1-C_{60} heteroaryl group and the C_1-C_{60} heteroarylene group each include two or more rings, the rings may be fused to each other.

[0341] A C_6-C_{60} aryloxy group as used herein indicates —OA_{102} (wherein A_{102} is the C_6-C_{60} aryl group), and a C_6-C_{60} arylthio group as used herein indicates —SA_{103} (wherein A_{103} is the C_6-C_{60} aryl group).

[0342] A monovalent non-aromatic condensed polycyclic group as used herein refers to a monovalent group (for example, having 8 to 60 carbon atoms) that has two or more rings condensed to each other, only carbon atoms as a ring forming atom, and which is non-aromatic in the entire molecular structure. A detailed example of the monovalent non-aromatic condensed polycyclic group is a fluorenyl group. A divalent non-aromatic condensed polycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed polycyclic group.

[0343] A monovalent non-aromatic condensed heteropolycyclic group as used herein refers to a monovalent group (for example, having 2 to 60 carbon atoms) that has two or more rings condensed to each other, has a heteroatom selected from N, O P, and S, other than carbon atoms, as a ring forming atom, and which is non-aromatic in the entire molecular structure. An example of the monovalent non-aromatic condensed heteropolycyclic group is a carbazolyl group. A divalent non-aromatic condensed heteropolycyclic group as used herein refers to a divalent group having the same structure as the monovalent non-aromatic condensed heteropolycyclic group.

[0344] In the present specification, at least one of substituents of the substituted C_r C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group may be selected from

[0345] 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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;

[0346] 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 a 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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, —$N(Q_{11})(Q_{12})$, —$Si(Q_{13})(Q_{14})(Q_{15})$, —$B(Q_{16})(Q_{17})$, and —$P(=O)(Q_{18})(Q_{19})$;

[0347] 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;

[0348] 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, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid group or a salt thereof, a sulfonic acid group or a salt thereof, a phosphoric acid group or a salt thereof, 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, —$N(Q_{21})(Q_{22})$, —$Si(Q_{23})(Q_{24})(Q_{25})$, —$B(Q_{26})(Q_{27})$, and —$P(=O)(Q_{28})(Q_{29})$; and

[0349] —$N(Q_{31})(Q_{32})$, —$Si(Q_{33})(Q_{34})(Q_{35})$, —$B(Q_{36})(Q_{37})$, and —$P(=O)(Q_{38})(Q_{39})$,

[0350] wherein Q_1 to Q_9, Q_{11} to Q_{19}, Q_{21} to Q_{29}, and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

[0351] When a group containing a specified number of carbon atoms is substituted with any of the substituents listed above, the number of carbon atoms in the resulting "substituted" group may be the number of atoms contained in the original (base) group plus the number of carbon atoms (if any) contained in the substituent. For example, the "substituted C_1-C_{30} alkyl" may refer to a C_1-C_{30} alkyl group substituted with C_{6-60} aryl group, in which the total number of carbon atoms may be C_7-C_{90}.

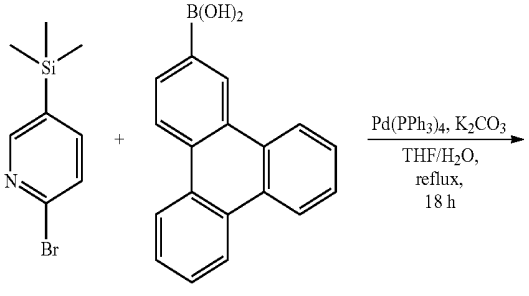
[0352] Hereinafter, a compound and an organic light-emitting device according to embodiments are described in detail with reference to Synthesis Example and Examples. However, the organic light-emitting device is not limited thereto. The wording "B was used instead of A" used in describing Synthesis Examples means that an amount of A used was identical to an amount of B used, in terms of a molar equivalent.

EXAMPLES

Synthesis Example 1

Synthesis of Compound 1

[0353]



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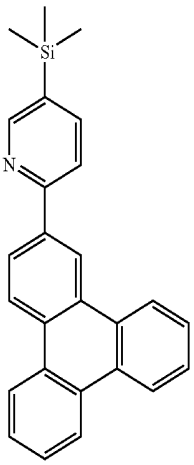
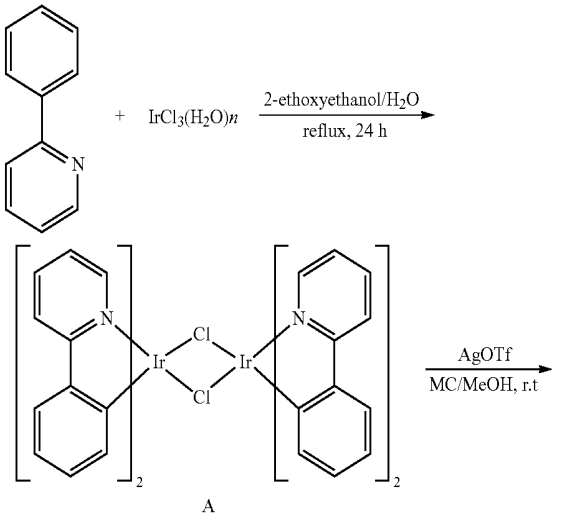
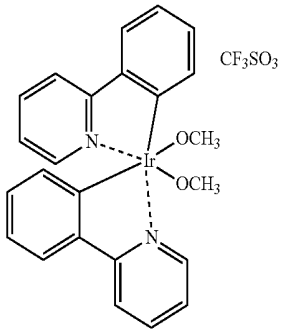


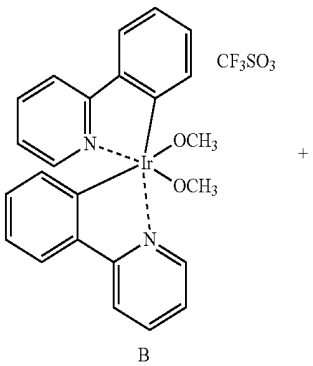
L1



A



B



B

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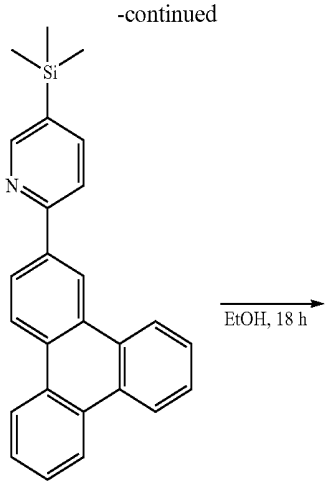
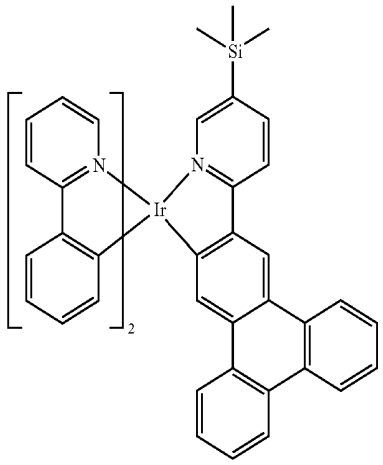


L1



1

Synthesis of Compound L1

[0354] 2-bromo-5-(trimethylsilyl)pyridine (9.15 grams (g), 39.73 millimoles (mmol)), triphenylen-2-ylboronic acid (12.43 g, 45.69 mmol), $Pd(PPh_3)_4$ (3.06 g, 2.65 mmol), and K_2CO_3 (21.94 g, 158.74 mmol) were mixed with 210 milliliters (mL) of tetrahydrofuran (THF) and 70 mL of distilled water, and the mixture was stirred for 18 hours under reflux. The temperature was decreased to room temperature, and the organic layer was extracted by using methylene chloride (MC). Anhydrous magnesium sulfate ($MgSO_4$) was added thereto to remove moisture therefrom. The result was filtered to obtain a filtrate, and the solvent was removed under reduced pressure. The residual was purified by column chromatography using MC and hexane at a ratio of 1:1 to obtain 10.40 g (69%) of Compound L1.

[0355] MALDI-TOFMS (m/z): $C_{26}H_{23}NSi$ (M^+) 378.

[0356] Synthesis of Compound A

[0357] 2-phenylpyridine (14.66 g, 94.44 mmol) and iridium chloride (14.80 g, 41.97 mmol) were mixed with 210 mL of ethoxyethanol and 70 mL of distilled water. The mixture was stirred for 24 hours under reflux to perform a reaction. The temperature was then decreased to room temperature. A solid obtained therefrom was separated therefrom by filtration, and was thoroughly washed with water, methanol, and hexane sequentially in this stated order. The resultant solid was dried in a vacuum oven to obtain 19.5 g (87%) of Compound A.

[0358] Synthesis of Compound B

[0359] Compound A (4.51 g, 4.20 mmol) was mixed with 45 mL of MC, and AgOTf (2.16 g, 8.41 mmol) dissolved in 15 mL of methanol was added thereto. While light was blocked by using an aluminum foil, the mixture was stirred at room temperature for 18 hours to perform a reaction. The reaction mixture was filtered through celite to remove generated solid therefrom. A filtrate was placed under reduced pressure to obtain a solid (Compound B), which was used in the subsequent reaction without additional purification.

[0360] Synthesis of Compound 1

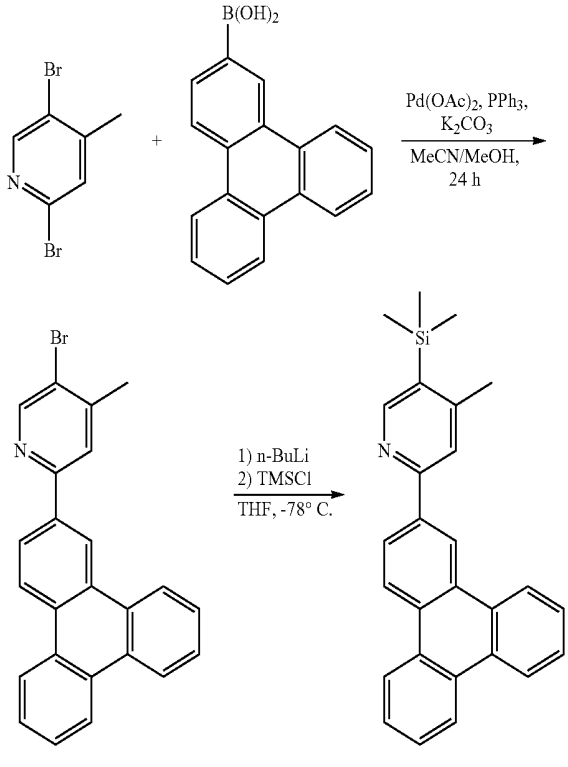
[0361] Compound B (6.0 g, 8.41 mmol) and Compound L1 (3.81 g, 10.10 mmol) were mixed with 100 mL of ethanol, and the mixture was stirred for 18 hours under reflux to perform a reaction. After the temperature was decreased, the resultant mixture was filtered to obtain a solid, which was thoroughly washed with ethanol and hexane. The crude product was purified by column chromatography using MC and hexane at a ratio of 40:60 to obtain 1.4 g (19%) of Compound 1. The obtained compound was identified by Mass and HPLC.

[0362] HRMS (MALDI-TOF) calcd for $C_{48}H_{38}IrN_3Si$: m/z 877.2464. Found: 877.2461

Synthesis Example 2

Synthesis of Compound 2

[0363]



C

L2

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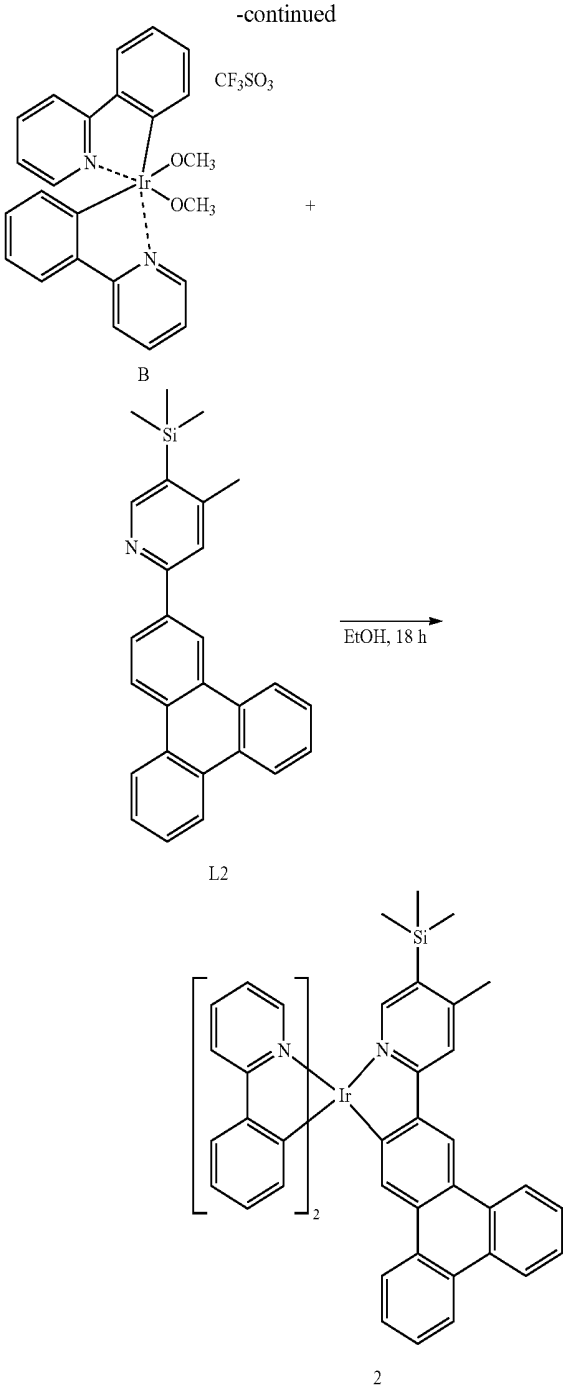


[0364] Synthesis of Compound C

[0365] 9.5 g (60%) of Compound C was prepared in the same manner as Compound L1 in Synthesis Example 1, except that 2,5-dibromo-4-methylpyridine (10 g, 39.86 mmol) was used instead of 2-bromo-5-(trimethylsilyl)pyridine.

[0366] MALDI-TOFMS (m/z): $C_{27}H_{25}NSi$ (M^+) 397.

[0367] Synthesis of Compound L2

[0368] 100 mL of tetrahydrofuran (THF) was added to Compound C (6.09 g, 15.31 mmol), and the mixture was cooled to a temperature of −78° C. . n-BuLi (14.4 mL, 22.96 mmol) was slowly added thereto, and the result was stirred at a temperature of −78° C. for 1 hour. Trimethylsilyl chloride (TMSCl) (2.91 mL, 22.96 mmol) was added thereto, and a reaction was performed at a temperature of −78° C. for 1 hour. The reaction product was heated to room temperature to perform a reaction for 12 hours. An organic layer was extracted therefrom by using MC, and anhydrous magnesium sulfate was added thereto to remove moisture therefrom. The filtrate obtained by filtration was placed under reduced pressure to evaporate the solvent. The residue was purified by column chromatography using EA and hexane at a ratio of 5:95 to obtain 4.8 g (80%) of Compound L2.

[0369] MALDI-TOFMS (m/z): $C_{27}H_{25}NSi$ (M^+) 391.

[0370] Synthesis of Compound 2

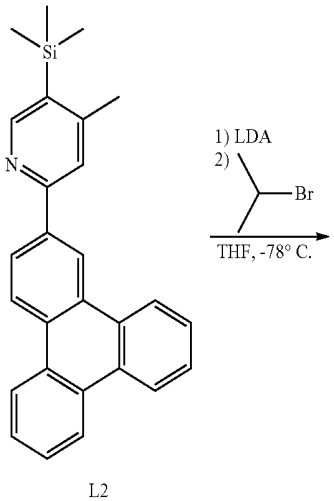
[0371] 1.9 g (32%) of Compound 2 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound L2 (3.17 g, 8.08 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

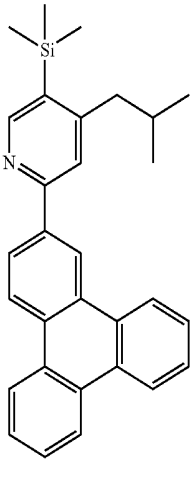
[0372] HRMS (MALDI-TOF) calcd for $C_{49}H_{40}IrN_3Si$: m/z 891.2621. Found: 891.2621.

Synthesis Example 3

Synthesis of Compound 3

[0373]





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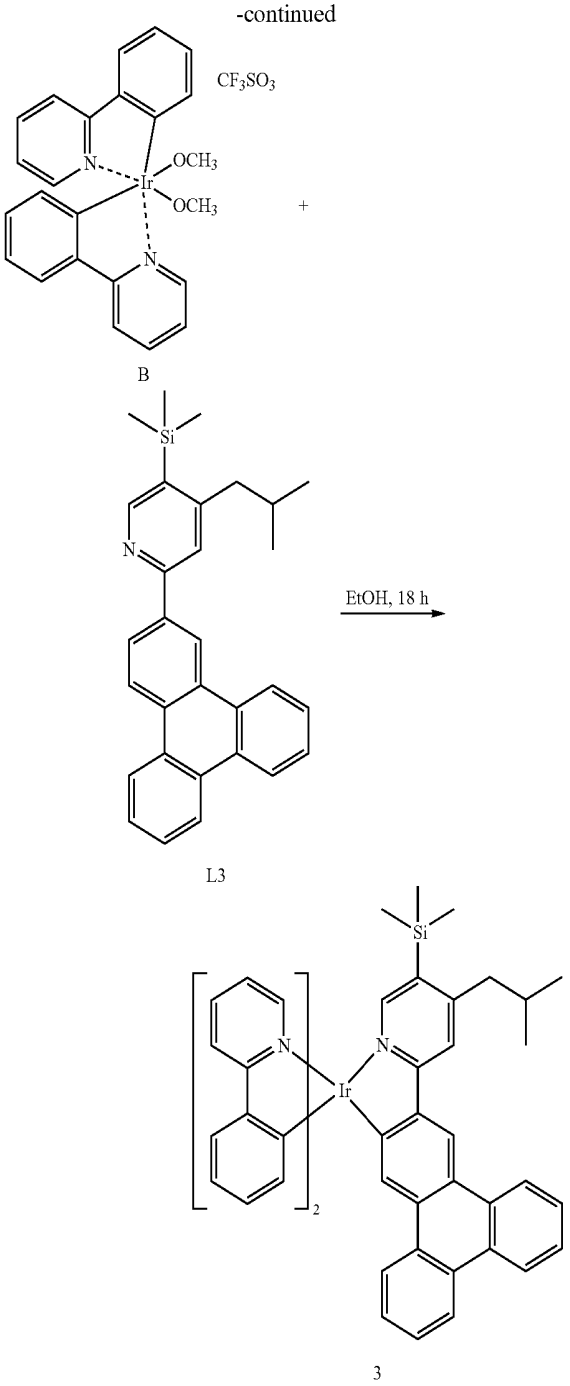


[0374] Synthesis of Compound L3

[0375] Compound L2 (4.52 g, 11.52 mmol) was mixed with 70 mL of THF, and the mixture was cooled to a temperature of −78° C. Lithium diisopropylamide (LDA, 14.4 mL, 28.8 mmol) was slowly added thereto. The resulting mixture was stirred at a temperature of −78° C. for 1 hour to perform a reaction, and then at room temperature for an additional 1.5 hours. Subsequently, the temperature was decreased to −78° C., and 2-bromopropane (2.70 mL, 28.8 mmol) was slowly added thereto. The temperature was increased to room temperature and a reaction was performed for 12 hours. The organic layer obtained therefrom was extracted using MC, and anhydrous magnesium sulfate was added thereto to remove moisture therefrom. A filtrate obtained by filtration was placed under reduced pressure to remove solvent.

[0376] The residual was subjected to column chromatography using EA and hexane at a ratio of 10:90 to obtain 4.3 g (86%) of Compound L3.

[0377] MALDI-TOFMS (m/z): $C_{30}H_{31}NSi$ (M^+) 434.

[0378] Synthesis of Compound 3

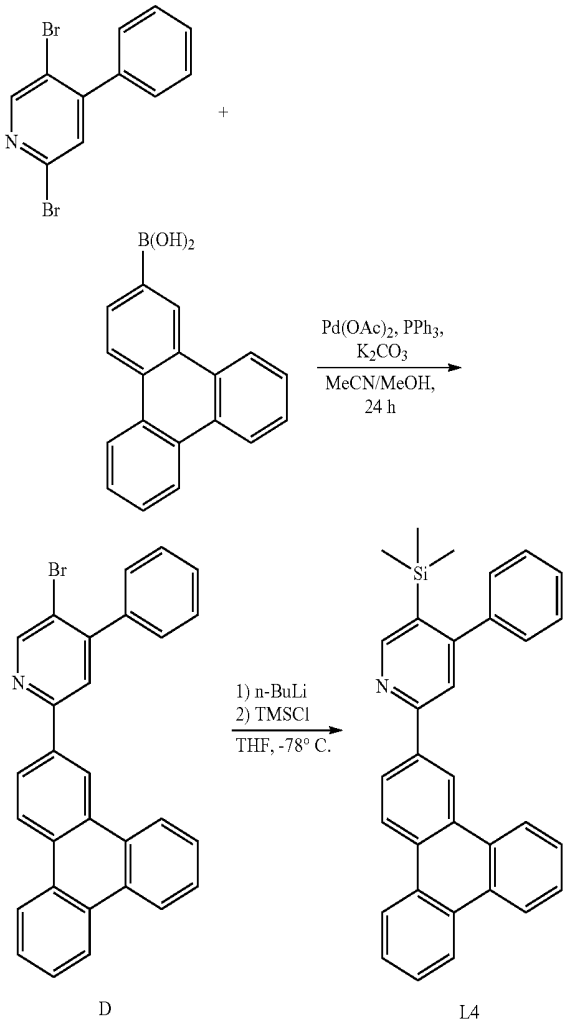
[0379] 1.8 g (32%) of Compound 3 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound L3 (3.35 g, 7.71 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0380] HRMS (MALDI-TOF) calcd for $C_{52}H_{46}IrN_3Si$: m/z 933.3090. Found: 933.3092.

Synthesis Example 4

Synthesis of Compound 4

[0381]



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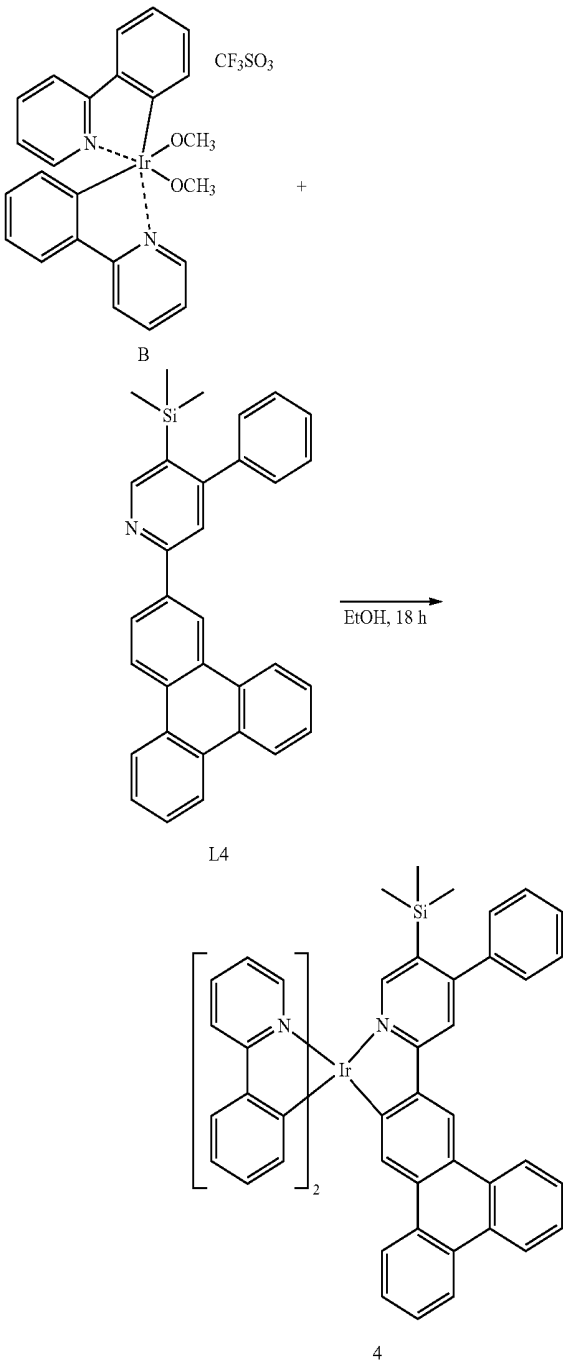


[0382] Synthesis of Compound D

[0383] 10.4 g (74%) of Compound D was prepared in the same manner as Compound L1 in Synthesis Example 1, except that 2,5-dibromo-4-phenylpyridine (9.518 g, 30.41 mmol) was used instead of 2-bromo-5-(trimethylsilyl)pyridine.

[0384] MALDI-TOFMS (m/z): $C_{29}H_{18}BrN$ (M^+) 459.

[0385] Synthesis of Compound L4

[0386] 6.7 g (84%) of Compound L4 was prepared in the same manner as Compound L2 in Synthesis Example 2, except that Compound D (8.106 g, 17.66 mmol) was used instead of Compound C.

[0387] MALDI-TOFMS (m/z): $C_{32}H_{27}NSi$ (M^+) 453.

[0388] Synthesis of Compound 4

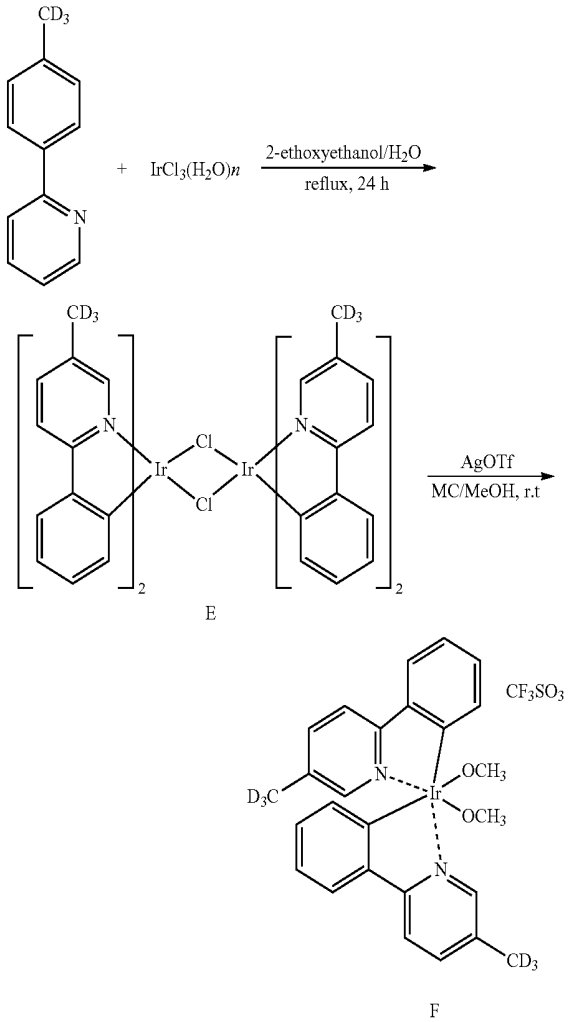
[0389] 1.1 g (22%) of Compound 4 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound L4 (2.912 g, 6.43 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0390] HRMS (MALDI-TOF) calcd for $C_{54}H_{42}IrN_3Si$: m/z 953.2777. Found: 953.2775.

Synthesis Example 5

Synthesis of Compound 97

[0391]



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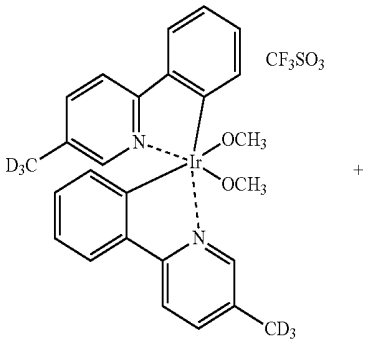
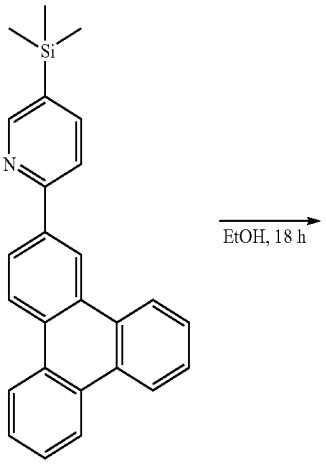
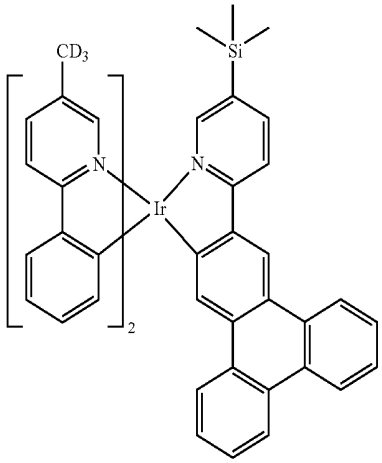


F



L1



97

[0392] Synthesis of Compound E

[0393] 2-(5-(methylD_3))phenylpyridine (8.74 g, 33.07 mmol) and iridium chloride (7.95 g, 22.5 mmol) were mixed with 120 mL of ethoxyethanol and 40 mL of distilled water. The mixture was stirred for 24 hours under reflux to perform a reaction. The temperature was then decreased to room temperature. A solid generated therefrom was separated by filtration, and thoroughly washed with water, methanol, and hexane sequentially in this stated order. The resultant solid was dried in a vacuum oven to obtain Compound E (11 g, 86%).

[0394] Synthesis of Compound F

[0395] Compound E (4.59 g, 4.02 mmol) was mixed with 210 mL of MC, and AgOTf (2.07 g, 8.04 mmol) dissolved in 70 mL of methanol was added thereto. Thereafter, while light was blocked by using an aluminum foil, a reaction was performed at room temperature for 18 hours. The generated solid was removed therefrom by celite filtration. A filtrate was placed under reduced pressure to obtain a solid (Compound F), which was used in the subsequent reaction without additional purification.

[0396] Synthesis of Compound 97

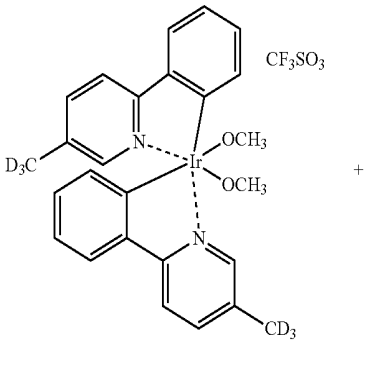
[0397] 1.7 g (34%) of Compound 97 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound F was used instead of Compound B. The obtained compound was confirmed by Mass and HPLC.

[0398] HRMS (MALDI-TOF) calcd for $C_{50}H_{36}D_6IrN_3Si$: m/z 911.3154. Found: 911.3154.

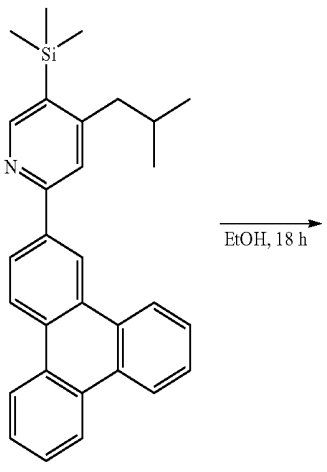
Synthesis Example 6

Synthesis of Compound 99

[0399]



F



L3

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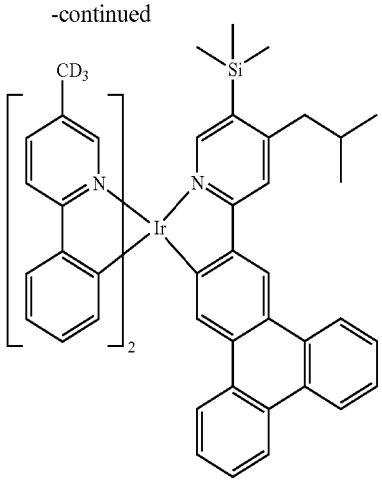


99

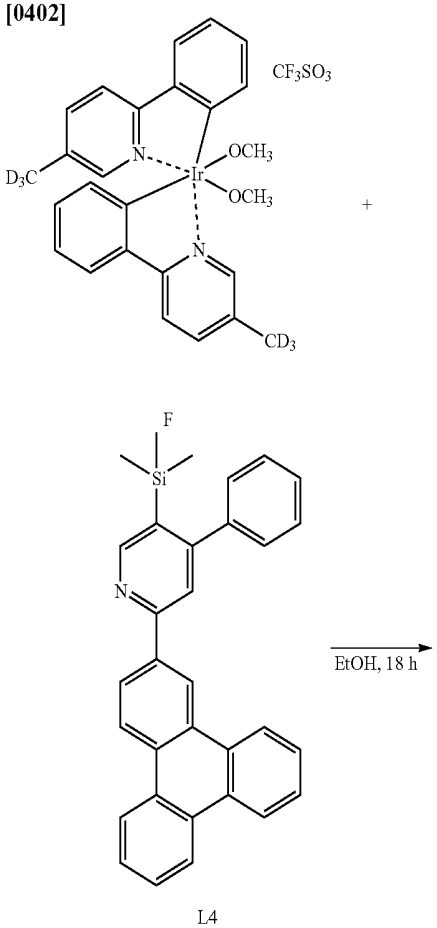
[0400] 1.4 g (28%) of Compound 99 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound F was used instead of Compound B and Compound L3 (2.767 g, 6.39 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0401] HRMS (MALDI-TOF) calcd for $C_{54}H_{44}D_6IrN_3Si$: m/z 967.3780. Found: 967.3781.

Synthesis Example 7

Synthesis of Compound 100

[0402]



L4

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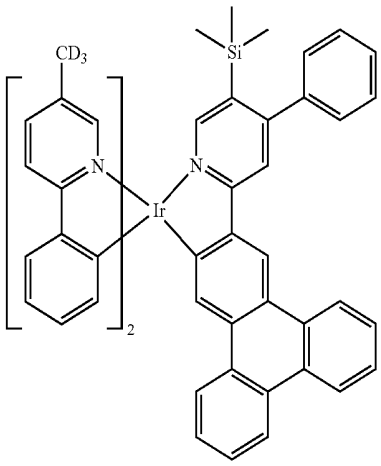


100

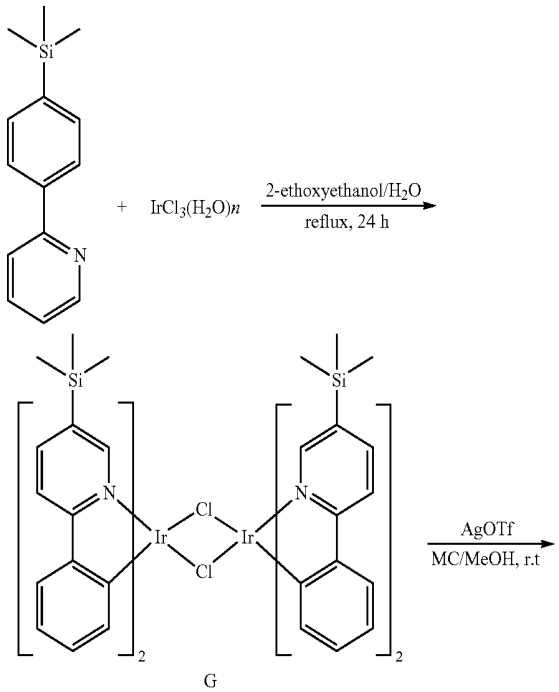
[0403] 1.07 g (21%) of Compound 100 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound F was used instead of Compound B and Compound L4 (2.755 g, 6.08 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0404] HRMS (MALDI-TOF) calcd for $C_{56}H_{40}D_6IrN_3Si$: m/z 987.3467. Found: 987.3469.

Synthesis Example 8

Synthesis of Compound 145

[0405]



G

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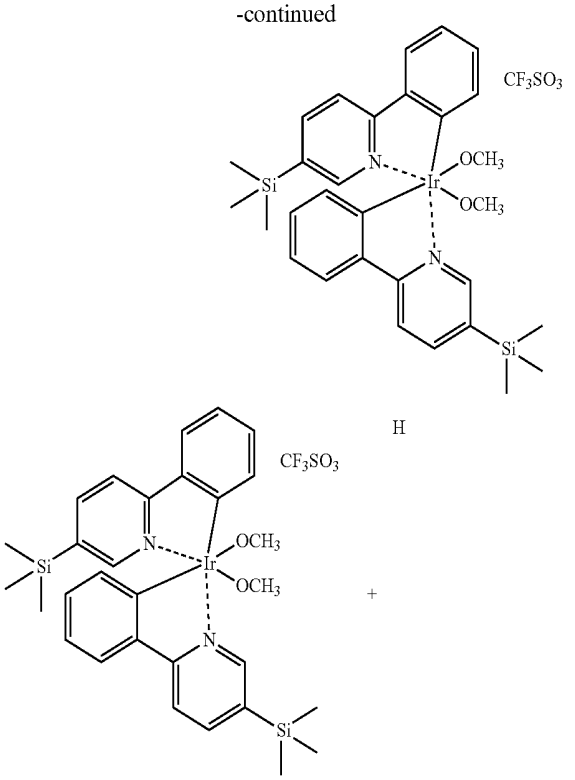
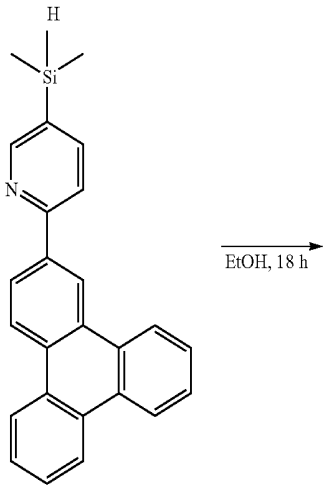
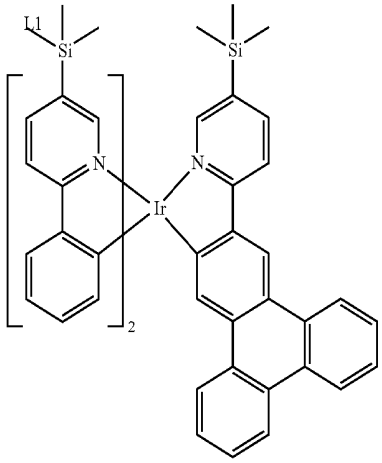


H





145

[0406] Synthesis of Compound G

[0407] 2-(4-(trimethylsilyl))phenylpyridine (7.05 g, 33.07 mmol) and iridium chloride (5.18 g, 14.7 mmol) were mixed with 75 mL of ethoxyethanol and 25 mL of distilled water. The mixture was stirred for 24 hours under reflux to perform a reaction. The temperature was then decreased to room temperature. A solid generated therefrom was separated by filtration, and thoroughly washed with water, methanol, and hexane sequentially in this stated order to obtain a solid, which was then dried in a vacuum oven to obtain Compound G (9.01 g, 90%).

[0408] Synthesis of Compound H

[0409] Compound D (2.78 g, 2.04 mmol) was mixed with 60 mL of MC, and AgOTf (1.05 g, 4.08 mmol) dissolved in 20 mL of methanol was added thereto. While light was blocked by using aluminum foil, a reaction was performed at room temperature for 18 hours. The generated solid was removed by filtration through celite and a filtrate was placed under reduced pressure to obtain a solid (Compound H), which was used in the subsequent reaction without additional purification.

[0410] Synthesis of Compound 145

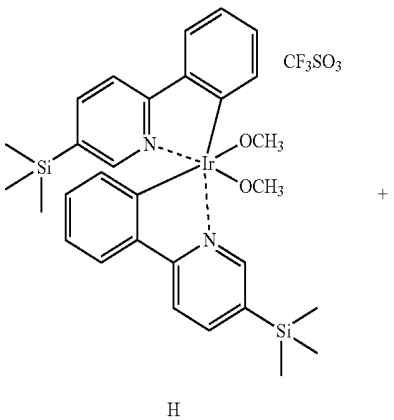
[0411] 1.4 g (27%) of Compound 145 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound H was used instead of Compound B. The obtained compound was confirmed by Mass and HPLC.

[0412] HRMS (MALDI-TOF) calcd for $C_{54}H_{44}D_6IrN_3Si$: m/z 1021.3255. Found: 1021.3253.

Synthesis Example 9

Synthesis of Compound 146

[0413]



H

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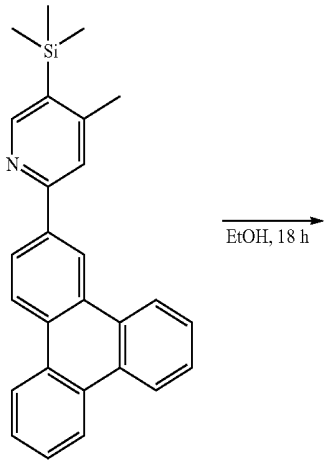
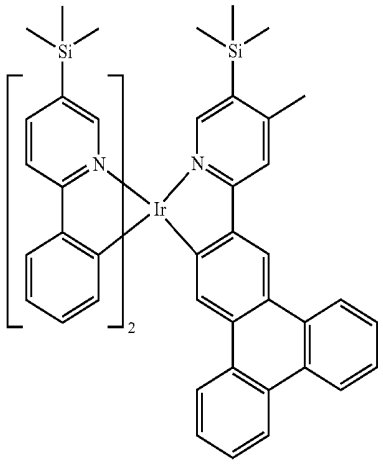


L2



146

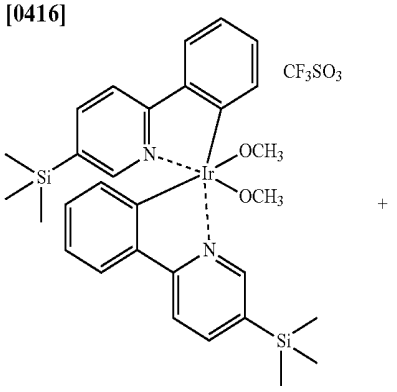
[0414] 1.9 g (32%) of Compound 146 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound H was used instead of Compound B and Compound L2 (2.727 g, 6.96 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0415] HRMS (MALDI-TOF) calcd for $C_{55}H_{56}D_6IrN_3Si$: m/z 1035.3411. Found: 1035.3410.

Synthesis Example 10

Synthesis of Compound 147

[0416]



H

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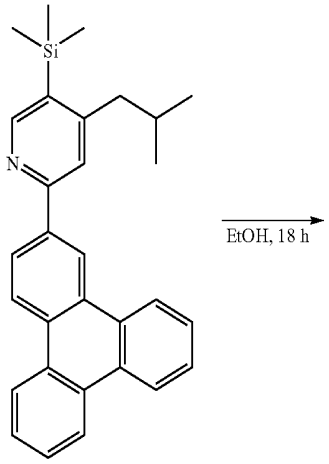
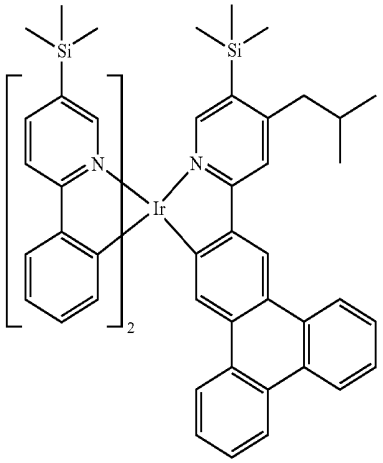


L3



147

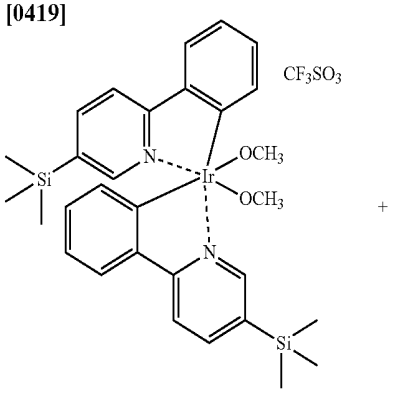
[0417] 1.8 g (30%) of Compound 147 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound H was used instead of Compound B and Compound L3 (2.901 g, 6.69 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0418] HRMS (MALDI-TOF) calcd for $C_{58}H_{62}D_6IrN_3Si$: m/z 1077.3881. Found: 1077.3881.

Synthesis Example 11

Synthesis of Compound 148

[0419]



H

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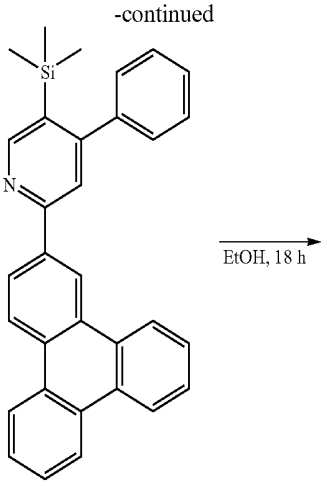
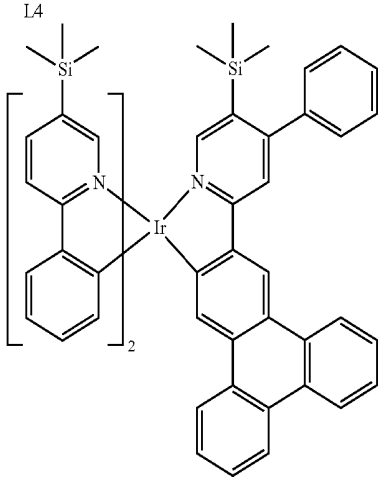


L4



148

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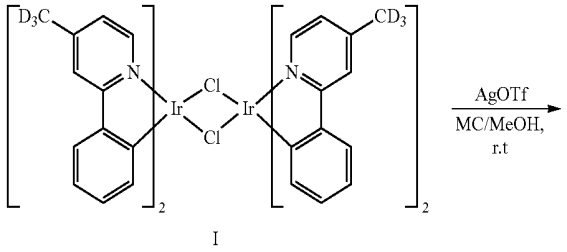
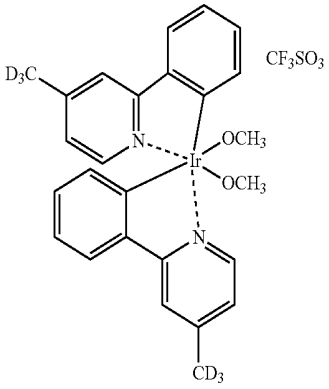
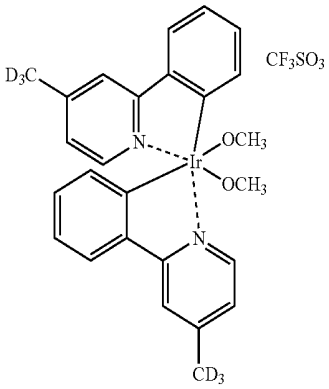


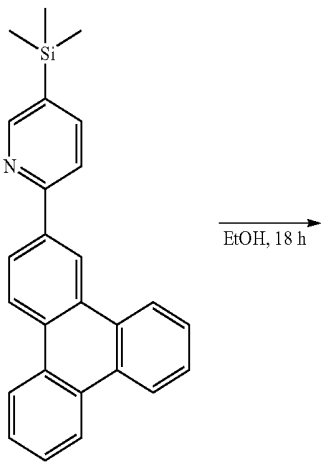
I



J



J



L1

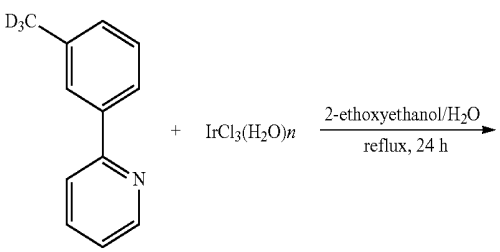
[0420] 1.7 g (28%) of Compound 148 was prepared in the same manner as Compound 1 in Synthesis Example 1, except that Compound H was used instead of Compound B and Compound L4 (2.973 g, 6.56 mmol) was used instead of Compound L1. The obtained compound was confirmed by Mass and HPLC.

[0421] HRMS (MALDI-TOF) calcd for $C_{60}H_{58}D_6IrN_3Si$: m/z 1097.3568. Found: 1097.3569.

Synthesis Example 12

Synthesis of Compound 217

[0422]



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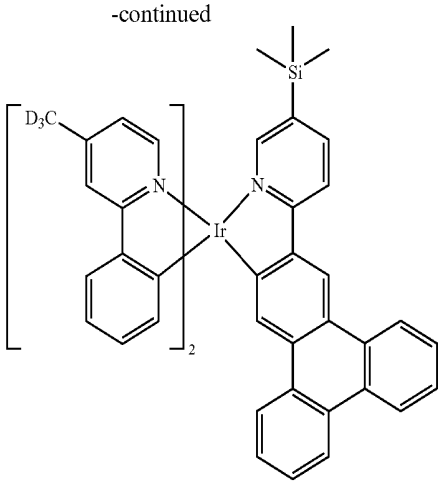


217

[0423] Synthesis of Compound I

[0424] Compound I (10.6 g, 83%) was prepared in the same manner as Compound E in Synthesis Example 5, except that 2-(4-(methylD_3))phenylpyridine (8.74 g, 33.07 mmol) was used instead of 2-(5-(methylD_3))phenylpyridine.

[0425] Synthesis of Compound J

[0426] Compound J was prepared in the same manner as Compound F in Synthesis Example 5, except that Compound I (8.74 g, 33.07 mmol) was used instead of Compound E.

[0427] Synthesis of Compound 217

[0428] 1.3 g (22%) of Compound 217 was prepared in the same manner as used to synthesize Compound 97 in Synthesis Example 5, except that Compound J was used instead of Compound F. The obtained compound was confirmed by Mass and HPLC.

[0429] HRMS (MALDI-TOF) calcd for $C_{50}H_{36}D_6IrN_3Si$: m/z 911.3154. Found: 911.3152.

Evaluation Example 1

Evaluation on HOMO, LUMO, and Triplet (T_1) Energy Levels

[0430] HOMO, LUMO and T_1 energy levels of Compounds 1, 2, 3, 4, 97, 99, 100, 145, 146, 147, 148, and 217 were evaluated according to the method indicated in Table 2, and results thereof are shown in Table 3.

TABLE 2

HOMO energy level evaluation method	A potential (V)-current (A) graph of each compound was obtained by using cyclic voltammetry (CV) (electrolyte: 0.1 molar (M) Bu_4NPF_6/solvent: CH_2Cl_2/electrode: 3-electrode system (working electrode: Pt disc (in a diameter of 1 millimeter (mm)), reference electrode: Pt wire, and auxiliary electrode: Pt wire)). From oxidation onset of the graph, a HOMO energy level of the compound was calculated.
LUMO energy level evaluation method	Each compound was diluted at a concentration of 1×10^{-5} M in $CHCl_3$, and an UV absorption spectrum thereof was measured at room temperature by using a Shimadzu UV-350 spectrometer. A LUMO energy level thereof was calculated by using an optical band gap (Eg) from an edge of the absorption spectrum and HOMO energy levels.
T1 energy level evaluation method	A mixture (each compound was dissolved in an amount of 1 milligram (mg) in 3 cubic centimeters (cc) of toluene) of toluene and each compound was loaded into a quartz cell. The resultant quartz cell was loaded into liquid nitrogen (77 Kelvins (K)) and a photoluminescence spectrum thereof was measured by using a device for measuring photoluminescence. The obtained spectrum was compared with a photoluminescence spectrum measured at room temperature, and peaks observed only at low temperature were analyzed to calculate T_1 energy levels.

TABLE 3

Compound No.	HOMO (eV) (found)	LUMO (eV) (found)	T_1 energy level (eV)
1	−5.054	−2.594	2.358
2	−5.029	−2.573	2.354
3	−5.025	−2.540	2.383
4	−5.038	−2.607	2.329
97	−5.002	−2.547	2.353
99	−4.975	−2.500	2.373
100	−4.984	−2.553	2.329
145	−5.012	−2.557	2.353
146	−4.992	−2.541	2.349
147	−4.986	−2.509	2.375
148	−5.003	−2.581	2.320
217	−4.984	−2.547	2.335

[0431] From Table 3, it was confirmed that Compounds 1, 2, 3, 4, 97, 99, 100, 145, 146, 147, 148, and 217 have electric characteristics suitable for use as a material for an organic light-emitting device.

Example 1

[0432] An ITO glass substrate was cut to a size of 50 mm×50 mm×0.5 mm sonicated in acetone isopropyl alcohol and pure water, each for 15 minutes, and then, washed by exposure to UV ozone for 30 minutes.

[0433] Subsequently, on the ITO electrode (anode) on the glass substrate, m-MTDATA was deposited at a deposition speed of 1 Angstroms per second (A /sec) to form a hole injection layer having a thickness of 600 Å, and α-NPD was deposited on the hole injection layer at a deposition speed of 1 Å/sec to form a hole transport layer having a thickness of 250 Å.

[0434] Compound 1 (dopant) and CBP (host) were co-deposited on the hole transport layer at a deposition speed of 0.1 Å/sec and a deposition speed of 1 A/sec, respectively, to form an emission layer having a thickness of 400 Å.

[0435] BAlq was deposited on the emission layer at a deposition speed of 1 Å/sec to form a hole blocking layer having a thickness of 50 Å. Alq_3 was deposited on the hole blocking layer to form an electron transport layer having a thickness of 300 Å. LiF was deposited on the electron transport layer to form an electron injection layer having a thickness of 10 Å. Al was vacuum deposited on the electron injection layer to form a second electrode (cathode) having a thickness of 1,200 Å, thereby completing the manufacture of an organic light-emitting device having a structure of ITO/m-MTDATA (600 Å)/α-NPD (250 Å)/CBP+10% (Compound 1) (400 Å)/Balq (50 Å)/Alq_3(300 Å)/LiF(10 Å)/Al(1200 Å).

Examples 2 to 4 and Comparative Examples 1 and 2

[0436] Organic light-emitting devices were manufactured in the same manner as in Example 1, except that in forming an emission layer, for use as a dopant, corresponding compounds shown in Table 4 were used instead of Compound 1.

Evaluation Example 2

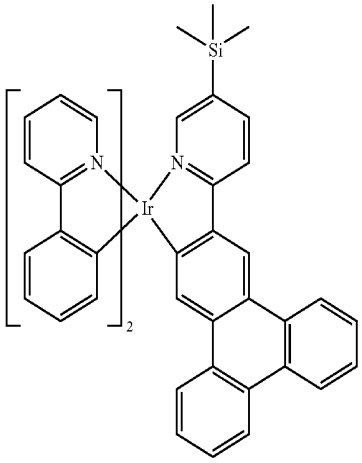
Evaluation on Characteristics of Organic Light-Emitting Devices

[0437] The driving voltage, current efficiency and lifespan of the organic light-emitting devices manufactured according to Examples 2 to 4 and Comparative Examples 1 and 2 were evaluated by using Keithley 2400 and luminance meter Minolta Cs-1000A. The driving voltage and current efficiency of the organic light-emitting devices of Examples 2 to 4 and Comparative Examples 1 and 2 were expressed in a relative value with respect to the driving voltage and current efficiency of the organic light-emitting device of Example 1 which were each expressed as "100". Their relative values are shown in Table 4. Regarding Table 4, a lifespan (T_{95}) indicates a time that lapses when luminance is decreased to 95% of the initial luminance under 6,000 nit, which is 100%, after driving. In Table 4, the lifespans (T_{95}) of Examples 2 to 4 and Comparative Examples 1 and 2 are expressed as relative values when the lifespan (T_{95}) of the organic light-emitting device of Example 1 is "100."

TABLE 4

	Dopant	Driving voltage (V) (relative value)	Efficiency (cd/A) (relative value)	Lifespan (hr) (T_{95}, at 6,000 nit) (relative value)
Example 1	1	100	100	100
Example 2	145	88	121	114
Example 3	147	87	129	113
Example 4	217	92	109	105
Comparative Example 1	$Ir(ppy)_3$	121	86	36
Comparative Example 2	Compound A	108	91	43

1



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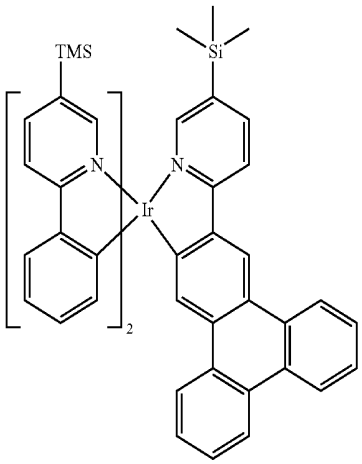

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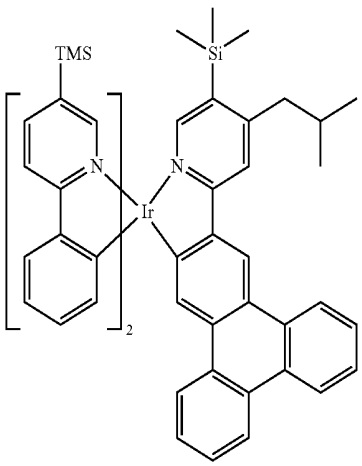
147



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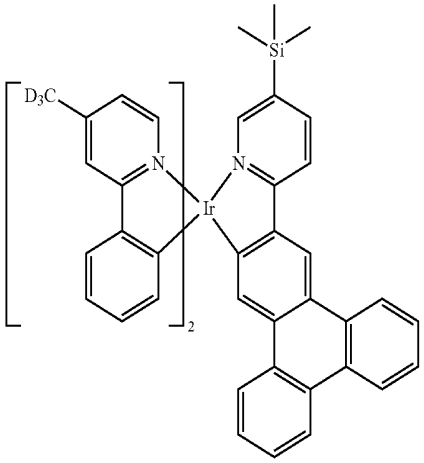
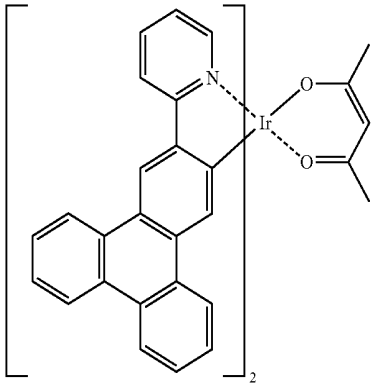


Compound A

(4)



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[0438] From Table 4, it was confirmed that the organic light-emitting devices of Examples 1 to 4 had lower driving voltage, higher efficiency, and longer lifespan than the organic light-emitting devices of Comparative Examples 1 and 2.

[0439] Organometallic compounds according to embodiments of the present disclosure have excellent electric characteristics and thermal stability. Accordingly, organic light-emitting device including such organometallic compounds may have excellent driving voltage, current efficiency, power, and lifetime characteristics.

[0440] It should be understood that exemplary embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each exemplary embodiment should typically be considered as available for other similar features or aspects in other exemplary embodiments.

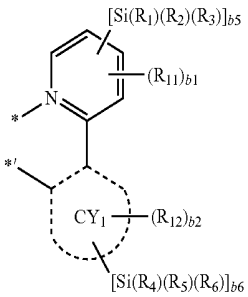
[0441] While one or more exemplary embodiments have been described with reference to the figures, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present inventive concept as defined by the following claims.

What is claimed is:

1. An organometallic compound represented by Formula 1:

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

Formula 2



wherein M in Formula 1 is selected from Ir, Pt, Os, Ti, Zr, Hf, Eu, Tb, Tm, and Rh,

L_1 in Formula 1 is selected from ligands represented by Formula 2,

n1 is 1, 2, or 3, provided that when n1 is 2 or greater, two or more groups L_1 are identical to or different from each other,

L_2 in Formula 1 is selected from a monovalent organic ligand, a divalent organic ligand, a trivalent organic ligand, and a tetravalent organic ligand,

n2 is 0, 1, 2, 3, or 4, provided that when n2 is 2 or greater, two or more groups L_2 are identical to or different from each other,

L_1 and L_2 in Formula 1 are different from each other,

CY_1 in Formula 2 is a C_1-C_{18} condensed cyclic ring i) in which two to four unsaturated 6-membered rings are condensed to each other and ii) which optionally has N as a ring forming atom,

R_1 to R_6, R_{11}, and R_{12} in Formula 2 are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, —SF_5, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_8)(Q_9)$,

b1, b2, b5, and b6 in Formula 2 are each independently an integer selected from 0 to 4, provided that the sum of b5 and b6 is 1 or greater,

each of * and *' in Formula 2 indicates a binding site to M in Formula 1, and

at least one of substituents of the substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{14})(Q_{15})$, —$B(Q_{16})(Q_{17})$, and —$P(=O)(Q_{18})(Q_{19})$;

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, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{24})(Q_{25})$, —$B(Q_{26})(Q_{27})$, and —$P(=O)(Q_{28})(Q_{29})$; and

—$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{34})(Q_{35})$, —$B(Q_{36})(Q_{37})$, and —$P(=O)(Q_{38})(Q_{39})$, wherein Q_1 to Q_9, Q_{11} to Q_{19}, Q_{21} to Q_{29}, and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

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

in Formula 1, M is Ir and the sum of n1 and n2 is 3; or M is Pt and the sum of n1 and n2 is 2.

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

CY_1 in Formula 2 is selected from a naphthalene, a phenanthrene, an anthracene, a triphenylene, a pyrene, a chrysene, a naphthacene, a tetraphene, a tetracene, a quinoline, an isoquinoline, a benzoquinoline, a phthalazine, a naphthyridine, a quinoxaline, a quinazoline, a cinnoline, a phenanthridine, an acridine, a phenanthroline, and a phenazine.

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

R_{11} and R_{12} in Formula 2 are each independently selected from

hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF_5, C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2,

—CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl 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;

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 benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl 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 benzoimidazolyl 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

—$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

wherein Q_6 to Q_9 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

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

R_{11} and R_{12} in Formula 2 are each independently selected from

hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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;

a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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, each substituted with at least one selected from deuterium, —F, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} 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 pyridinyl group, and a pyrimidinyl group; and

—$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

wherein Q_6 to Q_9 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

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

R_1 to R_6 in Formula 2 are each independently selected from

a C_1-C_{10} alkyl group, a phenyl group, and —$Si(Q_1)(Q_2)(Q_3)$; and

a C_1-C_{10} alkyl group and a phenyl group, each substituted with at least one selected from a deuterium and a C_1-C_{10} alkyl group,

wherein Q_1 to Q_3 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group.

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

R_{11} and R_{12} in Formula 2 are each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38, and

R_1 to R_6 in Formula 2 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, a phenyl group, and —$Si(Q_1)(Q_2)(Q_3)$; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group a tert-pentyl group, and a phenyl group, each substituted with at least one selected from deuterium and a C_1-C_{10} alkyl group,

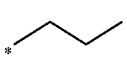
wherein Q_1 to Q_3 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group:

Formula 9-1

Formula 9-2

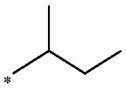


Formula 9-3

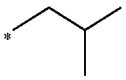
Formula 9-4

-continued

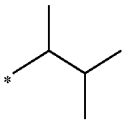
Formula 9-5



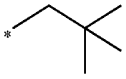
Formula 9-6



Formula 9-7



Formula 9-8



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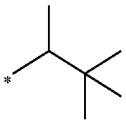

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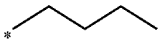
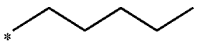


Formula 9-11



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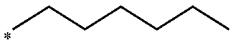
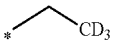
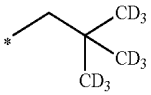


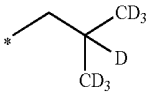
Formula 9-13



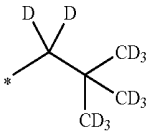
Formula 9-14



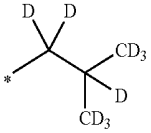
Formula 9-15



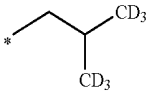
Formula 9-16



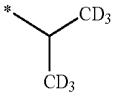
Formula 9-17



Formula 9-18



Formula 9-19



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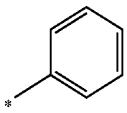
Formula 10-1



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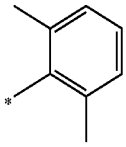

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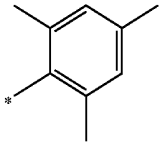

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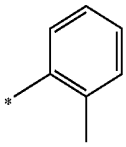

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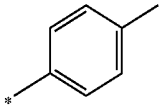

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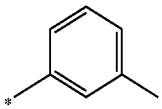

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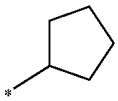

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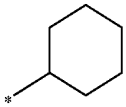

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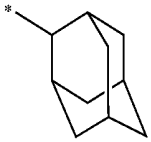

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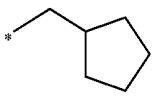

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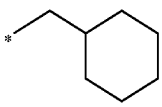

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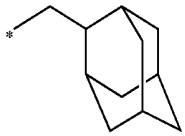

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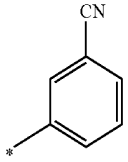

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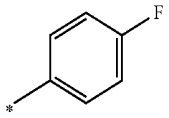

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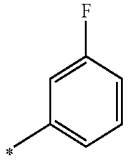

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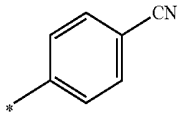

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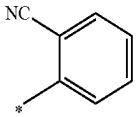

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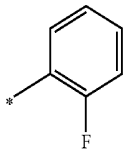

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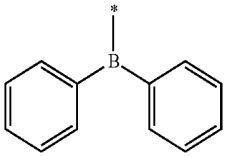

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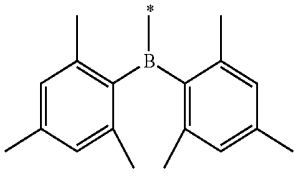

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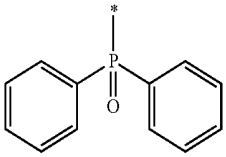

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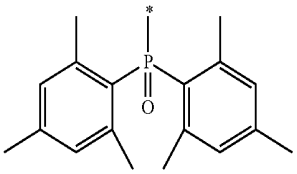

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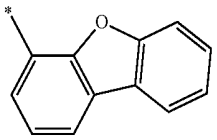

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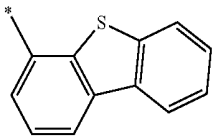

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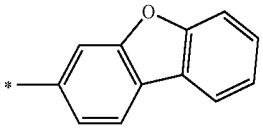

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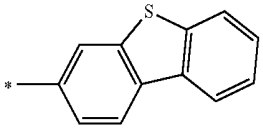

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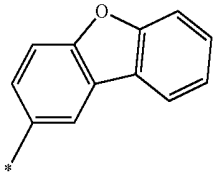

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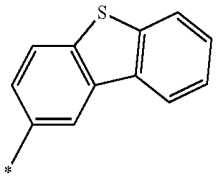

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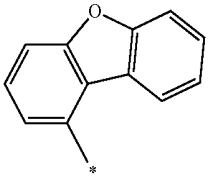

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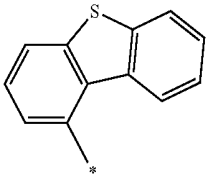

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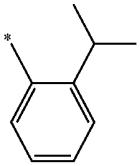

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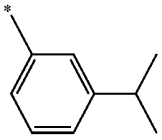

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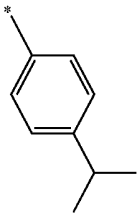

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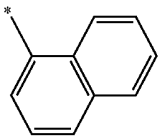

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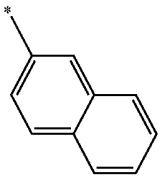

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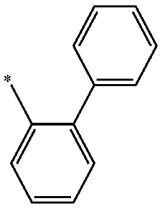

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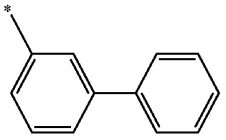
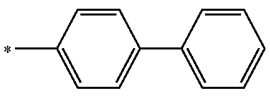


Formula 10-38



wherein * in Formulae 9-1 to 9-19 and 10-1 to 10-38 indicates a binding site to a neighboring atom.

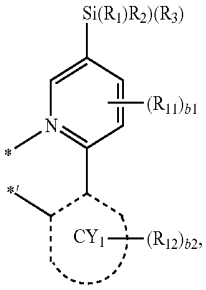
8. The organometallic compound of claim **1**, wherein

b5 is 1, 2, or 3.

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

L_1 in Formula 1 is selected from ligands represented by Formula 2(1):

Formula 2(1)

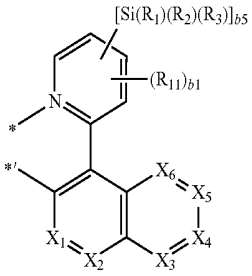


wherein CY_1, R_1 to R_3, R_{11}, R_{12}, b1, and b2 in Formula 2(1) are the same as in claim **1**, and each of* and *' indicates a binding site to M in Formula 1.

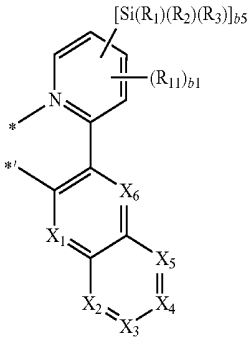
10. The organometallic compound of claim **1**, wherein

L_1 in Formula 1 is selected from ligands represented by Formulae 2-1 to 2-47:

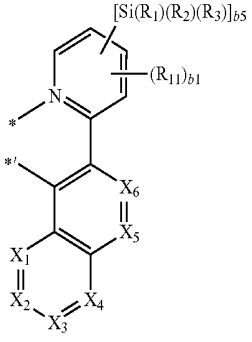
Formula 2-1



Formula 2-2



Formula 2-3



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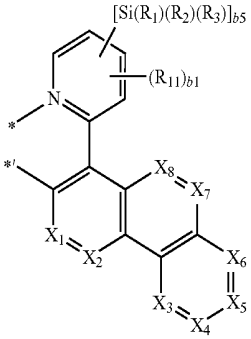
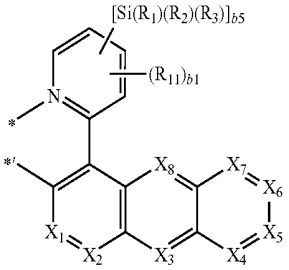
Formula 2-4



Formula 2-5



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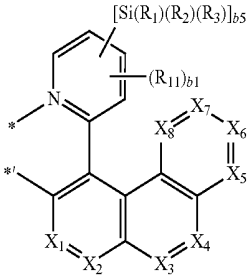

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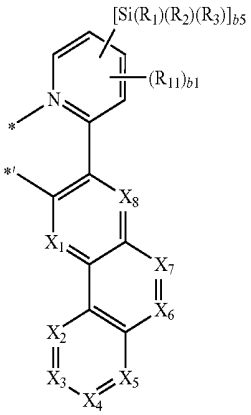

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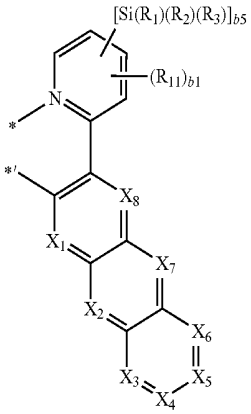
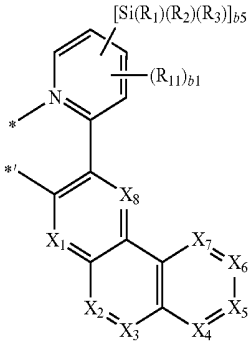


Formula 2-9



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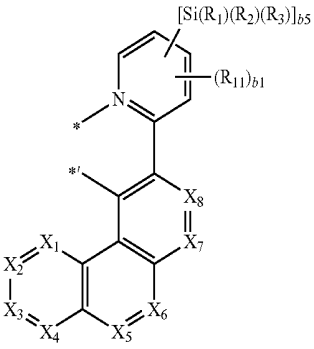

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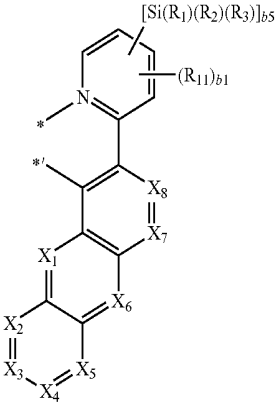

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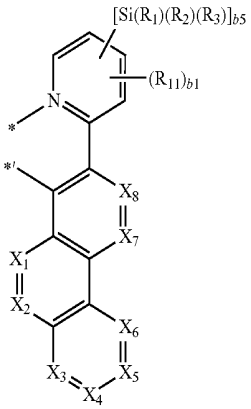
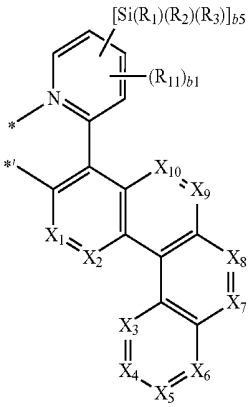
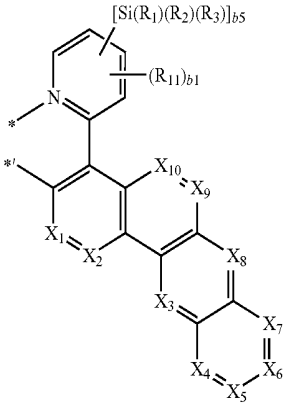
Formula 2-12



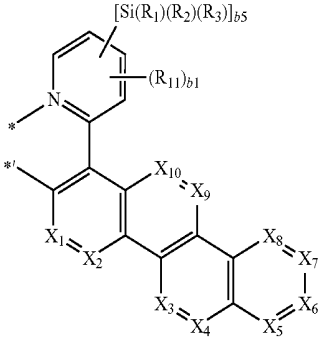
Formula 2-13



Formula 2-14



Formula 2-15



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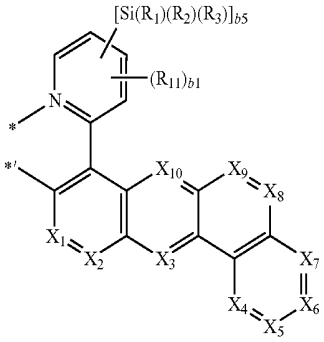

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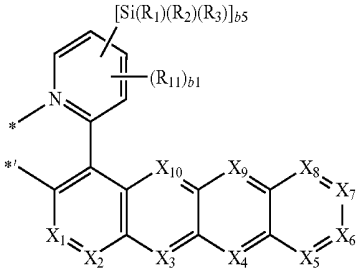

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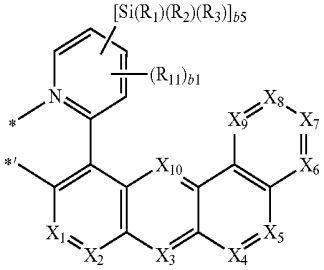
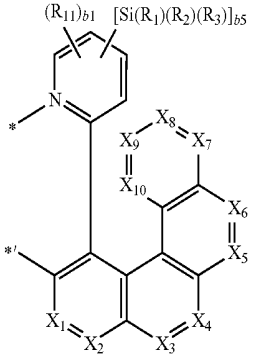
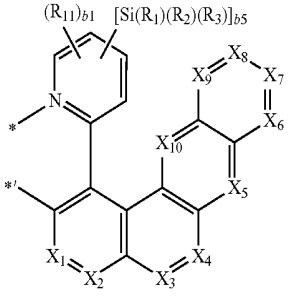


Formula 2-19



Formula 2-20



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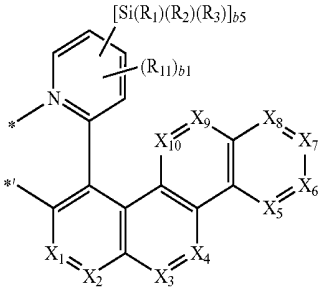
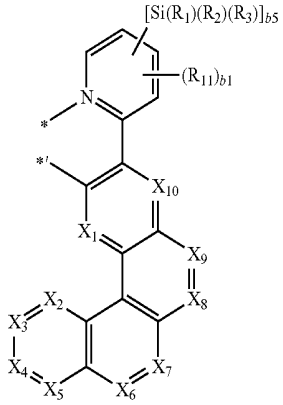
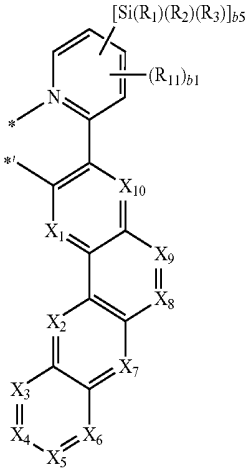
Formula 2-21



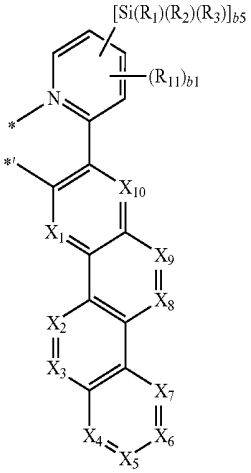
Formula 2-22



Formula 2-23



Formula 2-24



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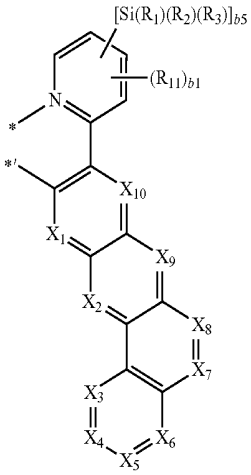
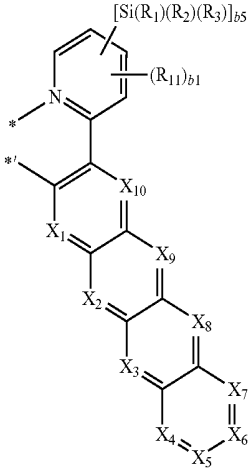
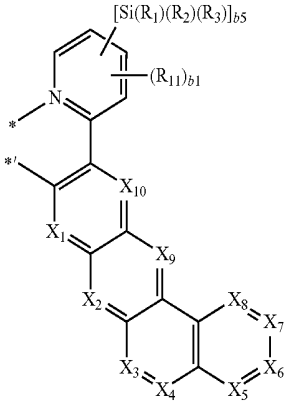


Formula 2-26



Formula 2-27



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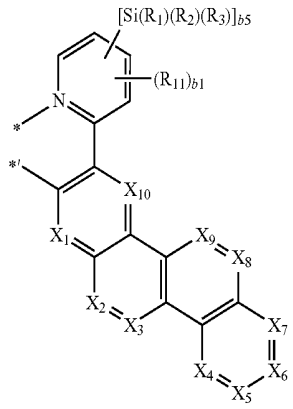
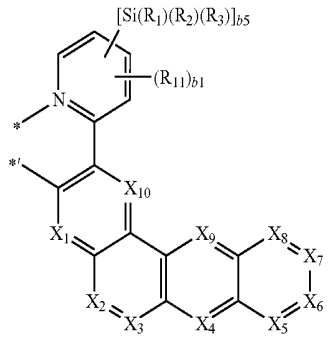
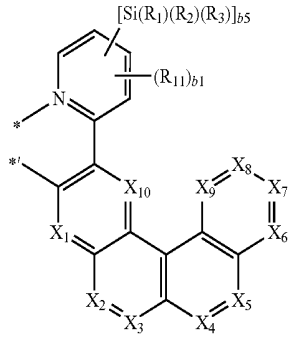
Formula 2-28



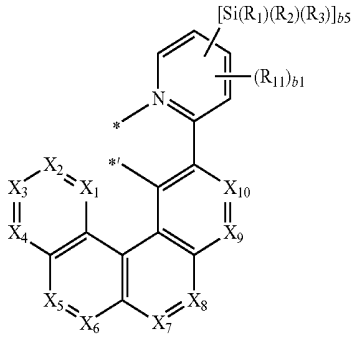
Formula 2-29



Formula 2-30



Formula 2-31



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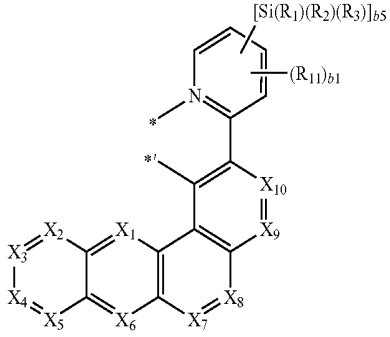
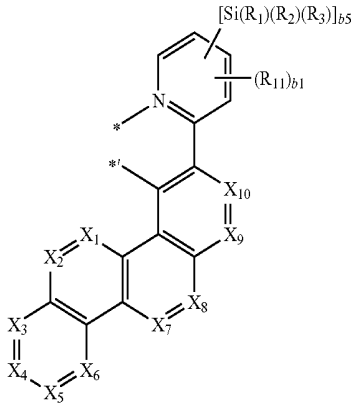
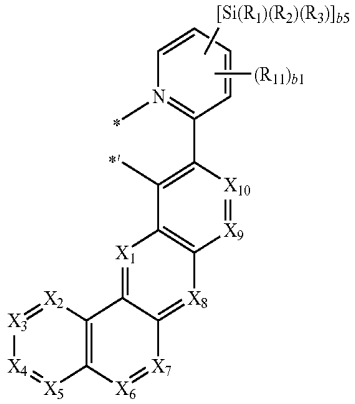


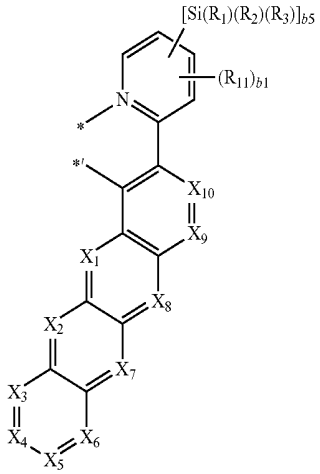
Formula 2-33



Formula 2-34



Formula 2-35



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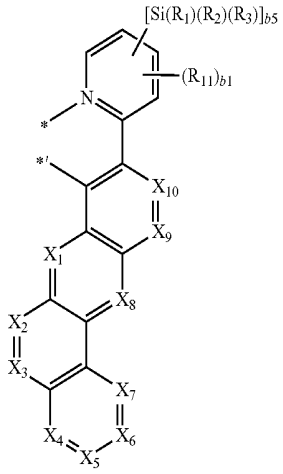
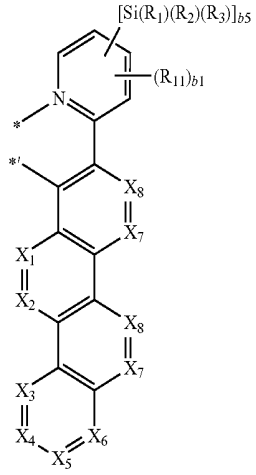
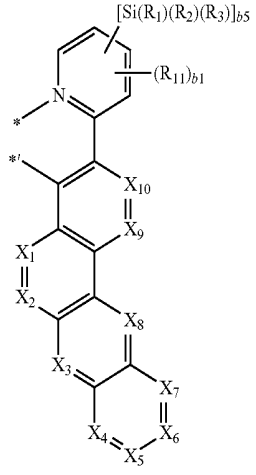
Formula 2-36



Formula 2-37



Formula 2-38



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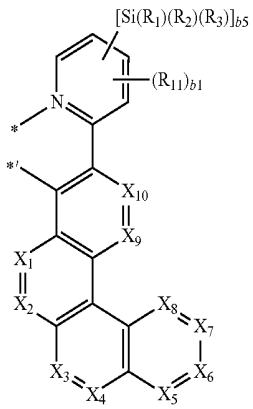
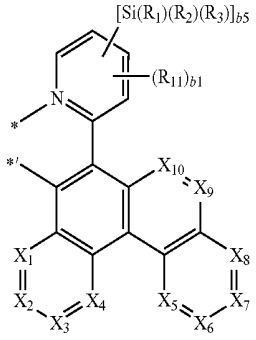
Formula 2-39



Formula 2-40



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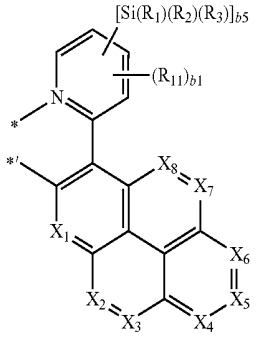
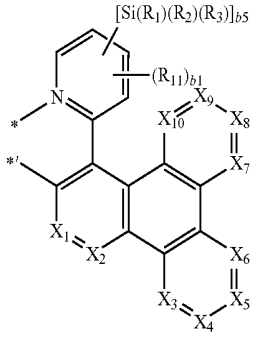


Formula 2-42



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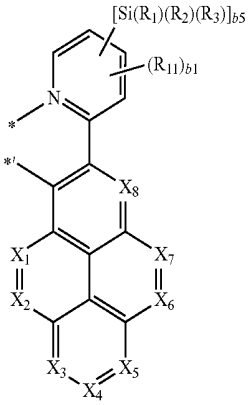
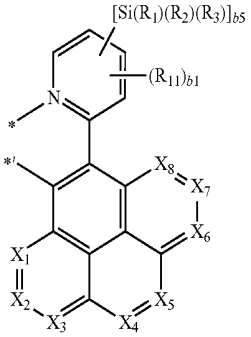
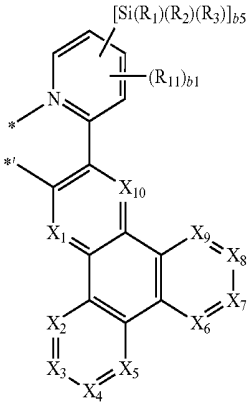
Formula 2-43



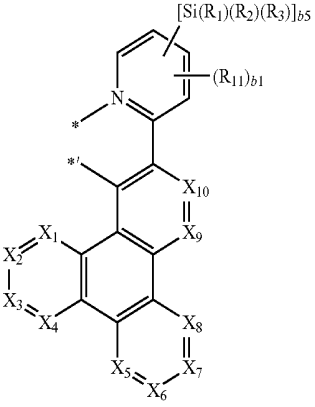
Formula 2-44



Formula 2-45



Formula 2-46



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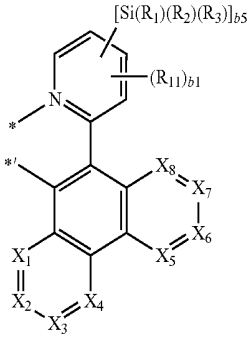
Formula 2-47



wherein, in Formulae 2-1 to 2-47,

R_1 to R_3, R_{11}, and b1 are the same as in claim **1**,

b5 is 1, 2, or 3,

X_1 is N or $C(R_{21})$, X_2 is N or $C(R_{22})$, X_3 is N or $C(R_{23})$, X_4 is N or $C(R_{24})$, X_5 is N or $C(R_{25})$, X_6 is N or $C(R_{26})$, X_7 is N or $C(R_{27})$, X_8 is N or $C(R_{28})$, X_9 is N or $C(R_{29})$, X_{10} is N or $C(R_{30})$,

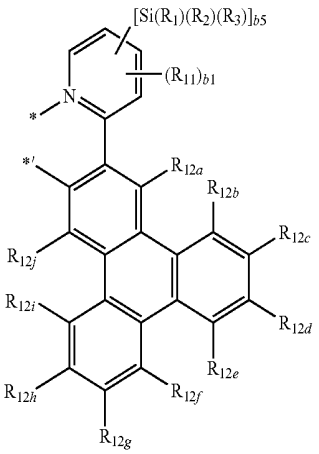
R_{21} to R_{30} are the same as in claim **1** in connection with R_{12}, and

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

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

L_1 in Formula 1 is selected from ligands represented by Formula 2BA:

Formula 2BA



wherein, in Formula 2BA,

R_1 to R_3, R_{11}, and b1 are the same as in claim **1**,

b5 is an integer selected from 1 to 4,

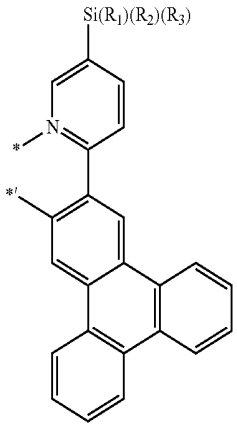
R_{12a} to R_{12j} are the same as in claim **1** in connection with R_{12}, and

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

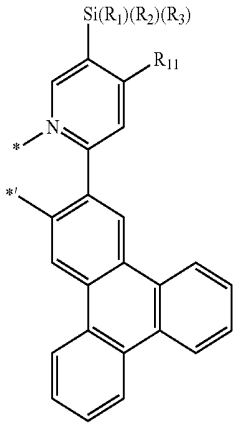
12. The organometallic compound of claim **1**, wherein

L_1 in Formula 1 is selected from ligands represented by Formulae 2BA-1 to 2BA-5:

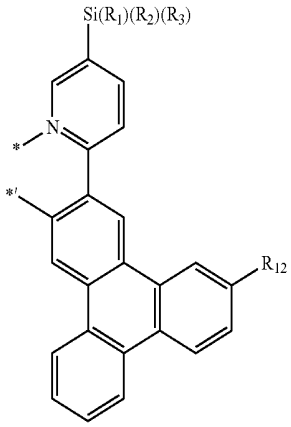
Formula 2BA-1



Formula 2BA-2



Formula 2BA-3



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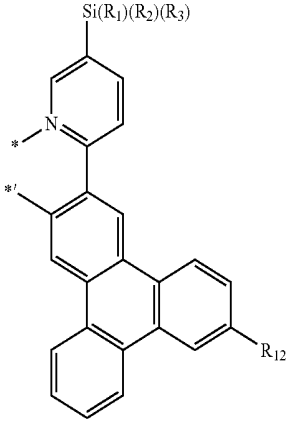
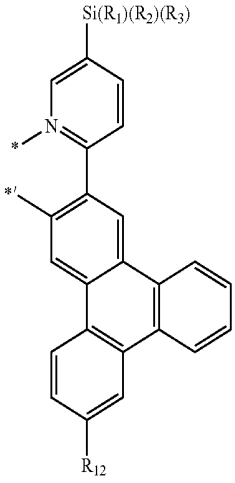
Formula 2BA-4



Formula 2BA-5



wherein, in Formulae 2BA-1 to 2BA-5,

R_{11} and R_{12} are each independently selected from

deuterium, —F, a cyano group, a nitro group, —SF_5, a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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;

a methyl group, an ethyl group, an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, an n-hexyl group, an isohexyl group, a sec-hexyl group, a tert-hexyl group, an n-heptyl group, an isoheptyl group, a sec-heptyl group, a tert-heptyl group, an n-octyl group, an isooctyl group, a sec-octyl group, a tert-octyl group, an n-nonyl group, an isononyl group, a sec-nonyl

group, a tert-nonyl group, an n-decyl group, an isodecyl group, a sec-decyl group, a tert-decyl group, a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy 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, each substituted with at least one selected from deuterium, —F, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a cyano group, a nitro group, a C_1-C_{10} alkyl group, a C_1-C_{10} 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 pyridinyl group, and a pyrimidinyl group and

—$B(Q_6)(Q_7)$ and —$P(=O)(Q_8)(Q_9)$,

wherein Q_6 to Q_9 are each independently selected from

—CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group,

R_1 to R_3 are each independently selected from

—CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

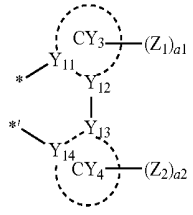
an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, and a phenyl group, and

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

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

L_2 in Formula 1 is selected from ligands represented by Formulae 3A to 3G:

Formula 3A



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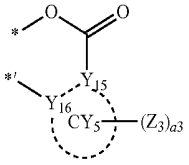
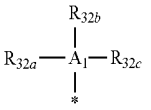
Formula 3B

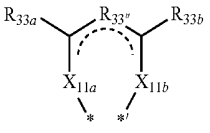


Formula 3C

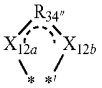
Formula 3D



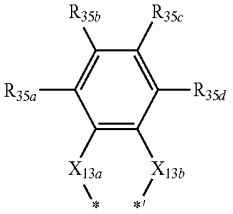
Formula 3E



Formula 3F



Formula 3G



wherein, in Formulae 3A to 3G,

Y_{11} to Y_{16} are each independently C or N, Y_{11} and Y_{12} are connected to each other via a single bond or a double bond, Y_{13} and Y_{14} are connected to each other via a single bond or a double bond, Y_{15} and Y_{16} are connected to each other via a single bond or a double bond,

CY_3 to CY_5 are each independently selected from a C_5-C_{60} carbocyclic group and a C_2-C_{60} heterocyclic group,

a1 to a3 are each independently an integer selected from 1 to 5, A_1 is P or As,

X_{11a}, X_{11b}, X_{12a}, X_{12b}, X_{13a}, and X_{13b} are each independently selected from N, O, $N(R_{34})$, $P(R_{35})(R_{36})$, and $As(R_{37})(R_{38})$ (provided that X_{12a}, X_{12b}, X_{13a}, and X_{13b} are neither N nor O),

$R_{33''}$ and $R_{34''}$ are each independently selected from a single bond, a double bond, a substituted or unsubstituted C_1-C_5 alkylene group, a substituted or unsubstituted C_2-C_5 alkenylene group, and a substituted or unsubstituted C_6-C_{10} arylene group,

Z_1 to Z_3, R_{31}, R_{32a}, R_{32b}, R_{32c}, R_{33a}, R_{33b}, R_{34} to R_{38}, R_{35a}, R_{35b}, R_{35c}, and R_{35d} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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} cycloalk-

enyl 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, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_8)(Q_9)$,

each of * and *' indicates a binding site to M in Formula 1, and

at least one of substituents of the substituted C_1-C_5 alkylene group, substituted C_2-C_5 alkenylene group, substituted C_6-C_{10} arylene group, substituted C_1-C_{60} alkyl group, substituted C_2-C_{60} alkenyl group, substituted C_2-C_{60} alkynyl group, substituted C_1-C_{60} alkoxy group, substituted C_3-C_{10} cycloalkyl group, substituted C_1-C_{10} heterocycloalkyl group, substituted C_3-C_{10} cycloalkenyl group, substituted C_1-C_{10} heterocycloalkenyl group, substituted C_6-C_{60} aryl group, substituted C_6-C_{60} aryloxy group, substituted C_6-C_{60} arylthio group, substituted C_1-C_{60} heteroaryl group, substituted monovalent non-aromatic condensed polycyclic group, and substituted monovalent non-aromatic condensed heteropolycyclic group is 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group;

a C_1-C_{60} alkyl group, a C_2-C_{60} alkenyl group, a C_2-C_{60} alkynyl group, and a C_1-C_{60} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, —$Si(Q_{11})(Q_{12})(Q_{13})$, —$N(Q_{14})(Q_{15})$, —$B(Q_{16})(Q_{17})$, and —$P(=O)(Q_{15})(Q_{19})$;

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, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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_{69} heteroaryl group, a monovalent non-aromatic condensed polycyclic group, a monovalent non-aromatic condensed heteropolycyclic group, —$Si(Q_{21})(Q_{22})(Q_{23})$, —$N(Q_{24})(Q_{25})$, —$B(Q_{26})(Q_{27})$, and —$P(=O)(Q_{28})(Q_{29})$; and

—$Si(Q_{31})(Q_{32})(Q_{33})$, —$N(Q_{34})(Q_{35})$, —$B(Q_{36})(Q_{37})$, and —$P(=O)(Q_{38})(Q_{39})$,

wherein Q_1 to Q_9, Q_{11} to Q_{19}, Q_{21} to Q_{29}, and Q_{31} to Q_{39} are each independently selected from hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, 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, and a substituted or unsubstituted monovalent non-aromatic condensed heteropolycyclic group.

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

L_2 is selected from ligands represented by Formulae 3A, 3B, and 3F,

Y_{11} in Formula 3A is N,

Y_{12} to Y_{14} in Formula 3A is C,

CY_3 in Formula 3A is selected from a pyridine, a 5,6,7,8-tetrahydroquinoline, a 5,6,7,8-tetrahydroisoquinoline, a quinoline, and an isoquinoline,

CY_4 in Formula 3A is selected from a benzene, 1,2,3,4-tetrahydronaphthalene, a naphthalene, a fluorene, a dibenzofuran, a dibenzothiophene, a benzofuropyridine, and a benzothienopyridine,

Y_{15} in Formula 3B is C,

Y_{16} in Formula 3B is N,

CY_5 in Formula 3B is a pyridine or a pyrimidine,

Z_1 to Z_3 in Formulae 3A and 3B are each independently selected from a hydrogen, deuterium, —F, —Cl, —Br, —I, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, —SF_5, C_1-C_{20} alkyl group, and a C_1-C_{20} alkoxy group;

a C_1-C_{20} alkyl group and a C_1-C_{20} alkoxy group, each substituted with at least one selected from deuterium, —F, —Cl, —Br, —I, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, a hydroxyl group, a cyano group, a nitro group, an amino group, an amidino group,

a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{10} alkyl 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;

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 benzoimidazolyl group, a benzofuranyl group, a benzothiophenyl group, an isobenzothiazolyl group, a benzoxazolyl group, an isobenzoxazolyl group, a triazolyl group, a tetrazolyl group, an oxadiazolyl group, a triazinyl group, a dibenzofuranyl group, a dibenzothiophenyl group, a benzocarbazolyl group, a dibenzocarbazolyl group, an imidazopyridinyl group, and an imidazopyrimidinyl group;

a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a cyclooctyl group, an adamantanyl group, a norbornanyl group, a norbornenyl group, a cyclopentenyl group, a cyclohexenyl group, a cycloheptenyl group, a phenyl group, a naphthyl group, a fluorenyl group, a phenanthrenyl group, an anthracenyl group, a fluoranthenyl group, a triphenylenyl group, a pyrenyl group, a chrysenyl group, a pyrrolyl group, a thiophenyl group, a furanyl group, an imidazolyl group, a pyrazolyl group, a thiazolyl group, an isothiazolyl group, an oxazolyl group, an isoxazolyl group, a pyridinyl group, a pyrazinyl group, a pyrimidinyl group, a pyridazinyl group, an isoindolyl group, an indolyl group, an indazolyl group, a purinyl group, a quinolinyl group, an isoquinolinyl group, a benzoquinolinyl group, a quinoxalinyl group, a quinazolinyl group, a cinnolinyl group, a carbazolyl group, a phenanthrolinyl group, a benzoimidazolyl 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 amino group, an amidino group, a hydrazine group, a hydrazone group, a carboxylic acid or a salt thereof, a sulfonic acid or a salt thereof, a phosphoric acid or a salt thereof, a C_1-C_{20} alkyl 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 benzoimidazolyl 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

—$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, and —$P(=O)(Q_8)(Q_9)$,

wherein a1 to a3 are each independently an integer selected from 0 to 4,

from among groups Z_1 in the number of a1, groups Z_2 in the number of a2, and groups Z_3 in the number of a3, two or more neighboring substituents are optionally bonded to form a C_5-C_{30} carbocyclic group or a C_2-C_{30} heterocyclic group,

Q_1 to Q_9 are each independently selected from

—CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from a deuterium and a C_1-C_{10} alkyl group,

X_{12a} and X_{12b} in Formula 3F is 0, and

$R_{34''}$ in Formula 3F is selected from

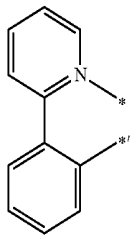
a C_2-C_5 alkenylene group; and

a C_2-C_5 alkenylene group, substituted with at least one selected from deuterium, a C_1-C_{10} alkyl group, a C_1-C_{10} alkoxy group, and a phenyl group.

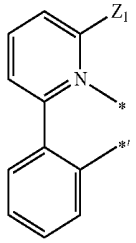
15. The organometallic compound of claim **1**, wherein

L_2 in Formula 1 is selected from ligands represented by Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3- 1(98), 3-111 and 3-112:

Formula 3-1(1)



Formula 3-1(2)



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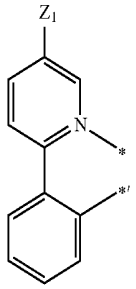

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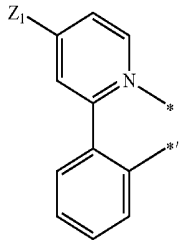

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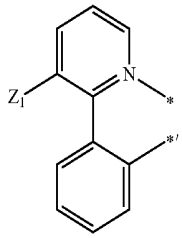

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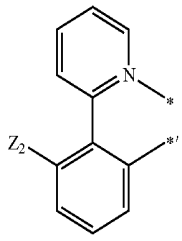

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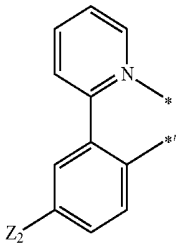
Formula 3-1(7)



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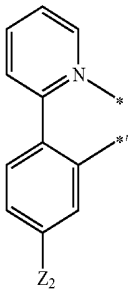

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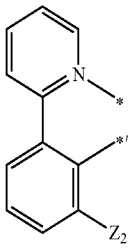

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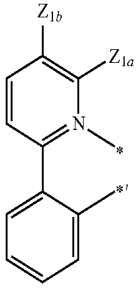

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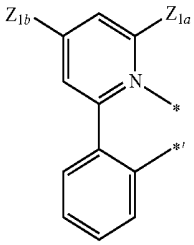

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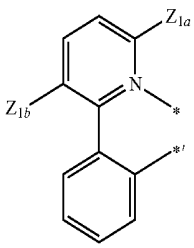

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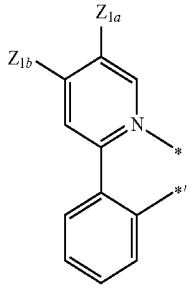
Formula 3-1(13)



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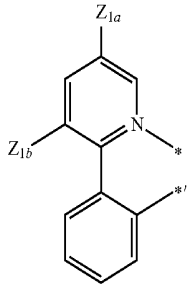

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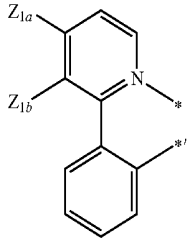

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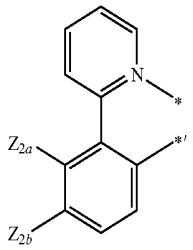

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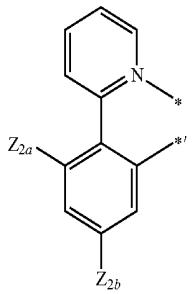

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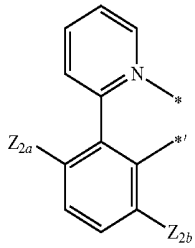

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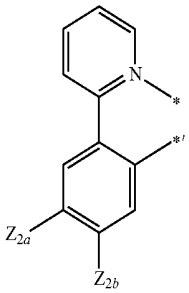

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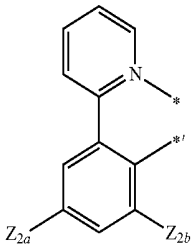
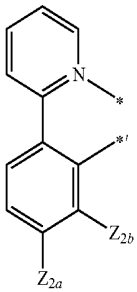


Formula 3-1(21)



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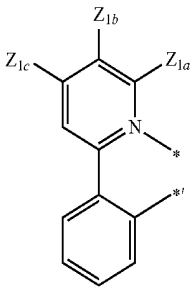

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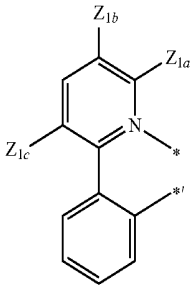

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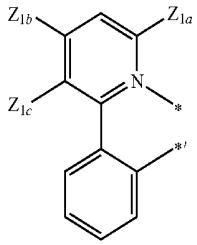

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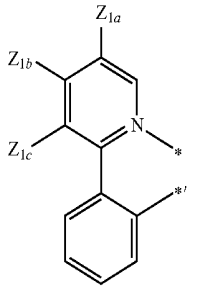

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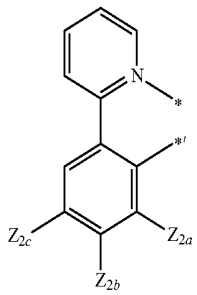

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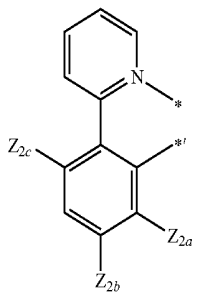

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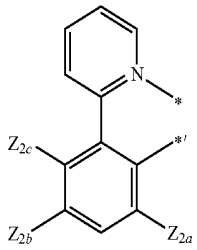

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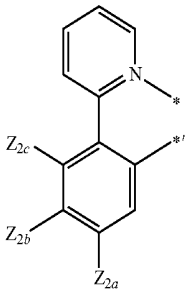

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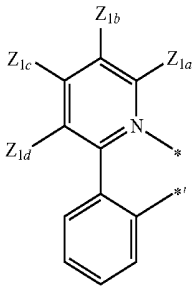

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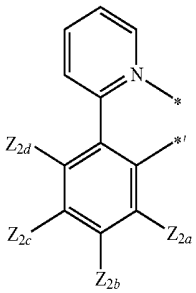

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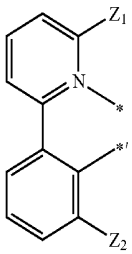

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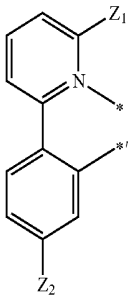

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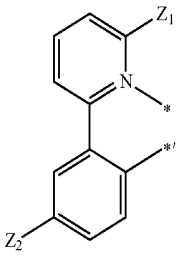

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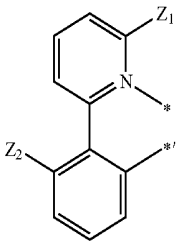

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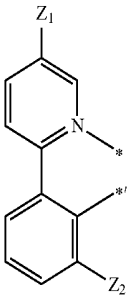

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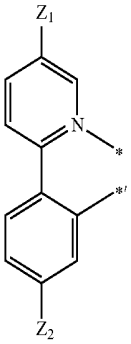

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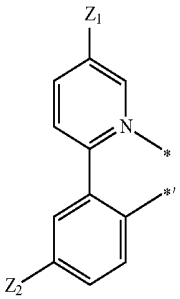

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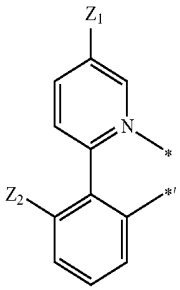

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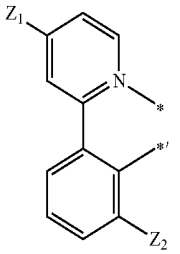

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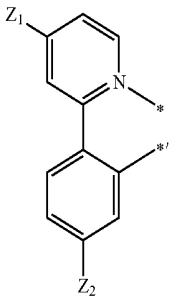

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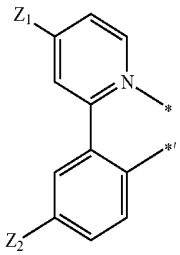

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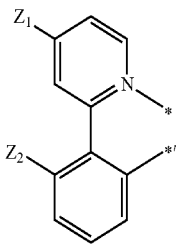

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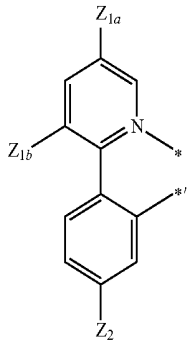

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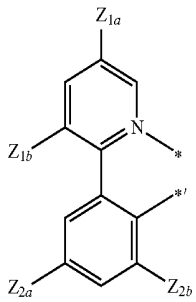

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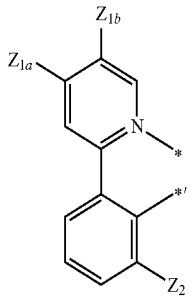

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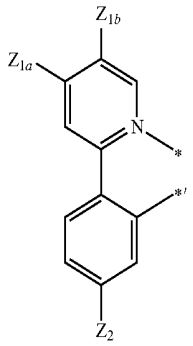

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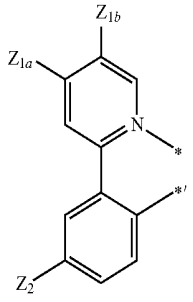

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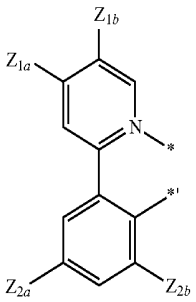

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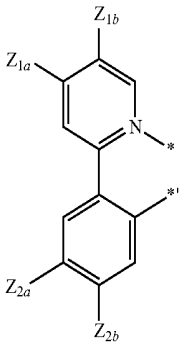

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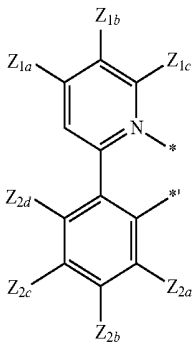

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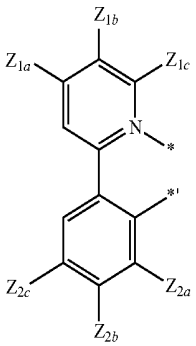

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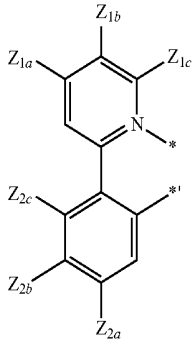

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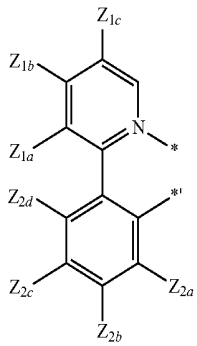

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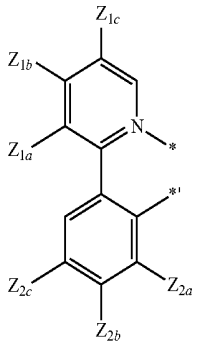

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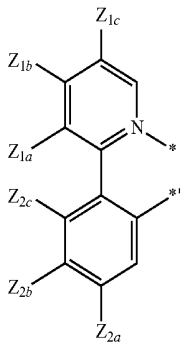

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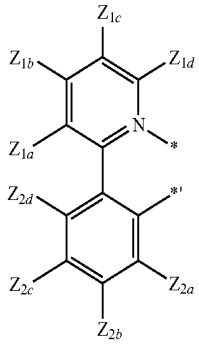

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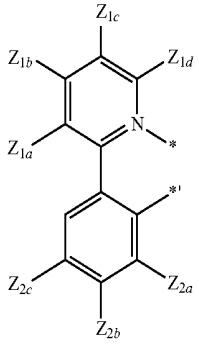

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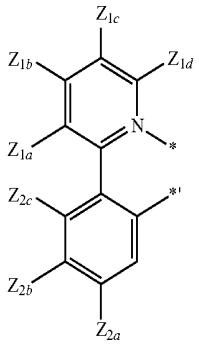

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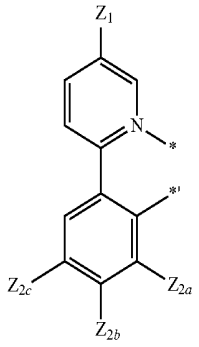

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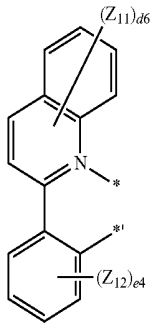

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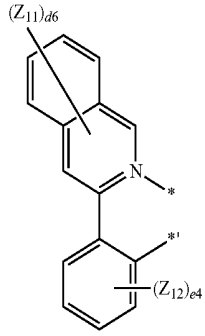

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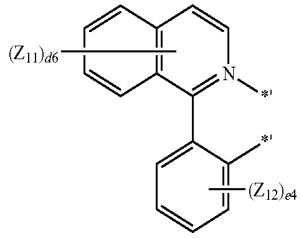

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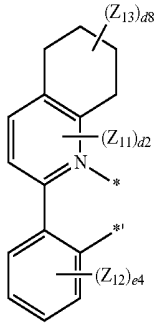

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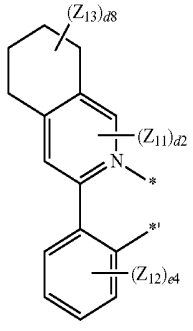

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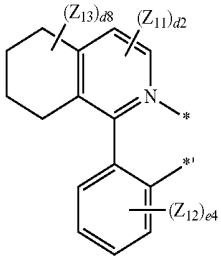

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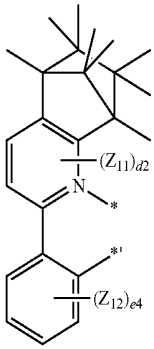

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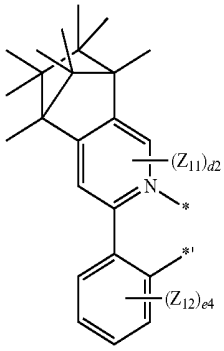

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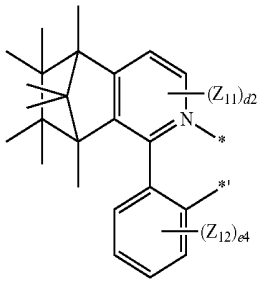

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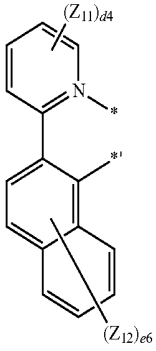

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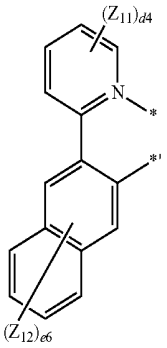

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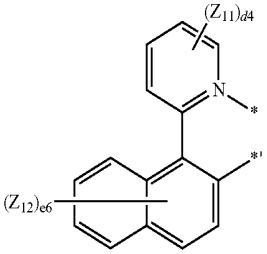

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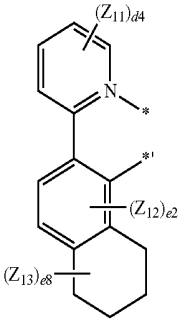

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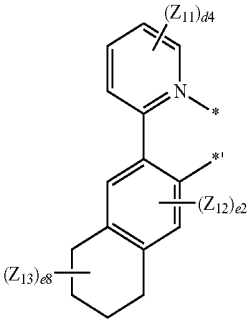

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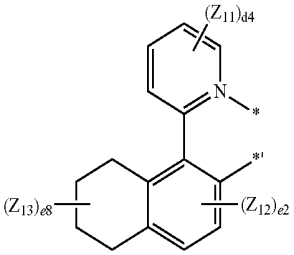

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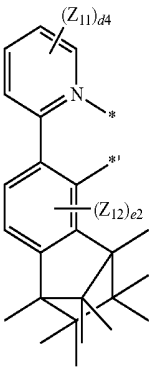
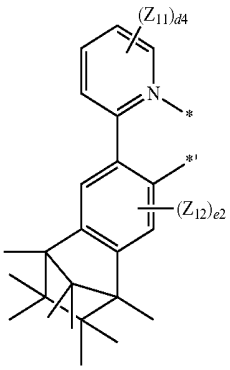
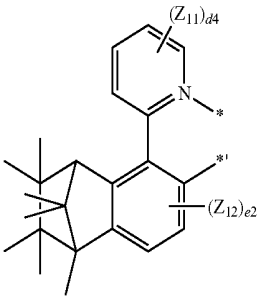


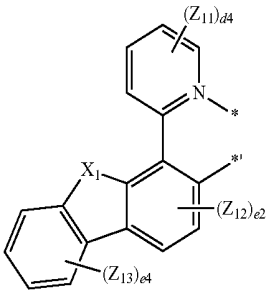
Formula 3-1(78)



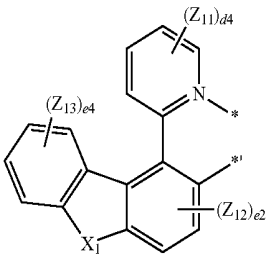
Formula 3-1(79)



Formula 3-1(81)



Formula 3-1(82)



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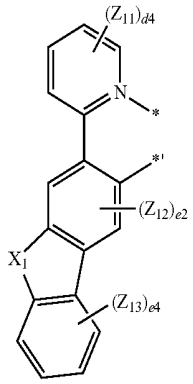
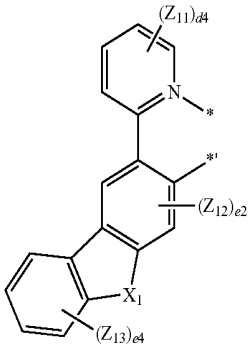
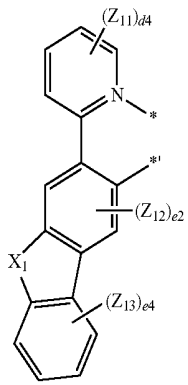
Formula 3-1(83)



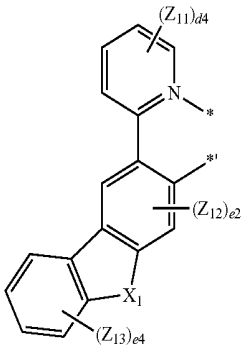
Formula 3-1(84)



Formula 3-1(85)



Formula 3-1(86)



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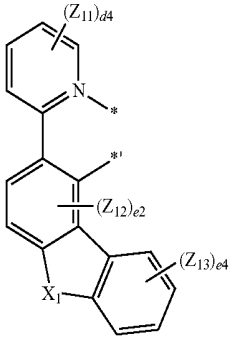
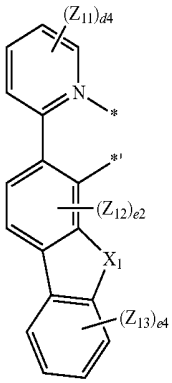
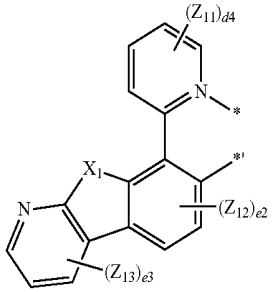


Formula 3-1(88)



Formula 3-1(91)



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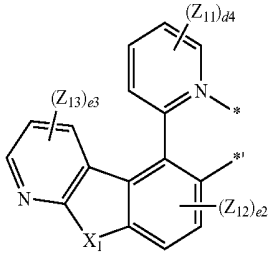
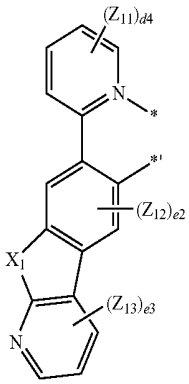


Formula 3-1(93)



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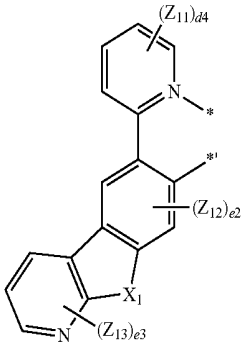
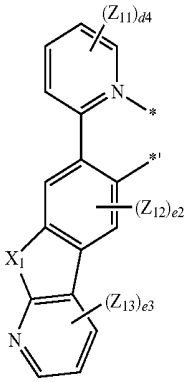


Formula 3-1(95)



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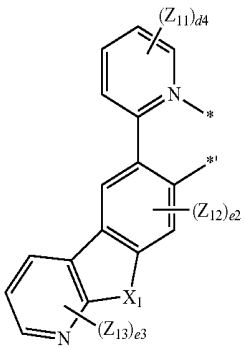
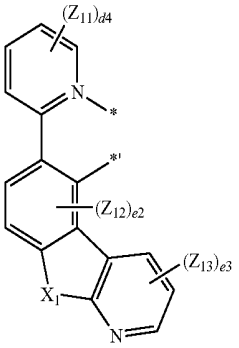


Formula 3-1(97)



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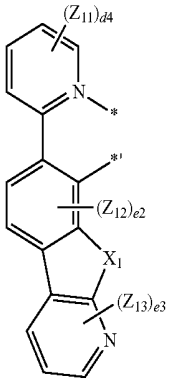
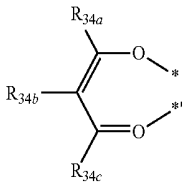
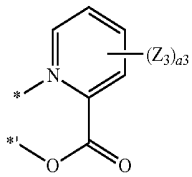
Formula 3-1(98)



Formula 3-111



Formula 3-112



wherein, in Formulae 3-1(1) to 3-1(60), 3-1(61) to 3-1(69), 3-1(71) to 3-1(79), 3-1(81) to 3-1(88), 3-1(91) to 3-1(98), 3-111, and 3-112,

Z_1, Z_2, Z_{1a}, Z_{1b}, Z_{1c}, Z_{1d}, Z_{2a}, Z_{2b}, Z_{2c}, Z_{2d}, R_{34a}, R_{34b}, and R_{34c} are each independently selected from deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, —$P(=O)(Q_8)(Q_9)$, ligands represented by Formulae 9-1 to 9-19, and ligands represented by Formulae 10-1 to 10-38,

X_1 is O, S, $C(Z_{21})(Z_{22})$, or $N(Z_{23})$,

Z_3, Z_{11} to Z_{13}, and Z_{21} to Z_{23} are each independently selected from hydrogen, deuterium, —F, a cyano group, a nitro group, —SF_5, —CH_3, —CD_3, —CD_2H, —CDH_2, —CF_3, —CF_2H, —CFH_2, —$Si(Q_1)(Q_2)(Q_3)$, —$N(Q_4)(Q_5)$, —$B(Q_6)(Q_7)$, —$P(=O)(Q_8)(Q_9)$, groups represented by Formulae 9-1 to 9-19, and groups represented by Formulae 10-1 to 10-38,

wherein Q_1 to Q_9 are each independently selected from —CH_3, —CD_3, —CD_2H, —CDH_2, —CH_2CH_3, —CH_2CD_3, —CH_2CD_2H, —CH_2CDH_2, —$CHDCH_3$, —$CHDCD_2H$, —$CHDCDH_2$, —$CHDCD_3$, —CD_2CD_3, —CD_2CD_2H, and —CD_2CDH_2;

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group; and

an n-propyl group, an isopropyl group, an n-butyl group, an isobutyl group, a sec-butyl group, a tert-butyl group, an n-pentyl group, an isopentyl group, a sec-pentyl group, a tert-pentyl group, a phenyl group, and a naphthyl group, each substituted with at least one selected from deuterium and a C_1-C_{10} alkyl group,

d2 and e2 are each independently 0 or 2,

e3 is an integer selected from 0 to 3,

d4 and e4 are each independently an integer selected from 0 to 4,

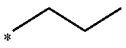
d6 and e6 are each independently an integer selected from 0 to 6,

d8 and e8 are each independently an integer selected from 0 to 8, and

each of * and *' indicates a binding site to M in Formula 1:

Formula 9-1

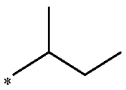
Formula 9-2



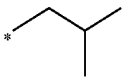
Formula 9-3

Formula 9-4

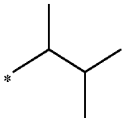
Formula 9-5



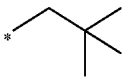
Formula 9-6



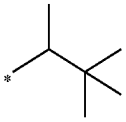
Formula 9-7



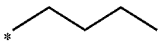
Formula 9-8



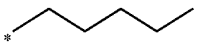
Formula 9-9



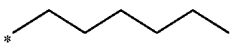
Formula 9-10



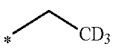
Formula 9-11



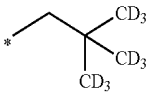
Formula 9-12



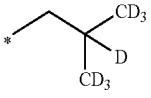
Formula 9-13



Formula 9-14



Formula 9-15



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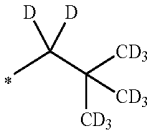
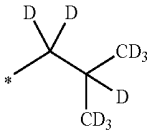
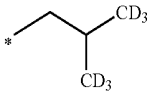
Formula 9-16



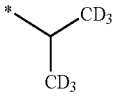
Formula 9-17



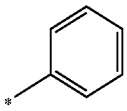
Formula 9-18



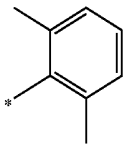
Formula 9-19



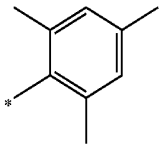
Formula 10-1



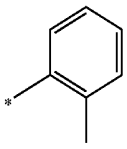
Formula 10-2



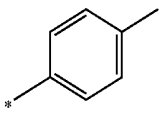
Formula 10-3



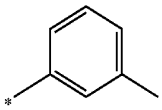
Formula 10-4



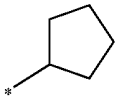
Formula 10-5



Formula 10-6



Formula 10-7



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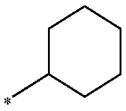
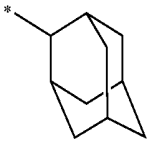
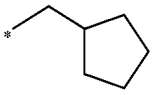
Formula 10-8



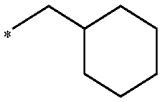
Formula 10-9



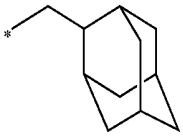
Formula 10-10



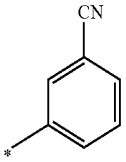
Formula 10-11



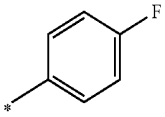
Formula 10-12



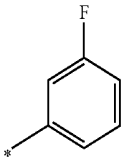
Formula 10-13



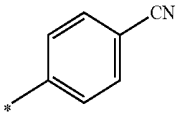
Formula 10-14



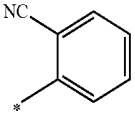
Formula 10-15



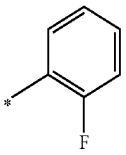
Formula 10-16



Formula 10-17



Formula 10-18



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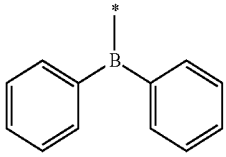
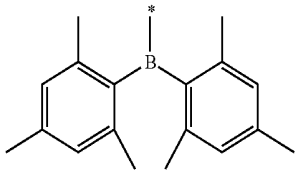
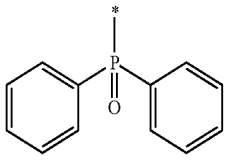


Formula 10-20



Formula 10-21



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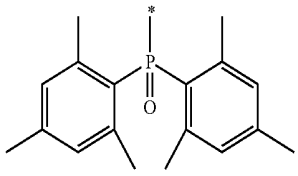

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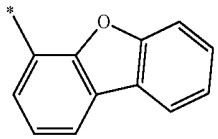

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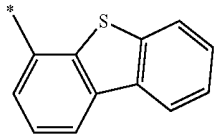
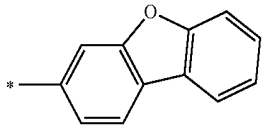


Formula 10-25



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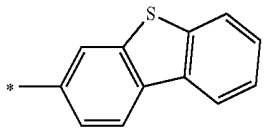

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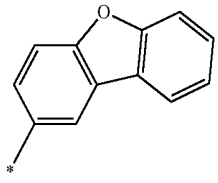

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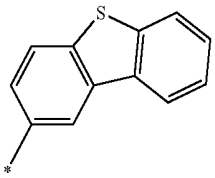

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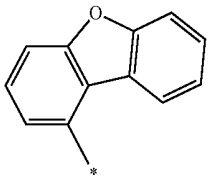

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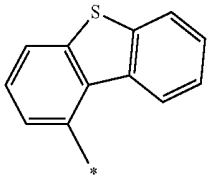

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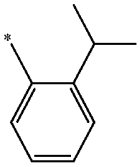
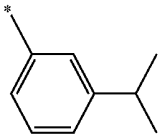
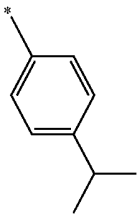


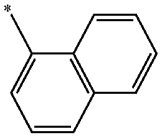
Formula 10-32



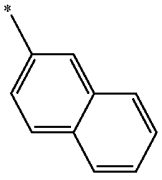
Formula 10-33



Formula 10-34



Formula 10-35



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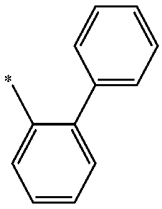
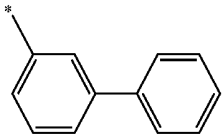
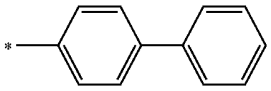
Formula 10-36



Formula 10-37



Formula 10-38

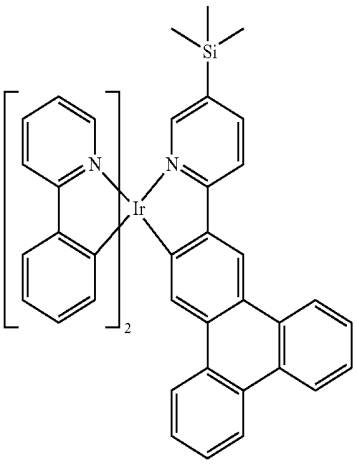


wherein * in Formula 9-1 to 9-19 and 10-1 to 10-38 indicates a binding site to a neighboring atom.

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

the organometallic compound is one of Compounds 1 to 288:

1



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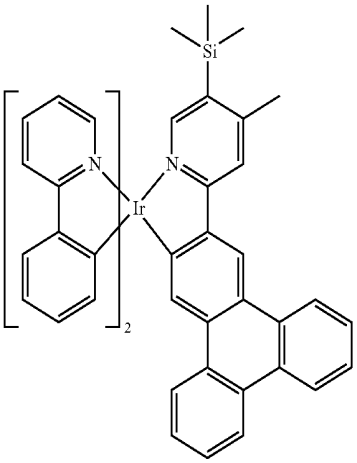

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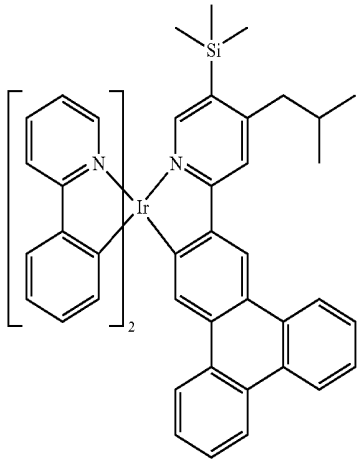

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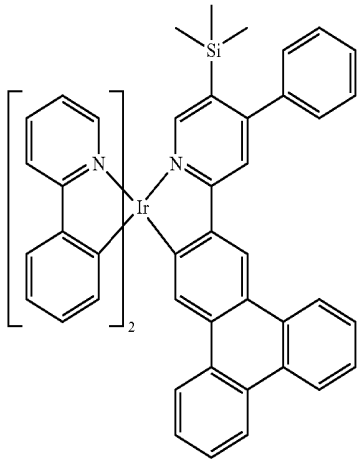

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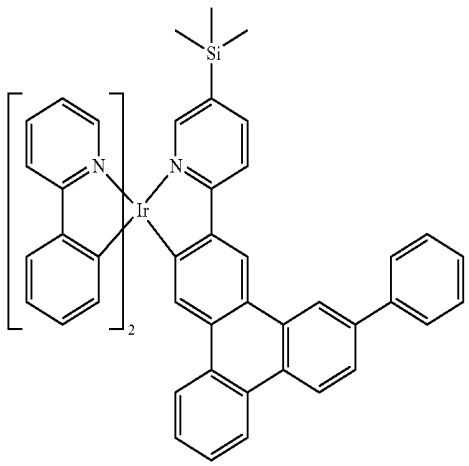

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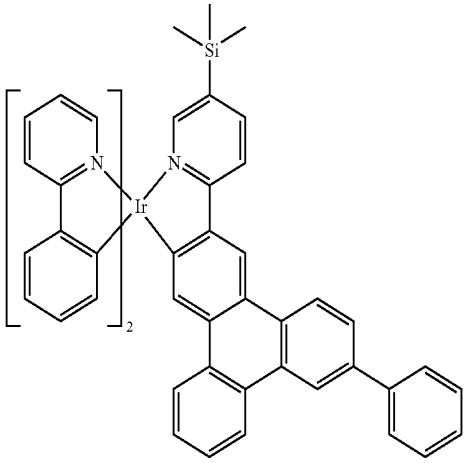

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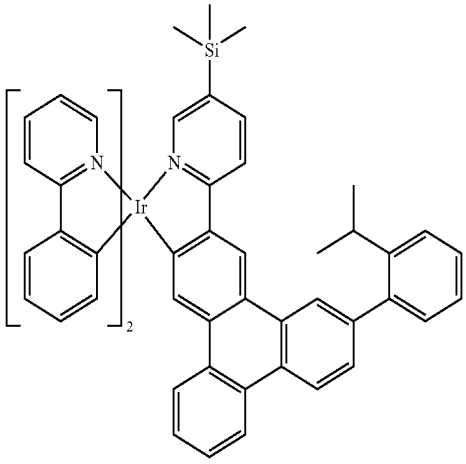

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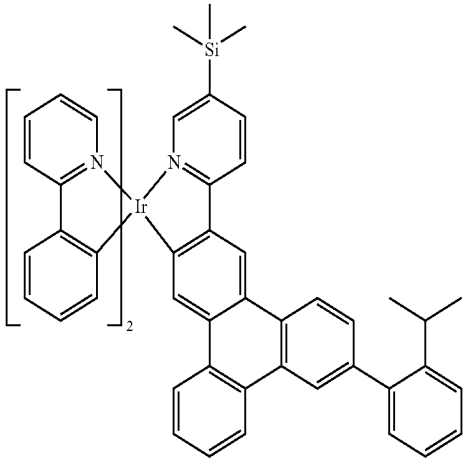

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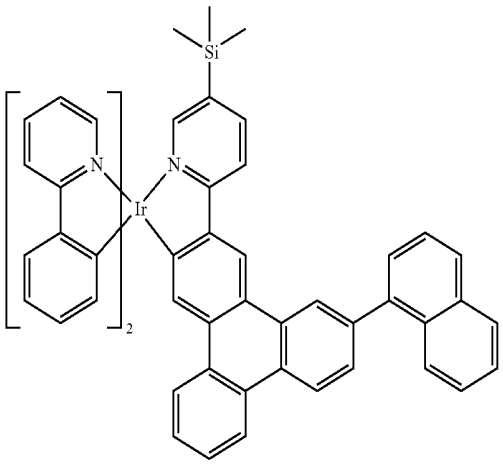

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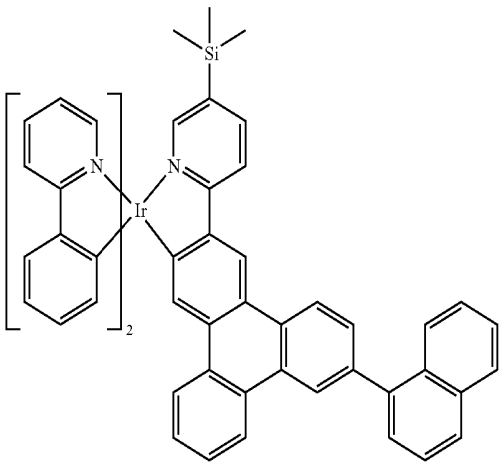

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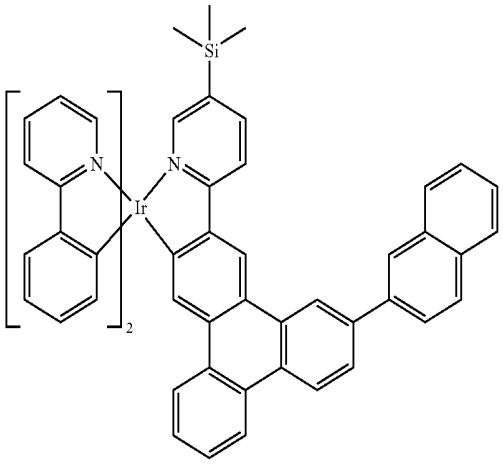

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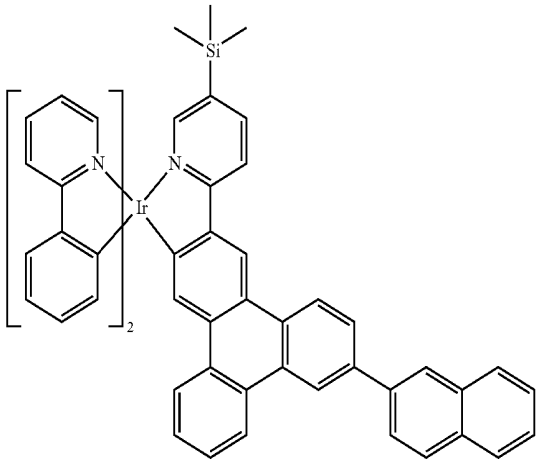

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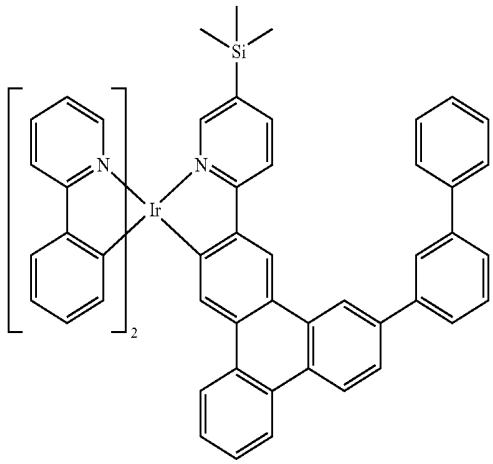

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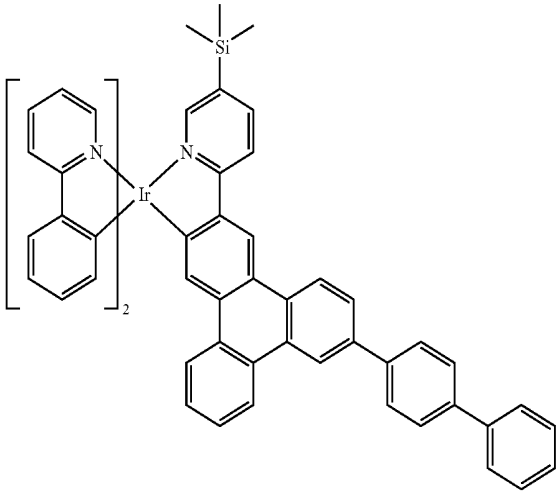

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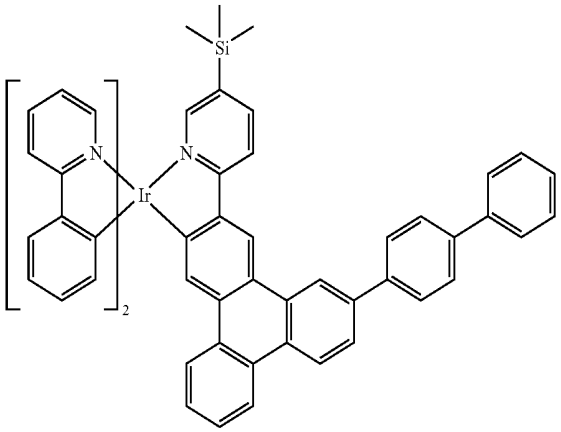

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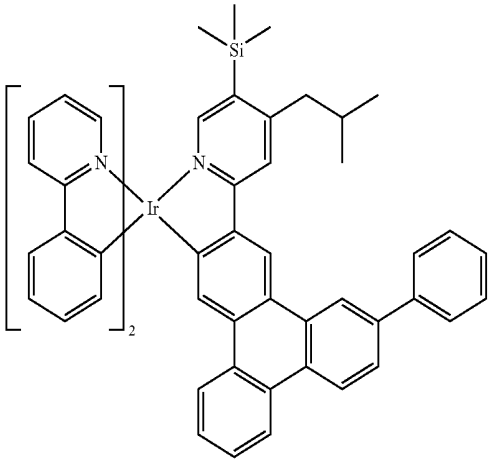

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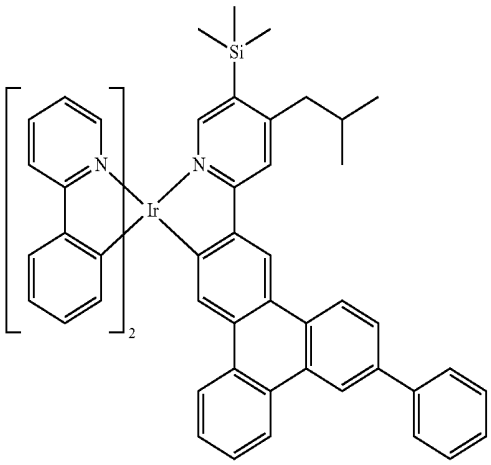

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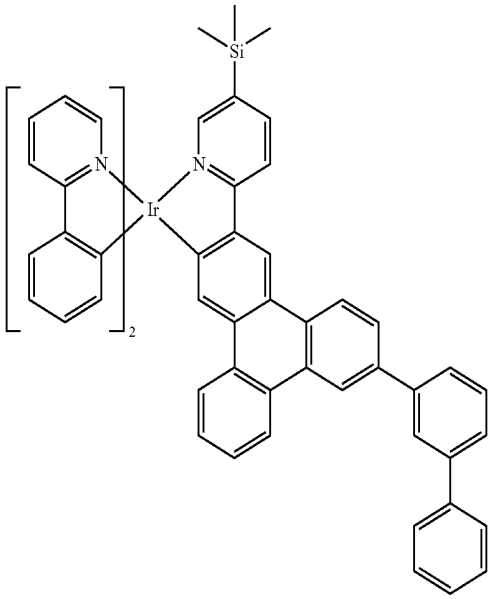

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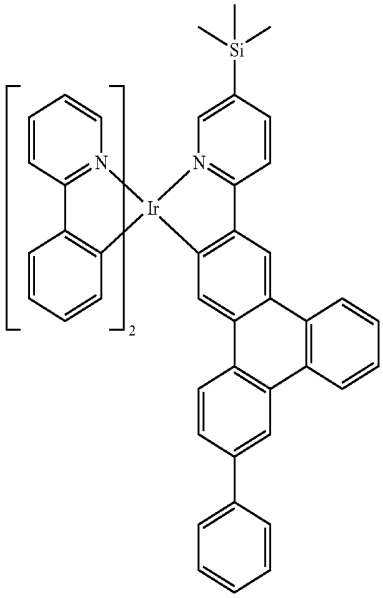

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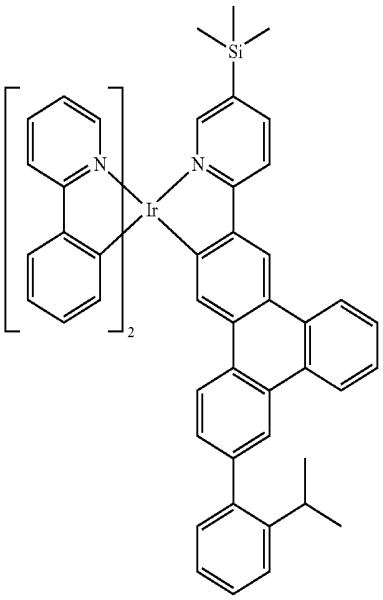

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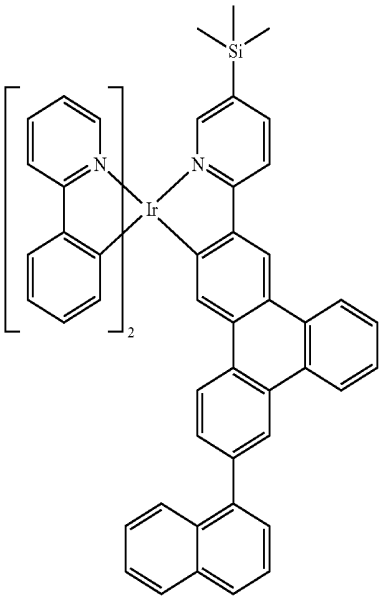

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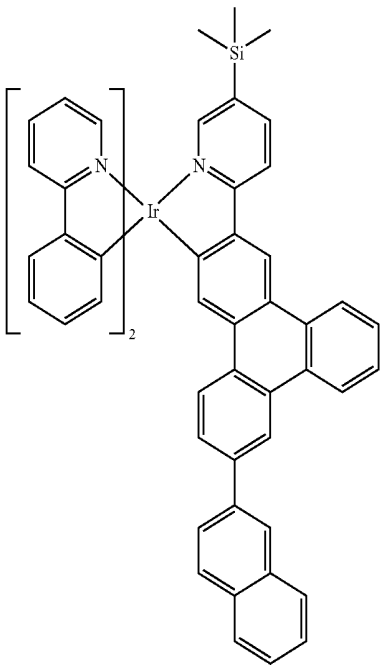

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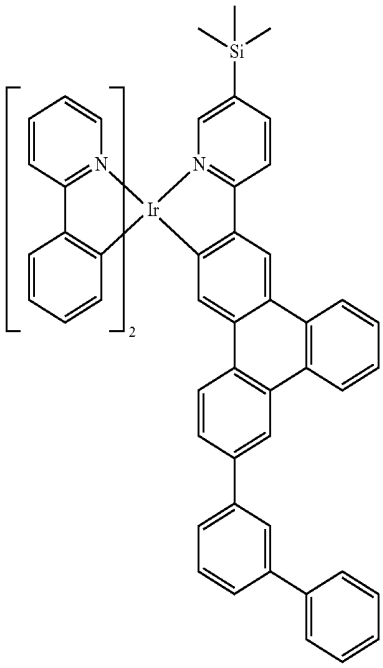

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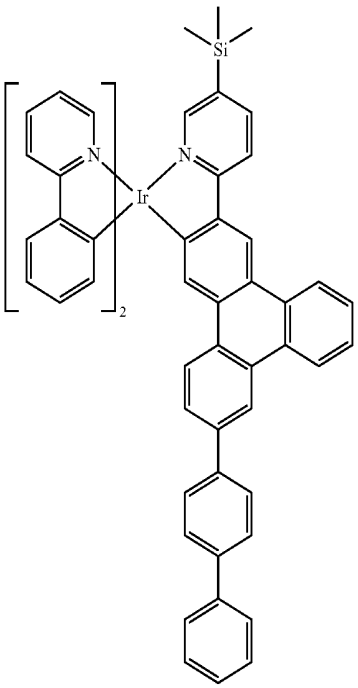

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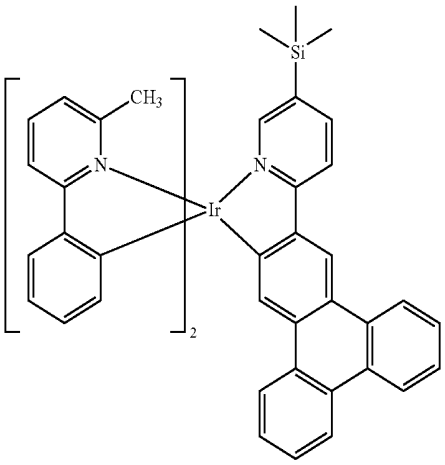

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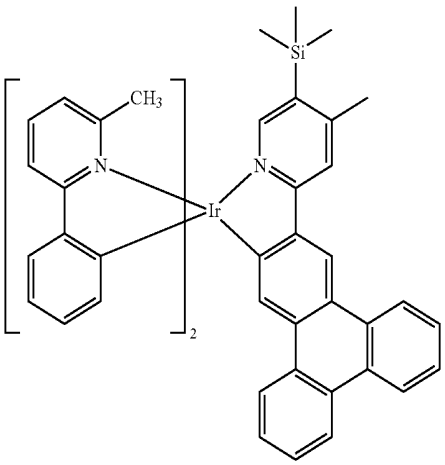

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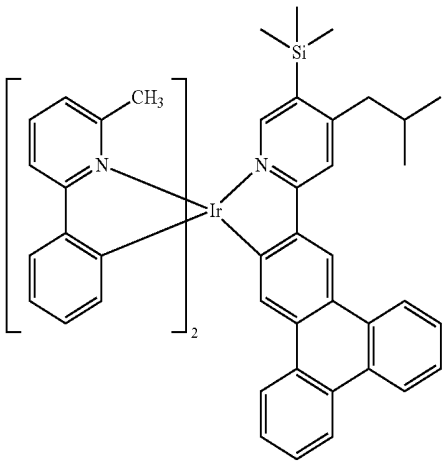

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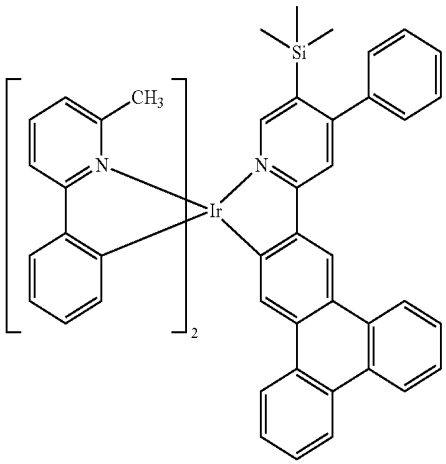

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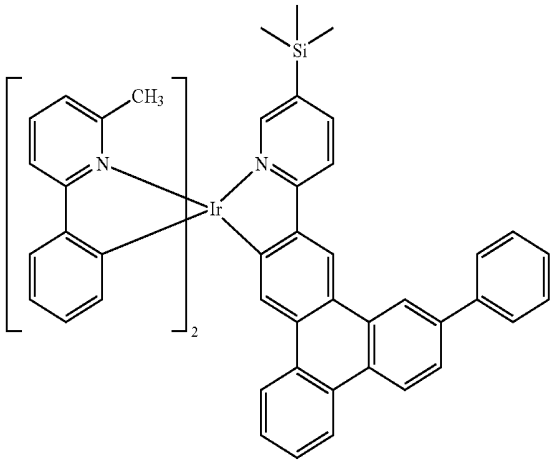

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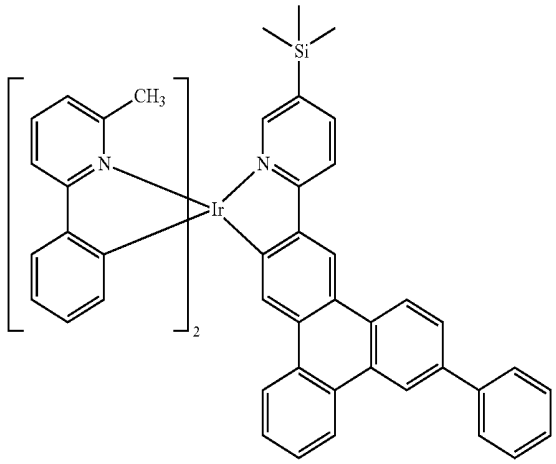

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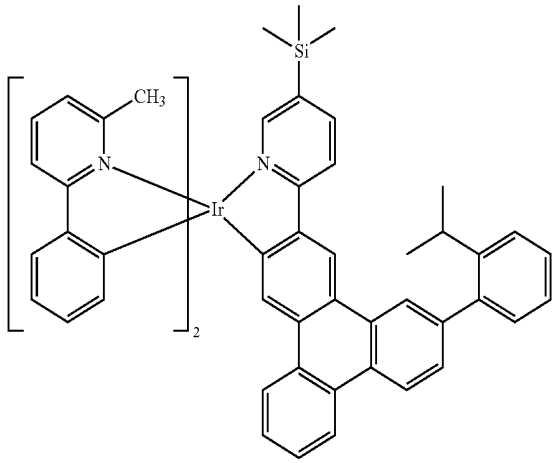

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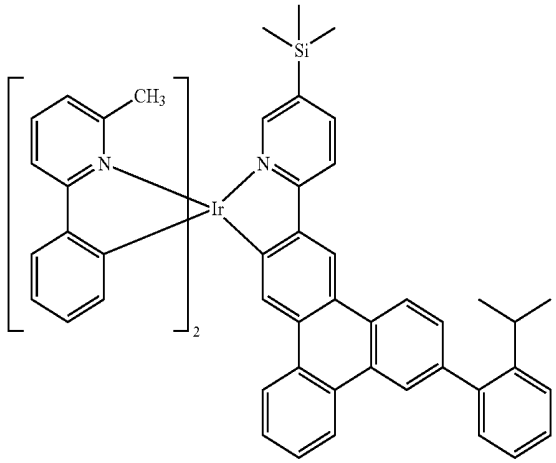

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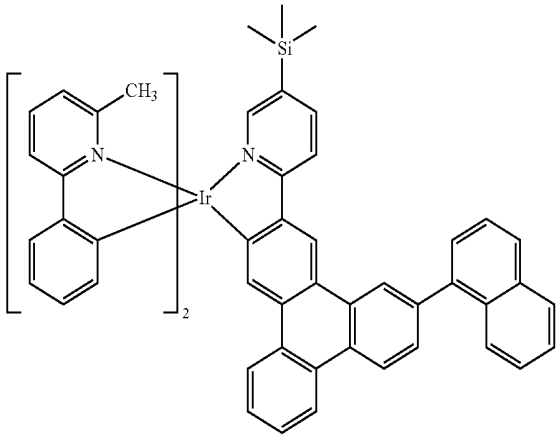

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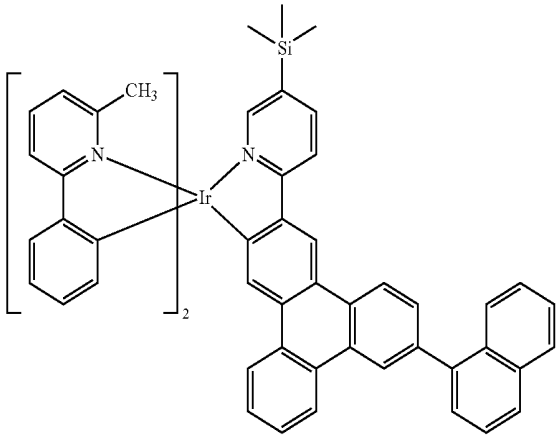

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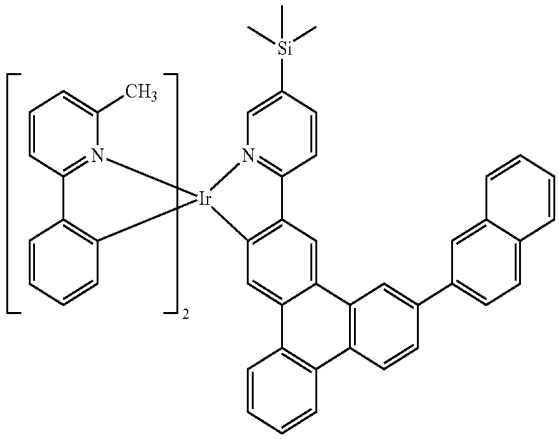

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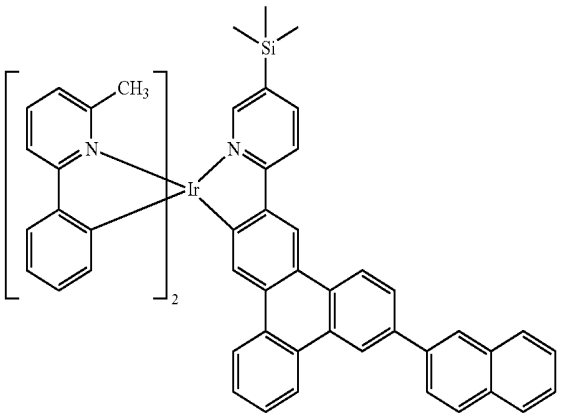

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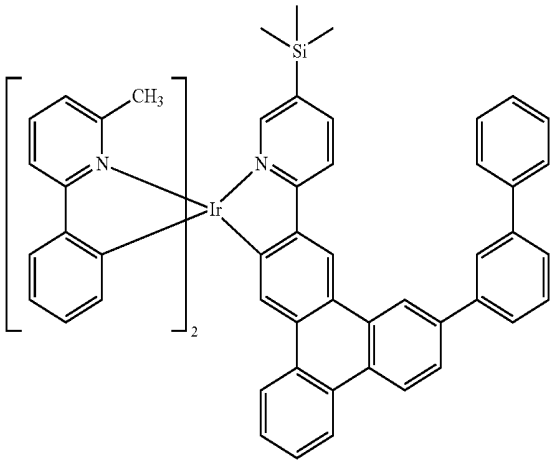

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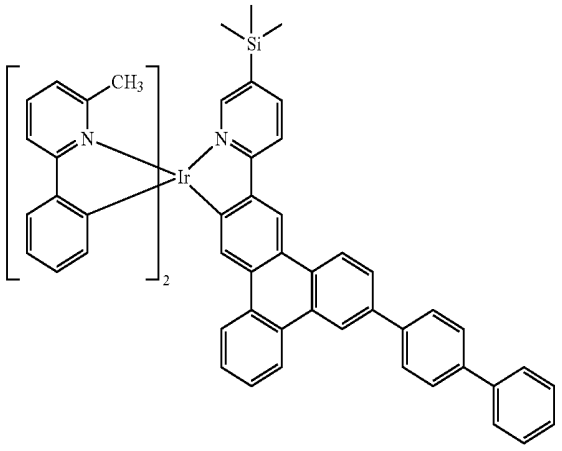

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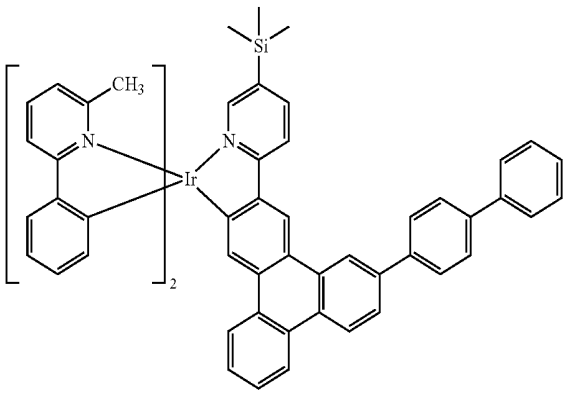

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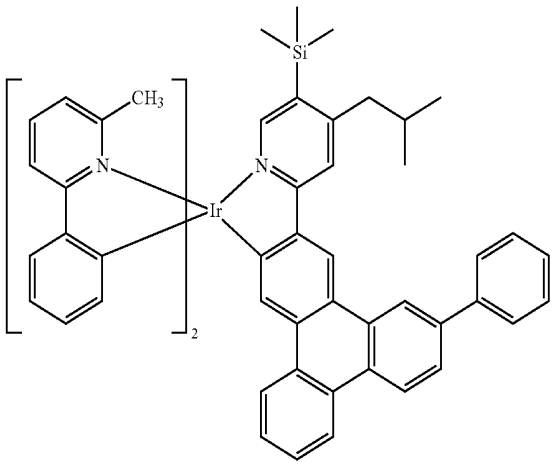

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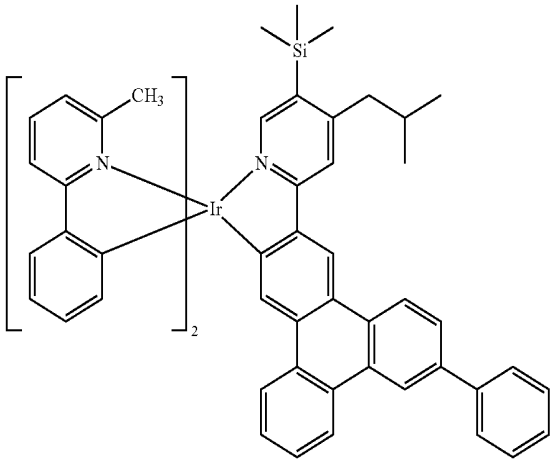

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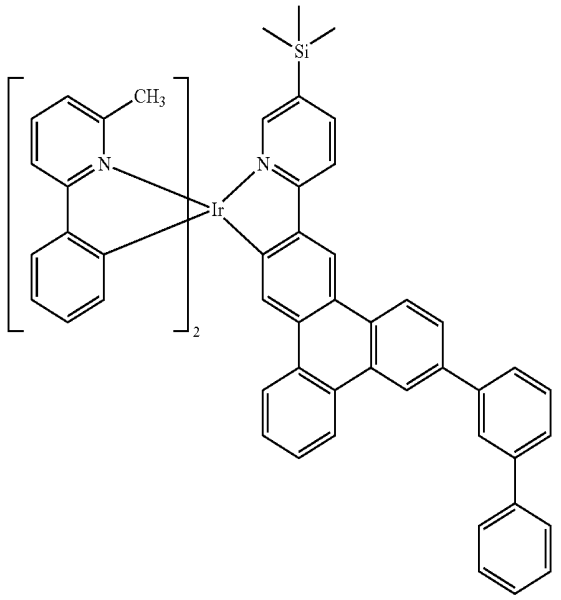

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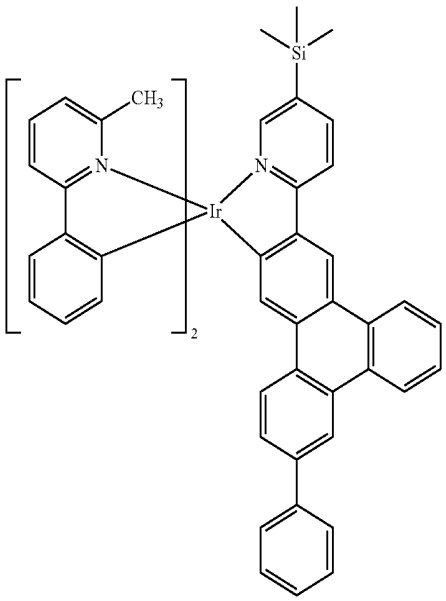

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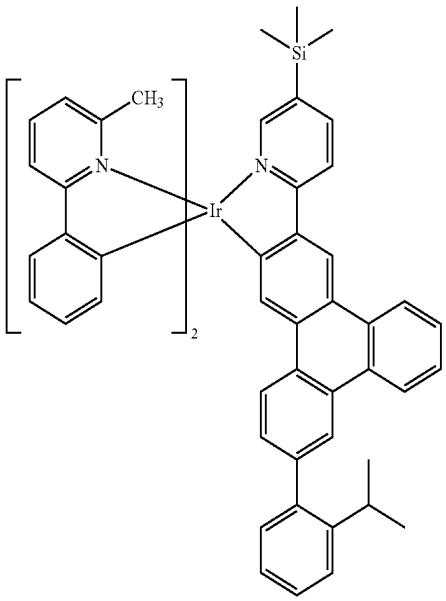

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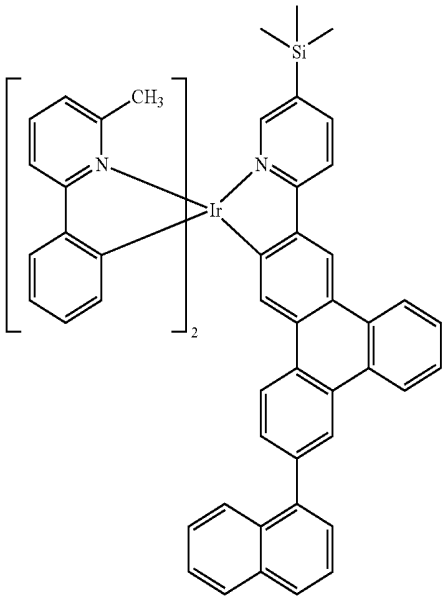

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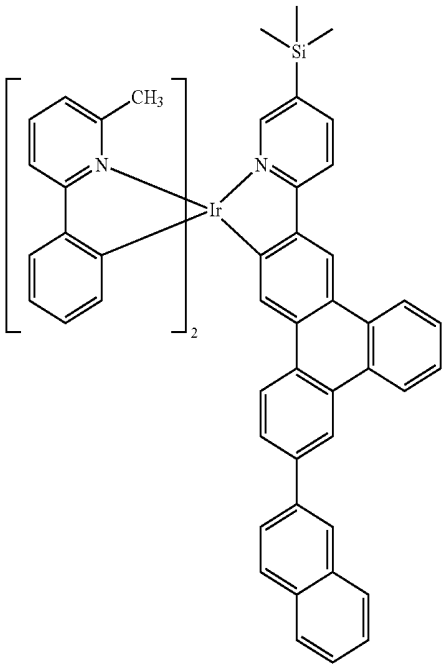

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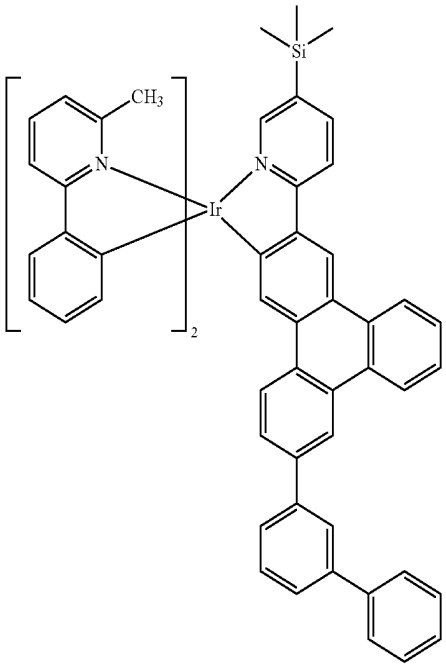

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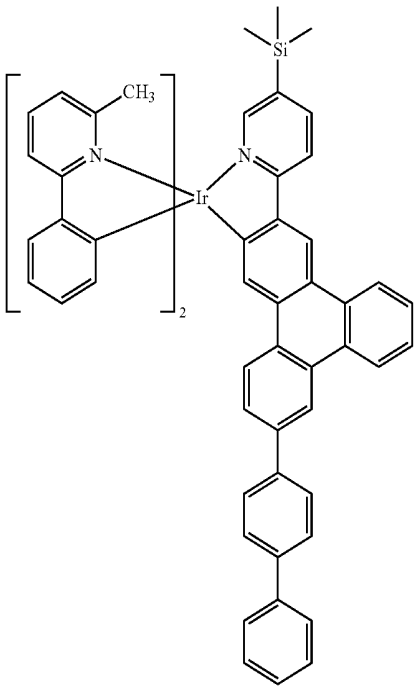

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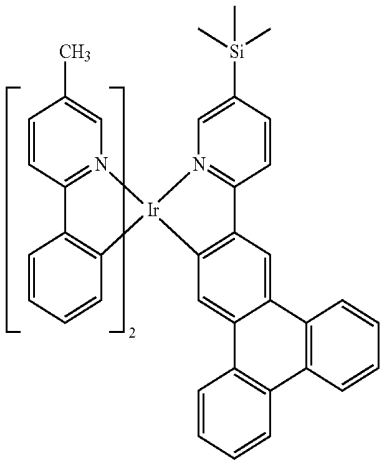

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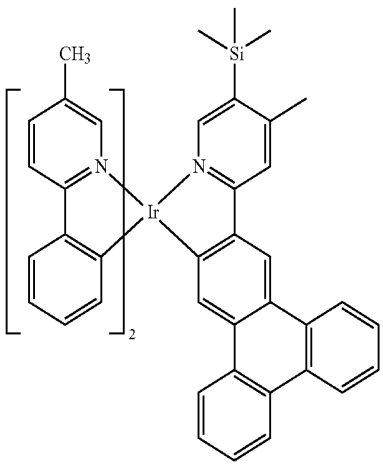

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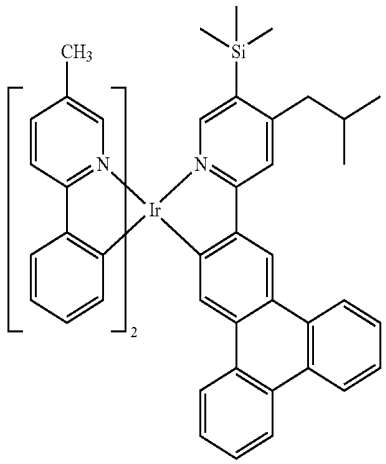

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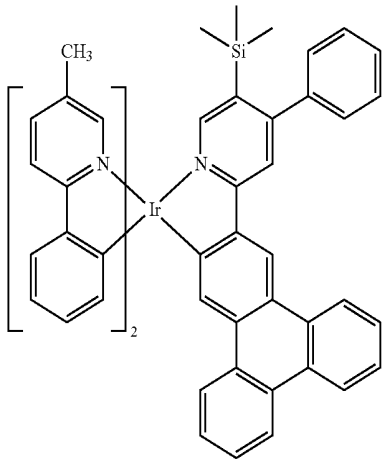

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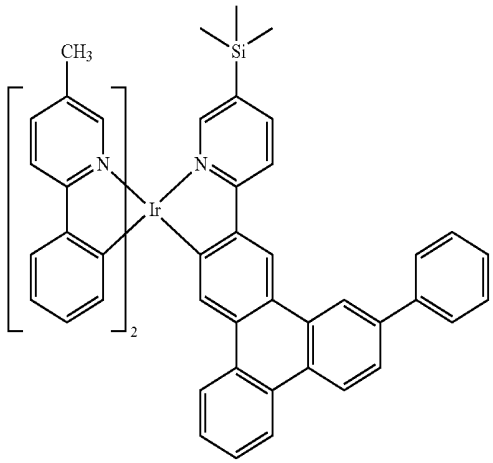

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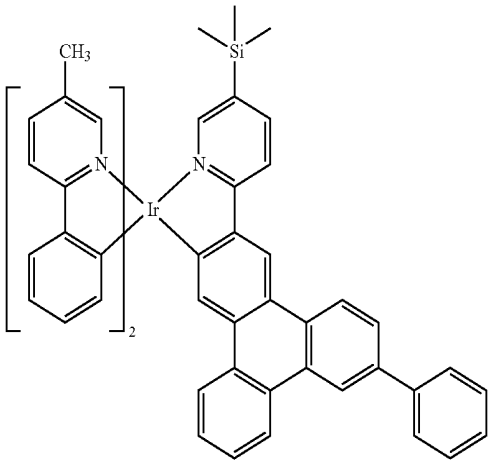

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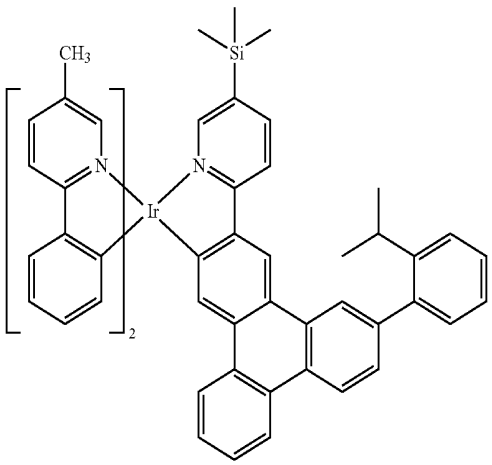

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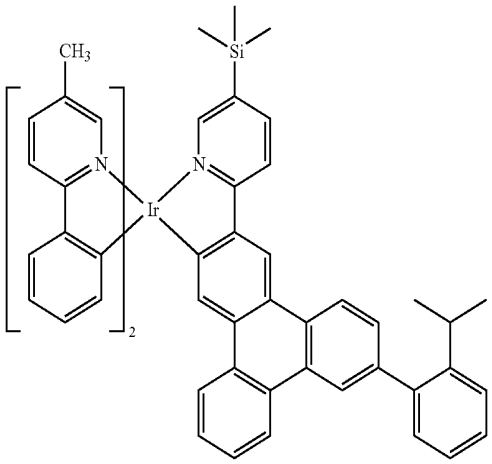

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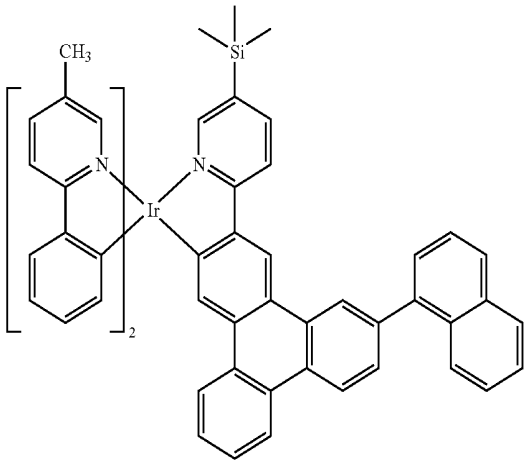

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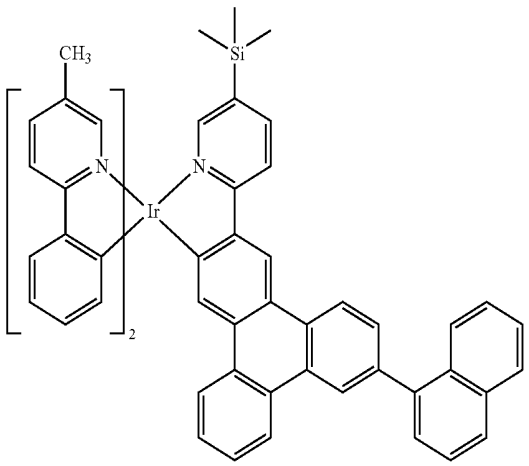

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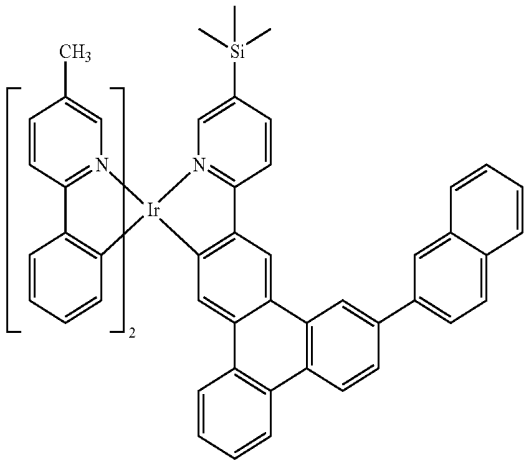

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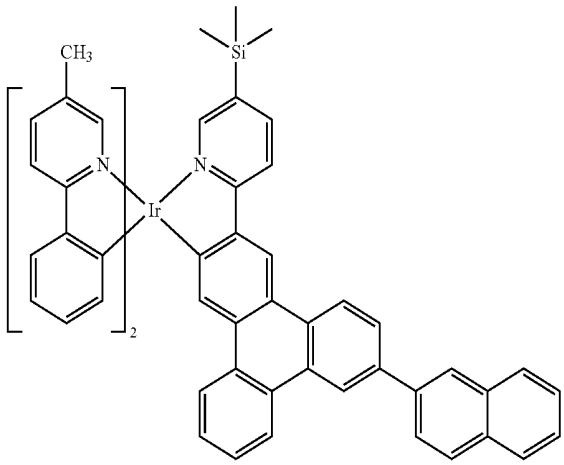

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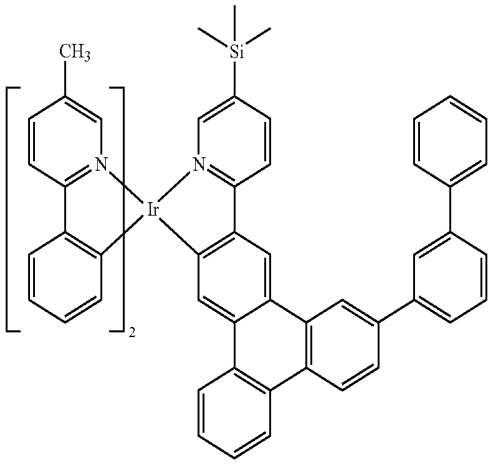

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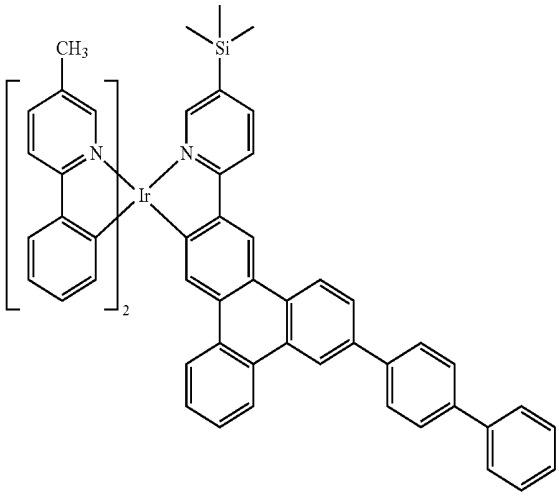

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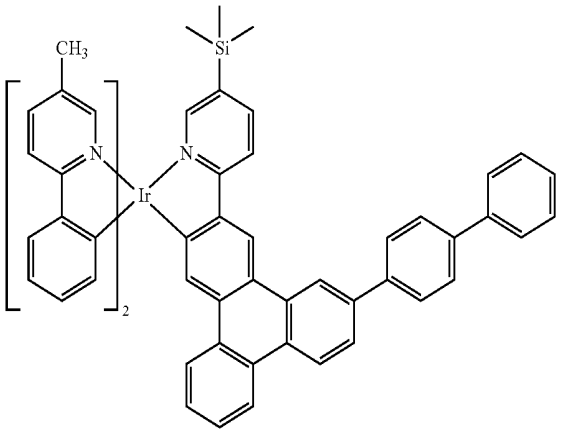

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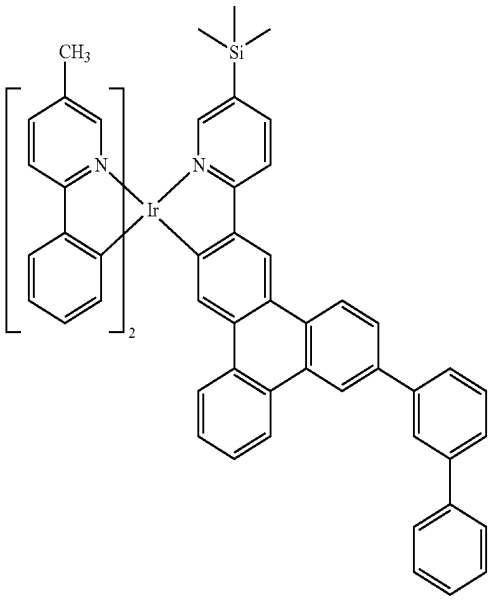

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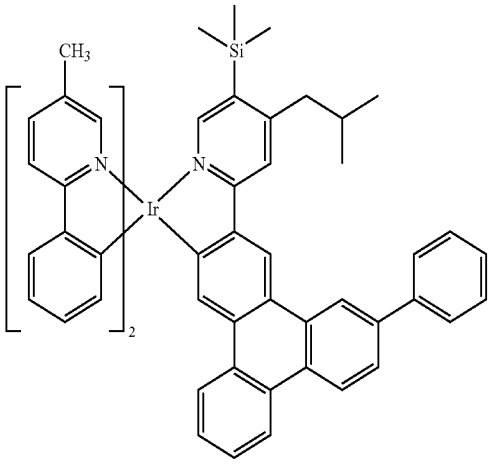

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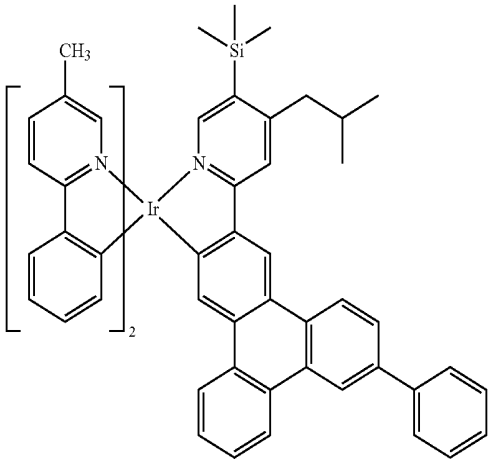

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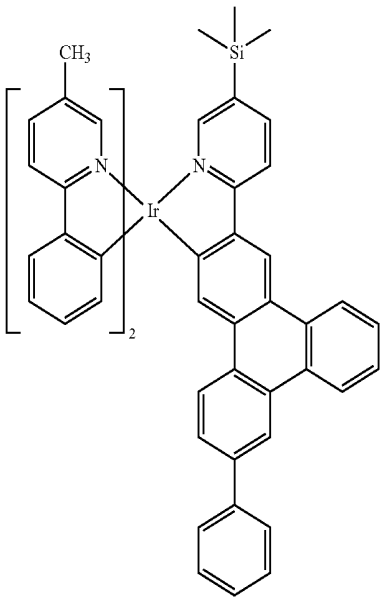

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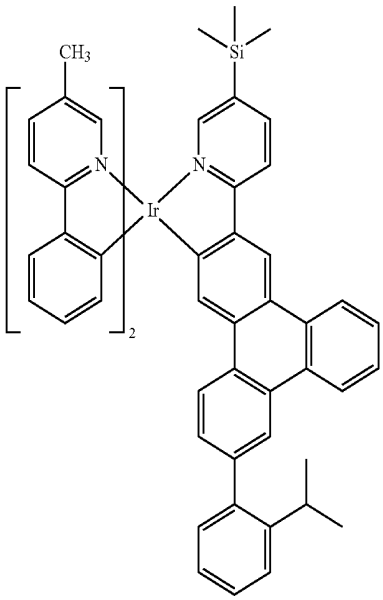

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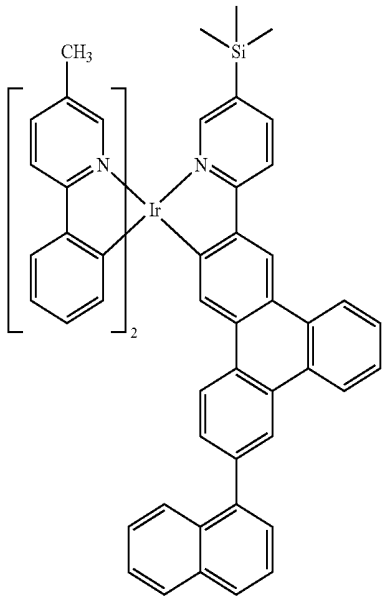

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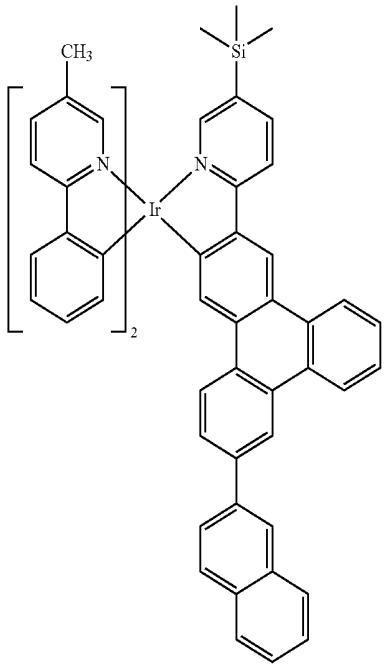

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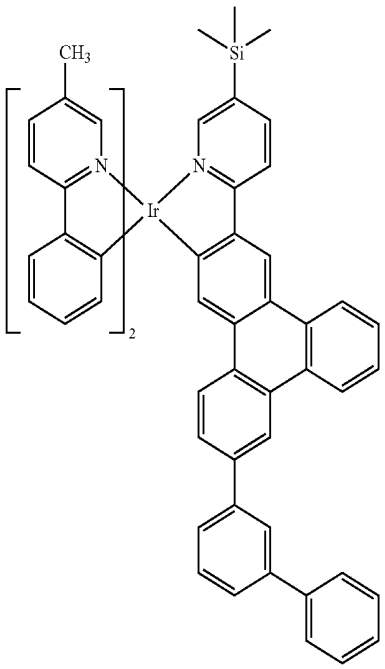

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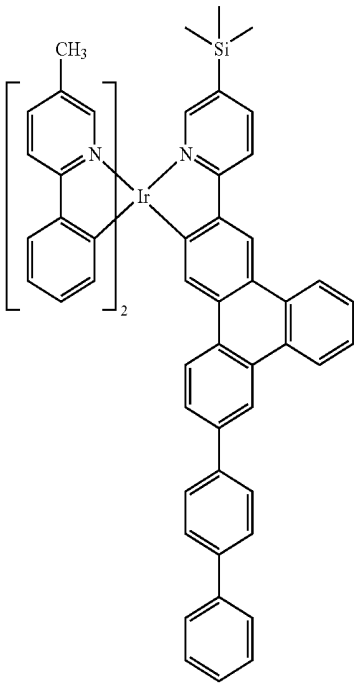

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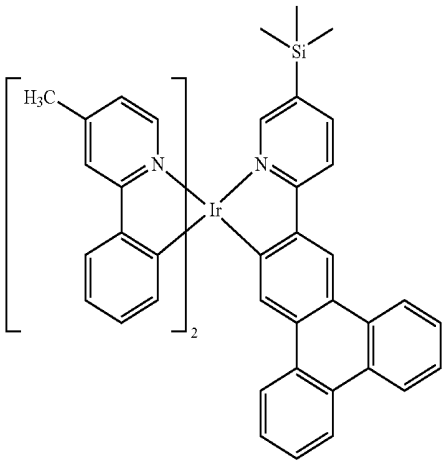

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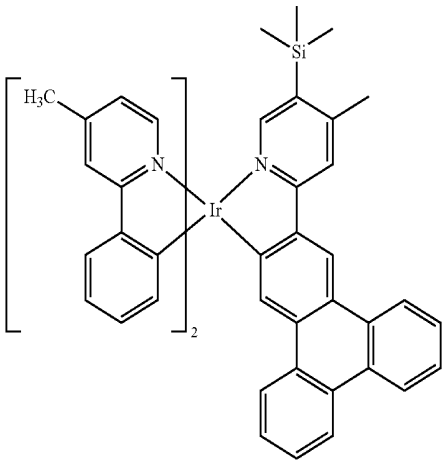

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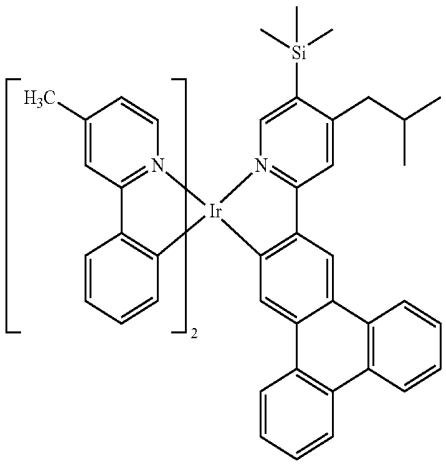

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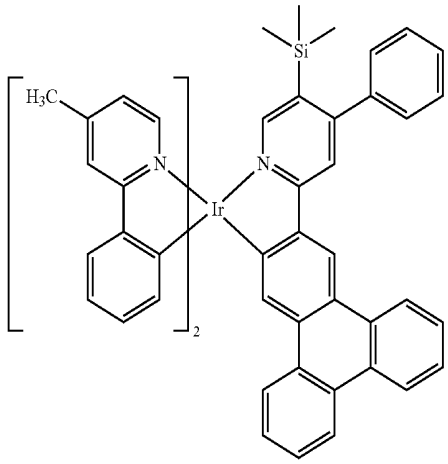

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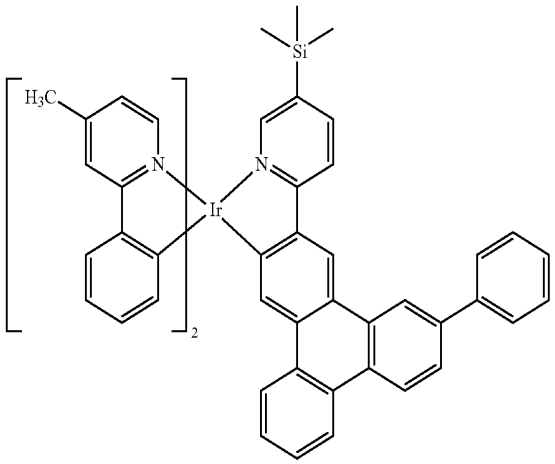

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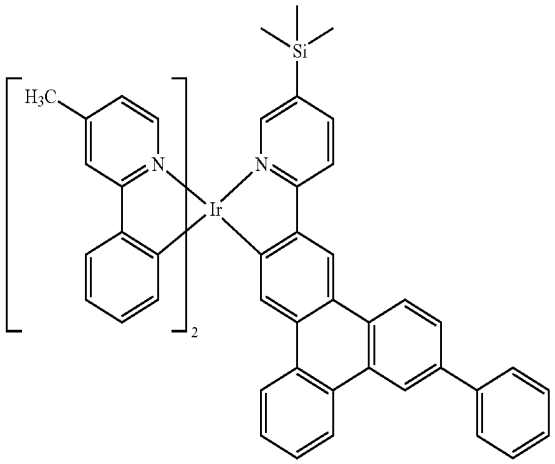

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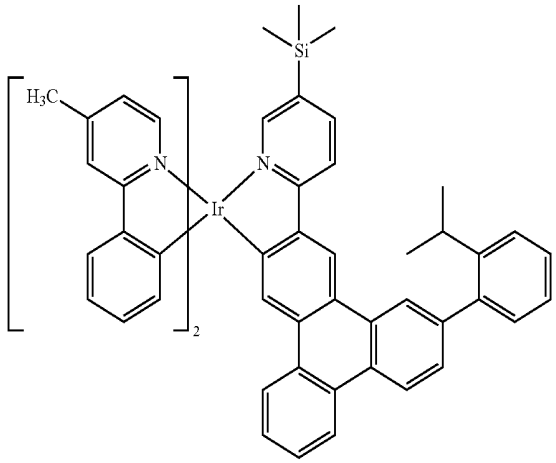

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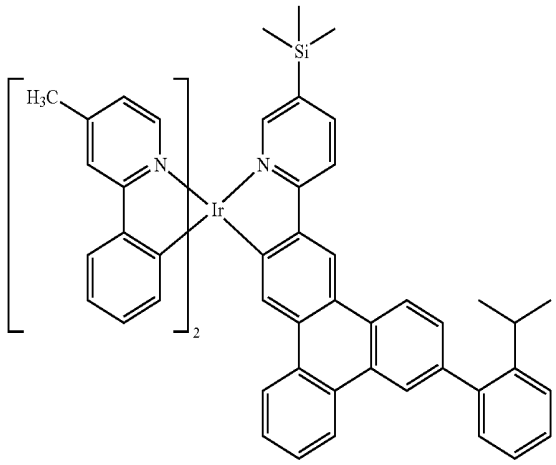

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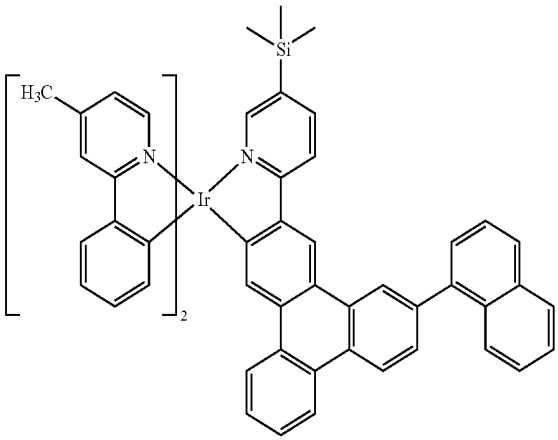

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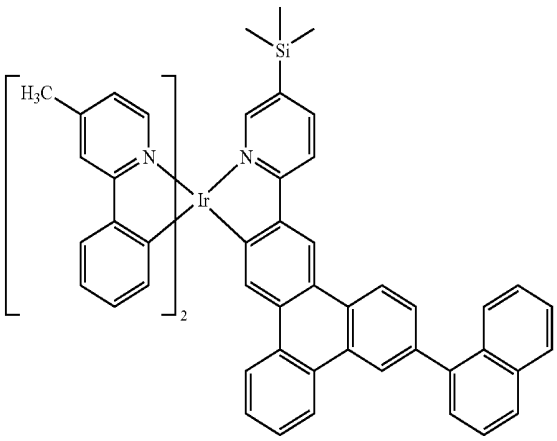

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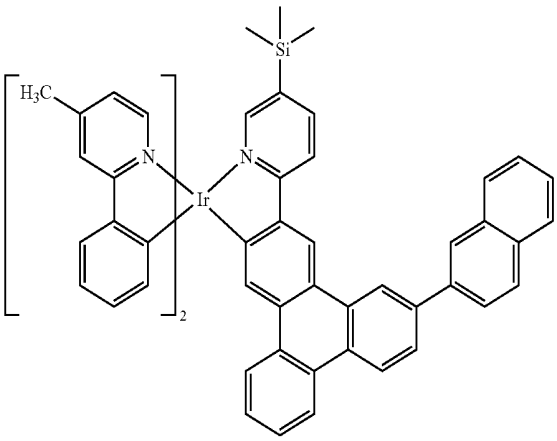

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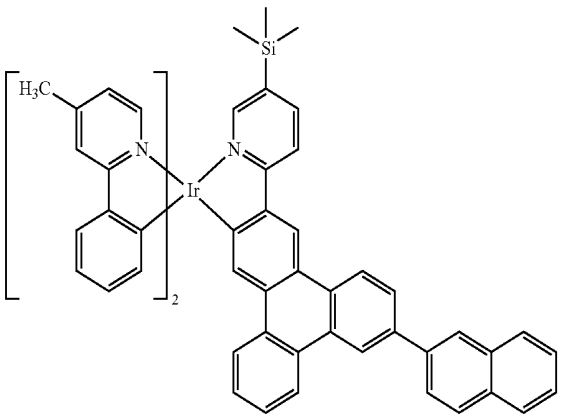

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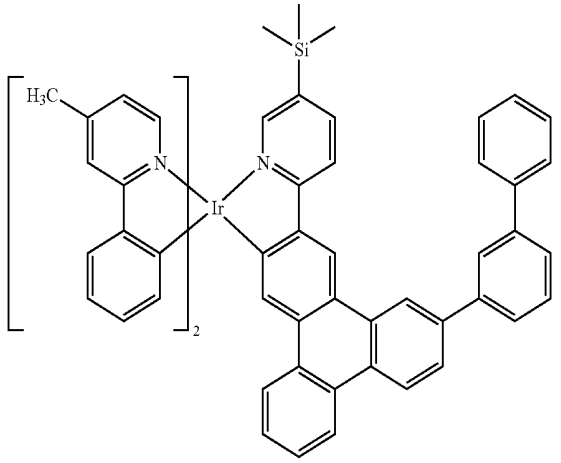

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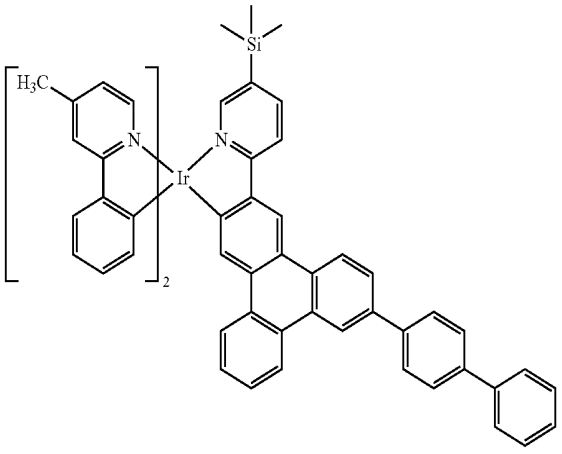

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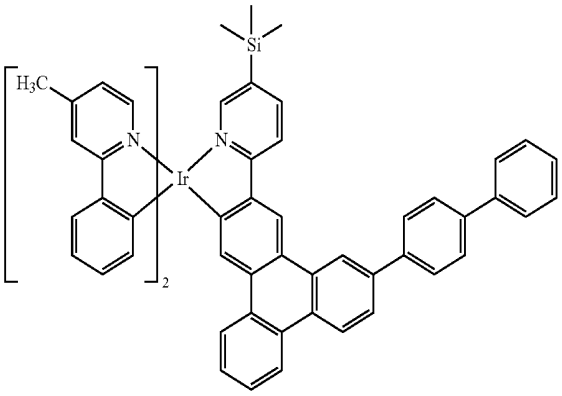

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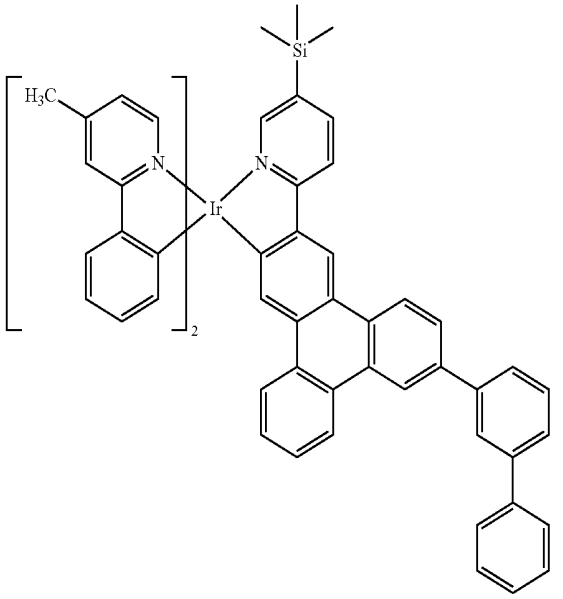

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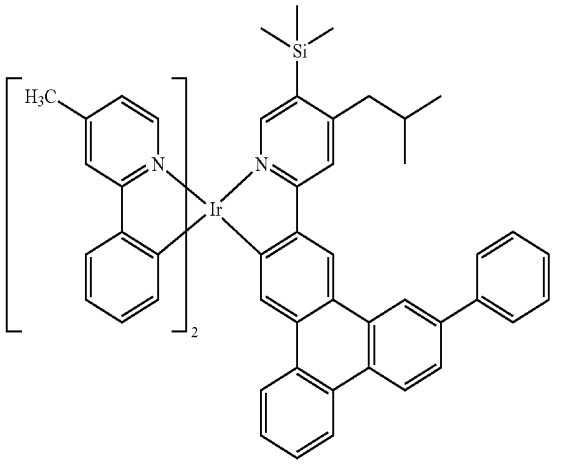

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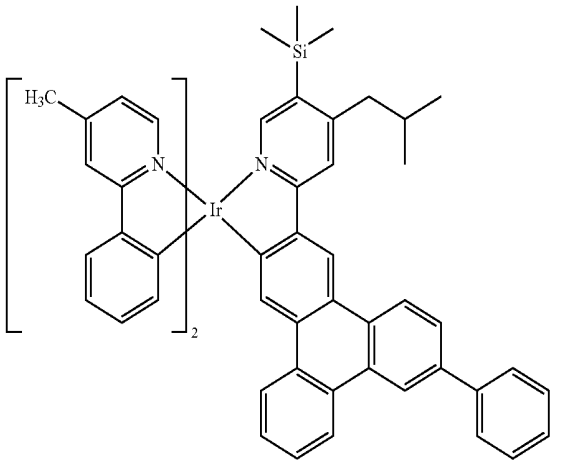

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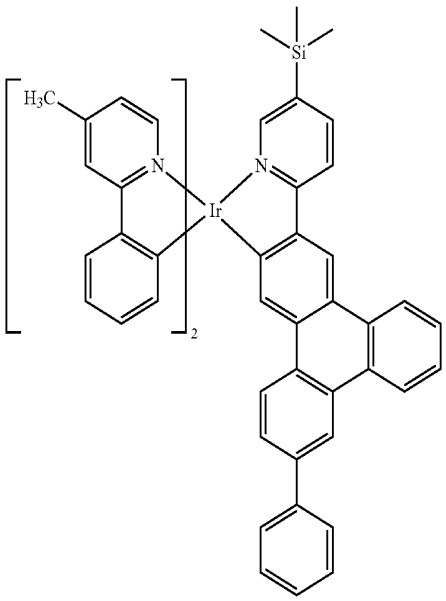

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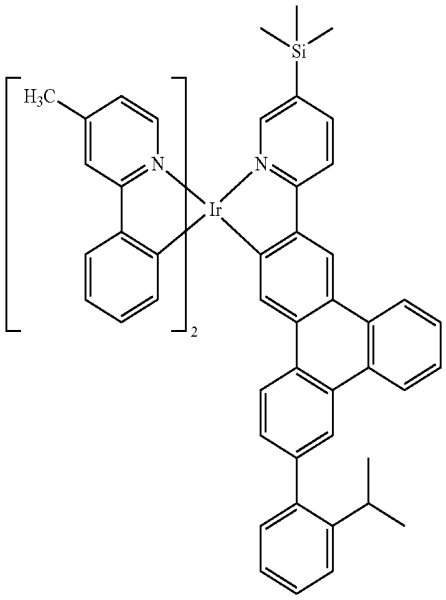

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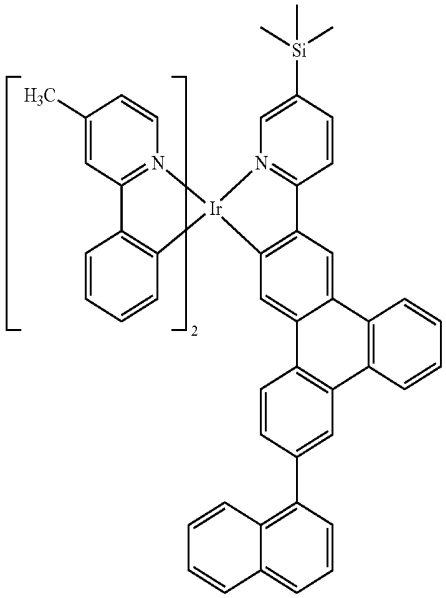

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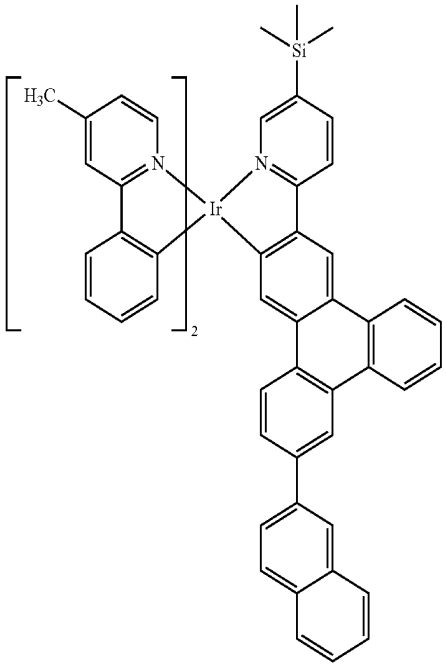

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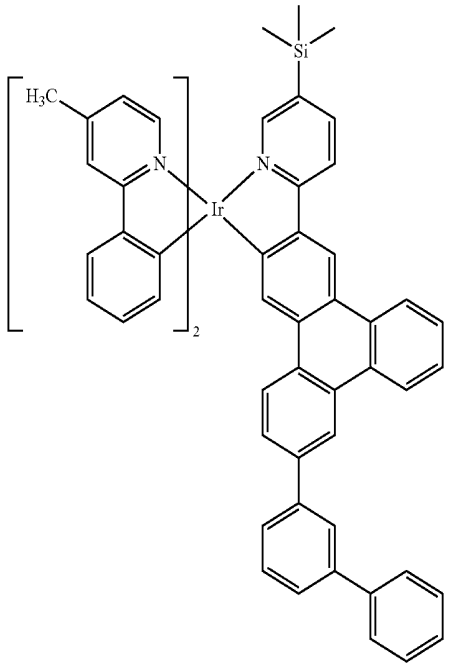

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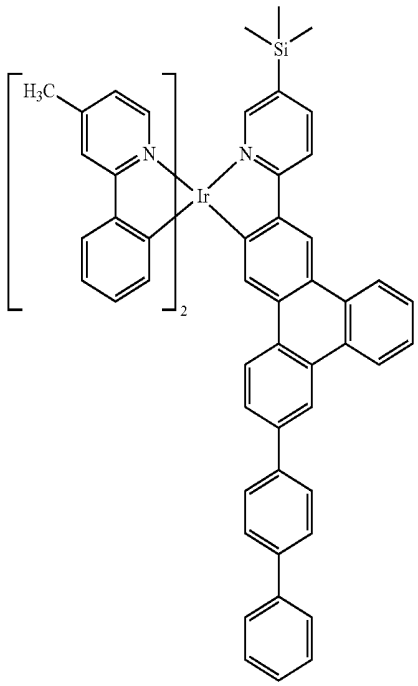

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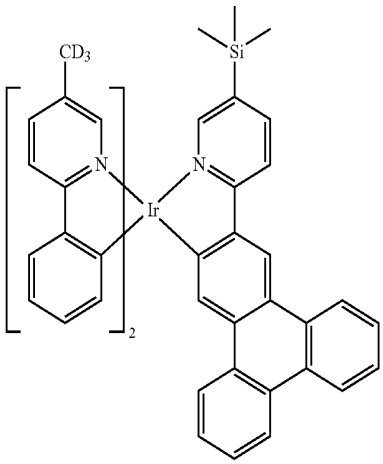

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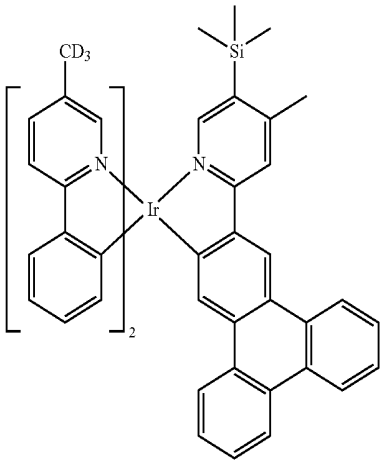

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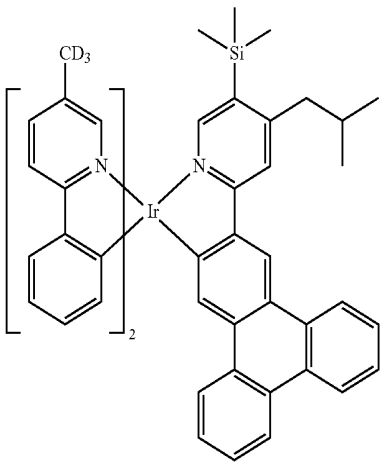

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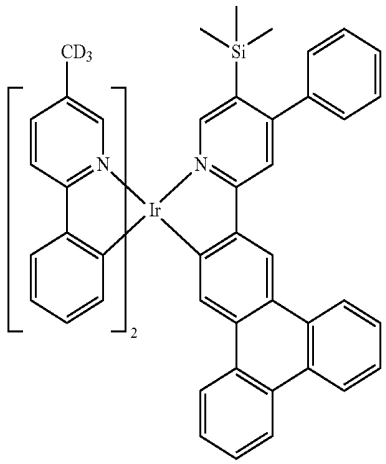

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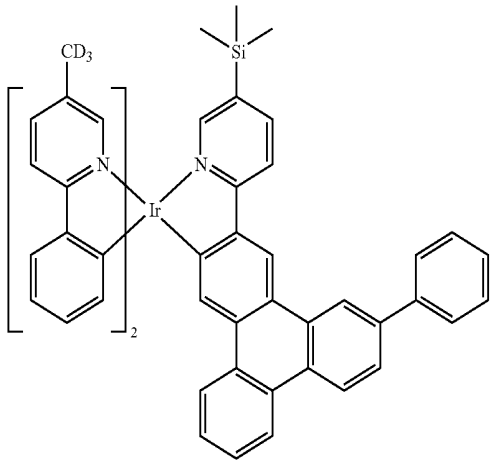

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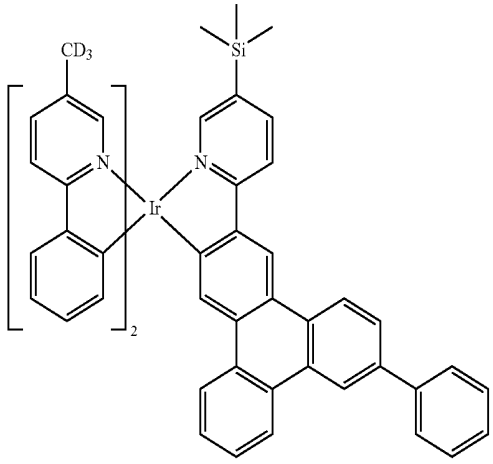

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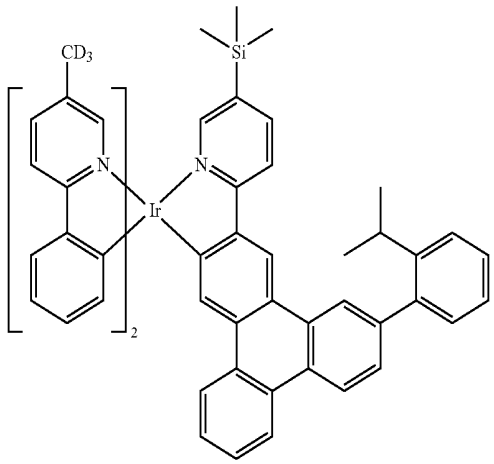

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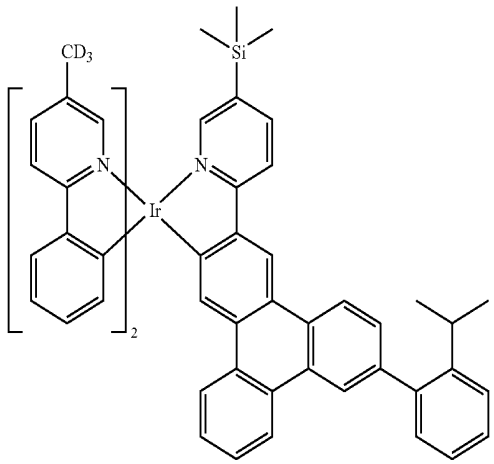

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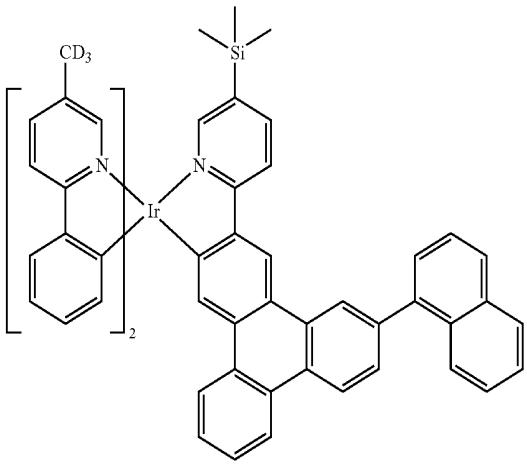

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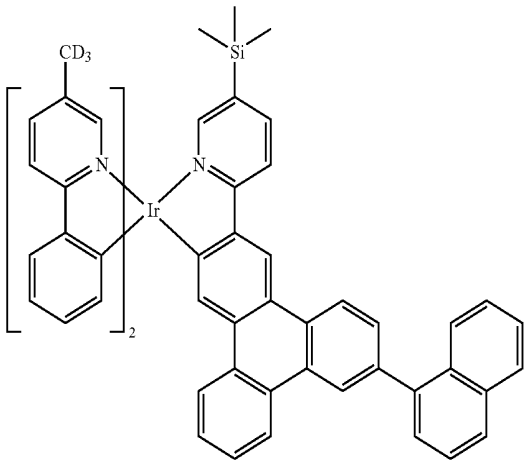

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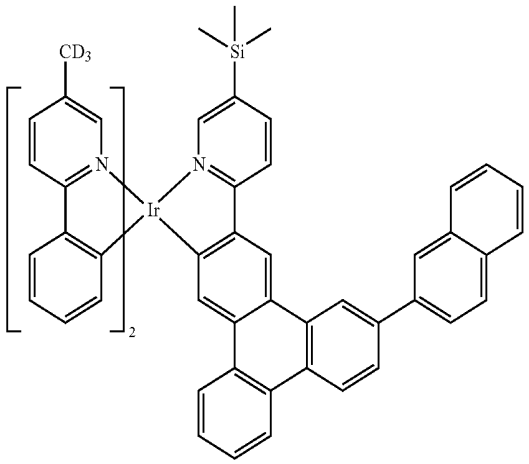

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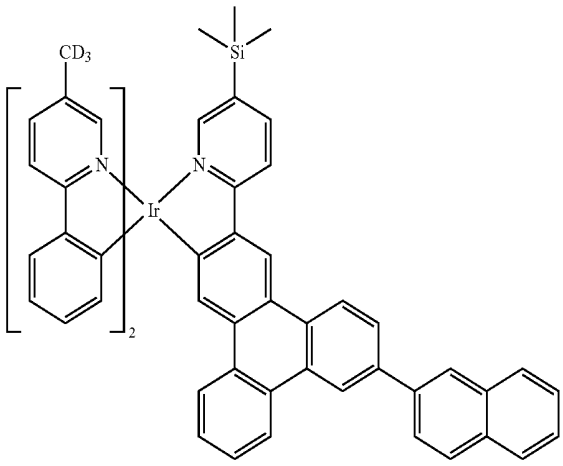

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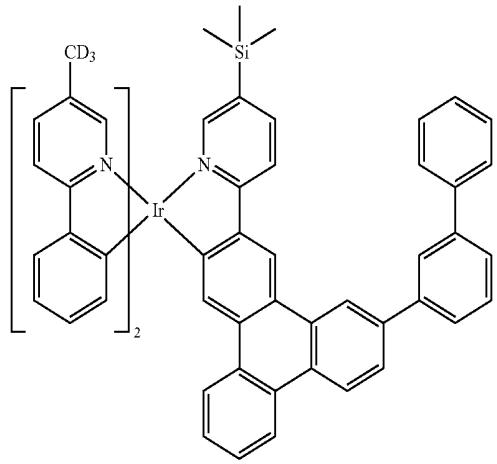

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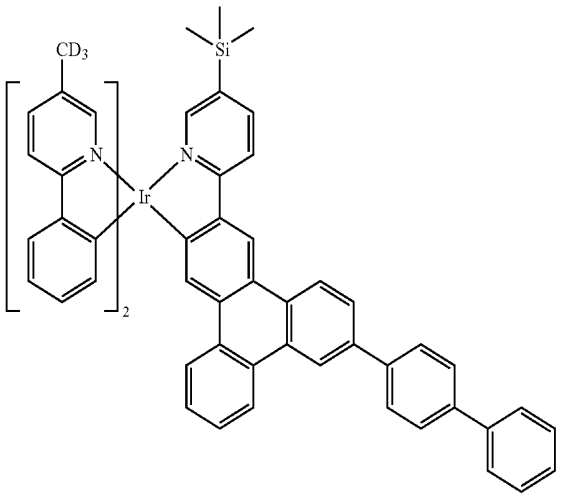

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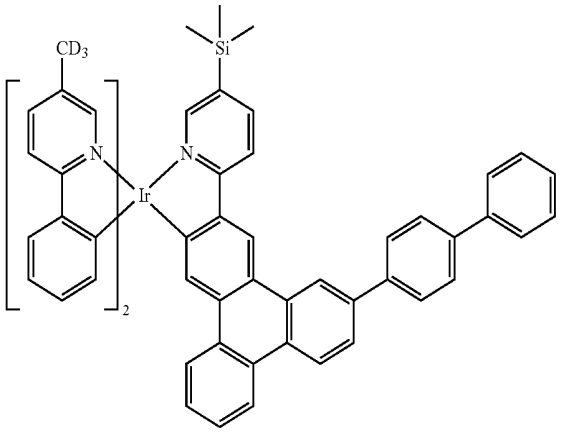

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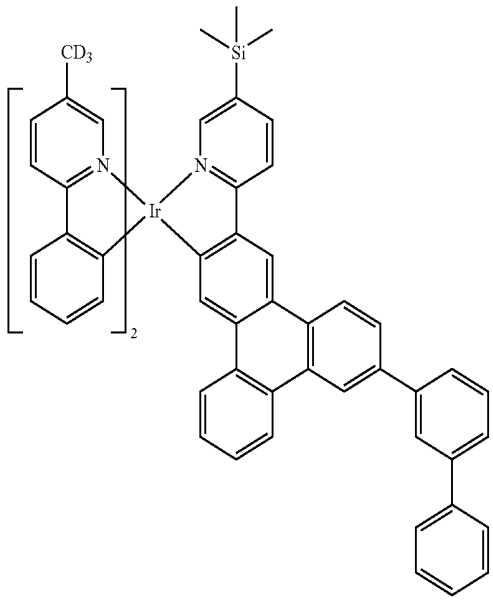

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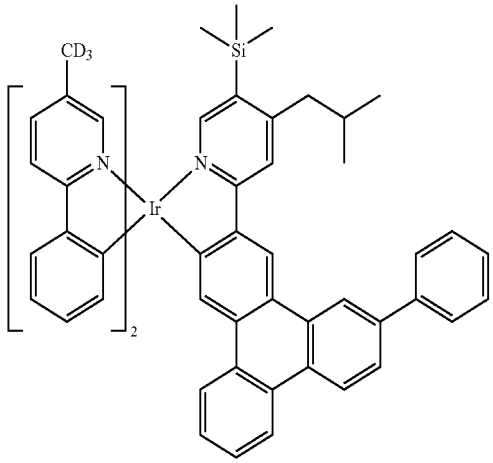

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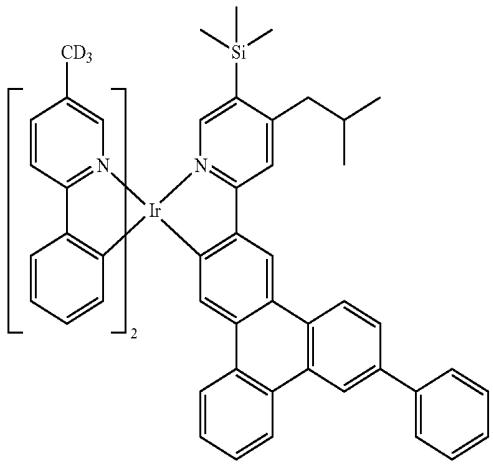

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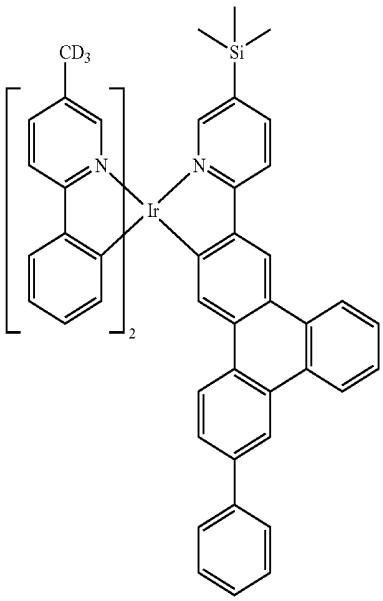

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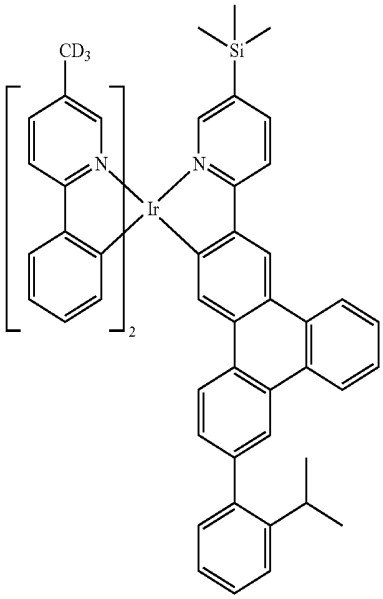

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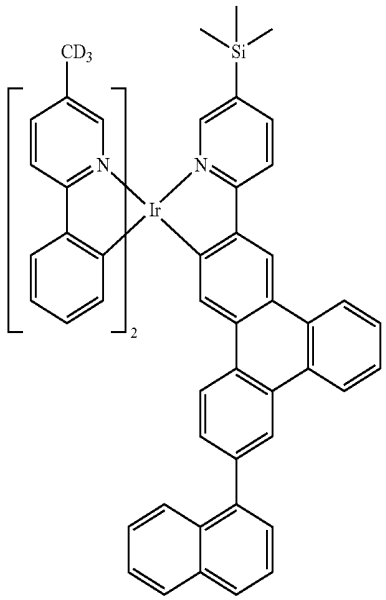

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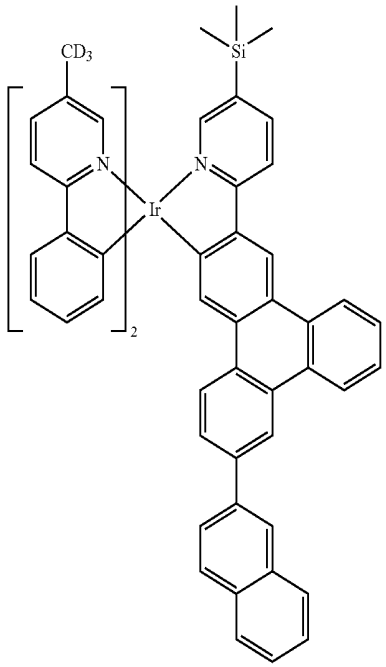

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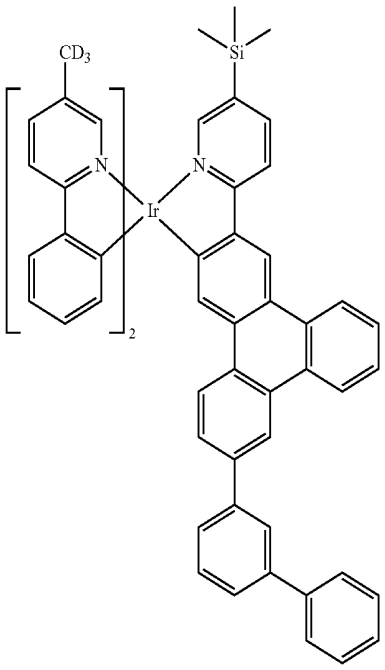

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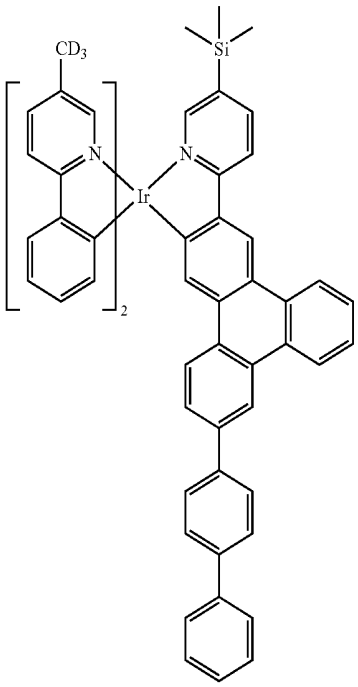

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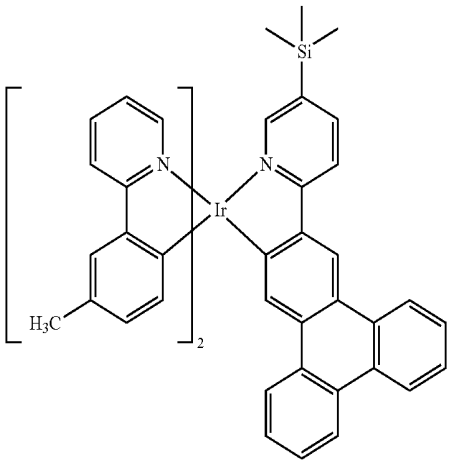

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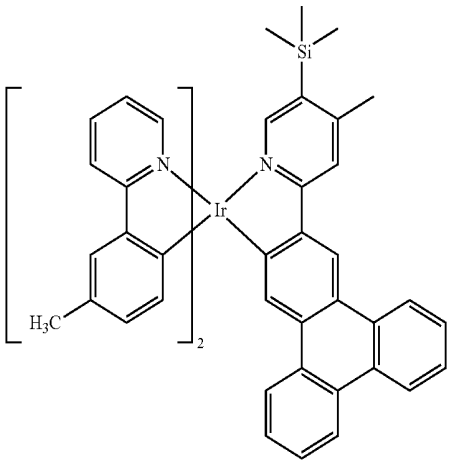

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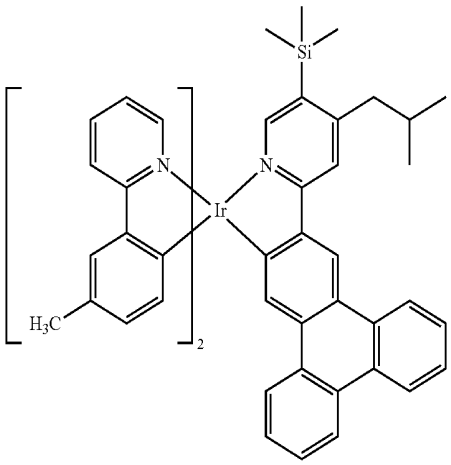

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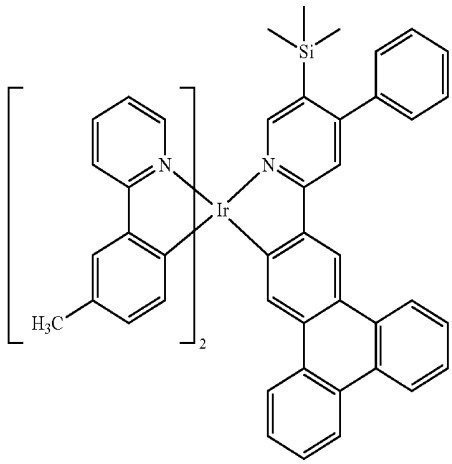

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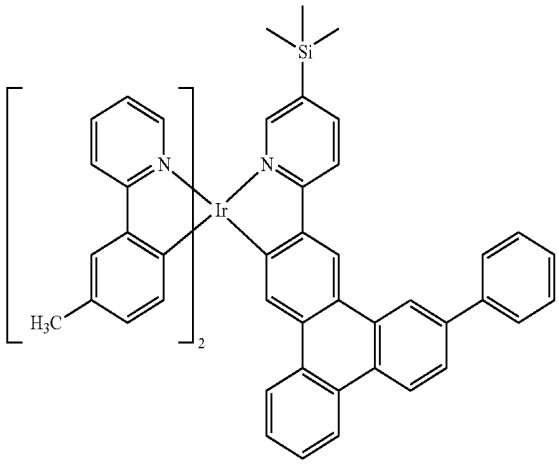

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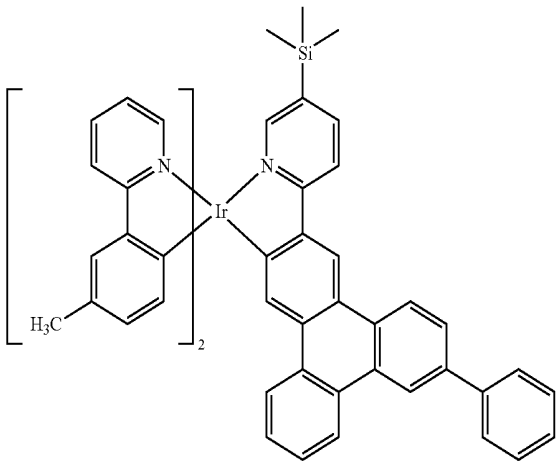

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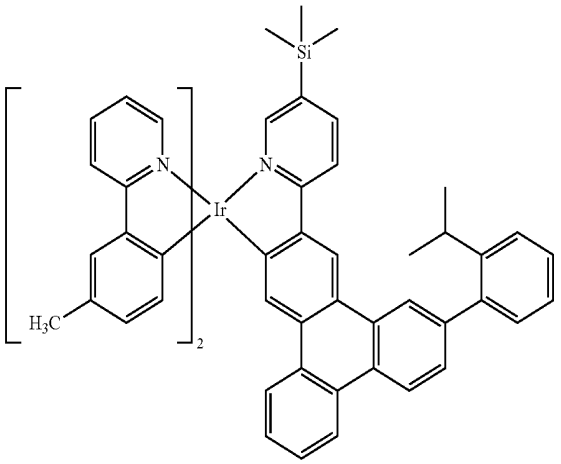

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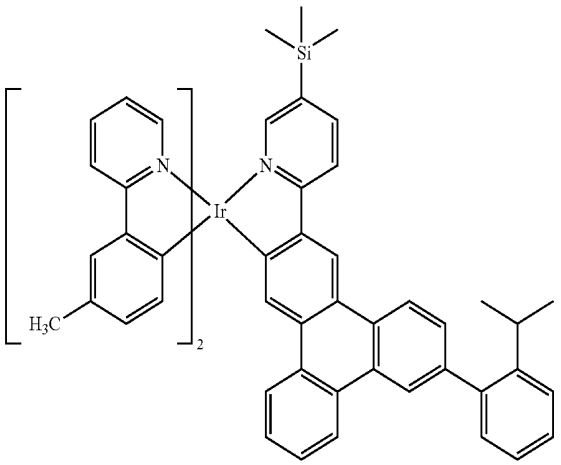

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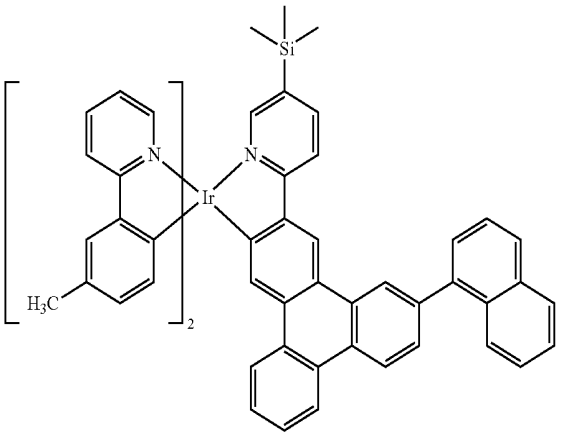

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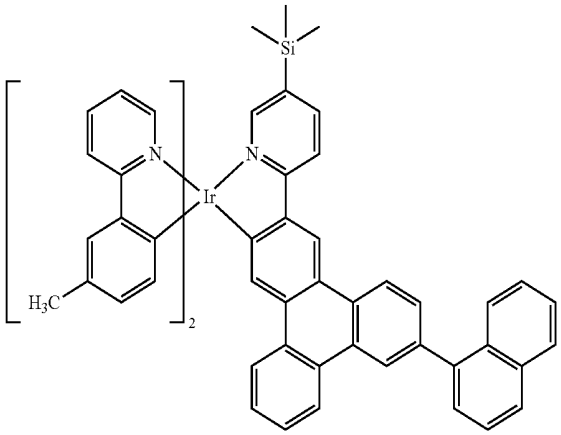

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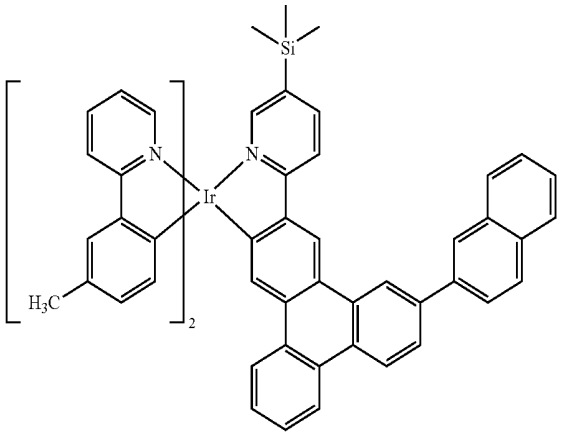

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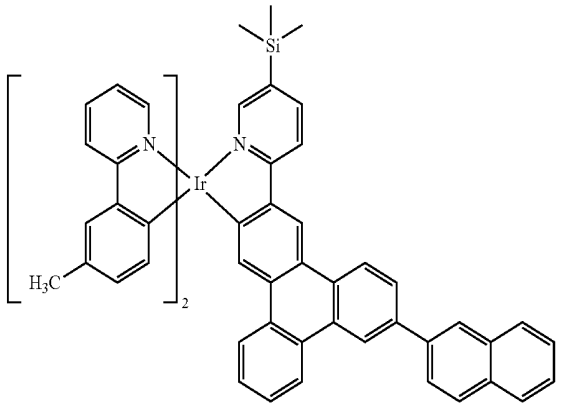

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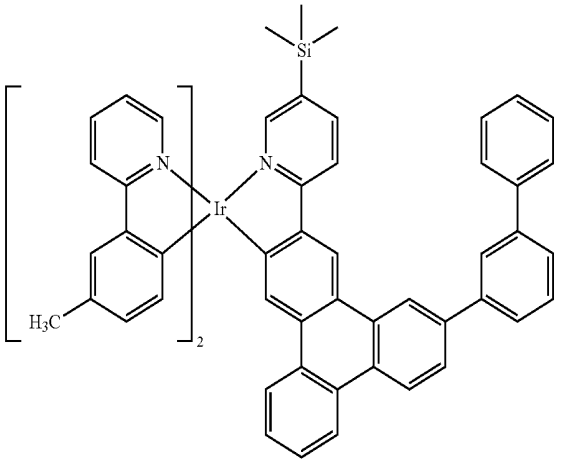

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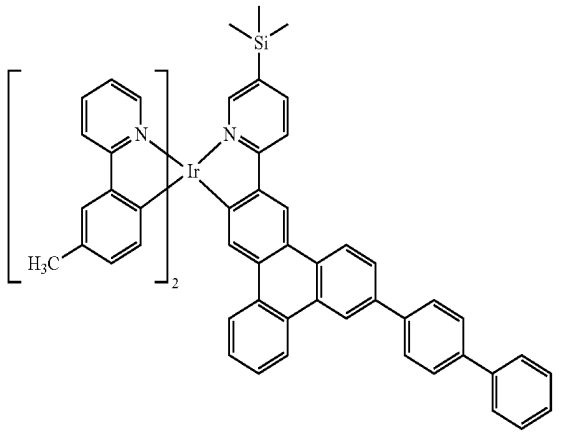

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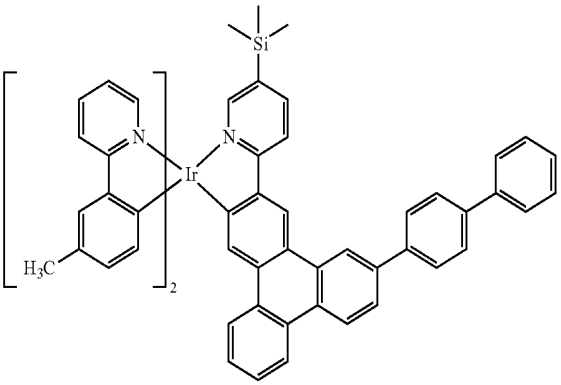

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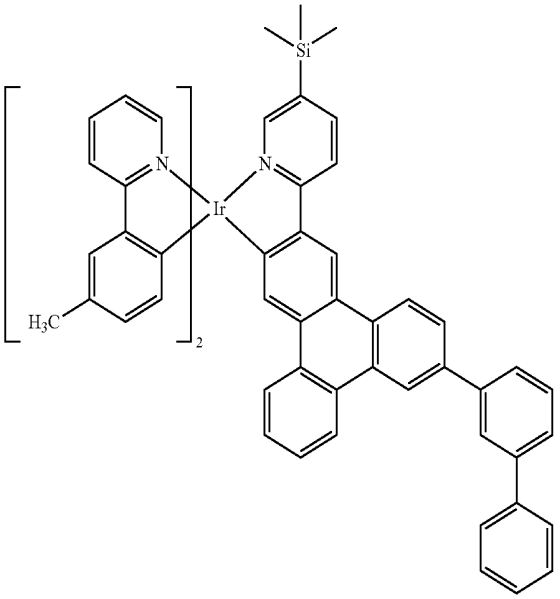

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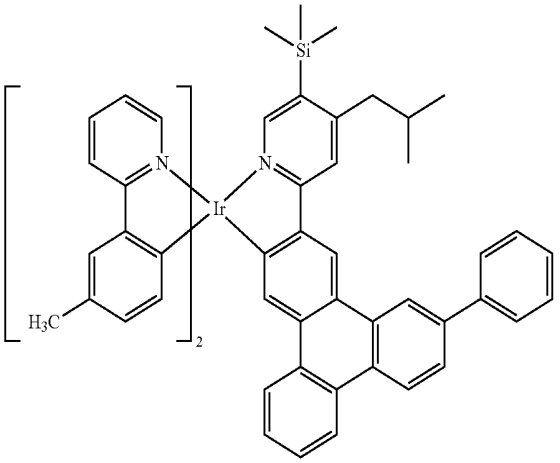

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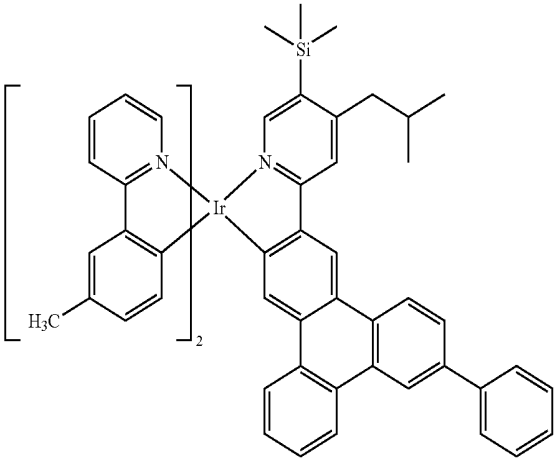

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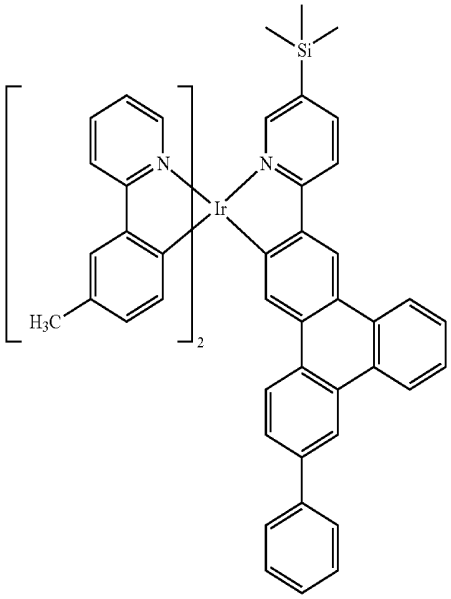

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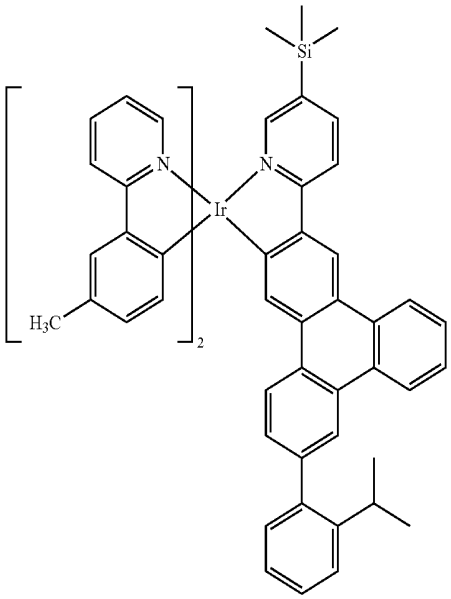

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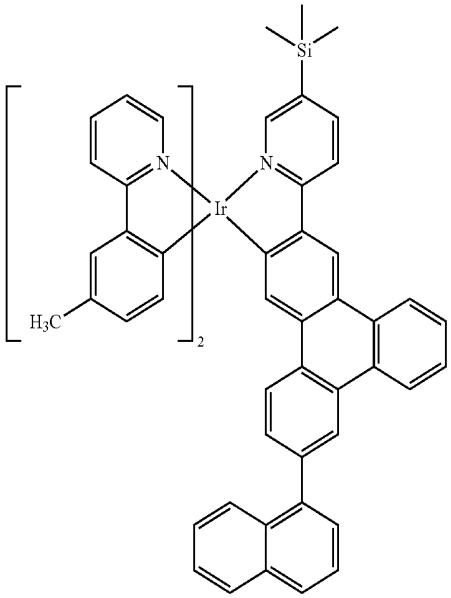

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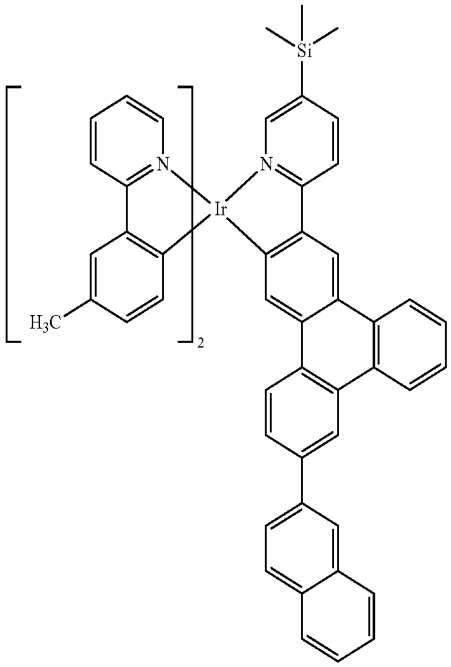

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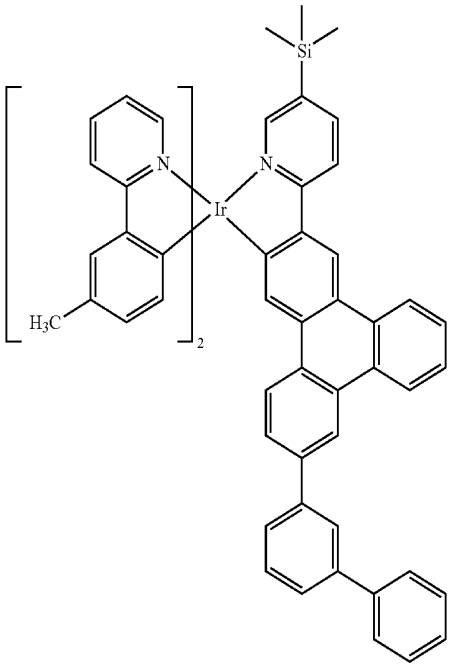

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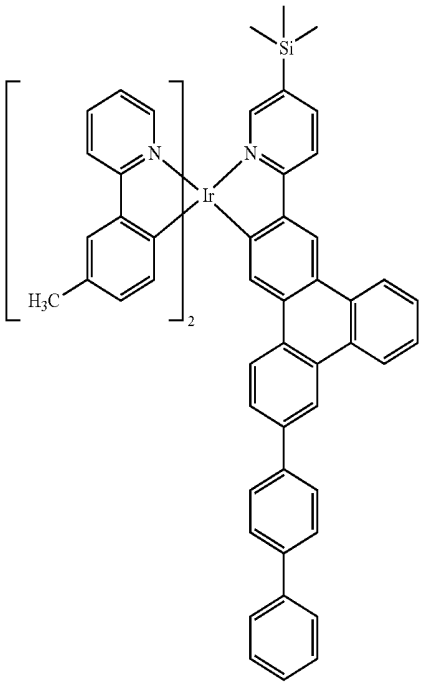

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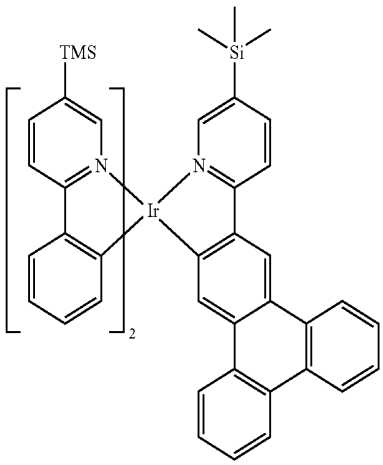

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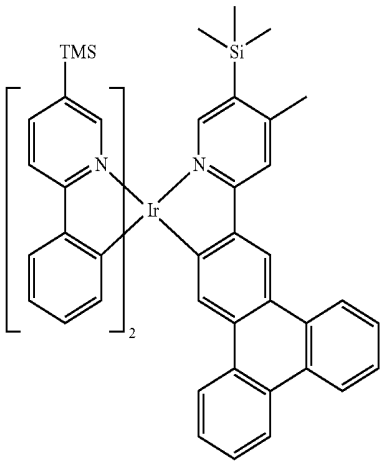

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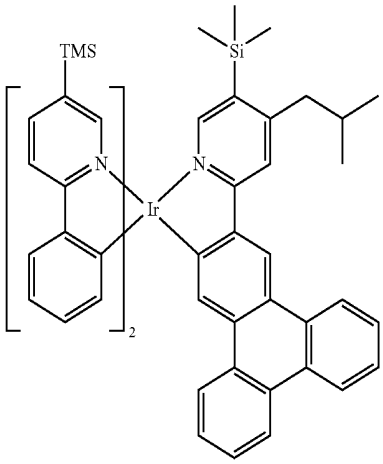

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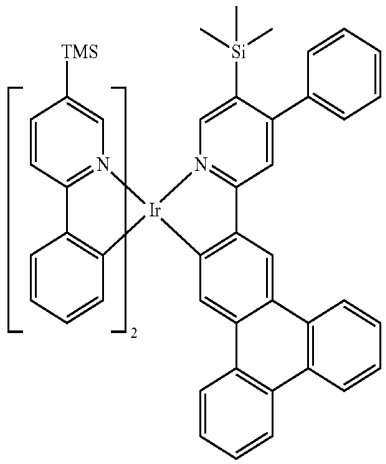

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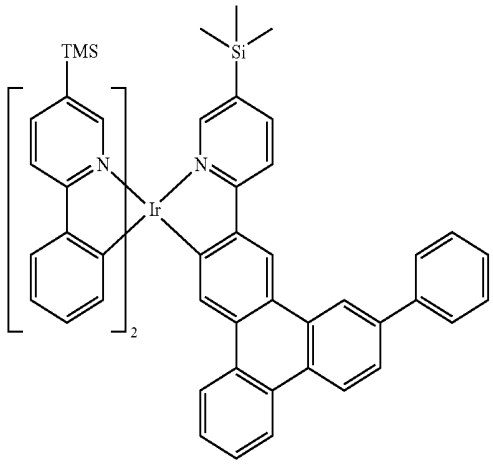

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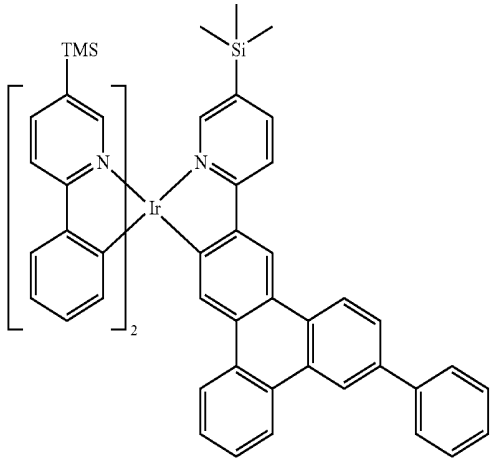

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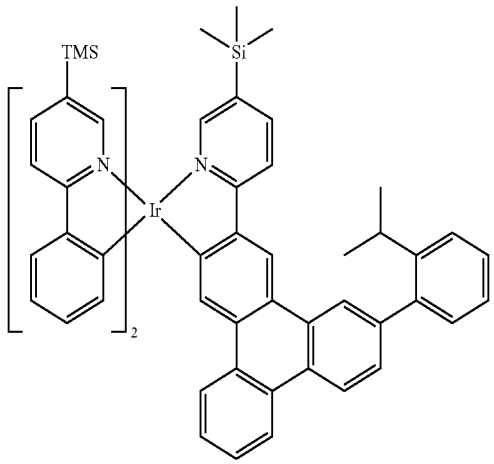

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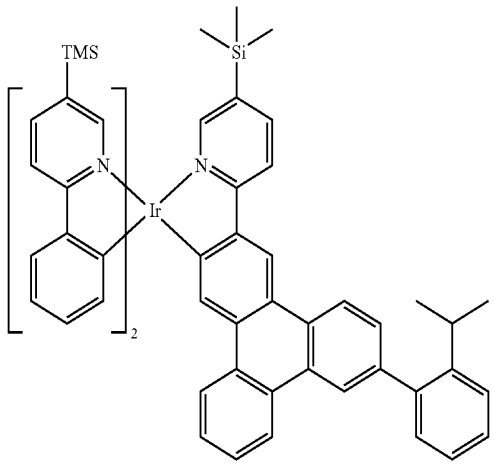

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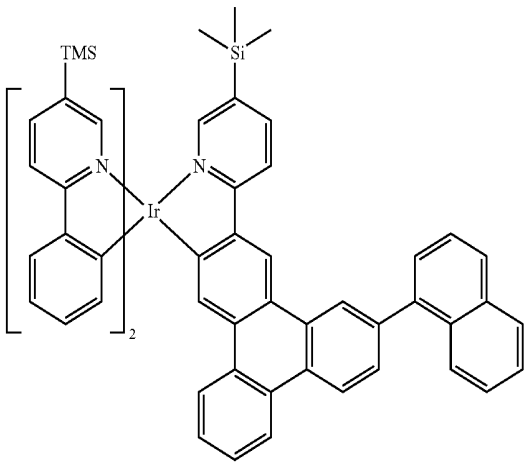

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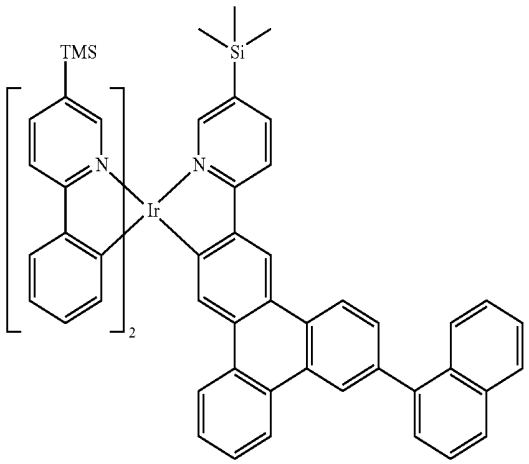

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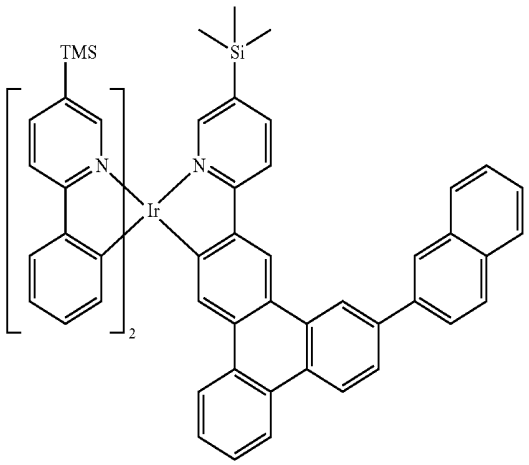

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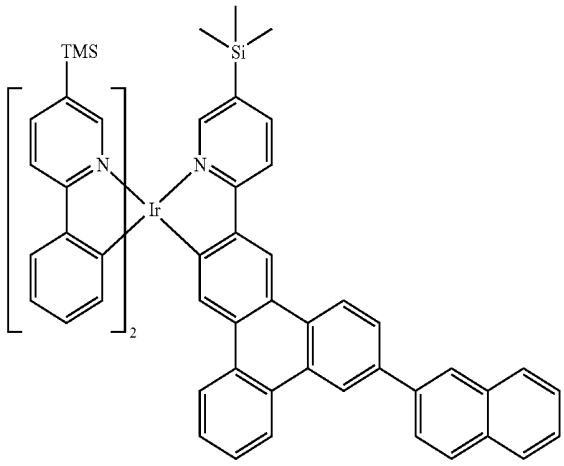

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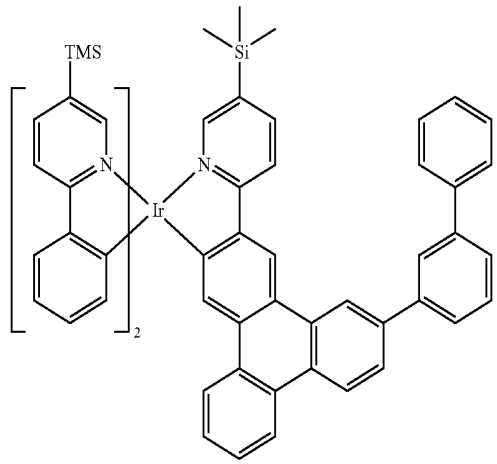

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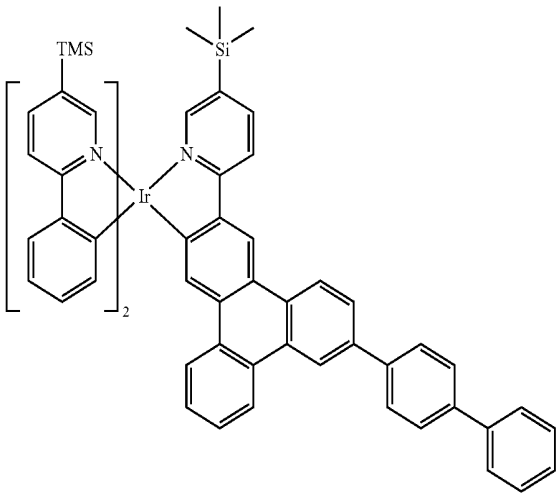

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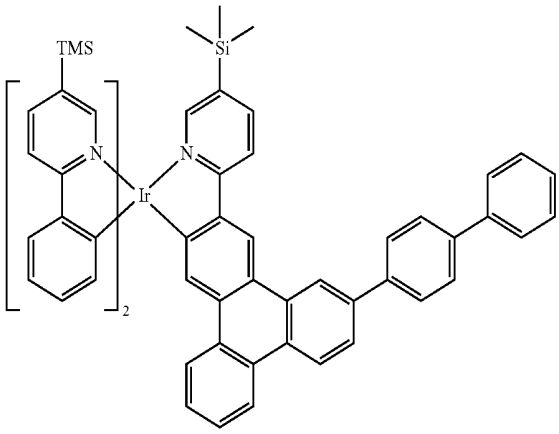

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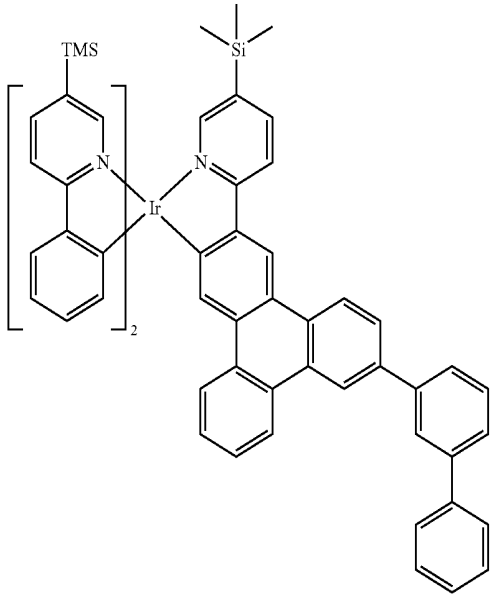

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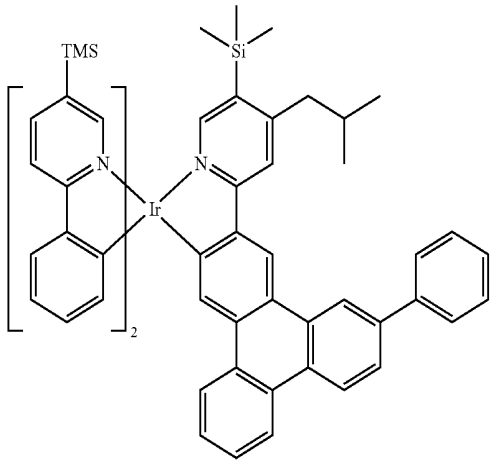

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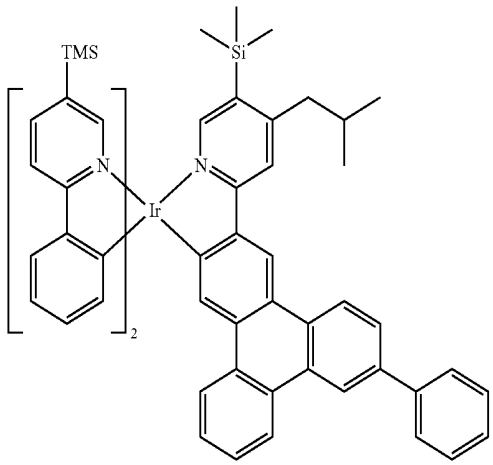

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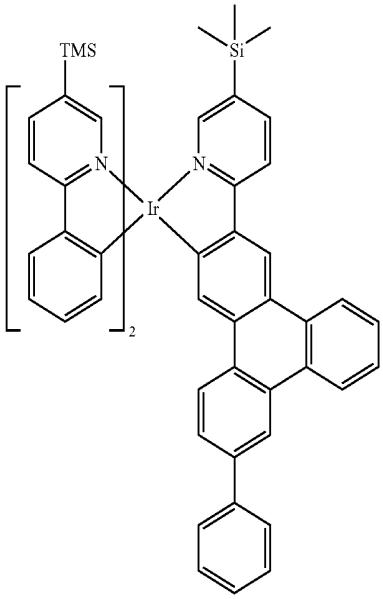

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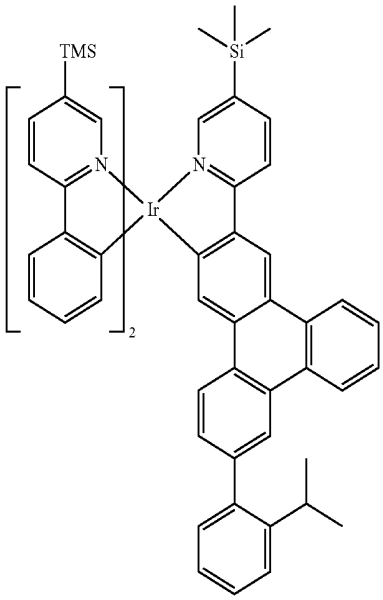

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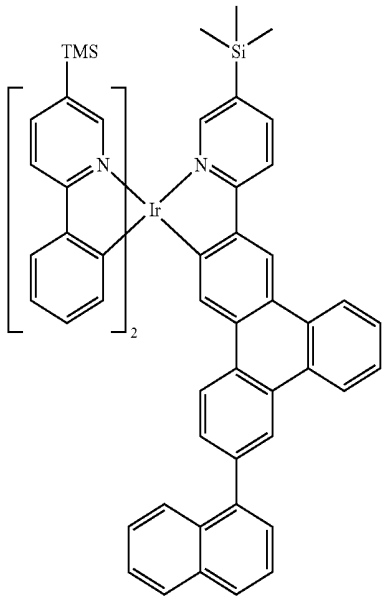

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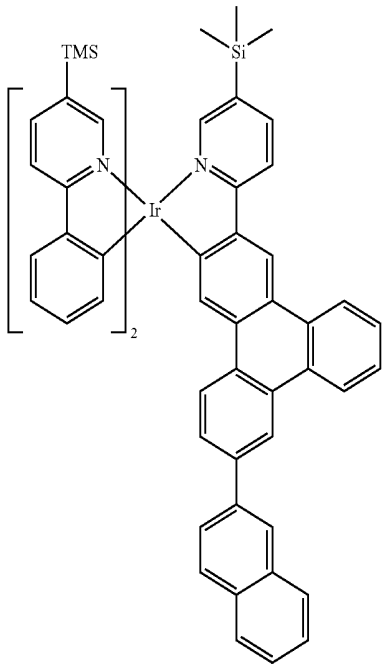

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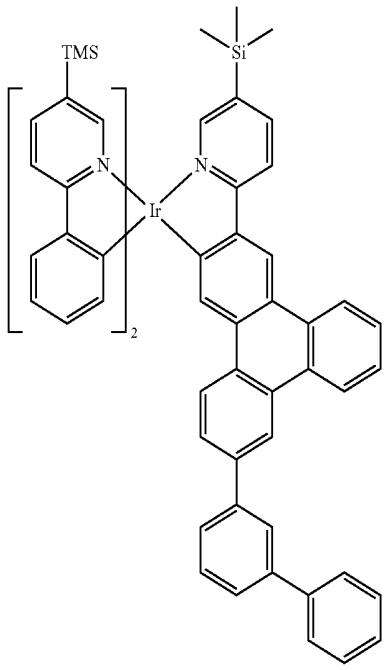

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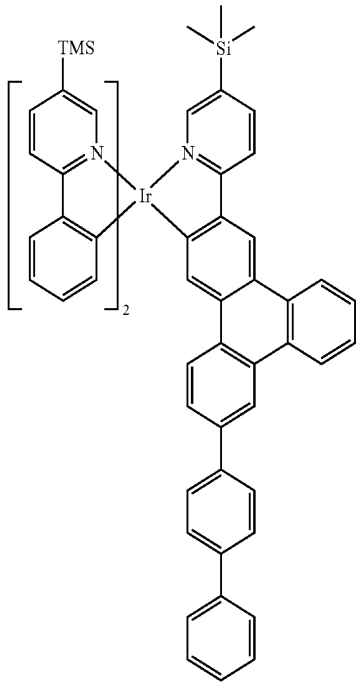

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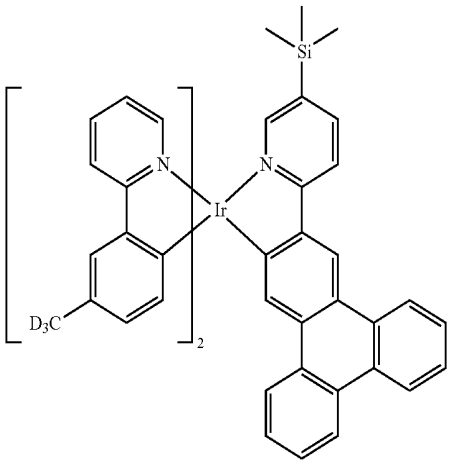

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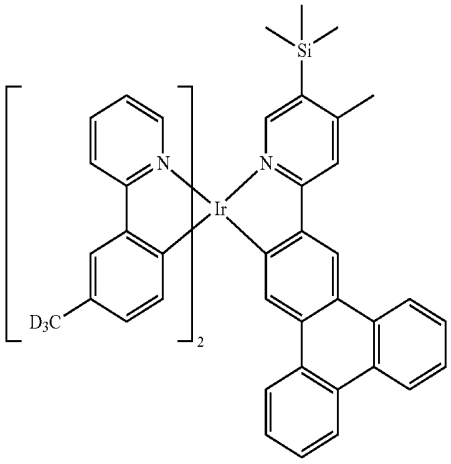

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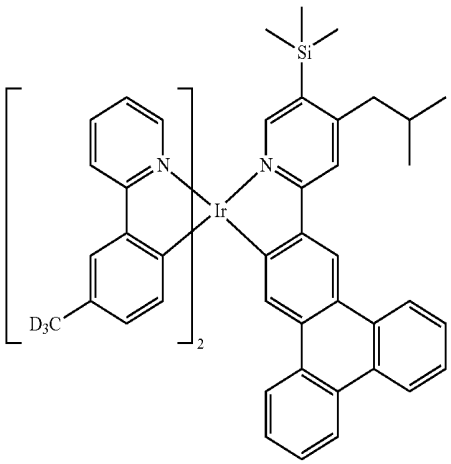

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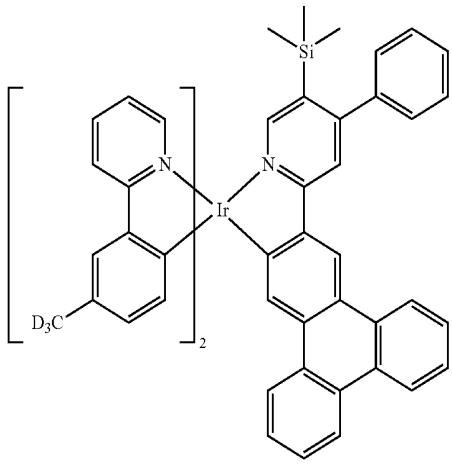

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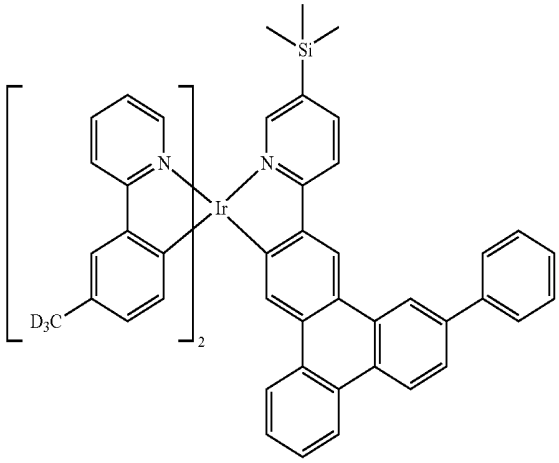

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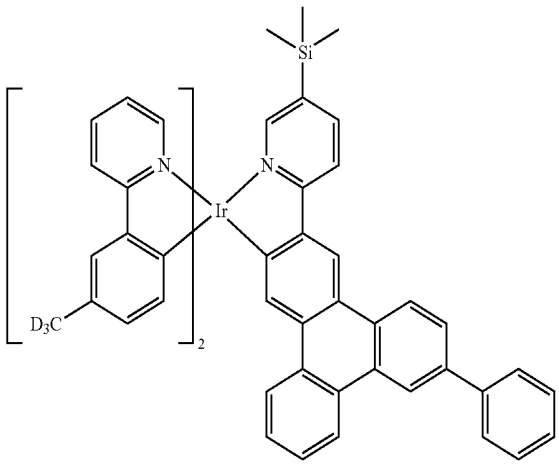

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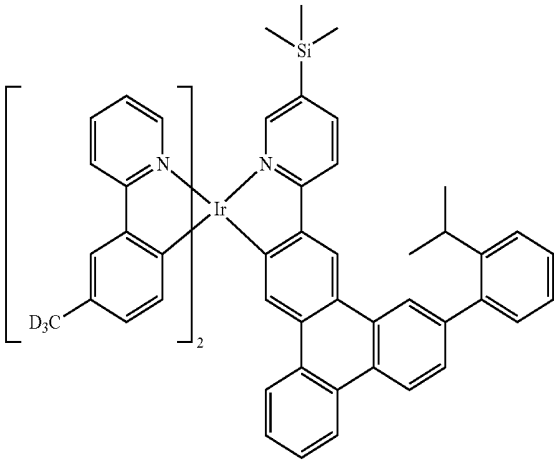

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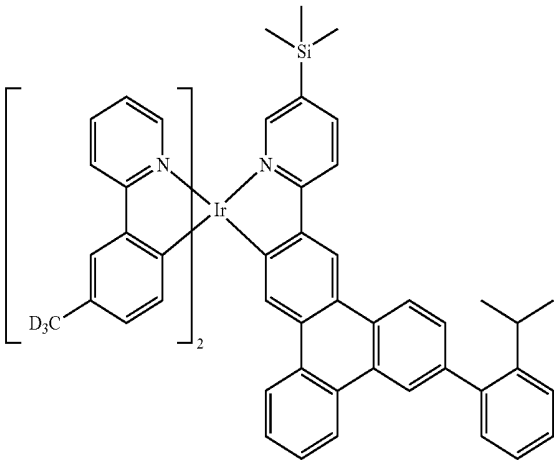

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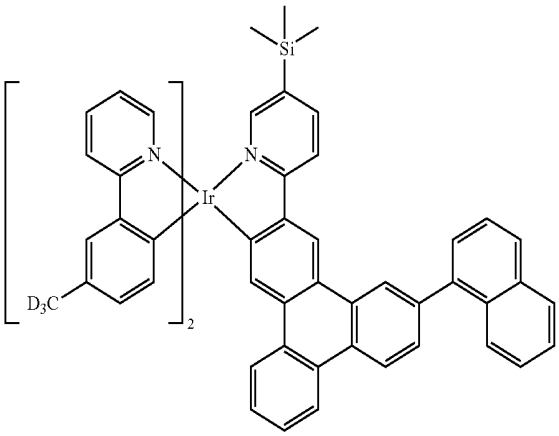

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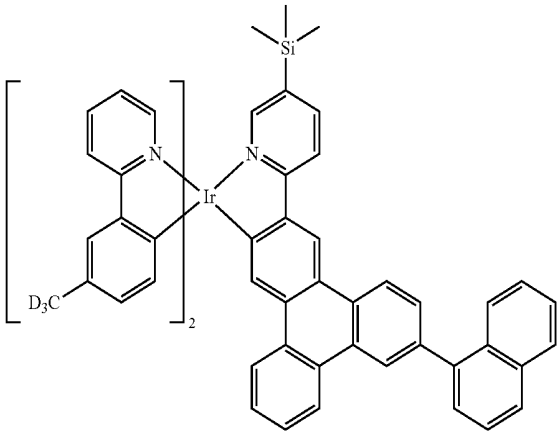

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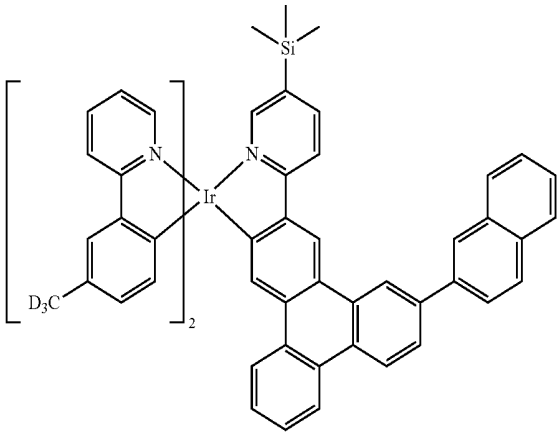

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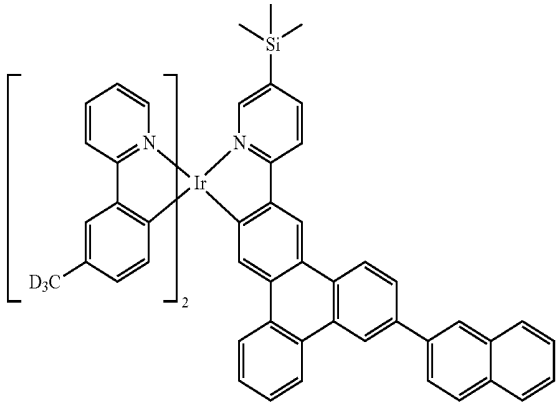

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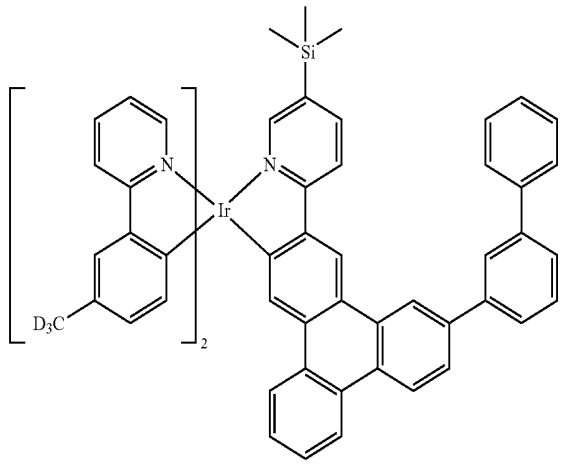

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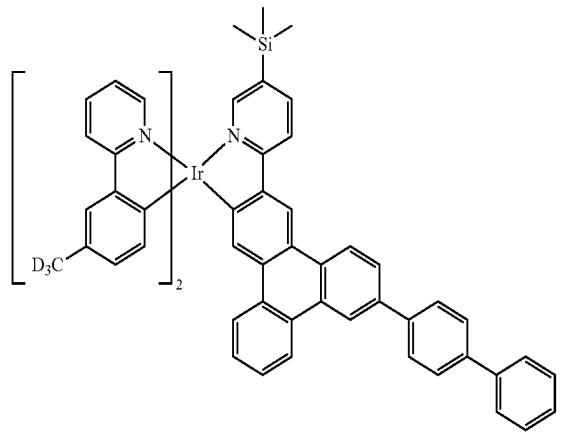

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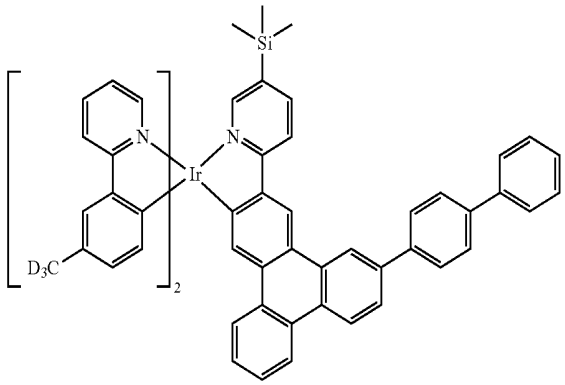

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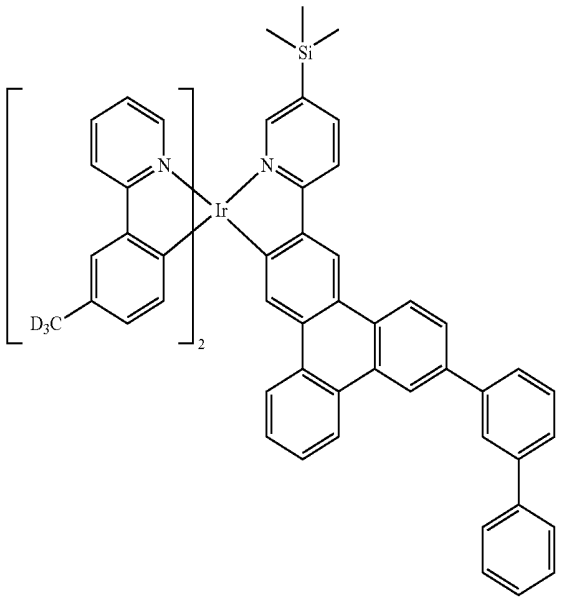

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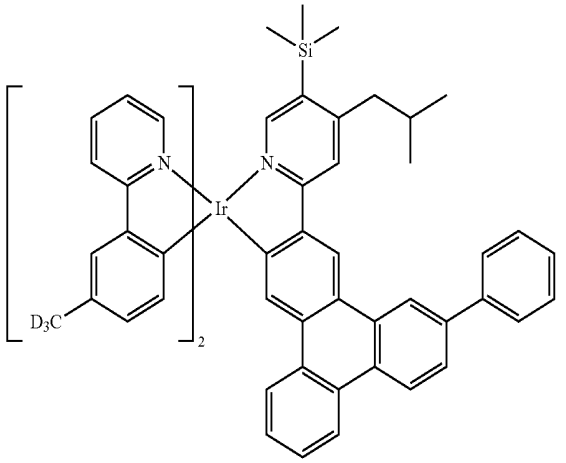

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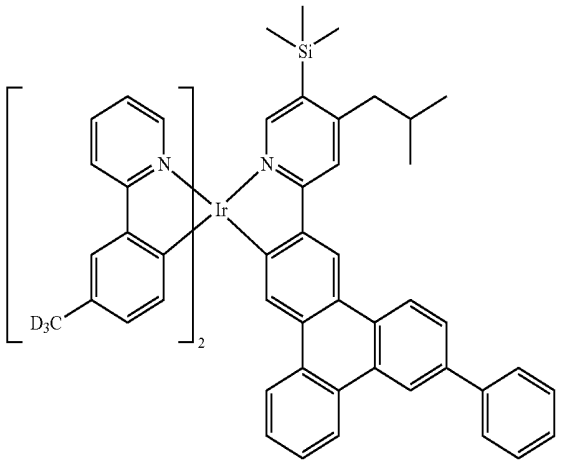

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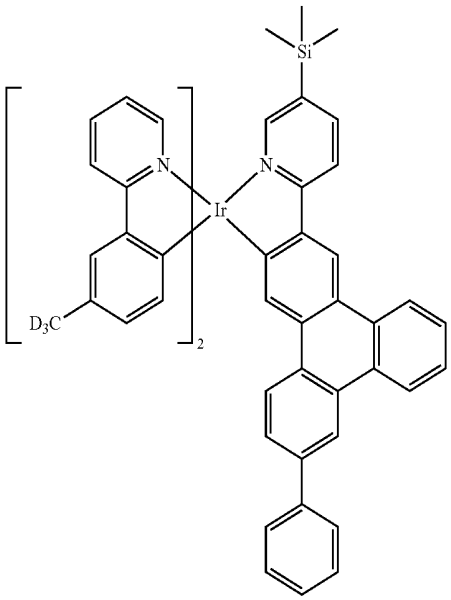

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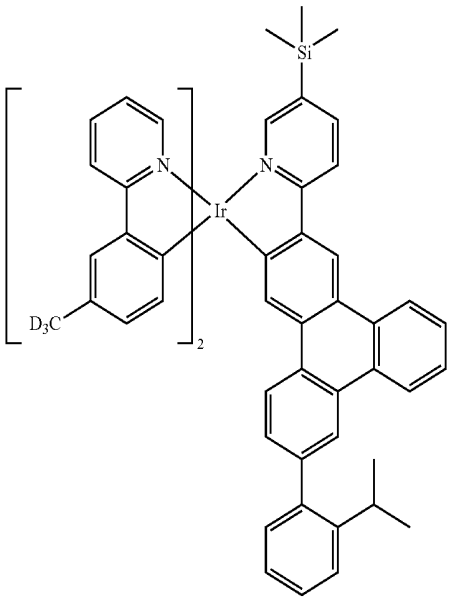

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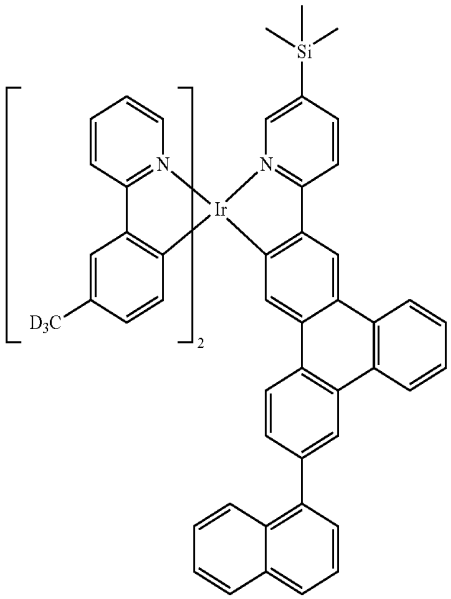

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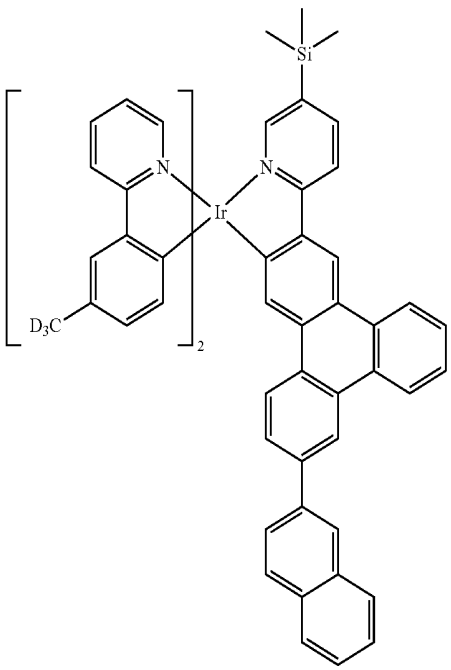

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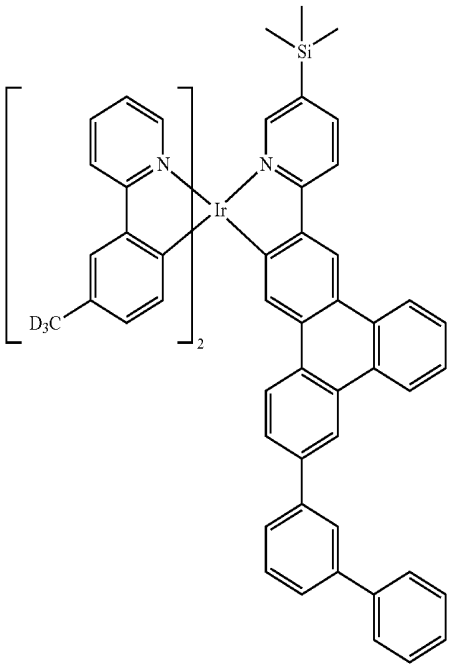

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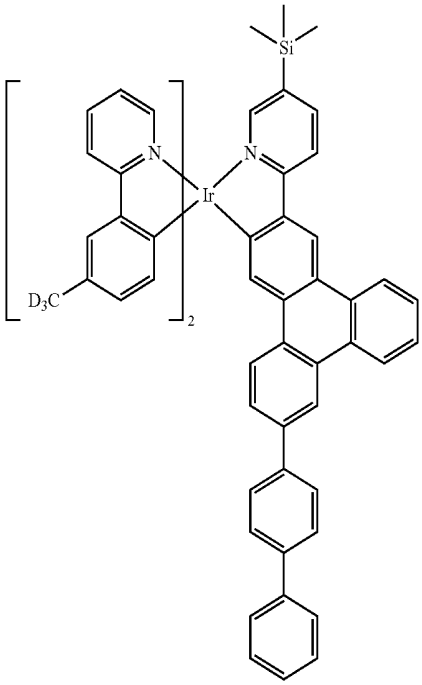

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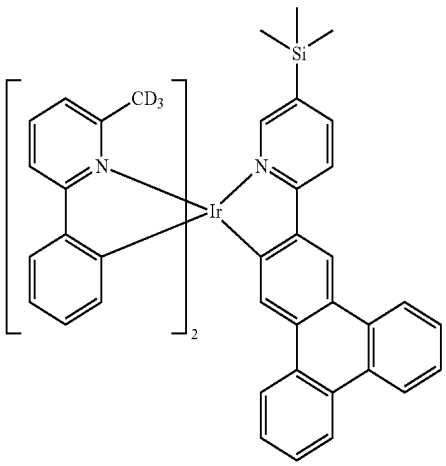

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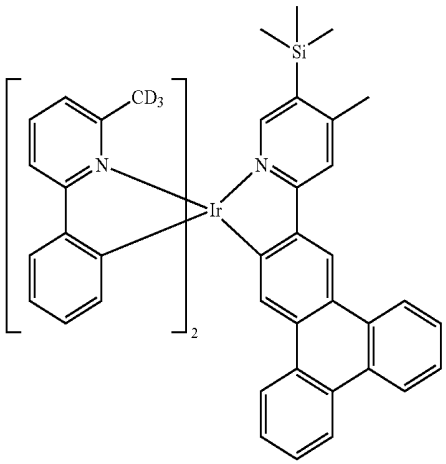

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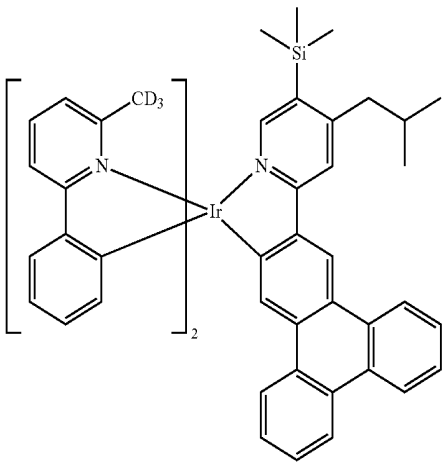

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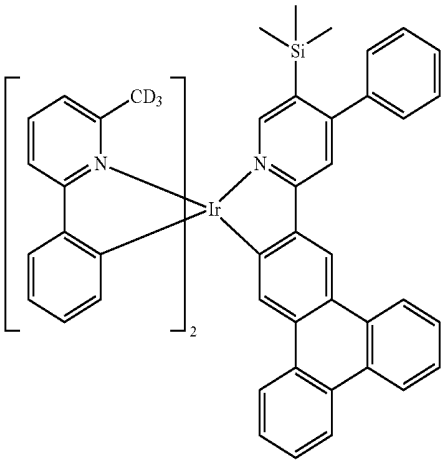

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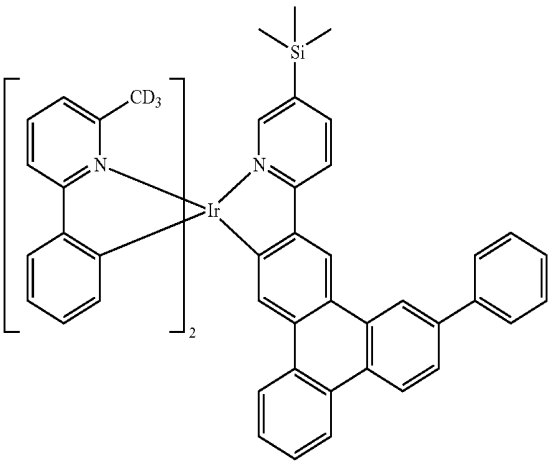

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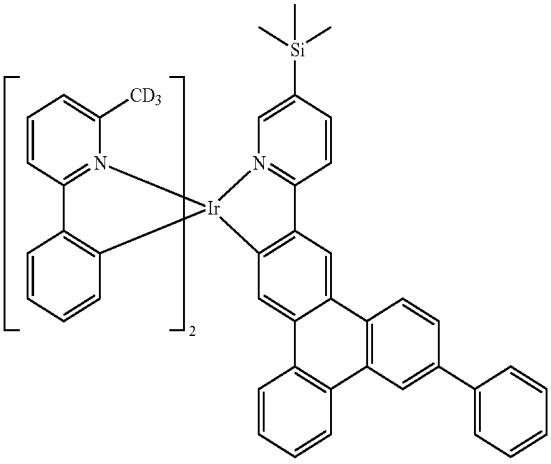

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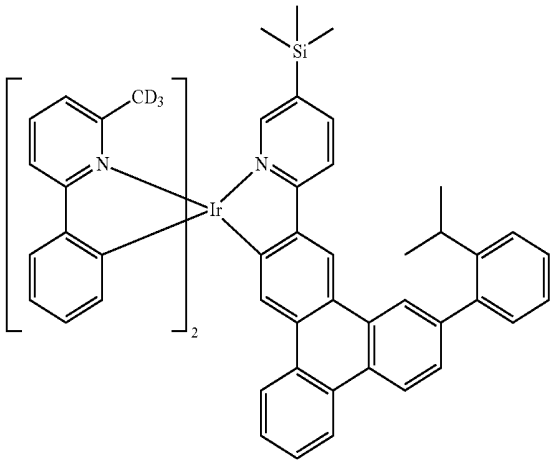

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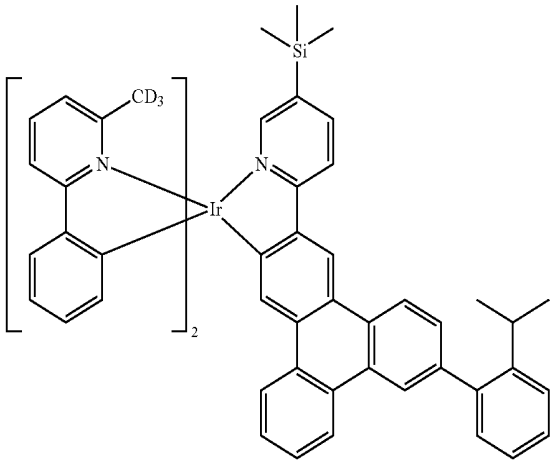

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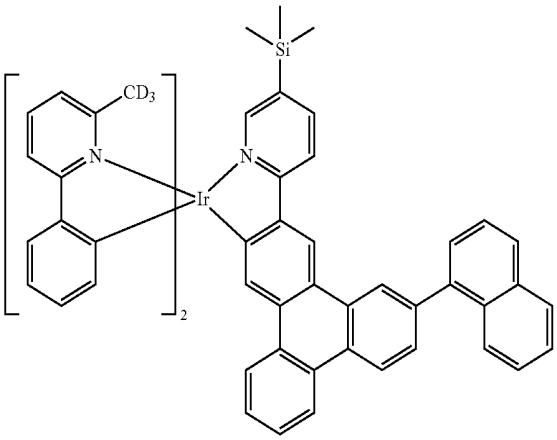

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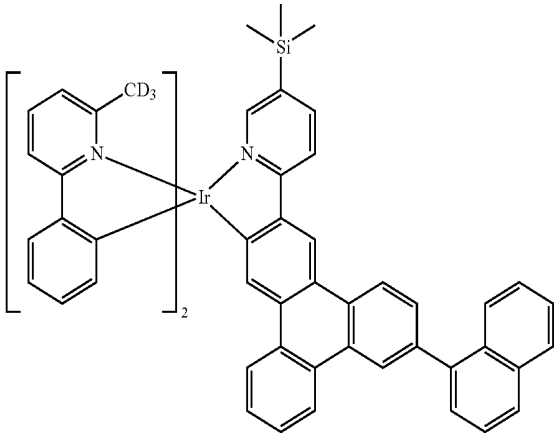

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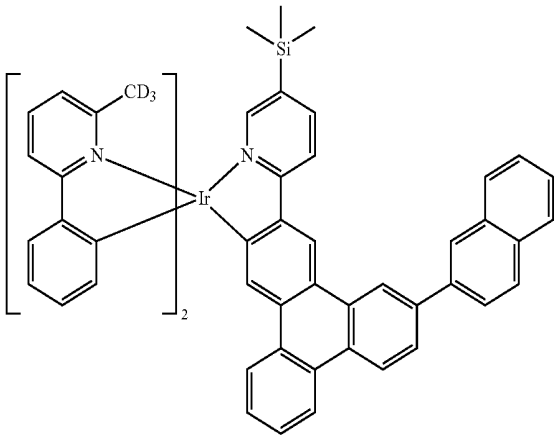

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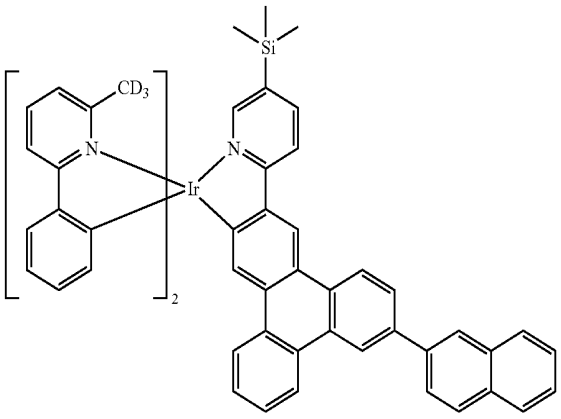

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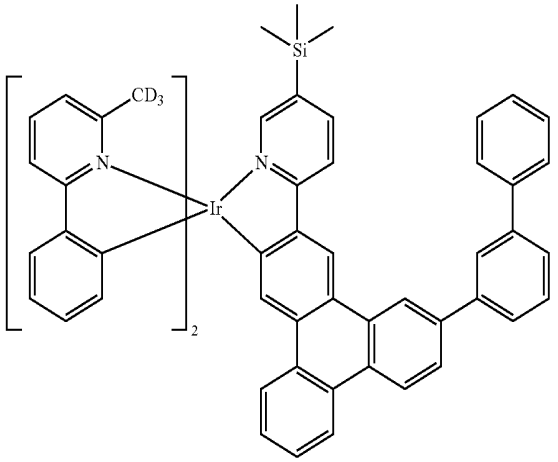

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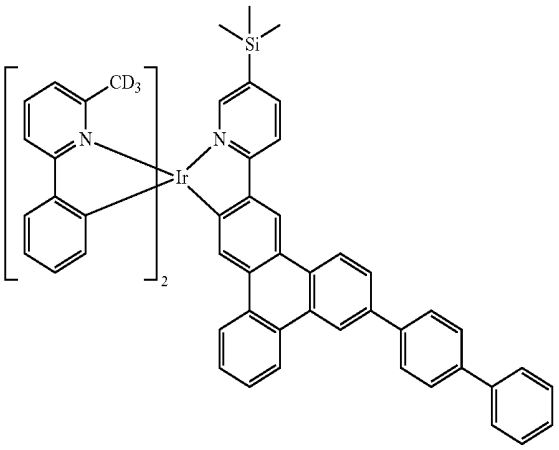

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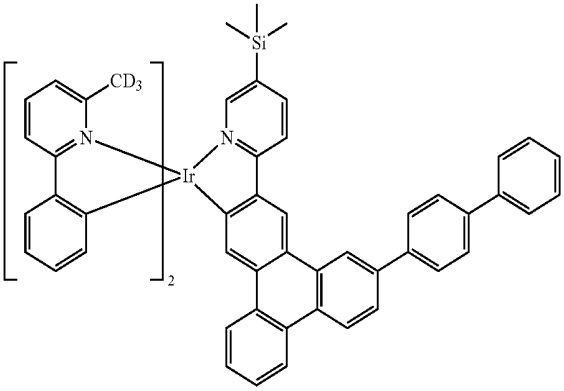

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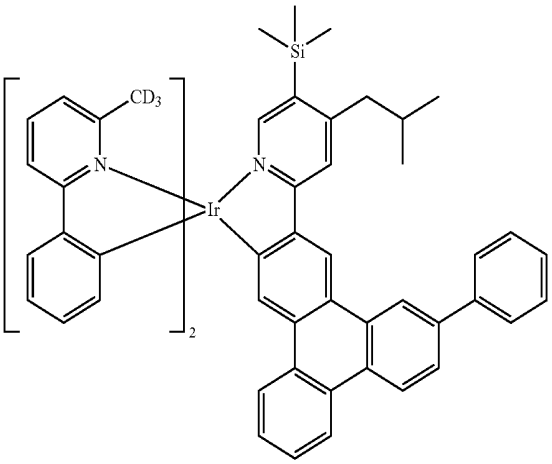

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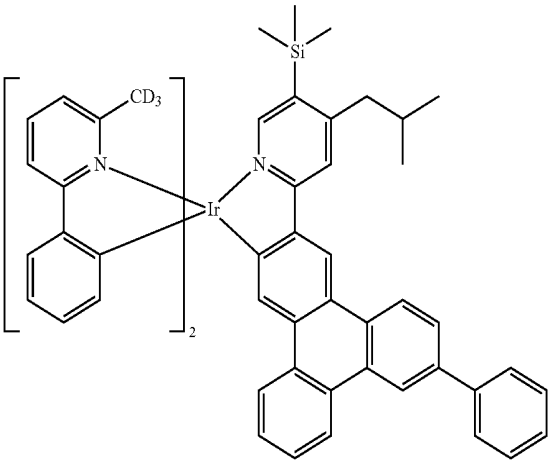

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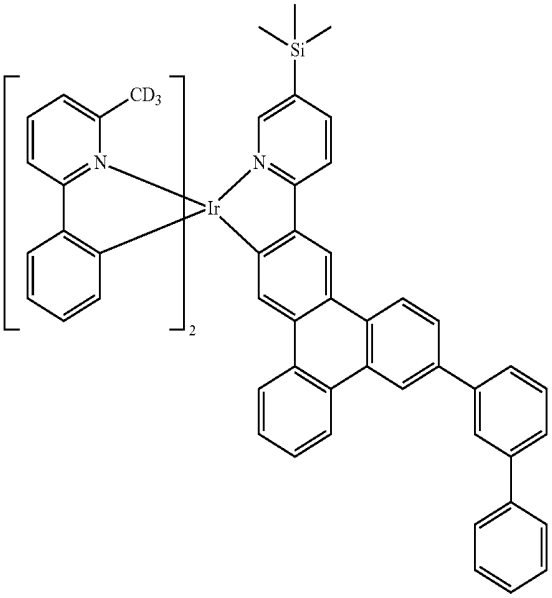

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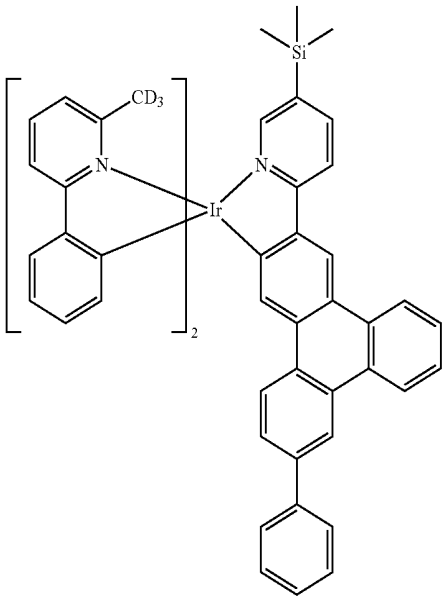

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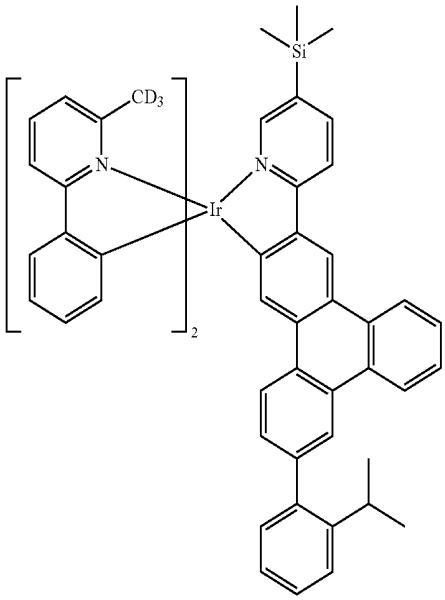

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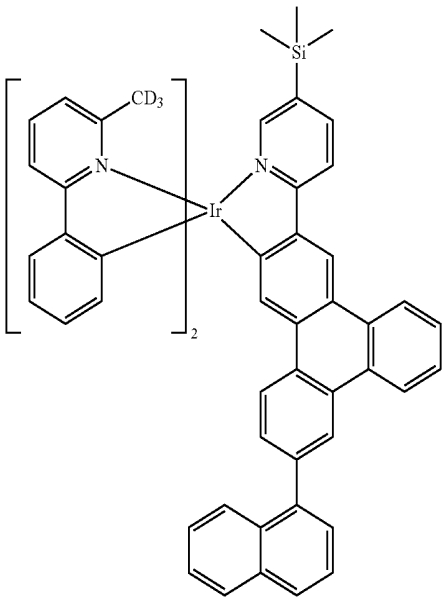

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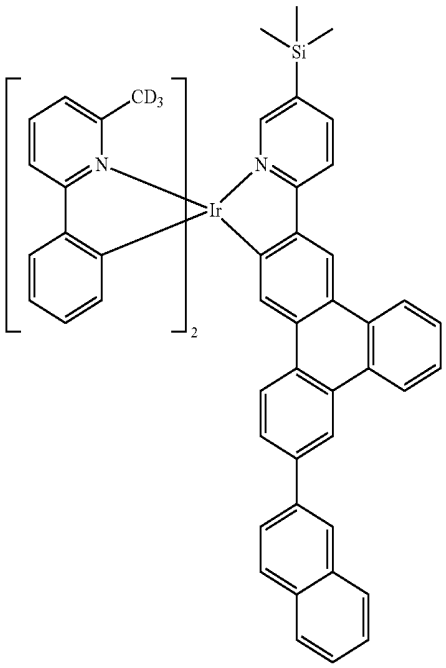

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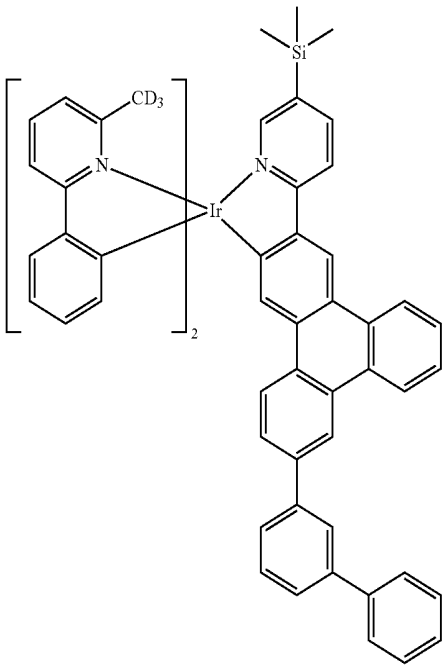

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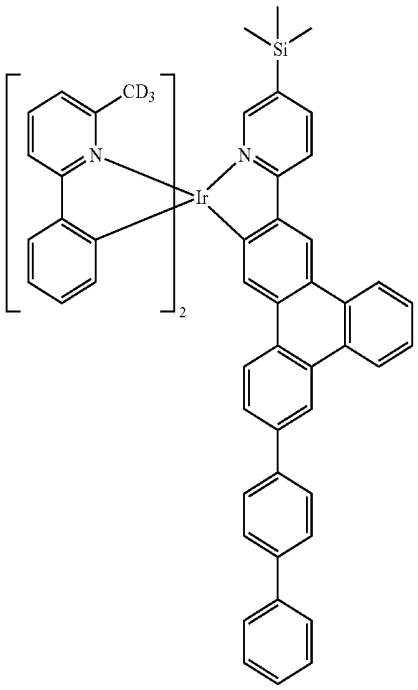

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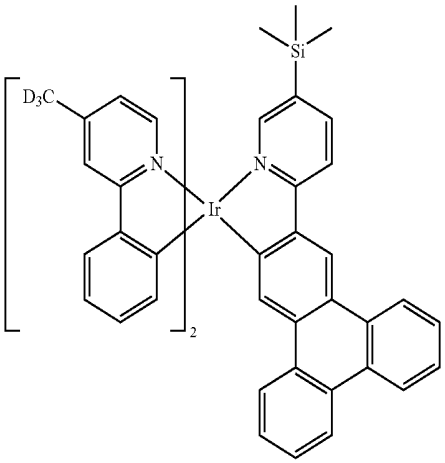

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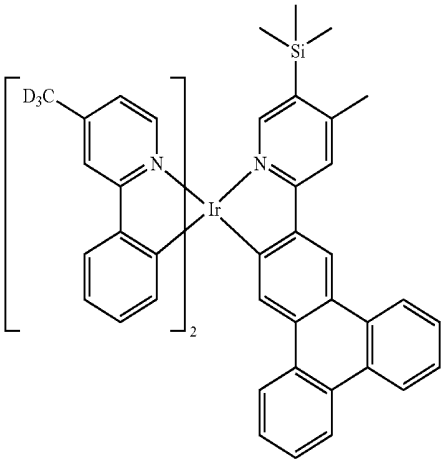

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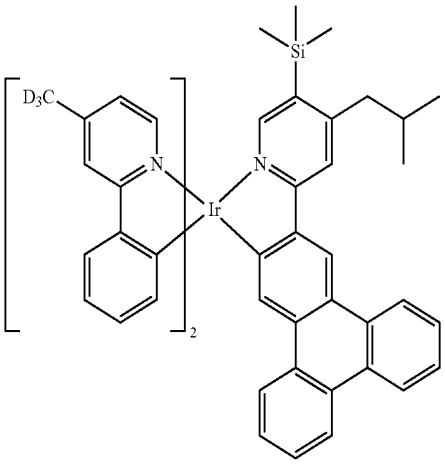

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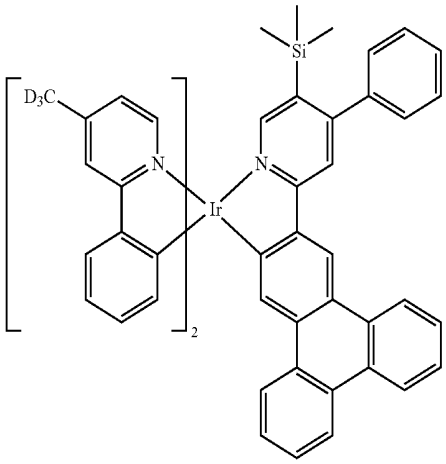

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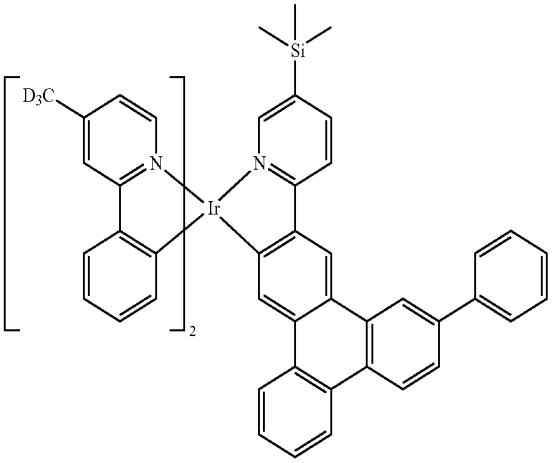

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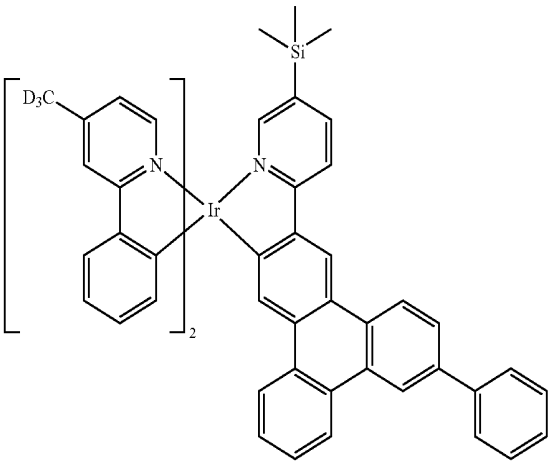

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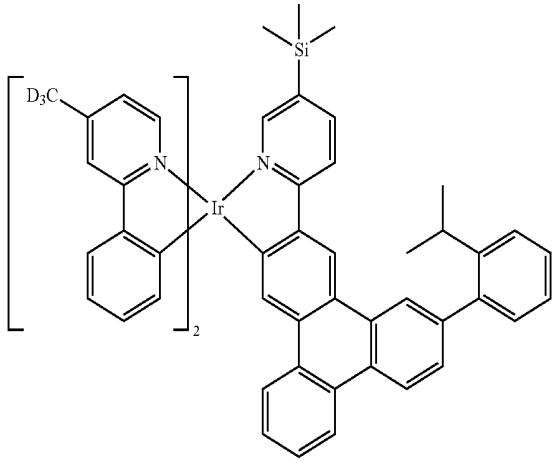

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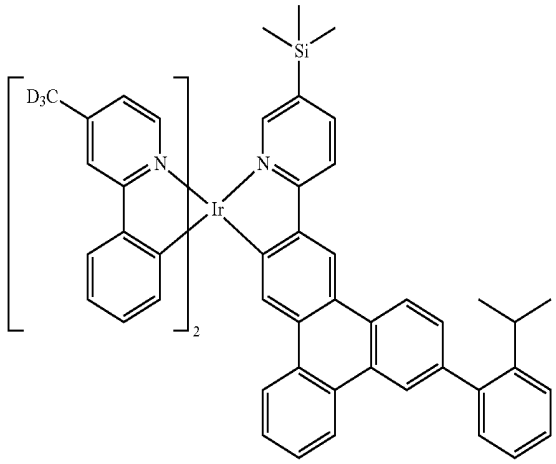

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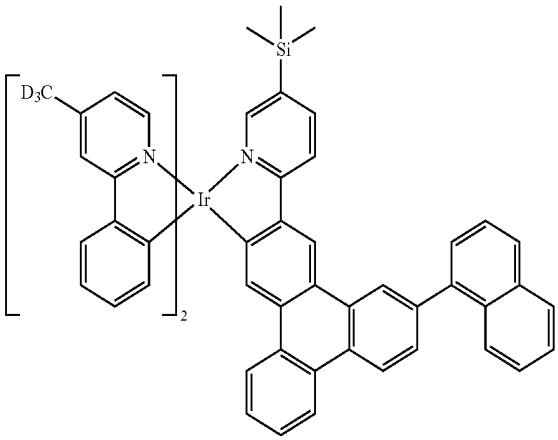

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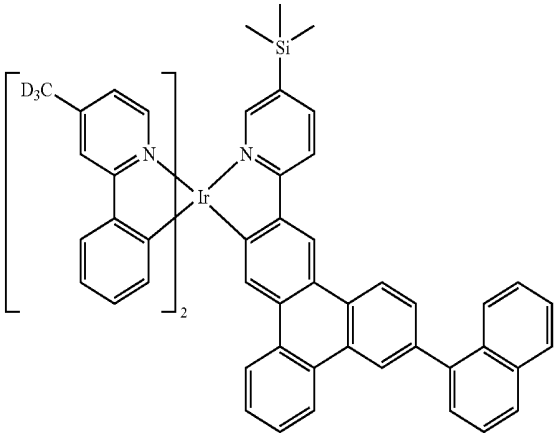

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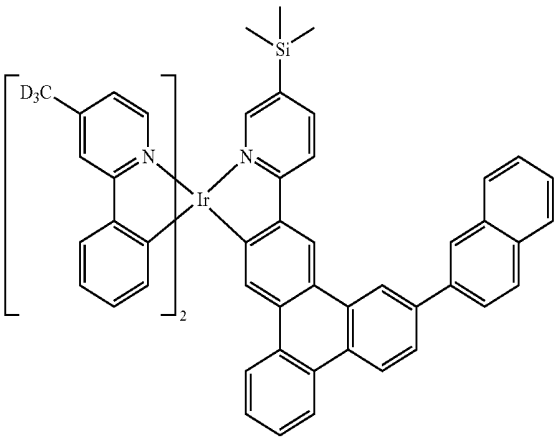

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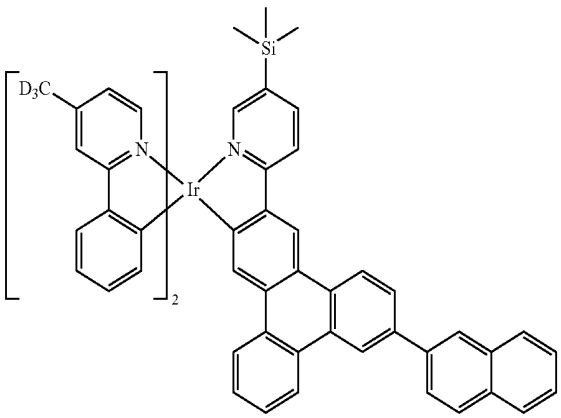

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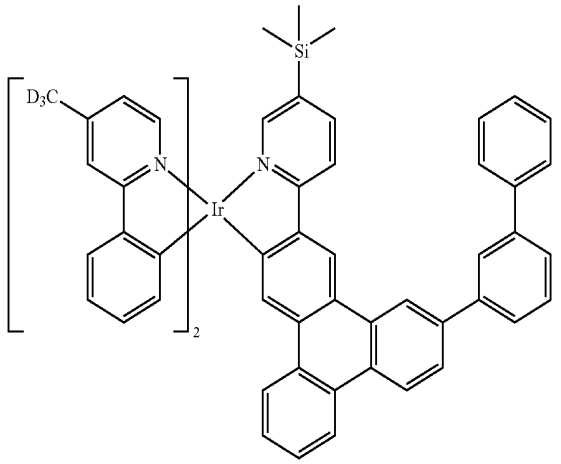

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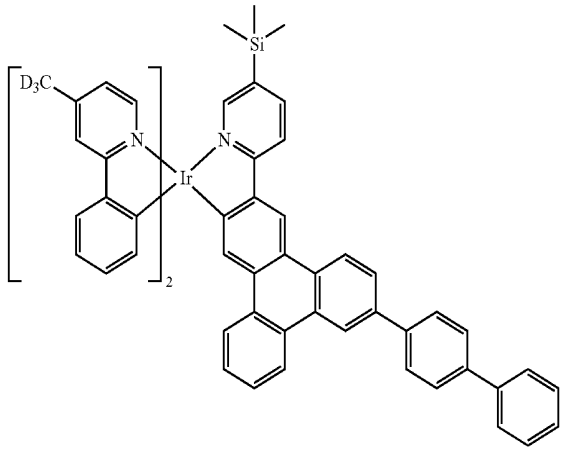

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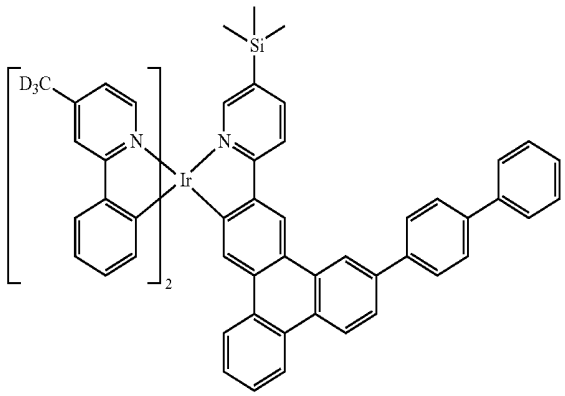

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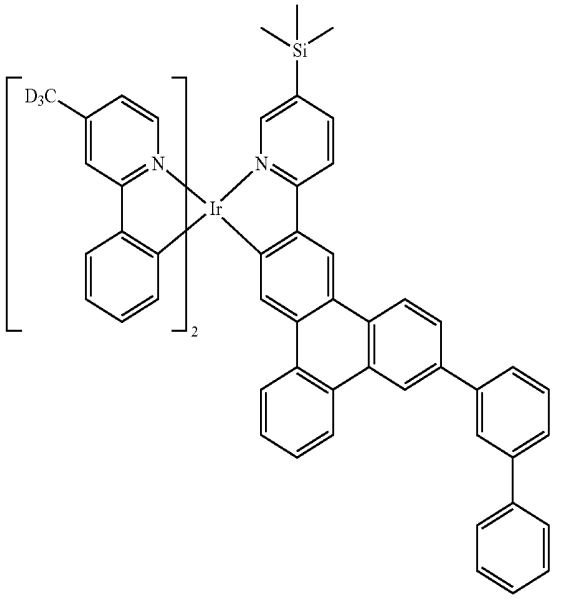

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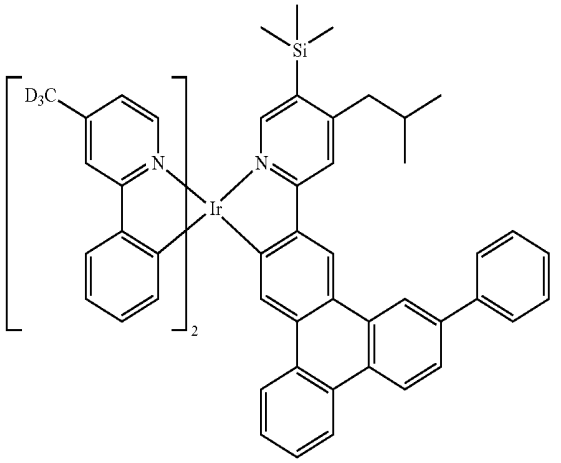

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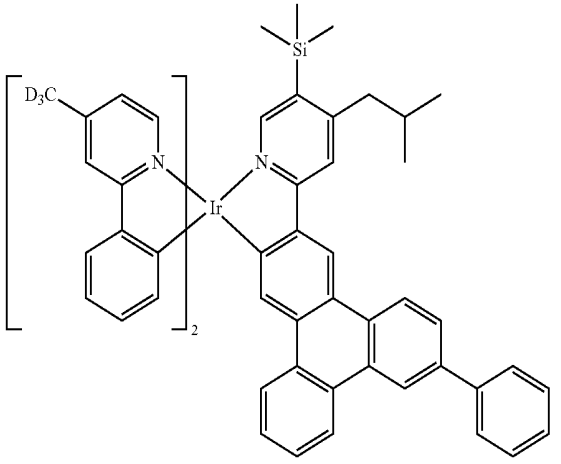

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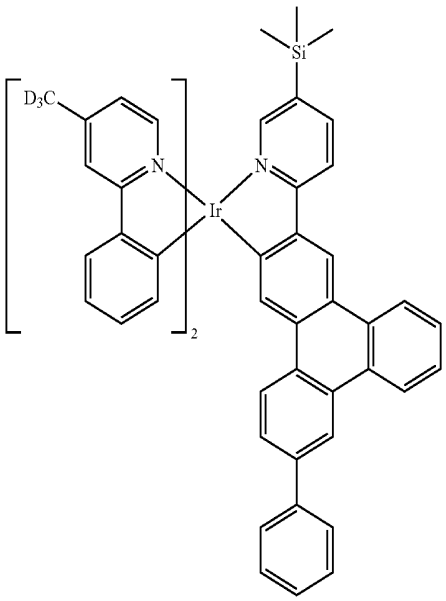

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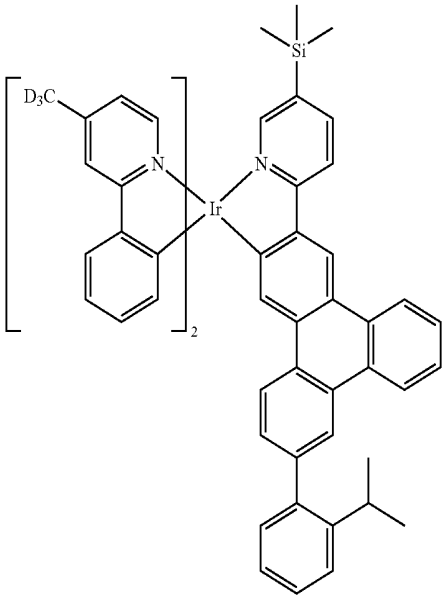

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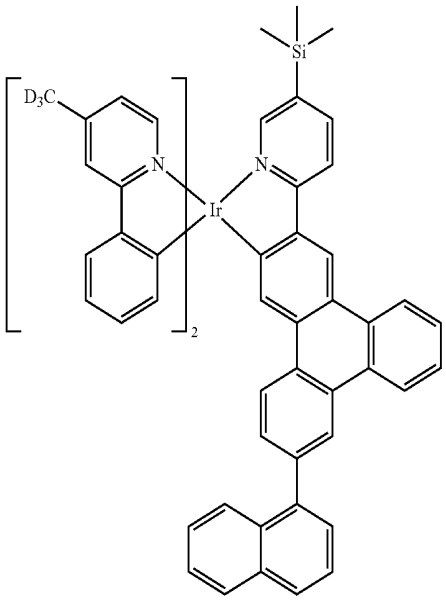

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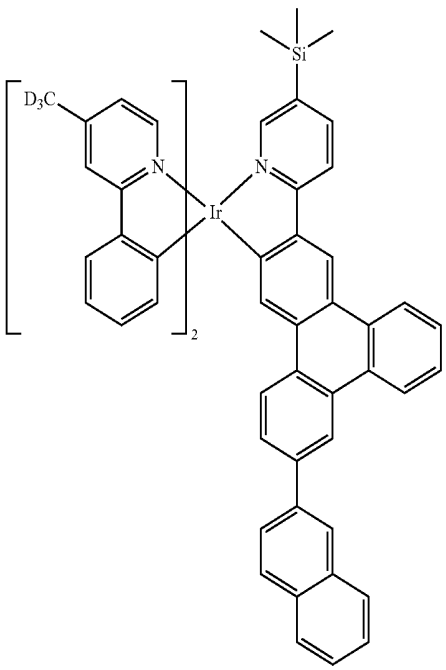

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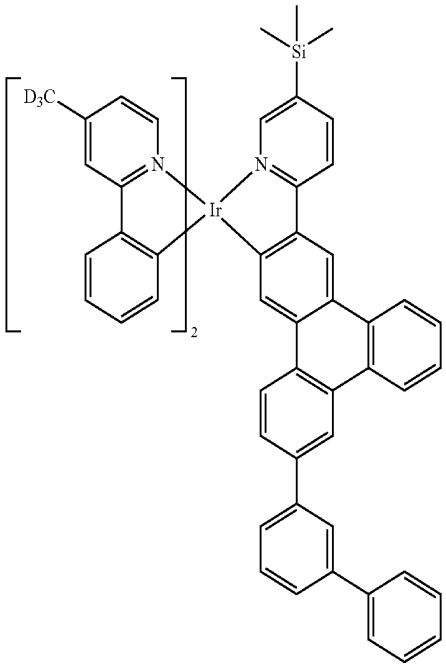

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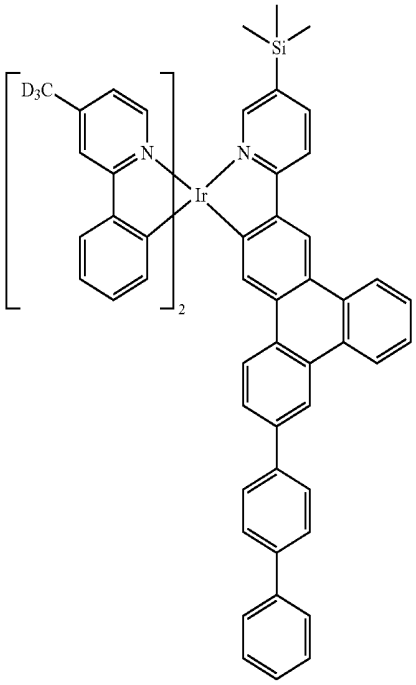

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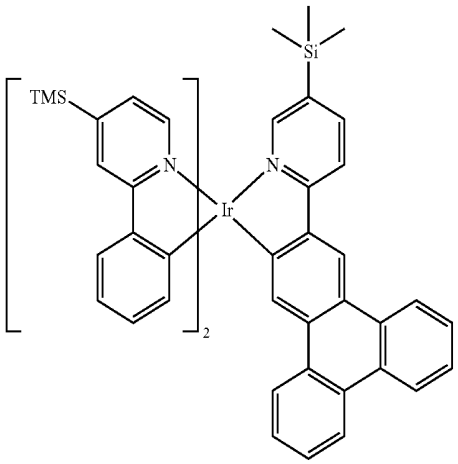

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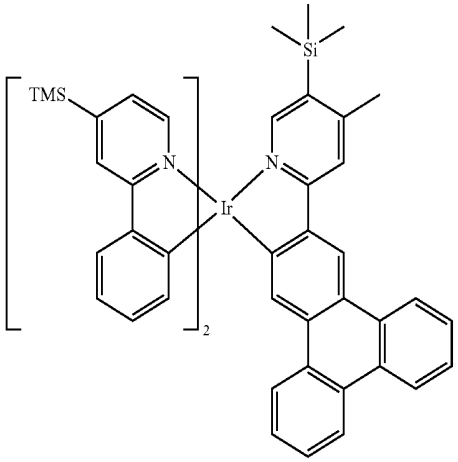

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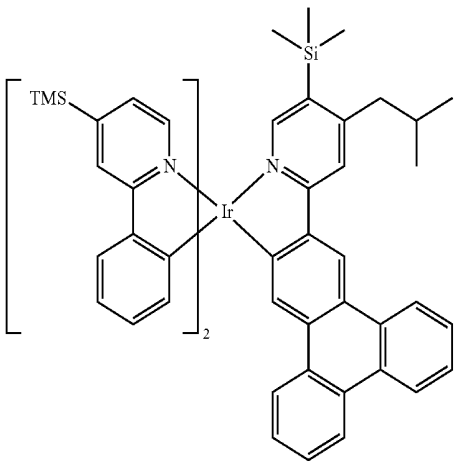

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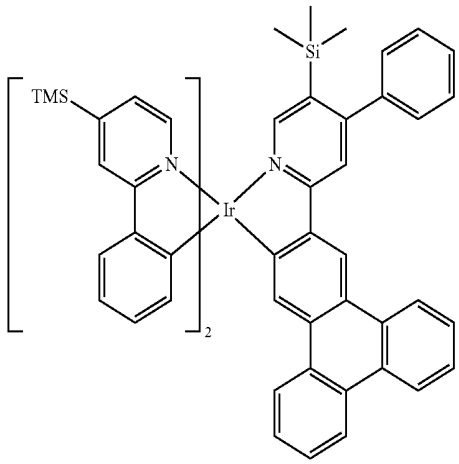

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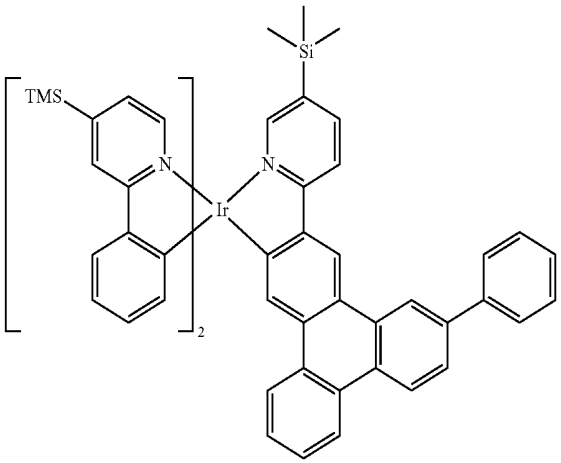

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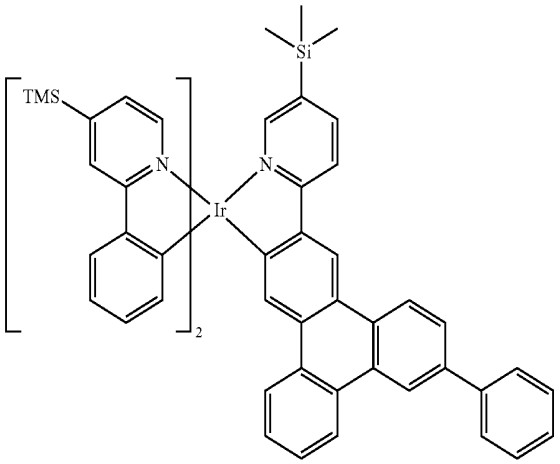

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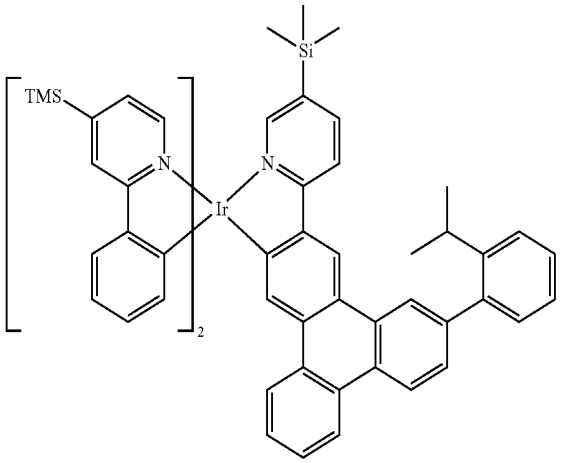

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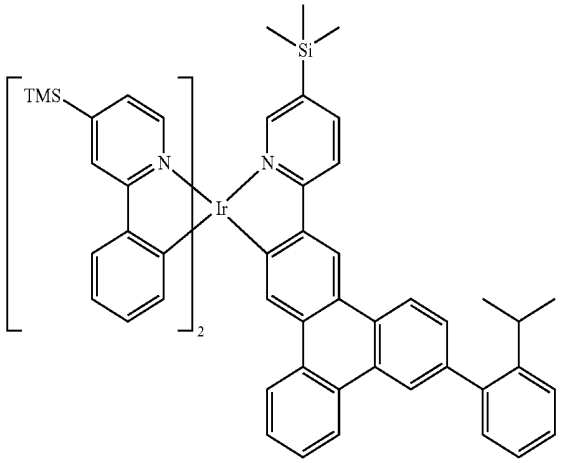

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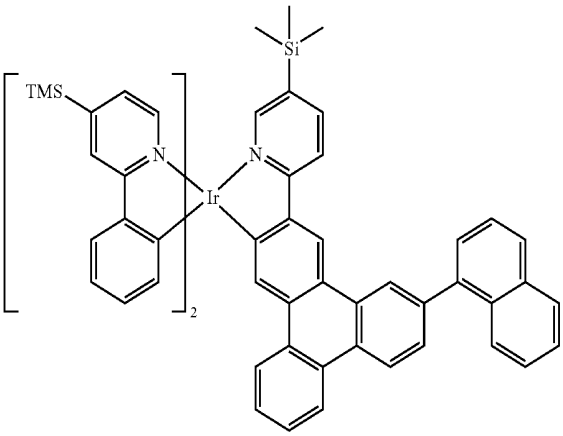

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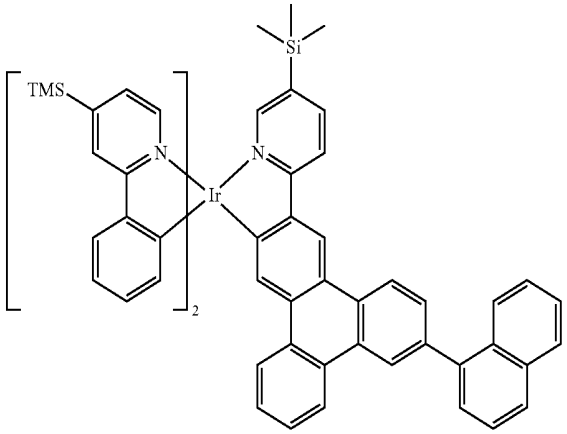

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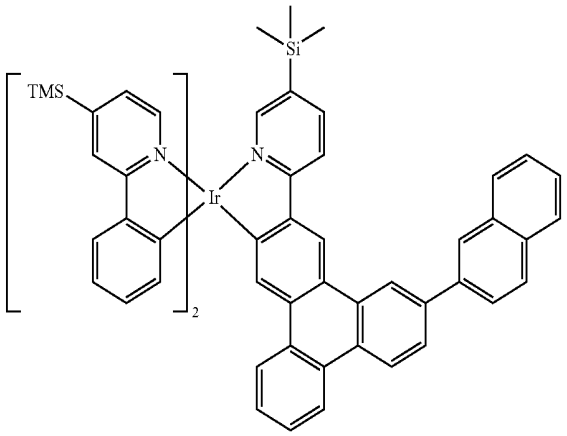

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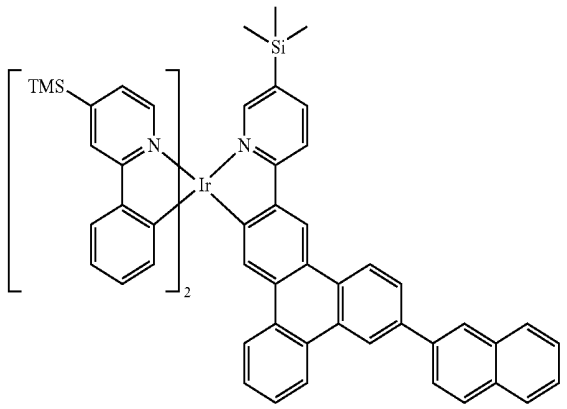

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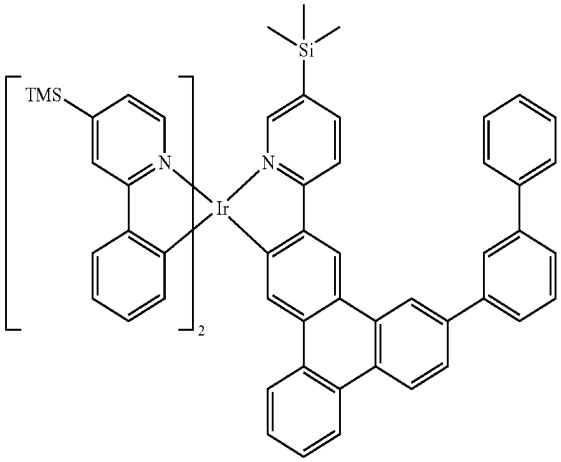

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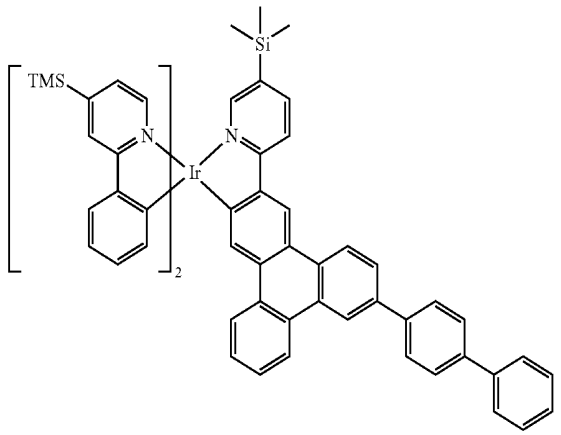

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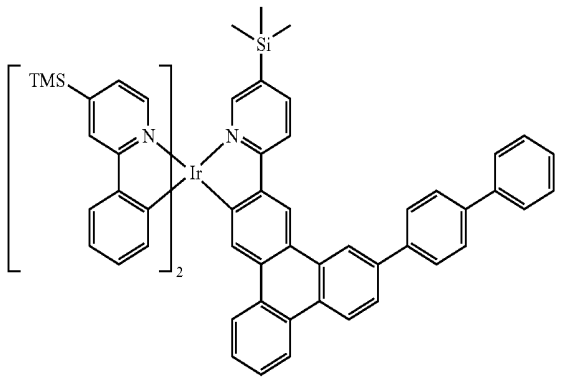

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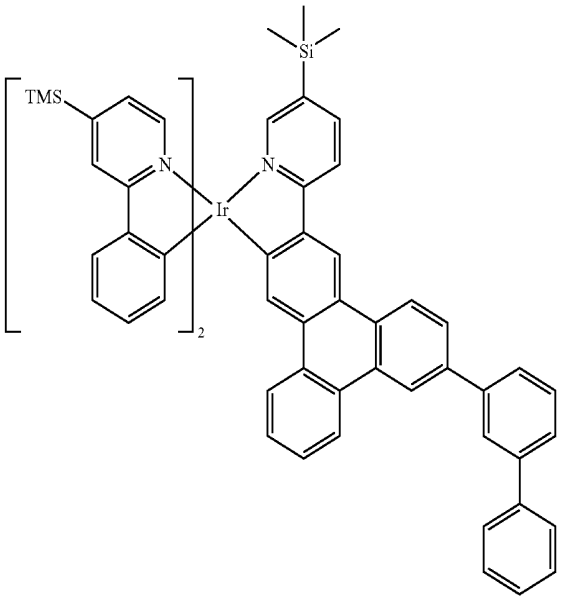

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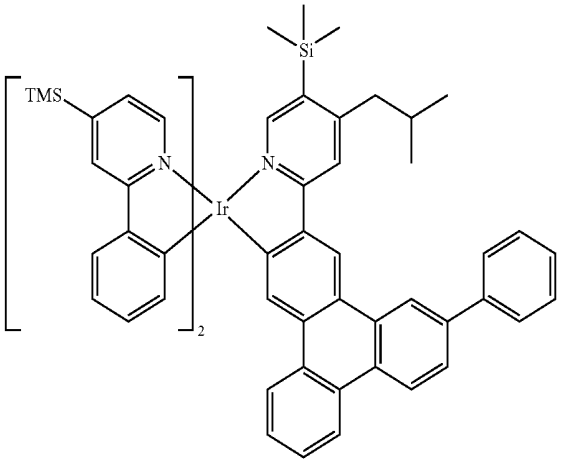

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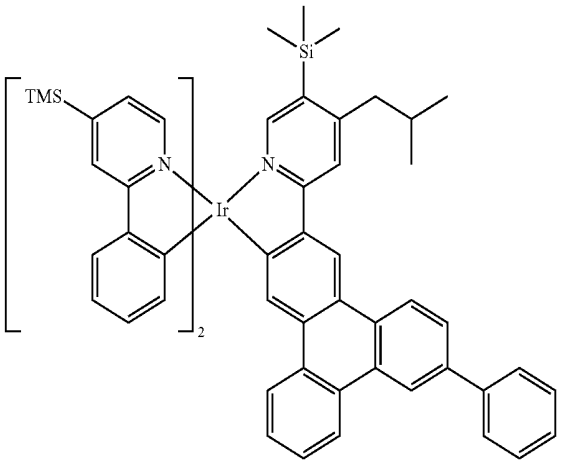

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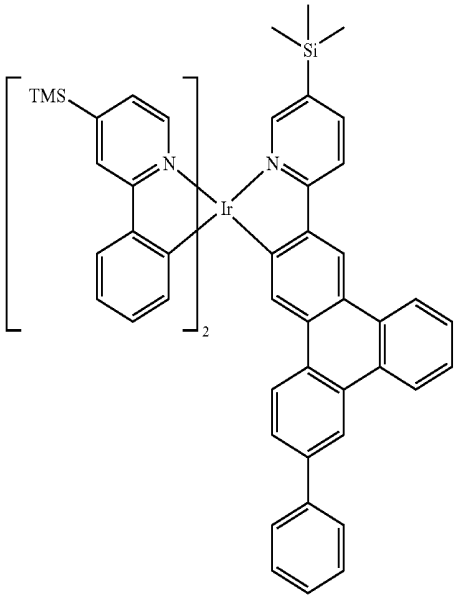

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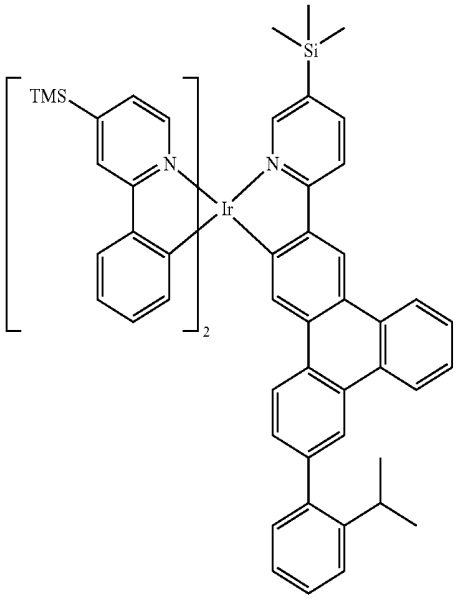

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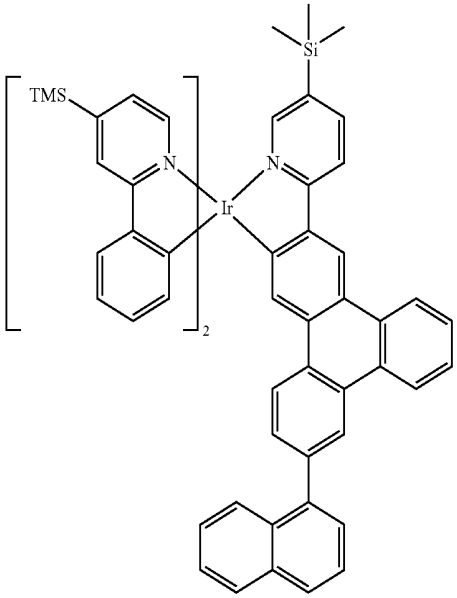

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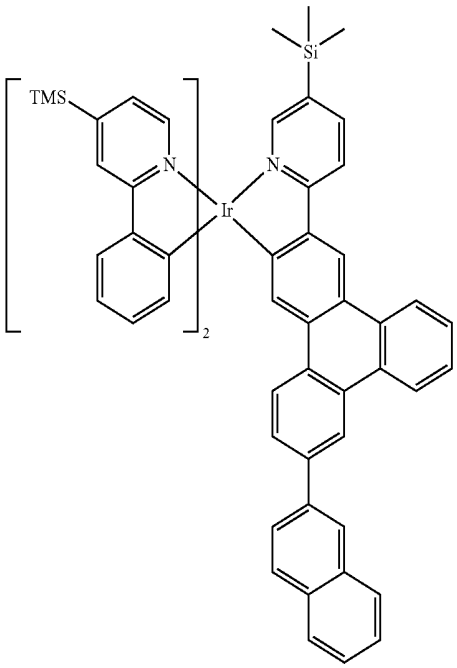

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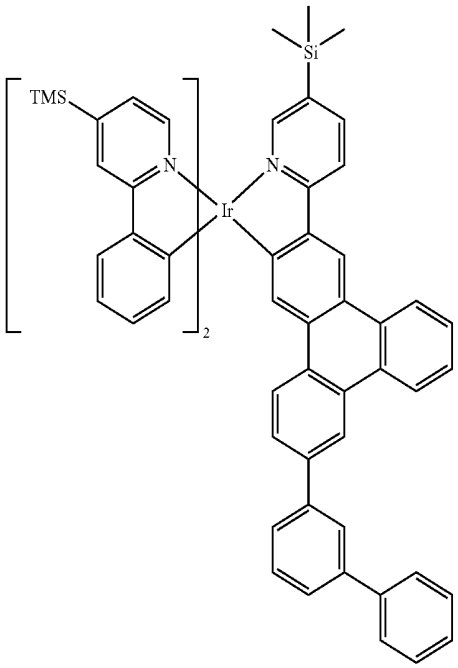

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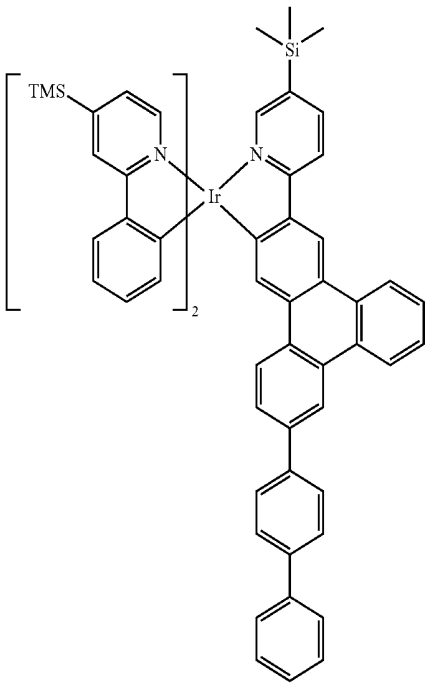

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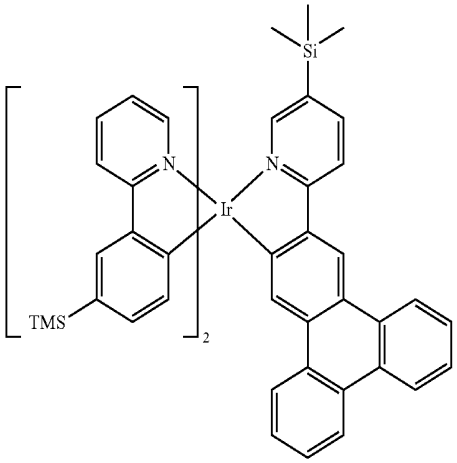

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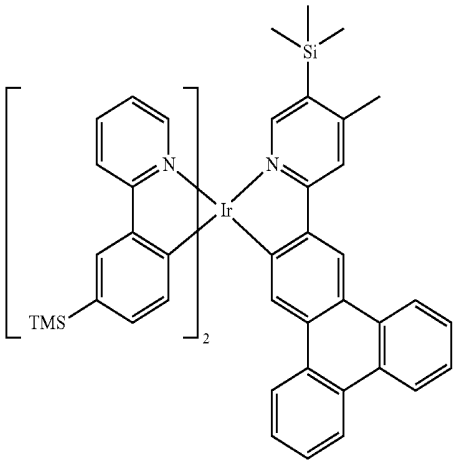

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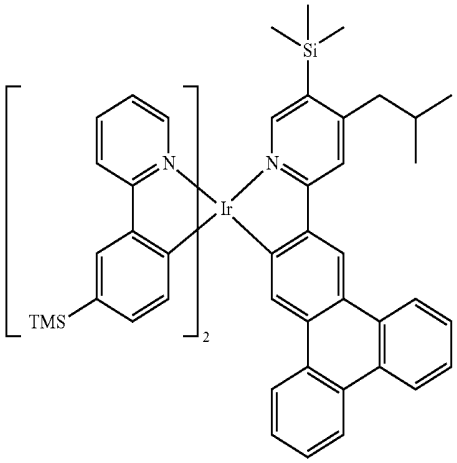

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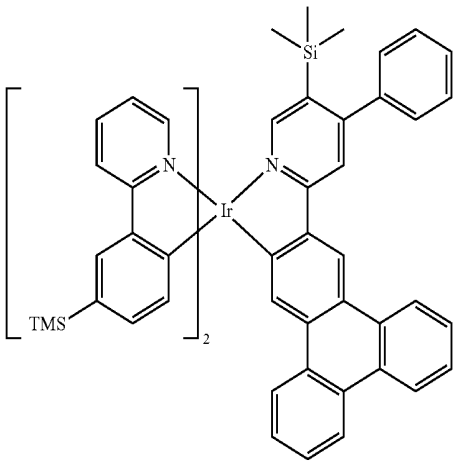

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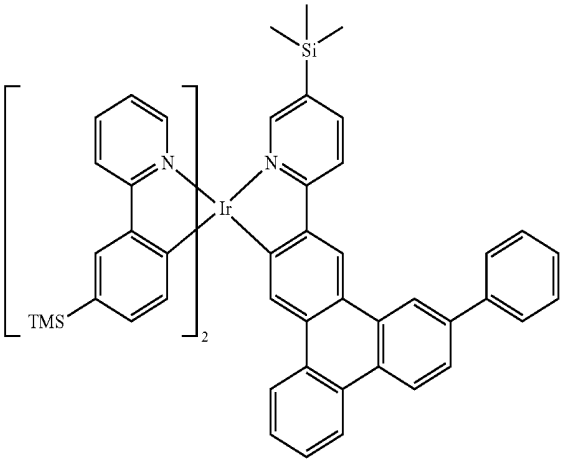

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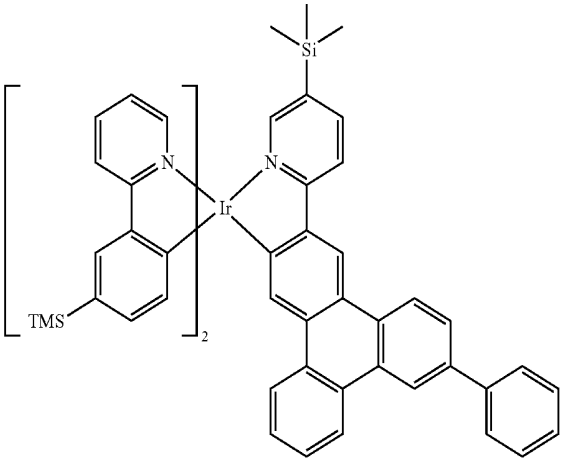

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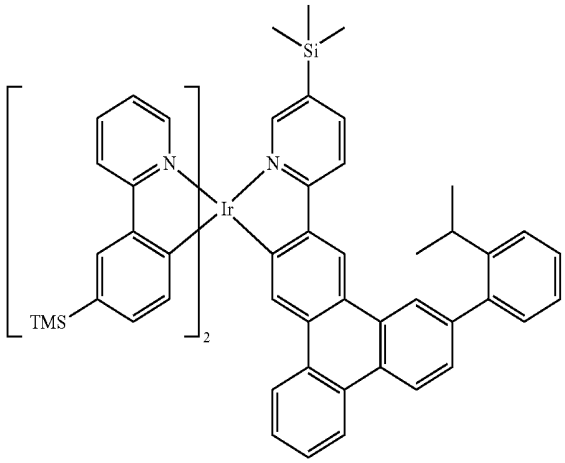

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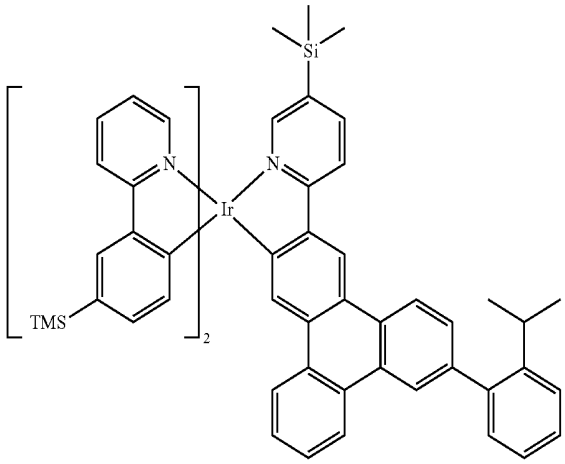

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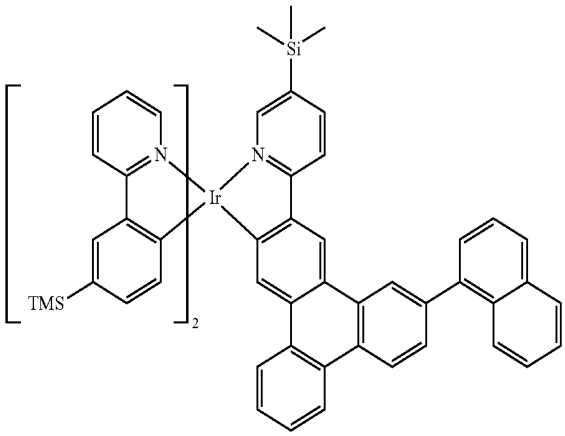

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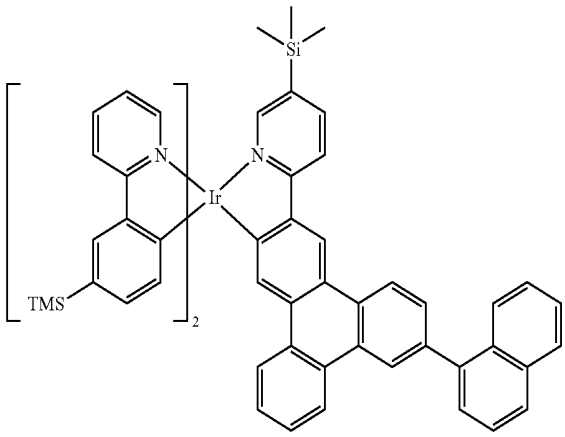

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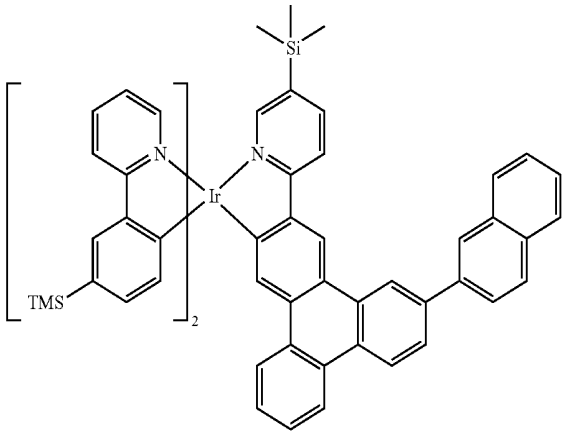

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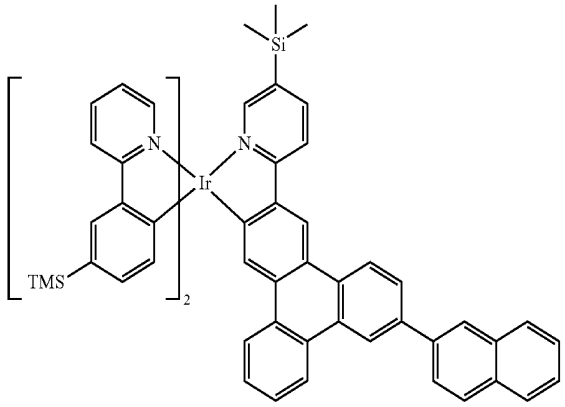

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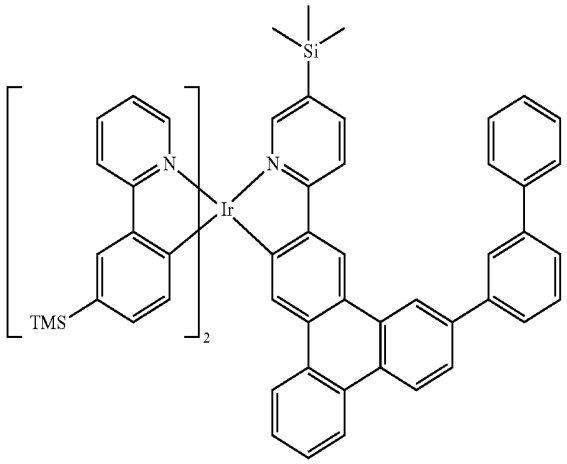

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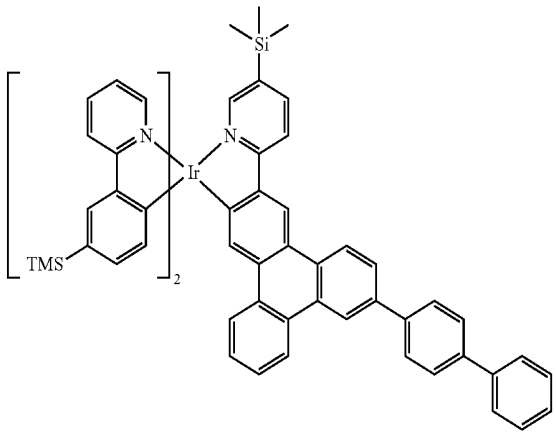

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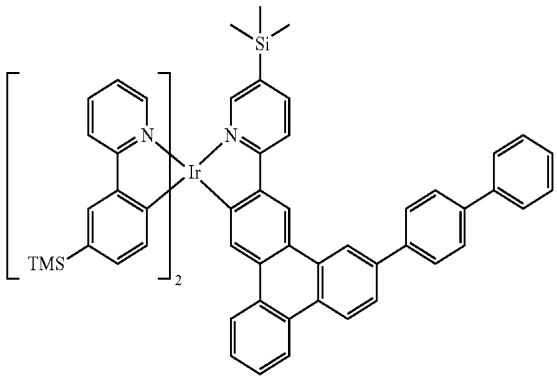

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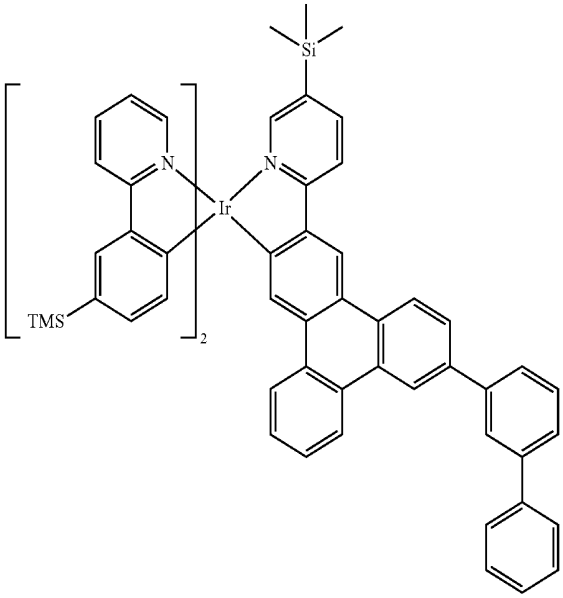

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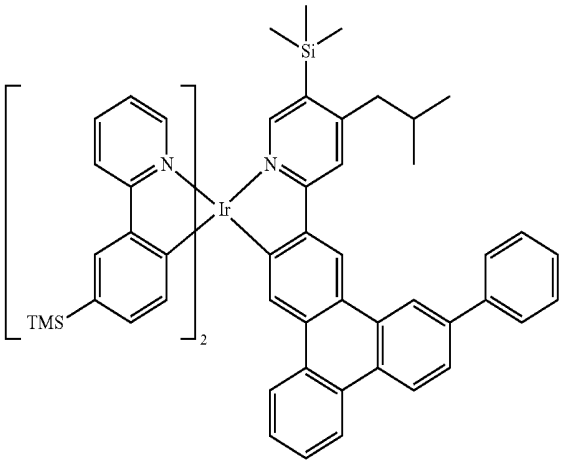

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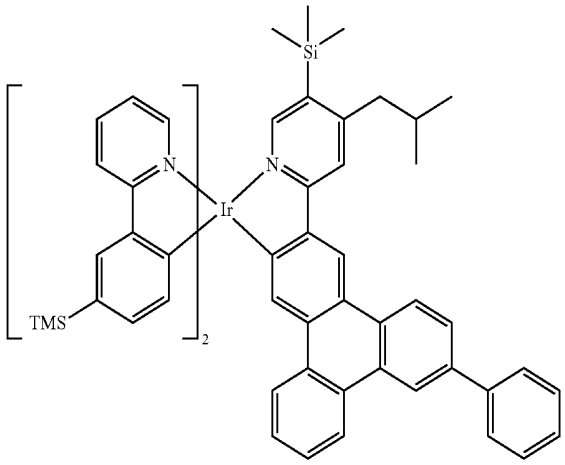

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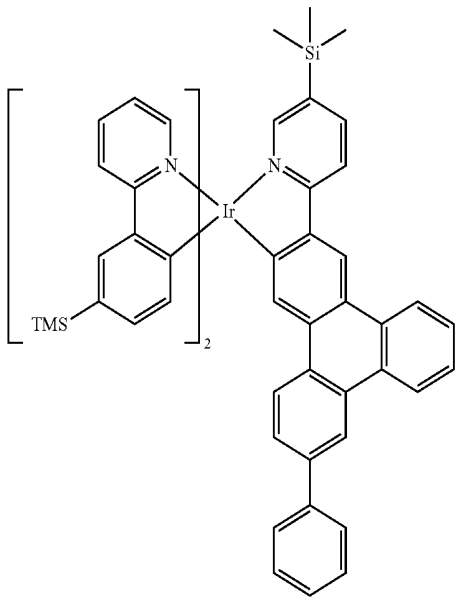

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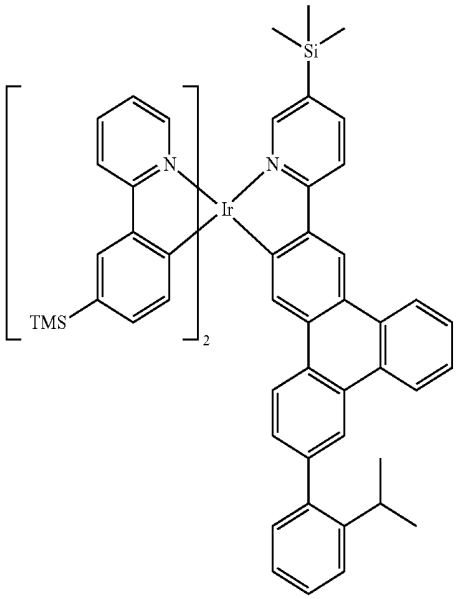

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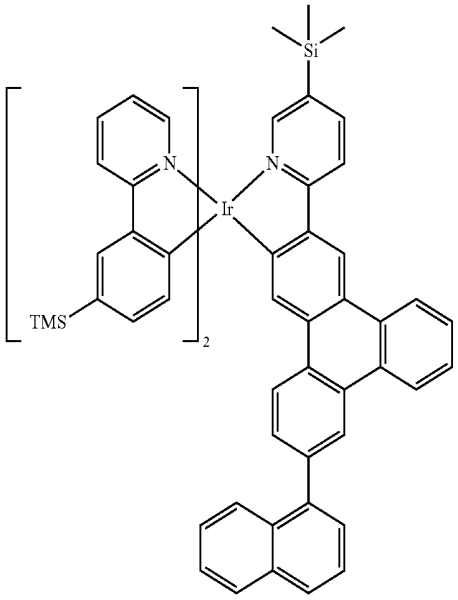

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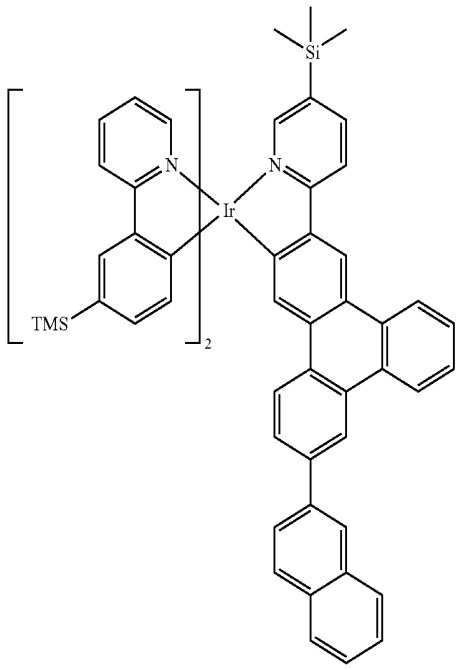

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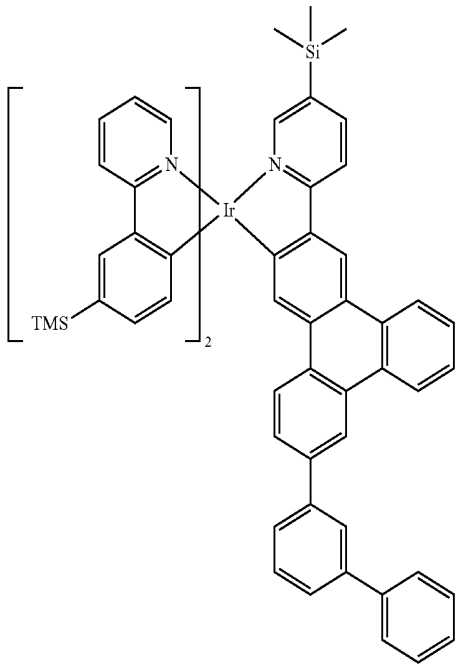

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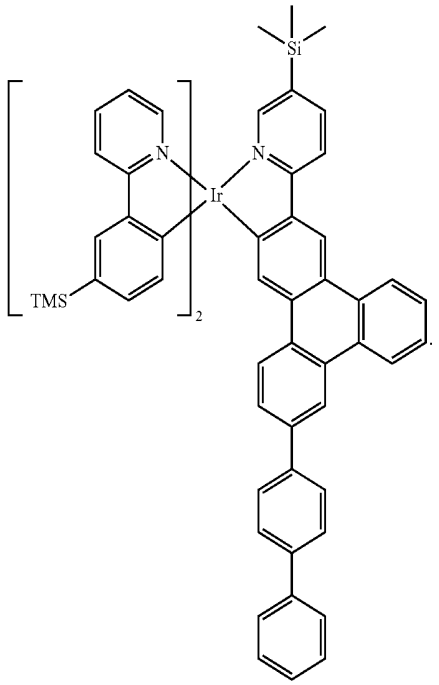

17. An organic light-emitting device, comprising:

a first electrode;

a second electrode; and

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

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

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

the first electrode is an anode,

the second electrode is a cathode,

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

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

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

19. The organic light-emitting device of claim **17**, wherein the emission layer comprises the at least one organometallic compound.

20. The organic light-emitting device of claim **19**, wherein the emission layer further comprises a host, and an amount of the host is greater than an amount of the at least one organometallic compound.

* * * * *

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	US20160164012A1	公开(公告)日	2016-06-09
申请号	US14/953091	申请日	2015-11-27
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO.，LTD.		
[标]发明人	LEE KUM HEE KWON OHYUN HWANG KYUYOUNG KWAK YOONHYUN CHOI HYEONHO		
发明人	LEE, KUM HEE KWON, OHYUN HWANG, KYUYOUNG KWAK, YOONHYUN CHOI, HYEONHO		
IPC分类号	H01L51/00 C09K11/06 C09K11/02 C07F15/00		
CPC分类号	H01L51/0094 C07F15/0033 C09K11/06 C09K11/025 H01L51/0072 C09K2211/1029 H01L51/5012 C09K2211/185 C09K2211/1007 C09K2211/1011 H01L51/5004 H01L51/0081 H01L51/0085 H01L51/5016		
优先权	1020140169185 2014-11-28 KR 1020150103013 2015-07-21 KR		
外部链接	Espacenet USPTO		

摘要(译)

由式1表示的有机金属化合物： M（L 1 ）n1 （L 2 ）n2 公式1 其中在公式1中，M，L 1 ，L 2 ，n1和n2与说明书中描述的相同。